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ABSTRACT

The purpose of the Tectonic Effects study is to synthesize and integrate site characterization data to generate analyses of potential impacts on the natural and engineered barrier systems resulting from tectonic processes and events. The tectonic processes and events to be addressed are faulting, folding, uplift (or subsidence), ground motion, volcanic eruption and magmatic intrusion. These will be evaluated for the following potential impacts: (1) waste package rupture, (2) changes in percolation flux rates, (3) changes in water-table elevation, (4) changes in fracture permeability and effective porosity, and (5) changes in rock geochemical properties. Several of the above topics, especially ground motion, volcanic eruption, magmatic intrusion, and rock geochemical properties, are largely treated in other ongoing studies, and the role of the present study in these areas is one of integration.

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INTRODUCTION

This study plan combines the studies and activities initially assigned to three different Site Characterization Plan (SCP) investigations: (1) Investigation 8.3.1.8.2, Studies to provide information required on rupture of waste packages due to tectonic events; (2) Investigation 8.3.1.8.3, Studies to provide information required on changes in unsaturated- and saturated-zone hydrology due to tectonic events; and (3) Investigation 8.3.1.8.4, Studies to provide information required on changes in rock geochemical properties resulting from tectonic processes. The reason for the consolidation is that much of the work in the 26 activities that comprise the 5 separate studies in these three investigations in the SCP duplicates ongoing work in other investigations. Eliminating the redundancy, the remaining work is sufficiently closely related and limited in scope to the extent that the planned work elements and the designated objectives and parameters can logically and appropriately be integrated into a single investigation with one study and five activities, titled and renumbered as follows (see figs. 1-1 and 1-2):

Investigation 8.3.1.8.2 - Studies to provide information required to evaluate changes in the natural and engineered barrier systems resulting from tectonic processes and events. (Formerly Investigations 8.3.1.8.2, 8.3.1.8.3, and 8.3.1.8.4).

Study 8.3.1.8.2.1 - Tectonic Effects: Evaluations of changes in the natural barrier and engineered systems resulting from tectonic processes and events.

a. Activity 8.3.1.8.2.1.1 - Analysis of waste package rupture due to tectonic processes and events. (Formerly Study 8.3.1.8.2.1).

b. Activity 8.3.1.8.2.1.2 - Analysis of the effects of tectonic processes and events on average percolation flux rates over the repository. (Formerly Study 8.3.1.8.3.1).

c. Activity 8.3.1.8.2.1.3 - Analysis of the effect of tectonic processes and events on changes in water-table elevation. (Formerly Study 8.3.1.8.3.2).

d. Activity 8.3.1.8.2.1.4 - Analysis of the effects of tectonic processes and events on local fracture permeability and effective porosity. (Formerly Study 8.3.1.8.3.3).

e. Activity 8.3.1.8.2.1.5 - Analysis of the effects of tectonic processes and events on rock geochemical properties. (Formerly Study 8.3.1.8.4.1).

Study 8.3.1.8.2.1 Tectonic Effects: Evaluations of changes in the natural and engineered barrier systems resulting from tectonic processes and events

The SCP lists 45 parameters for the activities in Investigations 8.3.1.8.2, 8.3.1.8.3, and 8.3.1.8.4. The disposition of these parameters in the context of combined Study 8.3.1.8.2.1 is explained in the appendix of this study plan; of the 45 listed in the SCP, 16 parameters are retained in the present study.

Owing to the elimination of redundant activities, the titles of the five activities in this study may be inappropriate in some cases to reflect a redefined scope of work. However, the original titles as listed in the SCP are retained in order to maintain a traceable connection between the description given in the SCP and the work plans presented in this study plan. This study plan supersedes Study Plan 8.3.1.8.2.1, Rev. 0A, which was prepared in November, 1991, and submitted to the Nuclear Regulatory Commission in December, 1992.

1. PURPOSE AND OBJECTIVES

The Yucca Mountain Project (YMP) is conducting studies of the Neogene tectonic history of the Yucca Mountain region, including determination of the types, magnitudes, and recurrence rates of tectonic processes and events. The forecasts of seismic and volcanic hazards that are derived from these studies will be used, in combination with other site characterization data, to generate performance assessments of the proposed high-level nuclear waste repository at Yucca Mountain, and as one basis for designs of the engineered barrier system (EBS).

Three different types of tectonic information are required as inputs to performance assessment and to EBS design: (1) evidence of tectonic processes and events that have operated at the site in the past, along with probability estimates for their recurrence in the future; (2) characterization of the features of the site, including models of the tectonic, hydrologic, rock-geochemical, and geologic (3-D structure & stratigraphy) systems; and (3) analyses of the potential effects of tectonic processes and events that could potentially impact repository performance. Within that framework, the primary objective of Study 8.3.1.8.2.1 is to compile and synthesize tectonic data collected in other site characterization studies, and to apply these data in addressing item (3), above, for the postclosure period. Accordingly, the study deals almost exclusively with an analysis of consequences involving questions about what physically might happen in and around the potential repository if tectonic events of various kinds and magnitudes did actually occur. Speculative interpretations, probability estimates, and detailed computer modeling will not be attempted; these are tasks being performed in other studies.

Important emphasis will therefore be placed on those events and processes (termed "scenarios" in the SCP, section 8.3.5.13) that could significantly affect the repository, and are sufficiently credible to warrant consideration in performance assessment. Tentative lists of scenarios are included in the discussions for each of the activities in this study. Further study may result in adding or deleting scenarios from these lists. It should be noted that a performance assessment group at SNL has prepared a preliminary event tree of the potential tectonic impacts on the hydrologic system, including scenarios in which changes occur in percolation flux through the unsaturated zone. Accordingly, the present study is designed to supplement the SNL work. Another interface is with USGS Study 8.3.1.17.4.12 (Tectonic models and synthesis), which has primary responsibility for developing tectonic failure scenarios for both the preclosure and postclosure periods. The analysis of tectonic scenarios in the present activity will be done cooperatively with Study 8.3.1.17.4.12. The tectonic processes and events to be addressed are: faulting, folding, uplift and (or) subsidence, ground motion, volcanic eruption, and magmatic intrusion. The available geologic hydrologic, and related site characterization data will be analyzed to evaluate the potential impacts of these tectonic processes and events on the rupturing of waste packages; on causing changes in percolation flux rates, water-table elevations, and local fracture permeability and effective porosity; and on altering rock geochemical properties along ground-water flow paths. The subdivision of the study into 5 activities is designed to separately address each of these subjects.

Study 8.3.1.8.2.1 Tectonic Effects: Evaluations of changes in the natural and engineered barrier systems resulting from tectonic processes and events

This study, combined with Study 8.3.1.8.1.2, (Physical processes of magmatism and potential effects), is required to develop data bearing on four issues (see Fig. 1-2):

- Issue 1.1: Probability and effects of radionuclide releases resulting from tectonic events and processes
- Issue 1.8: Evaluation of potentially adverse tectonic conditions.
- Issue 1.11: Tectonic conditions relative to design of the underground facility and engineered system.
- Issue 1.9a: Evaluation for purpose of the "higher-level findings" as to whether the site is disqualified on the basis of potential tectonic effects.

Objectives specific to each activity will be discussed in section 2 of this study plan.

2. SCOPE OF WORK

Most elements of this study can be viewed as consisting of two stages: (1) compiling and synthesizing data on tectonic processes and events, as well as data on the systems that may be impacted by these processes and events, and (2) evaluating the impacts of tectonic processes and events on the natural and engineered barrier systems of the potential repository in the post-closure period.

There are two keys to forecasting the future behavior of the natural and engineered barrier systems. First, we must understand the nature of these systems as they are today. For example, a prediction of how the water-table elevation and configuration under Yucca Mountain will be changed by a seismic event must be based on an understanding of why the water table has the elevation and configuration that it has today. Second, we must understand the geologic record. Evidence of past changes in the water-table elevation and configuration, and their causes, may provide the best criteria for predicting future changes. Although the planned work elements, tasks, or tests for Study 8.3.1.8.2.1 primarily involve the compilation and analysis of existing data and data currently being collected in other site characterization studies, gaps in the informational data bases may be identified during the course of this study that require additional investigation to achieve all of the designated objectives. A few such gaps have been identified already, and a small number of data collection tasks to fill these gaps are included in this plan.

It should be emphasized that few guidelines exist as to the best and most effective manner in which one of the principal topics of this study -- tectonic effects on the hydrologic system -- can be addressed. Accordingly, one of the major tasks is to formulate and test various approaches to determine which avenue(s) of investigation holds the most promise for achieving study objectives.

The following discussions are organized by activity. A description of the objectives and parameters for each activity, together with the planned approach for addressing them, is followed by the tectonic scenarios (initiating events) to be considered, and the specific products to be generated. The relationships and needs for coordination with other site characterization studies are also identified as appropriate.

2.1 Activity 8.3.1.8.2.1.1 Analysis of waste package rupture due to tectonic processes and events

Several geologic evaluations are needed by waste package engineers as input to design and performance studies. These primarily include evaluations that are being done in other studies, in particular, the probabilistic hazards assessment of Study 8.3.1.17.3.6, the ground motion

evaluations of Study 8.3.1.17.3.3, and the volcanic hazards and volcanic consequence analyses of Studies 8.3.1.8.1.1 and 8.3.1.8.1.2, respectively.

A principal objective of Activity 8.3.1.8.2.1.1 is to determine the adequacy of the existing data, including the results of the above-listed studies, for evaluating the potential impacts of tectonic processes and events on waste package lifetime and performance. If additional data needs to achieve this objective are identified, then such data will be collected as part of this activity to the extent necessary to satisfactorily address the following parameters: (1) number of waste packages affected by a fault penetrating the repository, and (2) amount and nature of deformation resulting from faulting in the repository horizon.

