STAFF EXHIBIT Q

PREDECISIONAL

SEISMIC GROUND MOTION AND FAULTING HAZARD AT PRIVATE FUEL STORAGE FACILITY IN THE SKULL VALLEY INDIAN RESERVATION, TOOELE COUNTY, UTAH—FINAL REPORT

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ACRONYMS

2D	Two-Dimensional
CFR	Code of Federal Regulations
CNWRA	Center for Nuclear Waste Regulatory Analyses
CTB	Canister Transfer Building
DE	Design Earthquake
DOE	U.S. Department of Energy
DSHA	Deterministic Seismic Hazard Analysis
HLW	High-Level Waste
ISFSI	Independent Spent Fuel Storage Installation
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
PC	Performance Categories
PFSF	Private Fuel Storage Facility
PFSLLC	Private Fuel Storage Limited Liability Company
PGA	Peak Ground Acceleration
PHA	Peak Horizontal Acceleration
PSHA	Probabilistic Seismic Hazard Analysis
PVA	Peak Vertical Acceleration
Q/T	Quaternary-Tertiary
SAR	Safety Analysis Report
SNF	Spent Nuclear Fuel
SSCs	Structures, Systems, and Components
SSE	Safe Shutdown Earthquake
SVIR	Skull Valley Indian Reservation
TMI-2	Three Mile Island Unit-2
YM	Yucca Mountain

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QUALITY OF DATA, ANALYSES, AND CODE DEVELOPMENT

Data: All CNWRA-generated original data contained in this report meet the quality assurance requirements described in the CNWRA Quality Assurance Manual. Sources of other data should be consulted for determining the level of quality for those data.

Analyses and Codes: The computer codes EZ-FRISK™ Version 4.11, OASIS Montaj Version 4.2, and GM-SYS Version 4.04.08C were used for some of the independent analyses contained in this report. All these codes are controlled under the CNWRA software configuration procedures.

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EXECUTIVE SUMMARY

The Private Fuel Storage Limited Liability Company (PFSLLC) is seeking a Nuclear Regulatory Commission (NRC) license for an Independent Spent Fuel Storage Installation (ISFSI) in the Skull Valley Indian Reservation in Tooele County, Utah. The proposed ISFSI is known as the Private Fuel Storage Facility (PFSF) and is intended to store spent nuclear fuel (SNF) from commercial nuclear power plants (NPPs). The PFSF will utilize a dry cask storage technology. The request for a license is for a term of 20 years, with the option open for an additional 20-year renewal.

NRC licensing actions for such facilities are performed in accordance with Title 10 Code of Federal Regulations (10 CFR) Part 72. According to 10 CFR 72.122(b)(2), structures, systems, and components (SSCs) important to safety must be designed to withstand the effects of natural phenomena, including earthquakes, without impairing their capability to perform safety functions. For sites west of the Rocky Mountains, such as Skull Valley, 10 CFR Part 72 requires that seismicity be evaluated by techniques set forth in Appendix A of 10 CFR Part 100 for NPPs. This appendix defines the safe shutdown earthquake (SSE) as the earthquake that produces the maximum vibratory ground motion at the site and requires that the SSCs be designed to withstand the ground motion produced by the SSE. This seismic design method implies use of a deterministic seismic hazard analysis (DSHA) approach because it considers only the most significant event, and it is a time-independent statement (i.e., it does not take into consideration the planned operating period of the facility). Also, 72.102(f)(1) requires that analyses using the Appendix A methodology should use a design peak horizontal acceleration (PHA) equivalent to that of the SSE for a nuclear power reactor. Furthermore, NUREG–0800, Section 2.5.2.6, states the NRC preference that the 84th-percentile value of the ground motion spectrum be used to calculate a reactor SSE PHA.

The PFSLLC performed a DSHA in 1997 in accordance with the requirements of 10 CFR 72.102(f)(1) to support its license application for the proposed Skull Valley PFSF. The DSHA estimated a PHA of 0.67g and a peak vertical acceleration (PVA) of 0.69g. Therefore, in its first revision of the Safety Analyses Report (SAR), the PFSLLC proposed to use these DSHA results for seismic design. A recent detailed geological survey conducted by Geomatrix Consultants, Inc., however, has identified additional faults in the vicinity of the PFSF site. After taking into account these newly discovered faults in the DSHA, the PHA and PVA values rose to 0.72 and 0.80g, respectively, exceeding the SAR proposed design values. Also, the new survey indicated the potential of surface faulting hazards at the PFSF site.

The PFSLLC is seeking resolution of the issue of seismic design by using a probabilistic approach for seismic and surface faulting hazard analyses. For this purpose, PFSLLC submitted to the NRC a request for exemption from the seismic design requirement of 10 CFR 72.102(f)(1) to use probabilistic seismic hazard analysis (PSHA) along with considerations of risk to establish design earthquake ground motion levels at the proposed PFSF. The exemption request also proposes to design the PFSF to the ground motions produced by 1,000-year return period earthquakes. These design ground motion levels are a PHA of 0.40g and a PVA of 0.39g resulting from a recent site-specific PSHA conducted by the Geomatrix Consultants, Inc.

To support evaluation of the PFSLLC exemption request, the NRC directed the Center for Nuclear Waste Regulatory Analyses (CNWRA) to conduct a technical review of seismic and faulting hazard investigations at the Skull Valley PFSF site. The objectives of the CNWRA seismic and faulting hazard investigations are to (i) conduct an independent review of existing seismic and faulting hazard studies at Skull Valley, in particular, to identify seismic and faulting issues important to siting the proposed PFSF; (ii) evaluate the adequacy and acceptability of the PFSLLC seismic and faulting design approach; and (iii) make recommendations regarding the PFSLLC proposed seismic design approach and design basis ground motion values. These objectives were accomplished through a survey of state-of-the-art literature (including those submitted by the PFSLLC), analyses of current relevant NRC regulations, and CNWRA independent analysis of geophysical data, sensitivity studies of model alternatives, and considerations of uncertainties.

Seismic issues important to siting the proposed Skull Valley PFSF include characterization of potential seismic sources, estimation of ground motion attenuation, assessment of probabilistic and deterministic ground motion hazards, assessment of probabilistic surface faulting hazard, and development of design basis ground motion parameters in compliance with applicable regulations and regulatory guidance. These issues are summarized in the following paragraphs.

The literature survey indicates that a significant portion of the literature pertinent to the proposed Skull Valley PFSF site was produced by the PFSLLC and its contractors or subcontractors, most notably, the faulting evaluation study, seismic ground motion hazard analyses, and development of design basis earthquakes conducted by Geomatrix Consultants, Inc. In these studies, the PFSLLC has sufficiently identified, utilized, and referenced previously existing data and information and adopted state-of-the-knowledge techniques in identifying and characterizing potential earthquake sources, estimating ground motion attenuations, and assessing probabilistic seismic ground motion and faulting hazards.

In addition to the extensive review of existing information, Geomatrix Consultants, Inc. and their subcontractors, under contract to Stone and Webster Engineering Corporation, conducted an extensive site investigation. That investigation encompassed (i) detailed geologic mapping of surficial and bedrock features including construction of cross sections; (ii) acquisition and interpretation of S- and P-wave seismic reflection profiles; (iii) analysis of proprietary industry seismic reflection and gravity data, supported by a confirmatory drilling program; and (iv) interpretation of detailed paleoseismic results, supported by trenching studies, air-photo interpretation, and geochronologic age-dating studies. Results of those investigations provided a detailed characterization of all known seismic sources that could potentially contribute to the seismic hazard at the PFSF site. Of particular significance was the identification of two new faults within Skull Valley, informally named the East and West faults. Those faults, together with the Stansbury fault, East Cedar Mountain fault, and possibly the Springline fault, as a northern continuation of the East or Springline fault, constitute the most significant seismic sources.

Geomatrix Consultants, Inc. used a logic tree approach to combine alternative models of source geometry, activity, and seismicity to formulate the PSHA. Review of the PSHA indicates that the seismic source characterization was thorough and complete. Uncertainties in fault

geometry and seismic activity were incorporated into the PSHA. CNWRA review of the alternative models shows that the Geomatrix Consultants, Inc. analysis may have led to an overly conservative hazard result. Reanalysis of the proprietary industry gravity data provided in this report does not support the interpretation that the West fault is an independent seismic source. Rather, CNWRA staff interpret the West fault as a splay of the East fault, incapable of independently generating large-magnitude earthquakes.

In estimating ground motion attenuation, Geomatrix Consultants, Inc. utilized the methodology and results developed from the PSHA conducted for the proposed geological repository at Yucca Mountain (YM) for high-level nuclear wastes (HLW). The YM methodology was developed for estimating ground motions in the Basin and Range based on the results of scientific evaluations and expert elicitation from a group of seven ground motion experts. This study provides a valuable resource for the PFSF PSHA and represents state-of-the-art knowledge in ground motion estimation in the Basin and Range tectonic province. The CNWRA review, however, identified some differences in Geomatrix Consultants, Inc. implementation of the YM methodology for the PFSF PSHA and the original YM approach. The most significant difference is the consideration of epistemic uncertainty. For the PFSF PSHA, Geomatrix Consultants, Inc. considered only epistemic uncertainty associated with the choice of different median ground motion models, not the uncertainty in the models themselves. As a consequence, the Geomatrix Consultants, Inc. implementation underestimates the total epistemic uncertainty and, therefore, underestimates the mean seismic hazard at the site. Nevertheless, CNWRA sensitivity calculations indicated that this effect is not significant and is compensated, to some extent, by the conservatism built in Geomatrix Consultants, Inc. earthquake source models.

The recent site-specific PSHA conducted by Geomatrix Consultants, Inc. produced a set of hazard curves for free-field motions at the ground surface. In developing design-basis ground motion, PSHA results were modified using a deterministic approach to account for the near-source effects of rupture directivity and the polarization of ground motions and, then, Regulatory Guide 1.165 procedures were implemented. The CNWRA review indicates that the deterministic approach taken by Geomatrix Consultants, Inc. in considering near-source effects is conservative despite the fact that some deficiencies were identified. The study resulted in a design ground motion PHA of 0.40g and PVA of 0.39g for 1,000-year return period earthquakes and a PHA and PVA of 0.53g for 2,000-year return period earthquakes.

In a similar way to the seismic hazard evaluation, Geomatrix Consultants, Inc. performed a fault displacement hazard analysis. The analysis was built on two methodologies developed for the YM. These methodologies, termed the earthquake approach and displacement approach, use Basin and Range empirical relationships with site-specific data to generate fault displacement hazard curves similar to seismic hazard curves.

Geomatrix Consultants, Inc. identified three potential faults capable of fault displacement. These faults, named the C, D, and F, were primarily imaged from the detailed seismic profiles and confirmed by boreholes. Faulting recurrence rates and displacement per event were quantified based on vertical separation of well established Quaternary marker horizons. After careful review of the data, interpretations, and models, it is concluded that the results from the displacement approach are representative of site conditions, and that these results should be

used to assess the faulting hazard at the PFSF site. These results show that, based on the 95th percentile curve, significant displacements, above 0.1 cm, are expected only with an annual frequency of less than 3×10^{-4}, or once in 3,333 years. Significant displacements of 10 cm or more are expected only with an annual frequency of less than 2×10^{-4}, or once in 5,000 years. For a 2,000-year return period (annual frequency of 5×10^{-4}), displacements due to faulting are smaller than 0.1 cm, which is less than the settlement allowance for the concrete foundations.

In summary, the PFSLLC seismic and surface faulting hazard results are conservative and represent the best estimates. Therefore, a judgment of whether the PFSLLC design approach is acceptable depends on two aspects: (i) whether there are regulatory and technical bases to accept the PFSLLC design approach using PSHA and (ii) whether there are regulatory and technical bases to accept the PFSLLC proposed design ground motion values calculated using 1,000-year return period earthquakes.

Although 10 CFR Part 72 requires a deterministic approach for the seismic design of an ISFSI site west of the Rocky Mountain Front, a probabilistic approach for seismic design is acceptable by the 1997 amended 10 CFR Parts 50 and 100 that apply to new NPPs and 10 CFR Part 60 that applies to the disposal of HLW in geologic repositories. Also, the NRC issued Regulatory Guide 1.165 to provide guidance on PSHA methodology. In addition, a planned NRC rulemaking for the amendment of 10 CFR Part 72 intends to allow use of a probabilistic seismic-hazard methodology and risk-informed graded approach for seismic design of ISFSI SSCs. Furthermore, the NRC has reviewed and approved the request for exemption to 10 CFR 72.102(f)(1) seismic design requirements to allow seismic design using PSHA results of 2,000-year return period earthquakes for the Three Mile Island Unit-2 (TMI-2) ISFSI. Technically, PSHA has many advantages over DSHA. For example, DSHA considers only the most significant earthquake sources and events with a fixed site-to-source distance. PSHA, on the other hand, considers contributions from all potential seismic sources and integrates across a range of source-to-site distances and magnitudes. Most importantly, DSHA is a time-independent statement, whereas PSHA estimates the likelihood of earthquake ground motion occurring at the location of interest within the time frame of interest. It is concluded that there are sufficient regulatory and technical bases to accept the PSHA methodology for seismic design of the proposed Skull Valley PFSF.

There is also an adequate regulatory basis to adopt a graded approach similar to U.S. Department of Energy (DOE) Standard 1020 for natural hazard characterization and design, including ground motion seismic hazard (e.g., 10 CFR Part 60). However, the level of ground motion that a particular SSC needs to be designed to depends on the importance of that particular SSC to public safety. As described in the NRC rulemaking plan for 10 CFR Part 72, an individual SSC may be designed to withstand only Frequency Category 1 events if the licensee analysis provides reasonable assurance that the failure of the SSC will not cause the facility to exceed the radiological requirements of 10 CFR 72.104(a). If the licensee analysis cannot support this conclusion, then the designated SSC must have a higher importance to safety, and the SSC must be designed such that the facility can withstand Frequency Category 2 events. To reiterate, Frequency Category 1 design basis ground motion refers to a mean recurrence interval of 1,000 years and Frequency Category 2 design basis ground motion refers to a mean recurrence interval of 10,000 years.

In support for choosing a 1,000-year return period to calculate design basis ground motions, the PFSLLC (Parkyn, 1999) argues (i) it is the same as that selected by the DOE for preclosure seismic design of important to safety SSCs for NRC Frequency Category 1 design basis events at the proposed YM HLW geologic repository and (ii) the consequences of a major seismic event at the PFSF can be bounded using the HI-STORM and TranStor™ systems technology and are limited to a storage cask tipover event, which produces a dose below the 100-mrem public dose limit of 10 CFR 20.1301(a)(1) at 1,000 years. The CNWRA review found these arguments lack regulatory and technical bases. First, the DOE classification of YM HLW geologic repository SSCs to design for Frequency Category 1 and Frequency Category 2 events has not been reviewed or accepted by the NRC staff. Second, PFSLLC provided no technical basis for classifying all the important to safety SSCs for the proposed Skull Valley PFSF as those that could be designed for NRC Frequency Category 1 design basis events. Finally, the consequence analysis using the HI-STORM and TranStor™ systems technology includes only a particular accident scenario (i.e., cask tipover), and it is independent of ground motion level. The PFSLLC did not demonstrate that the cask tipover event envelops other unanalyzed conditions such as the effect of collapse of the Canister Transfer Building on canisters or the effects of sliding and bearing failures of the foundation and concrete pad on storage casks. Based on these considerations, it is concluded that there are insufficient regulatory or technical bases to accept a 1,000-year return period for seismic design.

The CNWRA review found it appropriate to design the proposed Skull Valley PFSF using a 2,000-year return period for the following reasons.

- The Uniform Building Code and the National Earthquake Hazards Reduction Program both recommend using peak ground motion values that have a 90-percent probability of not being exceeded in 50 years for the seismic design of structures. Considering the radiological safety aspects of a dry SNF storage facility, conservative peak ground motion values that have a 99 percent likelihood of not being exceeded in the 20-year licensing period of the PFSF are considered adequate for its seismic design. This exceedance probability corresponds to a return period of 2,000 years.

- The DOE Standard, DOE–STD–1020–94, defines four performance categories (PCs) for SSCs important to safety, with PC3 facilities being those with potential accident consequences similar to a dry SNF storage facility. The DOE standard requires that PC3 facilities be designed for the mean ground motion with a 2,000-year return period.

- In its Fault Evaluation Study and Seismic Hazard Assessment report for the PFSF site, Geomatrix Consultants, Inc. concluded that an appropriate design probability level for both vibratory ground motion and fault displacement for the PFSF site is 5×10^{-4} (or a 2,000-year return period).

- The NRC has accepted a design seismic value that envelops the 50th-percentile deterministic ground motion value and the 2,000-year return period probabilistic ground motion value for the design of the TMI-2 ISFSI. The radiological

consequences of the TMI-2 ISFSI are similar to those of the proposed Skull Valley PFSF.

- Whereas a 84th-percentile design earthquake (DE) is required for licensing NPPs, a lower design value (e.g., 50th-percentile DE) may be adequate for licensing dry storage ISFSIs because an operating ISFSI is inherently less hazardous and less vulnerable to earthquake-initiated accidents than is an operating nuclear power reactor. The PFSLLC 2,000-year PSHA response spectra generally envelop the 50th-percentile updated DSHA response spectra.

In summary, using a 2,000-year return period to calculate design ground motion and fault displacement provides reasonable assurance for accepting the PFSLLC request for exemption to 10 CFR 72.102(f)(1) to use PSHA seismic design and fault displacement approach. Analyses for all the SSCs that require seismic should use a response spectrum that envelops the 2,000-year return period response spectra.

REFERENCE

Parkyn, J.D. 1999. *Request for Exemption to 10 CFR 72.102(f)(1), Seismic Design Requirement.* Letter (April 2) to M.S. Delligatti, Nuclear Regulatory Commission. Private Fuel Storage Facility. La Crosse, WI: Private Fuel Storage Limited Liability Company.

1 INTRODUCTION

The Private Fuel Storage Limited Liability Company (PFSLLC) plans to store spent nuclear fuel (SNF) from commercial nuclear power plants (NPPs) in an independent spent fuel storage installation (ISFSI) called the Private Fuel Storage Facility (PFSF) in the Skull Valley Indian Reservation (SVIR), Tooele County, Utah (Private Fuel Storage Limited Liability Company, 1999). This action was motivated by a determination by the U.S. Department of Energy (DOE) that it could not meet the 1982 Nuclear Waste Policy Act mandated deadline of January 31, 1998, to take title of SNF from commercial NPPs and that the NPPs are rapidly reaching their maximum capacity for onsite storage of SNF. The PFSF will use a dry cask storage technology. The initial request for a license is for a term of 20 years. Prior to the end of the initial license term, the PFSLLC intends to submit an application for license renewal for another 20 years, by which time it is anticipated that all of the SNF will be transferred offsite and the facility will be ready for decommissioning.

On June 20, 1997, the PFSLLC submitted a license application (Private Fuel Storage Limited Liability Company, 1997) to the Nuclear Regulatory Commission (NRC) for a Title 10 Code of Federal Regulations (10 CFR) Part 72 license for design, construction, operation (including receipt, handling, transfer, storage, retrieval, surveillance, and maintenance), and decommissioning of the PFSF in the SVIR. The license was requested for the storage of SNF discharged from licensed United States commercial NPPs in dry storage cask systems designed by Holtec International (1999) and Sierra Nuclear Corporation (1997).

According to 10 CFR 72.122(b)(2), structures, systems, and components (SSCs) important to safety must be designed to withstand the effects of natural phenomena, such as earthquakes, without impairing their capability to perform safety functions. For sites west of the Rocky Mountains, such as SVIR, 10 CFR Part 72 requires that seismicity be evaluated by techniques set forth in appendix A of 10 CFR Part 100 for NPPs. This appendix defines the safe shutdown earthquake (SSE) as the earthquake that produces the maximum vibratory ground motion at the site and requires that the SSCs be designed to withstand the ground motion produced by the SSE. This seismic design method implies use of a deterministic seismic hazard analysis (DSHA) approach because it considers only the most significant event, and it is a time-independent statement (i.e., it does not take into consideration the planned operating period of the facility). Also, 10 CFR 72.102(f)(1) requires that analyses using Appendix A methodology should use a design earthquake (DE) equivalent to that of the SSE for an NPP. Furthermore, NUREG–0800, Section 2.5.2.6, states the NRC preference that the 84th-percentile value of the ground motion spectrum be used to calculate a NPP SSE (Nuclear Regulatory Commission, 1997a).

The PFSLLC performed a DSHA in accordance with the requirements of 10 CFR 72.102(f)(1) to calculate the magnitude of the DE at the PFSF, as discussed in Revision 2 of PFSF Safety Analysis Report (SAR) (Private Fuel Storage Limited Liability Company, 1998) and Geomatrix Consultants, Inc. (1997). The DSHA for the PFSF site yields a peak horizontal acceleration (PHA) of 0.67g in each of two horizontal directions, a peak vertical acceleration (PVA) of 0.69g, and corresponding response spectra. A recent detailed geological survey conducted by Geomatrix Consultants, Inc. (1999a), however, has identified additional faults in the vicinity of

the PFSF site. After considering these newly discovered faults in the DSHA, the resulting PHA and PVA values rose to 0.72 and 0.80g (Geomatrix Consultants, Inc., 1999b).

On April 2, 1999, the PFSLLC submitted to the NRC a request for exemption from the seismic design requirements of 10 CFR 72.102(f)(1) that specify that the DE at the PFSF site, which is west of the Rocky Mountain Front, be equivalent to the SSE for an NPP calculated using the deterministic methods of 10 CFR Part 100, Appendix A (Parkyn, 1999). The request for exemption also included a proposal to allow the PFSLLC to use a probabilistic seismic hazard analysis (PSHA) along with consideration of risk to establish an adequate DE at the PFSF.

Recent site-specific PSHA studies conducted by Geomatrix Consultants, Inc. (1999a,c) at the proposed Skull Valley PFSF site yielded a PHA of 0.40g and a PVA of 0.39g for a 1,000-year return period and a PHA and PVA of 0.53g for a 2,000-year return period. These studies were conducted in accordance with methodologies and requirements set forth in Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997b). The studies also included near source effects. In light of these recent PSHA studies, the PFSLLC proposed to design the Skull Valley PFSF based on the 1,000-year return period probabilistic hazard results (i.e., a design PHA of 0.40g and a design PVA of 0.39g) in its SAR revision 3 (Private Fuel Storage Limited Liability Company, 1999) and exemption request for seismic design (Parkyn, 1999). Recognizing that 10 CFR Part 72 has not been revised to include PSHA as an acceptable methodology for deriving a DE for an ISFSI, the PFSLLC argues that its choice of a PSHA methodology is supported by: (i) recent revisions of NRC regulations (10 CFR Parts 50, 60, and 100) to include PSHA for the calculation of a DE, (ii) NRC planned rulemaking for geological and seismological characteristics for siting and design of dry cask ISFSIs under 10 CFR Part 72 (Nuclear Regulatory Commission, 1998a), and (iii) NRC acceptance of PSHA seismic design methodology for other similar facilities [e.g., Three Mile Island Unit-2 (TMI-2) (Nuclear Regulatory Commission, 1998b) and Yucca Mountain (YM) (Nuclear Regulatory Commission, 1997a; U.S. Department of Energy, 1997)]. In support of choosing the 1,000-year return period for calculating a DE, the PFSLLC mainly referred to NRC acceptance of the DOE topical report (U.S. Department of Energy, 1997) for the proposed geological repository at YM, in which a 1,000-year return period was selected by the DOE for preclosure seismic design of surface facilities.

Recognizing complications with regard to the PFSLLC request for exemption and the applicable NRC regulations, the NRC directed the Center for Nuclear Waste Regulatory Analyses (CNWRA) to conduct an investigation of seismic and faulting hazard evaluation at the PFSF site. The objectives of the CNWRA seismic and faulting hazard investigations are to (i) conduct an independent review of existing seismic and faulting hazard studies at the SVIR, in particular, to identify seismic and faulting issues important to siting the proposed PFSF; (ii) evaluate the adequacy and acceptability of the PFSLLC seismic and faulting design approach; and (iii) make recommendations regarding the PFSLLC-proposed seismic design approach and design basis ground motion value. These objectives were accomplished through a survey of state-of-the-art literature (including material submitted by PFSLLC) and analyses of current relevant NRC regulations. CNWRA staff also used independent analysis of geophysical data and sensitivity studies of model alternatives and considerations of uncertainties in ground motion estimates to support findings.

A number of pertinent technical reports, journal articles, and conference papers were reviewed to achieve the objectives of the study. The reviewed documents included those referenced in the PFSLLC SARs for the proposed PFSF (Private Fuel Storage Limited Liability Company, 1998, 1999), other technical reports produced by the PFSLLC and its contractors, literature referenced in those documents, and additional literature available in journals and published reports.

An initial screening of existing literature shows that the most significant hazards related to seismicity at the proposed Skull Valley PFSF are seismic ground motion and surface faulting. Other secondary seismic hazards (including avalanches, landslides, mudslides, soil settlement, and soil and sand liquefaction) are not likely to occur at the PFSF site because the geologic conditions are not conducive (Private Fuel Storage Limited Liability Company, 1998, 1999; Geomatrix Consultants, Inc., 1999a; Donnell, 1999a,b; Atwood and Mabey, 1995; Silver and Seed, 1971).

Chapter 2 of this report presents the major findings from the literature with emphasis on seismic ground motion and surface faulting issues important to siting the proposed PFSF. Chapter 3 discusses the adequacy of the PFSLLC-proposed seismic design approach and states recommendations based on major findings from the literature and relevant NRC regulations.

The findings with respect to any parts of the PFSLLC seismic design methodology, PSHA, and faulting hazard analyses are specific to the proposed Skull Valley PFSF. They are not applicable to the studies for other SNF-related facilities (such as the proposed geological repository at YM). Particularly, in estimating the ground motions in its site-specific PSHA for the proposed Skull Valley PFSF, Geomatrix Consultants, Inc. (1999a) used ground motion models that resulted from the PSHA for the proposed geological repository at YM (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998). Similarly, in estimating the probabilistic fault displacement hazard, Geomatrix Consultants, Inc. (1999a) used methodologies derived by the DOE expert panel and published in the DOE PSHA for YM (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998). The staff evaluation of these ground motion models and fault displacement methodologies is based on specific site conditions and required levels of studies for the proposed Skull Valley PFSF. The associated findings are not applicable to ground motion models and fault displacement methodologies for YM.

2 REVIEW OF SEISMIC AND FAULTING HAZARD INVESTIGATION

2.1 SEISMIC SOURCE CHARACTERIZATION

The seismic source characterization of the proposed PFSF was developed from examination of the available literature integrated with detailed site geological studies, including site stratigraphy, geologic mapping, cross-sectional construction, and geophysical investigations (Geomatrix Consultants, Inc.,1999a; Bay Geophysical Associates, Inc., 1999). Most important aspects to evaluations of seismic and faulting hazards were the identification and characterization of active faults based on paleoseismic and geophysical investigations. Identification of a detailed Quaternary stratigraphy was essential because it provided critical constraints on faulting activity.

In this section, the seismic source characterization is reviewed with regard to PFSLLC application for an exemption to 10 CFR 72.102(f)(1) and related methods outlined in 10 CFR Part 100, Appendix A. Because the PFSF site is west of the Mississippi River and following NRC Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997b), specific site interpretations of seismic sources need to be assessed and applied in the evaluation of the earthquake hazard. Critical aspects of this review center on interpretations of fault geometries for newly discovered East and West faults in Skull Valley based on reflection seismic data and forward modeling of gravity data in Geomatrix Consultants, Inc. (1999a). In this report, an alternative interpretation of the valley faults is presented that is consistent with the gravity, seismic reflection, and geological data. The implications of this alternative model to the overall seismic hazard are also assessed. Based on an assessment of this alternative interpretation and in light of the review of the other aspects of the probabilistic assessment, staff conclude that the Geomatrix Consultants, Inc. (1999a) model is conservative in the sense that, of the possible interpretations, it results in the greatest predicted ground motions at the PFSF site.

2.1.1 Tectonic Setting

The proposed PFSF site is located in west central Skull Valley, Utah, approximately 80 km south-southwest of Salt Lake City. Skull Valley lies within the eastern part of the Basin and Range province (Figure 2-1) in the North American Cordillera.

The tectonic history of the North American Cordillera dates back to the Archean, more than 2.5 Ga ago, when Precambrian tectonostratigraphic elements that now constitute the western North American crust were assembled. The age of the crust underlying the PFSF site in western Utah ranges between 2.3 and 1.6 Ga (after Hoffman, 1989). Since Precambrian time, the Cordillera has been the locus of a complex sequence of tectonic activity including: (i) development of a thick passive margin stratigraphy following the breakup of the Neoproterozoic super continents (e.g., Dalziel, 1997), rocks that comprise the bedrock stratigraphy presently exposed in the Stansbury and Cedar Mountains; (ii) intermittent

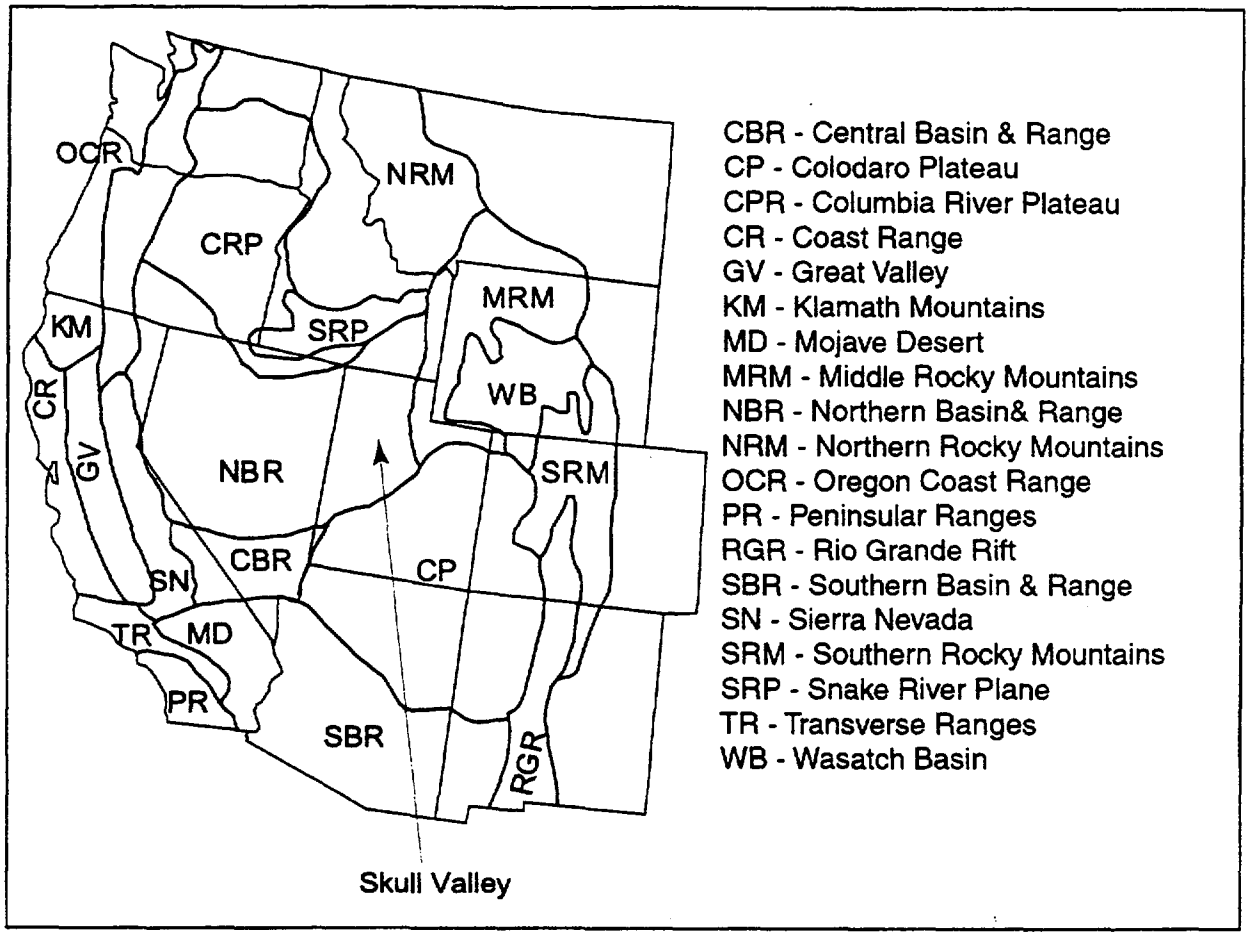

Figure 2-1. Map of the western United States showing the physiographic provinces, modified from Burchfiel et al. (1992) and Wernicke (1992). The proposed Private Fuel Storage Limited Liability Company facility is located within the northern Basin and Range province, also referred to as the Great Basin.

incorporation of a collage of accreted terranes (e.g., Roberts Mountain Allochthon) and development of an Andean-style margin in the Early Mesozoic; (iii) Jurassic and Cretaceous thin- and thick-skinned thrusting and folding associated with Sevier and Laramide orogenies (e.g., Cowan and Bruhn, 1992); and (iv) normal and detachment faulting associated with the Eocene to present extension of the Basin and Range (e.g., Wernicke, 1992; Axen et al., 1993).

Present extension of the intermountain western United States appears to be driven by both gravitationally derived buoyancy forces (Jones et al., 1996; England and Jackson, 1989) and external plate tectonic forces from motion of the Pacific and Sierra Nevada north and west relative to North America (Thatcher et al., 1999). Global Positioning Satellite measurements show that the western United States is presently experiencing active east-west extension and right-lateral transtensional shear (e.g., Martinez et al., 1998; Dixon et al., 1995).

2.1.2 Seismotectonic Provinces

Seismicity in the intermountain region of the western United States is generally concentrated along the Wasatch Front (which separates the Basin and Range from the middle Rocky Mountains), the eastern Sierra Nevada Front, and a medial zone called the Central Nevada Seismic Belt (dePolo et al., 1991) (Figure 2-2). Within this region, the following seismotectonic provinces are identified: (i) Basin and Range, (ii) Wasatch Front as part of the Intermountain Seismic Belt, (iii) Snake River Plain, and (iv) Colorado Plateau (Figure 2-2). The following provides a brief summary of the tectonic and seismicity characteristics of these seismotectonic provinces. This summary follows discussion of these provinces provided in Geomatrix Consultants, Inc. (1997).

2.1.2.1 Eastern Basin and Range Province

The proposed site is located in the northeastern margin of the Basin and Range province in west central Utah (Figure 2-2). Topography within the Basin and Range province reflects Miocene to recent (roughly the last 30 Ma), east-west extensional seismicity and faulting, in which tilted and exhumed footwall blocks form subparallel north-south striking ranges separating elongated and internally drained basins (Figure 2-3). Ranges are up to several hundred kilometers long with elevations up to 2 km above the basin floors. Much of the surface faulting took place at the base of the ranges along normal faults that dip moderately (~60°) beneath the adjacent basins (generally defined as range-front faults), although complex faulting within the basins is also common (see, for example, the fault-rupture patterns of the 1954 Rainbow Mountain-Stillwater or the 1959 Hebgen Lake earthquakes as summarized in dePolo et al., 1991).

Seismicity in the Basin and Range includes significant historical earthquakes this century. The largest of these were the 1915 ($\mathbf{M_S}$ 7.5) Pleasant Valley and the 1954 ($\mathbf{M_S}$ 7.5) Fairview Peak earthquakes in central Nevada, the 1983 ($\mathbf{M_S}$ 7.5) Borah Peak earthquake in Idaho, and the 1934 ($\mathbf{M_S}$ 6.6) Hansel Valley earthquake in Utah.

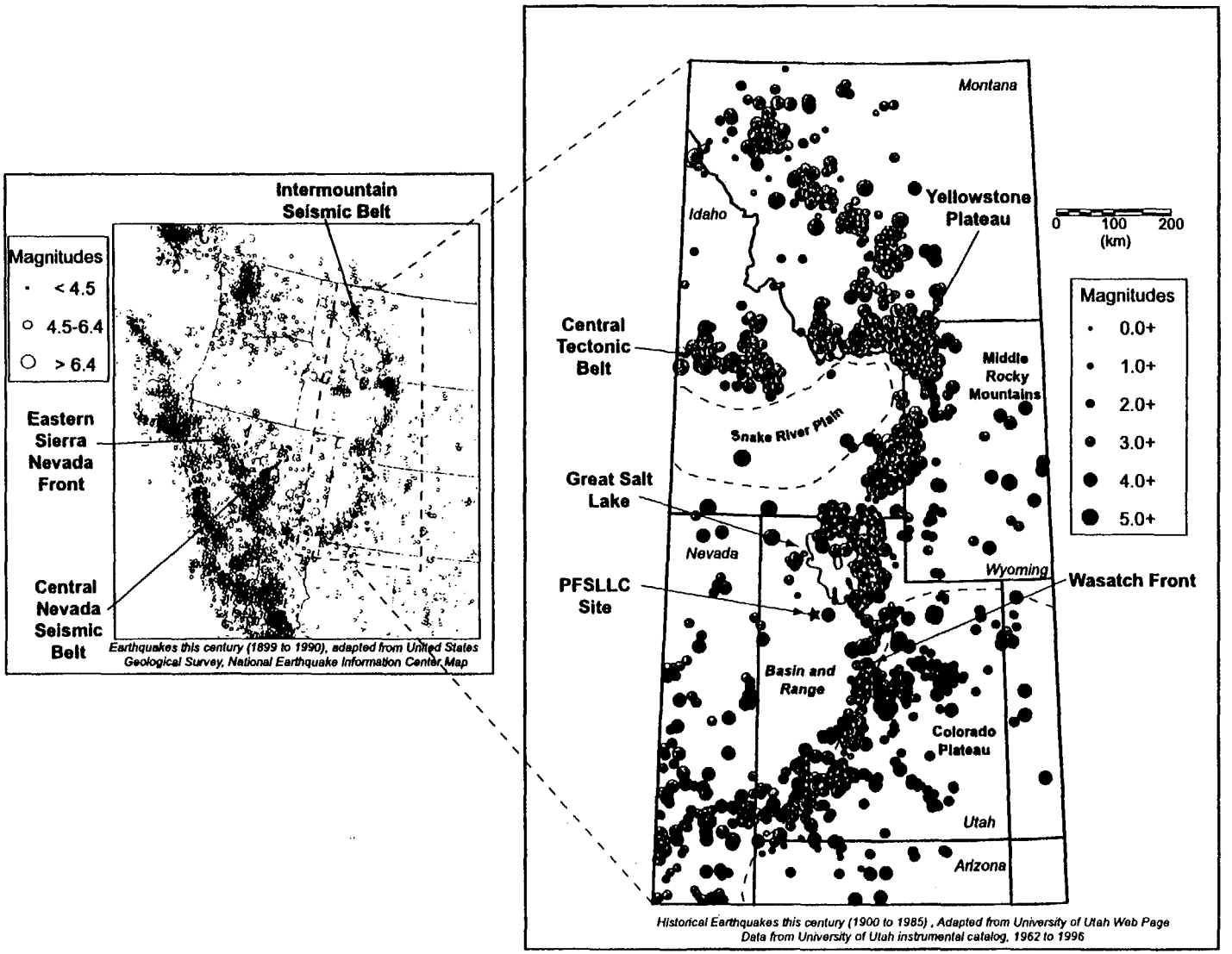

Figure 2-2. Seismicity maps of the western United States and the intermountain region showing the location and magnitudes of historic earthquakes that occurred this century

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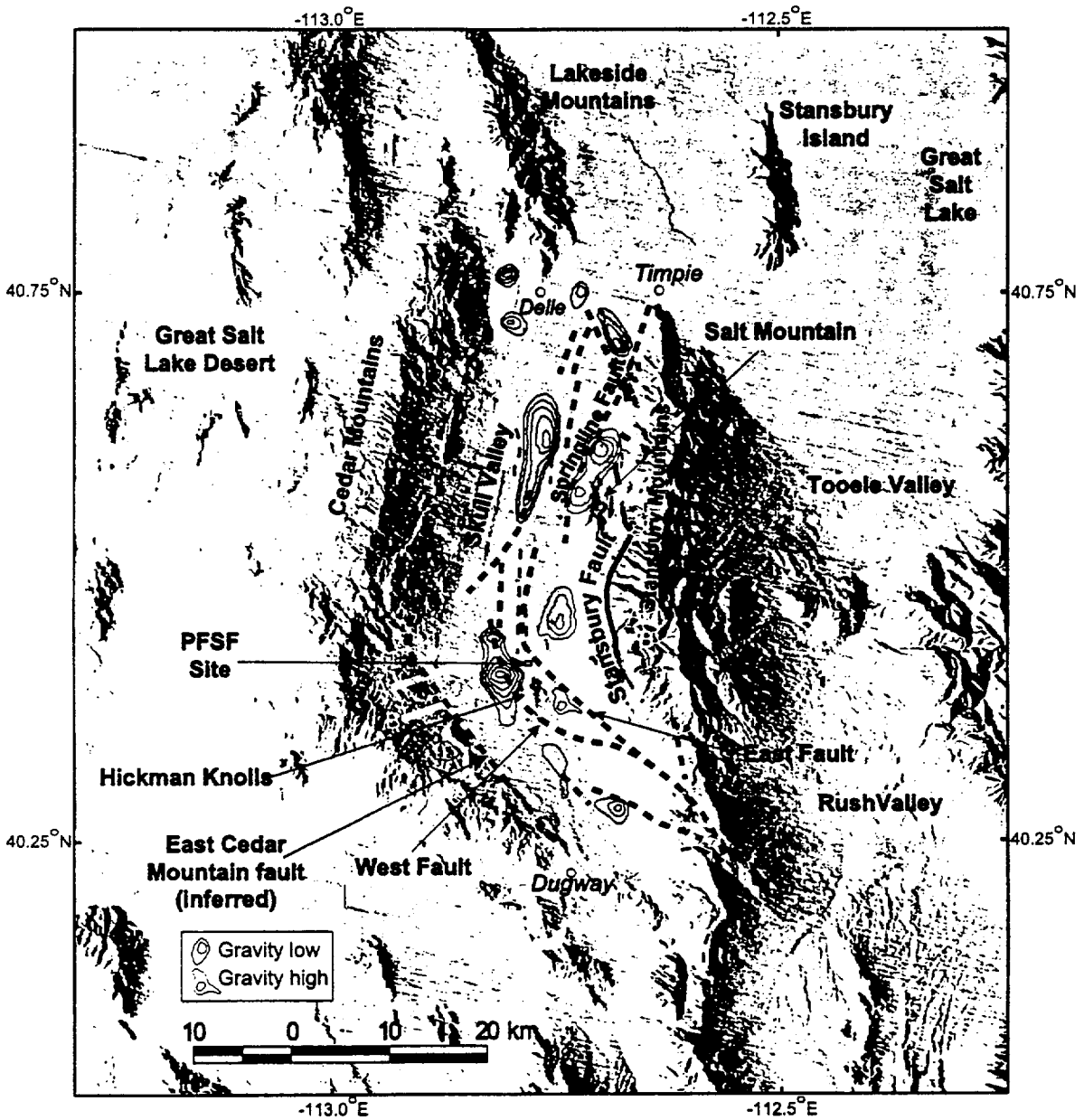

Figure 2-3. Shaded relief map of approximate 100-m digital elevation model for the proposed Private Fuel Storage Facility in Skull Valley, Utah. Vertical exaggeration is approximately 8:1 to enhance topography. Red and blue contours show locations of significant gravity anomalies. Yellow lines show the location of modeled gravity profiles. Yellow dots are communities. Yellow rectangle shows the location of the proposed Private Fuel Storage Facility site.

2.1.2.2 Wasatch Front

The Wasatch Frontal zone constitutes the transitional zone between relatively inactive seismic activity in the Colorado Plateau and middle Rocky Mountains and more active seismicity in the Basin and Range. Deformation and seismicity are concentrated along the front, mainly along the Wasatch fault zone, a 370-km long west-dipping normal fault. The Wasatch fault zone poses the greatest seismic risk to Salt Lake City and other communities along the front and has been the locus of repeated large-magnitude earthquakes in the Holocene (e.g., Machette et al., 1991). The Wasatch fault zone was considered by PFSLLC as a potential source in their seismic hazard evaluation (see specific discussion on the fault in Section 2.1.3 of this report).

The Wasatch Front forms the central stretch of the larger Intermountain Seismic Belt (Smith and Arabasz, 1991; Arabasz et al., 1980). The Intermountain Seismic Belt is a roughly north-south sinuous zone of seismicity that extends from western Montana, through western Wyoming and eastern Idaho, across Utah to southern Nevada (Figure 2-2). Just north of the Snake River Plain, a zone of concentrated seismicity extends westward from the Intermountain Seismic Belt into central Idaho. This zone is referred to as the Central Tectonic Belt (Figure 2-2) and may be an extension of the Intermountain Seismic Belt (Smith and Arabasz, 1991). The 1959 ($\mathbf{M_S}$ 7.5) Hebgen Lake earthquake occurred within the Central Tectonic Belt. Seismicity associated with the Wasatch Front was incorporated in the areal source zones (Section 2.1.5.6).

2.1.2.3 Snake River Plain

The Snake River Plain is a wide zone of volcanism that extends from Yellowstone National Park across Idaho to north central Nevada. Both intrusive and extrusive volcanism occurred in response to the relative southwestward drift of the North American plate over a fixed mantle hot spot. Volcanism started in Nevada in the Miocene (approximately 17 Ma) and continues to the present, manifest by the current hydrothermal and volcanic activity of the Yellowstone Plateau (e.g., Pierce and Morgan, 1992).

The Snake River Plain is further subdivided into eastern and western halves based on patterns of sedimentation and volcanism. The eastern Snake River Plain is just north of the PFSF site and is characterized by bi-modal volcanism. Low silica basaltic lava flows overlie high silica rhyolitic domes. The eastern Snake River Plain is relatively aseismic with small-magnitude earthquakes (>$\mathbf{M_S}$ 5.0) associated with volcanism (Smith et al., 1996). The lack of large-magnitude earthquakes suggests that extension of the Snake River Plain is accommodated by magmatic processes rather than the brittle deformation and associated large-magnitude earthquakes in the Basin and Range. Extensional magmatic features include basaltic dike swarms, fissures, shield volcanoes, and silicic domes. Because of the lack of large-magnitude earthquakes in the Snake River Plain and its distance from the Skull Valley site, seismicity from the province does not contribute to the hazard at the PFSF site.

2.1.2.4 Colorado Plateau

The Colorado Plateau is a large block of relatively coherent uplifted crust surrounded by more actively deforming regions. Sedimentary rocks of the plateau are generally flat-lying or tilted in

broad monoclines. Geologic evidence indicates that structural differentiation between the plateau and the Basin and Range initiated at about 30 Ma and peaked at about 17 Ma as Basin and Range extension reached its maximum (Stewart, 1978). Seismicity of the Colorado Plateau, although substantially less than the Basin and Range, has been characterized as small to moderate with concentrations of earthquakes along the eastern Wasatch Plateau–Book Cliffs region and in northern Arizona, where $\mathbf{M_S}$ 5-6 earthquakes have been recorded (Wong and Humphrey, 1989). Because of the small magnitudes of these earthquakes, their relatively low activity, and the large distance between the Plateau and the Skull Valley site, the Colorado Province does not contribute to the hazard at the PFSF site.

2.1.3 Geologic Setting

The proposed PFSF site lies near the center of a typical Basin and Range valley between roughly north-south and northwest-southeast ranges of bedrock (Figure 2-3). Subsidence of the basins and exhumation of the ranges was accomplished by extensional faulting along range-front normal faults. Faulting tilted the ridges to the east while the adjacent basins accumulated sediment shed from the eroding highlands. In Skull Valley, as in much of central and western Utah, the valleys were also flooded by transgressions of the intramontane saline lakes. Tertiary and Quaternary deposits in and around Skull Valley document numerous transgressions associated with Lake Bonneville and pre-Lake Bonneville lacustrian cycles. The Great Salt Lake is the present-day remnant of Lake Bonneville.

2.1.3.1 Site Stratigraphy

The valley fill soils and sediments underlying the proposed PFSF site were examined by Geomatrix Consultants, Inc. (1999a) from natural outcrops, test borings, and trenching of selected geomorphologic features. Valley fill sediments in Skull Valley consist of Tertiary age (65–2 Ma) siltstones, claystones, and tuffaceous sediments overlain by Quaternary (2 Ma to present) lacustrian deposits (e.g., Sack, 1993). Middle Miocene to Pliocene (17–2 Ma) deposits of the Salt Lake Formation were exposed in Trench T1 and in boring C-5. Microprobe analyses of glass shards from vitric tuffs (ash fall deposits) within the sediments were used to correlate the tuffs with volcanic rocks of known age. The correlations indicate ages for the stratigraphic units between 6 and 16 Ma, consistent with the known age of the Salt Lake Formation (Rigby, 1958). Microprobe analyses, performed by M. Perkins at the University of Utah, are documented in Appendix D of Geomatrix Consultants, Inc. (1999a).

During the Quaternary (approximately the last 2 Ma) and especially during the last 700 ka, sedimentation in Skull Valley was dominated by fluctuations associated with lacustrian cycles in the Bonneville Basin (e.g., Machette and Scott, 1988; Oviatt, 1997; Currey and Oviatt, 1985). Geomatrix Consultants, Inc. (1999a) provides a detailed analysis of these deposits from trenches, test pits, and borings, including two radiocarbon ages on Ostracodes and Charophytes. The radiocarbon ages were determined by Beta Analytic, Inc. under the direction of D.G. Hood and are documented in Appendix D of Geomatrix Consultants, Inc. (1999a). These relationships provided the primary control on assessments of slip rates on many of the local and regional faults.

The stratigraphy was critical to interpretations of the reflection seismic profiles. Two prominent paleosols developed during interpluvial periods near the Tertiary–Quaternary boundary (~2 Ma) and between the Lake Bonneville and Little Valley cycles (130–28 ka). These soils are characterized by relatively well developed pedogenic carbonate, both in the soil matrix and as coatings on pebbles. As such, these soils form strong reflectors that are readily apparent on the seismic reflection profiles. The seismic profiles provided good correlation of the reflective horizons between boreholes located along the seismic lines. These detailed constraints on the Quaternary stratigraphy and the high-quality seismic reflection profiles document the Quaternary geologic record of the site and provide a detailed stratigraphic framework for reliable paleoseismic analyses of active faults in and around Skull Valley (Geomatrix Consultants, Inc., 1999a).

