7. REFERENCES

The following is a list of the references cited in this document. Column 1 represents the unique six digit DIRS number, which is placed in the text following the reference callout (e.g., CRWMS M&O 2000 [144054]). The purpose of these numbers is to assist the reader in locating a specific reference. Within the reference list, multiple sources by the same author (e.g., CRWMS M&O 2000) are ordered numerically by the DIRS number.

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7.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

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7.3 SOURCE DATA, LISTED BY TRACKING NUMBER

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149980 GS971000012847.004. Water Quality Data Collected from Springs and Wells in the Yucca Mountain Region from May 6, 1997 to May 15, 1997. Submittal date: 10/23/1997.

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149557 LA0003JC831362.001. Preliminary Matrix Diffusion Coefficients for Yucca Mountain Tuffs. Submittal date: 4/10/2000.

147285 LA0003MCG12213.002. Cumulative Probabilities for Colloid Transport Between One Matrix and Another Calculated from Interpolation of Pore Volume Data from Yucca Mountain Hydrologic (Stratigraphic) Samples. Submittal date: 03/10/2000.

149593 LA0004FP831811.002. Volume of Volcanic Centers in the Yucca Mountain Region. Submittal date: 04/14/2000.

151391 LA0004FP831811.004. Summary Frequencies of Disruptive Volcanic Events. Submittal date: 04/25/2000.

146932 LA9911GZ12213S.001. SZ Flow and Transport Model. Submittal date: 12/23/1999.

144279 LAFP831811AQ97.001. Chemical and Geochronology Data for the Revision and Final Publication of the Volcanism Synthesis Report. Submittal date: 08/29/1997.

141284 LL000112205924.112. Long Term Corrosion Test Facility Data. Submittal date: 01/25/2000.

142902 LL991109851021.095. Colloid Size and Concentration Investigations in Scientific Notebook SN 1381. Submittal date: 01/10/2000.

144927 LL991212305924.108. Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier. Submittal date: 12/20/1999.

144567 MO0001SPASUP03.001. Data to Support Calculation of Probability and Size of Defect Flaws in Waste Package Closure Welds to Support WAPDEG Analysis. CAL-EBS-PA-000003 REV 00. Submittal date: 01/31/2000.

150755 MO0002SPADVE03.001. Disruptive Volcanic Event BDCF. Submittal date: 02/14/2000.

149168 MO0002SPALOO46.010. Lookup Tables for PH, CL, and Ionic Strength Predicted by Precipitates/Salts Model for THC Abstraction. Submittal date: 02/07/2000.

148338 MO0002SPASDC00.002. Self-Diffusion Coefficient of Water. Submittal date: 02/24/2000.

150886 MO0003RIB00083.000. Dissolution Rate and Waste Form Degredation. Submittal date: 03/14/2000.

148872 MO0003SPAABS07.006. Abstracted BDCF Distributions with Soil Erosion for Use in TSPA-SR. Submittal date: 03/23/2000. Submit to RPC URN-0560

148453 MO0003SPAABS08.004. Abstracted BDCF Distributions for Use in TSPA-SR. Submittal date: 03/21/2000. Submit to RPC URN-0561

147949 MO0003SPAHIG12.002. Highest and Lowest Observed or Expected Masses of Iron-(hydr)Oxide Colloids Per Unit Volume or Mass of Water. Submittal date: 03/02/2000.

147952 MO0003SPAHLO12.004. Highest and Lowest Observed or Expected Groundwater Colloid Masses Per Unit Volume or Mass of Water; Values of Ionic Strength Above Which Groundwater Colloid Dispersions Are Unstable and Below Which Groundwater Colloid Dispersions Are Stable (Within Defined pH Range). Submittal date: 03/16/2000.

147951 MO0003SPAION02.003. Values Of Ionic Strength That Define The Stability Limits Of Iron-(Hydr)Oxide Colloids. Submittal date: 03/03/2000.

147953 MO0003SPALOW12.001. Lowest Observed or Expected Concentration of Radionuclide Element Rn Associated with Waste-Form Colloids. Submittal date: 03/02/2000.

148992 MO0003SPAPCC03.004. Supporting Media for Abstraction of Models for Pitting and Crevice Corrosion of Drip Shield and Waste Package Outer Barrier. Submittal date: 03/31/2000.

151075 MO0003SPASGU01.003. Stochastic Groundwater Usage in Amargosa Valley for TSPA-SR. Submittal date: 03/21/2000. Submit to RPC URN-0562

147299 MO0003SPASUP02.003. Supporting Media for Calculation of General Corrosion Rate of Drip Shield and Waste Package Outer Barrier to Support WAPDEG Analysis. Submittal date: 03/02/2000.

149092 MO0004MWDRIFM3.002. Results of the Yucca Mountain Probabilistic Seismic Hazard Analysis (PSHA). Submittal date: 04/14/2000.

148923 MO0004SPABDCFS.001. Preliminary Biosphere Dose Conversion Factors (BDCFS) to be Used in the TSPA for SR. Submittal date: 04/10/2000.

151368 MO0004SPACLD07.043. Clad Degradation - Summary and Abstraction. Submittal date: 04/04/2000. Submit to RPC URN-0563

151713 MO0004SPASOL10.002. Radionuclide Solubility Limits. Submittal date: 04/24/2000.

151768 MO0006SPAPVE03.001. Preliminary Volcanic Eruption Biosphere Dose Conversion Factors. Submittal date: 06/15/2000. Submit to RPC URN-0565

151712 MO0007RIB00091.000. Defense High Level Waste Glass Degradation. Submittal date: 07/26/2000.

151812 MO0008SPATHS03.001. Thermal-Hydrological Sensitivity Calculations for Various Ventilation Times, Lineal Heat Loading, and Infiltration Rates in Support of the Report CAL-EBS-HS-000003. Submittal date: 08/24/2000. Submit to RPC URN-0657

153039 MO0009MWDPEN01.009. Pena Blanca Natural Analogue Modeling of the Nopal I Uranium Deposit. Submittal date: 09/15/2000. Submit to RPC URN-0668

152884 MO0010MWDSUP04.010. Supporting Data for Abstraction of Models of Stress Corrosion Cracking of Drip Shield and Waste Package Outer Barrier and Hydrogen Induced Corrosion of Drip Shield. ANL-EBS-PA-000004 REV 00 ICN 01. Submittal date: 10/25/2000. Submit to RPC URN-0646

153127 MO0010MWDWAP01.009. WAPDEG models for tspa-sr. ---*.gsm files are goldsim 6.04.007/ WAPDEG 4.0 inputs and outputs---*.jnb files are sigmaplot 4.0 graphs---files in the runfiles directory are WAPDEG 4.0 input files and dlls---files in the prewap_for_no_backfill directory are for the prewap routine. Submittal date: 10/24/2000. URN-0723

152605 MO0010SPASIL02.002. Silica Adjusted General Corrosion Rates of Alloy 22 and Titanium Grade 7. Submittal date: 10/10/2000.

139569 MO9911SPACDP37.001. In-Package Chemistry Abstraction for Co-Disposal Packages. Submittal date: 11/24/1999.

148596 MO9912SPAPAI29.002. PA Initial Abstraction of THC Model Chemical Boundary Conditions. Submittal date: 01/11/2000.

147818 SN0001T0801500.001. Calculation Tables for the Number of Waste Packages Hit by Igneous Intrusion. Submittal date: 01/21/2000.

147198 SN0001T0872799.006. In-Drift Thermodynamic Environment and Percolation Flux. Submittal date: 01/27/2000.

146931 SN0002T0571599.002. Uncertainty Distributions for Stochastic Parameters. Submittal date: 02/28/2000.

149556 SN0003T0503100.001. Weighting Factors for Low, Middle and High Climate Infiltration Rate Maps. Submittal date: 03/20/2000.

151021 SN0003T0810599.010. Revised Average Radionuclide Activities for Commercial Spent Nuclear Fuel (CSNF) and Co-Disposal Waste Packages for Total System Performance Assessment-Site Recommendation (TSPA-SR) and Final Environmental Impact Statement (TSPA-FEIS). Submittal date: 03/15/2000.

149288 SN0004T0501600.004. Updated Results of the Base Case Saturated Zone (SZ) Flow and Transport Model. Submittal date: 04/10/2000.

151515 SN0004T0501600.005. Updated Input Files to the Base Case Saturated Zone (SZ) Flow and Transport Model for TSPA Abstractions. Submittal date: 04/10/2000.

149254 SN0004T0571599.004. Uncertainty Distributions for Stochastic Parameters Revision to Include New U Sorption Coefficients in the Alluvium and Supporting Electronic Files. Submittal date: 04/10/2000.

150856 SN0006T0502900.002. Updated Igneous Consequence Data for Total System Performance Assessment-Site Recommendation (TSPA-SR). Submittal date: 06/15/2000.

146900 SN9908T0581699.001. Files to Support 1-D Comparison Between FEHM Particle Tracking and T2R3D Advective-Dispersive Transport Simulations Along SD-9. Submittal date: 08/16/1999.

132867 SN9908T0581999.001. Recharge and Lateral Groundwater Flow Boundary Conditions for the Saturated Zone (SZ) Site-Scale Flow and Transport Model. Submittal date: 08/19/1999.

108437 SN9908T0872799.004. Tabulated In-Drift Geometric and Thermal Properties Used in Drift-Scale Models for TSPA-SR (Total System Performance Assessment-Site Recommendation). Submittal date: 08/30/1999.

126110 SN9910T0581699.002. Post-Processed Flow Fields for RIP: Developed Data from AMR U0125 (Abstract Flow Fields for RIP). Submittal date: 10/15/1999.

146902 SN9912T0511599.002. Revised Seepage Abstraction Results for TSPA-SR (Total System Performance Assessment-Site Recommendation). Submittal date: 12/15/1999.

136370 SN9912T0512299.002. Annual Surface Soil Removal Estimates for Amargosa Valley Soils. Submittal date: 12/09/1999.

143657 SNT05070198001.001. Three-Dimensional Rock Property Models for FY98. Submittal date: 07/30/1998.

7.4 OUTPUT DATA

151716 MO0007MWDTSP01.002. TSPA SR, REV 00B, Case SR00 049NM5 Base Case; Nominal Scenario; No Backfill; 300 Realizations; 100,000 Years. Submittal date: 07/19/2000. Submit to RPC URN-0566

151706 MO0007MWDTSP01.003. TSPA SR, REV 00B1, CASE SR00 091NM5 Base Case; Nominal Scenario; No Backfill; 300 Realizations; 100,000 Years. Submittal date: 07/19/2000. Submit to RPC URN-0567

152184 MO0008MWDBARRI.000. Barrier Sensitivity Cases TSPA SR, REV 00B Nominal Scenario; 100,000 Years. Submittal date: 08/31/2000. Submit to RPC URN-0578

152186 MO0008MWDHUMAN.000. Human Intrusion Cases TSPA SR, REV 00B Human Intrusion Scenario, No Backfill. Submittal date: 08/31/2000. Submit to RPC URN-0576

152185 MO0008MWDIGNEO.000. Igneous Sensitivity Cases TSPA SR, REV 00B Igneous Scenario; No Backfill, 300 Realization, 100,000 Years. Submittal date: 08/31/2000. Submit to RPC URN-0577

151720 MO0008MWDIM501.006. TSPA SR, REV 00B, Case SR00_016IM5.---Base Case; Igneous Scenario; No Backfill; 300 Realizations; 100,000 Years. Submittal date: 08/15/2000. Submit to RPC URN-0568

152188 MO0008MWDJUVEN.000. Juvenile Failure Cases TSPA SR, REV 00B Nominal Scenario; No Backfill, 100 Realizations, 100,000 Years. Submittal date: 08/31/2000. Submit to RPC URN-0573

152187 MO0008MWDNEUTR.000. RSS4 Neutralization Cases TSPA SR, REV 00B Nominal Scenario; No Backfill, 100 Realizations, 100,000 Years. Submittal date: 08/31/2000. Submit to RPC URN-0575

151714 MO0008MWDNM501.005. TSPA SR, REV 00B, Case SR00_047NM5.---Base Case; Nominal Scenario; No Backfill; 100 Realizations; 100,000 Years. Submittal date: 08/15/2000. Submit to RPC URN-0569

151719 MO0008MWDNM501.007. TSPA SR, REV 00B, Case SR00_161NM5.---EBS Only Run for Chemistry Plots---Base Case; Nominal Scenario; No Backfill; 300 Realizations; 100,000 Years. Submittal date: 08/15/2000. Submit to RPC URN-0570

153123 MO0009MWDIM401.015. TSPA_SR, REV. 00B, CASE SR00_005IM4, BASE CASE; IGNEOUS SCENARIO; NO BACKFILL; 5000 REALIZATIONS; 50,000 YEARS. Submittal date: 09/20/2000.

153132 MO0009MWDNM501.017. TSPA_SR, REV. 00B1, CASE SR00_108NM5, BASE CASE; NOMINAL SCENARIO; NO BACKFILL; 500 REALIZATIONS; 100,000 YEARS. Submittal date: 09/20/2000.

152839 MO0009MWDNM601.018. Million-Year Sensitivity Cases for the Nominal Scenario. TSPA_SR, Rev. 00B, Case SR00_023NM6 and Case SR00_024NM6. Submittal date: 09/20/2000. Submit to RPC

153131 MO0009MWDTSP01.019. Regression analyses and classification tree analyses for TSPA_SR. Submittal date: 09/20/2000.

153128 MO0011MWDMIL01.022. MILLION-YEAR SENSITIVITY CASES FOR THE NOMINAL SCENARIO, SECONDARY PHASES AND LONG-TERM CLIMATE CHANGE, WITH FIXED PU242 BDCF. TSPA_SR MODEL CASES SR00_034NM6 AND SR00_035NM6. Submittal date: 11/06/2000.

153126 MO0011MWDNM601.021. TSPA_SR MODEL CASE SR00_042NM6. GROUNDWATER PROTECTION BASE CASE; NOMINAL SCENARIO; NO BACKFILL; 300 REALIZATIONS; 1,000,000 YEARS. Submittal date: 11/06/2000.

153269 MO0011MWDREG01.001. REGRESSION ANALYSES AND CLASSIFICATION TREE ANALYSES FOR TSPA_SRCR, REV 00, ICN 01. Submittal date: 11/21/2000.

APPENDIX A
GLOSSARY

APPENDIX A

GLOSSARY

The glossary is divided into two sections. Section A.1 is a general glossary of terms used in the TSPA-SR. Section A.2 contains a listing of statistical terms that are used in or are relevant to other statistical terms used in the TSPA-SR. Definitions are written with emphasis on the relationship of the term to the TSPA-SR process and are taken from previous performance assessment documentation, where possible, or from standard reference materials.

Many of the definitions in this Glossary are Yucca Mountain Site Characterization Project specific.

A.1 GENERAL GLOSSARY

This section is a general listing of terms used in the TSPA-SR. Statistical terms are in Section A.2.

Abiotic	Characterized by the absence of living organisms.
Absorbed Dose	The energy absorbed from ionizing radiation per unit mass of irradiated material. Units of absorbed dose are the rad and the gray (Gy).
Abstracted Model	Model that reproduces, or bounds, the essential elements of a more detailed process model and captures uncertainty and variability in what is often, but not always, a simplified or idealized form. See Abstraction.
Abstraction	Distillation of the essential components of a process model into a suitable form for use in a total system performance assessment. The distillation must retain the basic intrinsic form of the process model but does not usually require its original complexity. Model abstraction is usually necessary to maximize the use of limited computational resources while allowing a sufficient range of sensitivity and uncertainty analyses.
Actinide	A series of chemically similar, mostly synthetic, radioactive elements with atomic numbers from 89 (actinium) through 103 (lawrencium).
Activity	Cumulative curie count. See Radioactivity.
Adsorb	To collect a gas, liquid, or dissolved substance on a surface as a condensed layer.
Adsorbate	A substance that is adsorbed. See Adsorb.

Adsorbent	A substance upon which another substance is adsorbed. See Adsorb.
Adsorption	Transfer of solute mass, such as radionuclides, in groundwater to the solid geologic surfaces with which it comes in contact. The term sorption is sometimes used interchangeably with this term.
Adsorption Isotherm	Relationship of the quantity of an adsorbed component to its quantity in the fluid phase (expressed in concentration) at constant temperature (i.e., under isothermal conditions).
Adsorption Coefficient	See Sorption Coefficient.
Advection	The process in which solutes are transported by the motion of flowing groundwater. Advection in combination with dispersion (hydrodynamic dispersion) controls flux into and out of the elemental volumes of the flow domain in groundwater transport models. The term convection is sometimes used for advection but is not used interchangeably in the TSPA-SR.
Advisory Committee On Nuclear Waste	A committee established under the U.S. Nuclear Regulatory Commission to provide independent reviews of, and advice on, nuclear waste facilities, including application to such facilities of 10 CFR Parts 60 and 61 (disposal of high-level radioactive wastes in geologic repositories and land disposal of radioactive waste) and other applicable regulations and legislative mandates.
Aerobic	Living or active only in the presence of oxygen, as used in reference to bacteria that require oxygen; a condition in which oxygen is present.
Air Mass Fraction	Mass of air divided by the total mass of gas (typically air plus water vapor) in the gas phase. This expression gives a measure of the "dryness" of the gas phase, which is important in waste package corrosion models.
Algorithm	(1) The set of well-defined rules that governs the solution of a problem in a finite number of steps. (2) A mathematical formulation of a model of a physical process.
Alkaline	See pH.
Alloy-22	See Inner Barrier.

Alluvium	Sedimentary material (clay, mud, sand, silt, gravel) deposited by flowing water or by wind.
Alternative	Plausible interpretations or designs based on assumptions other than those used in the base case that could also fit or be applicable based on the available scientific information. When propagated through a quantitative tool such as performance assessment, alternative interpretations can illustrate the significance of the uncertainty in the base case interpretation chosen to represent the repository's probable behavior.
Ambient	(1) Undisturbed, natural conditions such as ambient temperature caused by climate or natural subsurface thermal gradients. (2) Surrounding conditions.
Anaerobic	(1) Living or active only in the absence of oxygen; used in reference to bacteria that do not require oxygen. (2) A condition in which oxygen is absent.
Anionic	An atom or group of atoms having a negative charge.
Anisotropy	The condition in which physical properties vary when measured in different directions or along different axes. For example, in a layered rock section the permeability is often anisotropic in the vertical direction from layer to layer but is isotropic in the horizontal direction within a layer.
Annual Dose	For human exposure scenarios, a measure of an individual's exposure to radiation in a year.
Annual Committed Effective Dose Equivalent	Composed of terms in 40 CFR 191[103644], Subpart B, in which an annual committed effective dose means the committed effective dose caused by 1-year intake from released radionuclides plus the annual effective dose caused by direct radiation from facilities or activities. See Effective Dose Equivalent and Committed Dose Equivalent.
Annual Frequency	Number of occurrences on an annual basis.
Anthropogenic	Alterations of the environment resulting from the presence or activities of humans.
Aqueous	Pertaining to water, such as aqueous phase, aqueous species, or aqueous transport.

Aquifer	A subsurface, saturated rock unit (formation, group of formations, or part of a formation) of sufficient permeability to transmit groundwater and yield usable quantities of water to wells and springs.
Areal Mass Loading	Used in thermal loading calculations, the amount of heavy metal (usually expressed in metric tons of uranium or equivalent) emplaced per unit area in the potential repository. This number is 85 metric tons of uranium (MTU) per acre and remains a constant value over time for calculations in which the amount of waste per acre in the potential repository is assumed to remain constant.
AREST-CT Computer Program	A general modeling code that considers both equilibrium and kinetically controlled chemical reactions between solid phases, aqueous solutions, and gas under flowing conditions.
Average Individual	An individual representative of the lifestyle in the Amargosa Valley with regard to eating, drinking, and other activities that may be relevant in a human exposure scenario as determined by a survey of Amargosa Valley residents by TSPA-SR researchers.
Backfill	The general fill that is placed in the excavated areas of the underground facility. If used, the backfill for the potential repository may be tuff or other material.
Background Radiation	Radiation arising from natural radioactive material always present in the environment, including solar and cosmic radiation, radon gas, soil and rocks, and the human body.
Basalt	A dark, fine-grained igneous rock originating from a lava flow or minor intrusion, composed mainly of plagioclase clinopyroxene and sometimes olivine, and often displaying a columnar structure.
Base Case	The sequence of anticipated conditions expected to occur in and around the potential repository, without the inclusion of unlikely or unanticipated features, events, or processes. The components that contribute to the base case model are intended to encompass this probable behavior of the potential repository, based on the range of uncertainty for the various parameters and conceptual models used in constructing the base case. In this sense the term is synonymous with nominal case. Base case is also used as a general modeling term to describe a case against which other cases using a different set of assumptions or inputs is compared. Thus, it is possible to have a base case analysis of both nominal and disruptive scenarios.

Base Case Model	A computer model that represents an assessment of the most likely range of behavior for the overall potential repository system and is a combination of the most likely ranges of behavior for the various component models, processes, and associated parameters.
Biosphere	The ecosystem of the earth and the living organisms inhabiting it.
Biosphere Dose Conversion Factor	A multiplier used in converting a radionuclide concentration at the geosphere/biosphere interface into a dose that a human would experience for all pathways considered, with units expressed in terms of annual dose (i.e., the effective dose equivalent) per unit concentration. Depends on the radionuclide(s), pathway(s), climate, and other factors. A key assumption is that the dose is a linear function of concentration at the geosphere/biosphere interface.
Boiling Regime	One of two divisions (the other being the cooling regime) used to delineate the reactions between the gas, water, and minerals in the rock that occur as the system heats and boiling of the pore water occurs through time.
Borehole	A hole drilled from the surface for purposes of collecting information about an area's geology or hydrology. Sometimes referred to as a drillhole or well bore.
Borosilicate Glass	High-level radioactive waste matrix material in which boron takes the place of the lime used in ordinary glass mixtures.
Boundary Condition	For a model, the establishment of a set condition (set value), often at the geometric edge of the model, for a given variable. An example is using a specified groundwater flux from infiltration as a boundary condition for a flow model.
Breach	An opening in the waste package caused by gradual degradation of the outer and inner barriers that allows the waste to be exposed, and possibly released, to the external environment.
Breakthrough	The time at which the concentration of a substance, usually in groundwater, arrives at a particular point of interest after having been tracked as it moves through space.

Breakthrough Curve	A means of describing transport of radionuclides along a geosphere pathway by constructing a curve that is a cumulative probability distribution. The breakthrough curve calculation includes the effects of all flow modes, flow in rock matrix, flow in fractures, and retardation and determines the expected proportion of the radionuclide mass that has traveled the pathway at any specified time.
Buoyant Convection	Fluid movement, typically in the gas phase, in response to a density gradient in a gravitational field. An example is the rising of air when it becomes less dense because of heating followed by its subsequent fall when it cools and becomes denser.
Burnup	A measure of nuclear-reactor fuel consumption expressed either as the percentage of fuel atoms that have undergone fission or as the amount of energy produced per unit weight of fuel.
Calcite	A crystalline mineral composed of calcium carbonate ($CaCO_3$).
Calibration	(1) The process of comparing the conditions, processes, and parameter values used in a model against actual data points or interpolations (e.g., contour maps) from measurements at or close to the site to ensure that the model is compatible with "reality" to the extent feasible. (2) For tools used for field or lab measurements, the process of taking instrument readings on standards known to produce a certain response to check the accuracy and precision of the instrument.
Canister	The structure surrounding the waste (e.g., high-level radioactive waste immobilized in glass rods) that facilitates handling, storage, transportation, and/or disposal. A metal receptacle with the following purpose: (1) a pour mold for solidified high-level radioactive waste, and (2) for spent nuclear fuel, structural support for loose rods, non-fuel components, or containment of radionuclides during postclosure operations.
Capillarity	(1) A phenomenon that results from the force of mutual attraction (cohesion) between water molecules in conjunction with the force of molecular attraction (adhesion) between water and different solid materials. (2) A means by which water will rise in small diameter tubes and, in combination with the effects of gravity, a means of water movement in the unsaturated zone.
Capillary Barrier	A contact in the unsaturated zone between a geologic unit containing relatively small-diameter openings and a unit containing relatively large-diameter openings across which water does not flow.

Capillary Force	In the unsaturated zone, the forces acting on moisture that can be attributed to the attraction between rock grain, or matrix, surfaces and water.
Capillary Pressure	The difference in a fluid pressure at a given point between a nonwetting phase such as air and a wetting phase such as water.
Capillary Suction	A condition in unsaturated rocks in which the attraction of fluids to particle surfaces is stronger than the force of gravity on the fluid.
Carbon Steel	A steel that is tough but malleable and contains a small percentage of carbon. The inner barrier of waste packages is composed of carbon steel.
Carbonate	Any compound formed by the reaction of carbonic acid with either a metal or an organic compound. Any compound containing the carbonate ion.
Carbonation	A chemical process involving the change of concrete and cement into a carbonate.
Carboniferous	Producing, containing, or pertaining to carbon or coal.
Cationic	An atom or group of atoms having a positive charge.
Center For Nuclear Waste Regulatory Analyses	A federally funded research and development center in San Antonio, Texas, sponsored by the Nuclear Regulatory Commission to provide the Nuclear Regulatory Commission with technical assistance for the repository program.
Ceramic Coating	A layer of ceramic material such as alumina that has been applied to a metallic product to protect against extremely high temperatures and corrosion.
Cladding	The metallic outer sheath of a fuel element generally made of stainless steel or a zirconium alloy. It is intended to isolate the fuel element from the external environment.
Clay	A rock or mineral fragment of any composition that is smaller than very fine silt grains, having a diameter less than 0.00016 in. (1/256 mm). A clay mineral is one of a complex and loosely defined group of finely crystalline hydrous silicates formed mainly by weathering or alteration of primary silicate minerals. They are characterized by small particle size and their ability to adsorb large amounts of water or ions on the surface of the particles.

Climate	Weather conditions, including temperature, wind velocity, precipitation, and other factors, that prevail in a region.
Climate Proxies	The physical remains of substances that carry the imprint of past climates.
Climate States	Representations of climate conditions.
Code (Computer)	The set of commands used to solve a mathematical model on a computer.
Codisposal	A packaging method for disposal of radioactive waste in which two types of waste, such as commercial spent nuclear fuel and defense high-level radioactive waste, are combined in disposal containers. Codisposal takes advantage of otherwise unused space in disposal containers and is more cost-effective than other methods to limit the reactivity of individual waste packages.
Coefficient of Multiple Determination	See Section A.2 of this glossary.
Colloid	As applied to radionuclide migration, a colloidal system is a group of large molecules or small particles that have at least one dimension with the size range of 10^{-9} to 10^{-6}m that are suspended in a solvent. Naturally occurring colloids in groundwater arise from clay minerals such as smectites and illites. Colloids that are transported in groundwater can be filtered out of the water in small pore spaces or very narrow fractures because of the large size of the colloids.
Colloid-Facilitated, Radionuclide Transport Model	A model that represents the enhanced transport of radionuclides by particles that are colloids.
Commercial Spent Nuclear Fuel	Commercial nuclear fuel rods that have been removed from reactor use.
Committed Dose Equivalent	The dose equivalent that is committed to specific organs or tissues that will be received from an intake of radioactive material by an individual during the 50 years following the intake.
Committed Effective Dose Equivalent	The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

Complementary Cumulative Distribution Function	See Section A.2 of this glossary.
Component Models	The 9 process models that are run separately and then combined for running in the TSPA-SR GoldSim computer model.
Concentration Gradient	For a substance dissolved in a solute, the change in concentration of the substance over a distance.
Conceptual Model	A set of qualitative assumptions used to describe a system or subsystem for a given purpose. Assumptions for the model should be compatible with one another and fit the existing data within the context of the given purpose of the model.
Conduction	Transport of heat in static groundwater, controlled by the thermal conductivity of the geologic formation and the contained groundwater and described by a linear law relating heat flux to temperature gradient.
Confidence	See Section A.2 of this glossary.
Confidence Interval	See Section A.2 of this glossary.
Consequence	A measurable outcome of an event or process that, when combined with the probability of occurrence, gives risk.
Conservative Assumption	(1) An assumption that has the effect of maximizing the calculated amount of radionuclides released from the hypothetical repository to the accessible environment. (2) An assumption that uses uncertain inputs and does not attempt to include any potentially beneficial effects.
Conservative Tracer	Substances with no retardation effect. See Tracer.
Continuous Random Variable	See Section A.2 of this glossary.
Continuum Model	A model that represents fluid flow through numerous individual fractures and matrix blocks by approximating them as continuous flow fields.

Convection | (1) Thermally driven groundwater flow or a heat-transfer mechanism for a gas phase. The bulk motion of a flowing fluid (gas or liquid) in the presence of a gravitational field, caused by temperature differences that, in turn, cause different areas of the fluid to have different densities (e.g., warmer is less dense). (2) One of the processes that moves solutes in groundwater. See Transport.

Convolution Integral Method | (1) A computational method used to calculate the radionuclide concentration in the saturated zone as it changes with time. (2) The abstraction method for the saturated zone flow and transport component model of the TSPA-SR GoldSim computer model.

Cooling Regime | One of two divisions (the other being the boiling regime) used to delineate the reactions between the gas, water, and minerals in the rock, which occur as the system cools after heating and boiling of the pore water occurs through time.

Correlation Coefficient | See Section A.2 of this glossary.

Corrosion | The process of dissolving or wearing away gradually, especially by chemical action.

Corrosion Model (for inner barrier and outer barrier) | A model that includes the time histories of first and subsequent pit and patch penetrations for the waste package layers.

Corrosion Resistant Material | A material that develops a protective film on its surface, creating a high resistance to corrosion. This material, usually the nickel-base alloy, Alloy-22, is used as the outer barrier of the two-layer waste-disposal container.

Coupling | The ability in a performance assessment to assemble separate analyses so that information can be passed among them to develop an overall analysis of system performance.

Covariance | See Section A.2 of this glossary.

Crevice Corrosion | A type of localized corrosion that forms in splits or cracks.

Critical Event | See Criticality.

Critical Group	With regard to annual dose, the maximally exposed individuals. A group of members of the public whose exposure is reasonably homogeneous and includes individuals receiving the highest dose. The individuals making up the critical group may change with changes in source term and pathway.
Criticality	(1) A condition that would require the original waste form, which is part of the waste package, to be exposed to degradation followed by conditions that would allow concentration of sufficient nuclear fuel, the presence of neutron moderators, the absence of neutron absorbers, and favorable geometry. (2) The condition in which nuclear fuel sustains a chain reaction. It occurs when the number of neutrons present in one generation cycle equals the number generated in the previous cycle. The state is considered critical when a self-sustaining nuclear chain reaction is ongoing.
Critical Population	See Critical Group.
Cumulative Distribution Function	See Section A.2 of this glossary.
Cumulative Probability	See Section A.2 of this glossary.
Cumulative Release	The sum of the radionuclide curies released over a certain period at a specific location.
Curie	A unit of radioactivity equal to 37 billion disintegrations per second.
Darcy's Law	Used in hydrology to describe fluid flow in a porous medium. Darcy's Law states that the fluid velocity is directly proportional to the hydraulic gradient between the two locations.
Data	Facts or figures measured or derived from site characteristics or standard references from which conclusions may be drawn. Parameters that have been derived from raw data are sometimes, themselves, considered to be data.
Decay	See Radioactive Decay.
Deep Percolation	Precipitation moving downward, below the plant-root zone, toward storage in subsurface strata.

Defense in Depth	The term used to describe the property of a system of multiple barriers to mitigate uncertainties in conditions, processes, and events by employing barriers that are redundant and independent, such that failure in any one barrier does not result in failure of the entire system.
Defense Spent Nuclear Fuel	See DOE Spent Nuclear Fuel.
Department of Energy, U.S. (DOE)	A Cabinet-level agency of the United States federal government charged with the responsibilities of energy security, national security, and environmental quality.
Design Concept	As mentioned in the Energy and Water Development Appropriations Act, consists of the subsurface repository layout, the engineered barrier segments, and the waste package.
Desorption	A physical or chemical process by which a substance that has been adsorbed or absorbed by a liquid or solid material is removed from the material.
Deterministic	A single calculation using only a single value for each of the model parameters. A deterministic system is governed by definite rules of evolution leading to cause and effect relationships and predictability. Deterministic calculations do not account for uncertainty in the physical relationships or parameter values.
Diffusion	(1) The spreading or dissemination of a substance. (2) The gradual mixing of the molecules of two or more substances due to random thermal motion.
Diffusive Transport	Movement of solutes due to their concentration gradient. The process in which substances carried in groundwater move through the subsurface by means of diffusion because of a concentration gradient.
Diffusivity	A measure of the rate of heat diffusion. It varies with the nature of the involved atoms, the structure, and changes in temperature.
Dike	A tabular body of igneous rock that cuts across the structure of adjacent rocks or cuts massive rocks. Most dikes are caused by the intrusion of magma. Some dikes occur as columnar structures.
Dimensionality	Modeling in one, two, or three dimensions.

Dimensionality Abstraction	An abstraction in which there is a change in the dimensions of a problem, such as from three dimensional to two dimensional, for modeling purposes. This is done either to simplify the problem or reduce the computational requirements of the problem to implement modeling results in a more efficient or usable form.
Discrete Heat Source	An attribute of drift-scale thermal hydrology models in which the model includes a representation of heat output for discrete waste packages with varying heat outputs depending on the type and amount of waste in the package.
Dispersion (Hydrodynamic Dispersion)	(1) The tendency of a solute (substance dissolved in groundwater) to spread out from the path it is expected to follow if only the bulk motion of the flowing fluid (defection) moved it. The tortuous path the solute follows through openings (pores and fractures) causes part of the dispersion effect in the rock. (2) The macroscopic outcome of the actual movement of individual solute particles through a porous medium. Dispersion causes dilution of solutes, including radionuclides, in groundwater and is usually an important mechanism for spreading contaminants in low flow velocity situations.
Disposal Container	The container barriers or shells, spacing structures or baskets, shielding integral to the container, packing contained within the container, and other absorbent materials designed to be placed internal to the container or immediately surrounding the disposal container (i.e., attached to the outer surface of the container). The disposal container is designed to contain spent nuclear fuel and high-level radioactive waste, but exists only until the outer lid weld is complete and accepted. The disposal container does not include the waste form or the encasing containers or canisters (e.g., high-level radioactive waste pour canisters, DOE spent nuclear fuel codisposal canisters, multi-purpose canisters of spent nuclear fuel, etc.).
Dissolution	Change from a solid to a liquid state. Dissolving a substance in a solvent.
Distribution	See Section A.2 of this glossary.
Distribution Frequency	See Section A.2 of this glossary.
Disturbed Performance	Refers to the behavior of the system if perturbed by disruptive events such as human intrusion or natural phenomena such as volcanism, or nuclear criticality. This is as used in a description of scenario classes, scenarios, or features, events, or processes making up scenarios.

Disruptive Event	An unexpected event that, in the case of the potential repository, includes human intrusion, volcanic activity, seismic activity, and nuclear criticality. Disruptive events have two possible effects: (1) direct release of radioactivity to the surface or (2) alteration of the nominal behavior or the system. For the purposes of screening features, events, and processes for the total system performance assessment, a disruptive event is defined as an event that has a significant effect on the expected annual dose and that has a probability of occurrence during the period of performance less than 1.0 but greater than the cutoff of $10^{-4}/10^{4}$ year defined by the NRC at proposed 10 CFR 63.114(d) (64 FR 8640 [101680]).
Disruptive Event Scenario Class	The scenario, or set of related scenarios, that describes the behavior of the system if perturbed by disruptive events. The disruptive scenarios contain all disruptive features, events, and processes that have been retained for analysis.
Domain (Model)	(1) The set of elements that a mathematical model describes. (2) Individual process areas, such as the unsaturated zone flow domain.
DOE Spent Nuclear Fuel	Radioactive waste created by defense activities that consists of over 250 different types of spent nuclear fuel and is expected to contribute 2,333 metric tons of heavy metal (MTHM) to the total potential repository. The major contributor to this waste form is the N-reactor fuel currently stored at the Hanford Site..
Dose	The amount of radioactive energy that passes the exchange boundaries of an organism (e.g., skin and mucous membranes) and is taken into living tissues. Dose arises from a combination of the energy imparted by the radiation and the absorption efficiency of the affected organism or tissues. It is expressed in terms of units of the radiation taken in, the body weight or mass impacted, and the time over which the dose occurs or the impact is measured.
Dose Conversion Factor	(1) Any factor used to change an environmental measurement to dose in the appropriate units. (2) The multipliers that convert an amount of radionuclides ingested or inhaled to an estimate of dose.
Dose Equivalent	The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. See also Effective Dose Equivalent and Total Effective Dose Equivalent.
Dose Rate	An organism's exposure to radiation over time.

Downgradient	An area toward which water will tend to flow as the result of several factors. The most important factor is the elevation of water levels in wells in that area relative to other areas. The downgradient is the direction in which contaminants released from the potential repository at Yucca Mountain and migrating in the saturated zone might be expected to move. Based on current understanding of the hydraulic gradient below Yucca Mountain, downgradient is toward the south to southeast of the potential repository location in the area within about 5 km.
Drift	From mining terminology, a horizontal underground passage. The nearly horizontal underground passageways from the shaft(s) to the alcoves and rooms. Includes excavations for emplacement (emplacement drifts) and access (access mains).
Drift Scale	The scale of an emplacement drift, or approximately 5 m in diameter.
Drip Shield	A sheet of impermeable material placed above the waste package to prevent seepage water from directly contacting the waste packages.
Dripping Condition	Assumed for a certain fraction of the waste packages based on water seepage into a drift. The following set of assumptions apply: (1) a small number of the waste packages will be emplaced in drifts with fractures that periodically drip water, and water may drip on a certain fraction of these packages after emplacement; (2) if water drips onto a waste package, it is 100 percent wet from the dripping; and (3) the dripping rate, frequency of drip periods, and water chemistry (especially pH and chloride concentration) will contribute significantly to waste package degradation.
Dual Permeability Conceptual Model	A conceptual model of groundwater flow in which fractures and rock matrix are represented as separate, interacting continua, with no assumption of pressure equilibrium between fractures and rock matrix. This concept allows modeling groundwater flow as occurring mostly in the fractures, with less flow in the rock matrix depending on the degree of connection between the rock matrix and fractures and the capillary pressure gradient. The dual permeability model is one of the conceptual models for groundwater and heat flow for fractured, porous media.
Dual Permeability/Weeps Model	A dual-permeability approximation of the Weeps Model. Also see Dual Permeability Conceptual Model and Weeps Model.

Edge Effects	Conditions at the edges of the potential repository that are cooler and wetter because heat dissipates more quickly than at the center of the repository.
Effective Dose Equivalent	The sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.
Effective Porosity	The fraction of a given medium's porosity available for fluid flow and/or solute storage, as in the saturated zone.
Electric Power Research Institute	A nonprofit organization that serves as a research and development consortium serving the entire power industry, from power generation to delivery, to end use products and services. This group has performed an independent performance assessment on the Yucca Mountain site.
Elicitation	See Expert Elicitation.
El Niño	A complex set of changes in the water temperature in the Eastern Pacific equatorial region, producing a warm current. This occurs annually to some degree between October and February, but in some years intensifies and causes unusual storms and destruction of marine life.
Empirical Model	A model whose reliability is based on observation and/or experimental evidence and is not necessarily supported by any established theory or law. Validity or applicability of such an empirical model is normally limited to situations that lie within the range of the data that were used to develop the model.
Emplacement Drift	See Drift.
Energy Policy Act of 1992	Comprehensive energy legislation enacted in 1992. Section 801 of the Act directs the U.S. Environmental Protection Agency (EPA) to contract with the National Academy of Sciences to provide "findings and recommendations on reasonable standards that would govern the long-term performance of a repository at the Yucca Mountain site." The EPA Administrator is to promulgate public health and safety standards after the receipt of the findings and recommendations of the National Academy of Sciences, and these shall be the only standards applicable to the Yucca Mountain site.

Engineered Barrier Segments	As mentioned in the 1997 Energy and Water Development Appropriations Act, include (1) the invert and pedestal systems to support the waste package, (2) any packing or backfill materials that may be used within the drift, and (3) any drip shield that may be placed over or around the waste package.
Engineered Barrier System	The waste packages and the underground facility. The designed, or engineered, components of the disposal system and the waste package.
Engineered Barrier System Transport Model	A computer model that includes the key processes: (1) in-drift thermal hydrology and geochemistry, (2) degradation of the drip shield (if used), (3) degradation of the waste package and cladding, (4) alteration and dissolution of the waste form, (5) degradation of the invert, (6) mobilization of the radionuclides in the waste form, and (7) transport of radionuclides in the drift.
Enrichment	The percentage of the fuel matrix that is fissile.
Environmental Impact Statement (EIS)	A detailed written statement to support a decision to proceed with major Federal actions affecting the quality of the human environment. This is required by the National Environmental Policy Act of 1969 [103924]. The environmental impact statement describes:

> ...the environmental impact of the proposed action; any adverse environmental effects which cannot be avoided should the proposal be implemented; alternatives to the proposed action (although the Nuclear Waste Policy Act, as amended, precludes consideration of certain alternatives); the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Preparation of an environmental impact statement requires a public process that includes public meetings, reviews, and comments, as well as agency responses to the public comments.

Environmental Protection Agency (EPA), U.S.	The agency charged by the Nuclear Waste Policy Act of 1982, and subsequently by the Energy Policy Act of 1992, with promulgating generally applicable standards for protection of the general environment. The potential repository at Yucca Mountain is overseen by this agency.
Equilibrium	The state of a chemical system in which the phases do not undergo any spontaneous change in properties or proportions with time, a dynamic balance.
Equilibrium Batch Reactor	A concept describing the conditions in a computer model cell in which the value of any given parameter is homogeneous and in equilibrium throughout the cell area. Used when referring to concentration conditions within an individual cell during modeling of engineered barrier transport.
Equivalent Continuum Model	A conceptual model of groundwater and heat flow that is also called a composite porosity model. Key assumptions are that the temperatures and capillary pressures in the rock matrix and fractures are equal. Therefore, the fractures and matrix can be treated as a single composite material, and the hydraulic properties are a combined effect of both fracture and matrix properties.
Evapotranspiration	The combined processes of evaporation and plant transpiration that remove water from the soil and return it to the air.
Event Tree	A structurally tree-like diagram that is useful in representing sequences of events and their possible outcomes. Each node, or branching point, represents an event, such as volcanic activity, and each branch from that node represents one of its possible outcomes. Each branch can continue to branch many times. Each possible pathway along the tree, from beginning to end of a given line of branching, represents a specific scenario.
Events	(1) Occurrences that have a specific starting time and, usually, a duration shorter than the time being simulated in a model. (2) Uncertain occurrences that take place within a short time relative to the time frame of the model. For the purposes of screening features, events, and processes for the total system performance assessment, an event is defined to be a natural or anthropogenic phenomenon that has a potential to affect disposal system performance and that occurs during an interval that is short compared to the period of performance.
Expected Behavior	The nominal behavior of the potential repository system and the geologic barrier in the absence of disruptive events.

Expected Value — See Section A.2 of this glossary.

Expected Value Realization — The single realization derived by sampling all uncertain input parameters in the component models at the expected values of their ranges.

Expert Elicitation — A formal process through which expert judgment is obtained.

Exploratory Studies Facility — An underground laboratory at Yucca Mountain that includes a 7.9-km (4.9-mile) main loop (tunnel), a 2.8-km (1.75-mile) cross-drift, and a research alcove system constructed for performing underground studies during site characterization. The data collected will contribute toward determining the suitability of the Yucca Mountain site. Some or all of the Exploratory Studies Facility may eventually be incorporated into the potential repository.

External Criticality — A condition in which a critical configuration of fissile material occurs after this material is released from the waste packages. See also Criticality.

Far-Field — With reference to processes, those occurring at the scale of the mountain. The area of the geosphere and biosphere far enough away from the potential repository that, when numerically modeled, represents releases from the repository as a homogeneous, single-source effect.

Fast Path — Localized unsaturated zone flow pathways that might have high advective velocities. Fast paths move water, carrying radionuclides, through the unsaturated zone more quickly than if movement were predominantly through the pores of the rock matrix. Fractures are potential fast paths.

Fault (Geologic) — A fracture in rock along which movement of one side relative to the other has occurred.

Features — Physical, chemical, thermal, or temporal characteristics of the site or potential repository system.

For the purposes of screening features, events, and processes for the total system performance assessment, a feature is defined to be an object, structure, or condition that has a potential to affect disposal system performance.

FEHM Computer Code — The Finite Element Heat and Mass transfer computer code that is a process model for unsaturated flow and transport.

Fick's Law	The mass of solute diffusing is proportional to the concentration gradient when a solute in water moves from an area of greater concentration toward an area of lesser concentration by molecular diffusion.
Film Flow	Movement of water as a thin film along a surface.
Finite Difference Computer Code	A commonly used numerical method for solving flow problems. An approximating technique in which algebraic equations are used for approximating the partial differential equations that comprise mathematical models in order to produce a form of the problem that can be solved on a computer. For this type of approximation, the real world area being modeled is formed into a grid with cubical or rectangular blocks. Values for parameters, such as head, are computed at the grid nodes with the same value also being the average for the area surrounding the node.
Finite Element Computer Code	A commonly used numerical method for solving flow problems. An approximating technique in which algebraic equations are used for approximating the partial differential equations that comprise mathematical models in order to produce a form of the problem that can be solved on a computer. For this type of approximation, the real world area being modeled is formed into a grid with irregularly shaped blocks. This method provides an advantage in handling irregularly shaped boundaries, internal features such as faults, and simulation of point sources (of contamination), seepage faces, and moving water table elevations. Values for parameters are frequently calculated at nodes for convenience, but are defined everywhere in the blocks by means of interpolation functions.
Fissile	Sometimes used as a synonym for fissionable (see Fission). Fissile material can undergo fission with neutrons of any energy, including thermal, or slow, neutrons. The three primary materials in this category are uranium-233, uranium-235, and plutonium-239. Fissionable nuclides require fast neutrons to undergo fissions.
Fissile Material	See Fissile.
Fission	The splitting of a nucleus into at least two other nuclei, resulting in the release of two or three neutrons and a relatively large amount of energy.
Fission Products	A complex mixture of nuclides produced by the process of fission that includes radioactive (and some nonradioactive nuclides) as well as the daughter products of the radioactive decay of these nuclides, which can result in more than 200 isotopes.

Flow	The movement of a fluid such as air or water. Flow and transport are groundwater processes that can move potential contaminants; it usually means flow based on Darcy's law.
Flow Pathway	The subsurface course that a water molecule or solute (including radio nuclides) would follow in a given groundwater velocity field governed principally by the hydraulic gradient.
Flux	The rate of transfer of fluid, particles, or energy passing through a unit area per unit time. For water, also known as specific discharge.
Fractures	Breaks in rocks caused by the stresses that cause folding and faulting. A fracture along which there has been displacement of the sides relative to one another is called a fault. A fracture along which no appreciable movement has occurred is called a joint. Fractures may act as fast paths for groundwater movement.
Fracture Aperture	(1) The space that separates the sides of a fracture. (2) The measured width of the space separating the sides of a fracture.
Fracture Permeability	The capacity of a rock to transmit fluid that is related to fractures in the rock.
Fracture-Matrix Exchange Coefficient	(1) A multiplier used in unsaturated groundwater flow simulations that alters the geometric conductance between fracture and matrix elements to account for reduced wetting and contact area. (2) A coefficient that assists in capturing the effect of groundwater being distributed unevenly over fracture surfaces as it moves through fractured rock.
Frequency Distribution	See Section A.2 of this glossary.
Fuel Assembly	A number of fuel rods held together by plates and separated by spacers, used in a reactor. This assembly is sometimes called a fuel bundle.
Fuel Matrix	The physical form and composition of the substance that holds the fissile material.
Fugacity	A parameter that measures the chemical potential of a real gas in the same way that partial pressure measures the free energy of an ideal gas.

Galvanic	Pertaining to an electrochemical process in which electron flow is produced between two dissimilar metals when they are immersed in an electrolyte solution and placed in contact or are electrically connected. The electron flow results from the difference in electrical potential of the metals.
Galvanic Corrosion	Electrochemical corrosion (eating into a substance) caused by the flow of electricity that occurs when two dissimilar metals, with differing electrical potentials, are near each other in the presence of a conductor such as water with solutes in it.
Gaseous Diffusion	The selective transfer of gas by molecular diffusion through microporous barriers. Used to refer to the mechanism for movement of gas through concrete and rock and for movement of gas out of the waste package by means not involving water.
GENII	A deterministic computer software code that evaluates dose from the migration of radionuclides introduced into the accessible environment, or biosphere, that may eventually affect humans through ingestion, inhalation, or direct radiation. It is used to develop biosphere dose conversion factors.
GENII-S	A quasi-stochastic computer software code that can create distributions and sample them and is run in conjunction with GENII for biosphere modeling.
Geochemical	The distribution and amounts of the chemical elements in minerals, ores, rocks, soils, water, and the atmosphere, and the circulation of the elements in nature on the basis of their properties.
Geochemistry	The study of the abundance of the elements and atomic species (isotopes) in the earth. Geochemistry, or geochemical study looks at systems related to chemicals arising from natural rock, soil, soil processes such as microbe activity, and gases, especially as they interact with man-made materials from the potential repository system. In the broad sense, all parts of geology that involve chemical changes.
Geologic-Framework Model	A nonmathematical model of the geologic system.
Geologic Repository	A system for disposing of radioactive waste in excavated geologic media, including surface and subsurface areas of operation, and the adjacent part of the geologic setting that provides isolation of the radioactive waste.

Geologic Time	The period of time over which the earth has existed. The time scale over which geologic processes produce change. In general discussion, the term geologic time implies very long periods of time such as tens of thousands of years, hundreds of thousands of years, or millions of years.
Geosphere	The combination of the earth's rock, water, and air layers (spheres).
Glass	See High-Level Radioactive Waste Glass.
Goethite	An iron oxide mineral that is yellowish, reddish, or brownish black. It is the most common constituent of many forms of natural rust or of limonite.
Gradient	The change in value of a quantity per unit distance in a specified direction.
Groundwater	Water contained in pores or fractures in either the unsaturated or saturated zones below ground level.
Groundwater Flux	The rate of groundwater flow through a unit area of the aquifer. Means the same as specific discharge.
Groundwater Travel Time	The time required for a unit volume of groundwater to travel between two locations. The travel time is the length of the flow path divided by the velocity, where velocity is the average groundwater flux divided by the effective porosity along the flow path. If discrete segments of the flow path have different hydrologic properties, the total travel time will be the sum of the travel times for each discrete segment.
Handling Container	The container in which the fuel matrix and cladding are placed. If the waste form is solidified, this is called a pour container. In some cases, this is the only container for storage, handling, and transportation prior to disposal.
Heavy Metal	All uranium, plutonium, and thorium used in a nuclear reactor.
Herbivore	An organism that feeds on plants, especially an animal whose diet is exclusively plants.

Heterogeneity	The condition of being composed of parts or elements of different kinds. A condition in which the value of a parameter such as porosity, which is an attribute of an entity of interest such as the tuff rock containing the potential repository, varies over the space an entity occupies, such as the area around the repository, or with the passage of time.
High-Level Radioactive Waste	(1) The highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing, and any solid material derived from such liquid waste that contains fission products in sufficient concentrations. (2) Other highly radioactive material that the U.S. Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent isolation.
High-Level Waste	See High-Level Radioactive Waste.
High-Level Radioactive Waste Glass	The waste form of defense high-level radioactive waste in which the radioactive waste is mixed with borosilicate glass.
Histogram	See Section A.2 of this glossary.
Homogeneous	Consisting of or composed of similar elements or ingredients.
Host Rock	The rock unit in which the potential repository will be located. For the potential repository at Yucca Mountain, the host rock would be the middle portion of the of the Topopah Spring tuff formation of the Paintbrush Group. See also tuff.
Hydraulic Conductivity	A measure of the ability to transmit water through a permeable medium. A number that describes the rate at which water can move through a permeable medium. The hydraulic conductivity depends on the size and arrangement of water-transmitting openings such as pores and fractures, the dynamic characteristics of the water such as density and viscosity, and the strength of the gravitational field.
Hydraulic Gradient	The change in the height of water levels with respect to the distance between two locations.
Hydrodynamic Dispersion	See Dispersion.
Hydrogeology	A study that encompasses the interrelationships of geologic materials and processes involving water.

Hydrologic	Pertaining to the properties, distribution, and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.
Hydrology	(1) The study of water characteristics, especially the movement of water. (2) The study of water, involving aspects of geology, oceanography, and meteorology.
Hydrostratigraphy	A stratigraphic classification of layered rocks based on rock characteristics and the hydrologic, or water-conducting, properties of the units.
Human Intrusion	The inadvertent disturbance of a disposal system by humans that could result in release of radioactive waste. The regulations require that performance assessments consider the possibility of human intrusion.
Igneous	(1) A type of rock that has formed from a molten, or partially molten, material. (2) A type of activity related to the formation and movement of molten rock either in subsurface (plutonic) or on the surface (volcanic).
Imbibition	The absorption of a fluid, usually water, by porous rock (or other porous material) under the force of capillary attraction and without pressure.
Incolloy 625	Under past reference design specifications, the corrosion-resistant inner layer of the two-layer metallic disposal container..
Infiltration	The process of water entering the soil at the ground surface and the ensuing movement downward when the water input at the soil surface is adequate. Infiltration becomes percolation when water has moved below the depth at which it can be removed (to return to the atmosphere) by evaporation or evapotranspiration.
Infiltration Flux	Volumetric infiltration rate per unit area.
Infiltration Rate	See Infiltration Flux.
Inner Barrier	An inner layer of the two-layer metallic disposal container.
Inner Canisters	High-level radioactive waste canisters placed within the overpack.
In Situ	In its natural position or place. The phrase distinguishes in-place experiments, conducted in the field or underground facility, from those conducted in the laboratory.

Integral-Finite-Difference Computer Code	A commonly used numerical method for solving flow problems. An approximating technique in which algebraic equations are used for approximating the partial differential equations that comprise mathematical models in order to produce a form of the problem that can be solved on a computer. Similar in capability to a finite element code in that it can handle irregularly shaped areas well. See Finite Element Computer Code.
Inventory	The amount of radioactive elements in a fuel, usually stated in curies per metric ton of heavy metal. Also termed radionuclide inventory.
Invert	A construction associated with the precast concrete structure for the purpose of providing a level drift floor and enabling transporting and support of the waste package.
Ion	(1) An atom that contains excess electrons or is deficient in electrons, causing it to be chemically active. (2) An electron not associated with a nucleus.
Ionizing Radiation	(1) Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. (2) Any radiation capable of displacing electrons from an atom or molecule, thereby producing ions.
Ionic Strength	A measure of the level of electrical force in an electrolytic solution.
Irradiated Fuel	Burned fuel. See also Burnup.
Isothermal	Pertaining to constant temperature.
Isotope	One of two or more atomic nuclei with the same number of protons (i.e., the same atomic number) but with a different number of neutrons (i.e., a different atomic weight). For example, ^{235}U and ^{238}U are both isotopes of uranium.
Isotropy	The condition wherein all significant physical properties are equal when measured in any direction or along any axes. See also Anisotropy.
Iterative	Conditions or results that are repeated in an analysis. The processes in which analysts rerun calculations or refine models as new data are gathered or new insights occur.
ITOUGH2 Computer Code	A computer code that estimates hydrogeologic model parameters for the numerical simulator TOUGH2.

J-13 Water	The groundwater taken from Wellbore J13. The chemical composition of this water is used as the standard for Yucca Mountain ambient groundwater composition for modeling purposes.
Joint	A fracture in rock, usually more or less vertical to bedding, along which no appreciable movement has occurred.
Juvenile Failure	Premature failure of a waste package because of material imperfections or damage by rockfall during emplacement.
Key Technical Issues	Issues important for assessing the long-term safety of a potential Yucca Mountain repository, as defined by the U.S. Nuclear Regulatory Commission (NRC). The issues are (1) Support Revision of the U.S. Environmental Protection Agency Standard/NRC Rule Making; (2) Total System Performance Assessment and Technical Integration; (3) Igneous Activity; (4) Unsaturated and Saturated Flow Under Isothermal Conditions; (5) Thermal Effects on Flow; (6) Container Life and Source Term; (7) Structural Deformation and Seismicity; (8) Evolution of Near-Field Environment; (9) Radionuclide Transport; (10) Repository Design and Thermal Mechanical Effects.
Kinetic	Of or due to motion.
Latin Hypercube Sampling	A sampling technique that divides the cumulative distribution function into intervals of equal probability and then samples from each interval.
License Application	An application to the Nuclear Regulatory Commission for a license to construct a repository.
Line Loading Repository Design	A waste emplacement design in which waste containers are spaced very closely along the drift, with emplacement drifts relatively far apart.
Lithophysal	Pertaining to tuff units with lithophysae, voids having concentric shells of finely crystalline alkali feldspar, quartz, and other materials that were formed due to entrapped gas that later escaped.
Lithosphere	The earth's crust, as distinguished from the atmosphere or hydrosphere, and as distinguished from the deeper portion of the earth underlying the crust.

Localized Corrosion	A type of corrosion induced by local variations in electrochemical potential on a microscale over small regions. Variations in electrochemical potential may be caused by localized irregularities in the structure and composition of usually protective passive films on metal surfaces and in the electrolyte composition of the solution that contacts the metal. See Pitting Corrosion and Crevice Corrosion.
Log Normal Distribution	A distribution of a random variable X such that the natural logarithm of X is normally distributed.
Lookup Table	A multidimensional table containing columns of data representing relationships between parameters in the table. A lookup table is a convenient way to represent and implement functional relationships between parameters considered in the model.
Longitudinal Dispersion	(1) Dispersion of a solute moving in groundwater in the same direction as the groundwater flow path. (2) Spreading of a solute in the direction of bulk flow.
Magma	Molten or partially molten rock material that is naturally occurring and is generated within the earth.
Mass Balance	The procedure of accounting for conservation of mass, such as the mass of radionuclides released from waste packages, in real world processes or in models of real world processes.
Mathematical Model	A mathematical description of a conceptual model.
Matrix	Tuff rock material and its pore space exclusive of fractures. As applied to Yucca Mountain tuff, the groundmass of an igneous rock that contains larger crystals.
Matrix Diffusion	As used in TSPA-SR conceptual models, the process by which molecular or ionic solutes, such as radionuclides in groundwater, move from areas of higher concentration to areas of lower concentration. This movement is through the pore spaces of the rock material as opposed to movement through the fractures.
Matrix Permeability	The capacity of the matrix to transmit fluid.
Mean (Arithmetic)	See Section A.2 of this glossary.

Mechanistic Analysis	An analysis of processes that is based on the well-established fundamentals of the processes considered, such as: thermodynamics, reaction kinetics, mass transfer laws, heat transfer laws, etc. This is as opposed to empirical analysis, which is based on a model that has been developed from the numerical value of data taken from tests or measurements of the model.
Median	A value such that half of the observations are less than that value and half are greater than the value.
Meteorological	Of, or relating to meteorology, or to weather and other atmospheric phenomena.
Metric Ton Heavy Metal (MTHM)	A metric ton is a unit of mass equal to 1,000 kg (2,205 lb.). Heavy metals are those with atomic masses greater than 230. Examples include thorium, uranium, plutonium, and neptunium. When used in the Civilian Radioactive Waste Management Program, the term usually pertains to heavy metals in spent nuclear fuel in scientific text. In this document, MTHM is equal to MTU (metric tons of uranium).
Metric Ton of Uranium (MTU)	A metric ton, which is 1,000 kg, or 2,205 lb., of uranium in scientific text.
Microbe	An organism too small to be viewed with the unaided eye. Examples of microbes are bacteria, protozoa, and some fungi and algae.
Microbially Influenced Corrosion	Corrosion of the waste package that is enhanced by the activity of microbes.
Microbiologically Influenced Corrosion	See Microbially Influenced Corrosion.
Migration	Radionuclide movement from one location to another within the engineered barrier system or the environment.
Mild Steel	See Carbon Steel.
Mineral Assemblage	Minerals that compose a rock, especially an igneous or metamorphic rock. The term includes the different kinds and relative abundance of minerals but excludes the texture and fabric of the rock.
Mineralogical	Of or relating to the chemical and physical properties of minerals, their occurrence, and classification.

Mobile Radionuclides	Radionuclides that can move within a water system with little or no retardation.
Mobilization	The process of breaking down the waste form and releasing radionuclides. After its initial mobilization a radionuclide can be removed from transport by being precipitated or adsorbed and later become remobilized in a cycle of changes that can be repeated many times.
Model	A depiction of a system, phenomenon, or process including any hypotheses required to describe the system or explain the phenomenon or process.
Molal	Of a solution, containing one mole of solute per one kilogram of solvent.
Mole	The fundamental metric unit used to measure the amount of a substance. Avogadro's number of particles (6.023×10^{23}).
Monte Carlo Uncertainty Analysis	See Section A.2 of this glossary.
Mountain Scale	(1) Similar to far-field for processes that are related to the area of the geosphere and biosphere far enough away from the potential repository that, when numerically modeled, show that releases from the repository are represented as a homogeneous, single source term. The effects of individual, small-scale components such as individual waste packages are not modeled because they are considerably smaller than the scale of the model. (2) A scale of hundreds of meters, or even kilometers, as opposed to tens of meters.
National Academy of Sciences	A congressionally chartered, private, nonprofit, self-perpetuating organization of scientists devoted to the expansion of science and its use for the general welfare. This organization is mandated to advise the Federal government on scientific and technical matters. Section 801 of the Energy Policy Act of 1992 directed the U.S. Environmental Protection Agency to contract with the National Academy of Sciences to provide, "findings and recommendations on reasonable standards that would govern the long-term performance of a potential repository at the Yucca Mountain site."
National Research Council	The working arm of the National Academy of Sciences and the National Academy of Engineering that carries out most of the studies done on behalf of the academies. Most of the studies are done in response to specific questions presented by federal agencies or Congress.

Natural Analogs	Natural geologic systems that parallel situations that can develop in man-made systems, in which the formation and transport of minerals over hundreds of thousands and millions of years can be studied directly. An example of natural analog is the natural reactor studied at the Oklo uranium deposit in Gabon, Africa, which can be used as a source of analog data for conceptual models of criticality.
Near-Field	The area and conditions within the potential repository including the drifts and waste packages and the rock immediately surrounding the drifts. The region around the potential repository where the natural hydrogeologic system has been significantly impacted by the excavation of the repository and the emplacement of waste.
Near-Field Geochemical Environment Model	A model that focuses on major-element geochemistry within the potential emplacement drifts. The boundary of the model domain is defined as the drift wall. This model includes coupling to thermohydrologic processes.
Net Infiltration	The water that has infiltrated down from the soil zone or exposed rock surface to a depth below which it cannot be removed by evapotranspiration. The amount of water that is net infiltration is the total infiltration at the surface minus water lost to evaporation and plant transpiration.
Neutron Absorber	A material such as boron or gadolinium that is placed in a radioactive waste package and that absorbs neutrons to reduce ionizing radiation and to help reduce the likelihood of criticality.
Node	A junction point in a network.
Nominal Case	The case, or conceptual model, representing the expected conditions of the disposal system as perturbed only by the presence of the potential repository, in the absence of disruptive events.
Nominal Conditions	The site conditions, including features and processes, which are expected, based on current site knowledge.
Nominal Behavior	(1) Expected behavior of the system as perturbed only by the presence of the potential repository. (2) Behavior of the system in the absence of disruptive events.

Nominal Scenario Class	The scenario, or set of related scenarios, that describes the expected or nominal behavior of the system as perturbed only by the presence of the potential repository. The nominal scenarios contain all expected features, events, and processes that have been retained for analysis.
Nominal Features, Events, and Processes	Those features, events, and processes expected, given the site conditions as described from current site characterization information.
Nonequilibrium Thermodynamics	The study of heat flow systems that have not stabilized (i.e., are not in equilibrium).
Nuclear Chain Reaction	A process in which some of the neutrons released in one fission event cause other fissions.
U.S. Nuclear Regulatory Commission	Promulgates technical regulations that are consistent with standards established by the U.S. Environmental Protection Agency and considers license applications from the U.S. Department of Energy for a potential repository. It determines, with reasonable assurance, whether EPA standards can be met. It also has the continuing regulatory responsibility to oversee repository operation. U.S. Nuclear Regulatory Commission was formed by the Atomic Energy Commission with the Energy Reorganization Act of 1974 [100213].
Nuclear Regulatory Commission Radioactive Waste Program Annual Progress Report	A status report made each fiscal year that documents the technical work performed on 10 key technical issues that are most important to performance of the potential geologic repository at Yucca Mountain.
Nuclear Waste Policy Act (42 U.S.C. 10101 et seq.)	The federal statute enacted in 1982 that established the Office of Civilian Radioactive Waste Management and defined its mission to develop a federal system for the management and geologic disposal of commercial spent nuclear fuel and other high-level radioactive wastes. The Act also: (i) specified other federal responsibilities for nuclear waste management, (ii) established the Nuclear Waste Fund to cover the cost of geologic disposal, (iii) authorized interim storage under certain circumstances, and (iv) defined interactions between Federal agencies and the states, local governments, and Indian tribes. The act was substantially amended in 1987 and 1992.

Nuclear Waste Policy Amendments Act of 1987	Legislation that amended the Nuclear Waste Policy Act to: (i) limit repository site characterization activities to Yucca Mountain, Nevada, (ii) establish the Office of the Nuclear Waste Negotiator to seek a state or Indian tribe willing to host a repository or monitored retrievable storage facility, (iii) create the Nuclear Waste Technical Review Board, and (iv) increase state and local government participation in the waste management program.
Nuclear Waste Technical Review Board	An independent body established within the executive branch, created by the Nuclear Waste Policy Amendments Act of 1987 to evaluate the technical and scientific validity of activities undertaken by the U.S. Department of Energy, including site characterization activities and activities relating to the packaging or transportation of high-level radioactive waste or spent nuclear fuel. Members of this Board are appointed by the President from a list composed by the National Academy of Sciences.
NUFT Computer Code	A computer code that simulates three-dimensional flow of groundwater, heat, and contaminants in unsaturated and saturated porous and fractured media. It is named for Non-isothermal Unsaturated Flow and Transport and is used for drift scale, thermal-hydrologic calculations.
Numerical Model	An approximate representation of a mathematical model that is constructed using a numerical description method, such as finite volumes, finite differences, or finite elements. A numerical model is typically represented by a series of program statements that are executed on a computer.
Office of Civilian Radioactive Waste Management	A U.S. Department of Energy office created by the Nuclear Waste Policy Act of 1982 to implement the responsibilities assigned by the Act.
One-Dimensional Model	A model that represents physical conditions and/or processes by a vertical column composed of a stack of single grid cells or by a horizontal row of single grid cells.
Order of Magnitude	A range of numbers extending from some value to 10 times that value.
Outer Barrier	The outer layer of the two-layer metallic disposal container. It consists of carbon steel, which is a corrosion allowance material.
Outer Barrier and Inner Barrier Corrosion Models	See Corrosion Models.

Outer Barrier Corrosion Model	See Outer Barrier and Inner Barrier Corrosion Models.
Overburden	Geologic material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials. As used by the Yucca Mountain Site Characterization Project, this is geologic material overlying the mined repository horizon.
Oxidation	(1) A chemical reaction, such as the rusting of iron, that increases the oxygen content of a substance. (2) A reaction in which the valence of an element or compound is increased as a result of losing electrons.
Oxidation State	For an ion, expressed as a positive or negative number representing the ionic or effective charge.
Oxidize	(1) To increase the oxygen content of a substance. (2) To increase the valence of an element or compound as a result of losing electrons.
Paleoclimates	The climate of a past interval of geologic time.
Parameter	Data, or values, that are input to computer codes for a TSPA calculation.
Passive Institutional Control	From 40 CFR 191, methods of preserving information about the location, design, and contents of the potential repository system. These include permanent markers placed around the disposal site area, public records and archives, government ownership, and regulations controlling use of land.
Patch	For corrosion modeling, one of two geometries for an opening in a waste package layer created by corrosion (the other geometry is a pit). A patch is generally wider than it is deep.
Pathway	A potential route by which radionuclides might reach the accessible environment and pose a threat to humans.
Peer Review Panel	A panel of individuals independent of those who performed the TSPA-SR but who have technical expertise at least equivalent to those who performed the original work who produce a documented critical review of the work.
Percentile	See Section A.2 of this glossary.

Perched Water	A saturated condition that is not continuous with the water table, because there is an impervious or semipervious layer underlying the perched zone or a fault zone that creates a barrier to water movement and perches water.
Percolation	The passage of a liquid through a porous substance. In rock or soil it is the movement of water through the interstices and pores under hydrostatic pressure and the influence of gravity. The downward or lateral flow of water that becomes net infiltration in the unsaturated zone.
Percolation Flux	Volumetric percolation rate per unit area. The flux anywhere below the root zone of plants and is no longer susceptible to removal back into the atmosphere by evapotranspiration.
Percolation Rate	See percolation flux.
Performance Assessment	An analysis that predicts the behavior of a system or system component under a given set of constant and/or transient conditions. Performance assessments will include estimates of the effects of uncertainties in data and modeling. See Total System Performance Assessment.
Permeability	In general terms, the capacity of a medium such as rock, sediment, or soil to transmit liquid or gas. Permeability depends on the substance transmitted (oil, air, water, etc.) and on the size and shape of the pores, joints, and fractures in the medium and the manner in which they are interconnected. "Hydraulic conductivity" has replaced "permeability" in technical discussions relating to groundwater. See also Relative Permeability.
pH	A number indicating the acidity or alkalinity of a solution. A pH of 7 indicates a neutral solution. Lower pH values indicate more acidic solutions while higher pH values indicate alkaline solutions.
Phase	A physically distinct portion of matter, such as the aqueous, gas, or solid phase.
Phase Equilibria	The relationships between phases of a substance undergoing a phase change, such as from solid to liquid, under various conditions of temperature and pressure.
Phase Stability	A measure of the ability of matter to remain in a given phase.
Pit	For corrosion modeling, one of two geometries for an opening in a waste package layer created by corrosion (the other geometry is a patch). A pit is generally deeper than it is wide.

Pitting Corrosion	A type of localized corrosion that forms in indentations called pits.
Pitting Factor	A factor that is used to measure local variations of general, or uniform, corrosion penetration from corrosion allowance materials such as carbon steel.
Playa	The shallow central basin of a desert plain in which water gathers after a rain and then evaporates.
Plume	A measurable discharge of a contaminant, such as radionuclides, from a point of origin. The contaminants are usually moving in groundwater, and the plume may be defined by chemical concentration gradients.
Pluvial	(1) In climatology, relating to former periods of abundant rains, especially in reference to glacial periods. (2) In geology, said of a geologic episode, change, process, deposit, or feature caused by the action or effects of rain.
Point Loading Thermal Design	An emplacement drift design in which commercial spent nuclear fuel waste packages are spaced away from each other along the drift using emplacement drift spacing similar to the commercial spent nuclear fuel-package spacing.
Pore Fluid	The water and any material it is carrying that exist in the pore spaces of the rock matrix.
Pore Waters	Interstitial water, or subsurface water in the pores in rock or soil.
Porosity	The ratio of openings, or voids, to the total volume of a soil or rock expressed as a decimal fraction or as a percentage. See also Effective Porosity.
Pour Canister	A metallic canister into which high-level radioactive waste mixed with molten glass-making materials is poured. The material cools and solidifies in the pour canister.
Precipitate	A substance that separates as solid particles from a liquid as a result of physical or chemical changes.
Precipitation	(1) The process of depositing a substance from a solution, by the action of gravity or by a chemical reaction. (2) Any form of water particles, such as frozen water in snow or ice crystals, or liquid water in raindrops or drizzle, that fall from clouds in the atmosphere and reaches the earth's surface. (3) An amount of water that has fallen at a given point over a specified period of time, measured by a rain gauge.

