



Department of Energy
Office of Civilian Radioactive Waste Management QA: N/A
Yucca Mountain Site Characterization Office
P.O. Box 30307
North Las Vegas, NV 89036-0307

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C. William Reamer, Chief
High-Level Waste and Performance
Assessment Branch
Division of Waste Management
Office of Nuclear Materials Safety
and Safeguards
U.S. Nuclear Regulatory Commission
Two White Flint North
Rockville, MD 20852

**TRANSMITTAL OF INFORMATION COPY OF REPORT ON CONSERVATISM IN
PROCESS MODELS AND TOTAL SYSTEM PERFORMANCE ASSESSMENT**

Enclosed for your information is a report entitled, "Evaluation of Process Models for their Representation of Postclosure Repository Performance." This report summarizes an independent assessment of how realistic the process models and model abstractions that were the basis for the Total System Performance Assessment for Site Recommendation (TSPA-SR) are in their representation of features, events, and processes relevant to the performance of a potential Yucca Mountain, Nevada, repository. Our Management and Technical Support contractor prepared the report.

Selected model components were evaluated to assess the reasonableness of the representations, the importance of the component models to the make up of the process models, and the significance of the models to estimates of repository performance. The evaluation also included an assessment of whether the process models could be modified to be more representative of expected repository performance. The results indicate that various levels of conservatism exist in the representations for the component models, process models, and their abstractions, and that the reliance on conservative approaches (e.g., use of conservative parameter values or assumptions) was driven primarily by uncertainty. The results of this task are being used as input to our evaluation of the significance of the unquantified uncertainty associated with the conservative approach reflected in these models. The ultimate goal is to quantify key uncertainties and refine our models for use in TSPA to make use of representative parameter distributions and reflect a credible representation of system behavior.

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C. William Reamer

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JAN 16 2001

cc w/o encl continued:

T. C. Gunter, DOE/YMSCO, Las Vegas, NV

A. V. Gil, DOE/YMSCO, Las Vegas, NV

J. T. Sullivan, DOE/YMSCO, Las Vegas, NV

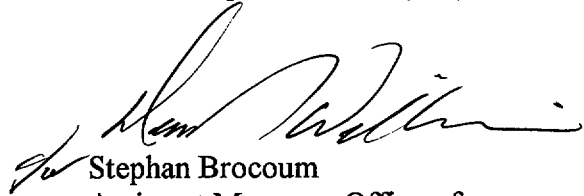
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Stephan Brocoum
Assistant Manager, Office of
Licensing and Regulatory Compliance

OR&LC:AVG-0540

Enclosure:
Evaluation of Process Models for their
Representation of Postclosure Repository
Performance

cc w/encl:
N. K. Stablein, NRC, Rockville, MD
S. L. Wastler, NRC, Rockville, MD
D. J. Brooks, NRC, Rockville, MD
Richard Major, ACNW, Rockville, MD
W. D. Barnard, NWTRB, Arlington, VA
W. C. Patrick, CNWRA, San Antonio, TX
B. J. Garrick, ACNW, Rockville, MD
R. R. Loux, State of Nevada, Carson City, NV
D. A. Bechtel, Clark County, Las Vegas, NV
L. W. Bradshaw, Nye County, Pahrump, NV

cc w/o encl:
Ivan Itkin, DOE/HQ (RW-1) FORS
L. H. Barrett, DOE/HQ (RW-2) FORS
A. B. Brownstein, DOE/HQ (RW-52) FORS
N. H. Slater, DOE/HQ (RW-52) FORS
R. A. Milner, DOE/HQ (RW-2) FORS
John Meder, State of Nevada, Carson City, NV
Michael King, Inyo County, Edmonds, WA
J. N. Bailey, M&O, Las Vegas, NV
J. H. Smyder, Naval Reactors, Las Vegas, NV
M. K. Cline, MTS, Las Vegas, NV
J. R. Dyer, DOE/YMSCO, Las Vegas, NV
D. G. Horton, DOE/YMSCO, Las Vegas, NV
Stephan Brocoum, DOE/YMSCO, Las Vegas, NV

EVALUATION OF PROCESS MODELS FOR THEIR REPRESENTATION OF POSTCLOSURE REPOSITORY PERFORMANCE

Introduction

This report summarizes an independent assessment of the consistency of process models with the YMSCO direction to the performing organization (DOE FY00 Planning Guidance (May 1999); Project Operations Review Board (PORB) Position Papers 00216-03, 03A, and 03B; and Technical Direction letter (Dyer to Bailey) of July 19, 2000). The objective of this activity is to complete a preliminary qualitative evaluation of how realistic the process models and model abstractions are in their representation of features, events, and processes related to repository performance. Selected model components (parameters and assumptions) were evaluated for the character of their representation (representative, conservative, or optimistic), importance to the process model, significance to repository performance, and difficulty in modifying the abstractions. The results of this task are used as input to the Phase I: Unquantified Uncertainties Activity initiated in September 2000 and approved by the PORB (October 4, 2000). It is anticipated that the results of this model representation activity will continue to be modified and refined as the uncertainty activities continue.

Summary of DOE Direction on Development of Process Models and TSPA-SR

Process models used in the evaluation of postclosure performance should, to the extent practicable, reflect a credible representation of the total system, and the natural and engineered subsystems of the total system. The reasonably expected (defined as the mean value of a probabilistic distribution) behavior of the total system and the different barriers contributing to performance should reflect the uncertainty associated with the representation of long-term performance. This approach is consistent with the regulatory framework and applicable to both the site suitability evaluation for site recommendation (SR) and the evaluation of performance to be presented in the license application (LA). Any other approach will tend to underestimate (or overestimate) repository performance, limit the ability to understand and demonstrate the relative contributions of each barrier to the total system, and reduce flexibility in the regulatory environment.

Regulatory Perspective

The Nuclear Regulatory Commission (NRC) has stated in its proposed repository licensing criteria (10 CFR Part 63) that DOE's performance assessment model should reflect a credible representation of a geologic repository and that complete assurance that the postclosure performance objective can be met is not expected (see Attachment A). The NRC further defines its postclosure performance objective in terms of the "expected annual dose" based on a credible representation of the system. The Advisory Committee on Nuclear Waste (ACNW) is of the opinion that conservatism should be applied only in evaluating the results of Total System Performance Assessment (TSPA), and that the models making up the TSPA should be as realistic as possible. The Environmental Protection Agency (EPA) has indicated in its proposed performance standard for Yucca

Mountain (40 CFR Part 197) that “reasonable expectation” can be achieved, not absolute proof. NRC and EPA statements that establish their regulatory framework and provide guidance for modeling expected performance are presented in Attachment A. This Attachment also addresses suggested appropriate use of conservative values and bounding conditions.

Approach to Evaluating Representation of Process Models and TSPA-SR

The overall approach to this evaluation of conservatism was initially developed in a workshop at Lawrence Berkeley Laboratory in May 2000, to address realistic model components in the unsaturated and saturated flow models. DOE staff and managers, principal investigators, and performance assessment (PA) analysts met for two days to identify and evaluate model components significant to the unsaturated and saturated zone flow models. At the request of DOE, the MTS Team advanced this evaluation to consider all the process models making up the TSPA-SR.

The MTS team performing this activity consisted of the Process Model Report (PMR) and Analysis and Modeling Report (AMR) review leads, PA team members, technical managers, and regulatory team representatives. The evaluations were qualitative in nature. The Team collectively selected 87 model components that were considered to be 1) important to the make up of the process models and 2) potentially significant (specific influence on the PA results) to repository performance including peak dose. The basis for this selection of model components and their subsequent evaluations was the Team’s knowledge of PMRs and AMRs, contents of the TSPA-SR, the design elements, and the testing program. The model components that were selected are listed in Attachment B. These model components were evaluated for their representation of features, events and processes associated with TSPA for a potential repository at Yucca Mountain, and to assess if there was available information that could be considered in any additional near term evaluations to better reflect a more realistic representation of behavior. Attachment C is the database for these qualitative analyses. It provides the detail of the analyses and includes:

- Rationale for selecting the levels of how representative the model components are of features, events, and processes of a potential repository at Yucca Mountain.
- Evaluation of model component importance to repository performance for the regulatory time-frame (10,000 years) and peak dose
- Availability of existing information not previously considered in the development of the process model or its components
- Assessment of the schedule for modifying the model components considering specific time frames leading to major program milestones and availability of additional information

The 87 model components were comparatively evaluated for importance; therefore, the designations of “high”, “medium”, or “low” should be considered relative to the selected group of model components specific to the process models they make up. Attachment B summarizes these evaluations and Attachment C provides the detail. To focus on those model components most important to the process models and repository performance those components ranked “low” for importance were given no further consideration.

Evaluation Results

The overall evaluation suggests that a limited number of model components of the process models are optimistic, a few are either very conservative or representative, and most are conservative in their representation of features, events, and processes significant to a potential repository at Yucca Mountain (see Attachment B). The amount of conservative model components within each process model makes quantifying the overall assessment of how representative the results of TSPA are very difficult. Preliminary TSPA results indicates that the repository performance within the regulatory time frame is dominated by the long lasting waste package concept. Taking this into consideration, those model components of each process model that were judged to be most significant to the process models and most important to long term repository performance are addressed in the following subsections.

Biosphere Model Components

The level of conservatism embedded in the parameters making up the biosphere models is primarily driven by regulatory requirements. None of the parameters were considered to be overly conservative or given a “high” assignment of importance. Some conservatism has been built into the Biosphere model, GENII-S, although the sum total is not considered to significantly impact the biosphere dose conversion factors. The conservatism attributed to the prescriptive nature of the proposed regulations include parameters such as:

- Prescribing 100 percent of the local groundwater available in the hypothetical farming community as contaminated
- Defining the critical group as those individuals residing within a farming community and exhibiting behaviors or characteristics that will result in the highest expected annual dose

Disruptive Events Model Components

Igneous Activity – Two conceptual models for disruptive events 1) Volcanic Eruption (extrusion) Model and 2) Igneous Intrusion Model comprise the igneous activity scenario. The Analysis and Model Report for igneous consequence modeling for the TSPA-SR describes two criteria that are used to evaluate the validity of the conceptual models. One criterion states that a conceptual model is valid if it is shown to be conservative with respect to the overall performance of the system in response to igneous disruption.

Depending how the disruptive igneous event is treated in TSPA for the regulatory timeframe, the consequences of potentially conservative modeling assumptions could be significant. Since the annual probability of igneous activity is on the order of one in a million to one in ten million, estimates of mean annual consequences are inherently different than for nominal case estimates. The following model components could negatively impact repository performance particularly for the volcanic eruption model; therefore, it is important that this disruptive event be treated separately from the nominal case for TSPA.

- Ability of future igneous activity to occur independent of structural controls
- Wind direction fixed to the south toward the critical group
- All volcanic eruptions are violent strombolian for their entire duration

While the concept of violent strombolian for the duration of the eruption is conservative compared to observations in the region, large volume ash plumes may dilute the concentration of radionuclides; therefore the assumption could be optimistic in how it is treated in TSPA.

Seismic Activity – The near-surface (i.e., approximately first 1 km of the crust) attenuation of ground motion is expressed by the parameter kappa. The average value of kappa for sites at the surface of Yucca Mountain was previously estimated based on small to moderate magnitude aftershocks of the Little Skull Mountain earthquake of June 1992. The original analyses considered data from 12 sites, only two of which are located on tuff in the immediate YM area. More recent analyses have indicated that the earlier estimate of kappa is probably too small, which results in higher levels of ground motion (acceleration and velocity) predicted at the surface and potential repository level and would result in conservative seismic design inputs and an over design for surface facilities.

Kappa also directly affects the seismic hazard curve that is used in failure analyses of key underground and waste package components (i.e., spent nuclear fuel cladding). As demonstrated in the TSPA-SR, clad failure caused by seismic ground motion is an important contributor to peak dose as currently modeled. While a consensus on the magnitude of a possible change to the kappa value used in the determination of the probabilistic seismic hazard has not been reached, it does appear that the mean kappa value may increase which would lower the hazard. Incorporating a lower seismic hazard curve in clad failure modeling could lower the peak dose estimate.

Engineered Barrier System Model Components

Distribution of Seepage in the drift - Water seeping into the drift is assumed to (a) all get onto the drip shield and (b) be able to get into and through any existing breach in the drip shield. Each of these assumptions provides about a factor of 2 conservatism because (a) the drip shield projected area is about half the drift width and (b) any existing breach in

the drip shield would occur on one side or the other of the drip shield for some period of time. The first aspect should be fairly constant, whereas the latter aspect would change with time as the drip shield incurred further breaches. However, the latter aspect also ignores the extent of the drip shield breaches, which should be much less than the length of the drip shield itself. The importance to peak dose is diminished by the relatively small percentage of packages/drip shields that actually get Seepage flux (about 10%); however, peak dose could increase significantly (three times (3X)) for long term climate (after a few thousand years) in TSPA.

