THE U.S. DEPARTMENT OF ENERGY'S RESOLUTION STRATEGY FOR THE U.S. NUCLEAR REGULATORY COMMISSION'S KEY TECHNICAL ISSUE AGREEMENTS: AN INTEGRATED APPROACH

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ABSTRACT

The Nuclear Waste Policy Act required the U.S. Nuclear Regulatory Commission (NRC) to comment on the Yucca Mountain Site Recommendation relative to the sufficiency of the Project's information to support a potential license application. As part of the NRC's associated review process a series of meetings held between August, 2000 and September, 2001, the U.S. Department of Energy (DOE) and the NRC established 293 agreements to address NRC's questions and information needs relative to Key Technical Issues related to postclosure performance and preclosure safety and operations of a geologic repository for high-level spent fuel and nuclear waste at Yucca Mountain, Nevada. These Key Technical Issues (KTIs) are: Container Life and Source Term; Evolution of the Near Field Environment; Igneous Activity; Repository Design and Thermal Mechanical Effects; Radionuclide Transport; Structural Deformation and Seismicity; Thermal Effects on Flow; Total System Performance Assessment Integration; Unsaturated and Saturated Flow under Isothermal Conditions; and Preclosure Issues.

Since the KTI agreements were established, DOE and NRC have had a series of interactions focused on resolution in order to facilitate NRC acceptance and review of DOE's license application for construction authorization, currently scheduled in December 2004. In fact, these agreements have been an effective way to focus program resources and attention on those issues most important to licensing the geologic repository. DOE's original approach to issue resolution involved submittal of documentation on single or small groups of related KTI agreements. However, recognizing that addressing each agreement in isolation was not as effective as a more comprehensive approach, in 2003 DOE significantly revised its issue resolution methodology by developing resolution documents that group the KTI agreements in an integrated holistic view of the repository system's natural and engineered components. The majority[1] of the original KTI agreements will be addressed in these groups, which are: 1) Climate and Infiltration; 2) Unsaturated Zone Flow; 3) Water Seeping into Drifts; 4) Mechanical Degradation and Seismic Effects; 5) In-Drift Chemical Environment; 6) Waste Package and Drip Shield Corrosion; 7) In-Package Environment and Waste Form Degradation and Solubility; 8) Colloid Transport; 9) Engineered Barrier System Transport; 10) Unsaturated Zone Transport; 11) Saturated Zone Flow and Transport; 12) Biosphere Transport; 13) Volcanic Events; and, 14) Low-Probability Seismic Events. This revised approach is consistent with the U.S. Nuclear Regulatory Commission's Yucca Mountain Review Plan [1] and the regulatory requirements at 10 CFR Part 63 [2]. Documentation addressing the remaining KTI agreements is scheduled to be submitted to the NRC by August 2004.

INTRODUCTION

Interactions between DOE and NRC in the prelicensing period have focused on resolution of regulatory and technical issues in order to facilitate NRC acceptance and review of the license application for construction authorization, currently scheduled to be submitted to NRC in December 2004. As mandated by the Nuclear Waste Policy Act of 1982 [3], the NRC has three years to issue a final decision approving or disapproving the issuance of a construction authorization after the date of the submission of such application (the NRC may extend this deadline by not more than 12 months).

In order to focus attention and resources on those issues that are most critical to assessing the performance of the repository system at Yucca Mountain, Nevada, the NRC identified nine Key Technical Issues [4]. The issues were first identified in 1996 and were based on the results of DOE and NRC laboratory and field experiments, natural analog studies, expert elicitations, and performance assessments. These Key Technical Issues are: Container Life and Source Term; Evolution of the Near Field Environment; Igneous Activity; Repository Design and Thermal Mechanical Effects; Radionuclide Transport; Structural Deformation and Seismicity; Thermal Effects on Flow; Total System Performance Assessment Integration; Unsaturated and Saturated Flow under Isothermal Conditions; and Preclosure Issues.[2]