Probabilistic	(1) Based on or subject to probability. (2) Involving a variate, such as temperature or porosity. At each instance of time, the variate may take on any of the values of a specified set with a certain probability. Data from a probabilistic process is an ordered set of observations, each of which is one item from a probability distribution.
Probabilistic Risk Assessment	(1) A systematic process of identifying and quantifying the consequences of scenarios that could cause a release of radioactive materials to the environment. (2) Using predictable behavior to define the performance of natural, geologic, human, and engineered systems for thousands of years into the future using probability distributions (see Section A.2 of this glossary).
Probability	See Section A.2 of this glossary.
Probability Density Function	See Section A.2 of this glossary.
Probability Distribution	See Section A.2 of this glossary.
Probability Model	A model that quantifies uncertainties in the model parameters and predicts the likelihood of the scenarios used for the model.
Probable Behavior	A combination of the concept of predicted future behavior of the various system components with the uncertainty associated with the prediction.
Process Model	A depiction or representation of a process along with any hypotheses required to describe or to explain the process.
Processes	Phenomena and activities that have gradual, continuous interactions with the system being modeled. For the purposes of screening features, events, and processes for the total system performance assessment, a process is defined as a natural or anthropogenic phenomenon that has a potential to affect disposal system performance and that operates during all or a significant part of the period of performance.
Pyroclastic Flow	A flow of detrital volcanic materials that have been explosively ejected from a volcanic vent. The flow is generally a dense cloud of incandescent volcanic glass, in a semimolten or viscous state, that solidifies into rock. The rock that results is chiefly a fine-grained rhyolitic tuff formed of glass shards that may be welded or nonwelded.

Quantitative	A variable that is expressed numerically.
Quality Factor	The modifying factor that is used to derive dose equivalent from absorbed dose.
Quasi-Static Thermodynamic Processes	Reversible processes resulting in a change to system or body.
Quasi-Transient	Describing the diffusive mass transport model. This means the solution used in the model incorporates steady-state diffusive mass transfer through the perforations of the failed waste container. This is combined with transient mass transfer through the spherical shell of the invert surrounding the waste container. The quasi-transient mass transfer model is used to calculate diffusive release of radionuclides at the engineered barrier system edge.
Rad	The unit of measure for the absorbed dose of radiation. Rad is short for radiation absorbed dose.
Radiation	Ionizing radiation.
Radioactive Decay	The process in which one radionuclide spontaneously transforms into one or more different radionuclides, which are called daughter radionuclides.
Radioactivity	The property possessed by some elements (i.e., uranium) of spontaneously emitting alpha, beta, or gamma rays by the disintegration of atomic nuclei.
Radiocolloid	Colloids, or colloidal systems, containing radionuclides.
Radiolysis	Chemical decomposition by the action of radiation.
Radionuclide	Radioactive type of atom with an unstable nucleus that spontaneously decays, usually emitting ionizing radiation in the process. Radioactive elements characterized by their atomic mass and number.
Random Variable	See Section A.2 of this glossary.
Range (Statistics)	See Section A.2 of this glossary.
REACT Computer Code	The reaction mass transfer code.
Reaction Kinetics	The study of the rates and mechanisms of chemical reactions.
Reaction Rate	The rate at which a chemical reaction takes place.

Realization	A complete calculation using a randomly selected value. Many of these calculations are done in a Monte Carlo analysis.
Recharge	The movement of water from the unsaturated zone to the saturated zone.
Reducing Conditions	With regard to criticality, the important aspect of reducing conditions is that they reduce the oxidation state of materials (deoxidize), and the material that is reduced becomes less soluble. Radionuclides being transported in groundwater can precipitate out and collect in an area of reducing conditions. With regard to corrosion, reducing conditions slow corrosion, because oxygen is less available, or not available, to combine with the iron and form rust.
Reference Person	With regard to dose, a hypothetical collection of human physical and physiological characteristics arrived at by international consensus. This collection may be used by researchers to relate biological damage to a stimulus such as radiation exposure. The reference adult person lives 20 km (12 miles) from Yucca Mountain and will be defined using a survey of the existing population.
Reflux Water	Water that is vaporized near waste packages, migrates to cooler areas, condenses, and then flows back toward the waste packages.
Regression Analysis	See Section A.2 of this glossary.
Relative Permeability	The permeability of rock material to a given substance compared to the absolute (total) permeability of the rock. The term is usually used to signify the permeability to one fluid when two or more fluids are present in the rock.
rem	The unit of a dose equivalent from ionizing radiation to the human body. It is used to measure the amount of radiation to which a person has been exposed) (rem means roentgen equivalent man).
Repository Layout	The host rock, depth, and areal extent of the repository facility, drift size and spacing, mechanical support system, thermal load, and ventilation system used during the operational phase of the facility. This is as mentioned in the Energy and Water Development Appropriations Act of 1997.

Repository Safety Strategy	A document used to assist management in prioritizing testing and analysis activities to focus on the most important issues in postclosure safety. Identification of the important issues allows resource use (e.g., sampling and testing activities) to be focused on gathering information that will reduce the uncertainty in parameters and processes related to the key issues. Key elements of the document include the following: (1) Limited water contacting waste packages (2) Long waste package lifetime (3) Low rate of release of radionuclides from breached waste packages (4) Radionuclide concentration reduction during transport from the waste packages.
Retardation	Slowing or stopping of radionuclide movement in groundwater by mechanisms that include sorption of radionuclides, diffusion into rock matrix pores and microfractures, and trapping of large colloidal molecules in small pore spaces or dead ends of microfractures.
RIP Computer Program	RIP is an initialism for repository integration program, the executive TSPA "driver" program. An integrating software code into which simplified analytical expressions, or callable subroutines describing the behavior of the different components, can be placed. RIP sequentially advances through time while keeping track of the changes in environments and the fate of the radioactive constituents within the engineered and natural barriers.
Risk	The probability that an undesirable event will occur multiplied by the consequences of the undesirable event.
Risk Assessment	An evaluation of potential consequences or hazards that might be the outcome of an action. This assessment focuses on potential negative impacts on human health or the environment.
Rock Matrix	See Matrix.
Salt Deposit Effect	(1) Potential buildup of salt scales on the waste package surface from water dripping onto the waste package while its surface is at elevated temperatures. (2) The development of potentially aggressive conditions to the waste package corrosion degradation under and around the salt deposits by providing a wetter environment than the surroundings and causing concentration of aggressive species in the local salt solution.

Saturated Zone The region below the water table where rock pores and fractures are completely saturated with groundwater.

Scenario A well-defined, connected sequence of features, events, and processes that can be thought of as an outline of a possible future condition of the potential repository system. Scenarios can be undisturbed, in which case the performance would be the expected, or nominal, behavior for the system. Scenarios can also be disturbed, if altered by disruptive events such as human intrusion or natural phenomena such as volcanism, or nuclear criticality.

Scenario Class A set of related scenarios that share sufficient similarities that they can usefully be aggregated for the purposes of screening or analysis. The number and breadth of scenario classes depends on the resolution at which scenarios have been defined. Coarsely defined scenarios result in fewer, broad scenario classes, whereas narrowly defined scenarios result in many narrow scenario classes. Scenario classes (and scenarios) should be aggregated at the coarsest level at which a technically sound argument can be made, while still maintaining adequate detail for the purposes of the analysis.

Secondary Phase Occurs when spent nuclear fuel is contacted by water and dissolves, forming uranyl minerals. The major secondary phase minerals are schoepite, uranophane, Na-boltwoodite, and soddyite.

Seepage The inflow of groundwater moving in fractures or pore spaces of permeable rock to an open space in the rock such as a drift. Specifically, the amount of percolation flux that enters the drift in a given time period. An important factor in waste package degradation and mobilization and migration of radionuclides out of the potential repository.

Seepage Fraction The fraction of the total number of waste packages that is contacted by drips from seepage into the drifts.

Seismic Pertaining to, characteristic of, or produced by earthquakes or earth vibrations.

Sensitivity Study (Analysis) An analytic or numerical technique for examining the effects of varying specified parameters when a model run is performed. Shows the effects that changes in various parameters have on model outcomes and can illustrate which parameters have a greater impact on the predicted behavior of the system being modeled. Also, called sensitivity analysis because it shows the sensitivity of the consequences (e.g., radionuclide release) to uncertain parameters (e.g., the infiltration rate that results from precipitation).

Simulation	The generation of a sample set by selecting a parameter value from each input distribution and calculating the consequences for the sample set. See also Realization.
Single Heater Test	A field test in the Exploratory Studies Facility that uses a single heated element emplaced directly into Yucca Mountain tuff (Topopah Spring Middle Nonlithophysal hydrogeologic unit). The test is designed to determine the thermal hydrologic responses of the unit to heating.
Site Characterization Plan	The plan that contains the strategy for completing a detailed set of activities that was expected to provide all of the information needed to comprehensively describe the potential repository system. The plan also documented methods for assessing the performance of the total repository system and its individual components. This was published by the U.S. Department of Energy in 1988 with subsequent, ongoing updating.
Site Recommendation	A recommendation by the Secretary of Energy to the President that the Yucca Mountain site be approved for development as the nation's first high-level radioactive waste repository. If the site is determined to be suitable, this recommendation is expected in fiscal year 2001.
Smeared Heat Source	An attribute of mountain-scale thermal hydrology models in which the model handles heat output for waste packages by using the total heat produced by all assemblies in all waste packages, arrives at the entire repository-wide thermal load, and averages the thermal load across the entire repository heat area (~740 acres).
Sorb	To undergo a process of sorption.
Sorption	The binding, on a microscopic scale, of one substance to another. A term that includes both adsorption and absorption. The sorption of dissolved radionuclides onto aquifer solids or waste package materials by means of close-range chemical or physical forces is an important process modeled in this study. Sorption is a function of the chemistry of the radioisotopes, the fluid in which they are carried, and the mineral material they encounter along the flow path.
Sorption Coefficient (K_d)	Coefficient for a term for the various processes by which one substance binds to another.
Source Term	Types and amounts of radionuclides that are the source of a potential release from the potential repository.

Spalling	Flaking off of corrosion products from the metal substrate as it undergoes corrosion. The layer of corroded material thickens. The spalling could be caused by an expansive action of the corrosion products because they occupy a greater volume than the uncorroded metal substrate.
Spatial Variability	A measure of how a property, such as rock permeability, varies in an object such as a rock formation.
Speciation	The existence of the elements, such as radionuclides, in different molecular forms in the aqueous phase.
Spent Nuclear Fuel	Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. Spent fuel that has been burned (irradiated) in a reactor to the extent that it no longer makes an efficient contribution to a nuclear chain reaction. This fuel is more radioactive than it was before irradiation, and it is hot. See also Burnup.
Steady-State Modeling	Modeling a system under the assumption that the variables are not changing with time. For example, flow fields can be simulated at a steady state if the boundary conditions, saturations, and fluxes are not changing with time.
Stream Tube	A modeling method used to represent the groundwater flow path from the water table to the biosphere. There are six stream tubes used for saturated zone modeling with one tube associated with, and having the cross-sectional shape of, one of six regions designated at the water table. Each stream tube takes in groundwater flux and radionuclide mass flux data at the water table representing flux from the potential repository that has gone through the unsaturated zone.
Stochastic	Involving a variable (e.g., temperature and porosity) that may take on values of a specified set with a certain probability. Data from a stochastic process is an ordered set of observations, each of which is one item from a probability distribution. Random.
Stochastic Model	A model whose outputs are predictable only in a statistical sense. A given set of model inputs produces outputs that are not the same, but follow statistical patterns.

Stratigraphy	The branch of geology that deals with the definition and interpretation of the rock strata, the conditions of their formation, character, arrangement, sequence, age, distribution, and especially their correlation by the use of fossils and other means of identification.
Stress Corrosion Cracking	A cracking process that requires the simultaneous action of a corrosion mechanism and sustained tensile stress.
Structural Failure	Loss of waste package integrity to contain radionuclides.
Structure	In geology, the arrangement of the parts of the geologic feature or area of interest such as folds or faults. Structural features develop as a result of stresses that cause movements of the earth's crust and result in events such as earthquakes as the crust deforms.
Surface Complexation	The process that describes the formation of complex molecules between the solute in the aqueous phase and the reactive groups on the solid surface, under specific chemical conditions.
Surrogate	Using one thing in place of another. An example is using a single important parameter, radionuclide travel time, as a surrogate for performance when the actual performance measure takes into account the effects of many factors. If the calculated travel time of radionuclides of interest is fast, that implies that performance of the natural and engineered barriers in containing the radionuclides is not as effective as it would be if radionuclide travel time was slow.
Tectonic	Pertaining to geologic forms or effects created by deformation of the earth's crust.
Tectonism	A general term for all movement of the earth's crust produced by tectonic processes.
Temperature Gradient	The rate of change of temperature with distance. When applied to the earth, the term geothermal gradient may be used.
Thermal-Chemical	Relating to thermal chemistry, the chemistry branch that studies heat changes that accompany chemical reactions and changes of state.
Thermal Conduction	The flow of thermal energy through a material. This conduction is affected by the amount of heat energy present, the nature of the heat carrier in the material, and the amount of dissipation.

Thermal-Hydrologic	Of or pertaining to changes in groundwater movement due to the effects of changes in temperature.
Thermal-Hydrologic Processes	Processes that are driven by a combination of thermal and hydrologic factors. These processes include evaporation of water near the potential repository when it is hot and subsequent redistribution of fluids by convection, condensation, and drainage.
Thermal Hydrology	The study of a system that has both thermal and hydrologic processes. A thermal-hydrologic condition, or system, is expected to occur if heat-generating waste packages are placed in the potential repository at Yucca Mountain.
Thermal Loading	The application of heat to a system, usually measured in terms of watt density. The thermal loading for a repository is the watts per acre produced by the radioactive waste in the active disposal area. The spatial density at which waste packages are emplaced within the potential repository as characterized by the areal power density and the areal mass loading.
Thermal Period	The time period in which thermal effects, such as higher temperatures or dried rock, are present in the region surrounding the potential repository.
Thermal Power Per Waste Package	The rate of heat released in watts by a particular waste package type. This will vary with fuel type and age, waste package capacity, and disposal configurations within waste packages.
Thermodynamic	Pertaining to the mechanical action of heat.
Thermodynamic/Kinetic Coefficients	Numbers that represent the rate of heat flow through a porous medium. An example is a coefficient that represents the rate of heat flow in a given type of rock.
Three-Dimensional Model	A three-dimensional representation of physical conditions and/or processes.
Time History	The predicted response of a system, expressed as a function of simulation time.
TOSPAC Computer Code	A computer code that simulates one-dimensional groundwater flow with the transport of decaying contaminants in partially saturated, fractured media.
Total Effective Dose Equivalent	The sum of the deep-dose equivalent, for external exposures, and the committed effective dose equivalent, for internal exposures.

Total System Performance Assessment (TSPA)	A risk assessment that quantitatively estimates how the potential Yucca Mountain repository system will perform in the future under the influence of specific features, events, and processes, incorporating uncertainty in the models and data. Its purposes follow: (1) Provide the basis for predicting system behavior and testing that behavior against safety measures in the form of regulatory standards (2) Provide the results of TSPA analyses and sensitivity studies (3) Provide guidance to site characterization and repository design activities (4) Help prioritize testing and selection of the most effective design options.
TOUGH2 Computer Code	A computer program that simulates three-dimensional flow of groundwater and heat in unsaturated and saturated porous and fractured media. The code name is derived from Transport of Unsaturated Groundwater and Heat.
Toxicity	The ability of a substance to cause damage to cells or tissues of living organisms when the substance is inhaled, ingested, or absorbed by the skin. Acute toxicity is that which occurs over a short term of exposure, and chronic toxicity is that which occurs over a long term of exposure.
Tracer Testing	A procedure in which a soluble substance (tracer) is added to groundwater at one location, and its movement to another location is observed. Tracer testing is a technique by which groundwater flow directions and velocities and other hydrologic properties of rocks can be estimated.
Transient	Describing a variable that is changing with time. This occurs before development of a steady-state condition.
Transient Modeling	Modeling of a system in which the variables are changing through time. Heating of the potential repository by the waste is a transient condition for which transient modeling is done.

Transparency	According to the Nuclear Waste Technical Review Board, the ease of understanding the process by which a study was carried out, which assumptions are driving the results, how they were arrived at, and the rigor of the analyses leading to the results. According to a Peer Review Panel report, transparency "requires ensuring completeness and using a logical structure that facilitates in-depth review of the relevant issues achieved when a reader or reviewer has a clear picture of what was done in the analysis, what the outcome was, and why."
Transpiration	The process in which water enters a plant through its root system, passes through its vascular system, and is released into the atmosphere through openings in its outer covering. It is an important process for removal of water that has infiltrated below the zone where it could be removed by evaporation.
Transport	A process in which substances carried in groundwater move through the subsurface by means of the physical mechanisms of convection, diffusion, and dispersion and the chemical mechanisms of sorption, leaching, precipitation, dissolution, and complexation. Types of transport include advective, diffusive, and colloidal transport.
Transverse Dispersion	Dispersion of a solute moving in groundwater in directions transverse to the direction of the groundwater flow path. This movement may also be called lateral dispersion.
Tritium	A radioactive isotope of hydrogen that can be taken into the body easily, because it is chemically identical to natural hydrogen. Tritium decays by beta emission with a half-life of about 12.5 years.
TSPA Peer Review Panel	See Peer Review Panel.
Tuff	Igneous rock formed from compacted volcanic fragments from pyroclastic (explosively ejected) flows with particles generally smaller than 4 mm (0.16 in.) in diameter. The most abundant type of rock at the Yucca Mountain site.
Tuffaceous	A general term referring to any rock containing tuff.

Two-Dimensional Model	A two-dimensional slice through an entity, such as the earth's crust, usually in the horizontal and vertical directions, on which known features are placed and are used to predict likely features that may exist between points of known data. Mathematically, a model that represents physical conditions and/or processes; this mathematical model is composed of both horizontal rows and vertical columns of grid cells arrayed in L-shaped configurations only one grid cell thick. Also called a cross section.
Uncertainty	A measure of how much a calculated or estimated value, that is used as a reasonable guess or prediction, may vary from the unknown true value.
Undisturbed Performance	Refers to the expected or nominal behavior of the system as perturbed only by the presence of the potential repository. This is as used in the description of scenario classes, scenarios, or features, events, or processes making up scenarios.
Unsaturated Zone	The zone of soil or rock below the ground surface and above the water table in which the pore spaces contain water, air, and other gases. Generally, the water saturation is below 100 percent in this zone, although areally limited perched water bodies (having 100 percent water saturation) may exist in the unsaturated zone. Also called the vadose zone.
Unsaturated Zone Flow	The flow of water in the unsaturated zone by downward percolation and by capillary action.
Unsaturated Zone Radionuclide Transport Model	A computer software code that defines the movement of radionuclides from the edge of the engineered barrier system, through the unsaturated zone, and to the boundary of the saturated zone.
Vadose Zone	See Unsaturated Zone.
Variable	See Section A.2 of this glossary.
Variability (Statistical)	A measure of how a quantity varies over time or space.
Velocity Field	The velocities of fluid flow, gas or liquid, in a region, which are generally depicted by arrows to indicate the direction and magnitude of the velocity.
Vitrified	Pertaining to a type of processed high-level radioactive waste where the waste is mixed with glass-forming chemicals and put through a melting process. The melted mixture is then put into a canister where it becomes a dry "log" of waste in a glassy matrix.

Vitrified Defense High-Level Radioactive Waste	A type of processed defense high-level radioactive waste that has been contained in a glass matrix.
Volcanism	Pertaining to volcanic activity.
WAPDEG Computer Code	A computer software code that was developed to model long-term corrosion degradation of waste disposal containers in the potential repository.
Waste Containment and Isolàtion Strategy	A document designed to assist the project management in prioritizing testing and analysis activities to focus on the most important issues in postclosure safety. It is also designed to help resolve uncertainty in processes and parameters of greatest significance to long-term performance. The document is still evolving. The key elements include the following: (1) Low groundwater flow amounts through storage area (2) Long-lived waste packaging (3) Cladding on the waste and low water content in waste to slow degradation (4) Engineered systems that promote slow dispersion/migration of radionuclides (5) Natural systems that promote slow dispersion/migration of radionuclides.
Waste Form	A generic term that refers to radioactive materials and any encapsulating or stabilizing matrix.
Waste Package	The waste form and any containers (i.e., disposal container barriers and other canisters), spacing structures or baskets, shielding integral to the container, packing contained within the container, and other absorbent materials immediately surrounding an individual waste container placed internally to the container or attached to the outer surface of the disposal container. The waste package begins its existence when the outer lid welds are complete and accepted.
Waste Package Design Organization	The management and oversight department responsible for the waste package design and testing.
Waste Stream	Input of waste into the potential repository over time.
Water Flux	See Flux.

Water Table	The upper surface of a zone of saturation above which the majority of pore spaces and fracture openings are less than 100 percent saturated with water most of the time (unsaturated zone), and below which the opposite is true (saturated zone).
Weeps Model	A stochastic conceptual model of groundwater flow through fractured rock. The flow is assumed to occur through stochastically generated fracture paths, or weeps, with no interaction occurring between fracture and matrix.
Welded	Fused.
Welded Tuff	A tuff that was deposited under conditions where the particles making up the rock were heated sufficiently to cohere. In contrast to nonwelded tuff, welded tuff is considered to be denser, less porous, and more likely to be fractured (which increases permeability).
Young Spent Fuel, Old Spent Fuel	Terms used to designate groups of commercial spent nuclear fuels by their age since discharge from the power reactor. The young spent nuclear fuels are characterized by higher radiation levels and resulting higher heat outputs than the old spent nuclear fuels.
Yucca Mountain Waste Containment and Isolation Strategy	See Waste Containment and Isolation Strategy.
Zeolites	A large group of hydrous aluminosilicate minerals that act as molecular "sieves" because they can adsorb molecules with which they interact. At Yucca Mountain, they are secondary alteration products in tuff rocks when the rocks are exposed to groundwater and could act to retard the migration of radionuclides by their sieving action.
Zircaloy	An alloy material that may have any of several compositions including zirconium oxide. It is used as a cladding material.

A.2 GLOSSARY OF STATISTICS TERMS

Terms in this section are presented separately from the general glossary in Section A.1 because many of the statistical terms are defined in relation to other statistical terms. The terms are numbered to allow reference from the general glossary in Section A.1.

Coefficient of Multiple Determination	A measure of goodness of fit of a linear-regression model; a value near 1 indicates a good fit, meaning that the model is accounting for most of the uncertainty in the performance measure being analyzed.

Complementary Cumulative Distribution Function	A method of depicting the probability that a performance measure, such as dose, exceeds a given value. For most measures, the higher the value, the lower the probability.
Confidence	In statistics, a measure of how close the estimated value of a random variable is to its true value.
Confidence Interval	An interval that is believed, with a preassigned degree of confidence, to include the particular value of the random variable that is estimated.
Continuous Random Variable	Those variables whose value is determined by taking measurements and that can take <u>any</u> value of an infinite number of possible values within a certain value range. The concentration of radionuclides in water is a continuous random variable and, although ranging from zero to a value limited by the solubility of an individual radionuclide under given conditions, possible outcomes of dissolving a given radionuclide in water cannot be represented by a finite number of discrete values. This type of variable has a probability density function.
Correlation Coefficient	A coefficient (designated r) calculated in the analysis of paired data when neither of the variables can be singled out as of prior importance to the other and the study seeks to analyze their interdependence, as opposed to the dependence of one upon the other. This term is a dimensionless quantity that can be used (with certain reservations) as an absolute measure of the relationship between two variables. Mathematically, for two random variables, the ratio of their covariance to the product of their standard deviations. The correlation coefficient is also a measure of how close a scatter plot of points produced by one variable plotted against the other comes to falling on a straight line drawn through the trend of the points. In a negative correlation between the two variables, larger values of one are associated with smaller values of the other. In a positive correlation, larger values of one variable are associated with larger values of the other.

Covariance	For a pair of random variables, the expected value of the product of the deviations from their respective means. It measures the extent to which two variables vary together and, if the variables are independent, the covariance is zero (so is the correlation coefficient). If large values of one variable are associated with large values of the other, the covariance is positive, while if small values of one are associated with large values of another, the covariance is negative. The covariance is usually calculated to find the correlation coefficient.
Cumulative Distribution	For grouped data, a distribution that shows how many of the values are less than or more than specified values. For random variables, this term is synonymous with distribution function.
Cumulative Distribution Function	For a continuous random variable, a function that quantifies the probability that the variable is no greater than any specified value of interest. The derivative of the cumulative distribution function is the probability density function. The cumulative distribution function is most commonly used to analyze continuous variables when data are not divided into categories (grouping by some qualitative description), and the probability density function is more appropriate when categorical studies of continuous random variables are performed.
Cumulative Probability	The probability that a random variable will have a value equal to, or less than, some specified value.
Dependent Variable	A variable whose value depends on one or more other variables. For example, the value (amount) of body weight is a variable that depends on several independent variables—the amount of calories taken in and the amount of calories burned, as well as genetics and probably other factors. As another example, the thermal load per acre of the potential repository is a dependent variable—it depends on the type, number, and spacing of waste packages emplaced.

Discrete Random Variables	Those variables whose values are finite, or countable in numbers. The number of waste packages of each type is a discrete variable. Discrete random variables have associated with them probability functions that tell the probability that the variable takes on any particular value. For example, in throws of two unbiased dice, the probability that the value of the numbers shown on the dice (a discrete random variable) for any throw will be two is one in 36; the probability function is 1/36.
Distribution	The overall scatter of values for a set of observed data. A term used synonymously with frequency distribution. Distributions have probability structures that are the probability that a given value occurs in the set.
Distribution Frequency	A representation of how values of an outcome or variable are distributed over the range of expected values.
Distribution Function	A function whose values are the probabilities that a random variable assumes a value less than or equal to a specified value. Synonymous with cumulative distribution.
Expected Value	A variable's mean, or average, outcome. The weighted average of the number of possible outcomes, with each outcome being weighted by its probability of occurrence. The mean of a probability distribution of a random variable that one would expect to find in a very large, random sample. The sum of the possible values, each weighted by its probability—the center of the random variable's histogram (frequency distribution).
Frequency Distribution	Formed when data are grouped into classes (or ranges of values within the overall set of values, such as 1 to 5, 5 to 10, 10 to 20, etc.), with the classes listed in a table (or other format) showing the number of data points that occur in each class.
Function (Mathematics)	A quantity that is variable and whose value depends on and varies with the value of another quantity or quantities. Functions show the mathematical relationship between dependent variables and the independent variables upon which the value of the dependent variables depend.

Histogram	A bar graph representation of a frequency distribution having frequency of occurrence as the ordinate (y axis) and classes of values observed in sampling of the variable as the abscissa (x axis). The area of each rectangle in the histogram represents the proportion of observations (relative frequency) that fall in that interval. This is the relative frequency of observations that lie between the two values that form the class boundary. It is not for a single value but is relative frequency of the class interval.
Linear Correlation	The relationship between two or more random variables for which the regression equations are linear.
Linear Regression	A regression where the relationship between the (conditional) mean of a random variable and one or more independent variables can be expressed by the mathematical equation that describes a line. A relationship between two variables such that the dependence of one variable on the other can be described by (the equation of) a straight line.
Linear Stepwise Regression	An analysis designed to determine variables that have the greatest influence on an output value (e.g., peak dose rate) when there are many variables whose input values go into the calculation. In simple terms, a linear regression is performed for a line in a multidimensional space, and the correlation of the values of different variables to the line are examined by performing the calculation multiple times and varying the value of one variable at a time while holding the others constant. This is a stepwise process in which one variable at a time is examined to determine the impact of its influence on the final outcome (peak dose rate, for instance).
Mean (Arithmetic)	For a statistical data set, the sum of the values divided by the number of items in the set. The arithmetic average.
Mode	A measure of location in a data set defined as the value that occurs with the highest frequency. For qualitative data it is the attribute that occurs most frequently. A set of data or a distribution can have more than one mode, or if no two values are alike, no mode. For the distribution of a random variable, the mode is the value for which the probability function or probability density is at the relative maximum.

Monte Carlo (Uncertainty) Analysis	An analytical method that uses random sampling of parameter values available for input into numerical models as a means of approximating the uncertainty in the process being modeled. A Monte Carlo simulation comprises many individual runs of the complete calculation using different values for the parameters of interest as sampled from a probability distribution. A different final outcome for each individual calculation and each individual run of the calculation is called a realization. Each realization is equally likely to occur in the Monte Carlo process.
Percentile	For a large data set where specific values are not repeated extensively, used to indicate where a value lies in relation to the entire group of values. For example, the 25th percentile indicates that about 25 percent of the items are smaller than this value and about 75 percent are larger than this value.
Probability	The relative frequency with which an event occurs in the long run. Statistical probability is about what really happens in the real world and can be verified by observation or sampling. Knowing the exact probability of an event is usually limited by the inability to know, or compile the complete set of, all possible outcomes over time or space.
Probability-Density Function	A frequency distribution such that the bars of a histogram that would represent it are so narrow that their tops would form a smooth curve if connected by a line. The curve is the probability density function. This type of distribution can be made if the number of observations of the value of a continuous random variable increases indefinitely, and the width of the range represented by each class (class interval) becomes smaller and smaller. The area under the density function curve between any two points on the curve, such as x_1 and x_2, represents the probability that the value of the random variable will lie between these two values.
Probability Distribution	The set of outcomes (values) and their corresponding probabilities for a random variable.
Quantile	A value at or below that lies a given fraction (1/5, 30 percent, etc.) of a set of data. Also called fractile.
R^2	A correlation coefficient that quantifies the goodness of fit of a linear regression model to an output value such as peak dose rate. A value of one corresponds to a perfect fit.

R^2 - Loss

The amount of change in fit when a variable is dropped from a linear stepwise regression analysis. For example, look at a linear stepwise regression analysis such that the output (e.g., dose) is calculated using 10 variables and the total R^2 is 0.80 (1 corresponds to a perfect fit). If the analysis is then performed with one of the variables left out and the R^2 is 0.78 (meaning it changed or lost very little), then that variable does not contribute strongly to the fit. If the loss is large such as going from 0.80 to 0.60, then the variable does contribute strongly to the fit. This is a method of showing to which variables the outcome (peak dose) is most sensitive or responsive.

Random Variable

A property that has a numerical description and is determined by the outcome of a random experiment or random sampling. The different values of the random variable have different probabilities of occurrence. Also called variates.

Range (Statistics)

The numerical difference between the highest and lowest value in any series.

Rank Transformation

A type of data transformation used either to reduce the influence of extreme values or to deal with non-linearities in data sets. Data will fit better to a non-linear curve if it is first put into ranks. In ranking, the data values of both input and input data are replaced with the rank of that data value within the data set. The smallest value of a data set is replaced with the number 1, the second smallest is replaced with the number 2, and so forth up to the largest value in the set.

Regression

The relationship between the (conditional) mean of a random variable and one or more independent variables.

Regression Analysis

The analysis of paired data such that one member of the pair is a constant and the other is a random variable. The analysis of a paired dependent variable and the independent variable upon which it depends. For example, the term was first used in a study of the heights of fathers and sons where a regression (or turning back) was observed toward the mean height of the population in the heights of sons whose fathers were taller or shorter than the mean.

Scatter Plot

(1) A set of points arrived at by plotting paired values as points in a plane. (2) A two-dimensional dot plot.

Standard Deviation — (1) For a set of observations or a frequency distribution, the square root of the average of the squared deviations from the mean divided by n-1 (where n is the sample size). (2) The square root of the variance.

Variable — A nonunique property or attribute.

Variance — (1) The square of the standard deviation. (2) The expected squared distance from the population mean of a random variable, sometimes called the population variance.

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APPENDIX B

SUMMARY OF SCREENING DECISION AND BASIS INFORMATION CONTAINED IN REVISION 00 OF THE YUCCA MOUNTAIN PROJECT AND FEATURES, EVENTS, AND PROCESSES DATABASE

APPENDIX B

ACRONYMS AND ABBREVIATIONS

AECL	Atomic Energy of Canada, Ltd.
AMR	Analysis Model Report
Bio	Biosphere
CA	comparison approach
CRIT	Criticality
CSNF	commercial spent nuclear fuel
DE	disruptive events
DOE	U.S. Department of Energy
DSNF	Department of Energy spent nuclear fuel
EBS	engineered barrier system
FEP	feature, event, and process
FFC	far-field criticality
HLW	high-level radioactive waste
HMIP	Her Majesty Inspectorate of Pollution
IDGE	in-drift geochemical environment
IRSR	Issue Resolution Status Report
ISC	in-situ criticality
MLD	master logic diagram
NAGRA	National Cooperative for the Disposal of Radioactive Waste (Nationale Genossenschaft Fur die Lagerung Radioaktiver Abfalle) (Switzerland)
NEA	U.S. Nuclear Energy Agency
NFC	near-field criticality
NFE	near-field environment
NRC	U.S. Nuclear Regulatory Commission
PMR	Process Model Report
RIG	Revised Interim Guidance
SAM	Safety Assessment Management, Ltd.
SKB	Svensk Karnbranslehantering AB (Swedish Nuclear Fuel and Waste Management Co.)
SKI	Swedish Nuclear Power Inspectorate
SYS	system-level

APPENDIX B

ACRONYMS AND ABBREVIATIONS (Continued)

SZ	saturated zone
TBV	to be verified
TH	thermal-hydrology
THC	Thermal-Hydrologic-Chemical
TM	Thermal-Mechanical
TSPA	Total System Performance Assessment
TSPAI	Total System Performance Assessment and Integration
TSPA-SR	Total System Performance Assessment for Site Recommendation
UZ	unsaturated zone
WF	waste form
WF Misc.	waste form degradation – miscellaneous
WF Clad	waste form – cladding
WF Col	waste form – colloids
WIPP	Waste Isolation Pilot Plant
WP	waste package
YMP	Yucca Mountain Project
YSCP	YMP Site Characterization Plan

APPENDIX B

SUMMARY OF SCREENING DECISION AND BASIS INFORMATION CONTAINED IN REVISION 00 OF THE YUCCA MOUNTAIN PROJECT AND FEATURES, EVENTS, AND PROCESSES DATABASE

B.1. INTRODUCTION

Under the provisions of the U.S. Department of Energy's (DOE) Interim Guidance (Dyer 1999 [105655]), a performance assessment is required to demonstrate compliance with the postclosure performance objectives for the Yucca Mountain Project (YMP). Dyer (1999 [105655], Section 102[j]) defines a performance assessment as a systematic analysis that (1) identifies the features, events, and processes (FEPs) that might affect the performance of the potential geologic repository, (2) examines the effects of such FEPs on the performance of the potential geologic repository, and (3) estimates the expected annual dose to a specified receptor group. The performance assessment must also provide the technical basis for inclusion or exclusion of specific FEPs in the performance assessment (Dyer 1999 [105655], Section 114). To address these requirements, the YMP has adopted an approach to selecting scenarios for analysis in the Total System Performance Assessment for the Site Recommendation (TSPA-SR) that is based on the identification and screening of FEPs potentially relevant to the postclosure performance of the potential Yucca Mountain repository (see Section 2.1.1.1 of the main body of this report).

The electronic YMP FEP Database (CRWMS M&O 2000 [150806], Appendix D) catalogs the YMP FEPs and their associated screening information, which are an integral part of the scenario analysis for TSPA-SR. The five-step scenario-analysis approach for TSPA-SR is consistent with the five elements of Subissue 2, Scenario Analysis outlined in the Issue Resolution Status Report (IRSR) Key Technical Issue: Total System Performance Assessment and Integration (TSPAI) (NRC 2000 [149372], Section 4.2). The five steps are:

1. Identification of FEPs
2. Classification of FEPs
3. Screening of FEPs
4. Formation of Scenario Classes
5. Screening of Scenario Classes.

The information in the YMP FEP Database REV00 (CRWMS M&O 2000 [150806]) was developed external to the database—no original information or calculations were generated within the database itself. REV00 of the database contains the following information, which specifically addresses the first three steps of the scenario analysis approach (and, correspondingly, the first three elements of TSPAI IRSR Subissue 2):

- **YMP FEP List**–A comprehensive list of FEPs that have the potential to influence repository performance

- **FEP Classifications**–The categorization of FEPs in accordance with a hierarchical organizational structure that groups similar FEPs together and allows for relationships between FEPs to be identified

- **FEP Screening Decisions and Supporting Documentation**–For each FEP, the technical basis for inclusion or exclusion in the TSPA-SR analyses is summarized, as taken from FEP Analysis Model Reports (AMRs).

The information catalogued in the database, specifically the included (screened-in) FEPs, provides the basis for scenario class formation and screening, the final two steps of the scenario analysis approach. However, these two steps (and, correspondingly, the fourth and fifth elements of TSPAI IRSR Subissue 2) are outside the scope of the database and are addressed in Section 2.1 of the main body of this report.

This Appendix discusses the following:

- The origin and development of a comprehensive list of FEPs potentially relevant to the postclosure performance of the repository

- The development and structure of an electronic database capable of storing and retrieving information about the inclusion and (or) exclusion of these FEPs in TSPA-SR

- A summary of the FEPs and their dispositions (i.e., inclusion and [or] exclusion of these FEPs in the TSPA-SR).

The origin and development of the YMP FEP list is described in Section B.2 of this Appendix. The development of the FEP classifications and the organizational structure of the database are described in Section B.3. Section B.4 is an overview of the screening criteria and guidance for exclusion of FEPs from the TSPA-SR. A summary of screening decisions and bases for all primary FEPs is given in Section B.5. Section B.6 discusses the transparency and traceability, comprehensiveness, categorization, and screening of the YMP FEPs relative to the TSPAI IRSR subissues. A brief summary of this Appendix is given in Section B.7.

The FEP screening decisions and supporting documentation (collectively referred to as the screening discussions) provided in the YMP FEP Database REV00 (CRWMS M&O 2000 [150806], Appendix D) and in Section B.5 were taken from FEP AMRs listed in Table B-1. Each FEP AMR was associated with a Process Model Report (PMR) subject area. Each FEP AMR was prepared in accordance with AP-3.10Q [152363], *Analyses and Models,* and provided qualified documentation of the screening decisions for each FEP relevant to the subject area. Technical details of specific screening discussions and screening criteria are documented in the FEP AMRs, not in this Appendix or in the YMP FEP Database REV00 (CRWMS M&O 2000 [150806]). However, a general discussion of the nature of the screening discussions is presented in Section B.4.

Table B-1. Features, Events, Processes Analysis Model Reports Contributing Screening Information to the Yucca Mountain Project Features, Events, and Processes Database

PMR Subject Area	FEP AMR Document Identifier	Reference
Unsaturated Zone (UZ) Flow and Transport	ANL-NBS-MD-000001 REV00	CRWMS M&O 2000 [142945]
Saturated Zone (SZ) Flow and Transport	ANL-NBS-MD-000002 REV00	CRWMS M&O 2000 [137359]
Biosphere (Bio)	ANL-MGR-MD-000011 REV00	CRWMS M&O 2000 [142844]
Disruptive Events (DE)	ANL-WIS-MD-000005 REV00	CRWMS M&O 2000 [146681]
Waste Package (WP) Degradation	ANL-EBS-PA-000002 REV00	CRWMS M&O 2000 [146538]
Waste Form (WF) Degradation–Miscellaneous FEPs (WF Misc.) – Cladding FEPs (WF Clad) – Colloid FEPs (WF Col)	ANL-WIS-MD-000009 REV00 ANL-WIS-MD-000008 REV00 ANL-WIS-MD-000012 REV00	CRWMS M&O 2000 [146498] CRWMS M&O 2000 [150099] CRWMS M&O 2000 [125156]
Near Field Environment (NFE)	ANL-NBS-MD-000004 REV00	CRWMS M&O 2000 [142895]
Engineered Barrier System (EBS) Degradation, Flow, and Transport	ANL-WIS-PA-000002 REV00	CRWMS M&O 2000 [136951]
System-Level (SYS[a]) FEPs	ANL-WIS-MD-000019 REV00B	CRWMS M&O 2000 [152216]
Criticality (CRIT[a]) FEPs	Not available for database REV00	N/A

Source: CRWMS M&O 2000 [150806]

NOTES: [a] Not a PMR
NA = Not Available

The YMP FEP Database REV00 (CRWMS M&O 2000 [150806]) evolved from preliminary versions REV00A, REV00B, and REV00C. The evolution of the database versions leading to REV00 is described in *The Development of Information Catalogued in REV00 of the YMP FEP Database* (CRWMS M&O 2000 [150806], Section 5).

B.2. IDENTIFICATION OF THE YUCCA MOUNTAIN PROJECT FEATURES, EVENTS, AND PROCESSES LIST

The development of a comprehensive list of FEPs potentially relevant to the postclosure performance of the potential Yucca Mountain repository is an ongoing, iterative process, based on site-specific information, design, and regulations. The list of FEPs catalogued in the YMP FEP Database REV00 (CRWMS M&O 2000 [150806], Appendix D) was developed using the following approach:

- Develop an initial list of general FEPs from other radioactive waste disposal programs.
- Supplement the general list with FEPs from project-specific literature.
- Augment the list through brainstorming and iterative review from CRWMS M&O subject matter experts (e.g., at technical workshops and in technical reports).
- Augment the list with feedback from external sources (e.g., U.S. Nuclear Regulatory Commission (NRC)/DOE Technical Exchange and Appendix 7 Meetings, NRC IRSRs).

This approach combines the bottom-up (i.e., nonsystematic, all-inclusive) identification of an initial FEP list, with a top-down (i.e., systematic) series of reviews.

B.2.1 INTERNATIONAL FEATURES, EVENTS, AND PROCESSES

The YMP FEPs list was initially populated with 1,261 FEPs compiled by other radioactive waste programs. The FEPs were taken from Version 1.0 of an electronic FEP database (SAM n.d. [139333]) maintained by the U.S. Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development. The NEA database contains FEPs from seven programs and is the most complete attempt, internationally, at compiling a comprehensive list of FEPs potentially relevant to radioactive waste disposal. Consistent with the diverse backgrounds of the waste disposal programs contributing to the NEA list, FEPs were identified by a variety of methods, including expert judgment, informal elicitation, event tree analysis, stakeholder review, and regulatory stipulation.

Version 1.0 of the NEA database exists in draft form only. It contains extensive descriptions of potentially relevant FEPs from each of the seven programs, along with program-specific technical discussions regarding their applicability. The YMP FEPs list includes the relevant portions of each of the NEA FEPs but does not include the program-specific details unless they are also relevant to YMP. SAM (n.d. [139333], Section B-2.3) identifies the publications listed in Table B-2 as the basis for the NEA FEPs. However, in many cases the draft NEA database contains more extensive FEP descriptions than the supporting publications. The number of FEPs in the database from each of these international programs is also listed in Table B-2.

Table B-2. Origin of the 1,261 Features, Events, and Processes in the U.S. Nuclear Energy Agency Database

Nation	Organization	Type of Study	Number of FEPs[a]	Reference
Canada	Atomic Energy of Canada, Ltd. (AECL)	Scenario Analysis	281	Goodwin et al. 1994 [100983]
International	U.S. Nuclear Energy Agency (NEA)	Scenario Working Group	146	Nuclear Energy Agency 1992 [100479]
Sweden	Swedish Nuclear Power Inspectorate (SKI)	SITE-94	106	Chapman et al. 1995 [100970]
Sweden	Joint SKI and Swedish Nuclear Fuel and Waste Management Co. Svensk Karnbranslehantering AB (SKB)	Scenario Development	158	Andersson 1989 [100956]
United Kingdom	Her Majesty Inspectorate of Pollution (HMIP)	Intermediate- and low-level waste disposal	79	Miller and Chapman 1993 [100996]
Switzerland	National Cooperative for the Disposal of Radioactive Waste (NAGRA)	Kristallin-1	245	NAGRA 1994 [124260]
United States	Waste Isolation Pilot Plant (WIPP)	Compliance Application	246	DOE 1996 [100975]

NOTE: [a] These include FEPs from both the cited reference and the draft NEA database.

B.2.2 YMP-SPECIFIC FEPS

The 1,261 NEA FEPs in the YMP FEP list were supplemented with 292 YMP-specific FEPs identified in a search of YMP literature (Barr 1999 [139292]). Because the YMP is the only potential repository proposed for an unsaturated fractured tuff, many of these FEPs represent events and processes not otherwise included in the international compilation. The 1988 Site Characterization Plan (DOE 1988 [100282], Section 8.3.5.13) itemized 99 specific issues, from which 91 YMP-specific FEPs were identified. The other eight issues were considered to be better captured or subsumed in other similar, but more broadly defined, FEPs. Other project documents provided the general basis for 201 additional YMP-specific FEPs, as described in "Origin of Yucca Mountain FEPs in the database prior to the last set of workshops" (Barr 1999 [139292]). The origin of the 292 YMP-specific FEPs are summarized in Table B-3.

Table B-3. Origin of the 292 Features, Events, and Processes Identified by a Review of the Yucca Mountain Project Literature

Source Document	Number of FEPs	Reference
YMP Site Characterization Plan (YSCP)	91	DOE 1988 [100282]
Other YMP Documents	201	Barr 1999 [139292]

B.2.3 ITERATIVE CIVILIAN RADIOACTIVE WASTE MANAGEMENT SYSTEM MANAGEMENT AND OPERATING CONTRACTOR REVIEW OF THE YUCCA MOUNTAIN PROJECT FEATURES, EVENTS, AND PROCESSES LIST

The resulting YMP list of 1,553 FEPs identified from the NEA database and YMP literature was taken to a series of technical workshops convened between December 1998 and April 1999 (Table B-4). At these workshops, the FEPs relevant to each subject area were reviewed and discussed by subject matter experts within the project. During these reviews and the associated intensive discussions, workshop participants identified 82 additional YMP-specific FEPs, as summarized in Table B-4. Workshop participants also proposed several issues that were related to FEPs already in the database, in which case, the existing FEP descriptions were expanded to include the new issues.

Table B-4. Origin of the 82 Features, Events, and Processes Identified at the Yucca Mountain Project Workshops Held between December 1998 and April 1999

Workshop	Date	Number of FEPs	Reference
Unsaturated-Zone Flow and Transport (UZ)	Dec. 14-16, 1998	0	[b]
DOE Spent Nuclear Fuel (DSNF) FEPs	Jan. 19, 1999	40	Eide 2000 [149435]
Waste Form (WF)	Feb. 2-4, 1999	12	[a]
Disruptive Events (DE)	Feb. 9-11, 1999	18 6	CRWMS M&O1998 [101095][a]
Saturated Zone Flow/Transport and Biosphere (SZ/Bio)	Feb. 17-19, 1999	1	[a]

Table B-4. Origin of the 82 Features, Events, and Processes Identified at the Yucca Mountain Project Workshops Held between December 1998 and April 1999 (Continued)

Workshop	Date	Number of FEPs	Reference
Thermal-Hydrology (TH) and Coupled Processes	Mar. 24-25, 1999	1	a
In-Drift Geochemical Environment (IDGE) and EBS Transport	Apr. 13-15, 1999	2	a
Waste Package Degradation (WP)	Apr. 20-21, 1999	2	a

NOTES: [a] Indicates that new FEPs were generated by roundtable discussions and subsequently entered directly into the database.

[b] Indicates that no new FEPs were generated at this workshop.

Except for the 40 FEPs from the DSNF Workshop and 18 criticality-related FEPs from the DE Workshop, these additional YMP-specific FEPs were developed informally during roundtable discussions at the workshops and have no formal documentation. Eide (2000 [149435], Tables 1 and 2) documents 25 YMP DSNF-related FEPs derived using a master logic diagram (MLD) approach and an additional 15 DSNF FEPs derived using a comparison approach (CA) between DSNF and commercial spent nuclear fuel (CSNF). The origin of the 18 criticality FEPs from The *Disposal Criticality Analysis Methodology Topical Report* (CRWMS M&O 1998 [101095], Section 3.1) is noted in specific entries in the database. These FEPs include in-situ criticality (ISC), near-field criticality (NFC), and far-field criticality (FFC).

A second round of reviews by subject matter experts was performed in 1999 and 2000, in association with the development of FEP AMRs (listed in Table B-1). During the preparation of the FEP AMRs, subject matter experts reviewed the existing FEPs relevant to their subject area and, where necessary, identified new or missing FEPs. This review and documentation process identified nine additional FEPs, as summarized in Table B-5.

Table B-5. Origin of the Nine Features, Events, and Processes Identified in Features, Events, and Process Analysis Model Reports

FEP AMR Subject Area and ID		Number of FEPs	Reference
WF Misc.	ANL-WIS-MD-000009	2	CRWMS M&O 2000 [146498]
WF Clad	ANL-WIS-MD-000008	2	CRWMS M&O 2000 [150099]
WF Col	ANL-WIS-MD-000012	3	CRWMS M&O 2000 [125156]
EBS	ANL-WIS-PA-000002	2	CRWMS M&O 2000 [136951]

For FEPs related to EBS degradation, flow, and transport, a systematic top-down study (CRWMS M&O 2000 [146680]) was performed to identify any potential FEPs not on the list of FEPs distributed to the EBS FEP AMR (CRWMS M&O 2000 [136951]). The results of the top-down study confirmed the existing EBS-related FEPs and identified the two new FEPs noted in Table B-5, which were incorporated into the EBS FEP AMR (CRWMS M&O 2000 [136951]).

B.2.4 EXTERNAL REVIEW OF THE YUCCA MOUNTAIN PROJECT FEATURES, EVENTS, AND PROCESSES LIST

An interim version of the YMP FEP list was provided to the NRC in association with the NRC/DOE Appendix 7 Meeting on the FEPs Database held September 8, 1999. A subsequent NRC audit of this interim version of the YMP FEP list identified one potential FEP unrelated to any existing FEPs (Pickett and Leslie 1999 [150373], Section 3.3). The audit also identified three potential FEPs that were possibly related to existing FEPs. Two of these FEPs were subsequently determined to be redundant to or subsumed in existing FEPs. The other two FEPs, noted in Table B-6, were added to the YMP FEP list.

Table B-6. Origin of the Two Features, Events, and Processes Identified in External Reviews

Review	Number of FEPs	Reference
NRC NFE Audit	2	Pickett and Leslie 1999 [150373]

B.2.5 FUTURE DEVELOPMENT OF THE YUCCA MOUNTAIN PROJECT FEATURES, EVENTS, AND PROCESSES LIST

While the FEPs catalogued in the YMP FEP Database REV00 (CRWMS M&O 2000 [150806], Appendix D) are considered to be reasonably comprehensive, the YMP FEP list is open and may continue to expand if additional FEPs are identified either, within the CRWMS M&O and DOE or from external sources. New FEPs, if identified, will be incorporated into subsequent revisions of the database.

B.3. YUCCA MOUNTAIN PROJECT FEATURES, EVENTS, AND PROCESSES CLASSIFICATIONS

B.3.1 DATABASE STRUCTURE

Many FEP classification schemes are possible, and there is no inherently correct way to order FEPs. The structure of the YMP FEP Database REV00 (CRWMS M&O 2000 [150806]) follows the NEA classification scheme (SAM n.d. [139333], Section 3), in which FEPs are organized under a hierarchical structure of layers, categories, and headings. The NEA structure comprises a comprehensive group of subject areas potentially relevant to radioactive waste disposal that was developed to systematically classify the FEPs from seven different international programs (Section B-2.1). The NEA classification scheme was selected because it maintains consistency between NEA and YMP databases, which facilitates reviewing for completeness.

The structure of the NEA FEP Database Version 1.0 is defined by 4 layers, 12 categories, and 134 headings. The search of YMP literature for FEPs by Barr (1999 [139292]) identified an additional heading relevant to YMP (the Nuclear Criticality heading in the Geologic Environment category) that was not in the NEA database. Therefore, the YMP FEP Database REV00 (CRWMS M&O 2000 [150806]) has 4 layers, 12 categories, and 135 headings. The hierarchical relationship between these layers, categories, and headings is shown in Table B-7.

Table B-7. Hierarchical Structure of the Yucca Mountain Project Features, Events, and Processes Database

Layers	Categories	Headings [a]
0. Assessment Basis		0.1.01 Impacts of concern 0.1.02 Time scales 0.1.03 Spatial domain 0.1.04 Potential repository assumptions 0.1.05 Future human action assumptions 0.1.06 Future human behavior assumptions 0.1.07 Dose response assumptions 0.1.08 Aims of the assessment 0.1.09 Regulatory requirements and exclusions 0.1.10 Model and data issues
1. External Factors	1.1 Repository Issues	1.1.01 Site investigation 1.1.02 Excavation/construction 1.1.03 Emplacement of wastes 1.1.04 Closure and sealing 1.1.05 Records and markers 1.1.06 Waste allocation 1.1.07 Design 1.1.08 Quality control 1.1.09 Schedule and planning 1.1.10 Administrative control of site 1.1.11 Monitoring 1.1.12 Accidents and unplanned events 1.1.13 Retrievability
	1.2 Geologic Processes and Effects	1.2.01 Tectonic movements 1.2.02 Deformation 1.2.03 Seismicity 1.2.04 Volcanic activity 1.2.05 Metamorphism 1.2.06 Hydrothermal activity 1.2.07 Erosion and sedimentation 1.2.08 Diagenesis 1.2.09 Salt diapirism and dissolution 1.2.10 Hydrologic response to geologic changes
	1.3 Climatic Processes and Effects	1.3.01 Climate change, global 1.3.02 Climate change, regional 1.3.03 Sea level changes 1.3.04 Periglacial effects 1.3.05 Glacial and ice sheet effects 1.3.06 Warm climate effects 1.3.07 Hydrologic response to climate change 1.3.08 Ecological response to climate change 1.3.09 Human response to climate change

Table B-7. Hierarchical Structure of the Yucca Mountain Project Features, Events, and Processes Database (Continued)

Layers	Categories	Headings [a]
1. External Factors	1.4 Future Human Actions (Active)	1.4.01 Human influences on climate 1.4.02 Inadvertent/deliberate human actions 1.4.03 Unintrusive site investigation 1.4.04 Drilling activities 1.4.05 Mining and other underground activities 1.4.06 Surface environment 1.4.07 Water management (wells, reservoirs) 1.4.08 Social developments 1.4.09 Technological developments 1.4.10 Remedial actions 1.4.11 Explosions and crashes
	1.5 Other	1.5.01 Meteorite impact 1.5.02 Species evolution 1.5.03 Miscellaneous (earth tides)
2. Disposal System Domain: Environmental Factors	2.1 Wastes and Engineered Features	2.1.01 Inventory 2.1.02 Waste form 2.1.03 Waste container 2.1.04 Backfill 2.1.05 Seals, cavern/tunnel/shaft 2.1.06 Other features (drip shield, invert) 2.1.07 Mechanical processes and conditions 2.1.08 Hydrogeologic processes and conditions 2.1.09 Geochemical processes and conditions 2.1.10 Biological processes and conditions 2.1.11 Thermal processes and conditions 2.1.12 Gas sources and effects 2.1.13 Radiation effects 2.1.14 Nuclear criticality
	2.2 Geologic Environment	2.2.01 Excavation disturbed zone 2.2.02 Host rock 2.2.03 Geologic units, other 2.2.04 Discontinuities, large scale 2.2.05 Contaminant transport pathways 2.2.06 Mechanical processes and conditions 2.2.07 Hydrogeologic processes and conditions 2.2.08 Geochemical processes and conditions 2.2.09 Biological processes and conditions 2.2.10 Thermal processes and conditions 2.2.11 Gas sources and effects 2.2.12 Undetected features 2.2.13 Geological resources 2.2.14 Nuclear criticality

Table B-7. Hierarchical Structure of the Yucca Mountain Project Features, Events, and Processes Database (Continued)

Layers	Categories	Headings [a]
2. Disposal System Domain: Environmental Factors	2.3 Surface Environment	2.3.01 Topography 2.3.02 Soil 2.3.03 Aquifers/water-bearing features, near surface 2.3.04 Lakes, rivers, streams, springs 2.3.05 Coastal features 2.3.06 Marine features 2.3.07 Atmosphere 2.3.08 Vegetation 2.3.09 Animal populations 2.3.10 Meteorology 2.3.11 Hydrologic regime and water balance 2.3.12 Erosion and deposition 2.3.13 Ecological/biological/microbial systems
	2.4 Human Behavior	2.4.01 Human characteristics 2.4.02 Adults, children, infants 2.4.03 Diet and fluid intake 2.4.04 Habits, nondiet-related 2.4.05 Community characteristics 2.4.06 Food and water processing and preparation 2.4.07 Dwellings 2.4.08 Wild/natural land and water use 2.4.09 Rural/agricultural land and water use 2.4.10 Urban/industrial land and water use 2.4.11 Leisure and other uses of the environment
3. Disposal System Domain: Radionuclide/ Contaminant Factors	3.1 Contaminant Characteristics	3.1.01 Radioactive decay and ingrowth 3.1.02 Chemical/organic toxin stability 3.1.03 Inorganics 3.1.04 Volatiles 3.1.05 Organics 3.1.06 Noble Gases
	3.2 Contaminant Release/ Migration Factors	3.2.01 Dissolution, precipitation, crystallization 3.2.02 Speciation and solubility 3.2.03 Sorption/desorption processes 3.2.04 Colloids 3.2.05 Chemical/complexing agents, effect on transport 3.2.06 Microbiological/plant-mediated processes 3.2.07 Water-mediated transport 3.2.08 Solid-mediated transport 3.2.09 Gas-mediated transport 3.2.10 Atmospheric transport 3.2.11 Animal, plant, microbe mediated transport 3.2.12 Human-action-mediated transport 3.2.13 Food chains, uptake of contaminants

Table B-7. Hierarchical Structure of the Yucca Mountain Project Features, Events, and Processes Database (Continued)

Layers	Categories	Headings [a]
3. Disposal System Domain: Radionuclide/ Contaminant Factors	3.3 Exposure Factors	3.3.01 Drinking water, food, drugs, concentrations 3.3.02 Environmental media, concentrations 3.3.03 Nonfood products, concentrations 3.3.04 Exposure modes 3.3.05 Dosimetry 3.3.06 Radiological toxicity/effects 3.3.07 Nonradiological toxicity/effects 3.3.08 Radon exposure

Source: CRWMS M&O 2000 [150806]

NOTE: [a] Some heading descriptions are paraphrased.

Each of the 1,646 FEPs in the YMP FEP list identified in Section B.2 of this Appendix was assigned (mapped) to a single heading in the YMP FEP Database. For the 1,261 FEPs adopted from other international programs (Table B-2), preliminary mappings were based on the relationships identified in the NEA database, although some adjustments were made to reflect YMP-specific conditions. The task of finding unique mappings was complicated by the fact that many FEPs in the NEA database are mapped to multiple headings. In cases where more than one heading was identified, the most relevant one for YMP was selected, and cross-references were made to the others. This approach eliminated duplicative entries in the YMP FEP Database. For the 385 YMP-specific FEPs (Tables B-3 through B-6), which are not included in the NEA database, preliminary mappings were made to the most relevant heading. The preliminary mappings were reviewed during the December 1998 to April 1999 workshops (Table B-4) and during preparation of the FEP AMRs (Table B-1), and some changes in mapping were made as defined by subject matter experts.

Each of the 1,646 FEPs in the YMP FEP list is an individual entry (record) in the YMP FEP Database, as are the 151 layer, category, and heading entries that define the YMP FEP classifications. Therefore, the YMP FEP Database REV00 (CRWMS M&O 2000 [150806], Appendix D) contains a total of 1,797 individual entries. The mapping of FEP entries to the heading entries resulted in a database where all related entries were grouped together under the same classification heading (with overarching categories and levels). Links between database entries and specific FEP AMR PMR subject areas (see Section B.3.4) allow for additional groupings to be examined. A further categorization of the entries, to better facilitate systematic screening, is described in Section B.3.2.

B.3.2 PRIMARY AND SECONDARY FEATURES, EVENTS, AND PROCESSES

There is no uniquely correct level of detail at which to define and (or) aggregate FEPs. In the case where FEPs are too narrowly defined, it is infeasible to develop specific screening decisions for each FEP. Instead, it becomes more efficient to develop more broadly based screening decisions that apply to multiple, related FEPs. In cases where FEPs are too coarsely defined, it becomes difficult to isolate important subissues, and, consequently, some important subissues may get excluded, while other unimportant issues may get included. For efficiency, FEPs need to be aggregated at the coarsest level at which technically sound screening decisions can be made, while still maintaining adequate detail for the purposes of the analysis.

The all-inclusive bottom-up approach used to develop the YMP FEP list resulted in considerable redundancy in the FEP list, because the same FEPs were frequently identified by multiple sources. This was especially true of the international FEPs, where each of the seven programs would often identify the same FEP (e.g., meteorite impact). It was also true of the YMP-specific FEPs (and some of the more general international FEPs), where variations of the same FEP would be identified in various literature or reviews.

To eliminate the redundancy and to create a more efficient aggregation of FEPs to carry forward into the screening process (Section B.4), each of the 1,797 entries catalogued in the YMP FEP Database REV00 (CRWMS M&O 2000 [150806], Appendix D) was further identified as either a primary, secondary, or classification (layer, category, or heading) entry. Assignments to each of the three types of entries were based on the follow criteria:

Primary FEP Entry–These are database entries that encompass a single process or event, or a few closely related or coupled processes or events, that can be addressed by a specific screening discussion. Each primary FEP is addressed by a YMP-specific screening discussion taken from one or more FEP AMRs. A primary FEP may also include one or more related secondary FEPs that are covered by the same screening discussion.

Secondary FEP Entry–These are database entries that are (1) redundant to another FEP (e.g., several NEA contributors identified the same FEP), (2) specific to another program (captured more generally in a different YMP-specific FEP), or (3) better captured or subsumed in another similar, but more broadly-defined, YMP-specific FEP. Each secondary FEP is mapped to a primary FEP and must be completely addressed by the screening discussion of that primary FEP.

Classification (Layer, Category, Heading) Entry–These are database entries that represent the hierarchical levels of classification within the database (see Table B-7). Classification entries are neither primary FEPs nor secondary FEPs. They are defined too broadly to be addressed by a single screening discussion (as with a primary FEP) and cannot be encompassed by an overlying FEP (as with a secondary FEP). Rather, they classify one or more underlying, related, primary FEPs and do not require screening discussions.

Based on the preliminary mapping of the FEP entries to the heading entries (described in Section B.3.1), a preliminary attempt was made to identify primary, secondary, and classification entries. The following steps were followed:

1. The 4 layer, 12 category, and 135 heading entries were initially defined as classification entries (as described in Step 4, below, some heading entries were subsequently re-classified as primary FEPs).

2. The FEP entries mapped under each heading were informally separated into groups of related FEPs (e.g., under 2.1.03 Waste Container were such groupings as corrosion, mechanical damage, and early failures).

3. Each of the informal groupings of related FEPs from step 2, above, was further evaluated to identify FEPs that would likely require separate screening discussions. These independent FEPs were identified as primary FEPs (with no associated secondary FEPs).

4. In some cases, the informal groupings of FEPs under a specific heading entry were closely enough related that they could all be addressed by a screening discussion at the overlying heading level. In these cases, the heading entry (previously defined as a classification entry in step 1, above) was designated as a primary FEP. The underlying FEPs were designated as secondary FEPs to the heading level primary FEP.

5. Each of the remaining informal groupings of related FEPs from step 2, above, (that were not mapped as independent in step 3, above, or heading level in step 4, above) was further evaluated to better identify (a) multiple FEPs covering related or coupled processes or events that could likely be addressed by a single screening discussion, or (b) redundant FEPs. The resulting groups of FEPs were each selected to be represented by a primary FEP.

6. Each of the primary FEP groups identified from step 5, above, was examined to select a specific primary FEP. The primary FEP was chosen from the group of related or redundant FEPs as the FEP that best represented and was most inclusive of the group of FEPs as a whole. The other FEPs in the group were designated as secondary FEPs to the selected primary FEP.

7. For each of the primary FEPs (selected in steps 3, 4, and 6, above), a YMP primary FEP description was prepared. This description was based on the FEP description provided by the originator (e.g., the NEA database or YMP literature). The originator description was (a) edited to ensure that it was specific to YMP, and (b) expanded to ensure that all aspects of the related secondary FEPs were also addressed.

Because any categorization of FEPs is subjective, the preliminary identification of primary, secondary, and classification entries was reviewed by subject matter experts. During the December 1998 to April 1999 workshops (Table B-4), some primary and secondary categorizations were revised, and some of the FEPs were remapped to different headings. During preparation of the FEP AMRs (Table B-1), additional changes to primary and secondary FEP mappings and to the YMP primary FEP descriptions were identified. The FEP AMRs also confirmed that the remaining mappings were appropriate and that the YMP primary FEP descriptions did encompass all aspects of the related secondary FEPs.

After all the reviews and confirmations, the YMP FEP Database REV00 (CRWMS M&O 2000 [150806]) contains 111 classification entries (151, less 40 heading entries that are also primary FEPs), 323 primary FEP entries (including the 40 headings) and 1,363 secondary FEP entries.

The objective of the categorization into primary, secondary, and classification entries was to identify a subset of FEP entries, the primary FEPs, which capture all of the issues relevant to the postclosure performance of the potential Yucca Mountain repository and that can be addressed at an appropriate level of screening. As a result of the categorization described in this section, it was only necessary to develop screening decisions and supporting documentation (as described in Section B.4) for the 323 primary FEPs, not for all 1,797 YMP FEP list entries. A minor exception was found in the input AMRs. Two secondary FEPs—2.1.02.08.04 and 1.4.01.03.01—were addressed explicitly. All other secondary FEPs were screened at the overlying primary FEP level.

B.3.3 ORGANIZATION AND NUMBERING OF DATABASE ENTRIES

The organization of the FEP entries within the YMP FEP Database REV00 (CRWMS M&O 2000 [150806]) to follow the NEA hierarchical structure is controlled by the YMP FEP database number associated with each FEP entry. This number has the form x.x.xx.xx.xx and defines classification (layer, category, heading), primary, and secondary entries as follows:

- x.0.00.00.00 Layer
- x.x.00.00.00 Category
- x.x.xx.00.00 Heading (some of these are also Primary FEPs)
- x.x.xx.xx.00 Primary FEP (where the first number x.x.xx is the overlying Heading)
- x.x.xx.xx.xx Secondary FEP (where the first number x.x.xx.xx is the overlying primary FEP).

With this numbering scheme, the YMP FEP database number always identifies to which heading a primary FEP is mapped and to which primary FEP a secondary FEP is associated.

B.3.4 DATABASE FIELDS

For each of the 1,797 entries in REV00 of the database, there are 26 data/text fields. Each of these fields is described below. Fields that contain input or confirmation from the FEP AMRs are noted with a double underline.

YMP FEP Database Number–This is a numeric identifier that places the FEP in the proper location within the database structure. The numbering scheme follows a hierarchical structure classifying FEPs into layers (x...), categories (x.x...), headings (x.x.xx...), primary FEPs (x.x.xx.xx...), and secondary FEPs (x.x.xx.xx.xx).

FEP Name–This is a short, descriptive title of an FEP.

FEP Class–This is the identification used for primary, secondary, and classification (layer, category, heading) entries. Primary FEPs are those FEPs for which the YMP has developed and documented screening discussions. Secondary FEPs are mapped to primary FEPs, either because they are redundant with the associated primary FEP, or because they represent a subcase of the primary FEP that is more effectively addressed at a higher level. Secondary FEPs are retained in the database for completeness, but users of the database are referred to the related Primary FEPs for the screening discussions.

Related FEPs–This is the identification used for entries containing related information. For primary FEPs, other related primary FEPs (if any) are listed. For secondary FEPs, the associated primary FEP is listed. However, for layer, category, and heading classification entries, underlying headings are assumed to be related and are not listed explicitly.

Source Identifier–This is the alphanumeric identifier that provides traceability to the originator (e.g., NEA contributing program, YMP workshop, FEP AMR) as shown in Table B-8. Note that the Source Identifier is not related to the NEA structure or YMP FEP Database Number.

Table B-8. Abbreviations Used in Source Identifier Field

Source (see Tables B-2 through B-6)	Source Identifier Format
AECL	Ax.xxx
NEA	Nx.x.xx
SKI/SKB	Jx.x.xx
SKI	Sxxx
HMIP	HMIPx.x.x
NAGRA	Kx.xx
DOE-WIPP	Wx.xxx
YMP Site Characterization Plan (YSCP)	YSCPxx
Other YMP Documents	Ymxx
UZ Workshop	UZ/xxxx
DSNF Workshop	CA-x, MLD-x
WF Workshop	WF/xxxx
DE Workshop	DE/xxxx, ISC-x, NFC-x, FFC-x
SZ/Bio Workshop	SZ/xxxx, BIO/xxxx
TH Workshop	TH/xxxx
IDGE Workshop	ID/xxxx
WP Workshop	WP/xxxx
NEA Layer, Category, Heading	NEA xxxxxxxx
Other Layer, Category, Heading	Non-NEA xxxxxxxx
WF Miscellaneous FEP AMR	WF Misc AMR-x
WF Cladding FEP AMR	WF Clad AMR-x
WF Colloid FEP AMR	WF Col AMR-x
EBS FEP AMR	EBS AMR-x
NRC NFE Audit	NRC-x

Source: Table B-1

NEA Category–This is the alphanumeric used for identifying the preliminary mapping of the FEPs relative to the NEA database headings. This field is based on preliminary mapping and has been superceded by the YMP FEP Database Number field. It is retained only for traceability to earlier versions of the database. Note that for new FEPs that were identified during and subsequent to the December 1998 to April 1999 workshops, the Source Identifier is repeated in the NEA Category field.

YMP Primary FEP Description–This is the description of each FEP and its potential relevance to YMP, typically edited from the originator description. Where secondary FEPs are associated with a primary FEP, the description also includes all of the FEPs described by the secondary FEPs.

Originator FEP Description–This is the verbatim text of an FEP description from originator documentation. The originator is noted in parentheses, where possible.

Screening Decision–This is a statement of whether the FEP is included in the quantitative Total System Performance Assessment (TSPA) models or excluded from the TSPA on specific criteria provided by the regulations.

Screening Argument–This is a summary discussion of the technical basis for the Screening Decision, with citations to appropriate AMRs. (For excluded FEPs, this is the key text.)

TSPA Disposition–This is a summary discussion of the treatment of the FEP in the TSPA, with citations and cross-references to the appropriate AMRs. (For included FEPs, this is the key text.)

PMR–This identifies the PMR subject area that was assigned initial responsibility for technical evaluation of the FEP. This field was not updated for REV00. Instead, the subject area where the FEP was ultimately addressed is listed in the Input AMR field.

Input AMR–This identifies the FEP AMR where the qualified screening discussion is documented. Verbatim text for several fields, including the Screening Decision, Screening Argument, TSPA Disposition, Supplemental Discussion, and References, are taken from the Input AMR. The Input AMR identifier also indicates the subject area in which the FEP is grouped.

IRSR–This identifies NRC IRSR subissues related to the FEP.

Supplemental Discussion–This discussion provides additional information supporting the Screening Decision beyond what is summarized in the Screening Argument and TSPA Disposition fields.

References–These identify the references cited in the Screening Argument and (or) TSPA Disposition summaries.

