Effects of Uncertainty/Variance Partitioning

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Variance and Uncertainty in Total System Performance Assessment (TSPA) Modeling

- Experimental data will be uncertain, and also spatially and temporally varying.
- Differences between uncertainty and variability often blurred.
- Current example concerns treatment of corrosion-rate data for waste packages, and its effects on release rate and dose.

Variance and Uncertainty in TSPA Modeling (Cont'd)

- **Most weight-loss corrosion data neither support nor refute spatial variation in corrosion rate; i.e., data could be either:**

  1. a fixed but uncertain rate, or
  2. a non-uniform, spatially varying rate.

Treatment of Variability and Uncertainty

- How uncertainty and variability are treated in models can often make a significant difference in results.

- NRC's TSPA model (TPA 4.1) has little variability for waste package (WP) failure within a single run (realization). There are 9 representative WPs that fail at a corrosion rate sampled once per realization.

- DOE's TSPA uses "Patch Failure" model that can incorporate significant variability.

NRC Demonstration Model

NRC Staff created a highly abstracted model of release rate to show effects of variance/uncertainty partitioning (*Not* in TPA code)

Assumptions:

- **300 WPs, 1000 patches for each WP in patch model.**
- **Release rate from WP proportional to failed area (Likely to be true whether release is controlled by diffusion or advection).**

NRC Demonstration Model (Cont'd)

- **Three Conceptual Models for Uncertainty/Variance:**

  Model 1 - All WPs fail at about same (random) time. Single corrosion rate applies to all WP surfaces. Sampled once per realization (100% Uncertainty)

  Model 2 - Within a realization, corrosion rate is sampled once per WP (Mixed uncertainty and variability).

  Model 3 - Within a realization, corrosion rate is sampled for each individual patch (100% variability).

NRC Demonstration Model (Cont'd)

- **Contents of WP have very long half life, no daughters, and no retardation.**

- **With 100% failure of WP, all radionuclides would be released at steady rate for 10,000 years.**
  - **Acceleration factor used to increase or decrease this rate ("Accel").**

- **Dose proportional to engineered barrier release (*i.e.*, ignore effect of geosphere).**

NRC Demonstration Model (Cont'd)

- Small correction, T_{RH}, added to corrosion time for each WP to account for spatial variability of RH caused by temperature difference in repository:
-

$$T_{RH} = 2000 + 324\ N(0,1),\ \text{years}$$

where N(0,1) is a normally distributed random number with mean zero and standard deviation 1.

NRC Demonstration Model (Cont'd)

- Corrosion rate data taken from Figure 1, "Calculation of General Corrosion Rate of Drip Shield and Waste Package Outer Barrier to Support WAPDEG Analysis"
  {CAL-EBS-PA-000002 REV 01}

- Conservatively includes factor of 2 for inside-out corrosion, factor of (1 to 2) for Microbial Influenced Corrosion (MIC), and factor of (1 to 2.5) for thermal phase stability.

Results of Model Studies

- Models run for 400 realizations each
- Doses from model 1 have high peaks within a realization, but at widely different times. Model 3 doses had individually smaller peaks, but were less different from realization to realization.
- Doses averaged over all realizations (Peak-of-Mean approach) sensitive to uniformity among random runs.

Results of Model Studies (Cont'd)

- **Rate at which radionuclides released from WP, and depletion of WP inventory also determines results:**

  - **Mid-range of factor Accel between 0.1 and 10 gives result that Model 3 has highest dose.**

  - **For very slow release and no source term depletion (Accel = 0.01), all models give same result.**

  - **For fast release (Accel > 10), results change to Model 1 giving the worst results.**

Conclusions

- **Uncertainty/Variance partitioning can be important for engineered barrier, and may be important in other areas of TSPA.**

- **Patch failure model with corrosion rate data interpreted as 100% variability can yield highest Peak-of-Mean dose, but depends on release rate from WP and depletion of inventory.**

- **A very slow release rate for EBS would lead to conclusion that all three models give same result.**

Figure 1 - 5 vectors for Accel = 1.0

Figure 2 - Mean Surrogate dose for Accel = 1

Figure 3 - Mean Surrogate Dose for Accel = 0.1

Figure 4 - Mean Surrogate Dose for Accel = 10

Figure 5 - Mean Surrogate Dose for Accel = 0.01

Figure 6 - Mean Surrogate Dose for Accel = 100

Figure 1 - 5 vectors for Accel = 1.0

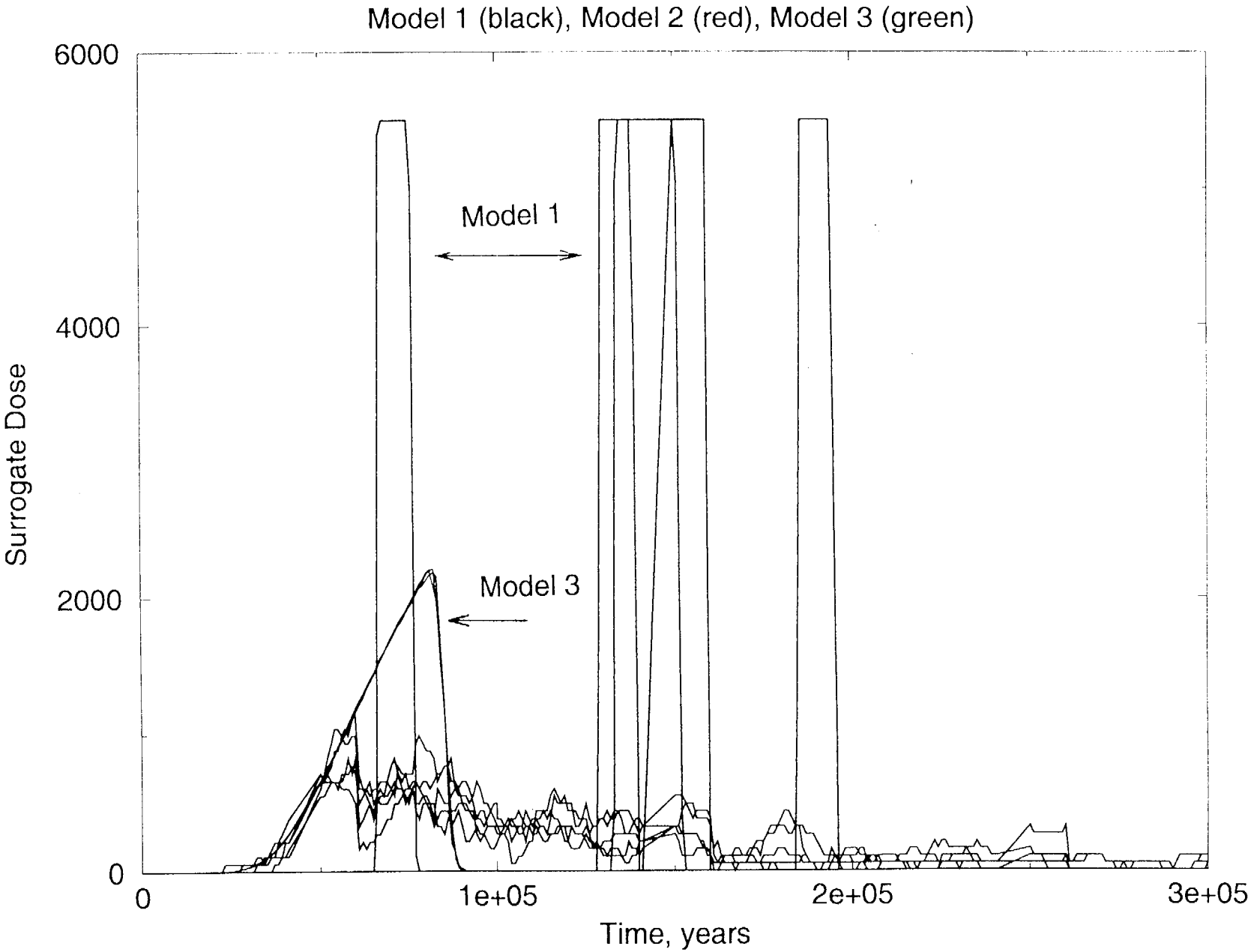


Figure 2 - Mean Surrogate dose for Accel = 1

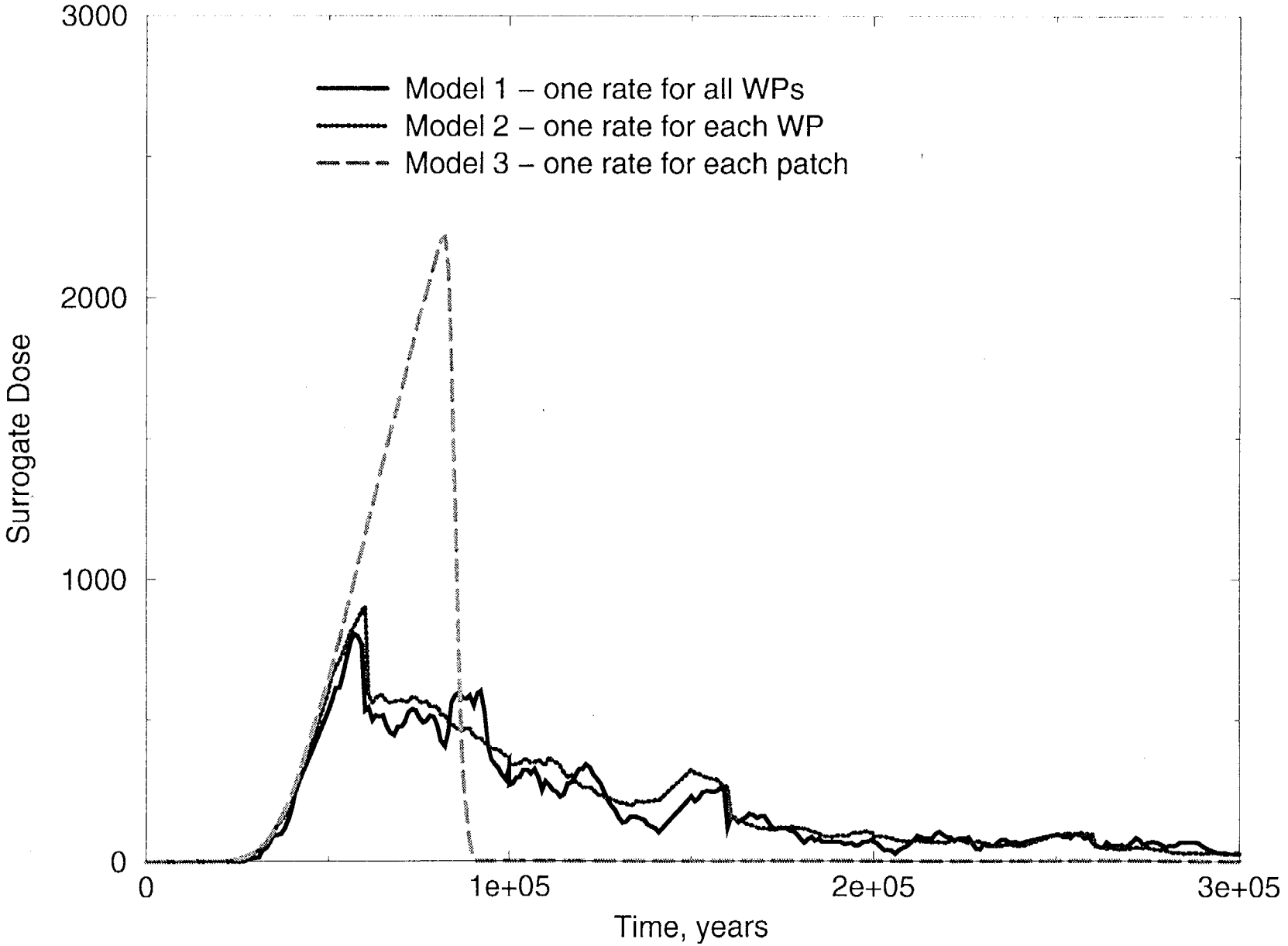


Figure 3 - Mean Surrogate Dose for Accel = 0.1

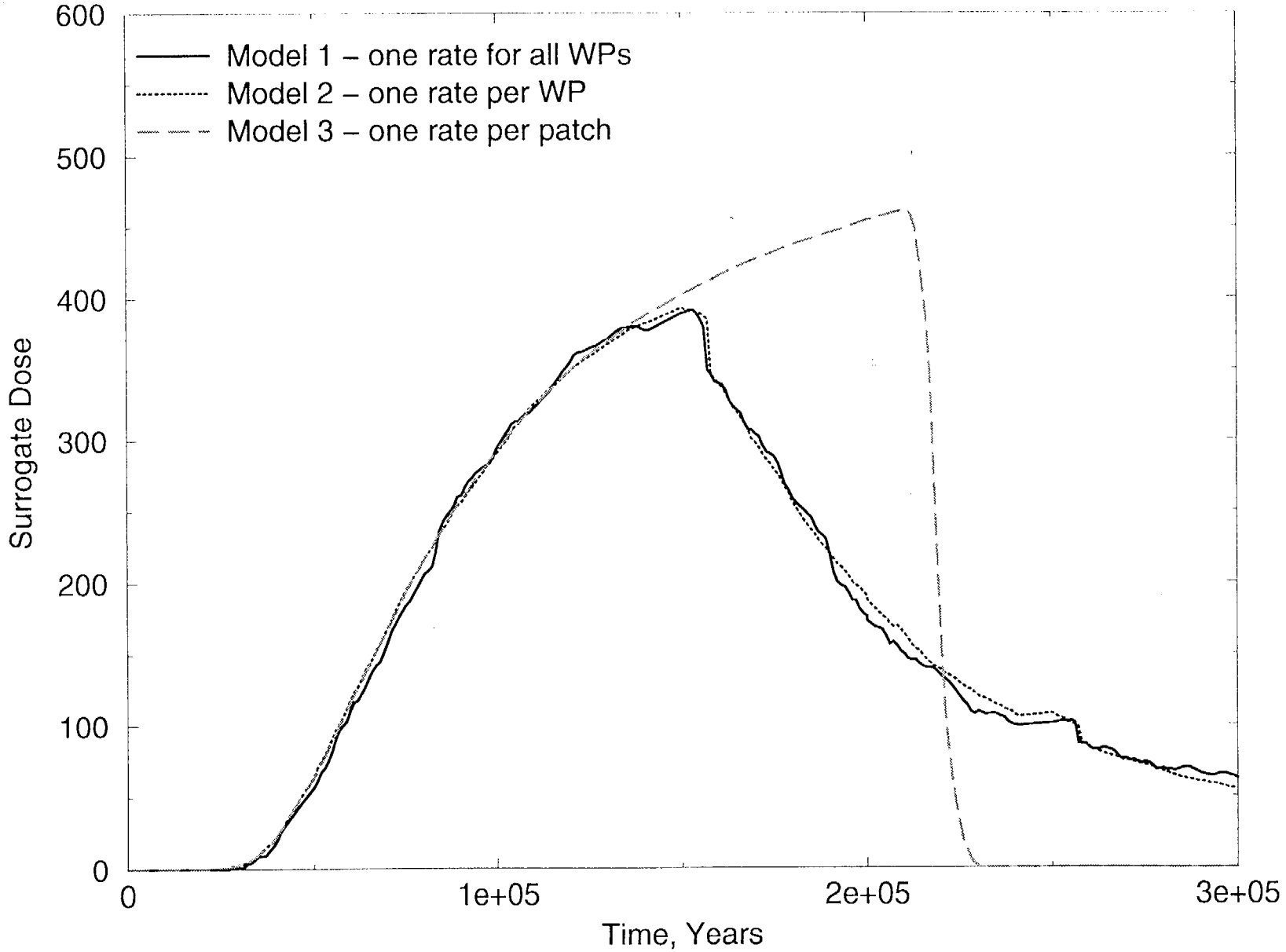


Figure 4 - Mean Surrogate Dose for Accel = 10

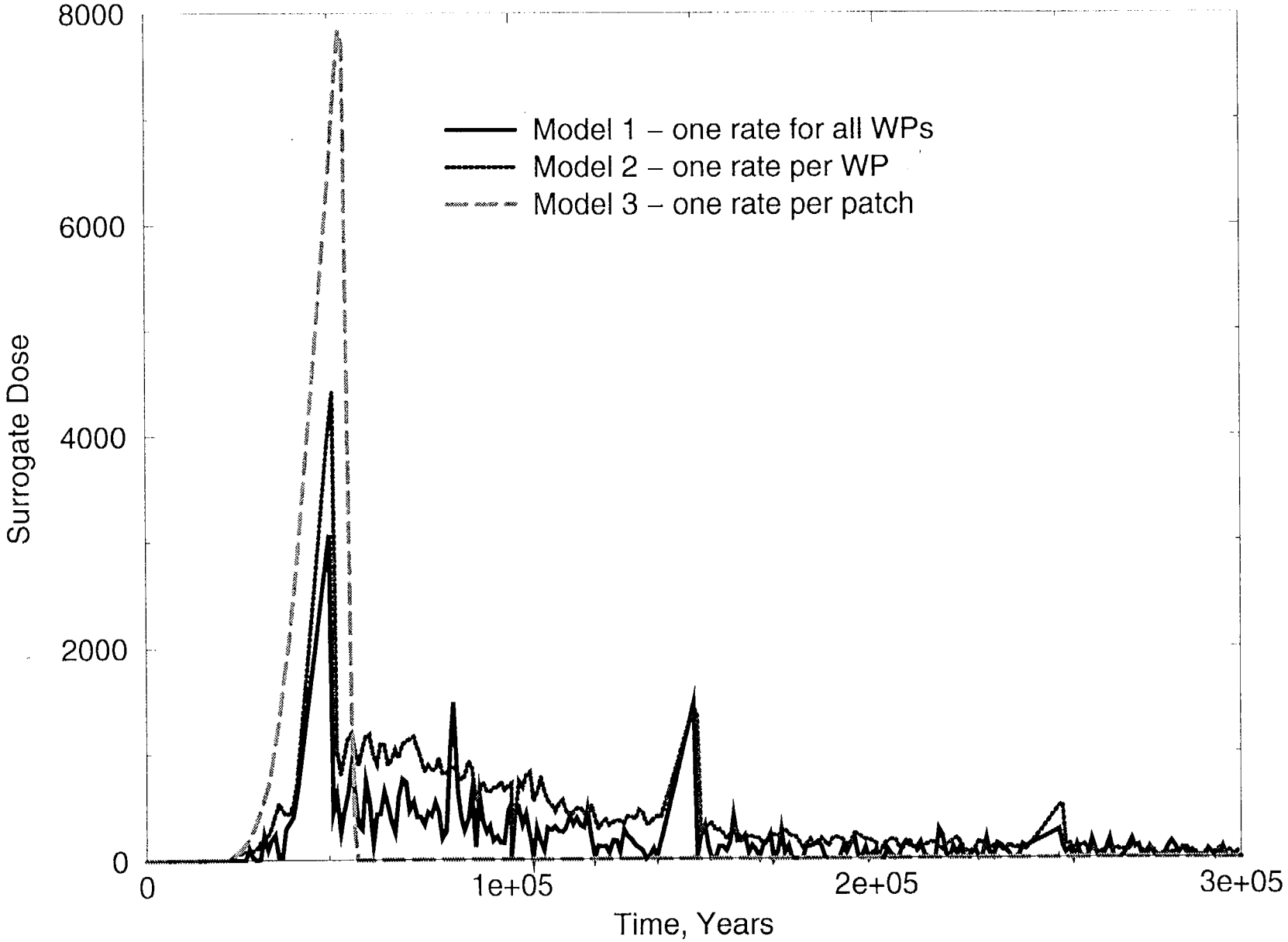


Figure 5 - Mean Surrogate Dose for Accel = 0.01

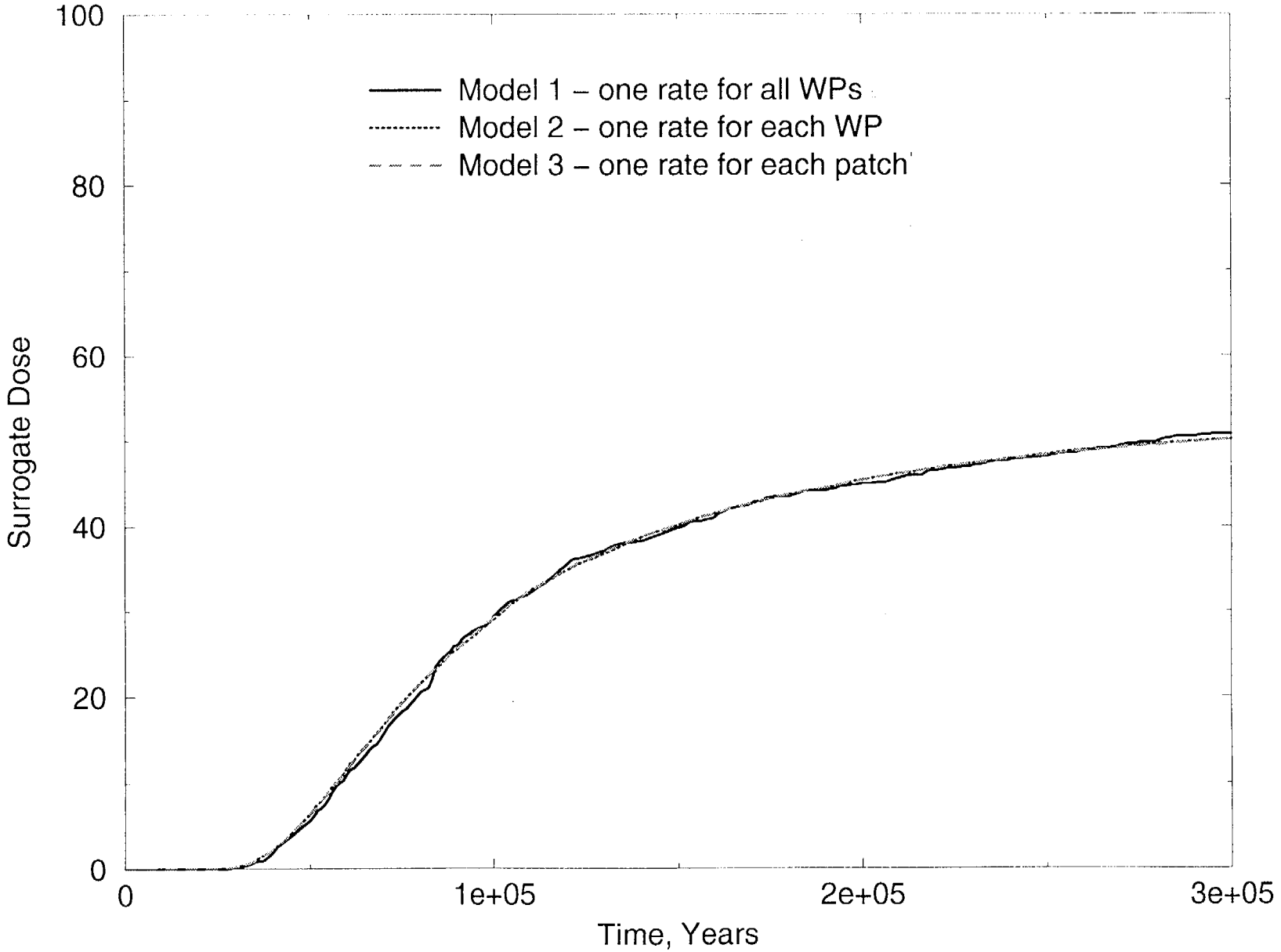
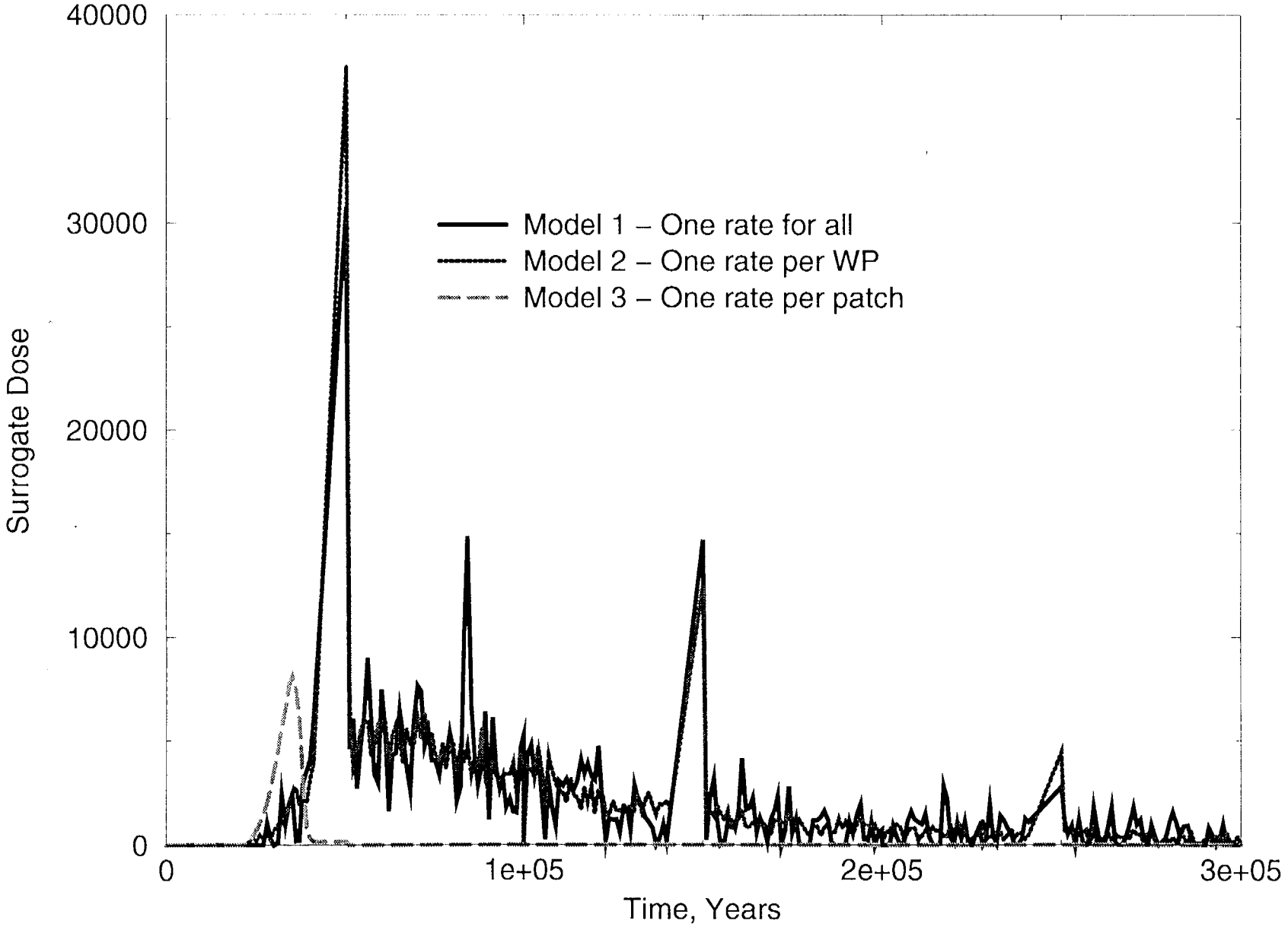


Figure 6 - Mean Surrogate Dose for Accel = 100



U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Total System Performance Assessment and Integration Key Technical Issue Subissue 1 - Multiple Barriers

Presented to:
DOE/NRC Technical Exchange on the Total System Performance Assessment and Integration Key Technical Issue

Presented by:
Srikanta Mishra
Performance Assessment Department
Bechtel SAIC Company, LLC/Duke Engineering

August 6 - 9, 2001
Las Vegas, Nevada

Outline

- Objectives
- For Subissue 1 in the Total System Performance Assessment and Integration Issue Resolution Status Report, Revision 3, this presentation will
  - Identify current subissue status
  - Identify applicable proposed regulations and acceptance criteria
  - Summarize technical basis for resolution
  - Identify basis documents
  - Summarize technical adequacy of basis
- Conclusions

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Objectives

- **Describe process and techniques for multiple barrier analysis to:**
  - **Address approach to describing capability of barriers to prevent or substantially delay movement of water or radionuclides**
  - **Differentiate between contributions of barriers that perform similar functions and address possible masking of one barrier by another**
  - **Account for uncertainties in characterizing and modeling barriers**
  - **Address interdependency of barriers**

Objectives
(Continued)

- Account for time evolution of barrier characteristics
- Address spatial variability in performance of the barriers
- Provide adequate basis for correlations or independence among models and parameters

- Discuss path forward to License Application for multiple barrier analysis
- Describe the basis for resolving Subissue 1, in the Total System Performance Assessment and Integration Issue Resolution Status Report, Revision 3

Current Subissue Status

- **Total System Performance Assessment and Integration Issue Resolution Status Report, Revision 3 indicates that this Subissue is Open**

Applicable Proposed Regulations in 10 CFR Part 63

- **Multiple Barriers**
  - 63.102(h) ⇒ Multiple barriers required to ensure expected annual dose to critical group is less that 25* mrem Total Effective Dose Equivalent
  - 63.113(a) ⇒ Geologic repository to include multiple barriers – both natural and engineered
- **Performance Assessment**
  - 63.114(h) ⇒ Identify natural and engineered barriers important to waste isolation
  - 63.114(i) ⇒ Describe capability of barriers important to waste isolation, taking into account uncertainties in characterizing and modeling the barriers
  - 63.114(j) ⇒ Provide technical basis for analyses in support of barriers capability to isolate waste

*EPA standard of 40 CFR Part 193 is 15 mrem

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Acceptance Criteria

- Barriers relied on to achieve compliance with the overall performance objective, as demonstrated in the TSPA, are adequately identified. The barriers include at least one from the engineered system and one from the natural system
- The capability of the identified barriers to contribute to the isolation of radioactive waste is adequately identified and described such that the
  - Uncertainty associated with each barrier's capability is described
  - Relationship to assumptions and parameters in the TSPA is clear, and
  - Degree of reliance placed on each barrier is described relative to each barrier's performance in the TSPA

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Acceptance Criteria

(Continued)

- **A technical basis for assertions of barrier capability is provided that is commensurate with the degree of reliance placed on a particular barrier and the associated uncertainties**

Acceptance Criteria
(Continued)

- **Summary of information needs identified by NRC**
  - **Clarify barrier importance analysis to address**
    - **Approach**
    - **Techniques**
    - **Comparison of techniques**
    - **Path forward to License Application**
    - **Meeting regulatory requirements**

Acceptance Criteria
(Continued)

- **Basis for closure**
  - Combination of techniques described in Project documents that assess individual components, subsystem and system performance
  - Documented description of approach to multiple barrier analysis
  - Implementation of approach in appropriate analyses
- **References**
  - *Total System Performance Assessment for the Site Recommendation*, TDR-WIS-PA-000001 REV 00 ICN01
  - *Repository Safety Strategy, Postclosure Safety Strategy, Volume II*, TDR-WIS-RL-000001 REV 04 ICN01
  - *Yucca Mountain Science and Engineering Report*, DOE/RW-0539

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Barrier Importance Analysis

- **Definition of barriers**
  - **Physically distinct components that prevent or substantially delay movement of water or radionuclides**
  - **Isolate waste by reducing mass and/or concentration**
  - **Process model factors are not barriers, but considerations affecting the barriers**

Barrier Importance Analysis
(Continued)

- **Examples of barriers:**
  - **Engineered**
    - **Waste form**
    - **Waste package**
    - **Engineered components within drift**
  - **Natural**
    - **Unsaturated zone**
    - **Saturated zone**

Barrier Importance Analysis
Approach

- **Based on model configuration of waste disposal system:**
  - **"As-Is" System: Examine system behavior with all components in place (i.e., everything working as expected) and allocate performance to individual barriers**
  - **"Modified" System: Examine reduction in system performance from full/partial "exclusion" of select components (i.e., when certain barriers are malfunctioning) and rank barriers accordingly**

Barrier Importance Analysis
Approach

- **TSPA model primary analytical tool**
  - **Building blocks of TSPA (scenarios, models and parameters) aggregated into "barriers" denoting physically distinct entities**
  - **Uncertainties in characterizing and modeling barriers incorporated via probabilistic total system modeling framework**
  - **Spatial variability and temporal evolution also incorporated**

Barrier Importance Analysis
Techniques

- **"As-is" reference system**
  - **Intermediate performance analysis (Science and Engineering Report, and Repository Safety Strategy, REV 04 ICN01)**
  - **Pinch-point analysis (TSPA-Site Recommendation Methods and Assumptions)**
- **"Modified" reference system**
  - **Robustness analysis (TSPA-Site Recommendation REV 00 ICN01, and Repository Safety Strategy, REV 04 ICN01)**
  - **Neutralization analysis (TSPA-Site Recommendation REV 00 ICN01, and Repository Safety Strategy, REV 04 ICN01)**

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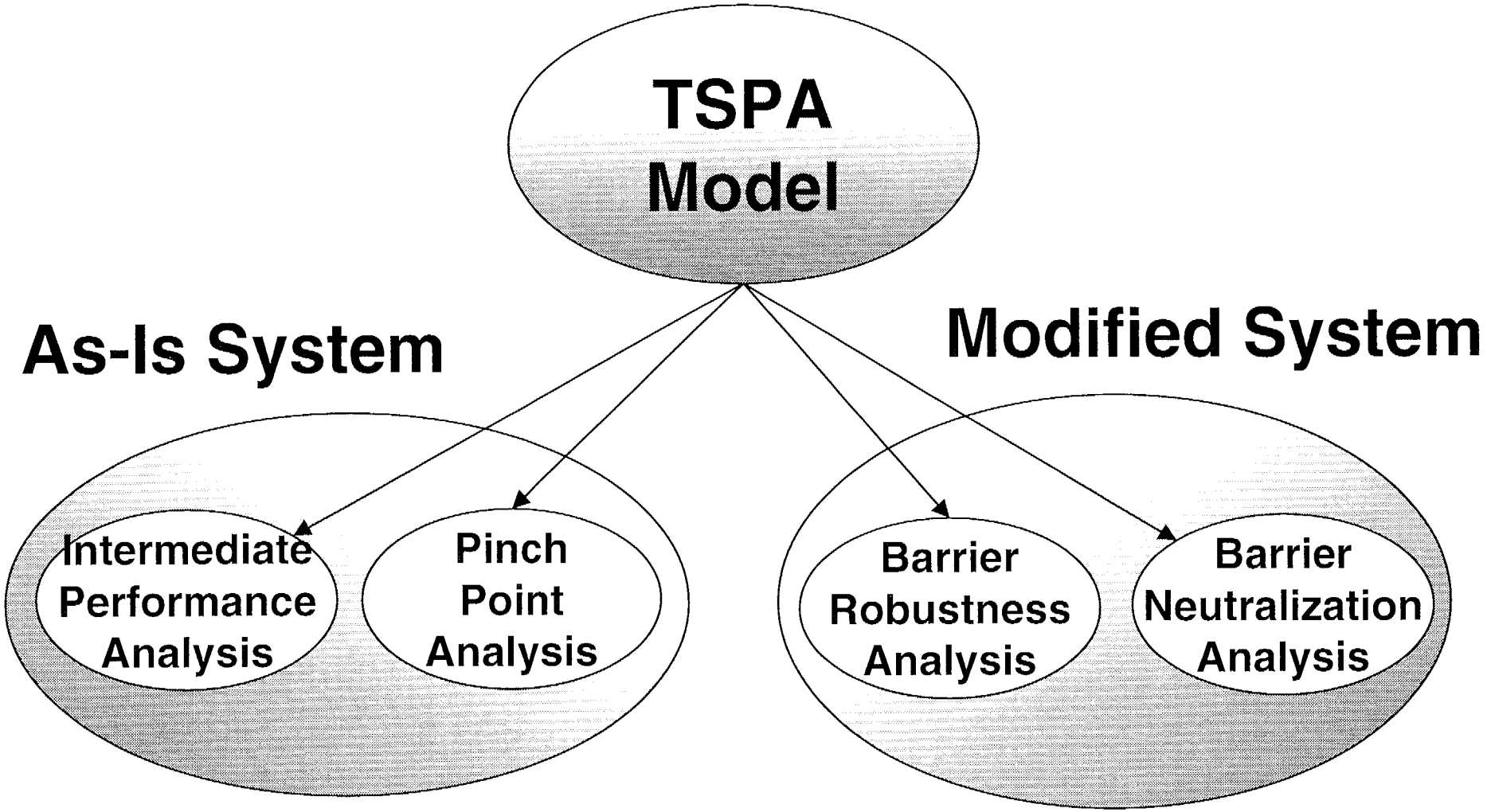
Barrier Importance Analyses Flow Naturally Out of TSPA Model



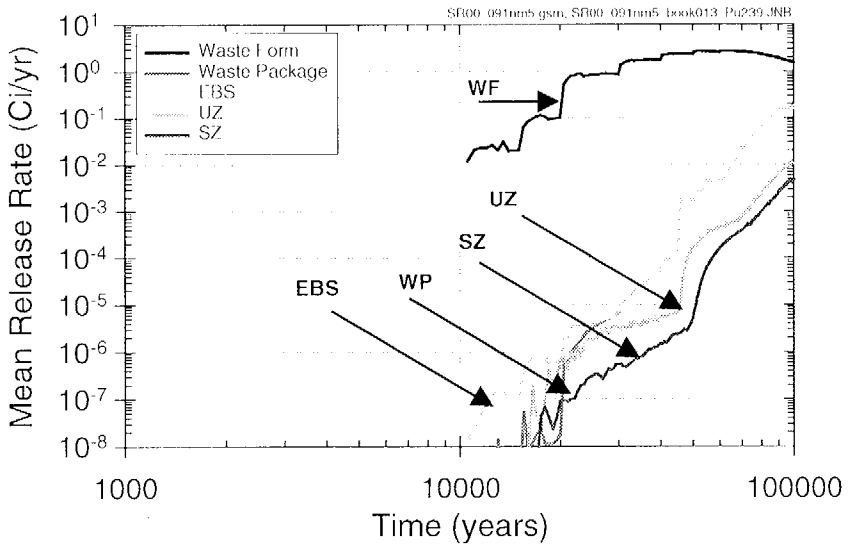
Intermediate Performance Analysis

- Probabilistic analysis that provides quantitative estimates of performance
- Involves review of TSPA model results to look at intermediate outputs (e.g., radionuclide release from engineered barrier system)
- Provides insight into how different components contribute to total system performance

Source: TSPA-Site Recommendation, TDR-WIS-PA-000001 REV 00 ICN01, Section 4.1

Intermediate Performance Analysis

(Continued)



Source: TSPA-Site Recommendation, TDR-WIS-PA-000001 REV 00 ICN 01

- Shows curies/year of Pu-239 transported through and out of each barrier
- Output shows both
  - Capability of barrier to delay movement of radionuclides
  - Contribution of each barrier to waste isolation
- Uncertainty in barrier characteristics and barrier interdependence taken into account via TSPA model
- Spatial variability effects and temporal evolution in barrier performance easily shown

Pinch Point Analysis

- Probabilistic analyses where output of TSPA is processed at "pinch points" to provide indications of subsystem performance
- Metrics related to reduction in mass and reduction in concentration used as measures of barrier effectiveness for waste isolation
- Approach similar to previous study on performance allocation
- Described in TSPA-Site Recommendation Methods and Assumptions document, but not previously implemented
- Requires no additional simulations as in robustness or neutralization analyses