An additional objective is to contribute to a LANL analysis of the structural controls on basaltic volcanism (Activity 8.3.1.8.1.1.2), a topic that is relevant to predicting the probability of magma penetrating the repository. There are two work elements involved in this additional task:

- Synthesize tectonic data from the southwestern volcanic field, and from Crater Flat basin in particular, that are relevant to interpretation of structural controls on basaltic volcanism

- Conduct geophysical surveys to test alternative tectonic models relevant to structural controls on basaltic volcanism and to investigate the subsurface geometry of basaltic vents

2.1.1 General approach

2.1.1.1 Number of waste packages affected by a fault penetrating the potential repository

A prediction of the number of waste packages that would be affected by initiation of a new fault, or by activation of an existing one, requires data on the geometry of presently mapped faults in and near the potential repository, and on the nature and extent of the zones of deformation around them, combined with the spatial "layout" of the repository itself. The geologic data, which are being collected in other studies (see section 2.1.1.2), will be synthesized in the present study to provide input to a numerical model being generated by LANL in Study 8.3.1.8.1.2 (Physical processes of magmatism and potential effects). Although that model addresses the parameter "number of waste packages affected by an igneous intrusion", it is anticipated that it can be adapted for use in modeling the effects of faulting.

The level of effort necessary to complete this evaluation may be dependent on the design and emplacement mode of the waste package/disposal canister. The disposal concept may vary from the SCP concept (thin wall waste package emplaced in a borehole) to a more robust waste package emplaced in a drift (with or without backfill).

2.1.1.2 Amount and nature of deformation due to faulting in the repository horizon

Data bearing on this parameter will be derived principally from other fault studies in the potential site area. For example, Study 8.3.1.17.4.6, Quaternary faulting within the site area, provides information on the surface and near-surface character of fault zones. Mapping of the Ghost Dance fault in the exploratory studies facilities (ESF) and on the surface, in Study 8.3.1.4.2.2 (Characterization of structural features within the site area), will be the principal source of data on the width and character of fracturing and brecciation in and adjacent to normal faults at the depth of the repository. In addition, all faults within and around the potential repository are being comprehensively studied and characterized in Studies 8.3.1.17.3.1 (Relevant earthquake sources) and 8.3.1.17.3.6 (Probabilistic analyses of ground motion and fault displacement at Yucca Mountain) and the hydrologic properties of fault zones encountered in the ESF are being determined in Study 8.3.1.2.2.4 (Characterization of Yucca Mountain percolation in the unsaturated zone-ESF study). The analysis of deformation due to faulting will address several issues including: the width and character of fracture and breccia zones associated with faults, the width, nature, and development of drag folding associated with faults, and the evolution of fault zones over time.

The analysis of deformation resulting from a faulting event is important because it forms the basis for several other analyses in this study. For example, the analysis of deformation resulting from a faulting event forms the basis for estimating the number of waste canisters affected by such an event, as discussed in section 2.1.1.1. It also forms the basis for an analysis of changes in fracture permeability and effective porosity resulting from the strain accompanying a faulting event, which is a major part of Activity 8.3.1.8.2.1.4, as will be discussed below. The output of the latter activity is, in turn, an input to Activities 8.3.1.8.2.1.2, 8.3.1.8.2.1.3, and 8.3.1.8.2.1.5; hence, the analysis of deformation due to faulting is important as a direct, or indirect, input to all of the activities in Study 8.3.1.8.2.1.

2.1.1.3 Synthesize tectonic data relevant to interpretation of structural controls on basaltic volcanism

The potential impacts of a volcanic eruption penetrating the repository are largely being determined in LANL Studies: 8.3.1.8.1.1, (Probability of magmatic disruption of the repository); 8.3.1.8.1.2, (Physical processes of magmatism and potential effects), and 8.3.1.8.5.1, (Characterization of volcanic features). The present study will contribute to LANL's effort by supplying data and analyses on structural controls of basaltic volcanism that will assist in assessing the probability of magma penetrating the repository.

Geologic map data on the field relations of basaltic centers in the vicinity of Yucca Mountain are being collected in a number of studies, most notably in Study 8.3.1.17.4.5, (Detachment

faults at or proximal to Yucca Mountain). Initial results, based on the preliminary observations of the principal investigator, indicate that: (1) The basaltic centers in the Crater Flat basin form several north-to-northeast-trending alignments, perpendicular to the least principal stress direction, (2) the alignments in turn form an array that comprises a northwest-trending belt, (3) the belt of basalts is coincident with a northwest-trending zone of distributed dextral shear which accommodated differential extension along the southwest margin of the Crater Flat basin during its opening, and (4) together with the northwest-trending belt, the major volume of basalts coincides with the longitudinal axis of the Crater Flat basin, the zone of maximum extension and subsidence on the west side of this asymmetric basin. These and other observations from the mapping are being used to develop a conceptual model for the structural control of basaltic volcanism in the Yucca Mountain region. Additional geologic mapping, as well as geophysical studies (described below), will be undertaken to test the model, and the results will be integrated with data collected and developed in LANL Study 8.3.1.8.5.1 (Characterization of volcanic features). The resulting final conclusions of this structural analysis will be used as input to LANL Study 8.3.1.8.1.1.

2.1.1.4 Conduct geophysical surveys of basaltic centers

Plans regarding the geophysical surveys to be undertaken to investigate the subsurface geometry of basaltic vents and to test alternative models for structural controls on basaltic volcanism are being made in collaboration with the LANL volcanism group, with the input of an expert consultant retained by LANL (as part of Study 8.3.1.8.1.1) to review the use of geophysical surveys in addressing volcanism issues. Decisions as to the methods being planned are based on the kinds of information needed for site characterization and on the resolution of the various methods being considered. Cost-benefit analysis is also used to establish priorities.

The primary purpose of the geophysical surveys is to test the applicability of the conceptual models that have been developed as a result of analog studies by LANL (Study 8.3.1.8.1.2) and of surface geologic mapping and related studies of volcanic features in the vicinity of Yucca Mountain by both LANL and the USGS. These studies show that small-volume basalt centers, such as are found in Crater Flat basin, are commonly fed by individual feeder dikes or swarms of dikes. The feeder dikes typically are 1-6 km long and 1-5 m wide, and are subvertical (Crowe and others, 1983; Valentine and others, 1992, 1993). Locally along some dikes, usually at shallow depth, a cylindrical conduit (plug) is developed in a place where flow was concentrated, eroding the dike walls. The field relations suggest a range of possible models, rather than a single model for the formation of plugs along dikes. In most of these models, plug formation is depicted as being confined to depths less than the projected repository depth. However, possible alternative interpretations need to be explored (through geophysical surveys as here being recommended) because, if plugs did form at repository depth, they could possibly cause releases of radionuclides to the accessible environment.

Tentatively, plans are to conduct geophysical surveys at the Quaternary basalt centers of Crater Flat, including Red Cone, Black Cone, Makani Cone (formerly North Cone), Little Cones, and Lathrop Wells cone. Aeromagnetic data supplemented by ground-based magnetic

data will be collected and interpreted to evaluate alternative geometric models of the basaltic intrusion feeder systems under these centers. These data will be supplemented by the results of the seismic reflection, refraction, magnetic, and gravity surveys being conducted across Crater Flat (and Yucca Mountain) as part of Study 8.3.1.4.2.1 (Characterization of the vertical and lateral distribution of stratigraphic units within the site area). Consideration is also being given to the acquisition of multi-directional electrical survey data at the Crater Flat basalt centers. The latter have the potential for improving the resolution of the geophysical imaging of the volcanic features at depth, inasmuch as magnetic data are affected to some degree by surface lava flows and debris eroded from the centers.

The same types of geophysical surveys as discussed above may be undertaken in other locations, such as along the Solitario Canyon fault and in Nye and Scarp canyons, to further investigate structural controls on basaltic volcanism in the vicinity of Yucca Mountain.

2.1.2 Scenarios

The SCP lists four scenarios to be evaluated in Activity 8.3.1.8.2.1.1 (formerly Study 8.3.1.8.2.1) relative to waste packages: (1) rupture due to igneous intrusion, (2) rupture caused by ground motion, (3) rupture due to faulting, and (4) rupture due to folding. Of these, (1) is covered by the volcanic studies discussed in sections 2.1.1.3 and 2.1.1.4, and (2) is covered by the ground motion investigations being conducted in Studies 8.3.1.17.3.3 (Ground motion from regional earthquakes and underground nuclear explosions) and 8.3.1.17.3.4 (Effects of local site geology on surface and subsurface motions). Folding in the region consists of two types: possible low-amplitude, low-wavelength folding across major portions of the Crater Flat structural basin, which is not an issue with respect to waste package rupture; and high-amplitude, short wavelength drag folding associated with normal faulting, which is an issue. This study will therefore address scenarios 3 and 4 as a single issue, namely rupture due to faulting, including the effect of possible fault-related folding.

2.1.3 Presentation of results

The following products are anticipated from Activity 8.3.1.8.2.1.1:

1. Report on the structural controls of basaltic volcanism, to be coordinated with appropriate LANL personnel.

2. Report on geophysical data pertaining to the structural setting and intrusive underpinnings of Quaternary basalts in Crater Flat in two parts: (a) a data report, and (b) an analysis of the data.

3. Report: Conceptual model for the amount and nature of deformation resulting from a faulting event at Yucca Mountain. Information anticipated to be in the model that will impact mechanical and hydrologic properties of the fault after rupture includes rupture

length, width, offset, fracture spacing, amount of brecciation, and resultant porosity and brecciation.