Acceptance criteria for the Key Technical Issue agreements were originally developed as part of the NRC's Issue Resolution Status Reports, which were consolidated into a single integrated report in 2002 [4]. These acceptance criteria eventually evolved into the NRC Yucca Mountain Review Plan. In a series of public meetings, DOE and NRC established 293 agreements related to NRC questions, and information needs associated with the Key Technical Issues. At the time of DOE's Site Recommendation, the Key Technical Issues were categorized by NRC as "closed" or "closed-pending." As defined in NRC's Integrated Issue Resolution Status Report [4], issues are considered "closed" if the DOE approach and available information acceptably address NRC staff questions; "closed-pending" means that the NRC staff has confidence that the DOE proposed approach, together with the agreement to provide the NRC with additional information (through specified testing, analysis, additional documentation, etc.) acceptably responds to the NRC's questions such that no information beyond that provided, or agreed to, will likely be required at the time of license application. An "open" issue meant that the NRC had identified questions regarding the DOE approach or information and that the DOE had not yet acceptably addressed the questions or agreed to provide the necessary additional information in a potential license application. NRC staff has stated that the completeness and acceptance for review of any license application are dependent on the extent to which DOE addresses the Key Technical Issues in preparing the license application for a repository at Yucca Mountain [4]. DOE has committed to address the agreements prior to license application by: 1) providing sufficient information to the NRC to allow closure of the agreement; or, 2) providing a plan for resolution of the issue that was acceptable to the NRC.

DOE's original approach to KTI agreement resolution involved the submittal of responses to individual or small groups of agreements. However, DOE realized an integrated approach to KTI resolution would be more effective in that it would provide a more comprehensive view of the repository system and a more complete description and context for how the agreements related to the system. The revised approach reflects a postclosure system view and provides a summary of the conceptual understanding of the natural and engineered systems at a Yucca Mountain geologic repository (see Figure 1: Components of the Postclosure Technical Basis for the License Application). The revised approach also correlates well to the NRC's Yucca Mountain Review Plan [1] and chapters of the Safety Analysis Report that will be part of the license application. DOE implemented the revised approach and submitted the documentation to NRC in September 2003 that addressed the first group of Key Technical Issue agreements (Biosphere Transport).