2.1.3.2 Fault Models

Classical structural models for the Basin and Range envision a simple horst and graben framework in which range-front faults are planar and extend to the base of the transition between the brittle and ductile crust, 15 to 20 km below the surface (e.g., Stewart, 1978). More recent work has shown that many normal faults are not planar but curved or listric and that they sole into detachments that may or may not coincide within the brittle-ductile transition in the crust (e.g.,Wernicke and Burchfiel, 1982). In Skull Valley, the detachment model places the Stansbury fault as the master or controlling fault of a half graben. The other side of the half graben would include the antithetic East Cedar Mountain fault and a series of antithetic and synthetic faults within the basin, all of which would sole into the Stansbury fault 2–20 km deep in the crust.

The most important implications of the end-member Basin and Range models to earthquake and fault displacement hazard assessment are differences in interpretations of fault characteristics; namely fault segment length, down-dip width, fault dip and change in fault dip, and mechanical and kinematic relationships of individual faults to the tectonic framework. In the horst and graben model, fault systems are regarded as mechanically and kinematically independent of each other. Earthquakes are isolated to individual faults without significant interaction among the other faults in the region.

By contrast, the detachment models predict a controlling detachment structure under the basin, in this case the Stansbury fault. Slip along the Stansbury fault could trigger opposing slip on faults in the basin and on the opposing East Cedar Mountain fault to accommodate extension and rollover of the hangingwall into the Stansbury fault. Depending on how strain is distributed in the hangingwall above the master fault (Dula, 1990), faults in the basin and along the Cedar Mountain front could be as shallow as several kilometers, greatly reducing their potential to generate large earthquakes.

The relative difference of the seismic potential of the Stansbury fault itself in this model, especially along the shallowly dipping listric portion of the fault, is less clear. Earthquakes on detachment faults are rare and several alternative interpretations have been suggested. Wernicke (1995) argued that because detachment faults are much more efficient at facilitating crustal extension than steep faults, they are capable of large albeit infrequent earthquakes, with recurrence rates one-tenth to one-hundredth of their moderately to steeply dipping

counterparts. In contrast, mechanical analysis of listric normal faults suggests that deformation on the shallow dipping segments of the fault may be aseismic (Ofoegbu and Ferrill, 1997).

Geologic interpretations of detachment faults in Utah are controversial. Otton (1995) suggested the existence of the Sevier Desert detachment along the western frontal zone of the Canyon Range, 150 km south of the proposed PFSF site in Skull Valley. The fault is principally recognized from seismic reflection data (Planke and Smith, 1991). Based on the geophysical data, the fault has been interpreted to be shallow and west-dipping with 30–60 km of late Oligocene (~30 Ma) to Pliocene (1.4 Ma) displacement. The Sevier Desert detachment has alternatively been interpreted as a more ancient thrust fault related to Mesozoic (~70–90 Ma) contractional deformation (Hamilton, 1994) or an unconformity in the Proterozoic stratigraphic section (Anders and Cristie-Blick, 1994).

In Geomatrix Consultants, Inc. (1999a), two regional cross sections were developed that depict the overall structural framework of Skull Valley and the surrounding ranges. These cross sections were constructed from a compilation and analysis of existing geological map data, reprocessed and new seismic profiles across the valley, and interpretation of proprietary gravity data. The cross sections were based on acceptable structural geology procedures for cross-sectional restoration and interpretation of subsurface geometries (e.g., Woodward et al., 1989; Suppe, 1983). The cross sections depict a series of pre-Tertiary folds and thrusts related to the Sevier and older contraction deformation that have been cut by a series of Tertiary and Quaternary normal faults related to Basin and Range extension. The normal faults are considered to be moderately dipping (~60°) planar faults following the horst and graben model described previously. Geomatrix Consultants, Inc. (1999a) did not consider the possibility of seismically active detachments in their hazard assessment.

For seismic hazard analyses, this horst-graben model is conservative, in the sense that it predicts a maximum earthquake potential for these faults. Faults that extend all the way to the base of the seismogenic crust define a larger area for earthquake rupture and thus greater maximum magnitude earthquakes than those that terminate into a detachment above the brittle-ductile transition. The added feature of a detachment beneath the valley does not contribute to the earthquake hazard because, as noted previously, large earthquakes on detachment faults are exceedingly rare or nonexistent.

The cross sections in Geomatrix Consultants, Inc. (1999a) show three first-order west-dipping normal faults and one east-dipping fault (the East Cedar Mountain fault). The west-dipping faults are the Stansbury and two previously unknown faults in the basin informally named the East and West faults. These new faults were interpreted based mainly on analyses of the gravity and seismic reflection data and by analogy to other faults in the Basin and Range. The interpretation of these new faults is one of the most significant departures from interpretations of the regional and site geology given in the original SAR (Private Fuel Storage Limited Liability Company, 1997). Discovery of these new faults and related structures has important implications to both the seismic and fault displacement hazard assessments (see discussion in Sections 2.1.5 and 2.5.1).

2.1.4 Historical Seismicity

Geomatrix Consultants, Inc. (1999a) used the earthquake catalog compiled by the University of Utah, which includes historical earthquakes from about 1850–1962 and instrument-recorded earthquakes from the University of Utah network of 26 statewide stations. The compiled catalog was filtered by Arabasz et al. (1989) to remove duplicates and man-made events such as quarry and mining blasts. All magnitudes were also converted by Arabasz et al. (1989) to a common magnitude scale. Foreshocks and aftershocks were removed following the methodology of Youngs et al. (1987). The 1962 to 1996 portion of the catalog is shown in Figure 2-2. The largest earthquake in the catalog is the 1909 **M** 6.0 event. Seismicity is generally concentrated along the Wasatch front (east of the site) and in the Central Nevada Belt (west of the site).

Because the reporting techniques improved through time, the catalog is incomplete; small-magnitude events below about $\mathbf{M_S}$ 5.0 are absent from the record until primitive instruments came online in the early 1930s. As instrumentation improved, the record of smaller and smaller earthquakes became more complete. Completeness of the catalog for different magnitude scales was assessed using Stepp (1972) and reported in Youngs et al. (1987). The maximum likelihood technique (Weichert, 1980) was used by Geomatrix Consultants, Inc. (1999a) to derive recurrence parameters from the completeness record.

2.1.5 Seismic Sources

Seismic sources for the PFSF PSHA consisted of two types: fault sources and areal (or area) source zones. Fault sources specify seismicity along mapped causative faults and are represented in the hazard assessment as discrete lines, planes, or narrow zones. Areal sources specify seismicity on seismogenic structures whose locations are unknown and are constructed in the hazard assessment to delineate regions with different seismicity characteristics such as changes in tectonic settings, geologic boundaries, or concentration of seismicity. Most commonly, historical seismic records are used to define areal sources.

For each source, several critical factors and parameters must be established to calculate the contribution to the overall seismic hazard. For fault sources, Geomatrix Consultants, Inc. (1999a) identified several key parameters: probability of activity, maximum magnitude (including rupture length, fault dip, fault shape, depth of seismogenic crust, and average and maximum displacement per event), slip rate, and models to define earthquake recurrence on the sources.

Probability of activity. The probability of activity designates the likelihood that known fault sources are active under present crustal conditions. Geomatrix Consultants, Inc. (1999a) distinguished between faults with evidence indicating late Quaternary activity (last 780 ka) and those with suspected Quaternary (last 2 Ma) activity or limited seismogenic potentials. The former were assigned a probability of 1.0, the latter a probability of less than 1.0 using, mainly, scientific judgment based on geologic evidence. For example, probability of activity is selected to be 1.0 for the East, West, and Stansbury faults; 0.8 for the Springline fault; and 0.7 for the East Cedar Mountain fault. It is a way of ranking the relative likelihood of activity of all fault sources.

Maximum magnitude. Maximum magnitude is the largest earthquake each fault source can produce given its physical dimensions and possibly its slip history. Geomatrix Consultants, Inc. (1999a) used a range of established and published empirical and theoretical scaling relationships that relate magnitude to fault characteristics, including rupture length, rupture area, average or maximum displacement for a single event, and slip rate (Wells and Coppersmith, 1994; Mason, 1996; Anderson et al., 1996). Geomatrix Consultants, Inc. (1999a) weighted the different techniques following the expert opinions found in the DOE PSHA for YM (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998).

Slip rate. Slip rate is the average rate of fault slip, generally derived from geological constraints. Where possible, Geomatrix Consultants, Inc. (1999a) used published slip rates. Lacking that, slip rates were inferred from analogies to known faults or from descriptions of the faults.

Earthquake recurrence models. Recurrence relationship defines the rate of seismic activity and the relative frequency of earthquake magnitudes for a given source. For fault sources, Geomatrix Consultants, Inc. (1999a) converted slip rates into seismic moment rate using fault area and estimates of paleoseismic recurrence (when possible). The seismic moment rates were then partitioned into earthquakes of different magnitudes following three recurrence models: (i) truncated exponential (e.g., Gutenberg and Richter, 1954); (ii) characteristic (Youngs and Coppersmith, 1985); and (iii) maximum moment release (Wesnousky, 1986). Weights of the different models in the PFSF PSHA were derived from the YM PSHA (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998). The *b*-values for the truncated exponential and characteristic models were derived from regional historical seismicity.

2.1.5.1 Fault Sources

Fault sources are used in the hazard assessment to account for expected seismicity on known or suspected fault traces. Uncertainty in fault sources is accounted for by alternative interpretations of fault length, fault dip, closest approach to the site, depth within the seismogenic crust, and possible linkage with other faults. In the PFSF PSHA calculations, earthquakes are assumed to occur randomly along the fault surface, constrained by the size of the rupture area. Rupture area and rupture dimensions are specified by empirical relationships based on magnitude (e.g., Wells and Coppersmith, 1994).

Possible fault sources considered by Geomatrix Consultants, Inc. (1999a) are summarized in Table 2-1. These fault sources were identified by Geomatrix Consultants, Inc. (1999a) using two criteria: (i) ability to generate a maximum earthquake of **M** 5 or greater based on magnitude-fault size scaling relationships (e.g., Wells and Coppersmith, 1994) and (ii) possible multiple late Quaternary (last 2.0 Ma) ruptures based on evidence gleaned from the scientific literature (e.g., Crone, 1983). Sensitivity studies by Geomatrix Consultants, Inc. (1999a) show that, while all faults contribute to the hazard, the Stansbury, East, West, Springline, and East Cedar Mountain faults clearly dominate the hazard (Figure 2-4).

Table 2-1. Estimate of peak ground acceleration for fault sources

Fault Name	Distance (D) (km)	r_{jb} (km)	Trace Length (km)	M_{max}	Mean Rock PGA (g)	Mean Soil PGA (g)	Mean + σ_{lnY} Rock PGA	Mean + σ_{lnY} Soil PGA
East	0.9	1	28	6.8	.42	.54	.70	.91
West (Model A)	2.0	2	23	6.7	.38	.49	.64	.83
West (Model B)	2.0	2	36	6.9	.43	.55	.72	.93
Springline	13	13	18	6.6	.18	.24	.31	.40
East/Springline	13	1	46	7.0	.48	.62	.80	1.0
Stansbury	9.5	0	73	7.2	.54	.70	.90	1.1
East Cedar Mountain	9	0	72	7.2	.54	.70	.90	1.1
West Cedar Mountain	19	19	9	6.2	.12	.15	.19	.25
Clover	27	27	7	6.1	.08	.11	.14	.18
Mid-Valley Horst	32	32	6	6.0	.07	.09	.12	16
Lookout Pass	36	36	6	6.0	.07	.09	.11	.14
Mecur-Topliff Hill	40	27	56	7.1	.14	.19	.24	.32
Sheeprock	41	41	11	6.3	.07	.09	.12	.15
Oquirrh	45	32	21	6.6	.10	.13	.19	.25
Vernon Hills	47	47	6	6.0	.05	.07	.09	.12
Lakeside Mountain	49	49	5	5.9	.05	.06	.08	.11
Simpson Mountains	52	52	10	6.3	.06	.07	.10	.12
Sheeprock	57	57	5	5.9	.04	.06	.07	.09
Puddle Valley	61	61	6	6.0	.04	.06	.07	.10
East Great Salt Lake	66	53	82	7.3	.10	.12	.17	.22
East Tintic Mountain	72	59	36	6.9	.07	.09	.12	.16
West Valley	75	75	18	6.6	.05	.06	.08	.11
East Lakeside Mountain	78	78	38	6.9	.06	.07	.10	.13
Utah Lake	79	79	30	6.8	.05	.07	.09	.12
Drum Mountain	80	80	36	6.9	.06	.07	.09	.12
Fish Springs	81	81	12	6.3	.04	.05	.07	.09
Wasatch			370					
Salt Lake City Segment	81	68	46	7.0	.07	.09	.11	.15
Provo Segment	98	85	70	7.2	.06	.08	.11	.14
Nephi Segment	99	86	43	7.0	.06	.07	.09	.12
West Deep Creek	99	86	12	6.4	.04	.05	.07	.08

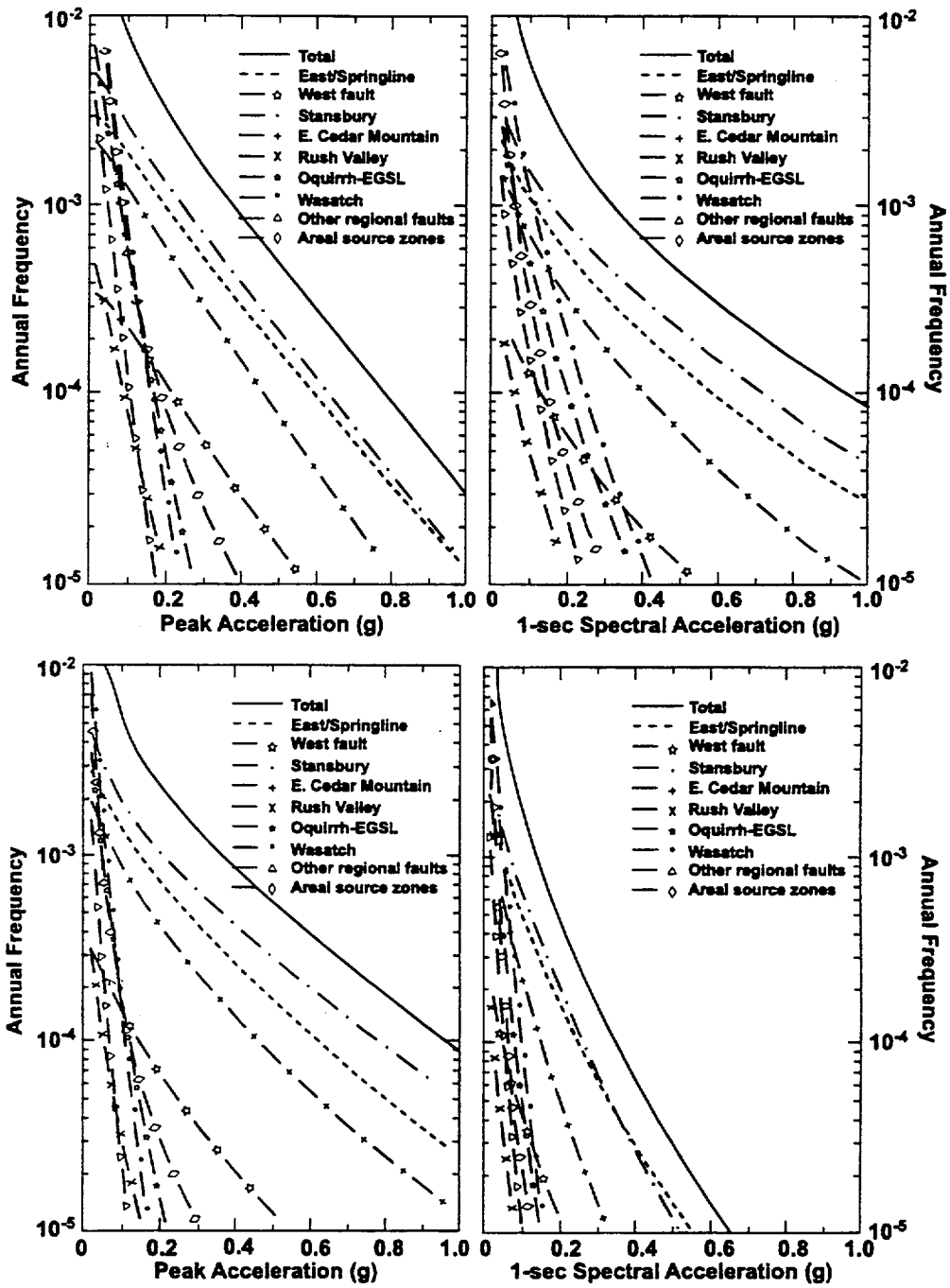

Figure 2-4. Seismic hazard curves showing the contribution of individual sources to peak and 1-second spectral acceleration, adapted from Geomatrix Consultants, Inc. (1999a)

This assessment is supported by the independent analysis presented here, in which the peak ground acceleration (PGA) is calculated for the faults listed in Table 2-1. The aim of this independent assessment was to develop a relative ranking of the seismic sources, following the methodology for identification of Type I Faults (McKague et al., 1996). Therefore, it is important to note that the PGA values listed in Table 2-1 are upper bounds and should not be compared directly to the deterministic numbers presented in the PFSLLC DSHA. Unlike Geomatrix Consultants, Inc. (1999a), variability in source geometry and maximum magnitude was not incorporated into this analysis. Instead, maximum magnitude for each source was derived using magnitude-length scaling (Wells and Coppersmith, 1994) from the longest possible surface trace lengths and shortest possible distance from fault trace to the site (Geomatrix Consultants, Inc.,1999a, Tables 6-1 and 6-2). In addition, the attenuation equation used was not modified for normal faulting despite some evidence that suggests normal faults produce smaller ground accelerations for a given magnitude earthquake than strike-slip or reverse faults (McGarr, 1984). For simplicity, the generic attenuation equation for both soil and rock conditions of Boore et al. (1994) was used [as printed in Boore et al. (1997)] and the b_{1ALL} constant was chosen in the equation, which is intended for generic faulting conditions (normal, reversed, or strike-slip). Boore et al. (1994) use a distance parameter called r_{jb}, which is the closest horizontal distance from the PFSF site to the nearest point on the vertical projection of the fault rupture surface. All ruptures were assumed to break the entire width of the fault from the surface to the base of the brittle crust. Thus, for faults that dip away from the site, r_{jb} was considered the surface distance *D*. For faults that dip toward the site, r_{jb} was calculated assuming a 60° dipping fault plane. For these analyses, the PGA values for both soil and rock conditions were calculated as well as the mean and the mean plus one sigma (given as Mean $+\sigma_{lnY}$ in Table 2-1).

Assessment of the fault sources confirms the Geomatrix Consultants, Inc. (1999a) sensitivity result. The dominant fault sources are the Stansbury, East Cedar Mountain, and mid-valley faults (i.e., the East, West, and Springline faults). All other fault zones have mean PGA values less than 0.20g. Especially critical are the possibilities that the West fault is an active independent source (Model B) and that the East and Springline faults are linked to form a single fault source.

2.1.5.2 Stansbury Fault

The Stansbury fault is a west-dipping normal fault that juxtaposes Paleozoic bedrock of the Stansbury Mountains against late Quaternary alluvium. Geomatrix Consultants, Inc. (1999a) identified four segments of the fault following Helm (1995) and Hecker (1993), labeled sections A, B, C, and D on Figures 2-5a and 2-5b. Detailed paleoseismic data obtained by Geomatrix Consultants, Inc. (1999a) indicate multiple late Quaternary and possibly Holocene fault ruptures. Using these segments, five rupture scenarios were developed, based on probable single and combined segment ruptures. Maximum rupture length for all four segments is 73 km. All rupture scenarios included Segment B because the large surface rupturing events are most pronounced along this segment of the fault.

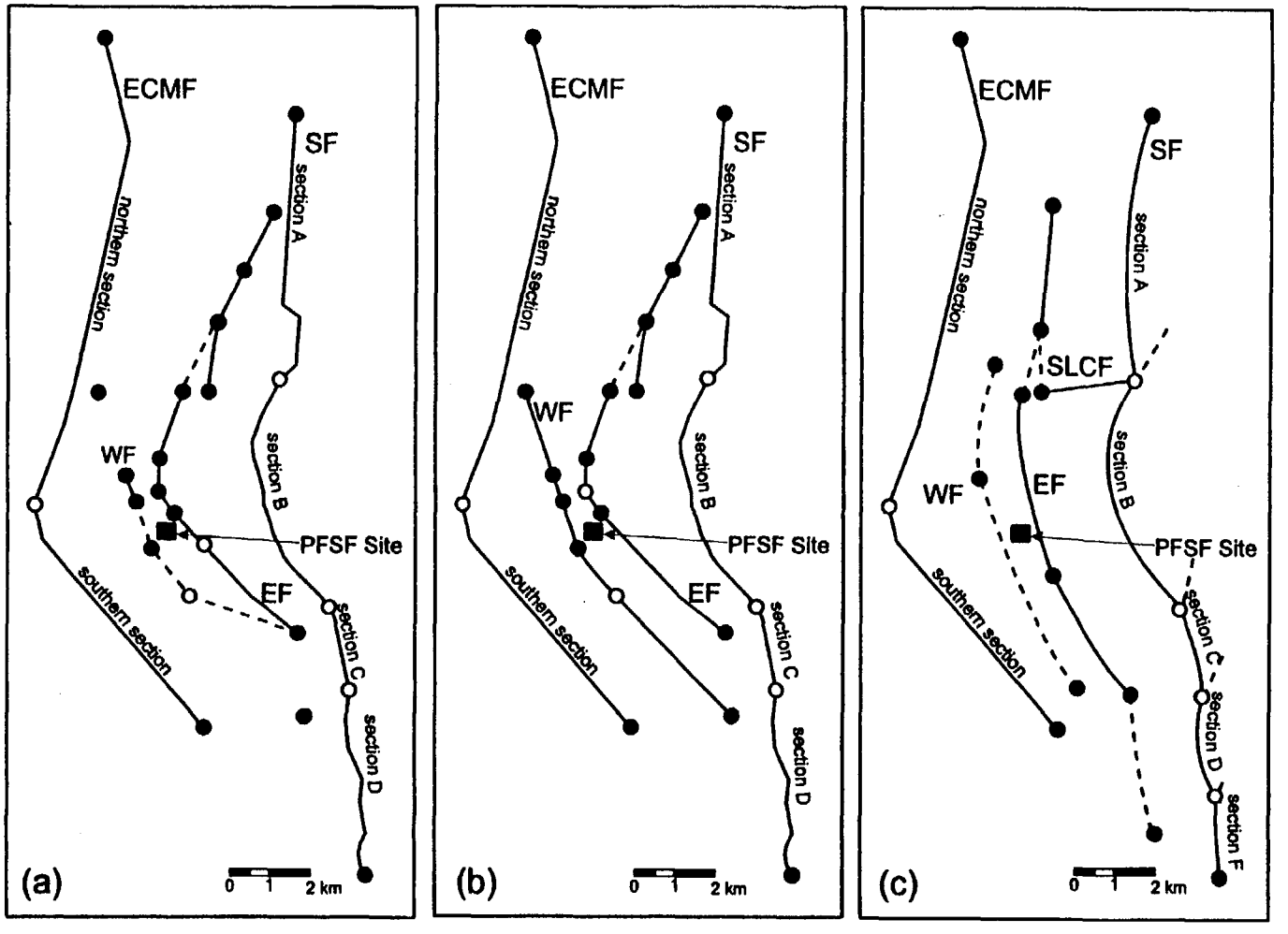

Figure 2-5. Seismogenic fault zone rupture models: ECMF-East Cedar Mountain fault, EF-East fault, SF-Stansbury fault, SLCF-Springline Connecting fault, and WF-West fault. In (a) and (b), fault-rupture Models A and B of Geomatrix Consultants, Inc. (1999a) are shown. In (c), an alternative fault-rupture model is shown based on interpretations of normal fault growth from overlapping *en echelon* fault segments (Crider and Pollard, 1998). Solid lines indicate preferred rupture models. Dashed lines indicate alternative rupture models. Gray circles define individual fault tips of individual rupture segments. Black circles define tips of entire fault length segment.

Probability of activity. Given the evidence of geologically recent activity, Geomatrix Consultants, Inc. (1999a) assigned a probability of activity value of 1 to the Stansbury fault.

Maximum magnitude. Based on the paleoseismic data, Geomatrix Consultants, Inc. (1999a) estimated average displacement for a single event to range between 1.0 and 4.5 m, depending on whether rupture was assumed along the principle fault trace or across the entire fault zone. Given the five possible rupture scenarios, differences in depth of the base of the seismogenic crust (15–20 km) and different possible fault dips (45–65°), a maximum magnitude distribution between **M** 6.4 and **M** 7.5, with a peak at **M** 7.0, was developed for the Stansbury fault.

Slip rate. The newly acquired paleoseismic and geologic evidence indicates a slip rate for the Stansbury fault of 0.4 ± 0.1 mm/yr.

2.1.5.3 East Cedar Mountain Fault

The East Cedar Mountain fault is an east-dipping normal fault that bounds the eastern flank of the Cedar Mountains and juxtaposes Paleozoic bedrock against Quaternary alluvial deposits of Skull Valley. Unlike the Stansbury fault, there is little direct evidence of faulting along the East Cedar Mountain fault other than suspected Quaternary (but not Holocene) fault scarps along the northeastern flank of the mountains (Arabasz et al.,1989). From the surface expression of bedrock outcrops and gravity anomalies that define the subsurface contrast in density between valley sediments and bedrock, Geomatrix Consultants, Inc. (1999a) identified two fault sections, labeled northern and southern on Figure 2-5. Because of the apparent lack of activity compared to the Stansbury fault, these two sections are partitioned into four possible rupture lengths. Maximum rupture length for all four segments is 72 km.

Probability of activity. Given only circumstantial evidence for recent seismic activity, Geomatrix Consultants, Inc. (1999a) assigned a probability of activity of 0.7 to the East Cedar Mountain fault.

Maximum magnitude. There is considerable variability in the maximum magnitude distribution for the East Cedar Mountain fault. In addition to the variability in fault length given the four possible rupture scenarios (Figures 2-5a and 2-5b), the down-dip width of the East Cedar Mountain fault is also uncertain. The balanced cross sections constructed in Geomatrix Consultants, Inc. (1999a) depict Skull Valley as a half graben in which the East Cedar Mountain fault is truncated against the east-dipping East fault (Geomatrix Consultants, Inc., 1999a, Figure 2-1). Thus, the faults may be truncated by the East fault before it intersects the base of the seismogenic crust, thereby limiting the potential rupture area. Considering all these variables, Geomatrix Consultants, Inc. (1999a) estimated a maximum magnitude distribution for the East Cedar Mountain fault between **M** 6.0 and **M** 7.2, with peaks at **M** 6.0, **M** 6.5, and **M** 6.8.

Slip rate. Because of the lack of significant late Quaternary or Holocene deformation on the fault, slip-rate estimates of between 0.04 and 0.1 mm/yr were used. These rates were derived from analogous Basin and Range faults. The slip-rate distribution also included the possibility of a faster slip rate of 0.45 mm/yr, but this alternative was assigned only a 5-percent likelihood in the PSHA.

2.1.5.4 Mid-Valley Faults

Field geological and geophysical modeling conducted by Geomatrix Consultants, Inc. in 1998 and summarized in Geomatrix Consultants, Inc. (1999a) reveals two west-dipping faults in the center of Skull Valley (Figure 2-3), informally named the East and West faults. The following lines of evidence support the existence of these faults: (i) both faults were imaged by proprietary reflection seismic data (Bay Geophysical Associates, Inc.,1999), (ii) at least the East fault matches a significant gravity anomaly revealed in newly acquired proprietary gravity data, and (iii) both faults apparently coincide with disrupted late Quaternary surficial features. The Springline fault in northern Skull Valley, first identified by Rigby (1958), is a similar mid-valley fault. There is, however, no direct evidence for Quaternary activity along the Springline fault.

Geomatrix Consultants, Inc. (1999a) developed several alternative structural models to evaluate the seismic potential of these faults [Figure 2-5(a) and (b)]. Several important alternative rupture scenarios were developed based on differences in interpretations of fault geometry and possible linkage between the faults at depth. First, Geomatrix Consultants, Inc. (1999a) considered whether the West fault is itself a significant and independent seismogenic source or a splay of the East fault. Details of the basis for those interpretations are summarized in Section 2.1.5.5. Second, Geomatrix Consultants, Inc. (1999a) considered the possibility that the East fault links with the Springline fault to form a single large mid-valley fault. Figure 2-6 illustrates the alternatives in which the West fault is a synthetic fault that connects its displacement to the East fault across an overlap zone under the proposed PFSF site and in which the East and Springline faults are connected at depth into a single rupture plane.

Probability of activity. Based on all the geological and geophysical considerations, Geomatrix Consultants, Inc. (1999a) developed the following probabilities of activities for these faults. In all the alternative models and because of the evidence for surface rupture of late Quaternary deposits, the East fault is considered seismogenic and assigned a probability of activity of 1. Depending on the two models shown in Figure 2-5(a) and (b), the probability of activity of the West fault is 0.5 [Model A, Figure 2-5(a)] and 0.7 [Model B, Figure 2-5(b)]. The probability that the Springline fault is seismogenic, independent of its connection with the East fault, is 0.8. There is a 0.3 probability that the Springline fault is connected at depth to the East fault.

Maximum magnitude. Geomatrix Consultants, Inc. (1999a) did not provide a plot to show all the alternative maximum magnitudes for the mid-valley faults. Although referenced in their report to Figure 2-6, the plot was omitted from the figure. Because of all the possible alternatives for fault geometry given the A and B models, coupled with differences in the depth of the seismogenic crust, fault dip, and fault intersection depth, the distribution of maximum magnitudes for the mid-valley faults is large. Independent assessment based on possible fault lengths indicates that the range in maximum magnitude is between about **M** 6.0 and **M** 7.5.

Slip rate. The newly acquired paleoseismic and geologic evidence obtained by Geomatrix Consultants, Inc. (1999a) indicates a slip rate for the East fault of 0.30 ± 0.15 mm/yr, with greatest weight given to 0.30 mm/yr. Because of geologic similarities to the East fault, a similar slip rate was assigned to the Springline fault, although the distribution was flatter to reflect the greater uncertainty. Paleoseismic data on the West fault indicate a slip rate of between 0.05 and 0.07 mm/yr, although this rate is uncertain because it is based on a single set of data.

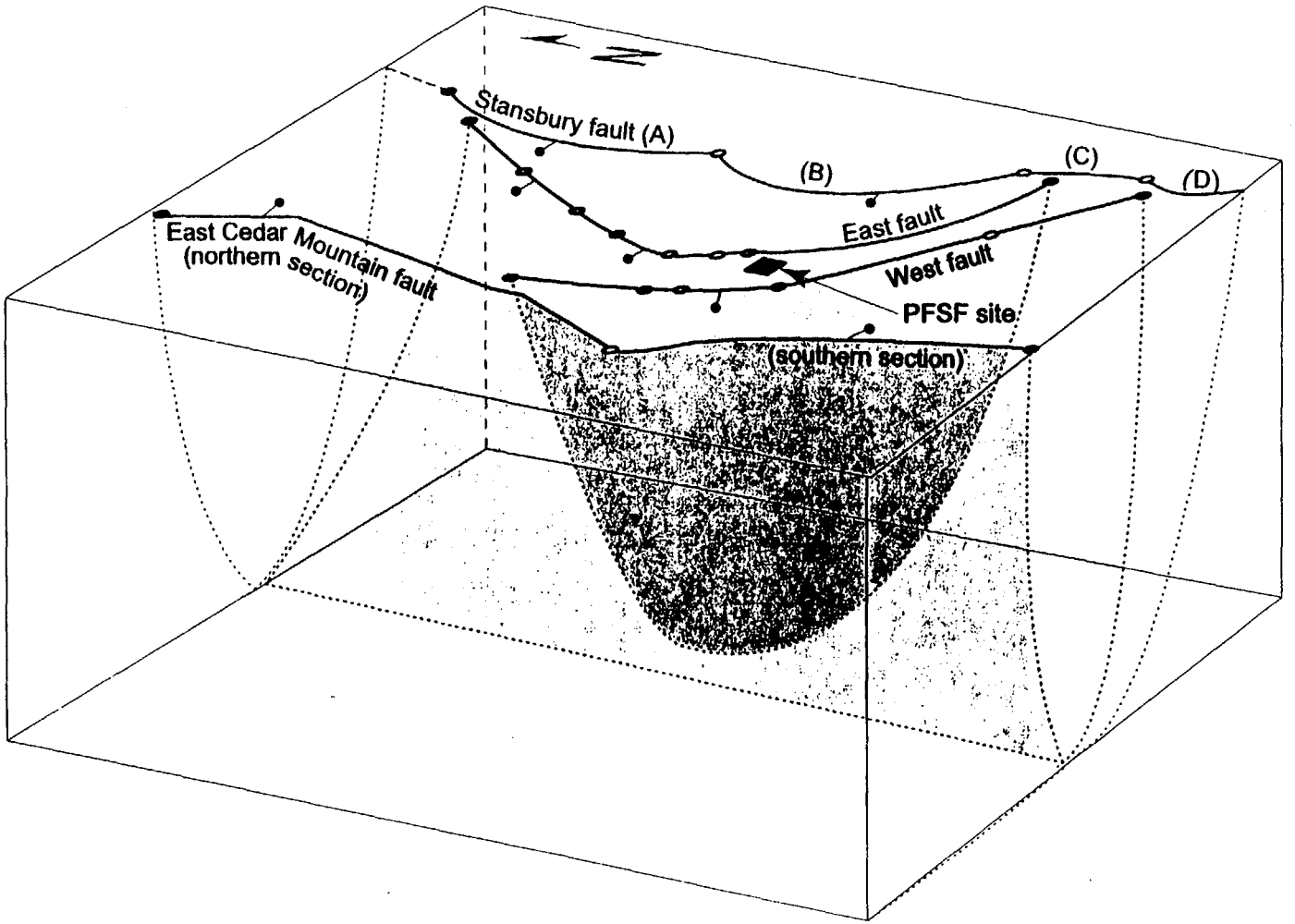

Figure 2-6. Block diagram showing a schematic representation of the three-dimensional configuration of faults in Skull Valley, Utah, based on rupture model B of Geomatrix Consultants, Inc. (1999a). Dashed lines show the fault tip lines in the subsurface.

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2.1.5.5 Alternative Interpretation of the East and West Faults

Origin of Hickman Knolls. A critical aspect of the interpretation of the East and West faults centers on the origin and nature of rocks exposed at Hickman Knolls (Figure 2-3), which are composed of monolithologic carbonate breccias. Two alternatives were presented by Geomatrix Consultants, Inc.

(1) The breccias are part of a detached landslide block of bedrock dislodged from one of the nearby ranges by Tertiary or Quaternary earthquake activity along the range fronts.

(2) The breccias are rooted to the Paleozoic basement beneath the basin fill. In this latter interpretation, brecciation and related features represent *in situ* deformation associated with early postdepositional processes.

Alternative (1), suggested in the original SAR (Private Fuel Storage Limited Liability Company, 1998, Appendix 2A, p. 2), was based on an interpretation of gravity data collected and analyzed by J. Baer of Brigham Young University. Although Geomatrix Consultants, Inc. (1999a) cited some geologic evidence indicating that Hickman Knolls breccias are rooted bedrock, that evidence is equivocal. Indeed, many characteristics of the Hickman Knolls breccias are similar to mapped landslide deposits throughout the Basin and Range (e.g., Yarnold, 1993; Bishop, 1997). Observations of chaotic and low-angle faulting and folding of the Tertiary deposits in trench T-1 also suggest Tertiary landslide activity (Geomatrix Consultants, Inc., 1999a).

Alternative (2), presented in Geomatrix Consultants, Inc. (1999a), was based on Geomatrix Consultants, Inc. modeling of the proprietary industry gravity data and detailed mapping of the meso-scale structures at Hickman Knolls (although the details were not provided for that modeling). Deformation features, especially low-angle and high-temperature ductile shears overprinted by minor low-temperature and brittle faults and fractures, suggest a protracted history of *in situ* deformation of rooted bedrock. In this interpretation, the deformation of the Tertiary sediments in Trench T-1 are considered to represent a local landslide that originated on the flanks of Hickman Knolls itself.

The difference is important to structural interpretations of Skull Valley. In alternative (1), the significant structural relief of the basin would lie east of Hickman Knolls, along both the East or West and Stansbury faults. This interpretation would reduce cumulative displacement along the valley faults, especially along the West fault, and thereby reduce their contribution to the overall seismic hazard. This interpretation is represented in Geomatrix Consultants, Inc. (1999a) seismogenic fault rupture Model A [Figure 2-5(a)], in which the West fault is portrayed as a splay of the East fault. In alternative (2), major relief in the basin lies west of Hickman Knolls with significant displacement along the West fault. In this alternative, the West fault becomes a significant contributor to the overall seismic hazard, as represented in Geomatrix Consultants, Inc. (1999a) seismogenic fault rupture Model B [Figure 2-5(b)]. Alternative (2) is favored in Geomatrix Consultants, Inc. (1999a), although some credence is given to alternative (1). In building the logic tree for seismogenic sources in the PSHA, alternative (1) is given a weight of 0.3 and alternative (2) a weight of 0.7.

Alternative (2), especially its depiction in the two Geomatrix Consultants, Inc. (1999a) cross sections, implies an unusual development of structures in the valley. The cross sections predict transfer of more than 4 km of dip-slip displacement from the West fault to the East fault across the site over a relatively short distance (less than 5 km). In cross section B-B′, there is nearly 5 km of cumulative dip-slip displacement on the West fault and less then 1 km of dip-slip displacement on the East fault. In cross section A-A′, the situation is reversed, with more than 4 km of dip-slip displacement on the East fault and less then 1 km of dip-slip displacement on the West fault. This large transfer of dip-slip displacement from the West fault to the East fault implies dramatic lateral throw gradients along the tips of the two faults (Figure 2-6). Although not unrealistic, such dramatic displacement gradients along faults differ substantially from those observed along many overlapping Basin and Range faults, in which throw gradients are more modest. For example, the largest displacement gradients observed along isolated fault tips are typically around 0.1 and rarely exceed 0.25 (Cartwright and Mansfield, 1998, and references therein). The transfer of such a large displacement as depicted in the Geomatrix Consultants, Inc. (1999a) cross sections requires displacement gradients of 0.8–1.0. The implication of such a large transfer of displacement from the East fault to the West fault is that the overlap zone or relay ramp would be the locus of abundant and active secondary faulting. These transfer zones often are fragmented by numerous small faults and fractures that accommodate significant strain along strike resulting from development of the *en echelon* system (Crider and Pollard, 1998).[1]

Independent analysis of EDCON, Inc. gravity data. To test these models, staff obtained the proprietary gravity data and performed an independent analysis. For this analysis, a series of two-dimensional (2D) models of the EDCON, Inc. gravity data (using the terrain-corrected Bouger gravity data of EDCON, Inc. with a 2.4 g/cm^3 density correction) were constructed using Oasis Montaj™ and GM-SYS™ Version 4.04 software. Two profiles parallel to the structural cross sections presented in Figures 2-1 and 2-2 of Geomatrix Consultants, Inc. (1999a) were modeled (Figure 2-7; see Figure 2-3 for locations of profiles). Overall geometries of faults in each 2D model were taken from the structural cross sections or geologic maps (e.g., Plate 6 of Geomatrix Consultants, Inc., 1999a). The goals of the 2D models were to examine uncertainties in basin thickness and cumulative fault displacement, and test whether Hickman Knolls is in place or a detached landslide block floating in valley fill sediments.

In the 2D gravity models, the crust was simplified to two rock-density types: bedrock consisting of Paleozoic and Precambrian basement rocks and valley fill consisting of Quaternary and Tertiary lacustrine, fluvial, and alluvial sedimentary units and Tertiary andesites. For each profile, several density contrasts were assumed. These ranged between 0.4 and 1.1 g/cm^3 (Tables 2-2 and 2-3). The 0.4 g/cm^3 variation was estimated based on seismic P-wave velocities (Geomatrix Consultants, Inc., 1999a, p.12) following Gardner et al. (1974). The 1.1 g/cm^3 value was estimated based on the different rock units given in Telford et al. (1976).

[1]Ferrill, D.A., J.A. Stamatakos, and D. Sims. 1999. Normal fault corrugation: Implications for growth and seismicity of active normal faults. *Journal of Structural Geology*. (In press).

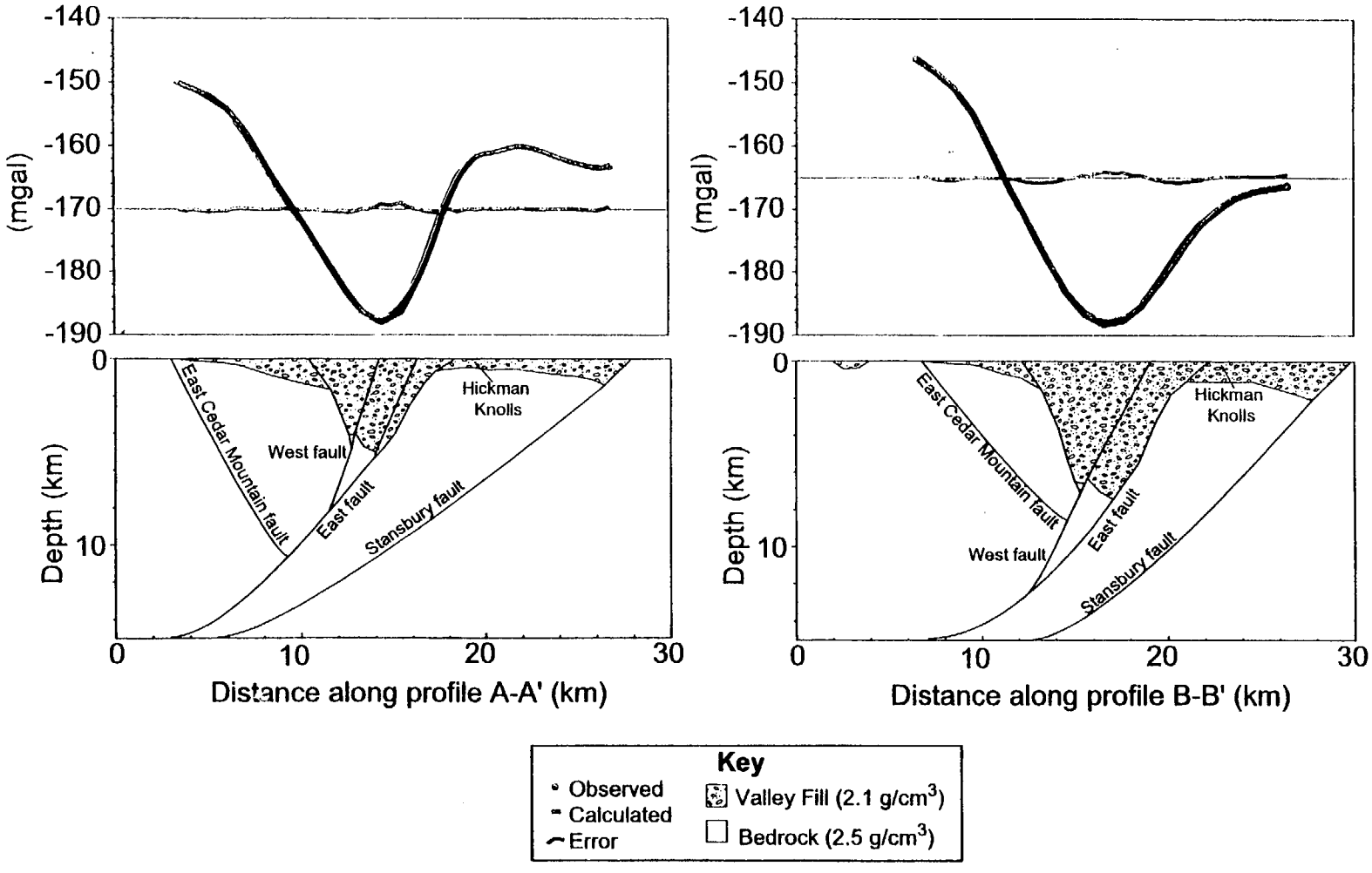

Figure 2-7. Gravity models of profiles across Skull Valley, Utah, based on structural cross sections A-A′ and B-B′. For these models, the densities were derived from P-wave seismic velocities following Gardner et al. (1974). Both gravity profile models predict significant valley fill below Hickman Knolls.

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Table 2-2. Thickness of valley fill below Hickman Knolls estimated from two-dimensional gravity models

Model Cross Section	Thickness of Valley Fill Sediments Below Hickman Knolls			
	Model I $\delta\rho = 0.40$ g/cm^3	Model II $\delta\rho = 0.67$ g/cm^3	Model III $\delta\rho = 0.87$ g/cm^3	Model IV $\delta\rho = 1.07$ g/cm^3
A-A′	5,160 m	2,040 m	1,370 m	1,040 m
B-B′	7,430 m	1,300 m	1,010 m	770 m

Notes: $\delta\rho$ = density contrast between bedrock and valley fill sediments.
Model I Bedrock Density = 2.50 g/cm^3, Valley Fill density = 2.10 g/cm^3
Model II Bedrock Density = 2.67 g/cm^3, Valley Fill density = 2.00 g/cm^3
Model III Bedrock Density = 2.67 g/cm^3, Valley Fill density = 1.80 g/cm^3
Model IV Bedrock Density = 2.67 g/cm^3, Valley Fill density = 1.60 g/cm^3

Table 2-3. Fault throw along the Stansbury, East, and West faults, Skull Valley, Utah

Model Cross Section and Density Contrast	Fault Throw		
	Stansbury	East	West
A-A′—0.40 g/cm^3	1,310 m	4,570 m	100 m
A-A′—0.67 g/cm^3	630 m	1,640 m	280 m
A-A′—0.87 g/cm^3	490 m	1,010 m	200 m
A-A′—1.07 g/cm^3	350 m	590 m	240 m
B-B′—0.40 g/cm^3	2,030 m	6,340 m	210 m
B-B′—0.67 g/cm^3	920m	200 m	1,530 m
B-B′—0.87 g/cm^3	680 m	150 m	660 m
B-B′—1.07 g/cm^3	510 m	100 m	410 m

Conclusions drawn in this review from detailed analyses of the gravity data suggest that alternative (1) is more viable—Hickman Knolls appears to be an isolated and detached block of bedrock dislodged from the nearby ranges as a landslide block. Estimates for the thickness of valley deposits below Hickman Knolls range between several hundred and several thousand meters depending on the density contrast between bedrock and valley fill (Table 2-2).

The greatest thickness of low-density material is for the model with 0.4 g/cm^3 contrast based on densities derived from the P-wave velocities. None of the existing models allows for bedrock to

be exposed at Hickman Knolls. These results support the conclusion that Hickman Knolls is detached bedrock that slid into the valley as a landslide. Given the observed strongly deformed Miocene sediments in Trench T-1, it seems likely that the landslide occurred during the late Tertiary and is not a recent or even Quaternary feature.

There are two important implications to the seismic hazard assessment from this result. First, the modeled geometry of faults is more consistent with observed paleoseismic information, which indicates that the Stansbury fault is the dominant active fault in the region, followed by the East fault. Based on this observation, and a more realistic projection of the valley faults south rather than southeast of the site, an alternative seismogenic fault zone rupture model can be developed [Figure 2-5(c)]. This rupture model predicts that seismicity will be mainly centered on the East and Stansbury faults. The West fault is considered a synthetic splay that connects with the East fault at depth that is not seismogenic (Figure 2-8). This interpretation also incorporates interpretations of normal fault growth from overlapping *en echelon* fault segments (Crider and Pollard, 1998).[2] Based on those models, the Springline fault rather than the East fault appears to connect to the Stansbury fault through Pass Canyon. In this interpretation, Salt Mountain forms a large relay ramp in the Stansbury–Springline *en echelon* system.

Second, the amount of throw along the West fault is significantly less than that predicted in cross section B-B′ (Geomatrix Consultants, Inc.,1999a, Figure 2-2). Maximum throw in the models is 1,500 m, and in most models it is less than 500 m (Table 2-3). Thus, less displacement needs to be transferred across the site from the West to the East fault and throw gradients along the faults are closer to observed values elsewhere in the Basin and Range.

Implications to seismic hazard. Comparisons of implications of the alternative model to the seismic hazard for the PFSF site are illustrated in Figure 2-9, in which the potential PGA and 1-second spectral accelerations are plotted for three different seismic source models. The models compare the interpretation that the West fault is an independent source and the East fault is linked to the Springline fault. Note that the modes are simplistic in that uncertainties in these parameters or in probability of activity are not included in the calculations. The aim of the modeling was to simply assess if Geomatrix Consultants, Inc. (1999a) interpretations of fault geometries and seismic activity lead to a reasonably conservative hazard result.

All three interpretations assessed in Figure 2-9 include the Stansbury and East Cedar Mountain faults assuming complete rupture of the faults with lengths of 73 and 72 km, respectively, and maximum slip rates of 0.46 and 0.07 mm/yr, respectively, as reported in Geomatrix Consultants, Inc. (1999a). In the model labeled PFSF, the East and West faults are considered as independent sources with maximum lengths of 46 and 36 km (Geomatrix Consultants, Inc., 1999a, Table 6-2), respectively, and slip rates of 0.30 and 0.07 mm/yr, respectively, as reported in Geomatrix Consultants, Inc. (1999a). In CNWRA1, the East fault is considered a source with a length of 46 km with a slip rate of 0.30 mm/yr. The West fault is not considered capable of independently generating seismicity. In CNWRA2, the East and West faults are considered as a single source with a combined length of 83 km, based on CNWRA interpretation of fault geometry, and a slip rate of 0.30 mm/yr.

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[2]Ferrill, D.A., J.A. Stamatakos, and D. Sims. 1999. Normal fault corrugation: Implications for growth and seismicity of active normal faults. *Journal of Structural Geology.* (In press).