Diffusion inside the Waste Package – There is no model for diffusion inside the waste package to limit the release rate in the absence of advective flow; therefore the assumption is that release is instantaneous. There is no data and no conceptual model developed for this process; however, if this could be modeled it could potentially have a high impact on reducing peak dose.

Evaporation of Water from the Waste Package - Preliminary calculations suggest that there is potentially enough decay heat produced by the spent fuel in the first 10,000 years to evaporate all of the water that could drip into a waste package based on current climate without flow focusing. If this could be demonstrated it could act as an effective “drip shield” and provide defense in depth as another barrier, thus supporting arguments for potential removal of the drip shield from the design.

Near Field Environment Model Components

The identified conservative or optimistic model components of this process model are assessed to not have large potential for impacting the resulting overall performance of the system given the current TSPA models. This is in part due to the level of conservatism/optimism represented by these, as well as due to the nature of the other subsystem models that would use the information generated from these models.

Use of Pore-Water Chloride – Measured values derived from the Topopah Spring welded tuff (TSw) pore waters are used as estimates for the boundary fracture water composition in the coupled thermal-hydrologic-chemical (THC) seepage model. This THC seepage model provides the boundary conditions for gas and water compositions entering the potential drifts. This water composition appears to be an end member and bound the chloride concentration (by about a factor of 2 to 3); however, it serves to provide a somewhat conservative constraint on the chloride content of fluids that are concentrated by evaporation in the drift. The importance of the conservatism depends on the response of conversion models to chloride concentration. Currently these models are insensitive to chloride concentration until very high values of chloride. Additional water compositions are being evaluated and their relevance will be assessed relative to how well they can be used to represent the ambient site geochemistry. These additional compositions could be used to decrease this somewhat conservative chloride concentration.

Thermally Perturbed Seepage Model – This model combines the ambient seepage model with the thermally perturbed percolation flux at 5 m above the drift as generated in the multi-scale thermo-hydrology model (MSTHM). The conservatism results from the

coupling of two models (the ambient seepage model and the MSTHM) for use in the TSPA and the lack of fracture heterogeneity in the MSTHM representation. It is not currently demonstrated that heterogeneity in the geologic system will not lead to cases of seepage even during the thermal period. Therefore, the results of such homogeneous TH models (which indicate fracture dry out at the drift wall) are not used directly to drive the seepage model during the thermal period. This is somewhat conservative and should not have major impacts to dose consequences for two reasons. First, the effect is transient such that any discrepancy between fracture saturation at the drift wall versus 5 meters away decays as the peak thermal pulse decays. Any difference is gone after a few hundred (to about one thousand) years. Second, this enhanced seepage applies only for about 10 to 20% of the waste package locations. The localized, transient nature of this model component decreases its capacity to have a major impact to the performance of the system. Additional analyses are being performed to incorporate the relevant scale of fracture heterogeneity into the thermal-hydrologic models. These analyses will be used to assess how much more realistic the thermal seepage model could be made within the SR to LA time frame.

THC Effects - There appear to be no lasting THC effects for the fracture permeability distribution in the system. This model component is neither conservative nor optimistic in contributing to performance given the large range of uncertainty; however, the values selected are at the optimistic end of the range. Based on the current THC model, this is the representative result. However, further THC sensitivity analyses will provide additional results that may indicate some changes to permeability. Because of the large changes needed to decrease the fracture permeability and the large margin (in terms of fluid flux capacity) in the permeability of the geologic system, this is not expected to have a major impact on the release of radionuclides to the accessible environment.

THC Alteration - Currently, there is no modeled THC alteration of the zeolitic units below the repository based on the thermal perturbation of the repository. Alteration of zeolites would release additional water and decrease the sorption path length. Not including such effects provides a somewhat optimistic view of the evolving unsaturated flow and transport pathway. However, for the current design this is expected to be a minor impact because of the temporal and spatial extent of the heating of the zeolitic zones. Duration of heating of zeolitic units will be relatively short and only a small part of the upper portion of the units will be affected above the lower temperature limit for such conversions. In addition, such alteration has been shown to be endothermic (requires heat) and therefore should result in even less propagation of the limiting temperature into the zeolitic zone. Therefore, this is not expected to lead to significant change to radionuclide transport, but ignoring any changes is somewhat optimistic. Analyses to assess the path lengths affected and the degree to which they are altered are being performed to quantify this within the SR to LA timeframe.

Unsaturated and Saturated Zone Model Components

Unsaturated zone (UZ) and saturated zone (SZ) groundwater flow had not been identified as principal factors in the Viability Assessment; hence the model components were developed using bounding rather than realistic parameters. The use of these bounding values resulted in groundwater travel times and the amount of water flowing through the UZ and SZ are perceived to be very conservative and considered by many Project participants (PIs) to not be defensible. The model components identified in this report are principally the result of principal investigator and DOE staff workshops held in May of 2000. In some cases actions have been taken by the Project to address those model components to develop a more realistic representation of UZ and SZ behavior (CR-M&O-00-084, "revise Project Baseline Work Scope for Development of an Expected Case Model for UZ and SZ Transport Behavior").

The list below contains the conservative conditions that affect TSPA as developed by the workshops. Of particular note are the flow and transport properties of faults and fractures in the Calico Hills non-welded (CHn) unit. The project's conceptual model of flow and transport views the hydrology in this unit as matrix-dominated leading to slow travel times and enhanced geochemical interaction with the rock mass. Lack of detailed understanding concerning the degree of fracturing led to the conservative position that this unit be considered fractured, which greatly increased the groundwater flow velocity through the unit. Similar conservatism was used for faults and fault properties especially in the CHn.

The following prioritized list summarizes the parameters for the unsaturated zone (UZ) that are conservatively applied in the respective process models. These parameters are predominately used in groundwater travel time calculations and will be re-evaluated for the expected case scenario. The expected case scenario is defined as a representation of the combined natural and engineered system that is judged to reflect the reasonably expected behavior of the system and its components. The list for the SZ is prioritized by the parameters that would affect the TSPA calculations the most if the uncertainty in each were reduced accordingly. Consideration of representative parameters would increase transport time and would push peak dose out in time. The UZ parameters are:

- Fracture flow in the Calico Hills nonwelded vitric tuff unit
- Different flow and transport computational methods
- Perched water models and lateral diversion
- Fault properties in the Calico Hills
- Synthesis of geochemical information
- Spatial distribution of infiltration and percolation
- Effects of drift degradation on drift seepage
- Effects of flow focusing on drift seepage
- Effects of episodic flow on drift seepage
- Gridding methods for the dual-permeability model

A similar list of model components was drawn up for the saturated zone models. The workshops were held prior to the reviews of the SZ PMR and subsequent reviews identified an additional conservatism that strongly affects groundwater travel times. The current SZ model consists of Monte Carlo simulations where the properties that are randomly sampled from distributions are assigned homogeneously to each layer. A more defensible approach would involve assigning properties heterogeneously to elements within each layer. When properties are assigned heterogeneously to each layer realization that produces a set of values that are all on the high or low side of mean porosity will result in an extreme high or low travel time. Consequently, individual realizations in the SZ model vary from a few years to several thousand years for breakthrough. This potentially non-representative approach does not likely affect the median travel times, but it does create extremes of high or low rates. In addition to this consideration the following model components were identified by the PI workshops for creating more realistic models. The SZ parameters are:

- Uncertainty distribution for specific discharge (groundwater flux).
- Effective diffusion coefficient.
- Implementation in the SZ flow and transport model;
 - conceptual model of colloid filtration,
 - Kc model parameter for colloid-facilitated transport,
 - only fracture flow in volcanic units (no matrix flow), and
 - no sorption in fractures.
- Uncertainty in the northern and western boundary of the alluvium.
- Sorption coefficients in the alluvium and volcanic units.
- Flowing interval porosity and spacing.

Waste Form Model Components

Secondary Phase or Recurring Conditions - The abstracted CSNF (commercial spent nuclear fuel) dissolution model was based on a large set of qualified flow-through experiments. This model was compared to unsaturated drip tests, batch tests, and a range of literature results. The model and uncertainty range adequately accounted for, or overestimated, all dissolution rate data. In addition, a comparison of the phases produced in the unsaturated drip tests compare well with that of natural analogs (from WF PMR, Section 3.3.2).

Fast rates are used to bound the upper end of uncertainties. Secondary phases were excluded because experimental results were inconclusive with regard to effect of such phases on degradation mechanisms. The PA Peer Review Panel (Budnitz et al. 1999) conservative approach since secondary phases would retard radionuclide release from CSNF that in turn may reduce peak dose.

Waste Form Solubility – Considerable discussion has focused on Np-bearing phase(s) that could form under repository conditions. Thermodynamically, NpO₂ is the stable phase. However, it has not been observed in solubility experiments, except for some unusual conditions. It is believed that a kinetic barrier prevents NpO₂ from precipitating.

Analysis of the stability field for Np(V) solid phases concluded that Np_2O_5 is the solubility controlling phase in J-13 well water (From Summary of Dissolved Concentration Limits AMR, Section 6.4.2). Using high Np solubility bounds uncertainties and is conservative, since using a low solubility value (if shown to be the case) will retard Np release and hence, may reduce peak dose. The present approach resulted from analyses of the currently available data on Np-bearing phases and solubility. Further analyses would be required to reduce conservatism in this bounding approach.

Waste Form Colloids - The abstractions are based on laboratory results from waste form corrosion testing and testing of adsorption and de-sorption properties of Pu and Am on clay and iron-(hydr)oxide colloids. To the extent that the laboratory tests and test conditions represent anticipated repository conditions, the abstraction is valid for calculating the colloid-associated radionuclide concentrations and colloid mass concentrations. The approach for the colloidal-radionuclide source term is based on YM-specific field and laboratory studies and results from YM-relevant studies.

The colloids formed from CSNF and DSNF are assumed to have reversibly attached radionuclides; and this assumption is potentially non-conservative and remains to be verified when results from on-going tests become available (Section 3.8.2.2 of the WF PMR).

Cladding fragility - The basis for matrix exposure analysis are measurements of gap inventories, experimental measurements of the release of radionuclides from damaged cladding, and intrinsic dissolution measurements. Although unzipping has not been observed for rods in storage pools for the past 40 years, the unzipping analysis is consistent with dry unzipping experiments. Uncertainties have been defined that are based on both experiments and extremes in the analysis. Therefore, this analysis is appropriate for TSPA-SR. Although it is conservative, it is not as conservative as the assumption of instantaneous unzipping to expose the CSNF that was used in TSPA -VA (From WF PMR, Section 3.4.2.7).

Seismic clad failure estimates include conservative inputs in order to simplify the analysis. Recent peak dose estimates (post 10,000 years) indicate that clad failure from strong ground motions is a significant contributor (about 25%) in determining peak dose. Reduction in clad failure estimates could significantly reduce peak dose estimates.

Waste Package Model Components

The waste package degradation process model components are based on limited testing and our basic understanding of material engineering; however, no information (analogs) exists on the performance of engineered materials for the necessary time frames of performance. In addition, no non-mechanistic, pre-specified number of waste package early breaches were included in the SR base case models (TSPA-SR does include a non-mechanistic waste package early breach as a sensitivity study). Projecting the performance of engineered materials for thousands of years is unprecedented; therefore,

considerable uncertainty may exist in this model. The following are model components identified as conservative in this process model.

Waste Package Materials - The level of conservatism in the model components making up the Waste Package Degradation models is primarily used to bound uncertainties in degradation phenomena. None of the parameters were considered to be overly conservative or given a "high" assignment of importance. Reducing conservatism in these parameters would increase the expected life of the waste package.

The waste package model components were generally judged as conservative by the MTS Team members; however, it is conceivable that the performance projections are less conservative than suggested. The evaluation concluded that considerable uncertainty may exist in waste package performance with the unprecedented projections of long-term performance and limited available information. Non-mechanistic juvenile failure was not explicitly considered in TSPA and therefore is not evaluated as a model component in this report. While it is assumed that waste packages may have manufacturing defects and may be damaged during emplacement and operations; however, there is no mechanism for failure. The inability to identify juvenile failure may lead to optimistic projections of waste package performance.

Conclusions

Many of the model components making up the process models and expected to be significant to repository performance are conservative. The selection of conservative representations appears to have been driven by uncertainty in the amount of relevant data, data analyses and modeling results.

The use of conservatism in the process models appears to be compounded in the model abstractions and TSPA-SR. This may lead to system model results that are unrealistically conservative (i.e., the model significantly underestimates performance). The most significant impact to the process models and TSPA are summarized below.