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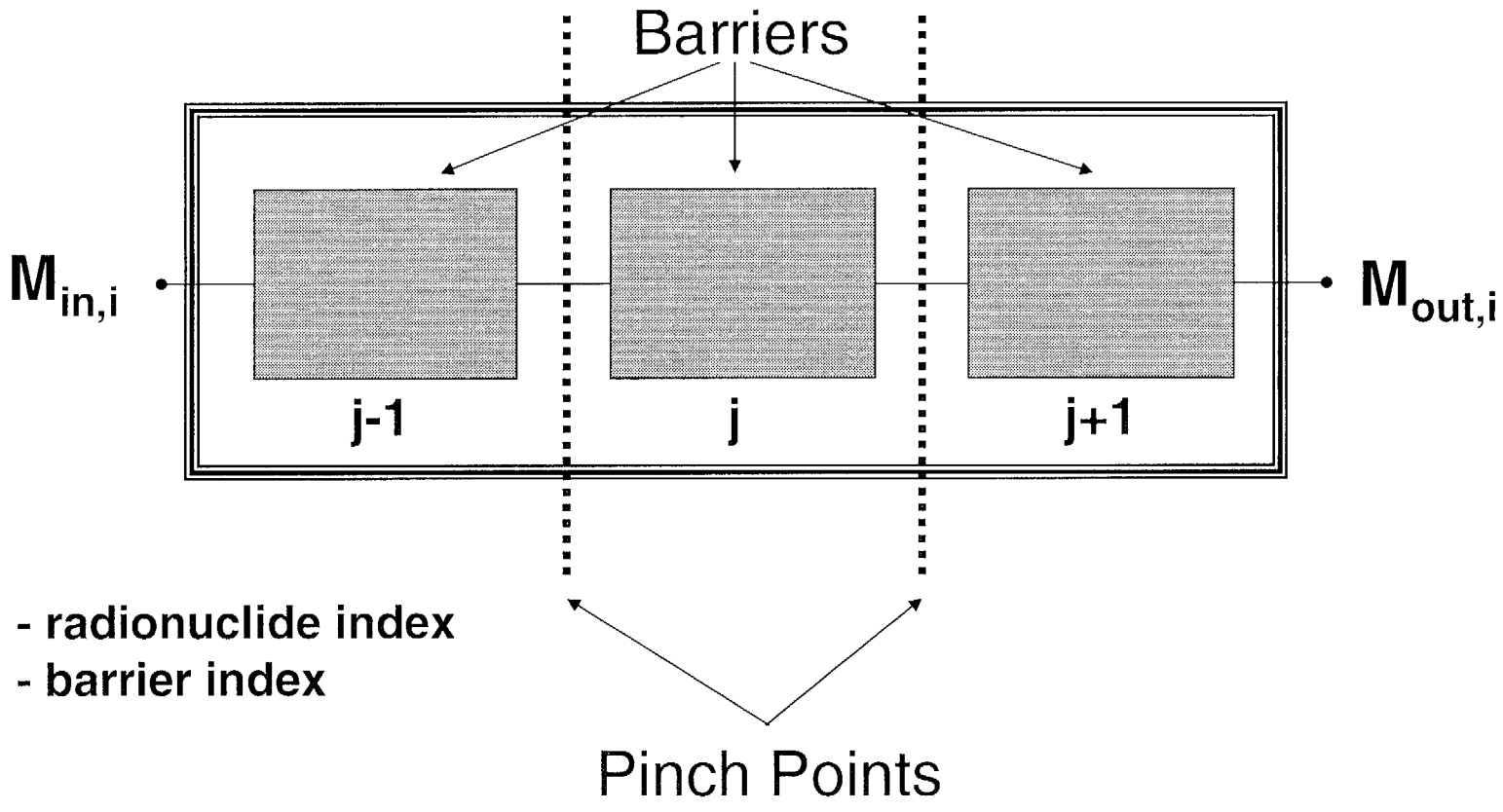
Pinch Point Analysis

(Continued)



Pinch points occur where outputs (material, energy or information flow) from one module of the total system become the inputs to another module

Pinch Point Analysis

(Continued)

- **Barrier effectiveness factors defined to quantify**
  - Absolute mass reduction within barrier
  - Relative mass reduction within barrier
  - Concentration reduction within barrier
- **Barrier effectiveness factors provide simple and transparent construct for determining individual barrier contributions to total system response**
- **Time-dependence is handled by making calculations at**
  - Time of peak dose during compliance period
  - Selected time slices
  - For all time steps

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Robustness Analysis

- **Probabilistic analysis that examines what happens when the system is stressed via unfavorable parameter values and/or conceptual models of low probability**
- **Key parameters associated with:**
  - **Single barrier fixed at extreme percentile values, as needed for modeling degraded performance and probabilistic analyses rerun**
  - **Several barrier types (natural and/or engineered) fixed at extreme percentile values and probabilistic analyses rerun**

Source: TSPA-Site Recommendation, TDR-WIS-PA-000001 REV 00 ICN 01, Section 5.3

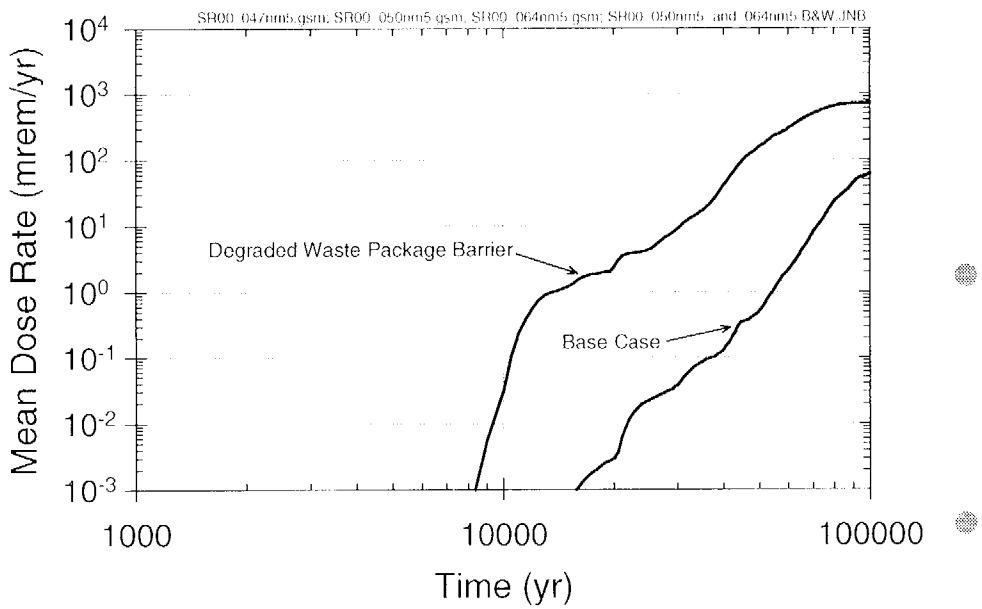
Robustness Analysis

(Continued)

- Results used for determining the importance of variables with a restricted range of uncertainty (typically masked in regression-based uncertainty importance analyses)
- Methodology of stressing system with unfavorable parameter values and/or conceptual models provides a better sense of the range and confidence of performance predictions
- Results indicate whether uncertainty in representing the barrier is significant with respect to predicting system performance

Robustness Analysis

(Continued)



Source: TSPA-Site Recommendation, TDR-WIS-PA-000001 REV 00 ICN 01

- **Several waste package degradation parameters simultaneously set to extreme percentile values**
- **Earlier waste package failure and higher release with degraded barrier**
- **Uncertainty in waste package performance significant to total system performance**

Neutralization Analysis

- **Probabilistic analysis to determine importance of individual barriers**
- **Extreme form of robustness analyses**
  - **Barrier remains in place**
  - **Ability to retard and/or attenuate water and/or radionuclide movement is completely ignored**
- **Several simulation scenarios possible**
  - **"One-offs" to evaluate contribution of a barrier to performance (e.g., what-if analyses)**
  - **"Two-offs" to evaluate contribution of combination of barriers (e.g., defense-in-depth)**

Source: Repository Safety Strategy, Vol. 2 TDR-WIS-RL-000001 REV 04 ICN 01

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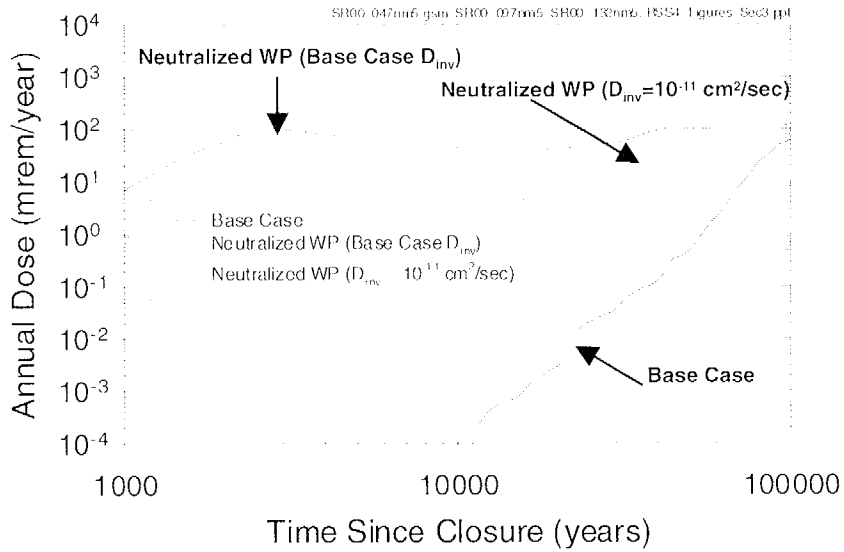
Neutralization Analysis

(Continued)

- **Provides insight into TSPA model**
  - **Results identify areas where uncertainty may be important (i.e., significance of unquantified uncertainties and bounding/conservative assumptions)**
  - **Results help determine factors that**
    - **Contribute substantially to postclosure performance**
    - **Provide significant defense-in-depth**
- **Can help examine issues of barrier independence and interdependence**
- **Can differentiate contributions of barriers that perform similar functions**

Neutralization Analysis

(Continued)



Source: Repository Safety Strategy, Vol. 2
TDR-WIS-RL-000001 REV 04 ICN 01

- **Effect of assuming all waste packages breached at 100 years after closure**
- **Calculations repeated with different diffusion transport model for drift invert**
- **Results show importance of waste package barrier for waste isolation**

Comparison of Barrier Analysis Techniques

- **Pinch point and intermediate performance analyses more appropriate for**
  - Showing capability of individual barriers to prevent or substantially delay movement of radionuclides
  - Showing individual barrier contributions to waste isolation
- **Robustness and neutralization analyses more appropriate for**
  - Differentiating contributions of barriers that perform similar functions
  - Examining impact of extreme scenarios
  - Corroborating reasonable assurance arguments
- **Need to supplement quantitative analyses with descriptive treatment of barrier capabilities**

Path Forward to License Application

- Finalize approach for multiple barrier analysis, including scope for enhanced descriptive treatment of capabilities of barriers to isolate waste
- Document approach in TSPA-License Application Methods and Assumptions Document
- Demonstrate methodology - results will be available for NRC review as they are developed

Meeting the Regulatory Requirements

- 63.102(h) ⇒ Multiple barriers required to ensure expected annual dose to critical group is less that 25* mrem Total Effective Dose Equivalent
  - Inherent to design evolution process
- 63.113(a) ⇒ Geologic repository to include multiple barriers – both natural and engineered
  - Inherent to design evolution process
- 63.114(h) ⇒ Identify natural and engineered barriers important to waste isolation
  - Barriers will be identified and role in preventing or substantially delaying movement of water will be described

*EPA standard of 40 CFR Part 193 is 15 mrem

Meeting the Regulatory Requirements
(Continued)

- **63.114(i) ⇒ Describe capability of barriers important to waste isolation**
  - **Combination of analyses will be used to describe barrier capability and to support identification of barriers important to waste isolation**
  - **Uncertainties explicitly taken into account in TSPA model**
- **63.114(j) ⇒ Provide technical basis for analyses in support of barriers capability to isolate waste**
  - **Technical basis for process models and TSPA model abstractions provided as part of TSPA**
  - **Technical basis for specific multiple barrier analyses (e.g., assumptions, system modifications, etc.) will be provided**

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Conclusions

- **Proposed multiple barrier analysis approach**
  - **Assists in describing barrier capability and contribution to performance**
  - **Accounts for uncertainties in characterizing and modeling barriers**
  - **Addresses interdependency of barriers and spatial variability in performance of the barriers**
  - **Accounts for time evolution of barrier characteristics**
- **Based on the implemented techniques and proposed complementary application of all techniques for TSPA-License Application, DOE believes that Subissue 1, Multiple Barriers is closed-pending**

MODEL VALIDATION AND COMPUTER CODE VERIFICATION:

NRC REGULATORY PERSPECTIVE

U.S. DEPARTMENT OF ENERGY/
U.S. NUCLEAR REGULATORY COMMISSION
TECHNICAL EXCHANGE ON
TOTAL SYSTEM PERFORMANCE ASSESSMENT
Las Vegas, Nevada
August 6-9, 2001

Michael P. Lee
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
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MODEL VALIDATION: BACKGROUND

- COMPUTER MODELS WILL BE USED TO EVALUATE LONG-TERM PERFORMANCE OF PROPOSED GEOLOGIC REPOSITORY

- CONFIDENCE[1] IN MODELS IS LIKELY TO BE KEY ISSUE AT TIME OF LICENSING
  - DECISION-MAKING BASED ON MODELING OF PHYSICAL/ ENGINEERING PROCESSES AND SYSTEMS
  - NEED TO ESTABLISH CONFIDENCE IN MODELS THAT REPRESENT (ABSTRACTED) PHYSICAL/ ENGINEERING PROCESSES AND SYSTEMS ARE APPROPRIATE

- USUAL AVENUE FOR DEVELOPING CONFIDENCE IN COMPUTER MODELS IS PRECLUDED
  - SPACE AND TIME SCALES
  - UNCERTAINTIES AND COMPLEXITIES IN MODELING REPOSITORY SYSTEM

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[1] i.e., "VALIDATION"

REGULATORY PERSPECTIVE: CONFIDENCE BUILDING

- *QUESTION:*
  - HOW MUCH CONFIDENCE IS NEEDED IN MODELS USED TO DEMONSTRATE COMPLIANCE WITH REGULATIONS ?

- *ANSWER*[2]*:*
  - CONFIRM THAT THE RELEVANT NUMERICAL PERFORMANCE STANDARDS HAVE BEEN MET
  - CONFIRM THAT THE REPOSITORY DEVELOPER'S ANALYSES OF SITE AND DESIGN ARE:
    - REALISTIC WITH REASONABLE CONSERVATISM FOR UNCERTAINTIES
    - LIMITATIONS IN THE ANALYSES ARE WELL UNDERSTOOD
    - APPROPRIATE ALLOWANCES HAVE BEEN MADE FOR TIME PERIOD, HAZARDS, AND UNCERTAINTIES
  - LEVEL OF CONFIDENCE SHOULD BE PROPORTIONAL TO IMPORTANCE TO PERFORMANCE

---

[2] CONSISTENT WITH PROPOSED PART 63

THE DILEMMA IS.....

- LACK OF CONSENSUS ON WHAT "VALIDATION" IS AND HOW IT CAN BE ACHIEVED

- VAST LITERATURE EXISTS ON SCIENTIFIC MODEL VALIDATION REPRESENTING DIVERSE VIEWS

- RECOGNITION OF DIFFERENCES BETWEEN THE GOAL OF SCIENTIFIC VALIDATION AND THE NEED TO DEVELOP CONFIDENCE THAT A MODEL SUFFICIENTLY VALID FOR REGULATORY PURPOSES

- INTERNATIONAL EFFORTS TO ACHIEVE CREDIBILITY AND CONFIDENCE PERFORMANCE ASSESSMENT MODELS [3]

  - **INTERNATIONAL STRIPA PROJECT**
  - INTERNATIONAL TRANSPORT MODEL VALIDATION (**INTRAVAL**) PROGRAM
  - BIOSPHERIC MODEL VALIDATION STUDY (**BIOMOVS**)
  - **CHEMVAL**
  - DEVELOPMENT OF COUPLED MODELS AND THEIR VALIDATION AGAINST EXPERIMENTS (**DECOVALEX**)

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[3] OTHERS INCLUDE **INTRACOIN** AND **HYDROCOIN**

NRC/SKI WHITE PAPER
NUREG-1636 – SKI REPORT 99:2

- JOINT EFFORT BETWEEN STAFF MEMBERS OF THE NRC, THE SWEDISH NUCLEAR POWER INSPECTORATE (SKI), AND THE CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

- OUTLINES AUTHOR'S[4] VIEWS ON AN APPROACH TO MODEL VALIDATION FROM A REGULATORY PERSPECTIVE FOR LICENSING A GEOLOGIC REPOSITORY

- IDENTIFIES TYPES OF INFORMATION REGULATORS WOULD EXPECT TO FIND IN AN ACCEPTABLE MODEL VALIDATION APPROACH

- IS NOT INTENDED AS FORMAL STAFF GUIDANCE OR AS A *DE FACTO* STAFF POSITION

- REFLECTS CURRENT THINKING OF THE AUTHORS IN BOTH AGENCIES

- NRC STAFF INTENT IS TO INTEGRATE CONCEPTS INTO YUCCA MOUNTAIN REVIEW PLAN (CURRENTLY UNDER DEVELOPMENT)

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[4] NRC: N. Eisenberg, M. Lee, M. Federline
SKI: S. Wingefors, J. Andersson, S. Norrby
CNWRA: B. Sagar, G. Wittmeyer

NUREG-1636 – SKI REPORT 99:2 RECOMMENDATIONS

- PRIMARY RESPONSIBILITY FOR MODEL VALIDATION RESTS WITH REPOSITORY DEVELOPER

- DEGREE OF VALIDATION NECESSARY SHOULD BE COMMENSURATE WITH THE EXTENT TO WHICH THE SAFETY CASE DEPENDS ON MODEL(S) IN QUESTION

- REPOSITORY DEVELOPER WILL NEED TO:
  - ESTABLISH ADEQUACY OF THE SCIENTIFIC BASIS FOR MODEL(S)
  - DEMONSTRATE THAT THE MODEL(S) IS SUFFICIENTLY ACCURATE

- DEGREE OF MODEL VALIDATION IN REGULATOR'S MODELS MAY BE LESS RIGOROUS
  - REVIEW INTENDED TO BE INDEPENDENT CONFIRMATION
  - FUNDAMENTAL DEMONSTRATION OF REPOSITORY SAFETY RESTS WITH THE DEVELOPER, NOT WITH THE REGULATOR

NUREG-1636 – SKI REPORT 99:2 RECOMMENDATIONS (continued)

- EXAMPLE APPROACH OF A MODEL VALIDATION STRATEGY (FIGURE 3 OF NUREG-1636 – SKI REPORT 99:2)

  1. DEFINE A COMPLIANCE DEMONSTRATION STRATEGY
  2. DETERMINE GOALS FOR MODEL VALIDATION
  3. DETERMINE THE EXISTING DEGREE OF VALIDATION FOR THE MODEL(S) SELECTED
  4. COMPARE VALIDATION GOALS TO EXISTING DEGREE OF VALIDATION
  5. DECIDE WHETHER TO REVISE COMPLIANCE DEMONSTRATION STRATEGY
  6. OBTAIN FURTHER SUPPORT/INFORMATION
  7. DOCUMENT STATEMENTS OF MODEL VALIDITY

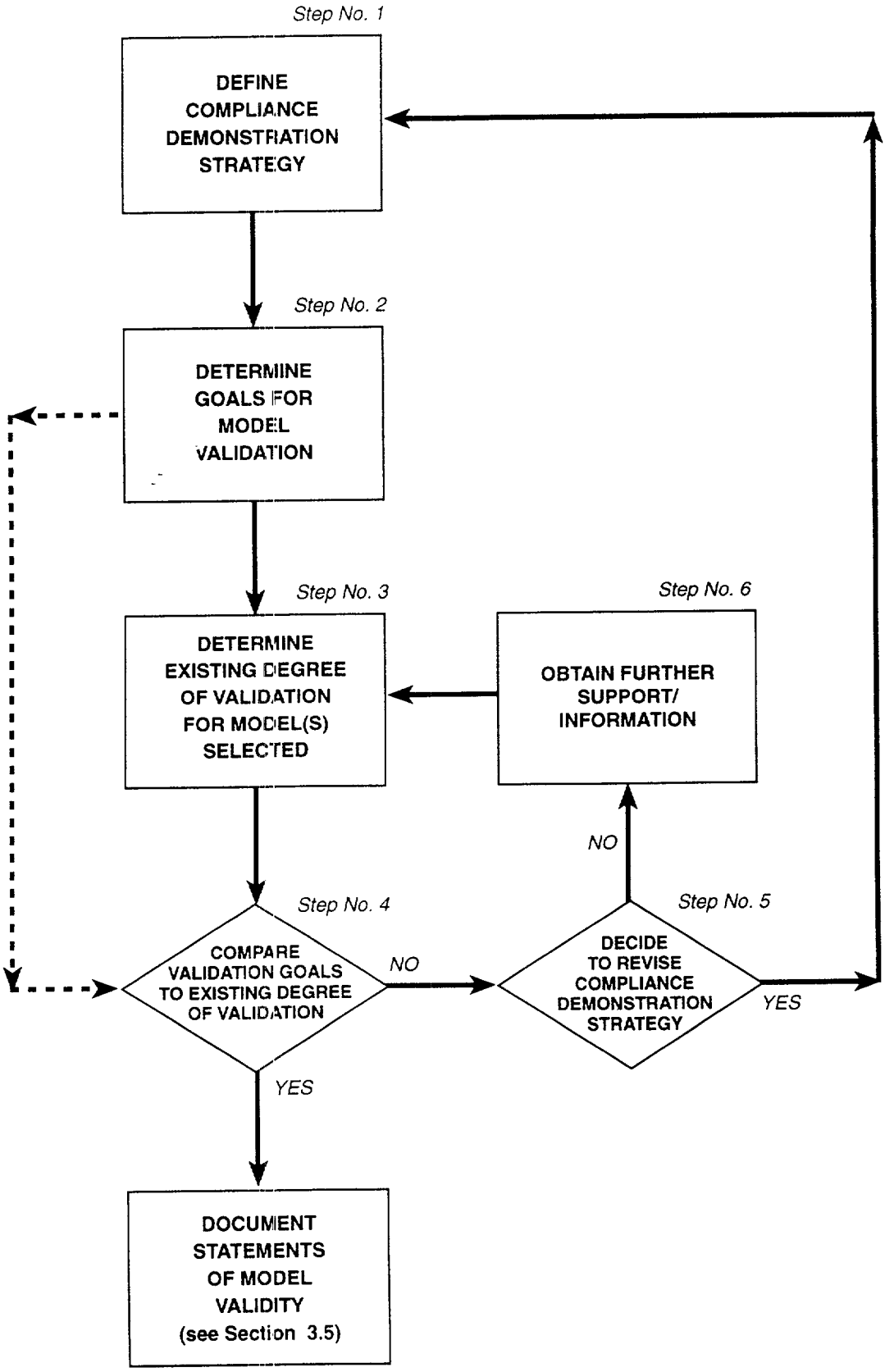

Figure 3. Regulatory strategy for developing confidence in models.

COMPUTER CODE VERIFICATION

- INTEGRAL TO MODEL VALIDATION
- IMPORTANT ELEMENT OF REPOSITORY DEVELOPER'S QUALITY ASSURANCE (QA) PROGRAM
- OVERALL QA REQUIREMENTS FOUND IN SUBPART G OF PROPOSED PART 63
- SPECIFIC NRC GUIDANCE CAN BE FOUND IN THE FOLLOWING:

NUREG-0856	FINAL TECHNICAL POSITION ON DOCUMENTATION OF COMPUTER CODES FOR HIGH-LEVEL WASTE MANAGEMENT
NUREG/BR-0167	SOFTWARE QUALITY ASSURANCE PROGRAM AND GUIDELINES
NUREG/CR-4640	HANDBOOK OF SOFTWARE QUALITY ASSURANCE TECHNIQUES APPLICABLE TO THE NUCLEAR INDUSTRY
NUREG/CR-4369	QUALITY ASSURANCE (QA) PLAN FOR COMPUTER SOFTWARE SUPPORTING THE U.S. NUCLEAR REGULATORY COMMISSION'S HIGH-LEVEL WASTE MANAGEMENT PROGRAM

Verification and Validation: Staff Reviews and Comments

presented by
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NRC/DOE TSPAI Issue Resolution
Technical Exchange

Las Vegas, Nevada
August 6-10, 2001

Working Definitions

- Verification (Software)
  - Provides assurance that a computer code correctly performs the operations specified in a numerical model

- Validation (Model)
  - Provides assurance that a model (e.g., conceptual or mathematical) as embodied in a computer code is a correct representation of the process or system for which it is intended

Verification: What is Involved?

- Conduct tests to provide adequate evidence of
  - Correct and successful implementation of algorithms
  - Correct model calculations over the whole uncertainty range of relevant data
  - Appropriate level of agreement with analytical models and other well-established software
- Implementation of adequate quality assurance and review procedures
  - Follow a well-defined and rational assessment procedure
  - Apply procedures across the software consistently
  - Document the verification process, potential deficiencies, and limitations
  - Disclose results fully

Validation: What is Involved?

- Provide information to demonstrate that
  - Processes are properly formulated mathematically and parameterized following "commonly" accepted theories
  - Model accurately represents a specific component (e.g., waste package) or aspect (e.g., heat flow) of a real system
  - If a new theory is used [e.g., the active fracture model] then the new theory is tested
  - Numerical schemes used have acceptable convergence properties
  - Dimensionality (space and time) is appropriate
  - Simplification does not introduce "optimistic" biases

Verification (Software)

Results of Staff Review

- General:
  - DOE has the elements of verification in their TSPA-SR and supporting documents, but rigorous verification yet to be accomplished
  - No verification plan
  - Verification not uniform across the document
  - Limited set of random hand calculations do not represent a systematic approach to verification

Results of Staff Review (cont'd)

- Specific:
  - Various errors found in DOE hand calculations
  - Abstracted models used outside the range for which they were developed
  - Significance of warnings and errors in the GoldSim error log file not explained
  - TSPA model behavior verification did not include extremes of the input values
  - Verification did not step through different parts of the model in large segments of the TSPA code

Current Status

- TSPA-SR Technical Document has several good examples of appropriate level of detail to explain how the models function. Examples:
  - Figures 4.1-10, 4.1-13, and 4.1-14
  - Discussions on pages 3-93 and 4-8 of the TSPA-SR Technical Document
- DOE has responded to the concerns noted in the May 17, 2001 letter from Reamer to Brocoum
- NRC is reviewing DOE's July 6, 2001, response

Path Forward (Summary)

- Provide a plan/strategy to verify and document the calculations and computer codes supporting TSPA
- Provide minimum requirements for completing verification
- Provide a plan for how verification action and results will be documented

Validation (Model)

Results of Staff Review

- DOE's model validation efforts are ineffective
  - Two Corrective Action Reports (CARs) have been issued
    - CAR BSC-01-C-001
      - Failure to consistently implement quality assurance (QA) program requirements (AP3.10Q)
    - CAR YMSCO-01-C-002
      - Failure to implement Quality Assurance program related to software
      - Lack of effective independent verification and validation

Results of Staff Review (Cont'd)

- Validation efforts are too limited
  - DOE has validated conceptual models but not the corresponding mathematical models (e.g., biosphere)
  - Objective comparisons are not provided for the constituent models
  - Validating a detailed process model does not validate the corresponding abstracted model
  - Rigorous model validation at the system level has either not been conducted or has not been adequately reported
  - DOE requirements for model validation (AP-3.10Q) have not been consistently implemented
- Use of peer review
  - Peer review is not a substitute for objective information that is reasonably available (e.g., field data, laboratory data, or natural analog information)

What Needs to be Done?

- DOE needs to define model validation program (strategy/plan)
  - A comprehensive strategy/plan that is transparent and traceable
  - Extent of model validation is commensurate with importance to performance (i.e., all models should be validated, but the important models should be validated more rigorously)
- Validation strategy should include the following attributes:
  - Theoretical support for models
  - Additional lines of supports
    - Natural analogs
    - Field tests {provide technical basis for selection}
    - Laboratory studies
  - Peer review can be used but not as a first recourse

What Needs to be Done? (cont'd)

- An example strategy has the following elements:
  - Define a compliance demonstration strategy
  - Determine the goals for model validation
  - Determine the existing degree of validation for the selected model(s)
  - Compare the validation goals to the existing degree of validation
  - Decide whether to revise the compliance demonstration strategy
  - Obtain additional information to support validation of the preferred model (where appropriate)

What Needs to be Done? (cont'd)

- Provide appropriate documentation
  - Document statements of model validity (i.e., a framework to facilitate acceptance (or rejection) of models used
    - Use transparent and logical reasoning
    - Show all steps of implementation of model validation strategy
    - Document the extent of peer review. Peer-reviewed material should find support from quantitative analyses of experiments or other proofs
  - Show explicitly validation results against the validation criteria

Path Forward (Summary)

- Provide an appropriate plan/strategy to validate the models
- Justify the qualitative and/or quantitative validation criteria in the plan and discuss further in the TSPA and other supporting models/results documents
- Provide documentation that the approach taken to validate the TSPA model satisfies the requirements of an adequate quality assurance procedure
- Provide appropriate documentation with statements of model validity with validation results against validation criteria

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Total System Performance Assessment and Integration Key Technical Issue Subissue 4 - Overall Performance

Presented to:
DOE/NRC Technical Exchange on the Total System Performance Assessment and Integration Key Technical Issue

Presented by:
Jerry NcNeish
Performance Assessment Department
Bechtel SAIC Company, LLC/Duke Engineering

August 6 - 9, 2001
Las Vegas, Nevada

Outline

- Objectives
- For Subissue 4 in the Total System Performance Assessment and Integration Issue Resolution Status Report, Revision 3, this presentation will
  - Identify current subissue status
  - Identify acceptance criteria
  - Summarize technical basis for resolution
  - Identify basis documents
  - Summarize technical adequacy of basis
- Conclusions

Objectives

- Present the important aspects of Total System Performance Assessment (TSPA) software and model verification and validation
- Discuss the stability of overall performance results
- Describe the basis for resolving Subissue 4, in the Total System Performance Assessment and Integration Issue Resolution Status Report, Revision 3

Current Subissue Status

- **Total System Performance Assessment and Integration Issue Resolution Status Report, Revision 3, indicates this Subissue is Open**

Acceptance Criteria

- Scenarios used in the calculation of the expected annual dose as a function of time are adequate
- Adequate demonstration that the average annual dose to the average member of the critical group in any year during the compliance period does not exceed 25 mrem Total Effective Dose Equivalent*
- TSPA code provides a credible representation of repository performance

*Limit as specified in the proposed 10CFR Part 63.
EPA standard in 40 CFR Part 197 is 15 mrem

Acceptance Criteria

(Continued)

- **Evaluation of a human intrusion event demonstrates that the average annual dose to the average member of the critical group in any year during the compliance period is acceptable. TSPA code provides a credible representation of the human intrusion event**
- **Adequate comparative evaluation of alternatives to the major design features that are important to repository performance is provided**

Acceptance Criteria

(Continued)

- **Summary of information needs identified by NRC**
  - **Software verification**
  - **Model verification**
  - **Model validation**
  - **Stability of analyses and calculations**
  - **Discretization of model**

Acceptance Criteria

(Continued)

- **Basis for closure**
  - **Demonstration of model verification and validation**
  - **Demonstration of proper use of alternative conceptual models**
  - **Evaluation of dose results from TSPA model, including human intrusion and alternative design evaluations**
- **References**
  - ***Total System Performance Assessment for Site Recommendation*, TDR-WIS-PA-000001 REV 00 ICN 01**
  - ***Total System Performance Assessment (TSPA) Model for the Site Recommendation*, MDL-WIS-PA-000002 REV 00**
  - ***GoldSim Version 6.04.007*. Validation Test Report**

TSPA Software Verification

- **Verification ensures that software performs as intended**
- **GoldSim software utilized for development of TSPA model**
  - **GoldSim developed by Golder Associates**
  - **Verified internally by Golder**
  - **Recent review of software configuration management system for GoldSim found adequate software configuration control and verification**
- **Verification of other software modules linked to GoldSim is being performed**

TSPA Model Verification

- Model developed within GoldSim software
- Model utilized functions within GoldSim
- Additional modules, dynamically linked libraries (dlls) "plugged in" to GoldSim for specific functions (e.g., FEHM, WAPDEG, other specific dlls)
- Verification testing
  - Intermediate results in TSPA model checked to ensure subsystem linkages function properly
  - Expected value case results checked to ensure overall system model performs properly

TSPA Model Verification

(Continued)

- "What if" analyses conducted to ensure that linked models work properly, and give expected results
- Subsystem conceptual framework integrated within TSPA model
- Assumptions and parameter values checked for consistency across the TSPA model

TSPA Model Validation

- Validation of a system model involves both submodel and integrated model validation
- Supporting submodels validated prior to implementation into TSPA in Analysis/Model Reports
- Alternate conceptual models filtered at subsystem level, others at TSPA level
- TSPA system model validation (ongoing activities)
  - Utilization of the subsystem model validations
  - Incorporation of natural analog analyses
  - Confidence building from external reviews

YUCCA MOUNTAIN PROJECT

TSPA Model Validation

(Continued)

- **TSPA system model validation (ongoing activities)**
  - **Comparison with other similar independent analyses (EPRI, State of Nevada) that may also support validation**
  - **Additional analyses and documentation required to validate TSPA model as identified in the TSPA delta table**
  - **Use of simplified calculations as support for reasonableness of TSPA results**
  - **Model validation currently being reviewed as described in TSPA Management Plan (later presentation)**
    - **Includes all Analysis/Model Reports utilized in Site Recommendation**
    - **Going forward, will only validate models to be used in the License Application**

Stability of Analyses and Calculations

- Stability of various aspects of the TSPA model (e.g., stability of mean dose) reviewed by DOE and NRC
- Multiple replicate sample approach being considered to demonstrate stability going forward
- Additional informal confirmatory analyses of stability were conducted

Discretization of TSPA Model

- **TSPA-Site Recommendation model uses spatial/environment binning and selected timesteps**
- **Informal evaluation conducted of the level of discretization's impact on performance**
  - **Timestep selection appears to be appropriate from a dose perspective**
  - **Number of spatial bins appears relatively unimportant (e.g., reduced number of seepage zones resulted in minor change in dose)**
  - **Additional formal analyses of these factors required**
- **Alternative design analysis, along with multiple barrier analysis, should aid in comparative evaluation of alternatives to the major design features**

Conclusions

- TSPA-Site Recommendation provides much of the information required to meet the NRC acceptance criteria
- TSPA model discretization (e.g., time/space) requires further analysis and documentation to justify current model settings
- DOE believes that Subissue 4, Overall Performance, can be statused as closed-pending completion of model stability and verification/validation analyses

Summary Highlights of NRC/DOE Technical Exchange and Management Meeting on Total System Performance Assessment and Integration Features, Events, and Processes

May 15-17, 2001
Las Vegas, Nevada

Introduction and Objectives

This Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (TSPAI) is one in a series of meetings related to the U.S. Nuclear Regulatory Commission (NRC) key technical issue (KTI) and sufficiency review, and the U.S. Department of Energy (DOE) site recommendation decision. Topics within TSPAI KTI will be discussed in two separate technical exchanges. This first technical exchange focuses on the NRC review and comments regarding part of the scenario analysis subissue, specifically the screening of features, events, and processes (FEPs) from the performance assessment. Another technical exchange, currently scheduled for June 25-29, 2001, will focus on the remaining subissues within the TSPAI KTI.

Consistent with NRC regulations on prelicensing consultations and a 1992 agreement with the DOE, staff-level resolution can be achieved during prelicensing consultation. The purpose of issue resolution is to assure that sufficient information is available on an issue to enable the NRC to docket a proposed license application. Resolution at the staff level does not preclude an issue being raised and considered during the licensing proceedings, nor does it prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issue resolution at the staff level, during prelicensing, is achieved when the staff has no further questions or comments at a point in time regarding how the DOE is addressing an issue. The discussions recorded here reflect NRC's current understanding of the screening of FEPs within DOE's performance assessment. This understanding is based on all information available to date which includes limited, focused, risk-informed reviews of selected portions of recently provided DOE documents (e.g., Analysis and Model Reports (AMRs) and Process Model Reports (PMRs)). Pertinent additional information (e.g., changes in design parameters) could raise new questions or comments regarding a previously resolved issue.

Although the status of the TSPAI subissues will not be discussed in this meeting, NRC discussed the issue resolution definitions in the beginning of the meeting. Specifically, NRC stated that issues are "closed" if the DOE approach and available information acceptably address staff questions such that no information beyond what is currently available will likely be required for regulatory decision making at the time of any initial license application. Issues are "closed-pending" if the NRC staff has confidence that the DOE proposed approach, together with the DOE agreement to provide the NRC with additional information (through specified testing, analysis, etc.) acceptably addresses the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at time of initial license application. Issues are "open" if the NRC has identified questions regarding the DOE approach or information, and the DOE has not yet acceptably addressed the questions or agreed to provide the necessary additional information in a potential license application.

Summary of Meeting

At the close of the Technical Exchange and Management Meeting, NRC and DOE reached a number of preliminary agreements which will be carried forward to the June 25-29, 2001, TSPAI Technical Exchange and Management Meeting. The preliminary NRC/DOE agreements made at the meeting are provided in Attachment 1. A table containing all the FEPs discussed during the meeting and their associated NRC/DOE agreed upon path forward is included in Attachment 2. The agenda and the attendance list are provided in Attachments 3 and 4, respectively. Copies of the presenters slides are provided in Attachment 5. Additional FEP comments, not discussed during this meeting (e.g., Unsaturated Zone Flow and Transport FEPs), will be addressed in the June technical exchange. Highlights from the Technical Exchange and Management Meeting are listed below.

Highlights

1) Opening Comments

In its opening comments, NRC provided a general overview of performance assessment and scenario analysis (see "Background for Total System Performance Assessment - Features, Events, and Processes Meeting" presentation given by James Firth). NRC stated that the performance assessment is one of many NRC safety requirements and is a systematic analysis of what could happen at a repository. NRC also defined some of the terms that would be used during the meeting, such as scenario, probability, consequence, scenario analysis, screening, and features, events, and processes. Finally, NRC stated that during the meeting it would address two main issues, specifically, whether DOE's list of FEPs is complete and whether DOE has an adequate technical basis to support the screening choice.

2) TSPAI KTI Subissue 2 - Scenario Analysis

DOE provided an overview of the FEP methodology, including the identification of FEPs, the classification of FEPs, and the screening of FEPs (see "Total System Performance Assessment and Integration Key Technical Issue Subissue 2 - Scenario Analysis" presentation given by Peter Swift and Geoff Freeze). DOE also discussed its electronic database and DOE's perspective on the status of the TSPAI acceptance criteria.

DOE stated that the objectives of the FEP methodology are to: (1) provide comprehensive documentation that potentially relevant FEPs have been considered, (2) identify the FEPs that should be included in the quantitative performance assessment scenario analysis, (3) document the bases for excluding FEPs from the performance assessment, and (4) map included FEPs to the performance assessment model. DOE discussed the basis for the current list of FEPs; specific sources include: (1) the Nuclear Energy Agency international database; (2) the Yucca Mountain Project literature; (3) DOE internal technical review; and (4) NRC review.

DOE then discussed the classification of FEPs; currently designated as primary and secondary FEPs. DOE stated that primary FEPs encompass a single process or event, or a few closely related or coupled processes. The primary FEPs are aggregated to the coarsest level at which a technically sound screening decision can be made while still maintaining adequate detail for

analysis. Primary FEPs include all issues from underlying secondary FEPs. DOE further stated that the scope of a given primary FEP may be broader than that encompassed by associated secondary FEPs.

Next, DOE discussed the screening of FEPs. DOE stated that FEPs are screened based on regulatory criteria, probability, or consequence (conditional or probability weighted). DOE further stated that screening is performed at the primary FEP level. Based on the results from the Total System Performance Assessment - Site Recommendation, DOE stated that 152 out of 328 primary FEPs have been excluded from the performance assessment.

Lastly, DOE discussed its electronic FEP database and a general overview of the NRC acceptance criteria documented in Revision 3 of the TSPAI Issue Resolution Status Report (IRSR). DOE stated that the database tracks FEP identification and screening, and enhances transparency and traceability. DOE stated that the new database addressed all the FEP issues raised in Revision 3 of the TSPAI IRSR.

