

**REGULATORY BASES FOR ASSESSMENT
OF TECTONICS**

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CONTENTS

Section		Page
	ACKNOWLEDGMENTS	
1	INTRODUCTION	1-1
2	STATUTORY BASES FOR CONSIDERING TECTONICS	2-1
2.1	ATOMIC ENERGY ACT OF 1954	2-1
2.2	ENERGY REORGANIZATION ACT OF 1974	2-1
2.3	NUCLEAR WASTE POLICY ACT OF 1982	2-2
2.4	NUCLEAR WASTE POLICY ACT AS AMENDED	2-4
3	TECTONICS AND LICENSING OF A HLW REPOSITORY: A REGULATORY HISTORY	3-1
3.1	PROPOSED LICENSING PROCEDURES	3-1
3.2	FIRST PUBLIC DRAFT OF TECHNICAL CRITERIA	3-2
3.3	FINAL PROCEDURAL RULE	3-6
3.4	PROPOSED TECHNICAL CRITERIA	3-6
3.5	FINAL RULE	3-12
3.6	STAFF ANALYSIS OF PUBLIC COMMENTS ON PROPOSED RULE AND SUPPLEMENTARY INFORMATION SECTION OF FINAL RULE	3-17
3.7	AMENDMENTS TO FINAL RULE	3-18
3.8	PROPOSED AMENDMENTS TO RULE	3-19
3.9	UPDATE TO FINAL RULE	3-19
4	CONCLUSIONS	4-1
5	REFERENCES	5-1

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1 INTRODUCTION

The Nuclear Waste Policy Act (NWPA) of 1982, as amended (1987), establishes the lines of responsibility in the civilian high-level radioactive waste disposal program for the Department of Energy (DOE), the license applicant; the Nuclear Regulatory Commission (NRC), the agency responsible for reviewing the License Application (LA) and issuing the license; and the Environmental Protection Agency (EPA), the agency responsible for promulgating release standards for long-term repository performance. Site characterization and licensing of a geologic repository for high-level radioactive waste will require that considerable scientific data and knowledge, and technical expertise be applied to address complex technical issues under a rigorous schedule and intense public scrutiny.

A fundamental issue in evaluation by NRC staff of DOE's anticipated LA is whether a mined geologic repository at that location will provide effective pre-closure and post-closure isolation of the waste material from the accessible environment in accordance with the requirements set forth by EPA and NRC. Because geologic faults and natural fractures are integral to the geologic setting of the proposed Yucca Mountain repository site, and because the site is in a tectonically active region, concerns exist about the potential for continued tectonic deformation, such as fault displacement and the possible effects of tectonic activity on long-term waste isolation at a mined geologic repository at Yucca Mountain. Early identification and resolution of technical uncertainties, and development of appropriate pre-licensing guidance related to tectonic processes and associated in-situ conditions are considered to be important by NRC staff to effectively implement the requirements of 10 CFR Part 60.

Specifically, construction of a geologic repository operations area by DOE is contingent on submittal of a LA to NRC, and on authorization of construction by NRC (10 CFR 60.3). DOE is required to conduct a program of site characterization prior to submittal of a LA (10 CFR 60.15). The license application will include a Safety Analysis Report (SAR) comprising descriptions and assessments of subsurface conditions at the proposed site (10 CFR 60.21(c)(1)(i)).

Detailed information required to comprise the description part of the SAR includes data on natural fractures and other discontinuities (such as geologic faults), ambient stress conditions and the hydrogeologic properties and conditions of the site and site area. The assessment part of the SAR must include an overall analysis of the geology and geophysics of the site, analyses of potentially favorable and adverse conditions as defined in 10 CFR 60.122, and evaluation of the waste isolation performance of the repository and effectiveness of engineered and natural barriers. Models are expected to be used in support of assessment activities, including prediction of future conditions and changes in the geologic setting (10 CFR 60.21). Models of tectonic processes and of the structural geology of the site are anticipated to be instrumental in assessing estimates of probabilities of potential repository disruption due to such tectonic processes as earthquake seismicity, fault rupture and magmatic/volcanic activity. These models will also be necessary to determine effects of tectonic processes, such as faulting and associated distributed deformation, on fracture patterns and hydrogeologic properties.

2 STATUTORY BASES FOR CONSIDERING TECTONICS

The role of the Nuclear Regulatory Commission (NRC) in licensing a geologic repository to contain high-level radioactive waste (HLW) is based on five sections of Federal statutes, as follows: (i) 42 USC 2232—Atomic Energy Act of 1954 (Sec. 182), (ii) 42 USC 2233—Atomic Energy Act of 1954 (Sec. 183), (iii) 42 USC 5842—Energy Reorganization Act of 1974, (iv) 42 USC 10132—Nuclear Waste Policy Act (NWPA) of 1982, and (v) 42 USC 10141—NWPA of 1982. The applicable wording and its importance to the consideration of tectonic processes are presented below.

2.1 ATOMIC ENERGY ACT OF 1954

As summarized in the preamble to [53 Fed. Reg. 16131 (1988)], the Atomic Energy Act of 1954 defines several types of regulatory and licensing responsibilities for NRC. Related to its responsibility concerning nuclear materials licensing, the Commission is charged with defining rules and regulations necessary to assure that regulated materials are possessed and used such that the public health and safety is protected and the common defense and security is preserved. The relevant statutory language from the Atomic Energy Act of 1954, Section 182 (42 USC 2232) states that:

"Each application for license. . .shall specifically state such information as the Commission, by rule or regulation, may determine to be necessary. . ."

This language applies to the rules and regulations formulated by NRC to regulate the disposal of HLW in a geologic repository. The language requires that the applicant include within its LA all the information which the Commission requests and requires to fulfill its statutory responsibilities. The applicable regulation to the disposal of HLW in a geologic repository is 10 CFR Part 60.

The Atomic Energy Act of 1954, Section 183 (42 USC 2233) further states that:

"Each license shall be in such form and contain such terms and conditions as the Commission may, by rule or regulation, prescribe to effectuate the provisions of this Act: . . ."