- TSPA-SR results may mask performance sensitivities and the relative importance of identified uncertainties with compounded conservatism. Such a lack of sensitivity may result in model components or features, events, and processes being characterized as not important to waste isolation.
- Lack of quantifiable model component uncertainties contributes to the inability to clearly understand how representative TSPA results are. This could have a significant impact on the ability to demonstrate the existence and contributions of multiple engineered and natural barriers to overall system performance.

- Ability to move to more conservative model components may not be possible during the regulatory process if the DOE adopts overly conservative models going into LA. Regardless of the level of conservatism adopted by the DOE, the NRC will have a different perspective and may lead to the DOE going to greater levels of conservatism.
- Compounded conservatism or overly conservative performance assessments may lead to the perception among external parties that the natural and engineered systems are not sufficiently understood to accurately represent repository performance.
- Some of the model components were identified as having a potentially significant affect on long term performance (peak dose). In addition, some model components of the Disruptive Events Process Model were identified as affecting dose in the regulatory time frame. Reduction in the conservative representation of these model components could positively enhance long term performance in time and magnitude, and further reduce dose in the igneous disruptive event scenario. Those model components that may affect long term performance are summarized as follows:
 - Assumption that all seepage begins at the crown of the drift is conservative and should be reassessed – modify for LA by December 2002
 - All waste is wetted from any seepage into the waste package is very conservative; however there are not planned activities to address this – identify work and address by LA in December 2002
 - Determine secondary phases for waste form – analyses can be completed by December 2002 for LA.
 - Re-evaluate data to determine more representative values for Np and other radionuclide solubilities – analyses can be complete by December 2000.
 - Determine more reasonable waste form colloid conditions (high sorption coefficients and irreversibility) – analyses can be completed by December 2002.
 - Re-evaluate seismic clad failure estimates using more representative system modeling – analyses can be completed by April 2001 for inclusion in TSPA for SR.

Model components of the igneous disruptive events scenario that most significantly impact dose are summarized as follows:

- Large eruptive volume may result in dilution of radionuclide concentration is optimistic assumption in terms of dose – re-evaluate models to remove optimism by December 2000
- Waste packages next to dike fail completely is somewhat conservative – there are no plans to modify this assumption

- Centering the eruptive scenario on the drift is conservative – reconsider more random distribution by December 2000
- Fixed wind direction to compensate for surface redistribution may be conservative, but is an indirect way of addressing contaminated soil redistribution – consider better definition of these scenarios by SR in April 2001.

The evaluation also identified optimism in some model components. These model components should be carefully re-evaluated and a more representative condition may want to be considered. The optimistic model components identified in this assessment are listed below.

- Volcanic disruptive event ash plume height, dispersion speed, and potential for higher dose to critical group – re-evaluate this by December 2000.
- No alteration of the zeolites under the thermal pulse is of low importance; therefore, no further consideration is necessary.
- No lasting changes to the fracture permeability in the UZ, due to coupled THC, is an optimistic assumption, but there are no plans to re-evaluate.
- Higher infiltration rates and episodic infiltration for extreme climate conditions should be considered – modify assumptions for December 2000.
- Although not explicitly addressed in this evaluation, it is conceivable that waste package performance projections may be less conservative than currently estimated because of the absence of juvenile failure mechanisms – explore mechanisms for juvenile failure by LA in 2002.

Recommendations

The approach to PA modeling to demonstrate compliance with the postclosure criteria for site suitability and licensing should consider the NRC's and EPA's positions (Attachment A) that TSPA should, to the extent possible, include a "credible representation" of the geologic repository system with "representative parameter distributions."

Models used to evaluate compliance with regulatory requirements for repository system performance after closure should reflect a credible representation of the natural and engineered system unless the uncertainty is so great that only a conservative representation can be made. In such a case the uncertainty should to the extent possible be quantified. This approach should be followed for both the postclosure site suitability evaluation performed for SR and the postclosure compliance evaluation presented in the LA. To the extent possible, the goal should be to present the most representative analysis of system performance that is permitted by the data that are available and the models that are consistent with and supported by these data and a quantified assessment of associated uncertainties.

The levels of conservatism associated with the component models most significant to long term performance should be reassessed in an attempt to achieve more realistic representations. Those model components recognized as optimistic should also be considered in any reassessment of their representation. Serious consideration should be given to explicitly considering juvenile failure of waste packages in TSPA. This should include a review of the current work activities and available information related to these model components. This assessment suggests that many of the model components can be addressed prior to LA and in some cases prior to SR.

The results of this report should form the basis for the follow on task to address unquantified uncertainties. The identification of model components important to the make up of the process models and repository performance should be given further consideration as candidates for the analysis of unquantified uncertainties, particularly those assessed as having high importance and conservative.

Work Prioritization Tables for Conservative Process Model Parameters

Importance to Repository Performance:

1. High
2. Medium
3. Low

PD – Important to peak dose

RMD – Important to regulatory time frame maximum dose

* - Currently being re-evaluated as part of representative case

Ability to Modify Model Based on Availability of Needed Information

- A. Choose – Data and analysis exist
- B. Analyze – Data exists, needs re-analysis
- C. Collect – Data being collected, needs analysis
- D. Plan Analyses – Data analyses need to be planned
- E. Plan Tests – Needs to be executed or planned for data collection
- F. Regulatory Requirements - Constrained by regulatory requirement

Availability of Results (Schedule)

- I. By DOE/HQ review of the SRCR (September 30, 2000)
- II. By release of the SRCR (Dec., '00)
- III. By HQ review of the SR (April, '01)
- IV. For input into the LA (Oct.-Dec., '02)
- V. Can't be done

PMR and Assumption or Parameter	Level	Import.	Ability to Mod.	Results
Biosphere				
Disruptive Volcanic Event Scenario assumes that volcanic eruption would result in a thin ash deposition on surface	Representative	L	-	-
Drinking Water Treatment and Holdup Time	Representative	L	-	-
Depth of Surface Soil	Representative	L	-	-
Population-Statistics	Representative	L	-	-
Annual Groundwater Usage	Representative	M	F	V
Site Specific Data vs. Literature Findings	Representative	L	-	-
RMEI vs. Average Member of the Critical Group	Somewhat Conservative	L	-	-
Fraction of Water that is Contaminated	Conservative	M	F	V
GENII-S Code and Input Parameters	Conservative	L	-	-
Dose Conversion Factors (DCF's) for Internal Exposure	Conservative	M	F	V
The Disruptive Volcanic Event Scenario	Optimistic	L	-	-

Disruptive Events				
Ash particle distribution used in TSPA	Representative	M	D	V
Assumed that only those waste packages located partially or entirely within the area of the eruptive conduit contribute to the radionuclide source term for the dispersal calculation	Representative	M	D	V
Intrusions that come within 300m of the surface are assumed to erupt somewhere along the length of the dike	Representative	M	-	-
Igneous Event Probabilities – Assumption that the event probabilities established in the AMR Char Igneous Activity pertain to the formation of a new volcano	Representative	H	-	-
Intrusive scenario – Any waste packages, drip shields, and other components of the EBS that are adjacent to an intrusive dike (3 packages on either side) fail completely	Somewhat Conservative	M(RMD)	B	V
Possible structural control (fault capture) and lateral diversion of ascending basaltic dikes from the repository block is not considered. Lack of detailed information on near-surface structural features	Somewhat Conservative	M	B	IV
Wind direction fixed in base case toward the critical group. While this assumption overestimates the dose, it is intended to compensate for surface redistribution processes not explicitly accounted for in TSPA. The representativeness of this assumption depends on how it treats surface redistribution.	Conservative	H(RMD)	A	II
Extrusive eruptive conduits that partially intersect drifts are assumed to be centered on the drifts. This mathematical simplification results in affecting more waste packages	Conservative	M(RMD)	B	II
All eruptions are violent strombolian for their entire duration (dependent on eruptive volume) with fragmentation of the ascending magma occurring below the repository horizon.	Conservative	M	B	III
Seismic Kappa – near surface attenuation parameter assigned a relatively conservative value based on limited data	Conservative	M	B & C	III
All waste is assumed to be unaltered commercial spent fuel for the purpose of estimating waste particle diameters in the eruptive environment. Reduced to small grain sizes.	Conservative	L	-	-
Erupted volume is assumed based on a combination of YM and very large modern volcanoes.	Eruption – Very Conservative	H(RMD)	A	III
Sensitivity analyses to date indicate that the inclusion of very large eruptive volumes may in fact lower the mean dose. More definitive results depend on incorporation of higher altitude wind data corresponding to heights of ash plumes associated with the larger volume eruptions.	Calculated Dose – Somewhat Optimistic	M(RMD)	A	II

EBS				
Invert diffusion – Uses a curve fit through the data and uncertainty, with a conservative adjustment of 30% to the mean of that fit for D as a function of porosity and saturation in the invert	Representative	H (PD)	A	I
Thermal expansion, floor heave, rock fall, seismic response, and emplacement pallet failure screened out	Representative	L	-	-
Sorption in WP and invert ignored	Somewhat Conservative	L	-	-
Diffusion in WP – Starts when Stress Corrosion Cracking exists because of assumed liquid pathway	Somewhat Conservative	L	-	-
Seepage in Drift – All seepage assumed to start at the crown of drift or drip shield so it all falls on drip shield or WP and has greatest probability of entering a hole	Somewhat Conservative	L (PD)	-	-
EBS Diffusion – Pallet is ignored and waste package is in intimate contact with invert	Somewhat Conservative	L	-	-
All mass moved to inner surface of WP – All mass is contacted by any seepage flux into the WP	Very Conservative	H (PD)	D	V
Evaporation of water from WP is neglected	Very Conservative	H	D	III
Near Field				
Seepage – No dryout during ventilation period and no dryout during thermal period (input to seepage model is 5 meters above the drift)	Somewhat Conservative	M	B & C	IV
Use of the pore-water CL-composition to represent the infiltration water provides an upper bound to the starting chloride concentration of ambient fluids moving potentially through the fractures	Somewhat Conservative	L	-	-
No alteration of zeolitic units under the repository calculated based on the thermal perturbation	Somewhat Optimistic	L (PD)	-	-
No lasting changes to the fracture permeability in the UZ due to coupled THC processes	Somewhat Optimistic	M	A-D	V
SZ – From May 11-12, 2000 Assessments at LBL				
Specific Discharge (Groundwater Flux)	Conservative	H*	C	II
Effective Diffusion Coefficient	Conservative	M	A	II
Sorption Coefficients for Alluvium	Conservative	H	C	IV
Flowing Interval Porosity (Fracture Porosity)	Conservative	H*	A & B	II
Conceptual Model of Colloid Filtration	Conservative	M	D	IV
Kc Model Parameters for Colloid-Facilitated Transport	Conservative	M	D	IV
Sorption Coefficients for Volcanic Units	Very Conservative	L	-	-
Homogeneous properties of hydrologic units used in Monte Carlo simulations	Very Conservative	H	B	II
Flowing Interval Spacing	Very Conservative	M*	B	IV

SZ - From May 11-12, 2000 Assessments at LBL				
Western boundary of Alluvial Uncertainty Zone. Short Term Long Term	Very Conservative	H*	C	II
Northern Boundary of the Alluvial Uncertainty Zone	Very Conservative	H*	A	II
No Sorption in Fractures	Very Conservative	L	-	-
Only Fracture Flow in Volcanic Units (no matrix flow)	Very Conservative	L	-	-
UZ - From May 11-12, 2000 Assessments at LBL				
Fracture porosity set to about 1%	Representative	-	-	-
Thermo-mechanical effects on seepage neglected	Somewhat Conservative	L	-	-
Thermal effects on Flow/transport are neglected	Somewhat Conservative	M	B & C	IV
Coupled process effects on flow/transport are neglected	Conservative	H*	B & C	II
Thermal effects on flow properties are neglected	Conservative	M	B	IV
Fracture-matrix interaction (and fracture velocities) determined by active fracture model	Conservative	H*	B	II
Broad Uncertainty and variability distributions used for K/alpha parameter	Conservative	M	B	II
Diversion of flow and transport around the perched water rather than through it might be conservative	Conservative	H*	B	II
Broad Uncertainty distributions used for flow-focusing factor	Conservative	H*	B	II
Colloid concentration and Kd's used to calculate Kc	Conservative	M	E	IV
FEHM particle-tracking method appears to be conservative compared to the DCPT or T2R3D methods	Conservative	H*	B	II
Seepage into drift specified seepage abstraction when drift wall is above boiling	Conservative	H*	B & C	II
All seepage into drift is counted (not just seepage above waste package) Consider allowance for film flow in drifts	Conservative	H*	B	II
Mountain scale TMH	Conservative	M	B & C	IV
Physical colloid filtration is neglected in most situations; in particular it is always neglected for transport in fractures	Conservative	M	E	IV
All host units treated the same in seepage abstraction	Conservative	H*	C	IV
Rc is neglected for reversible colloids in the SZ and for all colloids in the UZ	Conservative	M	E	III
Uncertainty distributions for Diffusion coefficient are higher in UZ than SZ	Conservative	M	B	III
Lithophysal porosity	Conservative	H	C	IV
All nuclides introduced into fractures	Conservative	M	A	I
Seep flux increased by 10% to account for possible correlation of k and alpha	Conservative	L	-	-
Thermal effect on Kd	Conservative	M	B	III
Single grid matrix	Conservative	H*	B & C	II
Fault Properties in CHn	Conservative	H*	E	IV