Following the DOE presentation, the NRC had a number of questions with regard to DOE's FEP methodology. NRC questioned DOE about the philosophy used for the difference between the scope of secondary FEPs and their associated primary FEP. DOE indicated that they used secondary FEPs from other projects, but that their intent was not to define new secondary FEPs. DOE stated that their intent is that primary FEPs contain all relevant technical information. DOE also stated that the underlying secondary FEPs, from which the primary FEPs were derived are artifacts of the database construction. A question was asked regarding how DOE adds FEPs to the database, specifically why DOE adds FEPs after they are introduced through a FEP AMR, rather than identifying the FEP and then to address the FEP in a later revision to a FEP AMR. DOE indicated that FEPs are added to the database when corresponding analyses indicate that additions are warranted. DOE was asked about how they tracked design assumptions used to screen FEPs from the performance assessment to make sure that the screening assumptions and the final design are consistent. DOE stated that design changes could affect screening arguments. DOE indicated that configuration management controls are adequate for pre-conceptual design, however, controls will adopt more rigor as the design advances.

3) NRC Positions on Treatment of FEPs

The NRC discussed its views and comments on FEPs screening methodology (see "FEP Screening Methodology: NRC Staff Views and Comments" presentation given by Michael Lee). NRC stated that proposed 10 CFR Part 63 (Part 63) requires a technical basis for either including or excluding those FEPs that might potentially affect the performance of a geologic repository at Yucca Mountain. However, proposed Part 63 does not specify the manner by which DOE should investigate FEPs. NRC staff then provided their perspective on four issues relating to scenario analysis:

1) Can design be used as a criterion to screen FEPs?

2) Can both qualitative and quantitative arguments be used to screen FEPs?

3) What is the time period of regulatory interest for any FEP screening methodology?

4) To what extent should a FEP resulting as a consequence of human-intrusion be factored into the stylized human intrusion calculation?

The NRC staff's views regarding these issues can be found in "NRC Comments on DOE Features, Events, and Processes - May 15-17, 2001, Technical Exchange" slides which are included in Attachment 5. Following this discussion, DOE questioned whether the final Part 63 would be consistent with the final Environmental Protection Agency (EPA) regulation (40 CFR 197) with regard to the inclusion of unlikely disruptive events in the human intrusion analysis. NRC stated that the final Part 63 would be consistent with the EPA rule in this regard.

Next, NRC presented its preliminary views and comments on the DOE FEP screening methodology. (NRC noted that most of its comments had been introduced as part of the discussions associated with Section 2, "TSPAI KTI Subissue 2 - Scenario Analysis.") Specifically, these comments were:

1) That the FEPs database did not appear to be complete;

2) That several areas had been identified where there may be a lack of correspondence between the scope of the AMRs and the FEPs database;

3) It was not clear that DOE has demonstrated or considered the extent of coupling between FEPs; and

4) The role of the FEP database in DOE decision-making was unclear.

In presenting these comments, the NRC staff noted that DOE was not expected to respond immediately; rather, it was anticipated that specific examples of the staff concerns and DOE responses thereto would be raised in the context of the subsequent discussions for each of the AMRs that would be taking place later in the technical exchange. Finally, NRC provided one general observation. Specifically, that the relegation of FEP attributes among more than one AMR could lead to (a) underestimation of importance of a FEP to performance; or (b) under-representation of the FEP in the performance assessment. Again, NRC stated that this issue will be further discussed in the NRC comments on the DOE FEPs AMRs.

In its overall response, DOE noted the following:

- DOE considers the FEPs database to be complete by virtue of the sources of information used to compile it. In general, DOE noted that practical considerations had driven internal decisions on the number and kind of primary FEPs chosen to represent the range of features, events, and processes believed to be present at Yucca Mountain. If there was a view by NRC staff that a particular FEP was missing, it was requested that it be identified so it could be evaluated by DOE for possible future consideration.

- To the extent that there may be discrepancies, DOE welcomed their identification.

- DOE believes that coupling between FEPs has been addressed by virtue of (a) the individual FEP screening arguments themselves; and (b) the appropriate process models intended to describe the FEPs of interest.

- The value of using a computerized database to manage FEPs information was discussed. However, DOE noted that the primary source of information for FEPs identification was the Nuclear Energy Agency database, project literature search, and the AMRs. Nevertheless, DOE did note that its thinking regarding the role of the FEPs database programmatically was still evolving, especially as elements of its overall performance assessment methodology and configuration management of the DOE design process. As part of its future program planning related to any potential license application submittal, DOE noted that it has not finalized the role of the database.

4) Discussion of NRC Comments on DOE FEPs

During this portion of the meeting, NRC and DOE discussed NRC comments related to the FEPs database and supporting FEPs AMRs. The NRC comments were broken down and discussed under the appropriate DOE FEPs AMR (see "NRC Comments on DOE Features, Events, and Processes - May 15-17, 2001, Technical Exchange" slides in Attachment 5). The specific FEPs discussed during this technical exchange, and the NRC/DOE agreed path forward for each related comment, are summarized in Attachment 2. Preliminary NRC/DOE agreements are discussed in Attachment 1 and reference the specific path forward information in Attachment 2. These preliminary agreements will be carried forward to the June 25-29, 2001, Technical Exchange and Management Meeting and will be included in the overall discussion of TSPAI Subissue 2.

During the meeting, NRC raised questions about the scope of several primary FEPs and about the differing level of detail encompassed by the primary FEPs. Rising from the discussions held during the meetings, NRC made the following observation.

Proposed Part 63 requires a systematic analysis of FEPs that might potentially affect the performance of a geologic repository at Yucca Mountain. Although it does not specify the manner by which FEPs should be investigated, proposed Part 63 requires that DOE "...provide the technical basis for either inclusion or exclusion of specific features, events, and processes...." The staff is interested in a transparent, traceable, and technically defensible investigative process that leads to a clear understanding of DOE's basis for FEP inclusion or exclusion. Based on the NRC staff review of the pertinent DOE documents, these attributes are not readily apparent for some FEPs. In addition, the level of information used to describe the scope of primary FEPs appears to vary. Therefore, the comprehensiveness of the FEPs list is not apparent. Specific examples were provided by the NRC during the technical exchange.

In response to this observation, the DOE acknowledged the importance of the FEPs to DOE's TSPA process and the FEP database to indicate the disposition of FEPs. DOE agreed with the NRC's concern, for the most part, and committed to clarify the FEP arguments in specific AMRs. DOE indicated that NRC should continue to focus on the primary FEPs and their associated arguments during its review, noting that the secondary FEPs are historical in nature. As a path forward, DOE also proposed to discuss improvements to the FEPs process at the June technical exchange, including a description of the method for adding new FEPs. In

addition, at the June technical exchange, DOE indicated it would also discuss the role of FEPs versus models, how they fit together, and how they roll up in the TSPA. NRC agreed that this was an acceptable path forward and would clarify details in the telephone conversations preparing for the next technical exchange.

During the discussion of the NRC comments, DOE indicated that several FEPs had been excluded because of conservatism in the uncertainty range for TSPA parameters. NRC indicated that to be transparent, the TSPA disposition should indicate these FEPs are included in the performance assessment, instead of being excluded.

Two other issues were addressed during this part of the meeting. Specifically, that: (1) insufficient information is provided on propagation of uncertainties in spent nuclear fuel dissolution data, and (2) there has been insufficient use of alternative models for spent nuclear fuel dissolution. After discussing these two issues, DOE agreed to provide additional information in the appropriate AMRs (see Attachment 1 for preliminary agreement wording).

5) Public Comments

No public comments were made.

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Summary of the Resolution of the Key Technical Issue on Total System Performance Assessment and Integration Features, Events, and Processes

Subissue #	Subissue Title	Status	Preliminary NRC/DOE Agreements
2	Scenario analysis within the total system performance assessment methodology	N/A	1) Provide clarification of the screening arguments, as summarized in Attachment 2. See Comment # 5, 7, 8, 9, 10, 13, 18, 19 (Part 5), 21, 29, 32, 41, 43, 44, 47, 49, 50, 51, 53, 58, 67, 78, and 79. DOE will clarify the screening arguments, as summarized in Attachment 2, for the highlighted FEPs. The clarifications will be provided in the referenced FEPs AMR and will be provided to the NRC in FY02 and FY03. 2) Provide the technical basis for the screening argument, as summarized in Attachment 2. See Comment # 19 (Parts 1, 2, and 6), 25, 26, 36, 37, 38, 39, 57, 60, and 61. DOE will provide the technical basis for the screening argument, as summarized in Attachment 2, for the highlighted FEPs. The technical basis will be provided in the referenced FEPs AMR and will be provided to the NRC in FY02 and FY03. 3) Add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. See Comment 19 (Part 7 and 8) and 20. DOE will add the FEPs highlighted in Attachment 2 to the appropriate FEPs AMRs. The FEPs will be added to the appropriate FEPs AMRs and the AMRs will be provided to the NRC in FY02 and FY03.

			4) Provide a clarification of the description of the primary FEP. See Comments 24, 31, and 33. DOE will clarify the description of the primary FEPs, as summarized in Attachment 2, for the highlighted FEPs. The clarifications will be provided in the referenced FEPs AMR and will be provided to the NRC in FY02 and FY03. 5) DOE needs to demonstrate how errors propagate in performance assessment from conservative (fast) rates of spent fuel dissolution. In addition, DOE needs to demonstrate that uncertainties in rates of spent fuel dissolution under low pH conditions are adequately represented in the performance assessment model, given the limited set of data. DOE will clarify propagation of uncertainties in spent fuel dissolution rates through TSPA in the In-package Chemistry Abstraction AMR, ANL-EBS-MD-000037 in FY02. DOE is conducting low pH flow-through experiments and will update the Commercial Spent Nuclear Fuel Degradation AMR, ANL-EBS-MD-000015 in FY02, as appropriate. In FY02, DOE will demonstrate in the Commercial Spent Nuclear Fuel Degradation AMR, ANL-EBS-MD-000015 that the CSNF models do not lead to optimistic results in the 10,000 year regulatory period. 6) DOE has alternative models for spent nuclear fuel dissolution (e.g., drip test results at ANL). DOE needs to clarify why the alternative models have not been incorporated in the DOE TSPA. DOE noted that Argonne National Laboratory Spent Nuclear Fuel drip tests corroborate the flow-through model. Other tests indicate that the model is bounding. This discussion in the Commercial Spent Nuclear Fuel Degradation AMR, ANL-EBS-MD-000015 will be clarified in FY02. In FY02, DOE will demonstrate in the Commercial Spent Nuclear Fuel Degradation AMR, ANL-EBS-MD-000015 that the models do not lead to optimistic results in the 10,000 year regulatory period.

Total System Performance Assessment and Integration
Features, Events, and Processes
Attachment 2

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
1	Generic	SZ		NRC stated that it is withdrawing the comment, no additional DOE action is required.
2	1.3.07.02.00	SZ	Water Table Rise	No additional DOE action is required.
3	2.2.10.03.00	SZ	Natural Geothermal Effects	This issue is addressed by existing DOE/NRC agreement (USFIC Subissue 5 Agreement 13). The Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 will be updated as necessary to reflect the results of this existing agreement.
4	1.2.06.00.00	SZ	Hydrothermal activity	This issue is addressed by existing DOE/NRC agreements (RT Subissue 1 Agreement 5 and Subissue 2 Agreement 10). The Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 will be updated as necessary to reflect the results of these existing agreements.
5	2.1.09.21.00	SZ	Suspension of Particles Larger than Colloids	DOE agreed to provide clarification for the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comments.
6	NA	SZ	NA	Initiation, tracking, resolution and closure of To Be Verified's in technical products are procedurally controlled per procedure AP-3.15Q. Resolution of this issue is being addressed at DOE and NRC Management meetings.
7	1.4.06.01.00	SZ	Altered soil or surface water chemistry	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comments. The AMR will also address the aggregate affects of this FEP on UZ and SZ.
8	1.2.04.07.00	SZ	Ashfall	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comment.
9	2.2.10.06.00	SZ	Thermo-chemical alteration (solubility speciation, phase changes, precipitation/ dissolution)	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comment.
10	2.3.11.04.00	SZ	Groundwater discharge to surface	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comment.
11	1.3.07.01.00	SZ	Drought/water table decline	This issue is addressed by existing DOE/NRC agreements (RT Subissue 2 Agreement 8 and USFIC Subissue 5 Agreement 4). The Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 will be updated as necessary to reflect the results of these existing agreements and clarify the screening argument.
12	2.2.10.13.00	SZ	Density-driven groundwater flow (thermal)	This issue is addressed by an existing DOE/NRC agreement (USFIC Subissue 5 Agreement 13). The Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 will be updated to clarify the screening argument and to reflect the results of this existing agreement.
13	2.2.10.02.00	SZ	Thermal convection cell develops in Saturated Zone	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002.
14	1.2.09.02.00	SZ	Large-scale dissolution	No additional DOE action is required.
15	2.3.09.01.00	BIO	Animal Burrowing/Inclusion	NRC stated that it is withdrawing the comment, no additional DOE action is required.
16	2.3.13.01.10	Bio	Natural Ecological Development	No additional DOE action is required.
17	NA	Bio	NA	No additional DOE action is required.
18	1.4.07.01.00	Bio	Water management activities	DOE agreed to provide clarification of the screening argument in the Features, Events, and Processes in SZ Flow and Transport, ANL-NBS-MD-000002 to address the NRC comment.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
19	Various	Bio	BDCF calculations	DOE will provide a technical basis in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*. ANL-MGR-MD-000011 to address the NRC comment for FEP 2.3.11.04.00 (Groundwater Discharge to Surface), FEP 1.3.07.02.00 (Water Table Rise), and FEP 2.2.08.11.00 (Distribution and Release of Nuclides from the Geosphere). No further action is required for FEP 3.2.10.00.00 (Atmospheric Transport of Contaminants) and FEP 1.2.04.01.00 (Igneous Activity). DOE agreed to provide clarification of the screening argument in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*. ANL-MGR-MD-000011, for FEP 2.2.08.02.00 (Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone). DOE will add links to the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*. ANL-MGR-MD-000011 for FEP 3.1.01.01.00 (Radioactive Decay and Ingrowth), and FEP 1.2.04.07.00 (Ashfall).
20	2.2.08.07.00	Bio	Radionuclide solubility limits in the geosphere	DOE will add this FEP to the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*. ANL-MGR-MD-000011 and present the DOE discussion in the screening argument.
21	2.3.13.01.00	Bio	Biosphere characteristics	DOE agreed to provide clarification of the screening argument in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*. ANL-MGR-MD-000011 to address the NRC comment.
22	2.3.13.01.00	Bio	Biosphere characteristics	No additional DOE action is required.
23	2.3.11.04.00	Bio	Groundwater discharge to surface	No additional DOE action is required.
24	2.3.13.02.00	Bio	Biosphere transport	DOE agreed to clarify the description of the primary FEP in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*. ANL-MGR-MD-000011
25	2.4.07.00.00	Bio	Dwellings	DOE agreed to provide the technical basis for the screening argument in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*. ANL-MGR-MD-000011.
26	3.3.08.00.00	Bio	Radon and daughter exposure	DOE agreed to provide the technical basis for the screening argument in the *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*. ANL-MGR-MD-000011.
27	2.1.09.09.00	WP	Electrochemical effects (electrophoresis , galvanic coupling)	NRC stated that it is withdrawing the comment, no additional DOE action is required.
28	2.1.03.04.00	WP	Hydride cracking of waste containers	NRC stated that it is withdrawing the comment, no additional DOE action is required.
29	2.1.06.07.00	WP	Effects at Material Interfaces	This issue is addressed by an existing agreement (CLST subissue 6 Agreement 1). DOE agreed to provide clarification of the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002, as necessary upon completion of the agreement item.
30	2.1.03.05.00	WP	Microbially mediated corrosion of waste container	This will be discussed at the TSPA&I Technical Exchange, June 25-29, 2001.
31	1.2.03.02.00	WP	Seismic vibration causes container failure	DOE agreed to clarify the description of the primary FEP in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002.
32	2.1.13.01.00	WF Misc WP	Radiolysis	DOE agreed to provide clarification of the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 to address the NRC comment.
33	NA	WP	NA	DOE agreed to clarify the description of the primary FEP in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002.
34	2.1.03.02.00	WP	Stress corrosion cracking of Waste Containers	This issue is covered by an existing DOE/NRC agreement (CLST Subissue 2 Agreement 8). DOE will update the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 screening argument upon completion of the agreement.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
35	2.1.03.08.00	WP	Juvenile and early failure of waste containers	Manufacturing defects associated with the drip shield will be addressed during the resolution of an existing agreement item for the waste package (CLST Subissue 2, Agreement 7). The FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 will be updated to reflect the results of this agreement. Mechanical integrity of the drip shield will be addressed during the resolution of an existing agreement item for the waste package (CLST Subissue 2, Agreement 6). The FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 will be updated to reflect the results of this agreement. Rockfall effects on the drip shield will be addressed during the resolution of an existing agreement item for the waste package (CLST Subissue 2, Agreement 8). The FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 will be updated to reflect the results of this agreement. The FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 will be revised to address damage from improper quality control and emplacement of the drip shield. The criteria for damage to waste package during emplacement will be addressed by administrative procedures for emplacement operations that will be developed prior to operation of the facility.
36	2.1.09.03.00	WP	Volume increase of corrosion products	DOE agreed to provide the technical basis for the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 to address the NRC comment.
37	2.1.07.05.00	WP	Creeping of metallic materials in the EBS	Treatment of creep of the drip shield will be addressed as part of an existing agreement related to drip shield rockfall analyses (CLST Subissue 2 Agreement 8). DOE agreed to provide the technical basis for the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002.
38	2.1.11.05.00	WP EBS	Differing thermal expansion of repository components	DOE agreed to provide the technical basis for the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 screening argument to address the NRC comment.
39	2.1.06.06.00	WP DE	Effects and degradation of drip shield	The ability of the additional loading combinations to initiate and/or propagate preexisting cracks are being addressed in existing agreements (CLST Subissue 2 Agreements 8 and 9). DOE agreed to provide the technical basis for the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002.
40	2.1.02.21.00	Clad	Stress corrosion cracking of cladding	This will be discussed at the TSPA&I Technical Exchange, June 25-29, 2001.
41	2.1.02.20.00	WFClad	Pressurization from Helium production causes cladding failure	DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
42	2.1.08.07.00	EBS	Pathways for unsaturated flow and transport in the waste and engineered barrier system	This issue is addressed by an existing DOE/NRC agreement (ENFE Subissue 2 Agreement 6, 10, and 14). The Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 will be updated upon completion of these agreement items.
43	2.1.02.27.00		Localized corrosion perforation from fluoride	This issue is addressed by an existing DOE/NRC agreement (CLST Subissue 3 Agreement 7). DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
44	2.1.02.16.00	WFClad	Localized Corrosion (pitting) of cladding	This issue is addressed by an existing DOE/NRC agreement (CLST Subissue 3 Agreement 7). DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
45	2.1.02.19.00		Creep rupture of cladding	This will be discussed at the TSPA&I Technical Exchange, June 25-29, 2001.
46	2.1.02.24.00	WFClad	Mechanical failure of cladding	This will be discussed at the TSPA&I Technical Exchange, June 25-29, 2001.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
47	2.1.02.17.00	WFClad	Localized corrosion (crevice corrosion) of cladding	DOE agreed to provide clarification of the screening argument in the Clad Degradation – FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment using data relevant to the proposed repository.
48	2.1.01.04.00	WFMisc WP	Spatial heterogeneity of emplaced waste	Spatial variability that may affect degradation of the waste package will be addressed as part of the resolution of an existing agreement (CLST Subissue 1 Agreement 1). The scope of the agreement includes the evaluation of the range of chemical environments on the waste package.
49	2.1.02.15.00	WFClad	Acid corrosion of cladding from radiolysis	This issue is addressed by an existing DOE/NRC agreement (CLST Subissue 3 Agreement 7). DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
50	2.1.02.13.00	WFClad	General Corrosion of Cladding	DOE agreed to provide clarification of the screening argument in the Clad Degradation Features, Events and Processes Analysis/Model Report (ANL-WIS-MD-000008) to address the NRC comment.
51	2.1.02.14.00	WFClad	Microbially induced corrosion of cladding	This issue is addressed by an existing DOE/NRC agreement (CLST Subissue 3 Agreement 7). DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment. The new cladding local corrosion model will reference the In-Drift Microbial Communities AMR, ANL-EBS-MD-000038, which includes discussion of iron oxidizing bacteria. The *Clad Degradation - FEPs Screening Arguments*, ANL-WIS-MD-000008 AMR will be revised to be consistent with the updated Summary-Abstraction AMR.
52	1.2.04.04.00	WFMisc	Magma Interacts w/ Waste	NRC stated that it is withdrawing the comment, no additional DOE action is required.
53	2.1.02.22.00	WFClad	Hydride embrittlement of cladding	DOE agreed to provide clarification of the screening argument in the Clad Degradation - FEPs Screening Arguments, ANL-WIS-MD-000008 to address the NRC comment.
54	2.1.09.02.00	EBS	Interaction w/ Corrosion products	This issue is addressed by an existing DOE/NRC agreements (ENFE Subissue 2 Agreement 6, 10, and 14). The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be updated upon completion of these agreement items.
55	2.1.09.07.00	EBS Misc WF	Reaction Kinetics in Waste and EBS	This issue is addressed by an existing DOE/NRC agreements (ENFE Subissue 2 Agreement 5, 8, 11, and 12). The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be updated upon completion of these agreement items.
56	2.1.07.06.00	EBS	Floor buckling	This issue is addressed by existing DOE/NRC agreements (RDTME Subissue 3 Agreements 2 – 13). DOE agreed to include the analysis of floor buckling for post-closure conditions, consistent with the site-specific parameters and loading conditions used to satisfy RDTME Subissue 3, Agreements 2-13. The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be revised to include this information.
57	1.1.02.03.00	EBS	Undesirable materials left	DOE agreed to provide the technical basis for the screening argument in the Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 to address the NRC comment. This will include a technical basis for the use of the Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction. BABE00000-01717-2200-00007 Rev 04.
58	Various	EBS	NA	DOE agreed to provide clarification of the screening argument in the Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 to address the NRC comment.
59	2.1.08.04.00	EBS	Cold traps	This issue is addressed by an existing DOE/NRC agreement (TEF Agreement Subissue 2 Agreement 5). The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be revised upon completion of this agreement.
60	2.1.12.01.00	EBS	Gas generation	This issue is partially addressed by an existing DOE/NRC agreement (ENFE Subissue 2 Agreement 6). DOE agreed to provide the technical basis for the screening argument in the Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 to address the NRC comment.
61	2.2.10.12.00	NFE UZ	Geosphere dry-out due to waste heat	DOE agreed to provide the technical basis for the screening argument in the Features, Events, and Processes in the *Features, Events, and Processes in UZ Flow and Transport*, ANL-NBS-MD-000001 to address the NRC comment.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
62	2.2.01.02.00	NFE	Thermal and other waste and EBS-related changes in the adjacent host rock	TM effects on fractures will be addressed by existing agreements between DOE and NRC (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work. Long term degradation of the host rock is addressed by existing agreements between DOE and NRC (RDTME Subissue 3 Agreement 11 and 19). DOE will provide an improved technical basis for this FEP by performing a postclosure drift deformation analysis that incorporates postclosure loads and rock properties using relevant information from existing agreements (RDTME Subissue 3 Agreements 2 – 13). The Engineered Barrier System Features, Events, and Processes, ANL-WIS-PA-000002 will be revised to include this information.
63	2.1.09.12.00	NFE	Rind (altered zone) formation in waste, EBS and adjacent rock	This issue is addressed by existing agreements between DOE and NRC (ENFE Subissue 1 Agreement 3). *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
64	2.2.10.06.00	NFE	Thermo-chemical alteration (solubility speciation, phase changes, precipitation/dissolution	This issue is addressed by existing agreements between DOE and NRC (ENFE Subissue 1 Agreement 3). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
65	2.1.11.02.00	NFE	Nonuniform heat distribution/edge effects in repository	Repository wide non-uniform heating effects are the subject of existing DOE/NRC agreements (TEF Subissue 2 Agreement 5, RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work. THM continuum modeling will address non-uniform effects at a mountain scale. This information will be provided in the Coupled Thermal-Hydrologic-Mechanical Effects on Permeability Analysis and Model Report AMR, ANL-NBS-HS-000037.
66	2.2.06.01.00	NFE DE	Changes in stress due to thermal, seismic or tectonic effects	The thermal mechanical effects on rock properties are addressed by an existing DOE/NRC agreement (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 and the Features, Events, and Processes: Screening for Disruptive Events. ANL-WIS-MD-000005 will be revised upon completion of this work.
67	2.2.10.05.00	NFE	Thermo-mechanical alteration of rocks above and below the repository	DOE has planned work to analyze the effects of thermal-hydrologic-mechanical coupled processes with regard to drainage in the pillars and flow in the vicinity of the drifts, and thermal-hydrological/ thermal-hydrological -chemical/ thermal-hydrological-mechanical analyses to quantify uncertainties in the thermal seepage model. In addition, THM continuum modeling will address thermal mechanical effects in rocks above and below the repository at a mountain scale in an update to the Coupled Thermal-Hydrologic-Mechanical Effects on Permeability Analysis and Model Report AMR, ANL-NBS-HS-000037. DOE will clarify the screening arguments in the *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 upon completion of this work.
68	1.2.02.01.00	NFE	Fractures	The thermal mechanical effects on rock properties are addressed by an existing DOE/NRC agreement (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
69	2.2.01.01.00	NFE	Excavation and construction-related changes in the adjacent host rock	The thermal mechanical effects on rock properties are addressed by an existing DOE/NRC agreement (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
70	2.2.10.04.00	NFE	Thermo-mechanical alteration of fractures near repository	The thermal mechanical effects on rock properties are addressed by an existing DOE/NRC agreement (RDTME Subissue 3 Agreement 20 and 21). The *FEPs in Thermal Hydrology and Coupled Processes*, ANL-NBS-MD-000004 will be revised upon completion of this work.
71	1.1.07.00.00	SYS	Repository design	No additional DOE action is required.
72	1.1.08.00.00	SYS	Quality control	No additional DOE action is required.
73	2.3.13.03.00	SYS Bio	Effects of repository heat on biosphere	No additional DOE action is required.
74	Various	SYS	Criticality in waste and EBS	No additional DOE action is required.

Item No.	FEP#	FEP AMR	FEP Name	NRC/DOE Agreed Path Forward
75	Various	DE	Excavation/ Construction Incomplete/ Closure Canister Failure(long term) Mechanical Degradation or Collapse of Drift Topography & Morphology	These issues will be discussed at the May 18, 2001, Igneous Activity Appendix 7 Meeting.
76	Generic	DE	Hydrothermal activity	These issues will be discussed at the May 18, 2001, Igneous Activity Appendix 7 Meeting.
77	2.1.07.02.00	DE	Mechanical degradation or collapse of drift	No additional DOE action is required.
78	1.2.03.02.00	WP DE	Seismic vibration causes container failure	Existing agreements from the Container Life and Source Term (Subissue 2 agreements 2 and 8), Repository Design and Thermal Mechanical Effects (Subissue 3 agreements 17 and 19) and Structural Deformation and Seismicity (Subissue 1 agreement 2 and Subissue 2 agreement 3) address related work. DOE agreed to provide clarification of the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 and Features, Events, and Processes: Screening for Disruptive Events, ANL-WIS-MD-000005.
79	2.1.07.01.00	DE WP	Rockfall (Large Block)	Existing agreements from Repository Design and Thermal Mechanical Effects agreements (Subissue 3 agreements 17 and 19) and Container Life and Source Term (subissue 2 agreements 2, 3 and 8) address related work. DOE agreed to provide clarification of the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 and Features, Events, and Processes: Screening for Disruptive Events, ANL-WIS-MD-000005.
80	2.3.02.02.00	Bio	Radionuclide Accumulation in Soil	These issues will be discussed at the May 18, 2001, Igneous Activity Appendix 7 Meeting.

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SATURATED ZONE

Item No.	FEP#	FEP Name	NRC Comment	DOE Discussion
1	Generic		General comment on Saturated Zone flow and transport FEPs: The SZ FEPs AMR (CRWMS M&O, 2001) tends to neglect issues associated with transport in the alluvium. Several screening arguments focus on aspects other than those in the alluvium that might be influenced by those FEPs (dissolution, for instance). Reference: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	Screening arguments for the Saturated Zone Features, Events and Processes are focused on those components of the Saturated Zone system to which the feature, event and process is most relevant (e.g., the thermal convection cells due to repository heat in the volcanic aquifer). The issue of dissolution in the alluvium is discussed in more detail in response to NRC comment on Feature, Event And Process 1.2.09.02.00 (Large-scale dissolution). The potential impact of water table decline with regard to flow path length in the alluvium is mentioned in the Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f). DOE believes that no additional work is needed in this regard. References: CRWMS M&O 2001f. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230.
2	1.3.07.02.00	Water Table Rise	FEP 1.3.07.02.00 (Water table rise). According to the SZ FEPs AMR (CRWMS M&O, 2001), this FEP is included on a preliminary basis because higher flow rates are included through the varying flux inputs included in the model. The screening argument is based on the assumption that the SZ model can effectively capture short circuits and changes in flow paths as a result of water table rise. Since the model is only calibrated to current conditions, it is difficult to discern how sensitivity analyses are adequate for screening. Moreover, it is known that as a result of higher water table elevations, springs have discharged within the 20 km radius in the past. Given the uncertainties associated with groundwater pathways, why aren't the effects of spring discharge (for example, at 9S and 1S) considered in the analysis? Thermal effects could also influence water table elevations and spring discharge, yet these are not considered either. Reference: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	The conclusion that water table rise has been adequately incorporated into the Saturated Zone flow and transport analyses is labeled as "Preliminary" in the Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f). In addition, the assumption that groundwater flow paths from the repository would not be significantly changed under wetter climatic conditions has been identified and as "To Be Verified" (TBV) in the Analysis/Model Report. Additional modeling with the Saturated Zone site-scale flow and transport model is planned to verify this assumption and to close the TBV. No groundwater discharge at springs along the Saturated Zone flow path from the repository (within 20 km) is anticipated for glacial climatic conditions, as indicated by the lack of paleospring deposits in this area and by regional-scale groundwater flow modeling results (D'Agnese et al. 1999). Paleospring deposits at the southern end of Crater Flats indicate that groundwater discharge has occurred in this area under past glacial conditions and would alter the groundwater flow to some extent. However, these potential discharge points are over 10 km to the west of the present groundwater flow path and are not expected to be a source of potential radionuclide releases to the accessible environment. References: CRWMS M&O 2001f. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230. D'Agnese, F.A.; O'Brien, G.M.; Faunt, C.C.; and San Juan, C.A. 1999. *Simulated Effects of Climate Change on the Death Valley Regional Ground-Water Flow System, Nevada and California.* Water-Resources Investigations Report 98-4041. Denver, Colorado: U.S. Geological Survey. TIC: 243555.

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Item No.	FEP#	FEP Name	NRC Comment	DOE Discussion
3	2.2.10.03.00	Natural Geothermal Effects	FEP 2.2.10.03.00 (Natural geothermal effects). The SZ FEPs AMR (CRWMS M&O, 2001) states that this FEP is included because the current geothermal gradient is included in the SZFT model. However, this discussion does not address the potential for spatial and temporal variation in that gradient, which is part of the FEP description. Resolution of this issue is necessary to address the issue of changes in the geothermal gradient in FEP 2.2.10.13.00 [Density-driven groundwater flow (thermal)]. Reference: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	**Response same as 2.2.10.13.00 -** Density-driven groundwater flow from natural thermal effects due to hydrothermal activity could result in greater dilution of radionuclide concentrations due to convection, as discussed in the section on Feature, Event and Process 1.2.06.00.00 in the Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f). In addition, potential impacts due to increased groundwater flow rates in the Saturated Zone are captured within the range of uncertainty in specific discharge analyzed in the Saturated Zone site-scale flow and transport model for Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000aq). Specific discharge in the Saturated Zone is scaled upward by a factor of 10 for a significant number of realizations of the Saturated Zone flow and transport system (CRWMS M&O. 2000ar). References CRWMS M&O 2001f. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230. CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328.
4	1.2.06.00.00	Hydrothermal activity	FEP 1.2.06.00.00 (Hydrothermal Activity). In the SZ FEPs AMR (CRWMS M&O, 2001), this item is excluded on the basis of low consequence. For SZ transport, the argument is that the adopted Kd distributions account for possible lithologic changes and thermal effects, with reference to CRWMS M&O (2000). However, the latter AMR does not provide a clear technical basis that the Kds were derived in such a fashion. In addition, though the screening argument is based on low consequence, there is a reference at the conclusion of the Supplemental Discussion to the low probability of hydrothermal activity (CRWMS M&O, 2001). Resolution of this issue is necessary to address the issue of changes in the geothermal gradient in FEP 2.2.10.13.00 [Density-driven groundwater flow (thermal)]. The DOE should provide a stronger technical basis for the assertion that possible hydrothermal effects on Kd values are accounted for in TSPA. References: CRWMS M&O. *2000. Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada; CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	The approach taken to assigning uncertainty distributions for Kd in the Saturated Zone transport model is to use the most conservative (i.e., lowest Kd values) from among the different volcanic rock types reported in CRWMS M&O (2000as). By taking the most conservative distribution of Kd for all volcanic rock types (including some that have experienced volcanic hydrothermal alteration, such as zeolitization), the Saturated Zone transport analysis implicitly incorporates the consideration of potential future hydrothermal alteration in a conservative manner. It is recognized that the analysis of Kd distributions in CRWMS M&O (2000as) does not directly discuss the issue of hydrothermal alteration, but does include analysis of Kd distributions for zeolitic volcanic units. The reference to low probability at the end of the Supplemental Discussion section is extraneous to the argument of low consequence and will be removed in the next revision of the Saturated Zone Features, Events, and Processes Analysis/Model Report. This comment is addressed in Radionuclide Transport agreement KRT0210. The agreement states in part, "Consistent with the less structured approach for informal expert judgement acknowledged in NUREG-1563 guidance and consistent with AP-3.10Q, DOE will document how it derived the transport distributions for performance assessment..." The information obtained from agreement KRT0210 will respond to this comment in full and no additional work is needed. The Saturated Zone Features, Events, and Processes Analysis/Model Report will be revised, to support any potential License Application, to include the new information obtained from agreement KRT0210.

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				References: CRWMS M&O 2000as. *Unsaturated Zone and Saturated Zone Transport Properties (U0100).* ANL-NBS-HS-000019 REV00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL20000829.0006.
5	2.1.09.21.00	Suspension of Particles Larger than Colloids	FEP 2.1.09.21.00 (Suspension of Particles Larger than Colloids). The SZ FEPs AMR (CRWMS M&O, 2001a) states that these particles will be included and treated as colloids. However, this FEP is not addressed in the UZ FEPs AMR (CRWMS M&O, 2000) and is noted as excluded under two other model components in the FEPs database (CRWMS M&O, 2001b). Furthermore, it is not clear how the effects of particles are included with colloids. This FEP should be addressed under the UZ Flow and Transport PMR and the integration of its disposition across the EBS, UZ, and SZ should be clarified. References: CRWMS M&O. 2001a. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada; CRWMS M&O. 2000. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01A.. Las Vegas, Nevada; CRWMS M&O. 2001b. *Yucca Mountain FEP Database.* TDR-WIS-MD-000003 REV00 ICN01. Las Vegas, Nevada.	It should be noted that particles larger than colloids are not included in the Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000aq) analysis and have been explicitly excluded by the waste form and near field environment components of the Total System Performance Assessment. This feature, event and process is identified as potentially included in the Saturated Zone to the extent that it cannot be shown to have sufficiently low consequence to the Saturated Zone component of the analysis. The point is that radionuclides associated with particulate matter (colloids or larger) are treated as colloids in the Saturated Zone analysis, if they are deposited in the Saturated Zone from other components of the Total System Performance Assessment. However, suspension of particles larger than colloids has been excluded from the analysis at the source. If particles larger than colloids are included in the Near Field Environment, Waste Form, and Unsaturated Zone models they will also be included in the Saturated Zone transport model and will be modeled conservatively using the colloid transport model. Likewise if they are excluded in the Near Field Environment, Waste Form, or Unsaturated Zone they will not be included in the Saturated Zone transport model. As indicated in the response to feature, event and process 1.4.06.01.00 (Altered soil or surface water chemistry) above, the treatment of any feature, event and process will be consistent throughout the Total System Performance Assessment components. Path forward – Update SZ FEP AMR to include above rationale
6	N/A	NA	Assumptions labeled as To-Be-Verified were found in the following reports: *FEPs in Thermal Hydrology and Coupled Processes.* ANL-NBS-MD-000004 REV 00 ICN1. 2001 *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 00. 2000 *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. 2001 It is necessary to disclose plans to verification.	Initiation, tracking, resolution and closure of To Be Verified's in technical products are procedurally controlled per procedure AP-3.15Q. To Be Verified conditions are identified, initiated and resolved by the authors of technical products. Tracking numbers are assigned by a Project-wide coordinator. Progress of TBV condition resolution is monitored and tracked by the coordinator. If technical product inputs are changed during the resolution of To Be Verified conditions, notification of potential downstream impacts is controlled per procedure AP-3.17Q. To Be Verified's are established to facilitate the resolution of information that may be preliminary, requires evaluation, or need confirmation, and as a placeholder for information that may not yet be developed. As the knowledge base of the project grows, these tracking items will either be resolved by the acquisition/confirmation of the required information or eliminated by a change in direction (e.g., re-design). Once the To Be Verified's have been resolved, the Features, Events and Processes Analysis/Model Reports will be revisited to ensure that the screening

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				arguments remain valid or require updates. The schedule for ongoing activities are integrated into the overall project schedule and prioritized based on project milestones and budget. As such, the resolution of those To Be Verified's required to support a potential license application will be considered in the scope of work during the associated planning activities. Recommend To Be Verified's be discussed on a case-by-case basis during the applicable Features, Events and Processes Analysis/Model Report discussions. To be discussed at the June Management Meeting
7	1.4.06.01.00	Altered soil or surface water chemistry	FEP 1.4.06.01.00 (Altered soil or surface water chemistry). This FEP is excluded for UZ on the basis of low probability (CRWMS M&O, 2000), but is not addressed by DOE under SZ. The probability argument is not supported by a calculation or estimate. This FEP is possibly relevant for SZ2 because of possible changes in groundwater chemistry. Reference: CRWMS M&O. 2000. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01A,, Las Vegas, Nevada.	The basis for excluding this Feature, Event and Process (FEP) is provided in the Unsaturated Zone (FEPs) Analysis/Model Report (BSC 2001d). This FEP is not considered in the Saturated Zone flow and transport since it has been excluded in the Unsaturated Zone flow and transport, i.e., any effect in the Saturated Zone would be less than that in the Unsaturated Zone. Reference: BSC 2001d. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321. Path forward - DOE will add this FEP to the SZ FEP AMR with the appropriate reference to UZ FEP 1.4.06.01.00 screening argument. The SZ FEP AMR will also address the combined affects of this FEP on UZ and SZ.
8	1.2.04.07.00	Ashfall	FEP 1.2.04.07.00 (Ashfall). DOE assumes that ashfall blankets the region between the repository and the compliance boundary. Radionuclides associated with ashfall are then assumed to be transported instantaneously into the SZ. DOE presented only the case for uniform distribution. Moreover, parameter values and models used in the Ashfall analysis are not clear. Some parameters used in the model are not well documented and other parameters such as the number of waste packets that fail are not viewed as conservative. DOE should provide additional bases for the choice of models and parameters used to screen this FEP. Reference: CRWMS M&O. 2000. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	The uniform distribution of ashfall along the flow path from the repository to the receptor is a stylized, conservative representation of volcanic ash distribution on the land surface that allows a relatively simple analysis of potential impacts. It is conservative to assume that all of the volcanic ash would be concentrated on a relatively narrow band of the land surface within the capture zone of the well(s) providing groundwater to the hypothetical farming community. The range of waste packages as a result of a volcanic eruption is 3 to 39. The number of waste packages that are assumed to fail in the ashfall analysis is the median number of packages from the Total System Performance Assessment-Site Recommendation modeling (CRWMS M&O 2000aq). The expected behavior with respect to the number of waste package failures is used in the ashfall analysis.; There is no regulatory requirement that conservative parameter values be used in every aspect of the screening analysis. DOE believes no additional work is needed in this regard. References: CRWMS M&O 2000aq. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001005.0282.

