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

Sensitivity and Barrier Importance Analyses for TSPA-SR

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Presented by:
Robert W. Andrews
Performance Assessment Department Manager
Civilian Radioactive Waste Management System Management & Operating Contractor

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YUCCA MOUNTAIN PROJECT

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- Requirements for Sensitivity and Barrier Importance Analyses
- Goals of Sensitivity and Barrier Importance Analyses
- Approaches to Sensitivity and Barrier Importance Analyses
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Introduction

- Uncertainty in parameters and models potentially affecting post-closure performance are included in TSPA-SR Model (> 100 uncertain parameters)
- Sensitivity and barrier importance analyses compliment the uncertainty analyses in evaluating the significance of parameter and model uncertainty
- Sensitivity and barrier importance analyses are used to evaluate robustness of system performance even given low probability scenarios
- Sensitivity and barrier importance analyses assist in quantifying the capability of barriers to isolate waste

Requirements for Sensitivity and Barrier Importance Analyses - 10 CFR Part 63

- **63.2 *Performance assessment* means a probabilistic analysis that . . . (2) examines the effects of such features, events and processes on the performance of the geologic repository**
- **63.21 (b) (5) An assessment to determine the degree to which those features, events and processes of the site that are expected to materially affect compliance with 63.113 (b) . . . and the extent to which they affect waste isolation**
- **63.102 (j) The performance assessment is a systematic analysis that identifies the features, events and processes . . . (and) examines their effects on performance**

Requirements for Sensitivity and Barrier Importance Analyses - 10 CFR Part 963

- **963.2 *Total System Performance Assessment* means a probabilistic analysis that is used to . . . (2) examine the effects of such features, events and processes on the performance**
- **963.16 (b) (3) . . . evaluate the effects that alternative models would have on the estimated performance of the geologic repository**
- **963.16 (b) (12) Conduct appropriate sensitivity studies**

Goals of Sensitivity and Barrier Importance Analyses for the SR

- Aid in identifying the significance of process models factors and barriers in meeting the post-closure performance objective
- Used to screen FEPs that may cross cut several subsystems
- Used as key element of Repository Safety Strategy Rev 4
- Assist in prioritizing additional scientific investigations and design optimization

Approach to Sensitivity and Barrier Importance Analyses

- **Sensitivity analysis**
  - **Fix single or several parameters at their 95th percentile value (conservative end of range) and rerun probabilistic analysis**
- **Degraded barrier importance analysis**
  - **Fix several parameters associated with a single barrier (which may represent multiple factors) at their 95th percentile values and rerun the probabilistic analyses**
  - **Fix several parameters associated with several barrier types (natural or engineered) at their 95th percentile value and rerun the probabilistic analyses**
- **Neutralized barrier importance analysis**
  - **Function of barrier is eliminated to provide insight into barrier redundancy and defense-in-depth**

Possible Sensitivity and Barrier Importance Analyses to Evaluate Significance of Process Model Factors

Key Attributes of System	Process Model Factor	Possible Sensitivity Analyses	Possible Barrier Importance Analyses
Water Contacting Waste Package	Climate	• Vary timing of climate change • Vary magnitude of precipitation	• Combine maximum precipitation and maximum infiltration to maximize infiltration rate
	Net Infiltration	• Vary magnitude of infiltration	
	Unsaturated Zone Flow	• Vary magnitude of flux	• Combine 95th %ile on flow focussing factor and fracture properties to maximize seepage fraction and amount
	Coupled Effects on UZ Flow	• Vary timing/amount of dryout/reflux	
	Seepage into Emplacement Drifts	• Vary degree of flow focusing • Vary percent of repository with seeps • Vary fracture properties • Vary episodicity	
	Coupled Effects on Seepage	• Vary changes to UZ flow	
Waste Package Lifetime	In-Drift Physical and Chemical Environments	• Vary T/RH • Vary rockfall/location of rockfall • Vary chemistry on DS (salt/dust) • Vary chemistry on WP without DS present	• Combine 95th %ile on flow focussing factor and fracture properties to maximize seepage fraction and amount
	In-Drift Moisture Distribution	• Vary range of moisture on DS • Vary condensation under DS • Vary range of moisture on WP	
	Drip Shield Degradation and Performance	• Vary corrosion rate • Evaluate drip shield separation • Evaluate leakage through drip shield joints	• Combine 95th %ile on rockfall, Titanium degradation rate, indrift chemistry and HIC to minimize dripshield lifetime
	Waste Package Degradation and Performance	• Evaluate phase stability/aging • Evaluate effect of phase stability on local/crevice corrosion • Vary stress and stress intensity at closure weld • Vary threshold stress • Vary corrosion rate • Vary initial defect size and probability • Vary heat sensitization near welds • Evaluate stainless steel barrier credit • Evaluate co-dependence of DS/WP failure • Vary MIC	• Combine 95th %ile on initial defects, stress state, threshold stress, corrosion rate, MIC, and aging to minimize waste package lifetime

