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OVERNIGHT MAIL

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TRANSMITTAL OF REPORT ADDRESSING KEY TECHNICAL ISSUE (KTI) AGREEMENT ITEM TOTAL SYSTEM PERFORMANCE ASSESSMENT AND INTEGRATION (TSPAI) 3.22

This letter transmits a report entitled *Response to TSPAI 3.22, Representation of Unsaturated Zone Flow* which provides information to satisfy the subject KTI agreement. The KTI agreement states:

> TSPAI 3.22: "Provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions (UZ2.3.1) [sic].
> DOE will provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions. This assessment will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003."

The subject KTI agreement is related to the technical basis for the representation of the unsaturated zone (UZ) flow system under future climate conditions and the resultant impact on the UZ flow. The level of detail of the information provided to address this agreement depends upon the importance of the UZ flow model in assessing the postclosure performance of a Yucca Mountain, Nevada, repository system. The enclosed report demonstrates that no reasonable representation of the uncertainty in either the amount of water or the details of the description of its movement through the UZ plays a significant role in determining whether the postclosure performance objectives of 10 CFR Part 63 would be met.

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Performance assessment sensitivity studies confirm the physical explanation of barrier capability and show explicitly that the estimates of and the change in mean annual dose to the reasonably maximally exposed individual are not significant compared to the 15-mrem dose standard, and therefore, are not considered sensitive to the details of the Total System Performance Assessment (TSPA) model component for UZ zone flow. The sensitivity studies examine a range of UZ flow that extends well outside of that accounted for in the TSPA model. Additionally, the particular representation of UZ flow does not play a significant role in the description of the capability of the unsaturated zone barriers with respect to postclosure performance.

Accordingly, the information that would be developed to address agreement TSPAI 3.22 is not considered important to the U.S. Department of Energy's (DOE) case regarding the individual and groundwater protection requirements, or essential to its description of capabilities of the barriers important to waste isolation. The enclosed risk information is provided as the assessment and discussion of the uncertainty as called for in the agreement.

Although agreement TSPAI 3.22 states that the assessment will be documented in an Analysis and Model Report, the information is provided in the enclosure to this letter as discussed at the April 15-16, 2002, U.S. Nuclear Regulatory Commission/DOE Technical Exchange and Management Meeting on KTIs.

Agreements TSPAI 3.11, TSPAI 3.21, and TSPAI 3.23 are also related to the UZ flow model. These agreements address the effects of temporal and spatial variability (e.g., infiltration, hydrologic properties) on the UZ flow system. Although similar risk information could be made to address these agreements, the proposed DOE resolution in this letter does not explicitly address these agreements.

There are no new regulatory commitments made in the body or enclosure to this letter. Please direct any questions concerning this letter and its enclosure to Timothy C. Gunter at (702) 794-1343 or Mark C. Tynan at (702) 794-5457.

William Boyle for

Joseph D. Ziegler
Acting Assistant Manager, Office of
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OL&RC:TCG-1668

Enclosure:
Response to TSPAI 3.22, Representation of Unsaturated Zone Flow

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RESPONSE TO TSPAI 3.22, REPRESENTATION OF UNSATURATED ZONE FLOW

August 2002

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for L.D. Rickertson — Date
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ENCLOSURE

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FIGURES

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ACRONYMS AND ABBREVIATIONS

AMR	analysis and modeling report
DOE	U.S. Department of Energy
KTI	key technical issue
mm	millimeter
mrem	millirem
NRC	U.S. Nuclear Regulatory Commission
TSPA	Total System Performance Assessment
TSPAI	Total System Performance Assessment and Integration

1. BACKGROUND

Key Technical Issue (KTI) agreement Total System Performance Assessment and Integration (TSPAI) 3.22 relates to the technical basis for the representation of the unsaturated zone flow system under future climate conditions. The issue is that the unsaturated zone flow model is calibrated to present-day climate and extrapolated to future climate states with limited technical basis for this extrapolation. The agreement specified that the U.S. Department of Energy (DOE) will improve the technical basis in this regard. Since the agreement was made, Total System Performance Assessment (TSPA) sensitivity studies have been conducted to evaluate the importance of the unsaturated zone flow model to the demonstration that the postclosure performance objectives would be met.