Modified by–The name of last person to modify an FEP record appears here.

Mod Date–The date of the last modification to an FEP record appears here.

Mod Time–The time of the last modification to an FEP record appears here.

Record Number–This is the numeric identifier of the record sequence.

F Keyword–This is an identifier feature keyword from a specified list that is used for keyword searches. For REV 00, this field is blank.

E Keyword–This is an identifier event keyword from a specified list that is used for keyword searches. For REV 00, this field is blank.

P Keyword–This is an identifier process keyword from a specified list that is used for keyword searches. For REV 00, this field is blank.

Workshop–This identifies all of the Workshops held between December 1998 to April 1999, where the FEP was reviewed and discussed. This field is retained only for traceability back to preliminary versions of the database.

Owner–This is the name of the technical, subject-matter expert given responsibility to address the FEP at the December 1998 to April 1999 workshops. This field has been superceded by the Input AMR field, which now establishes FEP ownership. For REV 00, this field is blank.

Notes–These consist of miscellaneous notes and comments related to the FEP.

B.4. YUCCA MOUNTAIN PROJECT AND FEATURES, EVENTS, AND PROCESSES SCREENING CRITERIA AND GUIDELINES

B.4.1 SCREENING CRITERIA

Each primary FEP (and, by association, each secondary FEP) was screened for inclusion or exclusion in the TSPA on the basis of three criteria, developed from DOE's Interim Guidance (Dyer 1999 [105655]). The three criteria are as follows:

1. **Regulatory**–DOE's Interim Guidance (Dyer 1999 [105655], Subpart E) provides regulatory guidance regarding certain assumptions about the TSPA. Some FEPs may be specifically exempted from consideration in TSPA because they are not in accordance with this regulatory guidance or are not applicable by regulation. FEPs that are inconsistent with the regulatory assumptions may be excluded (screened out) from the TSPA by regulation. The most notable examples are the regulatory specification of the human intrusion scenario and the critical group characteristics. Any FEPs which invoke human intrusion scenarios or critical group characteristics that are inconsistent with what is specified in the regulations are screened out by regulation.

2. **Probability**–The probability criterion is stated in DOE's Interim Guidance (Dyer 1999 [105655], Section 114):

    a. Consider only events that have at least one chance in 10,000 of occurring over 10,000 years.

    b. FEPs with a lower probability of occurrence may be excluded (screened out) from the TSPA on the basis of low probability.

3. **Consequence**–The consequence criteria are stated in DOE's Interim Guidance (Dyer 1999 [105655], Section 114):

   a. Provide the technical basis for either inclusion or exclusion of specific FEPs of the geologic setting in the performance assessment. Specific FEPs of the geologic setting must be evaluated in detail if the magnitude and time of the resulting expected annual dose would be significantly changed by their omission.

   b. Provide the technical basis for either inclusion or exclusion of degradation, deterioration, or alteration processes of engineered barriers in the performance assessment, including those processes that would adversely affect the performance of natural barriers. Degradation, deterioration, or alteration processes of engineered barriers must be evaluated in detail if the magnitude and time of the resulting expected annual dose would be significantly changed by their omission.

FEPs whose exclusion would not significantly change the expected annual dose may be excluded (screened out) from the TSPA on the basis of low consequence.

B.4.2 SCREENING GUIDELINES AND IMPLEMENTATION

Because DOE's Interim Guidance (Dyer 1999 [105655], Section 114) allows exclusion of FEPs on the basis of either low probability or low consequence, an FEP need not be shown to be both of low probability and low consequence to be excluded. Therefore, the order in which the criteria are applied is not essential. In some cases, a component of the FEP was included while another component of the FEP was excluded. In practice, regulatory criteria are examined first, and then, at the discretion of the analyst, either probability or consequence criteria are examined next.

As noted in Section B-1, the FEP screening was performed by subject matter experts and documented in FEP AMRs (listed in Table B-1). Specific screening data from the FEP AMRs was then imported into the YMP FEP Database REV00 (CRWMS M&O 2000 [150806], Appendix D), in accordance with the data transfer controls (CRWMS M&O 1999 [150395]). The screening data are catalogued in the database. The verification of the technical accuracy and completeness of the screening data is the responsibility of the FEP AMRs.

The specific database fields containing screening data from the FEP AMRs were identified in Section B-3.4. To satisfy the screening criteria of DOE's Interim Guidance (Dyer 1999 [105655], Section 114) and to satisfy the TSPAI IRSR subissues pertaining to FEPs and scenario analysis (NRC 2000 [149372], Sections 4.1.1.2 and 4.2), guidelines have been established for the content of four of these fields: YMP Primary FEP Description, Screening Decision, Screening Argument, and TSPA Disposition. Because the technical defensibility of the content of these fields is the responsibility of the FEP AMRs, the content cannot be changed outside of the FEP AMRs. Therefore, these guidelines apply to the FEP AMRs. Key aspects of the guidelines are summarized below:

YMP Primary FEP Description–It must be relevant to YMP and must include all of the related FEPs identified in associated secondary FEPs.

Screening Decision–It must state whether the FEP is included or excluded from the TSPA.

For excluded FEPs, the exclusion criteria (regulation, low probability, low consequence) must be explicitly identified.

For partially included and (or) partially excluded FEPs, the various components that are included and excluded must be identified (e.g., FEP 1.2.02.01.000, Fractures, includes the effects of the present-day fracture system but excludes the effects of changes to the fracture system on the basis of low consequence).

Screening Argument–For excluded FEPs, this is the main screening discussion. A summary of the technical basis for exclusion must be presented, and the summary must address all secondary FEP issues.

Low probability exclusions must include an explicit comparison of the probability of occurrence to the regulatory criteria ($<10^{-4}$ in 10,000 years). The probability must be quantified where possible, although nonquantitative, low-probability arguments are acceptable for not credible FEPs.

Low consequence exclusions must include an explicit statement that there is "no significant change in the expected annual dose." The change in expected annual dose must be quantified where possible, and the interpretation of significant change must be described. (It may be different for each FEP.) It is acceptable to quantify the change in an intermediate performance measure (e.g., radionuclide mass release to the SZ). However, in that case, the qualitative link to change in expected annual dose must be explicitly stated.

Regulatory exclusions must identify a specific regulation and clearly state the rationale for the exclusion.

TSPA Disposition–For included FEPs, this is the main screening discussion. A summary discussion of the treatment of the FEP in the TSPA must be presented. A statement of the scenario class, model and(or) abstraction is desirable.

In some cases, a primary FEP may affect multiple facets of the project and may be relevant to more than one FEP AMR subject area, or it may not fit neatly within the FEP AMR structure. In these cases, rather than create multiple, separate FEPs, the FEP was assigned to more than one FEP AMR. These shared FEPs then had separate screening discussions prepared in the separate FEP AMRs. While informal meetings were held to resolve any contradictory screening discussions for shared FEPs, the multiple screening discussions input to the database were not integrated. As a result, shared FEPs in REV00 may contain duplicative screening information. Similarly, some FEP AMRs modified the YMP Primary FEP Descriptions to ensure that all implications of the secondary FEPs were subsumed in the YMP Primary FEP Descriptions. Where these modified FEPs were shared FEPs, multiple YMP Primary FEP Descriptions were input to the database but not integrated.

B.4.3 FUTURE DEVELOPMENT OF THE YUCCA MOUNTAIN PROJECT FEATURES, EVENTS, AND PROCESSES SCREENING DATA

REV01 of the database is planned to be completed to support TSPA-SR REV01, conditional on the completion of REV01 of FEP AMRs where necessary. The FEP screening data in the database may be updated through the following activities:

- **Addition of screening data for criticality FEPs**–As noted in Table B-1, criticality FEP screening data were not available. One or more criticality FEP AMRs are planned. Upon completion, the screening data will be transferred to the database from these FEP AMRs.

- **Addition of screening data for the NRC NFE audit FEPs (Table B-6)**–These FEPs were not assigned to an FEP AMR, and, therefore, REV00 of the database does not contain any screening information for them. The NRC NFE audit FEPs will be assigned to an FEP AMR for inclusion in REV01 of the database.

- **Addition of screening data for FEP 2.2.01.04.00**–Ownership of this FEP was transferred from one FEP AMR to another, but the screening discussion was inadvertently omitted from both affected FEP AMRs. It will be reassigned to the appropriate FEP AMR for inclusion in REV01 of the database.

- **Addition of screening decisions based on the current no-backfill design**–The screening discussions in REV00 of the database are based on a potential repository design that includes backfill. The FEP AMRs will be revised to ICN 1 to add screening discussions for the no-backfill design. This information will be transferred to the database.

- **Integration of screening information and YMP primary descriptions for shared FEPs** (see Section B.4.2).

- **Identification of the scenario class (Nominal, Disruptive, or Human Intrusion) in the Screening Decision field for included FEPs.**

- **Creation of a master list of subject areas where regulatory exclusions may apply, tied to specific regulations**–This master list will enhance the defensibility of regulatory exclusions.

- **Revisions to screening discussions that did not meet the content guidelines outlined in Section B.4.2**–These revisions must be made in the FEP AMRs rather than in the database directly. Reviews of REV00 screening discussions may identify those FEPs requiring revision.

B.5. YUCCA MOUNTAIN PROJECT FEATURES, EVENTS, AND PROCESSES SCREENING DECISIONS AND BASES

The YMP FEP Database REV00 was developed as described in this Appendix and in *The Development of Information Catalogued in REV00 of the YMP FEP Database (*CRWMS M&O 2000 [150806]) and supersedes all prior versions. The FEP AMR subject matter experts reviewed each of their assigned primary FEP entries and the associated secondary FEP entries and produced a screening decision and supporting documentation within their FEP AMRs. The subject matter experts also reviewed and either confirmed, or suggested changes to, the YMP Primary FEP Descriptions, the primary/secondary mappings, and the FEP AMR assignments. The FEP AMRs were used as input to the YMP FEP Database REV00 (CRWMS M&O 2000 [150806]). A subset of this database and the screening decisions and bases, are summarized in Tables B-9 through B-17 for all primary FEPs. The tables are organized by subject area. As noted in Section B.4.2, many FEPs are shared among different subject areas and, therefore, appear in multiple tables. Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses, then the entire FEP is included or excluded, as indicated. Abbreviations used to indicate FEP AMR reports are given in Table B-1.

Table B-9. Screening Decisions and Bases for System Features, Events, and Processes

FEP Number	FEP Name	Screening Decision and Basis[a]
0.1.02.00.00	Time scales of concern	SYS Include
0.1.03.00.00	Spatial domain of concern	SYS Include
0.1.09.00.00	Regulatory requirements and exclusions	SYS Exclude – By regulation (Secondary FEPs) Include (Primary FEP)
0.1.10.00.00	Model and data issues	SYS Exclude – Low consequence (unmodeled design features) Include (everything except unmodeled design features)
1.1.05.00.00	Records and markers, repository	SYS Include (initial construction of markers and archiving of records, and for subsequent loss of records) Exclude – Low consequence and by regulation (efficacy of markers and record retention to prevent intrusion after 100-years post-closure)
1.1.07.00.00	Repository design	SYS Include (licensed design and design modifications) Exclude – Low consequence and by regulation (remaining Secondary FEPs) EBS Include (exclude deviations from design)

Table B-9. Screening Decisions and Bases for System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.1.08.00.00	Quality control	SYS Include "Quality Control" (primary FEP and secondary FEPs 1.1.08.00.05 and .06) Exclude – Low consequence / by regulation (remaining Secondary FEPs) EBS Include (exclude defects and deviations)
1.1.09.00.00	Schedule and planning	SYS Exclude – By regulation
1.1.10.00.00	Administrative control, potential repository site	SYS Include (for "Administrative Control, Potential Repository Site" during preclosure period, for initial construction of markers and archiving of records, and for subsequent loss of administrative control) Exclude – By regulation (efficacy of administrative controls beyond 100-years of the postclosure period)
1.1.11.00.00	Monitoring of potential repository	UZ Exclude – Low consequence. SYS Exclude – Low consequence (for monitoring operations) Include (monitoring wells and boreholes are addressed by the human-intrusion scenario)
1.1.12.01.00	Accidents and unplanned events during operation	SYS Exclude – Low consequence EBS Exclude – By regulation
1.1.13.00.00	Retrievability	SYS Include (design elements related to retrievability and emplacement) Exclude (operational and administrative considerations) EBS Include
1.2.05.00.00	Metamorphism	SYS Exclude – Low consequence
1.2.08.00.00	Diagenesis	SYS Exclude – Low consequence
1.2.09.00.00	Salt diapirism and dissolution	SYS Exclude – By regulation, Low consequence
1.2.09.01.00	Diapirism	SYS Exclude – By regulation
1.4.02.01.00	Deliberate human intrusion	SYS Exclude – By regulation (deliberate intrusion) Include (human- intrusion scenario)
1.4.02.02.00	Inadvertent human intrusion	SYS Include – By regulation
1.4.03.00.00	Un-intrusive site investigation	SYS Exclude – Low consequence

Table B-9. Screening Decisions and Bases for System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.4.04.00.00	Drilling activities (human intrusion)	SYS Include (stylized-drilling scenario) Exclude – By regulation (specific-types of drilling scenarios as presented in the secondary FEPs)
1.4.04.01.00	Effects of drilling intrusion	SYS Include (interactions and changes in condition) Exclude – By regulation (materials brought to the surface)
1.4.05.00.00	Mining and other underground activities (human intrusion)	SYS Exclude – By regulation
1.4.11.00.00	Explosions and crashes (human activities)	SYS Exclude – By regulation
1.5.01.01.00	Meteorite impact	SYS Exclude – Low probability (direct exhumation or direct fracturing to repository horizon) Exclude – Low consequence (alteration of flow paths, fracturing of overlying geologic units, and changes in rock stress)
1.5.01.02.00	Extraterrestrial events	SYS Exclude – Low consequence
1.5.03.01.00	Changes in the earth's magnetic field	SYS Exclude – Low consequence
1.5.03.02.00	Earth tides	SYS Exclude – Low consequence
2.2.06.05.00	Salt creep	SYS Exclude – By regulation
2.3.13.03.00	Effects of repository heat on biosphere	SYS Exclude – Low consequence
3.2.10.00.00	Atmospheric transport of contaminants	SYS Include (for various transport mechanisms and species [ashfall]) Exclude – Low consequence (for volatile radionuclides as a gaseous release)
3.3.06.01.00	Toxicity of mined rock	SYS Exclude – By regulation

Source: Table B1

NOTE: [a] Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses then the entire FEP is included or excluded, as indicated.

Table B-10. Screening Decisions and Bases for Near-Field Environment Features, Events, and Processes

FEP Number	FEP Name	Screening Decision and Basis[a]
1.1.02.00.00	Excavation / construction	NFE Include (fracture effects) Exclude (chemistry related effects) UZ Include (effects of stress relief and ground support on drift seepage) Exclude – Low consequence (changes in water chemistry) EBS Exclude – Low consequence
1.1.02.02.00	Effects of pre-closure ventilation	NFE Include EBS Include
1.2.02.01.00	Fractures	NFE Include (seepage) Exclude (permanent effects) UZ Include (effects of present-day fracture system) Exclude – Low consequence (effects of changes to the fracture system) SZ Exclude – Low consequence DE Include (existing fracture characteristics) Exclude – Low consequence (changes of fracture characteristics)
2.1.08.01.00	Increased unsaturated water flux at the repository	NFE Include (primary FEP. Climate change is included) Exclude – Low consequence (secondary FEP on water quenching hot waste package) UZ Include EBS Include
2.1.08.02.00	Enhanced influx (Philip's drip)	NFE Include UZ Include EBS Exclude – Low consequence
2.1.08.03.00	Repository dry-out due to waste heat	NFE Include
2.1.08.10.00	Desaturation / dewatering of the repository	NFE Include WF Misc. Include

Table B-10. Screening Decisions and Bases for Near-Field Environment Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.08.11.00	Resaturation of repository	NFE Include EBS Include
2.1.09.01.00	Properties of the potential carrier plume in the waste and EBS	NFE Include WF Misc. Include (potential effects of carrier plume by evaluating the influence of steel corrosion on the water chemistry in order to establish an uncertainty band) Exclude – Low consequence (the changing properties of incoming water, as evaluated by EBS) EBS Include
2.1.09.12.00	Rind (altered zone) formation in waste, EBS, and adjacent rock	NFE Included (in THC model) Excluded – Low consequence (from TH model) WF Misc. Included (in radionuclide mobilization) Excluded (in adjacent rock) EBS Include
2.1.11.01.00	Heat output / temperature in waste and EBS	NFE Include WF Misc. Include EBS Include
2.1.11.02.00	Nonuniform heat distribution / edge effects in repository	NFE Include (Primary FEP) Exclude – Low consequence (TM effects from secondary FEP)
2.2.01.01.00	Excavation and construction-related changes in the adjacent host rock	NFE Exclude – Low consequence UZ Include (the effects of stress relief and ground support on drift seepage) Exclude – Low consequence (changes in water chemistry)
2.2.01.02.00	Thermal and other waste and EBS-related changes in the adjacent host rock	NFE Exclude – Low consequence
2.2.01.03.00	Changes in fluid saturations in the excavation disturbed zone	NFE Exclude – Low consequence
2.2.06.01.00	Changes in stress (due to thermal, seismic, or tectonic effects) change porosity and permeability of rock	NFE Exclude – Low consequence DE Exclude – Low consequence

Table B-10. Screening Decisions and Bases for Near-Field Environment Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.07.10.00	Condensation zone forms around drifts	NFE Include UZ Exclude – Low consequence (mountain-scale effects) Include (effects on drift seepage)
2.2.07.11.00	Return flow from condensation cap / resaturation of dry-out zone	NFE Include (included in process models used in TSPA) UZ Exclude –Low consequence (mountain-scale effects) Include (effects on drift seepage)
2.2.08.03.00	Geochemical interactions in geosphere (dissolution, precipitation, weathering) and effects on radionuclide transport SZ-Groundwater Chemistry FEPs	NFE Include UZ Exclude – Low consequence SZ Include
2.2.08.04.00	Redissolution of precipitates directs more corrosive fluids to containers	NFE Include UZ Include EBS Include
2.2.10.04.00	Thermo-mechanical alteration of fractures near repository	NFE Excluded – Low consequence UZ Exclude – Low consequence
2.2.10.05.00	Thermo-mechanical alteration of rocks above and below the repository	NFE Exclude – Low consequence UZ Exclude – Low consequence
2.2.10.06.00	Thermo-chemical alteration (solubility, speciation, phase changes, precipitation/dissolution) SZ-Groundwater Chemistry FEPs	NFE Exclude – Low consequence (except for the in-drift geochemical model that uses water chemistry and gas-phase composition from the drift-scale THC model that includes thermal-chemical alteration) UZ Exclude – Low consequence SZ Include
2.2.10.10.00	Two-phase buoyant flow / heat pipes	NFE Include UZ Include
2.2.10.12.00	Geosphere dry-out due to waste heat	NFE Include

Table B-10. Screening Decisions and Bases for Near-Field Environment Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.10.13.00	Density-driven groundwater flow (thermal) SZ-Repository Induced Thermal Effects	NFE Include SZ Exclude – Assumed low consequence or probability

Source: Table B-1

NOTES: [a] Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses then the entire FEP is included or excluded, as indicated.

Table B-11. Screening Decisions and Bases for Unsaturated Zone Features, Events, and Processes

FEP Number	FEP Name	Screening Decision and Basis[a]
1.1.01.01.00	Open site investigation boreholes	UZ Exclude – Low consequence (effects of deep boreholes) Include (effects of ground-support boreholes on drift seepage)
1.1.01.02.00	Loss of integrity of borehole seals	UZ Exclude – Low consequence (effects of deep boreholes) Include (effects of ground-support boreholes on drift seepage)
1.1.02.00.00	Excavation / construction	NFE Include (fracture effects) Exclude (chemistry related effects) UZ Include (effects of stress relief and ground support on drift seepage) Exclude – Low consequence (changes in water chemistry) EBS Exclude – Low consequence
1.1.02.01.00	Site flooding (during construction and operation)	UZ Exclude – Low probability. EBS Exclude – By regulation
1.1.04.01.00	Incomplete closure	UZ Exclude – Low consequence (effects of deep boreholes) Include (effects of ground-support boreholes on drift seepage)
1.1.11.00.00	Monitoring of repository	UZ Exclude – Low consequence. SYS Exclude – Low consequence (for monitoring operations) Include (monitoring wells and boreholes are addressed by the human-intrusion scenario)

Table B-11. Screening Decisions and Bases for Unsaturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.2.02.01.00	Fractures	NFE Include (seepage) Exclude (permanent effects) UZ Include (effects of present-day fracture system) Exclude – Low consequence (effects of changes to the fracture system) SZ Exclude – Low consequence DE Include (existing fracture characteristics) Exclude – Low consequence (changes of fracture characteristics)
1.2.02.02.00	Faulting	UZ Include (effects of present-day faults) Exclude – Low consequence (the effects of changes to the faults) SZ Exclude – Low consequence DE Include (existing fault characteristics) Exclude – Low consequence (changes of fault characteristics)
1.2.03.01.00	Seismic activity	UZ Exclude – Low consequence SZ Exclude – Low consequence DE Exclude – Low consequence (indirect effects) Exclude TBV – Low consequence (waste package) Include (drip shield damage and cladding damage)
1.2.04.02.00	Igneous activity causes changes to rock properties	UZ Exclude – Low consequence DE Exclude – Low consequence
1.2.06.00.00	Hydrothermal activity	UZ Exclude – Low probability SZ Exclude – Low consequence
1.2.07.01.00	Erosion / denudation	UZ Exclude – Low consequence Bio Exclude – By regulation
1.2.07.02.00	Deposition	UZ Exclude – Low consequence Bio Exclude – By regulation

Table B-11. Screening Decisions and Bases for Unsaturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.2.09.02.00	Large-scale dissolution	UZ Exclude – Low probability SZ Exclude – Low consequence
1.2.10.01.00	Hydrological response to seismic activity	UZ Exclude – Low probability and Low consequence SZ Exclude – Low consequence DE Exclude – Low consequence
1.2.10.02.00	Hydrologic response to igneous activity	UZ Exclude – Low consequence DE Exclude – Low consequence
1.3.01.00.00	Climate change, global	UZ Include Bio Exclude – By regulation
1.3.04.00.00	Periglacial effects	UZ Exclude – Low probability Bio Exclude – By regulation
1.3.05.00.00	Glacial and ice sheet effects, local	UZ Exclude – Low probability Bio Exclude – By regulation
1.3.07.01.00	Drought / water table decline	UZ Exclude – Low consequence SZ Exclude – Low consequence
1.3.07.02.00	Water table rise	UZ Include SZ Include (changes in flux) Exclude – Assumed Low consequence (other effects not included in SZ Flow and Transport)
1.4.01.00.00	Human influences on climate	UZ Exclude – Low consequence Bio Exclude – By regulation
1.4.01.01.00	Climate modification increases recharge	UZ Exclude – Low consequence (effects of perched water below repository) Include (effects of increased flux through repository and water table rise)

Table B-11. Screening Decisions and Bases for Unsaturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.4.01.02.00	Greenhouse gas effects	UZ Exclude – Low consequence Bio Exclude – By regulation
1.4.01.03.00	Acid rain	UZ Exclude – Low consequence Bio Exclude – By regulation
1.4.01.04.00	Ozone layer failure	UZ Exclude – Low consequence Bio Exclude – By regulation
1.4.04.02.00	Abandoned and undetected boreholes	UZ Exclude – Low probability
1.4.06.01.00	Altered soil or surface water chemistry	UZ Exclude – Low probability Bio Exclude – By regulation
2.1.05.01.00	Seal physical properties	UZ Exclude – Low consequence
2.1.05.02.00	Groundwater flow and radionuclide transport in seals	UZ Exclude – Low consequence
2.1.05.03.00	Seal degradation	UZ Exclude – Low consequence
2.1.08.01.00	Increased unsaturated water flux at the repository	NFE Include (primary FEP. Climate change is included) Exclude – Low consequence (secondary FEP on water quenching hot waste package) UZ Include EBS Include
2.1.08.02.00	Enhanced influx (Philip's drip)	NFE Include UZ Include EBS Exclude – Low consequence
2.1.12.01.00	Gas generation	UZ Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude – Low consequence

Table B-11. Screening Decisions and Bases for Unsaturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.01.01.00	Excavation and construction-related changes in the adjacent host rock	NFE Exclude – Low consequence UZ Include (the effects of stress relief and ground support on drift seepage) Exclude – Low consequence (changes in water chemistry)
2.2.01.05.00	Radionuclide transport in excavation disturbed zone	UZ Exclude – Low consequence
2.2.03.01.00	Stratigraphy	UZ Include SZ Include
2.2.03.02.00	Rock properties of host rock and other units	UZ Include SZ Include
2.2.06.02.00	Changes in stress (due to thermal, seismic, or tectonic effects) produce change in permeability of faults	UZ Exclude – Low consequence SZ Exclude – Low consequence DE Exclude – Low consequence
2.2.06.03.00	Changes in stress (due to seismic or tectonic effects) alter perched water zones	UZ Exclude – Low consequence (effects of perched water changes below the potential repository) Include (effects of perched water changes above potential repository on drift seepage) SZ Exclude – Low consequence DE Exclude – Low consequence
2.2.06.04.00	Effects of subsidence	UZ Exclude – Low consequence
2.2.07.01.00	Locally saturated flow at bedrock/alluvium contact	UZ Include
2.2.07.02.00	Unsaturated groundwater flow in geosphere	UZ Include
2.2.07.03.00	Capillary rise	UZ Include Bio Exclude – By regulation

Table B-11. Screening Decisions and Bases for Unsaturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.07.04.00	Focusing of unsaturated flow (fingers, weeps)	UZ Include
2.2.07.05.00	Flow and transport in the UZ from episodic infiltration	UZ Exclude – Low consequence (effects of episodic flow resulting from episodic infiltration, effects of transient flow due to thermal-hydrologic processes on radionuclide transport) Include (effects of transient flow due to thermal-hydrologic processes on drift seepage)
2.2.07.06.00	Episodic / pulse release from repository	UZ Exclude – Low consequence (effects of episodic flow resulting from episodic infiltration, effects of transient flow due to thermal-hydrologic processes on radionuclide transport) Include (effects of transient flow due to thermal-hydrologic processes on drift seepage, effects of intermittent waste package failures) EBS Include
2.2.07.07.00	Perched water develops	UZ Exclude – Low consequence (effects of perched water below repository) Include (effects of increased flux through repository, water table rise and present-day perched water)
2.2.07.08.00	Fracture flow in the UZ	UZ Include
2.2.07.09.00	Matrix imbibition in the UZ	UZ Include
2.2.07.10.00	Condensation zone forms around drifts	NFE Include UZ Exclude – Low consequence (mountain-scale effects) Include (effects on drift seepage)
2.2.07.11.00	Return flow from condensation cap / resaturation of dry-out zone	NFE Include (included in process models used in TSPA) UZ Exclude – Low consequence (mountain-scale effects) Include (effects on drift seepage)
2.2.08.01.00	Groundwater chemistry / composition in UZ and SZ SZ-Groundwater Chemistry FEPs	UZ Include (effects of ambient-condition geochemistry) Exclude – Low consequence (changes in geochemical conditions) SZ Include

Table B-11. Screening Decisions and Bases for Unsaturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.08.02.00	Radionuclide transport occurs in a carrier plume in geosphere SZ-Radionuclide Transport in a Carrier Plume	UZ Exclude – Low consequence SZ Include
2.2.08.03.00	Geochemical interactions in geosphere (dissolution, precipitation, weathering) and effects on radionuclide transport SZ-Groundwater Chemistry FEPs	NFE Include UZ Exclude – Low consequence SZ Include
2.2.08.04.00	Redissolution of precipitates directs more corrosive fluids to containers	NFE Include UZ Include EBS Include
2.2.08.05.00	Osmotic processes	UZ Exclude – Low consequence
2.2.08.06.00	Complexation in geosphere	UZ Include (effects of ambient-condition complexation) Exclude – Low consequence (effects of changes to complex formation due to changes in geochemical conditions) SZ Include
2.2.08.07.00	Radionuclide solubility limits in the geosphere	UZ Exclude – Low consequence SZ Exclude – Low consequence
2.2.08.08.00	Matrix diffusion in geosphere SZ-Matrix Diffusion	UZ Include SZ Include
2.2.08.09.00	Sorption in UZ and SZ	UZ Include SZ Include
2.2.08.10.00	Colloidal transport in geosphere	UZ Include SZ Include

Table B-11. Screening Decisions and Bases for Unsaturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.09.01.00	Microbial activity in geosphere SZ-Groundwater Chemistry FEPs	UZ Exclude – Low consequence SZ Include
2.2.10.01.00	Repository-induced thermal effects in geosphere	UZ Exclude – Low consequence (mountain-scale thermo-chemical effects) Include (thermo-chemical effects on drift seepage) SZ Exclude – Assumed low consequence or probability
2.2.10.03.00	Natural geothermal effects SZ-Geothermal Effects	UZ Include SZ Include
2.2.10.04.00	Thermo-mechanical alteration of fractures near repository	NFE Excluded – Low consequence UZ Exclude – Low consequence
2.2.10.05.00	Thermo-mechanical alteration of rocks above and below the repository	NFE Exclude – Low consequence UZ Exclude – Low consequence
2.2.10.06.00	Thermo-chemical alteration (solubility, speciation, phase changes, precipitation/dissolution) SZ-Groundwater Chemistry FEPs	NFE Exclude – Low consequence (except for the in-drift geochemical model that uses water chemistry and gas-phase composition from the drift-scale THC model that includes thermal-chemical alteration) UZ Exclude – Low consequence SZ Include
2.2.10.07.00	Thermo-chemical alteration of the Calico Hills unit SZ-Repository Induced Thermal Effects	UZ Exclude – Low consequence SZ Exclude – Assumed low consequence or probability
2.2.10.09.00	Thermo-chemical alteration of the Topopah Spring basal vitrophyre	UZ Exclude – Low consequence
2.2.10.10.00	Two-phase buoyant flow / heat pipes	NFE Include UZ Include

Table B-11. Screening Decisions and Bases for Unsaturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.10.11.00	Natural air flow in the UZ	UZ Exclude – Low consequence
2.2.11.01.00	Naturally-occurring gases in geosphere	UZ Exclude – Low consequence and low probability SZ Exclude – Low consequence
2.2.11.02.00	Gas pressure effects	UZ Exclude – Low consequence and low probability EBS Exclude – Low consequence
2.2.11.03.00	Gas transport in geosphere	UZ Exclude – Low consequence and low probability
2.2.12.00.00	Undetected features (in geosphere) SZ-Undetected features	UZ Exclude – Low consequence and low probability SZ Include
2.3.01.00.00	Topography and morphology	UZ Include
2.3.11.01.00	Precipitation	UZ Include Bio Include (precipitation) Exclude – By regulation (recharge/and climate change)
2.3.11.02.00	Surface runoff and flooding	UZ Include Bio Include (dispersion of contaminants, precipitation, and infiltration) Exclude – By regulation (recharge, water balance)
2.3.11.03.00	Infiltration and recharge (hydrologic and chemical effects)	UZ Exclude – Low consequence (effects of changes to water chemistry) Include (effects of changing infiltration and water table rise)
3.1.01.01.00	Radioactive decay and ingrowth	UZ Include SZ Include WF Misc. Include

Source: Table B-1

NOTES: [a] Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses then the entire FEP is included or excluded, as indicated.

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes

FEP Number	FEP Name	Screening Decision and Basis[a]
1.1.02.00.00	Excavation / construction	NFE Include (fracture effects) Exclude (chemistry related effects) UZ Include (effects of stress relief and ground support on drift seepage) Exclude – Low consequence (changes in water chemistry) EBS Exclude – Low consequence
1.1.02.01.00	Site flooding (during construction and operation)	UZ Exclude – Low probability EBS Exclude – By regulation
1.1.02.02.00	Effects of pre-closure ventilation	NFE Include EBS Include
1.1.02.03.00	Undesirable materials left	EBS Exclude – Low consequence
1.1.03.01.00	Error in waste or backfill emplacement	WP Exclude – Low probability EBS Exclude – By regulation
1.1.07.00.00	Repository design	SYS Include (licensed design and design modifications) Exclude – Low consequence and by regulation (remaining Secondary FEPs) EBS Include (exclude deviations from design)
1.1.08.00.00	Quality control	SYS Include ("Quality Control" primary FEP and secondary FEPs [1.1.08.00.05 and .06]) Exclude – Low consequence / by regulation (remaining Secondary FEPs) EBS Include (exclude defects and deviations)
1.1.12.01.00	Accidents and unplanned events during operation	SYS Exclude – Low consequence EBS Exclude – By regulation
1.1.13.00.00	Retrievability	SYS Include (design elements related to retrievability and emplacement) Exclude (operational and administrative considerations) EBS Include

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.2.04.03.00	Igneous intrusion into repository	DE Include (as a dike rather than as a sill) EBS Exclude. N/A for EBS
2.1.03.01.00	Corrosion of waste containers	WP Include EBS Include
2.1.03.10.00	Container healing	WP Exclude – Low consequence EBS Include
2.1.03.12.00	Container failure (long-term)	WP Include EBS Include
2.1.04.01.00	Preferential pathways in the backfill	EBS Include
2.1.04.02.00	Physical and chemical properties of backfill	EBS Include
2.1.04.03.00	Erosion or dissolution of backfill	EBS Exclude – Low consequence
2.1.04.04.00	Mechanical effects of backfill	EBS Include
2.1.04.05.00	Backfill evolution	EBS Include
2.1.04.06.00	Properties of bentonite	EBS Exclude – Low (Zero) Probability
2.1.04.07.00	Buffer characteristics	EBS Exclude – Low (Zero) Probability
2.1.04.08.00	Diffusion in backfill	EBS Exclude – Low consequence
2.1.04.09.00	Radionuclide transport through backfill	EBS Exclude – Low consequence
2.1.06.01.00	Degradation of cementitious materials in drift	EBS Include
2.1.06.02.00	Effects of rock reinforcement materials	EBS Include
2.1.06.03.00	Degradation of the liner	EBS Exclude – Low (Zero) Probability
2.1.06.04.00	Flow through the liner	EBS Exclude – Low (Zero) Probability
2.1.06.05.00	Degradation of invert and pedestal	EBS Include

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.06.06.00	Effects and degradation of drip shield	WP Exclude – Low consequence (damage to drip shield by rock fall, damage to drip shield by ground motion during seismic events [TBV pending additional data and/or analysis]) Include (physical and chemical degradation processes) EBS Include
2.1.06.07.00	Effects at material interfaces	WP Include EBS Exclude – Low consequence
2.1.07.01.00	Rockfall (large block) WF Clad-Rockfall	WP Exclude – Low consequence DE Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.07.02.00	Mechanical degradation or collapse of drift	DE Exclude – Low consequence EBS Exclude – Low consequence
2.1.07.03.00	Movement of containers	EBS Include
2.1.07.04.00	Hydrostatic pressure on container	EBS Exclude – Low (Zero) Probability
2.1.07.05.00	Creeping of metallic materials in the EBS	WP Exclude – Low consequence (TBV pending additional inputs and/or analysis from Waste Package Design) EBS Exclude – Low consequence
2.1.07.06.00	Floor buckling	EBS Exclude – Low consequence
2.1.08.01.00	Increased unsaturated water flux at the repository	NFE Include (primary FEP. Climate change is included) Exclude – Low consequence (secondary FEP on water quenching hot waste package) UZ Include EBS Include

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.08.02.00	Enhanced influx (Philip's drip)	NFE Include UZ Include EBS Exclude – Low consequence
2.1.08.04.00	Condensation forms on backs of drifts	EBS Include
2.1.08.05.00	Flow through invert	EBS Include
2.1.08.06.00	Wicking in waste and EBS	EBS Include
2.1.08.07.00	Pathways for unsaturated flow and transport in the waste and EBS	WF Misc. Include (through the use of a series of linked one dimensional flowpaths and mixing cells through the EBS, drip shield, waste package and into the invert) Exclude – Low consequence (preferential pathways within the EBS, WF and invert based on beneficial consequence) EBS Include
2.1.08.08.00	Induced hydrological changes in the waste and EBS	WF Misc. Include (induced hydrological changes (flow areas) from corrosion for the waste package and drip shield, induced hydrological changes [exposed fuel area] for the WF) Exclude – Low consequence (changes to hydrological properties for the WF, changes to hydrological properties for the invert) EBS Include
2.1.08.09.00	Saturated groundwater flow in waste and EBS	EBS Exclude – Low consequence
2.1.08.11.00	Resaturation of repository	NFE Include EBS Include
2.1.08.12.00	Drainage with Transport - Sealing and Plugging	EBS Exclude – Low consequence
2.1.08.13.00	Drains	EBS Exclude – Low (Zero) Probability

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.09.01.00	Properties of the potential carrier plume in the waste and EBS	NFE Include WF Misc. Include (potential effects of carrier plume by evaluating the influence of steel corrosion on the water chemistry in order to establish an uncertainty band) Exclude – Low consequence (the changing properties of incoming water, as evaluated by EBS) EBS Include
2.1.09.02.00	Interation with corrosion products	WF Misc. Include (the presence of a rind around the fuel pellets on the availability of water for radionuclides dissolution; the interaction between the expanding rind and the cladding, both in sealing of the gap and in unzipping the cladding; selected chemical effects in the integrated source term for each WF) Exclude (the potential effects from corrosion products on advective or diffusive transport of water and radionuclides; the potential sorptive effects from corrosion products [see YMP No. 2.1.09.05.00]) EBS Include
2.1.09.05.00	In-drift sorption Package	WF Misc. Include (sorption on mobile colloidal material) Exclude (sorption within the WF/WP based on beneficial consequence [conservative]) EBS Exclude – Low consequence
2.1.09.06.00	Reduction-oxidation potential in waste and EBS	WF Misc. Include EBS Include
2.1.09.07.00	Reaction kineticsÿin waste and EBS	WF Misc. Include (reaction kinetics in the equilibrium model) Exclude – Low consequence (reaction transients) EBS Exclude – Low consequence
2.1.09.08.00	Chemical gradients / enhanced diffusion in waste and EBS	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.09.11.00	Waste-rock contact	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.09.12.00	Rind (altered zone) formation in waste, EBS, and adjacent rock	NFE Included (in THC model) Excluded – Low consequence (from TH model) WF Misc. Included (in radionuclide mobilization). Excluded (in adjacent rock) EBS Include
2.1.09.13.00	Complexation by organics in waste and EBS	WF Misc. Exclude – Low probability EBS Exclude – Low consequence
2.1.09.14.00	Colloid formation in waste and EBS	WF Col Include EBS Include
2.1.09.15.00	Formation of true colloids in waste and EBS	WF Col Exclude (Note: this FEP addresses WFs only) EBS Exclude – Low consequence
2.1.09.16.00	Formation of pseudo-colloids (natural) in waste and EBS	WF Col Include EBS Include
2.1.09.17.00	Formation of pseudo-colloids (corrosion products) in waste and EBS	WF Col Include EBS Include
2.1.09.18.00	Microbial colloid transport in the waste and EBS	WF Col Exclude EBS Exclude – Low consequence
2.1.09.19.00	Colloid transport and sorption in the waste and EBS	WF Col Exclude (in WF and waste package) EBS Exclude – Low consequence
2.1.09.20.00	Colloid filtration in the waste and EBS WF Col-Colloid filtration	WF Col Exclude EBS Exclude – Low consequence
2.1.09.21.00	Suspensions of particles larger than colloids	SZ Exclude – Low consequence WF Col Exclude EBS Exclude – Low consequence

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.10.01.00	Biological activity in waste and EBS	WP Include (waste container) Exclude – Low consequence (drip shield [TBV pending additional data and/or analysis]) WF Col Exclude EBS Include
2.1.11.01.00	Heat output / temperature in waste and EBS	NFE Include WF Misc. Include EBS Include
2.1.11.03.00	Exothermic reactions in waste and EBS Exothermic. Exothermic Reactions and Other Thermal Effects in Waste and EBS	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.11.04.00	Temperature effects / coupled processes in waste and EBS	WF Misc. Include EBS Include
2.1.11.05.00	Differing thermal expansion of repository components	WP Exclude – Low consequence (TBV pending additional inputs and/or analysis from Waste Package Design) WF Misc. Include EBS Exclude – Low consequence
2.1.11.07.00	Thermally-induced stress changes in waste and EBS	WF Misc. Include (thermally induced stress changes in NFE) Exclude – Low consequence (thermally induced stress changes in the waste and packaging based on low consequence [by design]) EBS Include
2.1.11.08.00	Thermal effects: chemical and microbiological changes in the waste and EBS	WF Misc. Include EBS Include

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.11.09.00	Thermal effects on liquid or two-phase fluid flow in the waste and EBS	WF Misc. Include (the amount of water reaching the EBS and eventually the waste is based on hydrologic calculations that consider the effects of temperature) Exclude – Low consequence (two-phase flow within the waste, thermally driven single-phase flow within the waste) EBS Include
2.1.11.10.00	Thermal effects on diffusion (Soret effect) in waste and EBS	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.12.01.00	Gas generation	UZ Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.12.02.00	Gas generation (He) from fuel decay	WF Misc. Exclude – Low consequence (the effects of He gas generation from performance-assessment calculations on the basis of low consequence to behavior of the waste package as part of overall repository performance assessment) EBS Exclude – Low consequence
2.1.12.03.00	Gas generation (H2) from metal corrosion	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.12.04.00	Gas generation (CO_2, CH_4, H_2S) from microbial degradation	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.12.05.00	Gas generation from concrete	EBS Exclude – Low consequence
2.1.12.06.00	Gas transport in waste and EBS	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.12.07.00	Radioactive gases in waste and EBS	WF Misc. Exclude – Low consequence (the effects of noble [Ar, He, Kr, Rn, Xe] and CO_2 and CH_4 gas generation on the basis of low consequence to waste package behavior within the overall repository performance assessment) EBS Exclude – Low consequence
2.1.12.08.00	Gas explosions	WF Misc. Exclude – Low probability EBS Exclude –Low consequence
2.1.13.01.00	Radiolysis	WP Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude
2.1.13.02.00	Radiation damage in waste and EBS	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence (the effects of radiolysis-enhanced dissolution of spent nuclear fuel on the basis of low consequence to the performance of the disposal system during the regulatory timeframe) EBS Exclude – Low consequence (backfill, seals, pedestal, etc.)
2.1.13.03.00	Mutation	WF Col Exclude WF Misc. Exclude – Low consequence EBS Exclude – Low consequences
2.2.07.06.00	Episodic / pulse release from repository	UZ Exclude – Low consequence (effects of episodic flow resulting from episodic infiltration, effects of transient flow due to thermal-hydrologic processes on radionuclide transport) Include (effects of transient flow due to thermal-hydrologic processes on drift seepage, effects of intermittent waste package failures) EBS Include
2.2.08.04.00	Redissolution of precipitates directs more corrosive fluids to containers	NFE Include UZ Include EBS Include

Table B-12. Screening Decisions and Bases for Engineered Barrier System Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.11.02.00	Gas pressure effects	UZ Exclude – Low consequence and low probability EBS Exclude – Low consequence

Source: Table B-1

NOTES: [a]Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses then the entire FEP is included or excluded, as indicated.

Table B-13. Screening Decisions and Bases for Waste Package Features, Events, and Processes

FEP Number	FEP Name	Screening Decision and Basis[a]
1.1.03.01.00	Error in waste or backfill emplacement	WP Exclude – Low probability EBS Exclude – By regulation
1.2.02.03.00	Fault movement shears waste container	WP Exclude – Low probability DE Exclude – Low probability
1.2.03.02.00	Seismic vibration causes container failure	WP Exclude (TBV) – Low consequence DE Exclude (TBV) – Low consequence (waste package) Include (drip shield and fuel-rod cladding)
1.2.04.04.00	Magma interacts with waste	WP Include DE Include WF Misc. Include
2.1.03.01.00	Corrosion of waste containers	WP Include EBS Include
2.1.03.02.00	Stress corrosion cracking of waste containers and drip shields	WP Include (waste container) Exclude – Low consequence (drip shield)
2.1.03.03.00	Pitting of waste containers and drip shields	WP Include

Table B-13. Screening Decisions and Bases for Waste Package Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.03.04.00	Hydride cracking of waste containers and drip shields	WP Exclude – Low consequence (drip shield) Exclude – Low probability (waste container TBV pending additional data and/or analysis). Low probability (for waste package outer barrier)
2.1.03.05.00	Microbially-mediated corrosion of waste container and drip shield	WP Include (waste container) Exclude – Low consequence (drip shield TBV pending additional data and/or analysis)
2.1.03.06.00	Internal corrosion of waste container	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence (prior to waste package breach Include (after waste package breach)
2.1.03.07.00	Mechanical impact on waste container and drip shield	WP Exclude – Low consequence (mechanical damage of the waste container and drip shield by rock fall, mechanical damage of the waste container and drip shield by ground motion during seismic events [TBV pending additional data and/or analysis], mechanical damage by internal gas pressure and swelling corrosion products)
2.1.03.08.00	Juvenile and early failure of waste containers and drip shields	WP Include (manufacturing and welding defects in waste container degradation analysis) Exclude – Low consequence (manufacturing defects in drip shield degradation analysis) Exclude – Low consequence (early failure of waste container and drip shield from improper quality control during the emplacement)
2.1.03.09.00	Copper corrosion	WP Exclude – Low probability
2.1.03.10.00	Container healing	WP Exclude – Low consequence EBS Include
2.1.03.11.00	Container form	WP Exclude – Low consequence
2.1.03.12.00	Container failure (long-term)	WP Include EBS Include
2.1.06.06.00	Effects and degradation of drip shield	WP Exclude – Low consequence (damage to drip shield by rock fall, damage to drip shield by ground motion during seismic events [TBV pending additional data and/or analysis]) Include (physical and chemical degradation processes) EBS Include

Table B-13. Screening Decisions and Bases for Waste Package Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.06.07.00	Effects at material interfaces	WP Include EBS Exclude – Low consequence
2.1.07.01.00	Rockfall (large block) WF Clad-Rockfall	WP Exclude – Low consequence DE Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.07.05.00	Creeping of metallic materials in the EBS	WP Exclude – Low consequence (TBV pending additional inputs and/or analysis from Waste Package Design) EBS Exclude – Low consequence
2.1.09.03.00	Volume increase of corrosion products	WP Exclude – Low consequence WF Misc. Include (clad unzipping due to wet oxidation of CSNF) Excluded – Low consequence (dry oxidation of CSNF)
2.1.09.09.00	Electrochemical effects (electrophoresis, galvanic coupling) in waste and EBS WP-Electrochemical Effects in Waste and EBS	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence
2.1.10.01.00	Biological activity in waste and EBS	WP Include (waste container) Exclude – Low consequence (drip shield (TBV pending additional data and/or analysis)) WF Col Exclude EBS Include
2.1.11.05.00	Differing thermal expansion of repository components	WP Exclude – Low consequence (TBV pending additional inputs and/or analysis from Waste Package Design) WF Misc. Include EBS Exclude – Low consequence

Table B-13. Screening Decisions and Bases for Waste Package Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.11.06.00	Thermal sensitization of waste containers and drip shields increases their fragility	WP Include
2.1.12.03.00	Gas generation (H2) from metal corrosion	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.13.01.00	Radiolysis	WP Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude
2.1.13.02.00	Radiation damage in waste and EBS	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence (the effects of radiolysis-enhanced dissolution of spent nuclear fuel on the basis of low consequence to the performance of the disposal system during the regulatory timeframe) EBS Exclude – Low consequence (backfill, seals, pedestal, etc.)

Source: Table B-1

NOTES: [a] Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses then the entire FEP is included or excluded, as indicated.

Table B-14. Screening Decisions and Bases for Waste Form Features, Events, and Processes

FEP Number	FEP Name	Screening Decision and Basis[a]
1.2.04.04.00	Magma interacts with waste	WP Include DE Include WF Misc. Include
2.1.01.01.00	Waste inventory	WF Misc. Include; however, only a limited number of radionuclides are shown to be important to repository performance.
2.1.01.02.00	Codisposal / co-location of waste	WF Misc. Include (co-location and codisposal, chemical interactivity between DSNF and high-level radioactive waste-glass affects both DSNF degradation and radionuclide mobilization) Exclude – no credit for DSNF cladding or for any beneficial effects of DSNF and glass-pour canisters as barriers to DSNF degradation, to high-level radioactive waste-glass dissolution, or to radionuclide release. Exclude – Low consequence (DSNF geometry area dependence, dependence of radionuclide release on DSNF surface area) Exclude – Low probability (chemical interactivity between waste packages) Exclude – Low probability or Low consequence (preferential condensation based on (1) thermal shielding caused by the near-field averaging of the thermal field renders preferential condensation a process of low consequence and (2) occurrence of repository condensation and added uncertainty regarding the occurrence of preferential condensation render preferential condensation a process of low probability)
2.1.01.03.00	Heterogeneity of WFs	WF Misc. Include
2.1.01.04.00	Spatial Heterogeneity of Emplaced Waste	WF Misc. Exclude – Low consequence
2.1.02.01.00	DSNF degradation, alteration, and dissolution	WF Misc. Include
2.1.02.02.00	CSNF alteration, dissolution, and radionuclide release	WF Misc. Include (See other FEPs on specific phenomenon included and excluded)
2.1.02.03.00	Glass Degradation, Alteration, and Dissolution	WF Misc. Include (in package chemistry-dependent corrosion rates and congruent dissolution) Exclude – Low probability [credibility] (phase separation) Exclude – Low consequence (selective leaching) Exclude – Conservatively bounded (precipitation of silicate and other minerals)
2.1.02.04.00	Alpha recoil enhances dissolution	WF Misc. Exclude – Low consequence (effects of alpha-recoil from performance-assessment calculations on the basis of low consequence to the performance of the disposal system)
2.1.02.05.00	Glass cracking and surface area	WF Misc. Include

Table B-14. Screening Decisions and Bases for Waste Form Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.02.06.00	Glass recrystallization	WF Misc. Exclude
2.1.02.07.00	Gap and grain release of Cs, I	WF Misc. Include (gap and grain-boundary inventory produced while in repository) Exclude (additional gap and grain-boundary inventory potentially produced while in repository, and any reactions which would mitigate the gap and grain-boundary inventory and, thereby, releases)
2.1.02.08.00	Pyrophoricity	WF Misc. Exclude – Low consequence
2.1.02.09.00	Void space (in glass container)	WF Misc. Include (concept of unfilled void volume in TSPA-SR/License Application calculations)
2.1.02.10.00	Cellulosic degradation	WF Misc. Exclude – Low probability
2.1.02.11.00	Waterlogged rods	WF Clad Exclude – Low consequence
2.1.02.12.00	Cladding degradation before YMP receives it	WF Clad Include
2.1.02.13.00	General corrosion of cladding	WF Clad Exclude – Low consequence
2.1.02.14.00	Microbial corrosion of cladding WF Clad-Microbiologically Influenced Corrosion of Cladding	WF Clad Exclude – Low probability
2.1.02.15.00	Acid corrosion of cladding from radiolysis	WF Clad Exclude – Low probability
2.1.02.16.00	Localized corrosion (pitting) of cladding	WF Clad Exclude – Low probability
2.1.02.17.00	Localized corrosion (crevice corrosion) of cladding	WF Clad Exclude – Low consequence
2.1.02.18.00	High dissolved silica content of waters enhances corrosion of cladding	WF Clad Exclude – Low consequence
2.1.02.19.00	Creep rupture of cladding	WF Clad Include
2.1.02.20.00	Pressurization from He production causes cladding failure	WF Clad Include
2.1.02.21.00	Stress corrosion cracking of cladding	WF Clad Include
2.1.02.22.00	Hydride embrittlement of cladding	WF Clad Exclude – Low probability

Table B-14. Screening Decisions and Bases for Waste Form Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.02.23.00	Cladding unzipping	WF Clad Exclude – Low probability (dry oxidation) Include (wet oxidation)
2.1.02.24.00	Mechanical failure of cladding	WF Clad Include
2.1.02.25.00	DSNF cladding degradation	WF Misc. Exclude – Low consequence and based on conservatism
2.1.02.26.00	Diffusion-controlled cavity growth WF Clad-Diffusion-Controlled Cavity Growth	WF Clad Exclude – Low probability Include (general creep rupture process, is included-see FEP 2.1.02.19.00)
2.1.02.27.00	Localized corrosion perforation from fluoride	WF Clad Include
2.1.03.06.00	Internal corrosion of waste container	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence (prior to waste package breach Include (after waste package breach)
2.1.07.01.00	Rockfall (large block) WF Clad-Rockfall	WP Exclude – Low consequence DE Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.08.07.00	Pathways for unsaturated flow and transport in the waste and EBS	WF Misc. Include (through the use of a series of linked one dimensional flowpaths and mixing cells through the EBS, drip shield, waste package and into the invert) Exclude – Low consequence (preferential pathways within the EBS, WF and invert based on beneficial consequence) EBS Include
2.1.08.08.00	Induced hydrological changes in the waste and EBS	WF Misc. Include (induced hydrological changes [flow areas] from corrosion for the waste package and drip shield, induced hydrological changes [exposed fuel area] for the WF) Exclude – Low consequence (changes to hydrological properties for the WF, changes to hydrological properties for the invert) EBS Include
2.1.08.10.00	Desaturation / dewatering of the repository	NFE Include WF Misc. Include

Table B-14. Screening Decisions and Bases for Waste Form Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.08.15.00	Waste-form and backfill consolidation	WF Misc. Excluded – Low consequence (or possible slight beneficial consequence which is conservatively ignored)
2.1.09.01.00	Properties of the potential carrier plume in the waste and EBS	NFE Include WF Misc. Include (potential effects of carrier plume by evaluating the influence of steel corrosion on the water chemistry in order to establish an uncertainty band) Exclude – Low consequence (the changing properties of incoming water, as evaluated by EBS) EBS Include
2.1.09.02.00	Interaction with corrosion products	WF Misc. Include (the presence of a rind around the fuel pellets on the availability of water for radionuclide dissolution; the interaction between the expanding rind and the cladding: both in sealing of the gap and in unzipping of the cladding; selected chemical effects in the integrated source term for each WF) Exclude (the potential effects from corrosion products on advective or diffusive transport of water and radionuclides; the potential sorptive effects from corrosion products [see YMP No. 2.1.09.05.00]) EBS Include
2.1.09.03.00	Volume increase of corrosion products	WP Exclude – Low consequence WF Misc. Include (clad unzipping due to wet oxidation of CSNF) Excluded – Low consequence (dry oxidation of CSNF)
2.1.09.04.00	Radionuclide solubility, solubility limits, and speciation in the WF and EBS	WF Misc. Include
2.1.09.05.00	In-drift sorption Package-In-Package Sorption	WF Misc. Include (sorption on mobile colloidal material) Exclude (sorption within the WF/waste package based on beneficial consequence [conservative]) EBS Exclude – Low consequence
2.1.09.06.00	Reduction-oxidation potential in waste and EBS	WF Misc. Include EBS Include
2.1.09.07.00	Reaction kineticsÿin waste and EBS	WF Misc. Include (reaction kinetics in the equilibrium model) Exclude – Low consequence (reaction transients) EBS Exclude – Low consequence

Table B-14. Screening Decisions and Bases for Waste Form Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.09.08.00	Chemical gradients / enhanced diffusion in waste and EBS	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.09.09.00	Electrochemical effects (electrophoresis, galvanic coupling) in waste and EBS WP-Electrochemical Effects in Waste and EBS	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence
2.1.09.10.00	Secondary phase effects on dissolved radionuclide concentrations at the WF	WF Misc. Exclude – Low probability (Low probability due to uncertainty in amount of radionuclide actually being chemically bound, reasonably conclude complete release of radionuclides)
2.1.09.11.00	Waste-rock contact	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.09.12.00	Rind (altered zone) formation in waste, EBS, and adjacent rock	NFE Included (in THC model) Excluded – Low consequence (from TH model) WF Misc. Included (in radionuclide mobilization) Excluded (in adjacent rock) EBS Include
2.1.09.13.00	Complexation by organics in waste and EBS	WF Misc. Exclude – Low probability EBS Exclude – Low consequence
2.1.09.14.00	Colloid formation in waste and EBS	WF Col Include EBS Include
2.1.09.15.00	Formation of true colloids in waste and EBS	WF Col Exclude (Note: this FEP addresses WFs only) EBS Exclude – Low consequence
2.1.09.16.00	Formation of pseudo-colloids (natural) in waste and EBS	WF Col Include EBS Include
2.1.09.17.00	Formation of pseudo-colloids (corrosion products) in waste and EBS	WF Col Include EBS Include

Table B-14. Screening Decisions and Bases for Waste Form Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.09.18.00	Microbial colloid transport in the waste and EBS	WF Col Exclude EBS Exclude – Low consequence
2.1.09.19.00	Colloid transport and sorption in the waste and EBS	WF Col Exclude (in WF and waste package) EBS Exclude – Low consequence
2.1.09.20.00	Colloid filtration in the waste and EBS WF Col-Colloid filtration	WF Col Exclude EBS Exclude – Low consequence
2.1.09.21.00	Suspensions of particles larger than colloids	SZ Exclude – Low consequence WF Col Exclude EBS Exclude – Low consequence
2.1.09.22.00	Colloid Sorption at the Air-Water Interface	WF Col Exclude
2.1.09.23.00	Colloidal stability and concentration dependence on aqueous chemistry	WF Col Include
2.1.09.24.00	Colloidal diffusion	WF Col Include
2.1.09.25.00	Colloidal phases are produced by coprecipitation (in waste and EBS)	WF Col Include (Note: only production of colloid phases by co-precipitation in the WP is considered here)
2.1.10.01.00	Biological activity in waste and EBS	WP Include (waste container) Exclude – Low consequence (drip shield TBV pending additional data and/or analysis) WF Col Exclude EBS Include
2.1.11.01.00	Heat output / temperature in waste and EBS	NFE Include WF Misc. Include EBS Include

Table B-14. Screening Decisions and Bases for Waste Form Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.11.03.00	Exothermic reactions in waste and EBS WF Misc. – Exothermic Reactions and Other Thermal Effects in Waste and EBS	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.11.04.00	Temperature effects / coupled processes in waste and EBS	WF Misc. Include EBS Include
2.1.11.05.00	Differing thermal expansion of repository components	WP Exclude – Low consequence (TBV pending additional inputs and/or analysis from Waste Package Design) WF Misc. Include EBS Exclude – Low consequence
2.1.11.07.00	Thermally-induced stress changes in waste and EBS	WF Misc. Include (thermally induced stress changes in NFE) Exclude – Low consequence (thermally induced stress changes in the waste and packaging based on low consequence by design) EBS Include
2.1.11.08.00	Thermal effects: chemical and microbiological changes in the waste and EBS	WF Misc. Include EBS Include
2.1.11.09.00	Thermal effects on liquid or two-phase fluid flow in the waste and EBS	WF Misc. Include (the amount of water reaching the EBS and eventually the waste is based on hydrologic calculations that consider the effects of temperature) Exclude – Low consequence (two-phase flow within the waste, thermally driven single-phase flow within the waste) EBS Include
2.1.11.10.00	Thermal effects on diffusion (Soret effect) in waste and EBS	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.12.01.00	Gas generation	UZ Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude – Low consequence

Table B-14. Screening Decisions and Bases for Waste Form Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.12.02.00	Gas generation (He) from fuel decay	WF Misc. Exclude – Low consequence (the effects of He gas generation from performance-assessment calculations on the basis of low consequence to behavior of the waste package as part of overall repository performance assessment) EBS Exclude – Low consequence
2.1.12.03.00	Gas generation (H2) from metal corrosion	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.12.04.00	Gas generation (CO_2, CH_4, H_2S) from microbial degradation	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.12.06.00	Gas transport in waste and EBS	WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.12.07.00	Radioactive gases in waste and EBS	WF Misc. Exclude – Low consequence (the effects of noble [Ar, He, Kr, Rn, Xe] and CO_2 and CH_4 gas generation on the basis of low consequence to waste package behavior within the overall repository performance assessment) EBS Exclude – Low consequence
2.1.12.08.00	Gas explosions	WF Misc. Exclude – Low probability EBS Exclude –Low consequence
2.1.13.01.00	Radiolysis	WP Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude

Table B-14. Screening Decisions and Bases for Waste Form Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.1.13.02.00	Radiation damage in waste and EBS	WP Exclude – Low consequence (TBV pending additional data and/or analysis) WF Misc. Exclude – Low consequence (the effects of radiolysis-enhanced dissolution of spent nuclear fuel on the basis of low consequence to the performance of the disposal system during the regulatory timeframe) EBS Exclude – Low consequence (backfill, seals, pedestal, etc.)
2.1.13.03.00	Mutation	WF Col Exclude WF Misc. Exclude – Low consequence EBS Exclude – Low consequences
2.2.08.12.00	Use of J-13 well water as a surrogate for water flowing into the EBS and waste	WF Misc. Include
3.1.01.01.00	Radioactive decay and ingrowth	UZ Include SZ Include WF Misc. Include
3.2.07.01.00	Isotopic dilution	SZ Exclude – Low consequence WF Misc. Include (in waste package) Exclude – Low consequence (outside waste package, excluding isotopic dilution is conservative bounding)

Source: Table B-1

NOTES: [a] Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses then the entire FEP is included or excluded, as indicated.

Table B-15. Screening Decisions and Bases for Saturated Zone Features, Events, and Processes

FEP Number	FEP Name	Screening Decision and Basis[a]
1.2.02.01.00	Fractures	NFE Include (seepage) Exclude (permanent effects) UZ Include (effects of present-day fracture system) Exclude – Low consequence (effects of changes to the fracture system) SZ Exclude – Low consequence DE Include (existing fracture characteristics) Exclude – Low consequence (changes of fracture characteristics)
1.2.02.02.00	Faulting	UZ Include (effects of present-day faults) Exclude – Low consequence (the effects of changes to the faults) SZ Exclude – Low consequence DE Include (existing fault characteristics) Exclude – Low consequence (changes of fault characteristics)
1.2.03.01.00	Seismic activity	UZ Exclude – Low consequence SZ Exclude – Low consequence DE Exclude – Low consequence (indirect effects) Exclude TBV – Low consequence (waste package) Include (drip shield damage and cladding damage)
1.2.06.00.00	Hydrothermal activity	UZ Exclude – Low probability SZ Exclude – Low consequence
1.2.09.02.00	Large-scale dissolution	UZ Exclude – Low probability SZ Exclude – Low consequence
1.2.10.01.00	Hydrological response to seismic activity	UZ Exclude – Low probability and Low consequence SZ Exclude – Low consequence DE Exclude – Low consequence
1.3.07.01.00	Drought / water table decline	UZ Exclude – Low consequence SZ Exclude – Low consequence

Table B-15. Screening Decisions and Bases for Saturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.3.07.02.00	Water table rise	UZ Include SZ Include (changes in flux) Exclude – Assumed Low consequence (other effects not included in SZ Flow and Transport)
1.4.07.01.00	Water management activities	Bio Exclude – By regulation SZ Include
1.4.07.02.00	Wells	Bio Include (wells for human and agricultural use) Exclude – By regulation (wells located at a point other than specified by Revised Interim Guidance [RIG]) SZ Include
2.1.09.21.00	Suspensions of particles larger than colloids	SZ Exclude – Low consequence WF Col Exclude EBS Exclude – Low consequence
2.2.03.01.00	Stratigraphy	UZ Include SZ Include
2.2.03.02.00	Rock properties of host rock and other units	UZ Include SZ Include
2.2.06.02.00	Changes in stress (due to thermal, seismic, or tectonic effects) produce change in permeability of faults	UZ Exclude – Low consequence SZ Exclude – Low consequence DE Exclude – Low consequence
2.2.06.03.00	Changes in stress (due to seismic or tectonic effects) alter perched water zones	UZ Exclude – Low consequence (effects of perched water changes below the potential repository) Include (effects of perched water changes above potential repository on drift seepage) SZ Exclude – Low consequence DE Exclude – Low consequence
2.2.07.12.00	Saturated groundwater flow	SZ Include

Table B-15. Screening Decisions and Bases for Saturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.07.13.00	Water-conducting features in the SZ-Water-Conducting Features	SZ Include
2.2.07.14.00	Density effects on groundwater flow	SZ Exclude – Low consequence
2.2.07.15.00	Advection and dispersion	SZ Include
2.2.07.16.00	Dilution of radionuclides in groundwater	SZ Include
2.2.07.17.00	Diffusion in the SZ	SZ Include
2.2.08.01.00	Groundwater chemistry / composition in UZ and SZ SZ-Groundwater Chemistry FEPs	UZ Include (effects of ambient-condition geochemistry) Exclude – Low consequence (changes in geochemical conditions) SZ Include
2.2.08.02.00	Radionuclide transport occurs in a carrier plume in geosphere SZ-Radionuclide Transport in a Carrier Plume	UZ Exclude – Low consequence SZ Include
2.2.08.03.00	Geochemical interactions in geosphere (dissolution, precipitation, weathering) and effects on radionuclide transport SZ-Groundwater Chemistry FEPs	NFE Include UZ Exclude – Low consequence SZ Include
2.2.08.06.00	Complexation in geosphere	UZ Include (effects of ambient-condition complexation) Exclude – Low consequence (effects of changes to complex formation due to changes in geochemical conditions) SZ Include
2.2.08.07.00	Radionuclide solubility limits in the geosphere	UZ Exclude – Low consequence SZ Exclude – Low consequence
2.2.08.08.00	Matrix diffusion in geosphere SZ-Matrix Diffusion	UZ Include SZ Include
2.2.08.09.00	Sorption in UZ and SZ	UZ Include SZ Include

Table B-15. Screening Decisions and Bases for Saturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.08.10.00	Colloidal transport in geosphere	UZ Include SZ Include
2.2.08.11.00	Distribution and release of nuclides from the geosphere SZ-Distribution and Release Of Nuclides	SZ Include
2.2.09.01.00	Microbial activity in geosphere SZ-Groundwater Chemistry FEPs	UZ Exclude – Low consequence SZ Include
2.2.10.01.00	Repository-induced thermal effects in geosphere	UZ Exclude – Low consequence (mountain-scale thermo-chemical effects) Include (thermo-chemical effects on drift seepage) SZ Exclude – Assumed low consequence or probability
2.2.10.02.00	Thermal convection cell develops in SZ	SZ Exclude – Low consequence
2.2.10.03.00	Natural geothermal effects SZ-Geothermal Effects	UZ Include SZ Include
2.2.10.06.00	Thermo-chemical alteration (solubility, speciation, phase changes, precipitation/dissolution) SZ-Groundwater Chemistry FEPs	NFE Exclude – Low consequence (except for the in-drift geochemical model that uses water chemistry and gas-phase composition from the drift-scale THC model that includes thermal-chemical alteration) UZ Exclude – Low consequence SZ Include
2.2.10.07.00	Thermo-chemical alteration of the Calico Hills unit SZ-Repository Induced Thermal Effects	UZ Exclude – Low consequence SZ Exclude – Assumed low consequence or probability
2.2.10.08.00	Thermo-chemical alteration of the SZ SZ-Repository Induced Thermal Effects	SZ Exclude – Assumed low consequence or probability
2.2.10.13.00	Density-driven groundwater flow (thermal) SZ-Repository Induced Thermal Effects	NFE Include SZ Exclude – Assumed low consequence or probability

Table B-15. Screening Decisions and Bases for Saturated Zone Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.11.01.00	Naturally-occurring gases in geosphere	UZ Exclude – Low consequence and low probability SZ Exclude – Low consequence
2.2.12.00.00	Undetected features (in geosphere) SZ-Undetected features	UZ Exclude – Low consequence and low probability SZ Include
2.3.02.02.00	Radionuclide accumulation in soils	Bio Include (Deposition) Exclude – By regulation (upwelling at other locations) SZ Exclude – Low consequence
2.3.11.04.00	Groundwater discharge to surface	SZ Exclude – Low consequence
3.1.01.01.00	Radioactive decay and ingrowth	UZ Include SZ Include WF Misc. Include
	Isotopic dilution	SZ Exclude – Low consequence WF Misc. Include (in waste package) Exclude – Low consequence (outside waste package, excluding isotopic dilution is conservative bounding)

Source: Table B-1

NOTES: [a] Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses then the entire FEP is included or excluded, as indicated.

Table B-16. Screening Decisions and Bases for Biosphere Features, Events, and Processes

FEP Number	FEP Name	Screening Decision and Basis[a]
1.2.07.01.00	Erosion/denudation	UZ Exclude – Low consequence Bio Exclude – By regulation
1.2.07.02.00	Deposition	UZ Exclude – Low consequence Bio Exclude – By regulation
1.3.01.00.00	Climate change, global	UZ Include Bio Exclude – By regulation
1.3.04.00.00	Periglacial effects	UZ Exclude – Low probability Bio Exclude – By regulation
1.3.05.00.00	Glacial and ice sheet effects, local	UZ Exclude – Low probability Bio Exclude – By regulation
1.4.01.00.00	Human influences on climate	UZ Exclude – Low consequence Bio Exclude – By regulation
1.4.01.02.00	Greenhouse gas effects	UZ Exclude – Low consequence Bio Exclude – By regulation
1.4.01.03.00	Acid rain	UZ Exclude – Low consequence Bio Exclude – By regulation
1.4.01.04.00	Ozone layer failure	UZ Exclude – Low consequence Bio Exclude – By regulation
1.4.06.01.00	Altered soil or surface water chemistry	UZ Exclude – Low probability Bio Exclude – By regulation
1.4.07.01.00	Water management activities	Bio Exclude – By regulation SZ Include

Table B-16. Screening Decisions and Bases for Biosphere Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.4.07.02.00	Wells	Bio Include (wells for human and agricultural use) Exclude – By regulation (wells located at a point other than specified by RIG) SZ Include
1.4.08.00.00	Social and institutional developments	Bio Exclude – By regulation
1.4.09.00.00	Technological developments	Bio Exclude – By regulation
1.5.02.00.00	Species evolution	Bio Exclude – By regulation
2.2.07.03.00	Capillary rise	UZ Include Bio Exclude – By regulation
2.3.02.01.00	Soil type	Bio Include (soil type) Exclude – By regulation (soil development/formation)
2.3.02.02.00	Radionuclide accumulation in soils	Bio Include (Deposition) Exclude – By regulation (upwelling at other locations) SZ Exclude – Low consequence
2.3.02.03.00	Soil and sediment transport	Bio Include (aeolian) Exclude – By regulation (fluvial, glacial, bioturbation)
2.3.04.01.00	Surface water transport and mixing	Bio Exclude – By regulation
2.3.06.00.00	Marine features	Bio Exclude – By regulation
2.3.09.01.00	Animal burrowing / intrusion	Bio Exclude – By regulation
2.3.11.01.00	Precipitation	UZ Include Bio Include (precipitation) Exclude – By regulation (recharge/and climate change)
2.3.11.02.00	Surface runoff and flooding	UZ Include Bio Include (dispersion of contaminants, precipitation, and infiltration) Exclude – By regulation (recharge, water balance)
2.3.13.01.00	Biosphere characteristics	Bio Include (biosphere characteristics) Exclude – By regulation (conditions vary over time)

Table B-16. Screening Decisions and Bases for Biosphere Features, Events, and Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.3.13.02.00	Biosphere transport	Bio Include (transport & transfer through biosphere compartments) Exclude – Low consequence and By regulation (radionuclide transfer to the biosphere via sediments, surface water, gas, and time dependent as well as chemical environment changes)
2.4.01.00.00	Human characteristics (physiology, metabolism)	Bio Include (adult) Exclude – By regulation (non-adult)
2.4.03.00.00	Diet and fluid intake	Bio Include (diet, fluids, and intakes other than drugs) Exclude – Low consequence and By regulation (filtration of water and food preparation and intake of drugs)
2.4.04.01.00	Human lifestyle	Bio Include (human lifestyle) Exclude – By regulation (hunter gathering)
2.4.07.00.00	Dwellings	Bio Include (household activities) Exclude – By regulation (location, building material, gas and water leakage, and space heating)
2.4.08.00.00	Wild and natural land and water use	Bio Exclude – Low consequence
2.4.09.01.00	Agricultural land use and irrigation	Bio Include (traditional crop and greenhouse farming) Exclude – By regulation (hydroponic gardening, peat and leaf harvesting and the use of ashes and sewage sludge and fire)
2.4.09.02.00	Animal farms and fisheries	Bio Include
2.4.10.00.00	Urban and industrial land and water use	Bio Exclude – By regulation
3.3.01.00.00	Drinking water, foodstuffs and drugs, contaminant concentrations	Bio Include (food stuff and water) Exclude – By regulation (drugs, non-well water)
3.3.02.01.00	Plant uptake	Bio Include (radionuclide uptake) Exclude – By regulation (natural outfalls)
3.3.02.02.00	Animal uptake	Bio Include (consumption of locally produced meat and associated produce) Exclude – Low consequence and By regulation (animal grooming & fighting, consumption of carcasses as well as scavengers and predators)
3.3.02.03.00	Bioaccumulation	Bio Include
3.3.03.01.00	Contaminated non-food products and exposure	Bio Exclude

Table B-16. **Screening Decisions and Bases for Biosphere Features, Events, and Processes (Continued)**

FEP Number	FEP Name	Screening Decision and Basis[a]
3.3.04.01.00	Ingestion	Bio Include (consumption of food stuffs and water) Exclude – By regulation (charcoal production, smoking, and tree sap consumption)
3.3.04.02.00	Inhalation	Bio Include
3.3.04.03.00	External exposure	Bio Include (external exposure to penetrating ionizing radiation) Exclude – Low consequence (dermal sorption and injection)
3.3.05.01.00	Radiation doses	Bio Include (exposure rate/dose conversion factors) Exclude (WIPP-specific FEP)
3.3.06.00.00	Radiological toxicity /effects	Bio Exclude – By regulation
3.3.06.02.00	Sensitization to radiation	Bio Exclude – By regulation
3.3.07.00.00	Non-radiological toxicity/effects	Bio Exclude – By regulation
3.3.08.00.00	Radon and radon daughter exposure	Bio Exclude

Source: Table B-1

NOTES: [a]Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses then the entire FEP is included or excluded, as indicated.