This language also applies to the rules and regulations formulated by NRC to regulate the disposal of HLW in a geologic repository. The language requires that the applicant presents an application in proper form and containing responses to Commission-prescribed rules and/or regulations, in this case, 10 CFR Part 60.

2.2 ENERGY REORGANIZATION ACT OF 1974

Under the Atomic Energy Act of 1954, disposal of HLW is subject to the materials licensing authority of the Commission. The Energy Reorganization Act of 1974 defines the role of DOE in receiving and possessing HLW, stating that DOE must obtain a license from NRC prior to disposal of HLW in a geologic repository. Section 202 of the Energy Reorganization Act of 1974 (42 USC 5842) states:

" . . .the NRC shall . . . have licensing and related regulatory authority pursuant to chapters 6,7,8, and 10 of the Atomic Energy Act of 1954, as amended, as to the following facilities of the Administration: . . .

(3) Facilities used primarily for the receipt and storage of high-level radioactive wastes resulting from activities licensed under such Act.

(4) Retrievable surface storage facilities and other facilities authorized for the express purpose of subsequent long-term storage of high-level radioactive waste generated by the Administration, which are not used for, or are part of, research and development activities."

The language specifically provides the Commission with appropriate licensing and regulatory authority for the disposal of HLW in the "long-term" and gives the Commission jurisdiction over both "retrievable surface storage facilities and other facilities" used for receipt and storage of HLW licensed under the Energy Reorganization Act of 1974. In this case "other facilities" is interpreted to include a geologic repository for the disposal of HLW.

2.3 NUCLEAR WASTE POLICY ACT OF 1982

The NWPA amplified the existing statutory authority and specifically provided for criteria to be promulgated by DOE for site selection and by NRC for site approval and the licensing of geologic HLW repositories. The proposed criteria, which NRC issued prior to passage of the NWPA, were under the authority of the Atomic Energy Act and the Energy Reorganization Act of 1974. The NWPA established a consolidated HLW management framework requiring DOE to establish and utilize site selection guidelines after consultation with a specified list of interested agencies and parties and with the concurrence of NRC. Specific statutory language in the NWPA (42 USC 10132):

Part A—Repositories for Disposal of HLWs and Spent Nuclear Fuels 10132.
Recommendation of candidate sites for characterization

"(a) Guidelines. . .the Secretary [of Energy], following consultation with the Council on Environmental Quality, the Administrator of the Environmental Protection Agency, the Director of the Geological Survey, and interested Governors, and the concurrence of the Commission [NRC] shall issue general guidelines for the recommendation of sites for repositories. Such guidelines shall specify detailed geologic considerations that shall be primary criteria for the selection of sites in various geologic media. . . specify factors that qualify or disqualify any site from development as a repository, including factors pertaining to . . . geophysics, seismic activity, and. . . require the Secretary to consider the various geologic media in which sites for repositories may be located and, to the extent practicable, to recommend sites in different geologic media. . .

(b)(3) In evaluating the sites nominated under this section prior to any decision to recommend a site as a candidate site, the Secretary [of Energy] shall use available geophysical, geologic, geochemical and hydrologic, and other information. . ." [emphasis added]

This language was provided by the legislature to the Secretary of Energy in order to guide the Department of Energy (DOE) in the recommendation of candidate sites for characterization. The specific language of the statute illustrates the concerns of the legislators with the geologic suitability of the candidate sites. Congress specifically directed DOE to establish qualifying and disqualifying criteria based on detailed geologic considerations. By inference, the Commission is, as the license grantor, to be considerate of the same conditions in its evaluation of the DOE License Application.

Additional language in the NWPA, 42 USC 10133 identified the general nature of site characterization activities:

"(a) In general

The Secretary [of Energy] shall carry out, in accordance with the provisions of this section, appropriate site characterization activities beginning with the candidate sites . . . and are located in various geologic media. . . and shall, to the maximum extent practicable . . . conduct site characterization activities in a manner that minimizes any significant adverse environmental impacts. . ."

This language charged DOE with conducting site characterization activities as defined in the NWPA, 42 USC 10101:

"(21)(B) activities, whether in the laboratory or in the field, undertaken to establish the geologic condition and the ranges of parameters of a candidate site. . ."

Additional language in the NWPA, 42 USC 10141 specifically addressed NRC:

"(b)(1)(A) . . .the Commission [NRC], pursuant to authority under other provisions of law, shall, by rule, promulgate technical requirements and criteria that it will apply, under the Atomic Energy Act. . .and the Energy Reorganization Act. . .in approving or disapproving—

(b)(1)(A)(i) applications to construct repositories;

(b)(1)(A)(ii) applications for licenses to receive and possess spent nuclear fuel and high-level radioactive waste in such repositories; and

(b)(1)(A)(iii) applications for authorization for closure and decommissioning of such repositories.

(b)(1)(B) Such criteria shall provide for the use of a system of multiple barriers in the design of the repository. . .

(b)(1)(C) Such requirements and criteria shall not be inconsistent with any comparable sections promulgated by the Administrator under subsection (a)."

This language from the NWPA specifically amplified the authority of the Commission to promulgate technical requirements and criteria for the licensing of a geologic repository for HLW.

Previously discussed existing statutory authority is referred to in the language of 42 USC 10141. Credence is given to the philosophy of multiple barriers at a geologic repository with the wording of (B). The presence of natural resources is of regulatory interest in the context of the performance of the geologic component of this multiple-barrier disposal system.

With the exception of seismic activity, this statute does not specify the type of geologic information that should be considered. The statutory language merely states that "The Secretary is required to specify in the guidelines factors which would qualify or disqualify a site from development as a repository."

2.4 NUCLEAR WASTE POLICY ACT AS AMENDED

In 1987, the NWPA was amended by Congress to narrow site characterization activities to the Yucca Mountain, Nevada, proposed geologic repository site. No substantive changes were made relative to the assessment of tectonic processes.