2.2 Activity 8.3.1.8.2.1.2 Analysis of the effects of tectonic processes and events on average percolation flux rates over the repository

The objective of this activity is to produce analyses and assessments of the probability and effects of tectonic initiating events that may result in changes in flow rates in the unsaturated zone. The principal work elements and tasks to achieve this objective and to address the parameters now assigned to this activity (see appendix) are:

- Develop conceptual models of scenarios under which a volcanic, intrusive, faulting, or other tectonic event could change percolation flux rates or flow patterns in the unsaturated zone under Yucca Mountain
- Produce quantitative determinations of geologic and hydrologic effects of these scenarios
- Format data and analyses into the form needed by studies (e.g., 8.3.1.2.2.9, Site unsaturated-zone modeling and synthesis) involved in producing advanced computer models of unsaturated-zone behavior

2.2.1 General approach

2.2.1.1 Analyze scenarios

The following is a tentative list of scenarios involving tectonic processes and events that may affect percolation flux rates in the unsaturated zone:

- A newly formed volcanic landform creates an impoundment or changes drainage patterns, resulting in a changed pattern of infiltration in the vicinity of the repository.
- An igneous intrusion changes flow patterns in the unsaturated and saturated zones, changing flux through the repository.
- Reactivation of an existing fault, or creation of a new one, through the repository, creates a zone of elevated infiltration through the repository.
- Creation of a fault scarp or the associated effects of uplift, subsidence, or tilting change drainage patterns on the surface, or change flow patterns within the unsaturated zone, or both, resulting in elevated infiltration into the repository.
- Deposition of an air-fall tuff from a nearby or distant volcanic source changes infiltration patterns into the unsaturated zone.

The key to evaluating these scenarios is to use existing data to formulate a representative case at the level of detail needed as a basis for modeling and for assessing probabilities. For example, in considering the first scenario above, we need to decide where such a volcanic landform may be located, the likely composition and dimensions of the landform (including lava flows, pyroclastic cone, intrusive underpinnings), how much of an impoundment may be created, what the likely hydrologic properties of the impounding landform would be, etc., based on features and conditions that are most representative of the Yucca Mountain area. The goal is to collate the data that are needed for such an analysis as well as to develop a justification for why the details chosen for the representative case are judged to be a reasonable conservative representation of what a potential scenario would consist of.

2.2.1.2 Scoping calculations

It is anticipated that progressive development and improvement of the preliminary conceptual models will eventually reach a stage where detailed modeling is in order. If so, the results will be made available to those workers in other studies who model the nominal case of unsaturated-zone flow (e.g., Study 8.3.1.2.2.9, Site unsaturated-zone modeling and synthesis) so that they can begin introducing changes brought about by various tectonic impacts on the existing regime.

2.2.2 Presentation of results

The following product is anticipated for Activity 8.3.1.8.2.1.2: Report on analysis of tectonic impacts on unsaturated-zone flow under Yucca Mountain in three stages -- preliminary, intermediate, and final. The first two will be combined with results from Activities 8.3.1.18.2.1.3 and 8.3.1.8.2.1.4 as reports of tectonic effects on the hydrologic system.

2.3 Activity 8.3.1.8.2.1.3 Analysis of the effect of tectonic processes and events on changes in water-table elevation

The objective of this activity is to produce analyses and assessments of tectonic initiating events that could result in significant changes in the elevation of the water table, changes in the hydraulic gradient, the creation of discharge points in the controlled area, or the creation of perched aquifers in the controlled area. The three parameters being addressed are (see appendix):

- Effects of intrusions on water-table elevation, due to barrier-to-flow or thermal effects
- Effect of faulting on water-table elevation
- Effect of a strain change (related to a seismic event) on the water-table elevation.

2.3.1 General approach

Although the three listed parameters above represent potential effects resulting from different forms of tectonism, they are discussed together because they all involve changes in water-table elevation. A collation of available data on the potential for tectonically induced changes in water-table elevation, and analysis of that data has already been undertaken by a National Academy of Sciences Panel on Coupled Hydrologic-Tectonic-Hydrothermal Systems at Yucca Mountain (National Research Council, 1992).

Specific recommendations of the National Academy panel include:

(1) additional studies be undertaken of secondary calcites, especially those found far below the surface but above the water table (in drill core), to see if they provide evidence of past water-table elevations that were significantly different from those found today,

(2) additional drilling and well testing be undertaken in the vicinity of the large hydraulic gradient under northern Yucca Mountain, to develop an understanding of this feature,

(3) modeling should be undertaken of the coupled thermal and pore-elastic problem of the effect of dike intrusion on the water table, and

(4) further studies should be undertaken to reduce the uncertainties in estimates of fault slip rates, lengths of faults, and ages of offsets.

The recommendations of the panel are matters being addressed by other studies in the Site Characterization Program, hence the approach in Activity 8.3.1.8.2.1.3 will primarily be one of synthesis, consisting of four parts:

1. Compile observed hydrologic effects associated with seismic and volcanic events from published reports.

2. Compile results from existing literature on computer modeling of water-table changes resulting from igneous and seismic events.

3. Compile results from other studies on evidence for paleo-water levels beneath and adjacent to Yucca Mountain.

4. Assess the information derived from the three items listed above, to determine:

   (a) whether the observed hydrologic effects define well-established patterns in terms of the type, magnitude, and duration of these effects;

(b) whether there is general scientific agreement on the theory of modeling the hydrologic effects, and whether that theory is consistent with the field observations;

(c) if the attempts to establish a paleo-water level under Yucca Mountain are conclusive or if different approaches yield convergent results, and whether the paleohydrology validates conceptual models of the hydrologic systems in both the unsaturated and saturated zones; and

(d) whether all of the combined evidence provides the required level of certainty that a significant increase in water-table elevation under Yucca Mountain is not a serious concern in the next 10,000 yr (this addresses the potentially adverse condition stated in 10CFR60.122(c)(22) that the water table will rise an amount that will cause saturation of the underground facility -- see parameter #4 for Activity 8.3.1.8.2.1.3 in appendix).

Existing computer modeling of changes in water table elevation induced by extensional faulting include published studies by Carrigan and others (1990), Bredehoeft (1992), and Wood and King (1993). In addition, a small number of studies concerning hydrologic effects induced by compressional tectonism (e.g., Ge and Garven, 1992) are based on principles that could also be applied to the case of extensional tectonism. Although all of these studies provide valuable information, no computer modeling of coupled hydrologic-tectonic effects has been done to date that incorporates the specific features of the Yucca Mountain hydrologic system. Computer modeling will therefore be undertaken in this study to fill that gap, using two different approaches. First, the methodology of Ge and Garven (1992) will be modified to incorporate the hydrologic features of Yucca Mountain, including the large hydraulic gradient and possible perched water in the large gradient zone, and an extensional tectonic regime. For this modeling effort, no specific codes have yet been chosen; however, we will experiment with the FEHMN code developed by LANL for the saturated-zone problem, and with the UNSAT2 code (Neuman and others, 1974) for the perched water problem. Second, an ongoing study that uses boundary-element modeling to develop a tectonic model for the Yucca Mountain region (Study 8.3.1.17.4.12, Tectonic models and synthesis) will be expanded to combine the approach of Wood and King (1993) with the specific hydrologic and tectonic features of Yucca Mountain.

2.3.1.1 Scenarios

A tentative list of the scenarios under which the water-table elevation could potentially be changed by a tectonic event is given at the beginning of the discussion of this activity, namely, the water table could be disturbed by:

- barrier-to-flow or thermal effects of an intrusion
- faulting effects such as "seismic pumping"

- a strain change related to a seismic event

These scenarios need to be developed further and, as indicated in section 2.2.1.1, this study will also address potential changes in the hydraulic gradient, creation of discharge points in the controlled area, and creation of perched aquifers in the controlled area in addition to changes in the water-table elevation.

2.3.2 Presentation of results

The following product is anticipated for Activity 8.3.1.8.2.1.3: Report on modeling of tectonically induced changes in water-table elevation under Yucca Mountain, including analysis of perched water problems, in three stages -- preliminary, intermediate, and final. The preliminary and intermediate versions will be combined with results from Activities 8.3.1.8.2.1.2 and 8.3.1.8.2.1.4 as reports of tectonic effects on the hydrologic system.

2.4 Activity 8.3.1.8.2.1.4 Analysis of the effects of tectonic processes and events on local fracture permeability and effective porosity.

The objective of this activity is to address possible changes in fracture permeability and effective porosity caused by tectonic events and processes. The parameters to be studied include:

- effect of magmatic intrusion on permeability and effective porosity
- effects of fault motion on fracture permeability and effective porosity

2.4.1 General approach

2.4.1.1 Effect of magmatic intrusion on permeability and porosity

This parameter can be divided into two parts: (1) permanent (irreversible) changes in rock hydrologic properties resulting from the strain and hydrothermal effects of magmatic intrusion, and (2) reversible changes in porosity and permeability resulting from the change in stress associated with magmatic intrusion. The first part of this parameter is being covered in large part by LANL Study 8.3.1.8.1.2 (Physical processes of magmatism and effects on the potential repository), and, more specifically, by Activity 8.3.1.8.1.2.2 (Effects of hydrovolcanic eruptions), which includes induced changes in rock hydrologic properties. The LANL study is currently directed mostly toward analyzing possible unsaturated-zone effects. Some work will be required in the present study to extend the LANL results to cover pertinent saturated-zone aspects of the problem. To the extent possible, that will be done cooperatively with the LANL volcanism team.

Existing data indicates that the most likely form and occurrence of an intrusion would be a dike that is about 2-4 m meters wide and perhaps a kilometer long, and feeds a cinder cone eruption over an interval probably about a month's duration (Valentine and others, 1992, 1993; Barnard and others, 1992; Garr and others, 1991). Eruption times longer than a couple of days would favor consolidation of flow into a single cylindrical conduit at a wide point in the dike, which would then reduce the volume of rock that is thermally impacted by the intrusion. In such cases, the major hydrologic effect probably would be related to the addition of the dike rock to the system and, to a lesser extent, to jointing induced in the immediately adjacent host rock parallel to the outer contacts of the dike as a consequence of the stresses associated with dike emplacement.