Table B-17. Screening Decisions and Bases for Disruptive Events Features, Events, Processes

FEP Number	FEP Name	Screening Decision and Basis[a]
1.2.01.01.00	Tectonic activity - large scale	DE Exclude – Low consequence
1.2.02.01.00	Fractures	NFE Include (seepage) Exclude (permanent effects) UZ Include (effects of present-day fracture system) Exclude – Low consequence (effects of changes to the fracture system) SZ Exclude – Low consequence DE Include (existing fracture characteristics) Exclude – Low consequence (changes of fracture characteristics)

Table B-17. Screening Decisions and Bases for Disruptive Events Features, Events, Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.2.02.02.00	Faulting	UZ Include (effects of present-day faults) Exclude – Low consequence (the effects of changes to the faults) SZ Exclude – Low consequence DE Include (existing fault characteristics) Exclude – Low consequence (changes of fault characteristics)
1.2.02.03.00	Fault movement shears waste container	WP Exclude – Low probability DE Exclude – Low probability
1.2.03.01.00	Seismic activity	UZ Exclude – Low consequence SZ Exclude – Low consequence DE Exclude – Low consequence (indirect effects) Exclude TBV – Low consequence (waste package) Include (drip shield damage and cladding damage)
1.2.03.02.00	Seismic vibration causes container failure	WP Exclude (TBV) – Low consequence DE Exclude (TBV) – Low consequence (waste package) Include (drip shield and fuel-rod cladding)
1.2.03.03.00	Seismicity associated with igneous activity	DE Exclude – Low consequence (most effects) Include (damage to drip shields and fuel-rod cladding)
1.2.04.01.00	Igneous activity	DE Include (eruptive and intrusive events) Exclude – Low consequence (indirect effects)
1.2.04.02.00	Igneous activity causes changes to rock properties	UZ Exclude – Low consequence DE Exclude – Low consequence
1.2.04.03.00	Igneous intrusion into repository	DE Include (as a dike rather than as a sill) EBS Exclude. N/A for EBS
1.2.04.04.00	Magma interacts with waste	WP Include DE Include WF Misc. Include

Table B-17. Screening Decisions and Bases for Disruptive Events Features, Events, Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
1.2.04.05.00	Magmatic transport of waste	DE Exclude – Low consequence (transport in liquid magma) Include (pyroclastic transport)
1.2.04.06.00	Basaltic cinder cone erupts through the repository	DE Include
1.2.04.07.00	Ashfall	DE Include (ash cloud and surface deposition) Exclude (pyroclastic flow)
1.2.10.01.00	Hydrological response to seismic activity	UZ Exclude – Low probability and Low consequence SZ Exclude – Low consequence DE Exclude – Low consequence
1.2.10.02.00	Hydrologic response to igneous activity	UZ Exclude – Low consequence DE Exclude – Low consequence
2.1.07.01.00	Rockfall (large block) WF Clad-Rockfall	WP Exclude – Low consequence DE Exclude – Low consequence WF Misc. Exclude – Low consequence EBS Exclude – Low consequence
2.1.07.02.00	Mechanical degradation or collapse of drift	DE Exclude – Low consequence EBS Exclude – Low consequence
2.2.06.01.00	Changes in stress (due to thermal, seismic, or tectonic effects) change porosity and permeability of rock	NFE Exclude – Low consequence DE Exclude – Low consequence
2.2.06.02.00	Changes in stress (due to thermal, seismic, or tectonic effects) produce change in permeability of faults	UZ Exclude – Low consequence SZ Exclude – Low consequence DE Exclude – Low consequence

Table B-17. Screening Decisions and Bases for Disruptive Events Features, Events, Processes (Continued)

FEP Number	FEP Name	Screening Decision and Basis[a]
2.2.06.03.00	Changes in stress (due to seismic or tectonic effects) alter perched water zones	UZ Exclude – Low consequence (effects of perched water changes below the potential repository) Include (effects of perched water changes above potential repository on drift seepage) SZ Exclude – Low consequence DE Exclude – Low consequence

Source: Table B-1

NOTES: [a]Issues or items given in parentheses are components of the FEP that are included or excluded, as indicated. If no issues or items are given in parentheses then the entire FEP is included or excluded, as indicated.

B.6. EVALUATION OF RELEVANT TOTAL SYSTEM PERFORMANCE ASSESSMENT ISSUE RESOLUTION STATUS REPORT ACCEPTANCE CRITERIA

Acceptance criteria for FEPs identification, classification, and screening are provided in the TSPAI IRSR (NRC 2000 [149372], Sections 4.1.1.2 and 4.2). Specific criteria are discussed below.

SUBISSUE 1–TRANSPARENCY AND TRACEABILITY, FEATURES, EVENTS, AND PROCESSES IDENTIFICATION AND SCREENING

These acceptance criteria address the screening process by which FEPs were included or excluded and the relationship between relevant FEPs. The origins of all YMP FEPs are described in Section B.2 of this Appendix and tracked in the database for each FEP. The screening process by which FEPs were included or excluded from the TSPA is described in Section B.4. Additional details on the screening process are provided in the individual FEP AMRs listed in Table B-1.

Relationships between relevant FEPs are identified in several ways. Related FEPs are inherently grouped together in accordance with the NEA-based hierarchical numbering scheme (Section B.3.1). The tree directory functionality in the database allows database users to graphically view and identify these groupings. Related FEPs are also grouped according to subject area (using database field input AMR). Finally, in future revisions to the database, related FEPs will be able to be identified using a keyword-search, pull-down menu.

SUBISSUE 2–SCENARIO ANALYSIS, IDENTIFICATION OF INITIAL FEATURES, EVENTS, AND PROCESSES

These acceptance criteria address the comprehensiveness of the FEP list. The YMP FEP list was initially developed from a comprehensive list of FEPs from other international radioactive waste disposal programs (Section B.2.1) and was supplemented with additional YMP-specific FEPs from project literature, technical workshops, and reviews (Sections B.2.2 through B.2.4). These bottom-up compilations produced an extensive, wide-ranging set of FEPs with the potential to influence the potential repository performance.

The comprehensiveness of the YMP FEP list derives in part from the NEA-based database structure. The NEA structure comprises a comprehensive group of subject areas (i.e., headings) potentially relevant to radioactive waste disposal that was developed to systematically classify the FEPs from seven different international programs. Continuous iterative review (i.e., at workshops and in FEP AMRs) of all database subject areas assures a strong degree of comprehensiveness, and ensures that no subject area is overlooked. Further assurance of comprehensiveness arises from the results of the most recent iterative reviews (Tables B-5 and B-6). Only nine and two new FEPs, respectively, were identified, and these new FEPs were variants of existing FEPs rather than representing entirely new subject areas. The diminishing returns of these iterative reviews suggest that the REV00 YMP FEP list is quite comprehensive.

SUBISSUE 2–SCENARIO ANALYSIS, CLASSIFICATION OF FEATURES, EVENTS, AND PROCESSES

These acceptance criteria address the grouping and categorization of FEPs. The all-inclusive bottom-up approach used to develop the YMP FEP list resulted in considerable redundancy in the FEP list. To eliminate the redundancy and to create a more efficient aggregation of FEPs to carry forward into the screening process, each of the 1,797 entries catalogued in the YMP FEP Database REV00 (CRWMS M&O 2000 [150806], Appendix D) was identified as either a primary, secondary, or classification (layer, category, or heading) entry. The process and criteria for assigning FEPs to one of these categories is described in Section B.3.2. Because any categorization of FEPs is subjective, the preliminary identification of primary, secondary, and classification entries was reviewed and, where necessary, revised by subject matter experts.

This categorization resulted in a list of 323 primary FEPs that were carried forward for screening. Screening of the secondary (and classification) FEPs was not required, because the aspects of the secondary FEPs were encompassed by the primary FEPs.

SUBISSUE 2–SCENARIO ANALYSIS, SCREENING OF FEATURES, EVENTS, AND PROCESSES

These acceptance criteria address the screening of the FEPs. The regulatory criteria for screening FEPs on the basis of low probability, low consequence, or regulatory specification are summarized in Section B.4.1. To satisfy these regulatory screening criteria and to satisfy the TSPAI IRSR FEP screening acceptance criteria, guidelines were established for the content of the screening discussions. However, in some cases the screening discussions input from the FEP AMRs did not fully satisfy the guidelines, and, consequently, the screening information catalogued in the YMP FEP Database REV 00 (CRWMS M&O 2000 [150806], Appendix D) for some FEPs does not completely address the acceptance criteria of this subissue. Subsequent revisions of the FEP AMRs are planned to fully address this subissue and will be reflected in subsequent revisions of the database.

B.7. SUMMARY

This Appendix provides an introduction to the YMP FEP Database REV 00 (CRWMS M&O 2000 [150806]) and a summary of the screening decisions and bases given in the database for primary FEPs. The database structure is hierarchical, consisting of overarching classification entries (levels, categories, and headings), primary FEPs, and secondary FEPs. The primary FEPs collectively capture all of the issues relevant to the postclosure performance of the potential Yucca Mountain repository. Each primary FEP requires a screening discussion identifying the technical basis for inclusion or exclusion of FEPs in the TSPA-SR analyses. Secondary FEPs are subsumed in or redundant to overlying primary FEPs and do not require screening discussions.

Full screening discussions (screening arguments or summaries of TSPA dispositions) are given in the YMP FEP Database REV00 (CRWMS M&O 2000 [150806], Appendix D). These screening discussions were prepared by subject matter experts and documented in FEP AMRs listed in Table B-1.

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APPENDIX C

NATURAL-ANALOGUE INVESTIGATIONS IN SUPPORT OF PERFORMANCE ASSESSMENT OF THE POTENTIAL YUCCA MOUNTAIN RADIOACTIVE-WASTE REPOSITORY

APPENDIX C

ACRONYMS AND ABBREVIATIONS

SZ	saturated zone
TSPA-VA	Total System Performance Assessment-Viability Assessment
UZ	unsaturated zone
YMP	Yucca Mountain Site Characterization Project

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APPENDIX C

NATURAL-ANALOGUE INVESTIGATIONS IN SUPPORT OF PERFORMANCE ASSESSMENT OF THE POTENTIAL YUCCA MOUNTAIN RADIOACTIVE-WASTE REPOSITORY

C.1 INTRODUCTION

Natural-analogue studies are useful in performance-assessment investigations of potential nuclear-waste repositories as a means to evaluate independently the various components of the system under evaluation. Natural-analogue investigations also attempt to provide confidence in estimated parameter values used to simulate the long-term behavior of the system under investigation. In practice, the goals of natural-analogue investigations are to find analogues for structures and materials planned for use in nuclear-waste disposal. Natural analogues refer to both natural and anthropogenic (human-induced) systems in which processes, similar to those that might be expected to occur in a radioactive-waste repository, have occurred over long time periods (decades to millennia) and over large spatial scales (up to tens of kilometers) that are not accessible to ordinary laboratory experiments. In addition, natural-analogue studies have attempted to characterize uranium ore deposits and their geologic/hydrologic/geochemical settings because they contain mineralogic assemblages similar to the mass of materials, both waste forms and waste containers, planned for geologic disposal at Yucca Mountain. The challenge in using natural-analogues to estimate parameters for performance-assessment studies is that the initial and boundary conditions of the analogues can be difficult to quantify accurately. Another challenge lies in the fact that, although natural geologic processes that may be analogous to those at potential nuclear-waste repositories have been active for millions of years, some analogous archaeological materials are only several thousand years old. In addition, many materials being considered for use in nuclear-waste disposal may not have analogues in nature, in the archaeological record, or in human history until very recently. However, despite their limitations, natural analogues can provide conservative bounding estimates of variable parameters and the natural progression of some geologic processes so that the performance of these natural analogues can provide enhanced confidence in the parameter set chosen for performance-assessment investigations.

The *Yucca Mountain Site Description* (CRWMS M&O 2000 [137917]) provides a comprehensive overview of past and ongoing natural-analogue investigations and describes the Yucca Mountain Project natural-analogue program. The *Yucca Mountain Site Description* (CRWMS M&O 2000 [137917]) describes the role of natural-analogues in providing an understanding of the unknown elements of the potential repository by comparing those elements with some known natural and anthropogenic elements. According to the *Yucca Mountain Site Description* (CRWMS M&O 2000 [137917], p. 13.1-1), "The results of the analog (sic) studies will be used to corroborate estimates of the magnitude and limitations of operative processes, thus building realism into conceptual and numerical-process models that underlie performance assessment...". The *Yucca Mountain Site Description* (CRWMS M&O 2000 [137917]) places a strong emphasis on analogues to processes and discusses specific natural analogues under the categories:

- Waste form, engineered barrier system, and repository-materials analogues
- Natural-system analogues
- Total-system analogues such as Cigar Lake.

More direct emphases on natural-analogue investigations are presented in *Natural Analogues for the Unsaturated Zone* (CRWMS M&O 2000 [141407]) and in *Archaeological Analogues for Assessing the Long-Term Performance of a Mined Geologic Repository for High-Level Radioactive Waste* (Stuckless 2000 [151957]).

C.2 MISCELLANEOUS EXAMPLES OF NATURAL-ANALOGUES FOR MATERIALS AND PROCESSES

Several classes of natural analogues have been considered in the performance-assessment investigation of Yucca Mountain. The investigations of these analogues are in various stages of evaluation. The areas of investigation that are most relevant to the materials considered likely for use in the potential Yucca Mountain repository have included:

- **Metalliferous Materials**–The most important metals being considered for use in the potential Yucca Mountain repository are exotic alloys of nickel, chromium, iron, and titanium. In addition, stainless steel will be used for many components including the inner sleeve of the waste package developed to contain the waste materials. Natural analogues of these materials are not found in nature, and they are very different from historic iron and steel. Only meteorites are potential analogues of these materials (Johnson and Francis 1980 [125291]). However, the composition of most meteorites is not analogous to the current suite of alloys being considered for use in the potential Yucca Mountain repository. The values of metal-corrosion parameters used in the Yucca Mountain performance assessment are conservative estimates based on the evaluation of historic man-made iron products and laboratory experiments of the atmospheric corrosion of metals used in construction and in operating machines (Miller et al. 1994 [126089]).

- **Cementitious Materials**–Although the current design of the potential Yucca Mountain repository specifies only limited use of cementitious materials, it is possible that future design changes may include the use of various formulations of concrete for support and added strength in potential repository construction. As with metals, modern concretes, which rely on the formation of alkaline-earth silicates for strength and durability, are much different from historic concretes. Roman concretes, one possible analogue, are mainly calcareous and behave differently from modern Portland-type siliceous cements. However, modern concretes are similar to the natural-cement deposits at Maqarin in northern Jordan. At Maqarin, the hyperalkaline geochemical conditions in the area of these deposits tend to immobilize radionuclides and metals. Unfortunately, under oxidizing conditions, hyperalkaline groundwater is corrosive to metalliferous material. In the case of Yucca Mountain, the waste packages and supporting structures would probably experience accelerated corrosion if large amounts of cementitious material were used in the potential repository.

- **Ceramics**–Archaeological ceramics are quite long-lived, up to 25,000 years, and the mineralogic components of ceramics demonstrate durability in terms of millions of years. Some material scheduled for disposal at Yucca Mountain, such as plutonium, will be immobilized in a specialized, high-temperature ceramic. Although archaeological ceramics are long-lived, they were generally fired at lower temperatures and do not have the exotic chemical composition anticipated for the Yucca Mountain ceramics. However, despite their general applicability as analogues, archaeological ceramics display protective alteration products that enhance their resistance to weathering and to atmospheric corrosion. Whether this protective coating will form on the ceramic material that may be used for Yucca Mountain remains to be determined in laboratory investigations. Nonetheless, the observed long-term performance of low-fire archeological ceramics is encouraging with respect to the modern, high-fire ceramics which by analogy should have significantly longer performance periods.

- **Glass**–Archaeological and natural glasses, such as basaltic or volcanic glass, have long fascinated humankind, and glassmaking using similar technology has existed for thousands of years. Natural geologic glasses tend to be more stable than archaeological glass, especially in regard to changing environments relative to humidity. The borosilicate glass intended for use at Yucca Mountain is more similar in composition to basaltic glass than to archaeological glass. The glass to be used at Yucca Mountain will also be subject to irradiation from the fission products and actinides in the waste products. The long-term effects of this irradiation have no obvious natural analogue. Laboratory studies are still underway to determine some of the potential long-term properties of borosilicate glass.

- **Radionuclide Transport**–The evaluations of models, data sets, and assumptions that will be used to predict performance of the potential Yucca Mountain repository would benefit from the use of a comparison of predicted system performance with that of a natural analogue or analogues. Waste form degradation, waste mobilization, and radionuclide transport are long-term phenomena that are difficult to evaluate with a high degree of certainty, especially if limited to information gained through short-term laboratory and field studies. Natural formations and deposits that have existed for very long periods of time may reveal the operative analogous transport processes and help to determine which factors most affect these processes. The natural reactors at Oklo, Gabon, Equatorial Africa, which achieved criticality about 2.7 billion years ago, have been studied extensively for waste degradation, mobilization, and radionuclide transport (including plutonium) in both reducing and oxidizing environments (Jakubick and Church 1986 [100459], Curtis et al. 1989 [100438], Brookins 1990 [100387]; Chapuis and Blanc 1993 [127825]).

  The 2.7-million-year-old uranium deposit at Oklo has evidence that the relative abundance of ^{235}U in the deposit approached that of modern nuclear reactors (Gauthier-LaFaye et al. 1989 [124997]). The evidence indicates that natural fission reactions took place at this location, and it has been determined that at least 16 reactors were active over a period of about one-million years (Gauthier-LaFaye et al. 1989 [124997]). Oklo is believed to be the only naturally occurring example of critically produced transuranic elements (Gauthier-LaFaye et al. 1996 [125005]). Examination of the mineralogy of the deposit reveals several reactor cells that produced plutonium (Gauthier-LaFaye et al. 1996 [125005]). Past investigations at Oklo show that 3 elements–^{234}U, ^{239}Pu, and ^{242}Pu–do not appear to have migrated from the reactor-core uraninites, and that this behavior may also apply to ^{237}Np (Menet et al. 1992 [150921]). Other investigations at Oklo indicate that ^{99}Tc may have migrated both to inclusions in the minerals in the core of the natural reactor and to the clays that seal the ore deposit (Eberly et al. 1996 [150899]). The short half-lives of ^{14}C, ^{79}Se, and ^{231}Pa are probably the reason they are not prominently present in and around the Oklo reactors. Half-life may also be important in the case of ^{129}I which, with its ionic radius about double that of uranium, probably has migrated away from the Oklo reactors rather than being incorporated into the uraninite before decaying. The migration of ^{99}Tc movement to inclusions was detected by analyzing for its daughter product ^{99}Ru (Hidaka et al. 1993 [151769]).

Extensive research has been conducted on the Cigar Lake uranium deposit in northern Saskatchewan (Cramer and Smellie 1994 [100437]). Although located in saturated sandstone, important analogue information may still be applicable to Yucca Mountain. Significantly, although 1.3 billion years old and located in a fractured, saturated environment, there is no evidence of the deposit expressed at the surface. A 3-year analogue study was conducted at Pocos de Caldas, Brazil, which focused on radionuclide transport issues (Chapman et al. 1991 [100423]). Other potential analogue sites that have included studies of transport phenomena include Alligator Rivers in Australia, Tono in Japan, and Palmottu in Finland.

Peña Blanca, in Chihuahua, Mexico, is a uranium deposit located in unsaturated tuff and is an excellent analogue to the processes and material at the potential Yucca Mountain repository. Section C.3.2 provides a summary of a planned detailed investigation concerning whether or not future investigations and field studies of this uranium deposit may provide important insights into the process of radionuclide transport.

Natural Analogues for the Unsaturated Zone (CRWMS M&O 2000 [141407]) investigated the distribution of radioisotopes of uranium (U), radium, thorium, and protactinium in secondary minerals at the Nopal I mine site (Murrell et al. 1999 [130408]). The results of sample analyses indicate that uranium (^{235}U and ^{238}U), thorium, and protactinium are found in fracture filling materials in mineralogies that indicate long-term stability on the order of 100,000 years. However, radium appears to be mobile on the scale of 50 ka indicating that radium could be used as a natural conservative tracer.

- **Coupled Processes in the Unsaturated Zone**–*Natural Analogues for the Unsaturated Zone* (CRWMS M&O 2000 [141407]) summarizes the results of completed and ongoing field and laboratory investigations of natural analogues dealing with UZ flow and transport. The report concluded that natural analogues could be important in confidence building regarding the conceptual and numerical models used to evaluate the potential Yucca Mountain repository site.

The Idaho National Engineering and Environmental Laboratory conducted field investigations in unsaturated, fractured Quaternary basalt flows at Box Canyon, Idaho. A two-phase, dual-permeability model was used to simulate the flow of air and water through the fractured basalt. Pneumatic and fluid-infiltration tests provided data used to calibrate the model. Although somewhat scale dependent, the model analysis indicates that the infiltration established a vertically and laterally uniform front with no strong channeling along fractures (CRWMS M&O 2000 [141407]). Future application of this study could include conducting similar field investigations and modeling at Rainier Mesa at the Nevada Test Site to determine whether or not the Box Canyon natural analogue is relevant to the potential Yucca Mountain repository site.

Analogues to coupled thermal-hydrologic-mechanical-chemical processes include active geothermal systems and shallow magmatic intrusions into the UZ with associated hydrothermal processes. The examples of these processes are many and varied and not all are suitable analogues to the Yucca Mountain repository site. *Natural Analogues for the Unsaturated Zone* (CRWMS M&O 2000 [141407]) note that some locations such as Banco Bonito flow associated with the Valles Caldera in New Mexico indicate that the intrusion was associated with pore-water vaporization and reflux conditions such as those expected at Yucca Mountain. Alternatively, *Natural Analogues for the Unsaturated Zone* (CRWMS M&O 2000 [141407]) show that at the Grant's Ridge site west of Albuquerque, New Mexico, there is thermal alteration of minerals but little evidence of hydrothermal alteration. Future examination of active geothermal systems may provide insights regarding the nature of fracture flow during the condensate-drainage period after the potential post-repository-closure heat pulse.

C.3 NATURAL-ANALOGUE INVESTIGATIONS IN SUPPORT OF THE YUCCA MOUNTAIN TOTAL SYSTEM PERFORMANCE-ASSESSMENT

In addition to investigating natural analogues to materials intended for use in the potential Yucca Mountain repository, the results of some preliminary investigations of analogues to geologic processes are underway. Two investigations of interest are the simulation of the 1995 volcanic eruption at Cerro Negro, Nicaragua and a preliminary investigation of potential radionuclide transport at the Nopal I uranium deposit in the Sierra Peña Blanca in Chihuahua, northern Mexico. These two investigations will be discussed separately. The information and analysis is presented as corroborative information only, and does not require further confirmation.

C.3.1 SIMULATION OF 1995 CERRO NEGRO, NICARAGUA, VOLCANIC ERUPTION

Cerro Negro is a basaltic, cinder-cone volcano located 20-km northeast of the city of Leon in northwestern Nicaragua. Following a volcanic eruption with a significant ashfall plume at Cerro Negro in November 1995, the thickness of the volcanic ash deposited during that eruption was measured immediately after the eruption (Hill et al. 1998 [151040]). The ash-thickness data provided an opportunity to use the ASHPLUME code (CRWMS M&O 1999 [132547]) to simulate this eruption. The goal was to compare an ash-deposition calculation predicted using the ASHPLUME code to an actual ashfall event from a small-volume basaltic volcano. The essence of the analogy is that the Cerro Negro volcano is similar in size and type to a possible volcanic event that could occur in the vicinity of Yucca Mountain.

The two-dimensional diffusion model of Suzuki (1983 [100489]) was implemented by the ASHPLUME code. Two versions of the code were compared to the Cerro Negro ash-thickness data. Version 2.0 uses eruption power and event duration to determine column height and mass of ejecta, as described in Jarzemba et al. (1997 [100987]). Version 1.4LV uses the volume and density of the ash to determine ash column height and mass (CRWMS M&O 1999 [132547]). Input parameters used in the Cerro Negro comparison for each version are given in Table C-1. These parameters are given in Hill et al. (1998 [151040]) for the November 1995 Cerro Negro eruption.

Table C-1. ASHPLUME Parameters Used for Cerro Negro Comparison

Parameter	Version 1.4LV	Version 2.0
Ash density, g/cm^3	1.2	1.2
Particle shape factor	0.5	0.5
Air density, g/cm^3	0.001293	0.001293
Air viscosity, g/cm-s	0.00018	0.00018
Constant C, $cm^2/s^{5/2}$	400.0	400.0
Constant beta	10.0	10.0
Lower limit on column height, km	0.001	0.001
Mean ash particle diameter, cm	0.07	0.07
Particle diameter standard deviation	0.8	0.8
Wind speed, cm/s	900.0	900.0
Initial eruption velocity, cm/s	10000.0	10000.0
Eruption power, watts	NA	7.34×10^9
Event duration, s	NA	3.46×10^5
Eruption volume, km^3	0.000288	N/A

NOTE: N/A = not applicable

The version 2.0 simulation was completed first, and the initial eruption-velocity and particle-size standard-deviation parameters were adjusted to obtain a reasonable fit to the observed data. Next, the version 1.4LV simulation was performed using the same parameter set and a value for ash volume that the model used to produce a total mass of ash equivalent to the version 2.0 calculation.

The two versions of the code produce similar results. Figure C-1 shows the results from each code version compared to the measured Cerro Negro ash-deposit data. The ASHPLUME calculations compare well with the observed data for distances from the volcanic vent greater than 10 km. For distances less than 10 km, the ASHPLUME results give ash-thickness values greater than the observed data. The lobe on the northern side of mapped ash-plume data indicates that a variation in wind direction, speed, or both occurred during the eruption. This probably accounts for some of the discrepancy between the observed and the simulated data because ASHPLUME assumes a constant wind speed and direction for a given simulation. The results generally show that the ASHPLUME model can reasonably predict the ash-fall distribution of a basaltic cinder cone volcano similar to Cerro Negro. The Cerro Negro ash-fall-calculation method could be used to simulate possible ash-producing events either near the potential Yucca Mountain repository or an ash-producing eruption through the potential repository involving waste-package destruction and aerial liberation of radionuclides.

C.3.2 RADIONUCLIDE-TRANSPORT SIMULATIONS FOR THE PEÑA BLANCA NATURAL-ANALOGUE SITE

C.3.2.1 General Introduction

Although several natural geologic deposits and environments analogous to nuclear-waste repositories have been analyzed (Miller et al. 1994 [126089], Appendix A), most are not analogous in geologic age, geologic setting, climate, or mineralogy to the Yucca Mountain site. One of the most promising areas investigated vis-à-vis the Yucca Mountain site has been the Nopal I uranium mine, located in the Sierra Peña Blanca approximately 50 km (31 mi.) north of Chihuahua City, Chihuahua, Mexico, and usually referred to as the Peña Blanca natural analogue (Murphy 1995 [121310]).

The purpose of this study was to analyze the possible mobilization and groundwater transport of radionuclides potentially released from the Nopal I ore deposit. The goal of the investigation was to estimate whether further field investigations and groundwater sampling at the Nopal I site would provide a basis for a natural-analogue comparison of the Peña Blanca site with the expected performance of the Yucca Mountain site.

The Peña Blanca Nopal I uranium deposit is temporally, geologically, climatically, geochemically, and hydrologically analogous to Yucca Mountain (Murphy et al. 1991 [151772]). Previous studies at Peña Blanca have focused on the mineralogy of the uranium-bearing materials and on estimates of the source term for hydrochemical migration in the near-field area of the ore body (Pickett and Murphy 1997 [109989], Murphy and Pearcy 1992 [151773], Leslie et al. 1993 [101714], Green et al. 1995 [149528], Murphy 1995 [121310]). However, to date, the only performance-assessment analysis of Peña Blanca has been conducted by Murphy and Codell (1999 [149529]). Several performance-assessment analyses have simulated the performance of the potential Yucca Mountain deep geologic repository using the following processes:

- Precipitation input to the land surface above the potential repository
- Flow through the UZ
- Corrosion and degradation of the waste packages and waste forms
- Groundwater flow of contaminants through the saturated zone (SZ)
- The use of biosphere dose-conversion factors to estimate radionuclide concentrations at receptor wells downgradient from the potential repository.

These analyses used a numerical model to simulate the various processes involved in the performance of the potential repository and its engineered components. The model configuration generating the contaminants leaving the potential repository and subject to flow and transport of radionuclides began with the radionuclide inventory of spent nuclear fuel and other waste components and implemented dissolution models to these components to estimate the potential release of radionuclides at Peña Blanca.

The performance-assessment model for the Peña Blanca uranium deposit began with the basic assumption that the uranium oxide comprising the bulk of the radionuclides at the deposit is directly analogous to spent nuclear fuel, which is largely composed of uranium oxide. The Nopal I uranium deposit is approximately 9 million years old (Murphy 1992 [106833]). The starting point for the numerical simulations is approximately 3 million years ago, when the Nopal I deposit was exposed to oxidizing conditions (Murphy and Codell 1999 [149529]).

The following analysis used the Repository Integration Program (Golder Associates 1998 [100449]) to analyze potential release and transport of radionuclides from the Nopal I ore deposit in the Peña Blanca uranium district. Because of the limited data available for the site, the analysis is, of necessity, a scoping study that will require validation through additional field-data collection. Therefore, the performance-assessment analysis of the Peña Blanca site is accompanied by specific plans for additional investigations and data collection at the mine site.

C.3.2.2 Setting

The Peña Blanca Nopal I ore deposit lies in the high desert in the Basin and Range geologic province approximately 50 km (31 mi.) north of Chihuahua City, Chihuahua, Mexico (Figures C-2 and C-3) (Pearcy et al. 1993 [151774]). The ore body lies on the southeast side of the Sierra Peña Blanca, which is named for the white color of oxidized mineral deposits in the range. Field observations indicate that the original land surface at the Nopal I deposit probably exposed a small portion of the ore body. The deposit lies in fractured, welded, and altered rhyolitic ash-flow tuffs similar to the volcanic rocks at Yucca Mountain (George-Aniel et al. 1991 [105636]).

When the deposit was mined in the 1970s and 1980s, two prominent benches were cut across the ore body at the 0-m and +10- m levels (local, vertical mine coordinates). Two adits enter the mined area from land surface at the 0- m and 70- m levels, and the one principal shaft connects the 0- m adit with adits at the 20-, 40-, and 70- m levels, as shown on Figure C-4 (Reyes-Cortes 1997 [149533]). The total depth of the main mine shaft is approximately 110 m from the -20 m level.

The Nopal I ore deposit has been estimated to be approximately 9 million years old (Murphy 1992 [106833]). Examination of the weathering mineralogy of the ore body indicates that the deposit probably lay stable and under reducing conditions until approximately 3 million years ago, when it was exposed to oxidizing groundwater, infiltration from precipitation, and weathering processes (Murphy and Codell 1999 [149529]). Since that time, an altered zone of oxidized uranium and accessory minerals and secondary minerals has developed around the ore body (Murphy and Codell 1999 [149529]).

The geologic characterization of the Nopal I ore body is described in Goodell (1981 [149484]) and shown on Figure C-5. The ore deposit occurs in ignimbritic ash-flow tuffs similar to those found at the Yucca Mountain site (DOE 1998 [100550]). The top 30 m of the deposit lie in the

Nopal Formation, a fractured rhyolitic tuff, and, the lower 70 m lie in the Colorados Formation, a weakly welded, fractured, ignimbritic tuff. Beneath the deposit, and probably containing the lower several meters of the ore body, lie 60 m of Pozos Formation, a silicified, detrital conglomerate composed principally of altered limestone clasts, and approximately 10 m of Cretaceous limestone. A near vertical fault, with greater than 10 m of offset, intersects the hill containing the ore body, and lies to the east of the deposit, but does not appear to cut the ore body. Minor faults and fractures are observed in the vertical walls of the open faces of the mine above the 0- and 10-m levels.

The ore body can be approximately described as a roughly cylindrical, breccia-pipe-like form, approximately 18 by 30 m in the horizontal plane and 100 m in the vertical dimension. The deposit is presently estimated to contain 333 metric tons of uranium (George-Aniel et al. 1991 [105636]). Uranium comprises approximately 0.23 percent of the deposit by volume (George-Aniel et al. 1991 [105636]). Using analyses of oxidized uranium minerals (Pearcy et al. 1993 [151774]), Murphy and Codell (1999 [149529]) estimated that the unoxidized ore body contained 408 metric tons of uranium as uranium oxide.

Elements of the site hydrogeology are presented in Green et al. (1995 [149528]) and Pearcy et al. (1993 [151774]). The Nopal I ore deposit lies in the UZ, and the water table has been estimated to be approximately 70 m below the ore deposit, although the base of the deposit has not been firmly established (Pearcy et al. 1993 [151774]). Green and Rice (1995 [149485]) conducted an artificial recharge study at the Nopal I mine, and the data obtained were used to estimate the hydraulic properties of the intact and oxidized portions of the ore body. Their investigations indicated that the porosity of the ore deposit ranged from 0.05 to 0.08 in unaltered rock, and to 0.30 in altered rock. The saturated hydraulic conductivity ranged from 6×10^{-12} cm/s in the unaltered rock, and to 1×10^{-7} cm/s in the altered rock.

Previous studies of the Nopal I deposit have focused on the geochemical aspects of the oxidation, transport, and reprecipitation of uranium mineral phases in the matrix and bedrock (Pearcy et al. 1993 [151774], Pickett and Murphy 1997 [109989], Pearcy 1994 [149523]). The possible release and transport of likely conservative species such as ^{99}Tc has not been previously considered in detail. The following performance-assessment analysis considers the possibility of the generation, liberation, and transport of ^{99}Tc and uranium species from the Nopal I deposit.

C.3.3 MODEL ELEMENTS

C.3.3.1 Radionuclide Inventory

The estimated uranium content of the original, preoxidized Nopal I deposit was 408 metric tons (Murphy and Codell 1999 [149529]). The inventory of uranium species and some daughter products, together with radiochemical analyses of Nopal I ore piles and vegetation residues (Leslie et al. 1999 [109967]), were used to estimate the inventory of radionuclides used for the Repository Integration Program simulations as shown on Table C-2, in Section C.3.3.6 below. The inventory is approximate, and the Repository Integration Program analyses were conducted using a range of values surrounding these estimates. The ^{99}Tc inventory was based on information found in Curtis et al. (1999 [110987]) and is not specifically related to Nopal I. More detailed radiochemical analyses are anticipated to be obtained from core and/or chip

samples from the planned drilling at the Nopal I site. These future analyses will provide a more definitive radionuclide inventory for future performance-assessment-type calculations.

C.3.3.2 Conceptual Model

The performance-assessment analysis of Nopal I assumed the Peña Blanca area to be located in an area where there is lateral to vertically downward groundwater flow (Green et al. 1995 [149528]). The site of the Nopal I mine is in a recharge condition relative to the regional groundwater flow (Green et al. 1995 [149528]). A significant playa, Playa Cuervo, exists east of the Sierra Peña Blanca and is assumed to be the regional discharge location for groundwater in the Peña Blanca area (Reyes-Cortes 1997 [149533]). The physiography of the area is similar to that of the Great Basin where long-term data on climate and precipitation patterns were assembled in preparation of the Total System Performance Assessment-Viability Assessment (TSPA-VA) (CRWMS M&O 1998 [100356]). Because of similarities in geography and physiography and the lack of local data for the state of Chihuahua, the use of the long-term infiltration patterns used in the TSPA-VA for Yucca Mountain are considered to be adequate for the scoping-type calculations for the Peña Blanca performance-assessment analysis.

The Nopal I deposit is approximately 9 million years old (Murphy 1992 [106833]), but the deposit was only exposed to oxidizing conditions over the last 3.2 to 3.4 million years (Pickett and Murphy 1997 [109989]). The Repository Integration Program model formulation considers a steady-state condition in which the source term depends on the degradation rate. The UZ and the SZ are divided into mixing cells to account for diffusion and dispersion.

The conceptual model for radionuclide transport assumes that ^{99}Tc has been generated primarily by the spontaneous fission of ^{238}U (Curtis et al. 1999 [110987]). Curtis et al. (1999 [110987]) also indicate that ^{99}Tc may also be generated by irradiation of molybdenum and, possibly, by neutron-induced fission of ^{235}U. However, there is not a strong molybdenum presence in the Peña Blanca mining district, and there is scant information on the generation of ^{99}Tc from ^{235}U at Nopal I (Reyes-Cortes 1997 [149533]). Therefore, the ^{99}Tc inventory for the Repository Integration Program simulations was developed based on the abundance of uranium species at the Nopal I deposit and used the estimation algorithm presented in Curtis et al. (1999 [110987]) to estimate possible ^{99}Tc production from spontaneous fission of ^{238}U.

The ^{99}Tc produced from ^{238}U is assumed to be subject to leaching from the ore body and to be largely conservative (Beasley et al. 1998 [102430]) as the soluble and mobile form of pertechnetate ion ($TcO4^-$) (Brown 1997 [151775]), and then available for transport by groundwater through the UZ and SZ. The work of the Southwest Research Institute indicates that uranium-mineral alteration at Nopal I has not led to significant migration of uraniferous species; rather, it has led to the precipitation of secondary uranium minerals and sorption of the liberated uranyl species after tens of meters of lateral travel distance (Pearcy et al. 1995 [110223]). Given the age of the Nopal I deposit, this performance assessment assumes that ^{99}Tc can be used as a surrogate radionuclide to estimate the potential transport of conservative species in the natural environment.

In the model, the Nopal I ore deposit was assumed to be accessed by infiltrating water, and it was assumed that the original and present uraninite in the ore body was subject to dissolution. The dissolution was followed by the release of uranium species in the same manner as the waste form in the waste packages in the performance-assessment modeling of the potential Yucca Mountain repository. However, in the Peña Blanca analysis, there was no waste package to delay water-uraninite interaction or to hinder direct release and transport. Also, all the dissolved species were subject to advective or to diffusive flux from the ore body to the UZ.

C.3.3.3 Infiltration

Precipitation infiltration has not been estimated at the Nopal I site, but the vegetation and soil of the area indicate that infiltration is likely (Leslie et al. 1999 [109967]). The climate of the Peña Blanca region is arid, with an estimated 250 mm/yr of precipitation (Pearcy et al. 1993 [151774]). The basic Peña Blanca performance-assessment model assumed that the present-day climate used in the TSPA-VA is the most likely climatic regime during the last 3 million years. The presence of perched water in shot holes drilled into the open bench of the +10 m level indicates that precipitation infiltration occurs in the area of the Nopal I mine (Picket and Murphy 1999 [110009]). Because of the climatic similarity of Sierra Peña Blanca and the Yucca Mountain site, and because there have been no detailed infiltration studies at the Nopal I mine site, the infiltration observations made at Yucca Mountain (CRWMS M&O 1998 [100356]) were used in the Peña Blanca performance assessment. The Peña Blanca modeling thus assumed an infiltration rate of 5 to 7 mm/yr (CRWMS M&O 1998 [100356]).

C.3.3.4 Unsaturated Zone

The vertical UZ section of rock below the ore body is approximately 70-m thick (Reyes-Cortes 1997 [149533]) and is composed both of the lower part of the volcanic tuff and volcanic conglomerate of the Pozos Formation and of the upper part of the Cretaceous limestone that underlies this region of northern Mexico. In the absence of sufficient data for Nopal I to create a sophisticated site-specific model, the potential for transport of ^{99}Tc through the UZ beneath the Nopal I deposit was modeled using mixing cells in the Repository Integration Program. The model assumed that infiltrating water contacts the ore body and that the volume of percolating water corresponds to that derived from the present-day climate. The cross-sectional area of the ore body (18 by 30 m) was used with the height of the deposit (100 m) (Pearcy et al. 1993 [151774]) and the porosity range of 7.5 to 30 percent of the rock (Green and Rice 1995 [149485]) to estimate the volume of fluid percolating through the deposit. Uranium-oxide degradation was assumed to be the operating mechanism for degradation and dissolution of the ore body. Therefore, the performance-assessment analysis performed with the Repository Integration Program model used the same uranium-oxide dissolution model used in the Repository Integration Program for uranium-oxide spent fuel in the Yucca Mountain Site Characterization Project (YMP) performance-assessment analyses.

C.3.3.5 Saturated Zone

In a manner similar to YMP performance assessment models, the Peña Blanca analysis accumulates the water flowing through the UZ and passes it to the SZ at the water table (CRWMS M&O 1998 [100364], CRWMS M&O 1998 [100365]). The fluid contains radionuclides leached from the ore body based on the inventory input into the model. The fluid at Peña Blanca contains primarily ^{99}Tc. The theoretically contaminated groundwater flows eastward in the SZ through the Cretaceous limestone according to the hydraulic gradient (Green et al. 1995 [149528]). The groundwater flow in the model is through a stream tube in the same manner as in the TSPA-VA model. Nuclide concentrations were calculated at various points along the stream tube at the estimated locations of proposed groundwater monitor/sampling wells approximately 150, 600, and 1,300 m downgradient from the ore body. The 1,300-m location is at the same distance as the location of the former mining-camp water supply well, approximately downgradient from the ore body. The one additional downgradient well that was considered is the Papalote ranch supply well, which is approximately 2-km downgradient from the ore body.

The Peña Blanca Repository Integration Program model did not calculate dose-to-receptor values because the goal of the investigation was to estimate concentrations in groundwater of ^{99}Tc and some uranium species at selected distances from the Nopal I mine. The calculations provided by the Repository Integration Program were compared to analyses of water samples collected at the mining-camp water-supply well and were presented in Pickett and Murphy (1999 [110009]). In that study, the uranium was estimated to be 1.69×10^{-4} mg/L.

C.3.3.6 Model Configuration

The performance-assessment model for the Peña Blanca natural analogue was configured based on the physical description of the Nopal I mine site found in Pearcy et al. (1993 [151774]) and Goodell (1981 [149484]). The physical description of the site was supplemented with field observations by author Saulnier, with additional information provided by Dr. I. Reyes-Cortes during a site visit on June 28 to 29, 1999 (Saulnier 1999 [151776]).

The source term was assumed to be an ovoid cylinder of uranium oxide based on the dimensions exposed at the cleared +10-m and 0-m levels of the mine. The source was defined using a single source-term group in the Repository Integration Program and was approximated as a single waste package. This methodology was used to allow definition of a dissolution rate for the uranium-oxide ore. The source was available for dissolution from time zero, the time when the ore body was exposed at or near land surface at 3 Ma. Ambient temperature was assumed, and all the remaining parameters for fuel-dissolution rate calculation correspond to those used in the YMP performance-assessment model.

The radionuclide inventory described in Table C-2 was used as the initial waste-package inventory for the Peña Blanca model. Because of its short half-life, ^{99}Tc was further defined with an accumulation function (Curtis et al. 1999 [110987]) based on a steady-state inventory of ^{238}U, which has a half-life of 4.5×10^9 years. Using the assumed inventory, the dissolved mass from the ore deposit was mixed in two mixing cells, with the volume set equal to the physical volume of the uranium deposit (i.e., the ovoid cylinder), taking into account the porosity (Green and Rice 1995 [149485]). The total flow out of the mixing cell was set equal to the infiltration flux times the cross-sectional area of the deposit.

Table C-2. Radionuclide Inventory for Peña Blanca Repository Integration Program Simulations

Radionuclide Inventory for Repository Integration Program		
Radionuclide	Ci	Grams
^{238}U	137.360	4.080E+08
^{235}U	6.394	2.955E+06
^{234}U	144.228	23096.624
^{231}Pa	6.489	137.336
^{232}Th	0.640	5506.678
^{230}Th	113.677	5.806E+06
^{99}Tc	1.088E-05	6.406E-04

DTN: MO0009MWDPEN01.009 [153039]

The 70-m thick UZ was discretized into five mixing cells. The mass release from the source mixing cell (i.e., the ore deposit) was fed into the first UZ mixing cell at a rate equal to the infiltration flux times the cross-sectional area. In a manner similar to that used for the UZ, the 1,300 m of SZ was discretized into 10 mixing cells. The rate of mass flux in the SZ was set equal to the infiltration times the cross-sectional area, which was assumed to be the same as the ore body. The concentration out of the SZ mixing cell at the distance of interest was monitored and stored in the Repository Integration Program output file. Radionuclide concentrations were captured at 150, 600, and 1,300 m downgradient from the Nopal I ore body.

C.3.4 RESULTS

C.3.4.1 Simulations

The Peña Blanca performance-assessment-model simulations were conducted for the scenarios previously described. The model captured uranium and technetium concentrations at various distances from the mine. The data tracking number (DTN) for the results presented in Figures C-6 through C-12 is MO0009MWDPEN01.009 [153039]. The only calibration data consisted of concentrations of uranium reported for water samples collected at the Nopal I mining camp water supply well, as reported in Pickett and Murphy (1999 [110009]). Figure C-6 shows the results of the base-case simulations using the best estimates of site parameters and capture of the radionuclide concentrations at 1,300 m from the ore deposit, approximately the distance of the mining-camp water-supply well. The data show that the total concentration is dominated by ^{238}U, with lesser contributions from other uranium species. The concentration of ^{231}Pa peaks and falls off because of the limited inventory of this radionuclide, Section C.3.3.1, its short half life of 3.25×10^4 years, and the fact that RIP does not include a generation function for ^{231}Pa. The data from Pearcy et al. (1993 [151774]) and Pearcy (1994 [149523]) indicate that, at least laterally, the majority of the uranium released from the ore body has been reprecipitated on fractures in the welded tuff around the ore body. However, there are no rock-analysis data from beneath the ore body, and the fate of uranium in downward percolating water, such as modeled by the Repository Integration Program, cannot be corroborated by field data at this time.

Figures C-7 and C-8 show the concentrations captured at a distance of 150 m and 600 m from the ore body, respectively. These results also show that the relatively short half-life of ^{99}Tc

(2.13×10^5 yr.) means that ^{99}Tc rapidly decays producing only very low, and comparable, concentrations for the majority of the simulation time at the capture distances used in the Peña Blanca model. The data for these flowpaths indicate that uranium is still the dominant species in the water and that the peak concentrations of ^{99}Tc occurred within the first 50,000 years of the simulation. As reflected in Table C-2, the initial peak concentration assumes that there was an accumulated inventory in the ore body at the time it was first exposed to weathering and other degradation processes. Thus, there is an initial peak concentration in the model output because of flushing out the accumulated inventory, shown by a different symbol on Figures C-6 to C-8. However, this peak concentration quickly reduces to negligible at all distances because of the relatively short half-life of ^{99}Tc.

After the initial peak concentration, the concentration of ^{99}Tc is maintained by taking into account ^{99}Tc production from spontaneous fission of ^{238}U (Curtis et al. 1999 [110987]). Because of the long half-life of ^{238}U, the resulting ^{99}Tc concentrations did not noticeably increase or decrease for the remainder of the simulation period but remained at a relatively low concentration throughout the entire 1-million-year simulation period at all capture distances.

The results of the model at the 1,300-m distance, the only distance for which there are corroborating data, were investigated using sensitivity analysis for parameters of interest. Figure C-9 shows the sensitivity of the results to the sorption coefficient (K_d) of material in the UZ. In this simulation, a relatively large K_d value was assumed for uranium (1 m^3/kg), but the K_d for ^{99}Tc was assumed to be zero. The results indicate that the ^{238}U concentrations were significantly reduced, whereas the ^{99}Tc concentrations remained at constant low concentration.

Figure C-10 indicates that reducing the infiltration to 10 percent of the base-case value reduces the amount of uranium released by an order of magnitude but does not significantly affect the ^{99}Tc concentration. Figure C-11 shows that a reduction in uranium solubility by one order of magnitude reduces the uranium concentration, but the release of ^{99}Tc remains at similar levels to that shown for the base case (see Figure C-6). Alternatively, Figure C-12 shows that when the solubility is decreased by reducing the surface area of the inventory of leachable mineral species, both uranium and ^{99}Tc concentrations are reduced.

C.3.4.2 Comparison to the Yucca Mountain Performance Assessment Modeling

In comparing the Repository Integration Program analysis of the Nopal I uranium mine in the Peña Blanca mining district to the Repository Integration Program analysis of Yucca Mountain, as included in the TSPA-VA (DOE 1998 [100550], Volume 3), the following contrasts and similarities are noted:

- The potential Yucca Mountain nuclear-waste repository would contain 154 times more uranium than the Nopal I mine (Murphy and Codell 1999 [149529]).
- The time scale at Nopal I is on the order of 3 million years, as opposed to a prediction time of 1 million years for Yucca Mountain.
- The ^{99}Tc is assumed to be primarily produced naturally from uranium at Nopal I and primarily deposited as a waste inventory of reactor products at Yucca Mountain.

- The hydrogeologic configuration of the Nopal I mine is relatively simple. The ore body is exposed at land surface with an approximately 200 meter-thick UZ above the water table. The SZ at Yucca Mountain is mainly in volcanic rocks at comparable distance from the potential repository; whereas, at Nopal I the SZ is primarily in the Cretaceous limestone found in and beneath the Sierra Peña Blanca.

- There are no naturally radioactive deposits in the host rocks for the potential Yucca Mountain repository. Thus, radionuclide transport calculations through the tuffs below the potential repository horizon are, of necessity, reasoned approximations of what could occur in the event that waste was emplaced at the potential repository. At Nopal I, there is natural uranium that not only dissolves and migrates but also has the potential for the production and transport of conservative daughter products.

- The regional, surface-water-discharge location for the Nopal I ore deposit is approximately 10 km from the deposit versus an approximate 60-km travel distance at Yucca Mountain.

C.3.5 CONCLUSIONS

The Nopal I uranium-ore deposit at the Sierra Peña Blanca was modeled as a natural analogue of the potential Yucca Mountain nuclear-waste repository. The objective of the study was to estimate the potential for migration of uranium species and potential analyzable quantities of dissolved ^{99}Tc using the same modeling techniques used in performance-assessment modeling for the YMP.

The analysis indicates that picogram quantities of ^{99}Tc generated by spontaneous fission of ^{238}U may be detectable at 150, 600, and 1,300 m from the Nopal I ore deposit. In addition, uranium appears to be transported in limited quantities. However, released uranium is apparently exchanging with uranium minerals that precipitate in fractures around the ore deposit. Despite this precipitation, there is sufficient uranium available to be transported through the Cretaceous limestone of north-central Chihuahua State. The analysis indicates that a groundwater-sampling program could provide data with which to estimate realistic transport parameters for the Peña Blanca site. By analogy, these parameters may be a useful tool in estimating the performance assessment of the Yucca Mountain site.

The results at 1,300-m downgradient from the ore body show potential considerable uptake of uranium because of the K_d values used in the model. Given the potential uranium uptake, the results indicate that the estimated concentration of ^{99}Tc may be increased relative to the uranium concentration. However, the model results indicate that the ^{99}Tc concentration would still be a very low, but analyzable concentration (1.E-8 mg/L).

The model results indicate that uranium concentration at an observation point varies directly with the quantity of infiltration and the solubility of the ore body, whether or not the solubility increase is due either to the value for solubility used in the model or to an increase in surface area available for dissolution.

The low concentration of uranium at the mining-camp water-supply well is due either to uranium uptake in the vicinity of the ore deposit or to the location of the well relative to the regional flow direction. Because of the paucity of well data and other hydrogeologic data for the area, the estimated direction and gradient of groundwater flow is highly uncertain. The tentative conclusions developed as a result of the modeling previously described could be enhanced or modified with the implementation of the drilling program described in Section C.2.6. These recommendations were designed to help provide data with which to more accurately define the magnitude and direction of the groundwater gradient in the vicinity of the Nopal I mine. The proposed additional monitor wells are also needed to provide water-sampling locations that will be used to calibrate future performance-assessment modeling in the Peña Blanca area.

C.3.6 FUTURE FIELD INVESTIGATIONS

The results of the modeling indicate that a modest drilling-and-coring program at the Nopal I uranium mine could provide valuable data for use in calibrating the model used in this study to predict the flow and transport of radionuclides released from the Nopal I ore body. Because the Peña Blanca performance-assessment model uses the same methodology as used for Yucca Mountain performance-assessment modeling, calibration of the Peña Blanca model would provide considerable improvement in the confidence in YMP performance-assessment modeling efforts.

Figure C-13 shows a proposed borehole layout for a drilling-and-coring program designed to obtain field data to corroborate this Peña Blanca modeling analysis. The goal of the drilling program would be both to obtain core samples of the ore deposit and the rocks immediately below the ore deposit and to provide locations for obtaining water samples from the Cretaceous limestone, which is the host horizon for the regional groundwater flowing through this region. The key elements of the proposal are as follows:

- Drill a borehole completely through the Nopal I ore deposit and continue to the water table with continuous core-sample recovery.
- Drill boreholes at selected distances east and west of the ore body along the projected gradient of groundwater flow.
- Drill one borehole in an upgradient location to obtain background water-quality data to compare to that obtained in the vicinity of the ore deposit.
- Use a downhole pump to collect water samples for laboratory analysis from the corehole and from all drilled boreholes.
- Rehabilitate the mining camp water supply well to allow collection of water samples for laboratory analysis.
- Collect water samples from the Papalote ranch supply well to obtain laboratory analyses from a location midway between the ore deposit and the probable regional discharge location, the Playa Cuervo.

- Analyze all water samples for the common suite of ionic constituents so that a geochemical balance can be obtained. In addition, analyze the water samples for fluoride (a natural tracer), uranium isotopes, ^{99}Tc, and thorium isotopes.

- Use groundwater-speciation models to analyze the geochemistry and distribution of radioactive isotopes in the flowing groundwater beneath and in the vicinity of the Nopal I ore deposit.

C.4 GENERAL CONCLUSIONS REGARDING THE USE OF NATURAL ANALOGUES IN SUPPORT OF PERFORMANCE ASSESSMENT AT YUCCA MOUNTAIN

The performance-assessment-related investigations described in this Appendix complement the modeling and experimental studies, and literature review and analysis in *Yucca Mountain Site Description* (CRWMS M&O 2000 [137917]), *Natural Analogues for the Unsaturated Zone* (CRWMS 2000 [141407]), and Murrell et al. (1999 [130408]). Use of the ongoing research of natural analogues in future confirmation analyses and performance-assessment calculations will provide improved confidence in the potential Yucca Mountain repository concept. Specifically, as discussed in *Yucca Mountain Site Description* (CRWMS M&O 2000 [137917]), continued research in the following areas will continue to improve overall confidence:

- Uranium mobility in natural environments, especially in and near analogous ore deposits

- Performance of borosilicate glass in adverse environments

- Metallic-corrosion analysis, especially with respect to alloys specified in the potential repository design

- Mobility of transuranics such as those in natural and anthropogenic reactors

- Fluid-transport parameters in analogous saturated and unsaturated media

- Mobility of analogous colloids

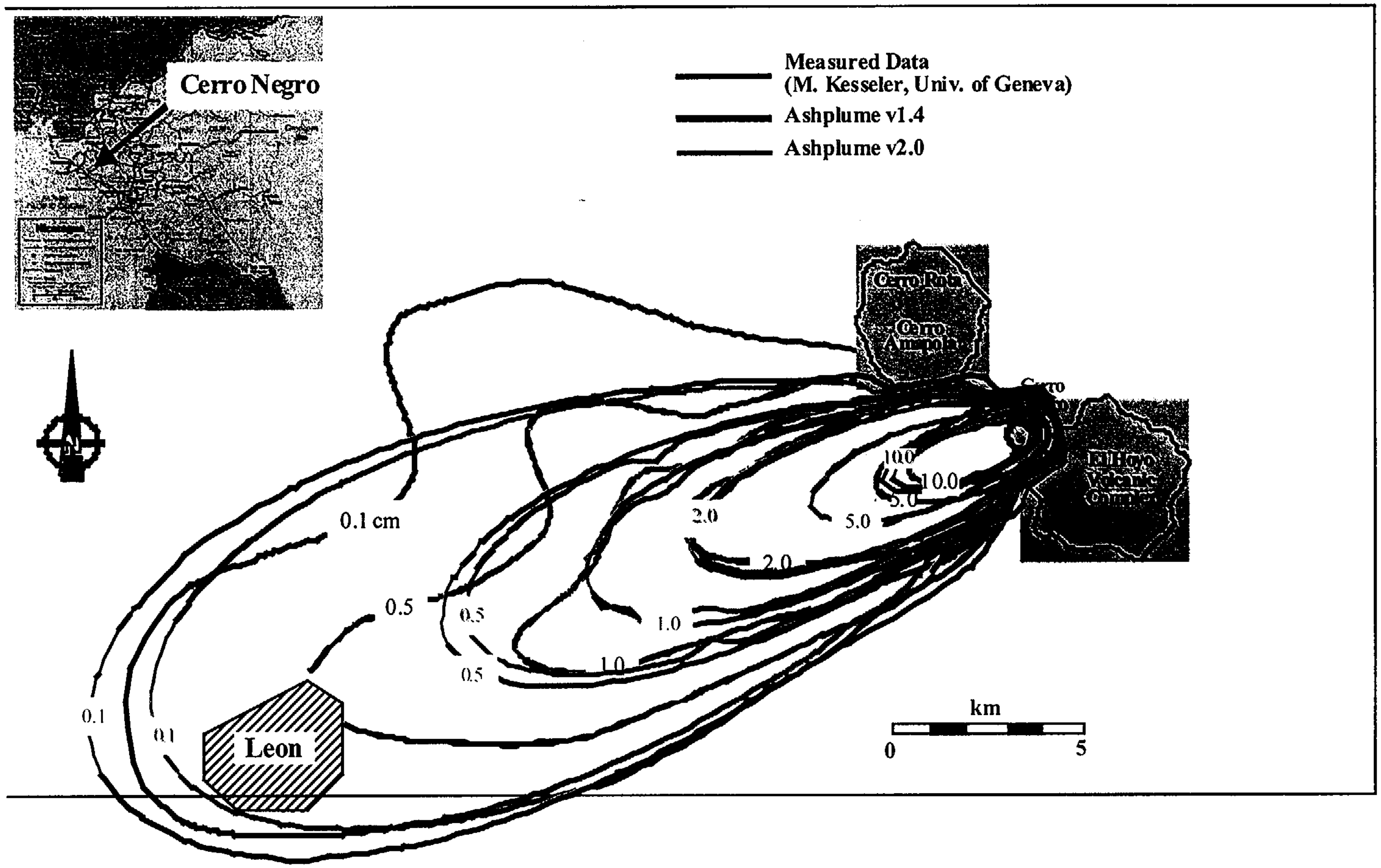
- Natural-retardation processes affecting mobile radionuclides expected to be released from the potential Yucca Mountain repository

- The role of fractures in enhancing or retarding flow and transport of radionuclides in environments analogous to the potential Yucca Mountain repository.

In addition to the investigations described in *Yucca Mountain Site Description* (CRWMS M&O 2000 [137917]) and *Natural Analogues for the Unsaturated Zone* (CRWMS M&O 2000 [141407]), this appendix has addressed specific performance-related analogues that were addressed using performance-assessment models. The location of Yucca Mountain is rather unique hydrogeologically and geographically. The most promising natural analogues are in those related to geologic processes. In particular, the investigations at the Cerro Negro volcano in Nicaragua and at the Nopal I uranium deposit at Peña Blanca near Chihuahua, Mexico. Using the field data from Cerro Negro, the performance-assessment group of the YMP developed a reasonable model representation of a 1995 volcanic event. This model is available to estimate the pattern of ash from a possible volcano at Yucca Mountain and can be simulated for credible scenarios using correlative parameters. Using the model, possible future volcanic events could be modeled as spreading ash downwind from Yucca Mountain, and the consequences of such an event could be analyzed to determine the potential effect on the repository and the surrounding environment.

Radionuclide transport by groundwater is the most likely offsite transport pathway that could possibly affect the performance of the potential Yucca Mountain repository. The Peña Blanca natural-analogue site offers a unique opportunity to examine the potential for groundwater flow and transport of uranium and some of its daughter products in a climatic and geologic setting very similar to that of Yucca Mountain. Both sites are set in volcanic tuff in an oxidizing UZ, and they are in similar desert environments. One major difference between the two sites is that the Yucca Mountain site has had considerably more site characterization of the geologic conditions beneath the site than has the Nopal I site. More detailed site characterization will be needed to more fully establish the utility of this site in comparison to Yucca Mountain.

The Nopal I mine is primarily composed of uraninite, which is essentially the same material as nuclear fuel, and the deposit can be analyzed using the metal-fuel dissolution model used in Yucca Mountain performance assessment. The performance-assessment department conducted scoping calculations for the Peña Blanca site using the same performance-assessment numerical model that was used to evaluate the performance of the potential Yucca Mountain repository. The model attempted to predict the transport of ^{99}Tc, an expected conservative ion that will be liberated from the waste packages to be placed in Yucca Mountain. The results of the model indicate that both ^{99}Tc and some forms of uranium may be detected in groundwater close to the Nopal I mine. Therefore, verification of Peña Blanca as a useful natural analogue will depend on the implementation of a field campaign to collect rock and water samples to corroborate the model results and for a more complete comparison to possible future conditions at Yucca Mountain. These recommended studies will complement those mineralogic and geochemical investigations recommended in *Natural Analogues for the Unsaturated Zone* (CRWMS M&O 2000 [141407]).



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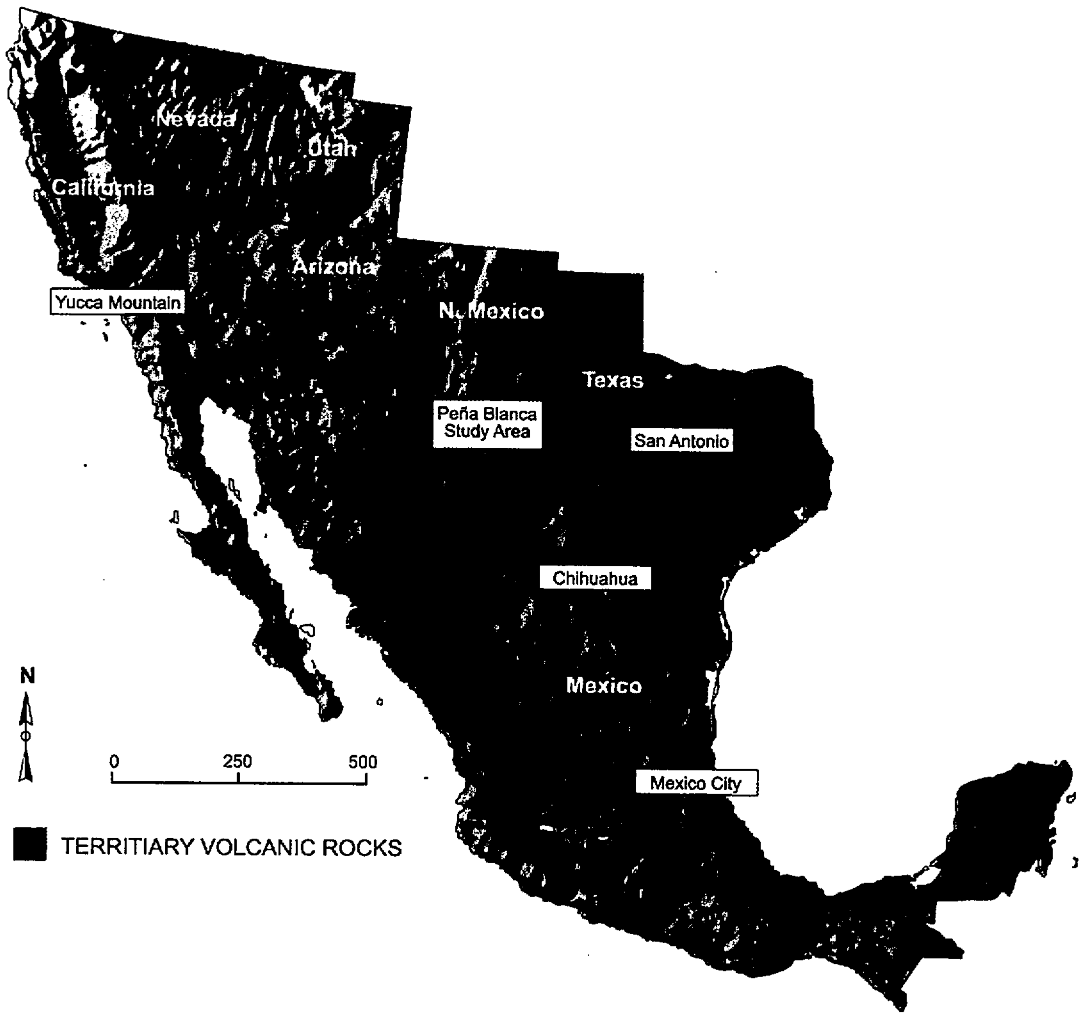
NOTE: Legibility of index map in upper left doesn't detract from the results shown in figure.