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				Path forward – Update SZ FEP AMR to include above rationale
9	2.2.10.06.00	Thermo-chemical alteration (solubility speciation, phase changes, precipitation/ dissolution)	FEP 2.2.10.06.00 [Thermo-chemical alteration (solubility, speciation, phase changes, precipitation/dissolution)]. This FEP is excluded on the basis of low consequence (CRWMS M&O, 2001) with reference to the screening argument for FEP 2.2.7.10.00 in the UZ FEPs AMR (CRWMS M&O, 2000a). The argument that repository thermal effects on SZ radionuclide transport will be minimal is based on a TBV assumption (CRWMS M&O, 2000a). There is no explicit technical basis presented that rock alteration or temperature effects on geochemical properties and processes will negligibly affect SZ transport. In addition, it is asserted in the SZ FEPs AMR (CRWMS M&O, 2001) that any such effects would be within the bounds of uncertainty ranges established for transport properties such as Kd. However, the relevant AMR (CRWMS M&O, 2000b) does not provide a clear technical basis that this is the case. DOE's current technical justification is considered inadequate. The Department should provide additional technical justification for exclusion. Same comment applies to FEP 2.2.10.08.00 (Thermo-chemical alteration of the saturated zone) References: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2000a. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01A. Las Vegas, Nevada CRWMS M&O. 2000b. *Unsaturated Zone and Saturated Zone Transport Properties.* ANL-NBS-HS-000019 REV 00. Las Vegas, Nevada.	The rationale for excluding this Feature, Event and Process from the Saturated Zone does rest on the conclusions of the unsaturated zone features, events and processes screening analysis that it can be excluded on the basis of low consequence. This rationale is reasonable and appropriate. If the higher temperature conditions in the unsaturated zone near the repository are insufficient to have a significant consequence on radionuclide transport, then the smaller temperature rise in the saturated zone would also have no significant consequences. However, it is recognize that this conclusion is based on a To Be Verified assumption in the unsaturated zone and if the screening decision is changed for the unsaturated zone, the screening decision and justification for the saturated zone would need to be revisited. This comment is addressed in Radionuclide Transport agreement KRT0210. The agreement states in part, "Consistent with the less structured approach for informal expert judgement acknowledged in NUREG-1563 guidance and consistent with AP-3.10Q, DOE will document how it derived the transport distributions for performance assessment...." The information obtained from agreement KRT0210 will respond to this comment in full and no additional work is needed. The Saturated Zone Features, Events and Processes Analysis/Model Report will be revised, to support any potential License Application, to include the new information obtained from the Radionuclide Transport agreement KRT0210. References: BSC 2001d. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321. CRWMS M&O 2000as. *Unsaturated Zone and Saturated Zone Transport Properties (U0100).* ANL-NBS-HS-000019 REV00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL20000829.0006. Path forward – DOE will add the correct pointer to the UZ FEP AMR (2.2.10.06.00) screening argument.
9	2.2.10.08.00	Thermo-chemical alteration of the saturated zone		See response to 2.2.10.06.00
10	2.3.11.04.00	Groundwater discharge to surface	FEP 2.3.11.04.00 (Groundwater discharge to surface). Excluded in the SZ FEPs AMR on the basis of low consequence (CRWMS M&O, 2001). Modeling shows that spring discharge within the 20-km radius is not likely, yet past discharges have occurred within the 20-km radius (e.g., paleospring deposits at 9S and 1S). See discussion of water table rise FEP 1.3.07.02.00. Any	No groundwater discharge at springs along the saturated zone flow path from the repository (within 20 km) is anticipated for glacial climatic conditions, as indicated by the lack of paleospring deposits in this area and by regional-scale groundwater flow modeling results (D'Agnese et al. 1999). Paleospring deposits at the southern end of Crater Flats indicate that groundwater discharge has occurred in this area under past glacial conditions and would alter the

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			screening argument that spring discharges are outside of the proposed compliance area is insufficient. Additional technical justification is required to fully exclude this FEP. Reference: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	groundwater flow to some extent. However, these potential discharge points are over 10 km to the west of the present groundwater flow path and are not expected to be a source of potential radionuclide releases to the accessible environment. References: D'Agnese, F.A.; O'Brien, G.M.; Faunt, C.C.; and San Juan, C.A. 1999. *Simulated Effects of Climate Change on the Death Valley Regional Ground-Water Flow System, Nevada and California.* Water-Resources Investigations Report 98-4041. Denver, Colorado: U.S. Geological Survey. TIC: 243555. Path forward – DOE will clarify within the SZ FEP AMR that groundwater discharge will not occur along the flowpath from the repository within the 20 km radius
11	1.3.07.01.00	Drought/water table decline	FEP 1.3.07.01.00 (Drought/water table decline). According to the SZ FEPs AMR (CRWMS M&O, 2000b), this FEP is excluded due to low consequence. DOE states that "a lower water table could result in less travel through the alluvial aquifer and as a result, less sorption and retardation of the contaminant plume." However, no evidence is presented that precludes a watertable decline. Current flow models assume that groundwater flow through the saturated alluvium is relatively shallow. As water tables decline, how will flow through the alluvium be affected? Is it possible that a larger component of flow will be through the deep carbonate system? Will the upward gradient observed at some locations be affected? Are there distinct pathways that are dependent on the elevation of the water table? It is likely that the transport times will stay the same or increase due to water table decline, but the exclusion argument provided seems insufficient. Additional technical justification is required to fully exclude this FEP. Reference: CRWMS M&O. 2001. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada. CRWMS M&O. 2000. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada	The possibility of shorter flow path lengths in the alluvium (due to hydrogeologic uncertainty or potential decline in the water table) is captured in Saturated Zone site-scale model simulations for Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000ar). The general pattern of groundwater flow is not expected to change with water table decline in the Saturated Zone. The regional-scale groundwater flow is controlled by the topographic distribution of recharge and discharge areas, as well as the large-scale distribution of hydrogeologic units and structural features. It is reasonable to expect that there would be relatively minor changes in the shallow groundwater flow paths with water table decline, but major features of the Saturated Zone flow system (e.g., the upward gradient from the carbonate aquifer) are expected to remain stable in the case of either water table decline or water table rise. This comment is addressed in Radionuclide Transport and Unsaturated and Saturated Flow Under Isothermal Conditions agreement KRT0208 and KUZ0504 respectively. The agreements state in part, "DOE will provide additional information to include Nye county data as available, to further justify the uncertainty distribution of flow path lengths in alluvium ..." The information obtained from agreement KRT0208 will respond to this comment in full and no additional work is needed. The Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f) will be revised, to support any potential License Application, to include the new information obtained from agreement KRT0208. References: CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328. Need input from Arnold.
12	2.2.10.13.00	Density-driven		Density-driven groundwater flow from natural thermal effects due to

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		groundwater flow (thermal)	FEP 2.2.10.13.00 [Density-driven groundwater flow (thermal)]. The SZ FEPs AMR (CRWMS M&O, 2001a) addresses this FEP in two parts: repository-induced effects ("excluded" low consequence) and natural geothermal effects ("include"). Exclusion of repository effects on flow based on DOE analyses is accepted. Natural effects are included only to the extent that the "natural geothermal gradient" is applied in the SZFT model. However, changes in thermal gradients are excluded on the basis of low consequence, with reference to FEPs 1.2.06.00.00 and 1.2.10.02.00 (CRWMS M&O, 2001a). A clear technical basis is not provided under these FEPs that all possible changes in thermal gradients will be localized. The screening argument for 1.2.06.00.00 focuses on geochemical effects (see separate entry), while 1.2.10.02.00 is focused on highly localized igneous intrusions. How these arguments apply to 2.2.10.13.00 is not entirely clear. References: CRWMS M&O, *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, NV, TRW Environmental Safety Systems, Inc., 2001a.	hydrothermal activity could result in greater dilution of radionuclide concentrations due to convection, as discussed in the section on Feature, Event and Process 1.2.06.00.00 in the Saturated Zone Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001f). In addition, potential impacts due to increased groundwater flow rates in the saturated zone are captured within the range of uncertainty in specific discharge analyzed in the saturated zone site-scale flow and transport model for Total System Performance Assessment-Site Recommendation. Specific discharge in the saturated zone is scaled upward by a factor of 10 for a significant number of realizations of the saturated zone flow and transport system (CRWMS M&O. 2000ar). References: CRWMS M&O 2001f. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230. CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328. Path forward – Update SZ FEP AMR to include above rationale
13	2.2.10.02.00	Thermal convection cell develops in Saturated Zone	FEP 2.2.10.02.00 (Thermal Convection Cell Develops in SZ). DOE indicates that temperatures at the watertable are expected to approach 80-degrees Celsius. The DOE further points out that the resulting concern is that thermally driven water flow in the upper tuff aquifer could increase groundwater velocities relative to the system without heat sources. Additional justification for exclusion is necessary. Reference: CRWMS M&O. 2000. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	The screening argument, for excluding this Feature, Event and Process, is that thermally driven groundwater flow in the Saturated Zone will not significantly alter the range of uncertainty in specific discharge that is already included in the Saturated Zone site-scale flow and transport model for Total System Performance Assessment-Site Recommendation and therefore will not significantly alter the expected dose. To account for uncertainties, specific discharge in the Saturated Zone is scaled upward by a factor of 10 for a significant number of realizations of the Saturated Zone flow and transport system (CRWMS M&O. 2000ar). In addition, for nominal-case behavior in Total System Performance Assessment-Site Recommendation there is negligible transport of radionuclides through the Unsaturated Zone during the period of significant thermal perturbation. References: CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328.
14	1.2.09.02.00	Large-scale dissolution	FEP 1.2.09.02.00 (Large-scale dissolution). This FEP is excluded (CRWMS M&O, 2001) from the TSPA-SR abstraction of radionuclide transport and flow in the saturated zone on the basis of low consequence. In the DOE screening argument, potential dissolution of the carbonate aquifer materials is discussed.	This Feature, Event and Process is identified as applying to large-scale dissolution processes, such as those that could lead to significant changes to groundwater flow in the aquifer, and does not apply to predominantly clastic hydrogeologic units, like the alluvium. Hence, no additional work is needed in this regard.

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			However, there is no mention of the calcite/carbonate that may exist in the saturated zone alluvium. Since retardation of radionuclides such as Np in the alluvium is, in part, explained by larger Kds due to the presence of calcite, an analysis of changes in the calcite concentration of alluvium seems warranted. This dissolution process may not be "large-scale" as defined, but certainly may be a response caused by a carrier plume of differing chemistry (said to be included in the model). A wetter climate may also result on dissolution of the alluvial calcite. Reference: CRWMS M&O, *Features, Events, and Processes in SZ Flow and Transport*. 2001. ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada.	Multiple episodes of wetter climatic conditions have existed in the geologic past, without apparent loss of calcite in the alluvium due to dissolution. Therefore, it is not expected that future glacial climatic conditions would result in significant loss of sorptive capacity in the alluvium. To address the concern regarding sorption of Np in the alluvium, it should be noted that the uncertainty distribution for the Np Kd in alluvium has a lower bound of zero (CRWMS M&O 2000har), with significant statistical density at lower values of Kd. This uncertainty distribution implicitly incorporates consideration of limited Np sorption in the alluvium. In addition, uncertainty in the flow path length through the alluvium in the Saturated Zone transport simulations significantly limits the sorptive effects of the alluvium in some realizations of the system. References: CRWMS M&O 2000ar. *Uncertainty Distribution for Stochastic Parameters.* ANL-NBS-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0328.

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15			Withdrawn	
16	2.3.13.01.10	Natural Ecological Development	FEP 2.3.13.01.10 (Natural Ecological Development) has a FEP description that is really a rationale for exclusion. Similar problem exists with FEP 3.3.04.03.05 (Irradiation). Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	Secondary Features, Events and Processes (FEP), as identified in Sec.3.2 of Freeze et al. 2001, are FEPs that are redundant to another FEP, specific to another Program, or better captured or subsumed in more broadly-defined primary FEP. Based on those criteria it would be appropriate to identify a secondary FEP based on an originator's description, statement, or exclusion of a FEP using verbatim text of the FEP description from originator documentation. The originator is noted in parentheses where possible. No attempt was made to edit this field and it was not used for any screening evaluations. For screening, a Yucca Mountain Project Primary FEP Description was developed for each Primary FEP which contains a Description of each FEP and its potential relevance to YMP, typically edited from the Originator FEP Description. Where secondary FEPs are associated with a primary FEP, the description also includes all of the features, events, and processes described by the secondary FEPs. Using this approach, only the Primary FEPs require screening evaluations and only the Yucca Mountain Project Primary FEP Descriptions require editing for consistency and relevance to Yucca Mountain Project. The Originator FEP Descriptions, whether they are for Primary or Secondary FEPs, are used only for traceability to the source, and are not used for screening.
17	N/A	NA	Screening criteria used by DOE in the biosphere FEP AMR (CRWMS M&O, 2001), in lieu of final regulations, derive from a Revised Interim Guidance report (RIG, Dyer, 1999). These criteria were excerpted, in 1999, from NRC proposed regulations in 10 CFR Part 63; however, the criteria are incomplete when compared to actual proposed NRC regulation. In the biosphere FEP AMR, DOE cites the RIG criteria to screen specific FEPs and cites the proposed Part 63 criteria for other FEPs, when all FEPs could be screened using the proposed Part 63 rule. It is unclear the purpose of establishing and citing a second set of 'regulatory' criteria since, ultimately, DOE should demonstrate compliance with NRC regulations. Referring to both the proposed Part 63 rule and the RIG criteria as regulations (as done in the Biosphere FEP AMR) is incorrect. References: Dyer, J.R. 1999. *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 1, July 22, 1999) for Yucca Mountain, Nevada.* Letter from J.R. Dyer (DOE/YMSCO) to D.R. Wilkins (CRWMS M&O), September 3, 1999, OL&RC:SB-1714, with enclosure, "Interim Guidance Pending Issuance of New NRC Regulations for Yucca Mountain (Revision 01)". CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	DOE will assess the differences between the Interim Guidance (Dyer 1999) and Part 63 once the final rule is issued. DOE will make modifications to project documents, as necessary.

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18	1.4.07.01.00	Waste management activities	Biosphere FEP AMR indicates that any future changes in FEP 1.4.07.01.00 (Water Management Activities) can be excluded based on the proposed 10 CFR Part 63. This FEP includes well pumping from an aquifer as a water management activity. The conclusion that changes to water management activities may be excluded is not supportable by the regulation. The draft regulation indicates that the behaviors and characteristics of the farming community shall be consistent with current conditions of the region surrounding the Yucca Mountain site and that climate evolution shall be consistent with the geologic record. As the climate becomes wetter and cooler, the farming community is likely to pump less water out of the aquifer, consistent with sites analogous to the predicted future climate of Yucca Mountain. This reduction in pumping would not be considered a change in the behavior or characteristics of the critical group since the community would still be raising similar crops using similar farming methods. Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	This Feature, Event and Process (FEP) can be excluded on the basis of the proposed regulation as this FEP deals with the use of man-made structures and not specifically with the use of groundwater. Since these features do not currently exist in the vicinity of the location of the critical group, not considering them is consistent with the current conditions. The use of groundwater, via well(s), and the changes associated with climate evolution are specifically related to FEP 1.4.07.02.00 "Wells" and is not considered to be part of this FEP. Effect of climate change, FEP 1.3.01.00.00, on water use is considered and addressed in Nominal Case Biosphere Dose Conversion Factor Analysis/Model Report. Path forward – DOE will make the treatment of this FEP in the SZ FEP AMR consistent with the treatment of this FEP in the Bio FEP AMR.
19	Various	BDCF calculations	DOE has selected a subset of the full FEPs list as applicable for biosphere screening in the biosphere FEP AMR report. Some FEPS that are potentially applicable to BDCF calculations (that should at least be considered for screening) have not been included in the scope of the Biosphere FEP AMR. These include: FEP 2.3.11.04.00 (Groundwater Discharge to Surface), FEP 1.3.07.02.00 (Water Table Rise), FEP 3.2.10.00.00 (Atmospheric Transport of Contaminants), FEP 1.2.04.01.00 (Igneous Activity) FEP 2.2.08.02.00 (Groundwater Chemistry/Composition in UZ and SZ) (i.e., chemical species can impact dose coefficient selection), FEP 2.2.08.11.00 (Distribution and Release of Nuclides from the Geosphere), FEP 3.1.01.01.00 (Radioactive Decay and Ingrowth), and FEP 1.2.04.07.00 (Ashfall). Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	Feature, Event and Process (FEP) 1.3.07.02.00 Water Table Rise and FEP 2.3.11.04.00 Groundwater Discharge to Surface. The processes addressed in FEPs 1.3.07.02.00 & 2.3.11.04.00 are not directly related to the biosphere and are not evaluated by the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e). Effects of any surface discharge or water table rise in the compliance area, if any, would be addressed within FEP 3.3.05.11.00 "Radiation Doses". The effects of climate change within the compliance area, if any, on the processes addressed in these FEP will be evaluated in support of any potential license application. Path forward – DOE will provide a technical basis to demonstrate that the screening approach is conservative. FEP 3.2.10.00.00 Atmospheric Transport of Contaminants - Those FEP, which deal with the mechanics of atmospheric transport of contaminants as a result of a volcanic event, are discussed, considered and evaluated within the scope of the Disruptive Event FEP Analysis/Model Report (CRWMS M&O 2000i). The effects of other atmospheric transport processes, such as wind erosion and resuspension, are currently considered in calculation of Biosphere Dose Conversion Factors. Specifically, wind erosion is considered under FEP #s 1.2.07.01.00, 1.2.07.02.00, and 2.3.02.02.00. FEP 1.2.04.01.00 Igneous Activity - As described in Freeze et al. 2001, the YMP Primary FEP Description, the Originator FEP Description, and the secondary FEP descriptions, this FEP is focused on the consequences of igneous activity in the geosphere. This FEP is not directly relevant to the biosphere and, as a result, does not need to be evaluated in the Biosphere FEP

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				Analysis/Model Report. FEP 2.2.08.02.00 Groundwater Chemistry/Composition in Unsaturated Zone and Saturated Zone - As cited Freeze et al. 2001, this FEP corresponds to a FEP titled "Radionuclide transport occurs in a carrier plume in the geosphere". The Yucca Mountain Project Primary FEP Descriptor, Originator Descriptor and associated secondary FEP descriptors all relate to transport in the geosphere. This FEP is not directly relevant to the biosphere and, as a result, it does not need to be evaluated in the Biosphere FEP Analysis/Model Report. DOE agrees that chemical species can effect the dose coefficient selection. In the analyses of radiation doses, FEP 3.3.05.01.00 ,which is considered in the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e), this effect is bounded by selecting the highest dose coefficient factor. Path forward – DOE will clarify in FEP 3.3.05.01.00, Radiation Dose and FEP 2.3.13.02.00, Biosphere Transport that the chemical form of radionuclides has been considered. FEP 2.2.08.11.00 Distribution and Release of Radionuclides from the Geosphere - As stated in the both the Yucca Mountain Project Primary FEP Description and the Originator Description, this FEP is focused exclusively on the transport of radionuclides in the groundwater. The release of radionuclides in groundwater, as cited in the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e), is considered via a well, FEP 1.4.07.02.00. This FEP is not directly relevant to the biosphere and, as a result, does not need to be evaluated in the Biosphere FEP Analysis/Model Report. Path forward – DOE will add links of this FEP to the Biosphere FEP AMR. 3.1.01.01.00 FEP Radioactive Decay and Ingrowth - DOE is reconsidering citing this as an applicable FEP. Although this FEP is not cited as an applicable FEP in the Biosphere, the analyses of radiation dose, FEP 3.3.05.01.00, was addressed in the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e) and did include the consideration of radioactive decay and progeny ingrowth along the various pathways to man. Path forward – DOE will add links of this FEP to the Biosphere FEP AMR. 1.2.04.07.00 Ashfall - DOE is reconsidering citing this as an applicable FEP. Although this FEP is not cited as an applicable FEP in the Biosphere, the analysis of radiation dose, FEP 3.3.05.01.00, was addressed in the Biosphere FEP Analysis/Model Report (CRWMS M&O 2001e) and did include ashfall for the disruption event scenario. Path forward – DOE will add links of this FEP to the Biosphere FEP AMR.
20	2.2.08.07.00	Radionuclide solubility limits in the geosphere	FEP Database does not indicate that FEP 2.2.08.07.00 (Radionuclide Solubility Limits in the Geosphere) is relevant to the biosphere. This FEP is relevant for	The Feature, Event and Process (FEP) as described in the FEP database is specific to "Geosphere." The Biosphere as described in the Biosphere Process Model Report excludes processes in the geosphere, therefore this FEP is not

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			limiting the quantity of radioactive material that can leach radionuclides out of the soil or tephra deposit in the biosphere compared to the quantity of radionuclides that would be predicted to leach out of the deposit using only leach rate limits. Reference: YMP FEP Database Rev 00 ICN01	considered in the Biosphere. The concern for limiting the quantity of radioactive material that can leach from soil or tephra deposits does have relevance to the biosphere. The process of leaching in which solubility limits apply is addressed in FEP 2.3.02.02.00, "Radionuclide Accumulation in soil." For the nominal scenario (groundwater contamination), the process depends on the radionuclide build-up in soil, which includes leaching, and partition coefficient (ratio of concentrations in liquid and solid matter). The process would be applicable to the leaching of the contamination from volcanic ash. However for volcanic release, the Biosphere model does not consider contamination removal by leaching and is thus bounding and conservative. In this scenario the dominant pathway is inhalation from resuspended particulate matter. The inclusion of leaching (with solubility limits) as a transport mechanism from the surfacial layer of contaminated ash (where all resuspension originates) into the deeper layers (where the contamination cannot be resuspended and is thus not available for inhalation) can only reduce the dose contribution from the primary pathway. Path forward – DOE will add this FEP to the Biosphere FEP AMR.
21	2.3.13.01.00	Biosphere characteristics	FEP 2.3.13.01.00 (Biosphere Characteristics) screening argument indicates YM region lacks permanent surface water. Is this statement consistent with the geologic record of past climate change in the area? Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	As described in Section 7.1 of the Yucca Mountain Site Description (CRWMS M&O 2000aw), the region around Yucca Mountain lacks permanent surface water bodies (see Feature, Event and Process 2.3.04.01.00 Surface Water Transport and Mixing). Intermittent sources of water on the Nevada Test Site were not considered since access to the Nevada Test Site is controlled and such sources would not be available to members of the critical group. At the present time, the presence of an intermittent seep or spring at the proposed location of the critical group has not been identified and is considered unlikely given the depth to groundwater (>90 meters) at that location. DOE considers that this issue is conservatively addressed in the current analysis of the nominal scenario. Path forward – DOE will clarify its screening argument to indicate that during the compliance period, DOE does not expect permanent surface expressions of water.
22	2.3.13.01.00	Biosphere characteristics	FEP 2.3.13.01.00 (Biosphere characteristics) includes a secondary FEP for Plants (FEP 2.3.13.01.07), but not one for animals, yet plants and animals are both listed in the FEP description (CRWMS M&O, 2000). Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	As cited in Freeze et al. 2001, the objective of the Features, Events and Processes (FEPs) Database is to document a manageable number of primary FEPs (a few hundred) that encompass, through comprehensively worded Yucca Mountain Project primary FEP descriptions, the relevant issues. To ensure comprehensiveness, a Yucca Mountain Project primary FEP description must include all issues identified in the underlying secondary FEPs. However, there is no requirement that an issue identified in a Yucca Mountain Project primary FEP description necessarily has a corresponding secondary FEP.

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				The ultimate evaluation of comprehensiveness will consider just the primary FEPs (i.e., issues identified in the corresponding Yucca Mountain Project primary FEP descriptions, whether they derive directly from a secondary FEP or from some other source). As new issues are identified, the DOE may add them to the database as new FEPs (primary or secondary) or by simply expanding the Yucca Mountain Project primary FEP description of an existing primary FEP. For all of these options, the documentation of the issue ends up in a Yucca Mountain Project primary FEP description. In the case of FEP 2.3.13.01.00, the issue (biosphere characteristics - animals) is already captured in the YMP primary FEP description, and DOE does not deem it necessary to create a new secondary FEP for animals. In cases where the new issue is a significant deviation from an existing FEP, DOE would consider creating a new FEP. "Animals" as a source of radioactive materials contributing to human exposure is specifically considered in Primary FEP 2.4.09.02.00 Animal Farms and Fisheries.
23	2.3.11.04.00	Groundwater discharge to surface	FEP 2.3.11.04.00 (Groundwater discharge to surface) screening argument states that surface discharge will not impact the annual dose without providing a reason why (e.g., low concentration, low exposure times etc). The screening argument that spring discharges are outside of the proposed compliance area is insufficient. The proposed 10 CFR Part 63 does not preclude residents of the farming community located at the proposed compliance point to visit spring areas to the south. The Ash Meadows area, for example, is a national park with facilitated access points and soils rich in minerals precipitated from groundwater discharge. Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	Groundwater discharge from springs along the flowpath from the repository could potentially occur at distances greater than 20 km under wetter climatic conditions. However, in the Total System Performance Assessment-Site Recommendation models discharge to the biosphere occurs through hypothetical pumping wells at the compliance point, assuming complete capture of radionuclides in the water supply of the critical group. This conservative approach is consistent with proposed rule 10 CFR Part 63 and effectively precludes radionuclide transport to more distant discharge points from the analysis. Thus, spring discharge beyond the compliance location will not have an effect on the simulated expected annual dose and can be excluded based on low consequence. Based on the methodology used for Total System Performance Assessment-Site Recommendation radionuclide discharge modeling, DOE does not consider this feature, event and process relevant to the biosphere and therefore it should be excluded from potential consideration Path forward – DOE believes that the concern raised by the NRC can be exclude based on the proposed Part 63. In addition, DOE believes that groundwater flow outside the 20 km compliance area will discharge at the Franklin Lake Playa and not at the springs.
24	2.3.13.02.00	Biosphere transport	FEP 2.3.13.02.00 (Biosphere Transport) contains only two secondary FEPs	The objective of the Features, Events and Processes (FEPs) Database, as cited in Freeze et al. 2001, is to document a manageable number of primary

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			related to surface water, gas, and biogeochemical transport processes. The YMP FEP description and the originator FEP description are different and call into question whether the focus of this FEP is transport processes, alterations during transport, or both. Reference: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01.	FEPs that encompass, through comprehensively worded Yucca Mountain Project primary FEP descriptions, all of the relevant issues. To ensure completeness, a Yucca Mountain Project primary FEP description must include those issues identified in the Originator FEP. For this particular FEP, the statement "Once in the biosphere, radionuclides may be transported through and between the different compartments of the biosphere" inherently captures the intent of the Originator FEP Description phrase "Within the biosphere..." The treatment of the this FEP in the biosphere is both transport processes and alterations during transport.
25	2.4.07.00.00	Dwellings	FEP 2.4.07.00.00 (Dwellings) includes a secondary FEP, household cooling, which has an inappropriate screening argument. The screening argument indicates that since the use of an evaporative cooler would only increase the inhalation and direct exposure pathways, and these pathways are only minor contributors to the current dose conversion factors, the use of evaporative coolers can be screened. However, the direct exposure and inhalation dose from evaporative coolers is the result of significantly different processes than the direct exposure and inhalation dose from radionuclides deposited on soils and could have a more significant dose impact. Reference: CRWMS M&O, 2001. Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP) (ANL-MGR-MD-000011, REV 01)	Household (evaporative) cooling is not expected to result in a significant increase in the relative contribution of the inhalation and external pathways to the expected annual dose. For the nominal case (ANL-MGR-MD-000009, Rev 01), which considers indoor exposure as a fraction of the outdoor exposure, the external pathway and the inhalation pathway generally contribute only a small fraction of the Biosphere Dose Conversion Factor. Given the fact that household cooling is used approximately 50% of the time and that people spend less than 50% of their time indoors, any increase in the relative contribution of the external and inhalation pathways to the expected annual as a result of household cooling is expected to be negligible. For the Disruptive Event (CRWMS M&O 2000p), groundwater is uncontaminated. Therefore, use of evaporative cooling would not present any additional source of indoor exposure in significant effect on the expected annual dose. DOE considers effects of this secondary Feature Event and Process to be adequately covered in the current analyses of Biosphere Dose Conversion Factors for the two scenarios. Pathforward – DOE will re-evaluate the consequence screening argument and technical basis associated with evaporative coolers. The screening decision will be revised, as necessary.
26	3.3.08.00.00	Radon and daughter exposure	Biosphere FEP AMR report states that FEP 3.3.08.00.00 (Radon and Daughter Exposure) is screened as excluded on the basis that the parent radionuclide (Th-230) will not reach the critical group in 10,000 years in the base case scenario. This rationale, however, does not apply to the direct release scenario where transport times are much shorter. References: CRWMS M&O. 2001. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 01. CRWMS M&O. 2000. *Disruptive Event Biosphere Dose Conversion Factor Analysis* . ANL-MGR-MD-000003, REV 00.	Inventory Abstraction Analysis/Model Report (CRWMS M&O 2000aj) does not identify either Th-230 or Ra-226 as a significant radionuclide, i.e. one of the radionuclides required to account for 95% of the dose, for the inhalation or ingestion pathway within 10,000 years after repository closure. Path forward – DOE will re-evaluate the screening decisions and arguments for radon and radon daughters based on revised radionuclide source terms stemming from eruptive events.

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80	2.3.02.02.00		Not included in NRC Comment Table but will be discussed in the Technical Exchange	DOE has agreed to revisit the issue of surface-redistribution of contaminated ash and soil as part of the resolution of agreement item for Igneous Activity Agreement KIA0206. Specifically, DOE has agreed to develop a linkage between soil removal rate and surface remobilization processes characteristics of the Yucca Mountain region and to document its approach to include uncertainty related to surface-redistribution processes in Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000aq). Section 14.3.6.7 of Supplemental Science and Performance Analyses (DOE 2001, n progress), will provide an overview of the work that may be conducted to address this issue. (Response applicable to each listed feature, event and process) No additional work is required beyond the existing agreement.

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27	2.1.09.09.00	Electrochemical effects (electrophoresis, galvanic coupling)	FEP 2.1.09.09.00 (Electrochemical effects [electrophoresis, galvanic coupling] in waste and EBS Electrochemical effects may establish an electric potential within the drift or between materials in the drift and more distant metallic materials that could affect corrosion of metals in the EBS and waste. It is excluded based on low consequence assuming that galvanic coupling between the inner and outer container or the outer container and the drip shield will not lead to accelerated corrosion. The effect of galvanic coupling between the Ti drip shield and steel components of the EBS (drift support, rock bolts, gantry rail, etc) should be included because it may enhance hydrogen entry in the drip shield and therefore hydride cracking (see FEP 2.1.03.04 on hydride cracking). Reference: CRWMS M&O. 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	See also response to FEP 2.1.06.07.00. Any electrochemical coupling of Alloy 22 with 316NG will result in increased corrosion degradation of 316NG and enhanced performance of Alloy 22. The similarity of the corrosion potentials of Alloy 22 and Titanium Grade 7 indicates that even if electrical contact were established, it would be of little consequence to the degradation characteristics of the waste package or the drip shield. Analyses (CRWMS M&O 2000a) indicate that crevice corrosion of the waste package outer barrier or the drip shield will not occur under repository-relevant exposure conditions. Galvanic coupling of the drip shield to steel components is discussed in FEP 2.1.03.04.00, Hydride Cracking of Waste Containers and Drip Shields and is determined to have no consequence to the performance of the drip shield. Reference: CRWMS M&O 2000a. *Abstraction of Models for Pitting and Crevice Corrosion of Drip Shield and Waste Package Outer Barrier.* ANL-EBS-PA-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0327CRWMS M&O 2001h. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004.
28	2.1.03.04.00	Hydride cracking of waste containers	FEP 2.1.03.04.00 Hydride cracking of waste containers *Excluded* low consequence for both drip shield and waste package Hydrogen induced cracking of the Alloy 22 waste package outer barrier is not expected at repository temperatures that are predicted o be 186C. Heating waste package in the range of 540 C for extended periods can result in ordering that substantially increases the susceptibility to hydride cracking. Hydride absorption of Ti alloys for the drip shield based on passive corrosion rates that do not consider accelerated corrosion rated from the presence of fluoride The technical basis for the minimum concentration of hydrogen absorbed in order to observe hydrogen embrittlement or hydrogen induced cracking is not well supported by DOE investigations Reference: CRWMS M&O. 2001. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation ANL-EBS-PA-000002. REV 01. Las Vegas, Nevada.	The waste package temperature never exceeds 186°C (CRWMS M&O 2000b, Section 6.3.1) therefore significant ordering and grain-boundary segregation does not occur and the degree of hydrogen embrittlement is negligible. CRWMS M&O 2000an, Section 4.3 details the effect of fluorides on the degradation behavior of Titanium alloys. Fluoride-enhanced passive dissolution coupled to hydrogen absorption will not occur under the alkaline exposure conditions expected for the drip shield, particularly for Palladium-containing alloys such as Titanium Grade 7. Also, the presence of other anions such as sulfate, bicarbonate, and silicates, also present in the concentrated Yucca Mountain waters, will decrease the aggressiveness of any fluoride ions present. The technical basis for the minimum concentration of hydrogen absorbed in order to observe hydrogen embrittlement or hydrogen induced cracking has been extensively documented in CRWMS M&O 2000an, Section 3.4. Reference: CRWMS M&O 2000b. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux.* ANL-EBS-HS-000003 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001206.0143. CRWMS M&O 2000an. *Review of the Expected Behavior of Alpha Titanium Alloys Under Yucca Mountain Conditions.* TDR-EBS-MD-000015 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010108.0011.

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				CRWMS M&O 2001h. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004.
29	2.1.06.07.00	Effects at Material Interfaces	FEP 2.1.06.07.00 (Effects at Material Interfaces). The basic chemical processes that occur at phase boundaries (principally liquid/solid) are included in others FEPs. Solid/solid contact either does occur or could occur between the drip shield and the invert and/or backfill (if included in the YMP design), between the waste package and the invert and/or backfill (if included in the YMP design); between the pedestal and the waste package and/or drip shield; and between the waste form and any of the other EBS component materials. Since these materials are all relatively inert, no solid/solid interaction mechanisms have been identified that are significant relative to the basic seepage water induced corrosion of the EBS components and hence this FEP is excluded on the basis of low consequence. However, interfaces between solid phases in contact with an aqueous phase can accelerate degradation processes such as crevice corrosion of WP or galvanic coupling of drip shield to steel components (see FEP 2.1.03.01.00 and 2.1.03.04.00). Reference: CRWMS M&O. 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	Any electrochemical coupling of Alloy 22 with 316NG will result in increased corrosion degradation of 316NG and enhanced performance of Alloy 22. The similarity of the corrosion potentials of Alloy 22 and Titanium Grade 7 indicates that even if electrical contact were established, it would be of little consequence to the degradation characteristics of the waste package or the drip shield. Analyses (CRWMS M&O 2000a) indicate that crevice corrosion of the waste package outer barrier or the drip shield will not occur under repository-relevant exposure conditions. Galvanic coupling of the drip shield to steel components is discussed in Feature, Event and Process 2.1.03.04.00, Hydride Cracking of Waste Containers and Drip Shields and is determined to have no consequence to the performance of the drip shield. Interfaces between the waste package and the pallets are not included because the same material is used for the construction. Reference: CRWMS M&O 2000a. *Abstraction of Models for Pitting and Crevice Corrosion of Drip Shield and Waste Package Outer Barrier.* ANL-EBS-PA-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0327. CRWMS M&O 2001h. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004.
30	2.1.03.05.00	Microbially mediated corrosion of waste container	FEP: 2.1.03.05.00 Microbially mediated corrosion of waste container *Included* for waste package *Excluded* for drip shield low consequence Quantitative data on microbially influenced corrosion of drip shield materials such as Ti grades 7 and 16 are not available from the literature. If microbially influenced corrosion of the drip shield occurs it would not have an effect on dose. Accelerated corrosion rates of drip shield have been evaluated in the TSPA-SR and shown not to have an affect on dose. Reference: CRWMS M&O. 2001. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation ANL-EBS-PA-000002. REV 01. Las Vegas, Nevada.	Microbial induced corrosion of Titanium Grade 7 has not been reported in the literature. Hence, the microbial induced corrosion of the drip shield was screened out. Accelerated corrosion of drip shield under the seismic event will be addressed and documented under Container Life and Source Term agreement KCL0208.
31	1.2.03.02.00	Seismic vibration causes container failure	There is no FEP addressing the response of the drip shield to static loads and seismic excitation. It is necessary to account for the degradation of the capability of the drip shield to avoid water infiltration due to the interaction of	DOE has agreed to (Container Life and Source Term agreement KCL0208) performing prior to License Application, calculations that address the effects of static loads from fallen rock on the drip shield during a seismic event. The calculations will consider both intact and degraded conditions of the drip shield.

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			seismic excitation with dead loads (such as those caused by rock fall or naturally occurring backfill) on the drip shield, and it is recommended to add a new FEP. FEP 1.2.03.02.00 (Seismic vibration causes container failure) assesses the effect of ground motion on the waste package and drip shield, without consideration of possible pre-existing static loads. The Screening argument for FEP 2.1.06.06.00 (Effects and degradation of drip shield) in (CRWMS M&O, 2001) states that A... seismic activity will not induce SCC of the waste packages or drip shields, regardless of magnitude, since a sustained tensile stress is required for SCC and an earthquake is only temporary in nature (CRWMS M&O 2000q, Section 5, Assumption 1).@ The above assumption does not account for the possibility of static loads affecting the drip shield and possibly, the waste package. References: CRWMS M&O. 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, NV. CRWMS M&O. 2000q. *Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier and the Stainless Steel Structural Material.* ANL-EBS-MD-000005 REV 00 ICN 01. Las Vegas, NV.	The results of the calculations will be documented in a future revision of the Analysis/Model Report *Design Analysis for the Ex-Container Components* (CRWMS M&O 2000l). DOE believes the existing agreements identified above for the Container Life and Source Term Key Technical Issue are sufficient to address the technical issue identified in the NRC comment without any new agreement items. Reference: CRWMS M&O 2000l. *Design Analysis for the Ex-Container Components.* ANL-XCS-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0374.
32	2.1.13.01.00	Radiolysis	FEP 2.1.13.01.00 (Radiolysis) is excluded based on low consequence. Screening argument considers only radiolysis of water to produce hydrogen and oxidants. No consideration of the formation of nitric acid resulting from radiolysis in presence of air. Spent fuel is expected to have higher dissolution rates at lower pH, thus ignoring nitric acid may underestimate radionuclide release. Potential production of nitric acid from radiolysis of N_2 in air should be considered. Necessary to consider potential effect of acid environments on the corrosion of Alloy 22 and Ti. Alpha, beta, gamma and neutron irradiation of air saturated water can cause changes in chemical conditions (Eh, pH, and concentration of reactive radicals) and positive shifts in corrosion potential due to the formation of hydrogen peroxide. DOE, on the bases of experimental work concluded that radiolysis will not lead to localized corrosion of Alloy 22. However, additional work by the DOE is necessary to complete the evaluation of the critical potentials related to localized corrosion of Alloy 22. Reference: CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada. CRWMS M&O, 2001. *FEPs screening of processes and issues in drip shield*	Container Life and Source Term agreement KCL0302 states in part, "...(DOE) will address specific NRC questions regarding radiolysis, incoming water, localized corrosion, corrosion products, transient effects, and a sensitivity study on differing dissolution rate of components." And Container Life and Source Term agreement KCL0303 states in part, "(DOE to) provide a more detailed calculation on the in package chemistry effects of radiolysis...." DOE believes that the Analysis/Model Report, In-Package Chemistry for Waste Forms (BSC 2001b) provided information on the effect on in-package chemistry of nitric acid produced by radiolysis, consistent with the Container Life and Source Term agreements KCL0302 and KCL0303. The Miscellaneous Waste Form Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001i) will be revised, to support any potential License Application, to reflect this new information.

