STAFF TECHNICAL POSITION ON INVESTIGATIONS TO IDENTIFY FAULT DISPLACEMENT AND SEISMIC HAZARDS AT A GEOLOGIC REPOSITORY

Revised Internal Draft - October 1990

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PREFACE

The United States Nuclear Regulatory Commission (NRC) is developing a series of guidance documents to address the potential effects of vibratory ground motion, faulting, and volcanism on the siting, design, and total system performance of a high-level radioactive waste (HLW) repository. The guidance is expected to be presented in staff technical positions (STPs), guidance letters, and rulemakings. This STP presents the staff position on appropriate investigations to identify seismic and faulting phenomena. Another STP under consideration will describe the staff position on suitable methods for using tectonic models to define the overall state of seismic and geologic conditions in the vicinity of the repository. A third STP under consideration would provide guidance on deterministic and probabilistic methods of analysis of fault displacement and vibratory ground motion hazards for input to the development of design bases for engineered systems.

Guidance on appropriate ways to use the information gathered on tectonic conditions and processes at the site, to develop design bases addressing the seismo-tectonic hazards and to apply these design bases to engineering design, is being considered. Additional guidance under consideration as a rulemaking will present the staff's view of how the characterization of the seismic and geologic hazards fits into the performance objectives of NRC's regulation addressing geologic repositories, as well as the standards established by the Environmental Protection Agency.

This STP addresses the investigatory aspect of the characterization of faulting and seismic hazards at a geologic repository.

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1. INTRODUCTION

According to 10 CFR Part 60 (see Ref. 1), the applicant for a license to dispose of high-level radioactive waste (HLW) at a geologic repository shall investigate potential fault displacement, and seismic or vibratory ground motion hazards (see glossary) that may affect the design, operation, and performance of the geologic repository. However, 10 CFR Part 60 does not specify the manner in which these fault displacement and seismic hazards are to be investigated. The purpose of this Staff Technical Position (STP), therefore, is to provide regulatory guidance to the U.S. Department of Energy (DOE) on appropriate investigations that can be used to identify fault displacement and seismic hazards at a geologic repository. The terms "fault displacement and seismic hazards", as used in this STP, are limited to the hazards resulting from fault displacement and vibratory ground motion that can affect the design and performance of the geologic repository.

The objective of the investigations is to provide information needed for both deterministic and probabilistic analyses of the fault displacement and seismic

hazards. Ultimately, these investigations provide input to the determination of the design bases of fault displacement and vibratory ground motion that need to be taken into account for the design of systems, structures, and components, of a geologic repository, that are important to safety, containment, or waste isolation. Consideration of the geologic history of faults, in the geologic setting (see glossary), that are thought to be capable of generating earthquakes and displacement, in accordance with criteria described in this STP, contributes to the determination of the most severe earthquakes and displacement associated with these faults. Likewise, the design basis for both the maximum vibratory ground motion and the expected vibratory ground motion reflects the seismology, geology, and the seismic and geologic history of the site (see glossary) and the surrounding region. Consideration of historical earthquakes that can be associated with tectonic structures or with the geologic setting, and other factors, can help to identify the most severe earthquakes associated with these features. An analysis of the information acquired through the investigations will lead to an identification of the rates of fault displacement and of seismic activity. Knowledge of such rates and of the fault and seismic characterisics of the site and the geologic setting is fundamental to the development of design bases.

In general terms, this STP draws on experience gained in applying the concepts in Appendix A of 10 CFR Part 100 (see Ref. 2), to establish appropriate investigations for providing input for the determination of design basis fault displacement and vibratory ground motion hazards for a geologic repository. Certain parts of Appendix A of 10 CFR Part 100, with modification, are

appropriate for addressing the investigations of the fault displacement and seismic hazard at a geologic repository.