3 TECTONICS AND LICENSING OF A HLW REPOSITORY: A REGULATORY HISTORY

This section details the regulatory history and the documented intent associated with the development of NRC regulations governing HLW repositories with respect to tectonics. NRC is concerned that certain adverse types of tectonic processes may reduce the ability of the repository to isolate HLW. Conversely, the presence of favorable structural features related to tectonic processes may enhance waste isolation. Therefore, it is necessary to consider tectonics and related geologic structures in assessing the performance of a repository. Early in the development of the regulations, this concern with tectonics was only dealt with in the broad context of geology. As the regulatory issues continued to evolve, the nature of the processes that might act as favorable or potentially adverse conditions and the circumstances under which they might be important were defined more carefully. The following discussion presents specific references to the identification and evaluation of tectonic processes and events in the rules as promulgated and prior to adoption throughout the rulemaking process.

3.1 PROPOSED LICENSING PROCEDURES

In November 1978, NRC published a proposed General Statement of Policy outlining procedures for licensing geologic HLW repositories. This General Statement was followed by a proposed rule [44 Fed. Reg. 70408 (1979)] which contained the procedural requirements for licensing. In this proposed rule, section 60.2 provides a definition for site characterization [44 Fed. Reg. 70416 (1979)]:

"§60.2 Definitions

- (n) 'Site characterization' means the program of exploration and research, both in the laboratory and in the field, undertaken to establish the geologic conditions and ranges of those parameters of a particular site relevant to the procedures under this part. . . " [emphasis added]

This language implied that geologic studies were to be undertaken as part of the LA. The technical criteria for the LA, however, were still under development, and this document [44 Fed. Reg. 70408 (1979)] contained no specific mention of tectonics. The contents of the LA were described in greater detail in the portions of section 60.21 that described the safety analysis report included as part of the LA shall contain [44 Fed. Reg. 70417 (1979)]:

"§60.21 Content of application. . .

- (c) The safety analysis report shall include:

- (c)(1) A description and analysis of the site at which the proposed geologic repository operations area is to be located with appropriate attention to those features that might affect facility design. The assessment shall contain an analysis of the geology, hydrology, geochemistry, and meteorology of the site. . . that bears significantly on the suitability of the geologic repository for disposal of radioactive waste. . .

(c)(3)(ii) A description and analysis of the design and performance structures. . .[which shall consider] 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. . ." [emphasis added]

There was also a general statement in section 60.51(a)(3) that the application to amend the license for decommissioning the repository will include [44 Fed. Reg. 70420 (1979)]:

"§60.51 License amendment to decommission

(a) The Department shall submit . . .

(a)(3) Geologic, hydrologic, and other site data that are obtained during the operational period pertinent to the long-term isolation of emplaced radioactive wastes."

Although it did not provide any specifics as to what types of studies are to be performed during the operational period, this general regulatory language expressed the desire that gathering of geologic information should continue during the operation of the repository.

3.2 FIRST PUBLIC DRAFT OF TECHNICAL CRITERIA

In the first public draft of 10 CFR Part 60 technical criteria {the advance notice of proposed rulemaking [45 Fed. Reg. 31393 (1980)]}, additional technical definitions were proposed for insertion as appropriate into section 60.2 of the licensing procedures proposed in [44 Fed. Reg. 70420 (1979)]. Terms relevant to consideration of tectonic processes and events included [45 Fed. Reg. 31399 (1980)]:

"§60.2 Definitions.

. . . 'Expected processes and events'—means (a) those natural processes or events that are likely to degrade the engineered elements of the geologic repository. . .

. . . 'Stability'—means the rate of natural processes affecting the site during the recent geologic past are relatively low and will not significantly change during the next 10,000 years." [emphasis added]

This language indicated that expected processes and events are those natural processes and events that are deleterious to the isolation of waste. Although the exact nature of natural processes was not defined by the regulatory language here, tectonic processes and events should be considered as natural processes and events. Further, natural (including tectonic) processes were considered principally with regard to the stability of the geologic setting following closure of the repository. Also implicit in this language was the fact that slow geologic rates for natural processes may be considered favorable to the isolation of waste.

The discussion in the preamble to this advance notice of proposed rulemaking further elaborated on the relevance of geologic stability relative to the three periods during the operational life of a geologic repository [45 Fed. Reg. 31394-31395 (1980)]:

" . . .the third period begins following closure of the repository. . .final protection is achieved by the ability of the geologic setting to inhibit migration of the wastes leached from the waste form in a controlled manner. Properties which affect leaching of the waste and transport of the wastes. . .and determination of the long-term stability of the geologic setting will dominate the criteria addressed to this period."

As discussed in the preamble to this advance notice of proposed rulemaking, this concern with geologic stability was also viewed by the Commission staff as a way of decreasing the uncertainty inherent in considering the geologic setting [45 Fed. Reg. 31396 (1980)]:

" . . .the Commission [NRC] may require measures which. . .will add confidence in those analyses, thus adding to the Commission's confidence in the degree to which the EPA standard can be or has been met. Such measures are likely to be aimed at simplifying the problem: such as requiring that precepts of simplicity and stability of the geologic settings govern the site selection process in order to reduce the overall uncertainty and thus render more tractable the problem of demonstrating that the criteria and the EPA standard are met." [emphasis added]

The preamble further stated that [45 Fed. Reg. 31396 (1980)]:

' . . .the Commission staff believes that sites which are relatively easily understood and can be expected to be stable for long times are the most desirable." [emphasis added]

This language clearly indicated the desirability, from the Commission staff's point of view, of selecting geologically simple candidate sites where the geologic setting can be expected to demonstrate stability in the long term following closure of the repository. It was also implicit in this wording that the future stability of the site was to be judged on its stability both at present and in the geologically recent past. This philosophy was solidified by the language chosen for portions of 10 CFR 60.111 [45 Fed. Reg. 31400 (1980)]:

"§60.111 Performance objectives. . .

(c) Performance of required barriers and engineered systems. . .