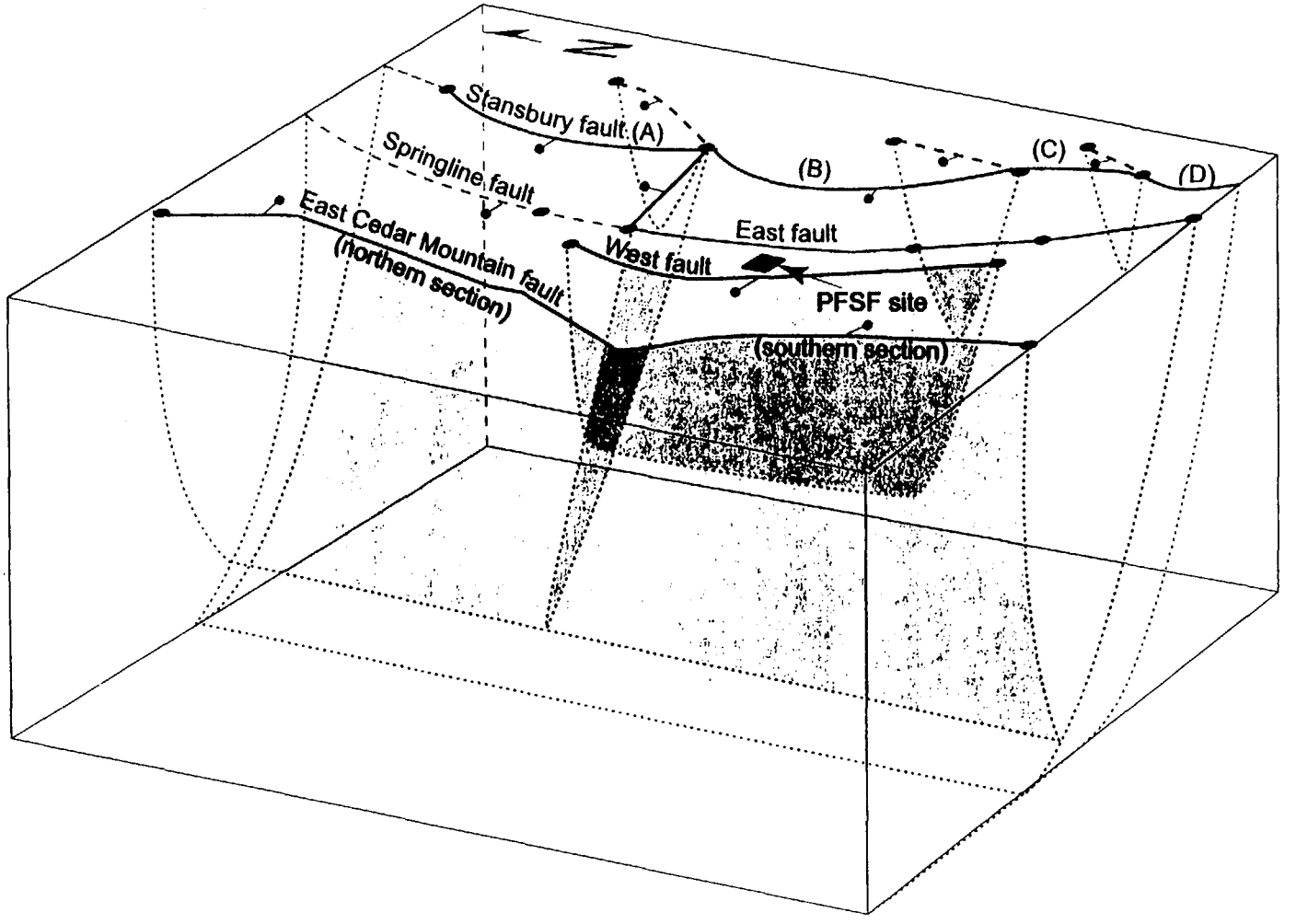

Figure 2-8. Block diagram showing the three-dimensional configuration of faults in Skull Valley, Utah, based on alternative rupture model and interpretations of normal fault growth from overlapping *en echelon* fault segments (Crider and Pollard, 1998). In this model, the West fault is interpreted as a small splay west of the East fault and the Pass Canyon fault as a connecting fault between the Stansbury and Springline faults.

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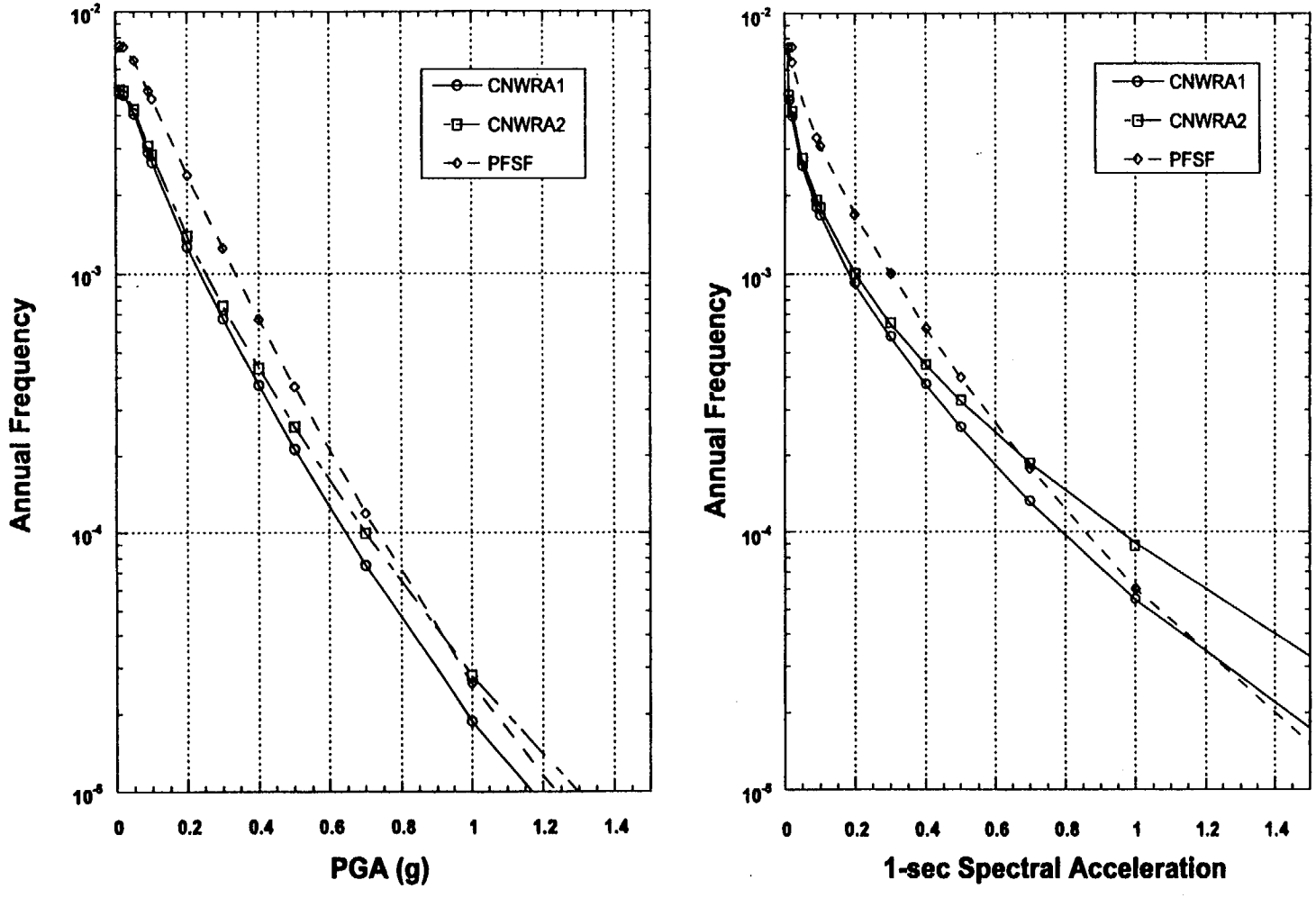

Figure 2-9. Seismic hazard curves showing the difference in peak ground motion and 1-second spectral ground motion for three alternative interpretations of fault source geometry and fault linkage for the East, West, Stansbury, and Springline faults

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Results show that the PFSF model yields the largest hazard compared to the two CNWRA alternatives. Naturally, the effect of including the West fault as an independent source in the PFSF PSHA is mitigated to some degree because varying interpretations of its probability of activity, maximum magnitude, and down-dip extent were not incorporated into this analysis as they were in the more sophisticated logic tree approach provided by Geomatrix Consultants, Inc. (1999a). Nevertheless, these analyses indicate that the Geomatrix Consultants, Inc. seismic hazard assessment is reasonably conservative, at least source characterization, and the PFSF PSHA bounds the independent interpretation of the seismic source geometry and activity developed in this report.

2.1.5.6 Areal Sources

Areal sources represent areas of distributed or background seismicity in which there is no geologic or geophysical evidence that can tie earthquakes to known faults. In this way, areal sources account for earthquakes that occur on unidentified or unidentifiable fault sources. Most commonly areal sources are developed to represent earthquakes with magnitudes that may not necessarily cause surface rupture—those earthquakes with magnitudes that produce rupture areas entirely contained below the surface within the seismogenic crust. In the PFSF PSHA, Geomatrix Consultants, Inc. (1999a) relied on empirical relationships that relate the probability of surface rupture to earthquake magnitude based on empirical data from historical ruptures in the Basin and Range (Wells and Coppersmith, 1994). For example, these results show there is greater than an 80-percent probability that earthquakes with magnitudes of 6.5 will rupture the surface; while there is less than a 20-percent chance that earthquakes with magnitudes of 5.5 will rupture the surface. There is a 50-percent chance that earthquakes with magnitudes of 6.0 will rupture the surface. Based on this empirical relationship, Geomatrix Consultants, Inc. (1999a) concluded that the maximum earthquake that could occur in the areal source zones is **M** 6.0 ± 0.5.

The boundaries of areal sources are drawn to define areas with relatively uniform seismicity and maximum magnitude, generally defined by the historical seismic record. Based on the patterns of historical seismicity (Figure 2-2), Geomatrix Consultants, Inc. (1999a) defined four longitudinal zones: Farwestern, Western, Central, and Eastern (Figure 2-10). As noted, the large concentration of seismicity just east of the Eastern zone was excluded because it was determined that this activity resulted from mining-induced activity (Arabasz et al., 1997).

As shown in Figure 2-4, areal sources do not contribute significantly to the seismic hazard. The significant historical seismicity is along the Wasatch Front in the Eastern zone and northeast and southeast of the site in the Central zone. This is expected given the maximum magnitude of the background earthquake is **M** 6.0 and because much of the area of the Central and Eastern zones is more than 100 km from the site.

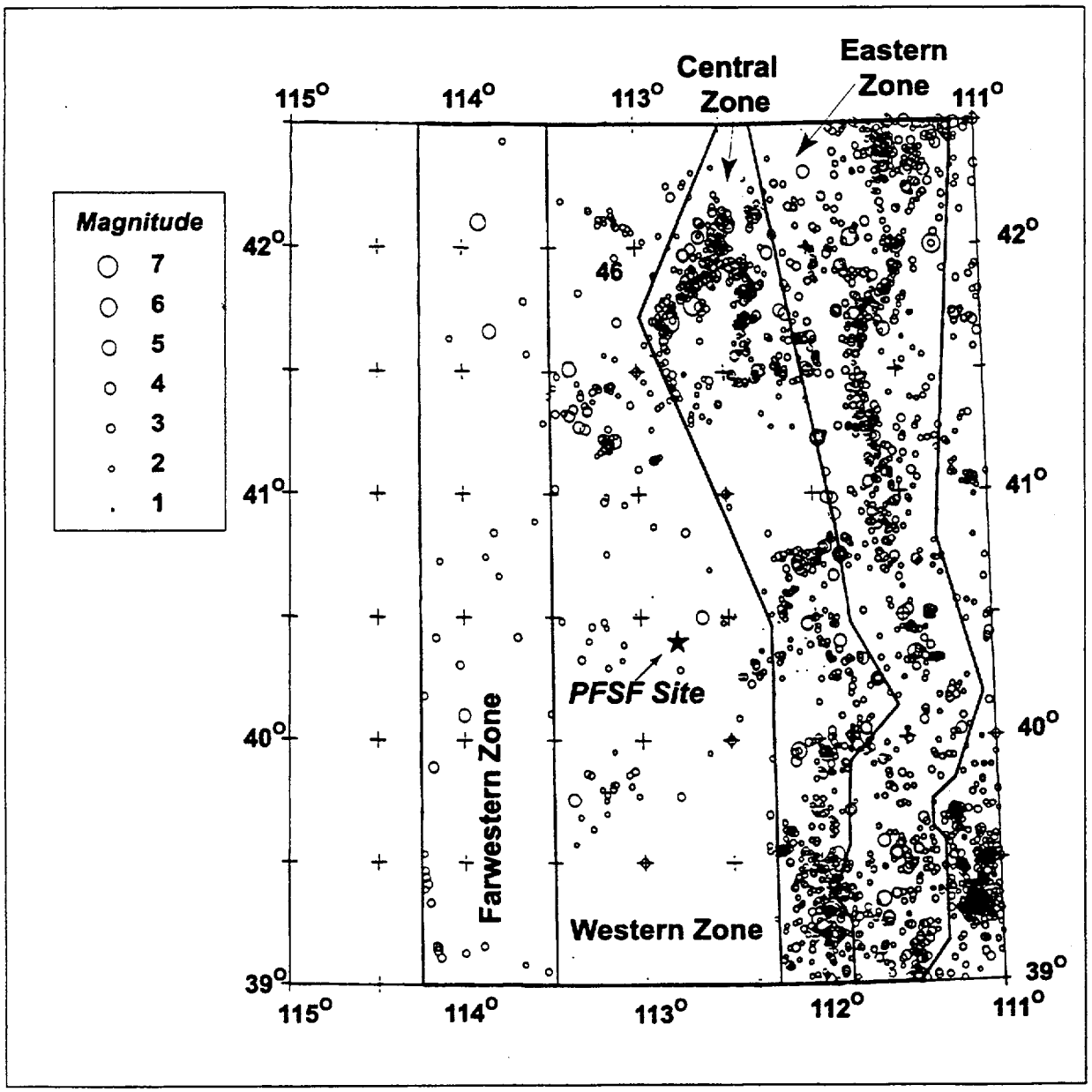


Figure 2-10. Areal source zones for the Private Fuel Storage Limited Liability Company site, adapted from Geomatrix Consultants, Inc. (1999a)

2.2 GROUND MOTION ATTENUATION

The ground motion part of the PSHA is described in Geomatrix Consultants, Inc. (1999a, Section 6.3 and Appendix F). The assessment of design ground motions is described in Geomatrix Consultants, Inc. (1999c).

For purposes of estimating ground motions that may be generated by earthquakes in the regional vicinity of the PFSF site, the results of the PSHA conducted for the proposed nuclear waste repository at Yucca Mountain, Nevada, were used (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998). The YM study provides the results of extensive scientific evaluations and expert elicitations from seven ground motion experts to estimate strong ground motion for a tectonic environment similar to Skull Valley, Utah.

2.2.1 Attenuation for Rock

In the PFSF PSHA, Geomatrix Consultants, Inc. (1999a) elected to use the "original" attenuation models (i.e., empirical and numerical models) that were the basis for the ground motion models developed by a group of experts as part of the YM PSHA. This approach was selected as opposed to using the YM median ground motion attenuation models that were derived as a result of the expert elicitation. As in the YM PSHA, the original ground motion attenuation models were modified to account for differences between California, where the majority of strong ground motion data are recorded, and the Basin and Range in Utah. These differences are attributed to attenuation characteristics associated with the regional geology and earthquake source mechanisms (i.e., strike-slip versus normal faulting). With some modification, 17 median horizontal ground motion attenuation models were used in the PFSF study. These models are shown in Figure 2-11. The same weights assigned to the original models by the experts in the YM PSHA were used in the PFSF study.

A comparison of the median ground motion models for horizontal PGA used in the PFSF PSHA to the expert models used in the YM study indicates that the range of ground motion estimates in the two studies is similar.

2.2.2 Site-Response Analysis

The effects of local site conditions at the PFSF were evaluated on the basis of a site response analysis. To develop a soil profile for the PFSF site, available shear-wave velocity data (Geosphere Midwest, 1997; Bay Geophysical Associates, Inc., 1999) for Skull Valley were used. To model near-surface soils, two sets of soil modulus and damping relationships were used, one developed by Electric Power Research Institute (1993) for alluvial sites and the other based on Silva et al. (1998). The estimation of relative site response factors considered the uncertainty in the site soil properties, alternative rock motion input time histories, and two alternative input ground motion levels corresponding to earthquakes of **M** 6.5 and 7.0.

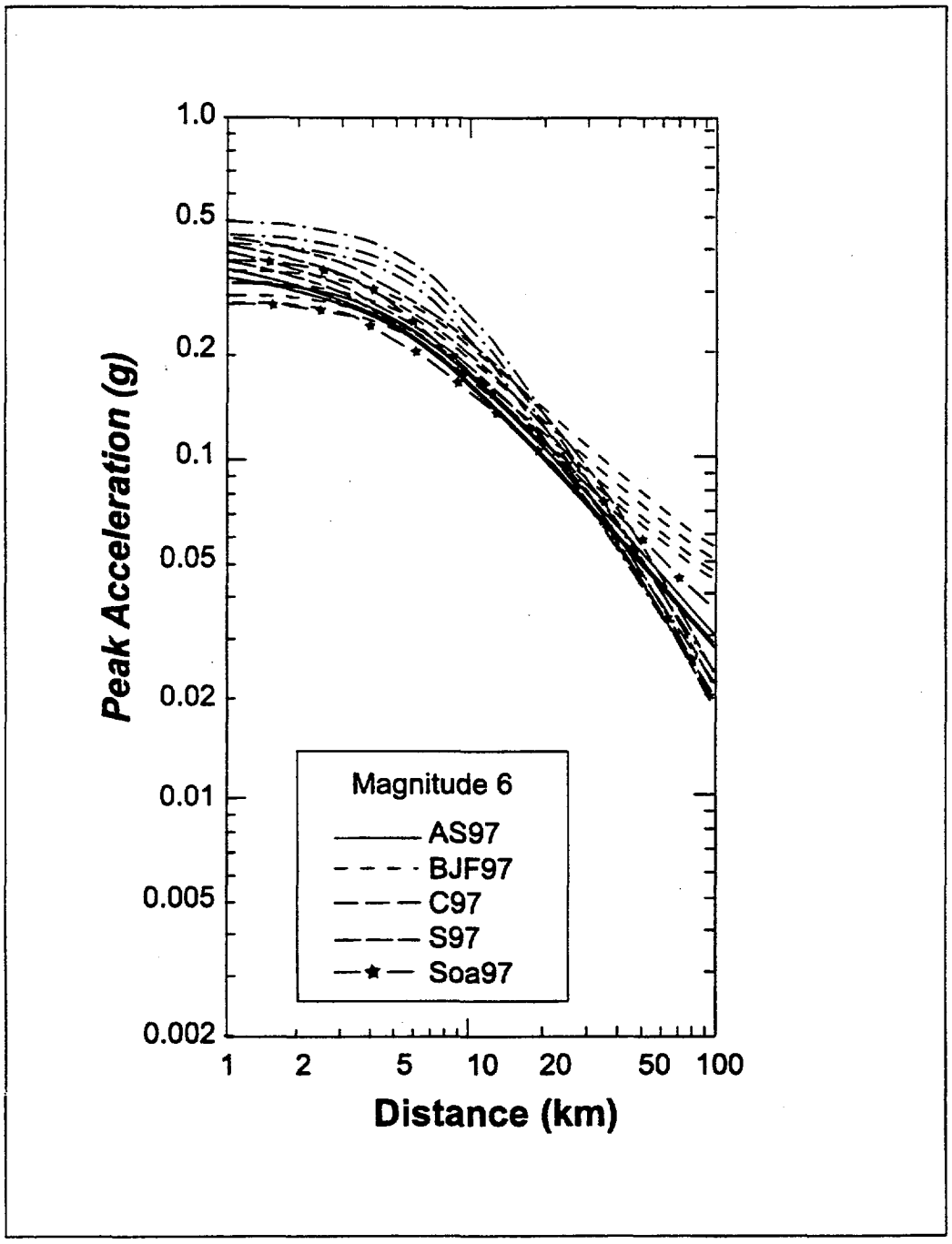


Figure 2-11. Median ground motion attenuation models for horizontal peak ground acceleration for magnitude 6 events used in the Private Fuel Storage Facility Probabilistic Seismic Hazard Analysis

The results of this analysis were used to determine the median relative site response factors for individual ground motion measures. For PGA and spectral acceleration frequencies of 1.33 Hz and greater, ground motion amplifications range from 1.0 (at 1.33 Hz) to 1.15 (at 5–6.7 Hz). For frequencies in the range of 0.25–1.33 Hz, response factors vary from 1.0 to 0.75 (at 0.33–0.67 Hz).

2.2.3 Uncertainties

In the YM PSHA, the ground motion experts provided estimates of ground motion for a range of earthquake magnitudes and source-site distances. These estimates were based on modified empirical California attenuation models and on numerical ground motion models. Based on the ground motion estimates provided by an expert, a functional relationship was fit to these data. This process was repeated for a series of ground motion measures (i.e., PGA spectral accelerations at specified frequencies). The functional models that were derived for each ground motion measure correspond to an expert's estimate of the median (or, equivalently, the mean log) ground motion as a function of earthquake magnitude and distance, and style of faulting. The experts also estimated the aleatory uncertainty in ground motion about the median. In the YM PSHA, the uncertainty in ground motion is estimated in two parts. The first is the range of alternative median ground motion models developed by the group of experts. The second is each expert's uncertainty in the median ground motion and the uncertainty in the aleatory parameter (i.e., logarithmic standard deviation).

Uncertainty model. The ground motion model that predicts the level of ground motion, *y*, that may occur at a site as provided by each expert in the YM study is given in the following form (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998):

$$\ln(y) = \mu + \varepsilon_A + \varepsilon_\mu + \varepsilon_\sigma \qquad (2\text{-}1)$$

$$\mu = g(m,r,sf) \qquad (2\text{-}2)$$

μ — mean log ground motion defined as a function of earthquake magnitude and distance from the earthquake source to the site and the style of faulting.

$g(m,r,sf)$ — function that describes the variation of the mean log ground motion as a function of earthquake magnitude, *m*, distance, *r*, and style of faulting, *sf*. The parameters of this function are derived from ground motion estimates provided by ground motion experts.

ε_A — standard normal variate with a mean of zero and a standard deviation σ_A. The standard deviation models the aleatory uncertainty in the estimate of ground motion.

ε_μ — standard normal variate with a mean of zero and standard deviation σ_μ. The standard deviation models the epistemic uncertainty in the expert's estimate of the mean log ground motion, μ. This parameter may vary with the type of ground motion parameter and earthquake magnitude and distance.

ε_σ — standard normal variate with a mean of zero and standard deviation σ_σ. The standard deviation models the epistemic uncertainty in the expert's estimate of the aleatory standard deviation, σ_A. This parameter may vary with the type of ground motion parameter and earthquake magnitude.

In the YM PSHA, seven experts estimated the parameters for each ground motion measure.

Ground motion aleatory uncertainty. The aleatory uncertainty in the logarithm of ground motions is modeled by a normal distribution with zero mean and a logarithmic standard deviation, σ_A. In the YM PSHA, the standard deviation was estimated by the ground motion experts and defined as a function of earthquake magnitude for each ground motion measure. The PFSF PSHA is silent as to how the aleatory variability is modeled. It is not apparent from the report whether results for the YM study were used or, alternatively, if the variability estimated in the original attenuation models was adopted.

Ground motion epistemic uncertainty. A major part of the YM PSHA involved the assessment of epistemic uncertainties associated with the estimation of earthquake ground motions. The assessment of epistemic uncertainties was based on expert elicitation on ground motions. In the YM PSHA, epistemic uncertainty was modeled in two parts: the variability between expert estimates of the median ground motion and the uncertainty associated with each expert's assessment of the parameters of their ground motion model, μ and σ_A [Eq. (2-1)]. In the PFSF PSHA, Geomatrix Consultants, Inc. did not adopt the approach for modeling epistemic uncertainties used in the YM PSHA.

Skull Valley approach. Based on the weights assigned by the YM ground motion experts and the adjustments made to the original attenuation models, 17 ground motion attenuation models were derived for use in the PFSF PSHA. The individual weights reflect the degree to which a model is considered a true or correct measure of the median ground motion in the PFSF site region. Geomatrix Consultants, Inc. did not consider the uncertainty in the median ground motion models themselves (i.e., σ_μ was not considered).

Because the approach taken in the PFSF PSHA to model the epistemic uncertainty in the median ground motion departs from that taken in the YM PSHA, a comparison of these assessments is made. In the PFSF PSHA, the set of 17 median ground motion attenuation models defines, for a given magnitude and distance, a probability distribution of the epistemic uncertainty (in the median). To assess whether the epistemic uncertainty in the estimate of the median ground motion in the PFSF PSHA is consistent with the YM PSHA, the two distributions are compared at selected magnitude and distances (for a given ground motion measure such as PGA or spectral acceleration).

As an alternative to deriving the full probability distribution for each study, three points on each distribution were determined and compared. These are lower and upper probability levels and the median of each distribution (Figure 2-12). This assessment of the epistemic uncertainty distribution is carried out for selected magnitude and distances.

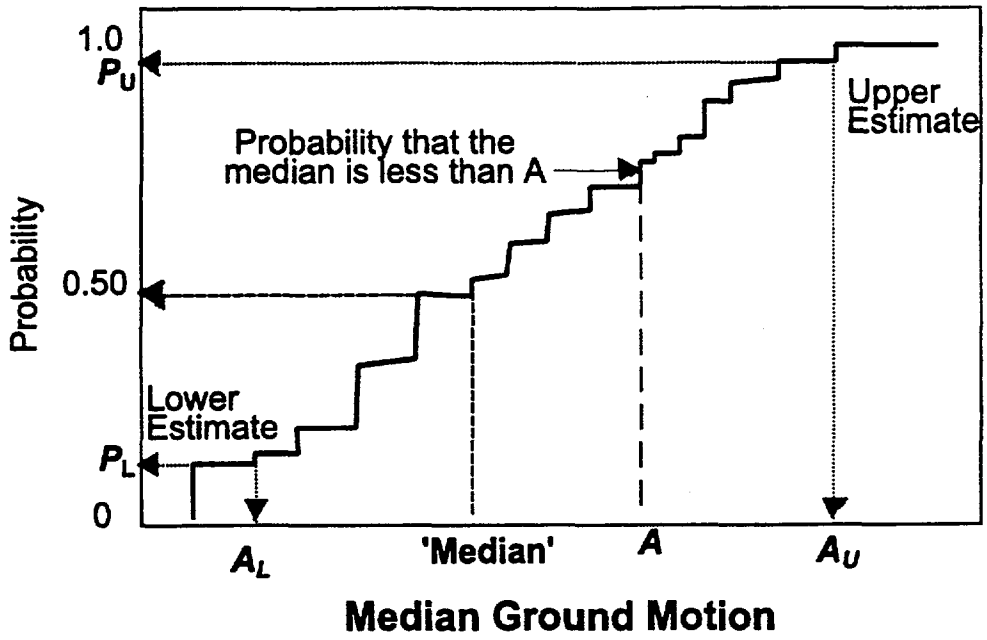


Figure 2-12. Illustration of the lower, median, and upper probability levels of the epistemic uncertainty distribution

Because the two studies are different, the process used to estimate the three points of each distribution is different and requires some explanation.

PFSF PSHA epistemic distribution of the median ground motion. In the PFSF PSHA, 17 median ground motion attenuation models are used to model the epistemic uncertainty. Figure 6-9 in the PFSF PSHA report shows the median attenuation models for PGA for events of magnitude 5, 6, and 7. From this figure, the lower and upper estimates of the median ground motion can be determined for selected distances. Table F-1 in Appendix F gives the weights assigned to each model. The lower and upper median values define the endpoints of the cumulative distribution (Figure 2-13). To estimate the median of this distribution, the geometric average of the lower and upper values is determined. To compare the epistemic distribution on ground motion for the two studies, these points are normalized to the estimated median value.

For purposes of comparison, the median ground motions for events of **M** 6 and 7 at distances of 1 and 10 km are considered. The results of this process are shown in Figure 2-14. In each case, the three points on the distribution are shown.

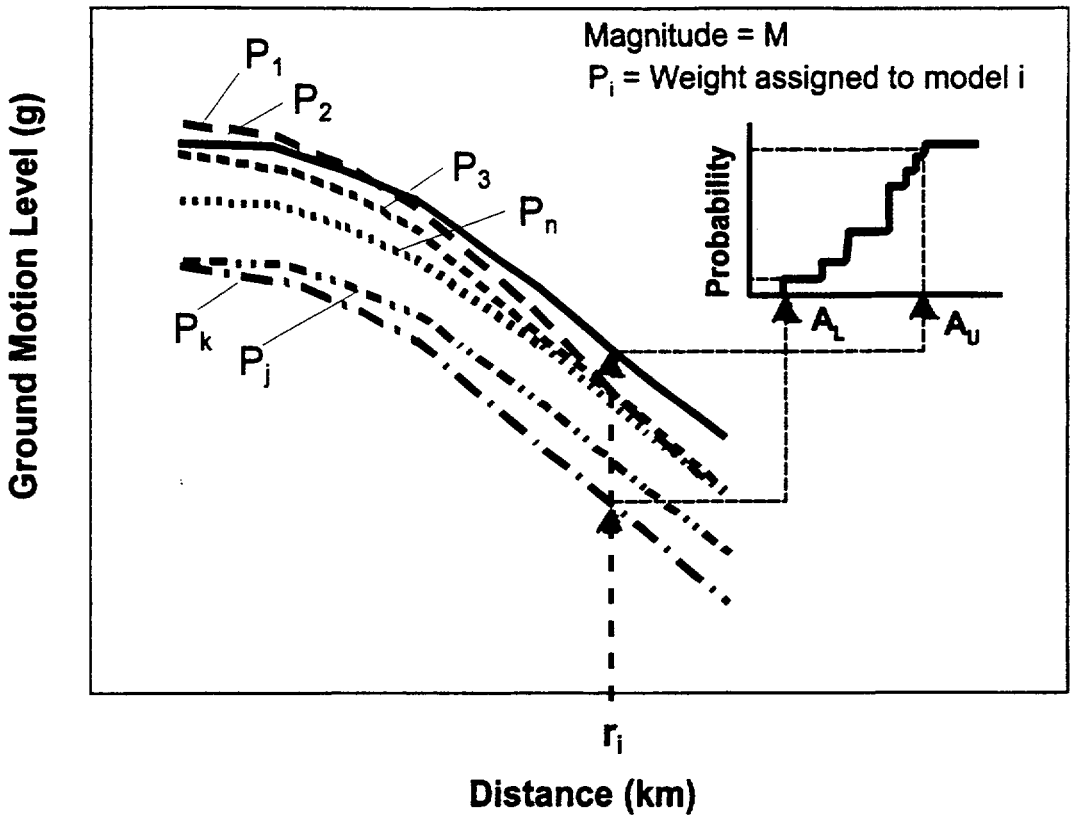
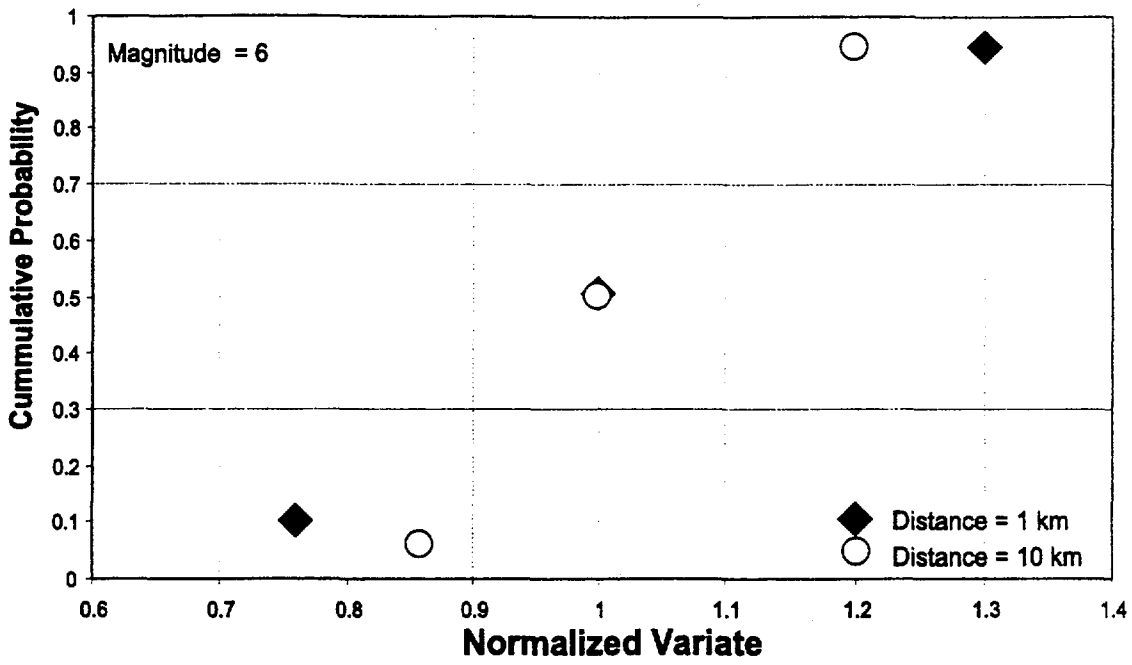


Figure 2-13. Illustration of the Private Fuel Storage Facility probabilistic seismic hazard analysis distribution of median ground motion attenuation models

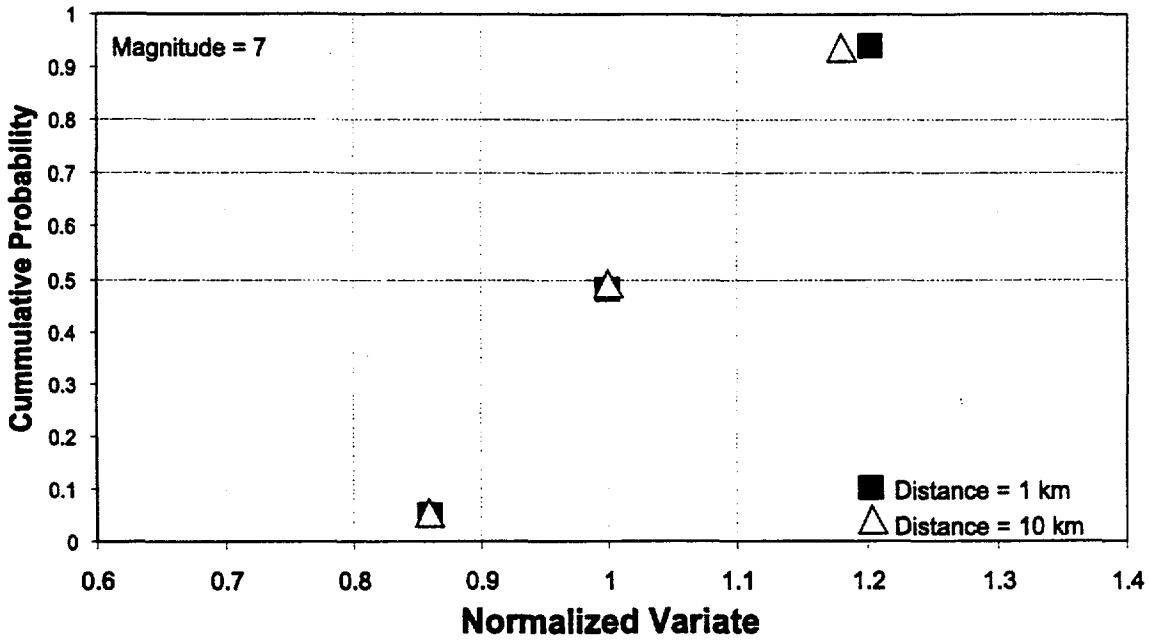
YM PSHA epistemic distribution of the median ground motion. The epistemic uncertainty in the median ground motion in the YM PSHA is estimated in two parts. The first part consists of estimates of the median (or, equivalently, the mean log) ground motion provided by each expert. The second part corresponds to each expert's uncertainty in the own estimate of the median ground motion. This uncertainty is modeled by a lognormal distribution (or a normal distribution in log space) with a median of 1.0 and a logarithmic standard deviation of σ_μ. To approximate the lower and upper estimates of the epistemic distribution on the median ground motion, the following procedure was used:

1. To determine a specified magnitude and distance, identify the low- and the high-median ground motion estimates (from Figure 6-9 in the PFSF PSHA report).

2. To estimate the median of the epistemic uncertainty distribution, take the geometric average of the low- and the high-median values (from Step 1).



(a)



(b)

Figure 2-14. Epistemic uncertainty on the median ground motion estimates in the Private Fuel Storage Facility probabilistic seismic hazard analysis for peak ground acceleration events of magnitudes (a) 6.0 and (b) 7.0 at distances of 1 and 10 km

3. To estimate the upper end of the epistemic distribution, determine the plus one standard deviation level from the high-median estimate (obtained in Step 1). The logarithmic standard deviation, σ_μ, of the lognormal distribution was provided by the ground motion expert whose model generated the highest median estimate. This step is illustrated in Figure 2-15. The cumulative probability that this value could be exceeded is 0.16 (the probability that the plus one standard deviation point will be exceeded) times the weight associated with the expert whose model produced the highest estimate (1/7, because the expert inputs were weighted equally).

4. To estimate the lower end of the epistemic distribution, the minus one standard deviation level is determined from the low median value (obtained in Step 1). The logarithmic standard deviation, σ_μ, of the lognormal distribution was provided by the ground motion expert whose model generated the lowest median estimate. This step is illustrated in Figure 2-15. The cumulative probability that the median will be less than this value is 0.16 (the probability that the plus one standard deviation point will be exceeded) times the weight associated with the expert whose model produced the lowest estimate (1/7, because the experts were equally weighted).

This process provides an approximate estimate of lower and upper cumulative probability points on the epistemic uncertainty distribution. This approximation is due in part to the fact that lognormal distribution, which defines the uncertainty in the expert's estimate of the median, extends beyond the plus/minus one standard deviation levels. As a result, some credibility is assigned by the experts to lower and higher median values. Figure 2-16 shows the results of this process for **M** 6.5 events for PGA and distances of 1 and 10 km.

Comparison of the PFSF and YM estimates of epistemic uncertainty. Figure 2-17 compares the epistemic uncertainty distributions for the two studies for the median PGA for events that occur 1 km from a site. Figure 2-18 provides a similar comparison for events that occur 10 km from a site. In both figures, the PFSF PSHA results for **M** 6 and 7 results are compared to the YM PSHA results for **M** 6.5.

At both distances, there is a significant difference in the range of the epistemic distributions, particularly at the upper level. For example, at the 1-km distance (Figure 2-17), the normalized variate at the 0.98 probability level in the YM study is more than a factor of 2 times higher (for **M** 6 and 7) than the 0.94 probability level in the PFSF distribution. A similar observation holds at 10 km where the YM PSHA value is approximately 1.74 times greater than the highest PFSF value (corresponding to **M** 6).

From these comparisons, it is concluded the uncertainty in the median ground motion as modeled in the PFSF PSHA is less than the epistemic uncertainty assessed by the ground motion experts in the YM PSHA. If the epistemic uncertainty in ground motion in the PFSF PSHA mirrored the approach followed in the YM analysis, it is anticipated the estimated mean hazard at the PFSF site would be higher.

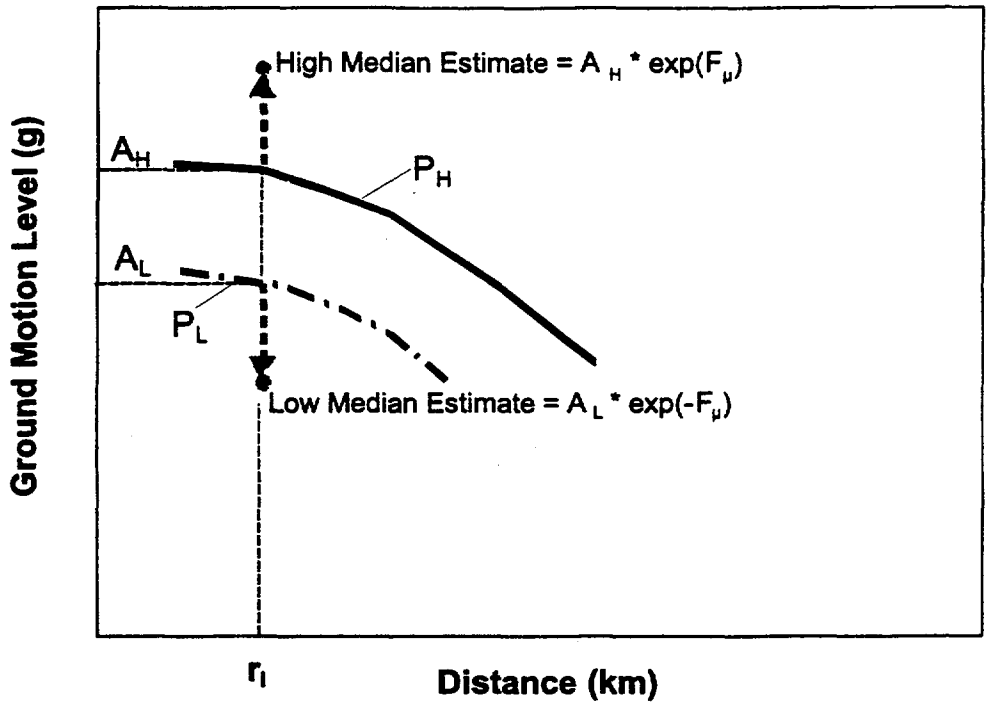


Figure 2-15. Illustration of the process to estimate the lower and the upper median ground motion levels in the Yucca Mountain probabilistic seismic hazard analysis

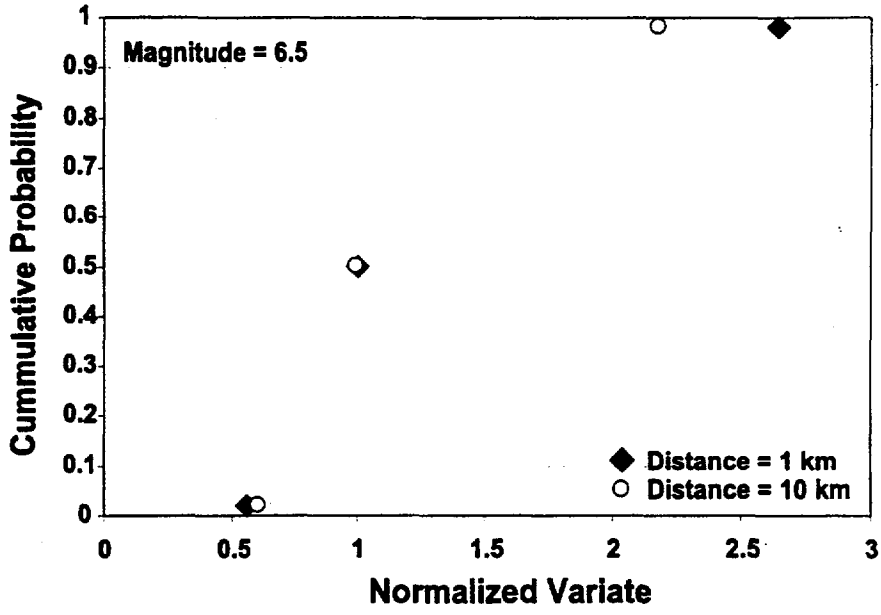


Figure 2-16. Epistemic uncertainty in the median ground motion estimates for peak ground acceleration in the Yucca Mountain probabilistic seismic hazard analysis for magnitude 6.5 events at distances of 1 and 10 km

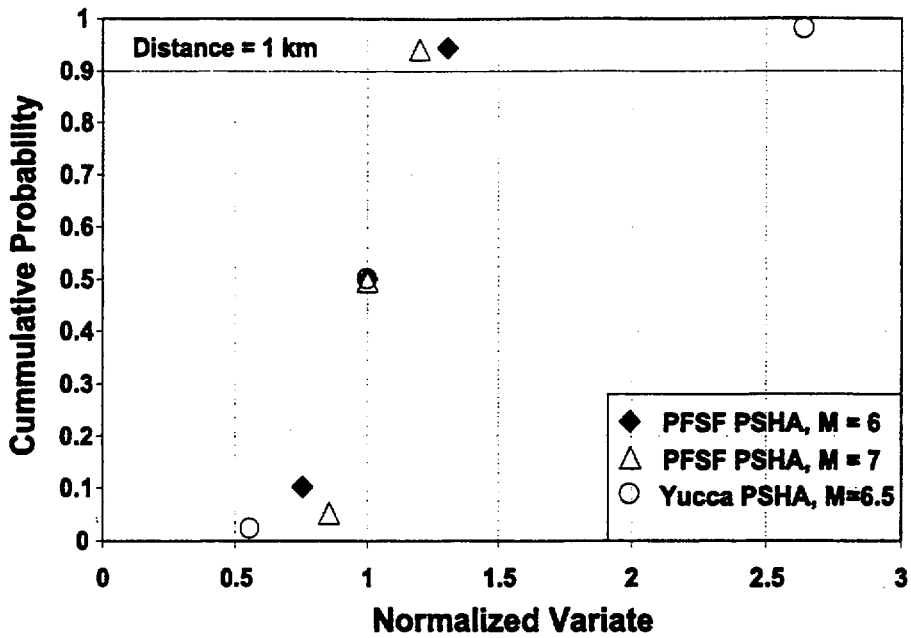


Figure 2-17. Comparison of the estimates of the epistemic uncertainty in the Private Fuel Storage Facility and the Yucca Mountain probabilistic seismic hazard analysis in the median peak ground acceleration at a distance of 1 km

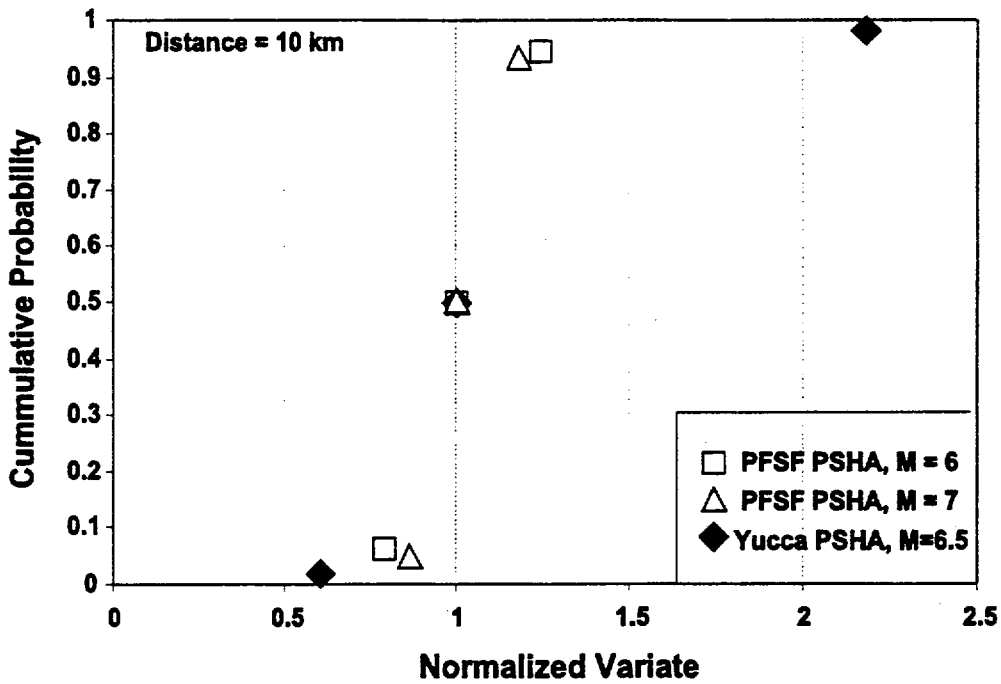


Figure 2-18. Comparison of the estimates of the epistemic uncertainty in the Private Fuel Storage Facility and the Yucca Mountain probabilistic seismic hazard analysis in the median peak ground acceleration at a distance of 10 km

To evaluate the effect the uncertainty in ground motion attenuation has on the site mean hazard, a series of example hazard calculations were performed. As a base case, the seismic hazard results for CNWRA1 for PGA and spectral acceleration at 1 Hz described in Section 2.1 were used. To model the epistemic uncertainty in the median ground motion, 100 values from a lognormal distribution were sampled. In the YM PSHA, σ_μ [Eq. (2-1)], which varies with magnitude and distance, was estimated by each ground motion expert. For source-to-site distances less than 10 km, σ_μ for PGA varies from approximately 0.20–0.76. However, the majority of the expert estimates of σ_μ lie in the range 0.20–0.55. For spectral acceleration at 1.0 Hz, the estimates of σ_μ lie in the range 0.20 to 0.80; however, the majority of the expert estimates are in the range 0.20–0.42. For purposes of the sensitivity analysis, two values of σ_μ were considered, 0.30 and 0.60. The same values of σ_μ were used for PGA and spectral acceleration.

Figure 2-19 compares the results for PGA for CNWRA1 and the mean of the 100 hazard calculations for σ_μ of 0.30 and 0.60. Figure 2-20 shows a similar comparison for spectral acceleration at 1 Hz. For σ_μ of 0.30, the difference between the CNWRA1 result and the mean of the 100 samples for both PGA and spectral acceleration is small, particularly for frequencies greater than 10^{-4} per year. For σ_μ of 0.60, the effect is greater, particularly for frequencies of exceedance of 10^{-3} and less. For example, at a frequency of exceedance per year of 10^{-4}, PGA levels increase from approximately 0.64 to 0.95g. For spectral acceleration at 1 Hz, ground motions increase from approximately 0.78 to 1.05g.

These sensitivity calculations further suggest the mean seismic hazard for the PFSF site may be underestimated, particularly for ground motion levels with frequencies of exceedance per year less than 10^{-3}. However, because the epistemic uncertainties vary with magnitude, distance, and ground motion parameter (i.e., PGA and spectral accelerations), it is difficult to estimate the magnitude of the increase in the mean hazard.

Modeling earthquakes in the near field. As part of the seismic hazard calculations, earthquake hypocenters are equally likely to occur along a fault. Given the occurrence of an earthquake, fault rupture was modeled in the PFSF PSHA using the mean rupture area-magnitude model of Wells and Coppersmith (1993). However, the variability in rupture area was not considered as part of the seismic hazard calculation. This approach is consistent with general PSHA practice, because it has been observed that consideration of this variability does not affect the estimate of the site hazard (Bender, 1984).

Given the proximity of the East, West, Stansbury, and East Cedar Mountain faults to the PFSF site, the potential sensitivity of the site seismic hazard results to the variability in fault rupture in the near field was examined. Sample hazard calculations for a fault similar in geometry to the East fault were made. In these calculations, a maximum magnitude of 6.5 was considered and the seismic activity rate for earthquakes of **M** 5 and greater was set to 10^{-3} events per year. A b-value of 0.9 was used. Ground motion was modeled using the Somerville attenuation model developed in the YM PSHA for spectral acceleration at 1 Hz. For these calculations, a line source model was used, with the source placed at a depth of 3 km.