This STP does not address deterministic or probabilistic fault displacement or seismic hazard analysis; guidance on this topic will be treated separately. Furthermore, it does not address the interpretation of the "anticipated processes and events and unanticipated processes and events" concepts, as defined in 10 CFR Part 60. Also, the criteria contained in this STP do not address investigations of volcanic or volcano-tectonic phenomena for candidate sites located in areas of such activity. Guidance on the investigation of the volcano-tectonic aspects of such sites also will be dealt with separately.

STPs are issued to describe and make available to the public criteria for methods acceptable to the NRC staff, for implementing specific parts of the Commission's regulations, or to provide guidance to the Department of Energy (DOE). STPs are not substitutes for regulations, and compliance with them is not required. They suggest one approach which is acceptable to the staff for meeting regulatory requirements. Methods and solutions different from those set out in the STP will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission. Published STPs will be revised, as appropriate, to accommodate comments and to reflect new information and experience. In addition, the staff will review in detail the information provided by DOE in light of Standard Format and Content Guide(s) to be prepared by the staff in preparation for license applications and such other guidance and regulatory documents (for

example, those detailing Quality Assurance requirements) as may have been provided to the public and the DOE.

2. REGULATORY BACKGROUND

The criteria set forth in §60.21(c)(1)(ii) form the basis for investigations to describe the fault displacement and seismic hazards at a geologic repository operations area. The following is an excerpt of the appropriate text of §60.21(c)(1)(ii):

> "§60.21(c) The Safety Analysis Report shall include:
> (1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.
> (i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area [see glossary]. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material...."
> (ii) The assessment shall contain: (A) An analysis of the geology [and] geophysics ... of the site[.]"

This description and analysis must be in sufficient depth to support the assessment of the effectiveness of engineered and natural barriers (§60.21(c)(1)(ii)(D)) as well as the analysis of design and performance requirements for systems, structures, and components important to safety, containment, or waste isolation (§60.21(c)(3)).

Performance objectives, siting and design criteria described in 10 CFR Part 60 establish the bases for considering the fault displacement and seismic hazard for the preclosure and postclosure periods. According to §60.111, during the preclosure period, the geologic repository operations area is to be designed to provide protection against radiation exposures and releases of radioactive material in accordance with standards set forth in 10 CFR Part 20 (see Ref. 3). Also, during the preclosure period, §60.111 requires that the geologic repository operations area be designed so that the option to retrieve the emplaced radioactive waste is preserved. Subsection 60.131(b)(1) states that structures, systems, and components important to safety be designed so that natural phenomena and environmental conditions expected at the geologic repository operations area will not interfere with necessary safety functions.

It is expected that much of the information gathered to support the fault displacement and seismic hazard evaluation required by §60.131(b)(1), for the preclosure period, can also be used to support fault displacement and seismic hazard evaluation, after permanent closure, with due consideration given to the uncertainties associated with projections over a much longer period of postclosure performance.

Unlike other nuclear facilities that handle, process, or use high-level radioactive materials, a geologic repository is unique in that it is a facility that not only processes the material, but also becomes the site of the final disposal of this material. Other nuclear facilities, once they have served their usefulness, are decommissioned, and radioactive material associated with the facility is removed to appropriate disposal facilities, including a

geologic repository. The investigations performed to address the requirements of §60.131(b)(1) should be conducted concurrently with investigations for postclosure evaluations such as the potentially adverse conditions regarding the fault displacement and seismic hazards found in §§60.122(c)(12), 60.122(c)(13), and 60.122(c)(14), and the fault displacement conditions addressed in §§60.122(c)(3), 60.122(c)(4), and 60.122(c)(11). These potentially adverse conditions are to be addressed according to the provisions of §60.122(a)(2).

3. TECHNICAL POSITION

It is the U.S. Nuclear Regulatory Commission (NRC) staff's position that a deterministic approach to investigations of fault displacement and seismic phenomena, defined in detail in succeeding parts of this section, should be applied to geologic repository investigations. Further, it is the position of the staff that the approach to investigations for fault displacement and seismic phenomena described in this section is appropriate for the collection of sufficient data for input to analyses of the fault displacement and seismic hazards, both for the preclosure period and for the period after permanent closure.