UZ – From May 11-12, 2000 Assessments at LBL-Cont.				
Flow models may have a significant amount of Fracture flow through the CHnv unit	Very Conservative	H*	B & C	II
Episodic flow/seepage neglected	Somewhat Optimistic	H	B	I
High Infiltration case should be higher	Optimistic	H*	B	II
Waste Form				
Colloid stability	Representative	M	-	-
DSNF degradation: No cladding credit is assumed, and characteristics of N-reactor fuel are assumed (dissolution occurs in one time step of TSPA) Cladding is not as robust or thick as that for CSNF	Representative	L	-	-
Local corrosion and unzipping of cladding are assumed to occur.	Conservative	M	E	V
HLW degradation: Fast degradation rates are assumed	Conservative	L	-	-
Waste form solubility: High Np solubility assumed to be controlled by Np205.	Conservative	H (PD)	B & C	II
Waste form colloids: High sorption coefficients are used and some colloids assumed to be highly irreversible	Conservative	M (PD)	C	IV
No secondary phases are assumed for CSNF degradation, which results in a fast degradation rate	Conservative	M (PD)	C	IV
Clad failure due to low probability seismic event contributes significantly to peak dose calculation	Very Conservative	H(PD)	B & C	III
Waste Package				
To address the effects of microbiological induced corrosion (MIC), an enhancement factor of 2.0 is applied to the corrosion rate of the waste package	Representative	L	-	-
Welded regions of the waste package are assumed to be 100% aged, and as a result, an enhancement factor of 2.5 is applied to the corrosion rate	Representative	L	-	-
Drift assumed to be wet at 50% relative humidity. This controls the chemical composition of water reacting with waste form	Somewhat Conservative	L	-	-
Environments for general/local corrosion and SCC tests are aggressive, yet plausible under repository conditions	Conservative	L	-	-
No credit is taken for crack initiation in stress corrosion cracking (SCC) modeling	Conservative	L	-	-

REGULATORY STATEMENTS AND APPROPRIATE USE OF CONSERVATIVE REPRESENTATIONS

Statements from NRC and EPA Documents Establishing the Framework and Providing Guidance for Performance Assessment Models

The Nuclear Regulatory Commission (NRC) stated its expectation for the DOE's performance assessment model in the Supplementary Information for its proposed repository licensing criteria at 10 CFR Part 63 (64 FR 8651):

“To the extent that DOE's performance assessment provides a credible representation of a geologic repository, the Commission expects no more than that and believes that no more is needed.”

The NRC describes its regulatory approach to decision-making in section 63.101 of its proposed rule (64 FR 8674):

Although the performance objective for the geologic repository after permanent closure . . . is generally stated in unqualified terms, it is not expected that complete assurance that the requirement will be met can be presented. A reasonable assurance, on the basis of the record before the Commission, that the performance objective will be met is the general standard that is required. Proof that the geologic repository will be in conformance with the objective for postclosure performance is not to be had in the ordinary sense of the word because of the uncertainties inherent in the understanding of the evolution of the geologic setting, biosphere, and engineered barrier system. For such long-term performance, what is required is reasonable assurance, making allowance for the time period, hazards, and uncertainties involved, that the outcome will be in conformance with the objective for postclosure performance of the geologic repository. Demonstrating compliance will involve the use of complex predictive models that are supported by limited data from field and laboratory tests, site-specific monitoring, and natural analog studies that may be supplemented with prevalent expert judgment. Further, in reaching a determination of reasonable assurance, the Commission may supplement numerical analyses with qualitative judgments including, for example, consideration of the degree of diversity among the multiple barriers as a measure of the resiliency of the geologic repository.

The NRC defines its postclosure performance objective in terms of the “expected annual dose,” which is defined as:

... the expected value of the annual dose considering the probability of the occurrence of the events and the uncertainty, or variability, in parameter values used to describe the behavior of the geologic repository. [section 63.2, 64 FR 8664]

In an April 8, 1999 letter to the Commission commenting on the NRC staff review of the DOE’s Viability Assessment (VA), the Advisory Committee on Nuclear Waste (ACNW) made a relevant observation (page 5) about the appropriate place for the application of conservatism in regulating nuclear facilities:

“... the appropriate place for conservatism is in the choice of a probability of exceedence of a risk standard.

“In the case of a PA for a geological repository, we believe that the analysis should be performed with as nearly realistic assumptions, models, and parameters as possible, including the uncertainty involved. The resultant [cumulative probability distribution function for annual dose] derived from the PA would show explicitly the probability that a standard would be exceeded.

“... a licensing decision would not be based exclusively on the probability (i.e., the [proposed] regulation is risk-informed rather than risk-based), but the decision about conservatism is made with the clearest view of the issues after the best information available has been used in an analysis.”

The EPA explains its regulatory approach regarding the basis for determining compliance with the proposed standards:

... we are proposing the concept of “reasonable expectation” to reflect our intent regarding the level of “proof” necessary for NRC to determine whether the projected performance of the Yucca Mountain disposal system complies with the standards We intend for this term to convey our position and intent that unequivocal numerical proof of compliance is neither necessary nor likely to be obtainable. [64 FR 46997]

In carrying out performance assessments under a “reasonable expectation” approach, all parameters that significantly affect performance would be identified and included in the assessments. The distribution of values for these parameters would be made to the limits of confidence possible for the expected conditions in the natural and engineered barriers and the inherent uncertainties involved in estimating those values. Selecting parameter values for quantitative performance assessments would focus upon the full range of defensible and reasonable parameter distributions rather than focusing only upon the tails of the distributions The “reasonable expectation” approach also would not exclude

important parameters from the assessments because they are difficult to quantify to a high degree of confidence. . . . Overestimating or underestimating the values of parameters, or ignoring the positive effects upon performance for other processes and parameters because they cannot be precisely estimated, would essentially result in the performance assessments actually being analyses of extreme performance scenarios. These extreme assessments have a high probability of being unrealistic or of such low probability that they would not represent the range of likely performance for the disposal system. [64 FR 46997-46998]

The proposed EPA standard at 40 CFR part 197 requires the following:

The DOE must demonstrate to NRC that there is a reasonable expectation of compliance with [the environmental standards for disposal] before NRC can issue a license. [section 197.13, 64 FR 47014]

Reasonable expectation means that the Commission is satisfied that compliance will be achieved based upon the full record before it. Reasonable expectation:
(a) Requires less than absolute proof because absolute proof is impossible to attain for disposal due to the uncertainty of projecting long-term performance;

. . . .
(c) Takes into account the inherently greater uncertainties in making long-term projections of the performance of the Yucca Mountain disposal system;

(d) Does not exclude important parameters from assessments and analyses simply because they are difficult to precisely quantify to a high degree of confidence; and

(e) Focuses performance assessments and analyses upon the full range of defensible and reasonable parameter distributions rather than only upon extreme physical situations and parameter values. [section 197.14, 64 FR 47014]

Appropriate Use of Bounding/Conservative Representations for Modeling

If the data are limited, or models cannot otherwise be constrained, a bounding or appropriately conservative approach is likely to provide the only credible representation for modeling the behavior of a particular system component. This approach should be the exception, not the rule in modeling for performance analyses.

If the results and conclusions of the performance analysis are not significantly affected by the use of a bounding/conservative approach in representing a particular system component or process (i.e., performance is insensitive to whether a credible or a conservative representation is used), the use of such an approach could simplify the analysis. However, such simplification should only be applied after there is a clear understanding of the potential contribution of each system component or process independent of the other elements of the system. Such an understanding is necessary

because the potential contribution of one component or process to overall system performance may be masked by the contribution of other components or processes. To identify those components and related processes that individually (or collectively) have the potential to significantly affect performance, each component or process must be modeled using a credible representation and appropriate steps taken to ensure that masking effects are accounted for in the analyses. Only then can appropriate simplifications be introduced in the system model and defensible conclusions about compliance be drawn from the results.

Where data are available and models can be developed based on these data that will provide a credible representation of anticipated/reasonably expected system behavior, conservative/bounding representations should be avoided for the reasons noted above. It is also not appropriate to use conservative/bounding approaches to limit the range of factors considered in the performance assessment model in order to avoid areas of uncertainty or because the factors are difficult to characterize and quantify. A probabilistic analysis, which is required by the regulations for a demonstration of compliance, provides the greatest information for decision-making when it is based on a credible representation of system behavior and uncertainty is appropriately quantified in the ranges of input parameters used. Selection of conservative representations focuses on the tails of the probability distributions and misrepresents both the reasonably expected behavior and the significance of the uncertainty.

For the purpose of the performance assessment that will support the postclosure site suitability determination and the SR, it is important to distinguish between using the best available data and models to provide a credible representation of the system, and the qualification/validation status of these data and models. Although the goal is to have a substantial portion of the data qualified and the models validated for the site suitability determination and SR, the more important goal is to have a credible, defensible, and traceable basis for the performance analysis. It is therefore inappropriate to employ conservative/bounding approaches in an effort to simplify the process for the qualification of data, or the verification of its qualification status, and the validation of the models that are the basis for the system performance analysis.

Evaluation of Process Model Conservatism

Attachment C

PMR Title	Level of Conservatism	Description	Rationale for Level of Conservatism	Availability of Existing Information Not Included	Ranking of Process Model Elements		
					Importance To The Model and PA	Ability to Modify Parameter or Assumption Based on	Availability of Data and Analyses Prior to Major Milestones
SZ	Representative	Defining Text	Defining Text	Defining Text		Choice of existing data and analyses	Input into model prior to September 30, 2000
UZ	Somewhat conservative						
Disruptive Events	Conservative					Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
EBS	Very conservative						
Near Field Biosphere	Somewhat optimistic					Use of data currently being collected but needs analysis	Input into model prior to issuance of the SR (April 2001)
Waste Package	Optimistic						
Waste Form	Very optimistic					Additional data needed that must be planned	Input into model prior to LA completion (December 2002)
ISM						Regulatory Requirement	Cannot be done within timeframes identified above or not planned

Task Lead: Mike Cline

Reviewers:
 Ralph Rogers
 Robert Gamble
 Mark Nutt
 Joe Ziegler

PMR Review Leads:
 Biosphere- B. Bowlby
 Disruptive Events- J. Savino
 EBS- H. Greenberg
 ISM- J. Savino
 Near Field- D. Sassani
 Saturated Zone- R. Salness/T. Doe
 Unsaturated Zone- R. Linden/T. Doe
 Waste Form- F. Wong
 Waste Package- F. Wong
 TSPA - E. Zwahlen

PMR Title	Level of Conservatism	Description	Rationale for Level of Conservatism	Availability of Existing Information Not Included	Ranking of Process Model Elements		
					Importance To The Model and PA	Ability to Modify Parameter or Assumption Based on	Availability of Data and Analyses Prior to Major Milestones
Biosphere	1	Representative	The disruptive volcanic event scenario assumes that a volcanic eruption would result in a thin ash deposition on the soil surface.	Assumption based on the results of the TSPA-VA calculations, which predicted the average ash thickness of 0.008 cm at the location 20 km south from the potential repository. The NRC and others have since suggested greater ash deposition, which would increase the possible exposure to the receptor for this scenario.	None	Low	
Biosphere	2	Representative	Drinking Water Treatment and Holdup Time -- It is assumed that there is no treatment (i.e., no application of a process to remove contaminants) of local drinking water, and no holdup time (time between pumping and consumption).	Most of the area surrounding Yucca Mountain is served only by private, individual wells, particularly in the Amargosa Valley.	None	Low	
Biosphere	3	Representative	Depth of Surface Soil -- Surface soil depth (or soil plow depth) defines the portion of the soil where the deposition from the atmosphere, irrigation, and resuspension occur. Fifteen cm surface soil depth for both plant growth and calculation of BDCF contribution from external exposure to radionuclides has been selected.	Consistent with current literature.	None	Low	
Biosphere	4	Representative	Population Statistics -- Population data were obtained from the 1990 Census. New census data may alter receptor information, specifically that associated with household statistics and occupations.	Best available information at the time. Census data is not anticipated to dramatically affect receptor information.	None	Low	

