NWTRB Repository Panel meeting
Postclosure Defense in Depth in the Design Selection Process

Presented to:
Nuclear Waste Technical Review Board
Panel For the Repository

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Defense in Depth

• DID is a safety philosophy that employs multiple barriers to ensure that failure in any one of them does not imply failure of the entire system

• For licensing safety case DOE expected to
  – Identify the principal barriers of the system
  – Provide transparent assessment of contribution of each barrier
  – Indicate system performance enhancement provided by multiple diverse barriers

• Approach to DID chosen to support development of a robust design and display the contribution of individual engineered and natural barriers for that design
Application to EDA Development

• Analytic approach developed to provide a measure for comparison of designs regarding DID
• Principal use will be in Phase 2 evaluation
• Although approach resembles TSPA, its focus is much different--it focuses on redundancy among barriers to mitigate uncertainties--it does not replace TSPA
• Focus in the approach is barrier “neutralization”
  – Determine contribution of each barrier to TSPA
  – Determine if system of barriers is resilient against uncertainties
Approach

Determine Contribution of Principal Barriers

1. Identify Principal Barriers
2. Assess Barriers for Common Uncertainty and Failure Mode
3. Conduct Barrier Neutralization Analyses
4. Evaluate Overall System Defense in Depth

Show Multiple Barriers Enhance System Performance

Data for Design Comparison
1. Identify Principal Barriers

• Principal barriers:
  
  Delay water or radionuclides at least 1,000 years
  
  (or)
  
  Limit fractional rate of release to $< 10^{-4}$ per year

• Assessment based on barrier properties, e.g.
  
  – Delay: longevity, porosity, permeability
  
  – Fractional rate of release: longevity, diffusivity, dispersivity
2. Assess Principal Barriers

- Assess common-mode failures and sources of uncertainty to determine barriers that should be neutralized together

- Considerations
  - Common materials subject to same uncertainties in properties
  - Representations derived from common model
  - Common-mode failure (e.g., failure of one barrier limits effectiveness of another)
3. Neutralize Barriers

- Process of stripping off barriers to see their importance to system
- “Neutralize” each barrier combination
  - Assume ineffective in limiting movement of water/radionuclides
  - In all other respects, barriers perform as in base case
- Because object is to determine contribution to base case performance, barrier combination completely neutralized
4. Evaluate Overall System Defense in Depth

- System performance evaluated from totality of neutralizations: e.g., identify barriers whose uncertainty is not compensated by other barriers

- Determine if system performance depends strongly on any single barrier

- Design should permit repository performance objective to be met even if a barrier fails to perform as anticipated
Example-VA Base Case
Example-VA Base Case
Barrier Combinations To Be Neutralized

• Overlying flow barriers (common flow model)
• UZ barriers (common flow and transport models)
• SZ barriers (common flow and transport models)
• Waste package (outer barrier protects inner barrier)
• Spent fuel cladding
• Invert
Example--TSPA Including All Barriers

Annual Dose (mrem/year) against Time after Closure (years)

25 mrem/year Performance Objective

Total for Base Case

I-129, Tc-99, Np-237, U-234, Pu-239, Pu-242, Pa-231 + Ac-227

Example--TSPA Including All Barriers
Neutralize Overlying Flow Barriers

Annual Dose (mrem/year)

Overlying Rock Units Neutralized

Base Case

25 mrem/year Performance Objective

Time (year after closure)
Neutralize Unsaturated Zone Transport Barrier

25 mrem/year Performance Objective

Base Case

Unsaturated Zone Transport Barrier Neutralized
Neutralize Saturated Zone Transport Barrier

Annual Dose (mrem/year) vs. Time (year after closure)

- **Base Case**
- **Saturated Zone Transport Barrier Neutralized**

25 mrem/year Performance Objective
Neutralize Waste Package

![Graph showing annual dose versus time after closure. The graph compares two scenarios: Base Case and Waste Package Neutralized. The y-axis represents annual dose (mrem/year), and the x-axis represents time after closure (year). The 25 mrem/year performance objective is marked.]

25 mrem/year Performance Objective

25 mrem/year Performance Objective
Neutralize Spent Fuel Cladding

Annual Dose (mrem/year)

Spent Fuel Cladding Neutralized

Base Case

25 mrem/year Performance Objective

Time (year after closure)
Neutralize Invert Transport Barrier

Annual Dose (mrem/year) vs. Time (year after closure)

- Base Case
- Drift Invert Neutralized

25 mrem/year Performance Objective

In Process/NWTRB/Panel/YMRichardson_1-25-99
Relative Contribution of Barriers - VA Design
(10,000 Years)
Neutralize Both UZ and SZ Transport Barriers

Transport Barriers (UZ and SZ) Neutralized

Base Case

25 mrem/year Performance Objective

Annual Dose (mrem/year)

Time (year after closure)
Notes on Postclosure Defense in Depth

• Analysis of VA illustrative only--Results for other designs will depend on barriers of those designs

• Analytic approach is tailored to indicate roles of barriers that might be obscured and to indicate where multiple barriers could enhance confidence

• Approach does not diminish need for sound scientific and engineering basis for system design and licensing case

• Approach is part of overall effort to address engineering uncertainties and those of the natural system