3.1 Investigation Considerations

This subsection provides guidance on the "Identification of the Region to be Investigated," the "Identification of Faults in the Geologic Setting

Susceptible to Displacement," that form the basis for more detailed investigations described in subsections 3.2 and 3.3.

3.1.1 Identification of the Region to be Investigated. The size of the region to be investigated should be determined by the nature of the proposed site's geologic setting. For the purposes of the identification of faults susceptible to displacement (see glossary), the term "geologic setting" applies to both preclosure and postclosure periods. With respect to the identification of fault displacement hazard, the identification process should be based on a review of the pertinent literature and relevant field investigations, and the consideration of alternative tectonic models. In Subsection 3.3, this STP provides specific guidance on areas to be investigated in the identification of seismic hazard.

3.1.2 Identification of Faults in the Geologic Setting Susceptible to Displacement. The purpose of this subsection is to provide DOE with an acceptable approach for identifying those faults in the geologic setting that should be considered for further investigation. These faults are termed faults susceptible to displacement ('susceptible' fault). The staff defines a fault within the geologic setting susceptible to displacement, as one that (a) has had movement within the Quaternary period; or (b) has seismicity, instrumentally determined with records of sufficient precision, that demonstrates a direct relationship with the fault; or (c) is susceptible to failure in the existing stress field; or (d) has a structural relationship to a fault that meets one or more of the above criteria.

An acceptable approach to the the identification of 'susceptible' faults should include:

(1) Determination of geologic conditions of the geologic setting, such as its lithology, stratigraphy, structural geology, stress field, and geologic history;

(2) Determination of existence of Quaternary-age displacement on faults within the geologic setting;

(3) Consideration of alternative tectonic models;

(4) Listing of all historically reported earthquakes that can reasonably be associated with faults, any part of which is within the geologic setting, including date of occurrence and the following measured or estimated data: magnitude or highest intensity, and a plot of the epicenter or region of highest intensity.

3.2 Investigations for Fault Displacement Hazard

The investigations described in this subsection should be conducted to obtain information needed as input for the determination of the design basis fault displacement. Following the identification of faults susceptible to displacement, consideration should be given to which 'susceptible' faults need to undergo further investigation. 'Susceptible' faults inside the controlled area should be investigated in greater detail, based on the methods described in this subsection. For 'susceptible' faults outside of the controlled area, iterative assessments of their possible impact on systems, structures, and components important to safety, containment, or waste isolation can be used as

screening criteria for determining the need for further investigation. Those 'susceptible' faults outside the controlled area to be investigated in greater detail should also be investigated based on the methods described in this subsection.

For 'susceptible' faults in the controlled area and those selected from beyond the controlled area for detailed investigation, the investigations should include consideration of alternative tectonic models at the scale of the controlled area or larger area, as appropriate, and the following:

(1) Character of the fault or fault zone, including its length, width, and three-dimensional geometry;

(2) Relationship of the fault to other tectonic structures in the controlled area and the geologic setting;

(3) Nature, amount, and geologic history of displacements along the fault, including particularly the estimated amount of the maximum Quaternary-age displacement; and

(4) Correlation of hypocenters, or locations of highest intensity, of historically reported earthquakes with faults, any part of which is within the controlled area;

The investigations described in Subsection 3.1.2 and this Subsection should be sufficient to provide input for the determination of the design basis fault displacement related to systems, structures, and components important to safety, containment, or waste isolation in the surface and underground facilities. Faults encountered in the underground facility should be correlated with their expressions at the surface. If faults encountered in the

underground facility cannot be correlated with surface expressions, then investigations should be performed in accordance with this subsection.

