



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

Multiple Lines of Evidence

Presented to:
Nuclear Waste Technical Review Board

Presented by:
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YUCCA
MOUNTAIN □
PROJECT □

What the Board Has Said

- **“The Board has recommended that the DOE focus significant attention on four priority areas dealing with managing uncertainty and coupled processes, which, in the Board’s view, are essential elements of any DOE site recommendation.”**
- **This presentation addresses the fourth area only:**
- **“... (4) Development of multiple lines of evidence to support the safety case of the proposed repository. These lines of evidence should be derived independently of performance assessment, and thus, not subject to the limitations of performance assessment.”** Transcript of NWTRB Meeting, Amargosa Valley, Nevada, January 30, 2001

Panel Discussion on Multiple Lines of Evidence, April 13, 2001

- **Considered various multiple lines of evidence, such as alternative analyses, natural analogs, simplified calculations, and direct observations**
- **Discussed use of multiple lines of evidence to provide a clear and transparent Safety Case (of which a Total System Performance Assessment is an important part)**
- **DOE will use multiple lines of evidence to show that the scientific work underlying the Site Recommendation is competent, technically defensible, and that there is a basis for having confidence in the Safety Case**

Panel Discussion on Multiple Lines of Evidence

(Continued)

- **The scientific method requires consideration of multiple lines of evidence in the development of conceptual models from data and observations**
- **The International Community also recognizes the importance of multiple lines of evidence**
 - **International Atomic Energy Agency**
 - **OECD/NEA Integration Group for the Safety Case**
- **The DOE agrees that multiple lines of evidence should be part of the documentation that provides the technical basis for a Site Recommendation**

Panel Discussion on Multiple Lines of Evidence

(Continued)

- **Prior to the Site Recommendation, the DOE has addressed, but did not emphasize, multiple lines of evidence in the scientific and engineering programs**
- **The documentation was in supporting project documents, such as the Yucca Mountain Site Description and Process Model Reports**
 - **Documentation was usually implicit, not explicit**
 - **Missed opportunity to highlight this work**
 - **Opportunity now being taken to correct this oversight**

Treatment of Multiple Lines of Evidence for Site Recommendation

- **The DOE is bringing discussions of multiple lines of evidence into current documents (e.g., the Supplemental Science and Performance Analyses Report [SSPA])**
 - **Discussions of other lines of evidence are being summarized for major process models**
 - **A synthesis report (November 2001) will summarize results of ongoing analog studies**
- **Work to provide more emphasis and visibility to multiple lines of evidence is ongoing**
 - **Identifying additional lines of evidence will be a continuing effort beyond the Site Recommendation**

Multiple Lines of Evidence in the SSPA

- **Chapter 3: Unsaturated Zone Flow and Transport**
 - 3.3.1 Climate Model
 - 3.3.2 Infiltration Model
 - **3.3.3 Flow in the PTn**
 - 3.3.4 Three-Dimensional Flow Fields
 - 3.3.5 Thermal/hydrological (TH) Effects-Mountain-Scale
 - 3.3.6 Thermal/hydrological/chemical (THC) Effects, Mountain-Scale
 - 3.3.7 Thermal/Hydrological/Mechanical (THM) Effects-Mountain-Scale

Multiple Lines of Evidence in the SSPA

- **Chapter 4: Seepage**
 - **4.3.1 General Seepage Evaluation**
 - 4.3.2 Flow Focusing
 - 4.3.3 Rock Bolts
 - 4.3.4 Drift Degradation
 - 4.3.5 TH Effects on Seepage
 - 4.3.6 THC Effects on Seepage
 - 4.3.7 THM Effects on Seepage

Multiple Lines of Evidence in the SSPA

- **Chapter 5: Effects of Decay Heat on In-drift TH Conditions**
 - 5.3.1. Multi-scale model of in-drift TH conditions
 - 5.3.2 Ventilation and Convection Modeling on In-drift TH Conditions
- **Chapter 6: In-drift Physical and Chemical Environment**

Multiple Lines of Evidence in the SSPA

- **Chapter 7: Waste Package and Drip Shield Degradation**
 - 7.3.1 Environment on Waste Package and Drip Shield
 - 7.3.2 Aging and Phase Stability
 - 7.3.3 Stress Corrosion Cracking
 - 7.3.4 Passive Film Stability
 - 7.3.5 General Corrosion
- **Chapter 8: Water Diversion Performance of the Engineered Barrier System**
- **Chapter 9: Waste Form Degradation**