1.1 NRC INITIAL COMMENTS

The U.S. Nuclear Regulatory Commission (NRC) commented that an assessment needed regarding the uncertainty involved in the use of a hydrologic property set obtained by calibrating a model on current climate conditions and the use of that model to forecast flow for future climate conditions.

1.2 DOE INITIAL RESPONSE

Test predictions for field tests (such as Alcove 8–Niche 3) will be conducted at higher flow rates that are expected to encompass flow behavior representative of future climates. Modeling predictions for these tests will be compared with testing results, which should enable an assessment of the uncertainty involved in using property sets calibrated under present-day climate for future climates.

2. APPLICABLE REQUIREMENTS

The following NRC requirements are considered applicable to models and analyses that examine the performance of the repository:

10 CFR 63.114 "(b) account for uncertainties and variabilities in parameter values and provide for the technical basis for parameter ranges, probability distributions, or bounding values used in the performance assessment."

10 CFR 63.304 "(d) reasonable expectation focuses performance assessments and analyses upon the full range of defensible and reasonable parameter distributions rather than only upon extreme physical situations and parameter values."

2.1 KTI AGREEMENT

TSPAI 3.22 reads as follows: "Provide an assessment or discussion of the uncertainty involved with using a hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions (UZ2.3.1)[sic]. The DOE will provide an assessment or discussion of the uncertainty involved with using a

hydrologic property set obtained by calibrating a model on current climate conditions and using that model to forecast flow for future climate conditions. This assessment will be documented in the UZ Flow Models and Submodels AMR (MDL-NBS-HS-000006) expected to be available to NRC in FY 2003."

2.2 DEFINITION

Significant is defined as an increase in magnitude of the expected annual dose, as a result of the omission of a feature, event and process or the omission or failure of an engineered barrier, that is more than a small fraction of the numerical limits associated with the postclosure performance objectives in 10 CFR 63.113.

2.3 RELATED AGREEMENTS

The following agreements are associated with the effects of unsaturated zone flow on flow and transport behavior within the repository. Although similar arguments can be made to address TSPAI 3.11, TSPAI 3.21, and TSPAI 3.23, the proposed DOE response in this letter is not intended to address these agreements. The disposition and schedule for TSPAI 3.11, TSPAI 3.21 and TSPAI 3.23 will be included in the FY03 through FY05 KTI Plan.

3. RISK INFORMED ASSESSMENT OF UNCERTAINTY

3.1 INTRODUCTION

The agreement addresses extrapolation of a model calibrated to present-day conditions to predict unsaturated flow under future climate conditions. The information to be provided in accordance with the agreement could provide support for assessing the appropriateness of this extrapolation.

The treatment of model uncertainty and data uncertainty for the unsaturated zone flow model and the propagation of these uncertainties into the TSPA model will be commensurate with the risk significance of unsaturated zone flow to system performance. A description of the uncertainties, the level of confidence that the uncertainties are adequately represented, and the impact of the uncertainties on the assessment of system and subsystem performance will be provided in the License Application or supporting documents. In addition, the description of the capability of the unsaturated zone to provide barriers to the movement of water or radionuclides will be documented in the License Application commensurate with the importance of the role of the unsaturated zone flow system to postclosure performance. Important to postclosure performance means important to meeting the postclosure performance objectives as specified in 10 CFR 63.113. Conclusions regarding the importance to postclosure performance can be informed by risk insights gained from sensitivity studies, such as the results presented in this report.

Sensitivity studies have been conducted that provide insight into the role of the unsaturated zone flow model in the assessment of postclosure performance. These studies examine the impact of the unsaturated zone flow on the distribution of flux and transport of radionuclides in the repository. For each study, the results show that the sensitivity of the mean annual dose to the effects of unsaturated zone flow is not significant, which indicates that the degree of waste

isolation provided by the repository system is not sensitive to the details of the unsaturated zone flow system.

Since the results of the sensitivity studies show no significant sensitivity of the estimate of the mean annual dose to the details of the unsaturated zone flow model, the information to be provided in accordance with agreement TSPAI 3.22 is not considered important to showing that the individual and groundwater protection requirements would be met.

