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

Status of the Repository Safety Strategy

Presented to:
NRC/DOE Technical Exchange on Yucca Mountain Pre-Licensing Issues

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YUCCA MOUNTAIN PROJECT

Legal/Main - 2U

Purpose of Presentation

- Show how the information in the technical basis of the Site Recommendation can be related to the DOE's postclosure safety case
- Show how this postclosure safety case relates to NRC's Key Technical Issues (KTIs)

DOE's Consideration of NRC's KTIs

- DOE continues to summarize data and analyses acquired in its work in terms of the KTIs and the Issue Resolution Status Reports (IRSRs)
  - Such a summary was provided in the Viability Assessment
  - Section 4 of each Process Model Report (PMR) provides summary discussion and cross-references for each KTI subissue and acceptance criterion

DOE's Consideration of NRC's KTIs
(Continued)

- All subissues and acceptance criteria are addressed in one or more PMRs, in associated Analysis and Model Reports (AMRs), or in other technical basis documents (e.g. Criticality Topical Report)

- DOE intends to continue the process to resolve KTIs for the License Application

Example of PMR IRSR Discussion: Unsaturated and Saturated Flow Under Isothermal Conditions

Table 4.3-1. Issue Resolution Status Reports, Subissues, Technical Acceptance Criteria, and PMR Approach

NRC Technical Acceptance Criteria	PMR Approach and Section Reference
IRSR: Evolution of the Near-field Environment	
Subissue 1 - Effects of Coupled THC Processes on Seepage and Flow	
Data and model justification acceptance criteria for Subissue 1	
1 - Available data relevant to both temporal and spatial variations in conditions affecting coupled THC effects on seepage and flow were considered.	The TSPA-VA did not explicitly consider the effects of coupled THC processes; the evaluation of coupled THC effects is documented in this PMR. Attachment I summarizes available site data. Section 3.10 documents the abstraction of coupled THC effects for TSPA, based on the process modeling results presented in the same section.
2 - DOE's evaluation of coupled THC processes properly considered site characteristics in establishing initial and boundary conditions for conceptual models and simulations of coupled processes that may affect seepage and flow.	Attachment I summarizes available data. These data on the site characteristics were used to establish initial and boundary conditions for the evaluation of THC effects on seepage and flow in the near field (Section 3.10).
3 - Sufficient data were collected on the characteristics of the natural system and engineered materials, such as the type, quantity, and reactivity of material, to establish initial and boundary conditions for conceptual models and simulations of THC coupled processes that affect seepage and flow.	Attachment I summarizes available site data. The THC model incorporates site data to establish initial and boundary conditions and incorporates specific aspects of the design, including in-drift geometry, drift spacing, and the TH properties of the components of the EBS, such as waste packages and invert (Section 3.10). The current design does not include concrete liners in the emplacement drifts limiting the potential effects of interactions between concrete and tuff on seepage and flow.
4 - Sensitivity and uncertainty analyses (including consideration of alternative conceptual models) were used to determine whether additional new data are needed to better define ranges of input parameters.	Sensitivity and uncertainty analyses will be included in TSPA-SR.
5 - If the testing program for coupled THC processes on seepage and flow is not complete at the time of license application, or if sensitivity and uncertainty analyses indicate additional data are needed, DOE will identify specific plans to acquire the necessary information as part of the performance confirmation program.	The DOE is developing a plan that will define the performance confirmation program. Performance confirmation testing is not covered in this PMR.

DOE's Consideration of NRC's KTIs

(Continued)

- At the same time, DOE continues to focus on its safety case
  - DOE is verifying the factors for the safety case described in Revision 03 of the Repository Safety Strategy to determine the Principal Factors for the postclosure safety case
  - This determination influences the emphasis of the work
  - Although each KTI subissue will be addressed, the information provided will reflect the importance of the subissues to the safety case
- Path to resolution of the KTIs should include understanding of DOE's safety case and the relationship of the KTIs to it

DOE's Postclosure Safety Case

- DOE's safety case includes
  - A total system performance assessment (TSPA) to demonstrate the postclosure performance objective of proposed 10 CFR 63.113 is met
  - Additional measures to increase assurance of safety
- The safety case explicitly identifies the Principal Factors, the aspects of the repository system essential to repository performance
- The Principal Factors are being identified in a risk-informed, performance-based approach that is consistent with the requirements of proposed 10 CFR 63.114

Preliminary Principal Factors

(Repository Safety Strategy Revision 3)

- Seepage into emplacement drifts
- Drip shield degradation/performance
- Waste package degradation/performance
- Dissolved radionuclide concentrations
- Retardation in unsaturated zone
- Retardation in saturated zone
- Dilution at the wellhead

Determining the Principal Factors

- The Principal Factors have developed as
  - Site information has increased
  - Repository system design has evolved
  - TSPA models have improved
- Now converging on the Principal Factors for postclosure performance
- The Site Recommendation Consideration Report (SRCR) technical bases will provide information supporting
  - Identification of the Principal Factors
  - Their representation in the postclosure safety case

Determining the Principal Factors
(Continued)

- Understanding of the relative importance of the KTI subissues, in the context of these Principal Factors

- Process to finalize the Principal Factors has involved technical staff from across the Project, oversight by DOE, and outside observers including the Nuclear Waste Technical Review Board and the NRC

- The process involves evaluation of the process models and supporting data described in the PMRs and AMRs

- The features, events, and processes (FEPs) included in the process models were identified and assembled into "process model factors"