PMR Title	Level of Conservatism	Description	Rationale for Level of Conservatism	Availability of Existing Information Not Included	Ranking of Process Model Elements			
					Importance To The Model and PA	Ability to Modify Parameter or Assumption Based on	Availability of Data and Analyses Prior to Major Milestones	
Biosphere	5	Representative	Annual Groundwater Usage -- In response to the draft NRC regulation, the Project has decided to dilute full inventory of 20 km radionuclides in whatever volume of water is determined to be used.	Changing the water usage does not affect quantity of radioactive material to the critical group, due to the Project's current approach. Predicting change is uncertain.	None	Medium	Regulatory Requirement	No Plans to Modify
Biosphere	6	Representative	Site Specific Data vs. Literature Findings -- Literature findings were used in lieu of site specific data. This is true for transfer coefficients and environmental transport parameters in particular. Because most of these values are related in part to the local climate, soil, and other environmental conditions, they should be ideally measured through site-specific studies. However, such site-specific data have not been collected, and collection of site-specific data is a very expensive and time-consuming task. Many experimental and field studies for collecting related data have been conducted and published as generic values during the past several decades. These values have been selected for use in the PMR.	Because selected values for these parameters are not site-specific, the uncertainty associated with the parameter values could potentially be very large. Variation of literature values for some parameters can be a few orders of magnitude.	None	Low		
Biosphere	7	Somewhat conservative	RMEI vs. Average Member of the Critical Group -- DOE/OPC directed the M&O in May to calculate the RMEI, which had been presented as the 95 percentile, as equivalent to the average member of the critical group. Decision reduced conservatism unjustifiably attached to RMEI, while enabling both receptors of interest to share a single set of BDCFs.	BDCFs for the RMEI and the average member of the critical group have been calculated to be equivalent. The RMEI currently proposed in the regulations appears to fall below the exposure level anticipated for the average member of the critical group.	None	Low		

PMR Title	Level of Conservatism	Description	Rationale for Level of Conservatism	Availability of Existing Information Not Included	Ranking of Process Model Elements			
					Importance To The Model and PA	Ability to Modify Parameter or Assumption Based on	Availability of Data and Analyses Prior to Major Milestones	
Biosphere	8	Conservative	Fraction of Water that is Contaminated--One hundred percent of the local groundwater available in the hypothetical farming community in which the critical group resides is contaminated. Assumption based on the guidance from DOE on the use of the proposed NRC regulations regarding the definition of the critical group (Dyer 1999, Section 115).	Assumption results in conservative estimates for the fractions of water for human and animal consumption, and crop and feed production that are contaminated.	None	Medium	Requirement	Cannot be done within timeframes identified above
Biosphere	9	Conservative	GENII-S Code and Input Parameters -- GENII-S was found to be the most comprehensive code available for biosphere modeling. However, conservatism's are inherently built into the code regarding some input parameters. There is currently no plan to remove the conservatism's found in the code because of the code limitations and the approach taken by the Project and the NRC.	The conservative nature of the code and the parameter values selection processes (1) accounted for the plant interception portion of irrigation water in the irrigation water to soil, (2) assumed all plant roots are in the upper layer of soil with contamination, (3) disallowed taking credit for washing food.	None	Low	Regulatory Requirement	N/A
Biosphere	10	Conservative	Dose Conversion Factors (DCFs) for Internal Exposure -- Used 50 year committed dose to project single year exposure for the whole life span. The chemical forms for the radionuclides of interest are unknown; therefore, the potential to reduce the conservatism is limited. Once TSPA defines the dose-dominant radionuclides, the merits of pursuing this conservatism further will be more apparent.	The DCFs are addressed in Federal Guidance Report 11, which restricts the removal of the conservatism. Because radionuclide chemical forms are currently uncertain, the most conservative values were selected.	None	Medium	Regulatory Requirement	Cannot be done within timeframes identified above

PMR Title	Level of Conservatism	Description	Rationale for Level of Conservatism	Availability of Existing Information Not Included	Ranking of Process Model Elements		
					Importance To The Model and PA	Ability to Modify Parameter or Assumption Based on	Availability of Data and Analyses Prior to Major Milestones

Biosphere	11	Optimistic	Disruptive Volcanic Event Scenario -- The receptor of interest is assumed to vacate the area during the eruption and subsequent deposition of the ash. Scenario based upon guidance received during the Disruptive Event symposium over two years ago. TSPA has since requested, through 3.14 submittals, BDCF's be calculated for those individuals who remain throughout such an event.	The potential impact to the receptor via inhalation and ingestion pathways would be less for this individual than for those who have historically stayed throughout similar events.	None	Low		
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PMR Title	Level of Conservatism	Description	Rationale for Level of Conservatism	Availability of Existing Information Not Included	Ranking of Process Model Elements		
					Importance To The Model and PA	Ability to Modify Parameter or Assumption Based on	Availability of Data and Analyses Prior to Major Milestones
Disruptive Events	1 Representative	The ash particle diameter distribution used in the TSPA-SR is a log triangular distribution with a minimum of 0.01 mm, mode of 0.1 mm, and a maximum of 1.0 mm. The distribution is based on observations from violent strombolian eruptions at modern volcanoes "assumed" to be analogs for the YMR. Volcanoes are Tolbachik and two eruptions at Cerro Negro.	Only available data from relatively large, modern, violent strombolian eruptions.	No existing data excluded.	Medium	No additional data available	No planned work
Disruptive Events	2 Representative	It is assumed that only those waste packages located partially or entirely within the area of the eruptive conduit contribute to the radionuclide source term for the dispersal calculation. Calc page 4.	Although magma may contact many other packages, the magma moving with sufficient velocity to entrain waste is assumed to be located only within the conduit.		Medium	No additional data available	No planned work

PMR Title	Level of Conservatism	Description	Rationale for Level of Conservatism	Availability of Existing Information Not Included	Ranking of Process Model Elements		
					Importance To The Model and PA	Ability to Modify Parameter or Assumption Based on	Availability of Data and Analyses Prior to Major Milestones
Disruptive Events	3 Representative	Intrusions that come within 300 m of the surface are assumed to erupt somewhere along the length of the dike. Calc page 3, Igneous Activity AMR pages 25 and 26..	<p>As stated on page 26 of the AMR Characterize Framework for Igneous Activity, this assumption is justified on the basis of the PVHA expert panel's general belief that magma that ascends to within a few hundred meters of the surface will produce a surface manifestation of the volcanic event.</p> <p>However, the authors of the Igneous Framework AMR point out that "the assumption is conservative in that the PVHA experts allowed for the possibility that not all past volcanic events reached the surface in assessing the rate of volcanic events. The rate of volcanic events used to compute the frequency of intersection of the repository footprint by a dike was obtained by multiplying the rate based on past volcanic events with observed surface manifestations by a "hidden event factor" greater than or equal to 1.0 Assuming all future volcanic events will produce an eruptive center produces the maximum rate of eruptive center occurrence."</p>	Adequately captured in the PVHA.	Medium		
Disruptive Events	4 Representative	Igneous Event probabilities established in the PVHA and updated in the AMR "Characterize Framework for Igneous Activity at Yucca Mountain" are appropriate for the YM region.	PVHA considered all information available on the spatial and temporal occurrence of igneous activity. The experts allowed for hidden events which has resulted in a robust probability distribution in light of recent studies suggesting additional buried volcanic centers.	All data available at time of analyses included.	High		

PMR Title	Level of Conservatism	Description	Rationale for Level of Conservatism	Availability of Existing Information Not Included	Ranking of Process Model Elements		
					Importance To The Model and PA	Ability to Modify Parameter or Assumption Based on	Availability of Data and Analyses Prior to Major Milestones
Disruptive Events	5 Somewhat conservative	<p>Intrusive Scenario-Any waste packages, drip shields, and other components of the EBS that are partially or completely intersected by an intrusive dike are fully destroyed. Number of waste packages disrupted by flow of magma down backfilled drifts is 3 or 4 on either side of the dike. PMR page 3-17 and Dike Prop Near Drifts.</p> <p>All waste material in waste packages damaged as a result of proximity to an igneous intrusion is assumed to be available for incorporation in the UZ transport model.</p> <p>For the no-backfill design, the TSPA-SR assumes that all packages in drifts intersected by intrusive dikes are damaged. Three packages on either side of the dike are assumed to be fully destroyed, as in the backfill case, and the remaining packages in each intersected drift are assumed to undergo endcap-weld-failure. (TSPA-SR, Section 3.10.2.3.2, Page 26)</p>	"It is acknowledged that for packages damaged due to proximity to an intrusive dike (rather than by direct intersection) the assumption describes a physically unlikely, and perhaps impossible, set of conditions. However, there is no defensible technical basis for choosing a less conservative model at this time." (Page 20, Igneous Conseq AMR).	Analyses of the effects of dike intersection of drifts without backfill in progress.	Medium (RMD)	Additional analyses based on existing and new data	No planned work

PMR Title	Level of Conservatism	Description	Rationale for Level of Conservatism	Availability of Existing Information Not Included	Ranking of Process Model Elements		
					Importance To The Model and PA	Ability to Modify Parameter or Assumption Based on	Availability of Data and Analyses Prior to Major Milestones
Disruptive Events	6 Somewhat conservative	Possible structural central-lateral diversion of ascending basaltic dikes captured by normal faults in the YMR (e.g., Solitario Canyon, Ghost Dance, Bow Ridge) is not taken into account.	<p>IRSR Structural Deformation and Seismicity discusses the complexities involved in modeling possible dike capture and lateral diversion by fault zones in ambient stress field.</p> <p>AMR Dike Propagation Near Drifts points out uncertainties with modeling dike propagation in the repository vicinity during the period of the thermally altered stress field.</p>	<p>Observations in the YM region indicate that there is a strong correlation at the local scale between geologic structures and basaltic volcanism. The strongest evidence supporting fault-channeling of dikes is the occurrence of basaltic dikes in fault zones within Miocene Tuffs at YM and in the nearby Bullfrog Hills. An approximately 11Ma basalt dike in the Solitario Canyon fault extends along a roughly 1-km segment of the fault near the NW edge of the repository block.</p> <p>Additional evidence includes:</p> <ol style="list-style-type: none"> 1) linear alignments of volcanoes in Crater Flat and the Amargosa Valley, 2) north-south structural grain beneath Northern Cone, 3) location of Lathrop Wells Cone along or near the projected intersection of up to three normal faults. <p>Lack of detailed information on the near-surface structural complexity of fault zones makes it unlikely that taking credit for such a mechanism can be defended.</p>	Medium	Choice of existing data and analyses	Input into model prior to LA completion (December 2002)

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Disruptive Events	7 Conservative	<p>Wind direction in the base case fixed toward the critical group.</p> <p>Wind speed and wind direction data obtained in the YMR over a seven year period (1957-1964) at altitudes ranging from 5000-16,000 ft (1,500-5000 meters) were collected as paired, fully-correlated parameters, but are treated as uncorrelated parameters. This allows sampling of variability in both speed and direction independently, assuring that the full range of reported speeds have the possibility of occurring in a southerly direction, toward the critical group.</p>	<p>While this assumption overestimates the dose, it is intended to compensate for surface redistribution processes not explicitly accounted for in TSPA. The degree of conservatism (or optimism) of this assumption depends on whether it overcompensates (or undercompensates) for surface redistribution effects.</p>	<p>Sensitivity calculation based on sampled wind direction results in about a factor of 5 reduction of dose rate compared to the case for fixed direction towards the critical group.</p> <p>Higher-altitude wind velocity (direction and speed) data from Desert Rock Airstrip will be incorporated in the TSPA calculations to model ash plumes for the larger volume (higher ash columns) eruptions. The higher wind speeds may result in more areal distribution, resultant dilution of contaminated ash. This effect could possibly be offset by higher wind speeds resulting in further downstream transport of larger ash particles. Need full analysis to determine answer.</p>	High (RMD)	Additional analyses based on existing and new data	Input into model prior to LA completion (December 2002)

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Disruptive Events	8 Conservative	<p>Extrusive Scenario-For mathematical simplification, all events are centered on drifts. Any waste packages, drip shields, and other components of the engineered barrier system that are partially or completely intersected by an eruptive conduit are fully destroyed. All waste within waste packages that are fully or partially intersected by an eruptive conduit is available to be entrained in the eruption.</p> <p>Although an eruptive conduit is not centered on a drift it would theoretically intersect fewer waste packages, this factor is ignored in the calculation as a conservatism. Calc. Page 5.</p> <p>When the consequences of multiple vents are calculated, all conduits are considered to be coincident (centered) with drifts, so the total number of packages hit is the number calculated for one conduit multiplied by the number of vents. Calc. Page 14.</p> <p>If a conduit diameter is large enough to span the inter-drift distance, the number of waste packages inside the conduit is doubled. Calc. Page 4.</p>	<p>This assumption is considered to be conservative. Actual conditions in eruptive magmatic environments and the response of the waste packages and other components of the EBS are uncertain.</p> <p>Bounding information for concluding that the assumption of complete failure is not unreasonably conservative from calculation "Waste Package Behavior in Magma."</p> <p>Calculation simplification.</p>	<p>No existing data known.</p> <p>Sensitivity calculation indicates performance only moderately sensitive to this assumption.</p>	Medium	Choice of existing data and analyses	Input into model prior to issuance of the SRCR (December 2000)