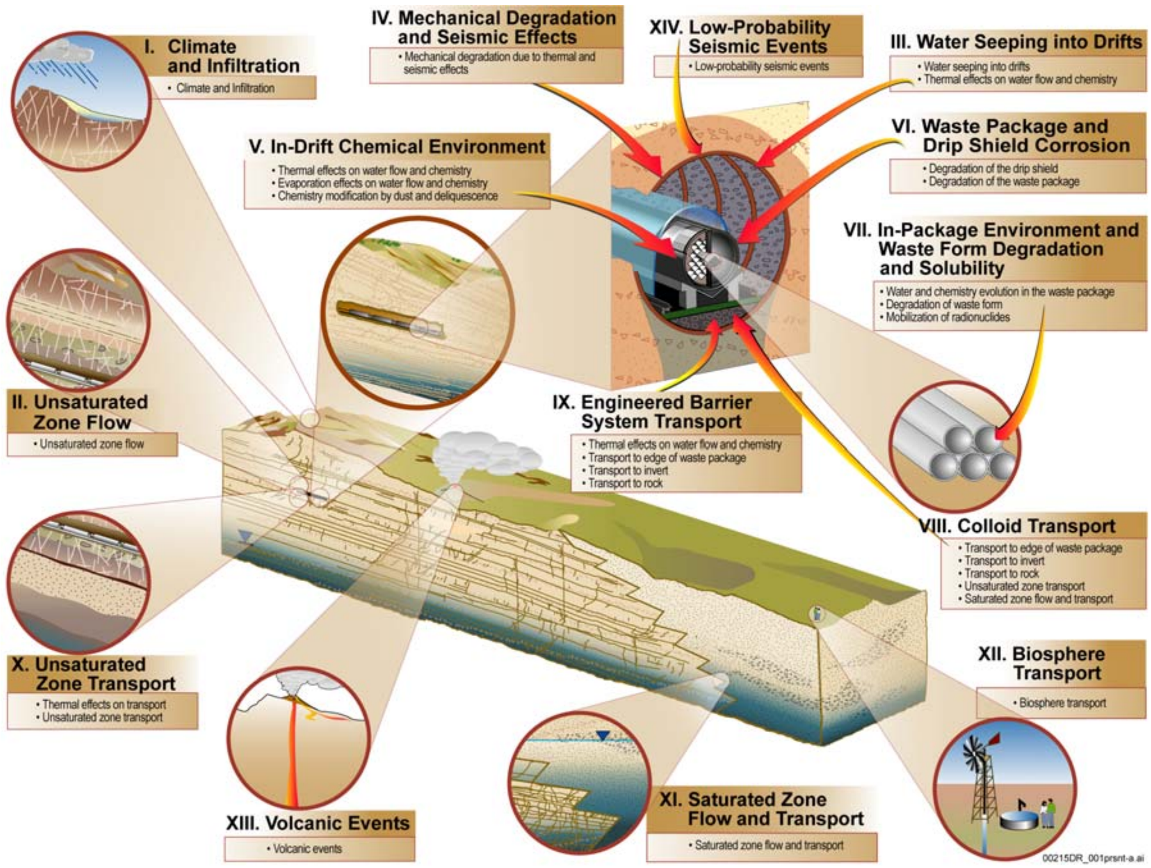

Fig. 1 Components of the Postclosure Technical Basis for the License Application

KEY TECHNICAL ISSUE AGREEMENT GROUPS

The Key Technical Issue agreement groups are based on a systems approach to repository components and reflect different spatial, temporal, and process scales. NRC’s original KTI agreements have been mapped to the groups, with the exception of a few agreements related to criticality, design, and preclosure. These agreements will be addressed separately from the grouped approach.

The groups are: 1) Climate and Infiltration; 2) Unsaturated Zone Flow; 3) Water Seeping into Drifts; 4) Mechanical Degradation and Seismic Effects; 5) In-Drift Chemical Environment; 6) Waste Package and Drip Shield Corrosion; 7) In-Package Environment and Waste Form Degradation and Solubility; 8) Colloid Transport; 9) Engineered Barrier System Transport; 10) Unsaturated Zone Transport; 11) Saturated Zone Flow and Transport; 12) Biosphere Transport; 13) Volcanic Events; and, 14) Low-Probability Seismic Events. Organization of the groups is loosely based on the pathway of water through the system. A brief description of each group and its relationship to repository system performance follows.

Climate and Infiltration

Climate controls the range of precipitation, which influences the rates of infiltration into the surficial soils and rocks, percolation through the unsaturated zone and the repository, and regional groundwater flux. The soils and rocks of the unsaturated zone at Yucca Mountain, Nevada are capable of reducing the amount of precipitation that infiltrates by processes such as surface runoff and evapotranspiration. The infiltration rate is used to determine the potential for seepage into waste emplacement drifts and the amount of water available which could eventually degrade waste packages and the waste and to transport the radioactive waste. An understanding of present-day infiltration is needed to provide initial conditions for predictions of future hydrologic changes, in association with climate predictions. Analysis of past climatic conditions are used to predict overall future climactic trends. Based on those climatic trends, an overall understanding of net infiltration associated with future climates is obtainable. Maps of the magnitude and distribution of net infiltration for the present-day, as well as for predicted future monsoon, and glacial-transition climate states (including lower-bound, mean, and upper-bound conditions for each of the states) over the Yucca Mountain region were prepared based on the results of numerical simulations. These net-infiltration rates are used to define specified flux upper boundary conditions for the unsaturated zone flow and transport models. Documentation related to this issue presents a summary of the bases for forecasting future climatic conditions and evaluations of present-day and future net infiltration at Yucca Mountain based on the results of field, laboratory, and modeling studies, as well as associated uncertainties.