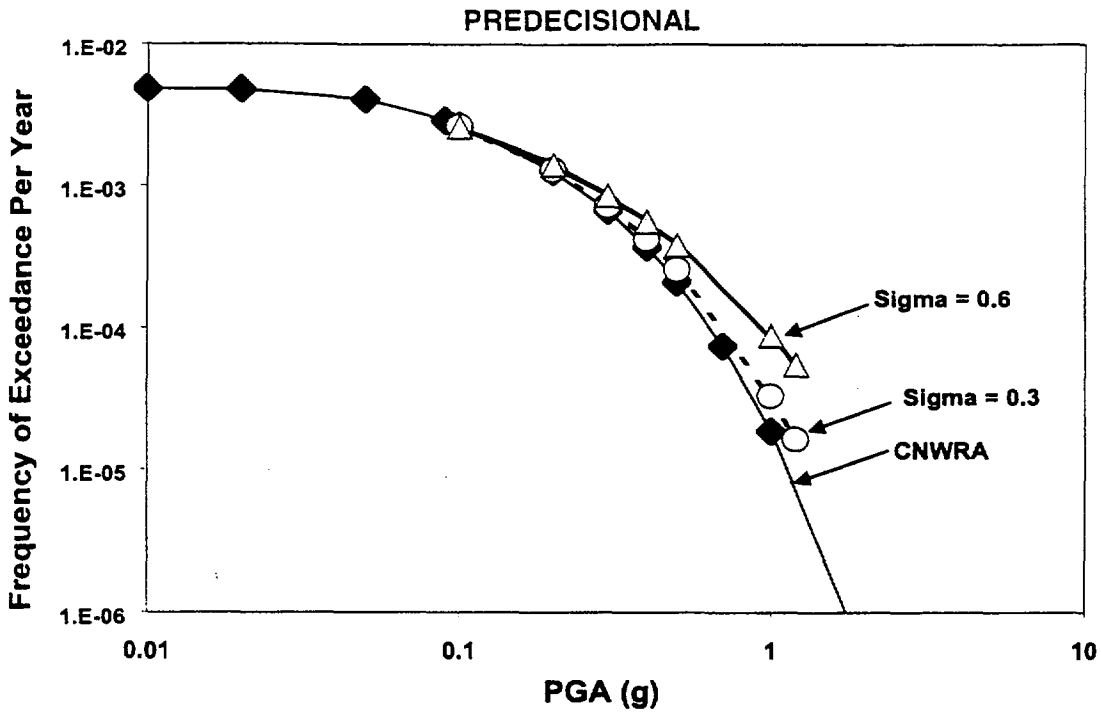


Figure 2-19. Sensitivity results for peak ground acceleration comparing the Center for Nuclear Waste Regulatory Analyses results with the mean hazard curve derived for two estimates of the epistemic uncertainty in the median ground motion; σ_μ of 0.30 and 0.60

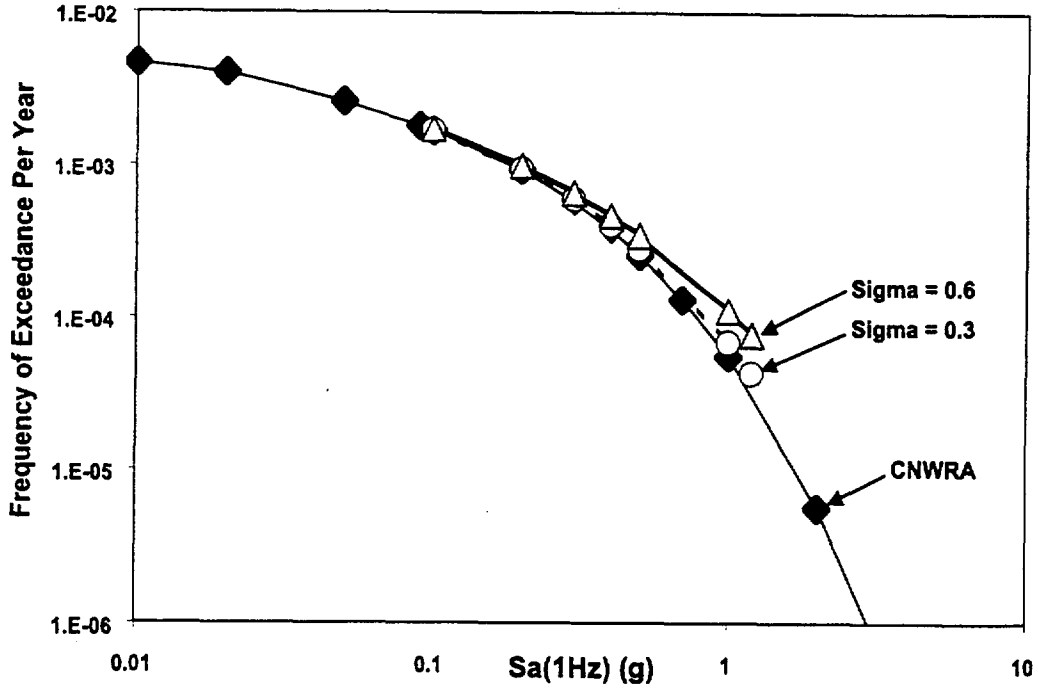


Figure 2-20. Sensitivity results for spectral acceleration at 1 Hz comparing the Center for Nuclear Waste Regulatory Analyses results with the mean hazard curve derived for two estimates of the epistemic uncertainty in the median ground motion; σ_μ of 0.30 and 0.60

The results of these calculations indicate that even for near-source conditions, considering the variability in fault rupture dimensions does not affect the estimate of the site hazard. Additional sensitivity calculations for other source-site geometries confirm this general observation.

2.3 PROBABILISTIC SEISMIC GROUND MOTION HAZARD

Potential seismic hazard at Skull Valley has been evaluated by Geomatrix Consultants, Inc. specifically for siting the proposed PFSF using both deterministic (Geomatrix Consultants, Inc., 1997, 1999b) and probabilistic approaches (Geomatrix Consultants, Inc., 1999a,c). No other site-specific seismic hazard analyses at Skull Valley exist in the literature. However, a wealth of information exists in historical earthquakes, seismicity, and seismic hazards in the surrounding areas. Examples of such previous studies include Arabasz et al. (1992), Hecker (1993), and Pechmann and Arabasz (1995). Although most of these previous studies could not be used to derive seismic ground motion hazard for the proposed Skull Valley PFSF site, they provide background information for characterizing potential seismic sources and earthquake recurrences. The Geomatrix Consultants, Inc. work relied, to some extent, on this existing information.

2.3.1 Methodology of Probabilistic Seismic Hazard Analysis and Implementation

The Geomatrix Consultants, Inc. (1999a) PSHA uses methodology and basic equations well established in the literature (e.g., Cornell, 1968, 1971; McGuire, 1976, 1978; Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998). Calculation of probabilistic seismic ground motion hazard requires specification of three basic inputs: (i) geometric characteristics of potential sources, (ii) earthquake recurrence characteristics for each potential source, and (iii) ground motion attenuation estimates. Details of these inputs to the PSHA at Skull Valley have been evaluated in Sections 2.1 and 2.2. The calculations of PSHA include calculation of seismic hazard from each individual source and calculation of total hazard from all potential sources. Such calculations establish hazard curves that depict the relationship between levels of ground motion and probabilities (frequencies) at which the levels of ground motion are exceeded. The treatment of uncertainty in the Skull Valley PSHA followed the logic tree approach, as discussed in Sections 2.1 and 2.2. In Geomatrix Consultants, Inc. (1999a) computations, fault sources were modeled as segmented planar surfaces. Areal sources were modeled as a set of closely spaced parallel fault planes occupying the source regions. The distance density functions were computed assuming that a rectangular rupture area for a given size earthquake is uniformly distributed along the length of the fault plain and located at a random point on the fault plain. Depth distribution for earthquakes was based on depth distribution of recorded historical earthquakes along the Wasatch Front. The rupture size (mean rupture area) of an event was estimated based on the empirical relation of Wells and Coppersmith (1994). The argument of using the mean rupture area is the study of Bender (1984) that shows nearly equal hazard results using the mean estimates of rupture size and considering statistical uncertainty in rupture size. The minimum earthquake magnitude considered in the Geomatrix PSHA was **M** 5 (Geomatrix Consultants, Inc., 1999a).

2.3.2 Hazard Results

Mean and percentile (95th, 85th, 50th, 15th, and 5th) peak ground motion and 1-Hz spectral (5-percent damped) acceleration hazard curves were calculated and presented in Geomatrix Consultants, Inc. (1999a) for horizontal and vertical motions. These curves are represented in Figures 2-21 and 2-22 of this review report. They are results for free-field motions at the ground surface accounting for the estimated local site effects. The mean PHA is 0.38 and 0.49g for 1,000- and 2,000-year return periods, respectively. The mean PVA is 0.36 and 0.54g for 1,000- and 2,000-year return periods, respectively. Equal-hazard response spectra for return periods of 1,000 and 2,000 years (mean annual probabilities of exceedance of 1×10^{-3} and 5×10^{-4}, respectively) were calculated and presented in Geomatrix Consultants, Inc. (1999c) and represented in Figure 2-23 of this review report.

Contributions of individual seismic sources were calculated and the results show that the dominating sources are the Stansbury, East-Springline, and East Cedar Mountain faults for PGA for return periods greater than 1,000 year and for 1-Hz spectral acceleration for a return period greater than 2,000 years. Deaggregation results show that the total hazard is dominated by ground motions from nearby **M** 6 to 7 events. Sensitivity results indicate that the choice of attenuation relationship is a major contributor to uncertainty in the hazard calculation. Geomatrix Consultants, Inc. (1999a) sensitivity results also indicate (i) alternative models for the geometry and extent of the West fault have little effect on the total hazard because the East fault dominates the hazard from the Skull Valley faults as a result of its higher estimated slip rate and the alternative models for West fault have only minor effects on the parameters of the East fault; (ii) the West fault, if considered as an independent source or as a secondary feature has minimal impact on the hazard; and (iii) the East and Springline faults, if combined as a single source produces slightly higher hazard at low probabilities of exceedance and for longer period motions than separating them as individual fault sources. Figure 2-24 shows Geomatrix Consultants, Inc. (1999a) summary of contributions to the uncertainty in the total hazard at the proposed Skull Valley PFSF site for a return period of 2,000 years. It shows that the major contributors to the total uncertainty in the hazard are the selection of attenuation relationships, assessment of maximum magnitude, recurrence rate, and magnitude distribution.

2.4 DETERMINISTIC SEISMIC GROUND MOTION HAZARD

2.4.1 1997 Geomatrix Consultants, Inc. Initial Deterministic Analyses

Site-specific deterministic ground motion hazard for the proposed Skull Valley PFSF was initially assessed by Geomatrix Consultants, Inc. (1997), in which two potentially capable fault sources were identified to be within 10 km of the site, namely, the East Cedar Mountain and Stansbury faults. Their closest distances to the site were estimated to be about 9.5 km to the Stansbury fault and 9 km to the East Cedar Mountain fault. The potential for a random nearby earthquake was considered by including an areal source within 25 km of the site.

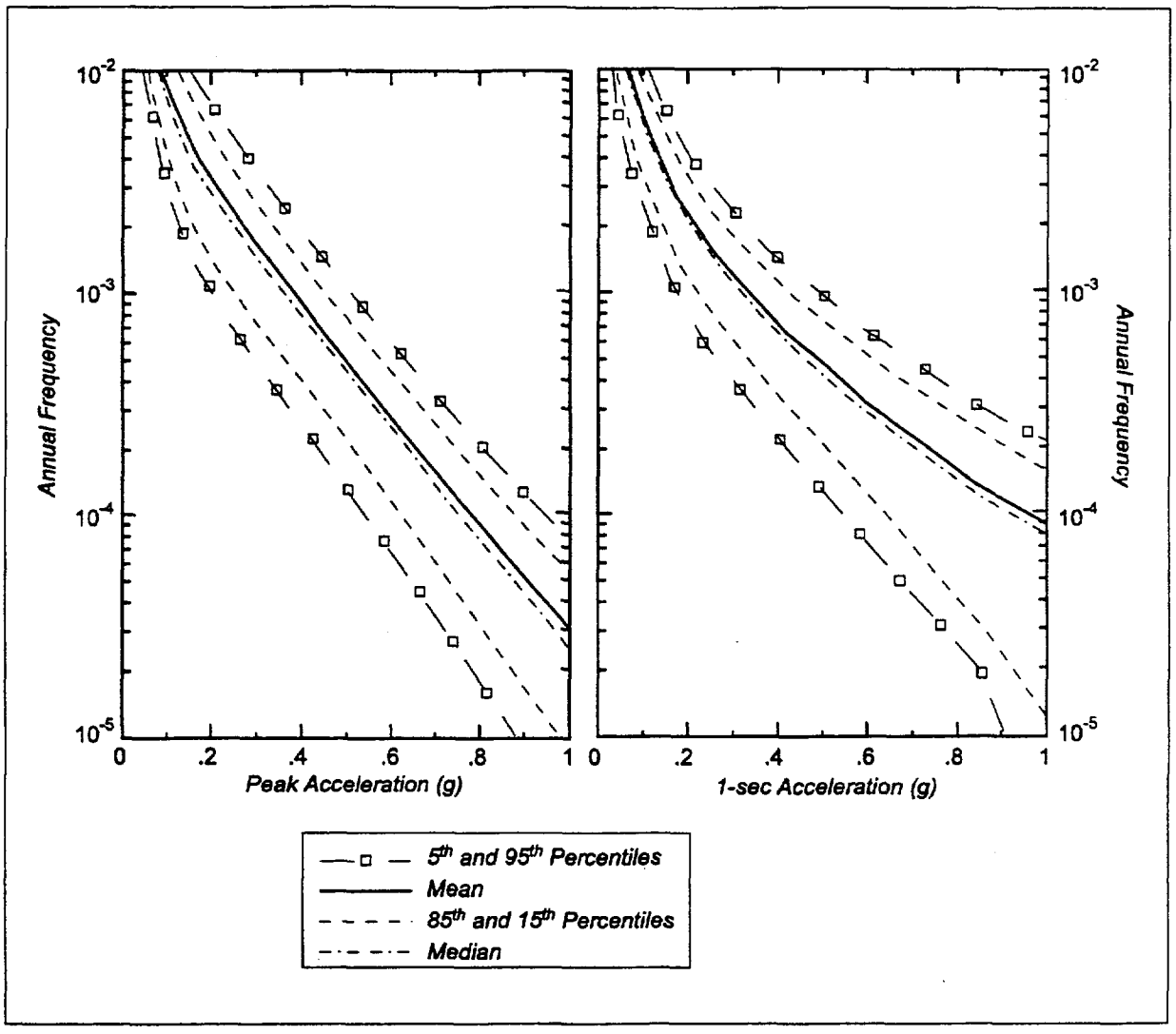


Figure 2-21. Peak and 1-Hz spectral (5-percent damping) horizontal ground motion hazard curves for the proposed Skull Valley Private Fuel Storage Facility site (after Geomatrix Consultants, Inc., 1999a)

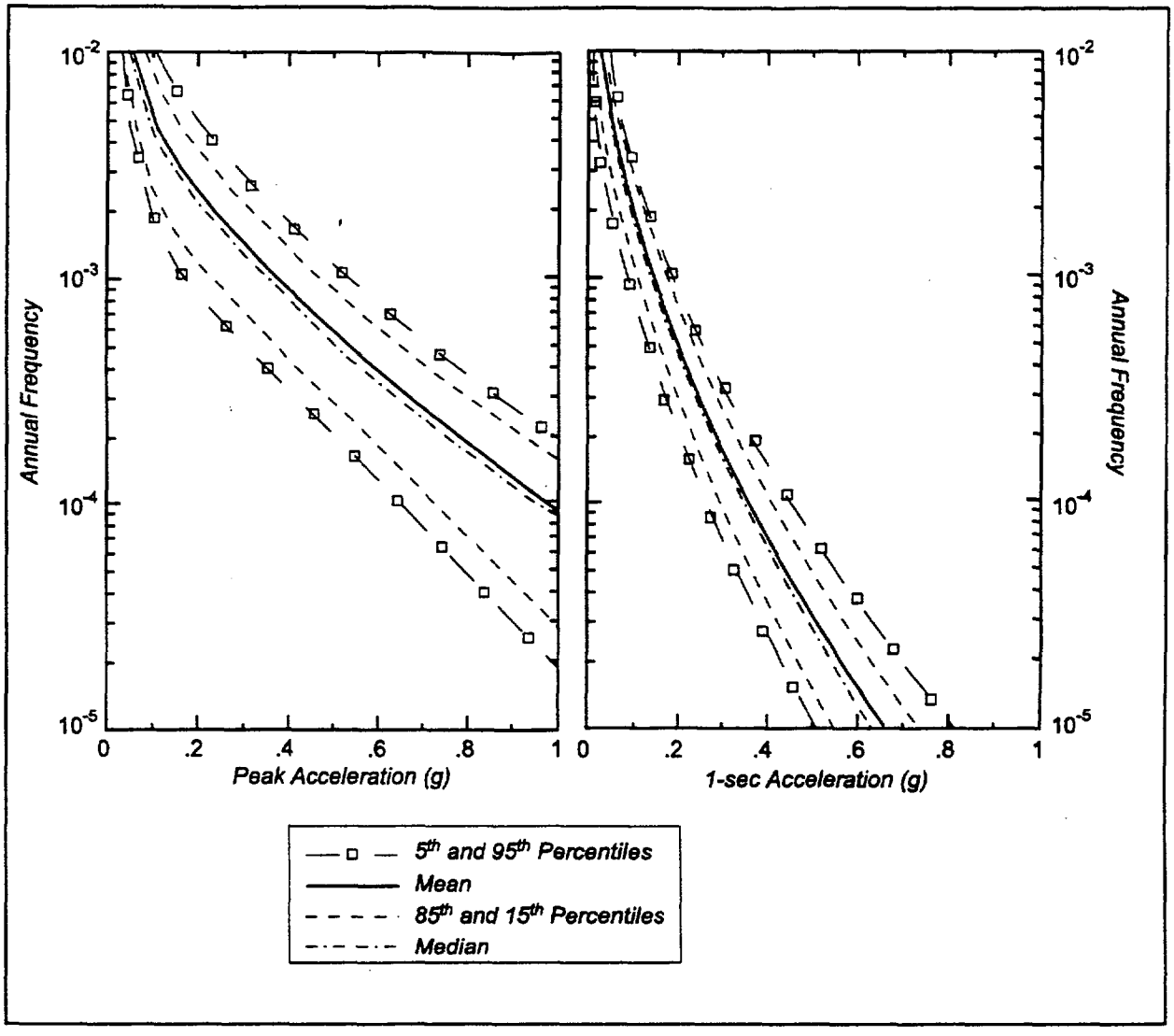


Figure 2-22. Peak and 1-Hz spectral (5-percent damping) vertical ground motion hazard curves for the proposed Skull Valley Private Fuel Storage Facility site (after Geomatrix Consultants, Inc., 1999a)

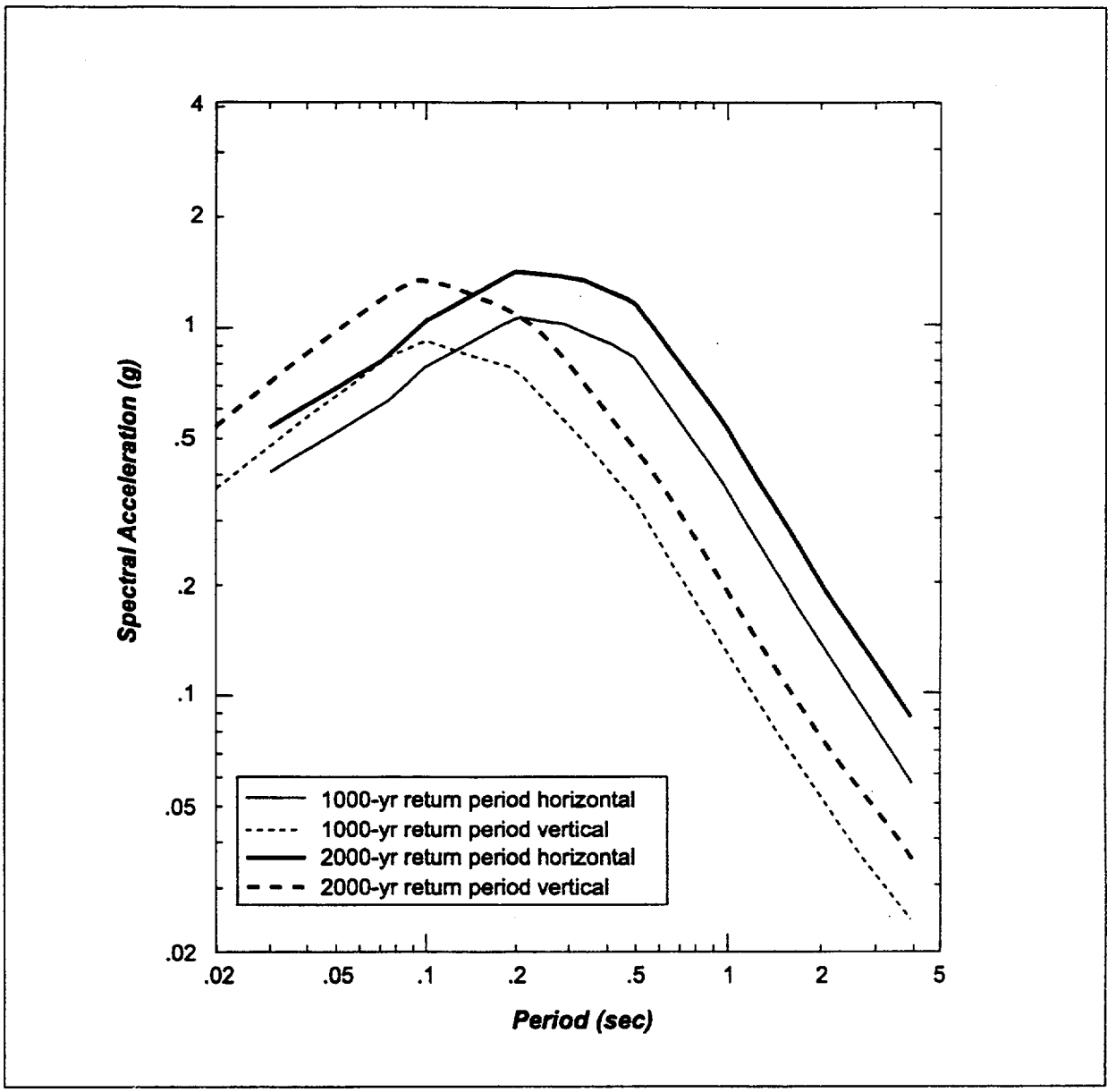


Figure 2-23. Equal hazard response spectra (5-percent damping) for the proposed Skull Valley Private Fuel Storage Facility site (after Geomatrix Consultants, Inc., 1999c)

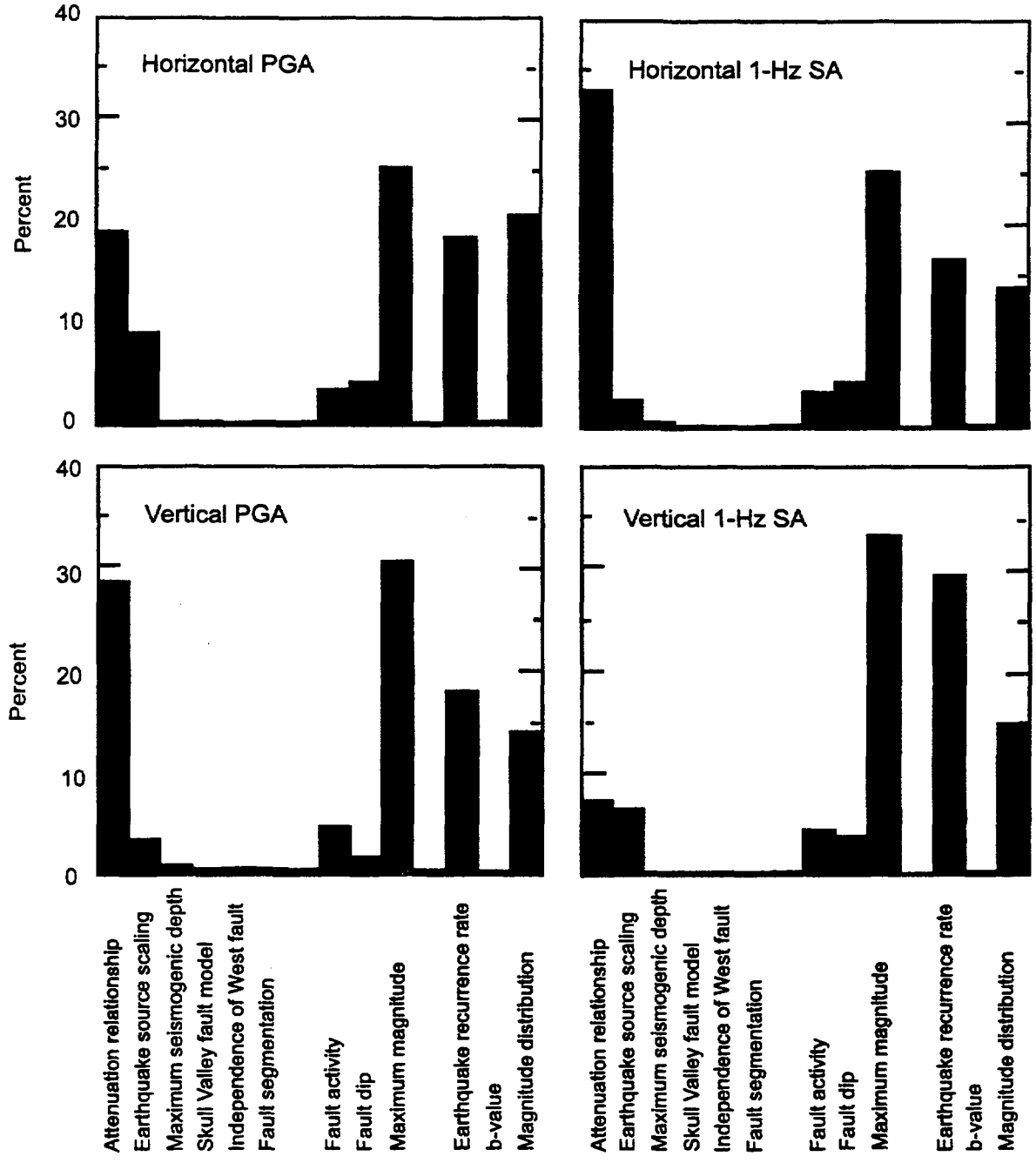


Figure 2-24. Relative contribution of uncertainties in the components of the seismic hazard model to the total uncertainty in the hazard at the proposed Skull Valley Private Fuel Storage Facility site (after Geomatrix Consultants, Inc., 1999a)

Maximum earthquake magnitudes for the two fault sources were estimated using the empirical relationships of Wells and Coppersmith (1994) and Anderson et al. (1996) based on estimated maximum rupture dimensions (rupture length and rupture area). The resulting mean estimates of maximum magnitudes are **M** 7.0 and 6.8 for the Stansbury and East Cedar Mountain faults, respectively. The maximum magnitude for the areal source was estimated to range from **M** 5.5 to 6.5, with a mean value of 6, based on the study of Wells and Coppersmith (1993) on a relationship between earthquake magnitude and the occurrence of associated surface faulting and the assumption that these random earthquakes do not produce significant surface faulting. A mixture of attenuation relationships for strike-slip faults in California and for extensional stress regimes was used to account for uncertainties. These include Abrahamson and Silva (1997), Campbell (1997), Sadigh et al. (1993, 1997), Idriss (1991), and Spudich et al. (1997). In Geomatrix Consultants, Inc. DSHA, uncertainties were included in maximum magnitude, minimum source-to-site distance, and the selection of attenuation relationships. The recommended 84th-percentile PGAs are 0.67 and 0.69g in horizontal and vertical directions, respectively. These accelerations envelop the calculated accelerations for a rock site and a deep soil site.

2.4.2 1999 Geomatrix Consultants, Inc. Updated Deterministic Analyses

Geomatrix Consultants, Inc. (1999b) updated its DSHA after the discovery of two new faults near the proposed Skull Valley PFSF site and additional in-depth characterization of other capable faults. These newly discovered faults were unofficially named West and East faults and are considered capable fault sources (Geomatrix Consultants, Inc., 1999a). The detailed characteristics of the two new faults, as well as other fault sources, are reviewed in Section 2.1.3 of this report.

In its updated DSHA, Geomatrix Consultants, Inc. (1999b) considered four nearby fault sources: Stansbury, East, West, and East Cedar Mountains faults. The mean maximum magnitudes of these fault sources were estimated to be **M** 7.0, 6.5, 6.4, and 6.5, respectively, based on distributions for maximum magnitude of each source developed in Geomatrix Consultants, Inc. (1999a). The closest distances to the Canister Transfer Building (CTB) from the surface traces of these faults were estimated to be 9, 0.9, 2.0, and 9 km, respectively.

The ground motion models used in the updated DSHA were the set of 17 horizontal and 7 vertical attenuation relationships used in the Geomatrix Consultants, Inc. (1999a) PSHA. These relationships were reviewed and discussed in Section 2.2 of this report. The ground motion attenuation relationships were adjusted for near-source effects using the empirical model developed by Somerville et al. (1997).

The updated DSHA results show that the ground motion from the East fault generally envelops ground motions from the other sources. The 84th-percentile peak accelerations for the East fault are 0.72 and 0.80g in horizontal and vertical directions. When compared with the PSHA results, it was indicated that the controlling deterministic spectra generally lie between the 5,000- and 10,000-year return period equal-hazard response spectra.

2.5 SURFACE FAULTING HAZARD

2.5.1 Secondary Faults

Within the valley fill itself, Geomatrix Consultants, Inc. (1999a) document several additional small fault zones designated A to F. Each fault zone has several smaller splays designated with numeral subscripts (e.g., A1 to A7, B1 and B2, and so forth). These faults are all considered secondary faults related to deformation of the hangingwall above the larger East and West faults. They are too small to be independent seismic sources but large enough to be considered in the fault displacement analysis. The two largest of the secondary faults are the F fault zone, which appears to be splays of the East fault, and the D fault zone. The C fault zone was also considered by Geomatrix Consultants, Inc., based on seismic evidence for small observed displacements. Both the C and D fault zones cross the PFSF site. The F fault zone is outside the current boundaries of the PFSF site. The remaining fault zones, A, B, and E, were too small to be significant.

The best documentation of these secondary faults is from the detailed shear wave seismic profiles taken across the site (Geomatrix Consultants, Inc., 1999a, Plate 4) and confirmed by a series of borings (C-9 to C-15). The seismic profiles documented offset of the Qp marker horizon, which represents the unconformity between Promontory soil, deposited 130–28 ka, Bonneville alloformation (28–12 ka), and the Quaternary-Tertiary (Q/T) contact, with a minimum age of 160 ka. Vertical separation across the largest strands of the F fault zone (F-1 and F-4) is approximately 1.5 m in the last 60 ka and 0.6 m in the last 20 ka. These separations yield average slip rates on these faults between 0.01 and 0.03 mm/yr. Based on similar observations of vertical separation of the Qp marker horizon, the D fault zone has slip rates between 0.03 and 0.01 mm/yr. Slip rates on the C fault zone are based on offset of the 160 ka Q/T marker, estimated between 0.001 and 0.02 mm/yr.

2.5.2 Probabilistic Fault Displacement Hazard Assessment Methodology

The objective of fault displacement analyses is to evaluate the potential hazards of an intersection of an active fault with vital components of the storage facility system. For this evaluation of faulting, both principal (including sympathetic) and secondary (or distributed) faulting must be considered (as defined in dePolo et al., 1991). Principal faulting refers to displacement along the main fault zone responsible for the release of seismic energy (i.e., an earthquake). At Skull Valley, principal faulting that generates earthquakes occurs only on primary faults based on seismic reflection, mapping, and borehole data. There are no evidences indicating that these primary faults intersect the PFSF site. In contrast, secondary or distributed faulting is defined as rupture of smaller faults that occurs in response to rupture in the vicinity of the principal fault.

Similar to the seismic hazard analysis, probabilistic methods have also been developed to evaluate fault displacement hazards, especially for principal faults for which detailed paleoseismic data are available. These methods construct individual fault displacement hazard curves, analogous to probabilistic seismic hazard curves, for each principal fault (Youngs and Coppersmith, 1985; Civilian Radioactive Waste Management System, Management and

Operating Contractor, 1998). Few techniques, however, exist to evaluate the probability of secondary faulting (e.g., Coppersmith and Youngs, 1985). The complexity of fault analyses, Geomatrix Consultants, Inc. (1999a) relied on assumptions, data, and models presented in the DOE PSHA (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998) for YM, because they are the only ones available in the literature and they represent state-of-the-art methodology for probabilistic faulting analysis. As stated later in this chapter, the CNWRA evaluation of faulting hazard at Skull Valley PFSF does not rely on the YM methodology.

Following the DOE YM PSHA (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998), recurrence and slip-rate data for faults were used in conjunction with regional seismicity parameters such as frequency of earthquakes to develop probabilistic fault displacement hazard curves for each fault of interest. The curves were derived from two different approaches, defined as the faulting-occurrence and magnitude-occurrence models (Cornell and Toro in Hunter and Mann, 1990). These methodologies, as applied in the DOE PSHA (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998), have been referred to as the displacement approach and earthquake approach, respectively. The first approach uses fault-specific data such as cumulative displacement, fault length, paleoseismic data from trenches, and historical seismicity. The second relates the frequency of fault slip events to the frequency of earthquakes on the seismic sources defined in the seismic source models developed for the corresponding seismic hazard analysis.

For both earthquake and displacement approaches, two important parameters were developed by the DOE expert elicitation teams, one describing the amount of fault displacement for each faulting event, the other how frequently those events will occur. It is important to note that, unlike the seismic hazard assessment, methods to develop these parameters are not well established in the scientific literature; the probabilistic methodology was essentially developed by the experts within the DOE PSHA (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998). Thus, the expert teams relied on a wide variety of data and models to develop these two parameters.

Of these two methodologies, the displacement approach is more straightforward because it relies on direct observational evidence of faulting. The two required parameters can be derived directly from paleoseismic displacement and recurrence rate data, geologically derived slip-rate data, or scaling relationships that relate displacement to fault length and cumulative fault displacement.

The earthquake approach uses earthquake recurrence models from the seismic hazard analysis. Three probabilities were assessed: (i) the probability that an earthquake will occur; (ii) the probability that this earthquake will produce surface rupture on the fault generating the earthquake (the primary fault where the earthquake occurs); and (iii) the probability that the earthquake will produce distributed surface displacement on other faults, primary or secondary.

- The probability that an earthquake will occur was derived from the seismic hazard assessment. In that assessment, the frequency distribution of earthquakes for each source (fault or area) was derived from available geologic, historical seismic, or paleoseismic data.

- The probability of surface rupture was determined by the expert teams in two ways: (i) statistical analysis of historical earthquake and surface rupture data from the Basin and Range (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998, Figure 4-11) and (ii) focal depth calculations. In focal depth calculations, the size and shape of the fault rupture for each earthquake (generally considered circular or elliptical) were estimated from empirical scaling relationships (e.g., Wells and Coppersmith, 1994). The surface displacement (if any) along the fault was determined as a function of focal depth.

- The probability of secondary or distributed faulting was determined by a best fit to data from Basin and Range historical ruptures in which secondary or distributed faulting was mapped after the earthquake (Pezzopane and Dawson in U.S. Geological Survey, 1996).

Geomatrix Consultants, Inc. applied both methodologies to assess the faulting hazard at the PFSF. The two approaches were weighted in the logic tree following the DOE PSHA expert elicitation (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998)—0.67 for the displacement approach and 0.33 for the earthquake approach.

It is important to note that the earthquake and displacement methodologies have not been reviewed fully as they apply to the YM PSHA. NRC and CNWRA staffs recommended to the DOE that these methodologies be published in the peer-reviewed literature so they can be assessed by the scientific community at large (Nuclear Regulatory Commission, 1999). Acceptance of one or both of these methodologies for the PFSF does not in any way imply broader acceptance of the methodologies as they may apply to YM.

Of the two approaches, the displacement approach is deemed by staff as appropriate for the PFSF site because of the high quality of fault displacement data offered by the Geomatrix Consultants, Inc. (1999a) study. Unlike YM, where direct observations of faulting rate and displacements per event are rare for secondary faults, borehole and seismic data from the Geomatrix Consultants, Inc. (1999a) study show strong evidence for repeated faulting events on the secondary fault zones (C, D, and F). Faulting recurrence rates and displacement per event used by Geomatrix Consultants, Inc. (1999a) were quantified based on vertical separation of well established Quaternary marker horizons. This observation is important because it suggests that future faulting events will likely occur along these same faults and not on new faults under the site. In addition, these observations of repeated slip event allowed Geomatrix Consultants, Inc. (1999a) to constrain average displacement per events for each fault, which ranged between a high of 0.9 m (F fault zone) and a low of 0.02 m (D fault zone). Given these observations, staff conclude that the results offered by the displacement approach are representative of site conditions and should be used to assess the faulting hazard at the PFSF site.

Geomatrix Consultants, Inc. (1999a) also considered other possible distributed faulting between the mapped faults. These displacements were small. For example, Geomatrix Consultants, Inc. (1999a) measured only 5.5 cm of cumulative displacement across 88 m of exposure in Trench T-2, with a fracture spacing between 1.0 and 1.5 m. This suggests cumulative vertical displacement across the entire width of the PFSF site (approximately 1,500 m) of less than 1 m accumulated over the last several million years.

2.5.3 Probabilistic Fault Displacement Results

Probabilistic fault displacement hazard results were calculated for the C, D, and F fault zones. Presentations of the results are similar to those for a probabilistic seismic hazard curves except the curves show the frequency of exceeding specified displacement levels. The difference in the shapes of the fault displacement curves and the ground motion curves reflects differences in the underlying processes. In ground shaking, all earthquakes from a large region around the site contribute to the ground motion at the site. As the historical seismic record shows, small earthquakes occur relatively frequently in this large region, and each may contribute a small degree of ground motion to the total hazard at the site. Thus, the seismic hazard curves become asymptotic to the y axis (annual frequency) of the plot. Fault displacement, on the other hand, is for a single fault source. The frequency of exceeding a specified fault displacement cannot be greater than the frequency at which faulting events occur on the fault. Thus, the curves for fault displacement intersect the y axis (annual frequency) at the frequency of a single displacement event or minimum recurrence rate for that fault.

Fault displacement results (Figure 2-25) show that the displacement approach yields a greater faulting hazard than the earthquake approach, except for fault C, at annual frequencies below about 10^{-5} where the two methods yield similar values. Based on the 95th-percentile curve, these results show that displacements greater than 0.1 cm are expected only with an annual frequency of less than 3×10^{-4}, or once in 3,333 years. Significant displacements of 10 cm or more are expected only with an annual frequency of less than 2×10^{-4}, or once in 5,000 years. For a 2,000-year return period (annual frequency 5×10^{-4}), displacements due to faulting are smaller than 0.1 cm.

2.6 DESIGN BASIS GROUND MOTION

The design ground motion response spectra for the proposed Skull Valley PFSF site were developed by Geomatrix Consultants, Inc. (1999c) based on its site-specific PSHA results as reviewed in Section 2.3 and documented in detail in Geomatrix Consultants, Inc. (1999a). The assessment of design ground motions for the PFSF is described in Geomatrix Consultants, Inc. (1999c). The design ground motions were determined using the procedure described in Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997b). However, prior to implementing the Regulatory Guide 1.165 procedure, the site seismic hazard results were modified to account for the near-source effects of rupture directivity and the polarization of ground motions. Adjustments to the PSHA results that account for these effects were made using empirical models developed by Somerville et al. (1997).

Analytical and observational evidence (Boore and Joyner, 1978; Boatwright and Boore, 1982; Mori, 1996) indicate the propagation of rupture along a fault at a velocity near the shear-wave velocity and the location of a site with respect to the rupture vector both can have a systematic impact on ground motions. For sites located in forward azimuths relative to the direction of rupture, constructive interference of seismic waves occurs leading to ground motions that are higher in amplitude and compressed in time (i.e., strong motion durations are shorter).

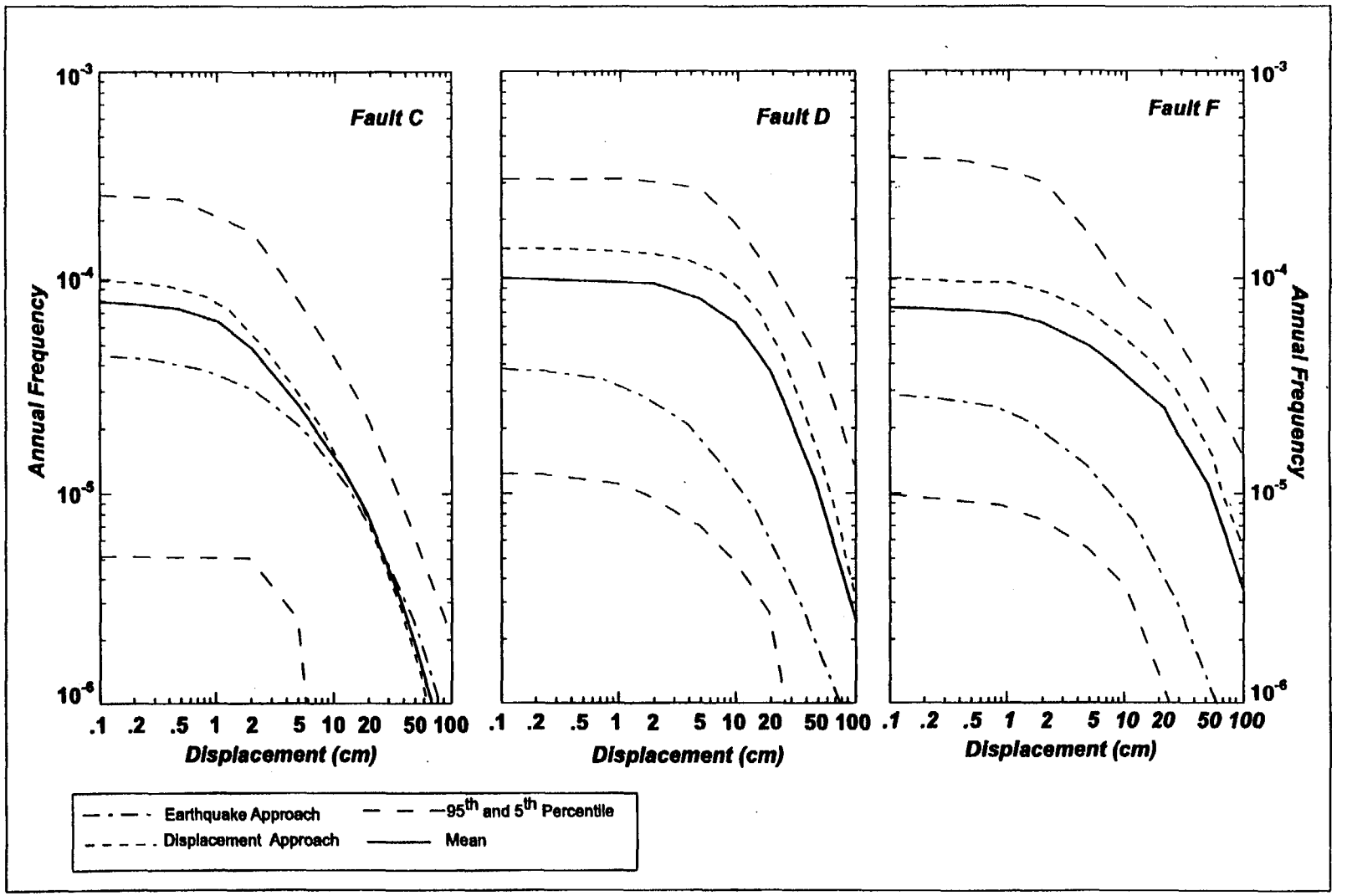


Figure 2-25. Probabilistic fault displacement hazard results for the C, D, and F fault zones (after Geomatrix Consultants, Inc., 1999a)

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For sites located at back azimuths (i.e., rupture proceeds away from a site), ground motions are lower in amplitude due to destructive interference and arrive over a longer duration.

In addition to the effects of rupture directivity, ground motions at sites in the near-source region tend to be highly polarized in the fault normal and fault parallel directions. The radiation pattern effect causes ground motions to be principally oriented in a direction perpendicular to the fault.

2.6.1 Near-Source Effects

The model developed by Somerville et al. (1997) to estimate the effects of rupture directivity is based on an analysis of the residuals of the Abrahamson and Silva (1997) ground motion model. The ground motion residuals were evaluated with respect to their dependence on source-site azimuth and the proportion of the fault rupture that occurs toward a site. Predictive relationships were developed for strike-slip and dip-slip fault events. A second relationship predicts the ratio of ground motions in the fault normal direction to the average horizontal ground motion as a function of earthquake magnitude and distance.

The adjustment factors for rupture directivity and fault normal motion were combined by Geomatrix Consultants, Inc. (1999c) to obtain a composite factor used to deterministically scale the ground motions in the site hazard analysis (shift the hazard curve), as shown in Figure 2-26.

The Somerville et al. (1997) model for source directivity is applicable for the following conditions

- Moment Magnitude: 6.5–7.5
- Frequency: 0.20–1.67 Hz (spectral acceleration)
- Faulting Style: Strike-slip and dip-slip (crustal events)
- Site Classification: All sites
- Source-Site Distance: 0–50 km

The range of applicability for the directional adjustment factor is the same as for the directivity factor, with the following exceptions:

- Moment Magnitude: 6.0–7.5
- Frequency: 0.20–2.0 Hz (spectral acceleration)
- Faulting Style: NA

For purposes of determining the directivity and directional factors, conservative values of the necessary input parameters were selected to maximize effect. To estimate the directivity factor, a forward source-site azimuth was conservatively assumed (to maximize the directivity effect) for the fault sources that dominate the site hazard. These are the East, West, Stansbury, and the East Cedar Mountain faults. The adjustment factor for direction (fault normal) effects was determined for the closest distance from the PFSF site to each fault and the mean magnitude contributing to the hazard for each fault.

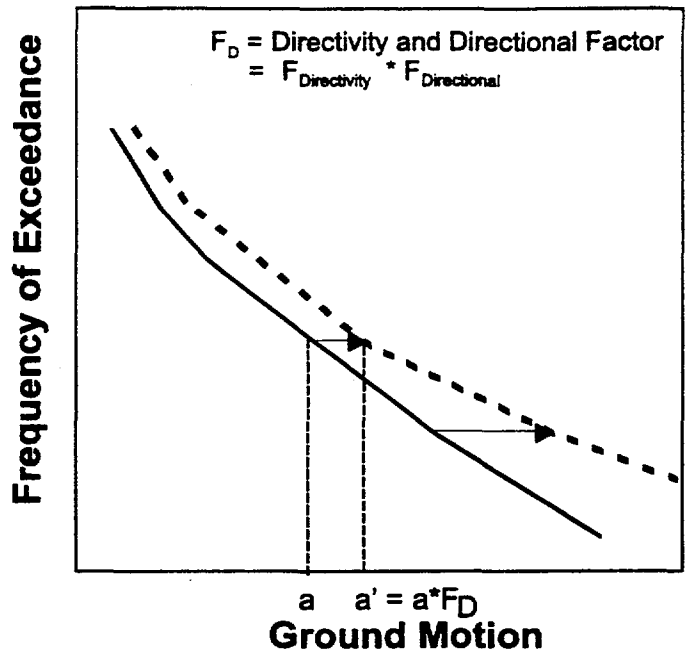

Figure 2-26. Illustration of the procedure used in the Private Fuel Storage Facility study to scale seismic hazard curves

The combined directivity/directional effect adjustment factors derived from the Somerville et al. (1997) model for fault normal motions range from 1.10 at 1 Hz to 1.53 at 0.25 Hz for ground motions with a frequency of exceedance of 10^{-3} per year. For ground motions with an annual frequency of exceedance of 5×10^{-4}, these factors range from 1.11 at 1 Hz to 1.54 at 0.25 Hz. For ground motion measures, including PGA, corresponding to frequencies greater than 1.67 Hz, no adjustment was applied (Somerville et al., 1997).

The adjustment factors just identified were used in a deterministic manner to shift the seismic hazard curves for horizontal ground motions for the applicable ground motion measures (Figure 2-26). The resulting hazard curves were then interpolated to determine the ground motions for return periods of 1,000 and 2,000 years. For vertical ground motions, only the directivity adjustment was applied.

The adjustment of the site ground motions assumes that rupture directivity and directional effects are deterministic and invariant with respect to earthquake magnitude and distance, which is not the case. The approach that was used by Geomatrix Consultants, Inc. is considered conservative.

Aleatory uncertainty. As part of the seismic hazard analysis, the aleatory uncertainty models the variability in ground motion not explained/predicted by the independent variables in the attenuation model (e.g., earthquake magnitude, source-site distance, and style of faulting). The

influence of factors that are not modeled—such as rupture directivity, the details of site geology, and local topography—are quantified as part of the aleatory variability. As such, the effect of source directivity is implicit in ground motion attenuation models and is, therefore, incorporated as a random effect in the PSHA calculations.

As described in the PFSF assessment of design ground motions, the explicit modeling of source-site azimuth as an independent variable should lead to reduced aleatory variability (because a source of the unexplained variability in ground motion residuals is eliminated). This reduction in the aleatory variability was not addressed in the PFSF analysis. As a result, the rupture directivity effects are double counted and the frequency of exceedance of ground motions is overestimated due to the higher variability. This level of conservatism is judged to be small.

Earthquake magnitude. The rupture directivity and directional models developed by Somerville et al. (1997) are applicable to earthquakes of **M** 6.5 and greater and 6.0 and greater, respectively. Because the adjustment factors have been applied to the total seismic hazard curve, which are aggregated with respect to magnitude and distance, the adjustment factors have been applied to ground motions produced by earthquakes of all magnitudes, including those less than the lower limit of their applicable range.

The applicable magnitude range of the Somerville et al. (1997) model for rupture directivity is a limitation with respect to its applicability to PSHAs. Observational evidence suggests directivity effects for events in the magnitude range of 5.0–6.5 can be significant. Boatwright and Boore (1982) show that for two events, **M** 5.4 and 5.8, that occurred in the Livermore Valley in 1980, the directivity effects were significant for PGA and peak ground velocity. Their analysis indicates a total variation of ground motions of a factor of 10 over all azimuths. They attribute this large variation to the apparent unilateral rupture that occurred in both events.

Others have also documented directivity effects for events with **M** less than 6.5 (Singh, 1981; Mori, 1996). This experience suggests the following observations.

- Circumstances can occur whereby directivity effects for moderate size events (i.e., 5.0–6.5) can be significant. Factors important to determining the potential directivity effects include the coherency of the fault rupture process and the distribution of fault rupture toward/away from a site (e.g., unilateral or bilateral). The latter of these factors is considered in the Somerville et al. (1997) model.