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Disruptive Events	9 Conservative	All eruptions include a violent strombolian phase with fragmentation of the ascending magma into pyroclasts occurring below the repository horizon. (Igneous Consequences AMR pages 18 and 19).	<p>According to the authors of the Igneous Consequence AMR (pages 18 and 19), this assumption is considered to be conservative. Uncertainty associated with the nature of the violent phase, including its duration and the volume of material erupted, is included in the analysis through the development of a distribution function characterizing uncertainty in the volume of erupted material. (Page 19 of Igneous Consequence Modeling AMR).</p> <p>Pages 37 and 38 of the Char Eruptive Processes AMR suggests that fragmentation depths for initial volatile contents between 0 and 4 wt% ranges from about 0 to 900 m.</p> <p>The author(s) of the TSPA-SR comment (Section 3.10.2.2.1, Page 16) that while the actual depth at which a conduit might form is uncertain, the effect of this uncertainty on repository performance is not as great as might appear.</p>	As noted by Greg Valentine in his Characterize Eruptive Processes AMR Page 29), information on the tie between concentration of volatiles and eruptive style for the YMR post-Miocene record is sparse. The range of wt% water and corresponding range of fragmentation depths represent his best estimate.	Medium	Choice of existing data and analyses	Input into model prior to issuance of the SR (April 2001)

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Disruptive Events	10 Conservative	<p>Kappa - near surface attenuation parameter assigned a relatively conservative value.</p> <p>The value of kappa impacts the level of ground motion calculated at the so-called reference rock outcrop at the repository horizon, and consequently at any surface or subsurface location where site-specific ground motion estimates are calculated. Changes in kappa can have a significant effect on high-frequency ground motions (e.g., a kappa increase of 0.01 seconds corresponds to a 35% reduction in the 20 Hz response spectral level, approximately 10% at 10 Hz).</p>	Lack of data for larger magnitude earthquakes within about 15 km of YM recorded at a sufficient number of representative YM sites.	<p>Two main data sets are used for estimating kappa at Yucca Mountain. One data set comes from small to moderate (M 3 - 4.5) aftershocks of the Little Skull Mountain earthquake. The other data set consist of a large number of recordings from small magnitude earthquakes (M<1) in the YMR.</p> <p>Differences in "kappa" estimates from these two data sets have to be reconciled (understanding of physical causes for different spectral rolloffs) before a significant change in kappa can be accepted.</p> <p>Reanalysis of the first data set suggests a logic tree approach with different estimates of kappa. This approach results in a median estimate of kappa that indicates a reduction in ground motion at the reference rock outcrop at 20 Hz of approximately 15%, approx. 8% at 10 Hz.</p>	Medium	Additional analyses based on existing and new data	Input into model prior to issuance of the SR (April 2001)

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Disruptive Events	11 Conservative	<p>All waste is assumed to be unaltered commercial spent fuel, for the purposes of estimating waste particle diameters in the eruptive environment.</p> <p>The range of waste particle diameters used in the TSPA-SR, 1 to 500 microns with a mode of 20 microns, is based on laboratory observations of particle sizes of unaltered spent nuclear fuel following mechanical grinding.</p>	The assumption to treat all waste as unaltered commercial spent fuel is conservative with respect to the unaltered glass waste forms that make up most of the waste volume, and which are likely to have particle diameters comparable to those of the ash itself, larger than the values used for spent fuel (waste particle diameters half and less than ash particle diameters are assumed incorporated)	Changes in the ash particle density due to incorporation of potentially denser waste particles could affect the transport dynamics of the combined ash/waste particles. Inclusion of this effect would tend to reduce the atmospheric transport time of the combined particles. As noted on page 23 of the Igneous Consequence AMR, this "complication" would be non-conservative with respect to the amount of waste transported relatively greater distances from the repository and, thus, is not considered further.	Low	Additional data needed that must be planned	No planned work

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Disruptive Events	12 Very conservative (mechanics)	<p>"Observations of both modern and past analog volcanoes indicate that violent phases account for only a portion of the total eruption, but for the purposes of the TSPA-SR, the entire volume of erupted material is conservatively assumed to be involved in a violent phase. This assumption overestimates, perhaps significantly, the amount of energy in the eruption and therefore the amount of ash transported away from the site."</p> <p>Quoted sentences are taken from the 6/5/00 draft (Storyboard) of the TSPA-SR, Section 3.10.2.2.1, page 17.</p> <p>The volume distribution assumed is given in Table 3.10-4 of the TSPA-SR; log-uniform 0.002 - 0.44 cubic km. This distribution is specified at the bottom of Page 32 in the Igneous Consequence AMR.</p> <p>Also from the Igneous Consequence AMR, Page 35, it's noted that in the current version of ASHPLUME (Version 1.4LV), the role of the event power parameter in determining eruption height has been superseded by the modification that derives eruption height from event volume. This code modification increases the importance of event volume to TSPA.</p>	<p>The section on event eruptive volume on Pages 32 and 33 of the Igneous Consequence AMR reads as follows: "A range for the event eruptive volume is defined in CRWMS M&O 2000b as 0.002 - 0.14 cubic km. The NRC IRSR for Igneous Activity, Rev 2 (Reamer 1999, p.129) defines an eruptive volume range that spans 0.004 - 0.44 cubic km. This AMR defines the eruptive volume as a log-uniform distribution that spans the range defined by these two documents (0.002 - 0.44 cubic km). By incorporating the IRSR range, the higher eruptive-volume events are incorporated into the ASHPLUME model."</p> <p>CRWMS M&O 2000b is the Igneous Framework AMR.</p>	<p>Sensitivity study in the TSPA-SR indicates that performance (dose) not sensitive to this parameter (eruptive volume). Basically, larger volume eruptions result in a dilution of dose at the critical group. One potential problem with this result is that wind speeds used in the calculations did not correspond to ash plume column heights.</p> <p>Until results are obtained for incorporation of higher altitude wind data to more appropriately account for the larger eruptive volumes and higher ash plumes, the degree of conservatism (or optimism) is unknown. However, if dispersion of the ash plume because of the higher wind speeds dominates gravity settling of combined particles downstream, then the current dose results may end up being too high and categorized as somewhat conservative.</p>	High	Choice of existing data and analyses	Input into model prior to issuance of the SR (April 2001)

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Disruptive Events	13 Somewhat optimistic (dose)	The very large volume of eruptive material may dilute the radionuclides released in the ash plume and available for dispersion.	The assumption that the full event is violent strombolian is very conservative, but the larger eruptive volume with same volume of water contributes to the dilution of the waste and may be optimistic.	Until results are obtained for incorporation of higher altitude wind data to more appropriately account for the larger eruptive volumes and higher ash plumes, the representation appears optimistic. However, if dispersion of the ash plume because of the higher wind speeds dominates gravity settling of combined particles downstream, then the current dose results may lead to a change in the representation of the results.	Medium (RMD)	Choice of existing data and analyses	Input into model prior to issuance of the SRCR (December 2000)

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EBS	1 Representative	Invert Diffusion - With the removal of backfill, preliminary TSPA results are showing a large percentage of the invert transport as diffusion limited (less water entering the drift by "wicking" induced by the backfill). The currently completed EBS Invert Diffusion AMR Rev. 01 used a single-sided 95% confidence band to bound a fit to existing data. This is conservative by a factor of about 2 to 3. However the EBS Radionuclide Transport Abstraction AMR Rev. 00, ICN 01 uses the curve fit through the data and uncertainty (on the fit in the Invert Diffusion AMR Rev. 01) with a conservative adjustment of 30% to the mean of that fit. Therefore, the model incorporated into TSPA can be considered realistic rather than conservative.	The EBS Radionuclide Transport Abstraction AMR Rev. 00, ICN 01 uses the curve fit through the data and uncertainty (on the fit in the Invert Diffusion AMR Rev. 01) with a conservative adjustment of 30% to the mean of that fit. Therefore, the model incorporated into TSPA can be considered realistic rather than conservative.	Current data included in Rev. 01 of the Invert Diffusion AMR, and in Rev. 00, ICN 01 of the Radionuclide Transport Abstraction AMR.	High (PD)	Choice of existing data and analyses	Input into model prior to September 30, 2000
EBS	2 Representative	Thermal expansion, floor heave, rock fall, seismic response, and emplacement pallet failure screened out.	FEPs analyses screened out these scenarios. If screened the analyses would be more conservative.		Low	Choice of existing data and analyses	Input into model prior to issuance of the SRCR (December 2000)
EBS	3 Somewhat conservative	Sorption in WP and invert ignored.	Consideration of sorption would most likely reverse conservatism, but absence of consideration is conservative.	None	Low		
EBS	4 Somewhat conservative	Diffusion in waste package starts when stress corrosion cracks exist, because of assumed liquid pathway.	There may not be a liquid pathway from the waste to the crack in the waste package, particularly if evaporation is considered.	None	Low		

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EBS	5 Somewhat conservative	Seepage - all seepage assumed to start at the crown of drift or drip shield so it all falls on drip shield or WP and has greatest probability of entering a hole. Fraction of seepage entering WP is scaled by hole length(s)/WP length. No possibility for seepage on left of WP to miss a hole on the right of WP. No seepage falls between WPs. Effects peak dose.	Some of the seepage may miss the package altogether. Some of the seepage may miss the hole in the package. Scaling the seepage flux may give different release rates than all or nothing--for soluble species, even a little flow can dissolve everything.	None	Low (PD)	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
EBS	6 Somewhat conservative	EBS diffusion - pallet is ignored and waste package is in intimate contact with invert	At early times, until pallet degrades, any diffusion from the waste package would have to be along the contact points with the pallet. Later, the waste package will settle onto the invert.	None	Low		
EBS	7 Very conservative	All mass moved to inner surface of waste package - All mass is contacted by any seepage flux into up.	A model for in-package transport could reduce release rates and reduce peak dose. The in-package transport could be through thin films inside the waste package.	None	High (PD)	Additional data needed that must be planned	Input into model prior to LA completion (December 2002)
EBS	8 Very conservative	Evaporation of water from WP is neglected. Waste form is wet as soon as WP fails.	Analyses show that heat can evaporate all of the water in all packages for nearly 10k years, average and hot packages for much longer. Without water inside the package, there should be no release from failed packages.	Preliminary analyses have been presented to the MGR Board. Also, there is text in the draft of SRCR.	High (DID)	Additional data needed that must be planned	Input into model prior to issuance of the SR (April 2001)

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Near Field	1 Somewhat conservative	Seepage - No dryout during ventilation period and no dryout during thermal period (input to seepage model is 5 meters above the drift). Seepage not allowed to go below initial calculated for present-day conditions.	Lack of applicable model and data. Note: The seepage model is in the UZ PMR and is for ambient conditions only. The implementation of thermal effects in the TSPA models for seepage assumes that using the 5M Perc Flux value offsets the lack of detail in fracture heterogeneity in the models.	Currently none that applies directly.	Medium	Additional analyses based on existing and new data	Input into model prior to LA completion (December 2002)
Near Field	2 Somewhat conservative	The use of the pore-water Cl- composition to represent the infiltrating water provides an upper bound to the starting chloride concentration for ambient fluids moving potentially through the fractures.	Lack of direct data on ambient fracture water compositions in the Unsaturated zone. High Cl concentrations are bounding relative to potential WP effects.	Variation in chloride content of infiltration as function of infiltration rate should be consistent with the data used for the UZ F&T model.	Low		
Near Field	3 Somewhat optimistic	No alteration of zeolitic units under the repository calculated based on the thermal perturbation. Dehydration/alteration of zeolites may occur above 70°C leading to increased porosity and/or permeability in the Calico Hills units. Generation of water from alteration also possible. Site data indicate that zeolite alteration starts at about 70C, which could be used for estimate of possible effects of heating.	Duration of heating of zeolitic units will be relatively short and only a small portion of the units will be affected. Lack of data on rates of alteration. In addition, direct accounting for this alteration would entail an energy sink that would reduce the migration of higher temperatures past these horizons.	Available	Low (PD)	Additional analyses based on existing and new data	Input into model prior to LA completion (December 2002)

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Near Field	4 Somewhat optimistic	No lasting changes to the fracture permeability in the UZ due to coupled THC processes. Uncertainties are large for kinetic parameters and reactive surface areas of minerals, but are largely unexplored.	Although this is a non-conservative estimate of the amount of change, this is not clearly conservative or non-conservative for performance. This is primarily an uncertainty that will need further exploration. Constraints are primarily from matching ambient and thermal test data.	Some data exists but we need to evaluate uncertainties	Medium	Additional data needed that must be planned	Cannot be done within timeframes identified above