Unsaturated Zone Flow

Percolation flux within the unsaturated zone provides the water for flow and transport mechanisms potentially resulting in seepage into drifts that may degrade the drip shield, waste package, and waste form and then move radionuclides from the repository to the water table. The site-scale unsaturated zone flow model is a three-dimensional dual-permeability model that has been developed, calibrated and validated based on the geology of the site, conceptual understanding of flow paths within the unsaturated zone, and field observations. A variety of data (including matrix saturation and water potential data, pneumatic data, perched water data, temperature data and geochemical data) has been used for calibrating the model. The model was validated with substantial field data not used for model calibration. Validation activities include checking for consistency between modeling results with hydrologic data, geochemical data, and data collected from in situ tests. Effects of thermal processes and the resultant coupled processes on unsaturated zone flow are also considered. The site-scale unsaturated zone flow model is used for generating unsaturated zone flow fields used directly by total system performance assessment.

Water Seeping into Drifts

The amount and chemical composition of water seeping into waste emplacement drifts is among the principal agents determining the potential for corrosion of the engineered barriers, waste dissolution, and radionuclide transport from the repository to the accessible environment. Seepage was examined using theoretical, experimental, numerical, and natural analog studies. The key factors affecting seepage were identified, and site-specific, seepage-relevant parameters were determined through in situ testing. Numerical models were developed and calibrated against data that contain seepage-relevant information. These models were extensively tested to gain confidence in their ability to make predictions of drift seepage.

Water percolating through the unsaturated zone that encounters a large underground opening is partly diverted around the cavity. This capillary barrier effect can reduce the amount of liquid water entering a waste emplacement drift or prevent dripping altogether. Moreover, during the early stages after repository closure, the heat from decaying radionuclides will vaporize water that approaches the waste emplacement drift. Both mechanisms limit the amount of water that potentially contacts the waste packages. Natural analogs were studied to corroborate the water-exclusion concept under unsaturated conditions.

Mechanical Degradation and Seismic Effects

The repository host horizon is approximately 300 m below ground surface within the welded Topopah Spring Tuff, which can be divided into two broad, mechanical rock mass categories: nonlithophysal and lithophysal.[3] Four primary drift degradation mechanisms can affect the stability of repository excavations: 1) stresses induced by in situ gravitational loading; 2) stresses induced by waste package heat generation; 3) stresses and shaking from seismic ground motions; and, 4) time-dependent strength.

Detailed geological mapping has been conducted and a database of rock properties has been compiled. Drift degradation models have been developed that adequately capture the physical phenomena associated with the various components of rock mass behavior anticipated within the repository horizon. Appropriate boundary and initial conditions have been applied to the models, and the technical bases for the development of these rockfall models have been documented. Data uncertainty has been characterized through parameter sensitivity studies in the rockfall models. Model uncertainty has been characterized through an evaluation of alternative conceptual models and the model results have been validated by comparison to field and laboratory data, alternative numerical approaches, and industry experience through external technical review.

Model results predict minor drift damage due to rock failure from preclosure ground motion for the lithophysal and nonlithophysal units and postclosure ground motion for the nonlithophysal units. The highly conservative postclosure ground motions result in predicted collapse of the drift, with fragmented rock particle sizes on the order of centimeters to decimeters. The most significant uncertainties impacting the results of the rockfall models are those associated with the postclosure ground motion and time-dependent degradation. Some of the highly conservative ground motions provided are larger than the largest ground motions observed and may not be physically realizable. Therefore, predictions of complete drift collapse with postclosure ground motion may be unrealistic.