(c)(4) The Department [of Energy] shall provide reasonable assurance that the degree of stability exhibited by the geologic environment at present will not significantly decrease over the long term." [emphasis added]

As a means of confirming the intent that predictions of future stability should be based on analyses of past stability, the general requirements of 10 CFR 60.122(a) [45 Fed. Reg. 31400-31401 (1980)] stated that:

"(a) General requirements

- (a)(2) The Department [of Energy] shall investigate and evaluate natural conditions. . .that can reasonably be expected to affect the design, construction, operation, and decommissioning of the geologic repository operations areas. The natural conditions include geologic, tectonic, hydrologic, and climatic process[es]. The Department shall evaluate the stability of the geologic repository. . .**
- (2)(ii) The Department shall emphasize those natural conditions active anytime since the start of the Quaternary Period in their investigations. . .**
- (9) The Department shall determine by appropriate analyses. . .**
 - (9)(i) The pattern, distribution and origin of fractures, [and] discontinuities. . .**
 - (9)(iii) The in situ determination of the. . .ambient stress conditions of the host rock and surrounding confining units." [emphasis added]**

This language explicitly identified geologic and tectonic processes as natural processes. For the first time, the time period of interest for analysis of natural (i.e., geologic and tectonic) processes (including rates) was specified as being since the start of the Quaternary Period, although this was not defined in the regulation. While not specifying completely the types of analyses to be used, the language implied that the current tectonic state of the geologic setting is to be defined, and "appropriate analyses" are to be used to evaluate scenarios involving natural processes that are reasonably likely to occur during the 10,000 years following decommissioning of the repository.

As is evident in the definitions cited above for "Expected processes and events" and for "Stability," it was implied that natural processes could be considered as being either potentially adverse conditions (PAC) or as favorable characteristics. This position was clarified in the language chosen for portions of section 60.122. Section 60.122(b) states that [45 Fed. Reg. 31401-31402 (1980)]:

- "(b) Potentially adverse conditions. . .[are] natural conditions which can adversely affect the stability of the repository site. . .**
- (b)(2) Potentially adverse natural conditions—geologic and tectonic [are present if]. . .**
- (b)(2)(iii) There is evidence of processes in the candidate area which could result in structural deformation in the volume of rock such as uplift, diapirism, subsidence, folding, faulting, or fracture zones.**

- (iv) The geologic repository operations area lies within the near field of a fault that has been active since the start of the Quaternary Period.
- (v) . . .there are indications, based on correlations of earthquakes with tectonic processes and features, that seismicity may increase in the future.
- (vi) There is evidence of intrusive igneous activity since the start of the Quaternary Period.
- (vii) There is a high and anomalous geothermal gradient relative to the regional geothermal gradient." [emphasis added]

There was also reference to natural phenomena as a potentially adverse condition related to hydrology in section 60.122(b)(3) [45 Fed. Reg. 31402 (1980)] if:

"(c)(2)(iii) There is reasonable potential for natural phenomena such as landslides, subsidence, or volcanic activity, to create large-scale impoundments that may affect the regional ground-water flow system." [emphasis added]

Evidence for geologic and tectonic stability can also be considered as favorable characteristics. Section 60.122(c) [45 Fed. Reg. 31402 (1980)] stated:

"(c) Favorable characteristics. Each of the following characteristics represent conditions which enhance the ability of the geologic repository to meet the performance objectives. . .

(c)(1) The Department [of Energy] shall select the site so that to the extent practicable the candidate area—

(c)(1)(i) Exhibits demonstrable surface and subsurface geologic, geochemical, tectonic, and hydrologic stability since the beginning of the Quaternary Period. . ." [emphasis added]

This language reinforced the selection of the beginning of the Quaternary Period (still undefined) as the period of interest in evaluating and establishing rates for natural processes. The language also provided, for the first time, specific examples of some of those types of geologic and tectonic processes which should be considered as potentially adverse conditions. The list was not meant to be all-inclusive, but specific attention was directed to the potential for structural deformation and volcanic and seismic hazards. The concept of geologic and tectonic stability is also specifically identified as a favorable condition.

3.3 FINAL PROCEDURAL RULE

A final rule outlining the procedural requirements for licensing a HLW repository was published in 1981 [46 Fed. Reg. 13971 (1981)]. The regulatory language relevant to geologic studies was essentially unchanged from the proposed rule [44 Fed. Reg. 70408 (1979)], only adding the word "geophysics" in the listing of analyses to be contained in the Safety Analysis Report (section 60.21(c)(1)) and the license amendment to decommission (section 60.51(a)(3)).

3.4 PROPOSED TECHNICAL CRITERIA

In 1981, NRC published proposed amendments [46 Fed. Reg. 35280 (1981)] to 10 CFR Part 60. This action proposed adding technical criteria to the existing rule and took into account the draft technical criteria presented in the 1980 advance notice of proposed rulemaking and the comments received on that document. The supplementary information (preamble) to this proposed rule included comments on the consequences of disruptive processes and events on a repository [46 Fed. Reg. 35281 (1981)]:

"Disruptive Processes and Events

The NRC's implementing regulations assume that licensing decisions will be based, in part, on the results of analysis of the consequences of processes and events which could potentially disrupt a repository. Thus, throughout the criteria are requirements that the design basis take into account processes and events with the potential to disrupt a geologic repository. If the process or event is anticipated, i.e., likely, then the design basis requires barriers which would not fail in a way that would result in the repository not meeting the performance objectives. Anticipated processes and events would include such items as waste/rock interactions that result from emplacement of the wastes or the gradual deterioration of borehole seals. If the process or event is unlikely, then the overall system must still limit the release of radionuclides consistent with the EPA standard as applied to such events. An example of an unlikely event would be the reactivation of a fault within the geologic setting which had not exhibited movement since the start of the Quaternary Period. In general, both likely and unlikely processes and events are expected to be site and design specific and would be identified by DOE in its license application." [emphasis added]

Although not explicitly identified, it was implied in the language of this preamble that natural (including geologic and tectonic) processes active since the start of the Quaternary Period (still undefined) were to be considered as anticipated processes and events in that they have the potential to disrupt a geologic repository. For the first time, the concept of unlikely events and processes was considered. From the example chosen, natural processes and events were considered to be unlikely if there was no evidence of occurrence since the start of the Quaternary Period. The preamble further stated that both anticipated (likely) and unlikely processes and events were considered to be site and design specific and that these potentially disruptive processes and events are to be identified in the LA of DOE.