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SZ	1 Conservative	Specific Discharge (Groundwater Flux). Average discharge per unit area through Darcy's Law	Uncertainty distribution for specific discharge used in TSPA-SR taken from SZ Expert Elicitation. Multi-well pump test at the C-holes considered to be the most reliable source of hydraulic conductivity by experts, but wide uncertainty range was elicited.	Pump test results at the alluvial testing complex would help to reduce uncertainty in permeability (and thus specific discharge) in the alluvium portion of the flow system. Results should help reduce the high end of uncertainty distribution in specific discharge (assuming pump test results for permeability are near or below expected value).	High*	Use of data currently being collected but needs analysis	Input into model prior to issuance of the SRCR (December 2000)
SZ	2 Conservative	Effective Diffusion Coefficient. Parameter used to determine rate of diffusion. Used in porous media when diffusion only occurs in pore spaces.	Uncertainty distribution for effective diffusion coefficient used in TSPA-SR extends to low (conservative) values to account for uncertainty in SZ Chemistry, fracture coatings, etc.	Reevaluate available data on effective diffusion coefficients for volcanic units. Search for available non-YMP data sets. Work more closely with experimentalists at LANL to define uncertainty distribution.	Medium	Choice of existing data and analyses	Input into model prior to issuance of the SRCR (December 2000)
SZ	3 Conservative	Sorption Coefficients for Alluvium. Parameter of the ability of specific substrate to sorb radionuclides on the surface. Critical parameter in retardation calculations.	Uncertainty distributions for sorption coefficients in alluvial units used in TSPA-SR based on laboratory data. Sorption experiments for Iodine (I) sorption were incomplete; final values of Kd may be higher.	Additional laboratory testing of sorption for alluvium samples from Nye County boreholes.	High	Use of data currently being collected but needs analysis	Input into model prior to LA completion (December 2002)
SZ	4 Conservative	Flowing Interval Porosity (Fracture Porosity). Interconnected fracture void space that dominates flow through the saturated volcanic aquifer.	Uncertainty distribution for the flowing interval porosity use in TSPA-SR extends to low (conservative) values with a lower bound of 1E-5. Field testing generally yields higher values of flow porosity, but the SZ expert elicitation results state that flow porosity in fractured units could be as low as 1E-5.	Definitive evaluation of flowing porosity in fractured units of the SZ is difficult. Sensitivity studies indicate that impacts to TSPA results may not be large for the dual-porosity conceptual model.	High*	Choice of existing data and analyses	Input into model prior to issuance of the SRCR (December 2000)

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SZ	5	Conservative	Conceptual Model of Colloid Filtration. The conceptual model of colloid filtration for colloids with irreversibly attached radionuclides used in TSPA-SR assumes that colloids are retarded by filtration.	Uncertainty and Modeling Restriction. Permanent removal of colloids by mechanical filtration is not considered in the SZ transport model.	Defensible demonstration of permanent filtration of colloids in field experiments is difficult to obtain at the time scale of a tracer test. Potential impacts to TSPA results could be large because of the high biosphere dose conversion factors for Pu and Am.	Medium	Additional data needed that must be planned	Input into model prior to LA completion (December 2002)
SZ	6	Conservative	Kc Model Parameters for Colloid-Facilitated Transport. Partition coefficient of certain radionuclides to be determined.	Uncertainty and Modeling Restriction. Uncertainty distribution for the Kc parameter used in TSPA-SR is for Americium (Am) on wasteform colloids (conservative relative to Plutonium (Pu) and filtration is not included.	Additional lab work on actinide sorption onto colloids and additional measurements of natural colloid concentrations.	Medium	Additional data needed that must be planned	Input into model prior to LA completion (December 2002)
SZ	7	Very conservative	Sorption Coefficients for Volcanic units. Ability of substrate to sorb radionuclides on surface area. Critical parameter in retardation calculations.	Uncertainty and Modeling Restriction. Uncertainty distributions for sorption coefficients in volcanic units used in TSPA-SR taken from the lowest (conservative) distribution among different rock types (I.e., vitric, devitrified, zeolitic).	A much higher resolution of data and representation in the hydrogeologic framework model would be required to explicitly distinguish between volcanic rock types in the SZ site-scale flow and transport model.	Low	Additional data needed that must be planned	Input into model prior to LA completion (December 2002)
SZ	8	Very conservative	Homogeneous layer properties in Monte Carlo simulations.	None - Assumes homogeneous layer properties more easily modeled than heterogeneous properties. Results in realizations with extreme fast or slow travel times. Medium probably okay.	Can use some distribution for elements within layer as for the layers as a whole.	High	Additional analyses based on existing and new data	Input to model by December 31, 2000.
SZ	9	Very conservative	Flowing Interval Spacing. Distance between the fractures where flow occurs.	Uncertainty distribution for flowing interval spacing used in TSPA-SR taken from analysis of older, relatively poor-resolution borehole flowmeter logs. Analysis may have overestimated (conservatively) the flowing interval spacing.	Obtain new high-resolution flowmeter survey data from boreholes in the volcanic units. New flowmeter survey data may indicate closer spacing between flow intervals.	Medium*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)

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SZ	10	Very conservative	Western Boundary of the Alluvial Uncertainty Zone. Stochastic parameter that defines the boundary of the alluvium with volcanic material to the west of the modeled flow path.	Uncertainty distribution for the western boundary of the alluvial uncertainty zone used in TSPA-SR is bounded approximately by well EWDP-2D and surface outcrops of volcanic units and surface outcrops of volcanic units. This linear western boundary is a highly simplified representation of what is probably a geologically complex system in the subsurface.	Subsurface data from the west side of Fortymile Wash required to reduce uncertainty for this issue. No Nye County wells are currently planned in the critical area.	High *	Use of data currently being collected but needs analysis	Input into model prior to LA completion (December 2002)
SZ	11	Very conservative	Northern boundary of Alluvial Uncertainty Zone. Short term Long Term. Stochastic parameter due to not knowing the location of the alluvium and fractured volcanic aquifer transition.	Uncertainty distribution for the northern boundary of the alluvial uncertainty zone used in TSPA-SR results in a minimum flow path length of about 1 km in alluvium for the simulated plume.	Data from Nye County wells will allow the minimum north-south flowpath length in the alluvium to be increased. Data from well EWDP-19D indicates a minimum flow path length of at least 2 km in the alluvium for the main portion of the simulated plume.	High*	Choice of existing data and analyses	Input into model prior to September 30, 2000
SZ	12	Very conservative	No Sorption in Fractures. Assumption that sorption, and therefore retardation, does not occur on the fracture coating surface of the fractured volcanic media.	Uncertainty. The radionuclide transport model in the SZ for TSPA-SR assumes (conservatively) no sorption onto fracture surfaces in the fractured units. Laboratory and field testing have not defensibly demonstrated this process.	Additional laboratory and field-scale testing of natural fractures in volcanic units may demonstrate sorption on fracture surfaces. Potential impact to TSPA results has not been investigated and may not be large.	Low	Additional data needed that must be planned	Cannot be done within timeframes identified above

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SZ	13 Very conservative	Only Fracture Flow in Volcanic Units (no matrix flow). Flow does not occur between pore space of bulk rock, only within the fractures of the rock.	Modeling Restriction. This issue is related to the continuum assumption for fractured units employed in the SZ site-scale flow and transport model. The dual-porosity formulation of the transport model assumes (conservatively) groundwater flow occurs only in the fracture network.	Significant groundwater flow may occur in the matrix of volcanic rocks in some parts of the SZ flow system; however, this has not been clearly demonstrated in field testing. To explicitly model this behavior would require significantly higher resolution data from the SZ, modeling, and a higher resolution flow and transport model.	Low	Additional analyses based on existing and new data	Input into model prior to issuance of the SR (April 2001)

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UZ	1	Representative	Fracture porosity set to about 1%	Several test methods indicate fracture porosities of about this magnitude, but are they really representative of fractures for flow/transport over long distances and coupled processes?	Data from cross drift systematic drilling in TSwll.	High	Choice of existing data and analyses	Input into model prior to issuance of the SRCR (December 2000)
UZ	2	Somewhat Conservative	Thermo-mechanical effects on seepage neglected (don't really know whether this is conservative or not)	No analysis or data available.	No analysis available at present.	Low		Input into model prior to LA
UZ	3	Somewhat conservative	Thermal effects on Flow/transport are neglected.	The mountain-scale TH model indicates the thermal perturbation to be relatively unimportant to far-field radionuclide transport.	No applicable data exists.	Medium	Additional analyses based on existing and new data	Input into model prior to LA completion (December 2002)
UZ	4	Conservative	Coupled process effects on flow/transport are neglected.	The drift-scale model indicates negligible effect on hydrologic properties. THM analysis is not available.	No applicable data exists.	High*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
UZ	5	Conservative	Thermal effects on flow properties are neglected.	AMR U0100 show that Kd values increase with temperature for cations but decrease for anions (which have low Kds typically). It would be difficult to model these thermal dependencies.	No sources other than AMR U0100	Medium	Additional analyses based on existing and new data	Input into model prior to LA completion (December 2002)
UZ	6	Conservative	Fracture-matrix interaction (and fracture velocities) determined by active fracture model (don't really know whether this is conservative or not)	There is al lot of uncertainty about fracture properties and fracture-matrix interaction. The active fracture model seems pretty reasonable, but has no direct confirmation.	Limited F-M interaction data available; additional data will be obtained in FY01.	High*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
UZ	7	Conservative	Broad Uncertainty and variability distributions used for K/alpha parameter.	Not enough information to pin it down better; in particular, no information for TS lower lith.	No applicable data available.	Medium	Additional analyses based on existing and new data	Input into model prior to LA completion (December 2002)

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UZ	8	Conservative	Diversion of flow and transport around the perched water rather than through it might be conservative.	We have no site information that can tell us the actual flow/transport paths in the vicinity of the perched water.	No applicable data available.	High*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
UZ	9	Conservative	Broad Uncertainty distributions used for flow-focussing factor.	Not enough information to pin it down better	No applicable data on flow focusing exists.	High*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
UZ	10	Conservative	Colloid concentration and Kd's used to calculate Kc are thought to be conservative.	There is so much uncertainty about colloid properties and transport that a more detailed representation was thought to be indefensible.	AMR V0100 provides the best compilation - incorporate as applicable.	Medium	Additional data needed that must be planned	Input into model prior to LA completion (December 2002)
UZ	11	Conservative	FEHM particle-tracking method appears to be conservative compared to the DCPT or T2R3D methods.	Time and resources were not available to incorporate another transport model into the TSPA.	Existing data can be used. Additional modeling with new code(s) required.	High*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
UZ	12	Conservative	Seepage into drift specified seepage abstraction when drift wall is above boiling.	This has been an issue with the NRC. They have maintained that water flow in channels might be able to penetrate through hot rock.	Thermal test (Alcove 5) observations may be available.	High*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
UZ	13	Conservative	All seepage into drift is counted (not just seepage above waste package). Consider allowance for film flow in drifts.	Amount of seepage was thought to be more defensible than the seepage locations in the model.	No applicable data available.	High*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
UZ	14	Conservative	Mountain scale TMH	Modeling studies suggest only minor impacts.	No applicable data available.	Medium	Additional analyses based on existing and new data	Input into model prior to LA completion (December 2002)
UZ	15	Conservative	Physical colloid filtration is neglected in most situations; in particular, it is always neglected for transport in fractures.	We have no data to support including it.	No applicable data available.	Medium	Additional data needed that must be planned	Input into model prior to LA completion (December 2002)

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UZ	16	Conservative	All host units treated the same in seepage abstraction. Probably conservative because seepage and drift-degradation behavior of TS lower lith is probably better than the others.	Most information not available for TS lower lith and lower nonlith. Having a single abstraction model for all locations is much simpler. Differentiating the units would require redefining the waste-package groups in the TSPA model.	Activities conducted in Niche 4, Niche 5, Alcove 8/Niche 3, and the systematic drilling in the cross drift will provide much needed data on TSwll and TSwmn.	High*	Use of data currently being collected but needs analysis	Input into model prior to LA completion (December 2002)
UZ	17	Conservative	Rc is neglected for reversible colloids in the SZ and for all colloids in the UZ.	No data are available for Rc in the unsaturated zone or for reversible colloids.	No applicable data available.	Medium	Additional data needed that must be planned	Input into model prior to LA completion (December 2002)
UZ	18	Conservative	Uncertainty distributions for Diffusion coefficient are higher in UZ than SZ	UZ distributions are based directly on lab data. SZ distributions include more uncertainty.	Busted butte data could be used from planned overcore analysis.	Medium	Additional analyses based on existing and new data	Input into model prior to issuance of the SR (April 2001)
UZ	19	Conservative	Lithophysal porosity	Preliminary results from lower Lithophysal unit indicate permeability is about an order of magnitude higher than middle nonlithophysal unit.	Results from ongoing Hydrologic characterization of TSwll in cross drift	High	Use of data currently being collected but needs analysis	Input into model prior to LA completion (December 2002)
UZ	20	Conservative	All nuclides introduced into fractures	Little credit is taken for sorption and matrix diffusion in UZ.	No applicable data available.	Medium	Choice of existing data and analyses	Input into model prior to September 30, 2000
UZ	21	Conservative	Seep flux increased by 10% to account for possible correlation of k and alpha (probably conservative)	Seepage simulations are easier and faster with K and alpha uncorrelated, and it isn't a very big effect anyway. We have no data on the actual amount of correlation.		Low	Additional analyses based on existing and new data	Input into model prior to LA completion (December 2002)
UZ	22	Conservative	Thermal effect on Kd	AMR U0100 shows Kd values increase with temperature for cations but decrease for anions.	Some recently completed studies may be applicable.	Medium	Choice of existing data and analyses	Input into model prior to LA completion (December 2002)
UZ	23	Conservative	Single grid matrix	Use of single grid may not provide sufficient resolution for flow and transport processes.	No applicable data available.	High*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)