In-Drift Chemical Environment

The in-drift chemical environment at Yucca Mountain will change with time as the radioactive waste decays and as geochemical processes modify the in-drift conditions. The thermal-hydrologic-chemical characteristics at Yucca Mountain will affect the compositions of aqueous solutions entering the drift and the gases within the drifts. The technical basis for thermal-hydrologic-chemical modeling includes mathematical process descriptions parameterized using site-specific measurements in addition to chemical constants and data supported by the technical literature (e.g., thermodynamic and kinetic constants, and diffusion coefficients).

Site characteristics that have been investigated and used for model development include the initial water and gas chemistry, initial mineralogy, mineral volume fractions, reactive surface areas, and boundary conditions. Models have been developed to assess the evolution of drift-scale temperature and relative humidity, evolution of seepage water, rehydration of soluble salts (deliquescence), and interaction of dusts on the surfaces of the drip shield and waste package to evaluate the environment for corrosion. The chemical evolution models address reactions among the major ionic species, with the importance of some minor and trace species also evaluated. The predicted evolution of the in-drift chemical environment is also applied to other process models including in-package chemistry, radionuclide solubility, and colloid formation. These detailed models are linked in the total system performance assessment, which also propagates uncertainties from various sources through the models..

Waste Package and Drip Shield Corrosion

The waste packages and drip shields will be subject to a number of degradation modes. At high temperature, in the absence of aqueous films on the surfaces of the engineered barriers, high temperature oxidation is the dominant degradation mode. As the temperature decreases during cooling, aqueous phase electrolytes will develop on the drip shield and waste package surfaces, first through the formation of deliquescent brines, and then through the evaporative concentration of seepage waters. Modes of corrosion experienced in aqueous electrolytes include uniform general corrosion, localized corrosion, and stress corrosion cracking. Finally, the presence of microbes can alter the chemistry of the aqueous films; hence the corrosion rates of the aqueous degradation modes.

Corrosion testing to determine the response of waste package, drip shield, and other in-drift materials has been carried out in environmental conditions consistent with those predicted by in-drift chemical modeling. Models have been used to analyze the degradation of the waste package and the drip shield by general and localized corrosion and stress corrosion cracking under the expected repository exposure conditions, and over the repository performance period.

The cumulative effect of several degradation modes on material performance are included in the waste package and drip shield design process. The design incorporates the effect of general corrosion and structural considerations by determining the appropriate thickness for the corrosion shell. For other modes, fabrication controls and specific design features will be used to ensure adequate waste package performance during the required regulatory period.

In-Package Environment and Waste Form Degradation and Solubility

The degradation of the waste form and the mobilization of radionuclides in the waste package provide the starting point for all radionuclide releases to the accessible environment. The waste form degradation model, along with the engineered barrier system transport model, determines the exposure rate (availability) of radionuclides and their mobilization. The waste form degradation model consists of five components that determine the exposure rate of radionuclides: in-package chemistry; degradation of commercial spent nuclear fuel cladding; degradation of commercial spent nuclear fuel pellets; degradation of DOE spent nuclear fuel; and degradation of high level waste vitrified in borosilicate glass.

Three additional components complete the model: available dissolved concentration of radionuclides; available high level waste colloidal concentration of radionuclides; and available rust and groundwater colloidal concentration of radionuclides. The first two of these three components form the first transport cell and the later component forms the second transport cell of the engineered barrier system model for determining radionuclide mobilization. All components are used in the nominal and seismic scenario classes. For the volcanic scenario class, only the solubility component is used in those emplacement drifts of the repository intersected by a basaltic dike.

Colloid Transport

Radionuclides can potentially be transported from the waste form to the biosphere as either dissolved species or in colloidal form. In order for colloid transport to be a significant contributor to the discharge of radionuclides to the biosphere, colloids must carry a significant mass of radionuclides.