3.2 DOE PROPOSED RESOLUTION

The unsaturated zone flow model is used to generate flow fields to predict the amount of flux and the transport of radionuclides in the unsaturated zone under various climatic conditions. The flow fields are developed based on the infiltration projected to occur over the next 10,000 years. Uncertainties in the infiltration may therefore affect the representation of the unsaturated zone flow fields and these effects could therefore be translated into uncertainties in the assessment of repository performance. Unsaturated zone flow can potentially affect performance in the following ways. First, it can potentially affect the estimated amount of seepage into the emplacement drifts and the resulting amount of water that might contact the waste and mobilize radionuclides. Second, the unsaturated zone flow can affect transport of radionuclides that reach the rock in the unsaturated zone. The issue is the extent to which the uncertainties in the representation of unsaturated zone flow are important to the determination of whether the individual or groundwater protection requirements are met.

Careful consideration of the information already available indicates that uncertainties in the unsaturated zone flow model do not play a significant role in the estimate of individual and groundwater protection provided by the system. There are two scenarios in which the unsaturated zone flow might play a role: (1) the nominal scenario (the scenario for expected conditions in which igneous activity does not occur), and (2) the igneous activity groundwater release scenario. The nominal scenario describes expected conditions for all the elements of the system, and low probability disruptive events such as igneous activity are not considered. The radionuclides that dominate the estimate of mean annual dose for this scenario are highly soluble (CRWMS M&O 2000), so that their release does not depend strongly on the amount of water that is present. This conclusion holds even considering flow focusing or episodicity effects in which locally high flows might occur. Uncertainties in the representation of the flow system are, therefore, not likely to have a significant effect on the estimate of mean annual dose for the nominal scenario.

The igneous activity groundwater release assumes that igneous activity occurs and intruding magma damages waste packages and drip shields, exposing the waste to water flowing down through the unsaturated zone. In this scenario, the repository does not benefit from diversion of water by the engineered barriers; consequently, the significance of variations and uncertainties in the unsaturated zone flow system may be more clearly ascertained. The radionuclides that dominate the estimate of the probability-weighted mean annual dose for the igneous activity groundwater release scenario includes radionuclides that are less soluble. The release of these radionuclides could be affected by the amount of water present and details of the flow model could translate into effects on the estimate of mean annual dose. However, the estimate of mean annual dose in this case is so low that it is not likely that these effects could result in an estimate

exceeding the regulatory standard. Accordingly, while uncertainties in the unsaturated zone flow model can play a role in understanding the flow system, significant effects on compliance with the individual protection requirement are not expected.

Two TSPA sensitivity studies have been conducted to quantify these effects and to confirm these physical arguments. The studies have been conducted using a TSPA model that is described in the risk prioritization report (BSC 2002). In the first sensitivity study, the results using the current unsaturated zone flow model are compared with the results using an extreme representation for the unsaturated zone flow. Precipitation onto Yucca Mountain averages about 190 mm/year under current conditions and the maximum average is estimated to be no more than 310 mm/year over the next 10,000 years. The corresponding net infiltration flux in the current model averages about 4.6 mm/year under present day conditions and about 12 mm/year over the next 10,000 years. The flux in the extreme model considered in the sensitivity analysis averages about 150 mm/year, more than an order of magnitude greater than the infiltration flux of the current model and a factor of 2 below the maximum precipitation projected for the next 10,000 years (BSC 2001a). That this infiltration flux represents a reasonable bound to the uncertainties in the flux is indicated in Figure 1. This figure shows the results of alternative approaches to estimating net infiltration or recharge flux for different precipitation rates at the Yucca Mountain site and other locations (BSC 2001b). These results generally indicate that, for a precipitation rate well beyond the maximum annual average of 310 mm/year estimated for the next 10,000 years, 150 mm/year provides a useful bound to the average infiltration flux.

Estimates of mean annual dose for the flow fields are shown in Figure 2. The results for the nominal scenario show little change to the estimate of mean annual dose. For the nominal scenario, the change in mean annual dose in the first 10,000 years is estimated to be less than 0.0001 mrem/year and is considered to be insignificant. The reason this change is small is that the mean annual dose is dominated by carbon-14 and technetium-99, highly soluble radionuclides whose release is not significantly affected by the amount of water present. These results confirm the physical arguments for the nominal scenario discussed at the beginning of this section of the document.