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			and waste package degradation. ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	
33	N/A	NA	FEP(s) related to the effect of trace metal cations on Alloy-22 and Ti corrosion and stress corrosion should be added to database, given results recently reported by Barkatt and Gorman (2000). Reference: A. Barkatt and J.A. Gorman, Tests to Explore Specific Aspects of the Corrosion Resistance of C-22, Nuclear Waste Technical Review Board Meeting, August 1, 2000, Carson City, NV, 2000.	The project has reviewed the results reported in Barkatt and Gorman (2000) and has concluded that the testing conditions used were not relevant to Yucca Mountain Project. However existing Container Life and Source Term agreements (KCL0101, KCL0110, and KCL0601) are intended to evaluate the effects of introduced materials on water chemistry and deleterious trace element concentrations on the corrosion behavior of titanium, similar to the electrochemically based studies on Alloy 22. Consideration will be given to adding a new feature, event and process or augmenting an existing feature, event and process to account for the effects of trace elements on Alloy-22 and Titanium corrosion and stress corrosion. DOE believes the existing Container Life and Source Term agreements identified above are sufficient to address the technical issue identified in the NRC comment without any new agreement items.
34	2.1.03.02.00	Stress corrosion cracking of Waste Containers	FEP 2.1.03.02.00 (Stress corrosion cracking of Waste Containers) *Included* *Excluded* drip shield- low consequence "...Source of stress for cracks is due to cold work stress and cracks caused by rockfall However these cracks tend to be tight (i.e., small crack opening displacement) and fill with corrosion products and carbonate minerals. These corrosion products will limit water transport through the drip shield and thus not contribute significantly to overall radionuclide release rate from the underlying failed waste packages... " Screening argument for drip shield is weak. Simplified calculations by DOE indicate cracks will take considerable time to fill with corrosion products (*Stress corrosion cracking of the Drip Shield, the Waste Package Outer Barrier and the Stainless Steel Structural Material* ANL-EBS-MD-000005). Cracks that develop in the DS may propagate and/or "open up" when subjected to subsequent loads caused by rockfall/drift collapse and/or seismic excitation allowing significant ground water infiltration through the drip shield. Reference: CRWMS M&O. 2001. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation ANL-EBS-PA-000002. REV 01. Las Vegas, Nevada.	It is agreed that simplified calculations by DOE indicate cracks will take considerable time to fill with corrosion products ([CRWMS M&O 2000ap), however, quantitative bounding analyses have been underway to determine whether calcite and other minerals can precipitate at a sufficiently high rate to plug cracks resulted from stress corrosion cracking. The calculation depends mainly on two parameters: the evaporation at the surface of the waste package or drip shield in particular in the vicinity of cracks and the precipitation rate of minerals (BSC 2001c) . The analyses consider calcite and amorphous silica as minerals that potentially precipitate within the stress corrosion cracks. The analyses consider two end-member scenarios for potential water flow characteristics in the cracks: film flow and water bridging across the crack opening (BSC 2001c, Section 5.3.3). The water bridging scenario employs highly conservative assumptions such as no corrosion of the crack wall, no mixing of the bridging water with the outside environment, no water transport along the crack wall, and no consideration of mineral precipitate in the presence of fine particulates of corrosion products along the crack wall. The analysis results show that for the film flow scenario, cracks are plugged by mineral precipitates within a decade (BSC 2001c, Tables 6-3 and 6-5). For the conservative scenario (i.e., water bridging scenario), plugging of stress corrosion cracks takes 600 to 1,000 years if the stress corrosion crack opening occurs prior to 20,000 years (BSC 2001c, Tables 6-4 and 6-6). Considering the conservatism employed in the water bridging scenario, the time to plugging the cracks would be sooner than the bounding estimates. In general the analysis results support the assumption for the stress corrosion crack plugging by

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				precipitates in Total System Performance Assessment-Site Recommendation REV 00 (CRWMS M&O 2000aq). The ability of the additional loading combinations to initiate and/or propagate preexisting cracks are being addressed in response to Container Life and Source Term agreement KCL0208. Evaluations of the ability of these loading combinations to initiate and/or propagate preexisting cracks will be documented in a future revision of the Design Analysis for Uncanistered Fuel Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). Reference: CRWMS M&O 2000ap. *Stress Corrosion Cracking of the Drip Shield, the Waste Package Outer Barrier, and the Stainless Steel Structural Material.* ANL-EBS-MD-000005 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0340.
35	2.1.03.08.00	Juvenile and early failure of waste containers	FEP 2.1.03.08.00 Juvenile and early failure of waste containers *Included* Manufacturing and welding defects in waste container degradation analysis *Excluded* Manufacturing defects in drip shield degradation analysis, early failure of Waste package and drip shield from improper quality control during the emplacement "Major effect of pre-existing manufacturing defects is to provide sites for crack growth by stress corrosion cracking. Tensile stress is required to have stress corrosion cracking. Because all fabrication welds of DS are fully annealed prior to emplacement, drip shield are not subject to stress corrosion cracking earthquakes are insignificant to cause stress corrosion cracking (stresses are temporary in nature)" "Manufacturing defects in the drip shield and early failures of the Waste package and drip shield from improper quality control during emplacement can be excluded based on negligible consequence to dose" The bases for this assessment is that slap down analysis of a 21-PWR waste package resulted in stresses in the waste package material that were less than 90 percent of the ultimate tensile strength. The impact energy associated with emplacement error is substantially less than that expected in a vertical tip over, emplacement errors are "not expected to result in any damage." The results of the Slap-down analysis is cited as the screening analyses of several FEPs. The damage reported in the Slap down analyses is concerning.	The potential early failure mechanisms discussed in CRWMS M&O 2000d indicates that improper heat treatment of waste packages should be included in the waste package degradation and Total System Performance Assessment analysis. Manufacturing defects in the waste package outer barrier closure welds are also considered as in past analyses. Exclusion of the drip shield failures due to manufacturing flaws is not based on slap down analysis but o the fact that they will be annealed to eliminated fabrication stresses. The slap down analyses pertain to waste package failures and the early failure Analysis/Model Report addresses the probabilities and effects of handling damages. Reference: CRWMS M&O 2000d. *Analysis of Mechanisms for Early Waste Package Failure.* ANL-EBS-MD-000023 REV 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001011.0196.

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			While the impact energy of emplacement errors may be substantially less than those experienced int eh slap-down analyses, a proper assessment of the extent of Waste package damage as a result of emplacement errors should be performed. Reference: CRWMS M&O. 2001. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002. REV 01. Las Vegas, Nevada.	
36	2.1.09.03.00	Volume increase of corrosion products	FEP 2.1.09.03.00 (Volume increase of corrosion products). The presence of WP corrosion products with higher molar volume than the uncorroded material that may change the stress state in the material being corroded is excluded in the case of WP based on low consequence. However, it may have an effect on corrosion processes such as SCC of outer container after its initial breaching that may affect radionuclide release (see FEP 2.1.03.07.00, Mechanical Impact on the Waste Container and Drip Shield). The possibility of additional sources of stress arising from the formation of corrosion products should be evaluated in regard to SCC. See comment for FEP 2.1.11.05.00 (Differing thermal expansion of repository components). Reference: CRWMS M&O 2000, *FEPs Screening of Process and Issues in Drip Shield and Waste Package Degradation*, ANL-EBS-Pa-000002 Rev. 00 ICN 01	Analyses cited in Degradation of Stainless Steel Structural Material (CRWMS M&O 2000j, Section 6.1), indicate that even under very conservative assumptions, the growth of this corrosion product will not exceed 93 μm after 10,000 years. This oxide layer is not thick enough to produce enough pressure to cause mechanical damage to the Alloy 22 container. Reference: CRWMS M&O 2000j. *Degradation of Stainless Steel Structural Material.* ANL-EBS-MD-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000329.1188.
37	2.1.07.05.00	Creeping of metallic materials in the EBS	FEP 2.1.07.05.00 (Creeping of metallic materials in the EBS) has been excluded from consideration in the TSPA code (CRWMS M&O, 2001a,b). Although DOE correctly points out in their screening argument (CRWMS M&O, 2001b) that " the deformation of many titanium alloys loaded to yield point does not increase with time," (American Society for Metals International 1990, p. 626), it still does not specifically address the potential for creeping of titanium grades 7 and 24. For example, some titanium alloys have been shown to creep at room temperatures (Ankem, S., et al., 1994). Creeping of the titanium drip shield subjected to dead loads caused by fallen rock blocks and/or drift collapse could significantly reduce the clearance between the drip shield and waste package over time. As a result, the drip shield may cause substantial damage to the waste package during its dynamic response to subsequent seismic loads. In addition, creeping could potentially cause separation of the individual drip shield units. References: American Society for Metals International. 1990. Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, Specific Metals and Alloys. Volume 2 of Metals Handbook. 10th Edition. Metals Park, Ohio:	Treatment of creep of the drip shield is appropriate for the static loads and temperatures expected. Prior calculations assuming the presence of backfill and rockfall on top of the backfill showed the static loads on the drip shield to be low (<25% of yield strength). However, this calculation will be revised to eliminate the backfill effects. In addition, the potential for creep of Titanium drip shield under the static load will be explicitly addressed in the future revision of the Design Analysis for the Ex-Container Components, (CRWMS M&O 2000l) as part of the Container Life and Source Term agreement KCL0208. Additional loading combinations are being addressed in response to Container Life and Source Term agreement KCL0208. Evaluations of these loading combinations will be documented in a future revision of the Design Analysis for UCF Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components, (CRWMS M&O 2000l)

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			American Society for Metals; Ankem, S., C.A. Greene, and S. Singh. 1994. Time Dependent Twinning During Ambient Temperature Creep of a Ti-Mn Alloy. Scripta Metallurgica et Materialia, Vol 30, No 6, pp 803-808; CRWMS M&O. 2001a. Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2001b. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation. ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	
38	2.1.11.05.00	Differing thermal expansion of repository components	FEP 2.1.11.05.00 (Differing thermal expansion of repository components) has been excluded from consideration in the TSPA code (CRWMS M&O, 2001a,b). The technical basis for excluding differing thermal expansion effects on repository performance is not comprehensive nor adequate. For example, according to the screening arguments (CRWMS M&O, 2001b), " the difference in temperature between the inside of the waste package inner barrier (316NG) and the outside of the waste package outer barrier (Alloy 22) never exceeds 2°C. As an illustrative example, using the coefficients of thermal expansion for the two materials discussed above [i.e., Alloy 22 and 316NG] and a bounding 5°C (or 5 K) temperature difference between them, the calculated strain is $2.15A10^{-5}$ m/m. This strain is so small that thermal expansion of waste package barriers will result in a negligible effect on expected mean dose rate. A ~1 mm gap will prevent the resultant stress due to the differing thermal expansion coefficients of the waste package materials from reaching a critical level that could lead to stresses in the waste package barriers. The Waste Package Operation Fabrication Process Report (CRWMS M&O, 2000[a], Section 8.1.8) requires a loose fit between the outer barrier (Alloy 22) and the inner shell (316NG stainless steel) to accommodate the differing thermal expansion coefficients, and so this FEP can be excluded for the waste packages based on low consequence to the expected annual dose." The quoted rationale is not technically correct and does not address the limited clearance between the inner and outer barriers of the waste package in the axial direction, which may be as small as 2-mm according to design drawings (CRWMS M&O, 2000b). In addition, the differential thermal expansion between various invert components and the drift wall (which they are attached to) has not been addressed. Excluded - low consequence (CRWMS M&O. 2001a; 2001b). Peak temperature of Waste package 278 with backfill and 176EC without backfill with 0.5 meter spacing and 50-yr ventilation. Screening argument is that the temperature differential between inner type 316NG barrier and outer Alloy 22 barrier is 5EC and the corresponding strain of	Tensile stresses due to differential thermal expansion between waste package barriers are eliminated by the introduction of a gap between the barriers. This is done to eliminate tensile stresses due to differential thermal expansion from contributing to stress corrosion cracking of the waste package barriers. With this source of stress eliminated, it does not contribute to calculated dose rates due to waste package failure. Thermal expansion calculations already performed and in the process of documentation have indicated a need to increase the gap between the outer barrier lid and the inner barrier lid from the current 3-mm to 6-mm in the next revision to the waste package design concepts. These modifications are underway and will be included in next revisions to the Design Analysis for the UCF Waste Packages (CRWMS M&O 2000n), Design Analysis for the Defense High Level Waste Disposal Containers (CRWMS M&O 2000k), and Design Analysis for the Naval SNF Waste Package (CRWMS M&O 2000m). A more comprehensive listing of interfaces where differing thermal expansion may be of relevance in the Engineered Barrier System will be developed. For each such location, the amount of differential expansion will be estimated relative to the potential impact of such expansion on Engineered Barrier System component performance. This will provide a quantified basis for the Exclude – Low Consequence screening.

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			2.15 H 10^{15} m/m. This calculation is performed using difference between thermal expansion coefficients for 316NG and Alloy 22 using the maximum expected temperature difference between the waste package barriers. There will be at least a 1 mm gap between the barriers no thermal stresses are predicted. The calculation should use a temperature of the waste package rather than the difference between waste package barriers. The clearance between the inner type 316NG and the outer Alloy 22 is specified in the waste package design and fabrication process report to be 0 to 4 mm (CRWMS M&O. 2000a). It is implicit that this clearance is specified at ambient temperature (i.e. 25EC) because (i) no temperature is specified and (ii) the outer Alloy 22 waste package outer barrier will be heated to 700 F (371EC) for inner 316NG cylinder installation. Using a temperature of 186EC the calculated strain is 7.99 H 10^{14} m/m. For waste package with clearance gaps of 1 mm or less at 25EC, thermal stresses will occur as a result of the difference in thermal expansion. References: CRWMS M&O. 2000a. *Waste Package Operations Fabrication Process Report.* TDR-EBS-ND-000003 REV 01. Las Vegas, Nevada CRWMS M&O. 2000b. *Design Analysis for the Ex-Container Components.* ANL-XCS-ME-000001 REV 00. Las Vegas, Nevada CRWMS M&O. 2001a. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2001b. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01	
38	2.1.11.05.00	Differing thermal expansion of repository components		DOE has 2 cells for this item. Second cell refers to first.
39	2.1.06.06.00	Effects and degradation of drip shield	FEP 2.1.06.06.00 (Effects and Degradation of Drip Shield). Excluded based on low consequence (CRWMS M&O, 2000a). The drip shield is an important component of the EBS and its function and degradation is explicitly considered in the TSPA. The degradation of the drip shield due to corrosion processes is considered directly in the model abstraction for WP degradation, whereas remaining aspects of drip shield behavior are considered as part of the EBS analysis. A secondary FEP is FEP 2.1.06.06.01, Oxygen embrittlement of Ti drip shield, which is a subset of the Primary FEP and DOE argues that is explicitly considered in the screening argument discussion. No discussion is presented but it is noted that this issue is most relevant to mechanical failure of the drip shield, which is discussed under FEP 2.1.07.01.00, rockfall, and FEP	In the current revision of the FEPs Screening of Process and Issues in Drip Shield and Waste Package Degradation (CRWMS M&O 2001h), oxygen embrittlement of titanium results from diffusion of interstitial oxygen into the metal at higher temperatures (>340°C) (ASM International 1987, p. 681). The time to failure depends on the alloy composition, material thickness, and stress state. For the thermal hydrologic time history files used in the Total System Performance Assessment analyses, the waste package surface temperatures never exceed 186°C (CRWMS M&O 2000b, Section 6.3.1), which is less than the threshold temperature of 340°C. Therefore, oxygen embrittlement of the titanium drip shields is excluded on the basis of low consequence to the expected annual dose.

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			2.1.07.02.00, mechanical degradation or drift collapse. Although physical and chemical degradation processes have been included for consideration in the TSPA code, their effects on the ability of the drip shield to withstand dead loads (caused by drift collapse and/or fallen rock blocks), rock block impacts, and seismic excitation is not accounted for in the screening arguments (CRWMS M&O, 2001a,b). In (CRWMS M&O, 2000b, p. 29, 64) it is stated that the impact of rockfall on the degraded drip shield has been screened out from the TSPA-SR until more detailed structural response calculations for the drip shield under various rock loads are available. No references are provided in this document as to when and where these analyses will be available. References: CRWMS M&O 2000a, FEPs Screening of Process and Issues in Drip Shield and Waste Package Degradation, ANL-EBS-PA-000002 Rev. 00 ICN 01 CRWMS M&O. 2000b. *AMR EBS Radionuclide Transport Abstraction.* ANL-WIS-PA-000001 REV 00. Las Vegas, NV; CRWMS M&O. 2001a. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2001b. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada.	Reference ASM International 1987. *Corrosion.* Volume 13 of *Metals Handbook.* 9th Edition. Metals Park, Ohio: ASM International. TIC: 209807. CRWMS M&O 2000b. *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux.* ANL-EBS-HS-000003 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001206.0143.
39	2.1.06.06.00	Effects and degradation of drip shield	No NRC double number comment	The ability of the additional loading combinations to initiate and/or propagate preexisting cracks are being addressed in response to Container Life and Source Term agreements KCL0208 and KCL0209. Evaluations of the ability of these loading combinations to initiate and/or propagate preexisting cracks will be documented in a future revision of the Design Analysis for UCF Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l).
78	1.2.03.02.00	Seismic vibration causes container failure	FEP 1.2.03.02.00 (Seismic Vibration Causes Container Failure). The Seismic Vibration Causes Container Failure FEP has been excluded from consideration in the TSPA code (CRWMS M&O, 2001a,b). The screening argument cites preliminary seismic analyses of the drip shield and waste package as the basis for this screening decision (CRWMS M&O, 2000a). Because these analyses were not available at the time of this review, it is not clear as to whether the appropriate combinations of dead loads (caused by drift collapse and/or fallen rock blocks), rock block impacts, and seismic excitation were considered. Moreover, the ability of these loads to initiate cracks and/or propagate preexisting cracks may not have been adequately addressed. In addition, DOE has not demonstrated that the drip shield, pallet, and/or waste package will respond in a purely elastic manner when subjected to the aforementioned loading conditions.	The screening argument is based on 1) The design criteria to address preclosure seismic events (it is assumed that these criteria will be met) and 2) The net effect of damage to the waste package (i.e. stated in terms of equivalent drop height) that would occur from median 10^{-8} accelerations of 3.2 g, is met by the preclosure drop height requirement for the initial conditions of the waste package. As NRC has noted, multiple combinations and degradation of material properties have not yet been considered. Pending the results of additional analysis to address agreements from the Container Life and Source Term, Repository Design and Thermal Mechanical Effects and Structural Deformation and Seismicity Key Technical Issue technical exchanges, the screening decision is subject to review. DOE will document its approach to post-closure seismic issues in response to Structural Deformation and Seismicity agreements KSD0102 and KSD0203.

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			The screening argument for this FEP also states that " it does not appear credible that the drip shield would be breached, because the drip shield has been designed to withstand up to a 6-MT rockfall." based on the rockfall on drip shield analyses performed by the DOE (CRWMS M&O, 2000b). DOE, however, has not adequately demonstrated that the drip shield has in fact been designed to withstand 6-MT rock blocks {see the comments on FEPs 2.1.07.01.00 [Rockfall (large block)], 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift), and 2.1.07.05.00 (Creeping of metallic materials in the EBS) for additional discussion relevant to rockfall and seismic analyses}. References: CRWMS M&O 2000a. Input Request for Seismic Evaluations of Waste Packages and Emplacement Pallets. Input Transmittal 00230.T. Las Vegas, Nevada; CRWMS M&O 2000b. Rock Fall on Drip Shield. CAL-EDS-ME-000001 REV 00. Las Vegas, Nevada; CRWMS M&O.2001a. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation. ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada; CRWMS M&O.2001b. Features, Events, and Processes: Screening for Disruptive Events. ANL-WIS-MD-000005 REV 00 ICN01	With regard to specific issues raised: Additional loading combinations are being addressed in response to Container Life and Source Term agreement KCL0208. Evaluations of these loading combinations will be documented in a future revision of the Design Analysis for UCF Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). The ability of the additional loading combinations to initiate and/or propagate preexisting cracks are being addressed in response to Container Life and Source Term agreement KCL0208. Evaluations of the ability of these loading combinations to initiate and/or propagate preexisting cracks will be documented in a future revision of the Design Analysis for UCF Waste Packages (CRWMS M&O 2000n), and the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). DOE believes that only tensile stresses contribute to the initiation and propagation of the stress corrosion cracks. A purely elastic response of the drip shield, pallet, and/or waste package under the aforementioned loading conditions is not a design requirement. Therefore, there has been no attempt to demonstrate that these components respond in an elastic manner. Plastic deformation is reported when the evaluations indicate such. The potential for stress corrosion cracking will be addressed. The drip shield, in new condition, has been shown to withstand the impact of a 6-metric ton rock block without rupture. Additional loading conditions are being evaluated in response to Container Life and Source Term agreements including point load rockfall (KCL0202), potential embrittlement of the drip shield (KCL0208), wall thinning due to corrosion (KCL0208), and multiple rock blocks (KCL0208). These evaluations will be documented in a future revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l).

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41	2.1.02.20.00	Pressurization from Helium production. causes cladding failure	FEP 2.1.02.20.00 (Pressurization from helium production causes cladding failure). Included as a process of internal gas pressure buildup that increases the cladding stress contributing to delayed hydride cracking (DHC) and strain (creep??) failures. The wording could be more precise in the text where it is clarified that helium production from alpha decay is the main source of pressure buildup. Reference: CRWMS M&O, 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	At 100,000 years, the pressure, stresses, and stress intensities are a factor of 2.38 higher than at 100 years (values reported in the Clad Degradation – Summary and Abstraction Analysis/Model Report, CRWMS M&O 2001a). These values are still less than the threshold stress intensity values for stress corrosion cracking from Chlorine, Iodine, and Bromine at room temperature. Hence, the conclusions in the original Analysis/Model Report remain unchanged; stress corrosion cracking is not expected even with alpha decay, the main source of Helium production and pressure buildup, for 100,000 years. The role of helium buildup in cladding degradation will be included in the next revision of the Clad Degradation Summary and Abstraction Analysis/Model Report (CRWMS M&O 2001a).
42			Withdrawn by NRC	
43			Withdrawn by NRC	
44	2.1.02.16.00	Localized Corrosion (pitting) of cladding	FEP 2.1.02.16.00 (Localized corrosion [pitting] of cladding). Included because localized corrosion by pits could produce penetration of cladding. Even though localized corrosion is included in the CSNF cladding degradation model abstraction, the effect of chloride ions as pitting promoters is not considered in the analysis of localized corrosion done by the DOE. It is stated that pitting corrosion is promoted by concentrated chloride and fluoride solutions at very low pHs and very high oxidation potentials, but these conditions are not predicted to occur in the bulk solution inside WPs. However, it accepted that certain processes such as MIC, galvanic coupling, radiolysis in a humid environment, and evaporation may generate locally concentrated solutions of aggressive species or pH decreases that a model for localized corrosion is necessary. Reference: CRWMS M&O, *2000. Clad Degradation-Local Corrosion of Zirconium and its Alloys under Repository Conditions,* ANL-EBS-MD-000012, REV 00, Las Vegas, Nevada; CRWMS M&O. 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	The localized corrosion model will be modified to include pitting by chlorides. This model will be used in future cladding abstractions for Total System Performance Assessment-License Application. Probability distributions for pH will also be included in the analysis. This comment is addressed in agreements KCL0306 and KCL0307. Container Life and Source Term agreement KCL0306 states in part, "(DOE) to provide additional technical basis for the (cladding) failure rate and how the rate is affected by localized corrosion." And Container Life and Source Term agreement KCL0307 states in part, "(DOE) to provide data to address chloride induced localized corrosion and stress corrosion cracking under the environment predicted by in-package chemistry modeling." The Analysis/Model Reports*: Clad Degradation – Summary and Abstraction,* ANL-WIS-MD-000007 (CRWMS M&O 2001a) and *Clad Degradation – FEPs Screening Arguments,* ANL-WIS-MD-000008 (CRWMS M&O 2000h) will also be revised, incorporating the results from agreement KCL0307 to support any potential License Application, to reflect this new information.
45			Withdrawn by NRC	
46	2.1.02.24.00	Mechanical failure of cladding	FEP 2.1.02.24.00 (Mechanical failure [of cladding]). Included as a failure process resulting from external stresses such as ground motion during earthquakes assuming a frequency of 1.1 $x10^{-6}$ events/year that cause failure of all cladding that is available for unzipping. On the contrary, cladding failure arising from rock fall is not included in the model abstraction assuming integrity of the WP for 10,000 years (See FEP 2.1.07.01.00).	The technical bases of the seismic analysis is presented in CAL-EDS-MD-000001 REV 00 (CRWMS M&O 2000ao). Since that work was performed, a sensitivity study was performed and will be presented in the upcoming Supplemental Science and Performance Analysis, Volumes 1 and 2 (DOE 2001, in progress). In this new work, a more detailed seismic hazard distribution is used and shown to reduce the dose by 15%. This sensitivity study shows that seismic hazard is not a significant contributor to risk and hence, a more detailed analysis is not needed. In addition to the seismic

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			Reference: CRWMS M&O, 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	sensitivity study, cladding failure from a rock overburden was added to the Supplemental Science and Performance Analysis, Volumes 1 and 2. This model addresses the failure of cladding as the Waste Package deteriorates and no longer protects the fuel from the fallen rocks. The robustness or the cladding to extreme accelerations has also been addressed in many transportation studies. E. L. Wilmot (1981, Table VII) recommends the use of 71g accelerations for the failure threshold for fuel rods experiencing side impacts. An experimental threshold of 122 g for spent fuel is referenced. Also noted is that in drop tests, rods were bent with end impacts of 38 g but did not fail. Wilmot references experimental thresholds for end impacts of 234 g. Fischer et al. (1987, Figure 8-3) suggested that 10% of the rods might fail with a 40 g end impact and 100% might fail with a 100 g end impact. Witte et al. (1989, Table 3) report that the acceleration needed to fail rods from side impact varies from 63 g to 211 g, depending on the fuel design. Sanders et al. (1992, Attachment III) presents detailed structural analysis of various assemblies under impacts and gives (Table III-10) the probability of rod failure from 9 meter drops of transportation casks. All these references show the robustness of spent fuel rods to failure from impacts. Because these references support current analysis, no further analysis is planned. These references and new analysis presented in Supplemental Science and Performance Analysis will be included in the next revision of the Clad Degradation Features, Events and Processes Analysis/Model Report (CRWMS M&O 2000h). References for Response: Fischer, L.E.; Chou, C.K.; Gerhard, M.A.; Kimura, C.Y.; Martin, R.W.; Mensing, R.W.; Mount, M.E.; and Witte, M.C. 1987. *Shipping Container Response to Severe Highway and Railway Accident Conditions.* NUREG/CR-4829. Volume 1. Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: NNA.19900827.0230. Sanders, T.L.; Seager, K.D.; Rashid, Y.R.; Barrett, P.R.; Malinauskas, A.P.; Einziger, R.E.; Jordan, H.; Duffey, T.A.; Sutherland, S.H.; and Reardon, P.C. 1992. *A Method for Determining the Spent-Fuel Contribution to Transport Cask Containment Requirements.* SAND90-2406. Albuquerque, New Mexico: Sandia National Laboratories. TIC: 232162.Wilmot, E.L. 1981. *Transportation Accident Scenarios for Commercial Spent Fuel.* SAND80-2124. Albuquerque, New Mexico: Sandia National Laboratories. ACC: HQO.19871023.0215. Witte, M.C.; Chun, R.C.; and Schwartz, M.W. 1989. "Dynamic Impact Effects on Spent Fuel Assemblies." *9th International Symposium on the Packaging and Transportation of Radioactive Materials, Washington, D.C., June 11-16, 1989. 1,* 186-194. Oak Ridge, Tennessee: Oak Ridge National Laboratory. TIC: 240741.
47	2.1.02.17.00	Localized		DOE will continue to review new crevice corrosion literature as part of the

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		corrosion (crevice corrosion) of cladding	FEP 2.1.02.17.00 (Localized corrosion [crevice corrosion] of cladding). Excluded based on low probability of occurrence. Experimental evidence is cited to indicate that crevice corrosion has not been observed in zirconium alloys exposed to chloride solutions, including NRC /CNWRA results. There is a need to develop a better understanding of localized corrosion of zirconium alloys before confirming this conclusion because the data are limited. In the report on Clad Degradation- Local Corrosion of Zirconium and Its Alloys Under Repository Conditions, ANL-EBS-MD-000012, Rev 00 it is noted that crevice corrosion may occur in the presence of fluoride ions. References: CRWMS M&O, 2000.*Clad Degradation-Local Corrosion of Zirconium and its Alloys under Repository Conditions*, ANL-EBS-MD-000012 REV 00, Las Vegas, Nevada; CRWMS M&O. 2000. *Clad Degradation B FEPs Screening Arguments*. ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	execution of Container Life and Source Term agreement KCL0307. Agreement KCL0307 states in part, "(DOE) to provide data to address chloride induced localized corrosion and stress corrosion cracking under the environment predicted by in-package chemistry modeling." The Analysis/Model Reports: *Clad Degradation – Summary and Abstraction*, ANL-WIS-MD-000007 and *Clad Degradation – FEPs Screening Arguments*, ANL-WIS-MD-000008 will be revised, incorporating information from agreement KCL0307, including a summary of any significant new crevice corrosion literature, in time to support any potential License Application
48	2.1.01.04.00	Spatial heterogeneity of emplaced waste	FEP 2.1.01.04.00 (Spatial Heterogeneity of Emplaced Waste). Waste placed in Yucca Mountain will have physical, chemical, and radiological properties that will vary. The effect of spatial heterogeneity of the waste on repository-scale response is excluded based on low consequence but the heterogeneity within a waste package is implicitly included in the evaluation of in-package temperature used to determine perforation of the CSNF cladding. However, spatial variability that may affect degradation of engineering barrier, such as conditions leading to crevice corrosion vs passive corrosion of outer container, is not considered in this FEP. Reference: CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs*. ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada.	Spatial heterogeneity of the waste is addresses below. Spatial variability that may affect degradation of the waste package will be addressed as part of the resolution of the Container Life and Source Term agreement KCL0101. The scope of the agreement includes the evaluation of the range of chemical environments on the waste package.
48	2.1.01.04.00	Spatial heterogeneity of emplaced waste	No second NRC comment for this number.	The Near Field agreement KEN0303 states in part, "The DOE will provide analysis justifying the use of bulk chemistry as opposed to local chemistry for solubility and waste form degradation models..." and Container Life and Source Term agreement KCL0307 states in part, "...the technical basis for the models used for localized corrosion and stress corrosion cracking (of cladding) will be expanded in future revisions..." The information obtained from these agreements will respond to this comment in full. The Miscellaneous Waste Form Features, Events and Processes Analysis/Model Report (CRWMS M&O 2001i) and In-Package Chemistry for Waste Forms Analysis/Model Report (BSC 2001b) will be revised incorporating the appropriate new information.
49	2.1.02.15.00	Acid corrosion of cladding from radiolysis	FEP 2.1.02.15.00 (Acid corrosion of cladding from radiolysis). Included as part of localized corrosion model on the basis that the formation of HNO_3 and H_2O_2 ions(sic) by radiolysis can enhance corrosion of cladding. It is stated, however, that zirconium has excellent corrosion resistance to HNO_3 and concentrated H_2O_2. The arguments are poorly worded stating that radiolysis is not expected	Radiolysis by itself is not expected to damage the cladding. Radiolysis as a possible cause of pH reduction and coupled with $FeCl_3$ pitting is a possible mechanism for cladding failure. A new cladding localized corrosion model addressing radiolysis and low pH (pH < 2) will be developed in time to support any potential License Application. This comment is addressed in Container Life and Source Term agreement KCL0307. Agreement KCL0307 states in part,

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			to occur until WP failure and then the gamma dose will be very low to produce sufficient HNO_3 and H_2O_2 to promote general corrosion but localized corrosion could be possible. The argument of local acidic pH causing localized corrosion of cladding is in contradiction with experimental evidence showing that zirconium alloys are resistant to corrosion in reducing and oxidizing acids. In addition, it is in contradiction with arguments to screen out pitting corrosion by chloride anions (See FEP 2.1.02.16.00). In the Basis for Screening undue consideration is given to alkaline conditions arising from concrete liner whereas possibility of very acidic conditions (pH < 2) are not discussed. Reference: CRWMS M&O, 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	"(DOE) to provide data to address chloride induced localized corrosion and stress corrosion cracking under the environment predicted by in-package chemistry modeling." The Analysis/Model Reports: *Clad Degradation – Summary and Abstraction*, ANL-WIS-MD-000007 (CRWMS M&O 2001a) and *Clad Degradation – FEPs Screening Arguments*, ANL-WIS-MD-000008 (CRWMS M&O 2000h) will be revised, incorporating information from agreement KCL0307, in time to support any potential License Application.
50	2.1.02.13.00	General Corrosion of Cladding	FEP 2.1.02.13.00 (General corrosion of cladding) Excluded based on low probability of occurrence. Although general corrosion of cladding could expose large areas of irradiated fuel matrix and produce hydrides it is argued that it is a very slow process. The arguments are based on extrapolation to low temperatures at test data obtained at temperatures above 250°C and in measurements of oxide thickness from specific fuel rods after reactor operation and exposure to water in reactor pool storage. Reference: CRWMS M&O, 2000. *Clad Degradation - FEPs Screening Arguments.* ANL-WIS-MD-000008 REV00 ICN01. Las Vegas, Nevada (This reference is consistent with updated Database as quoted and valid for all FEPs on cladding); CRWMS M&O. 2000. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	The distributions of fuel characteristics developed in the Analysis/Model Report: Initial Cladding Condition (CRWMS M&O 2000ah) addresses fuel burnup to 75 MWd/kgU and oxide thickness to 120 µm, 20 µm above the NRC allowable limit of 100 µm. The distribution developed has 10.1% of the rods exceeding the NRC limit and 2.55% at 120 µm. These projections adequately address the general corrosion of the higher burnup fuels. In all calculations involving stress, the oxide thickness is subtracted off of the wall thickness (no structural credit for oxides). The Clad Degradation Features, Events and Processes Analysis/Model Report (CRWMS M&O 2000h) will be revised to reflect this information.
51	2.1.02.14.00	Microbially induced corrosion of cladding	FEP 2.1.02.14.00 (Microbially induced corrosion of cladding). Included as part of localized corrosion model on the basis that microbial activity may induce local pH decreases and the local acidic environment may produce multiple penetrations of the cladding. It is stated, however, that MIC resulting from sulfide produced by sulfate reducing bacteria (SBR) and organic acid producing bacteria is not expected to occur due to resistance of zirconium to these species. The arguments are poorly worded stating that MIC is not expected to occur (not probable or credible) because microbial activity is screened out at the scale of the repository model as a significant bulk process. The argument of local acidic pH causing localized corrosion of cladding is in contradiction with experimental evidence showing that zirconium alloys are resistant to corrosion in reducing and oxidizing acids. In addition, it is in contradiction with arguments to screen out pitting corrosion by chloride anions (See FEP 2.1.02.16.00). Screening arguments for inclusion or exclusion	The impact of microbial induced corrosion on the cladding environment and corrosion will be re-evaluated and documented during the execution of the Container Life and Source Term agreement KCL0307. Agreement KCL0307 states in part, "(DOE) to provide data to address chloride induced localized corrosion and stress corrosion cracking under the environment predicted by in-package chemistry modeling." The Analysis/Model Reports: *Clad Degradation – Summary and Abstraction*, ANL-WIS-MD-000007 (CRWMS M&O 2001a) and *Clad Degradation – FEPs Screening Arguments*, ANL-WIS-MD-000008 (CRWMS M&O 2000h) will be revised, incorporating information from agreement KCL0307, in time to support any potential License Application.

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			should be consistent with screening decisions for related FEPs (See FEP 2.1.02.15.00). A third group of bacteria iron oxidizers should be considered in the analysis too (see CLST IRSR Rev. 3). Reference: CRWMS M&O, 2000. *Clad Degradation - FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada.	
52	1.2.04.04.00	Magma Interacts w/ Waste	FEP 1.2.04.04.00 (Magma Interacts with Waste) includes in the WFMisc screening argument a citation of a 1996 document to indicate the igneous activity is not a significant contributor to risk. Although they do not end up trying to screen IA, DOE's estimates of the consequences of volcanism have increased by many orders of magnitude in the last 5 years, and it is now considered the only risk during the regulatory period. DOE should be careful about citing out of date documents for their screening arguments, especially on consequence. Reference: CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada.	FEP 1.2.04.04.00 (Magma Interacts with Waste) includes in the WFMisc screening argument a citation of a 1996 document to indicate the igneous activity is not a significant contributor to risk. Igneous activity has been screened in for Total System Performance Assessment. The mean annual igneous hazard described in the Probabilistic Volcanic Hazard Analysis was nominally 1.5×10^{-8}. The revised probability for the repository and the contingency blocks was about 1.6×10^{-8}. DOE acknowledges that igneous activity is a contributor to postclosure risk, however, the risk in terms of dose (mrem/yr) is almost 3 orders of magnitude below the proposed standard. The Probabilistic Volcanic Hazard Analysis did not include the estimation of the consequences of igneous activity. Calculations by DOE indicate that the maximum annual dose during the 10,000 year performance period of about 0.03 mrem. The average annual peak dose during the first 100,000 years following closure is 0.2 mrem, which occurs at about 30,000 years after closure. Even if the NRC's preferred probability value of 10^{-7}/year is chosen as the basis for a dose calculation, the maximum annual dose during the 10,000 year performance period increases to about 0.16 mrem, and the average annual peak dose increases to about 3 mrem at about 22,000 years. Increasing the mean annual probability from about 1.6×10^{-8} to 10^{-7} results in an increase in dose during the performance period from about 0.03 mrem to about 0.16 mrem or about half an order of magnitude. Similarly, the average annual peak dose increases from about 0.2 mrem to about 3 mrem--an increase of about one and a half order of magnitude. Hence, there is no basis for the statement that the consequences of volcanism have increased by many orders of magnitude in the last 5 years. DOE has not tried to screen igneous activity probability or consequences; both subissues are included in the Total System Performance Assessment analyses. Hence, no screening argument was made. Furthermore, the Probabilistic Volcanic Hazard Analysis is not out-of-date. The document remains the basis for the probability analyses documented in the Analysis/Model Report, Characterize Framework for Igneous Activity at Yucca Mountain, Nevada (CRWMS M&O 2000ay) and the Disruptive Events PMR (CRWMS M&O 2000s). The Miscellaneous Waste Form Features, Events and Processes Analysis/Model Report (ANL-WIS-MD-000009) (CRWMS M&O 2001l) will be

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				revised, to support any potential License Application, incorporating the appropriate new information developed relative to assessing igneous activity as a significant contributor to risk.
53	2.1.02.22.00	Hydride embrittlement of cladding	FEP 2.1.02.22.00 (Hydride embrittlement of cladding). Excluded based on low probability of occurrence. DOE screening argument states that the in-package environment and cladding stresses are not conductive to hydride cracking. The NRC staff believes that reorientation of pre-existing hydride and embrittlement depend on temperature in addition to the required stresses. Clarification is needed on the cladding temperature and stress distributions used in the analysis. References: CRWMS M&O. 2000. *Hydride Related Degradation of SNF Cladding Under Repository Conditions*, ANL-EBS-MD-000011 REV 00. Las Vegas, Nevada CRWMS M&O, 2000. *Clad Degradation - FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada. Several secondary FEPs are listed related to various processes leading to hydrogen entry into the cladding are listed below: FEP 2.1.02.22.01 (Hydride embrittlement from zirconium corrosion [of cladding]). Excluded due to low probability of occurrence because the hydrogen pickup as a result of cladding corrosion is very low due to the low corrosion rate and the relatively small pickup fraction. The experimental hydrogen pickup fraction is given ans it is argued that the corrosion rate is very low. The conclusion attained by the DOE regarding failure of cladding as a result of hydrogen pickup due to general corrosion is acceptable However, the screening arguments can be better justified using quantitative arguments for the corrosion rate under disposal conditions. FEP 2.1.02.22.02 (Hydride embrittlement from WP corrosion and hydrogen absorption [of cladding]). Excluded due to low probability of occurrence because the hydrogen generated by corrosion of WP and WP internals and present as a molecule in gas or dissolved in water is not directly absorbed by the cladding. It is argued on the basis of experimental data that hydrogen absorption occurred through the reaction with water and not from the dissolved molecular hydrogen. The conclusion attained by the DOE regarding failure of cladding as a result of absorption of hydrogen gas generated by corrosion of WP materials is acceptable. However, the screening arguments can be better organized. FEP 2.1.02.22.03 (Hydride embrittlement from galvanic corrosion of WP contacting cladding) Excluded due to low probability of occurrence because corrosion of WP	This response is applicable to Features, Events and Processes 2.1.02.22.00 through 2.1.02.22.07. The next revision to the Clad Degradation Features, Events and Processes Analysis/Model Report (ANL-WIS-MD-000008 will update the discussion of each component of hydride embrittlement in the 8 Features, Events and Processes (2.1.02.22.00 through 2.1.02.22.07) with emphasis on providing better organized, more quantitative discussion and the combined effects of both stress and temperature. .2.1.02.22.07 will be changed from exclude to include based on recent experimental evidence.