To determine the importance of colloid-facilitated radionuclide transport to repository system performance, the pertinent processes regarding colloid transport are examined for four repository subsystems: waste package; invert; unsaturated zone; and saturated zone. From the results of these examinations it is concluded that, on a risk basis, colloid-facilitated transport is not a significant contributor to system performance. Therefore, uncertain technical issues associated with this transport mode are of relatively low importance compared to uncertain technical issues related to radionuclide transport as dissolved species. However, it is not suggested that colloid-facilitated transport be excluded from the total system performance assessment. It is also concluded that, for purposes of the total system performance assessment, the current treatment of colloid-facilitated transport of radionuclides is adequate.

Engineered Barrier System Transport

The drip shield, waste package, and other components of the engineered barrier system are expected to degrade over time, leading to the mobilization and transport of radionuclides to the unsaturated zone. The primary transport medium is anticipated to be water, either in the form of a thin film or moving water. If a drip shield is breached, water may contact the waste package, and if the waste package is breached, water may enter the package as water vapor or as drips. If the cladding around spent nuclear fuel or the canister around a vitrified waste form is also breached, radionuclides may start to dissolve in the water.

The dissolved concentration of each radionuclide mobilized from the waste form cannot exceed the radionuclide solubility limit unless suspended colloids are included. Radionuclides mobilized in water as dissolved or colloidal species may then be transported by advective and diffusive transport from the waste form, through the waste package, and out of breaches in the waste packages. Once outside the package, the radionuclides will be transported through the invert predominantly by diffusion if water is not flowing through the invert or by advection if an appreciable amount of water is flowing through the invert.

A one-dimensional contaminant transport equation was used to evaluate contaminant transport over the range of pore-water velocities and saturations representative of conditions in the repository. The results show that breakthrough times in the invert would occur by 1,000 years when advection was operational, but would take as long as 10,000 years under diffusion-dominated transport as would occur in the intergranular pore space. Additional sensitivity studies using the one-dimensional advection-dispersion-diffusion equation were used to estimate the effects of retardation. The results of these calculations show that compared to nonretarded transport, for the case of low sorption, the breakthrough time is delayed 1,000 to 5,000 years; for the case of intermediate and high sorption, breakthrough would be delayed 1,000 to 10,000 years; and for very high sorption, breakthrough is delayed by at least 1 million years.

A significant source of uncertainty is the interface zone flow between the crushed tuff and the surrounding host rock. The actual boundary may provide more resistance to flow than what has been analyzed. This analysis has conservatively assumed the interface offers no resistance to flow in the absence of definitive data to the contrary.

Unsaturated Zone Transport

Transport of radioactive solutes and colloids through the unsaturated zone at Yucca Mountain is affected by numerous geologic, hydraulic, and climatic conditions and factors. Processes including advection, matrix diffusion, dispersion, and sorption impact the transport of solute and colloidal species; while filtration and straining processes pertain specifically to colloid transport. Radioactive-related properties, such as type and rate of decay, chain species, and species-specific parameters for sorption and diffusion are also important. Temperature may alter conditions for sorption, diffusion, and filtration, further impacting transport.

Transport tests have been conducted that involve length scales to a maximum of 30 m and time scales to 2 years. These tests have been used in establishing the basic conceptual framework of transport and for forming the basis for extension to large-scale transport. The model of radionuclide transport considers a large three-dimensional mountain-scale domain with steady-state flow fields. The fractured rock is conceptualized as a heterogeneous dual-permeability system, in which the distinct hydraulic and transport behavior of fractures and matrix is described by using separate properties and parameters. This conceptualization allows the description of the complex unsaturated zone flow field in which fracture flow dominates.

The numerical process model used for estimating transport accounts for advection, molecular diffusion, hydrodynamic dispersion, sorption, radioactive decay and tracking of decays, colloid filtration, and colloid-assisted solute transport. The following general conclusions are drawn from the numerical simulation of radionuclide transport:

- Radionuclide transport from the bottom of the repository to the water table is dominated and controlled by the faults that provide fast pathways for downward migration but also limit lateral transport across the fault walls into the formation.