The results for the igneous activity groundwater release scenario also confirm the physical arguments. The release in this case is dominated by solubility-limited radionuclides (e.g., neptunium-237, plutonium-239, and plutonium-240). The estimate of mean annual dose is higher due to increased flux through the unsaturated zone. However, the change in the probability-weighted mean annual dose in the first 10,000 years is still less than 0.01 mrem/year and considered to be insignificant. Thus, the conclusion remains that uncertainties in the particular representation of the unsaturated zone flow system play little role in determining whether the repository system would meet the individual protection requirement of 15 mrem/year.

The question still remains whether the unsaturated zone flow could affect transport of radionuclides to a degree that could influence this determination. A second sensitivity study examines the effect of the flow system on transport explicitly. The results are shown in Figure 3. This figure compares the results for the unsaturated zone and saturated zone transport systems as modeled in the current approach with results of extreme models. The first extreme model neutralizes the transport system entirely, i.e., discharges radionuclides released from the

engineered barrier system directly to wells in Amargosa Valley. Thus, no effect of the flow system or of other characteristics (e.g., assumptions about whether radionuclide transport in the fractures or the matrix is diffusive or advective; or about sorption, colloid filtration, or matrix diffusion) that could affect transport of radionuclides in the flow system is included. The results show a change from the model where these effects are accounted for, particularly in the early period. The changes are not great compared to 15 mrem but are also not negligible.

Comparison of the above results is also made with the flow system included, but none of the transport characteristics are included (Figure 3). The results are not significantly different from those where the flow system is ignored. Thus, it can be inferred from the comparison that for this model, the flow alone does not have a significant effect on the estimate of mean annual dose. Therefore, this analysis provides an additional confirmation of the physical arguments presented above.

The physical arguments and the confirmation of these arguments indicate that the details of the representation of the unsaturated zone flow system do not play a significant role in determining whether the postclosure performance objectives are met. Accordingly, results of these sensitivity studies are provided to satisfy agreement TSPAI 3.22 and to provide perspective on level of importance of uncertainties in unsaturated zone flow model to the DOE case regarding these performance objectives.

4. REFERENCES

4.1 DOCUMENTS CITED

BSC (Bechtel SAIC Company) 2001a. *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses.* TDR-MGR-MD-000007 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010712.0062.

BSC 2001b. *Simulation of Net Infiltration for Modern and Potential Future Climates.* ANL-NBS-HS-000032 REV 00 (ICN 02). Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL. 20011119.0334.

BSC 2002. *Risk Information to Support Prioritization of Performance Assessment Models.* TDR-WIS-PA-000009 REV 00. Las Vegas, Nevada: CRWMS Bechtel SAIC Company. ACC: MOL.20020603.0291.

CRWMS M&O 2000 (Civilian Radioactive Waste Management System Management and Operating Contractor). *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045.

4.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

10 CFR (Code of Federal Regulations) 63. Energy: Disposal of High-level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Readily available.