3.3 Investigations for Vibratory Ground Motion Hazard

The investigations described in this subsection should be conducted to obtain information needed to provide input for the determination of the design basis vibratory ground motion. In addition to the investigations described in 3.1.2(1), the investigations should include the following:

(1) Listing of all historically reported earthquakes that have affected or that could reasonably be expected to have affected the location of the controlled area, including the date of occurrence and the following measured or estimated data: magnitude or highest intensity, and a plot of the epicenter or location of highest intensity. Where historically reported earthquakes could have caused a maximum ground acceleration of at least one-tenth the acceleration of gravity (0.1g) to the site, the acceleration or intensity, time history, and duration of ground-shaking at these facilities should also be estimated.

Since earthquakes have been reported in terms of various parameters such as magnitude, intensity at a given location, and effect on ground, structures, and people at a specific location, some of these data may have to be estimated by use of appropriate empirical relationships. Measured data are preferable to estimated data, when available. Consideration of the comparative characteristics of the material underlying the epicentral location or region of

highest intensity and of the material underlying the site in transmitting earthquake vibratory motion should include:

(a) A determination of the static and dynamic engineering properties of the materials underlying the site as well as an assessment of the properties needed to determine the behavior of the underlying materials during earthquakes and the characteristics of the underlying materials in transmitting earthquake-induced motions to those structures, systems, and components important to safety, containment, or waste isolation, such as seismic wave velocities, density, water content, porosity, and strength;

(b) An assessment of the physical evidence concerning the behavior, during prior earthquakes, of the surficial geologic materials and the substrata underlying the site from the lithologic, stratigraphic, and structural geologic studies described in Subsection 3.1.2.

(2) Determination of regional attenuation of vibratory ground motion;

(3) Correlation of epicenters or locations of highest intensity of historically reported earthquakes, where possible, with tectonic structures, any part of which is located within 200 miles of the site. Epicenters or locations of highest intensity that cannot be reasonably correlated with tectonic structures should be associated with seismic source zones, any part of which is located within 200 miles of the site;

(4) Determination of which 'susceptible' faults may be of importance in determining the design basis vibratory ground motion. The 'susceptible' faults that should be studied are those faults that could generate the equivalent of 0.1g or greater maximum ground acceleration at the location of the controlled area.

(5) Determination of the fault parameters described in Subsection 3.2 for those 'susceptible' faults that may be of importance in establishing the design basis vibratory ground motion.

Vibratory ground motion determinations for a point on the surface using accepted attenuation functions, which are typically derived from surface observations, will generally be conservative for the underground facility beneath the surface point (except for cases of unusual channeling of the motion). However, if 'susceptible' faults are located in the immediate vicinity of the underground facility, special investigations should be undertaken to determine if areas exist, within the underground facility where vibratory ground motion at depth would be higher than at the surface.

4. DISCUSSION

It is emphasized here that this position in no way suggests deferring to Appendix A of 10 CFR Part 100 for guidance in addressing the fault displacement and seismic hazards at a geologic repository. This is particularly true for those sections of Appendix A of 10 CFR Part 100 that address the determination of the need to design for fault displacement and the design bases for vibratory ground motion.

The reader of this position will find that the elements of investigation presented in Subsections 3.2 and 3.3 are similar to the elements presented in Section IV of Appendix A of 10 CFR Part 100. NRC could have adopted Appendix A of 10 CFR Part 100 for guidance concerning seismic and geologic criteria, as it

has done in 10 CFR Part 40 (see Ref. 4) with regard to tailings dams for uranium processing mills or in 10 CFR Part 72 (see Ref. 5) with regard to independent spent fuel storage installations or monitored retrievable storage systems. Appendix A of 10 CFR Part 100 was not adopted, in part, because of the very long performance period following permanent closure and the significant differences between preclosure and postclosure performance requirements and also because of the difference in nature between nuclear power plants and geologic repositories.

4.1 Investigation Considerations

This subsection provides supporting discussion for the identification of the region to be investigated and the concept of 'susceptible' fault.