Figure C-1. Comparison of the Measured and Calculated Ash-Deposit Thickness for the 1995 Cerro Negro, Nicaragua, Eruption



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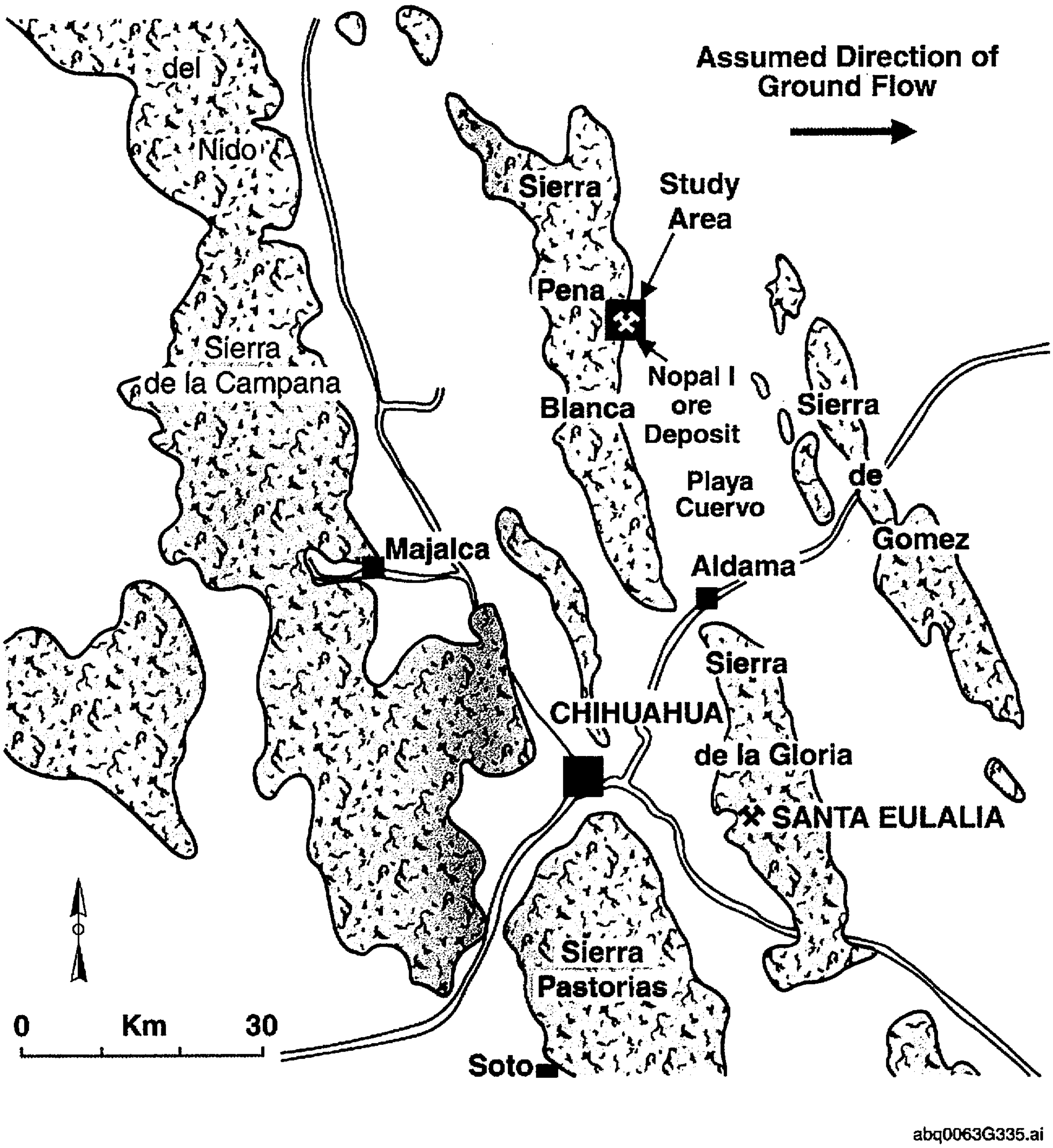
Source: Pearcy 1994 [149523], p.1-2

Figure C-2. Location of the Sierra Peña Blanca in Northern Mexico



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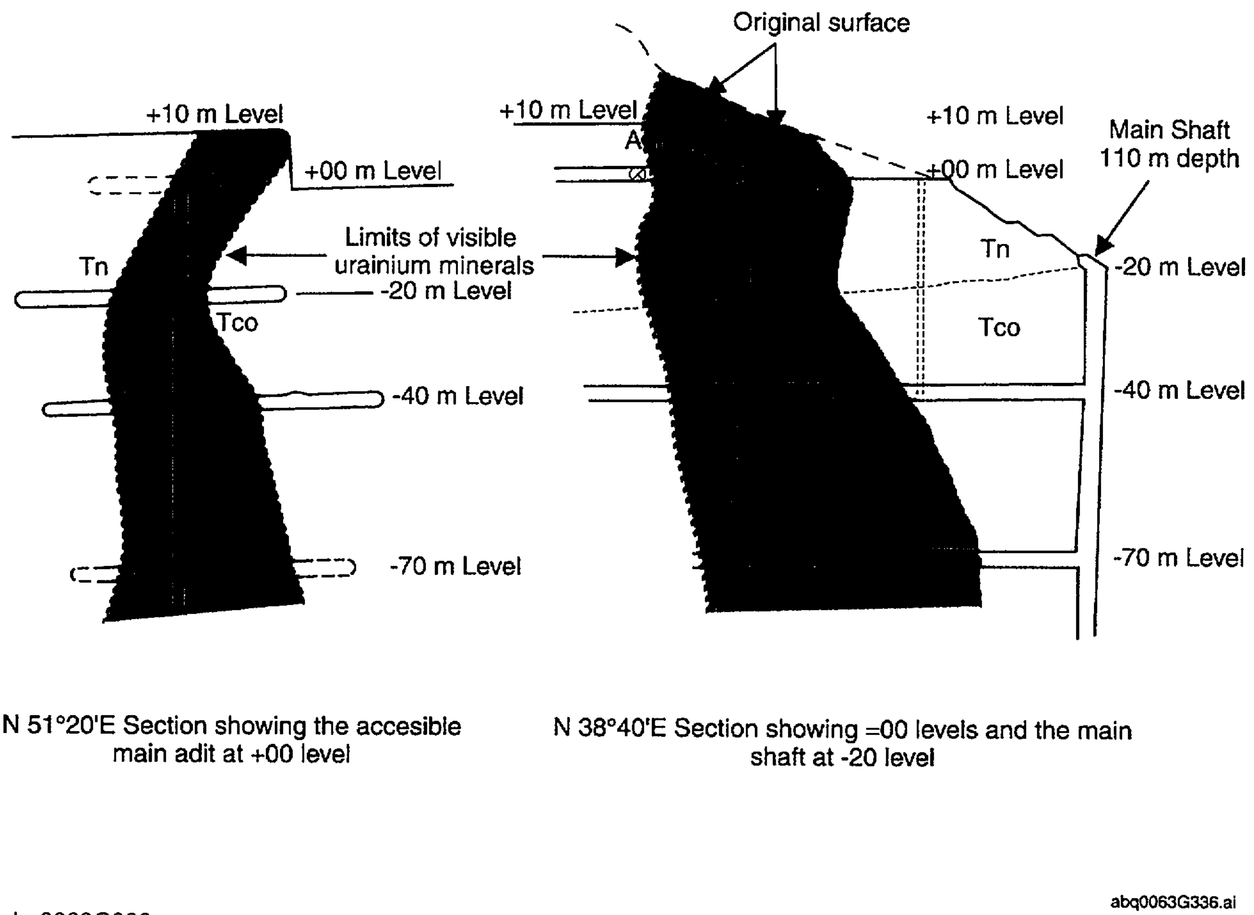
Source: Modified from George-Aniel et al. 1991 [105636]

Figure C-3. Location of the Nopal I Ore Deposit Relative to Chihuahua City



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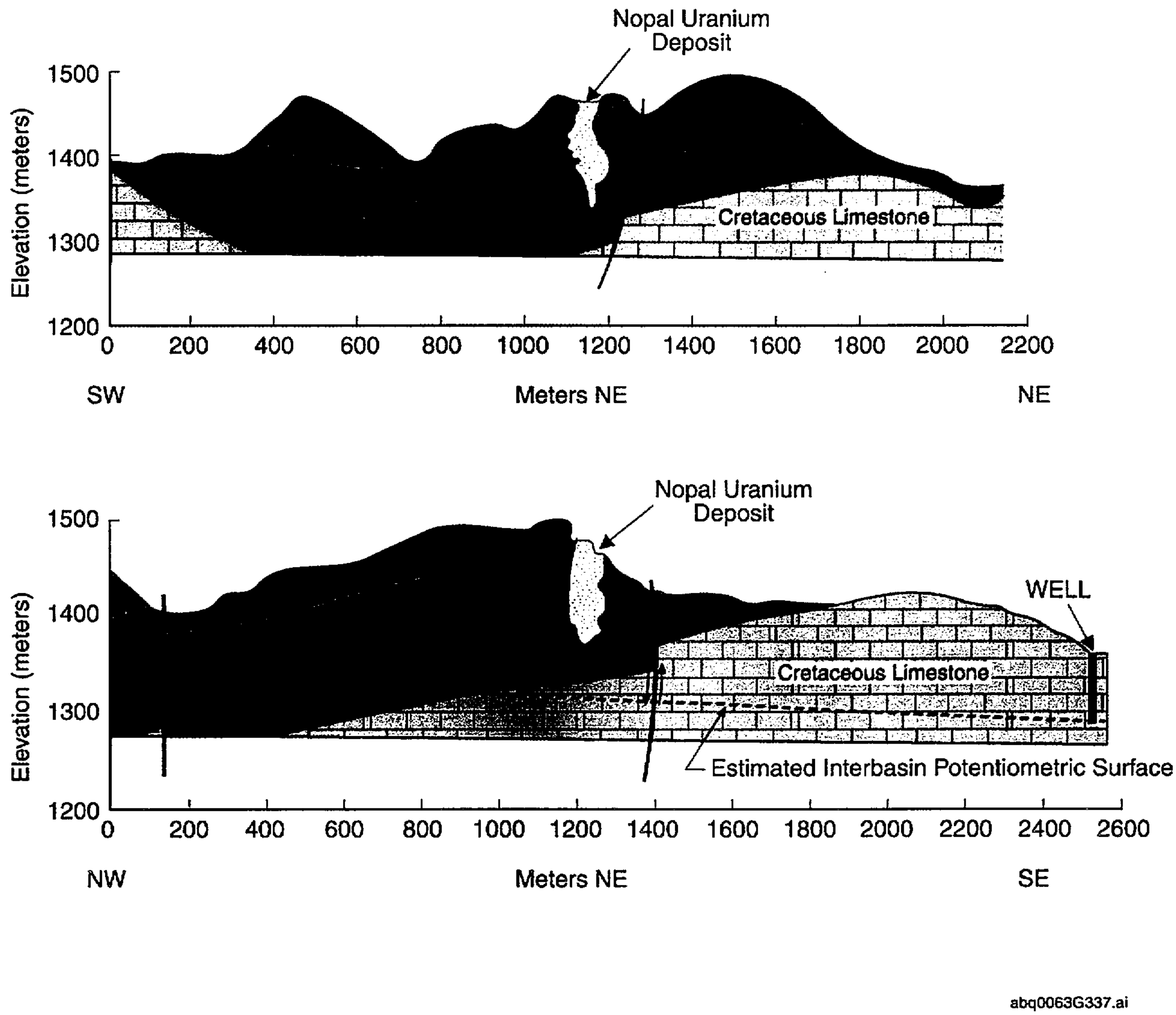
Source: Reyes-Cortez 1997 [149533], p. 205

Figure C-4. Cross-Sectional Views of the Nopal I Uranium Mine Showing the Shafts and Adits



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Source: Pearcy et al. 1993 [151774], p. 1-4

Figure C-5. Hydrogeology of the Nopal I Ore Deposit at Peña Blanca

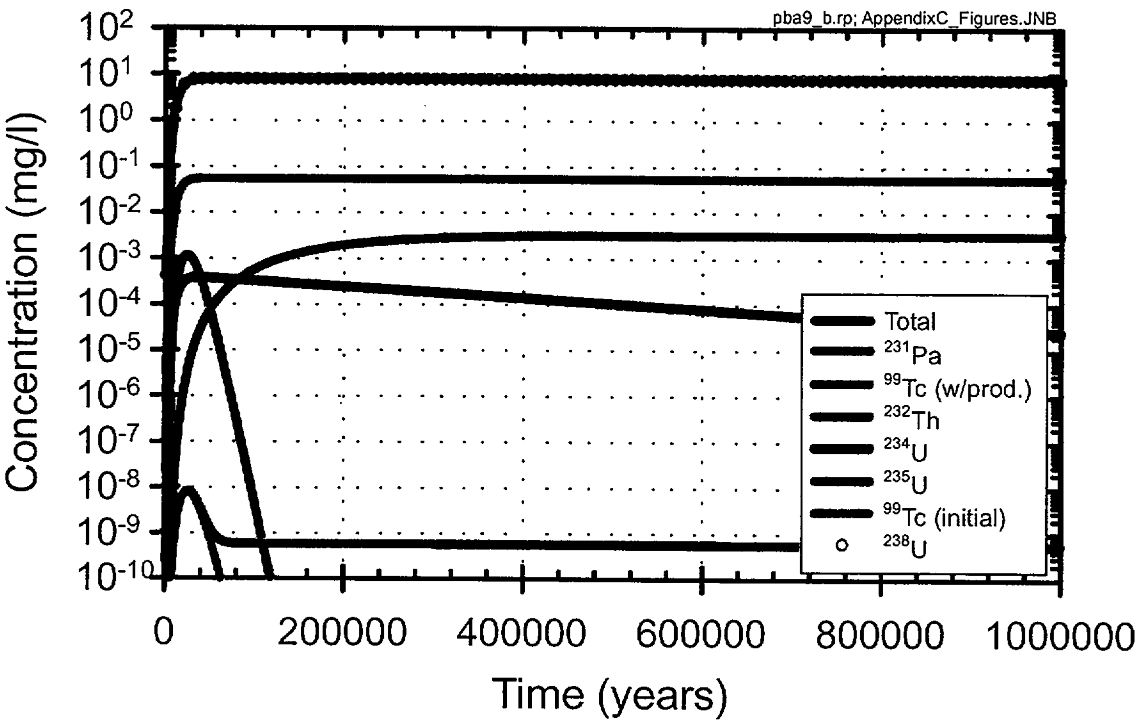

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Figure C-6. Radionuclide Concentrations 1,300 m Downgradient from the Nopal I Ore Deposit Using Constant ^{99}Tc and ^{238}U Production

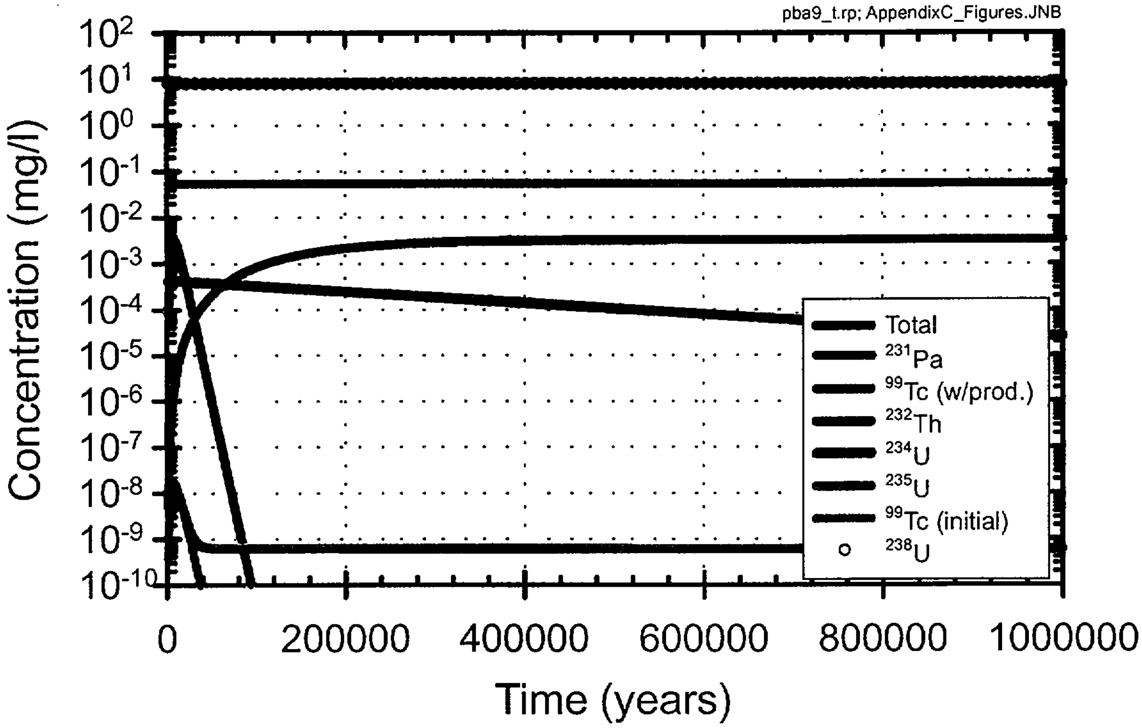

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Figure C-7. Radionuclide Concentrations 600 m Downgradient from the Nopal I Ore Deposit Using Constant ^{99}Tc and ^{238}U Production

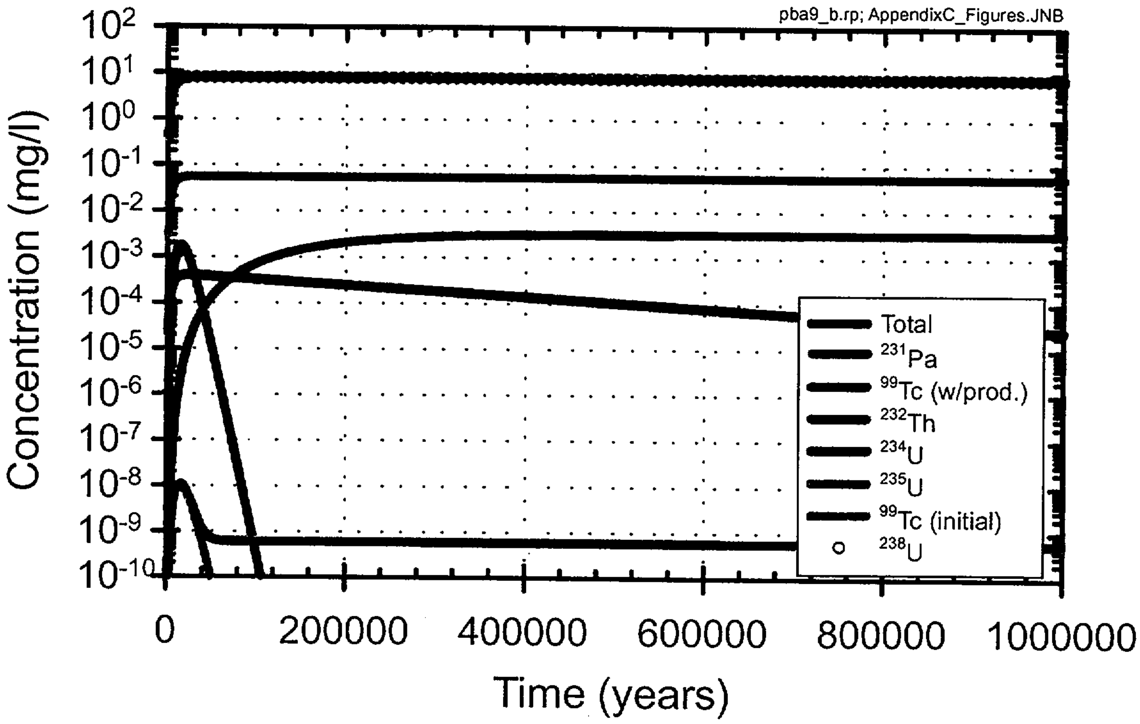

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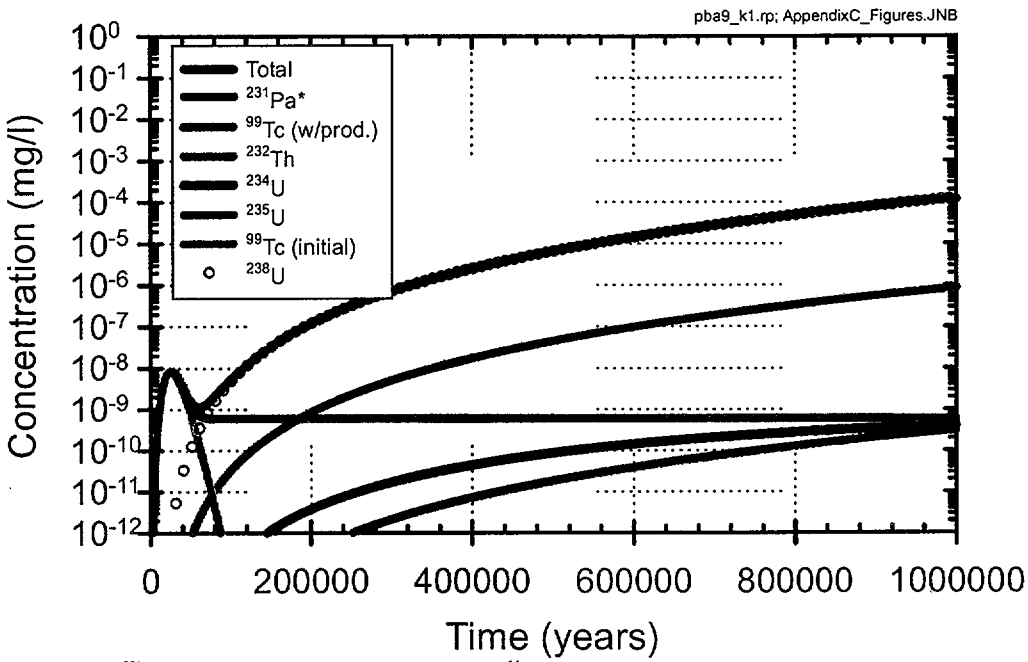
Figure C-8. Radionuclide Concentrations 150 m Downgradient from the Nopal I Ore Deposit Using Constant ^{99}Tc and ^{238}U Production



* The concentration of ^{231}Pa was calculated. The calculated values (<10^{-14} mg/l) are below the y-axis minimum and do not appear on this plot.

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Figure C-9. Radionuclide Concentrations 1,300 m Downgradient from the Nopal I Ore Deposit Using Constant ^{99}Tc and ^{238}U Production and Showing Sensitivity to K_d

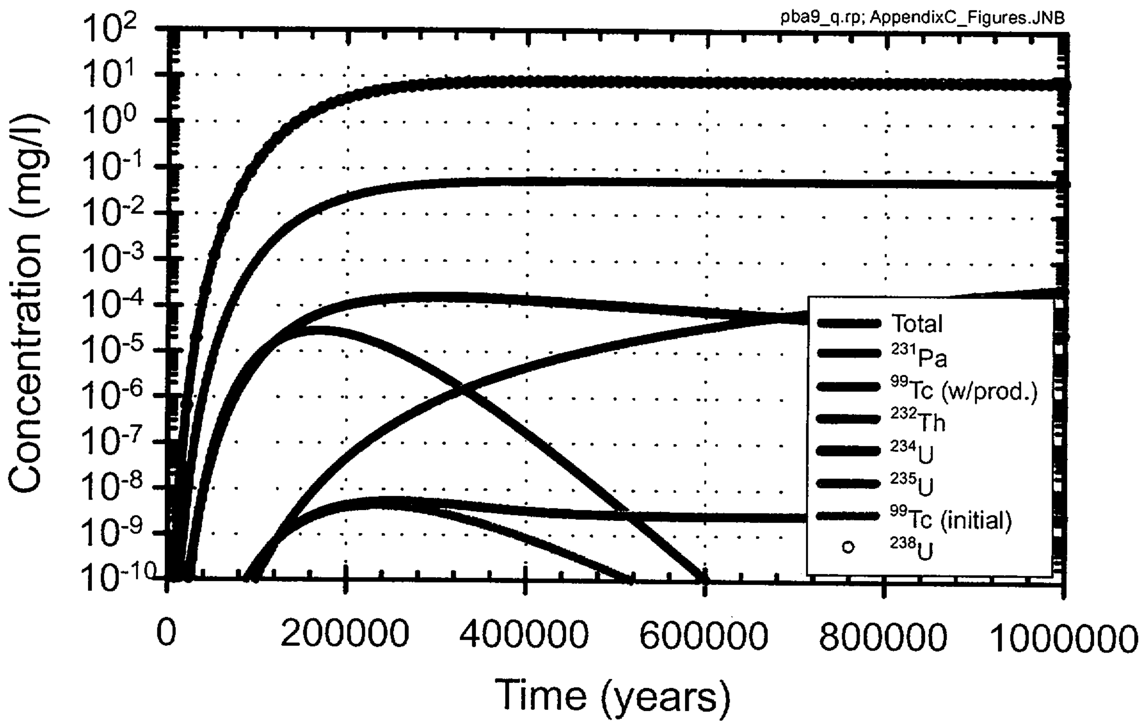

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Figure C-10. Radionuclide Concentrations 1,300 m Downgradient from the Nopal I Ore Deposit Using Constant ^{99}Tc and ^{238}U Production and Showing Sensitivity to Infiltration

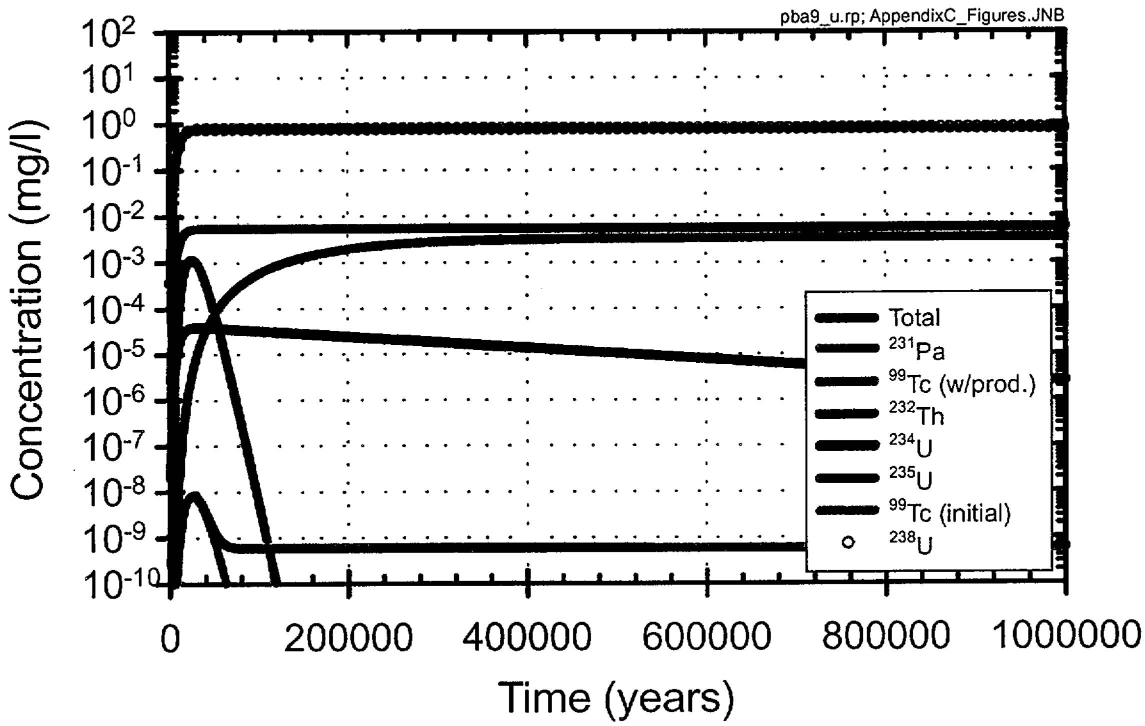

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Figure C-11. Radionuclide Concentrations 1,300 m Downgradient from the Nopal I Ore Deposit Using Constant ^{99}Tc and ^{238}U Production and Showing Sensitivity to Uranium Solubility

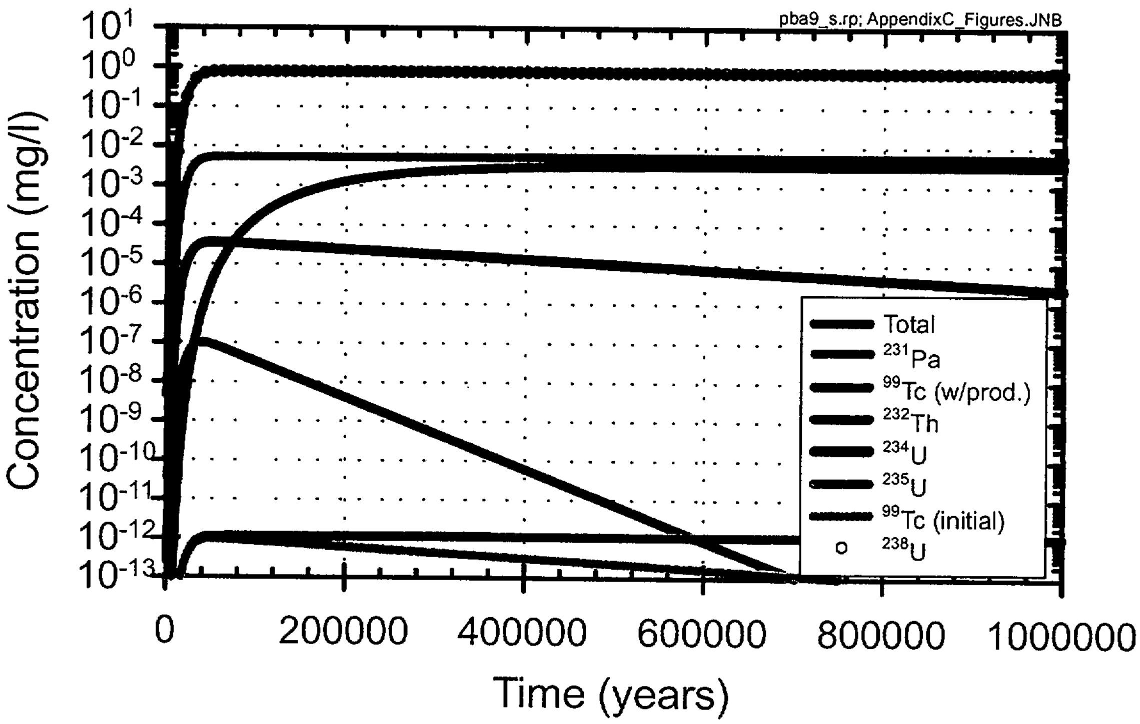

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Figure C-12. Radionuclide Concentrations 1,300 m Downgradient from the Nopal I Ore Deposit Using Constant ^{99}Tc and ^{238}U Production and Showing Sensitivity to Surface Area of the Source Term

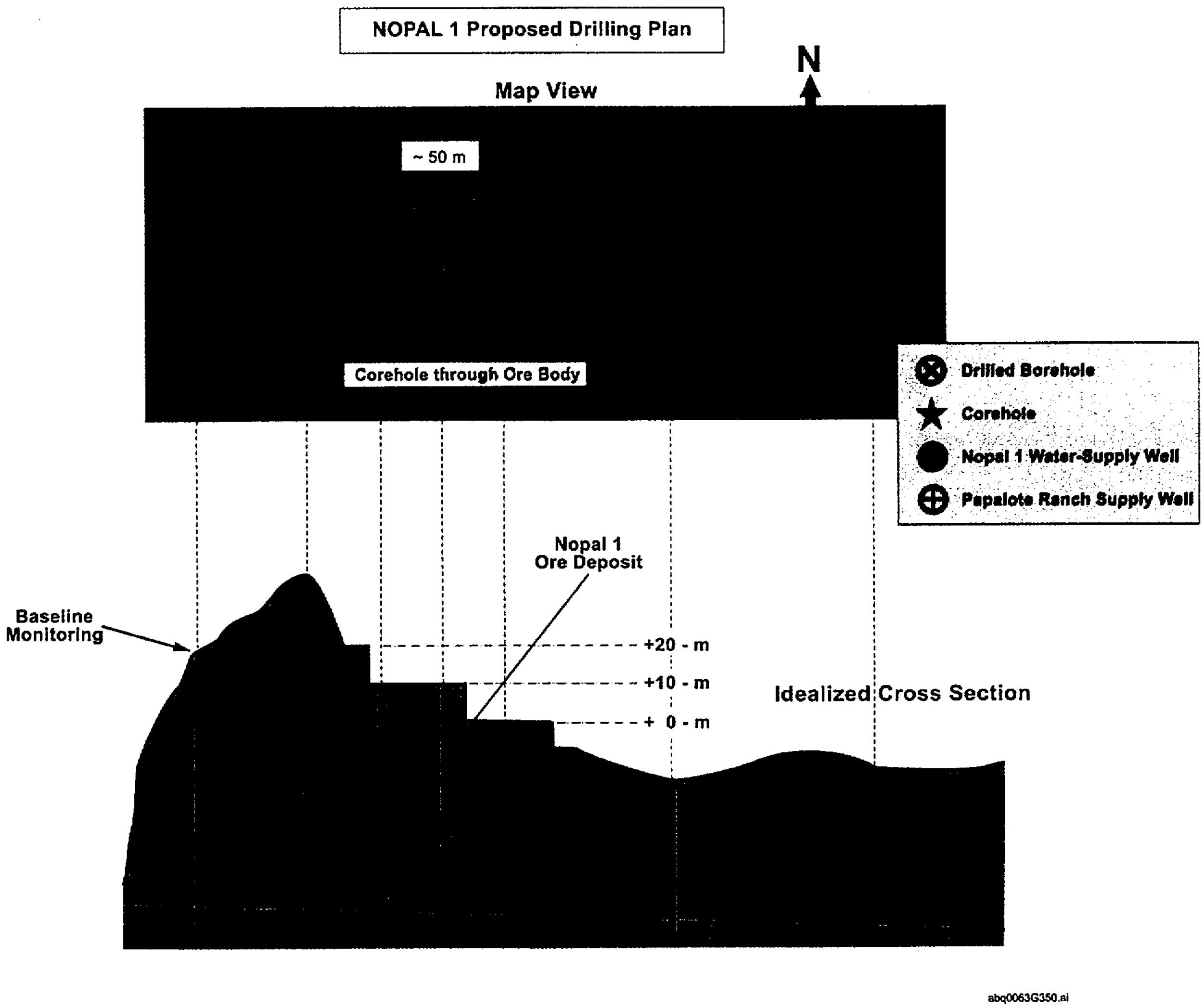

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Figure C-13. Proposed Drilling Plan for Further Study at Nopal I

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APPENDIX D

ISSUE RESOLUTION STATUS REPORTS TRACKING DATABASE

APPENDIX D

ACRONYMS AND ABBREVIATIONS

AMR	Analysis Model Report
BDCF	biosphere dose conversion factor
BIO	biosphere
CLST	container life and source term
DE	disruptive event
DOE	U.S. Department of Energy
EBS	engineered barrier system
ENFE	Evolution of the Near-Field Environment
FEP	feature, event, and process
HLW	high-level radioactive waste
IA	Igneous Activity
IRSR	Issue Resolution Status Report
ISIs	integrated subissues
KTI	key technical issue
NFE	near-field environment
NRC	U.S. Nuclear Regulatory Commission
PMR	Process Model Report
QARD	Quality Assurance Requirements and Description
RDTME	Repository Design and Thermal Mechanical Effects
RSS4	Repository Safety Strategy 4
RT	Radionuclide Transport
SDS	Structural Deformation and Seismicity
SNF	spent nuclear fuel
SZ	saturated zone
SZFT	saturated zone flow and transport
TEF	Thermal Effects on Flow
TSPA	total system performance assessment
TSPA&I	Total System Performance Assessment and Integration
TSPA-SR	Total System Performance Assessment-Site Recommendation

APPENDIX D

ACRONYMS AND ABBREVIATIONS (Continued)

USFUIC	UZ and SZ Flow Under Isothermal Conditions
UZ	unsaturated zone
UZFT	unsaturated zone flow and transport
WFD	waste form degradation
WPD	waste package degradation

APPENDIX D

ISSUE RESOLUTION STATUS REPORTS TRACKING DATABASE

The Issue Resolution Status Reports (IRSR) Tracking Database is designed to track how U.S. Nuclear Regulatory Commission (NRC) subissues within the Key Technical Issues (KTIs) have been addressed by total system performance assessment (TSPA).

D.1 ELEMENTS OF ISSUE RESOLUTION STATUS REPORTS TRACKING DATABASE

D.1.1 ISSUE RESOLUTION STATUS REPORTS

The NRC strategic plan calls for the early identification and resolution, at the staff level, of issues before the receipt of a potential license application to construct a geologic repository. The NRC's high-level radioactive waste (HLW) program has focused prelicensing work on those topics most critical to the postclosure performance of the potential geologic repository; these topics are called KTIs. An important step in the staff's approach to issue resolution is to provide the U.S. Department of Energy (DOE) with feedback regarding issue resolution before the forthcoming Site Recommendation and License Application. IRSRs are the primary mechanism that the NRC staff will use to provide DOE with feedback on KTI subissues. IRSRs focus on issue resolution and the status of resolution, including areas of agreement or when the staff has comments or questions.

D.1.1.1 Key Technical Issues and Subissues

The NRC has identified 10 KTIs. Nine of these issues comprise technical questions; the tenth is a nontechnical issue related to development of the U.S. Environmental Protection Agency standard. Each KTI is subdivided into a number of subissues (Table D.1-1). The KTIs are:

- Container Life and Source Term (CLST)
- Evolution of the Near-Field Environment (ENFE)
- Igneous Activity (IA)
- Radionuclide Transport (RT)
- Repository Design and Thermal Mechanical Effects (RDTME)
- Structural Deformation and Seismicity (SDS)
- Thermal Effects on Flow (TEF)
- Total System Performance Assessment and Integration (TSPA&I)
- UZ and SZ Flow Under Isothermal Conditions (USFUIC)
- Activities Related to Development of the U.S. Environment Protection Agency Standard.

Table D.1-1. Subissues in U.S. Nuclear Regulatory Commission Key Technical Issues

KTI	Subissue Identifier	Subissue
Unsaturated and Saturated Flow under Isothermal Conditions (USFIC)	USFIC1	Climate change
	USFIC2	Hydrologic effects of climate change
	USFIC3	Present-day shallow infiltration
	USFIC4	Deep percolation (present and future)
	USFIC5	Saturated zone ambient flow conditions and dilution processes
	USFIC6	Matrix diffusion
Thermal Effects on Flow (TEF)	TEF1	Sufficiency of thermal-hydrologic testing program to assess thermal reflux in the near field
	TEF2	Sufficiency of thermal-hydrologic modeling to predict the nature and bounds of thermal effects on flow in the near field
	TEF3	Adequacy of TSPA with respect to thermal effects on flow
Evolution of the Near-Field Environment (ENFE)	ENFE1	Effects of coupled thermal-hydrologic-chemical processes on seepage and flow
	ENFE2	Effects of coupled thermal-hydrologic-chemical processes on WP chemical environment
	ENFE3	Effects of coupled thermal-hydrologic-chemical processes on chemical environment for radionuclide release
	ENFE4	Effects of thermal-hydrologic-chemical processes on radionuclide transport (RT) through engineered and natural barriers
	ENFE5	Coupled thermal-hydrologic-chemical processes affecting potential nuclear criticality in the near field
Container Life and Source Term (CLST)	CLST1	The effects of corrosion processes on the lifetime of the containers
	CLST2	The effects of phase instability and initial defects on the mechanical failure and lifetime of the containers
	CLST3	The rate at which radionuclides in spent nuclear fuel are released from the engineered barrier subsystem through the oxidation and dissolution of spent fuel
	CLST4	The rate at which radionuclides in high-level waste (HLW) glass are released from the engineered barrier subsystem
	CLST5	The effects of in-package criticality on waste package and engineered barrier subsystem performance
	CLST6	The effects of alternate engineered barrier subsystem design features on container lifetime and radionuclide release from the engineered barrier subsystem
Radionuclide Transport (RT)	RT1	RT through porous rock
	RT2	RT through alluvium
	RT3	RT through fractured rock
	RT4	Nuclear criticality in the far field
Total System Performance Assessment and Integration (TSPAI)	TSPAI1	System description and demonstration of multiple barrier
	TSPAI2	Scenario analysis within the TSPA methodology
	TSPAI3	Model abstraction within the TSPA methodology
	TSPAI4	Demonstration of the overall performance objective
Igneous Activity (IA)	IA1	Probability of future igneous activity
	IA2	Consequences of igneous activity within the repository setting

Table D.1-1. Subissues in U.S. Nuclear Regulatory Commission Key Technical Issues (Continued)

KTI	Subissue Identifier	Subissue
Structural Deformation and Seismicity (SDS)	SDS1	Faulting
	SDS2	Seismicity
	SDS3	Fracturing and structural framework of the geologic setting
	SDS4	Tectonic framework of the geologic setting
Repository Design and Thermal-Mechanical Effects (RDTME)	RDTME1	Implementation of an effective design control process within the overall quality assurance program
	RDTME2	Design of the geologic repository operations area for the effects of seismic events and direct fault disruption
	RDTME3	Thermal-mechanical effects on underground facility design and performance
	RDTME4	Design and long-term contribution of repository seals in meeting post-closure performance objectives

Source: NRC 2000 [149372], Appendix B

D.1.1.2 Subsystems and Integrated Subissues

As stated in the TSPA&I IRSR Rev 2 (NRC 2000 [149372]), the NRC has been developing a systematic approach to reviewing DOE's TSPAs. The approach currently undertaken by the NRC staff is hierarchical, as illustrated in TSPA&I IRSR, Rev 2 (NRC 2000 [149372], Figure 3, p. 146). As shown in said figure, there are three repository subsystems: engineered system, geosphere, and biosphere. Each of these subsystems is further subdivided into discrete components of the respective subsystems: engineered barriers that make up the engineered system; unsaturated zone flow and transport, saturated zone flow and transport, and direct release to the geosphere; and the dose calculation for the biosphere. At the base of the hierarchy are the 14 integrated subissues (ISIs) of the repository system that need to be appropriately abstracted into a TSPA. The relationship between these ISIs and the NRC KTIs is illustrated in Table D.1-2.

D.1.2 TOTAL SYSTEM PERFORMANCE ASSESSMENT

D.1.2.1 Process Model Reports and Analysis Model Report

Nine Process Model Reports (PMRs) have been developed to summarize the technical basis for each of the process models supporting the TSPA model that will be used to evaluate the postclosure performance of a potential repository at Yucca Mountain. Details of these individual models are documented in supporting Analysis Model Reports (AMRs). These Process Model Reports cover the following areas:

- *Integrated Site Model Process Model Report* (CRWMS M&O 2000 [146988])
- *Unsaturated Zone Flow and Transport Model Process Model Report* (CRWMS M&O 2000 [145774])
- *Near Field Environment Process Model Report* (CRWMS M&O 2000 [146589])

Table D.1-2. Integrated Subissues Relationships to Key Technical Issues

KTI * Subissue	Integrated Subissue													
	ENG1	ENG2	ENG3	ENG4	UZ1	UZ2	UZ3	SZ1	SZ2	Direct1	Direct2	Dose1	Dose2	Dose3
USFIC1					■									■
USFIC2								■						■
USFIC3					■									■
USFIC4			■		■	■	■							
USFIC5								■	■			■		■
USFIC6							■	■	■					
TEF1	■		■		■	■								
TEF2	■		■		■	■								
TEF3														
ENFE1			■		■	■								
ENFE2	■		■											
ENFE3			■	■										
ENFE4				■			■							
ENFE5				■										
CLST1	■	■	■							■				
CLST2	■	■								■				
CLST3			■	■										
CLST4			■	■										
CLST5		■		■										
CLST6	■	■	■	■										
RT1							■		■					
RT2									■					
RT3							■		■					■
RT4							■		■					
TSPAI1														
TSPAI2														

Table D.1-2. Integrated Subissues Relationships to Key Technical Issues (Continued)

TSPAI3														
TSPAI4														
IA1										X				
IA2		X								X	X		X	X
SDS1		X						X		X				
SDS2		X			X									
SDS3		X	X		X	X	X	X	X					
SDS4		X								X				
RDTME1														
RDTME2		X												
RDTME3	X	X	X		X									
RDTME4														

ENG1 ENG - Degradation of Engineered Barriers
ENG2 ENG - Mechanical Disruption of Engineered Barriers
ENG3 ENG - Quantity and Chemistry of Water Contacting the Waste Packages and Waste Forms
ENG4 ENG - Radionuclide Release Rates and Solubility Limits
UZ1 GEO - Spatial and Temporal Distribution of Flow
UZ2 GEO - Flow Paths in the UZ
UZ3 GEO - RT in the UZ
SZ1 GEO - Flow Paths in the SZ
SZ2 GEO - RT in the SZ
Direct1 GEO - Volcanic Disruption of Waste Packages
Direct2 GEO - Airborne Transport of Radionuclides
Dose1 BIO - Dilution of Radionuclides in Groundwater
Dose2 BIO - Redistribution of Radionuclides in Soil
Dose3 BIO - Lifestyle of the Critical Group

Source: TSPA&I IRSR REV. 2 (NRC 2000 [149372])

- *Engineered Barrier System Degradation, Flow, and Transport Process Model Report* (CRWMS M&O 2000 [145796])
- *Waste Package Degradation Process Model Report* (CRWMS M&O 2000 [138396])
- *Waste Form Degradation Process Model Report* (CRWMS M&O 2000 [138332])
- *Saturated Zone Flow and Transport Process Model Report* (CRWMS M&O 2000 [145738])
- *Biosphere Process Model Report* (CRWMS M&O 2000 [151615])
- *Disruptive Events Process Model Report* (CRWMS M&O 2000 [141733]).

D.1.2.2 Process Model Factors

A set of 26 process model factors for the nominal scenario was identified as described in the Repository Safety Strategy 4 (RSS4). Table D.1-3 lists the set of process model factors and PMRs.

Table D.1-3. Process Model Factors and Related Key Technical Issues Subissues

PMR	Process Model Factor for the Nominal Scenario	Related KTI Subissues
UZ Flow and Transport Model (CRWMS M&O 2000 [145774]	Climate	USFIC1, USFIC2, TSPAI1, TSPAI2, TSPAI3
	Net Infiltration	USFIC3, TSPAI1, TSPAI2, TSPAI3
	UZ Flow	SDS3, TSPAI1, TSPAI2, TSPAI3
	Coupled Effects on UZ Flow	ENFE1, ENFE4, RT1, RT3, TEF2, TEF3, TSPAI1, TSPAI2, TSPAI3
	Seepage into Emplacement Drifts	USFIC4, TSPAI1, TSPAI2, TSPAI3
	Coupled Effects on Seepage	USFIC6, TSPAI1, TSPAI2, TSPAI3
SZ Flow and Transport (CRWMS M&O 2000 [145738]	SZ Flow	SDS3, USFIC2, USFIC5, TSPAI1, TSPAI2, TSPAI3
	Changes to SZ Flow	TSPAI1, TSPAI2, TSPAI3
	SZ RT	RT2, RT3, RT4, USFIC6, TSPAI1, TSPAI2, TSPAI3
Disruptive Events (CRWMS M&O 2000 [141733])	Seismic Activity	SDS1, SDS2, CLST2, CLST6, TSPAI1, TSPAI2, TSPAI3
	Igneous Activity	IA1, IA2, SDS4, CLST2, CLST6, TSPAI1, TSPAI2, TSPAI3
	Inadvertent Human Intrusion	CLST2, CLST6, TSPAI1, TSPAI2, TSPAI3
Biosphere (CRWMS M&O 2000 [151615]	Biosphere Dose Conversion Factors	IA2, TSPAI1, TSPAI2, TSPAI3

Table D.1-3. Process Model Factors and Related Key Technical Issues Subissues (Continued)

PMR	Process Model Factor for the Nominal Scenario	Related KTI Subissues
Engineered Barrier System (CRWMS M&O 2000 [145796])	In-Drift Physical and Chemical Environment	CLST3, CLST6, ENFE2, ENFE3, ENFE4, RDTME3, TEF1, TEF2, TEF3, TSPAI1, TSPAI2, TSPAI3
	In-Drift Moisture Distribution	CLST1, CLST4, ENFE1, TSPAI1, TSPAI2, TSPAI3
Waste Form (CRWMS M&O 2000 [138332])	Cladding Degradation and Performance	TSPAI1, TSPAI2, TSPAI3
	Colloid-Associated Radionuclide Concentrations	TSPAI1, TSPAI2, TSPAI3
	Commercial Spent Nuclear Fuel Degradation and Performance	CLST3, TSPAI1, TSPAI2, TSPAI3
	Defense High-Level Radioactive Waste Degradation and Performance	CLST4, TSPAI1, TSPAI2, TSPAI3
	Dissolved Radionuclide Concentrations	TSPAI1, TSPAI2, TSPAI3
	DOE-Owned Spent Nuclear Fuel Degradation and Performance	TSPAI1, TSPAI2, TSPAI3
	In-Package Environments	ENFE3, TSPAI1, TSPAI2, TSPAI3
	Radionuclide Inventory and Distribution	TSPAI1, TSPAI2, TSPAI3
Waste Package (CRWMS M&O 2000 [138396])	Waste Package Degradation and Performance	CLST1, CLST2, CLST6, TSPAI1, TSPAI2, TSPAI3
	Drip Shield Degradation and Performance	TSPAI1, TSPAI2, TSPAI3
Near Field Environments (CRWMS M&O 2000 [146589])	Coupled Effects on UZ Flow	ENFE4, RDTME3, TEF1, TSPAI1, TSPAI2, TSPAI3
	Coupled Effects on Seepage	ENFE1, ENFE2, TEF1, TEF2, TSPAI1, TSPAI2, TSPAI3
	Coupled Effects on UZ RT	ENFE4, TEF1, TSPAI1, TSPAI2, TSPAI3

D.1.2.3 Addressing Key Technical Issues Subissues

Guidance for the NRC review of the TSPA is contained in the TSPA&I IRSR (NRC 2000 [149372]). The TSPA&I IRSR describes an acceptable methodology for assessing repository performance and for using these assessments to demonstrate compliance with the overall performance objective and requirements for multiple barriers. The TSPA&I IRSR subissues are integrated into the nine PMRs described in Section D.1.2.1. Table D.1-4 lists all TSPA&I IRSR subissues, lists documentation related to the TSPA&I IRSR acceptance criteria, and provides a brief summary of the approach to resolve the TSPA&I IRSR acceptance criteria.

Each PMR discusses how analyses and calculations address relevant KTI subissues. The detailed discussions are included in Chapter 4, Relationship to NRC Issue Resolution Status Reports, of each PMR. A crosswalk of KTI subissues to PMRs is provided in Table D.1-5. These subissues are also mapped to applicable process model factors as shown in Table D.1-3.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
SUBISSUE 1 - System Description and Demonstration of Multiple Barriers		
Transparency and Traceability of the Analysis		
TSPA Documentation Style, Structure, and Organization		
T1) Documents and reports are complete, clear, and consistent.	TSPA-SR Technical Report, all PMRs, all AMRs	The TSPA-SR Technical Report, PMRs, and AMRs were carefully structured to be complete, clear, and consistent. Section 1 of the TSPA-SR Technical Report explains in detail what total performance assessment is and why it is applicable to repository development. Section 2 describes the specific way in which the general performance assessment approach was adopted for the total system performance assessment for the site recommendation. It also describes the traceability of the information used in the model. Reviews of the TSPA-SR Technical Report, PMRs, and AMRs included checks for completeness, clarity and consistency.
T2) Information is amply cross referenced.	TSPA-SR Technical Report, all PMRs, all AMRs	The TSPA-SR Technical Report, PMRs, and AMRs contain ample references to data sources, codes, assumptions, and conclusions. Extensive use is made of charts and tables to ensure that the total system performance assessment process is easy to visualize. Tables describe the relationship between documents to enhance understanding and traceability.
Features, Events, and Processes Identification and Screening		
T1) The screening process by which FEPs were included or excluded from the TSPA is fully described.	TSPA-SR Technical Report Section 2.1.1, Appendix B	Guidelines were established to ensure that the screening basis and content for each primary FEP was sufficient to satisfy the screening criteria. Section 2.1.1 of the TSPA-SR Technical Report describes the implementation of the features, events, and processes approach including screening of FEPs. It describes how each of the primary FEPs was screened for inclusion or exclusion in the TSPA based on three criteria. The criteria, described in detail in Section B.4 of Appendix B, are regulatory, probability and consequence. The screening results and rationale for the decisions is documented in the FEP AMRs.
T2) Relationships between relevant FEPs are fully described.	TSPA-SR Technical Report Section 2.1.1, FEP AMRs	The TSPA-SR Technical Report includes tables of included FEPs for each TSPA-SR component. If an included FEP affects more than one component it is listed under each relevant component. Also included is a description of the conceptual model based on included FEPs and a description of the TSPA implementation of the conceptual model based on the included FEPs. Section 2.1.1 of the TSPA-SR Technical Report describes the relationship between primary and secondary FEPs. The FEP AMRs provide additional documentation including the TSPA disposition of FEPs, IRSR issues relevant to specific FEPs, and analysis and discussion on specific FEPs.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
Abstraction Methodology		
T1) The levels and method(s) of abstraction are described starting from assumptions defining the scope of the assessment down to assumptions concerning specific processes and the validity of given data.	TSPA-SR Technical Report Section 2 and 3, all PMRs	For each model described in the PMRs, descriptions are provided of process models and, if the models are abstracted, descriptions of the abstractions of the models. The description includes a summary of data and assumptions used to construct models. The AMRs describing the models and the abstracted models provide additional details regarding data and assumptions. Section 2 of the TSPA-SR Technical Report provides a general discussion of the approach used to analyze the potential repository. Section 2.2.1 provides descriptions and figures showing the flow of information from the most basic detailed level to the total system model. Section 3 describes the individual components of the model, including implementation in the TSPA. These sections describe the abstraction models, if applicable, and describe the connection with other TSPA model components.
T2) A mapping (e.g., a road map diagram, a traceability matrix, a cross-reference matrix) is provided to show what conceptual features (e.g., patterns of volcanic events) and processes are represented in the abstracted models, and by what algorithms.	TSPA-SR Technical Report Section 2 and 3	In TSPA-SR Technical Report Section 3, the PMRs and supporting AMRs provide descriptions of the basis for decisions and assumptions that were made during the abstraction process. Section 3 addresses the major features, processes, and conceptualization of the nine process areas and the implementation of these components into the performance assessment analyses. Section 2 describes the different computer codes used to represent the various TSPA component models.
T3) An explicit discussion of uncertainty is provided to identify which issues and factors are of most concern or are key sources of disagreement among experts.	TSPA-SR Technical Report Sections 2.2.1, 3, and 5.1, all PMRs	The TSPA-SR Technical Report and the PMRs provide a discussion of uncertainties and limitations for the major process models included in the report. Section 2.2.1 describes that a key feature of the methodology used is the approach utilized to pass uncertainty at one level to uncertainty at another level. For each component model described in Section 3, the treatment of uncertainty and variability is discussed. Section 5.1, Uncertainty Importance Analysis, presents the results of analyses intended to identify those stochastic variables that have the greatest impact on the output of the TSPA-SR model. When used, expert elicitations were determined to be subject to the quality assurance program as described in the Quality Assurance Requirements Document (QARD). Appendix C of the QARD and implementing procedures for expert elicitation were developed using the guidance provided in NUREG-1563 (Kotra et al. 1996 [100909]).
Data Use and Validity		
T1) The pedigree of data from laboratory tests, natural analogs, and the site is clearly identified.	All PMRs	The PMRs and AMRs that support the TSPA explicitly identify the source and status of data. The PMRs summarizes the quality assurance status of the data and software used in the component models. The AMRs provide additional details regarding the pedigree of data. The qualification status of input data and references are tracked in the electronic Data Input Reference System (DIRS) in accordance with *Managing Technical Product Inputs*, AP-3.15Q [153184]. Data qualification was performed in accordance with procedure *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data*, AP-SIII.2Q [103748].

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T2) Input parameter development and basis for their selection is described.	All PMRs	The PMRs discuss input parameter development and the basis for using the parameters. The AMRs describing the models provide additional details regarding input parameter development and the basis for input selection.
T3) A thorough description of the method used to identify performance confirmation program parameters.	Performance Confirmation Plan	The *Performance Confirmation Plan* (CRWMS M&O 2000 [150657]) specifically addresses the methodology for identifying and selecting parameters that are important to performance based upon TSPA sensitivity analyses and the repository safety strategy. Methods used to collect information for each parameter will be described by the performance confirmation plan or relevant supporting documents to support the license application. Performance confirmation test selection and rationale is also described in the plan based upon the significance of the parameter being measured, and the ability of the test to distinguish construction, emplacement, or time dependent changes in the parameter significant to performance.
Assessment Results		
T1) PA results (i.e., the peak expected annual dose within the compliance period) can be traced back to applicable analyses that identify the FEPs, assumptions, input parameters, and models in the PA.	TSPA-SR Technical Report Sections 2.2, 3, and 4, All PMRs	The TSPA-SR Technical Report describes features, processes, conceptual models, and their implementation into the TSPA. This discussion will be based in part on information provided by the PMRs. Section 4 provides the results of the performance evaluations and includes a systematic analysis of the contribution of each component of the total system dose. The models that are integrated into the TSPA model are described in detail in Section 3 including a discussion of the FEPs relevant to each model component. Section 2.2 provides a detailed description of the method used to analyze the repository in the TSPA including the approach to combine the individual processes into an overall model and computer code.
T2) The PA results include a presentation of intermediate results that provide insight into the assessment (e.g., results of intermediate calculations of the behavior of individual barriers).	TSPA-SR Technical Report Section 4, All PMRs	Section 4 of the TSPA-SR Technical Report provides performance analysis results for the total system and includes intermediate results for the components of the system.
Code Design and Data Flow		
T1) The flow of information (input and output) between the various modules is clearly described.	TSPA-SR Technical Report Section 2.2	Section 2.2.1 of the TSPA-SR Technical Report provides a description of information flow between component models. Figure 2.2-1 illustrates the information major connections, abstractions and information feeds. Figure 2.2-2 provides a detailed description of information flow in the TSPA-SR, showing the principal pieces of information passed between the various component models.
T2) Supporting documentation (e.g., user's manuals, design documents) clearly describes code structure and relationships between modules.	TSPA-SR Technical Report	The TSPA-SR Technical Report describes the TSPA code and provides references to supporting documentation such as the user's guide. Section 2.2.2, Code Architecture, discusses the coding methods and couplings used for the major components. References are provided in Section 7.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
Demonstration Of Multiple Barriers		
Will be developed in Revision 3 of the IRSR		
SUBISSUE 2 - Scenario Analysis		
Identification of an Initial Set of Processes and Events Data		
1) DOE has identified a comprehensive list of processes and events that: (1) are present or might occur in the Yucca Mountain region and (2) includes those processes and events that have the potential to influence repository performance.	TSPA-SR Technical Report 2.1.1, and Appendix B	Section 2.1.1 of the TSPA-SR Technical Report describes the Implementation of the Features, Events, and Processes Approach including screening of FEPs in sufficient detail to demonstrate the comprehensiveness of the database. The comprehensiveness of the YMP FEP list derives from (a) the diverse backgrounds of the international waste disposal programs contributing to the list, (b) the variety of methods used to identify FEPs including expert judgment, informal elicitation, event tree analysis, stakeholder review, and regulatory stipulation, (c) the continuous iterative discussions and reviews (i.e., at technical workshops and in AMRs) of important YMP attributes, factors, and model components, (d) the systematic and comprehensive classification structure (as described in Step 2 below) ensures that no relevant subject area is overlooked, and (e) the fact that FEPs cannot be removed from the list; they can only be screened out (excluded) from the analysis. Section B.2 of Appendix B provides a detailed description of the process employed to ensure the list of features, events, and processes is comprehensive.
Classification of Processes and Events		
1) DOE has provided adequate documentation identifying how its initial list of processes and events has been grouped into categories.	TSPA-SR Technical Report Section 2.1.1 and Appendix B, FEP AMRs	Section 2.1.1 and Appendix B of the TSPA-SR Technical Report describes the process and criteria for assigning FEPs as either a primary, secondary, or classification entry. The classification approach adopted for TSPA-SR produced an aggregated set of primary FEPs for screening that covered all identified potentially relevant FEPs for screening potentially relevant Yucca Mountain FEPs. The FEP AMRs provide documentation and justification for screening arguments and dispositions. Documentation is maintained of all mapping of FEPs into primary and secondary categories. For comprehensiveness, traceability is maintained from the secondary to the related primary FEPs.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
2) Categorization of processes and events is compatible with the use of categories during the screening of processes and events.	TSPA-SR Technical Report Section 2.1.1 and Appendix B (Section B.3.2), FEP AMRs	Section 2.1.1 and Appendix B of the TSPA-SR Technical Report describe the process and criteria for assigning FEPs as either a primary, secondary, or classification entry. The classification approach adopted for TSPA-SR produced an aggregated set of primary FEPs for screening that covered all identified potentially relevant FEPs for screening potentially relevant Yucca Mountain FEPs. Section B.3.2 describes the objective of the categorization into primary, secondary and classification entries to identify a subset of FEP entries, the primary FEPs, which capture all the issues relevant to the postclosure performance of the potential Yucca Mountain repository and that can be addressed at an appropriate level of screening. The FEP AMRs provide documentation and justification for screening arguments and dispositions. Documentation is maintained of all mapping of FEPs into primary and secondary categories. For comprehensiveness, traceability is maintained from the secondary to the related primary FEPs.
Screening of Processes and Events		
1) Categories of processes and events that are not credible for the YM repository because of waste characteristics, repository design, or site characteristics are identified, and sufficient justification is provided for DOE's conclusions.	TSPA-SR Technical Report 2.1.1 and Appendix B, FEP AMRs	Section 2.1.1 and Appendix B of the TSPA-SR Technical Report describe the screening of FEPs for inclusion or exclusion in the TSPA. The FEP screening was performed by subject matter experts and documented in FEP AMRs and are listed in Appendix B of the TSPA-SR Technical Report. Specific guidelines for the basis for screening decisions and the content of screening documentation are also outlined in Appendix B. These guidelines were established to ensure that the screening basis and content for each primary FEP was sufficient to satisfy the screening criteria for low probability, low consequence, or regulatory exclusion. The FEP AMRs provide documentation and justification for screening arguments and TSPA dispositions. Documentation includes a statement of the screening decision for each FEP. Justification is provided for each excluded FEP including the criterion on which it was excluded and the technical basis for the screening argument.
2) The probability assigned to each category of processes and events not screened based on criterion T1 or criterion T2 is consistent with site information, well documented, and appropriately considers uncertainty.	TSPA-SR Technical Report 2.1.1 and Appendix B, FEP AMRs	Section 2.1.1 and Appendix B of the TSPA-SR Technical Report describe the screening of FEPs for inclusion or exclusion in the TSPA based on three criteria; regulatory, probability, and consequence. The probability is quantified where possible, although non-quantitative, low-probability arguments are acceptable for "not credible" FEPs. The FEP AMRs provide documentation and justification for screening arguments and dispositions. Probability estimates for FEPs are based on technical analysis of the past frequency of similar events consistent with site information, well documented, and appropriately consider uncertainty.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
3) DOE has demonstrated that processes and events screened from the PA on the basis of their probability of occurrence, have a probability of less than one chance in 10,000 of occurring over 10,000 years.	TSPA-SR Technical Report 2.1.1 and Appendix B (Section B.4.2), FEP AMRs	Section 2.1.1 and Appendix B of the TSPA-SR Technical Report describe the screening of FEPs for inclusion or exclusion in the TSPA based on three criteria; regulatory, probability, and consequence. Appendix B, Section B.4.2 describes the FEP database, including the documentation required for screening decisions and screening arguments. FEPs that have less than one chance in 10,000 of occurring over 10,000 years may be excluded (screened out) from the TSPA on the basis of low probability. The FEP AMRs provide documentation and justification for screening arguments and TSPA dispositions. Justification is provided for each excluded FEP including the criterion on which it was excluded and the technical basis for the screening argument. For excluded FEPs, documentation includes the criterion on which it was excluded and the technical basis for the screening argument.
4) DOE has demonstrated that categories of processes and events omitted from the PA on the basis that their omission would not significantly change the calculated expected annual dose, do not significantly change the calculated expected annual dose.	TSPA-SR Technical Report 2.1.1 and Appendix B (Section B.4.2), FEP AMRs	Section 2.1.1 and Appendix B of the TSPA-SR Technical Report describe the screening of FEPs for inclusion or exclusion in the TSPA based on three criteria; regulatory, probability, and consequence. Appendix B, Section B.4.2 describes the FEP database including the documentation required for screening decisions and screening arguments. Low consequence exclusions include an explicit statement that there is "no significant change in the expected annual dose." The change in expected annual dose is qualified where possible, and the interpretation of significant change must be described. It is acceptable to quantify the change in an intermediate performance measure, however the qualitative link to change in expected annual dose must be explicitly stated. The FEP AMRs supporting this section provide documentation and justification for screening arguments and TSPA dispositions. For omitted categories, documentation includes the criterion on which it was excluded and the technical basis for the screening argument.
Formation of Scenarios		
1) DOE has provided adequate documentation identifying: (i) whether processes and events have been addressed through consequence model abstraction or scenario analysis and (ii) how the remaining categories of processes and events have been combined into scenario classes.	TSPA-SR Technical Report 2.1.1 and Appendix B, FEP AMRs	Section 2.1.1 and Appendix B of the TSPA-SR Technical Report describe the formation of scenario classes and scenario development. All primary FEPs not screened out were retained for inclusion in one or both of the scenario classes. The two scenario classes identified for TSPA-SR, nominal and igneous disruption, are broadly defined and mutually exclusive. The FEP AMRs provide documentation and justification for screening arguments and TSPA dispositions. FEPs that have not been excluded are identified as either expected FEPs or disruptive FEPs. Expected FEPs are included in the TSPA-SR nominal scenario, which is simulated by the base case model described in the TSPA-SR Technical Report documentation. Disruptive scenarios are constructed from expected FEPs and combinations of disruptive FEPs.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
2) The set of scenario classes is mutually exclusive and complete.	TSPA-SR Technical Report 2.1.1 and Appendix B, FEP AMRs	Section 2.1.1 and Appendix B of the TSPA-SR Technical Report describe the formation of scenario classes and scenario development. All primary FEPs not screened out were retained for inclusion in one or both of the scenario classes. The two scenario classes identified for TSPA-SR, nominal and igneous disruption, are broadly defined and mutually exclusive. The FEP AMRs provide documentation and justification for screening arguments and TSPA dispositions. In addition, the AMRs describe the development of the FEPs database, including a description of the construction and screening of scenarios.
Screening of Scenario Classes		
1) Scenario classes that are not credible for the YM potential repository because of waste characteristics, repository design, or site characteristics, individually or in combination, are identified and sufficient justification is provided for DOE's conclusions.	TSPA-SR Technical Report Section 2.1.1	TSPA-SR Technical Report Section 2.1.1 provides justification for screening arguments and TSPA disposition. Scenarios are screened using the same regulatory, probability, and consequence criteria used for screening individual FEPs. For TSPA-SR, scenario screening criteria were evaluated, but all scenario classes were retained.
2) The probability assigned to each scenario class is consistent with site information, well documented, and appropriately considers uncertainty.	TSPA-SR Technical Report Section 2.1.1	The TSPA-SR Technical Report Section 2.1.1 provides justification for screening arguments and TSPA disposition. Probability estimates for scenario classes are based on analyses similar to probabilities assigned for individual FEPs. For TSPA-SR, scenario screening criteria were evaluated, but all scenario classes were retained.
3) Scenario classes that combine categories of processes and events may be screened from the PA on the basis of their probability of occurrence, provided: (i) the probability used for screening the scenario class is defined from combinations of initiating processes and events and (ii) DOE has demonstrated that they have a probability of less than one chance in 10,000 of occurring over 10,000 years.	TSPA-SR Technical Report Section 2.1.1	The TSPA-SR Technical Report Section 2.1.1 describes screening of scenario classes. For TSPA-SR, scenario screening criteria were evaluated, but all scenario classes were retained.
4) Scenario classes may be omitted from the PA on the basis that their omission would not significantly change the calculated expected annual dose, provided DOE has demonstrated that excluded categories of processes and events would not significantly change the calculated expected annual dose.	TSPA-SR Technical Report Section 2.1.1	The TSPA-SR Technical Report Section 2.1.1 describes screening of scenario classes. For TSPA-SR, scenario screening criteria were evaluated, but all scenario classes were retained.
SUBISSUE 3 - Model Abstraction		
Engineered Barrier Degradation	Related to KTI Subissues CLST1, CLST2, CLST6, ENFE2, RDTME3, TEF1, TEF2[1]	

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T1) Sufficient data (field, laboratory or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the WP corrosion abstraction in the TSPA-SR. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA-SR.	TSPA-SR Technical Report Section 3.4, WPD PMR, DE PMR	Section 3.4 of the TSPA-SR Technical Report describes waste package and drip shield degradation. Waste package and drip shield degradation are described in detail in the Waste Package Degradation (WPD) PMR. The WPD PMR describes how the TSPA model requires estimates of corrosion and threshold potentials, both of which are determined through electrochemical testing. Two-year test data has become available and is included in the WPD PMR. Section 3.4.2 of the TSPA-SR Technical Report describes implementation of the model. The computer implementation of the conceptual model provides a mechanism for incorporating the effects of the individual corrosion models in a probabilistic framework that captures the variability and uncertainty in the model parameters. Section 3.4.1 describes output data including the uncertainty and spatial variation of the degradation information on both a waste package and drip shield basis and at different locations within the repository. In the Disruptive Event (DE) AMRs, analog data are described and used as appropriate. The expert elicitations summarized in the framework AMRs were the source of the majority of data used, and data from other sources was qualified as described in the individual AMRs. The process followed for the expert elicitations ensured that relevant data were provided to the experts for consideration.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the WP corrosion abstraction, such as critical relative humidity (RH), material properties, pH, and chloride concentration are technically defensible and reasonably account for uncertainties and variabilities.	TSPA-SR Technical Report Section 3.4, WPD PMR, DE PMR	Section 3.4 of the TSPA-SR Technical Report describes waste package and drip shield degradation. Section 3.4.1 provides a description and illustration of model data sources, input data used by the model and output data generated by the model, including the uncertainty and spatial variation of the degradation information on both a waste package and drip shield. Waste package and drip shield degradation are described in detail in the WPD PMR. The WPD PMR and supporting AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews by a single review team to help ensure consistency. These measures provide confidence that consistency is maintained among the various TSPA models. The process followed for the expert elicitations, as described in disruptive event AMRs ensured that conditions described in this acceptance criterion were met. The methodology to ensure meeting this criterion for data from other sources used in DE AMRs is described in each AMR in Sections 4, 5, and 6 where parameter values, ranges, distributions and bounding assumptions are described. AMRs list assumptions and justify data values, ranges and distributions.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the WP corrosion abstraction.	TSPA-SR Technical Report Section 3.4, WPD PMR, DE PMR	Alternatives models have been considered for rates of dry oxidation, localized corrosion thresholds, stress corrosion thresholds, stress corrosion cracking, stress mitigation, and hydrogen induced cracking. These alternatives are summarized in Section 3.1.11 of the WPD PMR. The DE AMRs discuss alternative conceptual models and data values and ranges consistent with current scientific understanding and justify use of the conceptual models selected. In addition, significant alternative conceptual models are discussed in Section 4 of the DE PMR.
T4) WP corrosion abstraction output is justified through comparison to output of detailed process models or empirical observations (laboratory testings, natural analogs, or both).	TSPA-SR Technical Report Section 3.4, WPD PMR	Model validation, the process through which independent measurements are used to ensure that a model accurately predicts an alteration behavior of waste package materials under a given set of environmental conditions (e.g. under repository environment over the time periods required), is discussed in detail in Section 3.1.10 of the WPD PMR. Output is compared to experimental measurements used as the basis of calculations to verify that correct and reasonable results are obtained.
T5) Important design features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the WP corrosion abstraction.	TSPA-SR Technical Report Section 3.4, WPD PMR, DE PMR	The WPD AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models including the WPD corrosion abstraction.
Mechanical Disruption of Engineered Barriers	Related to KTI Subissues RDTME2, RDTME3, CLST1, CLST2, CLST6, IA2, SDS1, SDS2, SDS3, SDS4[1]	
T1) Sufficient data (field, laboratory or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing mechanical disruption of the engineered barriers abstraction in TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 4.2, DE PMR	TSPA-SR Technical Report Section 4.2 describes the results of the TSPA-SR analysis for igneous disruption. Supporting documentation, including the Disruptive Event (DE) PMR and supporting AMRs, provide details regarding DE models and abstractions. In all DE AMRs, analog data are described and used as appropriate. Expert elicitations were the source of the majority of data used, and data from other sources was qualified as described in the individual DE AMRs. The process followed for the expert elicitations ensured that relevant data were provided to the experts for consideration.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the mechanical disruption of the engineered barriers abstraction, such as probabilistic seismic hazard curves, probability of dike intrusion, and the probability and amount of fault displacement, are technically defensible and reasonably account for uncertainties and variabilities.	DE PMR	The process followed for the expert elicitations ensured that these acceptance criteria were met. The methodology to ensure meeting this criterion for data from other sources used in DE AMRs is described in each AMR in Sections 4, 5 and 6 where parameter values, ranges, distributions and bounding assumptions are described. AMR originators were required to list assumptions and to justify data values, ranges and distributions.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the mechanical disruption of the engineered barriers abstraction.	DE PMR	Section 6 of the AMRs discusses alternative conceptual models and data values and ranges consistent with current scientific understanding and justifies use of the conceptual models selected. In addition, significant alternative conceptual models as presented in NRC IRSRs are discussed in Section 4 of the DE PMR.
T4) Mechanical disruption of the engineered barriers abstraction output is justified through comparison to output of detailed process models or empirical observations (laboratory testing, natural analogs, or both).	DE PMR	Validation of model outputs is an activity performed by TSPA-SR analysis. All DE AMRs provide documentation of analyses that may be used when comparison with process models and empirical observations is required.
T5) Important design features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the mechanical disruption of the engineered barriers abstraction.	DE PMR	The AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models.
Quantity and Chemistry of Water Contacting Waste Packages and Waste Forms	Related to KTI Subissues CLST1, CLST3, CLST4, CLST6, ENFE1, ENFE2, ENFE3, RDTME3, TEF1, TEF2, USFIC4[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the quantity and chemistry of water contacting waste packages and waste forms abstraction in a TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.2, 3.4, 3.5, WFD PMR, UZFT PMR	The basic conceptual model for seepage is described in Section 3.2.4 of the TSPA-SR Technical Report. Section 3.2 also addresses the treatment of uncertainty and variability for each of the components of the UZ model. Sections 3.4 and 3.5 of the TSPA-SR Technical Report include descriptions of the waste package and waste form models. In addition, Section 3.9 of the UZFT PMR summarizes the available data and conceptual models for seepage into drifts. The UZFT PMR describes the effects of coupled processes and their impact on chemical conditions. Section 2.2 describes data collection and Section 3.6 describes the development of properties for the UZ Flow and Transport Model and summarizes available data used to define relevant parameters and conceptual models. The Waste Form Degradation (WFD) PMR summarizes the technical bases of models and corresponding parameters that are abstracted for TSPA-SR. The WFD PMR has been developed in according with applicable QA procedures (see WFD PMR Section 1). Sufficient data were collected by the project or were available in the literature to develop defensible bounding models of the chemical environment. The specific aspects of the water chemistry are discussed in Section 3.2 of the WFD PMR and in supporting AMRs, *In-Package Chemistry Abstraction* (CRWMS M&O 2000 [129287] and *Summary of In-Package Chemistry for Waste.* The UZFT and WFD PMRs have been developed in accordance with applicable QA procedures (see UZFT PMR Section 1.3) for documenting data, analysis, models, and computer code; and preparing and reviewing technical reports.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the quantity and chemistry of water contacting waste packages and waste forms abstraction, such as the pH, carbonate concentration, chloride concentration, and amount of water flowing in and out of the breached WP, are technically defensible and reasonably account for uncertainties and variability.	TSPA-SR Technical Report Section 3.2, 3.4, 3.5, WFD PMR, EBS PMR, UZFT PMR	Sections 3.4 and 3.5 of the TSPA-SR Technical Report include descriptions of the model inputs and outputs as well as implementation of the models into the TSPA model. Variations in water chemistry and their effects on in-package chemistry are discussed in Section 3.2 of the WFD PMR. In addition, as described in Section 3.4 of the WFD PMR, a specific model component was added to the total system performance assessment for site recommendation to reasonably account for uncertainties and variabilities in chemistry of water contacting the waste forms. The quantity of water entering the waste package was evaluated in the EBS PMR. The UZFT PMR (Section 3.6) describes the development of properties for the UZ Flow and Transport Model and summarizes available data used to define relevant parameters and conceptual models. Section 3.2 addresses the treatment of uncertainty and variability for each of the components of the UZ model. Also, in the UZFT PMR, Sections 3.7.2 through 3.7.4 summarize UZ flow models and Section 3.7.5 summarizes the results of abstractions of UZ flow.
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the quantity and chemistry of water contacting WPs and waste forms abstraction.	TSPA-SR Technical Report Section 3.2, 3.4, 3.5, WFD PMR, UZFT PMR	Each of the sections describing the components of the WFD Model of the WFD PMR describes alternative modeling approaches that could have been used. In the UZFT PMR, alternative conceptual models are discussed in various sections of Chapter 3, "UZ Flow and Transport Model and Abstractions."
T4) Output of quantity and chemistry of water contacting WPs and waste forms abstraction are supported by comparison to output of detailed process models or empirical observations (laboratory testing, natural analogs, or both).	TSPA-SR Technical Report Section 3.2, 3.4, 3.5, WFD PMR, UZFT PMR, *In-Package Chemistry Component* AMR	The WFD PMR summarizes the current technical basis of models. For most modeling components within the WFD PMR, a detailed process component model of the phenomena was not developed. Rather, a simplified (abstraction) component was directly developed from the experimental observations and information. For the AMR *In-Package Chemistry Component*, a detailed process model was developed, and then the numerical results used directly through regression to develop a simple empirical relationship. In the UZFT PMR, various sections describe different abstractions and the use of corroborative evidence. Section 3.7.5 describes UZ Flow abstractions for TSPA-SR and how the abstraction of flow was based on detailed process models.
T5) Important design features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the quantity and chemistry of water contacting WPs and waste forms abstraction.	TSPA-SR Technical Report Section 3.2, 3.4, 3.5, WFD PMR, UZFT PMR	The WFD AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
Radionuclide Release Rates and Solubility Limits	Related to KTI Subissues CLST3, CLST4, CLST5, CLST6, ENFE3, ENFE4, ENFE5[1]	
T1) Sufficient data (field, laboratory or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing RN release rates and solubility limits abstracted in TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.5, WFD PMR	Section 3.5 of the TSPA-SR Technical Report describes the Waste Form Degradation model. This model quantitatively describes the interrelationships among the in-package water chemistry, the degradation of the waste form (including cladding), and the mobilization of radionuclides. This section discusses the treatment of uncertainty and variability in the waste form model. Per the WFD PMR, sufficient data were collected by the project or available in the literature to develop defensible bounding models of the chemical environment. Specific aspects of the radioisotope release rates are discussed in Sections 3.3, 3.4, 3.5, and 3.6 of the WFD PMR and corresponding AMRs. Specific aspects of the solubility limits are discussed in Section 3.7.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the RN release rates and solubility limits abstraction, such as the pH, temperature, colloidal release, and amount of liquid contacting the waste forms, are technically defensible and reasonably account for uncertainties and variabilities.	TSPA-SR Technical Report Section 3.5, WFD PMR, *In-Package Chemistry Component* AMR	Section 3.5 of the TSPA-SR Technical Report describes the Waste Form Degradation model including discussions on the treatment of uncertainty and variability in the waste form model. The WFD PMR summarizes the technical bases of model parameters. Specific aspects of the radioisotope release rates are discussed in Sections 3.3, 3.4, 3.5, 3.6 and corresponding AMRs. Specific aspects of the solubility limits are discussed in Section 3.7 and the corresponding AMRs. To better characterize the uncertainty in the radionuclide release rates and solubility limits, the corresponding modeling components were directly coupled with the AMR *In-Package Chemistry Component* (Section 3.2). In turn, the AMR *In-Package Chemistry Component* uses the available data to couple temporal thermal effects (waste temperature), temporal hydrologic effects (seepage into the package), and temporal chemical effects (degradation rates of steel, aluminum, HLW, SNF) to evaluate the chemical environment inside the WPD.
T3) Alternative waste form dissolution and RN release modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the RN release rates and solubility limits abstraction.	TSPA-SR Technical Report Section 3.5, WFD PMR	In the WFD PMR, each of the sections describing the components of the WFD Model describes alternative modeling approaches that were considered.
T4) RN release rates and solubility limits abstraction output is supported by comparison to outputs of detailed process models or empirical observations (field, laboratory, or natural analog data).	TSPA-SR Technical Report Section 3.5, WFD PMR	The WFD PMR summarizes the current technical basis of models. For most modeling components within the WFD PMR, a detailed process component model of the phenomena was not developed. Rather, a simplified (abstraction) component was directly developed from the experimental observations and information. For radionuclides of neptunium, americium, and uranium, a detailed process model was developed and then the numerical results used directly through regression to develop a simple empirical relationship, as summarized in Sections 3.2 and 3.7. Although material analog data were not used directly, the paragenetic sequence observed in experiments mirrors natural analogs.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T5) Important design features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the RN release rates and solubility limits abstraction.	TSPA-SR Technical Report Section 3.5, WFD PMR	The WFD AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models.
Spatial and Temporal Distribution of Flow	Related to KTI Subissues ENFE1, RDTME3, SDS2, SDS3, TEF1, TEF2, USFIC1, USFIC2, USFIC3, USFIC4[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the spatial and temporal distribution of flow abstraction in TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.2, UZFT PMR	Section 3.2 of the TSPA-SR Technical Report describes the Unsaturated Zone Flow Model, including implementation into the TSPA model. Section 3.2 also addresses the treatment of uncertainty and variability for each of the components of the UZ model. The UZFT PMR (Section 3.6) describes the development of properties for the UZ Flow and Transport Model and summarizes available data used to define relevant parameters and conceptual models. The UZFT PMR has been developed in accordance with applicable QA procedures (see UZFT PMR Section 1.3) for documenting data, analysis, models, and computer code, and preparing and reviewing technical reports.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the spatial and temporal distribution of flow abstraction (such as the effects of climate change on infiltration, near surface influences [e.g., evapotranspiration and runoff] on infiltration, structural controls on the spatial distribution of deep percolation, and thermal reflux owing to repository heat load) are technically defensible and reasonably account for uncertainties and variabilities.	TSPA-SR Technical Report Section 3.2, UZFT PMR	The UZFT PMR (Section 3.6) describes the development of properties for the UZ Flow and Transport Model and summarizes available data used to define relevant parameters and conceptual models. Section 3.2 addresses the treatment of uncertainty and variability for each of the components of the UZ model. Also, in the UZFT PMR, Sections 3.7.2 through 3.7.4 summarize UZ flow models, and Section 3.7.5 summarizes the results of abstractions of UZ flow.
T3) Alternative modeling approaches, consistent with available data and current scientific understanding, are investigated and results and limitations appropriately factored into the spatial and temporal distribution of flow abstraction.	TSPA-SR Technical Report Section 3.2, UZFT PMR	In the UZFT PMR, alternative conceptual models are discussed in various sections of Chapter 3, "UZ Flow and Transport Model and Abstractions."