There are three possible irreversible effects of an intrusion on permeability: (1) a closing of fractures caused by strain and hydrothermal mineralization, in which case the dike and metamorphic aureole may act as a barrier to flow; (2) an increase in permeability owing to fracturing in the dike and, peripherally, in the host rock, in which case the dike zone may act as a channel; and (3) a mixed effect resulting in anisotropic behavior, namely the dike zone may act as a barrier to fluid flow perpendicular to it, and simultaneously as a channel along it. Data being collected in LANL Study 8.3.1.8.1.2 will determine which of these three options is most likely, which will permit an estimate as to the maximum credible change in hydrologic behavior resulting from an intrusion.

The task in the present activity will be to review the results of the LANL study when they become available, and to apply these results in studies of the saturated-zone hydrology (e.g., Study 8.3.1.2.3.3, Saturated-zone hydrologic system synthesis and modeling). The current plan is to: (1) undertake a scenario analysis, as described in activities above, (2) supply the LANL team with the data required to modify their existing unsaturated-zone analysis to fit the saturated-zone scenario, and (3) depend upon the LANL team to perform the necessary modeling of the permanent changes in rock hydrologic properties resulting from magmatic intrusions. With regard to the reversible changes associated with stress changes accompanying dike emplacement, this is a rock-mechanics problem and the analysis involved is similar to that required to study the effects of faulting on fracture permeability and effective porosity, which is described below.

2.4.1.2 Effects of faulting on fracture permeability and porosity

This parameter can also be divided into two parts: (1) irreversible changes in hydrologic properties resulting from rock strain during faulting events, and (2) reversible changes in hydrologic properties resulting from stress changes associated with faulting. The irreversible part of the problem will use the data resulting from the study of the amount and nature of deformation resulting from faulting in the repository horizon being conducted in Activity 8.3.1.8.2.1.1. The data bearing on the amount and type of faulting-induced rock deformation will be used to estimate the probable changes in hydrologic properties. For example, information on fractures observed in trenches during Quaternary fault studies (e.g., 8.3.1.17.4.6,

Quaternary faulting within the site) can be used in standard hydrologic equations, utilizing basic geologic data (e.g., fracture spacing, frequency, orientation, size, and density), to estimate the initial permeability of the very near-surface fractures, that is, before these fractures are filled with detritus and pedogenic calcrete.

For fractures at greater depths, direct information is generally lacking on the amount of deformation resulting from a single faulting event because fractures at greater depth generally do not become filled with detritus or pedogenic calcrete, the latter of which can be used to date fracturing events. Although the tuffs at depth under Yucca Mountain have abundant filled fractures, existing data indicate that these fillings largely are of hydrothermal origin and date from the volcanic period (Bish, 1989). The dimensions of fractures that could potentially be created at depth by single faulting events in the future will therefore have to be estimated by using fault offset data from surface and near-surface fault and fracture studies in combination with the mapping of faults at depth, such as mapping in the ESF to estimate the amount of change in deformation in a fault zone that is likely to occur in a single event. As mentioned above, standard hydrologic equations would then be used to estimate the hydrologic effect of new fault-induced fractures and brecciation. This same approach will be used to estimate the hydrologic properties of fractures created by emplacement of a dike.

The second part of this problem, reversible changes in hydrologic properties resulting from stress changes associated with faulting, is a rock mechanics problem as stated above. This is a non-controversial topic about which much has been published; a synthesis of the established approaches is given in the report by the National Academy of Sciences Panel on coupled hydrologic/ tectonic /hydrothermal systems at Yucca Mountain (National Research Council, 1992), and will not be repeated here.

The product from the rock-mechanics analysis of permeability and effective porosity changes associated with a change in stress, however, will not be used directly in the present activity, but it will be an input to analyses in Activities 8.3.1.8.2.1.2, 8.3.1.8.2.1.3, and 8.3.1.8.2.1.5.

2.4.1.3 Scenarios

The two scenarios for this activity are reflected in the two parameters listed above; both involve a change in fracture porosity or effective porosity resulting from a change in stress or strain accompanying either: (1) a magmatic intrusion event or (2) a faulting event. The analysis of these scenarios is covered by other activities, as discussed above.

2.4.2 Presentation of results

The following product is anticipated from Activity 8.3.1.8.2.4: Report on analysis of the effects of tectonic processes and events on local fracture permeability and effective porosity, in three stages -- preliminary, intermediate, and final. The preliminary and intermediate versions

will be combined with results from Activities 8.3.1.8.2.1.2 and 8.3.1.8.2.1.3 as reports of the tectonic effects on the hydrologic system.

2.5 Activity 8.3.1.8.2.1.5 Analysis of the effects of tectonic processes and events on rock geochemical properties

The objective of this activity is to provide assessments of the initiating events related to local changes in distribution coefficients resulting from tectonic processes and events. In achieving this objective, the following parameters will be addressed (see appendix):

- effects of intrusions on local distribution coefficients (sorbtive retardation to transport of radionuclides)
- degree of mineral change along faults in the next 10,000 yr
- effects of fault offset and dike emplacement on travel pathways (amount and nature of sorbtive minerals along travel pathways)

2.5.1 General approach

2.5.1.1 Effects of intrusions on local distribution coefficients

Studies of volcanism by LANL (Investigation 8.3.1.8.1) include investigations of the nature and extent of contact metamorphism around basaltic intrusions. Based on study results to date, the width of such zones is shown to be a function of the size of the intrusion, and the water content of the host rock. Because contact metamorphism largely or completely destroys sorptive minerals in the host rock, the major parameter to be considered is the size of the contact metamorphic zones in order to calculate the chemical effect (now being determined in the LANL studies). As discussed above in Activity 8.3.1.8.2.1.1, geophysical studies to be conducted in that activity will be combined with mineralogic studies by LANL to determine if an additional affected zone, beyond the metamorphic aureole, is present around basaltic dikes, and, if so, to quantify the width of such zones and the reduction in sorptive minerals.

Modeling the behavior of the geochemical system is, however, assigned to LANL Study 8.3.1.3.4.3 (Development of sorption models). Hence, the planned work for Activity 8.3.1.8.2.1.5 will be coordinated closely with LANL, and will be limited generally to synthesizing and supplying geologic data that may be needed for their investigations.

2.5.1.2 Degree of mineral changes along faults in the next 10,000 yr

This parameter is also being addressed as part of the geochemical modeling by LANL, and the work scope of Activity 8.3.1.8.2.1.5 on this problem will be limited to providing a synthesis of USGS geologic site characterization data to the LANL team according to their needs.

2.5.1.3 Effects of fault offset and dike emplacement on travel pathways

This topic is the major focus of Activity 8.3.1.8.2.1.5, involving primarily a synthesis of geologic and hydrogeologic data to be used in developing a model showing: (1) a hydrogeologically based interpretation of the present-day flow paths beneath Yucca Mountain, (2) the geochemical character of the rocks along the proposed flow paths, (3) potential changes in the flow paths caused by various tectonic processes and events, and (4) a comparison of the anticipated geochemical makeup of the rocks along the new flow paths with that of the rocks along the original flow paths.

Items (1), (2), and (4) above, are being addressed by a number of different studies in the site characterization program. For example, Study 8.3.1.2.3.3 (Saturated-zone hydrologic system synthesis and modeling) has primary responsibility for developing models of saturated-zone flow paths. LANL Study 8.3.1.3.2.1 (Mineralogy, petrology, and rock chemistry along potential flow paths) bears specifically on items (2) and (4). The objectives in the present activity are to contribute geological information primarily related to item (3) that will aid in their syntheses, and to maintain close coordination with personnel in other studies in further efforts to model the effects of tectonic processes and events on rock geochemical properties.

2.5.1.4 Scenarios

Modeling relative to items (3) and (4), above, is needed for a number of different scenarios or initiating events; some examples are:

- Reactivation of an existing fault enhances permeability laterally along fault-created flow pathways. Flow could be proportionately increased along the affected fault.

- The water table rises 100m (see SCP Table 8.3.1.8-46) as a consequence of a fault or dike creating a barrier to flow, or of seismic pumping or convective heating driving up the water table. Because flow in the saturated-zone is generally greatest just below the water table, a water table rise will result in a change in flow path and hence, a potential change in geochemical effects along the flowpath.

2.5.2 Presentation of results

The following product is anticipated from Activity 8.3.1.8.2.1.5: Report on the potential effects of fault offset on travel pathways.

3. APPLICATION OF RESULTS

Specific application of results is addressed throughout the foregoing discussions of the five activities in Study 8.3.1.8.2.1. In summary, the study compiles and analyzes data on tectonic events and processes that can be used by other investigations in the Site Characterization Program that have a need to consider the effects of tectonic processes and events in achieving their study objectives. These investigations include:

- Study 8.3.1.8.1.1 - Probability of magmatic disruption of the repository
- Study 8.3.1.8.1.2 - Physical processes of magmatism and potential effects
- Study 8.3.1.2.2.9 - Site unsaturated-zone modeling and synthesis
- Study 8.3.1.2.3.3 - Saturated zone hydrologic system synthesis and modeling
- Study 8.3.1.3.2.1 - Mineralogy, petrology, and chemistry of transport pathways
- Study 8.3.1.3.4.3 - Development of sorption models

As indicated in section 1, and shown on Figure 1-2, data resulting from Study 8.3.1.8.2 contributes directly to the resolution of Issues 1.1, 1.8, 1.9, and 1.11 as part of the postclosure tectonics program.

4. SCHEDULE AND MILESTONES

The schedule for the tectonic effects study is tentatively divided into three stages, spanning a six-year period.

In stage 1, the first year of the study, the goals will be:

(1) Complete report: geologic analysis of structural controls on basaltic volcanism (Activity 1)

(2) Preliminary report: tectonic effects on the hydrologic system under Yucca Mountain (Activities 2, 3, and 4).