4.1.1 Identification of the Region to be Investigated. The areal extent of the region to be investigated should be such that the geologic and seismic characteristics are understood in sufficient detail so as to permit an evaluation of the proposed site, to provide sufficient information to support the determinations based on these investigations, and to provide input for engineering solutions to actual or potential geologic and seismic effects at the proposed site.

4.1.2 Identification of Faults in the Geologic Setting Susceptible to Displacement. The concept of 'susceptible' fault is based on 10 CFR Part 60 requirements, and builds upon past regulatory experience (10 CFR Part 100,

Appendix A). For the purposes of this STP, the definition of a 'susceptible' fault serves only as an indicator (i.e., investigative tool) to identify faults to be considered for investigation. The term "capable fault," as defined in 10 CFR Part 100, Appendix A, was not used in this STP because "capable fault" was originated to help define the hazard posed to nuclear power facilities and thus was developed in a substantially different context than HLW repository performance. In contrast to 'susceptible' fault, as defined in this STP, "capable fault" was used as a site suitability tool, with established criteria under which nuclear power station sites that include capable faults are not considered suitable (see Refs. 6 and 7).

Following an assessment of existing geologic data and alternative tectonic models for the site; faults within the geologic setting that meet one, several, or all of the criteria listed in Subsection 3.1.2 above would be designated as 'susceptible' faults. The identification of 'susceptible' faults is considered to be an iterative process in that faults recognized during the characterization process must be evaluated using the criteria established in Subsection 3.1.2. Faults that cannot be clearly demonstrated to be "not susceptible to displacement" under the criteria listed in Subsection 3.1.2, should be assumed to be susceptible to displacement. Faults or fault zones demonstrated not to meet the criteria for 'susceptible' faults would generally require no further investigation, under the guidance provided in Subsection 3.2 of this position.

This STP does not provide specific limits on the dimensions of 'susceptible' faults that require investigation. DOE is afforded the flexibility to

demonstrate that displacement along 'susceptible' faults of a certain dimension will not adversely affect the performance of systems, structures, and components of a geologic repository important to safety, containment, or waste isolation. 'Susceptible' faults that fall in this category will require no further investigation, under the guidance in this STP. Consequently, the staff's concept of 'susceptible' fault is considered to be size-independent.

The definition of 'susceptible' fault considers the Quaternary Period as the basic time increment for the determination of fault significance. The staff does not believe that the use of this time increment as a baseline for characterization is unnecessarily conservative. The use of the entire Quaternary record in characterization activities is based on requirements of 10 CFR Part 60 and supported by the staff analysis of public comments on the draft of 10 CFR Part 60 (see Ref. 8), where it was stated that in regard to the investigation of potentially adverse conditions, "...all that is important is that processes 'operating during the Quaternary Period' be identified and evaluated...." The use of the entire Quaternary record also reflects technical points of view such as those expressed by Allen (see Ref. 9), who indicates that "...the distribution of faults with Quaternary displacements seems to be a valid general guide to modern seismicity" and "... understanding the Quaternary Period is much more important than understanding earlier periods, and this is where attention should first be concentrated." In addition, Hays (see Ref. 10) indicates that "...stratigraphic offset of Quaternary deposits by faulting is indicative of an active fault." Finally, consideration of the record for the entire Quaternary Period is necessary to ensure that faults having long recurrence intervals (i.e., greater than 100,000 years) will be investigated.

The definition of 'susceptible' fault is not intended to preclude an examination of the pre-Quaternary record. An assessment of the pre-Quaternary movement history may be needed to establish whether temporal or spatial clustering of fault activity is of importance to the repository. DOE is afforded the flexibility to determine the need or lack of need for an examination of the pre-Quaternary record of fault movements.