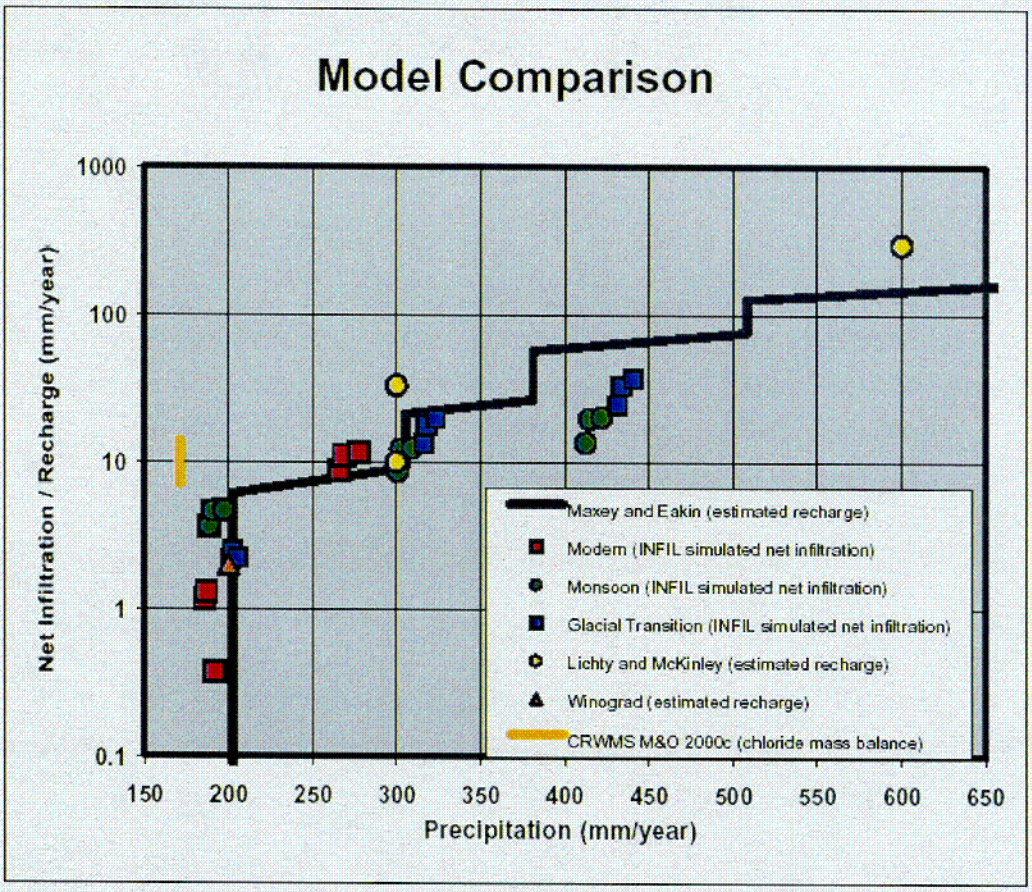
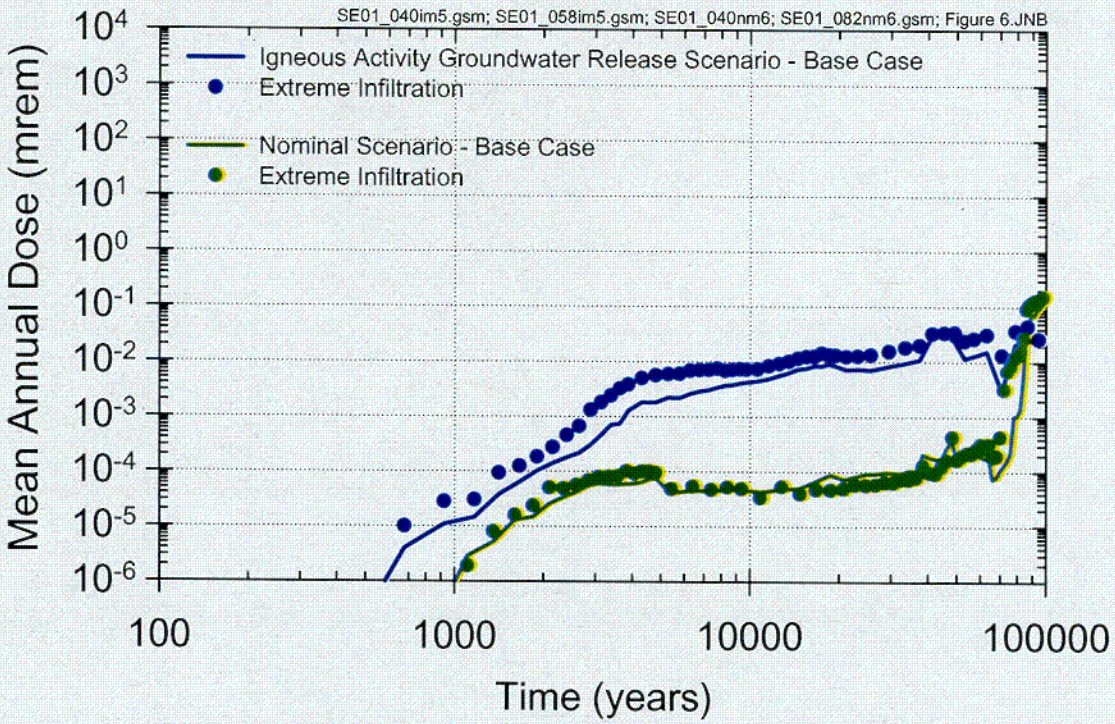


Figure 1. Comparison if INFIL V2.0 simulated average net-infiltration rates (DTN: GS000308311221.005) at Yucca Mountain (upper bound, lower bound and mean for three climates