(3) Data report: geophysics pertaining to the structural setting and intrusive underpinnings of Quaternary basalts in Crater Flat.

In stage 2, the next 2 years of the study, the goals will be:

(1) Analysis report: geophysics pertaining to the structural setting and intrusive underpinnings of Quaternary basalts in Crater Flat.

(2) Intermediate report: tectonic effects on the hydrologic system under Yucca Mountain (Activities 2, 3, and 4).

(3) Report: Conceptual model for the amount and nature of deformation resulting from a faulting event at Yucca Mountain.

In stage 3, the final 2 years of the study, the goals will be:

(1) Report on the potential effects of fault offset on travel pathways.

(2) Final report on modeling of tectonic impacts on unsaturated zone flow under Yucca Mountain.

(3) Final report on modeling of tectonically induced changes in water-table elevation under Yucca Mountain.

(4) Final report on analysis of the effects of tectonic processes and events on local fracture permeability and effective porosity

Study 8.3.1.8.2.1 Tectonic Effects: Evaluations of changes in the natural and engineered barrier systems resulting from tectonic processes and events

As indicated in various sections of this study plan, Study 8.3.1.8.2.1 is expected to utilize data being collected in several other studies in the site characterization program. Included are the following, with notations as to the principal kinds of data they are contributing:

- 8.3.1.4.2.1 Characterization of the vertical and lateral distribution of stratigraphic units within the site area - geophysical data
- 8.3.1.4.2.2 Characterization of structural features within the site area - geologic mapping of Paintbrush Tuff and of fractures and faults in the exploratory study facilities.
- 8.3.1.8.1.1 Probability of magmatic disruption of the repository-evaluation of future volcanic activity
- 8.3.1.8.1.2 Physical processes of magmatism and potential effects - effects of a potential volcanic eruption
- 8.3.1.17.3.6 Probabilistic analyses of ground motion and fault displacement at Yucca Mountain - amount of fault displacement that could possibly occur within the repository block
- 8.3.1.17.4.6 Quaternary faulting within the site area - characterization of Quaternary faults
- 8.3.1.17.4.12 Tectonic models and synthesis - synthesis and modeling of tectonic processes, and evaluation of the tectonic stability at the site

The scheduling for these data collections is beyond the control of the present study. If critical data are unavailable on a timely basis, the study will proceed to obtain such data as are necessary to achieve its objectives.

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APPENDIX

Correlation of parameters as originally designated in the SCP with the disposition of parameters among the various activities incorporated in combined Study 8.3.1.8.2.1.

Activity 8.3.1.8.2.1.1 - Analysis of waste package rupture due to tectonic processes and events (formerly Study 8.3.1.8.2.1)

Original Parameters	Disposition of these parameters
1. Probability of an igneous intrusion penetrating the repository	1. Deleted; covered by LANL Studies 8.3.1.8.1.1, 8.3.1.8.1.2, and 8.3.1.8.5.1. (USGS will contribute to analysis of structural controls on basaltic volcanism.)
2. Number of waste packages affected by an igneous intrusion	2. Partly retained - mostly covered by LANL Study 8.3.1.8.1.2, but USGS will collect geophysical data
3. Effects of igneous intrusion penetrating repository (parameter listed at investigation level)	3. Deleted - covered by LANL Study 8.3.1.8.1.2
4. Number of waste packages affected by a fault penetrating the repository	4. Retained; combined with parameter 9
5. Evidence of Quaternary activity on faults penetrating repository	5. Deleted - covered by USGS Study 8.3.1.17.4.6
6. Density, length, and total displacement of faults penetrating the repository	6. Deleted - covered by USGS Studies 8.3.1.17.4.6 and 8.3.1.4.2.2

Activity 8.3.1.8.2.1.1 - Analysis of waste package rupture due to tectonic processes and events (formerly Study 8.3.1.8.2.1)

Original Parameters	Disposition of these parameters
7. Slip rates and recurrence intervals of faults with Quaternary activity in and near the controlled area	7. Deleted - covered by USGS Study 8.3.1.17.4.6
8. Location, length, and total displacement of faults with Quaternary activity in and near the controlled area	8. Deleted - covered by USGS Study 8.3.1.17.4.6
9. Effect on waste packages of a fault penetrating repository	9. Retained
10. Probability of fault displacement over 5 cm in repository	10. Deleted - covered by USGS Studies 8.3.1.17.4.6 and 8.3.1.17.3.6.
11. Expected ground motion at emplacement bore holes in 1000 yrs	11. Deleted - covered by USGS Studies 8.3.1.17.3.5 and 8.3.1.17.3.6
12. Wavelength and amplitude of folds in the repository horizon	12. Deleted - will be covered by USGS Study 8.3.1.8.5.3
13. Amount and nature of deformation resulting from faulting (and folding) in the repository horizon	13. Retained; combined with parameter 14
14. Rate of deformation estimate due to folding and faulting in repository horizon	14. Retained - this is a combination of parameters 6, 7, 12, and 13

Activity 8.3.1.8.2.1.2 - Analysis of the effects of tectonic processes and events on average percolation flux rates over the repository (formerly Study 8.3.1.8.3.1)

Original Parameters	Disposition of these parameters
1. Annual probability of volcanic events within the controlled area	1. Deleted - covered by LANL Study 8.3.1.8.1.1
2. Annual probability of significant igneous intrusion within 0.5 km of the controlled area boundary	2. Deleted - covered by LANL Studies 8.3.1.8.1.1 and 8.3.1.8.1.2
3. The effects of a volcanic event on topography and average flux rates	3. Retained
4. The effects of igneous intrusion on average flux rates	4. Retained
5. Location and spacing of Quaternary faults in and near the controlled area	5. Deleted - covered by USGS Study 8.3.1.17.4.6
6. Slip rates on Quaternary faults in and near the controlled area	6. Deleted - covered by USGS Study 8.3.1.17.4.6
7. Recurrence intervals on Quaternary faults in and near the controlled area	7. Deleted - covered by USGS Study 8.3.1.17.4.6
8. Present dip of tuff beds at Yucca Mountain in and near the controlled area	8. Deleted - covered by USGS Study 8.3.1.4.2.2
9. Models of average flux rate change resulting from a range of faulting conditions	9. Partly retained - the USGS group that is modeling unsaturated zone flux in Study 8.3.1.2.2.9 does the nominal case on their own, and will model the disturbed case (with faulting) using data that is collated and synthesized in Study 8.3.1.8.2.1

Activity 8.3.1.8.2.1.2 - Analysis of the effects of tectonic processes and events on average percolation flux rates over the repository (formerly Study 8.3.1.8.3.1) (Continued)

Original Parameters	Disposition of these parameters
10. Probability of cumulative offset >2m on faults in controlled area in 10,000 yrs	10. Deleted - covered by USGS Studies 8.3.1.17.4.6 and 8.3.1.17.3.6.
11. Effects of faulting on average flux rates	11. Deleted - redundant to parameter 9 above
12. Uplift or subsidence rates in and around the controlled area	12. Include with parameter 16 below
13. Probability of changing dip by >2° in 10,000 yrs	13. Include with parameter 16 below
14. Probability of exceeding 30 m altitude change in 10,000 yrs	14. Redundant to parameter 13 above
15. Probability that folding, uplift or subsidence will significantly alter percolation flux rates	15. Retained

Activity 8.3.1.8.2.1.3 - Analysis of the effect of tectonic processes and events on changes in water-table elevation (formerly Study 8.3.1.8.3.2)

Original Parameters	Disposition of these parameters
1. Model effects of intrusions on water-table elevation due to barrier to flow or thermal effects	1. Partly retained - this probably is largely covered by published and ongoing studies, but Study 8.3.1.8.2.1 will insure a comprehensive analysis and modeling treatment
2. Barrier-to-flow effects of intrusions on WT elevations and hydraulic gradients	2. Redundant - retained as part of parameter 1, above
3. Thermal effects of intrusions on water-table and hydraulic gradients	3. Redundant - retained as part of parameter 1, above
4. Probability that strain change will raise water-table levels to more than 850 m in elevation	4. Retained
5. Probability that repository will be lowered by 100 m through folding uplift, or subsidence in 10,000 yr.	5. Partly retained, in conjunction with Study 8.3.1.4.2.2
6. Models for predicting the effects of faulting on water-table elevation	6. Retained - other studies largely cover this but Study 8.3.1.8.2.1 will insure a comprehensive treatment
7. Probability of >2m offset on faults within 0.5 km of the controlled area, in 10,000 yrs	7. Deleted - covered by USGS Studies 8.3.1.17.4.6 and 8.3.1.17.3.6.
8. Effects of faulting on water-table elevation and hydraulic gradient	8. Redundant - part of parameter 6

Activity 8.3.1.8.2.1.4 - Analysis of the effects of tectonic processes and events on local fracture permeability and effective porosity (formerly Study 8.3.1.8.3.3)

Original Parameters	Disposition of these parameters
1. Effects of intrusions on fracture permeability and porosity	1. Partly retained - largely covered by LANL Study 8.3.1.8.1.2; however, the USGS will play a supportive role, as needed
2. Annual probability of reactivation of Quaternary faults within 0.5 km of the controlled area boundary	2. Deleted - covered by Studies 8.3.1.17.3.6 and 8.3.1.17.4.6
3. Effects of fault motion on local fracture permeability and porosity	3. Retained
4. Effects of changes in stress or strain on hydrologic properties of the rock mass	4. Retained

Activity 8.3.1.8.2.1.5 - Analysis of the effect of tectonic processes and events on rock geochemical properties (formerly Study 8.3.1.8.4.1)

Original Parameters	Disposition of these parameters
1. Effects of intrusions on local distribution coefficients	1. Retained, in conjunction with LANL Study 8.3.1.8.1.2
2. Degree of mineral change along faults in 10,000 years	2. Retained
3. Effects of fault offset on travel pathway	3. Retained
4. Assess mineral change resulting from tectonically induced changes in water-table elevation	4. Retained; however, if the water-table were to change enough to significantly change the mineralogy, the mineral change would be of minor concern compared to the consequences of the water-table rise itself