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T4) Spatial and temporal distribution of flow abstraction output is justified through comparison to output of detailed process models or empirical observations (laboratory testing, natural analogs, or both).	TSPA-SR Technical Report Section 3.2, UZFT PMR	Section 3.2 of the TSPA-SR Technical Report describes the Unsaturated Zone Flow model including implementation into the TSPA model. Section 3.5.3 describes abstractions of climate and infiltration, and Section 3.2.3.2 describes implementation of the Mountain Scale Flow model into the TSPA. Climate and infiltration are not included directly in TSPA simulations, but only indirectly through its use as a boundary condition for the UZ flow and thermal hydrology models. In the UZFT PMR, various sections describe different abstractions and the use of corroborative evidence. Section 3.7.5 describes UZ Flow abstractions for TSPA-SR and how the abstraction of flow was based on detailed process models.
T5) Important design features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the spatial and temporal distribution of flow abstraction.	TSPA-SR Technical Report Section 3.2, UZFT PMR	The UZFT AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models. In the UZFT PMR, the abstraction of UZ flow is summarized in Section 3.7.5.
Flow Paths in the Unsaturated Zone	Related to KTI Subissues ENFE1, SDS3, TEF1, TEF2, USFIC4[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the flow paths in the UZ in the abstraction in TSPA. Where adequate data cannot be readily obtained, other information sources such as expert elicitation or bounding values have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.2, UZFT PMR	Section 3.2 of the TSPA-SR Technical Report describes the Unsaturated Zone Flow Model, including implementation into the TSPA model. Section 3.2 also addresses the treatment of uncertainty and variability for each of the components of the UZ model. The UZFT PMR (Section 3.6) describes the development of properties for the UZ Flow and Transport Model and summarizes available data used to define relevant parameters and conceptual models. The UZFT PMR has been developed in accordance with applicable QA procedures (see UZFT PMR Section 1.3) for documenting data, analysis, models, and computer code, and preparing and reviewing technical reports.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the flow paths in the UZ in the abstraction, such as hydrologic properties, stratigraphy, and infiltration rate, are technically defensible and reasonably account for uncertainties and variability.	TSPA-SR Technical Report Section 3.2, UZFT PMR	The UZFT PMR (Section 3.6) describes the development of properties for the UZ Flow and Transport Model and summarizes available data used to define relevant parameters and conceptual models. Section 3.2 addresses the treatment of uncertainty and variability for each of the components of the UZ model. Also, in the UZFT PMR, Sections 3.7.2 through 3.7.4 summarize UZ flow models, and Section 3.7.5 summarizes the results of abstractions of UZ flow.
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the distribution on mass flux between fracture and matrix in the abstraction.	TSPA-SR Technical Report Section 3.2, UZFT PMR	In the UZFT PMR, alternative conceptual models are discussed in various sections of Chapter 3, "UZ Flow and Transport Model and Abstractions."

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T4) Flow paths in the UZ abstraction output are justified through comparison to output of detailed flow process models or empirical observations (laboratory testings, natural analogs, or both).	TSPA-SR Technical Report Section 3.2, UZFT PMR	Section 3.2 of the TSPA-SR Technical Report describes the Unsaturated Zone Flow model, including implementation into the TSPA model. Section 3.5.3 describes abstractions of climate and infiltration. Section 3.2.3.2 describes implementation of the Mountain Scale Flow model into the TSPA. This section describes that direct use of the 3-D mountain-scale flow model eliminates the need to test simplified abstractions against more complex models. In the UZFT PMR, various sections describe different abstractions and the use of corroborative evidence. Section 3.7.5 describes UZ Flow abstractions for TSPA-SR and how the abstraction of flow was based on detailed process models. In the UZFT PMR, the abstraction was based on detailed process models described in Sections 3.7.2 through 3.7.4.
T5) Important design features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the flow paths in the UZ abstraction.	TSPA-SR Technical Report Section 3.2, UZFT PMR	The UZFT AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models. In the UZFT PMR, the abstraction of UZ flow is summarized in Section 3.7.5.
Radionuclide Transport in the Unsaturated Zone	Related to KTI Subissues RT1, RT3, RT4, SDS3, ENFE4, USFIC4, USFIC6[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the spatial and temporal distribution of flow abstraction in TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.7, UZFT PMR	Section 3.7 of the TSPA-SR Technical Report describes the Unsaturated Zone Transport Model including implementation into the TSPA model and the treatment of uncertainty and variability. In the UZFT PMR, Section 3.11.3 summarizes the transport properties that are used for the abstraction of radionuclide transport in the UZ. The AMR on UZ and SZ transport properties provides additional detail on transport properties for the UZ. The UZFT PMR has been developed in accordance with applicable QA procedures (see UZFT PMR Section 1.3) for documenting data, analysis, models, and computer code, and preparing and reviewing technical reports.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the spatial and temporal distribution of flow abstraction (such as the effects of climate change on infiltration, near surface influences [e.g., evapotranspiration and runoff] on infiltration, structural controls on the spatial distribution of deep percolation, and thermal reflux owing to repository heat load) are technically defensible and reasonably account for uncertainties and variabilities.	TSPA-SR Technical Report Section 3.7, UZFT PMR	In the UZFT PMR, Section 3.11.3 summarizes parameter values, ranges, distributions, and bounding assumptions for the abstraction of radionuclide transport, as applicable. The UZFT AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, Section 3.7.2 of the TSPA-SR Technical Report describes the implementation of the UZ Transport Model into the TSPA. This section describes the connections between UZ transport and other TSPA model components. The UZ transport model is directly coupled with the TSPA model.
T3) Alternative modeling approaches, consistent with available data and current scientific understanding, are investigated and results and limitations appropriately factored into the RT in the UZ abstraction.	TSPA-SR Technical Report Section 3.7, UZFT PMR	In the UZFT PMR, Section 3.11.9 summarizes an alternative conceptual model for transport in the UZ. An alternative conceptual model that does not allow diffusion (but still allows advection) into the matrix was investigated. The results are described in the section.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T4) RT in the UZ abstraction output is justified through comparison to output of detailed process models or empirical observations (laboratory testing, natural analogs, or both).	TSPA-SR Technical Report Section 3.7, UZFT PMR	In the UZFT PMR, Section 3.11.13 describes the abstraction of radionuclide transport. Section 3.11.13.4 describes how the abstraction is compared to alternate solution methods for a variety of problems.
T5) Important design features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the consideration of RT in the UZ abstraction.	TSPA-SR Technical Report Section 3.7, UZFT PMR	The UZFT AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models. In the UZFT PMR, Section 3.11.13 discusses the abstraction of radionuclide transport, including physical phenomena, couplings, and assumptions.
Flow Paths in the Saturated Zone	Related to KTI Subissues USFIC2, USFIC5, USFIC6, SDS1, SDS3[1]	
T1) Sufficient hydrogeologic data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the flow paths in the SZ abstraction in the TSPA-SR. Where adequate data does not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.8, SZFT PMR	Section 3.8 of the TSPA-SR Technical Report describes the Saturated Zone Flow Model, including implementation into the TSPA model. In addition, Section 3.8.1.3 addresses the treatment of uncertainty and variability for the SZ flow model. In the SZFT PMR, characterization and site data are discussed in Section 3.1; conceptual models are discussed in Section 3.2; and synthesis of SZ model and model abstractions are discussed in Section 3.6. Also, the SZFT PMR has been developed in accordance with applicable QA procedures (see SZFT PMR Section 1.4) for documenting data, analysis, models, and computer code, and preparing and reviewing technical reports.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the flow paths in the SZ abstraction, such as the effect of climate change on the SZ fluxes and water table level and well pumping practices, are technically defensible and reasonably account for uncertainties and variability.	TSPA-SR Technical Report Section 3.8, SZFT PMR	Section 3.8 of the TSPA-SR Technical Report describes the Saturated Zone Flow Model. Section 3.8.1 describes the relationship between the SZ flow and other components of the TSPA. Section 3.8.1.3 addresses the treatment of uncertainty and variability for the SZ flow model. The SZFT PMR and supporting AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews by a single review team to help ensure consistency. These measures provide confidence that consistency is maintained among the various TSPA models.
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the flow paths in the SZ.	TSPA-SR Technical Report Section 3.8, SZFT PMR	In the SZFT PMR, alternative conceptual models are discussed in Section 3.2.5.
T4) Flow paths in the SZ abstraction output are justified through comparison to output of detailed process models or empirical observations (laboratory testing, natural analogs, or both).	TSPA-SR Technical Report Section 3.8, SZFT PMR	In the SZFT PMR, the process of testing the validity of the conceptual, mathematical and numeric representation of the system is discussed in Section 3.4. Also, analog studies that have been conducted in saturated environments as a means of model "validation" or confidence building are discussed in Section 3.4.5 of the PMR.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T5) Important site (geologic and hydraulic) features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the flow paths in the SZ abstraction.	TSPA-SR Technical Report Section 3.8, SZFT PMR	The SZFT AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models. In the SZFT PMR, synthesis of SZ model and model abstractions is discussed in Section 3.6 and assumptions, uses, and limitations of models are discussed in Section 3.5.
Radionuclide Transport in the Saturated Zone	Related to KTI Subissues RT1, RT2, RT3, RT4, SDS3, USFIC5, USFIC6[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the RT in the SZ abstraction in TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.8, SZFT PMR	Section 3.8 of the TSPA-SR Technical Report describes the Saturated Zone Flow Model, including implementation into the TSPA model and a description of the data that supports radionuclide transport in the SZ. Section 3.8.2.4 addresses the treatment of uncertainty and variability for each of the components of the SZ model. In the SZFT PMR, SZ characterization and data is discussed in Section 3.1. Section 3.1.3 provides a summary of hydrochemical data pertinent to transport. Also, dilution in water supply in abstraction of radionuclide transport is discussed in Section 3.6.3, and synthesis of SZ model and model abstractions is discussed in Section 3.6. The SZFT PMR has been developed in accordance with applicable QA procedures (see SZFT PMR Section 1.4) for documenting data, analysis, models, and computer code, and preparing and reviewing technical reports.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the RT in the SZ abstraction, such as the sorption on fracture surfaces and Kd for matrix, are technically defensible and reasonably account for uncertainties and variability.	TSPA-SR Technical Report Section 3.8, SZFT PMR	Section 3.8 of the TSPA-SR Technical Report describes the Saturated Zone Flow Model including SZ transport. Section 3.8.2 describes the data that supports radionuclide transport and describes the relationship between the SZ flow and other components of the TSPA. Section 3.8.2.4 addresses the treatment of uncertainty and variability for the SZ flow model. The SZFT PMR and supporting AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews by a single review team to help ensure consistency. These measures provide confidence that consistency is maintained among the various TSPA models. In the SZFT PMR, SZ characterization and data are discussed in Section 3.1; dilution in water supply abstraction of radionuclide transport is discussed in Section 3.6.3; parameter uncertainty distributions are discussed in Section 3.7.2; probabilistic analyses are discussed in Section 3.7.3; and syntheses of SZ model and model abstractions are discussed in Section 3.6.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the RT in the SZ abstraction.	TSPA-SR Technical Report Section 3.8, SZFT PMR	In the SZFT PMR, alternative conceptual models are discussed in Section 3.2.5.
T4) RT in the SZ abstraction output is justified through comparison to output of detailed process models or empirical observations (laboratory testing, natural analogs, or both).	TSPA-SR Technical Report Section 3.8, SZFT PMR	In the SZFT PMR, the process of testing the validity of the conceptual, mathematical and numeric representation of the system is discussed in Section 3.4. Also, analog studies that have been conducted in saturated environments as a means of model "validation" or confidence building are discussed in Section 3.4.5 of the PMR.
T5) Important physical phenomena and couplings and consistent and appropriate assumptions are incorporated into the consideration of RT in the SZ abstraction.	TSPA-SR Technical Report Section 3.8, SZFT PMR	The SZFT AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models. In the UZFT PMR, dilution in water supply in abstraction of radionuclide transport is discussed in Section 3.6.3; assumptions, uses, and limitations of model are discussed in Section 3.5; and synthesis of SZ model and model abstractions is discussed in Section 3.6.
Volcanic Disruption of Waste Packages	Related to KTI Subissues IA1, IA2, SDS1, SDS4[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for abstracting the volcanic disruption of WPs in TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.10, DE PMR	Section 3.10.1 of the TSPA-SR Technical Report describes the development of the conceptual model for igneous activity at Yucca Mountain. The conceptual model has three main components. Each of the components is based on observations of the past geologic record and, for the characteristics of an eruption, observations of modern analogs. Basing the conceptual model for possible future igneous activity on the past record and modern analogs is consistent with the proposed regulatory requirement to assume that the "(evolution of the geologic setting shall be consistent with present knowledge of natural processes" [proposed 10 CFR 63.115(a)(4)] [64 FR 8640] [101680]). In all DE AMRs, analog data are described and used as appropriate. Expert elicitations were the source of the majority of data used, and data from other sources was qualified as described in individual AMRs. Section 3.10.1.2 describes how the probability of future igneous activity in the Yucca Mountain region used in the TSPA-SR is based on the *Probabilistic Volcanic Hazard Analysis for Yucca Mountain, Nevada* (PVHA) (CRWMS M&O 1996 [100116]) conducted by the DOE in 1995 and 1996. Ten experts in the field of volcanology evaluated available data on past volcanic activity in the region and provided expert judgement on the probability of future igneous activity. Their judgments (elicitations) were combined to produce an integrated assessment of the volcanic hazard that reflects a range of alternative scientific interpretations. The process followed for the expert elicitations ensured that relevant data were provided to the experts for consideration.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the volcanic disruption of WPs abstraction are technically defensible and reasonably account for uncertainties and variability. The technical basis for the parameter values used in the PA needs to be provided.	TSPA-SR Technical Report Section 3.10, DE PMR	Section 3.10 of the TSPA-SR Technical Report describes volcanism and the development of the conceptual model for igneous activity at Yucca Mountain. Each of the components of the model is based on observations of the past geologic records and for the characteristics of the eruption, observations of modern analogs. Information used in the TSPA-SR model to characterize the intrusive and eruptive processes comes from three sources: examination of the geologic record of past intrusive and eruptive events in the Yucca Mountain region; observations of eruptive processes during analogous modern volcanic events elsewhere in the world; and consideration of the range of physical processes that might occur during the interaction between the repository and an igneous dike. Variability in parameters was accounted for through consideration of the range of physical processes that might occur. In addition, DOE bases its TSPA-SR base case on the full range of probability values as described in the igneous framework AMR. This acceptance criterion is specifically addressed in the Igneous Activity IRSR, Probability Acceptance criterion 4. The expert elicitation process was used to ensure that uncertainty in estimates of the volcanic hazard was completely captured. Treatment of uncertainty in the volcanic hazard formulation is described in the PVHA.
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the volcanic disruption of WPs abstraction.	TSPA-SR Technical Report Section 3.10, DE PMR, Igneous Consequences Modeling for TSPA-SR AMR	Consideration given to alternative modeling approaches is described in the AMR Igneous Consequences Modeling for TSPA-SR (DE PMR Section 3.1.5). In addition, DE AMRs discuss alternative conceptual models and data values and ranges consistent with current scientific understanding and justify use of the conceptual models selected. In addition, significant alternative conceptual models as presented in NRC IRSRs are discussed in Chapter 4 of the DE PMR.
T4) Outputs of the volcanic disruption of WPs abstraction are justified through comparison to outputs of detailed process models or empirical observations (laboratory testing, natural analogs, or both).	TSPA-SR Technical Report Section 3.10, DE PMR	Section 3.10.2 of the TSPA-SR Technical Report describes the TSPA-SR model for volcanic eruption. This section describes how entrainment of waste and atmospheric transport of contaminated ash is modeled using the ASHPLUME code. Use of the ASHPLUME model is considered reasonable as discussed in the igneous consequences AMR. Additional analyses of the suitability of ASHPLUME to model tephra deposits at Cerro Negro based on the 1995 eruption have been completed. The results of the analysis are in good agreement with the observed ash distribution, and the agreement is considered to verify the utility of the model.
T5) Important site and design features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the volcanic disruption of WPs abstraction and the technical bases are provided.	TSPA-SR Technical Report Section 3.10, DE PMR	The DE AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
Airborne Transport of Radionuclides	Related to KTI Subissues ISI, IA2[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the airborne transport of RNs abstraction in TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.10, DE PMR	Section 3.10 of the TSPA-SR Technical Report describes volcanism and the development of the conceptual model for igneous activity at Yucca Mountain. Direct observations of volcanic processes in the subsurface are extremely rare and there are no precedents for modeling. Information used in the TSPA-SR model comes from three sources: examination of the geologic record of past intrusive and eruptive events in the Yucca Mountain region; observations of eruptive processes during analogous modern volcanic events elsewhere in the world; and consideration of the range of physical processes that might occur during the interaction between the repository and an igneous dike. Also, in all DE AMRs, analog data are described and used as appropriate. Expert elicitations are the source of the majority of data used, and data from other sources was qualified as described in individual AMRs. The process followed for the expert elicitations ensured that relevant data were provided to the experts for consideration.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the airborne transport of RNs abstraction, such as the magnitude of eruption and deposition velocity, are technically defensible and reasonably account for uncertainties and variability.	TSPA-SR Technical Report Section 3.10, DE PMR, Biosphere PMR, *Characterize Eruptive Processes at Yucca Mountain, Nevada* AMR, *Igneous Consequences Modeling for TSPA-SR* AMR	The basis for selection of parameter values, such as magnitude of eruption that are inputs to the igneous consequences modeling, are described in the AMR *Characterize Eruptive Processes at Yucca Mountain, Nevada* (DE PMR, Section 3.1.2). Deposition velocities used are described in the AMR *Igneous Consequences Modeling for TSPA-SR* (DE PMR Section 3.1.5). Section 3.10 of the TSPA-SR Technical Report describes how uncertainties and variability are reasonably accounted for through the specification of distributions of reasonably possible values. Information about eruption characteristics, the probability of eruptive conduits forming within the potential repository, and the potential repository response to eruption are used to develop a distribution of parameter values characterizing uncertainty in the extent of damage to waste packages and the amount of waste available to be entrained in the eruption. Modeling yields a distribution of results characterizing uncertainty in the concentration of waste particles on the ground surface. In addition, Section 3.2.4 of the Biosphere PMR discusses input parameters for GENII-S, and Section 3.3.2 discusses the disruptive event biosphere dose conversion factors to support dose consequence calculations in TSPA.
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the airborne transport of RNs abstraction.	TSPA-SR Technical Report Section 3.10, DE PMR, *Igneous Consequences Modeling for TSPA-SR* AMR	Consideration given to alternative modeling approaches is described in the AMR *Igneous Consequences Modeling for TSPA-SR* (DE PMR Section 3.1.5). In addition, DE AMRs discuss alternative conceptual models and data values and ranges consistent with current scientific understanding and justify use of the conceptual models selected. In addition, significant alternative conceptual models as presented in NRC IRSRs, are discussed in Chapter 4 of the DE PMR.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T4) Airborne transport of RNs abstraction output is justified through comparison to output of detailed process models or empirical observations (laboratory testing, natural analogs, or both).	TSPA-SR Technical Report Section 3.10, DE PMR	Section 3.10.2.2 of the TSPA-SR Technical Report describes the TSPA-SR model for volcanic eruption. This section describes how entrainment of waste and atmospheric transport of contaminated ash is modeled using the ASHPLUME code. Use of the ASHPLUME model is considered reasonable as discussed in the igneous consequences AMR. Additional analyses of the suitability of ASHPLUME to model tephra deposits at Cerro Negro based on the 1995 eruption have been completed and are being documented. The results of the analysis are in good agreement with the observed ash distribution, and the agreement is considered to verify the utility of the model.
T5) Important site features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the airborne transport of RNs abstraction.	TSPA-SR Technical Report Section 3.10, DE PMR	The DE AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models.
Dilution of Radionuclides Due to Well Pumping	Related to KTI Subissue USFIC5[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the dilution of RNs due to well pumping abstraction in the TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.9, SZFT PMR, Biosphere PMR, *Groundwater Usage by the Proposed Farming Community* AMR	Section 3.9 of the TSPA-SR Technical Report describes the Biosphere conceptual model. Included in this section is a discussion of the treatment of uncertainty and variability. In the SZFT PMR, dilution in water supply in abstraction of radionuclide transport is discussed in Section 3.6.3. The element of dilution of radionuclides in groundwater due to well pumping is addressed in the biosphere process by an alternative approach based on an approximation that removes uncertainty associated with dilution due to pumping dynamics. This approach is consistent with information presented in the statement of consideration to the proposed rule 10 CFR 63. Water usage is discussed in Section 3.4 of the Biosphere PMR. 10 CFR 63.115 provides a reference biosphere and receptor group criterion that allow use of a simple model that avoids speculation associated with detailed dilution modeling. The average annual concentration of the radionuclides in the groundwater is derived by distributing the mass of radionuclides crossing the 20-km boundary annually uniformly over the total annual water usage. The biosphere effort described in this document derived the annual volume of water estimated to be used by the community. The SZFT PMR developed the mass of each radionuclide crossing the 20-km boundary annually. The TSPA code divides the latter by the former to derive the annual average concentration from which the annual expected dose to an average member of the critical group is obtained when multiplied by the BDCFs. In deriving the annual water usage, this element is addressed to the extent possible with the simplistic but conservative dilution model found in the groundwater usage AMR (*Groundwater Usage by the Proposed Farming Community*). In addition, the TSPA assumes that all the mass of radionuclides crossing the 20-km boundary is captured in the pumped water.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the dilution of RNs in groundwater due to well pumping abstraction, such as the pumping well characteristics and water usage by the receptor groups, are technically defensible and account for uncertainty and variability.	TSPA-SR Technical Report Section 3.9, SZFT PMR, Biosphere PMR	Section 3.9 of the TSPA-SR Technical Report describes the Biosphere conceptual model. Included in this section is a discussion of the treatment of uncertainty and variability. The SZFT AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. Effective integration of the Biosphere into the TSPA, as described in Section 3.9.2, also helps ensure the consistent use of values. Also see T1 above for discussion of how the Biosphere PMR addresses acceptance criteria for this subissue.
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the dilution of RNs in groundwater due to well pumping abstraction.	TSPA-SR Technical Report Section 3.9, SZFT PMR, Biosphere PMR	See T1 above for discussion of how the Biosphere PMR addresses acceptance criteria for this subissue. In the SZFT PMR, Section 3.8 discusses other views and alternative models.
T4) Dilution of RNs due to well pumping abstraction output is justified through comparison to outputs of detailed process models or empirical observations (laboratory test).	TSPA-SR Technical Report Section 3.9, SZFT PMR, Biosphere PMR	See T1 above for discussion of how the Biosphere PMR addresses acceptance criteria for this subissue. In the SZFT PMR, validation is discussed in Section 3.4.
T5) PA analyses incorporate important hydrogeologic features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the dilution of RNs due to well pumping abstraction.	TSPA-SR Technical Report Section 3.9, SZFT PMR, Biosphere PMR	The Biosphere and SZFT AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models. Also see T1 above for discussion of how the Biosphere PMR addresses acceptance criteria for this subissue.
Redistribution of Radionuclides in Soil	Related to KTI Subissue IA2[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models necessary for developing the redistribution of RNs in soil abstraction in TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	TSPA-SR Technical Report Section 3.10, Biosphere PMR	Section 3.10.3 of the TSPA-SR Technical Report describes processes that must be considered after the ash is deposited including ash resuspension, redistribution and erosion, as well as radionuclide uptake in plants and animals. The Biosphere PMR discusses the abstraction of the soil processes in Section 3.3.1.1. The soil analysis incorporates representative sandy soil Kd values and other parameter values including bulk soil density, precipitation, evaporation, and irrigation rate based on data from the Amargosa Valley to calculate leaching coefficients and the rates of soil removal by erosion. These parameters support the analysis of soil build up and erosion processes affecting the BDCF abstractions for TSPA-SR. The SZFT PMR has been developed in accordance with applicable QA procedures (see SZFT PMR Section 1.4) for documenting data, analysis, models, and computer code, and preparing and reviewing technical reports.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the redistribution of RNs in soil abstraction, such as depth of the plowed layers and mass loading factor, are technically defensible and reasonably account for uncertainties and variability.	TSPA-SR Technical Report Section 3.10, Biosphere PMR, *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* AMR, *Abstraction of BDCF Distributions for Irrigation Periods* AMR	Implementing procedures compliant with the QARD controls DOE's development of parameter values, assumed ranges, probability distributions and bounding assumptions. These procedures require measures intended to help ensure technical defensibility and appropriate accounting for uncertainties and variabilities. The AMRs and PMR for the Biosphere PMR have been developed in accordance with these procedures. The *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* AMR addresses soil parameters. The *Abstraction of BDCF Distributions for Irrigation Periods* AMR describes how the build-up due to irrigation and erosion due to other processes are abstracted for use in TSPA code. Section 3.3.1.1 of the Biosphere PMR summarizes the abstraction process.
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and their results and limitations appropriately factored into the redistribution of RNs in soil abstraction.	TSPA-SR Technical Report Section 3.10, Biosphere PMR, *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* AMR	The Biosphere AMR, *Evaluate Soil/Radionuclide Removal by Erosion and Leaching,* addresses selection of parameter values and alternative approaches to evaluation of soil erosion and build-up. The analysis of soil processes is coupled with the BDCF abstraction to account for radionuclide build-up/erosion for use in TSPA.
T4) Redistribution of RNs in soil output is justified through comparison to output of detailed process models or empirical observations (laboratory testings, natural analogs, or both).	TSPA-SR Technical Report Section 3.10, Biosphere PMR	Evaluation of soil processes for dilution of radionuclides is based to the extent practical on analog processes. Section 3.2.4.1.2. of the Biosphere PMR discusses soil parameters pertinent to the biosphere model. Abstraction of BDCF distributions for irrigation periods couples the soil erosion processes with irrigation period build-up or radionuclides as discussed in Section 3.3.1.1 of the Biosphere PMR.
T5) Important site features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the redistribution of RNs in soil abstraction.	TSPA-SR Technical Report Section 3.10, Biosphere PMR	The Biosphere AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained among the various TSPA models. Abstraction of BDCF distributions for irrigation periods couples the soil erosion processes with irrigation period build-up or radionuclides as discussed in Section 3.3.1.1 of the Biosphere PMR. Consistent and appropriate assumptions have been applied to analysis of soil process for calculation of BDCFs for use in TSPA.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
Lifestyle of the Critical Group	Related to KTI Subissues USFIC1, USFIC2, USFIC3, USFIC5, RT3, IA2[1]	
T1) Sufficient data (field, laboratory, or natural analog data) are available to adequately define relevant parameters and conceptual models as necessary for developing the lifestyle of critical group abstraction in TSPA. Where adequate data do not exist, other information sources such as expert elicitation have been appropriately incorporated into the TSPA.	Biosphere PMR, TSPA-SR Technical Report Section 3.9	Section 3.9 of the TSPA-SR Technical Report describes the Biosphere. This section includes a description of how FEPs have been screened to identify those that are relevant to the biosphere in the vicinity of Yucca Mountain. Section 3.9.1 provides a description of the definition of the receptor including the characteristics of the receptor, the critical group and the local environment. Section 3.1.2.1 of the Biosphere PMR describes the data used to identify the critical group to support TSPA. The 1997 dietary survey data is used to characterize consumption for the critical group. Bureau of Census data is used to characterize other lifestyle characteristics of the critical group. These data are sufficient to adequately quantify parameters for the critical group. Characteristics of the human receptor related to the key exposure pathways are discussed in Section 3.2.4.2.
T2) Parameter values, assumed ranges, probability distributions, and bounding assumptions used in the lifestyle of critical group abstraction such as consumption rates, plant and animal uptake factors, mass loading factors, and BDCFs are technically defensible and reasonably account for uncertainties and variability.	TSPA-SR Technical Report Section 3.9, Biosphere PMR	Section 3.9 of the TSPA-SR Technical Report describes the Biosphere. This section includes a description of the integration of the Biosphere into the TSPA. Implementing procedures compliant with the QARD controls DOE's development of parameter values, assumed ranges, probability distributions and bounding assumptions. Section 3.2.4 of the Biosphere PMR discusses parameters pertaining to the environmental transport of radionuclides and characteristics of the human receptor. Biosphere AMRs provide a detailed description of parameter value for determination of critical group. Parameter values and associated ranges and distributions considered in the lifestyle of critical group abstractions are defensible and reasonable. The Biosphere AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency.
T3) Alternative modeling approaches consistent with available data and current scientific understanding are investigated and results and limitations appropriately factored into the lifestyle of critical group abstractions.	TSPA-SR Technical Report Section 3.9, Biosphere PMR	The Biosphere PMR conceptual approach to the critical group is qualitative. The DOE guidance for identification of the critical group (Dyer 1999 [105655], enclosure, Section 115[b]) is consistent with the NRC's proposed rule at 10 CFR 63.115(b) (64 FR 8640 [101680]). To select a critical group, individuals likely to be at the highest risk from among the exposed population were specified. An analysis constructed four screening groups that encompass the range of diet, lifestyle, and land use characteristics expected to be found in the region surrounding Yucca Mountain. The screening groups were analyzed against known data. The potential exposure of the screening groups was qualitatively evaluated. The relative ranking, by exposure potential of essential characteristics and attributes of the screening groups was determined. These four screening groups and their associated attributes are discussed in Section 3.1.2.2 of the Biosphere PMR.

Table D.1-4. Total System Performance Assessment and Integration Issue Resolution Status Report Rev. 2 Acceptance Criteria (Continued)

TSPAI IRSR REV. 2 Acceptance Criteria	Related Documentation	Approach
T4) Dose calculation output pertaining to lifestyle of the critical group is justified through comparison to output of detailed process models, and/or empirical observations (field data, laboratory data, or natural analogs).	TSPA-SR Technical Report Section 3.9, Biosphere PMR	Section 3.9.2 of the TSPA-SR Technical Report provides the principal results of the biosphere modeling work. The results are expressed as the amount of radiation dose received annually by the receptor for each unit of radioactivity concentration introduced into the Biosphere. Section 3.3 of the Biosphere PMR describes the development of the biosphere dose conversion factors for input to the TSPA code for calculation of expected annual doses.
T5) Important site features, physical phenomena and couplings, and consistent and appropriate assumptions are incorporated into the lifestyle of the critical group abstraction.	TSPA-SR Technical Report Section 3.9, Biosphere PMR	The Biosphere AMRs document assumptions, important site features, and physical phenomena and couplings. These documents have been subjected to thorough interdisciplinary reviews to help ensure consistency. In addition, the PMRs that summarize and integrate the results of the AMRs have been subjected to a review by a single review team. One of the main objectives of this review was to identify inconsistencies among PMRs. These measures provide confidence that consistency is maintained as appropriate among the various TSPA models.
SUBISSUE 4 - Demonstration of the Overall Performance Objective		
The final requirements for the overall performance objective will be established after the rule is published in final form.		

Table D.1.5. Crosswalk of Key Technical Issues to Process Model Reports

KTI * Subissues	Process Model Report								
	Biosphere[1]	Disruptive Events (DE)[2]	Engineered Barrier System (EBS)[3]	Near-Field Environment (NFE)[4]	SZ Flow and Transport (SZ)[5]	UZ Flow and Transport (UZ)[6]	Waste Form (WF)[7]	Waste Package (WP)[8]	ISM
USFIC1						■			
USFIC2					▒	■			
USFIC3						■			
USFIC4						■			
USFIC5					■				
USFIC6					■	■			
TEF1			▒	■					
TEF2			■	▒		■			
TEF3			■			■			
ENFE1			▒	▒		▒			
ENFE2			■	▒					
ENFE3			■				■		
ENFE4			■	▒		■			
ENFE5	(The subissue of criticality is addressed in a topical report on nuclear criticality and supporting documents.)								
CLST1			▒					■	
CLST2		▒						■	
CLST3			▒				■		
CLST4			▒				■		
CLST5	(The subissue of criticality is addressed in a topical report on nuclear criticality and supporting documents.)								
CLST6		▒	▒					▒	
RT1, Rev 1						▒			
RT2, Rev 1					■				
RT3, Rev 1					▒	■			
RT4, Rev 1	(The subissue of criticality is addressed in a topical report on nuclear criticality and supporting documents.)								
TSPAI1	▒	▒	▒	▒	▒	▒	▒	▒	
TSPAI2	■	■	■	■	■	■	■	■	
TSPAI3	▒	▒	▒	▒	▒	▒	▒	▒	
TSPAI4	(Criteria for this subissue will be established after the rule is published in final form.)								
IA1		■							
IA2	■	■							
SDS1		■							
SDS2		■							
SDS3					▒	■			
SDS4		■							
RDTME1	(Criteria for this subissue are elements of the Design Control part of the Quality Assurance program addressed in Section 3 of the QARD.)								
RDTME2	(This subissue will be addressed in the Seismic Topical Report.)								
RDTME3			▒	▒					
RDTME4	(Criteria for this subissue have not yet been developed.)								

■ The subissue is completely applicable to the PMR.

▒ The subissue is partially applicable to the PMR.

Source: [1]CRWMS M&O 2000 [151615], [2]CRWMS M&O 2000 [141733], [3]CRWMS M&O 2000 [145796], [4]CRWMS M&O 2000 [146589], [5]CRWMS M&O 2000 [145738], [6]CRWMS M&O 2000 [145774], [7]CRWMS M&O 2000 [138332], [8]CRWMS M&O 2000 [138396]

NOTE: QARD = *Quality Assurance Requirements and Description* (DOE 2000 [149540])

D.2 ISSUE RESOLUTION STATUS REPORTS TRACKING DATABASE - A MICROSOFT ACCESS 97 DATABASE

The IRSR Tracking Database was developed by using Microsoft Access 97. This Access database includes tables, queries, forms, reports, switchboard, macro, and modules. The information of IRSR Tracking Database is mainly stored in tables. Query is a tool for search. Forms are for data entry or update. Reports sorted and organized by different elements can also be found in the database.

D.2.1 ACCESS TABLES

There are four key tables included in the database. The Access tables can be exported to Microsoft Excel as well as other databases (e.g., Paradox, dBase).

D.2.1.1 Issue Resolution Status Reports Acceptance Criteria and Integrated Subissues Tables

The IRSR Acceptance Criteria table includes all of the acceptance criteria. The IRSR Acceptance Criteria table is able to link with the IRSR GODO Database that includes all IRSR Acceptance Criteria, NRC review methods, and NRC expectations. Additionally, an ISI table is created to link ISIs with KTI subissues.

D.2.1.2 Repository Safety Strategy 4 Table

The process model factors and FEPs are included in the RSS4 table. Since the RSS4 Workshop provides the list of process model factors and screened FEPs for the nominal scenario, the table is entitled RSS4.

D.2.1.3 Mapping Table

The Mapping table provides a roadmap to link PMR and process model factors with IRSR acceptance criteria. The PMRs responses to applicable IRSR acceptable criteria are also included. By using the "relationship" function provided in Access 97, detailed information of PMR, process model factors, FEPs, and IRSR acceptance criteria from the linked database or tables can be obtained. For example, since both RSS4 and Mapping tables consist of process model factors, the Mapping table can relate to the RSS4 table for FEP data. By using the same relationship function, the Mapping table can relate to IRSR Acceptance Criteria table for the detailed acceptance criteria.

D.2.1.4 Performance Assessment Operations Summary Table

Most of the data in the Performance Assessment Operations summary table are obtained from Total System Performance Assessment-Site Recommendation Methods and Assumptions (CRWMS M&O 1999 [123126]), issued in 1999. The data fields of this table consist of the following:

- Key Attributes of System
- RSS/Process Model Factor

- Process Model Report
- TSPA component
- NRC KTI
- NRC Components of Subsystem
- KESA (revised to ISI)
- Analysis and Model Report
- PA Lead
- IRSR Licensing Lead
- PMR Licensing Lead.

D.2.2 ACCESS REPORTS

Access 97 Report is designed for sorting, formatting, summarizing selected data, and others. Access reports can be exported to Microsoft Word. IRSR tracking reports have been sorted by KTI, PMR, and Key Attributes of System. Due to the complex nature of the IRSR tracking database, the IRSR tracking report may consist of several subreports with a total page count of 150 or more. Therefore, no IRSR tracking report is attached to this document.

D.2.3 LINK TO OTHER ACCESS DATABASES

The IRSR Tracking Database is also designed to link with the FEP Database and IRSR GODO Database. The FEP number and IRSR number have been included in the IRSR tracking database. The IRSR Tracking Database can relate to IRSR Acceptance Criteria table for the detail acceptance criteria as well as to FEP Database for specific FEP information.

D.3 WORKING WITH ISSUE RESOLUTION STATUS REPORTS TRACKING DATABASE

The IRSR Tracking Database provides a useful tool to assess how PMRs address IRSR acceptance criteria. A switchboard is built to give the user direct access to the common analysis, such as KTI subissues and process model factors analysis and analysis of acceptance criteria that have not been addressed in the database. The results of both analyses are discussed below.

D.3.1 KEY TECHNICAL ISSUES SUBISSUES AND PROCESS MODEL FACTORS ANALYSIS

In the IRSR tracking database, process model factors are assigned to KTI subissues creating a link from KTI subissues, process model factors, to FEPs. The summary of the KTI subissues addressed by PMR(s) and process model factors(s) is presented in Table D.3-1. It should be mentioned that the subissue title in each IRSR is slightly different from Appendix B, List of Subissues in NRC Key Technical Issues, in TSPA&I IRSR Rev 2 (NRC 2000 [149372]).

Table D.3-1. Summary of Process Model Reports and Process Model Factors that Address Nine Issue Resolution Status Report Key Technical Issues

KTI Subissue	PMR	RSS4/Process Model Factor
Container Lifetime and Source Term (CLST) IRSR		
Acceptance criteria applicable to all six subissues	DE[1]	All DE process model factors
	EBS[2]	All EBS process model factors
	Waste Form[3]	All WF process model factors
	Waste Package[4]	All WP process model factors
CLST 1: Effects of Corrosion Processes on Container Lifetime	EBS[2]	In-Drift Moisture Distribution
	Waste Package[4]	Waste Package Degradation and Performance
CLST 2: Effects of Phase Instability and Initial Defects on Mechanical Failure and Container Lifetime	Disruptive Events[1]	All DE process model factors
	Waste Package[4]	Waste Package Degradation and Performance
CLST 3: Rate of SNF Radionuclide Release from EBS	EBS[2]	In-Drift Physical and Chemical Environment
	Waste Form[3]	Commercial Spent Nuclear Fuel Degradation and Performance
CLST 4: Rate of HLW Glass Radionuclide Release from EBS	EBS[2]	In-Drift Moisture Distribution
	Waste Form[3]	Defense High-Level Radioactive Waste Degradation and Performance
CLST 5: Effects of In-Package Criticality on WP and EBS Performance	(The subissue of criticality is addressed in a topical report on nuclear criticality and supporting documents.)	
CLST 6: Effects of Alternative EBS Designs on Container Lifetime and Radionuclide Release	Disruptive Events[1]	All DE process model factors
	EBS[2]	In-Drift Physical and Chemical Environment
	Waste Package[4]	Waste Package Degradation and Performance
Evolution of the Near-Field Environment (ENFE) IRSR		
ENFE 1: The Effects of Coupled Thermal-Hydrologic-Chemical Processes on Seepage and Flow	EBS[2]	In-Drift Moisture Distribution
	Near-Field Environment[5]	Coupled Effects on Seepage
	UZ Flow and Transport[6]	Coupled Effects on UZ Flow
ENFE 2: Effects of Coupled Thermal-Hydrologic-Chemical Processes on the Waste Package Chemical Environment	EBS[2]	In-Drift Physical and Chemical Environment
	Near-Field Environment[5]	Coupled Effects on Seepage
ENFE 3: The Effects of Coupled Thermal-Hydrologic-Chemical Processes on the Chemical Environment For Radionuclide Release	EBS[2]	In-Drift Physical and Chemical Environment
	Near-Field Environment[5]	Coupled Effects on UZ Radionuclide Transport
	Waste Form[3]	In-Package Environments

Table D.3-1. Summary of Process Model Reports and Process Model Factors that Address Nine Issue Resolution Status Report Key Technical Issues (Continued)

KTI Subissue	PMR	RSS4/Process Model Factor
ENFE 4: The Effects of Coupled Thermal-Hydrologic-Chemical Processes on Radionuclide Transport Through Engineered and Natural Barriers	EBS[2]	In-Drift Physical and Chemical Environment
	Near-Field Environment[5]	Coupled Effects on UZ Radionuclide Transport
	UZ Flow and Transport[6]	Coupled Effects on UZ Flow
ENFE 5: Coupled Thermal-Hydrologic-Chemical Processes Affecting Potential Nuclear Criticality in the Near Field	(The subissue of criticality is addressed in a topical report on nuclear criticality and supporting documents.)	
Igneous Activity (IA) IRSR		
IA 1: Probability of Future Igneous Activity	Disruptive Events[1]	Igneous Activity
IA 2: Consequences of Igneous Activity Within the Repository Setting	Biosphere[7]	Biosphere Dose Conversion Factors
	Disruptive Events[1]	Igneous Activity
Radionuclide Transport (RT) IRSR		
RT 1: Radionuclide Transport Through Porous Rock	SZ Flow and Transport[8]	SZ Radionuclide Transport
	UZ Flow and Transport[6]	Coupled Effects on UZ Flow
RT 2: Radionuclide Transport Through Alluvium	SZ Flow and Transport[8]	SZ Radionuclide Transport
RT 3: Radionuclide Transport Through Fractured Rock	SZ Flow and Transport[8]	SZ Radionuclide Transport
	UZ Flow and Transport[6]	Coupled Effects on UZ Flow
RT 4: Nuclear Criticality in the Far Field	(This subissue of criticality is addressed in topical report on nuclear criticality and supporting documents.)	
Repository Design and Thermal Mechanical Effects (RDTME) IRSR		
RDTME 1: Implementation of an Effective Design Control Process within the Overall Quality Assurance Program	(Criteria for this subissue are elements of the Design Control part of the QA program addressed in Chapter 3 of the QARD [DOE 2000 [149540]).	
RDTME 2: Design of the Geologic Repository Operations Area for the Effects of Seismic Events and Direct Fault Disruption	(This subissue will be addressed in Seismic Topical Report.)	
RDTME 3: Thermal-Mechanical Effects on Underground Facility Design and Performance	EBS[2]	In-Drift Physical and Chemical Environment
	Near-Field Environment[5]	Coupled Effects on UZ Flow

Table D.3-1. Summary of Process Model Reports and Process Model Factors that Address Nine Issue Resolution Status Report Key Technical Issues (Continued)

KTI Subissue	PMR	RSS4/Process Model Factor
Structural Deformation and Seismicity (SDS) IRSR		
SDS 1: Faulting	Disruptive Events[1]	Seismic Activity
SDS 2: Seismicity	Disruptive Events[1]	Seismic Activity
SDS 3: Fracturing and Structural Framework of the Geologic Setting	SZ Flow and Transport[8]	SZ Flow
	UZ Flow and Transport[6]	UZ Flow
SDS 4: Tectonic Framework of the Geologic Setting	Disruptive Events[1]	Igneous Activity
Thermal Effects on Flow (TEF) IRSR		
TEF 1: Sufficiency of thermal-hydrologic testing program to assess thermal reflux in the near field	EBS[2]	In-Drift Physical and Chemical Environment
	Near-Field Environment[5]	All NFE process model factors
TEF 2: Sufficiency of thermal-hydrologic modeling to predict the nature and bounds of thermal effects on flow in the near field	EBS[2]	In-Drift Physical and Chemical Environment
	Near-Field Environment[5]	Coupled Effects on Seepage
	UZ Flow and Transport[6]	Coupled Effects on UZ Flow
TEF 3: Adequacy of total system performance assessment with respect to thermal effects on flow	EBS[2]	In-Drift Physical and Chemical Environment
	UZ Flow and Transport[6]	Coupled Effects on UZ Flow
Unsaturated Zone (UZ) and Saturated Zone (SZ) Flow Under Isothermal Conditions (USFUIC) IRSR		
USFIC1: Climate Change	UZ Flow and Transport[6]	Climate
USFIC2: Hydrologic Effects of Climate Change	SZ Flow and Transport[8]	SZ Flow
	UZ Flow and Transport[6]	Climate
USFIC3: Present-Day Shallow Infiltration	UZ Flow and Transport[6]	Net Infiltration
USFIC4: Deep Percolation (Present and Future [Post-Thermal Record])	UZ Flow and Transport[6]	Seepage into Emplacement Drifts
USFIC5: Saturated Zone Ambient Flow Conditions and Dilution Processes	SZ Flow and Transport[8]	SZ Flow
USFIC6: Matrix Diffusion	SZ Flow and Transport[8]	SZ RT
	UZ Flow and Transport[6]	Coupled Effects on Seepage

Table D.3-1. Summary of Process Model Reports and Process Model Factors that Address Nine Issue Resolution Status Report Key Technical Issues (Continued)

KTI Subissue	PMR	RSS4/Process Model Factor
Total System Performance Assessment and Integration (TSPAI) IRSR, Rev 1		
TSPAI1: Demonstration of the overall performance objective (TSPAI4, in Revision 2)	(Criteria for this subissue will be established after the rule is published in final form.)	
TSPAI2: Demonstration of Multiple Barriers (TSPAI1, in Revision 2)	(Criteria for this subissue developed in Revision 2 of the IRSR were not available during the preparation of PMRs.)	
TSPAI3: Model Abstraction (TSPAI3, in Revision 2)	All	All
TSPAI4: Scenario analysis (TSPAI2, in Rev 2)	All	All

Source: [1]CRWMS M&O 2000 [141733], [2]CRWMS M&O 2000 [145796], [3]CRWMS M&O 2000 [138332], [4]CRWMS M&O 2000 [138396], [5]CRWMS M&O 2000 [146589], [6]CRWMS M&O 2000 [145774], [7]CRWMS M&O 2000 [151615], [8]CRWMS M&O 2000 [145738]

Because TSPA&I IRSR Rev 2 (NRC 2000 [149372]) was issued after the PMRs were prepared, the field of PMR Approach and Section Reference in the current IRSR tracking database addresses TSPA&I IRSR, Rev 1 (NRC 1999 [103760]).

D.3.2 ACCEPTANCE CRITERIA HAVE NOT BEEN ADDRESSED

Using a query to select the blank cells of PMR Approach and Section Reference field can screen out the acceptance criteria that have not been addressed by PMRs. The query result of the IRSR tracking database shows that all of the applicable acceptance criteria have been addressed by PMRs.

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APPENDIX E

ANALYSES MODEL AND DATA TRACEABILITY

APPENDIX E

ACRONYMS AND ABBREVIATIONS

AMR	Analysis Model Report
ADTN	automated data tracking number
CSNF	commercial spent nuclear fuel
DIRS	Document Input Reference System
DOE	U.S. Department of Energy
DSNF	DOE-owned spent nuclear fuel
DTN	data tracking number
EBS	engineered barrier system
FEHM	finite element heat and mass
HIC	hydrogen induced cracking
HLW	high-level radioactive waste
NFE	near-field environment
NQ	not qualified
PMR	Process Model Report
RIP	Repository Integrated Performance model
SCC	stress corrosion cracking
SZ	saturated zone
TH	thermal hydrologic
TSPA	total system performance assessment
UZ	unsaturated zone

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APPENDIX E

ANALYSES MODEL AND DATA TRACEABILITY

The traceability of information from the Total System Performance Assessment–Site Recommendation back to its supporting documents is presented in this appendix. Several different approaches may be used to illustrate the traceability of the technical information used as the basis for the TSPA-SR. The individual sections of Chapter 3 have detailed the major inputs and assumptions used in the TSPA-SR. In this attachment, the sources of information and the flow of information in the TSPA-SR model are summarized. Additional details of the technical basis for the information in the TSPA-SR model may be found in the TSPA-SR Model Document (CRWMS M&O 2000 [148384]).

The primary technical input from each of the individual component parts of the TSPA-SR are contained in a hierarchy of Analysis/Model Reports (AMRs). The output of the source AMRs was either a data set (represented by a Data Tracing Number [DTN]) or an analytical expression or model that is implemented in the construct of the TSPA-SR model. Table E-1 summarizes each of the AMRs and corresponding DTNs that provided primary source information to the TSPA-SR. The AMRs represented on this table correspond to the source AMR used as the input as identified on the Document Input Reference System (DIRS) for the TSPA-SR Model Document (CRWMS M&O 2000 [148384]). The DTNs identified on this table correspond to the source DTNs used as direct input to the TSPA-SR Model. Generally, the DTN is created in the corresponding AMR. However, in some cases as noted in the footnote to this table, the source DTN is not derived directly from the applicable reference document. In these cases, the reference document discusses the applicability and appropriateness of the cited DTN for the purposes of evaluating the long-term performance of the potential Yucca Mountain repository system.

Figure E-1 shows schematically the integration of the AMR feeds within the TSPA-SR model itself. Each of the colored boxes on the figure represents one or more AMRs that directly feeds the TSPA model. The legend identifies the Process Model Report (PMR) category that each AMR supports, with each color representing a different PMR.

Both Table E-1 and Figure E-1 depict the final analyses, model and data feeds into the TSPA-SR model. It is important to recognize that these final feeds are built on a hierarchy of supporting AMRs, calculations, data and software that are contained in a family of supporting AMRs and their associated DTNs. Figures E-2 through E-7 depict the entire hierarchy of AMRs and DTNs that form the entire scientific basis for the TSPA-SR. This volume of work is summarized in the PMRs, discussed in Section 3.1. As with Figure E-1, these lower level model integration figures were developed by tracing the data and information flow through the DIRS and the Automated Technical Data Tracking (ATDT) system. The information available in these document and data tracking systems as of August 31, 2000 was used as the basis for these figures. As the supporting analyses and models are changed or revised, the actual information cited as being directly relied upon will also change.

The figures and tables that are presented here have been referred to as the "family trees" with the Total System Performance Assessment (TSPA) Model diagram. The purpose of the "family trees" is to show the interrelationships and integration of the AMRs that were used as inputs or information sources in developing the TSPA model. These "family trees" provide a more complete indication of the scientific basis for the analyses, models and data used in the development of the TSPA-SR model. It is beyond the scope of this document to summarize all of this technical information. That is the role of the nine individual PMRs. However, providing these roadmaps through the information flow leading up to the TSPA-SR allows the reader to trace the source information as far back as desired.

It bears noting that the family of AMRs that directly or indirectly support the TSPA-SR indicated on Figures E-1 through E-7 does not include a number of AMRs used to support feature, event and process screening arguments. These AMRs are indicated separately in Appendix B.

Table E-1. General Listing Inputs to the Total System Performance Assessment-Site Recommendation Model

Key System Attribute	Factor	Reference Document	Major Types of Input Parameters to the TSPA-SR	Data Tracking Number
Limiting Water contacting waste package	Climate	*Future Climate Analysis* (USGS 2000 [136368])	Climate states Timing and sequence	GS000308315121.003 [151139]
	Infiltration	*Analysis of Infiltration Uncertainty* (CRWMS M&O 2000 [143244])	Probabilities for different infiltration scenarios	SN0003T0503100.001 [149556]
	UZ flow above potential repository	*Abstraction of Flow Fields for RIP* (CRWMS M&O 2000 [123913])	Flow fields for different infiltration scenarios and climate states	SN9910T0581699.002 [126110]
	Seepage into drifts	*Abstraction of Drift Seepage* (CRWMS M&O 2000 [142004])	Seepage flux and seepage fraction as a function of percolation flux	SN9912T0511599.002 [146902]
		Draft of AMR Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux (CRWMS M&O 2000 [152204])	Percolation flux – f (multiple locations, waste type, time, climate)	SN0001T0872799.006 [147198]
	Coupled processes - effects on UZ flow	*Drift Scale Coupled Processes (DST and THC Seepage) Models* (CRWMS M&O 2000 [142022])	Flow fields affected by TH	N/A – Background Information Only
	Coupled processes - effects on seepage	*Abstraction of Drift Seepage* (CRWMS M&O 2000 [142004])	Seepage flux and seepage fraction as a function of percolation flux	SN9912T0511599.002 [146902]
		Draft of AMR Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux (CRWMS M&O 2000 [152204])	Percolation flux – f (multiple locations, waste type, time, climate)	SN0001T0872799.006 [147198]
	In-drift physical and chemical environments	*Draft of AMR Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux* (CRWMS M&O 2000 [152204])	Temperature and relative humidity on the drip shield surface – f (multiple locations, waste type, time, climate)	SN0001T0872799.006 [147198]

Table E-1. General Listing Inputs to the Total System Performance Assessment-Site Recommendation Model (Continued)

Key System Attribute	Factor	Reference Document	Input Parameters to TSPA-SR	Data Tracking Number
Limiting Water contacting waste package (Continued)	In-drift physical and chemical environments (Continued)	*In-Drift Precipitates/Salts Analysis* (CRWMS M&O 2000 [127818])	pH – f (region, time), response surface Chloride – f (region, time)	MO0002SPALO046.010 [149168]
	In-drift moisture distribution	*EBS Radionuclide Transport Abstraction* (CRWMS M&O 2000 [129284])	Seepage flux through the drip shield Fraction of drip shield surface that is wet	N/A – Equations
	Performance of drip shield	*Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier* (CRWMS M&O 2000 [146460])	Threshold for general corrosion initiation	LL991212305924.108 [144927]
		Calculation of General Corrosion Rate of Drip Shield and Waste Package Outer Barrier to Support WAPDEG Analysis (CRWMS M&O 2000 [147641])	General corrosion rate under drip and no-drip conditions	MO0003SPASUP02.003 [147299]
		WAPDEG Analysis of Waste Package and Drip Shield Degradation (CRWMS M&O 2000 [146427])	Drip shield geometry and thickness Drip shield failure time history Number of penetration openings in drip shield by general corrosion, crevice corrosion, SCC, HIC, and other degradation modes	N/A – Design information and WAPDEG Outputs
Long Waste package lifetime	Moisture, temperature, and chemistry effects on waste package	*In-Drift Precipitates/Salts Analysis* (CRWMS M&O 2000 [127818])	pH – f (region, time, response surface) Chloride – f (region, time, response surface) Ionic Strength	MO0002SPALO046.010 [149168]
		Draft of AMR *Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux* (CRWMS M&O 2000 [152204])	Average and maximum temperature on waste package surface – f (waste type, region, time, climate) Temperature and relative humidity on waste package surface – f (multiple locations, waste type, time, climate, infiltration)	SN0001T0872799.006 [147198]

Table E-1. General Listing Inputs to the Total System Performance Assessment-Site Recommendation Model (Continued)

Key System Attribute	Factor	Reference Document	Input Parameters to TSPA-SR	Data Tracking Number
Long Waste package lifetime (Continued)	Moisture, temperature, and chemistry effects on waste package (Continued)	*EBS Radionuclide Transport Abstraction* (CRWMS M&O 2000 [129284])	Seepage flux through waste package Fraction of waste package surface that is wet	N/A – Equations
	Performance of waste package barrier	*WAPDEG Analysis of Waste Package and Drip Shield Degradation* (CRWMS M&O 2000 [146427])	Waste package geometry Thickness of waste package barriers Waste package failure time history Number of penetration openings in waste package by general corrosion, crevice corrosion, SCC, and other degradation modes	N/A – Design Input and WAPDEG Output
		Aging and Phase Stability of Waste Package outer Barrier (CRWMS M&O 2000 [147639])	Kinetics of secondary phase formation in base metal and weld of waste package outer barrier Threshold secondary phase volume fraction above which corrosion resistance of waste package outer barrier is affected	N/A – Equations
		Environment on the Surfaces of the Drip Shield and Waste Package Outer Barrier (CRWMS M&O 2000 [146460])	Threshold relative humidity for general corrosion initiation under drip (after drip shield failure) and no-drip conditions	LL991212305924.108 [144927]
		General Corrosion and Localized Corrosion of Waste Package Outer Barrier (CRWMS M&O 2000 [144229])	General corrosion rate under drip (after drip shield failure) and no-drip conditions	LL000112205924.112 [141284]

Table E-1. General Listing Inputs to the Total System Performance Assessment-Site Recommendation Model (Continued)

Key System Attribute	Factor	Reference Document	Input Parameters to TSPA-SR	Data Tracking Number
Long Waste package lifetime (Continued)	Performance of waste package barrier (Continued)	*Abstraction of Models for Pitting and Crevice Corrosion of Drip Shield and Waste Package Outer Barrier* (CRWMS M&O 2000 [147648]) *Abstraction of Models of Stress Corrosion Cracking of Drip Shield and Waste Package Outer Barrier and Hydrogen Induced Corrosion of Drip Shield* (CRWMS M&O 2000 [135773])	Crevice corrosion initiation threshold of waste package outer barrier Pit density (under crevice) Pit penetration rate (under crevice) Stress and stress intensity factor profile in waste package outer barrier SCC initiation threshold SCC crack density SCC crack growth rate Effect of material and manufacturing defects on SCC initiation and crack growth rate SCC crack penetration opening size Effect of phase stability and aging of waste package outer barrier on SCC initiation and crack growth rate	MO0003SPAPCC03.004 [148992]
		Calculation of the Probability and Size of defect flaws in the Waste Package closure welds to support WAPDEG Analysis (CRWMS M&O 2000 [144551])	Probability of the occurrence of material and manufacturing defects Size of material and manufacturing defects	MO0001SPASUP03.001 [144567]
Limiting Radionuclide mobilization and release from the engineered barrier system	Moisture, temperature, and chemistry effects within waste package	*In-Package Chemistry Abstraction* (CRWMS M&O 2000 [129287])	pH – f (region, time) Total dissolved carbonate (CO_3^{2}) – f (region, time) Oxygen fugacity – f (region, time) Ionic strength – f (region, time) Fluoride – f (region, time) CO_2 fugacity	MO9911SPACDP37.001 [139569]
		Draft of AMR In-Package Source Term Abstraction (CRWMS M&O 2000 [152213]	Volume of water in the waste package/waste form cell, calculated internal to GoldSim	N/A – calculated internal to GoldSim

Table E-1. General Listing Inputs to the Total System Performance Assessment-Site Recommendation Model (Continued)

Key System Attribute	Factor	Reference Document	Input Parameters to TSPA-SR	Data Tracking Number
Limiting Radionuclide mobilization and release from the EBS (Continued)	Commercial Spent Nuclear Fuel (CSNF) waste form (with cladding or canister) performance	*Inventory Abstraction* (CRWMS M&O 2000 [136383])	Number of packages Zircaloy-clad fuel Stainless steel-clad fuel Inventory per package (actual and adjusted for ingrowth) Mass fraction	SN0003T0810599.010 [151021]
		Clad Degradation – Summary and Abstraction (CRWMS M&O 2000 [147210])	Fraction of surface area of Zircaloy-clad CSNF exposed as a function of time	MO0004SPACLD07.043 [151368]
		CSNF Waste Form Degradation: Summary Abstraction (CRWMS M&O 2000 [136060])	CSNF intrinsic dissolution rate equation	N/A - Equation
	DOE Spent Nuclear Fuel (DSNF) and plutonium disposition waste form performance	*Inventory Abstraction* (CRWMS M&O 2000 [136383])	Number of packages Inventory per package (actual and adjusted for ingrowth) Mass fraction	SN0003T0810599.010 [151021]
		DSNF and Other Waste Form Degradation Abstraction (CRWMS M&O 2000 [144164])	DSNF constant dissolution rate DSNF fuel surface area	MO0003RIB00083.000 [150886]
	High Level Waste (HLW) glass waste form (including canister) performance	*Inventory Abstraction* (CRWMS M&O 2000 [136383])	Number of packages Inventory per package (actual and adjusted for ingrowth) Mass fraction	SN0003T0810599.010 [151021]
		Defense High Level Waste Glass Degradation (CRWMS M&O 2000 [143420])	HLW intrinsic dissolution rate equation Specific surface area	MO0007RIB00091.000 [151712]

Table E-1. General Listing Inputs to the Total System Performance Assessment-Site Recommendation Model (Continued)

Key System Attribute	Factor	Reference Document	Input Parameters to TSPA-SR	Data Tracking Number
Limiting Radionuclide mobilization and release from the EBS (Continued)	Dissolved radionuclide concentration limits	*Summary of Dissolved Concentration Limits* (CRWMS M&O 2000 [143569])	Concentration limits (solubilities) for all isotopes included in TSPA	MO0004SPASOL10.002 [151713]
	Colloid-associated radionuclide concentrations	*Waste Form Colloid-Associated Concentration Limits: Abstraction and Summary* (CRWMS M&O 2000 [125156])	Types of waste form colloids Concentration of colloids K_d and/or K_c for various colloid types Fraction of inventory that travels as irreversibly attached to colloids	MO0003SPAHIG12.002 [147949] MO0003SPAHLO12.004 [147952] MO0003SPAION02.003 [147951] MO0003SPALOW12.001 [147953] *LL991109851021.095 [142902] *MO0004SPAKDS42.005
	EBS radionuclide migration—transport through invert	*Draft of AMR Abstraction of NFE Drift Thermodynamic Environment and Percolation Flux* (CRWMS M&O 2000 [152204])	Thermally perturbed saturation in the invert – f (waste type, region, time, climate) Saturation in the invert after thermal pulse – f(time)	SN0001T0872799.006 [147198]
	EBS radionuclide migration—transport through invert (continued)	*EBS Radionuclide Transport Abstraction* (CRWMS M&O 2000 [129284])	Invert geometry Porosity of the invert Diffusion coefficient	*SN9908T0872799.004 [108437] *MO0002SPASDC00.002 [148338]
Slow Transport away from the EBS	UZ flow and transport—advective pathways	*Particle Tracking Model and Abstraction of Transport Processes* (CRWMS M&O 2000 [141418])	FEHM particle-tracking model coupled to GoldSim (LANL 1999 [146971]) Grid nodes for each bin	N/A – not data
		Unsaturated Zone and Saturated Zone Transport Properties (CRWMS M&O 2000 [141440])	Transport parameters Fracture aperture in different unitsDispersivity of fracturesDispersivity of matrix	LA0003AM831341.001 [148751] LA0003JC831362.001 [149557]
		Abstraction of Flow Fields for RIP (CRWMS M&O 2000 [123913])	Flow fields for different infiltration scenarios and climate states (FEHM input files for the particle-tracking model [LANL])	SN9910T0581699.002 [126110]

Table E-1. General Listing Inputs to the Total System Performance Assessment-Site Recommendation Model (Continued)

Key System Attribute	Factor	Reference Document	Input Parameters to TSPA-SR	Data Tracking Number
Slow Transport away from the EBS (Continued)	UZ flow and transport—sorption and matrix diffusion	*Unsaturated Zone and Saturated Zone Transport Properties* (CRWMS M&O 2000 [141440])	K_d for all isotopes included in TSPA Matrix diffusion coefficients – f (isotopes, units)	LA0003AM831341.001 [148751] (K_d) LA0003JC831362.001 [149557] (Matrix)
	UZ flow and transport—colloid-facilitated transport	*Unsaturated Zone Colloid Transport Model* (CRWMS M&O 2000 [122799])	K_c and/or kinetic colloid parameters for plutonium, americium, thorium, etc. Colloid filtration factor	*LA0003MCG12213.002 [147285]
	Coupled processes—effects on UZ transport	*Unsaturated Zone and Saturated Zone Transport Properties* (CRWMS M&O 2000 [141440])	K_ds – f (isotopes, rock type)	LA0003AM831341.001 [148751]
	SZ flow and transport—advective pathways	*Input and Results of the Base Case Saturated Zone Flow and Transport Model for TSPA* (CRWMS M&O 2000 [139440])	Breakthrough curves – f (radionuclide, region) Input parameters for convolution code Climate change flux multiplication factor Transport parameters Dispersivity (longitudinal, horizontal transverse, and vertical transverse) Boundary definition of the alluvium K_d for all isotopes included in TSPA Matrix porosity Flowing-interval spacing Effective diffusion coefficient Flowing interval Bulk density Source region definition Horizontal anisotropy K_c and/or kinetic parameters for plutonium desorption	SN0004T0501600.005 [151515] SN0002T0571599.002 [146931] TBV – 4431 SN0004T0571599.004 [149254] SNT05070198001.001 [143657]

Table E-1. General Listing Inputs to the Total System Performance Assessment-Site Recommendation Model (Continued)

Key System Attribute	Factor	Reference Document	Input Parameters to TSPA-SR	Data Tracking Number
Slow Transport away from the EBS (Continued)	Wellhead dilution	*Groundwater Usage by the Proposed Farming Community* (CRWMS M&O 2000 [144056])	Annual groundwater use	MO0003SPASGU01.003 [151075]
	Biosphere transport and uptake	*Abstraction of BDCF Distributions for Irrigation Periods* (CRWMS M&O 2000 [144054])	Biosphere dose conversion factor – f (radionuclide, irrigation time)	MO0003SPAABS07.006 [148872]
		Distribution Fitting to the Stochastic BDCF Data (CRWMS M&O 2000 [144055])	Biosphere dose conversion factor – f (radionuclide, irrigation time)	MO0003SPAABS08.004 [148453]
Addressing effects of disruptive events	Intrusive indirect release	*Igneous Consequence Modeling for the TSPA-SR* (CRWMS M&O 2000 [139563])	Number of waste packages damaged by intrusion (for groundwater transport source term) In-drift chemical conditions	*SN0001T0801500.001 [147818] *MO9912SPAPAI29.002 [148596]
	Volcanic direct release	*Characterize Framework for Igneous Activity at Yucca Mountain, Nevada (T0015)* (CRWMS M&O 2000 [141044])	Annual probability of igneous intrusion into the waste	LA0004FP831811.004 [151391]
		Igneous Consequence Modeling for the TSPA-SR (CRWMS M&O 2000 [139563])	Input parameters for ASHPLUME Probability that an intrusion into the waste will result in one or more eruptive vents through the waste Number of vents through the waste for intrusions that result in one or more vents through the waste Wind direction factor	SN0006T0502900.002 [150856]
		Disruptive Event Biosphere Dose Conversion Factor Analysis (CRWMS M&O 2000 [143378])	Biosphere dose conversion factors – f (radionuclide)	MO0002SPADVE03.001 [150755]

Table E-1. General Listing Inputs to the Total System Performance Assessment-Site Recommendation Model (Continued)

Key System Attribute	Factor	Reference Document	Input Parameters to TSPA-SR	Data Tracking Number
Addressing Effects of disruptive events (Continued)	Volcanic direct release (Continued)	*Evaluate Soil/Radionuclide Removal by Erosion and Leaching* (CRWMS M&O 2000 [136281])	Factor to account for radionuclide removal from soil	SN9912T0512299.002 [136370]
	Seismic activity	*Characterize Framework for Seismicity and Structural Deformation at Yucca Mountain, Nevada* (CRWMS M&O 1999 [130569])	Probability of seismicity and structural deformation	MO0004MWDRIFM3.002 [149092]

NOTES: N/A = not applicable; In some cases, indicated by an asterisk (*), the original source of the DTN is not the cited document. In these cases, the cited document is the source of the background information, and the DTN is the number which covers the input data in the ATDT.