Multiple Lines of Evidence in the SSPA

- **Chapter 10: Engineered Barrier System Transport**
- **Chapter 11: Unsaturated Zone Flow and Transport**
 - **11.3.1 Drift Shadow Zone**
 - **11.3.2 Multiple Interactive Continua (MINC) Versus Dual Permeability Model (DKM)**
 - **11.3.3 Finite Element Heat and Mass (FEHM) Versus Dual Continuum Particle Tracker (DCPT)**
 - **11.3.4 3-D Transport**
 - **11.3.5 Effects of TH, THC, and THM Processes**

Multiple Lines of Evidence in the SSPA

- **Chapter 12: Saturated Zone Flow and Transport**
- **Chapter 14: Volcanic and Seismic Disruptive Events**
 - **14.3.1 Igneous Activity**
 - **14.4.2 Earthquake Activity**

Previous Presentations of Multiple Lines of Evidence Examples

- **Focus on analog studies to build confidence in process models (January 2000 NWTRB Meeting)**
 - Summarized examples of ongoing work, such as radionuclide flow and transport studies at Peña Blanca and other analog sites
 - Summarized qualitative verification of models for seepage using natural analogs
- **Passive film stability (January 2001 NWTRB Meeting)**
 - Summarized ongoing studies of Josephinite

Multiple Lines of Evidence in the SSPA

- **Example: Lateral flow within the Paintbrush Tuff nonwelded (PTn) units**
 - Montazer and Wilson (1984) hypothesized the PTn caused lateral flow so that flow within the Topopah Spring (TSw) would be smaller than in the PTn
 - Current models of the PTn show that lateral flow within the PTn changes the infiltration distribution so that fluxes in the PTn and the TSw are not significantly different
 - ◆ Dampening and lateral flow within the PTn reduce the spatial heterogeneity predicted by the infiltration model
 - ◆ Independent observations and analyses support the current conceptual model

Multiple Lines of Evidence in the SSPA – Lateral Flow the PTn, (Continued)

- **Current modeling results in the PTn are based on:**
 - Calculated fluxes within the PTn in six boreholes
- **The appropriateness of the current conceptual model was also tested against other observations and analyses:**
 - Geochemical and mineralogic data, such as spatial distribution of chloride concentration secondary minerals in lithophysal cavities
 - Modeled CI results using a chloride-based infiltration map

Multiple Lines of Evidence in the SSPA

- **Example: Seepage**

- Unsaturated zone flow model predicts most water will be diverted around emplacement drifts
- This conceptual understanding of drifts as capillary barriers evaluated in part by use of other lines of evidence
 - ◆ Minerals in Yucca Mountain lithophysal cavities
 - » No evidence of dripping (stalagmitic deposits)
 - » Seepage rate calculated from these deposits is less than seepage model predicts
 - ◆ Excavated openings
 - » Tombs in Egypt excavated 3,000 to 3,500 years ago- no clear evidence of dripping
 - » Preserved paintings in temples carved into basalt at Ajanta, India between second century B.C. and sixth century A.D.

Multiple Lines of Evidence-Seepage

(Continued)

- **Other lines of evidence, continued**
 - ◆ **Caves**
 - » **Relatively dry caves in southwestern US with plant & animal remains preserved for tens of thousands of years**
 - » **Preservation of artifacts and paintings in caves in Europe, Africa, Asia, and India**
 - ◆ **Exploratory Studies Facility (ESF)**
 - » **No natural seepage observed in the ESF**
 - » **No construction water observed to seep into ESF at crossover point of Enhanced Characterization of Repository Block (ECRB)**

Multiple Lines of Evidence-Seepage

(Continued)

- **Potentially or apparently conflicting lines of evidence**
 - ◆ **Water observed in ECRB middle- non-ventilated zone between second and third bulkheads**
 - » **Analysis and modeling suggests source of the water is condensation; work ongoing to evaluate if source is condensation, construction water, or seeping porewater**
 - ◆ **Seepage in tunnels at Rainier Mesa**
 - » **Stratigraphy similar, mean precipitation about double Yucca Mountain (YM) mean**
 - » **During tunnel construction, joints yielded water**
 - » **Seeping fractures thought to be pathways from an overlying perched zone**
 - » **Seeping fractures only in zeolitic- and not in vitric tuff**
 - » **Suggests seepage localized and restricted to certain flow paths and geologic units - not inconsistent with YM seepage modeling**

Conclusions – Multiple Lines of Evidence

- **The DOE is highlighting the consideration of multiple lines of evidence in current SR-related documents**
- **The contribution of the Board in stimulating this effort is acknowledged**
- **This effort results in a more complete & transparent discussion of scientific bases of models**
 - **Discussions not yet robust- focused primarily on analogs, direct observations, and alternative analyses**
 - **Work will continue to improve the documentation of multiple lines of evidence**