FIGURES

FIGURE

1-1 Proposed consolidation of studies to provide information on the effects of tectonic processes and events on the potential repository

1-2 Proposed organization of activities to provide information on the effects of tectonic processes and events on the potential repository, and to contribute data for issue resolution

RESPONSES TO NRC COMMENTS ON STUDY 8.3.1.8.2.1

SCA Comment 47

This comment requests additional discussion and clarification of the relationships between Study 8.3.1.8.2.1 and other studies and activities involved in the collection and synthesis of data on tectonic processes and events and their potential effects on waste containment. In recognition of the potential duplication of efforts and a perceived need to integrate certain closely related investigations on the above subjects, the USGS, with DOE concurrence, has prepared a revised study plan that incorporates all of the studies and activities now listed in the SCP for Investigations 8.3.1.8.2 (Studies to provide information required on waste packages due to tectonic events), 8.3.1.8.3 (Studies to provide information required on changes in the unsaturated- and saturated-zone hydrology due to tectonic events), and 8.3.1.8.4 (Studies to provide information required on changes in rock geochemical properties resulting from tectonic processes). The consolidation results in one investigation (8.3.1.8.2, Studies to provide information required to evaluate changes in the natural and engineered barrier systems resulting from tectonic processes and events) and one study (8.3.1.8.2.1, Tectonic effects: evaluations of changes in the natural and engineered barrier systems resulting from tectonic processes and events). The revised study plan (8.3.1.8.2.1), Rev. 1) incorporates all of the primary objectives listed in the SCP for the three integrated investigations, which primarily involve compilation and synthesis of data that are being collected in other investigations in the site characterization program. In order to eliminate duplication of effort, the revised study plan also discusses in detail the relationships between those data-collecting activities that are supplying basis information on tectonic events and processes and the consolidated study whose responsibility is to synthesize and evaluate these data in terms of the potential effects on waste containment. In particular, this study provides the interface performance assessment in the development of geology scenarios from the features, events and process that could affect system performance.

SCA comment 48

Documented slip rate determinations from trenching data is only one of the data sets that will be available for use in the probabilistic seismic hazard analysis described in Study Plan 8.3.1.17.3.6. Others include fault length and offset data from trenches at Yucca Mountain, stress measurement data, leveling data, alternate tectonic models, detailed surface and underground mapping, the results of empirical studies and numerical simulations of ground motion attenuation, and information from seismic network monitoring.

Comment #1 to Section 2.1.1, Study Plan 8.3.1.8.2.1 Rev. 0

Evaluation of performance goals is beyond the scope of this Study. The Appendix to the Study Plan tabulates SCP parameters and their disposition in the Study Plan.

Comment #2 to sections 2.2.1 and 3.1

The probability of an igneous intrusion penetrating the potential repository and its effects are

addressed in Studies 8.3.1.8.1.1, 8.3.1.8.1.2 and 8.3.8.5.1. This revised Study Plan will contribute to the analysis of structural controls on basaltic volcanism.

Comment #3 to sec. 2.2.2

Evaluation of performance goals is beyond the scope of this Study Plan. A probabilistic approach to fault displacement hazards is planned as discussed in Study Plan 8.3.1.17.3.6 and Seismic Topical Reports #1 and #2; thus consideration of fault offsets will not be limited to 5 cm.

Comment #4 to section 2.2.2

Consideration of the effects of thermal loading are beyond the scope of this Study Plan.

Comment #5 to sec. 3.2

The probability of an igneous intrusion penetrating the potential repository and its effects are addressed in Studies 8.3.1.8.1.1, 8.3.1.8.1.2 and 8.3.8.5.1. This revised Study Plan will contribute only to the analysis of structural controls on basaltic volcanism.

Comment #6 to section 3.2

All relevant methodologies for assessing fault displacement hazards will be considered in the Probabilistic seismic hazard analysis

Question #1 to sec. 1.3 and 1.4

This study together with the probabilistic seismic hazard analysis and the probabilistic volcanic hazard analysis will contribute to the development of the geology scenarios for performance assessment that will consider anticipated and unanticipated processes and events.

Question #2 to sec. 3.1

Study 8.3.1.8.1.2 addresses this issue.

Question #3 to sec. 2.2.3 and 3.3

Definition of a lower magnitude threshold for multiple events is beyond the scope of this study. Such thresholds will be defined as needed based on engineering analyses and on the hazard curves resulting from the probabilistic seismic hazard analysis.

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

NOV 19 1993

Mr. Dwight Shelor, Associate Director for
Systems and Compliance
Office of Civilian Radioactive Waste Management
U.S. Department of Energy, RW 30
1000 Independence Avenue
Washington, DC 20585

I-35036O

Dear Mr. Shelor:

SUBJECT: REVIEW OF U.S. DEPARTMENT OF ENERGY (DOE) STUDY PLAN "ANALYSIS OF WASTE PACKAGE RUPTURE DUE TO TECTONIC PROCESSES AND EVENTS"

On December 23, 1992, DOE transmitted the study plan, "Analysis of Waste Package Rupture Due to Tectonic Processes and Events" (Study Plan 8.3.1.8.2.1) to the U.S. Nuclear Regulatory Commission for review and comment. NRC has completed its review of this document using the Review Plan for NRC Staff Review of DOE Study Plans, Revision 2 (March 10, 1993). The material submitted in the study plan was considered to be consistent, to the extent possible at this time, with the revised NRC-DOE "Level of Detail Agreement and Review Process for Study Plans" (Shelor to Holonich, March 22, 1993).

A major purpose of the review is to identify concerns with studies, tests, or analyses that, if started, could cause significant and irreparable adverse effects on the site, the site characterization program, or the eventual usability of the data for licensing. Such concerns would constitute objections, as that term has been used in earlier NRC staff reviews of DOE's documents related to site characterization (Consultation Draft Site Characterization Plan and the Site Characterization Plan for the Yucca Mountain site). It does not appear that the conduct of the activities described in this study plan will have adverse impacts on repository performance and the review of this study plan identified no objections with any of the activities proposed.

In its letter of transmittal, DOE indicated that the study plan addresses Site Characterization Analysis (SCA) Comments 47, 48, and 59, but did not request closure of those comments. Although the staff believes that progress has been made toward resolution, the staff considers these comments to remain open. The staff's evaluation of how these comments were addressed in this study plan is provided in Enclosure 1.

As part of its study plan review, the NRC staff determines whether or not detailed comments or questions are warranted. The NRC staff's review of the subject study plan has resulted in the identification of seven comments and two questions (Enclosure 2). The enclosed comments and questions will be tracked by the NRC staff as open items similar to SCA comments and questions.

Although the objective of this study plan is to "provide the data necessary for an analysis and assessment of repository performance with respect to the possibility of tectonic processes and events adversely affecting the lifetime of

the waste packages" (Study Plan, Page 6), the plan only considers 10 CFR 60.113 requirements ("anticipated processes and events"). Because this study plan does not appear to consider "unanticipated processes and events," the staff believes it considers only a subset of the concerns related to tectonics and waste package performance (Question 1).

In addition, the study plan appears to use a definition of "substantially complete containment" (SCC) that the staff believes is not acceptable (Comment 1). Although the letter of transmittal of this study plan did not reference SCA Comments 5, 44, and 80, the discussion of SCC in the study plan appears to be related to these unresolved SCA Comments.

If you have any questions concerning this letter, please contact Charlotte Abrams (301) 504-3403 of my staff.

Sincerely,

Joseph J. Holonich, Director
Repository Licensing and Quality Assurance
Project Directorate
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards

Enclosures: As stated

cc: R. Loux, State of Nevada
T. J. Hickey, Nevada Legislative Committee
J. Meder, Nevada Legislative Counsel Bureau
C. Gertz, DOE/NV
M. Murphy, Nye County, NV
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R. Williams, Lander County, NV
L. Fiorenzi, Eureka County, NV
J. Hoffman, Esmeralda County, NV
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ENCLOSURE 1

REVIEW OF SCA OPEN ITEMS

Section 8.3.1.8 Overview of the postclosure tectonics program: Description of future tectonic processes and events required by the performance design issues

SCA COMMENT 47

The approach to incorporating data derived in the postclosure tectonics program into an assessment of whether performance issues related to the waste package and engineered barrier system (EBS) requirements 10 CFR 60.113(a) will be met is confusing and may result in inaccurate assessment of performance.

EVALUATION OF THE DOE RESPONSE

In general, Study Plan Section 3.2, Subsection Data input requirements for the analysis supplies the information as to what data are to be collected and what activities will feed into the assessment of the potential for disruption of the waste package and engineered barrier system.

There remains a question as to the relationship of Study Plan 8.3.1.8.2.1 to Study Plan 8.3.1.17.4.12, Activity 8.3.1.17.4.12.3 (Evaluate Tectonic Disruption Sequences), and Study Plan 8.3.4.2.4.3 (Mechanical Attributes of the Waste Package Environment). It appears that there may be a duplication of effort as the tectonic disruptive sequences addressed in Activity 8.3.1.17.4.12.3 should be the same sequences that are derived from Study Plan 8.3.1.8.2.1. In addition, the mechanical attributes of the waste package environment addressed in Study Plan 8.3.4.2.4.3 should be considered under Study Plan 8.3.1.8.2.1. The integration of these activities appears lacking; therefore, the interrelationship of this study plan with the other study plans listed needs to be better defined.

The NRC staff considers this comment still open due to apparent problems with integration.