- Rupture directivity can influence the amplitude of high-frequency ground motions.

The potential for coherent, unilateral rupture is greater for smaller events due to the relative size of the rupture itself. As suggested by the Livermore Valley events, the potential for large rupture directivity effects exists for events in the **M** 5–6.5 range. The fact that the Somerville et al. (1997) model does not consider these events suggests that the effect of rupture directivity is underestimated. However, because the Somerville et al. (1997) model was applied to the total seismic hazard for the faults that dominate the seismic hazard, the effects of rupture directivity have been considered for all size events modeled in the PSHA (**M** >5.0), at least to some degree. In view of the fact that a systematic analysis of rupture directivity for events in

the M 5–6.5 range is not available, it is not possible to assess the degree to which the effects of directivity for these events may be underestimated, if at all.

Progressively larger magnitude earthquakes rupture larger areas of the fault thereby, increasing the potential for rupture incoherency. Similarly, bilateral rupture may be more likely for larger events. Both of these factors contribute to reduced effects of rupture directivity. Therefore, for larger earthquakes, the Somerville et al. (1997) rupture directivity model may overestimate this effect.

For purposes of estimating directional effects, Geomatrix Consultants, Inc. (1999b) used the mean magnitude contributing to ground motions for each fault. For smaller events this assumption overestimates the fault normal motion, whereas for larger events the effect is underestimated.

Spectral frequency. The adjustment factors for directivity and directional effects were applied to ground motions with frequencies less than 1.67 Hz. No adjustment was made for higher frequency ground motions or for PGA. As discussed previously, there is observational evidence of directivity effects for higher frequency ground motions, including PGA. Various researchers have suggested the effect of source directivity tends to be greater for ground velocity and displacement and smaller for ground accelerations (Singh, 1981; Boatwright and Boore, 1982).

Despite empirical evidence that ground motions with frequencies greater than 1 Hz may be influenced by the effects of rupture directivity, there are no existing models of the type Somerville et al. (1997) developed to predict this effect.

Source-site azimuth/distance. For purposes of estimating the effect of rupture directivity on design motions, a single, conservative value for the source-site azimuth was determined for each fault. In addition, fault rupture was assumed unilateral for each fault, maximizing the directivity effect. For purposes of determining the directional factor, earthquakes were assumed to occur at the point on the fault closest to the site. The selection of these parameters to determine the directivity and directional effects was intended to maximize the value of the adjustment factors and, as a result, is conservative.

Direct modeling of source directivity and directional effects. For purposes of addressing the effects on ground motions of earthquakes that occur in the near field, Geomatrix Consultants, Inc. elected to adjust the results of the PSHA rather than incorporate these effects directly in the hazard calculation. If the effects of rupture directivity and fault normal motion were considered in the PSHA calculation, the following factors suggest the seismic hazard at the PFSF may be lower than that estimated by Geomatrix Consultants, Inc. (1999c).

- The aleatory variability in ground motions would be reduced, leading to lower estimates of the seismic hazard.
- Source-to-site azimuths would vary significantly from the conservative value that was assumed.

- Fault ruptures would not be unilateral for every earthquake as assumed, thus reducing the rupture directivity effect at all other azimuths.

- For earthquakes that do not occur on a fault adjacent to the site, the site will be in a "shadow" that does not experience rupture directivity effects (Somerville et al., 1997). For these events the rupture directivity effect is overestimated.

- Source-to-site distances will be greater than the closest point on a fault for many of the events modeled in the PSHA. For these events, the directional factor will be lower than the value estimated by Geomatrix Consultants, Inc.

- The mean earthquake magnitude for a fault that contributes to ground motion will be larger than the majority of events modeled in the PSHA. As a result, the directional effects factor used by Geomatrix Consultants, Inc. will be greater than the actual factor that would be used for these smaller events.

Conversely, if the effects of rupture directivity and fault normal motion were considered in the PSHA calculation, the following factors may contribute to higher ground motions than those estimated by Geomatrix Consultants, Inc.

- Earthquakes larger than the mean earthquake magnitude will have higher fault normal motions than estimated by Geomatrix Consultants, Inc.

- Rupture directivity effects greater than those considered by Geomatrix Consultants, Inc. may exist for **M** 5–6.5 events.

- Rupture directivity effects may exist for ground motions with frequencies greater than 1.67 Hz and PGA.

On balance, if the Somerville et al. (1997) model for rupture directivity and directional effects was incorporated into the seismic hazard analysis, it is judged the overall hazard would be lower than what has been estimated, with the possible exception of higher frequency ground motions, which were not considered.

2.6.2 Design Basis Ground Motion Spectra

The Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997b) process for determining design basis ground motion spectra involves computing the contributions to the total hazard at the specified design return period (or reference probability) from events in discrete magnitude and distance bins. In the Geomatrix Consultants, Inc. (1999c) calculation, a magnitude bin size of 0.25 was selected. The distance bin size increases gradually from 5 to 50 km as the source-to-site distance increases from 0 to 150 km. From these contributions and the average magnitude and distance for each bin, a weighted average magnitude, $\overline{\mathbf{M}}$, and log average distance, $\overline{\mathbf{D}}$, of the events contributing to the design level hazard were determined for spectral frequency ranges of 5–10 Hz and 1–2.5 Hz. These values are represented in Table 2-4. Free-field ground surface response spectral shapes were developed using the 84th-percentile peak acceleration and the 84th-percentile response spectra for each of the $\overline{\mathbf{M}}$ and $\overline{\mathbf{D}}$ pairs in

Table 2-4 using a weighted combination of the same ground motion attenuation relationships used for PSHA (Geomatrix Consultants, Inc., 1999a). These response spectral shapes were scaled to the appropriate equal hazard spectra. Design ground motion response spectrum was defined to be the envelope of the scaled spectra and equal hazard spectra. This envelope was further scaled by the adjustment factors for near-fault effects described in Section 2.6.1. The final response spectra are represented in Figures 2-27 and 2-28 for return periods of 1,000 and 2,000 years, respectively, and tabulated in Table 2-5.

Table 2-4. Weighted average magnitudes and log average distances for calculating design response spectra for the proposed Private Fuel Storage Facility site (after Geomatrix Consultants, Inc., 1999c)

Return Period and Ground Motion	Spectral Frequency Range (Hz)	$\overline{M}$	$\overline{D}$(km)
1,000-year horizontal	5–10	6.3	5
	1–2.5	6.4	5
1,000-year vertical	5–10	6.4	6
	1–2.5	6.4	7
2,000-year horizontal	5–10	6.3	4
	1–2.5	6.5	4
2,000-year vertical	5–10	6.5	6
	1–2.5	6.5	6

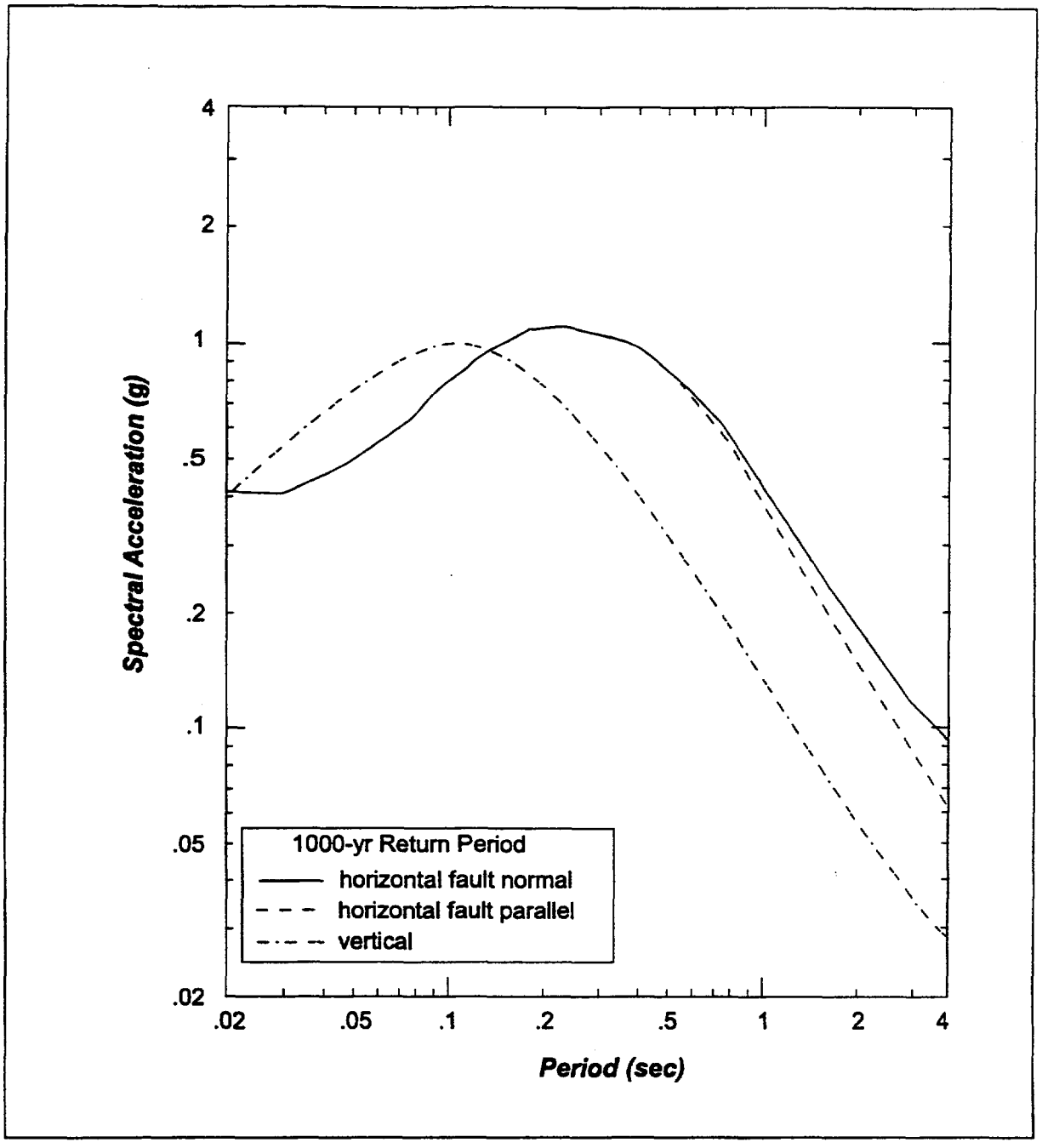

Figure 2-27. Design ground motion response spectra (5-percent damping) based on 1,000-year return period hazard for the proposed Skull Valley Private Fuel Storage Facility site (after Geomatrix Consultants, Inc., 1999c)

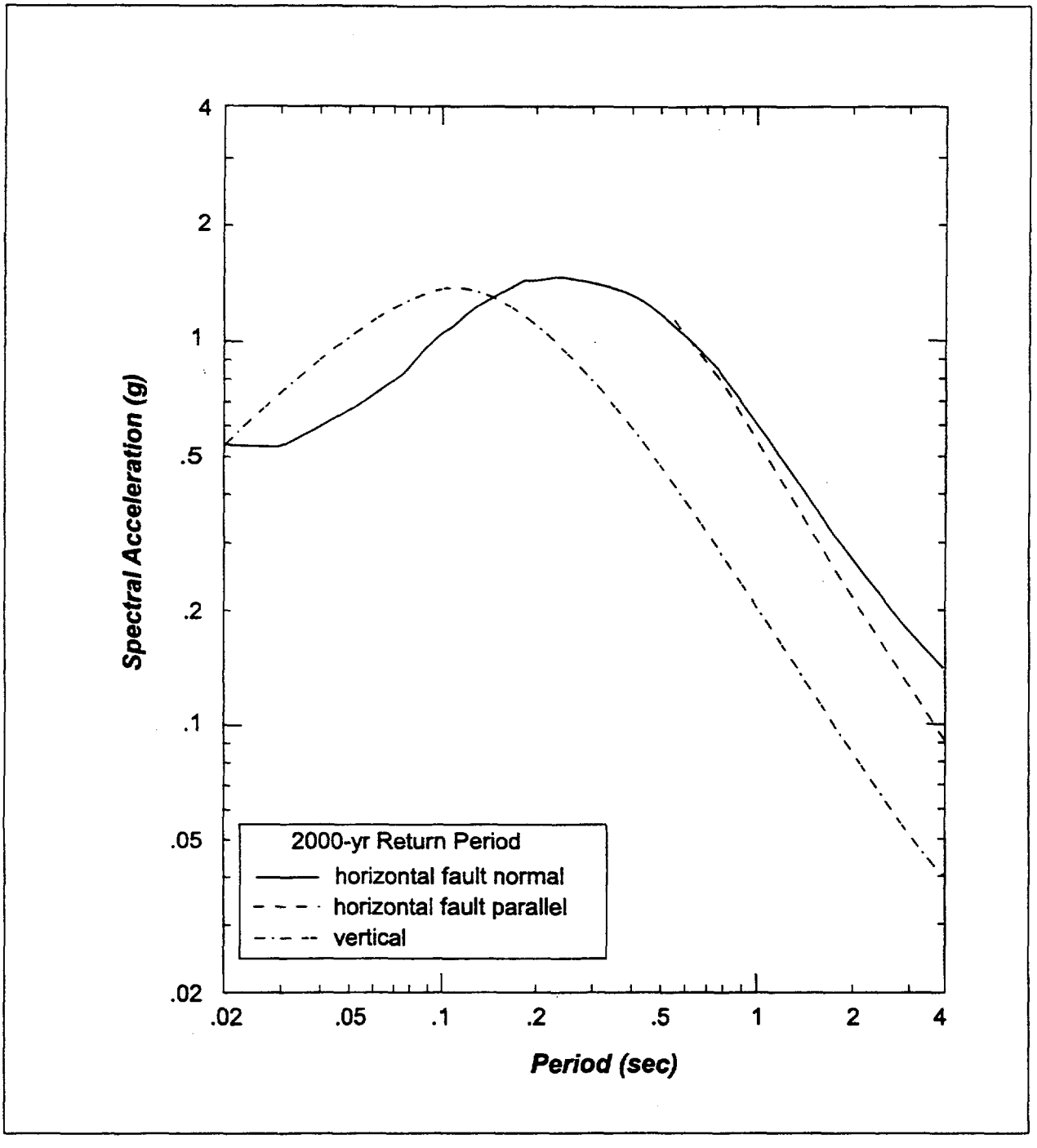

Figure 2-28. Design ground motion response spectra (5-percent damping) based on 2,000-year return period hazard for the proposed Skull Valley Private Fuel Storage Facility site (after Geomatrix Consultants, Inc., 1999c)

Table 2-5. Design ground motion response spectra for the proposed Skull Valley Private Fuel Storage Facility site (modified from Geomatrix Consultants, Inc., 1999c)

1,000-year Return Period Spectral Accelerations (g, 5-percent damping)			
	Horizontal		
Period (sec)	Fault Normal	Fault Parallel	Vertical
Peak ground acceleration	0.404	0.404	0.391
0.05	0.500	0.500	0.761
0.075	0.631	0.631	0.932
0.1	0.792	0.792	1.001
0.15	0.995	0.995	0.952
0.2	1.086	1.086	0.791
0.3	1.060	1.060	0.547
0.4	0.964	0.964	0.419
0.5	0.868	0.868	0.333
0.75	0.615	0.591	0.211
1.0	0.425	0.389	0.138
1.5	0.265	0.225	0.081
2.0	0.191	0.154	0.058
3.0	0.120	0.088	0.036
4.0	0.092	0.063	0.028
2,000-year Return Period Spectral Accelerations (g, 5-percent damping)			
	Horizontal		
Period (sec)	Fault Normal	Fault Parallel	Vertical
Peak ground acceleration	0.528	0.528	0.533
0.05	0.662	0.662	1.030
0.075	0.835	0.835	1.268
0.1	1.046	1.046	1.369
0.15	1.317	1.317	1.296
0.2	1.437	1.437	1.104
0.3	1.406	1.406	0.780
0.4	1.284	1.284	0.594
0.5	1.166	1.166	0.476
0.75	0.851	0.814	0.306
1.0	0.605	0.547	0.203
1.5	0.379	0.323	0.123
2.0	0.272	0.223	0.088
3.0	0.179	0.128	0.056
4.0	0.138	0.091	0.044

3 DISCUSSION AND RECOMMENDATIONS

3.1 DISCUSSION

Seismic issues important to siting the proposed Skull Valley PFSF include characterization of potential seismic sources, estimation of ground motion attenuation, assessment of probabilistic and deterministic ground motion hazards, assessment of probabilistic surface faulting hazard, and development of design basis ground motion parameters in compliance with applicable regulations and regulatory guidance. These issues have been discussed in detail in Chapter 2.

The literature survey conducted herein indicates that a significant amount of literature pertinent to the proposed Skull Valley PFSF site was produced by the PFSLLC and its contractors or subcontractors—most notably, the faulting evaluation study, seismic ground motion hazard assessment, and development of design basis earthquakes conducted by Geomatrix Consultants, Inc. (1999a,b,c). In these studies, the PFSLLC has sufficiently identified, used, and referenced previously existing data and information and adopted state-of-the-knowledge techniques in identifying and characterizing potential earthquake sources, estimating ground motion attenuations, and assessing probabilistic seismic ground motion and faulting hazards.

3.1.1 Seismic Source Characterization

The seismic source characterization of the proposed PFSF was developed from examination of the available literature integrated with detailed site geological studies, including site stratigraphy, geologic mapping, cross-sectional construction, and geophysical investigations (Geomatrix Consultants, Inc.,1999a; Bay Geophysical Associates, Inc., 1999). The most important aspects for the evaluations of seismic and faulting hazards were identification and characterization of active faults derived from paleoseismic and geophysical investigations. Identification of a detailed Quaternary stratigraphy was also essential because it provided critical constraints on faulting activity.

Based on detailed site investigations and proper consideration of the seismotectonic setting, Geomatrix Consultants, Inc. (1999a) identified 29 fault sources and 4 areal sources. A logic tree approach was used to combine alternative models of source geometry, activity, and seismicity to formulate the PSHA. Review of the assessment indicates that the seismic source characterization was thorough and complete. Selections of models important to the hazard assessment were appropriate and, in many instances, conservative. For example, Geomatrix Consultants, Inc. (1999a) considered all faults to be planar and to extend through the thickness of the brittle crust rather than considering the possibility that the primary faults could be listric and sole into an aseismic detachment above the base of the seismogenic crust. Uncertainties in other aspects of fault geometry and seismic activity were incorporated into the probabilistic assessment. Upper bounds of those parameters that describe fault geometry or seismic activity were constructed to adequately bound geologic and geophysical observations. The historical seismic record was appropriately used to develop b-values for recurrence relationships, and to develop the background areal source zone.

Critical aspects of this review center on interpretations of fault geometries for the newly discovered East and West faults in Skull Valley based on reflection seismic data and forward

modeling of gravity data in Geomatrix Consultants, Inc. (1999a). Staff review of the alternative models shows that the Geomatrix Consultants, Inc. assessment may have led to an overly conservative hazard result. Reanalysis of the proprietary industry gravity data provided in this report does not support the interpretation that the West fault is an independent seismic source. Rather, staff interpret the West fault as a splay of the East fault, incapable of independently generating large-magnitude earthquakes. Based on an assessment of this alternative interpretation and in light of the review of the other aspects of the probabilistic assessment, staff conclude that the Geomatrix Consultants, Inc. (1999a) model is reasonably conservative, in the sense that of the possible interpretations, the PFSLLC hazard curve bounds the anticipated ground motions at the PFSF site that could result from future seismicity in and around Skull Valley, Utah.

3.1.2 Ground Motion Attenuation Models

For purposes of estimating earthquake ground motions that may occur at the proposed Skull Valley PFSF site, the PFSLLC and its contractors or subcontractors used results of the PSHA conducted for the proposed HLW repository site at YM (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998). The YM study developed and implemented a methodology for evaluating earthquake ground motions in the Basin and Range, which includes the results of scientific evaluations and expert elicitations from seven ground motion experts. The YM study represents a valuable resource for the PFSF PSHA. Use of the YM study methodology and reasoned application of the ground motion modeling results for the PFSF analysis is appropriate.

For purposes of the PFSF seismic hazard analysis, Geomatrix Consultants, Inc. (1999a) selected and weighted published median ground motion attenuation models according to the judgment of the YM ground motion experts and did not use the actual median ground motion models developed by the ground motion experts. This difference in the selection of median ground motion models is not significant.

As part of the YM PSHA, a sophisticated methodology for modeling and quantifying the epistemic uncertainty in ground motions was used. The YM analysis attempted to quantify all of the sources of uncertainty involved in the estimation of strong ground motion. As part of the PFSF PSHA, Geomatrix Consultants, Inc. elected to consider only that part of the epistemic uncertainty associated with the choice of different median ground motion models and not the uncertainty in the models themselves. As a consequence, sources of epistemic uncertainty that were quantified in the YM PSHA were not considered in the PFSF analysis. This leads to an underestimate of the total epistemic uncertainty and, therefore, an underestimate of the mean seismic hazard at the site. Sensitivity calculations show this effect is small (i.e., the mean frequency of exceedance of ground motions changes by less than a factor of 2).

The results of the PFSF PSHA were used to determine design ground motions based the procedure described in Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997b). Prior to implementing the Regulatory Guide 1.165 procedure, however, the site seismic hazard results were modified to account for the near-source effects of rupture directivity and the polarization of ground motions. Adjustments to the PSHA results that account for these effects were made using empirical models developed by Somerville et al. (1997).

The approach used to estimate design ground motions is consistent with procedures described in Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997b). On review, it is judged the deterministic approach of shifting the seismic hazard results to account for rupture directivity and ground motion directional effects is conservative for the frequencies to which these adjustments were applied. Based on the results of Somerville et al. (1997), adjustments were not made for the PGA seismic hazard results or for spectral accelerations greater than 1.0 Hz. While there is empirical evidence that suggests PGA and high-frequency ground motions also may be influenced by rupture directivity and source radiation, there are no tools to predict a systematic effect in a PSHA. Furthermore, there is limited empirical evidence to verify the Somerville et al. (1997) model and to predict, in an absolute sense, the systematic effect of rupture directivity on strong ground motion. However, as discussed in Section 2.2 and in Geomatrix Consultants, Inc. (1999c), the random effects of rupture directivity are accounted for as part of the aleatory variability in ground motion. As such, it is an effect that is considered in the PSHA. In fact, for frequencies less than 1.0 Hz, these effects are double counted in the PFSF estimate of design motions.

On balance, the characterization of strong ground motion in the PFSF seismic hazard analysis is reasonable and appropriate. Considerations with regard to the approach taken to model the epistemic uncertainty in ground motions and near-source effects notwithstanding, by Geomatrix Consultants, Inc. (1999a) the approach to modeling strong ground motion is judged to provide a reasonable estimate of the site hazard. It is judged that alternative, improved approaches to modeling epistemic uncertainties and the effects of rupture directivity would have counteracting effects and, in the aggregate, would not produce results significantly different than those obtained in the PFSF PSHA.

3.1.3 Seismic Ground Motion Hazard Results

As discussed in Section 2.3.2 of this review report, Geomatrix Consultants, Inc. 1997 site-specific DSHA (Geomatrix Consultants, Inc., 1997) yielded the 84th-percentile PHA of 0.67g and PVA of 0.69g. After discovery of the West and East faults and more detailed characterization of other fault sources, an updated DSHA was conducted in 1999 (Geomatrix Consultants, Inc., 1999b). The updated DSHA yielded the 84th-percentile PHA of 0.72g and PVA of 0.80g. Thus, there is considerable difference between the results from the two DSHA studies. The recent PSHA studies (Geomatrix Consultants, Inc., 1999a) produced a set of hazard curves for free-field motions at the ground surface as shown in Figures 2-20 and 2-21. These figures indicate a mean PHA of 0.38g and PVA of 0.36g for 1,000-year return period earthquakes and a mean PHA of 0.49g and PVA of 0.54g for 2,000-year return period earthquakes. As indicated in Section 3.1.2, in developing design-basis ground motion, PSHA hazard results were modified to account for the near-source effects of rupture directivity and the polarization of ground motions and, then, procedures described in Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997b) were implemented (Geomatrix Consultants, Inc., 1999c). The resulting design response spectra are shown in Figures 2-27 and 2-28 and tabulated in Table 2-5. These studies resulted in design ground motion PHA of 0.40g and PVA of 0.39g for 1,000-year return period earthquakes and a PHA and PVA of 0.53g for a 2,000-year return period.

As discussed in detail in Sections 2.1 and 2.2 and summarized in Sections 3.1.1 and 3.1.2, the CNWRA sensitivity analyses show that the Geomatrix Consultants, Inc. consideration of fault

source models is conservative, whereas its treatment of epistemic uncertainty in the median ground motion is less conservative than those in the original YM ground motion models. To evaluate the overall conservatism of Geomatrix Consultants, Inc. hazard results, an attempt was made to aggregate the CNWRA sensitivity results. Figure 3-1 presents three hazard curves: (i) CNWRA1, which was obtained using the CNWRA preferred fault source model; (ii) the scaled mean hazard curve, which is the mean hazard curve after applying the full range of epistemic uncertainties to the CNWRA1 model following the YM approach for estimating the epistemic uncertainties; and (iii) the PFSF hazard curve, which is the hazard curve obtained using Geomatrix Consultants, Inc. fault source models and associated parameters. Figure 3-1 shows that the PFSF curve generally bounds the scaled mean and the CNWRA1 hazard curves for recurrence intervals less than 10,000 years. It indicates that the overall effect of underestimating the epistemic uncertainty in the median ground motion in Geomatrix Consultants, Inc. (1999a) PSHA is compensated by the conservatism built into its fault source model. Therefore, the overall hazard results are conservative. It is noted that only relative ground motion levels from each model are compared in Figure 3-1. These ground motion values do not represent the absolute ground motion values at the proposed Skull Valley PFSF site. This is because a simplified ground motion model was used and only a few significant fault sources were considered in these sensitivity studies.

3.1.4 Surface Faulting Hazard Results

Geomatrix Consultants, Inc. (1999a) documented several additional small faults in and around the PFSF site. These faults are all considered secondary faults, related to deformation of the hangingwall above the larger East and West faults. They are too small to be independent seismic sources but large enough to be considered in the fault displacement analysis.

Similar to the seismic hazard evaluation, Geomatrix Consultants, Inc. (1999a) developed a fault displacement hazard. The fault displacement hazard analysis was built on two methodologies developed for the YM PSHA (Civilian Radioactive Waste Management System, Management and Operating Contractor, 1998). These methodologies, termed the earthquake approach and displacement approach, use Basin and Range empirical relationships with site-specific data to generate fault displacement hazard curves similar to seismic hazard curves.

Probabilistic fault displacement hazard results were calculated for three potential secondary faults under or near the PFSF site. These faults—informally named the C, D, and F fault zones—were identified from detailed seismic reflection profiles and confirmed by boreholes. The seismic profiles document offset of the Qp marker horizon, which represents the unconformity between Promontory soil, deposited 130–28 ka, and Bonneville alloformation (28–12 ka). Vertical separation across the largest strands of the F fault (F-1 and F-4) is approximately 1.5 m in the last 60 ka and 0.6 m in the last 20 ka. A critical observation is that these faults show evidence of repeated fault slip. This is important because it suggests that future faulting events will likely occur along these same faults and not on new faults under the site. In addition, these observations of repeated slip events allowed Geomatrix Consultants, Inc. (1999a) to constrain the average displacement per event for each fault.

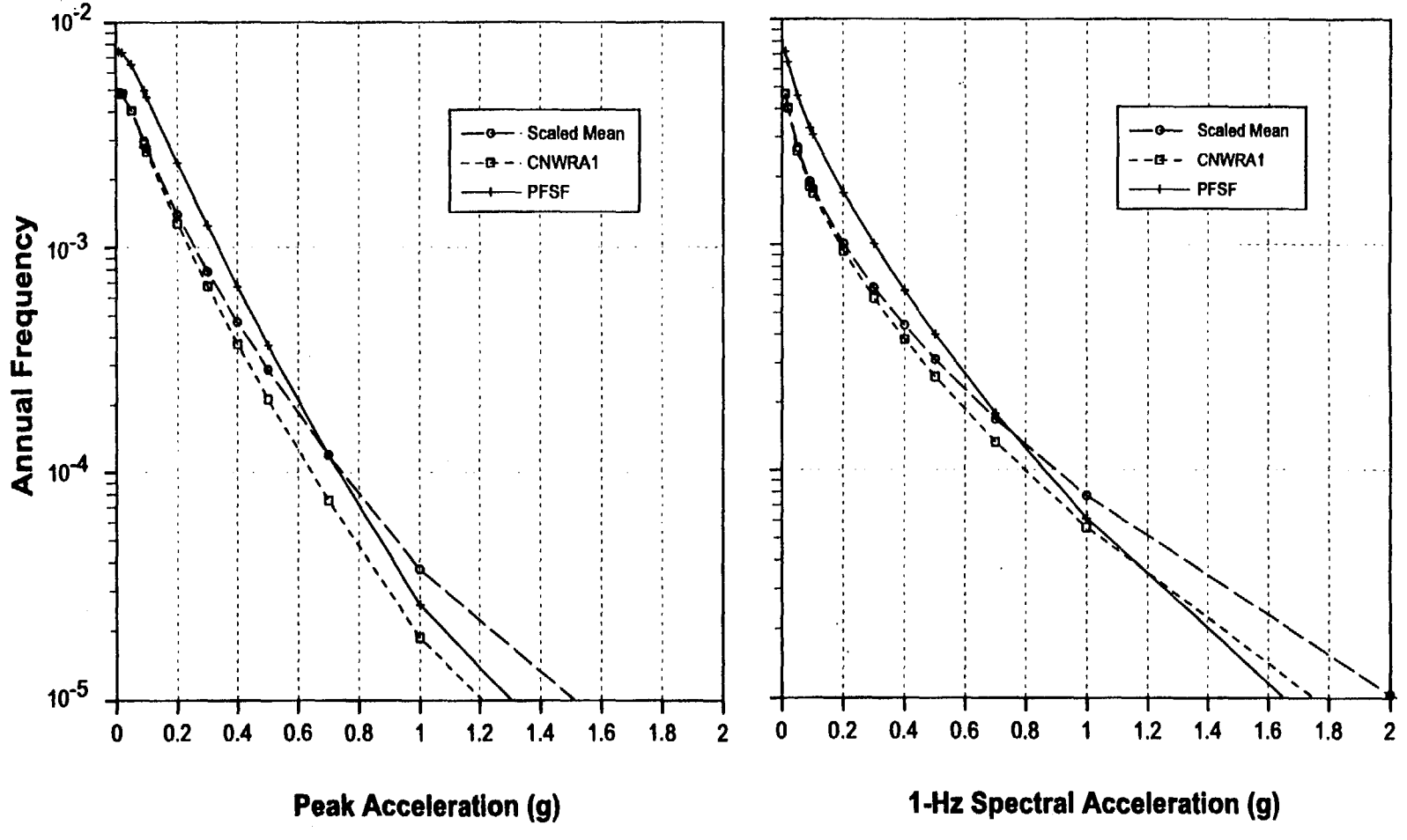

Figure 3-1. Comparison of seismic ground motion hazard curves from the Center for Nuclear Waste Regulatory Analyses sensitivity studies

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Faulting recurrence rates and displacement per event were quantified based on vertical separation of the Quaternary marker horizons. After careful review of the data, interpretations, and models, staff conclude that the results from the displacement approach are representative of site conditions, and these results should be used to assess the faulting hazard at the PFSF site. These results show that, based on the 95th-percentile curve, significant displacements, above 0.1 cm, are expected only with an annual frequency of less than 3×10^{-4}, or once in 3,333 years. Significant displacements of 10 cm or more are expected only with an annual frequency of less than 2×10^{-4}, or once in 5,000 years. For a 2,000-year return period (annual frequency of 5×10^{-4}), displacements due to faulting are smaller than 0.1 cm, which is less than the settlement allowance for concrete foundations.

Geomatrix Consultants, Inc. (1999a) also considered other possible distributed faulting between the mapped faults. These displacements were small. For example, Geomatrix Consultants, Inc. (1999a) measured only 5.5 cm of cumulative displacement across 88 m of exposure in Trench T-2, with a fracture spacing between 1.0 and 1.5 m. This suggests vertical displacement of less than 1 m accumulated across the entire width of the PFSF site (approximately 1,500 m) over the last several million years.

3.1.5 Regulatory and Technical Bases for Private Fuel Storage Limited Liability Company Exemption Request

In summary, the PFSLLC seismic and surface faulting hazard analysis techniques for the proposed Skull Valley PFSF appear technically sound and the resultant ground motion and faulting hazard values are conservative and represent best estimates. Therefore, a judgment of whether the PFSLLC-design approach is acceptable depends on two aspects: (i) whether there are regulatory and technical bases to accept the PFSLLC-design approach using PSHA and (ii) whether there are regulatory and technical bases to accept the PFSLLC-proposed design ground motion values calculated using a seismic event with a recurrence interval of 1,000 years.

Although 10 CFR Part 72 requires a deterministic approach for the seismic design of an ISFSI site west of the Rocky Mountain Front, a probabilistic approach for seismic design is acceptable by the 1997 amended 10 CFR Parts 100 and 50 that apply to new NPPs, and 10 CFR Part 60 that applies to the disposal of HLW in geologic repositories. Also, the NRC issued Regulatory Guide 1.165 to provide guidance on PSHA methodology (Nuclear Regulatory Commission, 1997b). In addition, as noted by the PFSLLC in its exemption request (Parkyn, 1999), a planned NRC rulemaking for the amendment of 10 CFR Part 72 intends to allow use of a probabilistic seismic-hazard methodology as part of the geologic and seismic siting criteria and to use a risk-informed graded approach to seismic design of ISFSI SSCs (Nuclear Regulatory Commission, 1998a). Furthermore, the NRC has reviewed and approved the request for exemption to 10 CFR 72.102(f)(1) seismic design requirement to allow seismic design using PSHA results of an event with a 2,000-year return period for the TMI-2 ISFSI (Nuclear Regulatory Commission, 1998b; Chen and Chowdhury, 1998). Technically, PSHA has many advantages over DSHA. For example, DSHA considers only the most significant earthquake sources and events (including maximum credible earthquake) with a fixed site-to-source distance. PSHA, on the other hand, considers contributions from all potential seismic sources and integrates across a range of source-to-site distances and magnitudes. Most importantly, DSHA is a time-independent statement, whereas PSHA estimates the likelihood of earthquake

ground motion occurring at the location of interest within the time frame of interest. It can be concluded that there are sufficient regulatory and technical bases to accept the PSHA methodology for seismic design of the proposed Skull Valley PFSF.

There is an adequate regulatory basis to adopt a graded approach similar to DOE Standard 1020 (U.S. Department of Energy, 1994) for natural hazard characterization and design, including ground motion seismic hazard (e.g., 10 CFR Part 60; Nuclear Regulatory Commission, 1998a,b). However, the level of ground motion that a particular SSC needs to be designed to depends on the importance of that particular SSC to public safety. As described in the NRC rulemaking plan (Nuclear Regulatory Commission, 1998a), an individual SSC may be designed to withstand only Frequency Category 1 events if the licensee analysis provides reasonable assurance that the failure of the SSC will not cause the facility to exceed the radiological requirements of 10 CFR 72.104(a). If the licensee analysis cannot support this conclusion, then the designated SSC must have a higher importance to safety, and the SSC must be designed such that the facility can withstand Frequency Category 2 events. To reiterate, Frequency Category 1 design basis ground motion refers to a mean recurrence interval of 1,000 years and Frequency Category 2 design basis ground motion refers to a mean recurrence interval of 10,000 years. The same NRC rulemaking plan (Nuclear Regulatory Commission, 1998a) also proposed an amendment to 10 CFR 72.212(b) to require design of cask storage pads and areas to adequately account for dynamic loads in addition to static loads.

In support for choosing a 1,000-year return period to calculate design basis ground motions, the PFSLLC (Parkyn, 1999) presented two main arguments: (1) the 1,000-year return period is the same as that selected by the DOE (1997) for preclosure seismic design of important to safety SSCs for NRC Frequency Category 1 design basis events at the YM HLW geologic repository. And, (2) the consequences of a major seismic event at the PFSF can be bounded using the HI-STORM and TranStor™ cask systems and are limited to a storage cask tipover event, which produces a dose limit below the 100 mrem public dose limit of 10 CFR 20.1301(a)(1) at 1,000 years. The CNWRA review found these arguments lack regulatory and technical bases. First, the DOE classification of YM HLW geologic repository SSCs to design for Frequency Category 1 and Frequency Category 2 events has not been reviewed or accepted by the NRC staff. Second, PFSLLC has provided no technical basis for classifying all the important to safety SSCs for the proposed Skull Valley PFSF as those that could be designed for NRC Frequency Category 1 design basis events. Finally, the consequence analysis using HI-STORM and TranStor™ includes only a particular accident scenario (i.e., cask tipover) that is independent of ground motion level. The PFSLLC did not demonstrate that cask tipover envelops other unanalyzed conditions such as the effect of collapse of the CTB on canisters or the effects of sliding and bearing failure of the foundation and concrete pad on storage casks. Based on these considerations, it is concluded there are insufficient regulatory or technical bases to accept the 1,000-year return period for seismic design.

The CNWRA review found it appropriate to design the proposed Skull Valley PFSF using a 2,000-year return period for the following reasons. This suggestion is based on the 20-year license term. Any applications for license renewal for additional time periods will need to be reviewed when such applications are submitted to the NRC, and the adequacy of seismic design for license renewal will be evaluated at that time.

- The Uniform Building Code and the National Earthquake Hazards Reduction Program (International Conference of Building Officials, 1994; Building Seismic Safety Council, 1995) both recommend using peak ground motion values that have a 90 percent probability of not being exceeded in 50 years for the seismic design of structures. Considering the radiological safety aspects of a dry SNF storage facility, conservative peak ground motion values that have a 99-percent likelihood of not being exceeded in the 20-year licensing period of the PFSF are considered to be adequate for its seismic design. This exceedance probability corresponds to a return period of 2,000 years.

- The DOE standard, DOE–STD–1020–94 (U.S. Department of Energy, 1994), defines four performance categories (PCs) for SSCs important to safety, with PC3 facilities being those with potential accident consequences similar to a dry SNF storage facility. The DOE standard requires that PC3 facilities be designed for the mean ground motion with a 2,000-year return period.

- In its Fault Evaluation Study and Seismic Hazard Assessment report for the PFSF site, Geomatrix Consultants, Inc. (1999a) concluded that an appropriate design probability level for both vibratory ground motion and fault displacement for the PFSF site is 5×10^{-4} (or a 2,000-year return period).

- The NRC has accepted a design seismic value that envelops the 50th-percentile deterministic ground motion value and the 2,000-year return period probabilistic ground motion value for the design of the TMI-2 ISFSI (Nuclear Regulatory Commission, 1998b; Chen and Chowdhury, 1998). The radiological consequences associated with TMI-2 ISFSI are similar to those of the proposed Skull Valley PFSF.

- Whereas a 84th-percentile DE is required for licensing NPPs, a lower design value (e.g., 50th-percentile DE) may be adequate for licensing dry storage ISFSIs because an operating ISFSI is inherently less hazardous and less vulnerable to earthquake-initiated accidents than is an operating nuclear power reactor. The PFSLLC 2,000-year PSHA response spectra generally envelop the 50th-percentile updated DSHA response spectra. Using lower DE requirements (i.e., 50th percentile versus 84th percentile) for the proposed PFSF is supported by the following considerations.

  — The NRC selected the 84th-percentile DE for NPPs to provide an extra level of conservatism for those higher risk facilities. An operating ISFSI is inherently less hazardous and less vulnerable to earthquake-initiated accidents than is an operating nuclear power reactor (Hossain et al., 1997). Unlike an NPP, an ISFSI does not need to meet requirements for active cooling and safe shutdown systems to ensure the integrity of the high-pressure reactor coolant boundary nor for shutting down the reactor in the event of a very large earthquake. Operations in an ISFSI facility need not be continuous but can be terminated, except for possible filtered ventilation systems and other confinement systems, in the event of a very large earthquake to repair any potential damage caused by the earthquake. For these reasons, the potential consequences of an accident are significantly smaller than from an NPP. Hence, it is appropriate that the design requirements for ISFSI structures,

which are important to public safety, be less stringent than the requirements for an NPP facility (Hossain et al., 1997).

— In 1980, when 10 CFR Part 72 was first promulgated, ISFSIs were largely envisioned to be SNF pools or massive dry storage structures, expected to be built at existing power plant sites. In Statements of Consideration accompanying the initial rulemaking, the NRC recognized that the design PHA for dry casks and canisters need not be as high as for a power reactor and should be determined on a case-by-case basis until more experience is gained with licensing these types of units. With over 10 years of experience licensing dry cask storage, and robust analyses demonstrating cask behavior in accident scenarios, the NRC staff now have a reasonable basis to consider a different design value that is adequate for licensing dry storage ISFSIs, where appropriate.

— The 2,000-year PSHA response spectra at the proposed PFSF site generally envelop the 50th percentile DSHA response spectra, whereas the 1,000-year PSHA response spectra do not (Figure 3-2).

In summary, using a 2,000-year return period to calculate design ground motion and fault displacement provides reasonable assurance for accepting the PFSLLC request for exemption to 10 CFR 72.102(f)(1) to use PSHA seismic design and fault displacement approach. This implies that the design analyses presented in the SAR using the original DSHA 84th-percentile results of a PHA of 0.67g and a PVA of 0.69g are acceptable. For any new SSCs or alternative designs, the analyses should be conducted using the corresponding 2,000-year return period response spectra or a design spectrum that envelops the 2,000-year return period response spectra.

3.2 RECOMMENDATIONS

Based on the activities reported herein, the following recommendations are made.

- The PFSLLC probabilistic seismic ground motion and faulting hazard results at the proposed Skull Valley PFSF site are reasonably conservative and represent the best estimates.

- There are sufficient regulatory and technical bases to accept the PFSLLC-proposed PSHA methodology along with a graded approach for seismic design for the proposed Skull Valley PFSF.

- There are insufficient regulatory and technical bases to accept the PFSLLC-proposed 1,000-year return period to calculate design basis seismic ground motions. However, using a 2,000-year return period to calculate design basis ground motions would provide reasonable assurance for accepting the PFSLLC request for exemption to 10 CFR 72.102(f)(1). Therefore, a 2,000-year return period is recommended for the seismic design of the proposed Skull Valley PFSF.

- The PFSLLC probabilistic fault displacement analysis shows that surface faulting is not significant to performance of the PFSF facility for either the 1,000- or 2,000-year return periods.

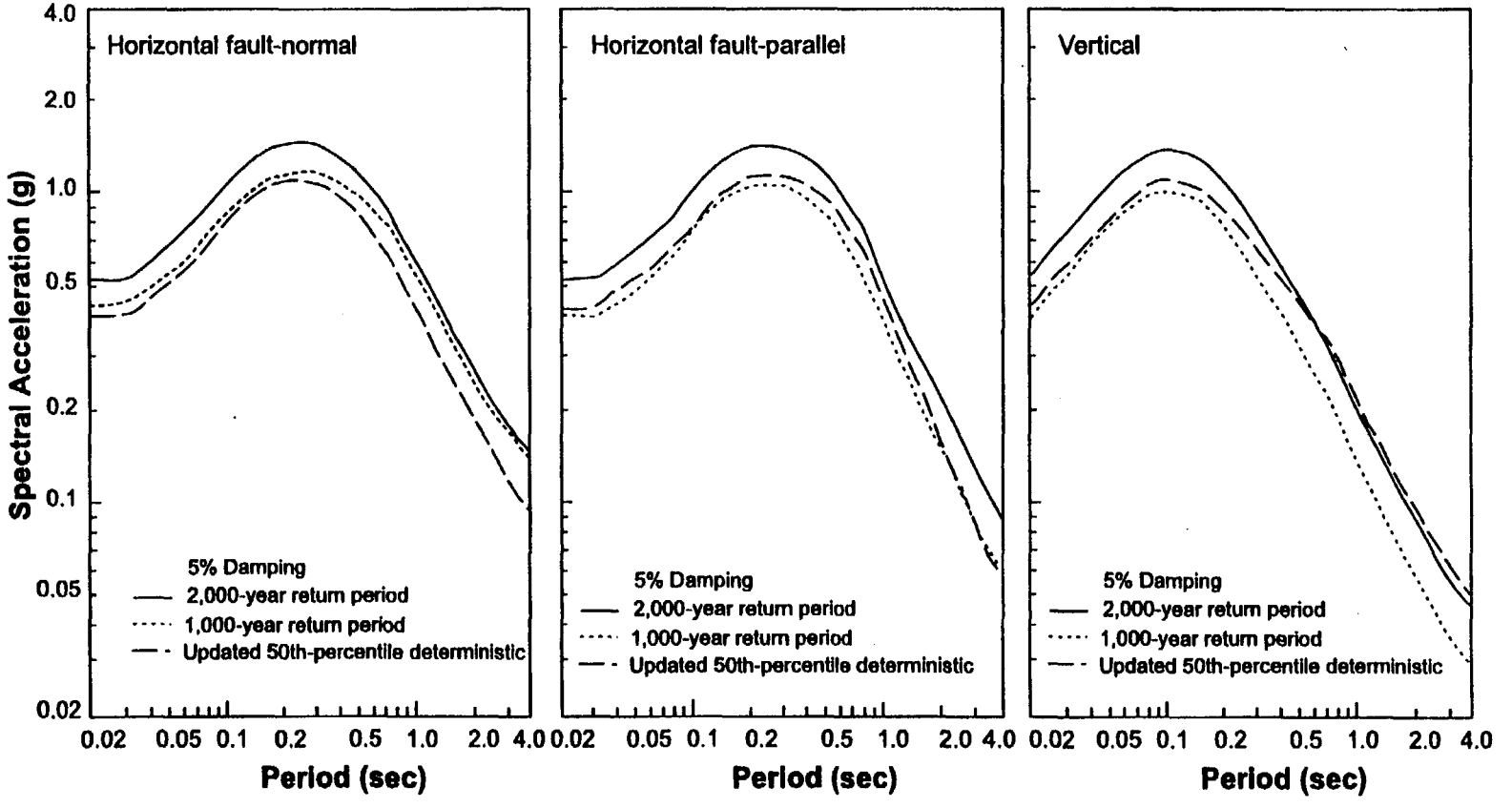

Figure 3-2. Comparison of 2,000- and 1,000-year probabilistic response spectra from Geomatrix Consultants, Inc. (1999c) with a 50th-percentile deterministic response spectrum from Geomatrix Consultants, Inc. (1999b)

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4 REFERENCES

Abrahamson, N.A., and W.L. Silva. 1997. Empirical response spectral attenuation relations for shallow crustal earthquakes. *Seismological Research Letters* 68(1): 94–127.

Anders, M.H., and N. Cristie-Blick. 1994. Is the Sevier Desert reflection of west-central Utah a normal fault? *Geology*: 771–774.

Anderson, J.G., S.G. Wesnousky, and M.W. Stirling. 1996. Earthquake size as a function of fault slip rate. *Bulletin of the Seismological Society of America* 86(3): 683–690.

Arabasz, W.J., R.B. Smith, and W.D. Richins. 1980. Earthquake studies along the Wasatch Front, Utah: Network monitoring, seismicity, and seismic hazards. *Bulletin of Seismological Society of America* 70: 1,479–1,499.

Arabasz, W.J., J.C. Pechmann, and E.D. Brown. 1989. Evaluation of seismicity relevant to the proposed siting of a Superconducting Supercollider (SSC) in Tooele County, Utah. *Utah Geological and Mineral Survey Miscellaneous Publications* 89(1): 107.

Arabasz, W.J., J.C. Pechmann, and E.D. Brown. 1992. Observational seismology and the evaluation of earthquake hazards and risk in the Wasatch Front area, Utah. *Assessment of Regional Earthquake Hazards and Risk Along the Wasatch Front, Utah.* P.L. Gori and W.W. Hays, eds. U.S. Geological Survey Professional Paper 1500–A–J.

Arabasz, W.J., S.J. Nava, and W.T. Phelps. 1997. Mining seismicity in the Wasatch Plateau and Book Cliffs coal mining districts, Utah, USA. S.J. Gibowicz and S. Lasocki, eds. Rockbursts and Seismicity in Mines. *Proceedings of the 4th International Symposium on Rockbursts and Seismicity in Mines, Krakow, Poland*, August 11–14.

Atwood, G., and D.R. Mabey. 1995. Flooding hazards associated with Great Salt Lake. W.R. Lund, ed. Environmental and Engineering Geology of the Wasatch Front Region. *Utah Geological Association* 24: 483–493.

Axen, G.J., W.J. Taylor, and J.M. Bartlet. 1993. Space-time patterns and tectonic controls of tertiary extension and magmatism in the Great Basin of the western United States. *Geological Society of America Bulletin* 105: 56–76.

Bay Geophysical Associates, Inc. 1999. *High-Resolution Seismic Shear-Wave Reflection Profiling for the Identification of Faults at the Private Fuel Storage Facility, Skull Valley, Utah—Final Report.* Traverse City, MI: Bay Geophysical Associates, Inc.

Bender, B. 1984. Seismic hazard estimation using a finite fault rupture model. *Bulletin of the Seismological Society of America* 74: 1,899–1,923.

Bishop, K.M. 1997. Miocene rock-avalanche deposits, Halloran/Sihrian Hills area, Southeastern California. *Environmental and Engineering Geosciences* III: 501–512.

Boatwright, J., and D.M. Boore. 1982. Analysis of the ground accelerations radiated by the 1980 Livermore Valley earthquakes for directivity and dynamic source characteristics. *Bulletin of the Seismological Society of America* 72(3): 1,843–1,865.

Boore, D.M., and W. Joyner. 1978. The influence of rupture incoherence on seismic directivity. *Bulletin of the Seismological Society of America* 68: 283–300.

Boore D.M., W.B. Joyner, and T.E. Fumal. 1994. Estimation of response spectra and peak accelerations from western North American earthquakes: An interim report, Part 2. *U.S. Geological Survey Open-File Report* 94(127): 40.

Boore D.M., W.B. Joyner, and T.E. Fumal. 1997. Equations for estimating horizontal response spectra and peak acceleration from western North American earthquakes: A summary of recent work. *Seismological Research Letters* 68: 128–153.

Building Seismic Safety Council. 1995. *NEHRP Recommended Provisions for Seismic Regulations for New Buildings.* 1994 Edition. FEMA 222A. Washington, DC: Federal Emergency Management Agency.

Burchfiel, B.C., D.S. Cowen, and G.A. Davis. 1992. Tectonic overview of the Cordilleran orogen in the western United States. The Cordilleran Orogen: Conterminous U.S. B.C. Burchfiel, P.W. Lipman, and M.L. Zoback, eds. Boulder, CO: Geological Society of America. *The Geology of North America Volume* G-3: 407–479.