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			internals will not result in hydriding of cladding. It is argued using some experimental data as basis that galvanic coupling to carbon steel will not be conducive to hydrogen charging because corrosion products will interrupt the electrical contact. It is claimed also that the Ni content both in Zircaloy 2- and -4 is not sufficient to induce the necessary hydrogen charging. The conclusion attained by the DOE regarding failure of cladding as a result of hydrogen entry due to galvanic coupling with internal components of the WP is in general acceptable However, the screening arguments could be better supported by more relevant experimental data. FEP 2.1.02.22.04 (Delayed hydride cracking [of cladding]) Excluded due to low probability of occurrence. The analysis is based on the use of calculated values for the distribution of the stress intensity factor which are compared with the threshold stress intensity for irradiated Zircaloy-2. The conclusion attained by the DOE regarding failure of cladding as a result of DHC is acceptable. However, the DOE analysis of DHC is based on material properties of cladding containing mostly circumferential hydrides. DOE need to provide cladding temperatures and stress distributions and demonstrate that are insufficient to cause hydride reorientation. FEP 2.1.02.22.05 (Hydride reorientation [of cladding]) Excluded due to low probability of occurrence because tested fuel rods did not exhibited hydride reorientation at stresses higher than those expected at the repository temperatures. It is argued, in addition, that with hydride reorientation stresses will be insufficient for hydride embrittlement and clad failure. Therefore hydride reorientation has not been included in the model abstraction for cladding degradation. DOE agreed to provide updated documentation on the distribution of cladding temperatures and hoop stresses, critical parameters needed to evaluate the propensity to hydride reorientation and embrittlement. See primary FEP (FEP 2.1.02.22.00). FEP 2.1.02.22.06 (Hydride axial migration [of cladding]). Excluded based on low probability since it is unlikely that sufficient hydrogen can be moved to the cooler ends of the fuel rods because of a lack of large temperature gradients in the WPs. Based on studies for storage up to 90 years, it is concluded that the temperature gradients are not sufficient to induce redistribution of hydrides. The conclusion attained by the DOE regarding redistribution of hydrides caused by temperature gradients is acceptable. The screening arguments, however, should include the combined effects of stress and temperature. FEP 2.1.02.22.07 (Hydride embrittlement from fuel reaction [causes failure if cladding]). Excluded based in low probability of occurrence because hydride embrittlement from fuel reaction (???) is only observed in BWRs and a high	

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			temperature steam environment is require for failure propagation, conditions which are unlikely even after WP failure. The conclusion is acceptable because it is not a credible failure mechanism. However, the screening arguments are to say the least, confusing.	
53		Hydride embrittlement from zirconium corrosion (of cladding		DOE has 7 cells which state, "See response to Features, Events and Processes 2.1.02.22.00."

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54	2.1.09.02.00	Interaction w/ Corrosion products	FEP 2.1.09.02.00 (Interaction with corrosion products) was excluded in the EBS (except for colloid-related effects) on the basis of low consequence (CRWMS M&O. 2001). As noted in the NRC/DOE technical exchange on ENFE, changes in seepage water chemistry resulting from interactions with engineered materials and their corrosion products were not adequately addressed in (CRWMS M&O, 2000).Water has been observed to drip preferentially along grouted rock bolts in the ECRB, for example, demonstrating that the introduced materials themselves can influence the location of preferred flow pathways. Seepage waters that have interacted with engineered materials and their corrosion products, can have a significant effect on evolved water and gas compositions. References: CRWMS M&O. 2000. *EBS Physical and Chemical Environmental Model AMR*,ANL-EBS-MD-000033 REV 01. Las Vegas, Nevada; CRWMS M&O. 2001. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada.	An estimate of potential heterogeneity in seepage water chemistry due to localized interactions with Engineered Barrier System components and their corrosion products in addition to the potential for such seepage interacting with Engineered Barrier System components and accelerating Engineered Barrier System degradation processes will be addressed as part of agreement KEN0206. An evaluation of the impact of the range of local chemistry (e.g., dripping of equilibrated evaporated cement leachate and corrosion products) conditions at the drip shield and waste package considering the chemical divide phenomena that may propagate small uncertainties into large effects. The DOE will evaluate the range of local chemical conditions at the drip shield and waste package (e.g. local variations in water composition associated with cement leaching or the presence of corrosion products), considering potential evaporative concentration and the chemical divide effect whereby small differences in initial composition could cause large differences in brine characteristics.
55	2.1.09.07.00	Reaction Kinetics in Waste and EBS	FEP 2.1.09.07.00 (Reaction kinetics in waste and EBS). Consideration of chemical reactions, such as radionuclide dissolution/ precipitation reactions and reactions controlling the reduction-oxidation state is included by considering reaction kinetics in the in-package equilibrium model but excluded based on low consequence for the EBS. However, these [processes may affect the composition of the near field environment, particularly for trace elements, and the effect on corrosion of container materials could be indirect and should be considered. Adequate technical bases have not been provided to demonstrate that the combination of transport processes and reaction kinetics in the EBS will not adversely impact performance by altering the composition of water contacting the drip shield and waste package Reference: CRWMS M&O. 2001. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada. CRWMS M&O. 2000. *Miscellaneous Waste Form FEPs* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada.	In the Near Field agreement KEN0211, the DOE will provide additional technical basis for the treatment of precipitation-dissolution kinetics by the in-drift geochemical models, in a revision to the Engineered Barrier System: Physical and Chemical Environment Model Analysis/Model Report (CRWMS M&O 2000w). The technical basis will include reaction progress simulation for laboratory evaporative concentration tests, and will include appropriate treatment of time as related to the residence times associated with the abstractions used to represent in-drift processes in Total System Performance Assessment. In addition, agreement KEN0208 indicates that DOE will provide additional technical basis for the suppression of individual minerals predicted by equilibrium models, in a revision to the Engineered Barrier System: Physical and Chemical Environment Model Analysis/Model Report (CRWMS M&O 2000w)
55	2.1.09.07.00	Reaction Kinetics in Waste and EBS		DOE has 2 cells, second indicates, "See response above"
56	2.1.07.06.00	Floor buckling	FEP 2.1.07.06.00 (Floor Buckling) has been excluded (CRWMS M&O, 2001)	The information on the buckling or heave of the floor of an emplacement drift can be inferred from computer output files generated for ground control

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			and *EBS Radionuclide Transport Abstraction* (CRWMS M&O, 2000) based on analyses documented in *Repository Ground Support Analysis for Viability Assessment* (CRWMS M&O, 1998), which indicate that floor heave from thermal-mechanical effects would not exceed about 10 mm. However, to address concerns raised by NRC staff about the appropriateness of the thermal-mechanical properties used in DOE calculations (such as the analyses cited above), the DOE has agreed to revise its assessment of floor buckling [RDTME Agreement 3.9 (DOE/NRC Technical Exchange on RDTME, February 6B8, 2001, Las Vegas, Nevada)]. Note that screening argument relies on analyses that DOE has agreed to revise to address outstanding NRC concerns in RDTME Agreements 3.2B3.13 (RDTME Technical Exchange, February 6B8, 2001, Las Vegas, Nevada). References: CRWMS M&O. 1998. *Repository Ground Support Analysis for Viability Assessment.* BCAA00000-01717-0200-0004 Rev 01. Las Vegas, Nevada CRWMS M&O. 2000. EBS Radionuclide Transport Abstraction AMR. ANL-WIS-PA-000001 Rev 00. Las Vegas, Nevada CRWMS M&O. 2001. Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada.	analyses, such as Ground Control for Emplacement Drifts for Site Recommendation (CRWMS M&O 2000ae). The topic was not addressed in ground control analyses in an explicit manner because it has no direct implications on ground control. An ICN is currently being issued to Ground Control for Emplacement Drifts for Site Recommendation, and the preliminary results using latest thermal properties indicate that the maximum differential movement of the invert area is well within 10 mm. The Repository Design and Thermal Mechanical Effects agreement on floor heave, KRD0309: "DOE will provide appropriate analysis that shows rock movements in the floor of the emplacement drift are within the range acceptable for preclosure operations. The analysis results will be provided in a revision to the Ground Control for Emplacement Drifts for Site Recommendation (CRWMS M&O 2000ae) (or other document) supporting any potential license application," will be addressed in detail in additional ground control analyses necessary for Key Technical Issue resolution.
57	1.1.02.03.00	Undesirable materials left	FEP 1.1.02.03.00 (Undesirable materials left) is screened out on the basis of low consequences (CRWMS M&O, 2000). Although a report cited by the DOE (CRWMS M&O, 1995b) provides an analysis of acceptable upper bounds on materials introduced into the repository, no analysis has been conducted to determine if the current design will meet these limits. An assumption that the limits will be adhered to during the preclosure period is considered inadequate to exclude this FEP. DOE should provide adequate technical basis for the effect of introduced materials on water chemistry Reference: CRWMS M&O. 1995b. Waste Isolation Evaluation: Tracers, Fluids, and Materials, and Excavation Methods for Use in the Package 2C Exploratory Studies Facility Construction. BABE00000-01717-2200-00007 Rev 04. Las Vegas, NV, 1995b CRWMS M&O. 2000. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada.	An inherent assumption in the licensing and construction process, as stated in the features, events and processes (FEPs) Analysis/Model Report, is that the repository will be built as designed, and that the quality control requirements will be adhered to, monitored, and enforced per the NRC's regulations. A review of the current repository design will be conducted to provide estimates of the quantities of "undesirable materials" (organics, cementitious materials, etc.) to be used in the current design pre-closure phase relative to the limits discussed in the referenced document. This review will also consider the assessment of trace material impact on Engineered Barrier System groundwater chemistry (both within the drift as well as the plume leaving the drift) being conducted as part of the Engineered Barrier System Thermo-hydrologic chemical modeling. Operational process controls, such as, (1) providing procedural assurance that future operational actions will be done according to a plan, and (2) including in FEPs analysis a reasonable estimate of the uncertainty associated with our ability to implement the plan exactly, is sufficient to account for the potential of undesirable conditions.
58	Various	NA	Screening arguments were labeled with the word *Preliminary* in *Features, Events, and Processes: Screening for Disruptive Events.* ANL-WIS-MD-000005 REV 00 ICN1. 2001. {FEPs 2.1.07.01.00 [Rockfall (Large Block)];	The use of the term "Preliminary" is intended to denote that the screening argument was ongoing analyses. Once these analyses are completed, the screening arguments will be strengthened and the Features, Events, and Processes Analysis/Model Report revised to remove "preliminary."

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			1.2.02.01.00 (Fractures); 1.2.02.02.00 (Faulting); 1.2.03.01.00 (Seismic activity); etc} *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. 2001. Attachment I includes 61 FEPs arguments that are considered preliminary. It is stated that "future modeling and analysis efforts may enhance these considerations, and in this sense they are preliminary." It is necessary to disclose plans to release of more solid screening arguments.	The schedule for ongoing activities are integrated into the overall project schedule and prioritized based on project milestones and budget. A final list of Features, Events, and Processes will be completed by License Application. The resolution of preliminary screening arguments required to support a potential license application will be considered in the scope of work during the associated planning activities. Recommend preliminary screening arguments be discussed on a case-by-case basis during the applicable the Features, Events, and Processes Analysis/Model Report discussions.
59	2.1.08.04.00	Cold traps	FEP 2.1.08.04.00 (Cold Traps). Emplacement of waste in the drifts creates thermal gradients within the repository that may result in condensation forming on the roof of the drifts or elsewhere in the EBS, leading to enhanced dripping on the drip shields, waste packages, or exposed waste material. This FEP is excluded on the basis of low consequence (CRWMS M&O, 2001). The DOE's Multiscale Thermohydrologic Model (MSTHM) does not account for mass transport along the length of drifts. The only MSTHM submodel that includes thermal hydrology (i.e. mass transport) is a cross-section of a drift so it accounts for potential condensation only along the radial axis. References: CRWMS M&O. 2001. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV01. Las Vegas, Nevada.	Thermal Effects on Flow agreement KTE0205 states that technical support for the inclusion or exclusion of the cold trap effect in the various scale models will be documented in the Multi-scale Thermal Hydrological Model. The analysis will consider repository edge effects and in-drift geochemical environment abstraction. The magnitude of such enhancement relative to the seepage flux will be considered relative to its impact on drip shield and waste package failure and on waste form dissolution and radionuclide transport. This will provide a quantified basis for the Exclude – Low Consequence screening.
60	2.1.12.01.00	Gas generation	The exclusion of 2.1.12.01.00 (Gas generation); and 2.1.12.05.00 (Gas generation from concrete) is unacceptable, because adequate technical bases have not been provided to justify the characterization of chemical environments in the EBS in terms of bulk water and gas compositions. The possibility of existence of local heterogeneity in gas composition in the drift, altering the chemistry of the DS/WP environment and adversely impacting repository performance should be explored. Local variations in the efficiency of advection/diffusion processes, relative to reaction rates, should be evaluated. References: CRWMS M&O, 2000. *Miscellaneous Waste Form FEPs.* ANL-WIS-MD-000009 REV 00 ICN01. Las Vegas, Nevada. CRWMS M&O. 2001. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada.	Engineered Barrier System will estimate the potential heterogeneity in local gas composition within the drift, due to gas generation from corrosion, microbial action, and concrete degradation. Based on such bounding estimates of compositional heterogeneity, the impact on local chemistry and key reaction rates will also be estimated.

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61	2.2.10.12.00	Geosphere dry-out due to waste heat	FEP 2.2.10.12.00 (Geosphere dry-out due to waste heat). Necessary to develop screening argument for this FEP under scope of UZ Flow and Transport FEP AMR. Elevated thermal effects on shallow infiltration due to changes in soil water content were not addressed for this FEP. DOE study of a natural thermal gradient on YM addresses this FEP (CRWMS M&O, 1998). This FEP is screened as included in (CRWMS M&O, 2001) for issues related to Near Field Environment, but does not address the effects of the FEP on infiltration. References: CRWMS M&O. 1998. *Final Report: Plant and Soil Related Processes along a Natural Thermal Gradient at Yucca Mountain, Nevada.* B00000000-01717-5705-00109 Rev 00. Las Vegas Nevada. CRWMS M&O. 2000. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001REV 00. Las Vegas, Nevada. CRWMS M&O, 2001. *FEPs in Thermal Hydrology and Coupled Processes.* ANL-NBS-MD-000004 REV 00 ICN01. Las Vegas, Nevada.	DOE will cite the suggested reference for this question and include this feature, event and process in the next revision of the Features, Events, and Processes in Unsaturated Zone Flow and Transport Analysis/Model Report (ANL-NBS-MD-000001, BSC 2001d)
62	2.2.01.02.00	Thermal and other waste and EBS-related changes in the adjacent host rock	FEP 2.2.01.02.00 (Thermal and other waste and EBS-related changes in the adjacent host rock). Excluded - Low consequence (TM effects). Excluded - Low Probability (THC and backfill effects). Changes in host rock properties result from thermal effects or other factors related to emplacement of the waste and EBS, such as mechanical or chemical effects of backfill. Properties that may be affected include rock strength, fracture spacing and block size, and hydrologic properties such as permeability. The screening argument did not consider mechanical degradation of the rock mass, such as fracture-wall rock alteration owing to long-term exposure to heat, moisture, and atmospheric conditions. Such degradation would increase the severity of mechanical failure, e.g., (Ofoegbu G.I., 2000). However, DOE is expected to reevaluate its assessment of long-term mechanical degradation to satisfy outstanding DOE/NRC agreements (RDTME Agreements 3.11 and 3.19). In the analyses, it is necessary to account for long-term mechanical degradation of the host rock mass in its assessment of drift degradation, rockfall, and changes in hydrological properties; and their effects on repository performance. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada. Ofoegbu G.I. 2000. *Thermal-Mechanical Effects on Long-Term Hydrological Properties at the Proposed Yucca Mountain Nuclear Waste Repository.* CNWRA 2000-03. San Antonio, TX: Center for Nuclear Waste Regulatory	The current Total System Performance Assessment increases the quantity of seepage that enters an intact drift by 50% to account for the degradation of the drift. This value was based on a sensitivity study performed in the seepage model. Although the drift is not expected to degrade everywhere, this 50% increase in seepage flow is used at all locations. In addition, the subject matter introduced by this question is the basis for two Repository Design and Thermal Mechanical Effects agreements between DOE and NRC (KRD0311 and KRD0319). In the Repository Design and Thermal Mechanical Effects agreement KRD0311, the DOE will justify the preclosure ground support system design (including the effects of long term degradation of rock mass and joint strength properties) in a revision to the Ground Control for Emplacement Drifts for Site-Recommendation (CRWMS M&O 2000ae) (or other document) supporting any potential license application. In the Repository Design and Thermal Mechanical Effects agreement KRD0319, the DOE states its belief that the Drift Degradation Analysis is consistent with current understanding of the Yucca Mountain site and the level of detail of the design to date. As understanding of the site and the design evolve, DOE will: (1) provide revised Discrete Region Key-Block Analysis (DRKBA) analyses using appropriate range of strength properties for rock joints from a design parameters analysis report (or other document), accounting for their long-term degradation; (2) provide an analysis of block sizes based on the full distribution of joint trace length data from the Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon(CRWMS M&O

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			Analyses.	2000ad), supplemented by available small joint trace length data; (3) verify the results of the revised DRKBA analyses using: (a) appropriate boundary conditions for thermal and seismic loading; (b) critical fracture patterns from the DRKBA Monte Carlo simulations (at least two patterns for each rock unit); (c) thermal and mechanical properties for rock blocks and joints from a design parameters analysis report (or other document); (d) long-term degradation of joint strength parameters; and (e) site-specific ground motion time histories appropriate for post-closure period. This will be documented in a revision to the Drift Degradation Analysis (CRWMS M&O 2000t). Based on the results of the analyses above and subsequent drip shield calculation revisions, DOE will reconsider the screening decision for inclusion or exclusion of rockfall in performance assessment analysis. Any changes to screening decisions will be documented in analyses prior to any potential License Application.
62	2.2.01.02.00	Thermal and other waste and EBS-related changes in the adjacent host rock		DOE has a 2nd cell for 62, it states "See response to Feature, Event and Process 2.2.01.01.00"
63	2.1.09.12.00	Rind (altered zone) formation in waste, EBS and adjacent rock	FEP 2.1.09.12.00 (Rind (altered zone) formation in waste, EBS, and adjacent rock). Included (THC model). Excluded - Low consequence (TH model, effects on transport). Thermo-chemical processes alter the rock forming the drift walls mineralogically. These alterations have hydrologic, thermal and mineralogic properties different from the current country rock. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	This technical issue introduced by this comment is the subject of an existing near field agreement KEN0103. KEN0103 commits to gathering information on the quantity of unreacted solute mass that is trapped in dry-out zone in TOUGHREACT simulations, as well as how this would affect precipitation and the resulting change in hydrologic properties. The DOE provided to NRC documentation of model validation, consistent with the DOE quality assurance requirements, in the Drift-Scale Coupled Processes (Drift-Scale Test and Thermal-hydrological-chemical Seepage) Analysis/Model Report (CRWMS M&O 2001c) in March 2001. In accordance with agreement KEN0103, DOE will provide information on the quantity of unreacted solute mass that is trapped in the dryout zone in TOUGHREACT simulations in the Drift-Scale Coupled Processes (Drift-Scale Test and Thermal-hydrological-chemical Seepage) Models Analysis/Model Report Rev 02. This information will be used to provide the basis for inclusion or exclusion of the subject scenario.
64	2.2.10.06.00	Thermo-chemical alteration (solubility speciation, phase changes, precipitation/dissolution	FEP 2.2.10.06.00 (Thermo-chemical alteration (solubility speciation, phase changes, precipitation/dissolution)). Excluded - Low Consequence. Changes in the groundwater temperature in the far-field, if significant, may change the solubility and speciation of certain radionuclides. This would have the effect of altering radionuclide transport processes. Relevant processes include volume effects associated with silica phase changes, precipitation and dissolution of fracture-filling minerals (including silica and calcite), and alteration of zeolites and other minerals to clays. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes	This Feature, Event and Process is conservatively ignored with respect to solubility reduction in the far-field, since Total System Performance Assessment assumes that all radionuclides remain soluble and do not precipitate. The effects of colloid formation are accounted for in the colloid source term and are included in the Performance Assessment model. Colloids are expected to be formed from the degradation of the High Level Waste and Spent Nuclear Fuel waste forms, Engineered Barrier System materials and rock. Radionuclides associated with colloids are assumed to be either irreversibly or reversibly attached to colloids (Refer to Particle Tracking Model and Abstraction of Transport Processes [CRWMS M&O 2000al], Section 6, and Unsaturated Zone Colloid Transport Model (CRWMS M&O 2000at), Section 6). The near-field

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			features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	thermal-chemical analysis indicates only small changes in hydrologic properties and mineralogy as a result of these coupled processes (Drift-Scale Coupled Processes [Drift-Scale Test and Thermal-hydrological-chemical Seepage] Models, [CRWMS M&O 2000u],Section 6). Therefore, far-field changes are likewise expected to be small (Assumption 11), including mineral precipitation/dissolution and alteration of minerals such as zeolites and clays. Therefore, this Feature, Event and Process is excluded from Total System Performance Assessment on the basis of low consequence. Additionally, this technical issue introduced by this comment is the subject of an existing Near Field agreement (KEN0103). KEN0103 commits to gathering information on the quantity of unreacted solute mass that is trapped in dry-out zone in TOUGHREACT simulations, as well as how this would affect precipitation and the resulting change in hydrologic properties. The DOE provided to NRC documentation of model validation, consistent with the DOE Quality Assurance requirements, in the Drift-Scale Coupled Processes (Drift-Scale Test and Thermal-hydrological-chemical Seepage) Analysis/Model Report (CRWMS M&O 2001c) in March 2001. In accordance with agreement KEN0103, DOE will provide information on the quantity of unreacted solute mass that is trapped in the dryout zone in TOUGHREACT simulations in the Drift-Scale Coupled Processes (Drift-Scale Test and Thermal-hydrological-chemical Seepage) Analysis/Model Report Rev 02. This information will be used to provide the basis for inclusion or exclusion of the subject scenario.
65	2.1.11.02.00	Nonuniform heat distribution/edge effects in repository	FEP 2.1.11.02.00 (Nonuniform heat distribution/edge effects in repository). Included (TH and THC aspects) Excluded - Low consequence (TM effects). Temperature inhomogeneities in the repository lead to localized accumulation of moisture. Uneven heating and cooling at repository edges lead to non-uniform thermal effects during both the thermal peak and the cool-down period. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	Repository wide non-uniform heating effects are the subject of Thermal Effects on Flow agreement KTE0205 this work will represent the cold-trap effect in the appropriate models or provide the technical basis for exclusion of it in the various scale models.
66	2.2.06.01.00	Changes in stress due to thermal, seismic or tectonic effects	FEP 2.2.06.01.00 [Changes in stress (due to thermal, seismic, or tectonic effects) change porosity and permeability of rock]. Excluded - Low consequence. Excluded - Low probability (one secondary FEP not relevant to YMP) (CRWMS M&O, 2001). Even small changes in the fracture openings cause large changes in permeability. The rock deforms according to the rock stress field. Changes in the groundwater flow and in the temperature field will change the stress acting on the rock which will in turn change the groundwater flow. FEP 2.2.06.01.00 [Change in stress (due to thermal, seismic, or tectonic	Thermal-mechanical effects may result in changes in fracture apertures in support pillars between drifts. If the horizontal fractures open up more than the vertical fractures, it may be possible that flow could divert towards the drifts. DOE is presently performing process-model simulations using both continuum and discrete fracture models to analyze the effects of thermal-hydrologic-mechanical coupled processes with regard to drainage in the pillars and flow in the vicinity of the drifts. Furthermore, DOE is performing thermal-hydrological/ thermal-hydrological-chemical/ thermal-hydrological-mechanical analyses to quantify uncertainties in the thermal seepage model. Based on the results, DOE will revisit the Feature, Event and Process screening arguments. Interim results are reported in the Supplemental Science and Performance Analysis.

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			effects) change porosity and permeability of rock] was excluded as having low consequence to dose (CRWMS M&O, 2000a). However, the DOE analyses used to support the screening argument (CRWMS M&O, 2000b) did not consider water-flux diversion toward a drift from the adjacent pillar caused by increased aperture of subhorizontal fractures in the pillar from thermal-mechanical response. Such flux diversion would cause increased water flow to the drifts and potentially significant effects on dose. References: CRWMS 1.2.02.01.00 M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada. CRWMS M&O. 2000a. *Features, Events, and Processes: Screening for Disruptive Events.* ANL-WIS-MD-000005 REV 00 ICN01. Las Vegas, NV. CRWMS M&O. 2000b. AMR *Fault Displacement Effects on Transport in the Unsaturated Zone* (ANL-NBS-HS-000020 Rev 00. Las Vegas, NV.	
66		Changes in stress due to thermal, seismic or tectonic effects		DOE has a 2nd cell which states, "See response to Feature, Event and Process 2.2.01.01.00"
67	2.2.10.05.00	Thermo-mechanical alteration of rocks above and below the repository	FEP 2.2.10.05.00 (Thermo-mechanical alteration of rocks above and below the repository). Thermal-mechanical compression at the repository produces tension-fracturing in the PTn and other units above the repository. These fractures alter unsaturated zone flow between the surface and the repository. Extreme fracturing may propagate to the surface, affecting infiltration. Thermal fracturing in rocks below the repository affects flow and radionuclide transport to the saturated zone. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	See response to Feature, Event and Process 2.2.01.01.00
68	1.2.02.01.00	Fractures	FEP 1.2.02.01.00 (Fractures). Included (seepage). Excluded - Low consequence (permanent effects). Generation of new fractures and re-activation of preexisting fractures may significantly change the flow and transport paths. Newly formed and reactivated fractures typically result from thermal, seismic, or tectonic events. Thermally induced changes in stress may result in permeability changes between drifts that could act to divert flow towards drifts. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las	Thermal-mechanical effects may result in changes in fracture apertures in support pillars between drifts. If the horizontal fractures open up more than the vertical fractures, it may be possible that flow could divert towards the drifts. DOE is presently performing process-model simulations using both continuum and discrete fracture models to analyze the effects of thermal-hydrologic-mechanical coupled processes with regard to drainage in the pillars and flow in the vicinity of the drifts. Furthermore, DOE is performing thermal-hydrological/ thermal-hydrological -chemical/ thermal-hydrological-mechanical analyses to quantify uncertainties in the thermal seepage model. Based on the results, DOE will revisit the Feature, Event and Process screening arguments. Interim results

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			Vegas, Nevada.	are reported in the Supplemental Science and Performance Analysis.
69	2.2.01.01.00	Excavation and construction-related changes in the adjacent host rock	FEP 2.2.01.01.00 (Excavation and construction-related changes in the adjacent host rock). Included (initial effects on seepage). Excluded - Low consequence (permanent THC and TM effects). Stress relief, leading to dilation of joints and fractures, is expected in an axial zone of up to one diameter width surrounding the tunnels. Reference: CRWMS M&O. 2001. Thermal hydrology and coupled processes features, events, and processes. ANL-NBS-MD-000004REV 00 ICN 01. Las Vegas, Nevada.	Thermal-mechanical effects may result in changes in fracture apertures in support pillars between drifts. If the horizontal fractures open up more than the vertical fractures, it may be possible that flow could divert towards the drifts. DOE is presently performing process-model simulations using both continuum and discrete fracture models to analyze the effects of thermal-hydrologic-mechanical coupled processes with regard to drainage in the pillars and flow in the vicinity of the drifts. Furthermore, DOE is performing thermal-hydrological/ thermal-hydrological-chemical/ thermal-hydrological-mechanical analyses to quantify uncertainties in the thermal seepage model. Based on the results, DOE will revisit the Feature, Event and Process screening arguments. Interim results are reported in the Supplemental Science and Performance Analysis.
70	2.2.10.04.00	Thermo-Mechanical alteration of fractures near repository	FEP 2.2.10.04.00 (Thermo-Mechanical alteration of fractures near repository). This FEP was excluded as having low consequence to dose (CRWMS M&O, 2001, 2000). See discussion under FEP 2.2.06.01.00. Heat from the waste causes thermal expansion of the surrounding rock, generating compressive stresses near the drifts and extensional stresses away from them. The zone of compression migrates with time. References: CRWMS M&O. 2001. Features, Events, and Processes in Thermal Hydrology and Coupled Processes. ANL-NBS-MD-000004 Rev 00 ICN01. Las Vegas, Nevada CRWMS M&O. 2000. Features, Events, and Processes in UZ Flow and Transport. ANL-NBS-MD-000001 REV 00. Las Vegas, Nevada.	See response to Feature, Event and Process 2.2.01.01.00

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71	1.1.07.00.00	Repository design	FEP 1.1.07.00.00 (Repository Design), specifically secondary FEP 1.1.07.05.00 (Access Tunnels and Shafts). Staff considers that, although this FEP was originally specified for the WIPP emplacement geometry, it is sufficiently general to require inclusion at the YMP. Reference: CRWMS M&O. 2000. *Features, Events, and Processes: System Level and Criticality.* ANL-WIS-MD-000019 REV 00. Las Vegas, Nevada.	The design will include access tunnels and shafts appropriate to the repository design basis. This will include as appropriate the effects of the tunnels and shafts, the range of the properties of materials that are likely to be encountered. These will have been the subject of extensive study and quantification of uncertainty. In this sense, access and tunnel and shafts, have been included as an element of the primary features, events and processes. The secondary features, events and processes (FEPs) were compiled from various sources including Waste Isolation Pilot Project, SKI/SKB, and NAGRA. The particular secondary FEP listed is from NAGRA as noted by designator in the description. The description includes the qualifier "higher-permeability rock zones in the crystalline basement". The FEP was excluded on regulatory grounds due to the "crystalline basement" descriptor. Because the access tunnels and shafts and the factors affecting the flow conditions are part of the design and have been included in the Total System Performance Assessment, the need to include this particular secondary FEP is unclear.
72	1.1.08.00.00	Quality control	FEP 1.1.08.00.00 (Quality Control), specifically secondary FEPs 1.1.08.00.01 - 1.1.08.00.04 (Poorly constructed repository, material defects, common cause failures, poor quality construction). Staff considers that, although there are quality control procedures in place to prevent performance degradation related to these secondary FEPs, it remains possible that defects and failures are not recognized. Reference: CRWMS M&O. 2000. *Features, Events, and Processes: System Level and Criticality.* ANL-WIS-MD-000019 REV 00. Las Vegas, Nevada.	An inherent assumption in the licensing and construction process, as stated in the features, events and processes (FEPs) Analysis/Model Report, is that the repository will be built as designed, and that the quality control requirements will be adhered to, monitored, and enforced per the NRC's regulations. Additionally, uncertainty and sensitivity analyses are being performed to identify critical systems and quantify the effect of uncertainty in the behavior of components through time. Operational process controls, such as, (1) providing procedural assurance that future operational actions will be done according to a plan, and (2) including in FEPs analysis a reasonable estimate of the uncertainty associated with our ability to implement the plan exactly, is sufficient to account for potential defects and failures.
73	2.3.13.03.00	Effects of repository heat on biosphere	FEP 2.3.13.03.00 (Effects of repository heat on biosphere) is screened as excluded on the basis of low consequence but the screening analysis states that the repository heat effect on the biosphere is included in the uncertainty analysis of the shallow infiltration model. The shallow infiltration model accounts for vegetation and soil water content changes caused by climatic change. However, there are two important points that contradict the inclusion of repository heat effects: (1) the changes caused by the repository heat pulse act in the opposite direction of the vegetative changes made for monsoonal and glacial transition climates (repository heat leads to decrease in perennial shrubs, whereas both of those climate change possibilities lead to increased vegetation cover); and (2) the Analysis of Infiltration Uncertainty AMR (ANL-NBS-HS-000027) does not incorporate repository heat pulse in its determination of parameter variation or uncertainty. Reference: CRWMS M&O. 2000. *Features, Events, and Processes: System*	The issues to be addressed are 1) Does the repository heat cause a change in vegetation leading to changes in infiltration 2) What is the magnitude/nature of the change in vegetation, and 3) Do existing infiltration models cover this change. For Item 1) Yes, a change in temperature due to repository heat has the potential to change the vegetative state from brush to grasses, with a subsequent change in infiltration rates. Item 2) The amount of change is unquantified. However, evapotranspiration from brush may account for as little as 2 to as much as 50 percent of the evapotranspiration losses, and 1 degree change in soil temps may cause a shift (decrease) for as much as a one percent change in brush concentrations. So assuming elimination of brush entirely would suggest a maximum possible increase in infiltration of 50 percent over the present conditions (if all factors are considered, it is likely much less of an increase). As stated in the Features, Events and Processes Analysis/Model Report, the average infiltration at present is estimated to be between 4.5 and

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			Level and Criticality. ANL-WIS-MD-000019 REV 00. Las Vegas, Nevada.	6.5 mm/yr, a 50 percent increase would suggest an average ranging from about 6 to 9 mm/yr. Item 3). The existing models already examine the effects of infiltration rates occurring at several times the resulting infiltration rates. With regard to the first point, regardless of the effect of vegetative effects in future climates, the net infiltration for future climate states is still significantly increased compared to either the current state, or the current state plus repository-induced (e.g. based on the glacial transition uncertainty model, the mean is about 22.5 mm/yr with a standard deviation of 19.5). Hence, the effects due strictly to repository-induced heat would be similar to some type of minimal increase (the low case of the uncertainty analysis) of the glacial transition climate, and fall within the bounds of that analysis - they are therefore insignificant to the expected annual dose. The net infiltration increase is BOUNDED by the existing analysis - not INCLUDED as suggested by the reviewer. On the second point, the uncertainty analysis was made purely for the purposes for evaluating the uncertainty for a given climatic scenario - glacial transitional and the distribution and weighting of possible ranges. There is no requirement that the analysis incorporate the repository heat effect on the net infiltration rate. The potential effect or repository heat is only potentially significant with regard to the present climate and the resultant change in net infiltration. The net infiltration due to a change climate state, and its potential effect, is significantly greater (order of magnitude) than that caused by repository-induced heat. The effects of repository-induced changes would be negated by the climatic change - again suggesting that repository-induced vegetative change are of low consequence to expected annual dose and are bounded by the present analysis using climate changes.
74	Various	Critically in waste and EBS	FEP 2.1.14.01.00 (Criticality in waste and EBS) was preliminarily excluded in the Document (CRWMS M&O, 2000) based on low probability. A preliminary screening status was assigned because the criticality calculations were not complete for (i) DSNF following igneous intrusion and (ii) near-field and far-field criticality of all waste types following igneous disruption. The excluded screening status will be regarded unacceptable until concerns on the calculation of the probability for criticality are addressed. Since the probability of criticality depends on the presence of a breach of the waste package barriers, most of the discussion of criticality probability is focused on the probability of waste package failure. DOE has referenced the document, *Probability of Criticality in 10,000 Years* (CRWMS M&O, 2000g) for addressing the criticality probability due early failure by stress corrosion cracking, waste package damage following igneous intrusion, and seismic events. DOE has referenced the screening argument for rockfall (2.1.07.01) for screening the damage to the waste package and drip shield from seismically-induced rockfall. [R. Benke/M. Rahimi] In general, DOE needs to address the concerns raised on the waste package related FEPS, Mechanical Disruption FEPS, and the issues raised at the CLST	DOE's process for evaluating criticality is stated in the *Disposal Criticality Analysis Methodology Topical Report*, (YMP 2000). The process includes calculating the probability and consequences of potential criticality events, based on mechanisms at the site, and evaluating them using the Total System Performance Assessment processes, including Features, Events and Processes (FEPs) screenings. DOE will finish the criticality calculations following an igneous event or develop an argument as to why the consequences to the source from such an igneous event can be ignored. Furthermore, DOE will re-evaluate the criticality FEPs, should the reevaluation (as agreed to in the Container Life and Source Term agreement K0106) of the waste package FEPs, related to seismicity and rock fall, show that waste packages will fail prior to 10,000 years. Specifically, agreement KCR0106 indicates that DOE will perform a "what if" (non-risk-informed) evaluation that determines the consequences of criticality for a non-mechanistic, waste package failure during the 10,000 year regulatory period. The results of this evaluation are not part of the normal Total System Performance Assessment process, and thus will not be included as part of the