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UZ	24	Conservative	Fault Properties in CHn	Faults in CHn are assumed to serve as conduits for flow. Results from busted butte do not support this.	Busted butte experiment data may be applicable.	High*	Additional data needed that must be planned	Input into model prior to LA completion (December 2002)
UZ	25	Very conservative	Flow models may have a significant amount of Fracture flow through the CHnv unit.	This is what came out of the calibration procedure with the property distributions that were used. Not consistent with data.	Busted butte experimental data (Phase I)	High*	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)
UZ	26	Somewhat optimistic	Episodic flow/seepage neglected	Available information indicates that episodic flow is probably not significant at the repository, except possibly close to faults	Limited data available	High	Additional analyses based on existing and new data	Input into model prior to September 30, 2000
UZ	27	Optimistic	High infiltration case probably should be higher.	The infiltration uncertainty study was not available until after the other simulations were done. The developed infiltration extends to higher infiltrations than were considered in the TSPA.	Infiltration uncertainty AMR	High*	Additional analyses based on existing and new data	Input into model prior to September 30, 2000

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Waste Form	1	Representative	Colloid stability based on many different groundwaters, some of which may overestimate or underestimate the colloid concentrations in Yucca Mountain groundwater.	All available data considered.	Models based on data from around the world as well as site specific data.	Medium		
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Waste Form	2	Representative	<p>DSNF degradation: No cladding credit is assumed, and characteristics of N-reactor fuel are assumed (dissolution occurs in one time step of TSPA) Cladding is not as robust or thick as that for CSNF, and DSNF was intended to be re-processed.</p>	<p>This approach bounds DSNF degradation processes. The application of the DSNF and immobilized ceramic Pu degradation models involves the extrapolation of the models over long periods of time, which are orders of magnitude greater than the experimental test periods used to generate the data used to derive the models. ASTM C1174-97 (Section 24) recommends that uncertainties in the extrapolation of such models be minimized through the use of models whose mathematical forms are as mechanistic as possible. However, it can be seen from the abstractions that they lack of any directly relevant experimental dissolution/degradation data for many of the DSNF waste forms, and the small amount of data for those which have been tested, precludes the development of mechanistic model at this time. Additionally, uncertainties in the data used to generate the models – such as in the surface area measurements used to calculate normalized dissolution rates – produce significant uncertainties even in the short-term application of the models. For this reason and because preliminary TSPA analyses have shown that the overall performance of the repository is very insensitive to the degradation rate of the DSNF, upper-limit or bounding degradation models will be used (from WF PMR, Section 3.5.2).</p>	All data considered	Low	

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Waste Form	3 Conservative	Local corrosion and unzipping of cladding are assumed to occur. For wet unzipping of the cladding, 5% of the inventory is assumed to be released once the cladding is perforated, and the unzipping propagates at a rate that is 40 times the forward dissolution rate.	<p>Inclusion of these phenomena bounds uncertainties in cladding behavior.</p> <p>The bases for matrix exposure analysis are measurements of gap inventories, experimental measurements of the release of radionuclides from damaged cladding and intrinsic dissolution measurements. Although unzipping has not been observed for rods in storage pools for the past 40 years, the unzipping analysis is consistent with dry unzipping experiments. Uncertainties have been defined that are based on both experiments and extremes in the analysis. Therefore, this analysis is appropriate for TSPA-SR. Although it is conservative, it is not as conservative as the assumption of instantaneous unzipping to expose the CSNF that was used in previous TSPAs (From WF PMR, Section 3.4.2.7).</p>	All data considered	Medium	Additional data needed that must be planned	Cannot be done within timeframes identified above

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Waste Form	4	Conservative	HLW degradation: Fast degradation rates are assumed	Using fast degradation rates bounds uncertainties - Limited data available.	All data considered	Low
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The abstracted model is designed to provide a conservative estimate of the rate (i.e. an upper bound or overestimate of the likely rate) at which glass will corrode when immersed in groundwater or exposed to humid air and/or dripping water in the repository. Because each of the model parameter values were evaluated using a conservative bounding approach, there is confidence that the abstracted model is likely to bound the long-term HLW degradation under neutral to basic conditions. The abstraction was compared to the dissolution rate of basalt glass recovered from the sea bed and shown to be conservative with regard to the long-term dissolution rate of basalt glass (From WF PMR, Section 3.6.2).

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Waste Form	5	Conservative	<p>Waste form solubility: High Np solubility, assumed to be controlled by Np₂O₅. During the first 1000 years, when the pH is low, Np solubility is between 10⁻⁴ and 10⁻¹M. After 1000 years, it is 10⁻⁷ and 10⁻³ M.</p> <p>There has been a lengthy discussion about Np-bearing phase(s) that could form under repository conditions. Thermodynamically, NpO₂ is the stable phase. However, it has not been observed in solubility experiments, except for some unusual conditions. It is believed that a kinetic barrier prevents NpO₂ from precipitating.</p> <p>Analysis of the stability field for Np(V) solid phases (Np₂O₅, NpO₂(OH), and NaNpO₂Co₃?5H₂O), it was concluded that Np₂O₅ is the solubility controlling phase in J-13 well water (From Summary of Dissolved Concentration Limits AMR, Section 6.4.2).</p> <p>Using high Np solubility bounds uncertainties and is conservative as a low solubility value (if shown to be the case) will retard Np release.</p>	No	High (PD)	Additional analyses based on existing and new data	Input into model prior to issuance of the SRCR (December 2000)

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Waste Form	6 Conservative	Waste form colloids: High sorption coefficients are used, and some colloids assumed to be highly irreversible.	<p>This approach bounds uncertainties in colloid behavior.</p> <p>The abstractions are based on laboratory results from waste form corrosion testing and testing of adsorption and desorption properties of Pu and Am on clay and iron-(hydr)oxide colloids. To the extent that the laboratory tests and test conditions represent anticipated repository conditions, the abstraction is valid for calculating the colloid-associated radionuclide concentrations and colloid mass concentrations. The approach for the colloidal-radionuclide source term is based on YM-specific field and laboratory studies and results from YM-relevant studies.</p> <p>Field evidence of small concentrations of radionuclides associated with colloids migrating considerable distances has underscored the potential significance for the irreversibility of radionuclide attachment to smectite colloids observed in the ANL waste form corrosion experiments. Irreversibly attached colloids are included in the abstracted model as a contribution to the colloid-associated radionuclide concentration. Per 3.8.2.2 (of the WF PMR) the colloids formed from CSNF and DSNF are assumed to have reversibly attached radionuclides; this assumption is potentially non-conservative and remains to be verified when results</p>	All Considered	Medium (PD)	Use of data currently being collected but needs analysis	Cannot be done within timeframes identified above

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Waste Form	7 Conservative	No secondary phases for CSNF degradation are assumed, which results in a fast degradation rate.	<p>from on-going tests become available (From WF PMR, Section 3.8.3).</p> <p>Did not consider secondary text.</p> <p>The abstracted CSNF dissolution model was based on a large set of qualified flow-through experiments. From an analysis of the fit of the model to the data, and from further consideration of the uncertainty of application of data from young spent fuel (< 30 year out of reactor) and unburned UO2 toward the prediction of long term (>1000 year) performance of spent fuel, the model was estimated to be valid to within 1.5 orders of magnitude. This model was compared to unsaturated drip tests, batch tests, and a range of literature results. The model and uncertainty range adequately accounted for, or overestimated, all dissolution rate data. In addition, a comparison of the phases produced in the unsaturated drip tests compare well with that of natural analogs (from WF PMR, Section 3.3.2). Fast rates are used to bound the upper end of uncertainties. Secondary phases were excluded because experimental results to date were inconclusive with regard to effect of such phases on degradation mechanisms. The PA peer review panel concurred with this conservative approach at this time, since secondary phases would retard radionuclide release from CSNF, if shown to be the case.</p>	All data considered	Medium (PD)	Use of data currently being collected but needs analysis	Input into model prior to LA completion (December 2002)

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Waste Form	8	Very Conservative	Seismic clad failure estimates include many conservative inputs in order to simplify the analysis. Recent peak dose estimates (post 10,000 years) indicate that seismic clad failure is a significant contributor (about 25%) in determining peak dose. Reduction in clad failure estimates could significantly reduce peak dose estimates.	Data regarding the magnitude of very low probability seismic events (<1.00E-05/year) are not available. Other conservative assumptions were made such as taking no credit for deformation of waste package or the drift wall in order to simplify the analysis.	It is not clear at this point how much, if any, of the conservatism in the analysis can be removed with reasonable level of effort. Meetings with authors of existing analysis are necessary to determine the path forward.	High (PD)	Additional analyses based on existing and new data	Input into model prior to issuance of the SR (April 2001)
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Waste Package	1	Representative	To address the effects of microbiological induced corrosion (MIC), a minimum enhancement factor of 2.0 is applied to the corrosion rate of the waste package.	<p>This factor is calculated as the ratio of corrosion rate (microbes to sterile) and from Table 25 (in the AMR). The value of GMIC for Alloy 22 in sterile media is approximately one (GMIC ~ 1), whereas the value of GMIC for Alloy 22 in inoculated media is larger (GMIC ~ 2). Assume that GMIC is uniformly distributed between these limits and that this distribution is half uncertainty and half variability.</p> <p>Using this enhancement factor results in a waste package life than is in excess of 10,000 years.</p>	All data considered	Low		
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Waste Package	2	Representative	<p>Welded regions of the waste package are assumed to be 100% aged, and as a result, a maximum enhancement factor of 2.5 is applied to the corrosion rate.</p> <p>Assuming 100% aging of the welds addresses the present uncertainty in the aging effects of the waste package materials. A minimum factor of 2.5 is conservative, as expected temperature ranges of the waste packages in the repository are not anticipated to be within the aging temperature window.</p> <p>The effect of thermal aging on the corrosion rate is accounted for in the enhancement factor, Gaged, and is based upon a ratio of the non-equilibrium current densities for base metal and aged material. The value of Gaged for base metal is approximately one (Gaged ~ 1) whereas the value of Gaged for fully-aged material is larger (Gaged ~ 2.5). Material with less precipitation than the fully aged material would have an intermediate value of Gaged (1 ? Gaged ? 2.5). Assume that Gaged is uniformly distributed between these limits and that this distribution is half uncertainty and half variability.</p> <p>Using this enhancement factor results in a waste package life than is in excess of 10,000 years.</p>	All data considered	Low		
Waste Package	3	Somewhat conservative	<p>Drift assumed to be wet at 50% relative humidity. This controls the chemical composition of water reacting with waste form.</p> <p>Provides a first attempt to model the transition from dry to wet conditions.</p>		Low		

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Waste Package	4 Conservative	The environments for general/local corrosion and SCC tests are aggressive, yet plausible under repository conditions. These environments assume that the drip shields are not present: - pH in the range of 12-13 - Sodium nitrate solution with no effect of buffering - Boiling point of about 120c	The materials testing program uses a wide range of water chemistries. Within these chemistries, the aggressive environments described here have exhibited significant general corrosion and SCC behavior. Conversely, in more benign environments has been shown not to occur. These aggressive environments are the best estimate of the worst case conditions that the waste package would experience under repository conditions. Even testing under these conditions, results have indicated that the waste package life is well in excess of 10,000 years.	No	Low	N/A	N/A
Waste Package	5 Conservative	No credit is taken for crack initiation in stress corrosion cracking (SCC) modeling. A surface crack is assumed to exist on the onset of SCC.	No modeling technique currently exists to predict crack initiation times for SCC. Taking no credit for crack initiation is conservative, since shortens the estimated life of a component. Using this approach, the waste package lifetime is well in excess of 10,000 years.	No	Low	N/A	N/A