Campbell, K.W. 1997. Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra. *Seismological Research Letters* 68(1): 154–179.

Cartwright, J.A., and C.S. Mansfield. 1998. Lateral displacement variations and lateral tip geometry of normal faults in the Canyonlands National Park, Utah. *Journal of Structural Geology* 20: 2–19.

Chen, R., and A.H. Chowdhury. 1998. *Seismic Ground Motion at Three Mile Island Unit 2 Independent Spent Fuel Storage Installation Site in Idaho National Engineering and Environmental Laboratory—Final Report.* CNWRA 98-007, San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.

Civilian Radioactive Waste Management System, Management and Operating Contractor. 1998. *Probabilistic Seismic Hazard Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada.* DE–AC04–94AL85000. Las Vegas, NV: U.S. Department of Energy.

Coppersmith, K.J., and R.R. Youngs. 1985. Capturing uncertainty in probabilistic seismic hazard assessments within intraplate tectonic environments. *Proceedings, 3rd U.S. National Conference on Earthquake Engineering, Volume 1.* El Cerrito, CA: Earthquake Engineering Research Institute: 301–312.

Cornell, C.A. 1968. Engineering seismic risk analysis. *Bulletin of the Seismological Society of America* 58: 1,583–1,606.

Cornell, C.A. 1971. Probabilistic analysis of damage to structures under seismic loads. *Dynamic Waves in Civil Engineering.* Wiley Interscience.

Cowan, D.S., and R.L. Bruhn. 1992. Late Jurassic to early Cretaceous geology of the U.S. Cordillera. The Cordilleran Orogen: Conterminous U.S. B.C. Burchfiel, P.W., Lipman, and M.L. Zoback, eds. Boulder, CO: Geological Society of America. *The Geology of North America. Volume* G-3: 169–204.

Crider, J.G., and D.D. Pollard. 1998. Fault linkage: Three-dimensional mechanical interaction between echelon normal faults. *Journal of Geophysical Research* 103: 24,373–24,391.

Crone, A.J. 1983. Amount of displacement and estimated age of a Holocene surface faulting event, eastern Great Basin, Millard County, Utah. *Geologic Excursions in Neotectonics and Engineering Geology in Utah.* Guidebook Part IV. Salt Lake City, UT: Utah Geological and Mineral Survey.

Currey, D.R., and C.G. Oviatt. 1985. Durations, average rates, and probable causes of Lake Bonneville expansions, still stands, and contractions during the last deep-lake cycle, 32,000 to 10,000 years ago. P.A. Kay and H.F. Diaz, eds. *Problems of and Prospects for Predicting Great Salt Lake Levels.* Salt Lake City, UT: University of Utah, Center for Public Affairs and Administration: 9–24.

Dalziel, I.W.D. 1997. Neoproterozoic-Paleozoic geography and tectonics: Review, hypothesis, environmental speculation. *Geological Society of America Bulletin* 109: 16–42.

dePolo, C.M., D.G. Clark, D.B. Slemmons, and A.R. Ramelli. 1991. Historical surface faulting in the Basin and Range province, western North America: Implications for fault segmentation. *Journal of Structural Geology* 13: 123–136.

Dixon, T.H., S. Robaudo, J. Lee, and M.C. Reheis. 1995. Constraints on present-day Basin and Range deformation from space geodesy. *Tectonics* 14: 755–772.

Donnell, J.L. 1999a. *Submittal of Commitment Resolution Letter No. 4 Information.* Letter (May 24) to M.S. Delligatti, Nuclear Regulatory Commission. Private Fuel Storage Facility. La Crosse, WI: Private Fuel Storage Limited Liability Company.

Donnell, J.L. 1999b. *Submittal of Commitment Resolution Letter No. 7 Information.* Letter (June 30) to M.S. Delligatti, Nuclear Regulatory Commission. Private Fuel Storage Facility. La Crosse, WI: Private Fuel Storage Limited Liability Company.

Dula, W.F., Jr. 1990. Geometric models of listric normal faults and rollover folds. *American Association of Petroleum Geologists Bulletin* 75: 1,609–1,625.

Electric Power Research Institute. 1993. *Guidelines for Determining Design Basis Ground Motions.* Volumes 1–5. EPRI TR–102293. Palo Alto, CA: Electric Power Research Institute.

England P., and J. Jackson. 1989. Active deformation of the continents. *Annual Reviews of Earth and Planetary Sciences* 17: 197–226.

Gardner, G.H.F., L.W. Gardner, and A.R. Gregory. 1974. Formation velocity and density—The diagnostics basics for stratigraphic traps. *Geophysics* 39: 770–780.

Geomatrix Consultants, Inc. 1997. *Deterministic Earthquake Ground Motions Analysis, Private Fuel Storage Facility, Skull Valley, Utah.* GMX #3801.1. Revision 0. San Francisco, CA: Geomatrix Consultants, Inc.

Geomatrix Consultants, Inc. 1999a. *Fault Evaluation Study and Seismic Hazard Assessment, Private Fuel Storage Facility, Skull Valley, Utah.* San Francisco, CA: Geomatrix Consultants, Inc.

Geomatrix Consultants, Inc. 1999b. *Update of Deterministic Ground Motion Assessments, Private Fuel Storage Facility, Skull Valley, Utah–Final Report.* Volumes II and III. San Francisco, CA: Geomatrix Consultants, Inc.

Geomatrix Consultants, Inc. 1999c. *Development of Design Ground Motion, Private Fuel Storage Facility, Skull Valley, Utah.* Project No. 4790. San Francisco, CA: Geomatix Consultants, Inc.

Geosphere Midwest. 1997. *Seismic Survey of the Private Fuel Storage Facility in Skull Valley, Utah.* Denver, CO: Stone & Webster Engineering Corporation.

Gutenberg, B., and C.F. Richter. 1954. *Seismicity of the Earth and Associated Phenomena.* Princeton, NJ: Princeton University Press 310.

Hamilton, W. 1994. Sevier Desert detachment, Utah—A nonexistent structure: *Geological Society of America Abstracts with Programs* 26: 57.

Hecker, S. 1993. Quaternary tectonics of Utah with emphasis on earthquake hazard characterization. *Utah Geological Survey Bulletin 127.* Salt Lake City, UT.

Helm, J.M. 1995. Quaternary faulting in the Stansbury zone, Tooele County, Utah. W.R. Lund, ed. *Environmental and Engineering Geology of the Wasatch Front Region.* Utah Geological Association Publication 24: 31–44.

Hoffman, P.F. 1989. Precambrian geology and tectonic history of North America. A.W. Bally and A.R. Palmer, eds. The Geology of North America: An overview: Boulder, CO: Geological Society of America. The Geology of North America, Volume A: 447–512.

Holtec International. 1999. *Topical Safety Analysis Report for the Holtec International Storage and Transfer Operation Reinforced Module Cask System (HI-STORM 100 Cask System.*

Report No. HI–951312). Volumes I and II. Revision 6. Docket No. 72-1014. Marlton, NJ: Holtec International.

Hossain, Q.A., A.H. Chowdhury, M.P. Hardy, K.S. Mark, J.E. O'Rourke, W.J. Silva, J.C. Stepp, and F.H. Swan, III. 1997. *Seismic and Dynamic Analysis and Design Consdierations for High-Level Nuclear Waste Repositories.* J.C. Stepp, ed. New York: American Society of Civil Engineers.

Hunter, R.L., and C.T. Mann. 1990. *Techniques for Determining Probabilities of Events and Processes Affecting the Performance of Repositories.* SAND 83-1342. NUREG/CR–3354. Albuquerque, NM: Sandia National Laboratories.

Idriss, I.M. 1991. *Selection of Earthquake Ground Motions at Rock Sites.* Davis, CA: National Institute of Standards and Technology, Department of Civil Engineering, University of California.

International Conference of Building Officials. 1994. *Uniform Building Code.* Whitter, CA: International Conference of Building Officials.

Jones, C.H., J.R. Unruh, and L.J. Sonder. 1996. The role of gravitational potential energy in active deformation in the southwestern United States. *Nature* 381: 37–41.

Machette, M.N., and W.E. Scott. 1988. Filed trip introduction—A brief review of research on lake cycles and neotectonics of the eastern Basin and Range Province. *Utah Geological and Mineral Survey Miscellaneous Publications* 88(1): 7–14.

Machette, M.N., S.F. Personius, and A.R. Nelson. 1991. The Wasatch fault zone, Utah—Segmentation and history of Holocene earthquakes. *Journal of Structural Geology* 13: 137–149.

Martinez, L.G., C.M. Meertens, and R.B. Smith. 1998. Rapid deformation rates along the Wasatch fault zone, Utah, from first GPS measurements with implications for earthquake hazard. *Geophysical Research Letters 25*: 567–570.

Mason, D.B. 1996. Earthquake magnitude potential of the Intermountain Seismic Belt, USA, from surface-parameter scaling of late Quaternary faults. *Bulletin of the Seismological Society of America* 86: 1,487–1,506.

McGarr, A. 1984. Scaling of ground motions parameters, state of stress, and focal depth. *Journal of Geophysical Research* 89: 6,969–6,979.

McGuire, R.K. 1976. *FORTRAN Computer Program for Seismic Risk Analysis.* OFR 76-67. Reston, VA: U.S. Geological Survey.

McGuire, R.K. 1978. *FRISK: Computer Program for Seismic Risk Analysis Using Faults as Earthquake Wources.* OFR 78-1007. Reston, VA: U.S. Geological Survey.

McKague, H.L., J.A. Stamatakos, and D.A. Ferrill. 1996. *Type I Faults in the Yucca Mountain Region.* CNWRA 96-007. San Antonio, TX: Center for Nuclear Waste Regulatory Analyses.

Mori, J. 1996. Rupture directivity and slip distribution of the **M** 4.3 foreshock to the 1992 Joshua Tree earthquake, southern California. *Bulletin of the Seismological Society of America* 86(3): 805–810.

Nuclear Regulatory Commission. 1997a. *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants.* NUREG–0800. Washington, DC: Nuclear Regulatory Commission.

Nuclear Regulatory Commission. 1997b. *Identification and Characterization of Seismic Sources and Determination of Safe Shutdown-Earthquake Ground-Motion.* Regulatory Guide 1.165. Washington, DC: Nuclear Regulatory Commission, Office of Standards Development.

Nuclear Regulatory Commission. 1998a. *Rulemaking Plan: Geological and Seismological Characteristics for Siting and Design of Dry Cask Independent Spent Fuel Storage Installation, 10 CFR Part 72.* SECY–98–126. Washington, DC: U.S. Government Printing Office.

Nuclear Regulatory Commission. 1998b. *Exemption to 10 CFR 72.102(f)(1) Seismic Design Requirement for Three Mile Island Unit 2 Independent Spent Fuel Storage Installation.* SECY–98–071. Washington, DC: U.S. Government Printing Office.

Nuclear Regulatory Commission. 1999. Issue Resolution Status Report, Key Technical Issue: Structural Deformation and Seismicity. Revision 2. Washington, DC: Nuclear Regulatory Commission, Division of Waste Management.

Ofoegbu, G.I., and D.A. Ferrill. 1997. Mechanical analyses of listric normal faulting with emphasis on seismicity assessment. *Tectonophysics* 284: 6,577.

Otton, J.K. 1995. Western frontal fault zone of the Canyon Range: Is it the breakaway zone of the Sevier Desert Detachment? *Geology* 23: 547–550.

Oviatt, C.G. 1997. Lake Bonneville fluctuations and global climate change. *Geology* 25: 155–158.

Parkyn, J.D. 1999. *Request for Exemption to 10 CFR 72.102(f)(1), Seismic Design Requirement.* Letter (April 2) to M.S. Delligatti, Nuclear Regulatory Commission. Private Fuel Storage Facility. La Crosse, WI: Private Fuel Storage Limited Liability Company.

Pechmann, J.C., and W.J. Arabasz. 1995. The problem of the random earthquake in seismic hazard analysis: Wasatch Front Region, Utah. *Environmental and Engineering Geology of the Wasatch Front Region.* W.R. Lund, ed. Utah Geological Association Publication 24: 77–93.

Pierce, K.L., and L.A. Morgan. 1992. The track of the Yellowstone hot spot: Volcanism, faulting, and uplift. *Geological Society of America Memoir.* P.K. Link et al., eds. Reston, VA: U.S. Geological Survey 179: 1–54.

Planke, S., and R.B. Smith. 1991. Cenozoic extension and evolution of the Sevier Desert Basin, Utah, from seismic reflection, gravity, and well log data. *Tectonics* 10: 345–365.

Private Fuel Storage Limited Liability Company. 1997. *License Application for Private Fuel Storage Facility*. Revision 0. Docket No. 72-22. La Crosse, WI: Private Fuel Storage Limited Liability Company.

Private Fuel Storage Limited Liability Company. 1998. *Safety Analysis Report for Private Fuel Storage Facility*. Revision 2. Docket No. 72-22. La Crosse, WI: Private Fuel Storage Limited Liability Company.

Private Fuel Storage Limited Liability Company. 1999. *Safety Analysis Report for Private Fuel Storage Facility*. Revision 3. Docket No. 72-22. La Crosse, WI: Private Fuel Storage Limited Liability Company.

Rigby, J.K. 1958. Geology of the Stansbury Mountains, Tooele County, Utah: *Utah Geological Society Guidebook* 13: 168.

Sack, D. 1993. *Quaternary Geological Map of Skull Valley, Tooele County, Utah*: Utah Geological Survey Map. 150. Scale 1:100,000.

Sadigh, K., C.Y. Change, N.A. Abrahamson, S.J. Chiou, and M.S. Power. 1993. Specification of long-period ground motions: Updated attenuation relationships for rock site conditions and adjustment factors for near-fault effects. *Proceedings of ATC–17–1 Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control*, March 11–12. San Francisco, CA: 59–70.

Sadigh, K., C.-Y. Change, J.A. Egan, F. Makdisi, and R.R. Youngs. 1997. Attenuation relationships for shallow crustal earthquakes based on California strong motion data. *Seismological Research Letters* 68(1): 154–179.

Sierra Nuclear Corporation. 1997. *Safety Analysis Report for the TranStor™ Storage Cask System*. SNC–96–72–SAR. Revision B. Atlanta, GA: Sierra Nuclear Corporation.

Silva, W.J., C. Constantino, and L. Sylvia. 1998. Quantification of nonlinear soil response for the Loma Prieta, Northridge, and Imperial Valley earthquakes. *The effects of Surface Geology on Seismic Motion*. Irikura, Kudo, Okada, and Sastani, eds.

Silver, M., and H.B. Seed. 1971. Volume changes in sands during cyclic loading. *Journal of the Soil Mechanics and Foundations, American Society of Civil Engineers* 97: SM9.

Singh, J.P. 1981. Source directivity and its role in estimation of strong ground motion. *Earthquake Notes* 52(1): 78.

Smith, R.B., and W.J. Arabaz. 1991. Seismicity in the intermountain seismic belt. D.B Slemmons, E.R. Engdahl, M.D. Zoback, and D.D. Blackwell, eds. Neotectonics of North America. *Geological Society of America, Decade Map Volume 1.* Boulder, CO: Geological Society of America: 185–228.

Smith, R.P., S.M. Jackson, and W.R. Hackett. 1996. Paleoseismology in extensional volcanic terrains. *Journal of Geophysical Research* 101: 6,277–6,292.

Somerville, P.G., N.F. Smith, R.W. Graves, and N.A. Abrahamson. 1997. Modification of empirical strong ground motion attenuation relations to include the amplitude and duration effects of rupture directivity. *Seismological Research Letters* 68(1): 199–222.

Spudich, P., J.B. Fletcher, M. Hellweg, J. Boatwright, C. Sullivan, W.B. Joyner, T.C. Hanks, D.M. Boore, A. McGarr, L.M. Baker, and A.G. Lindh. 1997. SEA96—A new predicative relation for earthquake ground motions in extensional tectonic regimes. *Seismological Research Letters* 68(1): 190–198.

Stepp, J.C., 1972. Analysis of completeness of the earthquake sample in the Puget Sound area and its effect on statistical estimates of earthquake hazard. *Proceedings of the International Conference on Microzonation* 2: 897–910.

Stewart, J.H. 1978. *Basin-Range Structure in Western North America: A Review.* Cenozoic Tectonic and Regional Geophysics of the Western Cordillera. R.B. Smith and G.P. Eaton, eds. Boulder, CO: Geological Society of America Memoir 152: 1–31.

Suppe, J. 1983. Geometry and kinematics of fault-bend folding. *American Journal of Science* 282: 684–721.

Telford W.M., L.P. Geldart, R.E. Sheriff, and D.A. Keys. 1976. *Applied Geophysics.* Cambridge, England. University Press, Cambridge.

Thatcher, W., G.R. Foulger, B.R. Julian, J. Svarc, E. Quilty, and G.W. Bawden. 1999. Present-day deformation across the Basin and Range province, western United States. *Science* 283: 1,714–1,718.

U.S. Department of Energy. 1994. *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities.* DOE–STD–1020–94. Washington, DC: U.S. Department of Energy.

U.S. Department of Energy. 1997. *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain.* YMR/TR–003–NP. Revision 2. Washington, DC: U.S. Department of Energy.

U.S. Geological Survey. 1996. *Seismotectonic Framework and Characterization of Faulting at Yucca Mountain, Nevada.* J.W. Whitney, Report Coordinator. Denver, CO: U.S. Geological Survey.

Weichert, D.H. 1980. Estimation of the earthquake recurrence parameters for unequal observations periods for different magnitudes. *Bulletin of the Seismological Society of America* 70: 1,337–1,346.

Wells, D.W., and K.J. Coppersmith. 1993. Likelihood of surface rupture as a function of magnitude. *Seismological Research Letters* 64(1): 54.

Wells, D.W., and K.J. Coppersmith. 1994. New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement. *Bulletin of the Seismological Society of America* 84: 974–1,002.

Wernicke, B.P. 1992. Cenozoic extensional tectonics of the western Cordillera. The Cordilleran Orogen: Conterminous U.S. B.C. Burchfiel, P.W., Lipman, and M.L. Zoback, eds. Boulder, CO: Geological Society of America. *The Geology of North America* G(3): 553–581.

Wernicke, B.P. 1995. Low-angle normal faults and seismicity: A review. *Journal of Geophysical Research* 100: 20,159–20,174.

Wernicke, B.P., and B.C. Burchfiel. 1982. Modes of extensional tectonics. *Journal of Structural Geology* 4: 104–115.

Wesnousky, S.G., 1986. Earthquakes, Quaternary faults, and seismic hazard in California. *Journal of Geophysical Research* 91: 12,587–12,631.

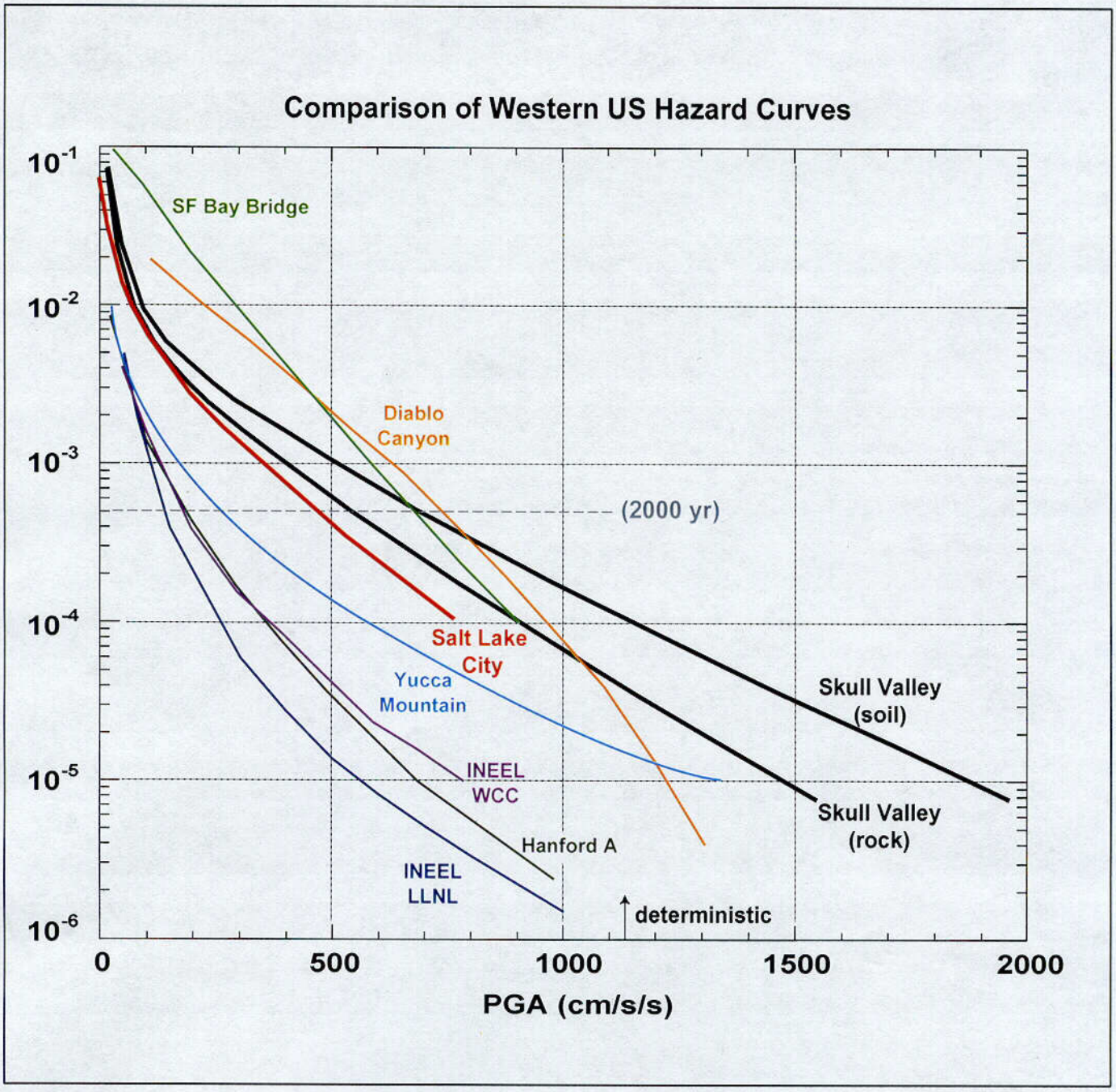
Wong, I.G., and J.R. Humphrey. 1989. Contemporary seismicity, faulting, and the state of stress in the Colorado Plateau. *Geological Society of America Bulletin* 101: 1,127–1,146.

Woodward, N.B., S.B. Boyer, and J. Suppe. 1989. Balanced geological cross-sections: An essential technique in geological research and exploration. American Geophysical Union Short Course in Geology 6. *American Geophysical Union*: 132.

Yarnold, J.C. 1993. Rock-avalanche characteristics in dry climates and the effects of flow into lakes: Insights from mid-tertiary sedimentary breccias near Artillery Peak, Arizona. *Geological Society of America Bulletin* 105: 345–360.

Youngs, R.R., and K.J. Coppersmith. 1985. Implications of fault slip rates and earthquake recurrence models for probabilistic seismic hazard estimates. *Bulletin of the Seismological Society of America* 75: 939–964.

Youngs, R.R., F.H. Swan III, M.P. Power, D.P. Schwartz, and R.K. Green. 1987. Analysis of earthquake ground shaking hazard along the Wasatch Front. P.L. Gori, and W.W. Hays, eds. *Assessment of regional earthquake hazards and risk along the Wasatch Front, Utah.* Volume II. U.S. Geological Survey Open-File Report 87-585: 1–110.



STAFF EXHIBIT R

C01

STAFF EXHIBIT S

POLICY ISSUE

(NEGATIVE CONSENT)

April 8, 1998 SECY-98-071

FOR: The Commissioners

FROM: L. Joseph Callan
Executive Director for Operations

SUBJECT: EXEMPTION TO 10 CFR 72.102(f)(1) SEISMIC DESIGN REQUIREMENT FOR THREE MILE ISLAND UNIT 2 INDEPENDENT SPENT FUEL STORAGE INSTALLATION

PURPOSE:

To request, by negative consent, Commission approval of the staff's intent to inform the U.S. Department of Energy, Idaho Operations Office (DOE-ID) of its finding that an adequate safety basis supports granting an exemption to the 10 CFR Part 72 seismic design requirement for the independent spent fuel storage installation (ISFSI) to store Three Mile Island Unit 2 (TMI-2) fuel debris.

BACKGROUND:

On October 31, 1996, DOE-ID submitted an application to the U.S. Nuclear Regulatory Commission to operate an ISFSI at the Idaho National Engineering and Environmental Laboratory (INEEL) for storing TMI-2 core debris. The core debris is presently stored in small canisters in a spent fuel pool at the Test Area North facility at INEEL. The ISFSI will be constructed within the Idaho Chemical Processing Plant (ICPP) site at INEEL. The ISFSI will use a modified version of the NUHOMS system technology, with the canisters housed horizontally in concrete modules. The safety and environmental reviews of the DOE-ID application are ongoing. DOE-ID is party to a settlement agreement with the State of Idaho, requiring construction of the ISFSI by December 31, 1998. Although the Commission is not a party to this agreement, the staff has committed to review the application as expeditiously as possible, to assist DOE-ID in meeting this schedule.

CONTACT: Stephen M. McDuffie, NMSS/SFPO
(301) 415-1085

NOTE: TO BE MADE PUBLICLY AVAILABLE WHEN THE FINAL SRM IS MADE AVAILABLE

On September 15, 1997, DOE-ID requested an exemption to the 10 CFR 72.102(f)(1) seismic design requirement for the TMI-2 ISFSI. Section 72.102(f)(1) requires sites west of the Rocky Mountain front to use a design earthquake (DE) ground motion equivalent to that of a safe shutdown earthquake (SSE) for a nuclear power plant (NPP), as evaluated by the methods of Appendix A of 10 CFR Part 100. Following the methods of Appendix A, DOE-ID determined that the design earthquake at the ICPP site would be a peak ground acceleration (PGA) of 0.56 g, with an appropriate response spectrum. However, DOE-ID proposes a design earthquake with a 0.36 g peak ground acceleration as an adequately conservative seismic design for the ISFSI.

DISCUSSION:

When Part 72 was first promulgated in 1980, ISFSIs were largely envisioned to be spent fuel pools or single, massive dry storage structures. A seismic design requirement equivalent to a nuclear power plant (Appendix A of Part 100) seemed appropriate for these types of facilities, given the potential accident scenarios. NRC recognized that a major seismic event at an ISFSI storing spent fuel in dry casks or canisters would have minor radiological consequences compared with a nuclear power plant, spent fuel pool, or single massive storage structure. NRC stated in the Part 72 "Statements of Consideration" that the design earthquake for cask and canister technology need not be as high as a nuclear power plant safe shutdown earthquake: "For ISFSIs which do not involve massive structures, such as dry storage casks and canisters, the required design earthquake will be determined on a case-by-case basis until more experience is gained with licensing these types of units" (45 FR 74697).

The staff is developing, for Commission approval, a plan to modify the Part 72 seismic requirement to better reflect robust cask and canister designs, as well as recent amendments to seismic siting criteria in other regulations. The existing Part 72 requires the use of Appendix A of Part 100, a deterministic method, in calculating the design earthquake at western sites. The seismic requirements in 10 CFR Parts 50 and 100, effective January 10, 1997, and 10 CFR Part 60, effective January 3, 1997, are based on probabilistic seismic hazard assessment (PSHA) techniques. Parts 50 and 100 allow PSHA methods to address uncertainties inherent in determining an safe shutdown earthquake value for a nuclear power plant. The Part 60 change, also known as the Design Basis Event (DBE) rulemaking, allows probabilistic methods in designing for hazards (including seismic) at a geologic repository, and allows two design levels based on risk. The staff will consider PSHA and relative risk in developing the new Part 72 seismic requirement.

DOE-ID has developed design earthquake values for the ISFSI site both deterministically (Appendix A of Part 100) and through a PSHA (10 CFR 100.23). To comply with the 10 CFR 72.102(f)(1) requirement, DOE-ID calculated a deterministic design earthquake of 0.56 g peak ground acceleration, with an appropriate response spectrum. Based on 10 CFR 100.23 requirements, as described in Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," a future nuclear power plant in the western United States can use as a safe shutdown earthquake the 10,000-year return period mean ground motion. DOE-ID derived 0.47 g peak ground acceleration as the 10,000-year return period mean ground motion for the ISFSI site. Likewise, DOE-ID derived 0.30 g peak ground acceleration as the 2000-year return period mean ground motion. DOE-ID proposes to use 0.36 g peak ground acceleration, with an appropriate response spectrum, as the design value for the ISFSI. DOE-ID selected this value based on consistency with its own site-specific design standard, which would also require a 0.36 g peak

ground acceleration design value for a power reactor at this site. This standard relies on a detailed geologic investigation similar to that required by Appendix A of Part 100, but without the benefit of some more recent geologic data. DOE-ID further justifies 0.36 g peak ground acceleration with a site-specific radiological risk analysis.

In reviewing DOE-ID's exemption request, the staff considered foremost the public health and safety consequence of a major seismic event at a cask or canister ISFSI. At an ISFSI using the NUHOMS system technology, the consequences are bounded by a canister drop onto the concrete pad. Although this would occur only at a ground motion well above the proposed design earthquake of 0.36 g peak ground acceleration, the canisters are designed to withstand such drops with no release of radioactive material. DOE-ID estimates that should a storage canister fail and one of the 12 inner core debris canisters release its contents (although the staff has not identified a credible mechanism for such a failure), the radiological consequences would be a dose of about 0.75 mSv (75 mrem) to a member of the public. This is well below the 0.05 Sv (5 rem) siting evaluation factor of 10 CFR 72.106(b).

The staff also considered the relative risk posed by the ISFSI. The staff examined relative risk by referring to DOE Standard 1020, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities." This standard takes a graded approach to designing critical facilities, requiring facilities with greater accident consequences to use higher design requirements for phenomena such as earthquakes and tornadoes. Standard 1020 defines four performance categories (PCS) for structures, systems, and components (SSCs) important to safety, with PC 4 facilities being those with potential accident consequences similar to a commercial nuclear power plant. Such facilities must have a design earthquake equal to the mean seismic ground motion with a 10,000-year return period. Dry spent fuel storage facilities such as the TMI-2 ISFSI, are PC 3 and must have a design earthquake equal to the mean ground motion with a 2000-year return period. Considering the minor radiological consequences from a canister failure, and the lack of a credible mechanism to cause a failure, the staff finds that the DOE approach of using the 2000-year return period mean ground motion as the design earthquake for dry storage facilities is adequately conservative. The design earthquake proposed by DOE-ID for the ISFSI exceeds the peak ground acceleration value of the mean 2000-year return period ground motion.

With the Part 60 Design basis event rulemaking, NRC adopted a graded approach similar to DOE Standard 1020 for natural hazard characterization and design. The Design basis event rulemaking defined a framework for two SSC design categories for repository surface facilities. For seismic events, the staff has accepted DOE's approach of designing SSCs with failure consequences within the public dose limit of 10 CFR 20.1302(a)(1), 1 mSv (100 mrem), to withstand the 1000-year return period mean ground motion. Meanwhile, SSCs with higher potential accident doses must be designed to withstand the 10,000-year return period mean ground motion.

In summary, the staff finds that the design earthquake proposed by DOE-ID for the TMI-2 ISFSI (0.36 g peak ground acceleration with an appropriate response spectrum) adequately protects public health and safety. The design earthquake is above the 0.30 g peak ground acceleration 2000-year return period mean ground motion obtained from the PSHA. The analysis provided by DOE-ID relies on widely accepted PSHA techniques that are consistent with the newer seismic design requirements in Parts 50, 60, and 100. In addition, the relative risk of the facility warrants a design earthquake below the Part 100 Appendix A value. The use of probabilistic

techniques and a risk-graded approach are compatible with the direction provided by the Commission on Direction Setting Issue 12, "Risk-Informed, Performance-Based Regulation."

Since the rulemaking to revise the Part 72 seismic requirement for ISFSIs is unlikely to be completed before issuance of the TMI-2 ISFSI license, the staff intends to grant the exemption as requested if the Environmental Assessment (EA) is favorable. A final decision on granting the exemption will be made when the staff completes an EA on the exemption request. If the exemption is granted, staff intends to formally issue the exemption at the time the license is issued.

If the staff grants the exemption to 10 CFR 72.102(f)(1), this may impact the licensing process for other ISFSIs in the western United States. Until the ISFSI seismic requirement in Part 72 is amended by rulemaking, the staff may receive similar exemption requests for other ISFSIs to be sited west of the Rocky Mountain front.

COORDINATION:

The Office of the General Counsel has reviewed this paper and has no legal objection.

RECOMMENDATION:

Unless the Commission directs otherwise, the staff intends to issue the attached letter to DOE-ID.

L. Joseph Callan
Executive Director
for Operations

Attachment: Draft Ltr C. Haughney, NRC,
to J. Wilcynski, DOE-ID

SECY NOTE: In the absence of instructions to the contrary, SECY will notify the staff on Thursday, April 23, 1998 that the Commission, by negative consent, assents to the action proposed in this paper.

DISTRIBUTION:
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March xx, 1998

Mr. J. M. Wilcynski, Manager
Idaho Operations Office
U.S. Department of Energy
850 Energy Drive
Idaho Falls, ID 83401-1563

SUBJECT: REQUEST FOR EXEMPTION TO 10 CFR 72.102(f)(1) SEISMIC DESIGN REQUIREMENT FOR THREE MILE ISLAND UNIT 2 INDEPENDENT SPENT FUEL STORAGE INSTALLATION (TAC NO. L22283)

Dear Mr. Wilcynski:

This responds to your September 15, 1997, request, pursuant to 10 CFR 72.7, for an exemption to the seismic design requirement of 10 CFR 72.102(f)(1), for the Three Mile Island Unit 2 (TMI-2) Independent Spent Fuel Storage Installation (ISFSI).

After reviewing the probabilistic seismic hazard assessment completed for the TMI-2 ISFSI site, the staff finds an adequate safety basis to grant your requested exemption, allowing a design earthquake of 0.36 g peak ground acceleration, with an appropriate response spectrum. This staff reached this decision after considering the origin of the 10 CFR 72.102(f)(1) seismic design requirement, recent amendments to the seismic and geologic criteria in 10 CFR Parts 60 and 100, and the on-going U.S. Nuclear Regulatory Commission effort to revise the 10 CFR Part 72 seismic design requirements for ISFSIs. A safety evaluation of the exemption request is enclosed. This safety evaluation will be incorporated into the final safety evaluation to be issued with the TMI-2 ISFSI license.

A final decision on granting the exemption cannot be made until the staff completes an Environmental Assessment (EA) on the exemption request. When the EA is completed, the staff will make the determination whether to grant the exemption. If the exemption is granted, staff intends to formally issue the exemption at the time the license is issued.

If you have any questions, please contact Mr. Michael Raddatz of my staff at 301-415-8544.

Sincerely,

Charles J. Haughney, Acting Director
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

Docket 72-20

Enclosure: Safety Evaluation

cc: Service List

Attachment

DOCKET: 72-20

APPLICANT: U.S. Department of Energy, Idaho Operations Office
Three Mile Island Unit 2 Independent Spent Fuel Storage Installation

SUBJECT: EVALUATION OF EXEMPTION REQUEST TO 10 CFR 72.102(f)(1) SEISMIC DESIGN REQUIREMENT

BACKGROUND

By request dated September 15, 1997, the U.S. Department of Energy, Idaho Operations Office (DOE-ID), requested an exemption to the 10 CFR 72.102(f)(1) seismic design requirement for the Three Mile Island Unit 2 (TMI-2) Independent Spent Fuel Storage Installation (ISFSI). The facility will use the NUHOMS system technology with dry, shielded canisters housed horizontally in concrete modules. DOE-ID plans to construct this facility at the Idaho Chemical Processing Plant within the Idaho National Engineering and Environmental Laboratory (INEEL) site. The DOE-ID seismic hazard analysis meeting the requirement of 10 CFR 72.102(f)(1) yields a design earthquake (DE) of 0.56 g peak ground acceleration (PGA), with an appropriate response spectrum, for the ISFSI site. DOE-ID proposes a DE of 0.36 g PGA, with an appropriate response spectrum. DOE-ID justifies this value with a site-specific radiological risk analysis.

DISCUSSION

Section 72.102(b) requires ISFSI sites west of the Rocky Mountain front, as is the INEEL site, to have seismicity evaluated by the techniques of Appendix A of 10 CFR Part 100, also known as a deterministic seismic hazard analysis (DSHA). A DSHA calculates, based on site-specific investigations, the largest credible earthquake likely to affect a site, regardless of the probability of this event through time. Section 72.102(f)(1) states, "For sites that have been evaluated under the criteria of Appendix A of 10 CFR Part 100, the design earthquake must be equivalent to the safe shutdown earthquake (SSE) for a nuclear power plant." In this context, "DE" and "SSE" refer to the design peak ground acceleration, with an appropriate response spectrum, caused by the largest credible earthquake. The most recent DSHA for the ISFSI site yields a DE of 0.56 g PGA, with an appropriate response spectrum.

When 10 CFR Part 72 was first promulgated in 1980, ISFSIs were largely envisioned to be spent fuel pools or single, massive dry storage structures. A DE equivalent to a nuclear power plant (NPP) SSE seemed appropriate for these facilities, given the potential accident scenarios. Furthermore, for ISFSIs to be located at an NPP, the DE value was readily available without additional site characterization work, save the geotechnical investigation at the specific ISFSI location. However, an ISFSI storing spent fuel in dry casks or in canisters

with horizontal storage modules is inherently less hazardous and less vulnerable to earthquake-initiated accidents than is an operating NPP (e.g., Hossain et al., 1997). The U.S. Nuclear Regulatory Commission recognized this in the initial Part 72 "Statements of Consideration," and stated that the DE for cask and canister technology need not be as high as an NPP SSE: "For ISFSIs which do not involve massive structures, such as dry storage casks and canisters, the required design earthquake will be determined on a case-by-case basis until more experience is gained with licensing these types of units."

The bounding consequences of a major seismic event at an ISFSI using the NUHOMS system technology are limited by a canister drop onto the concrete pad, although this would occur only at a ground motion well above the proposed 0.36 g PGA design value, as detailed in Section 8.2.3.2 of the TMI-2 ISFSI Safety Analysis Report (DOE-ID, 1996a) (SAR). The casks and canisters are designed to withstand such events with no release of radioactive material. The effects of a NUHOMS canister drop are analyzed in Section 8.2.5.2 of the SAR. In addition, analysis of beyond-design basis accidents leading to cask or canister rupture estimate off-site doses well below the 0.05 Sv (5 rem) whole body dose limit of 10 CFR 72.106(b). In a letter dated July 19, 1996 (DOE-ID, 1996b), DOE-ID presented a conservative analysis of off-site doses resulting from a beyond-design basis accident. In this hypothetical accident, for which neither DOE-ID nor the staff has identified a credible mechanism, both a NUHOMS dry shielded canister and one of the 12 inner core debris canisters are assumed to fail, allowing unmitigated dispersal of the contents. The calculated off-site dose from such an accident is 0.75 mSv (75 mrem), well below the 0.05 Sv (5 rem) siting evaluation factor of 10 CFR 72.106(b).

On January 10, 1997, 10 CFR Parts 50 and 100 were revised to allow the use of the probabilistic seismic hazard assessment (PSHA) methodology to address uncertainties inherent in determining NPP seismic design values. These revisions were accomplished through the addition of 10 CFR 100.23 and Part 50, Appendix S. The PSHA method considers the frequency, as well as magnitude, of earthquakes that may affect a site. Rather than base seismic design on the largest ground motion likely to ever affect a site, a PSHA derives a site-specific hazard curve showing ground motion level versus annual probability of exceedence or, inversely, ground motion return period. The present Part 72 seismic siting evaluation factor requires use of methods in Appendix A of Part 100 and does not allow use of the PSHA method. The staff is developing a plan to modify the Part 72 seismic requirement to a level commensurate with the risks of cask and canister ISFSIs. In addition, the new requirement will be based on the PSHA methodology. Options being considered for DE values are the 2000- or 1000-year return period mean ground motion, possibly derived from a U.S. Geological Survey seismic hazard.

In reviewing the DE proposed by DOE-ID for the ISFSI, the staff also considered DOE and NRC precedents. The staff considered DOE Standard 1020, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities," DOE-STD-1020-94. This standard takes a probabilistic, risk-graded approach to designing critical facilities, requiring facilities with greater accident consequences to use higher design requirements for phenomena such as earthquakes and tornadoes. DOE Standard 1020 defines four performance categories (PCs) for structures, systems, and components (SSCs) important to

safety, with PC 4 facilities being those with potential accident consequences similar to a commercial NPP. Such facilities must be designed to withstand the mean seismic ground motion with a 10,000-year return period. As described in Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," a future NPP licensed by NRC in the western United States would be allowed to design to this same level. Dry spent fuel storage facilities, such as the TMI-2 ISFSI at INEEL, are classified PC 3 and must be designed for the mean ground motion with a 2000-year return period. The DE proposed by DOE-ID for the ISFSI (0.36g PGA) exceeds that of the 2000-year mean ground motion (0.30 g PGA) derived from the site-specific PSHA. As a comparison, the U.S. Geological Survey hazard maps yield, for the ISFSI general vicinity, PGA values of 0.30 g for a 2500-year return period; 0.20 g for 1000-year; and 0.15 g for a 500-year return period.

In addition, the staff considered the seismic design philosophy in 10 CFR Part 60 for high-level waste repository surface facilities. On January 3, 1997, the definition of design basis event in Part 60 was revised to allow a probabilistic, risk-graded methodology, similar to that in DOE-STD-1020-94, in designing for hazards (including seismic) at a geologic repository. This set an NRC precedent by accepting a risk-graded approach in licensing a facility quite similar to an ISFSI in terms of radioactive material present and possible accident scenarios. For seismic events, the staff has accepted DOE's two-tier approach toward designing Part 60 SSCs. Those SSCs with potential failure consequences less than the public dose limit of 10 CFR 20.1302(a)(1), 1 mSv (100 mrem), must withstand the 1000-year return period mean ground motion. SSCs with higher potential failure consequences must withstand the 10,000-year return period mean ground motion, while maintaining doses in unrestricted areas below the 0.05 Sv (5 rem) total effective dose equivalent limit of 10 CFR 60.136(b).

CONCLUSIONS

DOE-ID has completed both a DSHA (Appendix A of Part 100) and PSHA (10 CFR 100.23) for the ISFSI site. The staff has evaluated these analyses and finds the resultant values acceptable: 0.56 g PGA for an SSE by the deterministic method and 0.30 g PGA mean ground motion with a 2000-year return period by the probabilistic method. Considering the lack of radiological consequences from credible accidents and the minor consequences from beyond-design basis accidents, the staff finds the present Part 72 requirement for an ISFSI DE to be an unnecessary regulatory burden. The staff finds acceptable the risk-graded approach to seismic hazard characterization and design in DOE Standard 1020, which is similar to the risk-graded approach to design basis events in Part 60. Given the absence of radiological consequences from any credible seismic event, the staff finds that the DOE Standard 1020 risk-graded approach of using the 2000-year return period mean ground motion as the DE is adequately conservative. Moreover, the expected life span of the ISFSI, 20 years with the possibility of renewal, per 10 CFR 72.42, justifies use of this ground motion as the DE. The DE proposed by DOE-ID for the ISFSI, 0.36 g PGA with an appropriate response spectrum, exceeds the 0.30 g PGA value for the 2000-year return period mean ground motion. Therefore, the staff concludes that granting the requested exemption from 10 CFR 72.102(f)(1) will maintain an adequate design margin for seismic events and will not be inimical to public health and safety.

This safety evaluation does not represent final approval of the TMI-2 ISFSI design. This evaluation approves a DE value other than that required by 10 CFR 72.102(f)(1); it does not evaluate DOE-ID's analysis of how this new requirement will be implemented. The staff evaluation of the design will be contained in the safety evaluation report provided with the TMI-2 ISFSI license.

REFERENCES

Hossain, Q.A., A.H. Chowdhury, M.P. Hardy, K.S. Mark, J.E. O'Rourke, W.J. Silva, J.C. Stepp, and F.H. Swan, III, "Seismic and Dynamic Analysis and Design Considerations for High-Level Nuclear Waste Repositories," J.C. Stepp, ed., American Society of Civil Engineers, New York, New York, 1997.

U.S. Department of Energy, Idaho Operations Office, "Safety Analysis Report for the INEL TMI-2 Independent Spent Fuel Storage Installation," Revision 0, October 1996a.

U.S. Department of Energy, Idaho Operations Office, Letter from J. Hagers (DOE-ID) to M. G. Raddatz (NRC), Subject: "License Application for the Three Mile Island Unit 2 Interim Storage System as an Independent Spent Fuel Storage Installation under 10 CFR Part 72 - Seismic Design Basis," July 19, 1996b.

U.S. Nuclear Regulatory Commission, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," Regulatory Guide 1.165, March 1997.

May 20, 1998

MEMORANDUM TO: L. Joseph Callan
Executive Director for Operations

FROM: John C. Hoyle /s/

SUBJECT: STAFF REQUIREMENTS : SECY 98-071 - EXEMPTION TO 10 CFR 72.102(f)(1) SEISMIC DESIGN REQUIREMENT FOR THREE MILE ISLAND UNIT 2 INDEPENDENT SPENT FUEL STORAGE INSTALLATION

The Commission has not objected to the staff's proposal to inform the U.S. Department of Energy, Idaho Operations Office (DOE-ID), of the staff's finding that an adequate safety basis supports granting an exemption to the 10 CFR Part 72 seismic design requirement for the independent spent fuel storage installation (ISFSI) to store Three Mile Island Unit 2 fuel debris. The staff should issue the proposed letter to DOE-ID promptly.

(EDO) (SECY Suspense: 5/29/98)

cc: Chairman Jackson
Commissioner Dicus
Commissioner Diaz
Commissioner McGaffigan
OGC
CIO
CFO
OCA
OIG
Office Directors, Regions, ACRS, ACNW, ASLBP (by E-Mail)
PDR
DCS

SECY NOTE: This SRM and SECY 98-071 will be made available to the public 5 working days from the date of issuance of the letter to the Department of Energy, Idaho Operations Office.

May 28, 1998

Mr. J. M. Wilcynski, Manager
Idaho Operations Office
U.S. Department of Energy
850 Energy Drive
Idaho Falls, ID 83401-1563

SUBJECT: REQUEST FOR EXEMPTION TO 10 CFR 72.102(f)(1) SEISMIC DESIGN REQUIREMENT FOR THREE MILE ISLAND UNIT 2 INDEPENDENT SPENT FUEL STORAGE INSTALLATION (TAC NO. L22283)

Dear Mr. Wilcynski:

This responds to your September 15, 1997, request, pursuant to 10 CFR 72.7, for an exemption to the seismic design requirement of 10 CFR 72.102(f)(1), for the Three Mile Island Unit 2 (TMI-2) Independent Spent Fuel Storage Installation (ISFSI).

After reviewing the probabilistic seismic hazard assessment completed for the TMI-2 ISFSI site, the staff finds an adequate safety basis to grant your requested exemption, allowing a design earthquake of 0.36 g peak ground acceleration, with an appropriate response spectrum. The staff reached this decision after considering the origin of the 10 CFR 72.102(f)(1) seismic design requirement, recent amendments to the seismic and geologic criteria in 10 CFR Parts 60 and 100, and the on-going Nuclear Regulatory Commission effort to revise the 10 CFR Part 72 seismic design requirements for ISFSIs. A safety evaluation of the exemption request is enclosed. This safety evaluation will be incorporated into the final safety evaluation to be issued with the TMI-2 ISFSI license.

A final decision on granting the exemption cannot be made until the staff completes an Environmental Assessment (EA) on the exemption request. When the EA is completed, the staff will make the determination whether to grant the exemption. If the exemption is granted, the staff intends to formally issue the exemption at the time the license is issued.

If you have any questions, please contact Mr. Michael Raddatz of my staff at 301-415-8544.

Sincerely,

ORIGINAL SIGNED BY /s/
Charles J. Haughney, Acting Director
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

Docket 72-20
Enclosure: Safety Evaluation
cc: Service List

Distribution: w/ encl

	EDO 9800265	SECY-98-071		
Docket	NRC File Center	PUBLIC	NMSS R/F	SFPO R/F
SFLS R/F	NMSS Dir Off R/F	JLinehan	CPoland	LGilbert
SShankman	~~VTharpe (2)~~	SMcDuffie	EShum	NJensen, OGC
TMadden, OCA	JThoma, EDO	BSpitzberg, RIV	VEverett, RIV	AChowdhury, CNWRA

*see previous concurrence

OFC	SFPO*	C	SFPO*	2C	SFPO*	C	OGC	SFPO
NAME	MRaddatz:dd		VTharpe		EJLeeds		WReamer	CJHaughney
DATE	05/28/98		05/28/98		05/28/98		05/[illegible]/98	05/28/98

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

DOCKET: 72-20

APPLICANT: U.S. Department of Energy, Idaho Operations Office
Three Mile Island Unit 2 Independent Spent Fuel Storage Installation

SUBJECT: EVALUATION OF EXEMPTION REQUEST TO 10 CFR 72.102(f)(1) SEISMIC DESIGN REQUIREMENT

BACKGROUND

By request dated September 15, 1997, the U.S. Department of Energy, Idaho Operations Office (DOE-ID), requested an exemption to the 10 CFR 72.102(f)(1) seismic design requirement for the Three Mile Island Unit 2 (TMI-2) Independent Spent Fuel Storage Installation (ISFSI). The facility will use the NUHOMS system technology with dry, shielded canisters housed horizontally in concrete modules. DOE-ID plans to construct this facility at the Idaho Chemical Processing Plant within the Idaho National Engineering and Environmental Laboratory (INEEL) site. The DOE-ID seismic hazard analysis meeting the requirement of 10 CFR 72.102(f)(1) yields a design earthquake (DE) of 0.56 g peak ground acceleration (PGA), with an appropriate response spectrum, for the ISFSI site. DOE-ID proposes a DE of 0.36 g PGA, with an appropriate response spectrum. DOE-ID justifies this value with a site-specific radiological risk analysis.