Possible Sensitivity and Barrier Importance Analyses to Evaluate Significance of Process Model Factors

Key Attributes of System	Process Model Factor	Potential Sensitivity Analyses	Barrier Importance Analyses
Radionuclide Mobilization and Release from the Engineered Barrier System	Radionuclide Inventory	• Vary burn-up/age variability across repository	• N/A
	In-Package Environments	• Vary water chemistry • Evaluate evaporation from breached waste packages during thermal period	
	Cladding Degradation and Performance	• Vary degradation rate • Vary perforations	• Combine 95th %ile on initial defects, unzipping rate, and Fluoride content to minimize cladding lifetime
	CSNF Degradation and Performance	• Vary degradation rate	• N/A
	DSNF Degradation and Performance	• Vary degradation rate	
	DHLW Degradation and Performance	• Vary degradation rate	
	Dissolved Radionuclide Concentrations	• Vary Pu, Np solubility • Evaluate secondary phases	• Combine 95th %ile colloids, pH, solubility, diffusion coefficient to maximize radionuclide mobilization and release
	Colloid-Associated Radionuclide Concentrations	• Vary fraction of irreversible colloids	
	In-Package Radionuclide Transport	• Vary Fraction of water removed from waste package	
	EBS (Invert) Degradation and Performance	• Vary sorption in invert • Vary diffusion coefficient in invert • Vary saturation of invert	

Possible Sensitivity and Barrier Importance Analyses to Evaluate Significance of Process Model Factors

Key Attributes of System	Process Model Factor	Potential Sensitivity Analyses	Barrier Importance Analyses
Transport Away from the Engineered Barrier System	UZ Radionuclide Transport (Advective Pathways; Retardation; Dispersion; Dilution)	• Vary matrix diffusion • Vary colloid filtration • Evaluate spatial variation of properties • Vary sorption	• Combine 95th %ile on K_d, matrix diffusion, flow rates to minimize transport times in the unsaturated zone
	SZ Radionuclide Transport	• Evaluate effect of climate change on pathways and flux • Evaluate water table rise • Vary flux • Evaluate flowing interval spacing • Vary amount of alluvium • Vary Kd in alluvium • Vary colloid filtration in alluvium	• Combine 95th %ile on K_d, matrix diffusion, percent alluvium, flow rate to minimize transport times in the saturated zone
	Wellhead Dilution	• Vary volume of water used by critical group	• N/A
	Biosphere Dose Conversion Factors	• Vary BCDFs	
Effects of Potentially Disruptive Processes and Events	Probability of Volcanic Eruption	• Vary probability	• N/A
	Characteristics of Volcanic Eruption	• Vary event eruption volume	
	Effects of Volcanic Eruption	• Vary waste particle diameter	
	Atmospheric Transport of Volcanic Eruption	• Vary wind speed and direction	
	Biosphere Dose Conversion for Volcanic Eruption	• Vary BDCF	
	Probability of Igneous Intrusion	• Vary probability	
	Characteristics of Igneous Intrusion	• Vary number of packages affected	
	Effects of Igneous Intrusion	• Vary degree of degradation of waste package	

Summary and Conclusions

- **Methodology for sensitivity and barrier importance analyses has been developed**
- **Preliminary results are being produced**
- **Results will serve as part of basis for 10 CFR Part 963 compliance evaluation in the SRCR and 10 CFR Part 63 compliance evaluation in the LA**
- **Sensitivity and barrier importance analyses are a key element of the FEPs screening process (quantify some of the qualitative arguments)**
- **Following promulgation of final Part 63, additional dialogue is required to clarify issues associated with barrier importance expectations of NRC**