The definition of 'susceptible' fault also incorporates a criterion that a fault is 'susceptible' if it is susceptible to failure in the existing stress regime. This criterion reflects two separate conditions. First, this criterion reflects situations where the existing stress regime is interpreted to suggest that faults that trend in certain directions (i.e., favorably-oriented faults) are in a state of incipient failure. An example of this occurs at the proposed repository site at Yucca Mountain where Rogers and others (see Ref. 11) have indicated that faults in the region with azimuths ranging from about north to east-northeast should be considered favorably oriented for activation in the current stress regime. The second condition reflected by this criterion is the possible perturbations to the stress regime by the emplaced radioactive waste. In the iterative process of the identification of 'susceptible' faults in the underground facility, the term "existing stress regime" is intended to include the stress regime that will exist in the repository following the emplacement of radioactive waste. Therefore, the effect(s) of emplaced radioactive waste should be considered in the identification of, and further study of 'susceptible' faults in the underground facility.

It is emphasized that of the criteria for definition of 'susceptible' faults, documented evidence of movement within the Quaternary Period is the most important criterion with respect to determining the significance of a fault to the repository. In cases where documentation of movement in the Quaternary period is lacking or accompanied by high levels of uncertainty, the other criteria for the identification of 'susceptible' faults should be considered.

4.2 Investigations for Fault Displacement Hazard.

All faults that are susceptible to displacement are not equally hazardous. Thus, the level of investigation can vary from that sufficient for identification (such as stated in subsections 3.1.2 and 4.1.2) to that sufficient for input for determination of design fault displacement (such as stated in subsections 3.2 and this subsection). 'Susceptible' faults that will not adversely affect the performance of systems, structures, and components of a geologic repository important to safety, containment, or waste isolation need not be investigated in as much detail as those that occur in, or have any part within, the controlled area or as those that may adversely affect repository performance, containment, or waste isolation. DOE is afforded the flexibility to demonstrate that displacement along 'susceptible' faults outside the controlled area will not adversely affect the performance of systems, structures, and components of a geologic repository important to safety, containment, or waste isolation, and thus will require no further investigation under guidance in this STP.

It is unlikely that fault displacement could occur at the surface above an underground facility without also occurring within the underground facility. If, however, faults are encountered in the underground facility, it may be impractical to study such faults in the manner described in Subsection 3.2. Instead, special emphasis should be given to the nature of the fault trace, its extent as observed in other openings, and its relation to the trends of faults identified as 'susceptible' faults in the vicinity of the underground facility.

4.3 Investigations for Vibratory Ground Motion.

A key element driving the investigations for vibratory ground motion is the peak horizontal acceleration value of 0.1g, below which the staff does not have a regulatory concern. Using 0.1g as a discriminator to determine the scope of investigations to be undertaken or the type of information to be gathered, facilitates the use of various relationships between maximum ground acceleration and parameters of interest. It should not be construed that maximum ground acceleration alone provides the necessary input for the determination of the design basis vibratory ground motion. A value of 0.1g is reasonable when considering the uncertainties encountered in the earthquake data base as well as in the various relationships that have been derived for earthquakes and faulting. This value has been cited in a number of regulatory and guidance documents as a discriminator for the minimum value of consideration for the determination of design basis earthquakes and is so used here.

The 200-mile radius, within which earthquakes should be correlated with structures or associated with seismic source zones, was chosen because this distance approximates the distance at which the peak horizontal acceleration due to the largest earthquakes expected in the contiguous United States would be attenuated to 0.1g. In a similar fashion, the 'susceptible' faults that should be studied are those faults that lie within circles, centered on the location of the controlled area, whose radii are a function of earthquake magnitude and the vibratory ground motion attenuation determined for the region. Each radius represents the distance at which vibratory ground motion of a particular magnitude earthquake would be attenuated to the equivalent of 0.1g, the acceleration of minimum concern at the location of the controlled area.