Definitions proposed earlier for section 60.2 [45 Fed. Reg. 31399 (1980)] are retained in a modified form in the proposed rule [46 Fed. Reg. 35285-6 (1981)] which read:

"§60.2 Definitions.

'Anticipated Processes and Events' means those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved and from which the design bases for the engineered system are derived. . .

'Stability' means that the nature and rates of natural processes such as erosion and faulting have been and are projected to be such that their effects will not jeopardize isolation of the radioactive waste." [emphasis added]

In this language, "Expected" was softened to "Anticipated" by the introduction of the word "reasonable." The negative implications of expected processes and events were removed from the language and anticipated processes and events were considered more as characteristics of the geologic system which must be considered in designing the engineered system. The definition of stability was expanded to consider further not only rates but also the nature of natural processes operating at a geologic repository and to include examples of the types of geologic properties which should be considered. All earlier references to a 10,000-year time frame were removed. From this language, stability was still considered as a desirable attribute of any site (geologic setting) under consideration. This view was supported by the discussion in the preamble [46 Fed. Reg. 35284 (1981)]:

"Although no specific site suitability or exclusion requirements are given in the criteria, stability. . . [is] specified as [a] required site characteristic. ALARA (as low as reasonably achievable) principles have not been applied to the natural features of a site because they are not amenable to modification once a site is chosen. . . To enable the Commission to reach a finding as to whether the generally applicable environmental standard for disposal of HLW is met and that public health and safety will be protected, a careful and exhaustive analysis of all the features of the repository will be needed." [emphasis added]

A portion of the licensing procedures (section 60.21) [promulgated in 46 Fed. Reg. 13971 (1981)] would be expanded by this proposal [46 Fed. Reg. 35284 (1981)] to read:

"§60.21 Content of application. . .

(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 facility design and performance. . .

(1)(i) The description of the site shall also include. . .

(A) The orientation, distribution, aperture in-filling and origin of fractures, discontinuities, and heterogeneities. . .

- (C) The bulk geomechanical properties and conditions, including pore pressure and ambient stress conditions. . .
- (ii) The assessment shall contain. . .
 - (A) An analysis of the geology, geophysics, hydrogeology, geochemistry, and meteorology of the site;
 - (B) Analyses to determine the degree to which each of the favorable and adverse conditions, if present, has been characterized and the extent to which it contributes to or detracts from isolation.
 - (C) An evaluation of the expected performance of the proposed geologic repository. . .In executing this evaluation DOE shall assume that those processes operating on the site are those which have been operating on it during the Quaternary Period and superpose the perturbations caused by the presence of emplaced radioactive waste on the natural processes. . .
 - (D) An analysis of the expected performance of the major design structures, systems, and components. . .of the geologic repository. . .assuming the anticipated processes and events and natural phenomena from which the design bases are derived. . .
 - (E) An explanation of measures used to confirm the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be confirmed. . .
- (3) A description and analysis of the design and performance requirements . . .of the geologic repository. . .[which shall consider]. . .
 - (3)(i) the margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin;
 - (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. . ." [emphasis added]

Both the preamble and the regulatory language reflected the Commission's concern that siting and design requirements be considered together in assessing whether performance objectives can be met for a geologic repository. The language in 10 CFR 60.21(c) describing the Safety Analysis Report was greatly

expanded to emphasize the need for assessment relative to prescribed performance objectives, in addition to analysis as to whether favorable or potentially adverse conditions are present at a proposed site. In this way, a site is not automatically disqualified if adverse conditions are present, nor is it automatically approved if one or more favorable conditions are present. Instead, the final decision should await application of predictive models in an assessment of the effect of favorable and potentially adverse conditions on whether or not performance objectives can be met. The new language also provided a list of the types of analyses which the Commission deemed necessary to use for models to predict future conditions and changes in the geologic setting.

The idea of favorable and potentially adverse conditions from the Advanced Notice of Proposed Rulemaking [45 Fed. Reg. 31393 (1980)] was preserved in modified form in this proposal [46 Fed. Reg. 35280 (1981)]. In Subpart E—Technical Criteria of this proposal [46 Fed. Reg. 35290-35291 (1981)], section 60.122 was a listing of "Favorable conditions" and sections 60.123 and 60.124 were created for "Potentially adverse conditions" and "Assessment of potentially adverse conditions" respectively. The provisions require certain assessments to be made with respect to the impact of tectonic processes upon waste isolation. However, these proposed rules also indicate that there may exist offsetting conditions such that an "adverse condition" is adequately mitigated or can be "remedied."

"§60.122 Favorable conditions. . .

- (a) The nature and rates of tectonic processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.
- (b) The nature and rates of structural processes that have occurred since the start of the Quaternary Period are such that, when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste." [emphasis added]

Much of the language in this section as presented was a combination and elaboration of language from the section 60.122 of the earlier Advance Notice of Proposed Rulemaking [45 Fed. Reg. 31393 (1980)]. In the language of section 60.122 of this proposal, a clear distinction was drawn between tectonic and structural processes. As in the definitions cited above, all mention of the 10,000-year time frame was removed, and the specific references to stability of the repository were also removed. Because of the wording chosen, however, it was implied that both of these processes should contribute to the stability of the repository as defined in section 60.2.

PAC relevant to natural processes and events were divided into those pertaining to the geologic setting (equivalent to the site in this proposed rule) and those affecting the disturbed zone and provided in sections 60.123 [46 Fed. Reg. 35290-35291 (1981)]:

"§60.123 Potentially adverse conditions. . .

- (a) Adverse conditions in the geologic setting. . .
 - (4) Earthquakes which have occurred historically that if they were to be repeated could affect the geologic repository significantly.