- Consistent with the geologic model, the three-dimensional site-scale simulations indicate that radioactive solutes from the repository move faster and reach the water table earlier in the northern part of the repository.
- Transport patterns follow the infiltration and percolation distributions.
- The Drill Hole Wash and Pagany Wash faults are the main pathways of transport in the northern part of the repository.
- Diffusion from the fractures into the matrix is one of the main retardation processes in radionuclide transport.
- The importance of faults and perched-water bodies in transport is directly dependent on the underlying conceptual models; changing these models may lead to substantially different results, given the sensitivity of transport to these geologic features.
- The presence of the drift in the rock mass results in a shadowing effect, which effectively diverts the presence of the drift shadow, can divert water around the drift, thereby reducing radionuclide transport.
- Under the approach taken in the three-dimensional site-scale studies, the unsaturated zone of Yucca Mountain appears to be an effective barrier to the transport of the strongly sorbing radionuclides to the water table.

Saturated Zone Flow and Transport

The saturated zone at Yucca Mountain is capable of both delaying the transport and reducing the concentration of dissolved and colloidal radionuclides before they reach the accessible environment. Radionuclides released into seepage water contacting breached waste packages in the repository would have to migrate downward through the unsaturated zone below the repository before reaching the water table where they would enter the saturated zone. Evaluation of the saturated zone at Yucca Mountain considers the possibility of radionuclide transport from their introduction beneath the repository to the accessible environment down gradient from the site.

Performance of the saturated zone is affected by both flow processes and radionuclide transport processes. Groundwater flow processes determine the rate of water movement within the saturated zone and the flow paths along which the water is likely to move. Radionuclide transport processes such as sorption, diffusion, hydrodynamic dispersion, decay and in-growth, and colloid transport determine the advective velocity of the radionuclides within the saturated fractures or pores of the geologic media and interactions between the dissolved or colloidally transported radionuclides and the rock or alluvium with which they come in contact. These flow and transport processes are represented by conceptual and numerical models that predict the behavior of the saturated zone as it relates to performance of the Yucca Mountain Repository.

Biosphere Transport

The biosphere model considers radionuclide transport pathways that could contribute to human exposure following the release of radionuclides from a repository at Yucca Mountain. Concentrations of radionuclides are calculated for soil, air, crops, animal products, and fish. Exposure pathways included are external exposure to soil; inhalation exposure to resuspended particles, aerosols from evaporative coolers, and radioactive gasses; and ingestion of water, fruits, vegetables, grains, animal products, fish, and soil. The input parameters used to calculate these concentrations and receptor exposure are based on site-specific information or analog data and are sampled as distributions to propagate uncertainty and variation in the parameter values. When required, separate sets of input parameters are used for current and future climate states.

The biosphere model calculates the annual dose to the receptor per unit concentration of radionuclides in groundwater and volcanic ash. These are combined in the total system performance assessment with estimates of radionuclide concentrations in groundwater or ash to calculate the potential annual dose resulting from the release of radionuclides to groundwater or from a volcanic eruption at Yucca Mountain. Propagation of uncertainty and variability in the input parameters through the biosphere model results in distributions with ninety percent or more of values within a range of an order of magnitude or less. For the groundwater scenario, ingestion or inhalation are the most important pathways for most radionuclides. For the volcanic ash scenario, inhalation of resuspended particulates is the most important exposure pathway for most radionuclides, although ingestion or external exposure is important for a few radionuclides.

Volcanic Events

The potential for future igneous intrusion or volcanic activity has been evaluated through an integrated approach utilizing information from geological, geophysical and geochemical investigations, and an expert elicitation and peer review. The mean probability of a future volcanic event intersecting a repository has been estimated to be on the order of 1.7×10^{-8} per year, or approximately one chance in 6,000 of occurring over the next 10,000 years. The sensitivity of the probability estimate has been tested through the consideration of a variety of alternative models and multiple lines of evidence. It is unlikely that new information will lead to a substantive upward revision of this probability estimate, because uncertainties associated with the available information and models used to calculate the probability have been incorporated into the analysis.