Example of Process Model Factors

will be in RSS rev. 4

PMR	Process Model Factor	FEP Number	FEP Title
Waste Package (FEPs analyzed in W0055)	Waste Package Degradation and Performance	2.1.03.01.00	Corrosion of waste containers
		2.1.03.02.00	Stress corrosion cracking of waste containers
		2.1.03.03.00	Pitting of waste containers
		2.1.03.05.00	Microbially mediated corrosion of waste container
		2.1.03.11.00	Container form
		2.1.03.12.00	Container failure (long-term)
		2.1.10.01.00	Biological activity in waste and EBS
		2.1.11.06.00	Thermal sensitization of waste containers increases fragility
	Drip Shield Degradation and Performance	2.1.06.06.00	Effects and degradation of drip shield (general corrosion, localized corrosion, microbial effects)
	Excluded from TSPA models	1.2.02.03.00	Fault movement shears waste container
		1.2.03.02.00	Seismic vibration causes container failure (effects on either waste package or drip shield excluded by design)
		2.1.03.04.00	Hydride cracking of waste containers
		2.1.03.06.00	Internal corrosion of waste container
		2.1.03.07.00	Mechanical impact on waste container (effects of rockfall on drip shield or on waste package—even if drip shield is not present—excluded by design)
		2.1.03.08.00	Juvenile and early failure of waste containers (initial defects of waste packages or drip shields sufficient to result in juvenile failure excluded)
		2.1.03.09.00	Copper corrosion
		2.1.03.10.00	Container healing
		2.1.06.07.00	Effects at material interfaces
		2.1.07.01.00	Rockfall (large block)
		2.1.07.05.00	Creeping of metallic materials in the EBS
		2.1.09.03.00	Volume increase of corrosion products
		2.1.09.09.00	Electrochemical effects (electrophoresis, galvanic coupling) in waste and EBS
		2.1.11.05.00	Differing thermal expansion of repository components
		2.1.12.03.00	Gas generation (H2) from metal corrosion
		2.1.13.01.00	Radiolysis

Determining the Principal Factors
(Continued)

- The process model factors are being evaluated through the risk-informed, performance-based approach
- This approach began with qualitative analyses supported by preliminary TSPA and barriers importance analyses
- These analyses are now being verified through TSPA analyses using updated component models
- All credible engineered and natural processes and events are incorporated in these analyses
- These TSPA analyses will be fully documented in the TSPA-Site Recommendation

Preliminary Results

- Understanding based on data and analyses for waste package degradation suggests waste package performance would be a principal contributor to system performance
- Importance of uncertainties in waste package degradation are being evaluated
  - Preliminary considerations suggest that, even accounting for uncertainties in conditions and measured corrosion rates, waste packages would remain intact for at least tens of thousand of years
  - Analyses of potential initial defects suggest the probability of those leading to failures in less than 10,000 years is less than 0.0001

Preliminary Results
(Continued)

- These analyses suggest waste package degradation and performance is likely to be a Principal Factor
- The risk-informed, performance-based approach includes evaluation of factors contributing margin and defense-in-depth
- The evaluation is considering a hypothetical, nonmechanistic waste package failure scenario to examine the contribution of factors other than the waste package
- These analyses indicate that other potential Principal Factors include:
  - Drip shield degradation/performance

Preliminary Results
(Continued)

- Retardation in the unsaturated zone
- Retardation in saturated zone

- In addition, to evaluate robustness of 10,000-year performance, analyses are conducted for periods beyond 10,000 years
- Additional factors that come into play in the longer period and that are potential Principal Factors include:
  - Seepage into emplacement drifts
  - Radionuclide concentrations at the source (dissolved radionuclide concentrations, colloid-associated radionuclide concentrations)
  - Dilution at the wellhead

Current Status of Safety Case

- **Preliminary Principal Factors for the Nominal Scenario**
  - Seepage into emplacement drifts
  - Drip shield degradation/performance
  - Waste package degradation/performance
  - Radionuclide concentrations at the source (new)
  - Retardation in unsaturated zone
  - Retardation in saturated zone
  - Dilution at the wellhead

Current Status of Safety Case
(Continued)

- In addition, factors for disruptive events are being evaluated to determine Principal Factors for these scenarios
- Determination of all Principal Factors will be complete before SRCR and documented in Repository Safety Strategy Revision 4

DOE Actions to Support NRC Sufficiency

- DOE intends to support NRC's sufficiency review by providing data and analyses regarding KTI subissues, including analyses showing the importance of these subissues to postclosure performance
- A top-level view of the relationship between DOE's understanding of the Principal Factors and the KTI subissues will be provided in this meeting
- More details will be provided in future meetings on each PMR

Example of Relation Between KTI and Principal Factors: Unsaturated and Saturated Zone Flow--Isothermal Conditions

KTI Subissues	Associated Factors of the Safety Case	Importance to Repository Performance
1 Climate Change	Climate	Preliminary analyses suggest these factors do not contribute strongly to postclosure performance. Completed analyses will be documented for SRCR.
2 Hydrologic Effects of Climate Change	Infiltration, Unsaturated Zone Flow	
3 Present-Day Shallow Infiltration	Infiltration	
4 Deep Percolation	Unsaturated Zone Flow, Seepage into Drifts	Seepage is a Principal Factor.
5 Saturated Zone Ambient Flow and Dilution	SZ Flow and Transport (Advective Pathways, Retardation, Dispersion, Dilution)	Retardation of radionuclide transport in the UZ and SZ are Principal Factors.
6 Matrix Diffusion	UZ and SZ Flow and Transport (Advective Pathways, Retardation, Dispersion, Dilution)	

Summary

- DOE plans to provide information in the context of a risk-informed, performance-based approach to safety
- Although each KTI subissue will be addressed, the information provided will reflect the importance of the subissues to DOE's safety case
- The documented basis for this safety case should
  - Facilitate resolution of KTI subissues related to non-Principal Factors
  - Provide a basis to focus DOE-NRC interactions on factors most important to postclosure performance