DISCUSSION

Section 72.102(b) requires ISFSI sites west of the Rocky Mountain front, as is the INEEL site, to have seismicity evaluated by the techniques of Appendix A of 10 CFR Part 100, also known as a deterministic seismic hazard analysis (DSHA). A DSHA calculates, based on site-specific investigations, the largest credible earthquake likely to affect a site, regardless of the probability of this event through time. Section 72.102(f)(1) states, "For sites that have been evaluated under the criteria of Appendix A of 10 CFR Part 100, the design earthquake must be equivalent to the safe shutdown earthquake (SSE) for a nuclear power plant." In this context, "DE" and "SSE" refer to the design peak ground acceleration, with an appropriate response spectrum, caused by the largest credible earthquake. The most recent DSHA for the ISFSI site yields a DE of 0.56 g PGA, with an appropriate response spectrum.

When 10 CFR Part 72 was first promulgated in 1980, ISFSIs were largely envisioned to be spent fuel pools or single, massive dry storage structures. A DE equivalent to a nuclear power plant (NPP) SSE seemed appropriate for these facilities, given the potential accident scenarios. Furthermore, for ISFSIs to be located at an NPP, the DE value was readily available without additional site characterization work, save the geotechnical investigation at the specific ISFSI location. However, an ISFSI storing spent fuel in dry casks or in canisters with horizontal storage modules is inherently less hazardous and less vulnerable to earthquake-initiated accidents than is an operating NPP (e.g., Hossain et al., 1997). The U.S. Nuclear Regulatory

ENCLOSURE

Commission (NRC) recognized this in the initial Part 72 "Statements of Consideration," and stated that the DE for cask and canister technology need not be as high as an NPP SSE: "For ISFSIs which do not involve massive structures, such as dry storage casks and canisters, the required design earthquake will be determined on a case-by-case basis until more experience is gained with licensing these types of units."

The bounding consequences of a major seismic event at an ISFSI using the NUHOMS system technology are limited by a canister drop onto the concrete pad, although this would occur only at a ground motion well above the proposed 0.36 g PGA design value, as detailed in Section 8.2.3.2 of the TMI-2 ISFSI Safety Analysis Report (DOE-ID, 1996a) (SAR). The casks and canisters are designed to withstand such events with no release of radioactive material. The effects of a NUHOMS canister drop are analyzed in Section 8.2.5.2 of the SAR. In addition, analysis of beyond-design basis accidents leading to cask or canister rupture estimate off-site doses well below the 0.05 Sv (5 rem) whole body dose limit of 10 CFR 72.106(b). In a letter dated July 19, 1996 (DOE-ID, 1996b), DOE-ID presented a conservative analysis of off-site doses resulting from a beyond-design basis accident. In this hypothetical accident, for which neither DOE-ID nor the staff has identified a credible mechanism, both a NUHOMS dry shielded canister and one of the 12 inner core debris canisters are assumed to fail, allowing unmitigated dispersal of the contents. The calculated off-site dose from such an accident is 0.75 mSv (75 mrem), well below the 0.05 Sv (5 rem) siting evaluation factor of 10 CFR 72.106(b).

On January 10, 1997, 10 CFR Parts 50 and 100 were revised to allow the use of the probabilistic seismic hazard assessment (PSHA) methodology to address uncertainties inherent in determining NPP seismic design values. These revisions were accomplished through the addition of 10 CFR 100.23 and Part 50, Appendix S. The PSHA method considers the frequency, as well as magnitude, of earthquakes that may affect a site. Rather than base seismic design on the largest ground motion likely to ever affect a site, a PSHA derives a site-specific hazard curve showing ground motion level versus annual probability of exceedence or, inversely, ground motion return period. The present Part 72 seismic siting evaluation factor requires use of methods in Appendix A of Part 100 and does not allow use of the PSHA method. The staff is developing a plan to modify the Part 72 seismic requirement to a level commensurate with the risks of cask and canister ISFSIs. In addition, the new requirement will be based on the PSHA methodology. Options being considered for DE values are the 2000- or 1000-year return period mean ground motion, possibly derived from a U.S. Geological Survey seismic hazard.

In reviewing the DE proposed by DOE-ID for the ISFSI, the staff also considered DOE and NRC precedents. The staff considered DOE Standard 1020, "Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities," DOE-STD-1020-94. This standard takes a probabilistic, risk-graded approach to designing critical facilities, requiring facilities with greater accident consequences to use higher design requirements for phenomena such as earthquakes and tornadoes. DOE Standard 1020 defines four performance categories (PCs) for structures, systems, and components (SSCs) important to safety, with PC 4 facilities being those with potential accident consequences similar to a commercial NPP. Such facilities must be designed to withstand the mean seismic ground motion with a 10,000-year return period. As described in Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," a future NPP licensed by

NRC in the western United States would be allowed to design to this same level. Dry spent fuel storage facilities, such as the TMI-2 ISFSI at INEEL, are classified PC 3 and must be designed for the mean ground motion with a 2000-year return period. The DE proposed by DOE-ID for the ISFSI (0.36g PGA) exceeds that of the 2000-year mean ground motion (0.30 g PGA) derived from the site-specific PSHA. As a comparison, the U.S. Geological Survey hazard maps yield, for the ISFSI general vicinity, PGA values of 0.30 g for a 2500-year return period; 0.20 g for 1000-year; and 0.15 g for a 500-year return period.

In addition, the staff considered the seismic design philosophy in 10 CFR Part 60 for high-level waste repository surface facilities. On January 3, 1997, the definition of design basis event in Part 60 was revised to allow a probabilistic, risk-graded methodology, similar to that in DOE-STD-1020-94, in designing for hazards (including seismic) at a geologic repository. This set an NRC precedent by accepting a risk-graded approach in licensing a facility quite similar to an ISFSI in terms of radioactive material present and possible accident scenarios. For seismic events, the staff has accepted DOE's two-tier approach toward designing Part 60 SSCs. Those SSCs with potential failure consequences less than the public dose limit of 10 CFR 20.1302(a)(1), 1 mSv (100 mrem), must withstand the 1000-year return period mean ground motion. SSCs with higher potential failure consequences must withstand the 10,000-year return period mean ground motion, while maintaining doses in unrestricted areas below the 0.05 Sv (5 rem) total effective dose equivalent limit of 10 CFR 60.136(b).

CONCLUSIONS

DOE-ID has completed both a DSHA (Appendix A of Part 100) and PSHA (10 CFR 100.23) for the ISFSI site. The staff has evaluated these analyses and finds the resultant values acceptable: 0.56 g PGA for an SSE by the deterministic method and 0.30 g PGA mean ground motion with a 2000-year return period by the probabilistic method. Considering the lack of radiological consequences from credible accidents and the minor consequences from beyond-design basis accidents, the staff finds the present Part 72 requirement for an ISFSI DE to be an unnecessary regulatory burden. The staff finds acceptable the risk-graded approach to seismic hazard characterization and design in DOE Standard 1020, which is similar to the risk-graded approach to design basis events in Part 60. Given the absence of radiological consequences from any credible seismic event, the staff finds that the DOE Standard 1020 risk-graded approach of using the 2000-year return period mean ground motion as the DE is adequately conservative. Moreover, the expected life span of the ISFSI, 20 years with the possibility of renewal, per 10 CFR 72.42, justifies use of this ground motion as the DE. The DE proposed by DOE-ID for the ISFSI, 0.36 g PGA with an appropriate response spectrum, exceeds the 0.30 g PGA value for the 2000-year return period mean ground motion. Therefore, the staff concludes that granting the requested exemption from 10 CFR 72.102(f)(1) will maintain an adequate design margin for seismic events and will not be inimical to public health and safety.

This safety evaluation does not represent final approval of the TMI-2 ISFSI design. This evaluation approves a DE value other than that required by 10 CFR 72.102(f)(1); it does not evaluate DOE-ID's analysis of how this new requirement will be implemented. If the TMI-2 ISFSI license is approved, the staff evaluation of the seismic design will be contained in the safety evaluation report.

REFERENCES

Hossain, Q.A., A.H. Chowdhury, M.P. Hardy, K.S. Mark, J.E. O'Rourke, W.J. Silva, J.C. Stepp, and F.H. Swan, III, "Seismic and Dynamic Analysis and Design Considerations for High-Level Nuclear Waste Repositories," J.C. Stepp, ed., American Society of Civil Engineers, New York, New York, 1997.

U.S. Department of Energy, Idaho Operations Office, "Safety Analysis Report for the INEL TMI-2 Independent Spent Fuel Storage Installation," Revision 0, October 1996a.

U.S. Department of Energy, Idaho Operations Office, Letter from J. Hagers (DOE-ID) to M. G. Raddatz (NRC), Subject: "License Application for the Three Mile Island Unit 2 Interim Storage System as an Independent Spent Fuel Storage Installation under 10 CFR Part 72 - Seismic Design Basis," July 19, 1996b.

U.S. Nuclear Regulatory Commission, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," Regulatory Guide 1.165, March 1997.

SERVICE LIST FOR TMI-2 FUEL ISFSI

cc:

Mr. Jan Hagers
TMI/FSV Licensing Project Manager
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Idaho Operations Office
850 Energy Drive
Idaho Falls, Idaho 83401-1563

Mr. Alan Merritt, NRC Liaison
State of Idaho INEEL Oversight Program
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Mr. Wayne Pierre
Federal Facility Section
U.S. Environmental Protection Agency
(M/S HW-124)
Seattle, WA 98101

Mr. Charles M. Rice
Chairman, INEEL EM Site Specific
Advisory Board
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INEEL Committee
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Idaho Falls, ID 83405-0498

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Idaho Falls, ID 83405

Snake River Alliance
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Pocatello, ID 83201

Mr. Chuck Broscious
Environmental Defense Institute
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1776 Science Center Drive
Idaho Falls, ID 83402

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

OFFICE OF THE
SECRETARY

June 24, 1998

STAFF EXHIBIT T

MEMORANDUM TO: L. Joseph Callan
Executive Director for Operations

FROM: John C. Hoyle, Secretary

SUBJECT: STAFF REQUIREMENTS - SECY-98-126 - RULEMAKING PLAN: GEOLOGICAL AND SEISMOLOGICAL CHARACTERISTICS FOR SITING AND DESIGN OF DRY CASK INDEPENDENT SPENT FUEL STORAGE INSTALLATIONS, 10 CFR PART 72

This is to advise you that the Commission has not objected to the proposed Rulemaking Plan as described in the subject paper.

cc: Chairman Jackson
Commissioner Dicus
Commissioner Diaz
Commissioner McGaffigan
OGC
CIO
CFO
OCA
OIG
Office Directors, Regions, ACRS, ACNW, ASLBP (via E-Mail)
PDR
DCS

SECY NOTE: THIS SRM AND SECY-98-126 WILL BE MADE PUBLICLY AVAILABLE 5 WORKING DAYS FROM THE DATE OF THIS SRM.

RULEMAKING ISSUE

(NEGATIVE CONSENT)

June 4, 1998 SECY-98-126

FOR: The Commissioners

FROM: L. Joseph Callan
Executive Director for Operations

SUBJECT: RULEMAKING PLAN: GEOLOGICAL AND SEISMOLOGICAL CHARACTERISTICS FOR SITING AND DESIGN OF DRY CASK INDEPENDENT SPENT FUEL STORAGE INSTALLATIONS, 10 CFR PART 72

PURPOSE:

To inform the Commission that the Executive Director for Operations intends to sign the enclosed Rulemaking Plan to amend certain sections in 10 CFR 72.102 and 72.212(b).

ISSUE:

The geological and seismological siting requirements for all types of independent spent fuel storage installations (ISFSIs) are contained in 10 CFR 72.102. Section 72.102 requires that, for any ISFSI located west of the Rocky Mountain Front or in any areas of known potential seismic activity, seismicity be evaluated by the techniques of Appendix A of 10 CFR Part 100. For sites evaluated under 10 CFR Part 100 Appendix A criteria, Section 72.102(f)(1) requires that the design earthquake be equivalent to the safe shutdown earthquake (SSE) for a nuclear power plant (NPP).

The issues that require rulemaking are twofold. First, in 1997, the Commission amended Parts 50 and 100 of its regulations to update the criteria used in decisions regarding NPP siting, including geologic, seismic, and earthquake engineering considerations for future NPPs. Part 100 as amended in 1997 placed a new 10 CFR 100.23 section in the regulations to allow the option of using a probabilistic seismic-hazard methodology as part of the geologic and seismic siting criteria. A conforming change to 10 CFR 72.102 is proposed which will allow new dry cask ISFSI licensees to take advantage of the 1997 Part 100 amendments, specifically Part 100.23.

CONTACTS: M. Au, NMSS/IMNS
(301) 415-6181

S. Rosenberg, NMSS/SFPO
(301) 415-1082

NOTE: TO BE MADE PUBLICLY AVAILABLE WHEN THE FINAL SRM IS MADE AVAILABLE

The second issue involves section 72.102(f)(1) which requires ISFSI sites west of the Rocky Mountain Front and in other areas of known seismic activity to use the SSE as determined by Appendix A of Part 100 as the design earthquake for the design of structures. The value determined by this process is equivalent to the SSE for a NPP. To date, one exemption to 10 CFR 72.102(f)(1) has been requested and reviewed. This type of exemption request is expected to continue in the future from other ISFSI applicants in the western United States. Thus, a change is proposed that will reduce the need for dry cask ISFSI licensees to request exemptions from Section 72.102(f)(1). The change would allow the use of a risk-informed graded approach to seismic design of ISFSI structures, systems and components (SSCs), while still maintaining reasonable assurance that public health and safety will be adequately protected. The risk-informed graded approach would be comparable to the 10 CFR Part 60 graded approach to design ground motion for SSCs in pre-closure facilities. It should be noted that the graded approach only applies to the seismic design of SSCs. The requirements for site characterization and level of investigation will remain as referenced in Part 72.102 (i.e., 10 CFR100.23).

The rulemaking plan also proposes a minor amendment to 10 CFR 72.212(b) to require that design of cask storage pads and areas must adequately account for dynamic loads in addition to static loads.

DISCUSSION:

Because the approach in 10 CFR 100, Appendix A for seismic and geologic siting criteria has not explicitly recognized uncertainties in geoscience parameters, probabilistic seismic-hazard analysis methods have been developed that allow explicit expressions for the uncertainty in ground motion estimates and provide a means for assessing sensitivity to various parameters. In 1997, the Commission amended Parts 50 and 100 of its regulations to update the criteria used in decisions regarding NPP siting, including geologic, seismic, and earthquake engineering considerations for future NPPs. Part 100 as amended in 1997 placed a new 10 CFR 100.23 section in the regulations to allow the option of using a probabilistic seismic-hazard methodology. This alternative probabilistic approach is based on developments in the field over the past 2 decades. This rulemaking will provide a conforming change to 10 CFR 72.102 that will require new applicants for dry cask ISFSIs that are West of the Rocky Mountain Front and in other areas of known seismic activity to evaluate seismicity by the techniques of Part 100 as amended in 1997, specifically Part 100.23 (instead of 10 CFR 100 Appendix A). The staff notes that while strict adherence to the requirements in Appendix A would be removed, those ISFSI applicants that are located on existing nuclear power plant sites would still be able to take advantage of all of the geophysical investigation information that was obtained from the original licensing process (which used the Appendix A requirements).

For the past several years, dry cask ISFSIs have become an increasingly used option to store spent fuel. This trend is expected to continue for the foreseeable future. The staff believes the current regulation in 10 CFR 72.102(f)(1) is outdated and places an unnecessary burden on dry cask ISFSI applicants. Section 72.102(f)(1) requires sites west of the Rocky Mountain Front and other areas of known seismic activity to use the SSE for an NPP (as evaluated by

Appendix A to Part 100) as the design earthquake for use in the construction of structures. To date, one exemption to 10 CFR 72.102(f)(1) has been requested and reviewed. The staff is in the process of granting this exemption request, pending Commission approval.

This rulemaking will alleviate the need for new Part 72 applicants to request exemptions from 10 CFR 72.102(f)(1) by providing them with the option of using a risk-informed graded approach to seismic design for ISFSI structures, systems and components. This risk-informed graded approach would be comparable to the 10 CFR Part 60 graded approach to design ground motion for structures, systems, and components in pre-closure facilities. Licensees would still be required to conform to Part 100 for siting characterization. The proposed approach in this rulemaking plan is consistent with SECY-98-071 addressing the exemption to 10 CFR Part 72.102(f)(1) seismic design requirements for Three Mile Island Unit 2 ISFSI.

COORDINATION:

The Office of the General Counsel has no legal objection to this Rulemaking Plan. The Office of the Chief Financial Officer has reviewed this Commission Paper for resource impacts and has no objection.

The Office of Chief Information Officer has reviewed the rulemaking plan for information technology and information management implications and concurs in it. However, the plan suggests changes in information collection requirements that must be submitted to the Office of Management and Budget at the same time the rule is forwarded to the Federal Register for publication.

RESOURCES:

Resources to complete and implement the rulemaking are included in the current budget.

RECOMMENDATION:

Note that it is my intention to approve the Rulemaking Plan within 10 days from the date of this paper, unless otherwise directed by the Commission.

L. Joseph Callan
Executive Director
for Operations

Enclosure: Rulemaking Plan

SECY NOTE: In the absence of instructions to the contrary, SECY will notify the staff on Friday, June 19, 1998, that the Commission, by negative consent, assents to the action proposed in this paper.

RULEMAKING PLAN
GEOLOGICAL AND SEISMOLOGICAL CHARACTERISTICS
FOR THE SITING AND DESIGN OF DRY CASK ISFSIs
10 CFR PART 72

REGULATORY PROBLEM

In 1980, the Commission added 10 CFR Part 72 to its regulations to establish licensing requirements for the storage of spent fuel in an independent spent fuel storage installation (ISFSI), (45 FR 74693). Subpart E of Part 72 contains siting evaluation factors that must be investigated and assessed with respect to the siting of an ISFSI, including a requirement for evaluation of geological and seismological characteristics. The original provision (10 CFR 72.66) (45 FR 74708) distinguished between massive water basin and air-cooled canyon types of ISFSI structures and other types of ISFSI designs. For the former, § 72.66 (now § 72.102) required seismic evaluations equivalent to those required for nuclear power plants (NPPs) when the ISFSI was located west of the Rocky Mountain Front or in areas of known potential seismic activity. At that time, ISFSIs were largely envisioned to be spent fuel pools or single, massive dry storage structures. A seismic design requirement, equivalent to the requirements for an NPP (Appendix A of Part 100) seemed appropriate for these types of facilities, given the potential accident scenarios. For other types of ISFSI designs, the regulation required a site specific investigation to establish site suitability commensurate with the specific requirements of the proposed ISFSI. The Commission explained that "[f]or ISFSI's which do not involve massive structures, such as dry storage casks and canisters, the required design earthquake will be determined on a case-by-case basis until more experience is gained with the licensing of these types of units." [45 FR 74697 (1980)]. NRC staff believed that a major seismic event at an ISFSI storing spent fuel in dry casks or canisters would most likely have minor radiological consequences compared with a major seismic event at an NPP, spent fuel pool, or single massive storage structure.

Part 72 was amended in 1988 to include monitored retrievable storage facilities (MRS), (53 FR 31651). The 1988 amendments also relocated the provision governing evaluation of geological and seismological characteristics to § 72.102. It also eliminated the distinction formerly made between criteria for massive water basin and air-cooled canyon types of ISFSI structures and other types of ISFSI designs such that the criteria designed for massive structures now applied to all ISFSIs and MRSs. Thus, § 72.102 requires that, for any ISFSI located west of the Rocky Mountain Front or in any areas of known potential seismic activity, seismicity be evaluated by the techniques of Appendix A of 10 CFR Part 100 and that, for sites evaluated under the Appendix A criteria, the design earthquake (DE) be equivalent to the safe shutdown earthquake (SSE) for a NPP. For ISFSIs located east of the Rocky Mountain Front and not in areas of known seismic activity, the Appendix A criteria may be used to determine a site specific DE or, alternatively, a standardized DE described by an appropriate response spectrum anchored at a peak ground acceleration of 0.25 g may be used.

The procedures in Appendix A of Part 100 for determining the quantitative vibratory ground motion design basis at a site requires the use of "deterministic" approaches in the development

of a single set of earthquake sources. The applicant develops for each source a postulated earthquake to be used as the source of ground motion that can affect the site, locates the postulated earthquake according to prescribed rules, and then calculates ground motions at the site. Because this approach has not explicitly recognized uncertainties in geoscience parameters, probabilistic seismic hazards analysis methods have been developed that allow explicit expressions for the uncertainty in ground motion estimates and provide a means for assessing sensitivity to various parameters.

In 1997, the Commission amended Parts 50 and 100 of its regulations to update the criteria used in decisions regarding NPP siting, including geologic, seismic and earthquake engineering considerations for future NPPs (61 FR 65157). The 1997 Part 100 amendments placed a new § 100.23 in the regulations (and its accompanying Regulatory Guide 1.165) to allow the option of using a probabilistic seismic hazard methodology. This alternative probabilistic approach takes account of the shortcomings in the earlier siting requirements and is based on developments in the field over the past two decades. The Commission left Appendix A to Part 100 in place to preserve the licensing basis for existing plants and confined the applicability of § 100.23 to new NPPs. Since § 72.102 requires that seismicity be evaluated by the techniques of Appendix A of Part 100, new applicants for ISFSI licenses are not able to take advantage of the amendments to Part 100 and must follow the rules that applied to NPPs before the Part 100 amendments.

For the past several years, dry cask storage ISFSIs have become an increasingly used option to store spent fuel. This trend is expected to continue for the foreseeable future. The purpose of this rulemaking is to provide the same, or even greater flexibility, to applicants for a Part 72 license for dry storage of spent fuel, and thereby relieve potential applicants from unnecessarily burdensome requirements. Section 72.102(f)(1) requires sites west of the Rocky Mountain Front and in other areas of known potential seismic activity to use the safe shutdown earthquake for a nuclear power plant (as evaluated by Appendix A to Part 100) as the design earthquake for use in the design of structures. This rulemaking is intended to alleviate the need for applicants to request exemptions from 10 CFR 72.102(f)(1). For example, DOE requested an exemption from 10 CFR 72.102(f)(1) for an ISFSI at INEEL to store TMI-2 fuel, stating that the requirement is an unnecessary burden. These types of exemption requests are expected to continue in the future from other ISFSI applicants in the Western U.S. unless rulemaking precludes this. New licensees would still be expected to conform to Part 100 (Section 100.23) for siting investigations and characterization. Staff does not intend to revise the Part 72 geological and seismological criteria as they apply to wet storage because of the greater consequences associated with the potential accident scenarios for these facilities.

EXISTING REGULATORY FRAMEWORK

Section 72.102 describes the geological and seismological criteria for siting of ISFSIs and MRS facilities. Separate siting criteria are specified in 10 CFR 72.102 for (1) west of the Rocky Mountain Front and in other areas of known potential seismic activity and (2) east of the Rocky Mountain Front if not located in areas of known seismic activity. Section 72.102(a)(2) allows sites east of the Rocky Mountain Front if not located in areas of known seismic activity to use a standardized design earthquake (DE) described by an appropriate response spectrum (RS) anchored at a peak ground acceleration of 0.25g, if the results from foundation and geological

investigations, literature review, and regional geological reconnaissance show no unstable geological characteristics, soil stability problems, or potential for vibratory ground motion (VGM) at the site in excess of an appropriate RS anchored at a peak ground acceleration of 0.2g. Alternatively, a site-specific DE may be determined by using the criteria and level of investigations required by Appendix A to 10 CFR Part 100. Appendix A describes the principal seismic and geological criteria for assessing the suitability of sites for nuclear power plants and the suitability of the reactor plant design basis. These criteria describe the nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability. Appendix A describes procedures for determining the quantitative VGM design basis from an earthquake at a site and describes information needed to determine whether and to what extent a nuclear power plant needs to be designed to withstand the effects of surface faulting.

For sites west of the Rocky Mountain Front, and in other areas of known potential seismic activity, seismicity is evaluated by the techniques of Appendix A to 10 CFR Part 100 with the design earthquake for an ISFSI of no less than the safe shutdown earthquake ground motion (SSE), (as defined in Appendix A of 10 CFR 100).

The rule also states that:

- Sites other than those on bedrock must be evaluated for their liquefaction potential or other soil instability caused by VGM (10 CFR 72.102(c)).
- Site specific investigations and laboratory analyses must show that soil conditions are adequate for the proposed foundation loading (10 CFR 72.102(d))
- Sites with unstable geologic characteristics should be avoided (10 CFR 72.102(e))
- For sites evaluated under the criteria of Appendix A to 10 CFR Part 100, the DE must be equivalent to the SSE of the nuclear power plant, with a value of no less than 0.1g with the appropriate RS (10 CFR 72.102(f)(1) and (2)).

HOW THE REGULATORY PROBLEM WILL BE ADDRESSED BY RULEMAKING

Staff intends to leave present § 72.102 in place to preserve the licensing basis of present ISFSIs. However, new provisions would be added to § 72.102 which would provide the requirements that would be utilized by new license applicants.

Rulemaking will be necessary to provide new Part 72 licensees flexibility in evaluating geological and seismological factors in siting and design of dry cask ISFSIs. The rulemaking options are discussed below. It should be noted that all options for rulemaking changes will necessitate a revision to NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems" and NUREG-1567," Standard Review Plan for Spent Fuel Dry Storage Facilities."

OPTION 1: No action. The siting requirements for new dry cask ISFSIs would conform to the existing requirements of 10 CFR 72.102.

The benefit of this option is that no NRC resources would be expended in conducting a rulemaking. However, new licensees would need to conform to outdated criteria, developed for power reactors, which are very conservative, not risk informed, and may not be cost-effective for dry cask ISFSIs, especially when not located at a NPP site. Hence, this option is not

recommended.

OPTION 2: Require new Part 72 licensees to conform to 10 CFR 100.23 in lieu of 10 CFR Part 100 Appendix A.

The staff notes that while strict adherence to the requirements in Appendix A for determining the SSE will be removed, those ISFSI applicants that are located on existing nuclear power plant sites will be able to use all of the geophysical investigation information obtained from the original licensing process (which used the Appendix A requirements). The benefit of this option is that it would enable potential licensees to take advantage of state-of-the-art methodology for evaluating geological and seismological criteria contained in § 100.23 (revised power reactor regulations). The Regulatory Guide 1.165, Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion, was developed to provide general guidance on procedures acceptable to the staff for satisfying the requirements of 10 CFR 100.23 for Nuclear Power Plants. This guidance would be considered acceptable for ISFSIs.

Among its other requirements, Section 100.23 stipulates evaluations that must be performed to arrive at estimates of the Safe Shutdown Earthquake ground motion (SSE). The SSE is the vibratory ground motion for which certain structures, systems, and components of an NPP are required to remain functional. However, the criteria for determining which SSCs of an NPP should remain functional during a SSE do not directly relate to ISFSI SSCs. Section 72.102(f)(1) which requires "....ISFSI structures" to be designed to the SSE does not delineate criteria for classification of SSCs, and therefore, may be excessive with respect to what is needed. Thus, this option is not risk-informed and does not achieve the objective of providing sufficient flexibility to licensees consistent with protection of public health and safety. Hence, this option is not recommended.

OPTION 3: Require new Part 72 licensees to conform to 10 CFR 100.23 in lieu of 10 CFR Part 100 Appendix A (Option 2) and also give them the option to use a graded approach to seismic design for ISFSI structures, systems, and components in conjunction with Option 2. In general, a graded approach to design of structures, systems, and components (SSCs) requires those SSCs, whose failure would result in greater accident consequences, to use higher design requirements for phenomena such as earthquakes and tornadoes. Likewise, those SSCs whose failure would result in lesser accident consequences would be designed to less stringent requirements. Therefore, a graded approach to seismic design for new Part 72 licensees would allow them to classify and design SSCs according to their importance-to-safety for seismic events. This graded approach would be in lieu of Section 72.102(f)(1) which requires sites that have been evaluated under the criteria of Appendix A of 10 CFR part 100 to design structures to a design earthquake that is equivalent to the SSE for a NPP. It should be noted that the requirements of 72.102 would still require licensees to conform to Part 100 for siting investigations and characterization.

The specific approach proposed for dry cask ISFSI systems, structures, and components would be comparable to the 10 CFR Part 60 graded approach to design ground motion for SSCs of pre-closure facilities. This graded approach would allow the structures, systems, and components of dry cask ISFSIs to be designed to either Frequency-Category-1 design basis

events or Frequency-Category-2 design basis events, depending upon their importance-to-safety. For seismic events, the staff has accepted the approach described in DOE Topical Report YMP/TR-003-NP, Rev. 2, Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain, pertaining to 10 CFR Part 60. In this approach, Frequency-Category-1 design basis ground motion refers to a mean annual probability of exceedance of 1.0E-03, which corresponds to a 1,000-year return period. Frequency-Category-2 design basis ground motion refers to a mean annual probability of exceedance of 1.0E-04, which corresponds to a 10,000-year return period. This quantitative interpretation of hazard levels would be provided in a guidance document for ISFSI licensees.

The utility of a graded approach is that it allows certain SSCs to be designed to a lower criteria, while requiring those other SSCs that have a high importance to safety to be designed to a more stringent criteria. An individual SSC may be designed to withstand only Frequency-Category-1 events (the less stringent criteria) if the licensee's analysis provides reasonable assurance that the failure of the SSC will not cause the facility to exceed the radiological requirements of 10 CFR 72.104(a). If the licensee's analysis cannot support this conclusion, then the designated SSC must have a higher importance to safety, and the SSC must be designed such that the facility can withstand Frequency-Category-2 events without impairing the ISFSI's capability to perform safety functions and without exceeding the radiological requirements of 10 CFR 72.106(b). Therefore, designing SSCs commensurate to their importance to safety follows the Commission's risk-informed approach to regulatory decision-making.

The seismic requirements in 10 CFR Parts 50 and 100, effective January 10, 1997, and 10 CFR Part 60, effective January 3, 1997, are based on probabilistic seismic hazard assessment techniques. Allowing new dry cask ISFSI licensees to use 10 CFR 100.23 in lieu of 10 CFR 100 Appendix A is considered a conforming change. Therefore, the technical basis for allowing Part 72 applicants to use 10 CFR 100.23 is the same as the technical basis used to change Part 100. The Part 60 change, also known as the design basis event (DBE) rulemaking, allows probabilistic methods in designing for hazards (including seismic) at a geologic repository, and allows two design levels based on risk (as described above). With the Part 60 DBE rulemaking, NRC adopted a graded approach similar to DOE Standard 1020 for natural hazard characterization and design. The proposed graded approach to dry cask ISFSI seismic design reflects the graded approach of Part 60 for repository pre-closure facilities. The radiological criterion that is required to be met by the present Section 72.102(f)(1), i.e., having the design earthquake equivalent to the SSE for an NPP as evaluated by Appendix A of 10 CFR Part 100, must also be met by this graded approach to seismic design as described in the preceding paragraph. Therefore, although this change for new ISFSI applicants may reduce the regulatory burden, it will continue to provide the level of protection to members of the public provided by present radiological criteria.

The advantages of this option for rulemaking are that (1) it would enable potential licensees to take advantage of state-of-the-art methodology for evaluating geological and seismological criteria contained in § 100.23 (revised power reactor regulations), (2) it would allow the industry the flexibility to design ISFSI SSCs so that the costs would be more commensurate with the probability of radiological consequences from an earthquake at an ISFSI (i.e., more cost-effective) and (3) it would be comparable to the graded approach to design requirements

for systems, structures and components for pre-closure facilities in 10 CFR Part 60 (Disposal of High-Level Wastes in Geologic Repositories).

PREFERRED OPTION

Option 3 is preferred. Under this option, licensees would have the choice of (1) using the newer reactor seismic siting and design criteria in 10 CFR 100.23, or (2) using the newer reactor seismic siting criteria in conjunction with a graded approach to seismic design for ISFSI SSCs.

Option 3 gives the licensees the flexibility to use the particular approach to siting and design that is the most cost-effective for them. This rulemaking option gives licensees the latitude to choose the most appropriate approach for their particular circumstances, but maintains reasonable assurance that public health and safety will be adequately protected.

The staff recommends proceeding with rulemaking for Option 3 for the reasons outlined below.

1. This option gives the licensees the flexibility to use the most suitable approach to siting and design that is the most cost-effective for them.

2. The seismic siting and design criteria would be consistent with both nuclear power reactors and pre-closure facilities of high-level waste geologic repositories.

3. The added criteria reflect the state of the art approach for reactors and the risk-informed, graded approach used for pre-closure facilities of high-level waste geologic repositories.

ADDITIONAL PROPOSED CHANGE

Changes to 10 CFR 72.212(b) are also needed to communicate that licensees for new ISFSI sites under the general license provisions should perform analyses to assure that casks are not placed in an unanalyzed condition. This proposed change to 10 CFR 72.212 would state that design of cask storage pads and areas must adequately account for dynamic loads (in addition to static loads). For example, dynamic effects can cause soil-structure interactions that could amplify ground motion to the point that the acceleration on the casks is greater than the design earthquake acceleration, or that soil liquefaction could cause unacceptable pad and foundation settlement. A dynamic analysis of ISFSI pads and areas would assure that the pad, which may be considered as failed in a seismic event, could continue to support the casks without placing them in an unanalyzed condition. In the past, this issue was addressed on a case-by-case basis. This is consistent with the Palisades Plant - NRC Final Safety Assessment of Independent Spent Fuel Storage Installation (ISFSI) Support Pad, September 20, 1994, which was first ISFSI approved for a general licensee.

OFFICE OF GENERAL COUNSEL LEGAL ANALYSIS

NRC staff has undertaken this rulemaking to reduce unnecessarily burdensome requirements with respect to evaluating the seismicity of potential ISFSI sites and determining a design earthquake for use in designing ISFSI structures as those requirements appear in 10 CFR § 72.102. The rulemaking proposes, as an alternative, a graded approach to seismic design for

ISFSI structures, systems, and components in conjunction with the Commission's revised methodology for evaluating geological and seismological criteria contained in 10 CFR 100.23 or, if the applicant or licensee prefers, use of 10 CFR 100.23 without a graded approach. The rulemaking plan indicates that this alternative will continue to meet the radiological criteria in Part 72 and therefore will continue to provide an adequate level of protection of public health and safety while reducing a regulatory burden. Given this, OGC does not foresee any basis for legal objection to this rulemaking.

The Backfit Rule in 10 CFR 72.62 may be implicated by the proposed amendment to 10 CFR 72.212 and a backfit analysis may be required. An environmental assessment and a regulatory analysis will be required. The options presented would reduce the burden on the licensee in the information collection requirements. An OMB clearance statement would be required in compliance with the Paperwork Reduction Act.

BACKFIT ANALYSIS

A backfit analysis could be implicated by the proposed amendment to 10 CFR 72.212. During of the development of the proposed rule, the staff will assess, if the addition to 10 CFR Part 72.212, a backfit is needed for this rulemaking action.

AGREEMENT STATE IMPLEMENTATION ISSUES

This rule is classified as compatibility category "NRC," and addresses areas of exclusive NRC regulatory authority.

MAJOR RULE

This is not a major rule.

SUPPORTING DOCUMENTS NEEDED

This rulemaking would require a Regulatory Analysis that would estimate the cost savings to licensees for each of the proposed changes. The information provided in the Regulatory Analysis for each change concerning the impact on small entities would be sufficient to support a Regulatory Flexibility Analysis or a certification that the proposed rule would not have a significant economic impact on a substantial number of small entities. An OMB Clearance Package will be needed because the rulemaking is expected to reduce reporting or recordkeeping requirements. An Environmental Assessment would be needed to show, as NRC staff currently believe, that there is no significant impact to public health and safety. A backfit analysis could be implicated by the proposed amendment to 10 CFR 72.212.

ISSUANCE BY EXECUTIVE DIRECTOR FOR OPERATIONS OR COMMISSION

It is recommended that the Commission issue this rulemaking because it involves additions to existing policy on the siting of new dry cask ISFSIs.

RESOURCES NEEDED TO COMPLETE RULEMAKING

The estimated resources to complete and implement the rulemaking are included in the FY1998 budget.

- NMSS 1.8 FTE (develop proposed rule, resolution of public comment, develop final rule)
- Others 0.3 FTE

Contractor: (for environmental assessment, regulatory analysis, assist in public comment analyses) $100K.

Staff Level Working Group		Concurring Official
NMSS	M. L. Au, Task Leader S. Rosenberg F. Young	C. Paperiello
OGC	Neil Jensen	J. Gray

MANAGEMENT STEERING GROUP

A management steering group is not required for this rulemaking.

PUBLIC PARTICIPATION

There is no need for enhanced public participation for this rulemaking. The rulemaking documents will be placed on the NRC electronic rulemaking bulletin board in addition to publishing the documents for public comments.

SCHEDULE

Establish technical working group	1 month after approval of rulemaking plan.
Proposed rule to EDO	12 months after approval of rulemaking plan.
Final rule to EDO	6 months following expiration of public comment period.

ruleplan.nw9
05-21-98

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

CHAIRMAN

November 27, 2001

STAFF EXHIBIT U

Dianne R. Nielson, Ph.D.
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168 North 1950 West
P.O. Box 144810
Salt Lake City, Utah 84114-4810

Jay Silberg, Esq.
Shaw Pittman, LLP
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Dear Dr. Nielson and Mr. Silberg:

This letter responds to your recent letters on the effect of a proposed recent modification to a rulemaking plan concerning seismological requirements for independent spent fuel storage installations.

On September 26, 2001, the NRC staff sent the Commission a proposed modified rulemaking plan outlining changes in its strategy for developing a regulation using a probabilistic seismic hazard analysis at an ISFSI (SECY 01-0178, Modified Rulemaking Plan: Geological and Seismological Characteristics for Siting and Design of Dry Cask Independent Spent Fuel Storage Installations, 10 C.F.R. Part 72, a copy of which is enclosed). The modified plan anticipates a rule requiring all structures to withstand a design basis earthquake, and abandons a previous proposal to use two different design basis earthquakes, depending on a structure's importance to safety.

Dr. Nielson argues that this modification is an "inappropriate[], and possibly illegal[]" attempt by the staff to use the rulemaking process to support its adjudicatory position on seismic design. She is concerned that the modification will undermine the adjudication. Mr. Silberg wrote to express his opinion that the Commission is free to resolve safety questions through adjudication or rulemaking.

The Commission has the authority to determine whether a particular issue should be decided through rulemaking, through adjudication, or through both means. We see no reason for the Commission to disrupt either the ongoing adjudication of seismic issues or the rulemaking. With regard to the rulemaking, the Commission has recently approved the staff's plan to revise the rulemaking plan, subject to comments provided in the enclosed staff requirements memorandum. At the same time, the Atomic Safety and Licensing Board, and the

Commission itself, as appropriate on appeal, will continue to address the seismic issues material to licensing the proposed Private Fuel Storage facility. *See Private Fuel Storage, L.L.C.* (Independent Spent Fuel Storage Installation), CLI-01-12, 53 NRC 459 (2001). This is not affected by the new rulemaking plan, which, of course, has no legally binding effect. *See id.*, at 471.

It would be inappropriate to comment further on issues still in litigation before the Board and the Commission.

Sincerely,

Richard A. Meserve

cc: Service List in *Private Fuel Storage, L.L.C.* (Docket No. 72-22-ISFSI)

Enclosures:
1. SECY-01-0178
2. SRM on SECY-01-0178

RULEMAKING ISSUE

September 26, 2001 (NEGATIVE CONSENT) SECY-01-0178

FOR: The Commissioners

FROM: William D. Travers
Executive Director for Operations

SUBJECT: MODIFIED RULEMAKING PLAN: 10 CFR Part 72 -- "GEOLOGICAL AND SEISMOLOGICAL CHARACTERISTICS FOR SITING AND DESIGN OF DRY CASK INDEPENDENT SPENT FUEL STORAGE INSTALLATIONS"

PURPOSE:

To request, by negative consent, Commission approval of the attached Modified Rulemaking Plan for amending certain sections in 10 CFR Part 72 dealing with seismic siting and design criteria for dry cask independent spent fuel storage installations (ISFSIs). The staff proposes modifications to the approved Rulemaking Plan, SECY-98-126, "Rulemaking Plan: Geological and Seismological Characteristics for the Siting and Design of Dry Cask Independent Spent Fuel Storage Installations, 10 CFR Part 72."

SUMMARY:

The Commission is amending certain sections in 10 CFR Part 72 dealing with seismic siting and design criteria for dry cask independent spent fuel storage installations (ISFSIs). The staff proposes modifications to the approved Rulemaking Plan, SECY-98-126, "Rulemaking Plan: Geological and Seismological Characteristics for the Siting and Design of Dry Cask Independent Spent Fuel Storage Installations, 10 CFR Part 72."

The Rulemaking Plan in SECY-98-126 provided three options. Option 3, recommended by the staff and approved by the Commission in its SRM to SECY-98-126, adopted the Probabilistic Seismic Hazard Analysis (PSHA) and also provided an option to use the risk-informed graded approach to seismic design for ISFSI SSCs. An additional change was recommended in SECY-98-126 to require that the design of cask storage pads and areas account for dynamic loads in addition to static loads for general licensees.

CONTACTS: Keith McDaniel, NMSS/IMNS
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Mahendra Shah, NMSS/SFPO
(301) 415-8537

Enclosure 1

After further consideration of the use of the graded approach in Option 3, the staff is recommending a fourth option that has been added to the attached Modified Rulemaking Plan. This new Option 4 retains the PSHA approach, described in Option 3, but provides for a single design earthquake ground motion rather than the graded approach in Option 3.

The Plan clarifies the applicability of the proposed changes to Part 72 general and specific licensees. Except as described above, the Modified Rulemaking Plan is consistent with all other aspects of the approved rulemaking plan in SECY–98-126.

BACKGROUND:

In a Staff Requirements Memorandum issued on June 24, 1998, in response to SECY-98-126, the Commission did not object to the staff's plan to develop a proposed rule for changing Part 72. The Rulemaking Plan, in SECY-98-126, would amend Part 72 to:

(1) Require new Part 72 applicants to use a probabilistic seismic hazard analysis (PSHA) approach (10 CFR 100.23) instead of the current deterministic approach (10 CFR Part 100, Appendix A) in determining the design earthquake ground motion.

(2) Allow for classification of systems, structures, and components (SSCs) that are important to safety into one of two different categories for earthquake designs, to account for the safety importance of the SSC and risk levels (risk-informed graded approach). SSCs whose failure would result in high accident consequences would be required to use a design earthquake equivalent to those used for SSCs of nuclear power plants (NPPs). SSCs whose failure would result in low accident consequences could be designed for a lower earthquake.

(3) Require that the design of cask storage pads and areas account for dynamic loads in addition to static loads.

In SECY-99-036, "Proposed Rulemaking Activity Plan," the staff informed the Commission of its intent to put this rulemaking activity on hold for higher-priority rulemakings, but to continue development of the technical basis. During the subsequent development of the technical basis, the staff determined that some of the changes proposed in the approved Rulemaking Plan required modification. The Modified Rulemaking Plan includes a new option to address these modifications.

DISCUSSION:

The Rulemaking Plan in SECY-98-126 provided three options. Option 1 took no action (maintained the current Part 72 requirements). Option 2 required the use of the PSHA approach as described in 10 CFR 100.23, in lieu of 10 CFR Part 100 Appendix A, for determining seismic design ground motion. Option 3 adopted the PSHA and also provided an option to use the risk-informed graded approach to seismic design for ISFSI SSCs. Option 3 was recommended by the staff. An additional change was recommended in SECY-98-126 to require that the design of cask storage pads and areas account for dynamic loads in addition to static loads for general licensees. After further consideration of the use of the graded approach in Option 3, the staff is recommending a fourth option, that has been added to the attached Modified Rulemaking Plan. This new Option 4 provides an alternative to the graded approach

for the seismic design of dry cask ISFSI SSCs. Except for incorporating an Option 4 and several minor editorial changes and clarifications, the rulemaking plan in SECY-98-126 has not otherwise been modified.

The Modified Rulemaking Plan clarifies the applicability of the proposed changes to Part 72 general and specific licensees. Applicants for a Part 72 specific license after the effective date of the rule for an ISFSI site, located in the western U.S. and not co-located with an NPP, must comply with the proposed changes. A Part 72 specific license applicant for an ISFSI site located in the western U.S. and co-located with an NPP has the option of using the proposed PSHA methodology for determining the design earthquake ground motion, or using the existing design criteria for the NPP. Where the existing design criteria for the NPP are used at sites with multiple NPPs, the criteria for the most recent NPP would be used. For all specific-license applicants, whose sites are located in the central and eastern U.S., the proposed changes are also optional. The proposed changes regarding the use of the PSHA method are not applicable to general licensees at existing NPPs operating an ISFSI under a Part 72 general license anywhere in the U.S. The proposed additional change, requiring that the design of cask storage pads and areas account for dynamic loads in addition to static loads, is applicable to general licensees for new ISFSIs after the effective date of the rule. Current practice already provides that specific licensees demonstrate that static and dynamic loads are considered.

The proposed changes also apply to the design basis of both dry cask storage ISFSIs and U.S. DOE monitored retrievable storage installations (MRS) because these facilities are similar in design. The Modified Rulemaking Plan uses the term "ISFSI" to include both ISFSI and MRS facilities. The staff does not intend to revise the Part 72 geological and seismological criteria as they continue to apply to wet storage facilities because of the greater consequences associated with the potential accident scenarios for these facilities.

In summary, the proposed changes related to the PSHA methodology are mandatory after the effective date of the rule for specific-license applicants for ISFSIs, located in the western U.S., and not co-located with a NPP. For all other dry cask storage specific-license applicants, the proposed changes are voluntary. The proposed additional change related to dynamic loads, is applicable to general licensees for new ISFSIs designed after the effective date of the rule.

Option 4 proposes changing Part 72 as follows:

<u>OPTION 4:</u>

(1) Require certain Part 72 applicants (as described above) to comply with a new 10 CFR 72.103 (use of PSHA based on 10 CFR 100.23, as described in Options 2 and 3), in lieu of 10 CFR 72.102(f), which requires the use of Part 100, Appendix A.

(2) Maintain the present Part 72 requirement of using a single-level design earthquake, but with a lower design earthquake ground motion that is commensurate with the level of risk associated with an ISFSI.

Item 1 of Option 4 differs slightly from that previously approved by the Commission in the Rulemaking Plan (SECY-98-126). It adds a new section in Part 72 that is based on 10 CFR

100.23, instead of referencing 10 CFR 100.23. This will make Part 72 independent of Part 100. The staff believes this is aligned with NRC's plain language initiative. Item 2 is a change to the approved Rulemaking Plan and is discussed further in the following sections. Detailed guidance for the use of Option 4 will be provided in a guidance document for ISFSI applicants that will be published as a draft document concurrently with the proposed rule.

The staff evaluated the recommendations related to the graded approach and concluded that the use of two earthquake levels for an ISFSI facility should be revised. A modified approach, using a single-level design earthquake with a ground motion that is commensurate with the level of risk associated with an ISFSI, has been added to the Modified Rulemaking Plan as Option 4. The current Part 72 regulations are based on the use of a single-level design earthquake. However, Option 4 uses a lower design earthquake ground motion than those used in the current Part 72 and in Option 3 for SSCs whose failure would result in greater accident consequences. The Modified Rulemaking Plan is consistent with all other aspects of the approved Rulemaking Plan. The basis for this change is summarized below and discussed in more detail in the Modified Rulemaking Plan.

The staff recognized that because SSCs important to safety in an ISFSI facility are few relative to those in an NPP, the use of a graded approach for classifying ISFSI SSCs into one of two different categories for earthquake designs would not benefit applicants and could unnecessarily increase the complexity in applications, without a commensurate improvement to safety.

In comparison to NPPs, an operating ISFSI facility is a relatively simple facility in which the primary activities are waste receipt, handling, and storage. An ISFSI facility does not have the variety and complexity of active systems necessary to support an operating NPP. After the spent fuel is in place, an ISFSI facility is a static operation. During normal operations, the conditions required for the release and dispersal of significant quantities of radioactive materials are not present. Temperatures and pressures are relatively low during normal operations or even under design basis accident conditions; therefore, the likelihood of release and dispersal of radioactive materials is low primarily due to low heat generation rates of spent fuel with greater than the required one year of decay before storage in an ISFSI, combined with low inventory of volatile radioactive materials readily available for release to the environs. The long-lived and potentially biologically hazardous materials present in spent fuel are tightly bound up in the fuel materials and are not readily dispersible. The short-lived volatile nuclides, such as I-131, are no longer present in aged spent fuel (e.g., cooled at least one year). Furthermore, even if the short-lived nuclides were present during an event of a fuel assembly rupture, the canister surrounding the fuel assemblies would confine these nuclides. The radiological risk associated with an ISFSI facility is significantly less than the risk associated with an NPP, and therefore, the use of a lower design earthquake ground motion is appropriate.

The Commission explained in the Statement of Considerations accompanying the initial Part 72 rulemaking that "[f]or ISFSI's which do not involve massive structures, such as dry storage casks and canisters, the required design earthquake will be determined on a case-by-case basis until more experience is gained with the licensing of these types of units." [45 FR 74697 (1980)]. With more than 10 years of experience licensing dry cask storage systems, together with analyses demonstrating their robust behavior in accident scenarios involving earthquakes,

the staff concludes that designing ISFSI SSCs using a single-level design earthquake with a ground motion that is commensurate with the level of risk associated with an ISFSI, is sufficient to provide reasonable assurance in demonstrating protection of public health and safety.

The use of a lower design earthquake ground motion is consistent with the Commission's approval of the U.S. Department of Energy's (DOE's) request for an exemption from 10 CFR 72.102(f)(1) for a proposed ISFSI at the Idaho National Engineering and Environmental Laboratory (INEEL). In its evaluation of the request to lower the design earthquake ground motion, the NRC staff considered the relative risk posed by the ISFSI. Considering the minor radiological consequences expected from a cask failure resulting from a seismic event and the lack of a credible mechanism to cause such a failure, the staff believed that the design earthquake proposed by DOE for dry storage facilities at INEEL was conservative. The design earthquake level proposed in the Modified Rulemaking Plan is the same as the design earthquake level used as the basis for approving DOE's request for an exemption. Furthermore, the staff notes that the proposed Option 4, as it relates to the design basis earthquake level, is consistent with DOE Standard 1020, "Natural Phenomena Hazards Design Evaluation Criteria for Department of Energy Facilities" for similar type facilities.

As demonstrated in the Modified Rulemaking Plan, the probability of exceeding the lower design earthquake event at an ISFSI facility with an operational period of 20 years is the same as the probability of exceeding the higher design earthquake event at the pre-closure facility at Yucca Mountain with an operational period of 100 years. Therefore, the probability of failure of an SSC important to safety is the same for these two types of facilities over their respective operational periods. In this respect, the proposed changes to Part 72 are consistent with the requirements of 10 CFR Parts 60 and 63.

The approach in the Modified Rulemaking Plan and the graded approach in Parts 60 and 63, as recommended in SECY-98-126, are similar in that they are both risk-informed. However, for ISFSI applications, the staff determined that maintaining the current Part 72 approach of a single design basis event is more appropriate than the use of the graded approach because of the relative simplicity of the ISFSI design and operation.