The physical processes and conditions associated with basaltic volcanism, and the potential effects of such activity on the integrity of the repository, have been evaluated. If basaltic magma intrudes into emplacement drifts, possible consequences could include damage to waste packages leading to eventual release of radionuclides to groundwater. An eruptive event through the repository could incorporate spent nuclear fuel or high-level radioactive waste into the volcanic ash ejected into the atmosphere. These possibilities have been incorporated into total system performance assessment calculations. Analyses to date have indicated that potential releases associated with these "disruptive events" are not likely to affect the ability of the repository to comply with the performance requirements specified in applicable regulations.

Low Probability Seismic Events

Low-probability seismic events are highly unlikely, but possible, earthquake fault displacements and vibratory ground motions that could affect the Yucca Mountain site. The identification of seismic effects that could be significant to repository postclosure performance was accomplished as part of a comprehensive effort to identify and address all features, events, and processes (FEPs) that could affect repository performance.

The geology and seismology of the Yucca Mountain site have been studied intensively for more than 20 years. Extensive site characterization activities have generated much data regarding the vibratory ground motion and fault displacement hazards at Yucca Mountain. A comprehensive list of seismic-related Features, Events and Processes (FEPs) was considered and each FEP was screened in or out of the total system performance assessment model based on assessments of their probability and consequence. The seismic hazard models that have been developed for Yucca Mountain account for both the variability in vibratory ground motion and fault displacement due to the inherent randomness of earthquake processes and uncertainty due to limitations in scientific knowledge. Large ground motions predicted by the probabilistic seismic hazard analysis ground-motion models at annual exceedance probabilities of 1×10^{-6} and below may be physically unrealizable and may substantially overestimate the severity of low-probability ground motions at Yucca Mountain. Seismic and tectonic effects on the natural systems at Yucca Mountain will not significantly affect repository performance. The engineered barrier system components are robust under seismic loads and will provide substantial protection of the waste form from seepage water, even under severe seismic loading.

CONCLUSION

DOE's goal during the prelicensing phase is effective issue resolution, and the revised grouped approach to KTI Agreement responses represents a substantial improvement in the resolution strategy for Key Technical Issue agreements. The grouped method is more effective, efficient, and better represents the relationship of the agreements to the total repository system. The approach as been an effective way to focus program resources, attention and interactions on those issues most important to address prior to submission of the license application for construction authorization. Although DOE remains committed to explicitly addressing every KTI agreement, the grouped approach provides a conceptual perspective that better integrates the agreements into the context of repository performance and their relationship to the system.

REFERENCES

1 U.S. Nuclear Regulatory Commission, 2003: Yucca Mountain Review Plan, NUREG-1804, Rev. 2, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, Washington, D.C.

2 10 Code of Federal Regulations Part 63: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada.

3 Nuclear Waste Policy Act of 1982. Pub. L 97-425. 96 Stat. 2202 (1982).

4 U.S. Nuclear Regulatory Commission, 2002: Integrated Issue Resolution Status Report, NUREG-1762, Division of Waste Management, Office of Nuclear Material Safety and Safeguards, Washington, D.C.

FOOTNOTES

[1] Every KTI agreement will be addressed; however, a few KTI agreements related to design, criticality, and preclosure issues will be addressed singly or in small groups.

[2] Although the Key Technical Issues focus on postclosure repository performance and "Preclosure" is not a Key Technical Issue per se, it was handled in a similar manner by NRC. That is, public interactions were held at which agreements were reached, and DOE is developing information to address these agreements.

[3] Lithophysae are hollow cavities in volcanic tuffs, usually lined with finely crystalline feldspar, quartz and other minerals.