- (5) A fault in the geologic setting that has been active since the Quaternary Period and which is within a distance of the disturbed zone that is less than the smallest dimension of the fault rupture surface. . .
 - (7) 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 would affect the performance of the geologic repository through changes in the regional groundwater flow.
- (b) Adverse conditions in the disturbed zone. For the purpose of determining the presence of the following conditions within the disturbed zone, investigations should extend to the greater of either its calculated extent or a horizontal distance of 2 km from the limits of the underground facility, and from the surface to a depth of 500 meters below the limits of the repository excavation. . .
- (6) The existence of a fault that has been active during the Quaternary Period. . .
 - (8) Structural deformation such as uplift, subsidence, folding, and fracturing during the Quaternary Period.
 - (9) More frequent occurrence of earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.
 - (10) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.
 - (11) Evidence of igneous activity since the start of the Quaternary Period."

In keeping with the desire of the Commission to assess the impact of PACs on the ability of a geologic repository to meet performance objectives, section 60.124 [46 Fed. Reg. 35291 (1981)] stated:

"§60.124 Assessment of potentially adverse conditions.

In order to show that a potentially adverse condition or combination of conditions cited in §60.123 does not impair significantly the ability of the geologic repository to isolate the radioactive waste, the following must be demonstrated:

- (a) The potentially adverse human activity or natural condition has been adequately characterized, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations; and

- (b) The effect of the potentially adverse human activity or natural condition on the geologic setting has been adequately evaluated using conservative analyses and assumptions, and the evaluation used is sensitive to the adverse human activity or natural condition; and
- (c)(1) The potentially adverse human activity or natural condition is shown by analysis in paragraph (b) of this section not to affect significantly the ability of the geologic setting to isolate waste, or
 - (2) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics cited in §60.122, or
 - (3) The potentially adverse human activity or natural condition can be remedied." [emphasis added]

In proposing the foregoing PAC, the Commission was not suggesting the establishment of absolute criteria for the disqualification of any specific site. Rather, as stated in the preamble, the proposal set out factors which would be considered in the evaluation [46 Fed. Reg. 35284 (1981)]:

"Thus, the Commission has judged that these should not be made absolute requirements. Presence of all the favorable characteristics does not lead to the conclusion that the site is suitable to host a repository. Neither is the presumption of unsuitability because of the presence of an unfavorable characteristic incontrovertible. Rather, the Commission's approach requires a sufficient combination of conditions at the selected site to provide reasonable assurance that the performance objectives will be achieved.

Natural phenomena, especially structural deformation, were also discussed in section 60.130 with regard to general design requirements [46 Fed. Reg. 35291 (1981)]:

"§60.130 General design requirements for the geologic repository operations area. . .

(b)(2) Protection against natural phenomena and environmental conditions.

- (i) The structures, systems, and components important to safety shall be designed to be compatible with anticipated site characteristics and to accommodate the effects of environmental conditions . . . during the entire period of construction and operations.
- (ii) The structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the site will not result, in any relevant time period, in failure to achieve the performance objectives."

Additional proposed language in section 60.132 [46 Fed. Reg. 35293 (1981)] stated that:

§60.132 Additional design requirements for the underground facility. . .

(e) Design of subsurface openings. . .

- (1) If structural support is required for stability, it shall be designed to be compatible with long-term deformation. . .
- (3) Subsurface openings shall be designed to reduce the potential for deleterious rock movement or fracturing of surrounding rock over the long term. . .[and]. . .shall take the following conditions into consideration—
 - (i) natural stress conditions."

This language reinforced the desire of the Commission to link design and siting requirements. This wording also stressed the need for site characteristics and anticipated processes and events to be considered with a view towards evaluating the ability of a site to meet performance objectives.

3.5 FINAL RULE

In June of 1983, NRC published a final rule, promulgating 10 CFR Part 60, including technical criteria and amended licensing procedures for a HLW repository [48 Fed. Reg. 28194 (1983)]. This final rule responded to comments on the earlier proposed technical criteria [46 Fed. Reg. 35280 (1981)]. It was noted in the preamble to this publication that, in general, the commenters accepted the proposed approach. However, some modifications were required to remove an apparent contradiction in the treatment of natural processes and events. References to design bases were removed from the definition of "anticipated processes and events" and a distinction was made between anticipated and unanticipated processes and events with regard to natural processes and events affecting the geologic setting [48 Fed. Reg. 28200 (1983)]:

"In the final rule, numerical performance objectives are established for particular barriers, assuming 'anticipated processes and events.' Such numerical criteria are not established for 'unanticipated processes and events.' . . .the distinction between anticipated and unanticipated processes and events relates solely to natural processes and events affecting the geologic setting. The Commission intends that a judgement whether a natural process or event is anticipated or unanticipated be based on a careful review of the geologic records. Such processes or events would not be anticipated unless they were reasonably likely, assuming that processes operating in the geologic setting during the Quaternary Period were to continue to operate but with the perturbations caused by the presence of emplaced waste superimposed thereon. Unanticipated processes and events would include those that are judged not to be reasonably likely to occur during the period the intended performance objective must be achieved, but which nevertheless are sufficiently credible to warrant consideration. These include processes and events which are not evidenced during the Quaternary Period or which, though evidenced during the Quaternary, are not likely to occur during the relevant time frame. Identification of anticipated and unanticipated processes and events for a particular site will require considerable judgement. . ."

These changes from the proposed rule were expressed in section 60.2 [Fed. Reg. 28217 (1983)] as:

"§60.2 Definitions. . .

'Anticipated processes and events' means those natural processes and events that are reasonably likely to occur during the period the intended performance objective must be achieved. To the extent reasonable in the light of the geologic record, it shall be assumed that those processes operating in the geologic setting during the Quaternary Period continue to operate but with the perturbations caused by the presence of emplaced radioactive waste superimposed thereon. . .

'Unanticipated processes and events' means those processes and events that are judged not to be reasonably likely to occur during the period the intended performance objective must be achieved, but which are nevertheless sufficiently credible to warrant consideration. Unanticipated processes and events may be either natural processes or events or processes and events initiated by human activities other than those activities licensed under this part. . ."

The objective of these changes was to accommodate evaluation of "events that are reasonably of concern." The Commission clearly intended that the geologic record since the beginning of the Quaternary Period be examined to provide information for assessments of the performance of the repository in the long-term. The subjective nature of this evaluation and the need for considerable judgement were also recognized.