It is generally observed that vibratory ground motion at depth is usually less than that observed on the surface above the underground observation point for sources at some distance from the observation points (see Ref. 12). Nevertheless, if feasible, vibratory ground motion should be monitored as early as possible during the site validation phase of investigations, both on the surface above the proposed underground facility and at the level of the proposed underground facility, to observe possible differences in the motion between these locations. Observed differences should be used to estimate the vibratory ground motion attenuation with depth. Obviously, if the underground facility is to encompass 'susceptible' faults, and these faults experience movement resulting in earthquakes, then there will exist some zone surrounding the faults where vibratory ground motion will exceed that experienced at the surface. For such vibratory ground motion, it will be necessary to identify

the extent of zones of potentially higher vibratory ground motion that may exist in the underground facility.

5. REFERENCES

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4. U.S. Code of Federal Regulations, "Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," Chapter 40, Part 191, January 1988.

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APPENDIX A

GLOSSARY

As used in this guidance:

"Controlled Area" means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be restricted following permanent closure (10 CFR Part 60).

"Fault susceptible to displacement" is a fault in the geologic setting that:

a) has had movement within the Quaternary; or

b) has seismicity, instrumentally determined, with records of sufficient precision to demonstrate a direct relationship with the fault; or

c) is susceptible to failure in the existing stress field; or

d) has a structural relationship to a fault that meets one or more of the above criteria.

"Geologic Setting" means the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located (10 CFR Part 60).

"Seismic hazard" is a set of conditions, based on the potential for the occurrence of earthquakes, that might operate against the health and safety of the public. Seismic hazard may be characterized in either deterministic or probabilistic terms.

"Site" means the location of the controlled area (10 CFR Part 60).

APPENDIX B

RELEVANT TEXT FROM TITLE 10, CHAPTER I, OF THE CODE OF FEDERAL REGULATIONS

10 CFR Part 60

10 CFR 60.21(c)(1)

(c) The Safety Analysis Report shall include:

(1) A description and assessment of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features of the site that might affect geologic repository operations area design and performance. The description of the site shall identify the location of the geologic repository operations area with respect to the boundary of the accessible environment.

(i) The description of the site shall also include the following information regarding subsurface conditions. This description shall, in all cases, include such information with respect to the controlled area. In addition, where subsurface conditions outside the controlled area may affect isolation within the controlled area, the description shall include such information with respect to subsurface conditions outside the controlled area to the extent such information is relevant and material.

(ii) The assessment shall contain:

(A) An analysis of the geology [and] geophysics ... of the site[.]

10 CFR 60.21(c)(1)(ii)(C)

[The assessment of the site at which the proposed geologic repository operations area is to be located, that is to be included in the Safety Analysis Report of the license application, shall contain:] An evaluation of the performance of the proposed geologic repository for the period after permanent closure, assuming anticipated processes and events, giving the rates and quantities of releases of radionuclides to the accessible environment as a function of time; and a similar evaluation which assumes the occurrence of unanticipated processes and events.

10 CFR 60.21(c)(3)

[The Safety Analysis Report of the license application shall include:] A description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository which are important to safety. This analysis shall consider -- (i) The margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin; and (ii) the adequacy of structures, systems, and components provided for the prevention of accidents and mitigation of the consequences of accidents, including those caused by natural phenomena.

10 CFR 60.111, Performance of the geologic repository operations area through permanent closure.

(a) Protection against radiation exposures and releases of radioactive material. The geologic repository operations area shall be designed so that until permanent closure has been completed, radiation exposures and radiation levels, and releases of radioactive materials to unrestricted areas, will at all times be maintained within the limits specified in Part 20 of this chapter and such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency.

(b) Retrievability of waste. (1) The geologic repository operations area shall be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and, thereafter, until the completion of a performance confirmation program and Commission review of the information obtained from such a program. To satisfy this objective, the geologic repository operations area shall be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. This different time period may be established on a case-by-case basis consistent with the emplacement schedule and the planned performance confirmation program.