C01

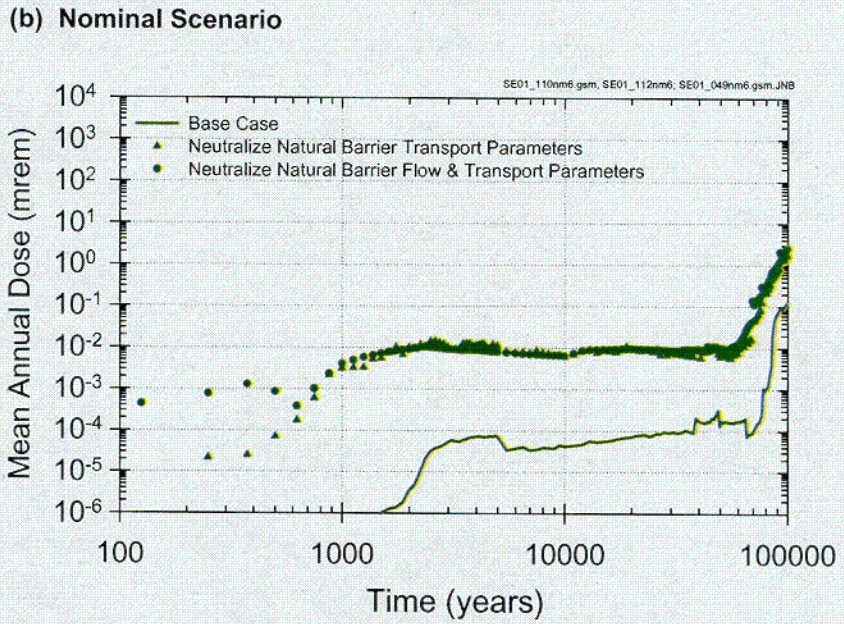


NOTE: Each mean annual dose curve is a probability-weighted average

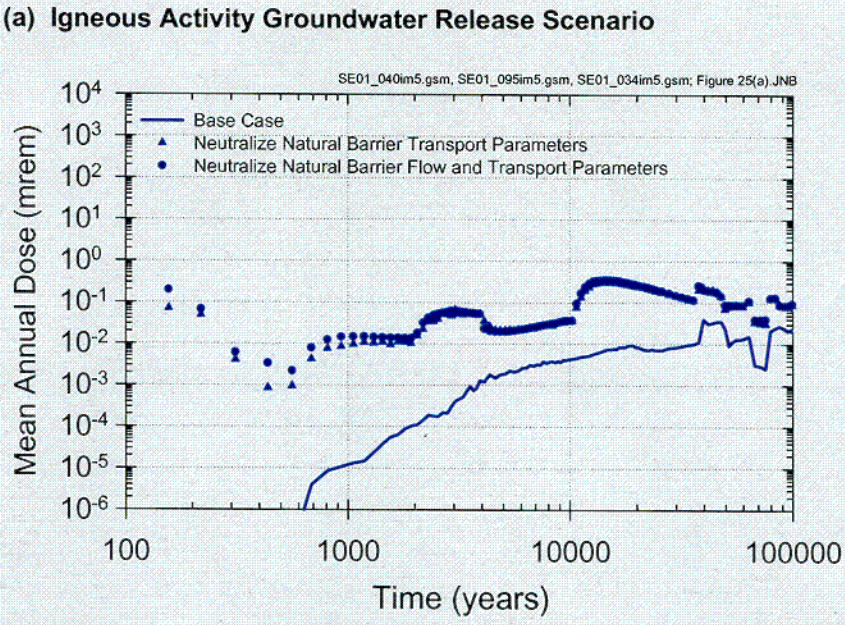
Figure 2. Sensitivity of Mean Annual Dose to the Unsaturated Zone Flow Model as Defined for Base-Case and Extreme Infiltration Fluxes

CO2

(a) Igneous Activity Groundwater Release Scenario



(b) Nominal Scenario



NOTE: Each mean annual dose curve is a probability-weighted average.

Figure 3. Sensitivity of Mean Annual Dose to Full Neutralization of the Unsaturated Zone and Saturated Zone Radionuclide Transport Barriers and to Neutralization of Only the Transport

C03