The explicit consideration of the term "stability" was also removed from the definitions in section 60.2 of the final rule. The preamble stated that [48 Fed. Reg. 28201 (1983)]:

". . . its [the Commission's] interest in specifying that the geologic setting shall have exhibited 'stability' since the start of the Quaternary Period was to assure only that the processes be such as to enable the recent history to be interpreted and to permit near-term geologic changes to be projected over the relevant time period with relatively high confidence. This concept is best applied by identifying, as potentially adverse conditions, those factors which stand in the way of such interpretation and projection. . ."

This acknowledged that the Commission's previous desire for geologic stability was related to uncertainty reduction in predicting the performance of the geologic setting and explained that only those conditions that could adversely affect stability would be considered specifically.

Revised definitions were also provided in the final rule [48 Fed. Reg. 28194 (1983)] for the words "geologic setting" and "site," and in response to specific comments, a definition of a "controlled area" was added:

"§60.2 Definitions. . .

"Controlled area" means a surface location. . . 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. . .

'Geologic setting' means the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located.

'Site' means the location of the controlled area."

In the proposed rule [46 Fed. Reg. 35280 (1981)], "geologic setting" would have been limited to systems that "provide isolation" of the waste. The Commission intended the adopted definition of "geologic setting" to cover a wider "region of interest" [48 Fed. Reg. 28202 (1983)]. The final rule calls for isolation to be provided within a "controlled area" rather than within the "geologic setting" [48 Fed. Reg. 28202 (1983)]. Therefore, the definition of "site" was changed to refer to the location of the "controlled area."

Section 60.21(c)(1)(i) was issued in this document [48 Fed. Reg. 28194 (1983)] with changes from the proposed rule [46 Fed. Reg. 35280 (1981)] to reflect the relationship between "controlled area", "geologic setting," and "site." No other changes were made that affected the consideration of natural processes and events [48 Fed. Reg. 28206 (1983)]. Section 60.21(c)(ii) was expanded to reflect the new philosophy towards PACs and the new definitions, especially "unanticipated processes and events." References to the term "expected" were removed to reflect the addition of unanticipated processes and events. The text in the final rule (with changes from the proposed rule underlined) [48 Fed. Reg. 28219 (1983)] stated that:

"§60.21 Content of application. . .

(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 facility design and performance. . .

(ii) The assessment shall contain. . .

(A) An analysis of the geology, geophysics, hydrogeology, geochemistry, climatology, and meteorology of the site;

(B) Analyses to determine the degree to which each of the favorable and adverse conditions, if present, has been characterized and the extent to which it contributes to or detracts from isolation. For the purpose of determining the presence of the potentially adverse conditions, investigations shall extend from the surface to a depth sufficient to determine critical pathways for radionuclide migration from the underground facility to the accessible environment. Potentially adverse conditions shall be investigated outside of the

controlled area if they affect isolation within the controlled area.

- (C) An evaluation of the performance of the proposed geologic repository. . . 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.
- (F) An explanation of measures used to support the models used to perform the assessments required in paragraphs (A) through (D). Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported. . ." [emphasis added]

The regulatory language of section 60.21(c)(ii) in the final rule is significant in that it stated that PACs outside the controlled area that affect isolation within the controlled area shall still be evaluated. This reflected the designation of the geologic setting as covering a region of interest beyond the limits of the controlled area considered to provide isolation of the waste [48 Fed. Reg. 28202 (1983)].

The Commission stated in the preamble to the final rule that changes to the proposed rule regarding Siting Criteria were made in order to clarify the Commission's purpose [48 Fed. Reg. 28201 (1983)]. The concepts of favorable and adverse conditions were retained; it was emphasized that there may exist a combination of adverse and favorable conditions which would be acceptable for a repository site. Significantly, as addressed above, changes were made to reflect the updated definitions of "geologic setting," "site," and "disturbed zone." In addition to merging sections 60.122, 60.123, and 60.124 into section 60.122, the new rules changed the siting criteria so that "the presence of any of the enumerated conditions is to be regarded as potentially adverse if it applies to the controlled area and, in addition, such a condition outside the controlled area is to be regarded as potentially adverse if it may affect isolation within the controlled area." Portions of the rule relevant to this discussion include:

"§60.122 Siting Criteria. . .

- (a)(2) If any of the potentially adverse conditions specified in paragraph (c) of this section is present, it may compromise the ability of the geologic repository to meet the performance objectives relating to isolation of the waste. In order to show that a potentially adverse condition does not so compromise the performance of the geologic repository the following must be demonstrated:
 - (a)(2)(i) The potentially adverse human activity or natural condition has been adequately investigated, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations; and
 - (a)(2)(ii) The effect of the potentially adverse human activity or natural condition on the site has been adequately evaluated using analyses

which are sensitive to the potentially adverse human activity or natural condition and assumptions which are not likely to underestimate its effect; and

(a)(2)(iii)(A) The potentially adverse human activity or natural condition is shown by analysis pursuant to paragraph (a)(2)(ii) of this section not to affect significantly the ability of the geologic repository to meet the performance objectives relating to isolation of the waste, or

(a)(2)(iii)(B) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics so that the performance objectives relating to isolation of the waste are met, or

(a)(2)(iii)(C) The potentially adverse human activity or natural condition can be remedied.

(b) Favorable conditions

(b)(1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes (or any of such processes) operating within the geologic setting during the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste. . .

(b)(5) Conditions that permit the emplacement of waste at a minimum depth of 300 meters from the ground surface. (The ground surface shall be deemed to be the elevation of the lowest point on the surface above the disturbed zone.). . .