Section 8.3.1.8	Overview of the postclosure tectonics program: Description of future tectonic processes and events required by the performance design issues
Section 8.3.1.8.2.1.4	Activity: Assessment of waste package rupture due to faulting
Section 8.3.1.17	Overview of preclosure tectonics: Description of tectonic and igneous events required by performance and design requirements
Table 8.3.1.17-3a	Design and performance parameters related to surface facilities and preclosure fault displacement
Section 8.3.1.17.2	Studies to provide required information on fault displacement that could affect repository design or performance

SCA COMMENT 48

The use of fault slip rates to determine the level of hazard posed to repository facilities by faults does not appear to be a conservative approach and may result in overly optimistic predictions about the effects of faulting on system performance.

EVALUATION OF THE DOE RESPONSE

This comment is primarily concerned with the use of slip rate calculations to determine the hazard of disruption of the waste packages and engineered barrier system.

On page 19 of Study Plan 8.3.1.8.2.1, it is recognized that there is uncertainty in projecting known faults, detecting new faults, determining if Quaternary offset has occurred along the various known faults, and determining if new faulting might occur during the period of performance. The staff does not consider that DOE has demonstrated that these various sources of uncertainty can be adequately assessed by using slip rate calculations.

As has been stated in Stock and others (1985), stress measurements at Yucca Mountain indicate that favorably oriented faults are in a state of incipient failure. The approach outlined within Study Plan 8.3.1.8.2.1 does not explain how this information will be factored into the analysis of the probability of displacement, along with the slip rate data.

It has not been demonstrated that displacements of less than 5 cm will not affect the canister performance.

There is no indication that the effects of repository thermal loading will be considered in the analysis.

The staff considers that the methodology proposed within this study plan may provide overly optimistic predictions of the effects of faulting on repository performance.

The staff considers this comment still open.

REFERENCES:

Stock, J.M., J.H. Healy, S.H. Hickman, and M.D. Zoback, 1985, Hydraulic fracturing stress measurements at Yucca Mountain, Nevada, and relationship to the regional stress field: Journal of Geophysics Research, Vol. 90, pp. 8691-8706.

Section 8.3.1.17 Overview of preclosure tectonics: Description of tectonic and igneous events required by performance and design requirements

SCA COMMENT 59

The information presented for the program of investigations for faulting does not allow the NRC staff to determine what investigations will actually be conducted. In addition, the sequencing of many geophysical and geologic activities related to faulting may lead to data collection activities that are inadequate to support assessments of performance and design bases.

EVALUATION OF THE DOE RESPONSE

This comment is primarily concerned with determination of what actual exploration programs will be conducted and the sequencing of these programs.

Although Study Plan 8.3.1.8.2.1 provides some information on exploration activities from which it will receive input, the study plan provides no actual description of the exploration activities themselves.

The staff notes that Figure 5-1, "Schedule showing planned completion dates of constraining data gathering activities," is out of date.

The staff considers this comment open.

ENCLOSURE 2

Section 2.1.1 Approach

COMMENT 1

The overall goal for the performance measure stated in this section is not consistent with DOE's response to Comment 5 of NRC's Site Characterization Analysis (SCA) and is not consistent with the requirements of 10 CFR 60.113 for substantially complete containment (SCC).

BASIS

In Section 2.1.1 of the Study Plan, DOE stated that "The performance goal for all modes of container failure is divided into two time intervals. The goal for the first 300 years after repository closure is that less than 0.05 percent per year of the total population of emplaced containers will fail. The goal for the interval from 300 to 1,000 years after repository closure is that less than 0.1 percent per year of the total population of emplaced containers will fail (SCP page 8.3.5.9-35)."

In the Site Characterization Plan (SCP), DOE stated its approach to comply with the SCC requirement of 10 CFR 60.113. In Section 8.3.5.9 of the SCP, DOE defined container "failure" (i.e., a breach large enough to allow air flow of .0001 atm-cubic centimeters per second into the container); presented goals for the maximum fraction of containers that "failed" in any given year (i.e., the goal for the first 300 years after repository closure is that less than 0.05 percent per year of the total population of emplaced containers will fail and the goal for the interval from 300 to 1,000 years after repository closure is that less than 0.1 percent per year of the total population of emplaced containers will fail); and presented goals for the annual release of radionuclides from the waste packages (i.e., 1 part in 1,000,000 for certain isotopes and 1 part in 100,000 of the current inventory for all other isotopes). In Section 8.3.5.9 of the SCP, DOE did not present any goal for the maximum cumulative "failures" and noted that "a value for the limit of cumulative failures will be determined as part of the container material studies and will be consistent with regulatory intent." However, in Section 8.3.1.8 of the SCP, DOE stated the overall goal for the cumulative failures was less than 5 percent in 300 years and less than 20 percent in 1,000 years and cross-referenced Section 8.3.5.9 of the SCP as the source of this goal.

In Comments 5, 44, and 80 of the SCA, NRC expressed reservations that DOE's goals in the SCP were not consistent with the SCC requirement, 60.113(a)(1)(ii)(A).

In its response to SCA Comment 5, DOE indicated that to satisfy the SCP radionuclide release goals, "breach during the containment period would be limited to 0.01% of the containers". In its response to the SCA Comment 44, DOE indicated that the goal stated in Section 8.3.1.8 of the SCP for the cumulative failures was in error and that Section 8.3.5.9 gave the overall design objective for the waste package program. In its response to SCA Comment 80, DOE discussed the basis for its radionuclide release rate goals for the containment period.

RECOMMENDATION

Reexamine the performance goals stated in Section 2.1.1 to assure that they are consistent with the requirements of 10 CFR 60.

REFERENCES:

DOE, 1988, Site Characterization Plan, Yucca Mountain Site, Nevada Research and Development Area, Nevada: U.S. Department of Energy DOE/RW-0199.

DOE, 1990, Responses to Nuclear Regulatory Commission (NRC) Site Characterization Analysis: U.S. Department of Energy, YMP/90-107.

NRC, 1989, NRC Staff Site Characterization Analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada: U.S. Nuclear Regulatory Commission, NUREG-1347.

Section 2.2.1 Activity 8.3.1.8.2.1.1 - Igneous Intrusion

Section 3.1 Activity 8.3.1.8.2.1.1 - Igneous Intrusion

COMMENT 2

The initiating event considered in this activity represents an incomplete description of magmatic events and, therefore, does not provide a suitable basis for determining compliance with the performance objectives.

BASIS

This comment reflects outstanding open items (Comments 1, 4, and 8) related to Study Plan 8.3.1.8.1.1. The concern that magmatic investigations were not considering a complete set of processes and events was raised during the review of Study Plan 8.3.1.8.1.1 in Comments 1, 4, and 8 (NRC, 1992). Comment 8 also raised concerns with the calculational methodology and the proposed use of the "disruption parameter." These comments related to Study 8.3.1.8.1.1 have not yet been resolved.

In Section 2.2.1 it is stated that the event being considered "... is similar to the one considered in investigation 8.3.1.8.1, but assumes that basaltic dikes or sills that might penetrate the repository do not feed a volcanic vent and do not directly result in releases at the ground surface." It is therefore recognized that the event being considered is only a subset of all events involving dikes or sills that might penetrate the repository.

As the objective of study 8.3.1.8.2.1 is to determine if the waste packages will be disrupted by tectonic activity, it makes no difference whether the igneous feature comes to the surface or not, but only whether such a feature could disrupt the waste package. The design and the analysis for 10 CFR 60.113 must consider a complete and comprehensive list of processes and events, not a subset.

In Section 3.1 it is stated that the principle source of information for this activity would come from Studies 8.3.1.8.1.1 and 8.3.1.8.1.2, and that the probability of an intrusion occurring will be derived from the probabilistic volcanic hazard analysis performed in Study 8.3.1.8.1.1.

RECOMMENDATION

Demonstrate how all relevant processes and events will be considered for the various design and performance requirements.

REFERENCES:

NRC, 1992, Letter from Joseph J. Holonich, NRC, to John P. Roberts, DOE, Subject: Results of the U.S. Nuclear Regulatory Commission Staff Review of Study Plan For Probability of Magmatic Disruption of the Repository.

Section 2.2.2 Activities 8.3.1.8.2.1.2, 8.3.1.8.2.1.3, and 8.3.1.8.2.1.4 - Faulting

COMMENT 3

The 5 cm performance parameter for faulting does not appear justified as it does not consider the effects on the waste package of secondary damage to the rock mass from fault events.

BASIS

Section 2.2.2 states that a value of 5 cm was selected as the performance parameter at which fault movement becomes significant over a 1,000 year-period, because, at this value, it is anticipated that the 7.6 cm air gap around the waste package would be partially closed and any additional displacement might result in an undesirable reduction of the air gap or possible waste package failure.

In Section 2.2.3 (Activity 8.3.1.8.2.1.5), it is recognized that earthquake induced ground motion occurring during the postclosure period could cause spalling or failure of the underground workings that could result in corrosion or mechanical failure of the waste package due to closure of the surrounding air gap or movement of the waste package in the emplacement hole.

Although there is the possibility of aseismic creep, earthquakes are caused by displacement along fault planes. Even along fault planes which may have total displacement less than 5 cm, there is normally earthquake ground motion. There appears to be no basis, therefore, for assuming that a displacement of a fault less than 5 cm will cause no undesirable reaction of the rock mass including spalling, raveling of the rock, and closure of the emplacement borehole.

It is recognized that there are two different failure mechanisms which could operate through faulting: 1) direct failure by shear and 2) indirect failure resulting from modification of the air gap. Modification of the air gap, no matter what the actual magnitude of direct fault movement, should be considered in performance assessment and design.

RECOMMENDATION

The design and performance assessment of the waste package should consider the effects of fault displacement less than 5 cm.