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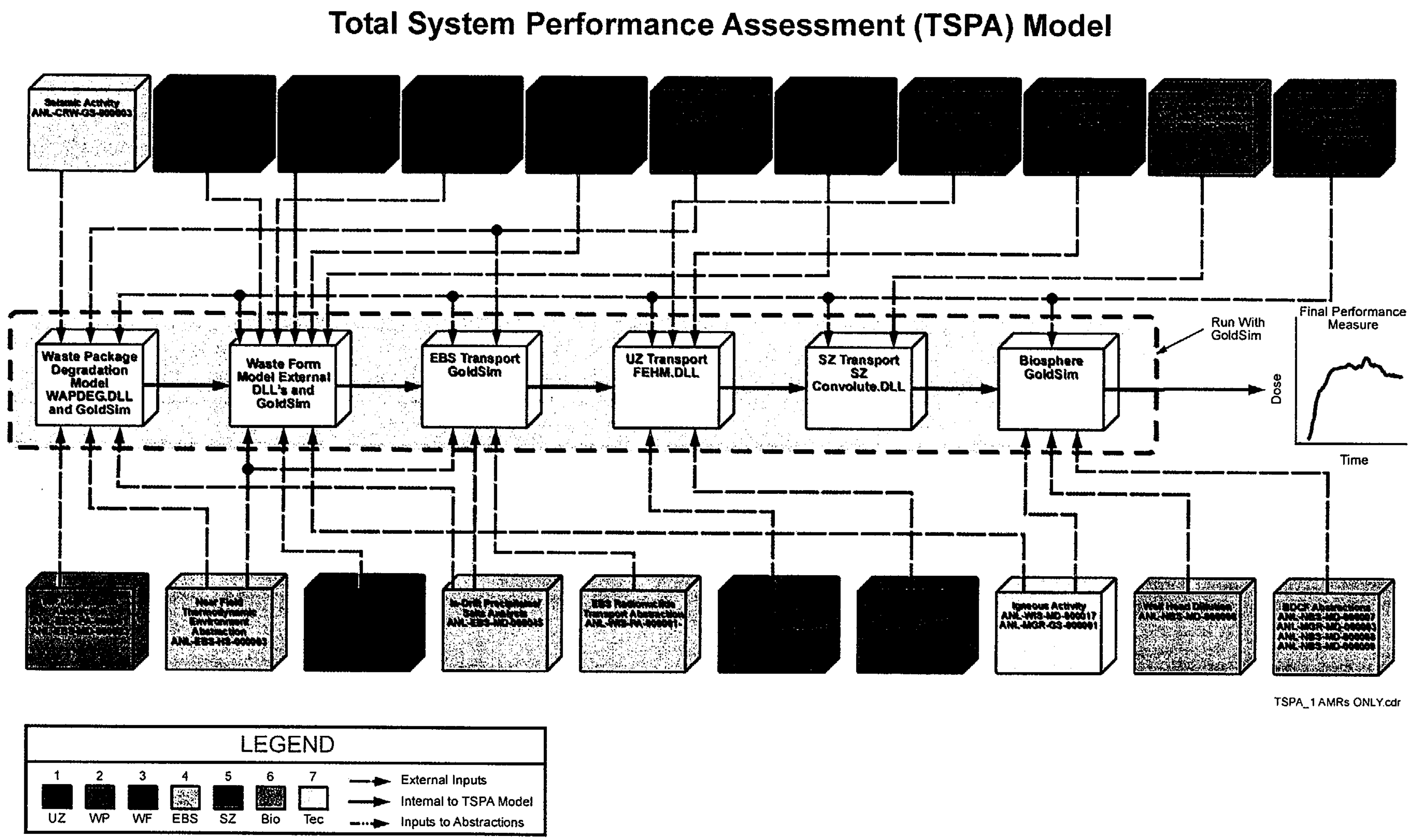
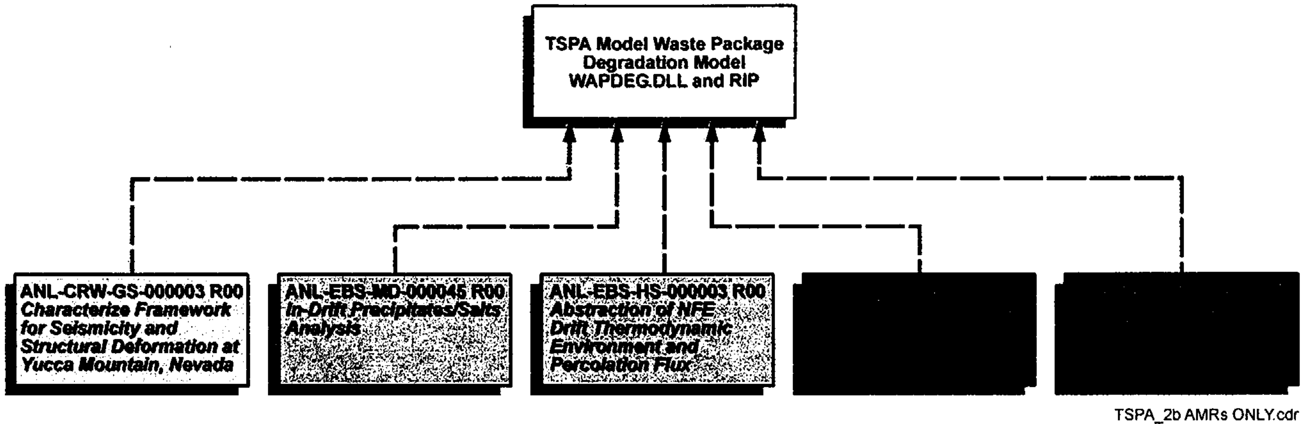


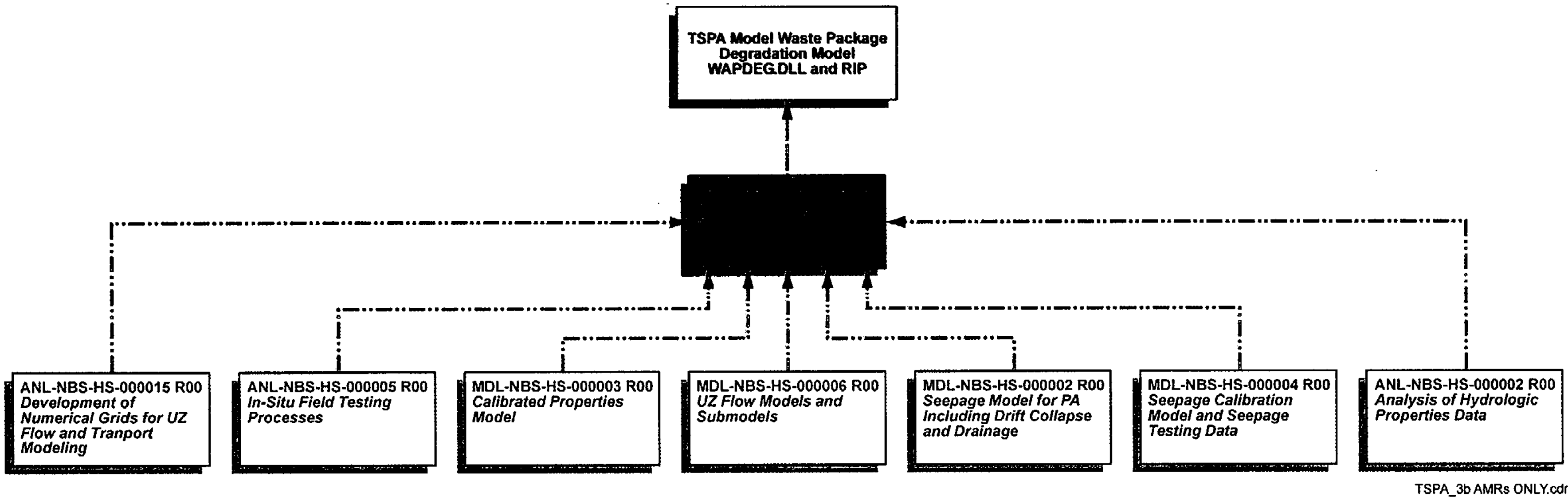
TSPA_1

Figure E-1. Hierarchy of Analyses and Models Supporting the Total System Performance Assessment-Site Recommendation



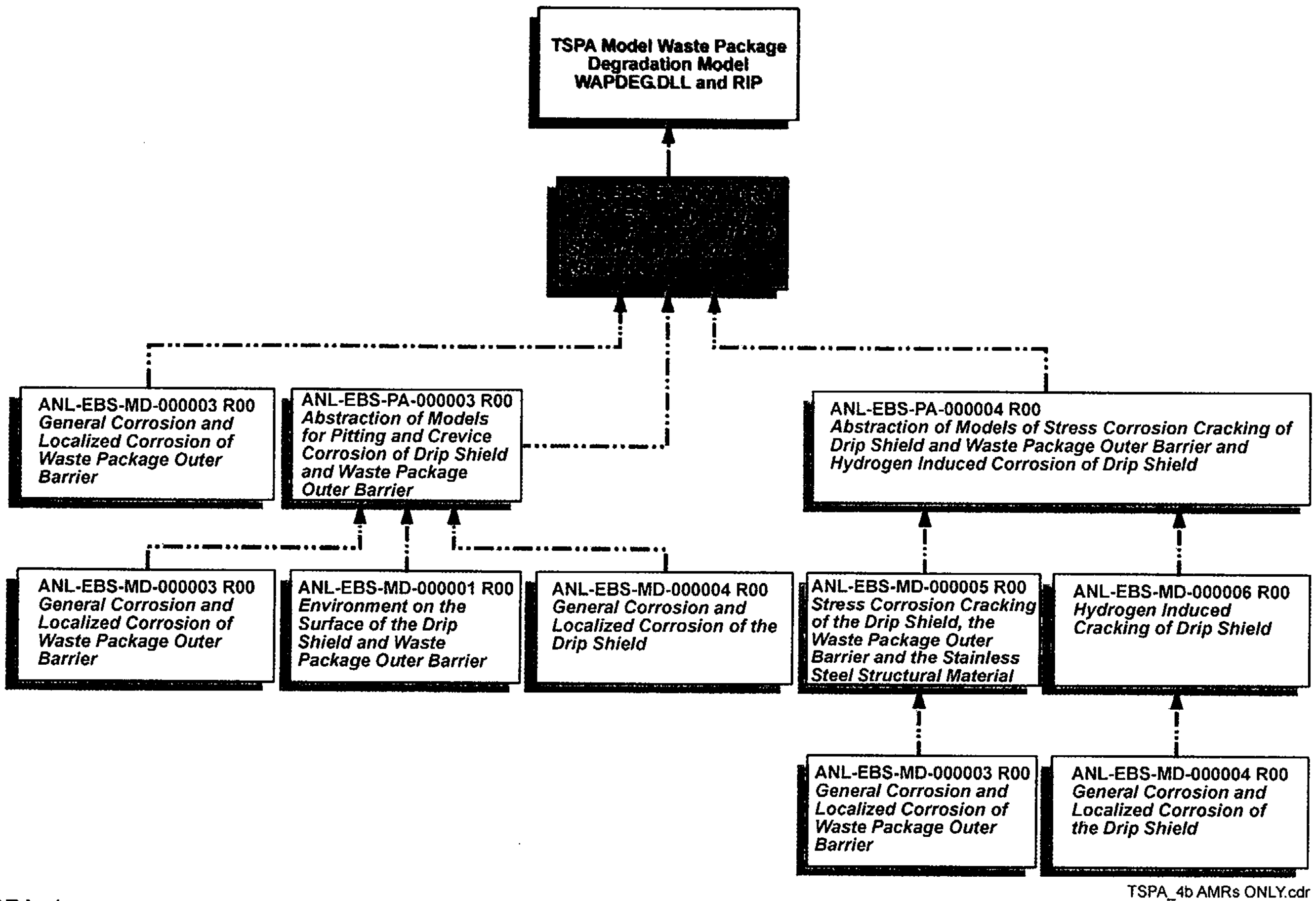
TSPA_2

Figure E-2a. Hierarchy of Analyses and Models Supporting the Waste Package Degradation Model of Total System Performance Assessment-Site Recommendation - Part A



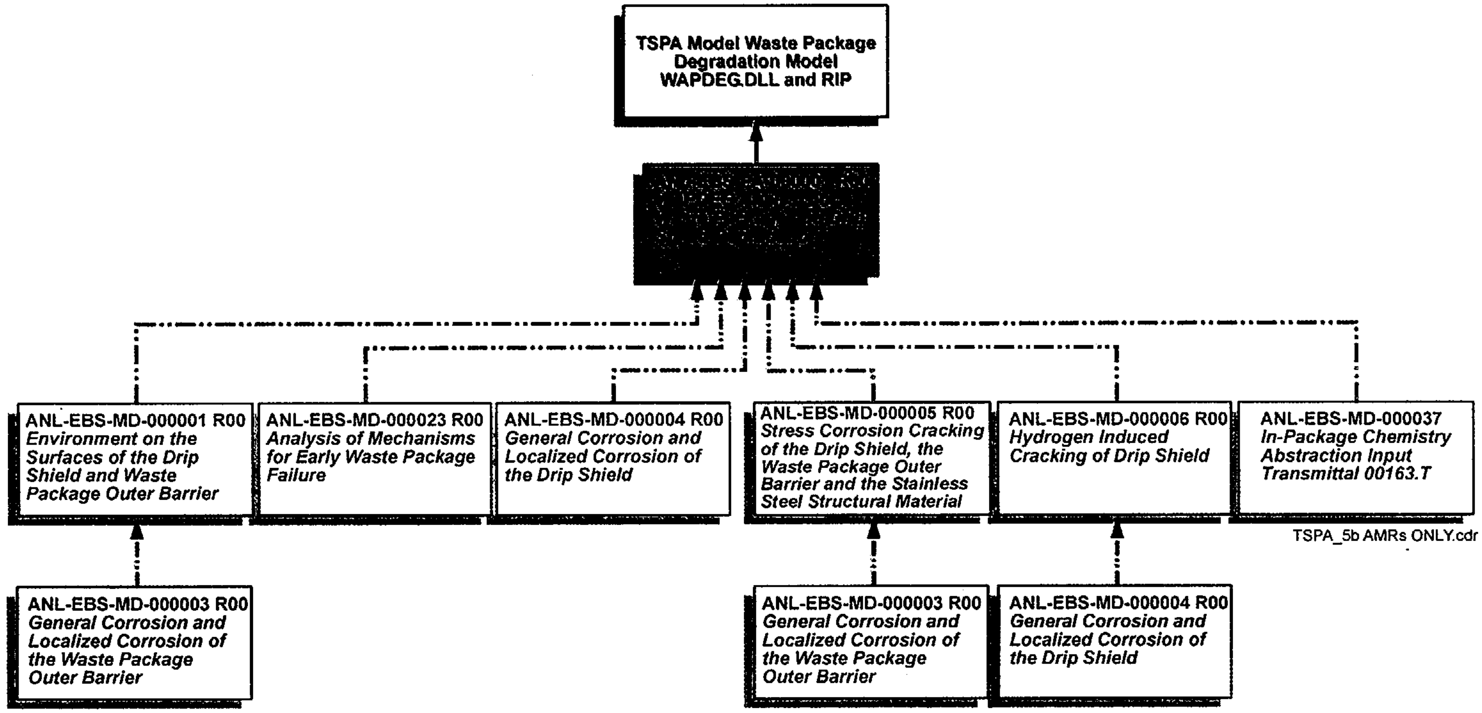
TSPA_3

Figure E-2b. Hierarchy of Analyses and Models Supporting the Waste Package Degradation Model of Total System Performance Assessment-Site Recommendation - Part B



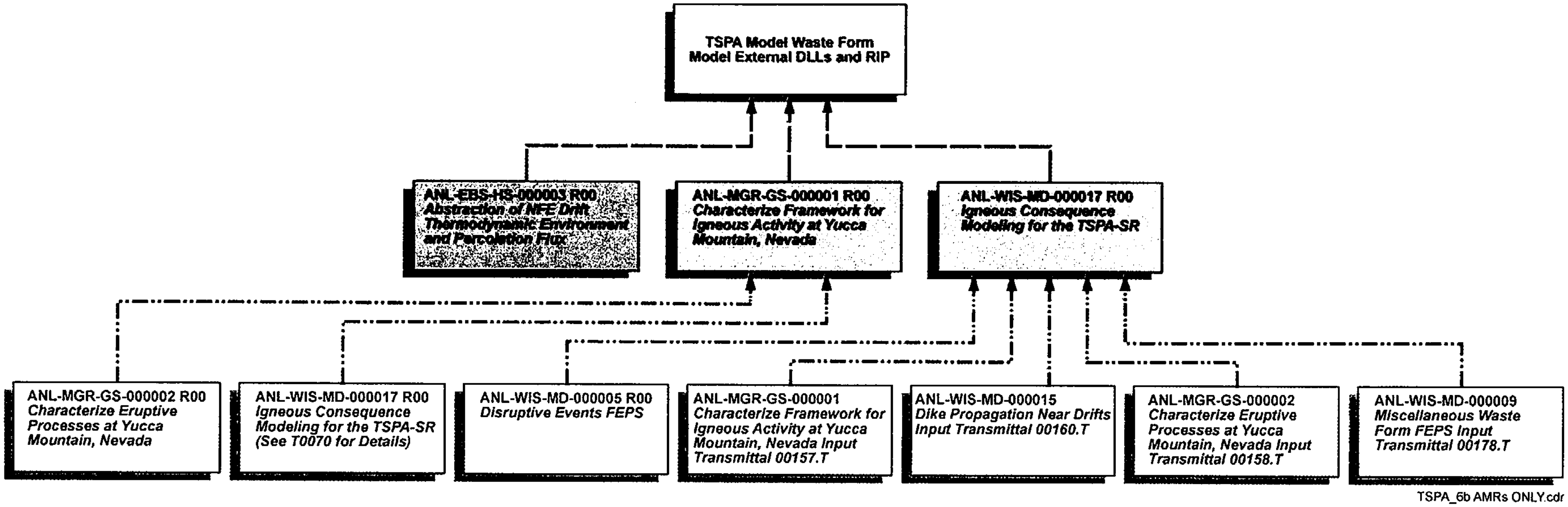
TSPA_4

Figure E-2c. Hierarchy of Analyses and Models Supporting the Waste Package Degradation Model of Total System Performance Assessment-Site Recommendation - Part C



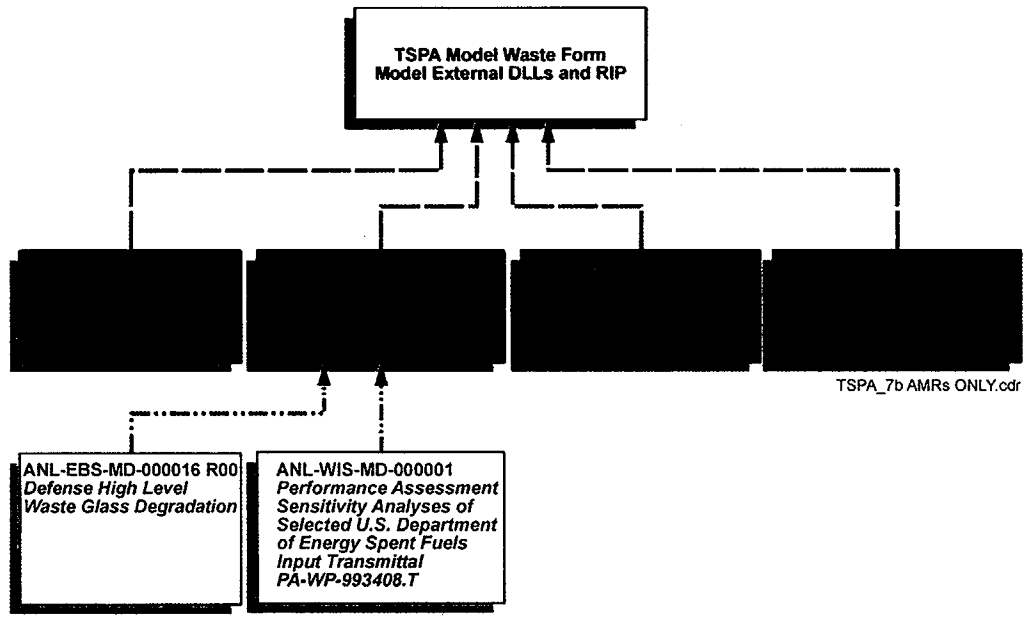
TSPA_5

Figure E-2d. Hierarchy of Analyses and Models Supporting the Waste Package Degradation Model of Total System Performance Assessment-Site Recommendation - Part D



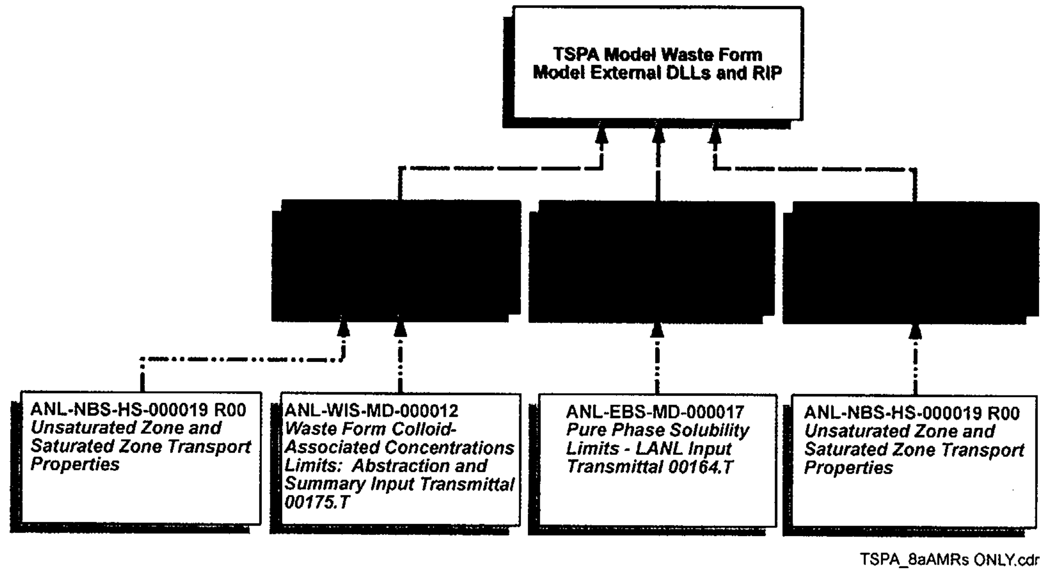
TSPA_6

Figure E-3a. Hierarchy of Analyses and Models Supporting the Waste Form Model of Total System Performance Assessment-Site Recommendation - Part A



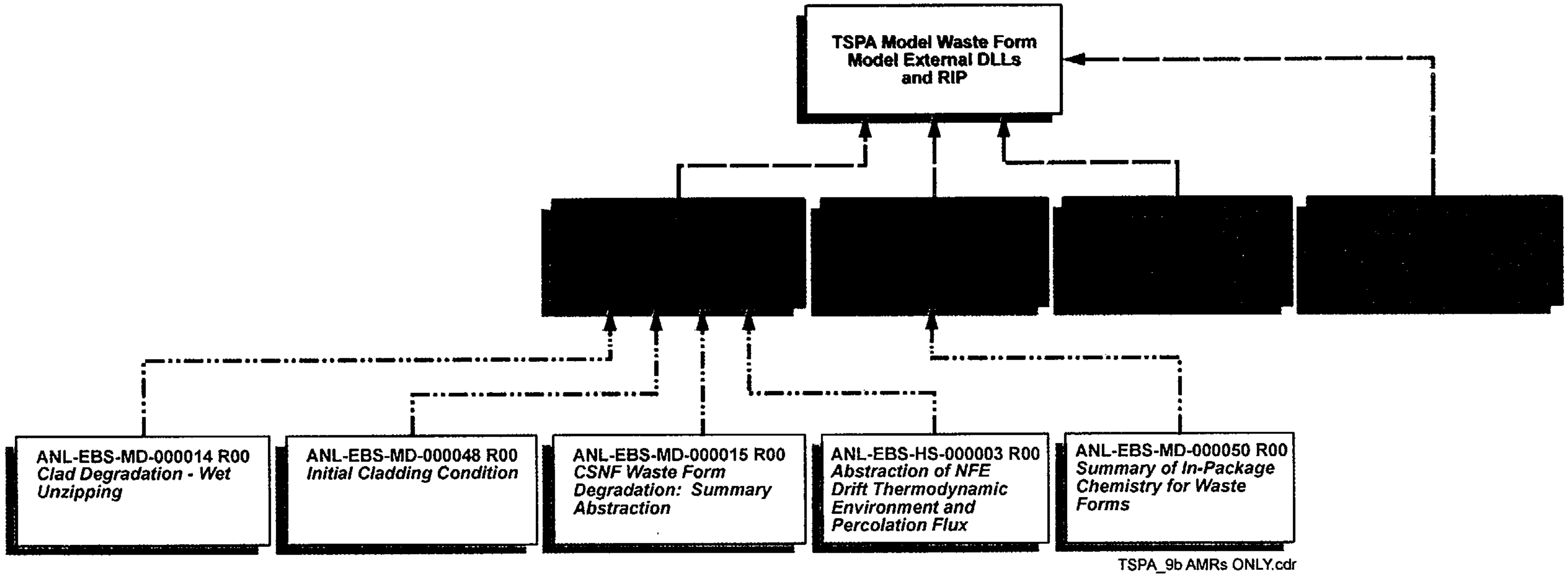
TSPA_7

Figure E-3b. Hierarchy of Analyses and Models Supporting the Waste Form Model of Total System Performance Assessment-Site Recommendation - Part B



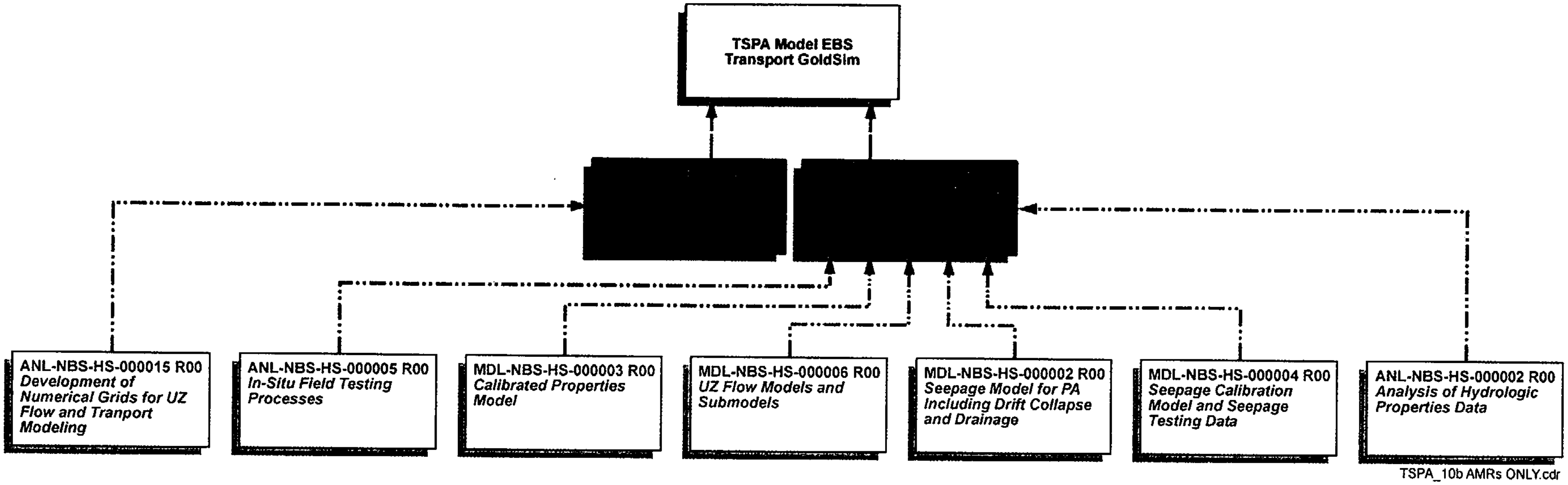
TSPA_8

Figure E-3c. Hierarchy of Analyses and Models Supporting the Waste Form Model of Total System Performance Assessment-Site Recommendation - Part C



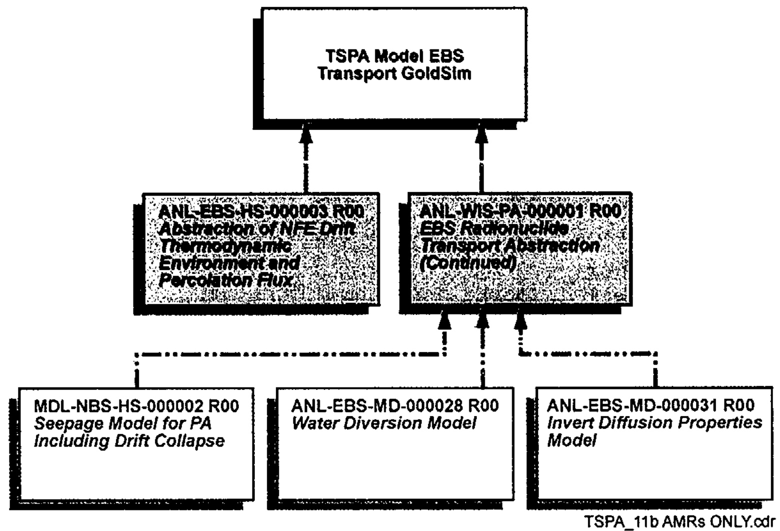
TSPA_9

Figure E-3d. Hierarchy of Analyses and Models Supporting the Waste Form Model of Total System Performance Assessment-Site Recommendation - Part D



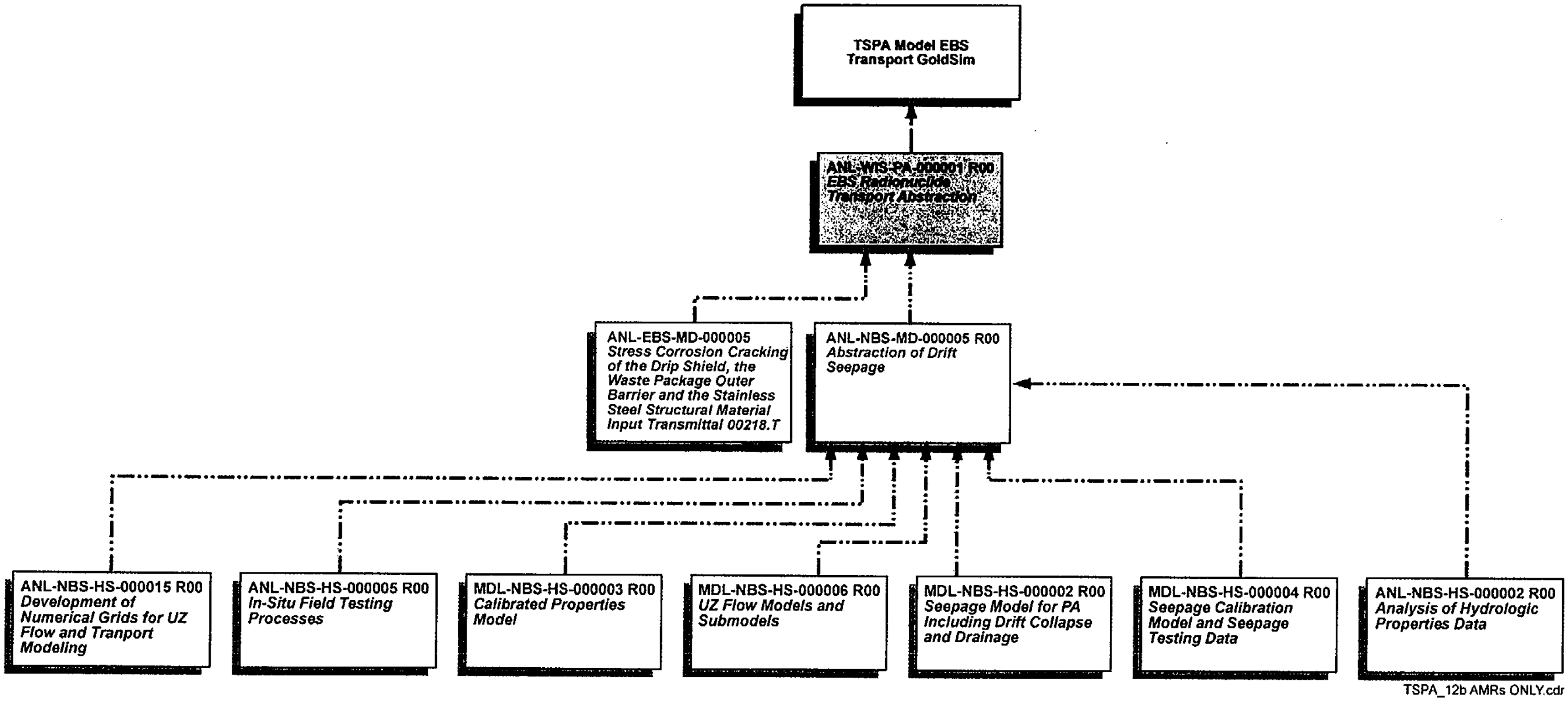
TSPA_10

Figure E-4a. Hierarchy of Analyses and Models Supporting the EBS Transport Model of Total System Performance Assessment-Site Recommendation - Part A



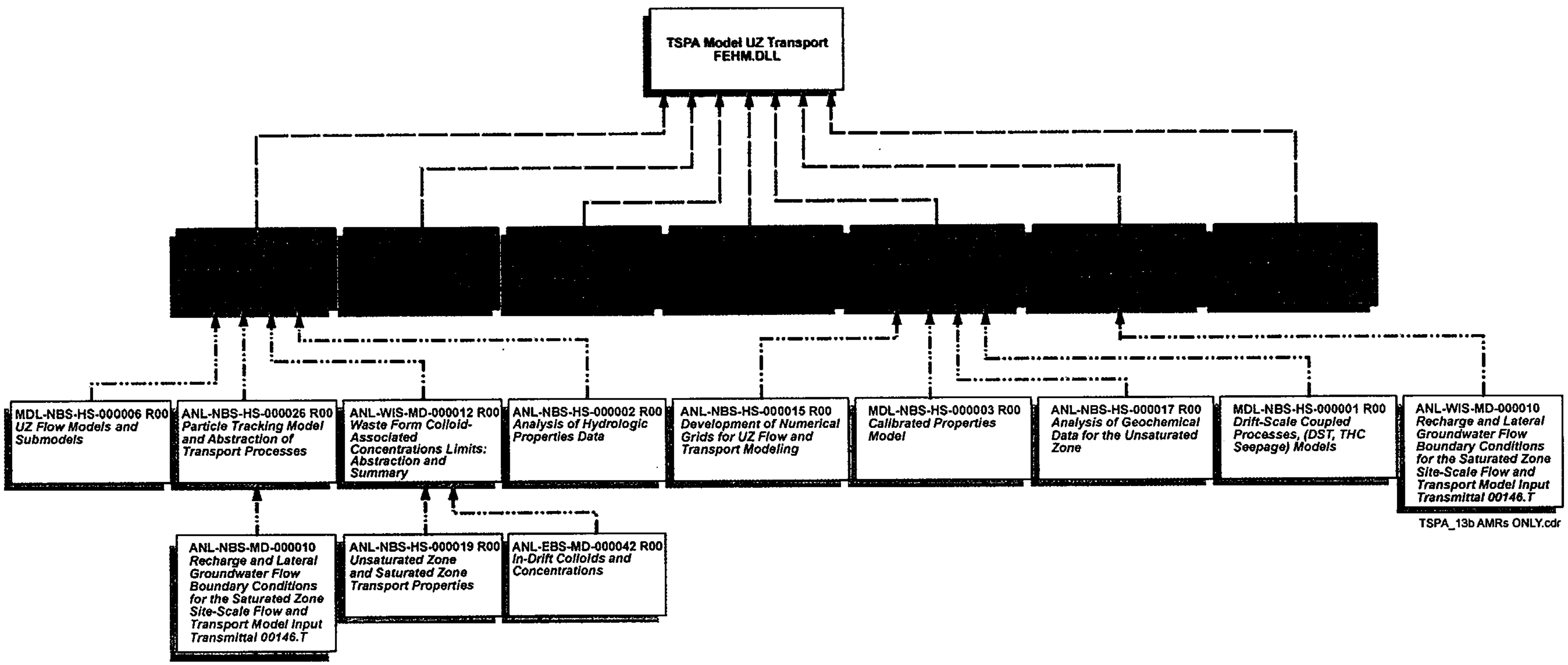
TSPA_11

Figure E-4b. Hierarchy of Analyses and Models Supporting the EBS Transport Model of Total System Performance Assessment-Site Recommendation - Part B



TSPA_12

Figure E-4c. Hierarchy of Analyses and Models Supporting the EBS Transport Model of Total System Performance Assessment-Site Recommendation - Part C



TSPA_13

Figure E-5. Hierarchy of Analyses and Models Supporting the Unsaturated Zone Transport Model of Total System Performance Assessment-Site Recommendation

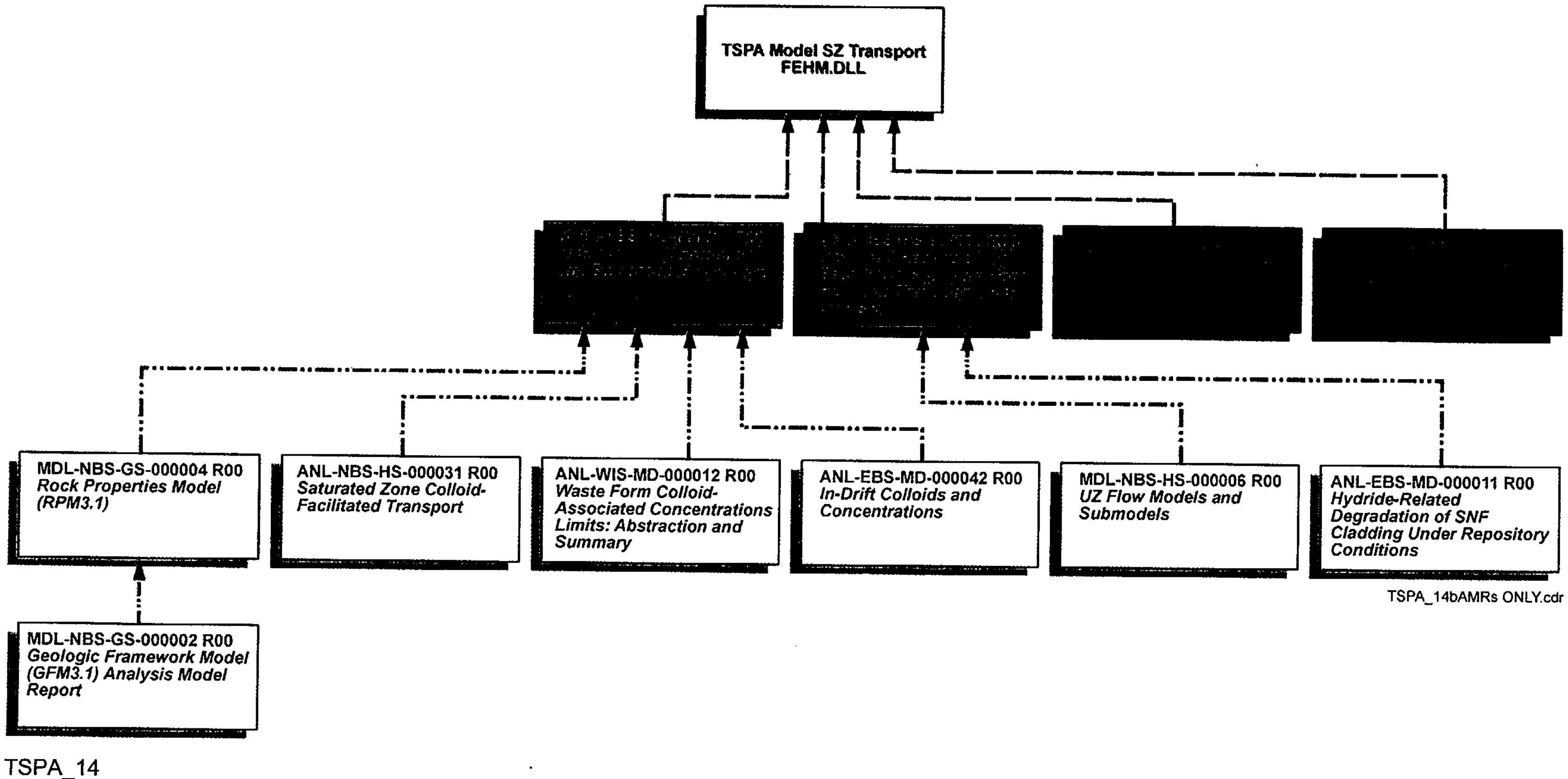
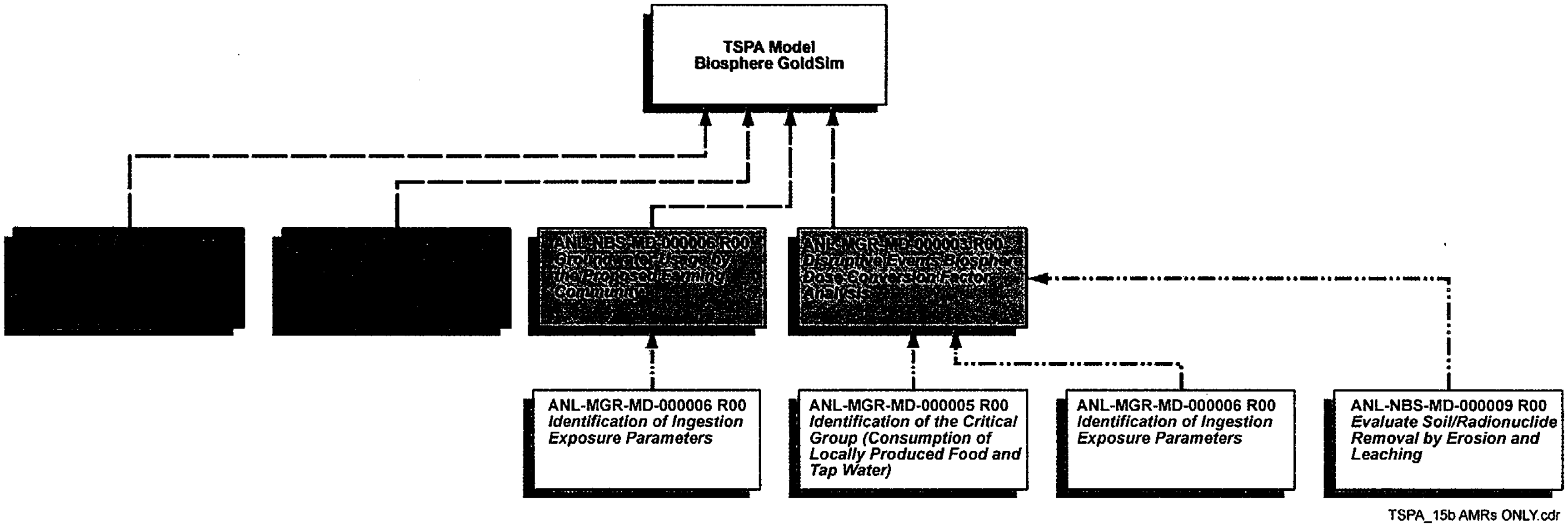
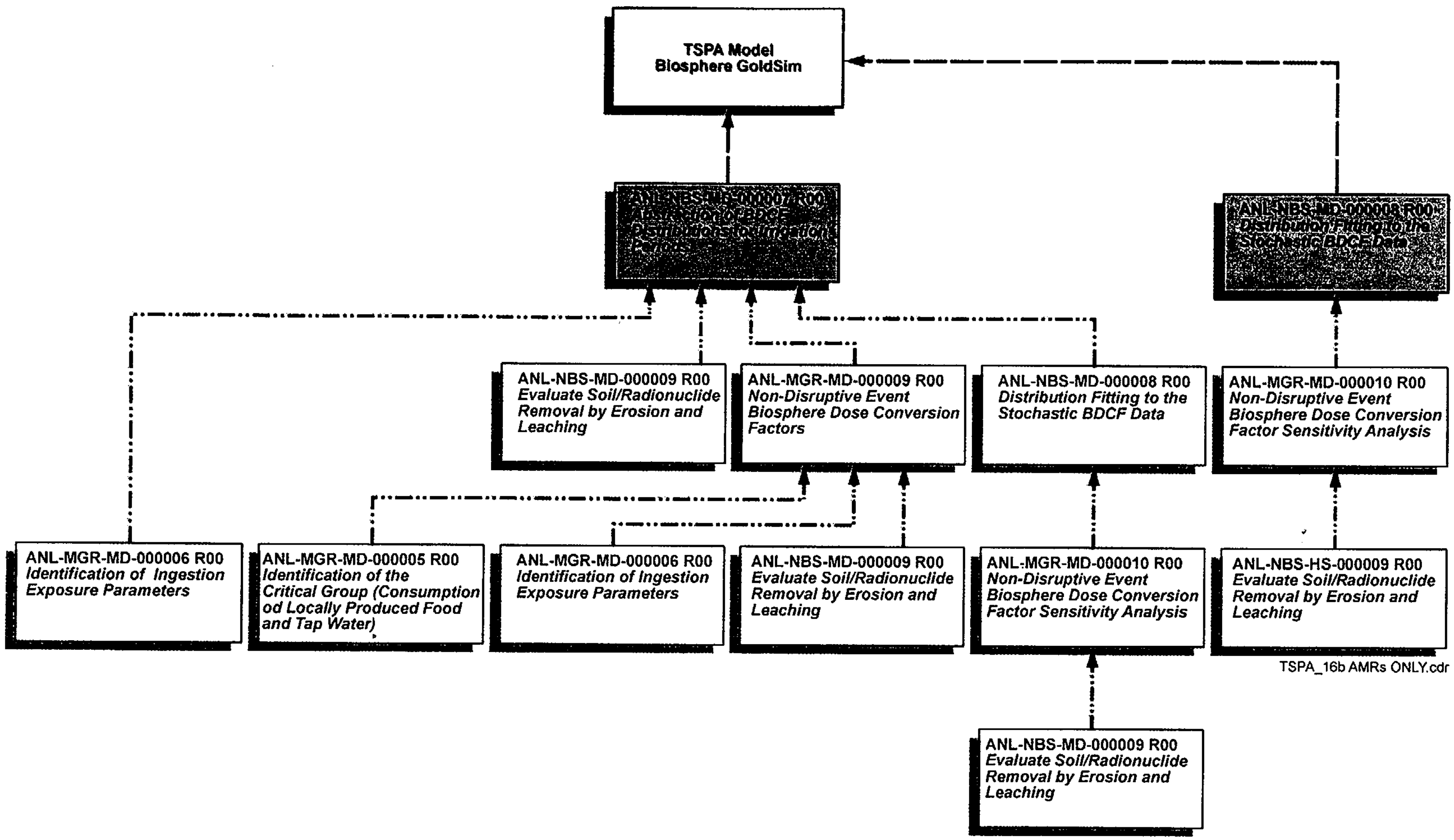


Figure E-6. Hierarchy of Analyses and Models Supporting the Saturated Zone Transport Model of Total System Performance Assessment-Site Recommendation



TSPA_15

Figure E-7a. Hierarchy of Analyses and Models Supporting the Biosphere Model of Total System Performance Assessment-Site Recommendation - Part A



TSPA_16

Figure E-7b. Hierarchy of Analyses and Models Supporting the Biosphere Model of Total System Performance Assessment-Site Recommendation - Part B

APPENDIX F

SYNTHESIS OF MAJOR ASSUMPTIONS AND CONSERVATISMS INCLUDED IN TOTAL SYSTEM PERFORMANCE ASSESSMENT-SITE RECOMMENDATION

APPENDIX F

ACRONYMS AND ABBREVIATIONS

BDCF	Biosphere dose conversion factor
CSNF	Commercial spent nuclear fuel
DHLW	Defense high-level radioactive waste
DSNF	DOE-owned spent nuclear fuel
EBS	Engineered barrier system
HLW	high-level radioactive waste
NRC	U.S. Nuclear Regulatory Commission
RH	relative humidity
SZ	Saturated zone
SCC	stress corrosion crack
SNF	spent nuclear fuel
TSPA-SR	Total System Performance Assessment-Site Recommendation
UZ	Unsaturated zone
WP	waste package

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APPENDIX F

SYNTHESIS OF MAJOR ASSUMPTIONS AND CONSERVATISMS INCLUDED IN TOTAL SYSTEM PERFORMANCE ASSESSMENT-SITE RECOMMENDATION

Throughout Chapter 3, the major information feeds to the Total System Performance Assessment-Site Recommendation (TSPA-SR) have been summarized to provide the reader a complete picture of the key aspects of the individual component models of the TSPA-SR. This Appendix summarizes in one sense the major assumptions used in the individual component models and, as applicable, the degree of conservatism that has been incorporated in these models in order to reduce the need to explicitly quantify the uncertainty in each of the models.

This Appendix is broken into two parts. In the first discussion, the major assumptions and conservatisms associated with each component model of the TSPA-SR model are summarized (Tables F-1 to F-14). This summary is accomplished in the following sequence:

- Unsaturated zone (UZ) flow and transport
- Near field environment
- Engineered barrier system (EBS) chemical environment and radionuclide transport
- Drip shield/waste package (WP)
- Inventory
- In-package chemistry
- Commercial spent nuclear fuel (CSNF) degradation
- DOE-owned spent nuclear fuel (DSNF) degradation
- High-level radioactive waste (HLW) degradation
- Dissolved concentration limits
- Colloid concentration limits
- Saturated zone (SZ) flow and transport
- Biosphere
- Disruptive events.

The list of major assumptions focuses on those aspects within the TSPA-SR model that are conservative. "Conservative" as used here indicates that the assumptions may result in overestimation of the consequences of processes that have potential to degrade subsystem performance, or in the underestimation of processes that might result in improved subsystem performance. Because assumptions have been identified as being conservative based on subsystem-level analysis, rather than on the overall TSPA, they may not have a direct impact on the system-level performance. For example, assumptions that lead to overestimation of water flux through the drifts are identified as being conservative, but they will have no effect on overall performance as long as WP remain intact. Similarly, assumptions that tend to overestimate the annual dose rate due colloidal transport of radionuclides are listed as conservative even though the peak expected annual dose rate is dominated by transport of dissolved species that are unaffected by assumptions about colloids.

The root cause of most of the assumptions identified in Tables F-1 through F-14 relates to the fact that limited data exist to justify a more "realistic" representation of the particular process or component model. This is to be expected. As noted by U.S. Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA) in their rulemaking process, it is acknowledged that significant uncertainty about processes acting over the spatial (kilometers) and temporal (tens of thousands of years) scales of interest in post closure performance assessments will remain, even after a detailed site characterization program. That is, we are not seeking the exact answer, only an acceptably representative answer based on the information available. Where information is lacking or significant complexity exists, the approach taken in all component models of the TSPA has been to simplify and bound the representation. This approach has generally been followed in technical areas where either reducing the uncertainty is not feasible (i.e., additional data would not significantly reduce the uncertainty) or where the uncertainty does not significantly affect the performance assessment analyses (i.e., the TSPA results are insensitive to that particular component within the bounds of the expected models). Therefore, this lack of data identified in Tables F-1 through F-14 does not detract from the representativeness or appropriateness of the models developed to assess the post closure performance. However, it is useful to note these issues so the reader can best appreciate where and why certain assumptions have been made in the Analysis Model Reports that support the TSPA-SR.

Table F-1. Unsaturated Zone Flow and Transport

Description of Assumption	Basis for Assumption	Comments
Transport and flow through UZ.	Limited data.	Connectivity of fracture network likely overestimated. Residence time in perched water likely underestimated.
The treatment of fracture/matrix diffusion assumes a stagnant matrix.	This model was already implemented in finite element heat and mass and is very computationally efficient. It has been tested against analytical solutions for dual-porosity system, but it appears to be conservative for dual-permeability systems.	The use of a fracture/matrix diffusion model that allows matrix/matrix transport following diffusion has been shown to increase travel times in the UZ by tens of thousands of years for weakly sorbing radionuclides. We are currently implementing a new model that can allow this feature.
Colloid concentrations and K_ds used to calculate K_c are conservative (i.e., high).	There is so much uncertainty about colloid properties and transport that a more detailed representation was thought to be indefensible.	
Colloid retardation is neglected for all colloids in the UZ.	No data are available for R_c in the UZ or for reversible colloids.	
Physical colloid filtration is neglected for transport in fractures.	Lack of data to support including it.	
Diversion of flow & 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.	

Table F-2. Near-Field Environment

Description of Assumption	Basis for Assumption	Comments
Percolation flux 5 m above the drift crown is used as input to seepage calculations.	Seepage implemented conservatively into the model due to lack of a good basis for TM effects on seepage.	Water is always assumed to be present 5 meters above the crown of the drift so that there is always the possibility of seepage into the drift. Percolation flux is used as an input to the abstracted seepage model that governs the amount of the water entering the drifts.
Drift Seepage.	Limited data, especially for lower lithophysal unit; insufficient time (and data) to develop detailed model of thermal effects on seepage.	Thermal dry-out neglected, possible better performance of lower lithophysal unit neglected, seepage threshold possibly underestimated. Seep flux increased by 55 percent to account for effects of drift degradation & rock bolts. With present TSPA model seepage is not very important; this could possibly change if dependence of corrosion on seepage were put back in the model.

Table F-3. EBS – Chemical Environment And Radionuclide Transport

Description of Assumption	Basis for Assumption	Comments
All seepage into drifts is assumed to hit drip shields , not just seepage above drip shield (conservative).	Simplify modeling approach.	Taking credit for seepage locations requires a degree of precision not suitable for the seepage model, which was intended to define amount and probability of seepage.
Treatment of transport through WP and EBS.	Limited data.	Evaporation of water in WP is neglected. Radionuclide transport through a stress corrosion crack (SCC) is by diffusive transport through a thin, continuous film that is assumed to be always present. The advective flow for radionuclide transport through the invert is a one-dimensional process and always vertically downward. The binary diffusion coefficient for all radionuclides is bounded by the self-diffusion coefficient of water. A zero concentration boundary condition at the invert/UZ interface is enforced during the post-closure simulation period.
The potential beneficial effects from adsorption of radioisotopes on immobile colloidal material and other corrosion products are neglected.	Limited data.	This approach bounds uncertainties in adsorption behavior.
Colloid retardation by filtration in the invert is neglected.	Limited data.	Efforts at reduction in conservative treatment of colloid behavior are best spent on other areas.

Table F-4. Drip Shield/Waste Package

Description of Assumption	Basis for Assumption	Comments
Threshold relative humidity (RH) for corrosion initiation.	Insufficient information/data to quantify the corrosion initiation threshold RH for varying dripping conditions.	The current model uses a threshold RH based on the deliquescence point of NaNO3 salt, and the same threshold RH for both drip and no-drip conditions. Use of the same threshold RH for no-drip condition (including WP under non-failed drip shield) is conservative.
Density and orientation of embedded defects/flaws.	Lack of YMP-related data to quantify defect density and orientation.	The current model includes surface breaking defects and embedded defects in WP closure-lid welds, and assumes in the WP SCC analysis that all the defects are oriented in radial direction. Embedded defects/flaws are likely oriented parallel to the weld centerline and, if subject to SCC, will likely to grow circumferentially along the WP weld circumference, not radially as currently assumed in the WAPDEG nominal case model (CRWMS M&O 1998 [145618]).
SCC Crack Initiation and Propagation is assumed to occur under highly aggressive water chemistry conditions.	Limited data, both on corrosion and on environmental conditions in the potential repository.	The slip dissolution model used for SCC crack propagation in the WAPDEG analysis includes a term to account for effect of chemistry of water contacting the WP. The current WAPDEG analysis uses a range of values for the term that represent highly aggressive water conditions and materials much less resistant to SCC than Alloy 22.

Table F-5. Inventory Component

Description of Assumption	Basis for Assumption	Comments
C-14 included in inventory is transported entirely in the aqueous phase.	Simplify modeling approach.	This approach is conservative since less dilution occurs in aqueous transport. Also, gaseous transport of C-14 has been screened out conservatively assuming that all C-14 might be in the gas phase.

Table F-6. In-Package Chemistry Component

Description of Assumption	Basis for Assumption	Comments
Transport pathways inside container excluded; rather, container assumed to be a mixing cell.	Limited data and large uncertainty in physical environment in WP.	Inclusion of pathways would delay release of radioisotopes through the decrease in advective and diffusive transport. Would need to assume short-circuits to pathway similar to fracture flow in UZ.
Minimum pH in first 1000 yr. selected for each EQ3/6 (CRWMS M&O 1998 [102837]) run rather than using distribution.	Limited data and large uncertainty in chemical environment in WP.	Approach bounds uncertainty in low pH values and results in conservative radionuclide solubilities and waste-form degradation rates.

Table F-7. CSNF Degradation Component

Description of Assumption	Basis for Assumption	Comments
For CSNF degradation, no reducing conditions are assumed, which results in a fast degradation rate.	Limited data and large uncertainty in chemical environment in WP.	This fast rate is used to bound the upper end of the uncertainties.
Conservative estimate of perforation from creep rupture is used.	Limited data for non-irradiated cladding.	A conservative model for non-irradiated cladding was used that over estimates the creep of irradiated cladding by almost a factor of 30. Creep data by various European and American experimenters is available for irradiated cladding.
Unknown localized corrosion method for perforating cladding included.	Limited data and uncertainty in micro-chemical environment surrounding cladding.	In-package chemistry component calculates bulk water chemistry that can not account for microenvironments or transients of concentrating chemicals within the WP that could produce localized conditions for pitting corrosion of the cladding.
Wet unzipping has uncertainty added that is in addition to the uncertainty in the CSNF degradation rate; the unzipping propagates at between 1 and 240 times faster than the CSNF degradation rate.	Insufficient data and large uncertainty.	Wet unzipping has not been observed in spent fuel pools and might not occur at all because the phase transitions are in liquids and might not occur at the interface of secondary phases and cladding.

Table F-8. DSNF Degradation Component

Description of Assumption	Basis for Assumption	Comments
No cladding credit is assumed.	Simplify modeling approach, no technical basis for credit on DSNF.	This approach bounds DSNF degradation processes. The naval spent nuclear fuel (SNF) degradation model does account for the performance of the naval SNF cladding.
A constant degradation rate is used that conservatively bounds degradation of metallic uranium present in N-reactor fuel; degradation of DSNF can occur in one time step of TSPA.	Little quality assurance data exists on DSNF fuel and so a very conservative approach is used to bound uncertainty in the characteristics of the DSNF fuel.	Unlike some DSNF, naval SNF is completely characterized and the degradation of naval SNF was modeled using the same environmental conditions used for the degradation of commercial SNF.

Table F-9. High-Level Radioactive Waste Degradation Component

Description of Assumption	Basis for Assumption	Comments
High degradation rates are assumed.	Lack of data.	Using high degradation rate bounds uncertainties.
In addition to a high degradation rate, a very conservative cracking surface enhancement factor of 20 over the geometric surface area is used (this uncertainty plus the uncertainty in degradation rate could make the degradation rate 1000 times faster than observed in experiments).	Simplify modeling approach.	A very conservative enhancement factor of 20 is used to bound uncertainty in the true value.

Table F-10. Dissolved Concentration Component

Description of Assumption	Basis for Assumption	Comments
High Np solubility is predicted because Np_2O_5 is conservatively assumed to be the controlling solid phase.	Limited data.	Using high solubility bounds uncertainties. During the first 1000 years after breach when the pH is predicted to be low, Np solubility is between 10^{-4} and 10^{-1} M (similar to CRWMS M&O 1995 [100198]. After 1000 years, Np solubility is between 10^{-7} and 10^{-4} M (similar to TSPA-VA DOE 1998 [100550]), Volume 3.
Np or other radioisotopes are not incorporated into secondary phases of uranium are assumed.	The effects have been conservatively excluded.	Experimental data are lacking to confirm this phenomenon with sufficient reliability to be used in a reasonable assurance evaluation.

Table F-11. Colloidal Concentration Component

Description of Assumption	Basis for Assumption	Comments
Assumption that groundwater colloids consist of montmorillonite (smectite) clay minerals.	Limited data.	This assumption overestimates the mass of radionuclides attached to groundwater colloids.
Concentration of iron-(hydr)oxide corrosion-product colloids not linked to corrosion rates.	Limited data.	Concentration of corrosion-product colloids is calculated based on an ionic strength stability relationship; it is assumed that there is always a sufficient number of corrosion-product colloids to satisfy this relationship.
Stabilities of colloid types (waste form, groundwater, and corrosion-product colloids) are treated independently.	Limited data.	Colloid concentrations are determined by a stability relationship that is a function of solution ionic strength only. This relationship is applied separately to each colloid type as opposed to all colloids simultaneously and therefore tends to overestimate colloid concentrations.

Table F-12. Saturated Zone Flow and Transport

Description of Assumption	Basis for Assumption	Comments
Sorption Coefficients for Alluvium.	Uncertainty.	Uncertainty distributions for sorption coefficients in alluvial units used in TSPA-SR based on limited laboratory data. Sorption experiments for I sorption were incomplete; final values of K_d may be higher.
No Sorption in Fractures.	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.
Conceptual Model of Colloid Filtration.	Uncertainty and Modeling Restriction.	The conceptual model of colloid filtration for colloids with irreversibly attached radionuclides used in TSPA-SR assumes that colloids are retarded by filtration. Permanent removal of colloids by mechanical filtration is not considered in the SZ transport model.
K_c Model Parameters for Colloid-Facilitated Transport.	Uncertainty and Modeling Restriction.	Uncertainty distribution for the K_c parameter used in TSPA-SR is for Am on waste form colloids (conservative relative to plutonium) and filtration is not included.
Only Fracture Flow in Volcanic Units (no matrix flow).	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.

Table F-13. Biosphere

Description of Assumption	Basis for Assumption	Comments
Annual Groundwater Usage (per Draft NRC regulation).	Uncertainty.	Site recommendation water usage based on individual withdrawal permits and not on existing agricultural units in Amargosa Valley. The annual water usage is estimated to be conservative (i.e., lower) by about a factor of two for the farming community proposed by NRC.
Dose Conversion Factors (DCFs).	Uncertainty.	Because of uncertainty in the final chemical/physical form of the radionuclides supplied to the biosphere from groundwater and the uncertainty in the subsequent evolution of the chemical/physical form soil, the pessimistic DCF values for possible gastrointestinal absorption fractions and lung clearance classes for chemical compounds were used.
Transfer Coefficients.	Lack of site specific data.	Value used for the transfer coefficients in the GENII-S code were the conservative values from the published scientific literature. The values used are judged to be either reasonable or conservative for the Amargosa Valley area. (i.e., they are very unlikely to be found non-conservative at a later date.)
Receptor Characteristics.	Lack of receptor specific data.	Behavioral parameters that were not quantified in the survey (such as time per day spent outdoors, and inadvertent soil ingestion, were set to conservative values or ranges of values.
Other GENII-S input parameters.	Uncertainty.	Other GENII-S input parameters that were not quantified in the survey (such as translocation factors, animal feed consumption, fraction of animal feed and water that is contaminated were set to conservative values or ranges of values.
The GENII-S code.	GENII-S sub-model and architecture.	In building the GENII-S code, each sub-model was constructed to err on the side of conservatism to avoid providing under estimates of dose. For example, the amount of radioactivity introduced into the biosphere with irrigation water is accounted for twice; once for deposition on the plant's surfaces and once for root uptake.

Source: GENII-S (CRWMS M&O 1998 [107723])

Table F-14. Disruptive Events

Description of Assumption	Basis for Assumption	Comments
Biosphere dose conversion factor (BDCFs) used for all times after eruptions based on dusty conditions corresponding only to the first few years after the eruption.	Simplification to avoid time-dependent BDCFs in GoldSim.	This may be a significant conservatism.
All eruptions are violent strombolian for their entire duration.	Conservative simplification that is consistent with ASHPLUME capabilities. Data are not readily available to defend a less conservative position.	Eruptions should reasonably be assumed to all have a violent phase for some portion of the eruption. Assuming the entire eruption is violent overestimates the total violent phase release.
All WPs and drip shields in the direct path of the eruption are fully destroyed and all waste is available for transport in the eruption.	Data are not available to defend a less conservative position.	Obtaining data to support package performance in an eruptive environment may not be possible..
Eruptive conduits that intersect drifts in any portion of their diameter are assumed to be centered on the drifts.	Simplification.	This assumption may be reasonable, in that it assumes that eruptive conduits that intersect drifts will spread to involve a segment of the drift as long as the full diameter of the conduit.
All waste (SNF and HLW) in packages in the direct path of the eruption is reduced to small (10s of microns) grain sizes.	Data are not available to defend a less conservative position.	The assumption is probably conservative for HLW, but may be realistic for SNF.
WPs and drip shields adjacent to an intrusive event (i.e., 3 packages on either side) are fully destroyed.	Data are not available to defend a less conservative position.	The assumption probably is conservative, but data are not likely to be available to support other interpretations.
Waste in packages adjacent to intrusive events is fully exposed to ground water transport.	Data are not available to defend a less conservative position.	The assumption probably is conservative, but data are not likely to be available to support other interpretations.
Waste in packages that are destroyed by eruption is double-counted in the groundwater release.	Modeling simplification.	
Wind direction fixed to the south.	Compensation for lack of model for surface redistribution of ash deposits.	This assumption overestimates the direct dose during and following the eruption, and it may overcompensate for the surface redistribution effect.

Source: GoldSim (Golder Associates 2000 [151202]); ASHPLUME (CRWMS M&O 2000 [151349]).

Following the summary of major assumptions and their bases, Table F-15 outlines the aspects of the TSPA-SR model that are treated as uncertain, variable and/or conservative.

Table F-15. Uncertainty, Variability, and Conservatism in the TSPA-SR Model

Key Attributes of System	Process Model	Uncertainty	Variability	Conservatism	Comments
Water Contacting Waste Package	Climate	✓	✓		• Uncertainty is captured by lower and upper bounds for climate. • Variability is captured through timing of climates.
	Net Infiltration	✓	✓		
	UZ Flow	✓	✓	✓	• 10% of flow through Calico Hills vitric unit (which is beneath about half the potential repository) is through the fractures. Results at Busted Butte indicate that 100% of flow through this unit should reside in the matrix.
	Coupled Effects on UZ Flow	✓			• Thermal effects of far-field UZ flow have been screened out.
	Seepage into Emplacement Drifts	✓	✓	✓	• Seepage threshold possibly underestimated. • Seep flux increased by 55% to account for effects of drift degradation & rock bolts.
	Coupled Effects on Seepage			✓	• Percolation flux taken 5 m above drift crown during thermal period as input to seepage model. • Thermal dry-out neglected, possible better performance of lower lithophysal unit neglected.
Waste Package Lifetime	In-Drift Physical and Chemical Environments		✓		• Laboratory A22 corrosion rates measured under extreme chemical environments.
	In-Drift Moisture Distribution		✓	✓	• Threshold RH based on the deliquescence point of NaNO3 salt, and the same threshold RH for both drip and no-drip conditions.
	Drip Shield Degradation and Performance	✓	✓	✓	• Corrosion initiated at threshold RH.
	Waste Package Degradation and Performance	✓	✓	✓	• Corrosion initiated at threshold RH. • Density and orientation of embedded defects/flaws. • Highly aggressive water chemistry conditions for SCC Crack Initiation and Propagation. • Laboratory A22 corrosion rates measured under extreme chemical environments.