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

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

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

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

- (c)(12) Earthquakes which have occurred historically that if they were to be repeated could affect the site significantly.
- (c)(13) Indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence or magnitude of earthquakes may increase.
- (c)(14) More frequent occurrence of earthquakes or earthquakes of higher magnitude than is typical of the area in which the geologic setting is located.
- (c)(15) Evidence of igneous activity since the start of the Quaternary Period. . .
- (c)(21) Geomechanical properties that do not permit design of underground openings that will remain stable through permanent closure." [emphasis added]

As discussed in the preamble to the final rule [48 Fed. Reg. 28211 (1983)] and expressed in the final regulatory language, the distinction that was drawn between "tectonic" and "structural" processes in section 60.122 "Favorable conditions" of the proposed rule [46 Fed. Reg. 35290 (1981)] was determined to be too fine. As a result, the distinction was discarded and only the former term is now used. In addition, although defined in the Staff Analysis in NUREG-0804 (NRC, 1983b; pg. 373), it was generally felt by that there are ambiguities inherent in dating this point in time. The regulatory language was revised to reflect the intent that what is of concern is that those processes that have operated during the Quaternary Period be identified and evaluated in order to predict repository performance in the long term. For this reason, references to the "start of the Quaternary Period" were removed from the regulation (except in section 60.122(c)(15)). The final version of these provisions reconciled the references to resources in section 60.122 to the requirements for the content of the Safety Analysis Report (60.21). The rule as adopted provides that section 60.122 applies to the site, rather than the disturbed zone, "since it is the site that provides isolation of the waste" [48 Fed. Reg. 28212 (1983)].

3.6 STAFF ANALYSIS OF PUBLIC COMMENTS ON PROPOSED RULE AND SUPPLEMENTARY INFORMATION SECTION OF FINAL RULE

The Commission received 93 comment letters in response to the July 1981 publication of the proposed technical criteria [see above, 46 Fed. Reg. 35280 (1981)], 89 of which arrived in time to be considered for the final criteria. The Commission had requested public comment on six issues:

- (1) A single overall performance standard versus minimum performance standards for each of the major elements of the geologic repository;
- (2) The need for, and appropriate duration of, a waste retrievability period;
- (3) The level of detail to be used in the criteria, particularly with respect to design and construction requirements;

- (4) The desirability of population-related siting criteria;
- (5) The application of an ALARA principle to the performance requirements dealing with containment and control of releases;
- (6) Alternative approaches on dealing with possibilities of human intrusion into the geologic repository.

Of these six issues, numbers 1 and 5 included tectonics-related considerations. NRC responses to the comments were considered in selecting the language used in the final rule [48 Fed. Reg. 28194 (1983)].

Issue 1—In the proposed rule, the Commission identified three approaches to assuring achievement of desired isolation, two of which were considered to be viable. The Commission considered that one "reasonable and practical" approach would be to adopt a strategy that would prescribe performance standards for each of the major components of the repository required in a multiple barrier system, including the underground facility, the waste packages, and the geologic setting. The EPA standard would be retained as a single overall performance objective. The alternative approach to be considered would be the specification of the EPA standard as an overarching measure of repository performance. After considering the arguments for adopting the single performance standard, the Commission considered that this approach would fail to provide the degree of confidence necessary for a licensing decision. There was concern by some commenters that the absence of an established EPA standard rendered it impossible to connect barrier performance with the overall system performance objective. For illustrative purposes, the Commission responded by using a draft EPA standard to demonstrate the application of multiple performance standards. The Commission found no inconsistencies between the two approaches. In fact, NRC noted that given the complicated nature of the problem at hand, it is necessary that both engineered and natural barriers contribute to meeting the overall performance objectives. For this reason, only the multiple performance standard approach will provide the confidence necessary to grant a license based on model predictions. The Commission also noted that the numerical criteria included in the rule for individual barriers were only appropriate for evaluating overall performance considering anticipated processes and events. Unanticipated processes and events might require higher levels of individual barrier performance to meet EPA standards. DOE would therefore have to design for higher performance levels to address unanticipated processes and events.

Issue 5—In the proposed rule, the Commission considered that ALARA principles could not be applied to the natural features of a site because they cannot be easily modified once a site is chosen. The Commission's position was not changed during the public comment period. The Commission believed that its rule addressed the underlying concerns of EPA, and the Commission recommended to EPA that the assurance requirements, including the ALARA provision, be omitted from the final rule.

3.7 AMENDMENTS TO FINAL RULE

In 1984, NRC proposed amendments to the technical criteria to include HLW disposal in either the saturated or unsaturated zone and solicited public comment. In 1985, the final rule was published [50 Fed. Reg. 29641 (1985)], with additional changes to sections 60.2, 60.122, 60.133, and 60.134. These changes were largely related to groundwater movement and did not directly affect regulatory language related to the consideration of tectonics.

3.8 PROPOSED AMENDMENTS TO RULE

In 1986, NRC issued a list of proposed amendments to 10 CFR Part 60 [51 Fed. Reg. 22288 (1986)] which were intended to conform existing NRC regulations to environmental standards published by EPA [50 Fed. Reg. 38066 (1985)]. The Commission found that EPA sometimes used terms differently from existing Part 60 wording. Most of the proposed changes in this document reflect attempts to reconcile wording differences. There were no direct changes related to consideration of tectonics.

3.9 UPDATE TO FINAL RULE

In 1989, NRC published a final rule updating Part 60 [54 Fed. Reg. 27864 (1989)] to adopt "procedures for implementation of the National Environmental Policy Act." These changes involved a requirement for inclusion of an environmental impact statement in the application and some changes for filing and distribution of an application. This rulemaking did not affect the provisions involving tectonics.

4 CONCLUSIONS

NRC rules governing licensing of a HLW repository have evolved to include requirements that address technical issues specifically related to tectonics. These requirements are included in response to concerns that the presence of such processes could result in disturbance of the repository and compromise of waste isolation. Natural processes and events related to tectonic activity at a repository site must therefore be evaluated when assessing the projected waste isolation performance of the repository. It is evident from the development of the rule that NRC intends for DOE to consider both favorable and potentially adverse impacts of tectonic activity with regard to assessing performance of a proposed repository following closure. The geologic record of processes operating during the Quaternary Period are of particular interest in supporting models used to predict occurrence and effect of tectonic processes into the long term. Furthermore, the Commission intends that analyses of tectonic activities be conducted outside of the controlled area if these processes are believed to affect the isolation of waste within the controlled area.

5 REFERENCES

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