Section 2.2.2	Activities 8.3.1.8.2.1.2, 8.3.1.8.2.1.3, and 8.3.1.8.2.1.4 - Faulting
Section 2.2.3	Activity 8.3.1.8.2.5 - Ground Motion
Section 2.2.4	Activities 8.3.1.8.2.1.6 and 8.3.1.8.2.1.7 - Folding
Section 3.2	Activities 8.3.1.8.2.1.2, 8.3.1.8.2.1.3, and 8.3.1.8.2.1.4 - Faulting
Section 3.3	Activity 8.3.1.8.2.5 - Ground Motion
Section 3.4	Activities 8.3.1.8.2.1.6 and 8.3.1.8.2.1.7 - Folding

COMMENT 4

Calculations of the probability of faulting, ground motion, or folding in a repository should consider the effect of change in the stress field from repository induced loading.

BASIS

The definition of anticipated processes and events requires consideration of the perturbations caused by the presence of emplaced radioactive waste.

One of the major perturbations that should be considered for analysis of potential faulting, ground motion, and folding is the change in the stress field around the repository due to thermal loading.

This study plan contains no indication that these effects will be considered in the analysis of probability and effects of faulting, ground motion, and folding.

RECOMMENDATION

Demonstrate that the effects of repository induced loading, and the interrelationship of this loading to faulting, vibratory ground motion, and folding, have been considered in both the repository design and analysis of waste package failure.

Section 3.1 Activity 8.3.1.8.2.1.1 - Igneous Intrusion

COMMENT 5

The methodology used by Link and others (1982) appears to provide too simplistic a description of the dike emplacement process to adequately evaluate the potential disruption of the repository.

BASIS

The work of Link and others (1982) assumed that dike emplacement could be represented by a straight line intersecting a repository.

Work by the State of Nevada in Crater Flat (Smith and others, 1990) suggests that the disruption pattern is much more complex than a straight line.

Previous work in areas such as Pahute Mesa and Piaute Ridge, as described in Crowe (1990), also suggests that the straight line representation is overly simplistic.

The NRC staff notes, however, that the information presented within Link and others (1982) stated that under certain conditions up to 448 canisters could be contacted. The 8-9 value quoted within the text of this section is the average value from the Link report.

It is unclear from review of this study plan, or from review of study plan 8.3.1.8.1.1, how the area of the repository or the number of waste packages that could be affected would be simulated. The use of procedures such as that shown by Link and others (1982), appears to be insufficient as there is no indication that such representation adequately reflects the igneous processes in the area of the site.

RECOMMENDATION

Models that more accurately represent the geologic processes in the area of the site should be used in the analyses of waste package performance. In addition, when the effects of these processes are presented they should include the range in values, not just the average values.

REFERENCES

Crowe, B. M., 1990, Basaltic volcanic episodes of the Yucca Mountain region: Proceedings of the International Conference on High-Level Radioactive Waste Management, Las Vegas, Nevada, April 1990.

Link, R.L., Logan, S.E., Ng, H.S., Rockenbach, F.A., and Hong, K.J., 1982, Parametric studies of radiological consequences of basaltic volcanism: SAND81-2375, Sandia National Laboratories, Albuquerque, New Mexico.

Smith, E.I., Feuerbach, D.L., Nauman, T.R., and Faulds, J.E., 1990, The area of most recent volcanism near Yucca Mountain, Nevada: implications of volcanic risk assessment: Proceedings of the International Conference on High Level Radioactive Waste Management, Las Vegas, Nevada, April, 1990.

Section 3.2 Activities 8.3.1.8.2.1.2, 8.3.1.8.2.1.3, and 8.3.1.8.2.1.4 - Faulting

COMMENT 6

The study appears to not consider a full range of alternative methods for calculation of fault displacement hazard.

BASIS

Ongoing work by DOE (Spengler, 1992) demonstrates that the Ghost Dance fault in the Yucca Mountain area is best characterized by a complex zone over 600 feet wide, not by a simple, single fault strand.

On Page 21, it is suggested that analysis for fault hazard would be similar to that previously conducted by Subramanian (1989).

Although Link and others (1982) conducted a simplified calculation for a similar problem, the calculation by Link assumed a narrow dike which would equate to a narrow fault zone. Performing a similar calculation, with all assumptions the same except with a fault width of 600 feet, a much larger number of canisters would be at risk. Although it is unlikely that all canisters in such a fault zone would be contacted in a single event, the 8-9 average quoted on Page 22 is considered overly optimistic as that number does not appear to based on an accurate representation of geologic conditions at Yucca Mountain.

Although it is too early to judge the ability to detect faulting in the underground openings, the Subramanian methodology appears to be highly dependent on the ability to detect faults and assign a slip rate to these faults. As is pointed out in this section of the study plan, this information may be hard to obtain at the Yucca Mountain site. In addition, the NRC has expressed concerns previously (SCA Comment 48) on the use of slip rates in determining faulting hazard.

Methods in addition to those proposed should be investigated. For example, Coppersmith (1992) has used a methodology that has both similarities to an differences from the procedures used by Subramanian. This and other methods, should be evaluated to determine if they provide a better representation of the fault displacement hazard at Yucca Mountain.

RECOMMENDATION

In addition to the methodologies proposed within this study plan, alternative methodologies should be examined to evaluate faulting hazard at Yucca Mountain.

REFERENCES

Coppersmith, K.J., 1992, Seismic hazard studies for the Electric Power Research Institute, High-Level Waste Project: Presentation to the U.S. Nuclear Waste Technical Review Board Panel on Structural Geology and Geoengineering, January 22-23, 1992, Irvine, California.

Link, R.L., Logan, S.E., Ng, H.S., Rockenback, F.A., and Hong, K.J., 1982, Parametric studies of radiological consequences of basaltic volcanism: SAND81-2375, Sandia National Laboratories, Albuquerque, New Mexico.

NRC, 1989, NRC staff site characterization analysis of the Department of Energy's Site Characterization Plan, Yucca Mountain Site, Nevada: U.S. Nuclear Regulatory Commission, NUREG-1347.

Spengler, R., 1992, Recently acquired structural information along the Ghost Dance fault, in Trip Report for Midway Valley Site Visit - September 17 and 18, 1992: U.S. Nuclear Regulatory Commission memorandum from K.I. McConnell to R.L. Ballard, November 9, 1992.

Subramanian, C.V., Abrahamson, N., Hadjian, A.H., Jardine, L.J., Kemp, J.B., Kiciman, O.K., Ma, C.W., King, J., Andrews, W., and Kennedy, R.P., 1989, Preliminary seismic design cost-benefit assessment of the tuff repository waste handling facilities: SAND88-1600, Sandia National Laboratories, Albuquerque, New Mexico.

Section 1.3 Objective of the Study

Section 1.4 Regulatory Rationale and Justification

QUESTION 1

Investigation 8.3.1.8.2, of which this study is a part, does not appear to completely address the possible effects on the waste package from tectonic processes and events. What study plan will provide a complete set of the tectonic processes and events needed to be assessed for the design and analysis of waste package performance?

BASIS

The objective of the study, as stated in Section 1.3, is to provide the data necessary for an analysis and assessment of repository performance with respect to the possibility to tectonic processes and events adversely affecting the lifetime of the waste package by rupture or unacceptable deformation.

The goal of the activities, as stated in Section 1.4, is to provide information on those tectonic processes and events that should be considered "anticipated."

Although it is true that 10 CFR 60.113 requires analysis for anticipated processes and events, 10 CFR 60.112 requires analysis of the performance of the total system under both anticipated processes and events and unanticipated processes and events. In this total system analysis the possibility of tectonic processes and events adversely affecting the lifetime of the waste package by rupturing or unacceptable deformation, thus providing an accessible source term for flow and transport, must be considered.

The design of the waste package and engineered barrier system must consider, not only anticipated processes and events, but unanticipated processes and events, as well as such things as the design criteria of 10 CFR 60.130 - 135. Figure 8.3.1.8-4 (SCP Page 8.3.1.8-65) does not clearly demonstrate how unanticipated tectonic processes and events will be addressed in considering the effects on the waste package.

The staff notes that the objective of Activity 8.3.1.17.4.12.3 is to "... evaluate disruptive sequences involving faulting, folding, uplift, and subsidence, and volcanism that are of potential significance to design or performance of the repository" (SCP, Page 8.3.1.17-205). It appears that the information regarding tectonic processes and vents necessary to resolve all design and performance issues may be available from Activity 8.3.1.17.4.12.3.

RECOMMENDATION

Either modify this study such that both anticipated processes and events and unanticipated processes and events are considered, as necessary, in both the design and analysis, or identify in what other study plan such processes and events will be considered.

DOE, 1988, Site characterization plan, Yucca Mountain site, Nevada Research and Development Area, Nevada: U.S. Department of Energy, DOE/RW-0199.

Section 3.1 Activity 8.3.1.8.2.1.1 - Igneous Intrusion

QUESTION 2

In which study plan will the potential chemical effects associated with magmatic intrusion be considered?

BASIS

On Page 17 it is stated that the assessment will consider both the mechanical and thermal effects of an intrusion. There is no mention of the assessment of potential chemical effects.

During a magmatic intrusion, in addition to the corrosive effects of the magma itself, fluids can be introduced which would affect the rock mass, the waste package, and the engineered barrier system. The introduction of such fluids could have a significant effect on both design and performance.

RECOMMENDATION

Indicate in which study plan chemical effects from igneous intrusion will be addressed.

Section 2.2.3 Activity 8.3.1.8.2.1.5 - Ground Motion

Section 3.3 Activity 8.3.1.8.2.1.5 - Ground Motion

QUESTION 3

What is the magnitude range that will be considered for the multiple events that may cause failure to the corroded canister?

BASIS

On Page 31, Paragraph 4, it is stated, "Consideration of multiple seismic events may be a significant factor if these suggestions are implemented."

It is uncertain what the lower magnitude cut-off value will be in the analysis. The methodology must consider a sufficient range of multiple, low magnitude events to address performance concerns.

RECOMMENDATION

The type of analysis and the magnitude range used for the analysis should be provided.