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			technical exchange before it can conclude that there is no waste package breach before 10,000 years. [M. Rahimi] The concerns on the probability calculation in the document, Probability of Criticality in 10,000 Years (CRWMS M&O, 2000b) are: - The conclusion of waste package failure probability of 2.7×10^{-11} due to stress corrosion cracking (SCC), based on the equation in Section 6.1.1, is contrary to the TSPA results which indicate the first waste package failure, using the upper-bound curve, due to SCC at approximately 10,000 years. [M. Rahimi] - The screening argument for FEP 1.2.03.02.00 (Seismic Vibration Causes Container Failure), fails to consider the appropriate combinations of dead loads (caused by drift collapse and/or fallen rock blocks), rock block impact, and seismic excitation or the ability of these loads to initiate cracks and/or propagate preexisting cracks. - The screening argument for seismic events does not consider the indirect effects, such as causing dents which could aid in the collection and channeling of water or tilting the waste packages, which would result in the greater height of the water within the waste package. Seismic shaking, combined with a sloped waste package, may also allow materials to accumulate at one end of a waste package and form a more reactive geometry. [M. Rahimi] - The screening argument for seismically-induced rockfall damaging the drip shield and waste package includes several deficiencies as documented in the staff review of the *Drift Degradation Analysis* (CRWMS M&O) Analysis Model Report (AMR) and FEP 2.1.07.01 Furthermore, the analysis of the effects of rockfall on the drip shield, referenced in FEP 2.1.07.01 fails to consider (i) the temperature effects on mechanical material behavior, (ii) seismic motion of the supporting invert, (iii) point load impacts, (iv) appropriate material failure criteria, (v) material degradation processes, (vi) multiple rock block impacts, and (vii) boundary conditions that account for the potential interactions between the drip shield and gantry rails. Consequently, DOE has not adequately demonstrated that the drip shield has been designed to withstand 6, 10, or 13-MT rock block impacts. Other concerns related to the impact of rockfall on the WP are reflected in the comments on the related FEPs. [M. Rahimi] - The calculation does not fully consider mechanisms that could result in accelerated degradation of the fuel during an igneous event, such as burning of Zircaloy or creep of the fuel at high temperatures. [D. Galvin] - The analysis of damage to Zone 2 waste packages (CRWMS M&O, 2000b) fails to consider long term exposure to high temperatures changing the	FEPs process. The results will be used as a sensitivity evaluation. The probability of 2.7×10^{-11} is per waste package. The probability of a waste package failure in the first 10,000 years with ~11,000 packages is 3.2×10^{-7}. The probability results for stress corrosion cracking based failure shown in Probability of Criticality before 10,000 Years (CRWMS 2000am, Section 6.1.1, page 19) are based on the information from Analysis of Mechanisms for Early Waste Package Failure (CRWMS 2000d, page 43) with inputs from Abstraction of Models of Stress Corrosion Cracking of Drip Shield and Waste Package Outer Barrier and Hydrogen Induced Corrosion of Drip Shield (CRWMS 2000aaa, page 28). DOE will examine the apparent discrepancy of waste package failure at 10,000 years in the Total System Performance Assessment at the 95th percentile with the calculational mean probability of 3.2×10^{-7} and if necessary, supercede this waste package failure probability The criticality FEPs screening is based on the current inputs for waste package failure. When the inputs are revised to address additional concerns (e.g., dead loads, indirect effects of rock block impacts, tilting of breached waste packages) then the criticality FEPs screening will be reassessed. The NRC concerns will be addressed when the seismic vibration Feature, Event and Process is modified (Container Life and Source Term agreement KCL0114). In addition, DOE will evaluate the rockfall effect and dead weight effects on the waste package. Other pertinent rockfall agreements are KCL0201, KCL0202, KCL0208, KCL0301, KRD0317, and KRD03019. The criticality FEPs screening is based on the current inputs for waste form degradation. When the inputs are revised to address additional concerns, then the criticality FEPs screening will be reassessed. With respect to cladding degradation, DOE notes that within zone 2 all of the cladding is perforated and all the drip shields are removed, thus cladding damage is already accounted for. In addition, DOE may argue that the combination of criticality and igneous intrusion on the source-term can be neglected based on low consequence in a future revision of this Feature, Event and Process. The effect of temperature with respect to damage to Zone 2 waste packages was addressed in the Analysis/Model Report Dike Propagation Near Drifts; (CRWMS &O 2000o). Reference to this Analysis/Model Report will be made in the future. As explained in § 3.10.2.3.2 of the Total System Performance Assessment-Site Recommendation (CRWMS M&O 2000aq), the failure size of the lid weld varies between 1 cm^2 and 1×10^4 cm^2 (cross section of a lid) with a

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			microstructure of Alloy 22 and reducing the mechanical strength of the material (e.g., Rebak et al., 1999) or the differences in thermal expansion between the inner alloy 316 NG SS and Alloy 22 (ASME, 1998) causing significant hoop-stress on waste package walls, in addition to the internal pressurization effects analyzed in CRWMS M&O (2000b). Analyses in CRWMS M&O (2000b) also do not consider potentially adverse chemical reactions, such as sulfidation reactions, in response to magmatic degassing or contact with basaltic magma. These processes could cause a more significant breach than the 10 cm^2 hole currently assumed for waste packages located in DOE Zone 2 during basaltic igneous events. [D. Galvin] - The calculation does not consider any changes to drift by the magma, such as magma solidifying in the lower part of the drift, causing ponding above and around the waste package. or fractures forming in the cooled magma that may provide preferential pathways to the waste package. Finally, the unsaturated flow may be modified by the presence of 1170 degree C magma so current parameters may no longer be valid. [D. Galvin] - The Criticality Probability document is inconsistent when discussing the water content of the magma in Section 5.3.2. The text indicates that the magma would consist of a very conservative 5 weight percent water content, but Table 5-1 lists the water content as only 0.05 weight percent. The computer files provided with the document that contained the actual calculations used a more realistic water content of 1.6%. A water content of 5 weight percent would clearly be very conservative, but justification needs to be provided if a lower water content is utilized in the calculations. [D. Galvin] References: CRWMS M&O. 2000. Features, Events, and Processes: System-Level and Criticality, ANL-WIS-MD-000019 REV 00. Las Vegas, Nevada: CRWMS M&O. CRWMS M&O. 2000b. Probability of Criticality in 10,000 Years, CAL-EBS-NU-000014 REV 00. Las Vegas, Nevada: CRWMS M&O. ASME, *B&PV Code, Section II, Part D B Properties.* 1998. Rebak, R.B., T.S.E. Summers, and R.M. Carranza. Mechanical properties, microstructure, and corrosion performance of C-22 alloy aged at 260EC to 800EC. *Materials Research Society, Boston Meeting, Paper QQ 14.4.* 1999.	mean of 10 cm^2. This failure is applied to all containers in zone 2. DOE notes that in zone 2 the shields have been removed and so a direct path to the waste package is possible. Furthermore, in Total System Performance Assessment-Viability Assessment (DOE 1998), the effect of dikes on fluid flow in the saturated zone was evaluated. The influence was negligible. DOE will cite this work in a future revision as indirect evidence that the secondary effects of igneous intrusion have only a secondary effect on dose. In addition, DOE may argue that the combination of criticality and igneous intrusion can be neglected based on low consequence in a future revision of this Feature, Event and Process. DOE has examine the inconsistency and determined the value listed in Table 5-1 for water content in magma is a typo (water fraction was listed instead of water wt%). The 5-wt% value listed in the rest of the document is correct. It is based on a conservative number from Characterize Eruptive Processes at Yucca Mountain, Nevada ANL-MGR-GS-000002 REV 00 (CRWMS 2000e, Section 6.2.2, pg. 28). DOE has reviewed its computer files and the value used was 5 wt%. DOE needs to look at the computer files supplied to the NRC to be able to identify the source of the 1.6-wt% number
82	1.5.01.01.00	Meteorite impact		DOE agrees. No further discussion on this FEP is necessary
83	1.5.01.02.00	Extraterrestrial events		DOE agrees. No further discussion on this FEP is necessary

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Item No.	FEP#	FEP Name	NRC Comment	DOE Discussion
75	Various	Excavation/ Construction Incomplete/ Closure Canister Failure(long term) Mechanical Degradation or Collapse of Drift Topography & Morphology	A number of FEPs that could potentially influence the evolution of an igneous event intersecting the repository have not been identified as being relevant for disruptive events. These include: FEP 1.1.02.00.00 (Excavation/Construction) - changes to the rock around the repository due to excavation and construction could affect dike/repository interactions and influence how a dike behaves near the surface. Additionally, repository features such as ventilation shafts could provide a path to the surface that would bypass the repository. FEP 1.1.04.01.00 (Incomplete Closure) - if the design of the repository includes a seal at the end of the drifts strong enough to contain magma which is relied upon for performance calculations, failure to complete these seals could significantly affect repository performance. FEP 2.1.03.12.00 (Canister Failure (Long-Term)) - for intrusive volcanism, credit is taken for the waste packages remaining mostly intact other than an end cap breach following magma interactions. The only waste package failure mechanism that is investigated to take this credit is internal gas pressure buildup. Other waste package failure mechanisms such as differential expansion of the inner and outer waste packages and phase changes in the Alloy 22 due to the long term exposure to elevated temperatures are not considered. FEP 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) - could affect magma-repository interactions and affect the dose as a result of an igneous event. FEP 2.3.01.00.00 (Topography and Morphology) - the topography may affect dike propagation near the surface and dike propagation probably should be discussed under this FEP.	The following Features, Events and Processes (FEPs) will be discussed at the May 18, 2001, Igneous Activity Appendix 7 Meeting. FEP 1.1.02.00.00 (Excavation/Construction) – It is not clear which specific rock changes due to excavation and construction with which the NRC is concerned. Changes in stress due to excavation and their possible effects on dike interactions with the drift are addressed in the Dike Propagation Near Drifts Analysis/Model Report (CRWMS M&O 2000o, Section 6.3.1). This effect is considered in the evaluation of FEP 1.2.04.03.00, Igneous Intrusion into the Repository, and thus consideration under FEP 1.1.02.00.00 is not needed. Magma flow through drifts to a ventilation shaft and then to the surface is not considered in the current DOE analysis. FEP 1.1.04.01.00 (Incomplete Closure) – The DOE analysis documented in the Dike Propagation Near Drifts Analysis/Model Report (CRWMS M&O 2000o) does not assume or rely upon drift seals to contain magma. Rather, the high energy nature of the system causes the drifts to become plugged or clogged with debris and materials from pyroclastic flows, cooling magma, and repository components. Therefore, consideration of FEP 1.1.04.01.00 with respect to igneous intrusion is not needed. FEP 2.1.03.12.00 (Canister Failure (Long-Term) –The effect of magma on waste packages is considered under FEP 1.2.04.04.00, "Magma Interacts with Waste." Therefore, consideration of FEP 1.1.04.01.00 with respect to igneous intrusion is not needed. The end-cap breach is used because it is the locus for the largest stress and deformation resulting from increased heat and pressure. The end cap weld damage is used as a "surrogate" as a means to estimate the extent of damage. As stated in the igneous consequence modeling Analysis/Model Report in Section 6.2 "Although the mean value can be thought of conceptually as corresponding to a 1-mm-wide crack that propagates for 1 m along a weld, or a 2-mm-wide crack that extends 50 cm, it was not chosen to represent any specific dimensions of a weld failure. Rather, it was chosen as an approximation of the size of opening necessary to permit rapid gas flow and pressure equilibration. Sampling the area of the breach from a distribution that includes much larger hole sizes is intended to account for both uncertainty regarding the nature of the magmatic fluids and the package response and spatial variability in the extent of damage within the drifts." DOE has evaluated this issue under the FEPs "Igneous Intrusion Into the

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				Repository" or "Magma Interacts with Waste. Consideration under FEP 2.1.03.12.00 is not needed. FEP 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) - To address this comment, DOE needs to know by what process the NRC believes collapse of the drift will increase dose determined for igneous disruption of a repository. Any effects of drift collapse can be covered in the screening evaluation for FEP 1.2.04.03.00, "Igneous Intrusion into the Repository." FEP 2.3.01.00.00 (Topography and Morphology) - To address this comment, the DOE needs to know in what manner the NRC believes topography will affect dike propagation. Any effects can be covered in the screening evaluation for the FEP 1.0.04.06.00, "Basaltic Cinder Cone Erupts Through the Repository."
76	Generic	Hydrothermal activity	Detailed processes related to the interaction of the ascending dike with the repository drift are not described as FEPs. Instead, the FEP database includes only general categories like "Magma interacts with waste" and "Igneous Activity". This very high level treatment of the igneous FEPs likely has caused the DOE to miss many of the FEPs that are relevant to repository/dike interactions and interactions between magma and waste packages and fuel, particularly for Type 2 waste package failures (waste packages that fail, but whose contents are not removed by the event) and the determination of the number of waste packages affected. FEPs related to magma/repository interactions that are not included in the FEP database include: mechanical and fluid dynamics at the dike tip; fragmentation; vesiculation; plume dynamics; effect of drip shield on magma/repository interactions; geologic factors; threshold flow characteristics; gas segregation; alternate models of vent formation; effects of air shafts and drifts; consideration of flow segregation; localization of magma; recirculation of magma; and evolution of flow conditions. Canister/magma interactions that appear to have been missed include hoop stress due to differential expansion of the inner and outer waste packages; melting of materials; thermal shock; and phase changes in the Alloy 22 due to the long-term exposure to elevated temperatures. Fuel/magma interactions that may have been missed could include: cladding burning at high temperatures in the presence of air; cladding/fuel chemical reactions causing damage to the fuel form (no credit is taken for cladding); dissolution of fuel in magma; mechanical shear; oxidation (during and post-eruption); reworking of spent fuel in conduit; and evolution of flow conditions.	The following Features, Events and Processes (FEPs) will be discussed at the May, 18, 2001, Igneous Activity Appendix 7 Meeting, The issues identified in the NRC's comment do not require definition of new features, events and processes. The processes listed are already included in existing features, events and processes. For example, Secondary features, events and processes that have been evaluated in conjunction with the Primary feature, event and process "Magma Interacts with Waste" (1.2.04.04.00) include: Magma volatiles attack waste (1.2.04.04.01) Dissolution of spent fuel in magma (1.2.04.04.02) Dissolution of other waste in magma (1.2.04.04.03) Heating of waste container by magma (without contact) (1.2.04.04.04) Failure of waste container by direct contact with magma (1.2.04.04.05) Fragmentation (1.2.04.04.06). Screening evaluation of these features, events and processes is based on simplified analyses. The DOE's approach has been to combine its simplified analyses with reasonable assumptions to appropriately abstract the consequences of dike/drift interactions for inclusion in the Total System Performance Assessment. This approach is documented in the following Analysis/Model Reports, which have been provided to the NRC: *Dike Propagation Near Drifts* (CRWMS M&O 2000o), *Igneous Consequence Modeling for TSPA-SR* (CRWMS M&O 2000aq), *Number of Waste Packages Hit by Igneous Intrusion* (CRWMS M&O 2000ak). The DOE does not attempt to model in detail the complicated interactions between an ascending dike and a waste emplacement drift containing waste packages and other engineered barrier system components. Rather, the DOE

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				assumes that waste packages within and near an intersecting dike are damaged such that they provide no further protection. Beyond the immediate vicinity of the intersecting dike, magma processes, such as those identified by the NRC, are assumed to damage all waste packages in an intersected drift, although not to the extent that they provide no further protection. Damage to end-cap welds is used as a surrogate for all types of waste package damage. Damage is characterized by a distribution of induced crack apertures ranging up to the size of an end-cap (CRWMS M&O 2000aq, Section 6.2). In this way DOE has reasonably taken into account dike/drift interactions.
77	2.1.07.02.00	Mechanical degradation or collapse of drift	FEP 2.1.07.02.00 (Mechanical degradation or collapse of drift) has been excluded (CRWMS M&O, 2001,a,b) based on (CRWMS M&O, 2000), which indicates that the emplacement drifts would essentially maintain their integrity through the period of regulatory concern. DOE is expected to revise the *Drift Degradation Analysis* to satisfy RDTME Agreements 3.17 and 3.19 (DOE/NRC Technical Exchange on RDTME, February 6B8, 2001, Las Vegas, Nevada). At this stage, the screening argument is considered closed-pending given the existence of the RDTME Agreements 3.17 and 3.19. It should be noted, however, that the current state of knowledge on unsupported openings in fractured rock indicates that majority of drifts are likely to collapse soon after cessation of maintenance. This opinion is consistent with the conclusion of the DOE expert panel on drift stability (Brekke, T.L., et al, 1999) and to recent analyses of the behavior of unsupported drifts in fractured rock during seismic loading from an earthquake (Hsiung, S.M., et al., 2001). Drift collapse could have implications on temperature, chemistry, seepage into drifts, and drip shield performance. References: Brekke T.L., E.J. Cording, J. Daemen, R.D. Hart, J.A. Hudson, P.K. Kaiser, and S. Pelizza. 1999. *Panel Report on the Drift Stability Workshop, Las Vegas, Nevada, 9B11 December, 1998.* Yucca Mountain Site Characterization Project CRWMS M&O. 2000.*Drift Degradation Analysis* AMR. ANL-EBS-MD-000027 Rev 01. Las Vegas, Nevada CRWMS M&O. 2001a. Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O. 2001b. Features, Events, and Processes: Screening for Disruptive Events. ANL-WIS-MD-000005 REV 00 ICN01. Las Vegas, Nevada Hsiung S.M. and G.-H. Shi. 2001. Simulation of earthquake effects on underground excavations using discontinuous deformation analysis (DDA). To appear in *Proceedings 38th U.S. Rock Mechanics Symposium*, Washington, DC: 7B10 July, 2001.	The screening decisions were based solely on the results of the Drift Degradation Analysis and will be revisited once the analysis to resolve the Repository Design Thermal Mechanical Effects agreement KRD0319 has been completed. NRC should consider providing an advanced copy of the cited paper (Hsuing and Shi 2001) since it is not currently available. The referenced expert panel report on drift stability also clearly states on page 2-3 that "Fracture propagation during cooling and tectonic events appears to have been arrested by the lithophysae so that continuous joints, which could form large rock blocks and overbreak, are largely absent. Overbreak or rock loosening in the form of slabs or block was almost nonexistent in the lithophysal zones in both the 7.6-meter diameter North Ramp and the 5-meter diameter Cross Drift." This would suggest that NRC's concerns about fracture length and the possible formation of extensive slabs of rock expressed during multiple Key Technical Issues is at conflict with the findings of this panel as well. DOE requests that the NRC provide a specific citation (section/conclusionary statement) from the expert panel report that they feel is in conflict with the Drift Degradation Analysis.

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78			FEP 1.2.03.02.00 (Seismic Vibration Causes Container Failure). The Seismic Vibration Causes Container Failure FEP has been excluded from consideration in the TSPA code (CRWMS M&O, 2001a,b). The screening argument cites preliminary seismic analyses of the drip shield and waste package as the basis for this screening decision (CRWMS M&O, 2000a). Because these analyses were not available at the time of this review, it is not clear as to whether the appropriate combinations of dead loads (caused by drift collapse and/or fallen rock blocks), rock block impacts, and seismic excitation were considered. Moreover, the ability of these loads to initiate cracks and/or propagate preexisting cracks may not have been adequately addressed. In addition, DOE has not demonstrated that the drip shield, pallet, and/or waste package will respond in a purely elastic manner when subjected to the aforementioned loading conditions. The screening argument for this FEP also states that " it does not appear credible that the drip shield would be breached, because the drip shield has been designed to withstand up to a 6-MT rockfall." based on the rockfall on drip shield analyses performed by the DOE (CRWMS M&O, 2000b). DOE, however, has not adequately demonstrated that the drip shield has in fact been designed to withstand 6-MT rock blocks {see the comments on FEPs 2.1.07.01.00 [Rockfall (large block)], 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift), and 2.1.07.05.00 (Creeping of metallic materials in the EBS) for additional discussion relevant to rockfall and seismic analyses}. References: CRWMS M&O 2000a. Input Request for Seismic Evaluations of Waste Packages and Emplacement Pallets. Input Transmittal 00230.T. Las Vegas, Nevada; CRWMS M&O 2000b. Rock Fall on Drip Shield. CAL-EDS-ME-000001 REV 00. Las Vegas, Nevada; CRWMS M&O.2001a. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation. ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada; CRWMS M&O.2001b. Features, Events, and Processes: Screening for Disruptive Events. ANL-WIS-MD-000005 REV 00 ICN01	No DOE comment on this item.
79	2.1.07.01.00	Rockfall (Large Block)	FEP 2.1.07.01.00 [Rockfall (Large Block)]. The effects of Rockfall (Large Block) on the drip shield and waste package has been excluded from consideration in the TSPA code (CRWMS M&O, 2001a-c). The *Drift Degradation Analysis* (CRWMS M&O, 2000a) Analysis Model Report (AMR) indicates that thermal loading, seismicity, and time-dependent mechanical degradation of the host rock would have minor effect on the integrity of the drifts through the entire period of regulatory concern. However, several deficiencies associated with this analysis were identified by the NRC staff at the NRC/DOE RDTME technical exchange [see the comments on FEP 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) for additional	The screening decision is dependent on the results of the Drift Degradation Analysis for Maximum Key Block Size and on the Design Criteria for the Drip Shield. The screening decision will be reviewed pending completion of the Repository Design and Thermal Mechanical Effects agreements (KRD0317 and KRD0319) to perform additional analyses. With regard to specific issues raised: i. The temperature effects on mechanical material behavior are being included in the evaluations being currently performed and will be included in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). ii. Seismic motion of the supporting invert is being included in the evaluations

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			discussion pertaining to the DOE rockfall analyses]. As was pointed out at the CLST and RDTME technical exchanges, the rockfall on drip shield analyses (CRWMS M&O, 2000b) did not consider (i) the temperature effects on mechanical material behavior, (ii) seismic motion of the supporting invert, (iii) point load impacts, (iv) appropriate material failure criteria, (v) material degradation processes, (vi) multiple rock block impacts, and (vii) boundary conditions that account for the potential interactions between the drip shield and gantry rails. Consequently, DOE has not adequately demonstrated that the drip shield has been designed to withstand 6, 10, or 13-MT rock block impacts. Because the framework for the invert is constructed from carbon steel, their potential degradation may affect the orientation of the waste packages over time. In other words, the invert floor cannot be expected to keep the waste packages in a horizontal position for the entire regulatory period. As a result, rock block impacts on the waste package may occur at angles that are not perpendicular to the waste package longitudinal axis. Angled rock block impacts near the closure lid welds may have significantly different results than nonangled impacts. This is a new scenario that has not presented to DOE. Mechanical failure of cladding due to rockfall is excluded based on low probability because rockfall on intact WP will not cause rod failure (CRWMS M&O, 2000c). Main screening argument is based on intact WP. However, the discussion is confusing because arguments based on the presence of backfill are also used in quantitative estimates. Although the conclusion can be acceptable due to presence of intact WP, the screening arguments should be improved on the bases of appropriate calculations. References: CRWMS M&O. 2000a. Drift Degradation Analysis AMR. ANL-EBS-MD-000027 Rev 01. Las Vegas, Nevada CRWMS M&O. 2000b. Rock Fall on Drip Shield. CAL-EDS-ME-000001 REV 00. Las Vegas, Nevada CRWMS M&O. 2000c. *Clad Degradation B FEPs Screening Arguments.* ANL-WIS-MD-000008 REV 00 ICN01. Las Vegas, Nevada. CRWMS M&O. 2001a. Engineered Barrier System Features, Events, and Processes. ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada CRWMS M&O.2001b. Features, Events, and Processes: Screening for Disruptive Events. ANL-WIS-MD-000005 REV 00 ICN01. Las Vegas, Nevada CRWMS M&O.2001c. FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation. ANL-EBS-PA-000002 REV 01	being currently performed and will be included in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). iii. Point load impact is being addressed in the current evaluations as agreed upon in the Container Life and Source Term agreement KCL0202. These evaluations will be included in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). iv. The material failure criteria used were questioned, and the DOE agreed in Container Life and Source Term agreement KCL0203 to justify whatever failure criteria are used in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l). v. Drip shield wall thinning due to corrosion is being addressed in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l) per the Container Life and Source Term agreement KCL0208. vi. Multiple rock block impacts is being addressed in the next revision of the Design Analysis for the Ex-Container Components (CRWMS M&O 2000l) per the Container Life and Source Term agreement KCL0208. vii. This was discussed at the time of the Container Life and Source Term Technical Exchange and was not listed as an agreement item because these boundary conditions are already included in DOE's evaluations. The DOE has performed and continues to perform evaluations to demonstrate that the drip shield has been designed to withstand 6-metric ton rock block impacts. Evaluations of impacts of blocks larger than 6-metric ton are performed to determine the consequences to the drip shield and waste package. The carbon steel members of the invert are surrounded by a ballast material, which will provide some support to the waste packages for the entire regulatory period. While the carbon steel invert may not keep the waste packages in a horizontal position for the entire regulatory period, it is designed to keep the waste packages in a horizontal position for the preclosure period. One of the repository closure activities is the installation of drip shields, which would prevent direct impact of rock blocks on the waste packages.
79		Rockfall (Large Block)		The revised Clad Degradation: Summary and Abstraction Analysis/Model Report (ANL-WIS-MD-000007 REV 00, ICN 01, CRWMS M&O 2001a) was forwarded to the NRC as part of the Container Life and Source Term Agreement KCL0306. The revised Analysis/Model Report expanded the mechanical failure model to include cladding failure from rock overburden as

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				the waste package deteriorates. The issue of rockfall is addressed in Container Life and Source Term agreement KCL0310. The Analysis/Model Report will be further revised as necessary to incorporate new information on rockfall, in time to support any potential License Application.
79		Rockfall (Large Block)		The screening decision is dependent on the waste package calculations and the Drift Degradation Analysis, which is used to determine the maximum key block size. When additional analyses identified in Repository Design and Thermal Mechanical Effects agreements (KRD0317 and KRD0319) are completed, the screening decision will be reviewed.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 1: Multiple Barriers

Importance to System Performance: This subissue focuses on the demonstration of multiple barriers and includes: (i) identification of design features of the engineered barrier system (EBS) and natural features of the geologic setting that are considered barriers important to waste isolation; (ii) descriptions of the capability of barriers to isolate waste; and (iii) identification of degradation, deterioration, or alteration processes of engineered barriers that would adversely affect the performance of natural barriers. In addition, it addresses staff's expectation of the contents of DOE's TSPA and the supporting documents. Specifically, it focuses on those aspects of the TSPA that will allow for an independent analysis of the results.

ACI - System description and model integration are adequate

Resp. Org	Item #	Comment	Response
Mishra Rickertsen	J-MB 1.1T	NRC Staff find the techniques used to identify barriers as presented in the Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i) document acceptable. However, the documentation of the process used to identify the barriers needs to be clarified to show that DOE has fully identified the barriers that are important to waste isolation. For example, it is not clear if the identification of barriers is based on expected barrier capability or from tracing parameters from TSPA sensitivity/importance analyses back to determine the important barriers in the system. References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	The barriers that are identified as important to waste isolation for any potential license application will be distinct physical elements of the repository system that are demonstrated to contribute to waste isolation. This demonstration will be made using a set of complementary analytic techniques. The capability of the barriers to prevent or substantially delay movement of water or radionuclides will be described in any potential license application. Uncertainties in characterizing and modeling the barriers in the analyses will be delineated. Identification of the barriers important to waste isolation in Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i) was based on elements of the system that are expected to play a role in limiting the amount of water that might enter emplacement drifts, limiting contact of water with the waste, limiting release of radionuclides from the engineered barrier system, delaying radionuclide transport to the accessible environment, or diluting radionuclide concentrations. Reference: CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.

Analysis of Resolution Status
Key Technical Issue: Total System Performance Assessment and Integration

Subissue 1: Multiple Barriers

AC2 - Data are sufficient for model justification

Resp. Org	Item #	Comment	Response
Mishra Rickertsen	J-MB 2.1	DOE needs to provide information on the capability of barriers to prevent or substantially delay movement of water or radionuclide materials and, consequently, limit the expected annual dose. For example, Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i, p. 2-5) describes barrier capability but no diagrams are presented to support the discussion. Diagrams for barrier neutralization analyses and degraded barrier analyses are based on dose and not on barrier capability to prevent or delay movement of water or radionuclides. Without this information, staff cannot assess the capability of the barriers to determine what is retained by each barrier, what is delayed by each barrier, and what moves through each barrier. The capabilities of individual barriers to prevent or delay movement of water or radionuclides (across the spectrum of radionuclides) should be discussed in the context of the important properties of the barrier (e.g. matrix diffusion, distribution coefficients). References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	The capability of the barriers important to waste isolation will be described in any potential license application. The specific characteristics of each barrier to prevent or substantially delay movement of water or radionuclides will be included. In addition, contribution of each of these barriers to waste isolation will be evaluated quantitatively through a set of complementary analyses. These analyses may include • Intermediate performance analysis (CRWMS M&O 2000ar, Section 4.1) • Pinch point analysis (CRWMS M&O 2000as, Section 4.5.3) • Barrier robustness analysis (CRWMS M&O 2000ar, Section 5.3; CRWMS M&O 2001i, Section 3.2) • Barrier neutralization analysis (CRWMS M&O 2000as, Section 4.5.4; CRWMS M&O 2001i, Section 3.4). These analyses provide information clarifying the specific contribution of the barrier to the estimate of mean annual dose, the capability of the barrier to prevent or delay the movement of water or radionuclides, the accumulation of radionuclides in the barriers, and the reduction in concentration (e.g., through dispersion). The analyses show the performance of individual radionuclides, including those most important to the estimated mean annual dose. Since the analyses are conducted with the TSPA model, uncertainty in models for processes affecting the barrier are explicitly considered. Further, time evolution of barrier performance and spatial variability of barrier characteristics are accounted for. Further interdependencies of barriers and correlations among models and parameters affecting the barriers can be addressed. Masking of one barrier by another can be addressed.

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Resp. Org	Item #	Comment	Response
			References: CRWMS M&O 2000ar. *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. CRWMS M&O 2000as. *Total System Performance Assessment-Site Recommendation Methods and Assumptions.* TDR-MGR-MD-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0384. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.
Mishra Rickertsen	J-MB 2.2	The methods used to differentiate the contributions of barriers that perform similar functions need to be explained. Barriers that perform similar functions could include components of natural and engineered systems (e.g., the combination of the natural system above the repository and the drip shield) along important boundaries. The discussion of barrier capabilities needs to discuss and differentiate between the independent and the interdependent contributions of the individual barriers. References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	The use of neutralization analysis in both "one-off" and "two-off" modes assist in differentiating between the independent and interdependent contributions of individual barriers.

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Resp. Org	**Item #**	**Comment**	**Response**
Mishra Rickertsen	J-MB 2.3	The description of the barrier capability for the drift invert is not clear, because the type of material (e.g. crushed tuff or limestone) has not been selected. The type of invert material used in the repository influences aqueous and mineral chemistry as well as diffusion rates and, consequently, affect radionuclide transport through the invert. References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	The capability of barriers important to waste isolation, including the drift invert—if it is determined to be important to waste isolation—will be described in any potential license application. The characteristics of the barrier to prevent or substantially delay movement of water or radionuclides will be included. In addition, quantitative analyses will be conducted to assess contribution the barrier makes to the estimate of mean annual dose.
Mishra Rickertsen	J-MB 2.4	The uncertainty associated with particular barriers needs to be described. The description needs to include model uncertainty, such as the performance of the barrier assuming alternative conceptual models, and uncertainty in the attributes of the barrier (e.g., parameter uncertainty). The performance needs to be discussed in terms of barrier capability to prevent or delay movement of water or radionuclides and, consequently, to limit the expected annual dose. References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	The primary analytical tool proposed for multiple barrier analysis is the probabilistic TSPA model, which includes model and parameter uncertainty. As such, uncertainty in characterizing and modeling barriers (e.g., physically distinct components of the waste disposal system) is included in the analyses.

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Resp. Org	Item #	Comment	Response
Rickertsen (PA)	J-MB 2.5	The DOE analyses of barriers need to be discussed in terms of the individual barriers and their interdependence with other barriers (as appropriate). Results from the degraded barrier analyses indicate that the described capabilities are consistent with the results from the total system performance assessment. However, there appears to be inconsistency in the treatment of combinations of barriers. For example, the combination of barriers treated in Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i) for the degraded barrier analyses are different from those used in the barrier neutralization analyses. Similarly, the combination of barriers presented in the TSPA Technical Document (CRWMS M&O 2000ar) are different from the combinations presented in the Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i) for degraded barrier analyses and barrier neutralization analyses. It is difficult to understand the basis for, and the results of, the degraded barrier analyses and barrier neutralization analyses without a discussion of the results in terms of the independent and interdependent contributions of the barriers. Example 1: The presence of the drip shield in the degraded waste package analyses (CRWMS M&O 2001i) could mask the effect of the waste package on radionuclide transport during the early period or at least until the drip shield fails. While such analyses (i.e., in the presence of drip shield) shows the protection afforded by the drip shield even after the waste package fails, the actual protection provided by each individual barrier in 10,000 years is not clearly identified. Example 2: It is not clear why performance improved for the degraded radionuclide concentration limits case, which represents non-mechanistic juvenile failure scenario-sensitivity to radionuclide concentration limits, between 2000 and 8000 years (CRWMS M&O 2001i, Figure 3-20, p. 3-18). References: CRWMS M&O 2000ar. *Total System Performance*	The capability of the barriers important to waste isolation will be described in any potential license application. The specific characteristics of each barrier to prevent or substantially delay movement of water or radionuclides will be included. In addition, contribution of each of these barriers to waste isolation will be evaluated quantitatively through a set of complementary analyses. These analyses may include • Intermediate performance analysis (CRWMS M&O 2000ar, Section 4.1) • Pinch point analysis (CRWMS M&O 2000as, Section 4.5.3) • Barrier robustness analysis (CRWMS M&O 2000ar, Section 5.3; CRWMS M&O 2001i, Section 3.2) • Barrier neutralization analysis (CRWMS M&O 2000as, Section 4.5.4; CRWMS M&O 2001i, Section 3.4). These analyses will directly address issues illustrated by the examples in this comment. For example, if the drip shield and waste package are identified as barriers important to waste isolation, potential masking of the performance of the waste package by the drip shield could be addressed in analyses that neutralize performance of the drip shield. As a second example, questions about relative performance of degraded barriers and neutralized barriers could be directly addressed. References: CRWMS M&O 2000ar. *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. CRWMS M&O 2000as. *Total System Performance Assessment-Site Recommendation Methods and Assumptions.* TDR-MGR-MD-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O.

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Resp. Org	Item #	Comment	Response
		Assessment for the Site Recommendation. TDR-WIS-PA-000001 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001220.0045. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	ACC: MOL.20000307.0384. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.
Mishra Rickertsen	J-MB 2.6	In the robustness analysis section (5.3.7) of TSPA-SR (CRWMS M&O 2000ar) DOE states that the similarity of the degraded and base cases for the saturated zone barrier is attributed to the influence of the high-dose realizations on the base case average. Barrier neutralization analyses reported in the Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i), where all saturated zone performance is removed gives essentially the same curve as the robustness analysis. Further discussion is needed to explain the saturated zone neutralization analysis. Furthermore, the analysis indicates significant performance for matrix diffusion (and sorption in the matrix) in the unsaturated zone. References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	The summary in the TSPA-Site Recommendation document (CRWMS M&O 2000ar) examined the contribution of individual realizations to the mean annual dose estimate. The summary revealed that the mean was dominated by a few realizations. The degraded barrier analyses examined the performance of the barrier (saturated zone transport barrier in the present case) to an extreme. The extreme did not significantly change the few realizations that dominated system performance. Consequently, the mean was not significantly affected. Likewise, the neutralization analyses conducted for Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i) also showed little change to the mean because the few realizations that dominated that mean was not significantly affected. Thus, the two separate analyses had the same result for the same reason. The degraded barrier analyses and neutralization analyses for the unsaturated zone transport barrier had the same conclusions with regard to this barrier as in the discussion above—a few realizations dominated the estimate of mean annual dose and degrading or neutralizing the barrier did not significantly affect the realizations. However, enhancing the performance of the barrier in terms of enhanced matrix diffusion and sorption in the matrix (i.e., enhanced in the sense of taking extreme values within the probability distribution) change the realizations that dominate the mean. It is

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			for this reason, matrix diffusion is identified as an important factor affecting the mean annual dose. References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.
Mishra Rickertsen	J-MB 2.7	The description of the capability for individual barriers to prevent or substantially delay movement of water or radionuclide materials needs to include a discussion of the changes in barrier capability over time (throughout the 10,000 year compliance period). The discussion should include the extent to which the conceptual models of the barriers consider cumulative degradation processes over time, processes that may significantly affect the performance of the barrier; and temporal changes within the repository system. For example, time-dependent environmental or physical-chemical variability of the system (pressure, temperature, spatial changes before, during, and after the thermal pulse); dynamic conditions (boiling zone/ refluxation; calcite-opal mobilization and precipitation in fractures, lithophysae, matrix pores; thermal-mechanical stresses inducing rockfall & drift collapse, etc.) may need to be discussed to appropriately describe the performance of particular barriers. References: CRWMS M&O 2000ar. *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.	The multiple barrier analysis approach utilized the probabilistic TSPA model as the primary analytical tool. As such, temporal evolution of the system and associated variations in barrier capabilities are included in the analyses.

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		CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	
Mishra Rickertsen	J-MB 2.8	The description of barrier capabilities needs to include a discussion of the effects of spatial variability on the ability of the barrier to prevent or substantially delay movement of water or radionuclide materials, including a discussion of the spatial resolution in the models and data used to evaluate the performance of the barriers. For example, say 50% of the CHn is strongly sorbing and 50% is not. As another example, in the analysis of the non-mechanistic juvenile failure scenario in the Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i, p. 3-15), a "what-if" analysis, one waste package was artificially set to fail after 100 years. The consequences associated with the failed waste package will be influenced by the location of the failed waste package (e.g., the characteristics of radionuclide release, water flow, and radionuclide transport in the vicinity of the failed waste package, where these characteristic may be affected by spatial heterogeneity and its representation in the model used in the analysis). References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	The multiple barrier analysis approach utilized the probabilistic TSPA model as the primary analytical tool. As such, spatial variability in parameter values and associated barrier characteristics and capabilities are included in the analyses. The single waste package considered in the non-mechanistic juvenile failure scenario of Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i) is not an identifiable waste package located at a single point. The location of this waste package is sampled. Consequently different realizations will have the waste package in different locations. Accordingly, spatial variability in characteristics affects the results of the complete set of realizations. Reference: CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.

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Resp. Org	Item #	Comment	Response
Mishra Rickertsen	J-MB 2.9T	Table 6.3-1 of the DOE's TSPA Technical Document (CRWMS M&O 2000ar) correlates barriers and process model factors. Section 5.3 of the same document identifies the barriers that are considered in the robustness analysis. Sections 3.2 and 3.4 of Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i) also identify degraded and neutralized barrier analyses. However, the discussions of these barriers are, in several instances, mixed with process model factors such as water usage, biosphere dose conversion factors (BDCF), and backfill. Although the identification of process model factors and the associated discussions in combination with multiple barriers provide useful information, a clear distinction should be made between the discussion on process model factors and barriers. References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	Barriers important to waste isolation correspond to physical entities and not abstract process model factors. In addition, the role of process model factors affecting performance of these barriers will be discussed in any potential license application. The analyses in Repository Safety Strategy, Rev. 4 (CRWMS M&O 2001i) were intended to identify areas considered for the postclosure safety case. Consequently, these analyses were not intended to assess the role of the barriers in preventing or substantially delaying movement of water or radionuclide materials. DOE's multiple barrier analysis approach involving the complementary use of 4 analytical techniques would focus on barriers, not on the role of process model factors in determining the mean annual dose. Reference: CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.

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AC3 - Data uncertainty is characterized and propagated through the model abstraction			
Resp. Org	**Item #**	**Comment**	**Response**
Mishra Rickertsen	J-MB 3.1	Analyses providing the technical basis for assertions of barrier capabilities need to consider correlations between parameters in an appropriate way. The basis for correlations (or independence) in the models needs to be discussed appropriately. References: CRWMS M&O 2000ar. *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. CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.	The multiple barrier analysis approach utilized the probabilistic TSPA model as the primary analytical tool. As such, correlation between parameters and component models was included in the analyses.

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Subissue 2: Scenario Analysis

Importance to System Performance. This subissue considers the process of identifying possible processes and events that could affect repository performance, assigning probabilities to categories of events and processes, and the exclusion of processes and events from the performance assessment (PA). This is a key factor in ensuring the completeness of a TSPA.

WASTE PACKAGE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-1	FEP 2.1.03.11.00	The Effects of Container Form	FEP 2.1.03.11.00 (The Effects of Container Form) have been excluded from consideration in the TSPA code (CRWMS M&O 2001e). The varying clearance between the drip shield and different waste package designs and the concomitant effects that this may have on the consequences of rock block impacts and/or seismic excitation have not been addressed by DOE. Reference: CRWMS M&O 2001e. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004.	Results of recently performed thermal expansion calculations indicated a need to increase the gap between the outer barrier lid and the inner barrier lid from the current 3-mm to 6-mm. DOE agreed to provide the technical basis for the screening argument in the FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation (CRWMS M&O 2001e) which will incorporate these results (Pathforward Item 38). In addition, in the Container Life and Source Term agreement 2.8, DOE agreed to perform, prior to any potential License Application, calculations that address the effects of static loads from fallen rock on the drip shield during a seismic event for both intact and degraded conditions of the drip shield (Pathforward Item 31). DOE believes the existing pathforward items and Container Life and Source Term agreement 2.8 identified above are sufficient to address the technical issue identified in the NRC comment. References: CRWMS M&O 2001e. *FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation.* ANL-EBS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010216.0004. (future revisions) CRWMS M&O 2000j. *Design Analysis for UCF Waste Packages.* ANL-UDC-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0336. CRWMS M&O 2000g. *Design Analysis for the Defense High-Level Waste Disposal Container.* ANL-DDC-ME-000001 REV 00.