Table F-15. Uncertainty, Variability, and Conservatism in the TSPA-SR Model (Continued)

Key Attributes of System	Process Model	Uncertainty	Variability	Conservatism	Comments
Radionuclide Mobilization and Release from the EBS	Radionuclide Inventory			✓	• C-14 included in inventory is transported entirely in the aqueous phase.
	In-Package Environments		✓	✓	• Thermal dry-out effects during first 5-10,000 years neglected. (No effect on DSNF/defense high-level radioactive waste (DHLW.)
	Cladding Degradation and Performance	✓	✓	✓	• Conservative estimate of perforation from creep rupture is used. • Wet unzipping has uncertainty added that is in addition to the uncertainty in the CSNF degradation rate.
	CSNF Degradation and Performance			✓	• Degradation rates do not consider secondary phase formation.
	DSNF Degradation and Performance			✓	• No cladding credit is assumed for DSNF (with the exception of naval SNF). • A constant degradation rate is used that conservatively bounds degradation of metallic uranium present in N-reactor fuel. • Degradation rates do not consider secondary phase formation.
	DHLW Degradation and Performance			✓	• High degradation rates are assumed. • Degradation rates do not consider secondary phase formation.
	Dissolved Radionuclide Concentrations	✓		✓	• High Np solubility is predicted because Np_2O_5 is conservatively assumed to be the controlling solid phase. • Np or other radioisotopes are not incorporated into secondary phases of uranium are assumed.
	Colloid-Associated Radionuclide Concentrations	✓		✓	• Concentration of iron-(hydr)oxide corrosion-product colloids not linked to corrosion rates. • Stabilities of colloid types (waste-form, groundwater, and corrosion-product colloids) are treated independently. • Assumption that groundwater colloids consist of montmorillonite (smectite) clay minerals.

Table F-15. Uncertainty, Variability, and Conservatism in the TSPA-SR Model (Continued)

Key Attributes of System	Process Model	Uncertainty	Variability	Conservatism	Comments
Radionuclide Mobilization and Release from the EBS (Continued)	In-Package Radionuclide Transport			✓	• Diffusion from altered waste form to inner wall of WP neglected.
	EBS (Invert) Degradation and Performance		✓	✓	• The advective flow for radionuclide transport through the invert is a one-dimensional process and always vertically downward. • The binary diffusion coefficient for all radionuclides is bounded by the self-diffusion coefficient of water. • A zero concentration boundary condition at the invert/UZ interface is enforced during the post-closure simulation period.
Transport Away from the EBS	UZ Radionuclide Transport (Advective Pathways; Retardation; Dispersion; Dilution)	✓	✓	✓	• The treatment of fracture/matrix diffusion assumes a stagnant matrix, which has been shown to be conservative. • Colloid concentrations and K_ds used to calculate K_c are conservative (i.e., high). • Colloid retardation is neglected for all colloids in the UZ. • Physical colloid filtration is neglected for transport in fractures.
	SZ Radionuclide Transport	✓	✓	✓	• Sorption coefficients for alluvium is likely low. • No sorption in fractures. • No removal of colloids by mechanical filtration.
	Wellhead Dilution	✓			
	BDCFs	✓		✓	• Pessimistic DCF values for possible gastrointestinal absorption.
Effects of Potentially Disruptive Processes and Events	Probability of Volcanic Eruption	✓	✓		• Spatial and temporal variability in igneous processes considered by Probabalistic Volcanic Hazard Analysis panel.
	Characteristics of Volcanic Eruption	✓		✓	• Eruptive events assumed to be violent for full duration.

Table F-15. Uncertainty, Variability, and Conservatism in the TSPA-SR Model (Continued)

Key Attributes of System	Process Model	Uncertainty	Variability	Conservatism	Comments
Effects of Potentially Disruptive Processes and Events (Continued)	Effects of Volcanic Eruption	✓		✓	• Volcanic eruption assumed to degrade all WPs, drip shields, and cladding that are intersected by eruptive conduit.
	Atmospheric Transport of Volcanic Eruption	✓	✓	✓	• Variability in Wind Speed with altitude and time included in cdf. • Assume wind always blows toward critical group (south). (Conservative approach to compensate for not including surface redistribution processes.)
	Biosphere Dose Conversion for Volcanic Eruption	✓		✓	• High air mass loading assumed to persist permanently following ash fall.
	Probability of Igneous Intrusion	✓	✓		• Spatial and temporal variability in igneous processes considered by Probabalistic Volcanic Hazard Analysis panel.
	Characteristics of Igneous Intrusion		✓	✓	• Variability in location (length and orientation) affects extent of damage. • Multiple dikes possible in a single event, assumed to be at least favorable spacing.
	Effects of Igneous Intrusion	✓	✓	✓	• Variability in location (length and orientation) affects extent of damage. • Igneous intrusion assumed to degrade all WP drip shields and cladding in all drifts that are intersected by dike. • Three WPs on either side of the dike are assumed fully degraded.

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APPENDIX G

DATA TRACKING INFORMATION FOR TOTAL SYSTEM PERFORMANCE ASSESSMENT-SITE RECOMMENDATION ANALYSES

APPENDIX G

ACRONYMS AND ABBREVIATIONS

BDCF	biosphere dose conversion factor
CDF	cumulative distribution function
CSNF	commercial spent nuclear fuel
DS	drip shield
DTN	data tracking number
EBS	engineered barrier system
FEHM	finite element heat and mass
GVP	Gaussian variance partitioning
GWPC	ground water protection case
Kd	batch distribution coefficient
MIC	microbiology influenced corrosion
NRC	U.S. Nuclear Regulatory Commission
SZ	saturated zone
TSPA	total system performance assessment
TSPA-SR	Total System Performance Assessment-Site Recommendation
UZ	unsaturated zone
WP	waste package

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APPENDIX G

DATA TRACKING INFORMATION FOR TOTAL SYSTEM PERFORMANCE ASSESSMENT-SITE RECOMMENDATION ANALYSES

Table G-1 lists the simulations that have been conducted for the Total System Performance Assessment-Site Recommendation (TSPA-SR). For each model case, the table provides the run number and run name by which the case is referred to, the basic scenario used, and a description of the run. The table also lists the figures illustrating the model case results, which can be found in this report, and finally the Data Tracking Number (DTN) through which the model data can be accessed in the Technical Data Management System's Model Warehouse. The documentation of the base case model is found in *Total System Performance Assessment (TSPA) Model for Site Recommendation* (CRWMS M&O 2000 [148384]).

Simulations referred to as "base case" involve one of the three scenarios: nominal, igneous (i.e., including volcano event), or human intrusion. The base case description includes the duration of the simulation, and the number of realizations.

Additional analyses modifying the "base case" were also conducted. These are identified as "sensitivity study" in the table. Sensitivity studies were carried by modifying key parameters or models and analyzing the Total System Performance Assessment (TSPA) Model response. The alterations to the base case for the particular sensitivity case are described in the table.

Table G-1. Listing of Simulations Conducted for the TSPA-SR

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
Nominal Cases (Rev 00B)					
Nominal Base Cases					
SR00_047nm5	Base Case 100 Realization	Nominal	Rev 00B Base Case 100 Realizations 1e5 years.	Fig. 3.5-8 Fig. 3.5-12 Fig. 3.5-15 Fig. 3.5-17a Fig. 3.5-17b Fig. 3.5-17c Fig. 3.5-17d Fig. 3.5-20a Fig. 3.5-20b Fig. 4.1-22 Fig 4.6-4 Fig 4.6-5 Fig. 4.6-7 Fig. 4.6-8 Fig. 4.6-9 Fig 4.6-10 Fig. 5.2-1 Fig. 5.2-2a Fig. 5.2-2b Fig. 5.2-3 Fig. 5.2-4 Fig. 5.2-5 Fig. 5.2-6 Fig. 5.2-7 Fig. 5.2-8 Fig. 5.2-9 Fig. 5.2-10	MO0008MWDNM501.005 [151714]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
				Fig. 5.2-11 Fig 5.2-12 Fig. 5.2-13 Fig. 5.2-14 Fig. 5.2-15 Fig. 5.2-16 Fig. 5.3-1 Fig. 5.3-2 Fig. 5.3-3 Fig. 5.3-4 Fig. 5.3-5 Fig. 5.3-6 Fig. 5.3-7 Fig. 5.3-8 Fig. 5.3-9 Fig. 5.3-10 Fig. 5.3-11 Fig. 5.3-12 Fig. 5.3-13	
SR00_023nm6	Base Case 100 Realization	Nominal	Rev 00B Base Case 100 Realizations 1e6 years.	N/A	MO0009MWDNM601.018 [152839]
SR00_049nm5	Base Case 300 Realization	Nominal	Rev 00B Base Case 300 Realizations 1e5 years.	Fig. 4.1-5 Fig. 4.1-8 Fig. 4.1-9 Fig. 4.1-14 Fig. 4.1-16 Fig. 4.1-17 Fig. 4.1-18 Fig. 4.1-22 Fig. 5.1-1	MO0007MWDTSP01.002 [151716]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
				Fig. 6.1-1	
			Post GoldSim Uncertainty Importance Runs.	Fig. 5.1-2 Fig. 5.1-3 Fig. 5.1-4 Fig. 5.1-5 Fig. 5.1-6 Fig. 5.1-7 Fig. 5.1-8 Fig. 5.1-9 Fig. 5.1-10 Fig. 5.1-12 Fig. 5.1-13 Fig. 5.1-14 Fig. 5.1-15 Fig. 5.1-16 Fig. 5.1-17	MO0009MWDTSP01.019 [153131]
SR00_091nm5	Base Case 300 Realization Rev00B1	Nominal	Rev 00B1 Base Case 300 Realizations 1e5 years. Same as SR00-049 nm5 except additional data has been saved	Fig 4.1-6 Fig 4.1-7 Fig 4.1-11 Fig 4.1-12 Fig 4.1-13 Fig 4.1-15 Fig 4.3-3 Fig. 6.1-3	MO0007MWDTSP01.003 [151706]
SR00_108nm5	500 Realization Base Case 1e5	Nominal	500 Realization Base Case 1e5, derived from Rev. 00B1.	Fig. 4.1-22	MO0009MWDNM501.017 [153132]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_161nm5	Engineered Barrier System (EBS) Only Run for Chemistry Plots	Nominal	Run Base Case with EBS only and saving all chemistry for analysis plots, 300 Realizations.	Fig. 3.5-6 Fig. 3.5-14 Fig. 4.1-10	MO0008MWDNM501.007 [151719]
Ground Water Protection Case					
SR00_042nm6	Ground Water Protection Case (GWPC) 300 Realization 1e6 with Fixed Ingrowth and New Saturated Zone (SZ) Curves	Nominal	300 realizations 1e6, additional radionuclides transported through finite element heat and mass (FEHM) (^{230}Th and ^{232}Th); additional nuclides included in dose (^{230}Th, ^{226}Ra, ^{210}Ph, ^{232}Th, ^{228}Ra); total Ra conc. in groundwater; gross alpha activity in groundwater; additional biosphere dose conversion factors (BDCFs) required; Calculate Nominal dose with additional radionuclides (^{230}Th, ^{232}Th, ^{226}Ra, ^{228}Ra, ^{210}Pb). ^{232}Th and ^{234}U were not correctly decayed to daughter products in the EBS for case SR00_149nm5, SR00_010nm6, SR00_015nm5, and SR00_019nm6. ^{232}Th decays to ^{228}Ra and ^{234}U decays to ^{230}Th. For the unsaturated zone (UZ) input file ptrk.multi, ^{234}U was corrected to decay to ^{230}Th as well. Additionally, for the calculation of dose for Th species, the SZ one-dimensional model was used instead of the SZ three-dimensional model. Set PTRK file to decay w/ingrowth for ^{230}Th, rather then just simple decay of ^{234}U. Used new SZ curves to eliminate mass generation in the SZ for select RNs over several realizations. Re-run SR00_021nm6 with fixed Pu242 BDCF.	Fig. 4.1-19a Fig. 4.1-19b Fig. 4.1-20 Fig. 4.1-21 Fig. 4.1-23 Fig. 4.1-24 Fig. 4.1-25 Fig. 4.1-26 Fig. 4.1-27 Fig. 6.1-6 Fig. 6.1-7 Fig. 6.1-8	MO0011MWDNM601.021 [153126]
			Post GoldSim Uncertainty Importance Runs.	Fig. 5.1-11	MO0011MWDREG01.001
SR00_035nm6	Secondary solubilities with fixed Pu242 BDCF	Nominal	Re-run of SR00_027nm6 with corrected Pu242 BDCF.	Fig. 4.1-20 Fig. 4.1-21 Fig. 5.2-12	MO0011MWDMIL01.022 [153128]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_034nm6	Secondary solubilities and long-term climate, with fixed Pu242 BDCF.	Nominal	Re-run of SR00_031nm6 with corrected Pu242 BDCF.	Fig. 4.1-21	MO0011MWDMIL01.022 [153128]
Barrier Sensitivity Cases					
SR00_072nm5	300 Realization WAPDEG Sens	Nominal	Set z.OL, z.ML,U.GVP.GA22x2P5.CDF, U.GVP.GA22SR00; qu.GVP.GA22x2P5.CDF and qu.GVP.GA22SR00 at Median Values. – Then perform Post GoldSim Uncertainty Importance Runs.	Figure 5.1-18	MO0008MWDBARRI.000 [152184]
SR00_050nm5	Waste Package (WP) Degraded Barrier	Nominal	95th percentile WAPDEG WP Failure Degraded Barrier case; 100 Realizations: 1) G(MIC), microbiology influenced corrosion (MIC) enhancement factor - 1.95 2) G(age), aging enhancement factor - 2.425 3) Set U's in (Gaussian variance partitioning (GVP) 1, 3, and 5 calls in \WP_Degradation\GVP_External\ to 0.05 and all qu's to 0.95 4) stress/stress intensity profile (95th percentile from +/- 30% uncertainty range); z_OL and z_ML set to = 2.05132 5) manufacturing defect probability (or defect number per WP) - b = 4.83, v = 2.9, Psi = 0.362445	Figure 5.3-5 Figure 5.3-6	MO0008MWDBARRI.000 [152184]
SR00_064nm5	WP Enhanced Barrier	Nominal	5th percentile WAPDEG WP Failure Improved Barrier Case, 100 Realizations: 1) G(MIC), MIC enhancement factor = 1.05 2) G(age), aging enhancement factor = 1.075 3) Set U's in GVP 1, 3, and 5 calls in \WP_Degradation\GVP_External\ to 0.95 and all qu's to 0.05 4) stress/stress intensity profile (5th percentile from +/- 30% uncertainty range); z_OL and z_ML set to = -2.05132	Figure 5.3-5 Figure 5.3-6	MO0008MWDBARRI.000 [152184]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
			5) manufacturing defect probability (or defect number per WP): b = 1.77, v = 1.1, Psi = 0.348855		
SR00_061nm5	Drip Shield (DS) Degraded Barrier	Nominal	95th percentile WAPDEG DS Failure Case, 100 Realizations: The GVP 2 and GVP 4 parameters U were fixed at 0.05. The GVP 2 and GVP 4 parameters qu were fixed at 0.95.	Figure 5.3-3 Figure 5.3-4	MO0008MWDBARRI.000 [152184]
SR00_065nm5	DS Enhanced Barrier	Nominal	5th percentile WAPDEG DS Failure Case, 100 Realizations: Set the GVP 2 and GVP 4 U parameters to 0.95. Set the GVP 2 and GVP 4 qu parameters to 0.05.	Figure 5.3-3 Figure 5.3-4	MO0008MWDBARRI.000 [152184]
SR00_066nm5	Cladding Degraded Barrier	Nominal	95th percentile Cladding Values on clad stochastics (4 parameters; unzip_uncertainty, uncert_a0; LC_uncert; Initial_Rod_Failures).	Figure 5.3-7	MO0008MWDBARRI.000 [152184]
SR00_067nm5	Cladding Enhanced Barrier	Nominal	5th percentile Cladding Values on clad stochastics (4 parameters; uzip_uncertainty, uncert_a0; LC_uncert; Initial_Rod_Failures).	Figure 5.3-7	MO0008MWDBARRI.000 [152184]
SR00_062nm5	UZ Flow Degraded Barrier (entire system)	Nominal	High infiltration throughout model (set infiltration_scenario = 3).	Figure 5.2.1	MO0008MWDBARRI.000 [152184]
SR00_063nm5	UZ Flow Enhanced Barrier (entire system)	Nominal	Low infiltration throughout model (set infiltration_scenario = 1).	Figure 5.2.1	MO0008MWDBARRI.000 [152184]
SR00_126nm5	UZ Flow and Transport Degraded Barrier (entire system)	Nominal	95th percentile UZ transport parameters (UZ_Params_Multi.sr File), High Infiltration UZ flow for the entire system (set infiltration_scenario = 3).	Figure 5.3-11	MO0008MWDBARRI.000 [152184]
SR00_125nm5	UZ Flow and Transport Enhanced Barrier (entire system)	Nominal	5th percentile UZ transport parameters (UZ_Params_Multi.sr File); Low Infiltration UZ Flow for the entire system (set infiltration_scenario = 1).	Figure 5.3-11	MO0008MWDBARRI.000 [152184]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_087nm5	SZ Flow and Transport Degraded Barrier	Nominal	FPLAN=0.05, NVF19=0.0962, FISVO=1.99, FPVO=-4.8, DCVO=-12.85, KDNPVO=0.0031, KDNPAL=0.202, KDIAL=0.335, KDUVO=0.2, KDUAL=0.4, GWSPD=0.95, KDRN10=0.95, KDRN9=0.95, CORAL=0.0403, CORVO=0.233, HAVO=0.25, LDISP=2., KDTCAL=0.287, KC_AM_GW_COLLOID=0.129; Used SZ breakthrough curves for 5th/95th percentile runs, set SZ_Index = 1 for 95th percentile run.	Figure 5.3-13	MO0008MWDBARRI.000 [152184]
SR00_084nm5	SZ Flow and Transport Enhanced Barrier	Nominal	FPLAN=0.95, NVF19=0.2639, FISVO=0.588, FPVO=-1.2, DCVO=-10.15, KDNPVO=1.542, KDNPAL=57.99, KDIAL=0.6145, KDUVO=3.8, KDUAL=7.6, GWSPD=0.05, KDRN10=0.05, KDRN9=0.05, CORAL=3.8743, CORVO=2.8079, HAVO=0.75, LDISP=2., KDTCAL=0.6025, KC_AM_GW_COLLOID=5.72e-5; Used SZ breakthrough curves for 5th/95th percentile runs, set SZ_Index = 2 for 5th percentile run.	Figure 5.3-13	MO0008MWDBARRI.000 [152184]
SR00_070nm5	EBS Transport Degraded Barrier	Nominal	Use Rev00a diffusion model (ϕ^1, S^1, no uncertainty term) and 95th percentile Radionuclide concentration case (95th solubilities, WP Chem in invert, max colloid stability, 95th batch distribution coefficient (Kd colloids).	Figure 5.3-9	MO0008MWDBARRI.000 [152184]
SR00_145nm5	EBS Transport Enhanced Barrier	Nominal	Use 1e-11 cm2/sec diffusion model and 5th percentile Radionuclide concentration case (5th solubilities, Invert Chem in invert, min colloid stability, 5th Kd colloids).	Figure 5.3-9	MO0008MWDBARRI.000 [152184]
SR00_130nm5	Seepage Degraded Barrier	Nominal	Set flow focus factor to 95th (9.5), set seepage uncert. to 95th (0.95).	Figure 5.3-1	MO0008MWDBARRI.000 [152184]
SR00_129nm5	Seepage Enhanced Barrier	Nominal	Set flow focus factor to 5th (1.21267), set seepage uncert. to 5th (0.05).	Figure 5.3-1	MO0008MWDBARRI.000 [152184]
SR00_128nm5	Seepage degraded + UZ Flow Degraded + UZ Transport Degraded	Nominal	Seepage degraded, high infiltration UZ flow throughout entire model set (infiltration_scenario = 3), 95th percentile UZ transport parameters (UZ_Params_Multi.sr file), set flow focus factor to 95th (9.5), set seepage uncert. to 95th (0.95).	Figure 5.3-12	MO0008MWDBARRI.000 [152184]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_127nm5	Seepage enhanced + UZ Flow enhanced + UZ Transport enhanced	Nominal	Seepage enhanced, low infiltration UZ flow throughout entire model set (infiltration_scenario = 1), 5^{th} percentile UZ transport parameters (UZ_Params_Multi.sr file), set flow focus factor to 5^{th} (1.21267), set seepage uncert. to 5^{th} (0.05).	Figure 5.3-12	MO0008MWDBARRI.000 [152184]
SR00_076nm5	Seepage degraded + UZ Flow Degraded	Nominal	Seepage degraded, high infiltration UZ flow throughout entire model, (infiltration scenario = 3), set flow focus factor to 95^{th} (9.5), set seepage uncert. to 95^{th} (0.95).	Figure 5.3-2	MO0008MWDBARRI.000 [152184]
SR00_075nm5	Seepage enhanced + UZ Flow enhanced	Nominal	Seepage enhanced, low infiltration UZ flow throughout entire model, (infiltration scenario = 1), set flow focus factor to 5^{th} (9.5), set seepage uncert. to 5^{th} (0.05).	Figure 5.3-2	MO0008MWDBARRI.000 [152184]
SR00_143nm5	Biosphere 95^{th}	Nominal	95^{th} percentile BDCFs Values.	Figure 5.2-15	MO0008MWDBARRI.000 [152184]
SR00_144nm5	Biosphere 5^{th}	Nominal	5^{th} percentile BDCFs Values.	Figure 5.2-15	MO0008MWDBARRI.000 [152184]
SR00_048nm5	Backfill Sensitivity Case	Nominal	Base Case with Backfill. 100 realizations 1e5.	Fig 4.6-4 Fig 4.6-5	MO0008MWDBARRI.000 [152184]
SR00_094nm5	Concentration Limits Degraded Barrier	Nominal	95^{th} percentile Solubilities, WP Chem in the invert, max colloid stability, 95^{th} percentile Kd colloids.	Figure 5.3-8	MO0008MWDBARRI.000 [152184]
SR00_093nm5	Concentration Limits Enhanced Barrier	Nominal	5^{th} percentile Solubilities, Invert Chem in the invert, min colloid stability, 5^{th} percentile Kd colloids.	Figure 5.3-8	MO0008MWDBARRI.000 [152184]
SR00_095nm5	Rev. 00A Diffusion Model	Nominal	REV 00A diffusion model (ϕ^1, S^1, no uncertainty term).	Figure 5.2-13	MO0008MWDBARRI.000 [152184]
SR00_131nm5	Low Diffusion Model	Nominal	1e-11 cm^2/sec diffusion model.	Figure 5.2-13	MO0008MWDBARRI.000 [152184]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_122nm5	UZ Transport Degraded Barrier	Nominal	95th percentile UZ Transport Parameters (UZ_Params_Multi.sr file changes): - 5th percentile (i.e., low) Kds for all nuclides. - 95th percentile Kc. - 5th percentile anion/cation matrix diffusion coefficients. - 95th percentile fracture apertures for all.	Figure 5.3-10	MO0008MWDBARRI.000 [152184]
SR00_123nm5	UZ Transport Enhanced Barrier	Nominal	5th percentile UZ Transport Parameters (UZ_Params_Multi.sr file changes): - 95th percentile (i.e., low) Kds for all nuclides. - 5th percentile Kc. - 95th percentile anion/cation matrix diffusion coefficients. - 5th percentile fracture apertures for all.	Figure 5.3-10	MO0008MWDBARRI.000 [152184]
SR00_056nm5	WAPDEG Sens #1	Nominal	10-40% Stress Threshold, Yield Strength.	Figure 5.2-5 Figure 5.2-6	MO0008MWDBARRI.000 [152184]
SR00_057nm5	WAPDEG Sens #3	Nominal	10-40% Stress Threshold, Stress Uncertainty =±10% Yield Strength (0.3-1.0 fys).	Figure 5.2-5 Figure 5.2-6	MO0008MWDBARRI.000 [152184]
SR00_052nm5	WAPDEG Sens #4	Nominal	Stress Uncertainty =±10% Yield Strength (0.3-1.0 fys).	Figure 5.2-5 Figure 5.2-6	MO0008MWDBARRI.000 [152184]
SR00_053nm5	WAPDEG Sens #5	Nominal	10-40% Stress Threshold; Stress Uncertainty =±10% Yield Strength (0.3-1.0 fys); and Radial Defects 1% Total Defects (psi * 0.1.).	Figure 5.2-5 Figure 5.2-6	MO0008MWDBARRI.000 [152184]
SR00_116nm5	Co-disposal Waste Package Sensitivity	Nominal	Run nominal scenario with only co-disposal packages failing.	Figure 5.2-11	MO0008MWDBARRI.000 [152184]
SR00_109nm5	Commercial Spent Nuclear Fuel (CSNF) WPs Sensitivity	Nominal	Run nominal scenario with only co-disposal packages failing.	Figure 5.2-11	MO0008MWDBARRI.000 [152184]
SR00_106nm5	Seepage Flow Focus 95th percentile	Nominal	Set seepage flow focus factor to 95th percentile value (9.5).	Figure 5.2-2a	MO0008MWDBARRI.000 [152184]
SR00_107nm5	Seepage Flow Focus 5th percentile	Nominal	Set seepage flow focus factor to 5th percentile value (1.21267).	Figure 5.2-2a	MO0008MWDBARRI.000 [152184]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_147nm5	Water Usage (95th)	Nominal	Set Annual_Ground_Water_Usage to 95th percentile value (3.49504 x 10^6 m^3/yr).	Figure 5.2-16	MO0008MWDBARRI.000 [152184]
SR00_148nm5	Water Usage (5th)	Nominal	Set Annual_Ground_Water_Usage to 5th percentile value (1.47989 x 10^6 m^3/yr).	Figure 5.2-16	MO0008MWDBARRI.000 [152184]
SR00_159nm5	Seepage Degraded Barrier (no flow focus, seepage fraction = 1.0, and seepage uncert = 0.95)	Nominal	No flow focus factor, local seepage fraction set to 1.0, seepage uncertainty set to 0.95.	Figure 5.2-2b	MO0008MWDBARRI.000 [152184]
SR00_160nm5	Seepage Degraded Barrier (no flow focus, seepage fraction = 1.0)	Nominal	No flow focus factor, local seepage fraction set to 1.0.	Figure 5.2-2b	MO0008MWDBARRI.000 [152184]
SR00_165nm5	UZ Matrix Diffusion Sensitivity (100 Times)	Nominal	UZ Matrix Diffusion. UZ anions and cations were set to 100 times sampled values for 100 realizations.	Figure 5.2-14	MO0008MWDBARRI.000 [152184]
SR00_166nm5	UZ Matrix Diffusion Sensitivity (0 Times)	Nominal	UZ Matrix Diffusion. UZ anions and cations were set to 0 times sampled values for 100 Realizations.	Figure 5.2-14	MO0008MWDBARRI.000 [152184]
SR00_077nm5	z.OL and z.ML 95th	Nominal	set z.OL and z.ML to 95th percentile values.	Figure 5.2-3 Figure 5.2-4	MO0008MWDBARRI.000 [152184]
SR00_078nm5	z.OL and z.ML 5th	Nominal	set z.OL and z.ML to 5th percentile values.	Figure 5.2-3 Figure 5.2-4	MO0008MWDBARRI.000 [152184]
SR00_079nm5	qu 's at 95th	Nominal	set qu.GVP.GA22x2P5.CDF and qu.GVP.GA22SR00 to 95th percentile values.	Figure 5.2-9 Figure 5.2-10	MO0008MWDBARRI.000 [152184]
SR00_080nm5	qu 's at 5th	Nominal	set qu.GVP.GA22x2P5.CDF and qu.GVP.GA22SR00 to 5th percentile values.	Figure 5.2-9 Figure 5.2-10	MO0008MWDBARRI.000 [152184]
SR00_082nm5	U's at 95th	Nominal	set U.GVP.GA22x2P5.CDF and U.GVP.GA22SR00 to 95th percentile values.	Figure 5.2-7 Figure 5.2-8	MO0008MWDBARRI.000 [152184]
SR00_081nm5	U's at 5th	Nominal	set U.GVP.GA22x2P5.CDF and U.GVP.GA22SR00 to 5th percentile values.	Figure 5.2-7 Figure 5.2-8	MO0008MWDBARRI.000 [152184]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
Igneous Cases (REV 00B)					
SR00_016im5	Base Case 300 Realization	Igneous	300 Realization Base Case Run.	Fig. 3.10-14 Fig. 3.10-15 Figure 5.2-18 Figure 5.2-19 Figure 5.2-20 Figure 5.2-21 Figure 5.2-22 Figure 5.2-25 Figure 5.2-26	MO0008MWDIM501.006 [151720]
SR00_044im5	Igneous 1,000 Realization Base Case	Igneous	1,000 Realization Base Case for 100,000 years.	Figure 4.2-5	MO0008MWDIGNEO.000 [152185]
SR00_002im4	Igneous 1,000 Realization Base Case	Igneous	1,000 Realization Base Case for 20,000 years.	Figure 4.2-5 Figure 4.6-6 Figure 5.2-17 Figure 5.2-23 Figure 5.2-24	MO0008MWDIGNEO.000 [152185]
SR00_005im4	Igneous 5,000 Realization Base Case	Igneous	5,000 Realization Base Case for 50,000 years.	Figure 4.2-1 Figure 4.2-2 Figure 4.2-3 Figure 4.2-4 Figure 4.2-5 Figure 4.3-3 Figure 6.1-2 Figure 6.1-3	MO0009MWDIM401.015 [153123]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
			Post GoldSim Uncertainty Importance Runs	Figure 5.1-19 Figure 5.1-20 Figure 5.1-21 Figure 5.1-22	MO0011MWDRE60V.001
SR00_039im5	Base Case 300 Realizations w/Backfill	Igneous	300 Realizations Base Case Run with backfill.	N/A	MO0008MWDIGNEO.000 [152185]
SR00_022im5	Combined Zone 2 Aperture 95th and Zone 1, Zone 2 packages hit CDF 95th	Igneous	95th percentile Zone 2 package apertures, and 95th percentile Zone 1 and Zone 2 packages hit.	N/A	MO0008MWDIGNEO.000 [152185]
SR00_031im5	Conduit Diameter 95th	Igneous	95th percentile Conduit Diameter.	N/A	MO0008MWDIGNEO.000 [152185]
SR00_033im5	Mean Ash Particle Diameter 95th	Igneous	95th percentile Mean Ash Particle Diameter.	N/A	MO0008MWDIGNEO.000 [152185]
SR00_024im5	1,000 year Soil Removal Factor	Igneous	1,000 year Soil Removal Factor.	Figure 5.2-20	MO0008MWDIGNEO.000 [152185]
SR00_019im5	U.S. Nuclear Regulatory Commission (NRC) 1e-7 Prob.	Igneous	NRC 1e-7 Event Probability Run.	N/A	MO0008MWDIGNEO.000 [152185]
SR00_017im5	Zone 1 & Zone 2 Cumulative Distribution Function (CDF) 95th	Igneous	Sample 95th percentile CDFs for number of damaged WPs (Zone 1 and Zone 2).	N/A	MO0008MWDIGNEO.000 [152185]
SR00_018im5	Zone 1 & Zone 2 CDF 5th	Igneous	Sample 5th percentile CDFs for number of damaged WPs (Zone 1 and Zone 2).	N/A	MO0008MWDIGNEO.000 [152185]
SR00_030im5	Eruptive Volume 95th	Igneous	Sample 95th percentile Value for Eruptive Volume.	Figure 5.2-21	MO0008MWDIGNEO.000 [152185]
SR00_027im5	Eruptive Volume 5th	Igneous	Sample 5th percentile Value for Eruptive Volume.	Figure 5.2-21	MO0008MWDIGNEO.000 [152185]
SR00_035im5	No Soil Removal Factor	Igneous	No soil removal factor.	N/A	MO0008MWDIGNEO.000 [152185]
SR00_028im5	Wind Speed 95th	Igneous	Sample Wind Speed CDF at 95th percentile value.	Figure 5.2-19	MO0008MWDIGNEO.000 [152185]
SR00_029im5	Wind Speed 5th	Igneous	Sample Wind Speed CDF at 5th percentile value.	Figure 5.2-19	MO0008MWDIGNEO.000 [152185]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_034im5	Mean Ash Particle 5th	Igneous	Sample Mean Ash Particle Diameter at 5th percentile value.	N/A	MO0008MWDIGNEO.000 [152185]
SR00_026im5	Igneous BDCF's 95th	Igneous	Sample Igneous BDCF's at the 95th percentile value.	Figure 5.2-25	MO0008MWDIGNEO.000 [152185]
SR00_025im5	Igneous BDCF's 5th	Igneous	Sample Igneous BDCF's at the 5th percentile value.	Figure 5.2-25	MO0008MWDIGNEO.000 [152185]
SR00_032im5	Conduit Diameter 5th	Igneous	Sample Conduit diameter at the 5th percentile value.	N/A	MO0008MWDIGNEO.000 [152185]
SR00_023im5	Combined 5th Zone 2 Aperture and 5th Zone 1 and Zone 2 Packages Damaged CDF	Igneous	Sample Zone 2 apertures at 5th percentile value, sample both Zone 1 and Zone 2 number of waste packages damaged CDF at the 5th percentile value.	N/A	MO0008MWDIGNEO.000 [152185]
SR00_036im5	95th percentile Number of Direct Release Packages Hit	Igneous	Sample Direct Release Packages Hit (using Base Case Igneous Results) at the 95th percentile value.	Figure 5.2-22	MO0008MWDIGNEO.000 [152185]
SR00_037im5	5th percentile Number of Direct Release Packages Hit	Igneous	Sample Direct Release Packages Hit (using Base Case Igneous Results) at the 5th percentile value.	Figure 5.2-22	MO0008MWDIGNEO.000 [152185]
SR00_038im5	Variable Wind Direction	Igneous	Used sampled wind direction value.	Figure 3.10-14 Figure 3.10-15 Figure 5.2-18	MO0008MWDIGNEO.000 [152185]
SROO_043iM5	Incorporation Ratio set 1	Igneous	Run 300 Realization Igneous scenario with incorporation ratio = .1 (Rhocut).	Figure 5.2-26	MO0008MWDIGNEO.000 [152185]
SR00_047im5	Incorporation Ratio set to 0.1	Igneous	Run 300 Realization Igneous scenario with incorporation ratio = .1 (Rhocut).	Figure 5.2-26	MO0008MWDIGNEO.000 [152185]
SR00_009im4	Igneous Base Case w/backfill 1,000 rlz/20k	Igneous	1,000 Realization igneous base case w/backfill run for 20,000 years.	4.6-6	MO0008MWDIGNEO.000 [152185]
SR00_003im4	95th percentile Number of Zone 2 Packages Hit 1,000 rlz/20k	Igneous	1,000 Realization igneous run for 20,000 years. Set the CDF for Zone 2 + Zone1 packages hit to 95th percentile value.	Figure 5.2-23	MO0008MWDIGNEO.000 [152185]
SR00_006im4	5th percentile Number of Zone 2 Packages Hit 1,000 rlz/20k	Igneous	1,000 Realization igneous run for 20,000 years. Set the CDF for Zone 2 + Zone1 packages hit to 5th percentile value.	Figure 5.2-23	MO0008MWDIGNEO.000 [152185]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_007im4	Combined 95^{th} percentile Number of Zone 2 Packages Hit and Zone 2 Apertures 1,000 rlz/20k	Igneous	1,000 Realization igneous run for 20,000 years. Set the CDF for Zone 2 + Zone1 packages hit to 95^{th} percentile value. Set zone 2 aperture sizes to the 95^{th} percentile values.	Figure 5.2-24	MO0008MWDIGNEO.000 [152185]
SR00_008im4	Combined 5^{th} percentile Number of Zone 2 Packages Hit and Zone 2 Apertures 1,000 rlz/20k	Igneous	1,000 Realization igneous run for 20,000 years. Set the CDF for Zone 2 + Zone1 packages hit to 5^{th} percentile value. Set zone 2 aperture sizes to the 5^{th} percentile values.	Figure 5.2-24	MO0008MWDIGNEO.000 [152185]
SR00_004im4	Combined NRC event probability 1e-7/year, vent probability = 1. 1,000 realizations/20k	Igneous	1,000 Realization igneous run for 20,000 years. Set the event probability to 1e-7 per year and set the vent probability factor equal to 1.	Figure 5.2-17	MO0008MWDIGNEO.000 [152185]
Human Intrusion					
SR00_005hm5	Human Intrusion 1e5, 100 realizations, CSNF WP failed at 100 years	H.I.	100 Realizations, derived from Rev. 00B of nominal base case,WP failed at 100 years; transport additional radionuclides through SZ (^{90}Sr, ^{137}Cs, ^{238}Pu, ^{241}Am).	Figure 4.4-12 Figure 5.2-27 Figure 6.1-5	MO0008MWDHUMAN.000 [152186]
SR00_006hm5	Human Intrusion 1e5, 300 realizations, CSNF WP failed at 100 years	H.I.	300 Realizations, derived from Rev. 00B of nominal, WP failed at 100 years; transport additional radionuclides through SZ (^{90}Sr, ^{137}Cs, ^{238}Pu, ^{241}Am).	Figure 4.4-11 Figure 6.1-4	MO0008MWDHUMAN.000 [152186]
SR00_007hm5	Human Intrusion 1e4 Failure	H.I.	Human Intrusion Scenario with 1e4 year WP breach.	Figure 4.4-12 Figure 6.1-5	MO0008MWDHUMAN.000 [152186]
SR00_008hm5	Human Intrusion 95^{th} percentile Seepage	H.I.	Human Intrusion Scenario with 95^{th} percentile borehole seepage value.	Figure 5.2-27	MO0008MWDHUMAN.000 [152186]
RSS4 Neutralization Runs					
SR00_099nm5	Neutralize DS	Nominal	Remove DS, set DS_Frac_Patch = 1.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_089nm5	Neutralize SZ	Nominal	Feed UZ releases directly to biosphere cell.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_090nm5	Neutralize SZ + UZ	Nominal	Feed EBS releases directly to biosphere cell.		MO0008MWDNEUTR.000 [152187]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_121nm5	Neutralize UZ	Nominal	Feed EBS releases directly to SZ.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_097nm5	Neutralize WP	Nominal	WP Neutralization Case, fail all WPs at T=100 years with one patch, have WAPDEG degradation proceed normally.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_096nm5	Neutralize WP and DS	Nominal	WP Neutralization Case, DS Neutralization Case	N/A	MO0008MWDNEUTR.000 [152187]
SR00_100nm5	Neutralize overlying rock	Nominal	Set seepage flux equal to precipitation, as a function of climate and infiltration scenario: Low Medium High Present day 191.6 196.9 277.5(mm/yr) Moonsoon 196.9 309.3 421.6(mm/yr) Glacial trans. 205.5 323.1 440.6(mm/yr)	N/A	MO0008MWDNEUTR.000 [152187]
SR00_124nm5	Neutralize Invert	Nominal	100% invert saturation, WP Chemistry in invert.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_088nm5	No Cladding	Nominal	Use only CSNF degradation rate instead of unzipping, fail all pins.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_113nm5	Neutralize WP and Cladding	Nominal	WP Neutralization Case, fail all WPs at T=100 years with one patch, have WAPDEG degradation proceed normally. Use only CSNF degradation rate instead of unzipping, fail all pins.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_112nm5	Neutralize WP, DS, and Cladding	Nominal	WP Neutralization Case, fail all WPs at T=100 years with one patch, have WAPDEG degradation proceed normally. Use only CSNF degradation rate instead of unzipping, fail all pins. Remove DS.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_114nm5	Neutralize UZ, SZ, and Overlying Rock	Nominal	Feed EBS releases directly to biosphere cell. Set seepage flux equal to precipitation, as a function of climate and infiltration scenario: Low Medium High Present day 191.6 196.9 277.5 (mm/yr) Monsoon 196.9 309.3 421.6 (mm/yr) Glacial trans. 295.5 323.1 440.6 (mm/yr)	N/A	MO0008MWDNEUTR.000 [152187]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_119nm5	Neutralize UZ, SZ, Overlying Rock, WPs, DS, Invert, and Cladding	Nominal	WP Neutralization Case, fail all WPs at T=100 years with one patch, have WAPDEG degradation proceed normally. Use only CSNF degradation rate instead of unzipping, fail all pins. Remove DS. Feed EBS releases directly to biosphere cell, Set seepage flux equal to precipitation, as a function of climate and infiltration scenario: Low / Medium / High Present day: 191.6 / 196.9 / 277.5 (mm/yr) Monsoon: 196.9 / 309.3 / 421.6 (mm/yr) Glacial trans.: 205.5 / 323.1 / 440.6 (mm/yr)	N/A	MO0008MWDNEUTR.000 [152187]
SR00_111nm5	Neutralize Concentration Limits	Nominal	No solubility limits, radionuclide mobilization controlled only by degradation rates and cladding.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_115nm5	Neutralized Concentration Limits and WP	Nominal	No solubility limits, radionuclide mobilization controlled only by degradation rates and cladding. WP Neutralization Case, fail all WPs at T=100 years with one patch, have WAPDEG degradation proceed normally.	N/A	MO0008MWDNEUTR.000 [152187]
SR00_132nm5	Neutralized WP with Low Diffusion	Nominal	WP Neutralization Case, fail all WPs at T=100 years with one patch, have WAPDEG degradation proceed normally. Use 1e-11 cm2/sec invert diffusion.	N/A	MO0008MWDNEUTR.000 [152187]
Juvenile Failure Runs					
SR00_153nm5	Juvenile Failure (co-disposal)	Nominal	Single co-disposal WP breach with one patch at 100 years.	N/A	MO0008MWDJUVEN.000 [152188]
SR00_117nm5	Juvenile Failure (CSNF)	Nominal	Single CSNF WP breach with one patch at 100 years.	N/A	MO0008MWDJUVEN.000 [152187]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_137nm5	Juvenile Failure and Degraded DS	Nominal	Fail Single WP with one patch at 100 years, Degraded WAPDEG DS Failure Case, 100 Realizations. The GVP 2 and GVP 4 parameters U were fixed at 0.05. The GVP 2 and GVP 4 parameters qU were fixed at 0.95.	N/A	MO0008MWDJUVEN.000 [152188]
SR00_146nm5	Juvenile Failure and Degraded Cladding Case	Nominal	Fail Single WP with one patch at 100 years, 95^{th} percentile Cladding values on clad stochastics (4 parameters; uzip_uncertainty, uncert_a0; LC_uncert; Initial_Rod_Failures).	N/A	MO0008MWDJUVEN.000 [152188]
SR00_138nm5	Juvenile Failure and Degraded Concentration Limits	Nominal	Fail Single WP with one patch at 100 years, 95^{th} percentile Solubilities, WP Chem in the invert, max colloid stability, 95^{th} percentile Kd colloids.	N/A	MO0008MWDJUVEN.000 [152188]
SR00_139nm5	Juvenile Failure and UZ Transport 95^{th} percentile	Nominal	Fail Single WP with one patch at 100 years, 95^{th} percentile UZ transport parameters (UZ_Params_Multi.sr file modified).	N/A	MO0008MWDJUVEN.000 [152188]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_140nm5	Juvenile Failure and Degraded SZ Flow and Transport	Nominal	Fail Single WP with one patch at 100 years, 95th percentile SZ break through curves, FPLAN=0.05, NVF19=0.0962, FISVO=1.99, FPVO=-4.8, DCVO=-12.85, KDNPVO=0.0031, KDNPAL=0.202, KDIAL=0.335, KDUVO=0.2, KDUAL=0.4, GWSPD=0.95, KDRN10=0.95, KDRN9=0.95, CORAL=0.0403, CORVO=0.233, HAVO=0.25, LDISP=2., KDTCAL=0.287, KC_AM_GW_COLLOID=0.129; Used SZ breakthrough curves for 5th/95th percentile runs, set SZ_Index = 2 for 5th percentile run.	N/A	MO0008MWDJUVEN.000 [152188]
SR00_134nm5	Juvenile Failure and Degraded Seepage & Degraded UZ Flow	Nominal	Fail Single WP with one patch at 100 years, seepage degraded, high infiltration UZ flow throughout entire model (set infiltration scenario = 3), set flow focus factor to 95th (9.5), set seepage uncert. to 95th (0.95).	N/A	MO0008MWDJUVEN.000 [152188]
SR00_135nm5	Juvenile Failure and Degraded Seepage & Degraded UZ Flow, Low Diffusion	Nominal	Fail Single WP with one patch at 100 years, seepage degraded, high infiltration UZ flow throughout entire model (set infiltration scenario = 3), set flow focus factor to 95th (9.5), set seepage uncert. to 95th (0.95). Use 1e-11 cm2/sec diffusion.	N/A	MO0008MWDJUVEN.000 [152188]
SR00_136nm5	Juvenile Failure and Enhanced Seepage & Enhanced UZ Flow, Low Diffusion	Nominal	Fail Single WP with one patch at 100 years, seepage enhanced, low infiltration UZ flow throughout entire model (set infiltration scenario = 1), set flow focus factor to 5th (1.21267), set seepage uncert. to 5th (0.05). Use 1e-11 cm2/sec diffusion.	N/A	MO0008MWDJUVEN.000 [152188]
SR00_141nm5	Juvenile Failure CSNF	Nominal	300 Realization CSNF Juvenile Failure Case.	N/A	MO0008MWDJUVEN.000 [152188]

Table G-1. Listing of Simulations Conducted for the TSPA-SR (Continued)

Simulation Number	Simulation Name	Scenario	Description	Figures	DTN
SR00_152nm5	Neutralize all barriers	Nominal	WP Neutralization Case, fail all WPs at T=100 years with one patch, have WAPDEG degradation proceed normally. Use only CSNF degradation rate instead of unzipping, fail all pins. Remove DS. Set seepage flux equal to precipitation, as a function of climate. Compute weighted average concentration in waste-form cells and multiply by BDCFs to get the dose rate. Low / Medium / High Present-day 191.6 196.9 277.5(mm/yr) Monsoon 196.9 309.3 421.6 (mm/yr) Glacial trans. 205.5 323.1 440.6 (mm/yr)	N/A	MO0008MWDJUVEN.000 [152188]
Low Thermal Load					
SR00_180nm5	T/H Sensitivity #4 (0.90/100 Temperature Case)	Nominal	100 Realization Base Case Run with 0.90 kW/m line load and 100 year ventilation T/H curves. (DTN: MO0008SPATHS03.001 [151812])	4.6-7 4.6-8 4.6-9 4.6-10	MO0008MWDBARRI.000 [152184]
Inventory Sensitivity					
SR00_162nm5	Inventory Sensitivity 100 rlz, 1e5 years.	Nominal	Modified Base Case Run to include "new" inventory to address impact of Navy Fuels. DOE-owned SNF Inventory was modified and number of CSNF packages increased.	N/A	MO0008MWDBARRI.000 [152184]

APPENDIX H

SUMMARY AND RESPONSE TO REVIEW COMMENTS ON PREVIOUS YUCCA MOUNTAIN TSPA ITERATIONS

APPENDIX H

SUMMARY AND RESPONSE TO REVIEW COMMENTS ON PREVIOUS YUCCA MOUNTAIN TSPA ITERATIONS

As the science and engineering associated with a potential repository at the Yucca Mountain site has evolved, so too have the analysis capability and the communication of the analyses, models and performance projections. At each stage of the investigation of the repository performance, which corresponds to each iteration of the total system performance assessment (TSPA), internal and external reviews have been performed. These reviews have identified various strengths and weaknesses in the approach, methodology, models, assumptions, data, as well as the documentation of the information in a clear and transparent fashion.

The most recently completed TSPA, TSPA-VA (DOE 1998 [100550], Volume 3) benefitted from a number of reviews, including: the TSPA-VA Peer Review Panel (see Budnitz et al. 1999 [102726] and CRWMS M&O 1999 [153111]), the NRC (Paperiello 1999 [146561]), Clark County, NV (Cohen 1999 [151783]), and the U.S. Geological Survey (Anderson et al. 1998 [101656]). In addition, several Nuclear Waste Technical Review Board (NWTRB) reports and letters have documented issues and concerns they have raised in their reviews of Yucca Mountain project reports.

This Appendix presents in tabular format a summary of the major comments on the TSPA-VA model components and how these components have been updated to address these issues. This summary follows as Table H-1. In order to more traceably identify the component model, this table has been formatted in the same fashion as several other summary-type table, wherein the first column in the key attribute of the repository system and the second column is process model factor or model component of the TSPA-SR model.

While it is difficult to enumerate every comment on the TSPA-VA, Table H-1 presents a summary of many of the most significant comments and how they have been addressed in the TSPA-SR. However, this comment resolution correlation matrix does not completely represent the breadth of comments received on all aspects of the TSPA-VA. For example, numerous issues associated with the models included in the TSPA-VA have been identified in the NRC's Key Technical Issues Issue Resolution Status Reports (IRSRs) as Acceptance Criteria for evaluating the sufficiency of DOE's site recommendation. These issues are addressed in the individual process model reports (PMRs) that most closely correlate to the corresponding key technical issues. Further information on the response to the Peer Review Panel final report is contained in Budnitz et al. 1999 [102726].

While the models and analyses that support the TSPA-SR may not have addressed every issue or comment raised on the previous TSPA iterations, they have addressed the most significant issues. For example, a significant cross-cutting issue raised on the TSPA-VA was the reliance on expert elicitation in the absence of sufficient site or engineering data. In the present analysis there have been no elicitations used in lieu of site data, with the exception of defining the probability of disruptive events.

A common comment raised by the Peer Review Panel and the NWTRB has been the treatment of uncertainties in the analyses and models. The Peer Review Panel noted three broad ways of treating uncertainty, which included (1) conducting additional testing and analyses to update the models and reduce the uncertainty, (2) modifying the design to mitigate the significance of the uncertainty on repository performance or (3) simplify and bound the models or analyses to accommodate the uncertainty without requiring a complete quantitative treatment of the uncertainty. All three of these methods have been used in the TSPA-SR. The models have been significantly updated since the VA The design has been significantly modified (notably to reduce the thermal load, place the corrosion-resistant metal on the outside of the waste package, and add a drip shield above the waste package). Finally, in areas of significant complexity, bounding conservative representations (as summarized in Appendix F) have been employed.

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Limited Water Contacting Waste Package	Climate	Various climatologic, geologic, and hydrologic evidence suggests that the VA's climate models are too conservative.	The climate model remains reasonably conservative but has been improved using additional climatologic evidence. Temporal variability is included as a sequence of climate states. To capture uncertainty, upper-bound and lower-bound climate analogs were chosen for each climate state.	USGS	3.2
	Net Infiltration	Various climatologic, geologic, and hydrologic evidence suggests infiltration/percolation rates are too conservative.	The net infiltration rates remain conservative because of the use of reasonably conservative values for uncertain input parameters. Net infiltration is determined by use of probabilistic simulations that incorporate surface topography and geology. Key uncertain input parameters include precipitation, bedrock and soil hydrologic properties, and evapotranspiration.	USGS	3.2
	UZ Flow	The TSPA-VA UZ flow model possesses uncertainties that have been applied without recognition of their potential limitations. These limitations could call into the usefulness of the sensitivity and uncertainty analyses that have been conducted.	The understanding of the uncertainties in the UZ flow model and their presentation have been improved. Potential limitations have been recognized, and the sensitivity and uncertainty analyses account for them.	TSPA-VA Peer Review Panel	3.2, 5.2
		Occurrence of "bomb-pulse" Cl-36 in Exploratory Studies Facility and implications for groundwater travel times	The occurrence of fast flow paths is implicitly included in the UZ flow model used in TSPA-SR.	State of Nevada	
	Coupled Effects on UZ Flow	The assumption that the fully coupled thermal-hydraulic-mechanical-chemical interactions are of secondary importance needs to be appropriately justified.	Analyses have been conducted to evaluate the effects of chemical and mechanical effects on large scale UZ flow. Based on the results of these analyses, these effects will be insignificant and therefore are neglected.	TSPA-VA Peer Review Panel	3.3

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Limited Water Contacting Waste Package (Cont'd)	Seepage into Emplacement Drifts	The Total System Performance Assessment-Viability Assessment (TSPA-VA) has not fully addressed the potential effects associated with the chemical and mechanical interactions in the thermo-hydrologic analyses.	Thermal-hydrologic-mechanical effects on drift-scale flow have not been fully evaluated but estimates indicate that these effects are likely to be of little importance and are neglected in TSPA simulations. A fully coupled thermal-hydrologic-chemical model has been developed to evaluate changes in hydrologic properties caused by mineral dissolution and precipitation. Predicted changes in hydrologic properties are insignificant and thus neglected in TSPA simulations.	TSPA-VA Peer Review Panel	3.3
		In the TSPA base case, seepage into the drifts is decoupled from Thermal Hydrology, and is assumed to only take place following the end of the thermal period and under ambient flow conditions. These assumptions may be invalid.	Near-drift transients caused by potential repository heating are included in the seepage extraction for TSPA by taking percolation flux above the drifts from the thermal hydrologic model as input rather than simply using the percolation flux from the mountain-scale flow model.	TSPA-VA Peer Review Panel	
	Coupled Effects on Seepage	The effects of the geometrical changes that may result from the collapse of the drift roof in response to thermo-mechanical or seismic processes need to be analyzed.	The seepage abstraction includes effects of drift degradation and flow focussing above the drifts.	TSPA-VA Peer Review Panel	3.3
		Flow in the UZ and thermal-mechanical-hydrologic-chemical interactions must be closely correlated to incoming-water flux.	Thermal-mechanical and thermal-chemical effects on seepage are estimated to be insignificant and thus neglected in the TSPA. Changes in drift geometry are accounted for as is near drift percolation transients caused by repository heating.	TSPA-VA Peer Review Panel	
Long Waste Package Lifetime	In-Drift Physical and Chemical Environments	The data and models used in the VA to calculate the quantity and chemistry of water dripping on waste packages are inadequate to describe process and extent of potential dripping under ambient and thermally-altered conditions.	A new fully coupled thermal-hydrologic-chemical model has been developed to provide compositions of water flowing into the drifts. These compositions are used as input to the new In-drift Salts/Precipitates model. This model uses a Pitzer approach and has been developed to predict the composition of water on the waste packages and in the invert.	NRC	3.3

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Long Waste Package Lifetime (Cont'd)	In-Drift Physical and Chemical Environments (Cont'd)	Not all of the incoming gas will remain in drift or be consumed by in-drift reactions. The cumulative outgoing flux of each constituent gas in the drift should also be taken into account in order to determine the in-drift gas fugacities.	Incoming gas compositions are calculated by the fully coupled thermal-hydrologic-chemical model and are used as input to the in-drift chemistry calculations. Sources and sinks of gas constituents within the drift are neglected based on an analysis that concluded that they are insignificant.	TSPA-VA Peer Review Panel	3.3
	In-Drift Moisture Distribution	When water finally enters the drift, the arbitrarily chosen percentage of evaporated water (90 percent) may give rise to uncertainties in the modeled compositions.	The approach of assuming a percentage of evaporated water was discarded. A new In-drift Salts/Precipitates model was developed using a Pitzer approach to alleviate the difficulties with calculating aqueous and solid compositions for evaporative concentrated solutions. Also, to account for uncertainty in moisture distribution on the waste package, the entire waste package is assumed to be wet and general corrosion is initiated once a critical relative humidity corresponding to the deliquescence point of $NaNO_3$ is reached.	TSPA-VA Peer Review Panel	3.4
	Drip Shield Degradation and Performance	N/A	Drip Shield was not a component of the VA design.		3.4
	Waste Package Degradation and Performance	The technical basis for the degradation characteristics and rates of the candidate waste package materials needs to be adequately justified.	Degradation characteristics and rates are based on experimental data from the Project's long-term Corrosion Testing Facility.	NRC	3.4, 5.2
		The TSPA-VA has not fully addressed the potential effects associated with degradation of the drift with time and the effects this may have on waste package performance.	Drift degradation analyses and drip shield structural analyses indicate that effects of rockfall on drip shield performance, WP performance, and thermal hydrology are negligible for TSPA calculations.	TSPA-VA Peer Review Panel	3.3, 3.4

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Slow Rate of Radionuclide Mobilization and Release from the EBS	Radionuclide Inventory and Distribution in Repository	The approach used for screening out unimportant radionuclides from the TSPA analyses needs to be well documented and the potential impacts of not considering the full suite of possible radionuclides present needs to be demonstrated.	A systematic radioisotope screening procedure was conducted and documented that considered the following factors: relative contribution to annual dose, radionuclide longevity, elemental solubility, transport affinity, release scenario, and containment time.	TSPA-VA Peer Review Panel	3.5
	In-Package Environments	There is a need for better definition of the composition of the water that seeps into the waste package and a determination of how this chemistry is modified by reaction with the waste package.	A new model has been developed to predict the evolution of fluid chemistry inside a failed waste package. This information is used by several waste form subcomponent models that are dependent on in-package chemistry.	NRC	3.5
	Cladding Degradation and Performance	Zircaloy may be susceptible to corrosion under certain chemical conditions in the waste package. These chemical processes were explicitly not considered in the TSPA-VA.	Localized corrosion due to fluoride ions in the waste package are considered. Other mechanisms for cladding perforation such as hydride failures, hydride embrittlement, delayed hydride cracking, microbial corrosion, acid corrosion from radiolysis, and enhanced corrosion due to high silica content in seepage waters have been screened out.	TSPA-VA Peer Review Panel	3.5
		The DOE appears to have ignored the judgements of its own experts by taking full cladding credit in the TSPA-VA.	A cladding model is implemented in the TSPA. This model determines the fraction of fuel rods in the commercial spent nuclear fuel packages with perforated cladding as a function of various failure mechanisms induced by physical and chemical processes.	Nuclear Waste Technical Review Board	
	Commercial Spent Nuclear Fuel Degradation and Performance	The presentation of the spent nuclear fuel corrosion models and these side-calculations leaves much to be desired in clarity and transparency. It is difficult to clearly identify when models or codes are used only for side-calculations *versus* their inclusion in the TSPA-VA.	The presentation, technical basis, and documentation of spent nuclear fuel corrosion models are much more transparent and improved. These improvements are, in part, a result of Analysis and Model Reports and Process Model Reports that provide technical bases for TSPA abstraction models and synthesize results, respectively.	TSPA-VA Peer Review Panel	3.5

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Slow Rate of Radionuclide Mobilization and Release from the EBS (Cont'd)	DOE-Owned Spent Nuclear Fuel Degradation and Performance	The presentation of the spent nuclear fuel corrosion models and these side-calculations leaves much to be desired in clarity and transparency. It is difficult to clearly identify when models or codes are used only for side-calculations *versus* their inclusion in the TSPA-VA.	The presentation, technical basis, and documentation of spent nuclear fuel corrosion models are much more transparent and improved. These improvements are, in part, a result of Analysis and Model Reports and Process Model Reports that provide technical bases for TSPA abstraction models and synthesize results, respectively.	TSPA-VA Peer Review Panel	3.5
	Defense High-Level Radioactive Waste Degradation and Performance	Confidence in the extrapolated behavior of corroding borosilicate glass would be greatly enhanced if a mechanism can be identified for this long-term process. Such knowledge could provide the basis for using bounding calculations for glass corrosion rates.	The high-level radioactive waste degradation model is implemented in the form of an analytical expression containing parameters that account for pH, temperature, surface area, glass composition, and solution composition. This expression is widely accepted and used in the scientific literature. Conservative estimates of these parameters are derived from laboratory data to bound long-term degradation rates.	TSPA-VA Peer Review Panel	3.5
	Dissolved Radionuclide Concentrations	The neptunium-bearing phases that control the solution compositions should be identified in the laboratory experiments, and a thoughtful case should be developed for the assumption that this phase will control Np-concentrations in the potential repository environment.	The commercial spent nuclear fuel dissolution model is based on fitting data from flow-through experiments over a wide range of conditions relevant to the repository. Long-term drip testing of commercial spent nuclear fuel has been done over the past six years to determine the relationship between commercial spent nuclear fuel alteration and the release of radionuclides. The model adequately bounds the spread of values reflected in the available dissolution rate data.	TSPA-VA Peer Review Panel	3.5

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Slow Rate of Radionuclide Mobilization and Release from the EBS (Cont'd)	Colloid-Associated Radionuclide Concentrations	The mechanistic basis for the partitioning coefficient for plutonium sorption onto colloids, as well as the stability and filtration characteristics of these colloids, needs to be better defined.	TSPA-SR includes two models for colloid-facilitated transport of radionuclides: one for radionuclides irreversibly bound to colloids, and one for radionuclides reversibly bound to colloids. The irreversible-colloid model is based on data from glass waste-form dissolution tests and colloid-transport tests conducted at the C-wells complex that involved microsphere surrogates for colloids. The C-wells tests were used to define the colloid filtration process, which was modeled as a retardation factor. The reversible-colloid model is based on data from waste-form dissolution tests for commercial spent fuel and estimates of sorption of radionuclides onto similar clays, because measurements of sorption of radionuclides onto colloids could not be completed in time. In order not to underestimate the affect of colloid-facilitated transport, the reversible-colloid model was simplified to use parameters that tended to produce more association of radionuclides to colloids; e.g., the sorption potential for americium onto clay, the largest sorption coefficient of those considered, was used for all radionuclides considered in the model.	NRC	3.5 3.8
	In-Package Radionuclide Transport	The TSPA-VA treatment of the movement of water into a damaged waste package and the transport of radionuclides from such a package were highly conservative.	The models for water movement into damaged waste packages and the subsequent transport and release of radionuclides are conservative and bounding to account for uncertainties in-package transport processes.	TSPA-VA Peer Review Panel	3.6
		In the TSPA-VA transport of corrosion products from the packages through waste package penetrations were judged not to provide any significant retardation to radionuclide releases. The Panel does not accept this view; we believe that it would have been more realistic to have assumed that the resulting penetrations will likely retard radionuclide releases from the waste packages.	There are potentially large uncertainties associated with radionuclide transport and retardation due to sorption onto waste package corrosion products. Because of these uncertainties, retardation due to corrosion products is neglected.	TSPA-VA Peer Review Panel	

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Slow Rate of Radionuclide Mobilization and Release from the EBS (Cont'd)	EBS (Invert) Degradation and Performance	A better definition of the pathways by which water from the corroded spent fuel may escape from the EBS is needed.	The seepage in the drift is conceptualized to flow from discrete fractures above the roof of the drift, falling vertically downward onto the drip shield, the invert, and the waste package if the drip shield has been breached. A detailed description of these flow pathways are provided in the EBS Flow Abstraction.	TSPA-VA Peer Review Panel	3.6
Long Transport away from the EBS	UZ Radionuclide Transport (Advective Pathways; Retardation; Dispersion)	Estimation of a reliable value for the matrix-fracture reduction factor, and validation of the assumptions regarding by-passing of the water around potentially sorbing formations, will add considerable confidence to the validity of the TSPA-VA UZ transport projections.	In general, fractures are modeled as a highly permeable continuum having a low porosity, and the matrix is modeled as a much less permeable continuum having a higher porosity. In the TSPA, fracture-matrix interaction is better represented with an "active-fracture" model, in which only a portion of the fractures is actively flowing under unsaturated conditions.	TSPA-VA Peer Review Panel	3.2, 3.7
		Extrapolation of Busted Butte results to potential repository is questionable.	Experiments conducted at Busted Butte are only used in TSPA-SR to support the results of the modeling, and not directly in the modeling itself. For instance, the imbibition of water into the nonwelded matrix seen at Busted Butte corroborates what is seen in the UZ flow model. Also, the high sorption coefficients measured in samples taken from Busted Butte for several radionuclides tends to justify as conservative the lower sorption coefficients used in the TSPA modeling.	Nuclear Waste Technical Review Board	3.2
	Coupled Effects on UZ Radionuclide Transport	The complexity of transport and sorption, particularly due to the interaction of the UZ with the near-field environment altered zone, requires considerably more work in order to reduce uncertainties to an acceptable level.	In TSPA simulations, the sorption characteristics of the rock are taken to be constant in time. Changes in sorption (or other transport properties) brought about by potential repository induced thermal effects have been considered and found to be insignificant.	TSPA-VA Peer Review Panel	3.7

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Long Transport away from the EBS (Cont'd)	SZ Radionuclide Transport (Advective Pathways; Retardation; Dispersion)	The TSPA-VA has not fully addressed the potential effects associated with dispersion and dilution of radionuclides in the groundwater especially at early times when small source areas may be more likely.	Three modifications have been made to TSPA-SR to address this issue. First, all radionuclides released from the repository during a simulation are concentrated into point sources in the SZ, thereby reducing the effect of dispersion and dilution of radionuclides in the UZ. Second, the particle-tracking method is used in the transport calculations for the SZ, thereby reducing the effect of dispersion and dilution of radionuclides in the SZ. Finally, all radionuclides traveling through the SZ in a simulation are dissolved in the volume of water that is estimated to be used by a farming community of 100 people, as specified in the proposed 10 CFR Part 63 (64 FR 8640), thus effectively eliminating dispersion and dilution as a modeling issue.	TSPA-VA Peer Review Panel	3.8 3.9
		The TSPA-VA lacks site-specific data for the SZ from Forty Mile Wash to the Amargosa Valley.	Nye County has drilled 3 new drill holes in the vicinity of this region. YMP is incorporating data from these drill holes as they become available. TSPA-SR incorporates sorption-coefficient data (in the transport calculations for the SZ), stratigraphic data (as input to the three-dimensional SZ flow and transport model), and water-level data (to calibrate the three-dimensional SZ flow and transport model) from these drill holes.	TSPA-VA Peer Review Panel	
	Wellhead Dilution	No comments on wellhead dilution were made.	Dilution at the well head is conservatively ignored. In the biosphere model, all radionuclides reaching the farming community in groundwater are assumed to be mixed in the volume of water that the community uses.		3.9

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Long Transport away from the EBS (Cont'd)	Biosphere Dose Conversion Factors	The TSPA-VA lacks site-specific data for soil properties for the determination of sorption characteristics.	TSPA-SR includes a description of buildup of radionuclides in the soil. Part of this description involves a leaching coefficient for each radionuclide based on the sorption characteristics of the radionuclide in soil. No sorption data are available for Amargosa Valley soils, so sorption data from similar soil types taken from international references were used in the calculations. Sorption data are available for some radionuclides in alluvium, based on measurements from samples taken from Nye County drill holes, and these data show lower sorption coefficients than those used in the soil-buildup model. Thus, the sorption coefficients used in the soil-buildup model could be conservative (i.e., allow more buildup of radionuclides in the soil). In any event, the TSPA calculations showed soil-buildup to have a small effect on the biosphere dose conversion factors.	TSPA-VA Peer Review Panel	3.9
Minimal Effects of Potentially Disruptive Processes and Events	Probability of Volcanic Eruption	The Panel believes that too much attention may have been devoted to the potential consequences associated with low probability disruptive events such as volcanic events.	The right level of attention has been given to this topic. Although the probability of recurrence is very low during the next 10,000 years, it cannot be ruled out. The conceptual model for igneous activity has three necessary components: 1) a review of the history of past igneous activity in the Yucca Mountain region, 2) development of an estimate of the likelihood of future igneous activity at the proposed repository site, and 3) an analysis of the possible characteristics of a future eruption at the site.	TSPA-VA Peer Review Panel	3.10

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Minimal Effects of Potentially Disruptive Processes and Events (Cont'd)	Characteristics of Volcanic Eruption	DOE's analyses are based on assumptions of physical conditions that are not representative of Yucca Mountain basaltic volcanism.	Information used in the TSPA model to characterize the eruptive and intrusive processes comes from three relevant sources: examination of the geologic record of past intrusive and eruptive events in the Yucca Mountain region; observations of eruptive processes during analogous modern volcanic events elsewhere in the world; and consideration of the range of physical processes that might occur during the interaction between the potential repository and an igneous dike.	NRC	3.10
	Effects of Volcanic Eruption	DOE assumptions about volcanism are not representative of Yucca Mountain; TSPA analyses may underestimate the contribution to risk associated with future igneous activity.	Assumptions are representative: DOE's conceptual model and analyses of volcanism in the Yucca Mountain region are based on expert elicitation from *Probabilistic Volcanic Hazard Analysis for Yucca Mountain, Nevada* (CRWMS M&O 1996 [100116]. This expert elicitation followed NRC guidelines (Kotra et al. 1996 [100909]). Contribution to risk is not underestimated: Expert elicitation produced a probability range of intersection of the repository by a dike, and a conceptual model of the volcanic regime in the Yucca Mountain geologic setting. The TSPA analyses incorporated that conceptual model and the volcanic hazard probability distribution produced by the experts. The current TSPA-SR model for igneous activity provides a reasonable to conservative estimation of the potential risks associated with an igneous event.	NRC	3.10

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Minimal Effects of Potentially Disruptive Processes and Events (Cont'd)	Atmospheric Transport of Volcanic Eruption	DOE assumptions about volcanism are not representative of Yucca Mountain; TSPA analyses may underestimate the contribution to risk associated with future igneous activity.	Contribution to risk is not underestimated: Expert elicitation produced a probability range of intersection of the repository by a dike, and a conceptual model of the volcanic regime in the Yucca Mountain geologic setting. The TSPA analyses incorporated that conceptual model and the volcanic hazard probability distribution produced by the experts. The transport of radioactive material following an eruption is modeled using reasonably conservative assumptions for input parameters. The quantity of ash deposited at any specified point is a function of wind speed and direction, the volume of ash erupted, and the ash particle diameter.	NRC	3.10
	Biosphere Dose Conversion for Volcanic Eruption	DOE assumptions about volcanism are not representative of Yucca Mountain; TSPA analyses may underestimate the contribution to risk associated with future igneous activity.	Contribution to risk is not underestimated: Expert elicitation produced a probability range of intersection of the repository by a dike, and a conceptual model of the volcanic regime in the Yucca Mountain geologic setting. The TSPA analyses incorporated that conceptual model and the volcanic hazard probability distribution produced by the experts. Furthermore, the biosphere modeling for the volcanic direct-release mechanism involves explicit construction of the biosphere dose conversion factors. These biosphere dose conversion factors are based on reasonably conservative assumptions and are in the form of discrete cumulative probability distributions that are used in the TSPA model.	NRC	3.10

Table H-1. Correlation between Principal Factors, Review Comments, and their Resolution in the TSPA-SR (Continued)

Key Attributes of System	Factor	Issue Description	TSPA-SR Response to Issue	Identified By:	Section of TSPA-SR
Minimal Effects of Potentially Disruptive Processes and Events (Cont'd)	Probability of Igneous Intrusion	The Panel believes that too much attention may have been devoted to the potential consequences associated with low probability disruptive events such as volcanic events.	The right level of attention has been given to this topic. Although the probability of recurrence is very low during the next 10,000 years, it cannot be ruled out. The conceptual model for igneous activity has three necessary components: 1) a review of the history of past igneous activity in the Yucca Mountain region, 2) development of an estimate of the likelihood of future igneous activity at the proposed repository site, and 3) an analysis of the possible characteristics of a future eruption at the site.	TSPA-VA Peer Review Panel	3.10
	Characteristics of Igneous Intrusion	DOE's analyses are based on assumptions of physical conditions that are not representative of Yucca Mountain basaltic volcanism.	Information used in the TSPA model to characterize the eruptive and intrusive processes comes from three relevant sources: examination of the geologic record of past intrusive and eruptive events in the Yucca Mountain region; observations of eruptive processes during analogous modern volcanic events elsewhere in the world; and consideration of the range of physical processes that might occur during the interaction between the repository and an igneous dike.	NRC	3.10
	Effects of Igneous Intrusion	The effectiveness of engineered barriers in the event of volcanic activity need to be evaluated.	The TSPA-SR has taken a much more conservative approach to the engineered barriers response during an igneous event than was done in the VA.	NRC	3.10