(2) This requirement shall not preclude decisions by the Commission to allow backfilling part or all of, or permanent closure of, the geologic repository operations area before the end of the period of design for retrievability.

(3) For purposes of this paragraph, a reasonable schedule for retrieval is one that would permit retrieval in about the same time as that devoted to construction of the geologic repository operations area and the emplacement of wastes.

10 CFR 60.112, Overall system performance objective for the geologic repository after permanent closure.

The geologic setting shall be selected and the engineered barrier system and the shafts, boreholes and their seals shall be designed to assure that releases of radioactive materials to the accessible environment following permanent closure conform to such generally applicable environmental standards for radioactivity as may have been established by the Environmental Protection Agency with respect to both anticipated processes and events and unanticipated processes and events.

10 CFR 60.113, Performance of particular barriers after permanent closure.

(a) General provisions -- (1) Engineered barrier system. (i) The engineered barrier system shall be designed so that assuming anticipated processes and events: (A) Containment of HLW will be substantially complete during the period when radiation and thermal conditions in the engineered barrier system are dominated by fission product decay; and (B) any release of radionuclides from the engineered barrier system shall be a gradual process which results in small fractional releases to the geologic setting over long times. For disposal in the saturated zone, both the partial and complete

filling with ground water of available void spaces in the underground facility shall be appropriately considered and analyzed among the anticipated processes and events in designing the engineered barrier system.

(ii) In satisfying the preceding requirement, the engineered barrier system shall be designed, assuming anticipated processes and events, so that:

(A) Containment of HLW within the waste packages will be substantially complete for a period to be determined by the Commission taking into account the factors specified in 10 CFR 60.113(b) provided, that such period shall be not less than 300 years nor more than 1,000 years after permanent closure of the geologic repository; and

(B) The release rate of any radionuclide from the engineered barrier system following the containment period shall not exceed one part in 100,000 per year of the inventory of that radionuclide calculated to be present at 1,000 years following permanent closure, or such other fraction of the inventory as may be approved or specified by the Commission; provided, that this requirement does not apply to any radionuclide which is released at a rate less than 0.1 percent of the calculated total release rate limit. The calculated total release rate limit shall be taken to be one part in 100,000 per year of the inventory of radioactive waste, originally emplaced in the underground facility, that remains after 1,000 years of radioactive decay.

(2) Geologic setting. The geologic repository shall be located so that pre-waste-emplacement ground water travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such other travel time as may be approved or specified by the Commission.

(b) On a case-by-case basis, the Commission may approve or specify some other radionuclide release rate, designed containment period or pre-waste-emplacement ground-water travel time, provided that the overall system performance objective, as it relates to anticipated processes and events, is satisfied. Among the factors that the Commission may take into account are:

(1) Any generally applicable environmental standard for radioactivity established by the Environmental Protection Agency;

(2) The age and nature of the waste, and the design of the underground facility, particularly as these factors bear upon the time during which the thermal pulse is dominated by the decay heat from the fission products;

(3) The geochemical characteristics of the host rock, surrounding strata and ground water;and

(4) Particular sources of uncertainty in predicting the performance of the geologic repository.

(c) Additional requirements may be found to be necessary to satisfy the overall system performance objective as it relates to unanticipated processes and events.

10 CFR 60.122(c), Potentially adverse conditions.

[Selected conditions considered directly or indirectly related to seismic hazard]

The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area.

(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional ground-water flow system and thereby adversely affect the performance of the geologic repository.

(4) Structural deformation, such as uplift, subsidence, folding, or faulting that may adversely affect the regional ground-water flow system.

(11) Structural deformation such as uplift, subsidence, folding, and faulting during the Quaternary Period.

(12) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.

(13) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.

(14) More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.

10 CFR 60.131(b)(1), Protection against natural phenomena and environmental conditions.

[With respect to the general design criteria for the geologic repository operations area,] The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the geologic repository operations area will not interfere with necessary safety functions.