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Subissue 2: Scenario Analysis

WASTE PACKAGE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
				Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000627.0254. CRWMS M&O 2000i. *Design Analysis for the Naval SNF Waste Package.* ANL-VDC-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O . ACC: MOL.20000615.0029. CRWMS M&O 2000h. *Design Analysis for the Ex-Container Components.* ANL-XCS-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0374.

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Subissue 2: Scenario Analysis

ENGINEERED BARRIER SYSTEM				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-2	FEP 2.1.06.05.00	Degradation of the Invert	FEP 2.1.06.05.00 (Degradation of the Invert) has been excluded from consideration in the TSPA code (CRWMS M&O 2001b). Rock block impact orientations with the waste package will be affected by degradation of the invert. As pointed out in the comment on FEP 2.1.07.01.00, angled rock block impacts near the closure lid weld may have undesirable consequences. Furthermore, the stability of the waste package during seismic excitation will be affected by a degraded invert foundation. The corrosion of the steel pallet components should be considered when evaluating the stability of the waste package on its supporting pallet on a degraded invert foundation. Reference: CRWMS M&O 2001b. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010312.0024.	Impact of degradation on mechanical response of waste package Additional loading combinations are being addressed in response to Container Life and Source Term agreement 2.8. Evaluations of these loading combinations will be documented in a future revision of the Design Analysis for UCF Waste Packages (CRWMS M&O 2000j), and the Design Analysis for the Ex-Container Components (CRWMS M&O 2000h). Seismic motion of the supporting invert Seismic motion of the supporting invert is being included in the evaluations being currently performed and will be included in the next revision of the *Design Analysis for the Ex-Container Components* (CRWMS M&O 2000h). The corrosion of the steel pallet components should be considered when evaluating the stability of the waste package on its supporting pallet on a degraded invert foundation. The carbon steel members of the invert are surrounded by a ballast material, which will provide some support to the waste packages for the entire regulatory period. While the carbon steel invert may not keep the waste packages in a horizontal position for the entire regulatory period, they are designed to keep the waste packages in a horizontal position for the preclosure period. One of the repository closure activities is the installation of drip shields, which would prevent direct impact of rock blocks on the waste packages. References: CRWMS M&O 2000j. *Design Analysis for UCF Waste Packages.* ANL-UDC-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000526.0336. (future revision)

Subissue 2: Scenario Analysis

ENGINEERED BARRIER SYSTEM				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
				CRWMS M&O 2000h. *Design Analysis for the Ex-Container Components.* ANL-XCS-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0374. (future revision)
J-3	FEP 2.1.06.01.00	Degradation of cementitious materials in drift	FEP 2.1.06.01.00 (Degradation of cementitious materials in drift). In the EBS FEPs AMR (CRWMS M&O 2001b), the effects of degradation of cementitious materials on seepage chemistry are excluded on the basis of low consequence. Exclusion is based on arguments under FEP 2.1.09.01.00 (Properties of the Potential Carrier Plume in the Waste and EBS, CRWMS M&O 2001b), on the basis that chemical models show a negligible effect of grout associated with rock bolts. NRC has raised questions about these models, pertaining to the treatment of evaporation and the chemical divide phenomenon (ENFE tech exchange). Concerns about grout chemical effects are related to recent observations of dripping from rock bolt holes in the sealed cross-drift test. The argument for screening chemical effects of cementitious materials in the drift is considered not adequate. Because degradation products may affect water chemistry, and therefore radionuclide sorption behavior, the effect of this FEP on radionuclide transport in the unsaturated zone should also be evaluated. Currently, this FEP is not addressed for the UZ (BSC 2001b). It is necessary to the development of technical bases that degradation of cementitious materials has a negligible effect on water chemistry within and below the drift. Screening would be supported by addressing the following	Although this FEP is not addressed by the Unsaturated Zone, the subject is covered by other FEPs that are addressed by the Unsaturated Zone. See FEPs 2.2.08.01.00 (Groundwater Chemistry/ Composition in Unsaturated Zone and Saturated Zone) and 2.2.08.02.00 (Radionuclide Transport Occurs in a Carrier Plume in Geosphere). DOE will cross-reference above FEPs that address cementitious material in the next revision of the FEP Analysis/Model Reports. An estimate of the impact on local water chemistry resulting from degradation of cementitious materials (grout) as well as the corrosion products from rockbolt degradation is being provided as part of the work being done in support of agreements Evolution of Near Field agreements 2.6, 2.10, and 2.14. The scope of these agreements takes into account evaporative concentrations and the chemical divide effect. Results of this work will be incorporated into the screening arguments for this FEP.

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Subissue 2: Scenario Analysis

ENGINEERED BARRIER SYSTEM				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
			technical exchange agreements: ENFE.2.6 and 2.14: These agreements deal with model and lab results pertinent to the effects of EBS materials, including cementitious, on water chemistry. RT.1.5 and 2.10: These agreements concern the technical bases for transport parameter uncertainty distributions. References: CRWMS M&O 2001b. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010312.0024. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	

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Subissue 2: Scenario Analysis

ENGINEERED BARRIER SYSTEM				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-4	FEP 2.1.06.05.00	Degradation of invert and pedestal	FEP 2.1.06.05.00 (Degradation of invert and pedestal). Invert degradation is excluded on the basis of low consequence (CRWMS M&O 2001b). The argument that changes to diffusive properties of the invert will be negligible to dose is not supported by demonstration (by sensitivity analyses) of the significant effect of diffusive release through the invert during the first 20,000 years (CRWMS M&O 2001i, Volume II, Section 3.3). The sensitivity shown in the Repository Safety Strategy also applies to the first 10,000 years. The screening argument contradicts this information. The screening argument should directly address possible effects of degradation on invert diffusive properties. References: CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825. CRWMS M&O 2001b. *Engineered Barrier System Features, Events, and Processes.* ANL-WIS-PA-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010312.0024.	<u>Impact of invert and pedestal degradation on waste package</u>. From an engineered barrier system modeling perspective, the pedestal is assumed to fail such that the waste package is in constant contact with the invert. Thus, no credit is taken for the potentially beneficial effect of radionuclide diffusion through a water film on the pedestal surface. Since this is a conservative assumption, no further evaluation is required. <u>Impact of invert degradation on diffusion through the invert</u> Such degradation could reduce diffusion rather than enhance it. However, as part of the screening argument for this FEP, a quantification of the impact of invert degradation on relevant parameters impacting diffusion (i.e. porosity) and the impact of these parameter changes on the invert diffusion coefficient will be provided. This will demonstrate that any invert degradation will reduce diffusion (conservative to ignore it), demonstrate that any effect on the diffusion coefficient is already covered by existing sensitivity studies, or provide the basis for an expanded sensitivity range for the invert diffusion coefficient. Updates to the Repository Safety Strategy (CRWMS M&O 2001i) will be made, if necessary. Reference: CRWMS M&O 2001i. *Repository Safety Strategy: Plan to Prepare the Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations.* TDR-WIS-RL-000001 REV 04 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010329.0825.

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WASTE FORM				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-5	FEP 2.1.09.21.00	Suspensions of particles larger than colloids	FEP 2.1.09.21.00 (Suspensions of particles larger than colloids). This FEP is excluded for the EBS transport and waste form release abstractions (CRWMS M&O 2001k, BSC 2001b). Exclusion is based on the assumption that although particles may be transported through fractures in the unsaturated zone, low groundwater velocities through the saturated zone would lead to particle settling (CRWMS M&O 2001k), suggesting inconsistency in the screening analysis. Without quantitative measures of particle size, pore size, groundwater velocity, and chemical variability, however, these qualitative assertions are difficult to evaluate. Since DOE includes colloid formation FEPs in its screening analysis, and because of the large amounts of Fe particles that may be introduced in the EBS, particle transport through the EBS into the unsaturated zone is plausible. Exclusion of this FEP may be acceptable, but it is necessary to have a more complete technical basis and calculations to support exclusion of the FEP on the basis of low consequence. References: CRWMS M&O 2001k. *Waste Form Colloid-Associated Concentrations Limits: Abstraction and Summary.* ANL-WIS-MD-000012 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010130.0002. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	DOE believes that the current exclusion of this FEP on the basis of low consequence is appropriate. However, DOE agrees to clarify the screening argument to provide additional information on the population, size and density of particles larger than colloids potentially generated within the waste form and engineered barrier systems. Also, additional information on probable pore sizes and distributions, groundwater velocities/chemical variability within the waste form and engineered barrier systems will be provided and the potential effects of these variables on the transport of suspended particles larger than colloids will be evaluated.

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-6	FEP 2.2.07.15.00	Advection and dispersion	FEP 2.2.07.15.00 (Advection and dispersion). As defined, this FEP does not apply to the unsaturated zone, and is not discussed in the UZ FEPs AMR (BSC 2001b). Given that advection and dispersion are key components of the DOE radionuclide transport in the unsaturated zone model abstraction, the FEP definition should be extended to enclose these aspects (advection and dispersion) in the UZ. Reference: BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	This FEP is currently a Saturated Zone FEP, and will be added as an Unsaturated Zone FEP.
J-7	FEP 2.2.08.01.00	Groundwater chemistry/composition in UZ and SZ	FEP 2.2.08.01.00 (Groundwater chemistry/composition in UZ and SZ) is excluded. The DOE has included the current ambient groundwater conditions in the TSPA-SR abstraction of radionuclide transport in the unsaturated zone, but has excluded future changes (CRWMS M&O 2000aw, 2001). The DOE asserts that the thermal effects on chemistry are minimal, but this focuses mainly on the effects of dissolution and precipitation on hydrologic properties. The screening argument refers to a model of thermo-chemical effects on seepage water chemistry at the drift wall (CRWMS M&O 2000o). Because modeled effects fell within the range of variation included in TSPA, it is asserted that effects further from the drift would be smaller, based on an unverified assumption (Assumption 11; BSC 2001b). This argument does not address chemical changes below the repository, which are likely to be more significant than changes above, due to interactions with EBS and waste materials. Even so,	Assumption 11 is designated as needing further verification prior to any potential license application. The technical work used to resolve the Evolution of Near Field Environment agreement items 1.4, 4.3, 4.4, and Radionuclide Transport agreement 1.5 will be sufficient to provide the additional technical bases needed for the FEPs screening argument. These agreements will take into account thermal-hydrological-chemical effects on radionuclide transport out of the drift.

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			predicted changes in key geochemical parameters (pH and total carbon) in seepage water are large enough to have an effect on sorption coefficients. Without the details on how expert judgement was used to derive the TSPA-SR sorption parameters, it is not clear how the effects of changes in the ambient chemistry system are incorporated in the transport calculations. The technical basis for this exclusion is not satisfactory. References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. CRWMS M&O 2000o. *Drift-Scale Coupled Processes (DST and THC Seepage) Models.* MDL-NBS-HS-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0523. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	
J-8	FEP 2.2.08.02.00	Radionuclide transport occurs in a carrier plume in geosphere	FEP 2.2.08.02.00 (Radionuclide transport occurs in a carrier plume in geosphere) is excluded. This FEP is excluded from the TSPA-SR abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O 2000aw; BSC 2001b). The key assumption (Assumption 11; BSC 2001b) is that results from the near-field THC coupled processes model (CRWMS M&O 2000o) can be used to bound the effects of similar coupled processes on far-field flow and	Assumption 11 is designated as needing further verification prior to any potential license application. The technical work used to resolve Evolution of Near Field Environment agreements 1.4, 4.3, 4.4, and Radionuclide Transport agreement 1.5 will be sufficient to provide the additional technical bases needed for the FEPs screening argument. These agreements will take into account thermal-hydrologic-chemical effects on radionuclide transport out of the drift.

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Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
			transport. This assumption has not yet been verified. Because the screening argument for this FEP is focused primarily on thermal effects on the chemistry of seepage water entering the emplacement drifts, it does not appear to include other potential effects (colloids, interactions with waste forms and EBS materials). Also, the FEP on properties of a carrier plume in the EBS is included in the EBS PMR (CRWMS M&O 2000q, 2000p), suggesting that radionuclide transport in a carrier plume should be included in transport beyond the EBS. The arguments presented for exclusion of this FEP (BSC 2001b) do not appear to be sufficient at this time. References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. CRWMS M&O 2000o. *Drift-Scale Coupled Processes (DST and THC Seepage) Models.* MDL-NBS-HS-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0523. CRWMS M&O 2000q. *Engineered Barrier System Degradation, Flow, and Transport Process Model Report.* TDR-EBS-MD-000006 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000724.0479. CRWMS M&O 2000p. *EBS FEPs/Degradation Modes Abstraction.* ANL-WIS-PA-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000525.0373. BSC 2001b. *Features, Events, and Processes in UZ Flow*	

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			and Transport. ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	
J-9	FEP 2.2.08.03.00	Geochemical interactions in geosphere [dissolution, precipitation, weathering] and effects on radionuclide transport	FEP 2.2.08.03.00 (Geochemical interactions in geosphere [dissolution, precipitation, weathering] and effects on radionuclide transport) is excluded (CRWMS M&O, 2000aw; BSC 2001b). This FEP is also excluded from the TSPA-SR abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence. The key assumption (Assumption 11; BSC 2001b) is that results from the near-field THC coupled processes model (CRWMS M&O 2000o) can be used to bound the effects of similar coupled processes on far-field flow and transport. This assumption has not yet been verified. Predicted mineralogical changes (CRWMS M&O 2000o) in response to the thermal effects of the repository are small (calcite only). Predicted changes in porosity and permeability are also small. Transport through fractures is conservatively modeled in TSPA-SR assuming no retardation. However, the screening argument only addresses changes in seepage water chemistry. It does not address the possibility of reduced (or enhanced) matrix diffusion through precipitation and dissolution. Diffusion into the matrix and sorption on matrix minerals can be an important retardation mechanism. The effect of small volume changes on fracture armoring and diffusion into the matrix may be important. The current screening arguments are not sufficient and will depend in part on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less	Assumption 11 is designated as needing further verification prior to any potential license application. The technical work used to resolve Evolution of Near Field Environment agreements 1.7, 2.6, and 1.4 will be sufficient to provide the additional technical bases needed for the FEPs screening argument. These agreements will address thermal-hydrological-chemical affects on mineral precipitation.

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			than calculated near-field changes (BSC 2001b). Effects on flow are excluded based on low consequence. Problems with modeling of drift-scale coupled processes (CRWMS M&O 2000o) used to support this screening argument have been raised by NRC. Current agreements from ENFE Technical Exchange may provide additional technical basis for the screening argument. References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. CRWMS M&O 2000o. *Drift-Scale Coupled Processes (DST and THC Seepage) Models.* MDL-NBS-HS-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0523. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	
J-10	FEP 2.2.08.06.00	Complexation in geosphere	FEP 2.2.08.06.00 (Complexation in geosphere) is excluded. The DOE has included the effects of ambient condition complexation in the TSPA-SR abstraction of radionuclide transport in the unsaturated zone, but has excluded future changes (CRWMS M&O 2000aw; BSC 2001b). The effects of complexation are "...implicitly included in the radionuclide sorption coefficients", but there is no clear technical basis regarding the effects of organics or other ligands provided in establishing the Kd	Assumption 11 is designated as needing further verification prior to any potential license application. The technical work used to resolve Evolution of Near Field Environment agreements 1.4, 4.3, 4.4, and Radionuclide Transport agreement 1.5 will be sufficient to provide the additional technical bases needed for the FEPs screening argument. These agreements will take into account thermal-hydrological-chemical effects on radionuclide transport out of the drift.

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			distributions (BSC 2001b). Experimental results reported in Triay et al. (1997) that form much of the basis for the sorption coefficient distributions only address the effects of organics on Np and Pu sorption. The Unsaturated Zone and Saturated Zone Transport Properties AMR (CRWMS M&O 2000au) does not provide any additional information on the effect of organics on other radionuclides. The current process models do not address the effects of complexation on transport parameters, and the exclusion of changes to complex formation does not have sufficient support. In addition, the screening argument refers to modeling results on repository effects on seepage chemistry, which may not be relevant to transport conditions below the repository (BSC 2001b). References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. CRWMS M&O 2000au. *Unsaturated Zone and Saturated Zone Transport Properties (U0100).* ANL-NBS-HS-000019 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000829.0006. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321. Triay, I.R.; Meijer, A.; Conca, J.L.; Kung, K.S.; Rundberg, R.S.; Strietelmeier, B.A.; and Tait, C.D. 1997. *Summary and Synthesis Report on Radionuclide Retardation for the*	

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
			Yucca Mountain Site Characterization Project. Eckhardt, R.C., ed. LA-13262-MS. Los Alamos, New Mexico: Los Alamos National Laboratory. ACC: MOL.19971210.0177.	
J-11	FEP 2.2.08.07.00	Radionuclide solubility limits in the geosphere	FEP 2.2.08.07.00 (Radionuclide solubility limits in the geosphere) is excluded. This FEP is excluded from the TSPA-SR abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O 2000aw; BSC 2001b). The DOE screening argument assumes that radionuclide solubility limits in the geosphere may be different and indicates that this FEP is conservatively ignored with respect to solubility reduction in the far-field (CRWMS M&O 2000aw). This argument makes valid points, but the possibility of increasing solubility limits must also be considered. Solubility limits in the geosphere will be determined by interaction between the contaminant plume and the host rock. This is not necessarily a conservative assumption and should be constrained by calculations including sensitivity analyses, bounding calculations and comparison to natural analog systems. References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	Changing solubility limits could affect radionuclide release from the waste form (in the waste emplacement drift) but cannot affect the unsaturated zone, given the assumptions used for unsaturated zone radionuclide transport. All radionuclides that pass from the engineered barrier system to the Unsaturated Zone are aqueous or colloidal and are assumed to remain in the dissolved or colloidal state unless sorbed to rock surfaces. There are no precipitation/ dissolution processes for radionuclides; they are either mobile (aqueous or colloidal) or sorbed. The conservative assumption is that there is no precipitate in the unsaturated zone associated with the radionuclides. Therefore, increasing solubility limits will have no effect.

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-12	FEP 2.2.10.01.00	Repository-induced thermal effects in geosphere	FEP 2.2.10.01.00 (Repository-induced thermal effects in geosphere) is excluded. This FEP is excluded from the TSPA-SR abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O 2000aw; BSC 2001b). The screening argument is only partially supported by near-field thermo-chemical modeling for a limited number of hydrochemical constituents and minerals (CRWMS M&O 2000o), and is not directly related to effects on radionuclide transport. The technical basis for the screening is not sufficient at this time and future evaluation of the exclusion of this FEP will depend in part on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than calculated near-field changes (BSC 2001b). References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. CRWMS M&O 2000o. *Drift-Scale Coupled Processes (DST and THC Seepage) Models.* MDL-NBS-HS-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0523. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	Assumption 11 is designated as needing further verification prior to any potential license application. The technical work used to resolve Evolution of Near Field Environment agreements 1.4, 4.3, 4.4, and Radionuclide Transport agreement 1.5 will be sufficient to provide the additional technical bases needed for the FEPs screening argument. These agreements will take into account thermal-hydrological-chemical effects on radionuclide transport out of the drift.

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-13	FEP 2.2.10.06.00	Thermo-chemical alteration (solubility, speciation, phase changes, precipitation/ dissolution	FEP 2.2.10.06.00 (Thermo-chemical alteration (solubility, speciation, phase changes, precipitation/dissolution)) is excluded. This FEP is excluded from the TSPA-SR abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O 2000aw; BSC 2001b). Thermal effects on chemistry at the mountain scale are expected to be low on the basis of near-field coupled THC models that indicate the thermal effects of the repository result in only small changes in major hydrochemical constituents and limited changes in mineralogy. However, the model results in the cited report (CRWMS M&O 2000o) only consider a few components in hydrochemistry important to container life (e.g., pH, total carbon, Ca), is limited to calcite precipitation/dissolution, and addresses only seepage water chemistry. Thermo-chemical effects on transport beneath the repository, which could reflect the influence of EBS and waste form materials, are not considered. In addition, although the assumption that far-field changes are likely to be less than near-field changes is reasonable, it has not been verified (BSC 2001b). The technical basis is not sufficient at this time to demonstrate low consequence. The evaluation of this exclusion will depend in part on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than calculated near-field changes (BSC 2001b). References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280.	Assumption 11 is designated as needing further verification prior to any potential license application. The technical work used to resolve Evolution of Near Field Environment agreements 1.4, 4.3, 4.4, and Radionuclide Transport 1.5 will be sufficient to provide the additional technical bases needed for the FEPs screening argument.. These agreements will take into account thermal-hydrological-chemical effects on radionuclide transport out of the drift.

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
			CRWMS M&O 2000o. *Drift-Scale Coupled Processes (DST and THC Seepage) Models.* MDL-NBS-HS-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0523. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	
J-14	FEP 2.2.10.07.00	Thermo-chemical alteration of the Calico Hills unit	FEP 2.2.10.07.00 (Thermo-chemical alteration of the Calico Hills unit) is excluded. This FEP is excluded from the TSPA-SR abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (BSC 2001b). The screening argument is based on prediction of small changes in aqueous geochemistry and mineralogy in response to coupled THC processes in the near-field (CRWMS M&O 2000o). Thermo-chemical changes in the far-field, including the Calico Hills unit will be even less significant (Assumption 11, BSC 2001b). The screening argument indicates that temperatures in the zeolite-bearing Calico Hills unit will not be high enough to cause significant zeolite alteration. Because the radionuclide transport abstraction assumes no retardation in fractures, this exclusion may be appropriate (however, see next paragraph). Again, final evaluation of this exclusion will depend in part on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than calculated near-field changes (BSC 2001b).	Assumption 11 is designated as needing further verification prior to any potential license application. The technical work used to resolve Evolution of Near Field Environment agreements 1.4, 4.3, 4.4, and Radionuclide Transport 1.5 will be sufficient to provide the additional technical bases needed for the FEPs screening argument. These agreements will take into account thermal-hydrological-chemical effects on radionuclide transport out of the drift. Alteration temperature of 85°C for zeolite is given in the Yucca Mountain Site Description – Section 6 Geochemistry, Section 6.1.5.3.1, page 6.1-129. Reference: Yucca Mountain Site Description, Revision 00, September 1998 - (Document Id B00000000-01717-5700-00019) Book 3, Frontmatter And Section 6 - Geochemistry

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
			Alteration of the uppermost nonwelded layers below the repository could significantly reduce the fraction of matrix flow below the repository. Nonwelded vitric horizons, either basal Topopah Springs vitrophyre or the uppermost Calico Hills unit, cover nearly half of the repository. In the southwestern portion of the repository footprint, the nonwelded, nonaltered tuffs lie as little as 45 m below the repository. The screening argument (BSC 2001b) includes the assertion that temperatures in the Calico Hills unit will remain below 70°C, which is not high enough to cause significant zeolite alteration. According to the cited reference, however, it appears temperatures can exceed 70°C (up to 85°C is estimated from figures in cited section of CRWMS M&O 2000af) where the nonwelded, nonaltered tuff is closest to the repository. References: CRWMS M&O 2000o. *Drift-Scale Coupled Processes (DST and THC Seepage) Models.* MDL-NBS-HS-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0523. CRWMS M&O 2000af. *Mountain-Scale Coupled Processes (TH) Models.* MDL-NBS-HS-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0528. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-15	FEP 2.2.10.09.00	Thermo-chemical alteration of the Topopah Spring basal vitrophyre	FEP 2.2.10.09.00 (Thermo-chemical alteration of the Topopah Spring basal vitrophyre) is excluded. This FEP is excluded from the TSPA-SR abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O 2000aw; BSC 2001b). The screening argument is based on prediction of small changes in aqueous geochemistry and mineralogy in response to coupled THC processes in the near-field (CRWMS M&O 2000o). Thermo-chemical changes in the far-field, including the Topopah Spring basal vitrophyre, are expected to be even less significant (Assumption 11, BSC 2001b). Although the assumption that far-field changes are likely to be less than near-field changes (Assumption 11) is reasonable, it has not been verified (BSC 2001b). It is important to note that the near-field analyses (CRWMS M&O 2000o) are performed with a focus on seepage chemistry and how it might affect container life, rather than with the purpose of considering thermal effects on radionuclide transport. The technical basis is not sufficient at this time to demonstrate low consequence to radionuclide transport. Because the TSPA-SR radionuclide transport abstraction assumes no retardation in fractures, this exclusion may be appropriate. Again, final evaluation of this exclusion will depend on the verification of Assumption 11 that far-field changes to radionuclide transport in the unsaturated zone will be less than calculated near-field changes (BSC 2001b). Alteration of the uppermost nonwelded layers below the repository could significantly reduce the fraction of matrix flow below the repository. Nonwelded vitric horizons, either basal Topopah Spring vitrophyre or the uppermost	Assumption 11 is designated as needing further verification prior to any potential license application. The technical work used to resolve Evolution of Near Field Environment agreements 1.4, 4.3, 4.4, and Radionuclide Transport 1.5 will be sufficient to provide the additional technical bases needed for the FEPs screening argument. These agreements will take into account thermal-hydrological-chemical effects on radionuclide transport out of the drift. See response for J-14 above. Alteration of vitric rock has not been addressed and will need to be included in the overall thermal-hydrological-chemical analyses. Regarding the maximum predicted temperatures in the CHn, the Mountain-Scale Coupled Processes Analysis/Model Report (CRWMS M&O 2000af, p. 94) states: "At the top of the CHn hydrogeologic unit, the maximum temperature rises to 75-80°C for a period between 2000 and 7000 years." Reference: CRWMS M&O 2000af. *Mountain-Scale Coupled Processes (TH) Models.* MDL-NBS-HS-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0528.

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			Calico Hills unit, cover nearly half of the repository. In the southwestern portion of the repository footprint, the nonwelded, nonaltered tuffs lie as little as 45 m below the repository. The screening argument for 2.2.10.07.00 (BSC 2001b) includes the assertion that temperatures in the Calico Hills unit will remain below 70°C, which is not high enough to cause significant zeolite alteration. According to the cited reference, however, it appears temperatures can exceed 70°C (up to 85°C is estimated from figures in cited section of CRWMS M&O 2000af) where the nonwelded, nonaltered tuff is closest to the repository. Temperatures would be higher in the overlying Topopah Spring basal vitrophyre than in the Calico Hills. References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. CRWMS M&O 2000o. *Drift-Scale Coupled Processes (DST and THC Seepage) Models.* MDL-NBS-HS-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0523. CRWMS M&O 2000af. *Mountain-Scale Coupled Processes (TH) Models.* MDL-NBS-HS-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0528. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	

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Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-16	FEP 1.2.07.01.00	Erosion/denudation	FEP 1.2.07.01.00 (Erosion/denudation). Incomplete rationale for excluding from UZ on the basis of low consequence. It is necessary to consider onset and extent of erosion caused by construction and characterization activity at the ground surface and its long-term effect on shallow infiltration. Reference: BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	DOE will include reference to the site Reclamation Implementation Plan, YMP/91-14 for post-closure to address this aspect of the FEP. Reference: YMP 2001. *Reclamation Implementation Plan.* YMP/91-14, Rev. 2. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.20010301.0238.
J-17	FEP 1.2.10.02.00	Hydrologic response to igneous activity	FEP 1.2.10.02.00 (Hydrologic response to igneous activity). Excluded based on low consequence. Argument to exclude focuses on intrusive events. It should be noted that extrusive events could increase shallow infiltration over the repository in two ways: (1) lava flow would modify or dam a wash overlying the repository, (2) volcanic fragment and ash layer, which would be highly permeable, may act to trap infiltrating water, shield it from evaporation, and reduce transpiration all leading to increased shallow infiltration across the repository; There is no data to support or exclude the temporal extent of increased shallow infiltration, though could be bounded from decades to thousands of years. References: BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	DOE will consider revisiting the low consequence arguments concerning extrusive volcanic events on infiltration (including effects on surface vegetation) for this FEP. Consideration will be given to including low probability arguments.

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Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-18	FEP 1.3.04.00.00	Periglacial effects	FEP 1.3.04.00.00 (Periglacial effects). Excluded by low probability. While other periglacial processes will not likely occur at Yucca Mountain, the freeze/thaw process is currently active. Freeze/thaw mechanical erosion will likely increase as the climate cools. However, the magnitude of erosion will not likely be significant even during the cooler climate condition. The screening argument should clarified to acknowledge the current freeze/thaw process. Reference: BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	DOE will clarify the screening argument in next revision of FEPs Analysis/Model Report to acknowledge the current freeze/thaw process. Reference: BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.
J-19	FEP 2.1.05.01.00	Seal physical properties	FEP 2.1.05.01.00 (Seal physical properties). Excluded based on low consequence. It is difficult to access this FEP solely based on the screening argument provided. The assessment can be done once the actual design (ventilation tunnel locations) is released, backfill is described, and the analysis of runoff and flooding incorporated into the FEP analysis. FEP 2.1.05.02.00 (Groundwater flow and radionuclide transport in seals) and FEP 2.1.05.03.00 (Seal degradation). Excluded based on low consequence, using screening argument for FEP 2.1.05.01.00. The adequacy of the screening argument cannot be assessed until the actual design (ventilation tunnel locations) is released, backfill is described, and the analysis of runoff and flooding incorporated into the FEP analysis (see also comments for FEP 1.1.02.01.00).	As indicated in the May 2001 FEPs Technical Exchange, DOE will adopt a more rigorous configuration controls as the design advances. These controls will identify FEP screening argument that could potentially change when design changes occur.

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
			Reference: BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	
J-20	FEP 2.2.07.05.00	Flow and transport in the UZ from episodic infiltration	FEP 2.2.07.05.00 (Flow and transport in the UZ from episodic infiltration). Excluded based on low consequence. Screening argument asserts that episodic infiltration is expected to be attenuated by flow in the PTn layer such that UZ flow beneath this layer is effectively steady-state. Analyses to support this assertion, however, have only considered episodic infiltration with an average of 5 mm/yr infiltration flux. Area-average infiltration flux over the proposed repository horizon at YM is expected to exceed 20 mm/yr during future wetter climate conditions. According to existing UZ Technical Exchange agreements, the DOE will provide additional documentation on effectiveness of PTn layer to dampen episodic infiltration. Reference: Reference: BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321	The technical work used to resolve Unsaturated and Saturated Flow under Isothermal Conditions agreement 4.4 will be sufficient to provide the additional technical bases needed for the FEPs screening argument. This agreement will address episodic flow in the repository. An analysis of 36 Cl will be included with respect to fast pathways through the PTn. Treatment of undetected features in PTn can be addressed through an analysis of 36Cl measurements in the TSw (which identifies fast pathways through the PTn). This will be added to the FEP argument.

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-21	FEP 2.2.11.02.00	Gas Pressure Effects	FEP 2.2.11.02.00 (Gas Pressure Effects) Excluded based on low consequence and low probability. Consistency is needed in the screening arguments. Buildup of water vapor pressure within rock matrix blocks due to waste heat has not been considered. Gas pressure can build up within matrix blocks which have low permeability. This can increase the boiling point and keep water in the liquid phase at higher temperatures. Flashing to vapor as liquid water leaves the matrix block can result in mineral deposition that can later affect flow pathways. Reference: BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	The technical arguments for this issue (related to repository heating) are addressed as part of the thermal-hydrological-chemical analyses. Additional technical work related to the Evolution of Near Field agreements 1.5, 1.7 and 2.16 will be sufficient to provide the additional technical bases needed for the FEPs screening argument. These agreements will address thermal-hydrological-chemical affects on mineral precipitation. DOE will cross-reference this FEP with FEPs treating thermal-hydrological-chemical effects: 2.2.08.02.00 (Geochemical Interactions in Geosphere (Dissolution, Precipitation, Weathering) and Effects on Radionuclide Transport), 2.2.10.01.00 (Repository Induced Thermal Effects in Geosphere) and 2.2.10.06.00 (Thermo-Chemical Alteration (Solubility, Speciation, Phase Changes, Precipitation/Dissolution)).
J-22	FEP 1.2.04.02.00	Igneous activity causes changes to rock properties	FEP 1.2.04.02.00 (Igneous activity causes changes to rock properties) is excluded. This FEP is excluded from the TSPA-SR abstraction of radionuclide transport in the unsaturated zone on the basis of low consequence (CRWMS M&O 2000aw; BSC 2001b). Although several of the arguments presented (scale, duration) may be reasonable, natural analogs (CRWMS M&O 2000ah) suggest time scales of thousands of years (i.e., Ratcliff et al. 1984) and alteration scales of tens of meters. Furthermore, modeling studies of the effects of silica redistribution on fracture porosity and permeability (CRWMS M&O 2000ah) have yielded conflicting results (Matyskiela 1997), suggesting additional clarification is needed. Probability may also be an aspect to use in developing a screening argument for this FEP, provided it is consistent with the probabilities used for the igneous	DOE will consider probability arguments to exclude larger intrusive events that may induce hydrothermal activity and pervasive alteration of country rock. The particular issues raised by the work of Matyskiela (1997) will be addressed through the Evolution of Near Field agreements 1.7, 1.5, and 4.3. The agreements will include a resolution of the differences in behavior predicted by Matyskiela (1997) and Hardin (1998), Near Field/Altered Zone Models MOL.19980504.0577). References: Matyskiela, W. 1997. "Silica Redistribution and Hydrologic Changes in Heated Fractured Tuff." *Geology, 25,* (12), 1115-1118. Boulder, Colorado: Geological Society of America. TIC: 236809. Hardin, E.L. 1998. *Near-Field/Altered-Zone Models Report.* UCRL-ID-129179 DR. Livermore, California: Lawrence

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
			disruptive scenario. References: CRWMS M&O 2000aw. *Unsaturated Zone Flow and Transport Model Process Model Report.* TDR-NBS-HS-000002 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000831.0280. CRWMS M&O 2000ah. *Natural Analogs for the Unsaturated Zone.* ANL-NBS-HS-000007 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990721.0524. BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321. Matyskiela, W. 1997. "Silica Redistribution and Hydrologic Changes in Heated Fractured Tuff." *Geology, 25,* (12), 1115-1118. Boulder, Colorado: Geological Society of America. TIC: 236809. Ratcliff, C.D.; Geissman, J.W.; Perry, F.V.; Crowe, B.M.; and Zeitler, P.K. 1994. "Paleomagnetic Record of a Geomagnetic Field Reversal from Late Miocene Mafic Intrusions, Southern Nevada." *Science, 266,* 412-416. Washington, D.C.: American Association for the Advancement of Science. TIC: 234818.	Livermore National Laboratory. ACC: MOL.19980504.0577.

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UNSATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-23	FEP 1.2.06.00.00	Hydrothermal Activity	FEP 1.2.06.00.00 (Hydrothermal Activity). Excluded on the basis of low consequence for basaltic magmatism, and low probability for silicic magmatism (BSC 2001b). A consistent approach for the screening arguments is needed. Screening argument is considered incomplete as (i) past hydrothermal activity in the YMR is not clearly related to basaltic igneous activity, and (ii) probability screening arguments (BSC 2001b) are incomplete with respect to silicic magmatism. In addition, the DOE cites unpublished work by the USGS and UNLV that reportedly demonstrates hydrothermal activity was a site characteristic until about 2 Ma. Additional unpublished work by Dublyanski and others, however, does not support this conclusion. None of the unpublished work, however, has supported the conclusion that the likelihood of hydrothermal activity at YM during the next 10,000 yr is clearly <1:10,000. Absent a clear linkage to the consequences of basaltic igneous activity, or a demonstrated technical basis for probability values below 1 in 10,000 in 10,000 yr, the DOE has an incomplete technical basis to screen this FEP from further consideration. Reference: BSC 2001b. *Features, Events, and Processes in UZ Flow and Transport.* ANL-NBS-MD-000001 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010423.0321.	The technical work used to resolve Evolution of Near Field agreement 2.3 will be sufficient to provide the additional technical bases needed for the FEPs screening argument.

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SATURATED ZONE				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-24	FEP 1.2.04.07.00	Ashfall	FEP 1.2.04.07.00 (Ashfall). Saturated Zone FEP AMR (CRWMS M&O 2001c) screening argument for ashfall impacting the saturated zone (i.e., secondary FEP 1.2.04.07.01, Soil Leaching Following Ashfall) includes a three order of magnitude error in the calculation of the concentration of radionuclides in the well water. Although conservative assumptions are used in the analysis, the error found in Table 6-1 would cause the calculated dose to be 16.1 rem, instead of 16.1 mrem, and would not support a low consequence screening argument. Reference: CRWMS M&O 2001c. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230.	The NRC comment regarding Table 6-1 and a three order of magnitude error in the calculation of the radionuclide concentrations is correct. The present analysis conservatively assumes instantaneous transport of radionuclides through the unsaturated zone to the water table. Simplified calculations of expected transport times through the unsaturated alluvium for short-to moderately short-lived radionuclides (e.g., Sr-90, Cs-137, Pu-238) indicate a reduction in mass for these radionuclides by many orders of magnitude. Consequently, these radionuclides can be removed from consideration in the analysis presented in Table 6-1. The screening argument will be expanded to consider loss of radionuclide mass by radioactive decay during transport through the unsaturated zone. The error noted in the calculation of the radionuclide concentrations in Table 6-1 will be corrected for the more restricted list of radionuclides and the results will be used as support for the low consequence screening argument. The expanded screening argument and corrected calculations will be documented in a revised version of the Saturated Zone FEPs Analysis/Model Report (CRWMS M&O 2001c). Reference: CRWMS M&O 2001c. *Features, Events, and Processes in SZ Flow and Transport.* ANL-NBS-MD-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20010214.0230.

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DISRUPTIVE EVENTS				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-25	FEP 1.2.02.02.00	Faulting	FEP 1.2.02.02.00 (Faulting). 'Changes of fault characteristics' has been excluded from consideration in TSPA code on the basis of low consequence; and 'formation of new faults' has been excluded on the basis of low probability. FEP 1.2.02.03.00 (Fault Movement Shears Waste Container) has been excluded on the basis of low probability. FEP 1.2.03.02.00 (Seismic Vibration Causes Container Failure) has been excluded on the basis of low consequence (CRWMS M&O 2000t). In these FEPs, DOE's screening argument relies, in large part, upon the median values of fault displacements and ground motions for postclosure (less than 10^{-6}/year), rather than the mean values. The FEP screening arguments do not provide sufficient technical justification for staff review. The staff considers that the mean more reliably incorporates uncertainty and is a more reasonable and prudent statistical measure than the median. DOE has agreed to address this concern in a forthcoming Request for Additional Information (RAI). Reference: CRWMS M&O 2000t. *Features, Events, and Processes: Disruptive Events.* ANL-WIS-MD-000005 REV 00 ICN 1. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001218.0007.	DOE will address this concern in the forthcoming Request for Additional Information.

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DISRUPTIVE EVENTS				
Item No.	FEP#	FEP Name	NRC Comment	DOE Proposed Response
J-26	FEP 1.2.02.03.00	Fault Movement Shears Waste Container	The screening argument for FEP 1.2.02.03.00 (Fault Movement Shears Waste Container) is based, in part, on specific setback distances that will be used by DOE in the repository design. The setback distances are a function of fault displacement magnitudes. Thus, the setback values used in the design may need to be reassessed after the displacement issue is resolved.	DOE will address this concern in the forthcoming Request for Additional Information.
J-27	FEP 1.2.03.01.00	Seismic Activity	FEP 1.2.03.01.00 (Seismic Activity) has been excluded on the basis of low consequence of effects on such components as drip shield and waste package, and included with regard to effects on cladding (CRWMS M&O, 2000). The distributions for ground-motion parameters were developed using the Probabilistic Seismic Hazard Assessment expert elicitation. There are apparent discrepancies among these input parameters from several experts. DOE has agreed to address this concern in a forthcoming RAI.	DOE will address this concern in the forthcoming Request for Additional Information.