APPLICATION OF THE SCREENING CRITERIA FOR RISK-INFORMING NMSS REGULATORY ACTIVITIES:

The Office of Nuclear Material Safety and Safeguards (NMSS) has developed a set of screening criteria to identify NMSS regulatory activities amenable to increased use of risk information. The staff applied the criteria to the proposed changes in the Modified Rulemaking Plan to determine if the risk-informed approach of lowering the design earthquake to a level that is commensurate with the lower risk associated with an ISFSI should be implemented. The proposed changes satisfy the screening criteria because they: (1) improve efficiency and effectiveness of the NRC regulatory process by eliminating the need for applicants to request exemptions from 10 CFR 72.102(a), 72.102(b), and 72.102(f)(1) (similar to DOE's request for the ISFSI at INEEL), and the need for NRC to review the exemption requests; (2) reduce unnecessary regulatory burden for the applicant or licensee by reducing the design earthquake level to account for the lower risk associated with ISFSI facilities; (3) can be supported by analytical models that evaluate the seismic behavior of a cask; (4) would not result in significant start-up or implementation costs to NRC and applicants, other than technical training and further development of analytical models; and (5) do not involve other factors, with the

exception of potential adverse stakeholder reaction as can be the case when using risk-informed approaches. Satisfying these criteria supports the implementation of the proposed risk-informed approach.

NRC STRATEGIC GOALS:

The staff considered the merits of the rulemaking within the context of the performance goals listed in the Agency's strategic plan. The rulemaking effort would increase NRC's effectiveness and efficiency and reduce unnecessary regulatory burden by reducing the number of exemption requests that would need to be submitted and reviewed. This rule would maintain safety by selecting the design earthquake level to be commensurate with the risk associated with an ISFSI. The changes to the design earthquake level are considered risk-informed, consistent with NRC policy to develop risk-informed regulations. This rule would increase realism by enabling ISFSI applicants to use the state-of-the-art approach to more accurately characterize the seismicity of a site. Public confidence may be adversely affected because the proposed risk-informed approach lowers the design earthquake level commensurate with the lower risk of an ISFSI facility.

COORDINATION:

The Office of the General Counsel has no legal objection to the modified rulemaking plan. The Office of the Chief Financial Officer has no objection to the resource estimates contained in this paper. However, the plan suggests changes in information collection requirements that must be submitted to the Office of Management and Budget before publication of the proposed rule.

SCHEDULE:

The staff believes that an expedited schedule for this rulemaking is appropriate. As a result of current activities being conducted by the NRC, the staff believes that expediting this rule would enhance the licensing process by potentially reducing exemption requests. It is anticipated that the need for new ISFSI facilities in the Western U.S. will continue to grow as the need for spent fuel storage increases. As a result, the staff expects to receive ISFSI licensing requests in the near future. In addition, the Commission has previously approved an exemption request for the storage of TMI-2 fuel at the Idaho National Engineering and Environmental Laboratory, based on an approach similar to that of the preferred option in the modified rulemaking plan. The staff has received a similar request for exemption by another ISFSI applicant (Private Fuel Storage, L.L.C.) which is currently the subject of an adjudicatory proceeding, referred to in CLI-01-12, 53 NRC ___ (June 14, 2001).

RESOURCES:

If the Commission directs the staff to go forward with Option 1, no additional resources would be required. Option 2 would cost 1.6 full-time equivalents (FTEs) and approximately $65,000 for technical support spread out over 2 years. For Option 3 and recommended Option 4, which includes the development of regulatory guidance, 3.8 FTE and approximately $200,000 for technical support would be required spread over fiscal years 2001 and 2002. Technical support will be used to assist in the development of the proposed and final rule and related guidance documents.

SECY-98-126 estimated 2.1 FTE and $100,000 would be needed to complete the rulemaking. During the development of the Modified Rulemaking Plan, the staff determined that an increase in rulemaking complexity beyond what was anticipated in SECY-98-126, an expected increase in stakeholder involvement, and the expedited schedule, resulted in additional resources being necessary. These resources will be reallocated through the Planning Budgeting Performance Management process for the office, pending Commission approval of the Modified Rulemaking Plan.

RECOMMENDATION:

Staff request action within 10 days. Action will not be taken until the SRM is received. We consider this action to be within the delegated authority of the EDO.

William D. Travers
Executive Director
for Operations

Attachment:
Modified Rulemaking Plan-Geological and Seismological Characteristics for the Siting and Design of Dry Cask ISFSIs, Part 72

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SECY NOTE:
IN THE ABSENCE OF INSTRUCTIONS TO THE CONTRARY, SECY WILL NOTIFY THE STAFF ON THURSDAY, OCTOBER 11, 2001, THAT THE COMMISSION, BY NEGATIVE CONSENT, ASSENTS TO THE ACTION PROPOSED IN THIS PAPER.

MODIFIED RULEMAKING PLAN
GEOLOGICAL AND SEISMOLOGICAL CHARACTERISTICS
FOR THE SITING AND DESIGN OF DRY CASK ISFSIs
10 CFR PART 72

REGULATORY PROBLEM

In 1980, the Commission added 10 CFR Part 72 to its regulations to establish licensing requirements for the storage of spent fuel in an independent spent fuel storage installation (ISFSI), (45 FR 74693). Subpart E of Part 72 contains siting evaluation factors that must be investigated and assessed with respect to the siting of an ISFSI, including a requirement for evaluation of geological and seismological characteristics. The original provision (10 CFR 72.66) (45 FR 74708) distinguished between massive water basin and air-cooled canyon types of ISFSI structures and other types of ISFSI designs. For the former, section 72.66 (now section 72.102) required seismic evaluations equivalent to those required for nuclear power plants (NPPs) when the ISFSI was located west of the Rocky Mountain Front (approximately 104° west longitude) or in areas of known potential seismic activity. At that time, ISFSIs were largely envisioned to be spent fuel pools or single, massive dry storage structures. A seismic design requirement, equivalent to the requirements for an NPP (Appendix A of 10 CFR Part 100) seemed appropriate for these types of facilities, given the potential accident scenarios. For other types of ISFSI designs, the regulation required a site-specific investigation to establish site suitability commensurate with the specific requirements of the proposed ISFSI. The Commission explained that "[f]or ISFSI's which do not involve massive structures, such as dry storage casks and canisters, the required design earthquake will be determined on a case-by-case basis until more experience is gained with the licensing of these types of units." [45 FR 74697 (1980)]. The NRC staff believed that a major seismic event at an ISFSI storing spent fuel in dry casks or canisters would most likely have minor radiological consequences compared with a major seismic event at an NPP, spent fuel pool, or single massive storage structure.

Part 72 was amended in 1988 to include the U.S. DOE Monitored Retrievable Storage Installation (MRS), (53 FR 31651). The 1988 amendment also relocated the provision governing evaluation of geological and seismological characteristics to section 72.102. It also eliminated the distinction formerly made between criteria for massive water basin and air-cooled canyon types of ISFSI structures and other types of ISFSI designs such that the criteria designed for massive structures now applied to all ISFSI and MRS facilities Thus, section 72.102 requires that, for any site located west of the Rocky Mountain Front or in any areas of known potential seismic activity, seismicity be evaluated by the techniques of Appendix A of Part 100 and that, for sites evaluated under the Appendix A criteria, the design earthquake be equivalent to the safe shutdown earthquake (SSE) for an NPP. For sites located east of the Rocky Mountain Front and not in areas of known seismic activity, the Appendix A criteria may be used to determine a site-specific design earthquake or, alternatively, a standardized design earthquake described by an appropriate response spectrum anchored at a peak ground acceleration of 0.25 g may be used.

The procedures in Appendix A of Part 100 for determining the design basis vibratory ground motion at a site require the use of "deterministic" approaches in the development of a single set

of earthquake sources. The applicant develops for each source a postulated earthquake to be used to determine the ground motion that can affect the site, locates the postulated earthquake according to prescribed rules, and then calculates ground motions at the site. Because this approach has not explicitly recognized uncertainties in geoscience parameters, probabilistic seismic hazard analysis (PSHA) methods have been developed that allow explicit expressions for the uncertainty in ground motion estimates and provide a means for assessing sensitivity to various parameters.

In 1997, the Commission amended Parts 50 and 100 of its regulations to update the criteria used in decisions regarding NPP siting, including geologic and seismic engineering considerations for future NPPs (61 FR 65157). The 1997 Part 100 amendments placed a new section 100.23 in the regulations (guidance provided in Regulatory Guide 1.165 and Standard Review Plan-NUREG 0800) requiring that the uncertainties associated with the determination of the safe shutdown earthquake ground motion be addressed through an appropriate analysis, such as a probabilistic seismic hazard analysis or suitable sensitivity analyses. This approach takes into account the shortcomings in the earlier siting requirements and is based on developments in the field over the past two decades. The Commission left Appendix A of Part 100 in place to preserve the licensing basis for existing plants and confined the applicability of section 100.23 to new NPPs. Because section 72.102 requires that seismicity be evaluated by the techniques of Appendix A of Part 100, new applicants for ISFSI licenses must follow the rules that applied to NPPs before the 1997 Part 100 amendments.

In the past several years, dry cask designs for ISFSIs have become a dominant option to store spent fuel. This trend is expected to continue for the foreseeable future. The purpose of this rulemaking is to require the applicants to use state-of-the-art seismic hazard methodologies for site characterization. This will result in alleviating the need for applicants to request exemptions from 10 CFR 72.102(f)(1). For example, the U.S. Department of Energy (DOE) requested an exemption from 10 CFR 72.102(f)(1) for an ISFSI at the Idaho National Engineering and Environmental Laboratory (INEEL) to store fuel generated at the Three Mile Island-Unit 2 nuclear power plant.

EXISTING REGULATORY FRAMEWORK

Section 72.102 describes the geological and seismological criteria for siting of ISFSI and MRS facilities. Separate siting criteria are specified in 10 CFR 72.102 for: (1) sites east of the Rocky Mountain Front, if not located in areas of known seismic activity, and (2) sites west of the Rocky Mountain Front and in other areas of known potential seismic activity. Section 72.102(a)(2) allows sites east of the Rocky Mountain Front, if not located in areas of known seismic activity, to use a standardized design earthquake described by an appropriate response spectrum (RS) anchored at a peak ground acceleration of 0.25 g, provided the results from foundation and geological investigations, literature review, and regional geological reconnaissance show no unstable geological characteristics, soil stability problems, or potential for vibratory ground motion at the site in excess of an appropriate RS anchored at a peak ground acceleration of 0.2 g. Alternatively, a site-specific design earthquake may be determined by using the criteria and level of investigations required by Appendix A of 10 CFR Part 100. Appendix A describes the principal seismological and geological criteria for assessing the suitability of sites for nuclear power plants and the suitability of the reactor plant design basis. These criteria describe the

nature of the investigations required to obtain the geologic and seismic data necessary to determine site suitability. Appendix A describes procedures for determining the design basis vibratory ground motion from an earthquake at a site and describes information needed to determine whether and to what extent a nuclear power plant needs to be designed to withstand the effects of surface faulting.

For sites west of the Rocky Mountain Front, and in other areas of known potential seismic activity, seismicity is evaluated by the techniques of Appendix A of Part 100 with the design earthquake for an ISFSI of no less than the SSE ground motion for an NPP (as defined in Appendix A of Part 100).

The rule also states that:

- Sites other than those on bedrock must be evaluated for their liquefaction potential or other soil instability caused by vibratory ground motion (10 CFR 72.102(c)).

- Site-specific investigations and laboratory analyses must show that soil conditions are adequate for the proposed foundation loading (10 CFR 72.102(d)).

- Sites with unstable geologic characteristics should be avoided (10 CFR 72.102(e)).

- For sites evaluated under the criteria of Appendix A of Part 100, the design earthquake must be equivalent to the SSE of the nuclear power plant, with a value of no less than 0.1g with the appropriate RS (10 CFR 72.102(f)(1) and (2)).

HOW THE REGULATORY PROBLEM WILL BE ADDRESSED BY RULEMAKING

This rulemaking will clarify the applicability of the proposed changes to Part 72 general and specific licensees. Applicants for a Part 72 specific license after the effective date of the rule for an ISFSI site, located in the western U.S. and not co-located with an NPP, must comply with the proposed changes. A Part 72 specific license applicant for an ISFSI site located in the western U.S. and co-located with an NPP has the option of using the proposed PSHA methodology for determining the design earthquake ground motion, or using the existing design criteria for the NPP. Where the existing design criteria for the NPP is used at sites with multiple NPPs, the criteria for the most recent NPP should be used. For all dry cask storage specific-license applicants, whose sites are located in the central and eastern U.S., the proposed changes are also optional. The proposed changes regarding the use of the PSHA method are not applicable to general licensees at existing NPPs operating an ISFSI under a Part 72 general license anywhere in the U.S.

The proposed changes also apply to the design basis of both dry cask storage ISFSIs and U S DOE monitored retrievable storage installations (MRS), because these facilities are similar in design. The Modified Rulemaking Plan uses the term "ISFSI" to include both ISFSI and MRS facilities. The NRC staff does not intend to revise the Part 72 geological and seismological criteria as they apply to wet storage because of the greater consequences associated with the potential accident scenarios for these facilities.

The NRC staff intends to leave present section 72.102 in place to preserve the licensing basis of present ISFSIs. The proposed provisions would be added as a new section 72.103, which would provide the requirements that would be utilized by new license applicants.

The rulemaking options are discussed below. It should be noted that all options for rulemaking changes (Options 2-4) will necessitate a revision to NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," and NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities," and development of a new regulatory guide to provide guidance in meeting the changes in regulation.

OPTION 1: No action. The siting requirements for new dry cask ISFSIs would conform to the existing requirements of 10 CFR 72.102.

The benefit of this option is that no additional NRC resources would be expended in conducting a rulemaking. However, new licensees would need to conform to outdated criteria developed for power reactors, which are very conservative, not risk-informed, and may not be cost-effective for dry cask ISFSIs, especially when not co-located with an NPP site. Hence, this option is not recommended.

OPTION 2: Require new Part 72 license applicants to conform to 10 CFR 100.23 in lieu of 10 CFR Part 100 Appendix A.

The NRC staff notes that while strict adherence to the requirements in Appendix A for determining the design earthquake for the ISFSI (equivalent to an NPP SSE) will be removed, those applicants for ISFSIs, co-located with existing nuclear power plant sites, would be allowed to use all of the geophysical investigation information obtained from the original licensing process (which used the Appendix A requirements), in verifying that all applicable seismic data are considered in determining the design basis. The benefit of this option is that it would be a conforming change to Part 100 for evaluating geological and seismological criteria. It should be noted that under this option, the extent of site investigations and characterization remains the same as required in Part 100. Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion," was developed to provide general guidance on procedures acceptable to the staff for satisfying the requirements of 10 CFR 100.23 for NPPs. This guidance would be considered acceptable for ISFSIs.

Section 100.23 stipulates evaluations that must be performed to arrive at estimates of the SSE. The SSE is the vibratory ground motion for which certain structures, systems, and components (SSCs) of an NPP are required to remain functional. However, the criteria for determining which SSCs of an NPP should remain functional during a SSE do not directly relate to ISFSI SSCs. In contrast, a dry cask ISFSI does not contain active SSCs that must perform a safety-related function after an earthquake. Section 72.102(f)(1), which requires ISFSI structures to be designed to the SSE, is not risk-informed and does not consider the lower risk of an ISFSI consistent with protection of public health and safety. Hence, this option is not recommended.

OPTION 3: Require new Part 72 applicants to conform to 10 CFR 100.23 in lieu of 10 CFR

Part 100 Appendix A (Option 2) and also give them the option to use a graded approach to seismic design for ISFSI SSCs in conjunction with Option 2. In general, a graded approach to design requires those SSCs whose failure would result in greater accident consequences to use higher design requirements for phenomena such as earthquakes and tornadoes. Similarly, those SSCs whose failure would result in lesser accident consequences would be designed to less stringent requirements. This graded approach would be in lieu of section 72.102(f)(1), which requires sites that have been evaluated under the criteria of Appendix A of Part 100 to design structures to a design earthquake that is equivalent to the SSE for an NPP. It should be noted that under this option, the extent of site investigations and characterization remains the same as required in Part 100.

The specific approach proposed for dry cask ISFSIs would be comparable to the 10 CFR Part 60/63 graded approach to design ground motion for SSCs of pre-closure facilities. This graded approach would allow the SSCs of dry cask ISFSIs to be designed to either Category 1 design basis events or Category 2 design basis events, depending upon their importance to safety. For seismic events, the NRC staff has accepted the approach described in DOE Topical Report YMP/TR-003-NP, Rev. 2, Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain, pertaining to 10 CFR Part 63. In this approach Category 1 design basis ground motion refers to a mean annual probability of exceedance of 1.0E-03.[1] Category 2 design basis ground motion refers to a mean annual probability of exceedance of 1.0E-04.

Individual SSCs that are required to maintain the annual dose within the regulatory limits of 10 CFR Part 20 would be designed to a Category 1 design basis earthquake. Other SSCs needed to be functional to prevent the dose limit of 5 rem from being exceeded at the controlled area boundary would be designed to a Category 2 design basis earthquake. Thus, the seismic design of the SSCs would be commensurate with their importance to safety. Therefore, this design approach follows the Commission policy of using a risk-informed approach.

The advantages of this option for rulemaking are that: (1) it would enable applicants to take advantage of state-of-the-art methodology for evaluating geological and seismological criteria contained in section 100.23 (revised power reactor regulations); (2) it would allow the industry the flexibility to design ISFSI SSCs so that the costs would be more commensurate with the probability of radiological consequences from an earthquake at an ISFSI (i.e., more cost-effective); and (3) it would be comparable to the graded approach to design requirements for systems, structures, and components for pre-closure facilities in 10 CFR Part 60 (Disposal of High-Level Wastes in Geologic Repositories).

The disadvantages of this option are that it may unnecessarily increase the complexity in applications without any risk reduction and would be inconsistent with the previous NRC licensing action in response to an exemption request for an ISFSI. Hence, this option is not recommended.

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[1]The mean annual probability of exceedance, p, of an event is the reciprocal of the return period of that event (i.e., p = 1/T). As an example, consider a site at which the return period for an earthquake is 2,000 years. In this case, the mean annual probability of exceedance is 5.0E-04 (1/2,000) or 0.05 percent.

OPTION 4:

(1) Require new Part 72 specific licensees for sites located in the western U.S. and not co-located with NPPs, to comply with a new 10 CFR 72.103 (based on 10 CFR 100.23 as described in Options 2 and 3), in lieu of 10 CFR 72.102(f), which requires the use of Appendix A of Part 100. A Part 72 specific license applicant for an ISFSI site located in the western U.S. and co-located with an NPP has the option of using the PSHA method for determining seismological and geological design criteria, or using the existing design criteria for the NPP. Where the existing design criteria for the NPP is used at sites with multiple NPPs, the criteria for the most recent NPP would be used. For all dry cask storage specific-license applicants whose sites are located in the central and eastern U.S., the proposed changes are also optional. The proposed changes regarding the use of the PSHA method are not applicable to general licensees anywhere in the U.S. The appendix to this modified rulemaking plan contains a table summarizing the information in this paragraph.

The proposed changes also apply to the design basis of both the dry cask storage ISFSI and MRS. The remainder of this plan uses the term "ISFSI" to include both ISFSI and MRS facilities because the facilities are similar in design. The NRC staff does not intend to revise the Part 72 geological and seismological criteria as they apply to wet storage because of the greater consequences associated with the potential accident scenarios for these facilities.

(2) Maintain the present Part 72 requirement of using a single-level design earthquake, but with a lower design earthquake ground motion that is commensurate with the level of risk associated with an ISFSI. This single-level design earthquake will have a mean annual probability of exceedance of 5.0E-04, which is lower than the current level for the SSE of an NPP.

Detailed guidance for the use of Option 4 will be provided in a guidance document for ISFSI licensees.

The NRC staff has determined that for new ISFSI facilities, a design earthquake with a mean annual probability of exceedance of 5.0E-04 is appropriate. The present design earthquake (equivalent to the SSE for an NPP) has a mean annual probability of exceedance of approximately 1.0E-04. In comparison with a nuclear power plant, an operating ISFSI facility is a relatively simple facility in which the primary activities are waste receipt, handling, and storage. An ISFSI facility does not have the variety and complexity of active systems necessary to support an operating nuclear power plant. After the spent fuel is in place, an ISFSI facility is a static operation. During normal operations, the conditions required for the release and dispersal of significant quantities of radioactive materials are not present. There are no high temperatures or pressures present during normal operations or under design basis accident conditions to cause the release and dispersal of radioactive materials. This is primarily due to the low heat-generation rate of spent fuel that has undergone more than one year of decay before storage in an ISFSI, and to the low inventory of volatile radioactive materials readily available for release to the environs. The long-lived and potentially biologically hazardous materials present in spent fuel are tightly bound up in the fuel materials and are not readily dispersible. The short-lived volatile nuclides, such as I-131, are no longer present in aged spent fuel. Furthermore, even if the short-lived nuclides were present during an event of a fuel assembly rupture, the canister

surrounding the fuel assemblies would confine these nuclides. Therefore, the radiological risk associated with an ISFSI facility is significantly less than the risk associated with an NPP and the use of a lower design earthquake ground motion is justified.

The Commission indicated in the Statement of Considerations accompanying the initial Part 72 rulemaking that "[f]or ISFSI's which do not involve massive structures, such as dry storage casks and canisters, the required design earthquake will be determined on a case-by-case basis until more experience is gained with the licensing of these types of units." [45 FR 74697 (1980)]. With more than 10 years of experience licensing dry cask storage systems, together with analyses demonstrating their robust behavior in accident scenarios involving earthquakes, the NRC staff concludes that designing ISFSI SSCs using a single-level design earthquake with a ground motion that is commensurate with the level of risk associated with an ISFSI, is sufficient to provide reasonable assurance in demonstrating public health and safety.

The rationale for the proposed mean annual probability of exceedance of 5.0E-04 (return period of 2,000 years) for a design earthquake is based on several points:

- Use of a mean annual probability of exceedance of 5.0E-04 (return period of 2,000 years) for the design earthquake is consistent with the Commission's approval of DOE's request for an exemption from section 72.102(f)(1) for a proposed ISFSI at the INEEL to store spent fuel generated at the Three Mile Island Unit-2 nuclear power plant. Section 72.102(f)(1) requires that for sites that have been evaluated under the criteria of Appendix A of Part 100, the design earthquake must be equivalent to the SSE for an NPP. In its evaluation of the request, NRC staff considered the relative risk posed by the ISFSI. The staff concluded that considering the minor radiological consequences expected from a cask failure resulting from a seismic event, and the lack of a credible mechanism to cause such a failure, the NRC staff believes that the design earthquake using a mean annual probability of exceedance of 5.0E-04 for dry storage facilities at INEEL would be conservative.

- The total probability of exceedance for a design earthquake at an ISFSI facility with an operational period of 20 years (20 years x 5.0E-04 = 1.0E-02) is the same as the total probability of exceedance for an earthquake event at the proposed pre-closure facility at Yucca Mountain with an operational period of 100 years (100 years x 1.0E-04 = 1.0E-02).

- Because SSCs important to safety in an ISFSI are few, relative to those found in an NPP, the use of a graded approach for classifying ISFSI SSCs into one of two different categories for earthquake designs would unnecessarily increase the complexity in applications, without a commensurate improvement to safety. The SSCs important to safety in an ISFSI are associated with the storage cask, and include the canister, the canister handling systems, concrete pad supporting the cask, the transfer building supporting the handling systems, and the transfer cask. Since these SSCs are needed to be functional to prevent the dose limit of 5 rem being exceeded at the controlled area boundary, they would be required to be designed for a Category 2 design basis earthquake. Other SSCs important to safety may include the pressure monitoring system, protective cover, security lock and wire, etc and can be designed for a lower Category 1 earthquake. However, it would be simpler to design all SSCs for a bounding Category 2 earthquake.

- The critical element for protection against radiation release is the confinement boundary for containing the spent fuel assemblies. Because the casks are rigid and have high natural frequencies, the damage from a drop or tip-over accident is expected to be far greater and more severe than the seismic inertial acceleration loads. Therefore, seismic inertia loads are bounded by other loads. The dry storage cask designs are very rugged and robust, and are expected to have substantial design margins to withstand forces from a seismic event greater than the design earthquake.

- During a seismic event, a cask may slide if lateral seismic forces are greater than friction resistance between the cask and the concrete pad. The sliding and resulting displacements are computed by the applicant to demonstrate that the casks, which are spaced to satisfy thermal requirements, are precluded from impacting other adjacent casks. Furthermore, the staff typically requests, as part of its approval process, that an applicant demonstrate that during a seismic event equal to the proposed design earthquake, the cask will not tip over. However, it follows from the discussion above that even if the casks slide or tip-over and then impact other casks or the pad during a seismic event greater than the proposed design earthquake, the casks have adequate design margins to ensure that they maintain their structural integrity to meet the Part 72 exposure limits for radiological protection.

- The mean annual probability of exceedance of 5.0E-04 for ISFSI facilities is consistent with the design approach used in DOE Standard DOE-STD-1020, "Natural Phenomena Hazards Design Evaluation Criteria for Department of Energy Facilities," for similar type facilities.

Based on the preceding analysis, the NRC staff concludes that the rationale for designing ISFSI SSCs for a single design earthquake, using a mean annual probability of exceedance of 5.0E-04, is sufficient to ensure the public health and safety.

PREFERRED OPTION

Option 4 is preferred over the other options because it (1) is consistent with a previous NRC licensing decision in response to an exemption request for an ISFSI facility and (2) results in the design of ISFSI SSCs to be commensurate with the risk level Additionally, Option 4, like other options, enables new licensees to take advantage of state-of-the-art methodology for evaluating geological and seismological criteria contained in proposed section 72.103 and would not unnecessarily increase the complexity in applications by classifying SSCs into more than one category.

ADDITIONAL PROPOSED CHANGE

Changes to 10 CFR 72.212(b)(2)(ii) are also needed to communicate that general licensees must perform both static and dynamic analyses for new ISFSIs after the effective date of the rule to ensure that casks are not placed in an unanalyzed condition This proposed change would be included with any of the options requiring rulemaking (Options 2-4). Current practice already provides that specific licensees demonstrate that static and dynamic loads are considered The change would state that the design of cask storage pads and areas must adequately account for dynamic loads (in addition to static loads). For example, dynamic effects can cause soil-

structure interactions that could amplify ground motion to the point that the acceleration on the casks is greater than the design earthquake acceleration, or that soil liquefaction could cause unacceptable pad and foundation settlement. A dynamic analysis of ISFSI pads and areas would ensure that the pad, which may be considered as failed in a seismic event, could continue to support the casks without placing them in an unanalyzed condition. In the past, this issue was addressed on a case-by-case basis. This is consistent with the Palisades Plant - NRC Final Safety Assessment of Independent Spent Fuel Storage Installation (ISFSI) Support Pad, September 20, 1994, the first ISFSI approved for a general licensee.

NRC STRATEGIC PLAN PERFORMANCE GOALS

The NRC staff considered the merits of the rulemaking within the context of the performance goals listed in the Agency's strategic plan. The rulemaking effort would increase NRC's effectiveness and efficiency and reduce unnecessary regulatory burden by reducing the number of exemption requests that would need to be submitted and reviewed. This rule would maintain safety by selecting the design earthquake level to be commensurate with the risk associated with an ISFSI. The changes to the design earthquake level are considered risk-informed, consistent with NRC policy to develop risk-informed regulations. This rule would increase realism by enabling ISFSI applicants to use the state-of-the-art approach to more accurately characterize the seismicity of a site. Public confidence may be adversely affected because the proposed risk-informed approach lowers the design earthquake level commensurate with the lower risk of an ISFSI facility.

OFFICE OF THE GENERAL COUNSEL LEGAL ANALYSIS

The Modified Rulemaking Plan proposes modifications to the approved Rulemaking Plan, SECY-98-126, "Rulemaking Plan: Geological and Seismological Characteristics for the Siting and Design of Dry Cask ISFSIs," dated June 4, 1998. During the development of the technical basis for the approved Rulemaking Plan, the staff determined that some of the changes proposed in the approved plan required modification. The Modified Rulemaking Plan includes a new option, Option 4, which reflects some of these proposed modifications

The intent of this proposed Part 72 rulemaking is to reduce unnecessarily burdensome requirements with respect to evaluating the seismicity of potential ISFSI sites and determining a design earthquake for use in designing ISFSI structures, as those requirements appear in 10 CFR 72.102. The approved Rulemaking Plan (SECY-98-126) proposed to amend Part 72 to (1) require certain new Part 72 specific license applicants to use a probabilistic seismic hazard analysis (PSHA) approach (10 CFR 100.23), instead of the current deterministic approach (which is required by 10 CFR 72.102(f) and contained in Appendix A of 10 CFR Part 100), in determining design earthquake ground motion; (2) allow the use of a risk-informed graded approach to seismic design for ISFSI structures, systems, and components, in which SSCs are required to use one of two categories or levels of design earthquakes (for lower and higher accident consequences), depending on safety importance and risk levels, and (3) in the case of general licensees, require that the design of cask storage pads and areas account for dynamic loads and soil-structure interactions in addition to static loads by amending 10 CFR 72.212(b)(2)(ii).

Like Option 3, the newly added Option 4 would require that certain new Part 72 specific license applicants use the PSHA methodology based on 10 CFR Part 100.23 in lieu of the current deterministic approach. However, instead of simply referencing 10 CFR 100.23, Option 4 proposes the addition of a new section (10 CFR 72.103) based on section 100.23. In addition, Option 4 of the Modified Rulemaking Plan proposes an alternative to the risk-informed graded approach for seismic design of dry cask ISFSI SSCs that is contained in Option 3. Specifically, Option 4 proposes the use of a single-level design earthquake with a variable ground motion that is commensurate with the level of risk associated with an ISFSI. Finally, the Modified Rulemaking Plan retains the proposed amendment to 10 CFR 72.212(b)(2)(ii) requiring consideration of dynamic loads.

The Modified Rulemaking Plan clearly explains the rationale for designing ISFSI SSCs using a single-level design earthquake, concluding that use of this alternative will continue to meet the radiological criteria in Part 72 and therefore adequately protect public health and safety while reducing a regulatory burden. Given this, OGC does not foresee any basis for legal objection to this proposed rulemaking.

The proposed rule should emphasize that use of the PSHA methodology in conjunction with a single-level design earthquake with a lower ground motion would be mandatory only for specific ISFSI (and MRS) applicants who (1) apply for a specific license after the effective date of the rule; (2) are located in the Western U.S. or in any area of known potential seismic activity; and (3) are not co-located with a nuclear power plant. Specific license applicants who do not meet all of these criteria (such as applicants co-located with an NPP) would have the option of using the PSHA approach. Therefore, OGC believes that PSHA component of proposed rulemaking will not require a backfit analysis because it provides only a voluntary alternative for existing licensees.

However, in developing the wording of the proposed revision to 10 CFR 72.212(b)(2)(ii), which involves consideration of dynamic loads and soil-structure interactions by general licensees prior to use of an ISFSI, OGC cautions the staff to avoid potential backfit concerns. The proposed revision should be prospective in nature, applying to general licensees that have yet to commence use of new or future ISFSIs. Imposing new evaluation requirements on general licensees that are already using their ISFSIs could implicate the Backfit Rule in 10 CFR 72 62 OGC notes that an environmental assessment and a regulatory analysis will be required in conjunction with the proposed rulemaking. Moreover, because the options presented would reduce the burden on the licensee with respect to information collection requirements, an OMB clearance statement would be required to comply with the Paperwork Reduction Act.

The proposed rule will not result in a $100 million impact upon nuclear power plant licensees Therefore, it is not a "major rule."

Because the rule addresses only areas of exclusive NRC regulatory authority, it does not raise any Agreement State implementation issues.

In conclusion, OGC has determined that there are no known bases for legal objection to the contemplated rulemaking.

BACKFIT ANALYSIS

A backfit analysis is not required for the proposed rule because the provisions of the PSHA methodology are mandatory for new applicants for Part 72 specific licenses only. The backfit provisions of 10 CFR 72.62 only apply to existing licensees. Existing general and specific licensees are not required to use the PSHA methodology contained in the proposed rule; however, they may choose to use the PSHA methodology provisions on a voluntary basis. Therefore, a backfit analysis is not required.

Additionally, the proposed change to 10 CFR 72.212(b)(2), related to designing ISFSI pads for both static and dynamic loads of the stored casks due to earthquake events, will be prospective in nature, applicable only to general licensees for new ISFSIs after the effective date of the rule. Therefore, a backfit analysis is not required.

AGREEMENT STATE IMPLEMENTATION ISSUES

This rule is classified as compatibility category "NRC" and addresses only areas of exclusive NRC regulatory authority.

MAJOR RULE

This is not a major rule.

SUPPORTING DOCUMENTS NEEDED

This rulemaking would require a Regulatory Analysis that would estimate the costs and benefits to licensees for each of the proposed changes. The information provided in the Regulatory Analysis for each change concerning the impact on small entities would be sufficient to support a Regulatory Flexibility Analysis or a certification that the proposed rule would not have a significant economic impact on a substantial number of small entities. An OMB Clearance Package may be needed because the rulemaking is expected to reduce reporting or recordkeeping requirements. This would require that the clearance package be submitted to OMB no later than the date the proposed rule is submitted to the Office of the Federal Register for publication. An Environmental Assessment would be needed to show, as the NRC staff currently believes, that there is no significant impact to public health and safety.

In addition, this rulemaking will necessitate a revision to NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," and NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities," The development of a new regulatory guide to provide guidance in meeting the changes in regulation will also be needed.

ISSUANCE BY EXECUTIVE DIRECTOR FOR OPERATIONS OR COMMISSION

It is recommended that the Commission issue this rulemaking because it involves additions to existing policy on the siting of new dry cask ISFSIs.

RESOURCES NEEDED TO COMPLETE RULEMAKING

The estimated resources to complete and implement Options 1 or 2 are included in the FY 2001-FY 2002 budgets. With Commission approval, the staff is prepared to redirect resources, using the Planning Budgeting Performance Management process, to support Options 3 or 4.

Option 1: No additional FTE required.

Option 2: Since Option 2 does not lower the design earthquake level, fewer public comments would be expected as compared to Options 3 and 4, which do provide for a lower design earthquake level. This would also reduce the need for an expedited rulemaking schedule.

NMSS	1.3 FTE	(develop proposed rule and draft guidance document, resolve public comments, develop final rule and guidance documents)
Other	0.3 FTE	(provide support to NMSS)
Contractor	$50-65 K	(develop Environmental Assessment, Regulatory Analysis, Information Collection Burden Report, and assist in public comment analysis and guidance development)

Options 3 and 4:

NMSS	3.0 FTE	(develop proposed rule and draft guidance document, resolve public comments, develop final rule and guidance documents)
Other	0.8 FTE	(provide support to NMSS)
Contractor	$200 K	(develop Environmental Assessment, Regulatory Analysis, Information Collection Burden Report, and assist in public comment analysis and guidance development)

STAFF LEVEL WORKING GROUP	Concurring Official
Keith McDaniel, NMSS/IMNS Task Leader	M. Virgilio, NMSS
Mahendra Shah, NMSS/SFPO	M. Virgilio, NMSS
Mysore Nataraja, NMSS/DWM	M. Virgilio, NMSS
Goutam Bagchi, NRR	S. Collins, NRR
Roger Kenneally, RES	A. Thadani, RES
Martin O'Neill, OGC	J. Gray, OGC

MANAGEMENT STEERING GROUP

A management steering group is not required for this rulemaking.

PUBLIC PARTICIPATION

There is no need for enhanced public participation for this rulemaking. The rulemaking documents will be placed on the NRC electronic rulemaking bulletin board in addition to publishing the documents for public comments.

SCHEDULE

Proposed rule to EDO	2.0 months after approval of rulemaking plan
Final rule to EDO	4.5 months following end of public comment period

The NRC has decided to conduct this rulemaking on an expedited basis to support current licensing activities.

APPENDIX

Applicability of Proposed Changes

Applicability of Proposed Section 72.103 to Specific License Applicants for ISFSI

Conditions	Western U. S.	Central and Eastern U. S.
Not co-located with NPP, and for applications received after the effective date	Mandatory	Voluntary
Not co-located with NPP, and for applications received prior to effective date but under review	Voluntary	Voluntary
Co-located with NPP, and for applications received after or prior to the effective date	Voluntary	Voluntary

Proposed change in section 72.103 regarding PSHA methodology does not apply to general licensees. General licensees must satisfy the conditions given in 10 CFR 72.212.

Applicability of Proposed Section 72.212(b)(2) to General License Applicants for ISFSI

Proposed changes in Section 72.212(b)(2) regarding dynamic loads apply to general licensees for new ISFSIs after the effective date of the rule, and not to specific licensees. Current practice already provides that specific licensees demonstrate that static and dynamic loads are considered.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

OFFICE OF THE
SECRETARY

November 19, 2001

MEMORANDUM TO: William D. Travers
Executive Director for Operations

FROM: Annette L. Vietti-Cook, Secretary

SUBJECT: STAFF REQUIREMENTS - SECY-01-0178 - MODIFIED RULEMAKING PLAN: 10 CFR PART 72 -- "GEOLOGICAL AND SEISMOLOGICAL CHARACTERISTICS FOR SITING AND DESIGN OF DRY CASK INDEPENDENT SPENT FUEL STORAGE INSTALLATIONS"

This is to advise you that the Commission has not objected to the staff's plan to revise the approved rulemaking plan for the geological and seismological characteristics for the siting and design of dry cask independent spent fuel storage installations (10 CFR Part 72), subject to the comments provided below.

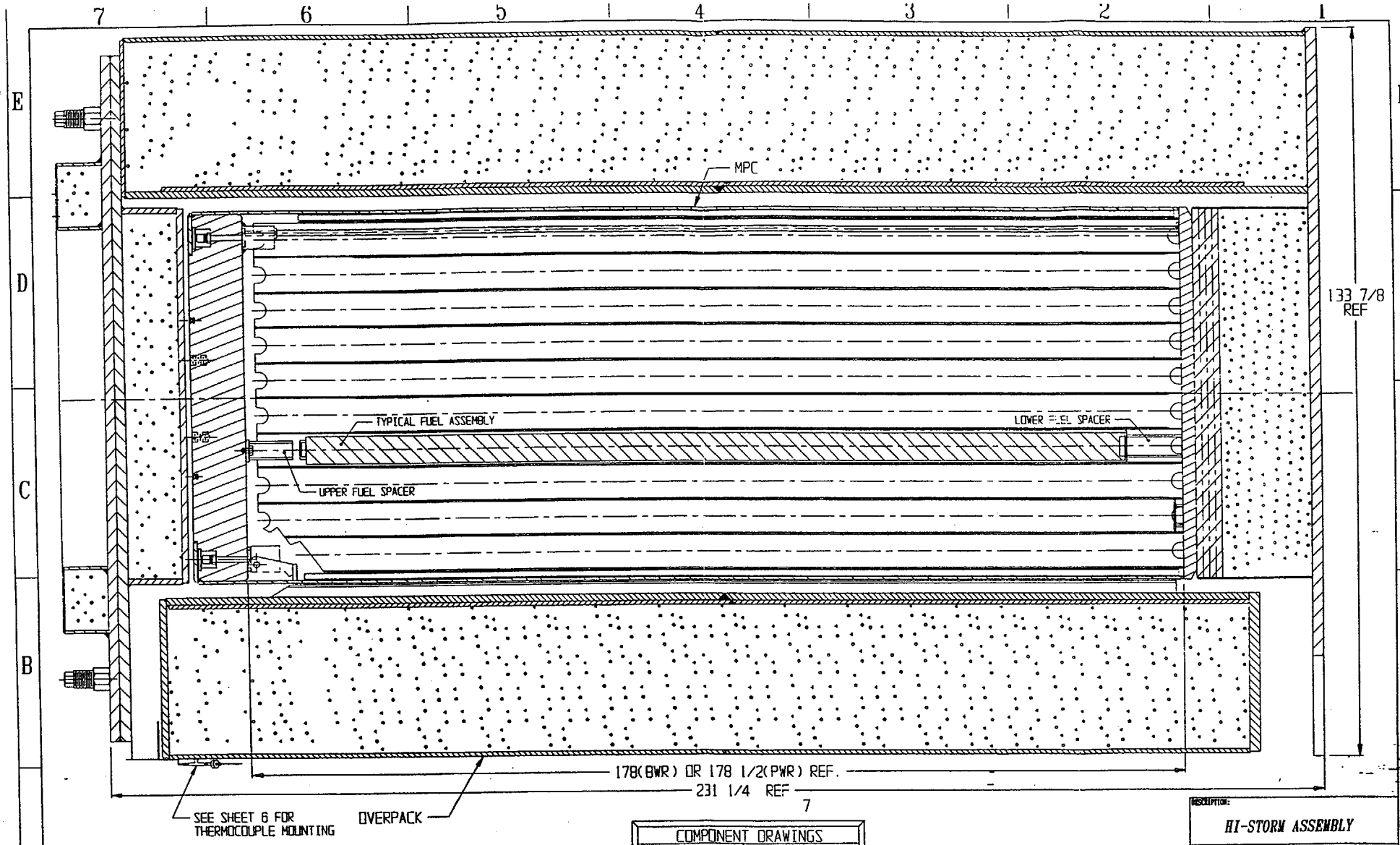
Central to this rulemaking is the determination of the mean annual exceedance probability of an earthquake at a proposed ISFSI. The proposed rule should solicit comment on a range of probability of exceedance levels from 5.0E-04 through 1.0E-04. Staff should undertake further analysis to support a specific proposal.

The proposed rule should be submitted to the Commission for review prior to publication.
(EDO) (SECY Suspense: 3/22/02)

cc: Chairman Meserve
Commissioner Dicus
Commissioner Diaz
Commissioner McGaffigan
Commissioner Merrifield
OGC
CFO
OCA
OIG
OPA
Office Directors, Regions, ACRS, ACNW, ASLBP (via E-Mail)
PDR

Enclosure 2

STAFF EXHIBIT V



COMPONENT DRAWINGS	
FOR OVERPACK	1495 AND 1561
FOR MPC-24	1395 AND 1396
FOR MPC-68	1401 AND 1402

REVISIONS					
REV	DESCRIPTION	DATE	CHECKED	ENG.	QA
8	INCORPORATED DCR 5014-132	J.A. 6-21-99	6/23/99	6-23-99	6-23-99

HOLTEC INTERNATIONAL
EQUIPMENT DESIGN
ANALYSIS
CONSULTING

DESCRIPTION: HI-STORM ASSEMBLY
CLIENT: N/A
CONTRACT DRAWING:
PROJECT No.: 5014
SCALE: .06 = 1
P.O. No.: N/A
DRAWING No.: 1495
REV.: 8
SHEET: 1 of 6

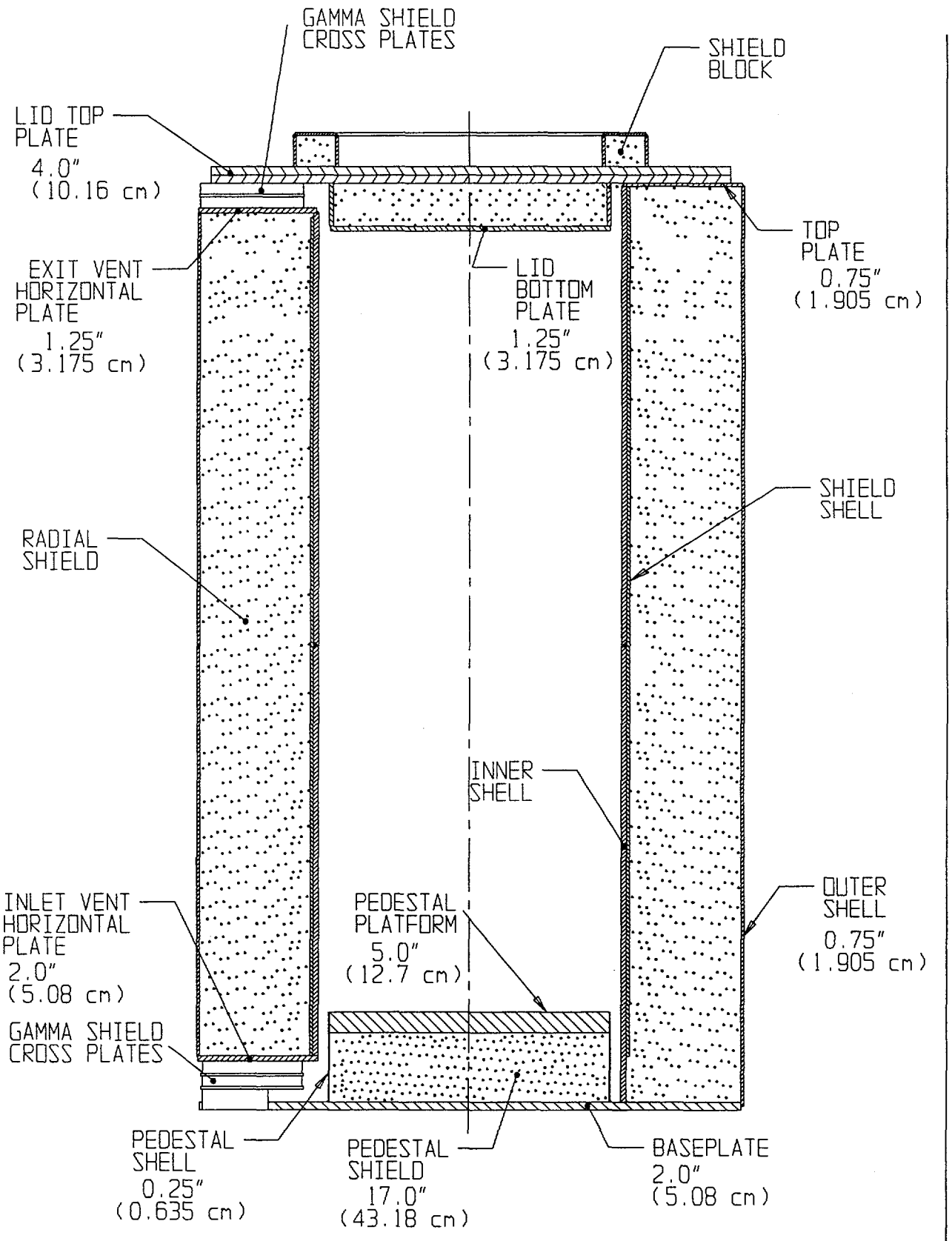
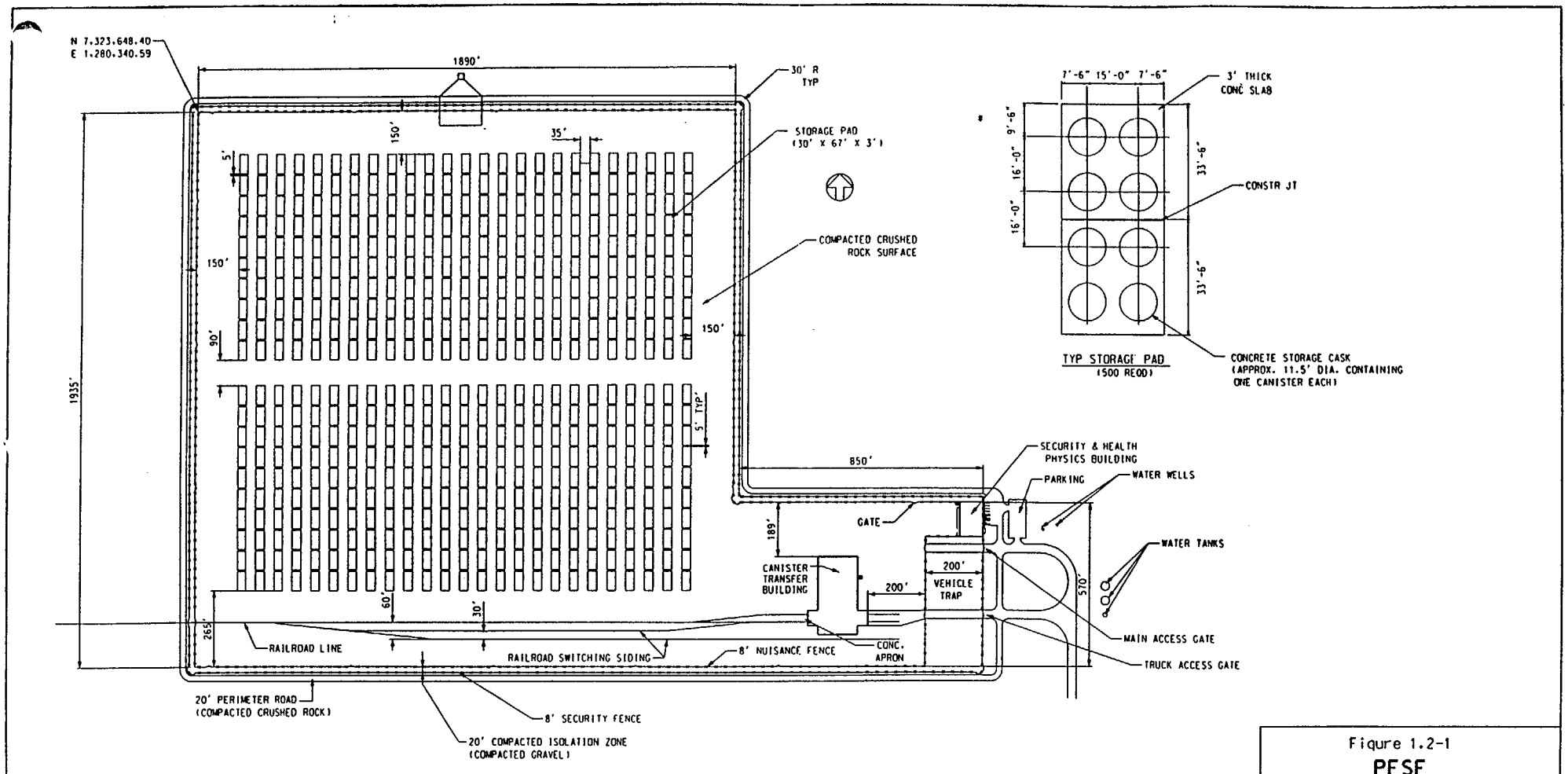


FIGURE 5.3.11; HI-STORM 100 OVERPACK CROSS SECTIONAL ELEVATION VIEW

STAFF EXHIBIT X



PLAN
PRIVATE FUEL STORAGE FACILITY
(STORAGE CAPACITY = 40,000 MTU)

Figure 1.2-1
PFSF
GENERAL ARRANGEMENT
PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

Revision 21

NRC Form 8–C
(4–79)
NRCM 0240

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