NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING

SUBJECT: USE OF REASONABLE JUDGMENT IN PERFORMANCE ASSESSMENT ANALYSES: EXAMPLES FROM TSPA-1995

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LAS VEGAS, NEVADA JANUARY 10-11, 1996
Outline

• Need for judgment in TSPA analyses
• Philosophy of judgments used in TSPA
• Examples of judgment evolution in TSPA analyses from 1991 to 1995
• Examples of judgment in TSPA-1995
• Summary and conclusions
Background
Need for Judgment in TSPA Analyses

- TSPA analyses are built upon a foundation of processes described by representative conceptual models and parameters

- Conceptual models and parameter values generally are uncertain and spatially variable

- Direct observations and models “validated” by direct observations are used to ensure that models and parameters are reasonable representations of expected conditions

- Many direct observations are uncertain and variable (or are lacking); therefore, assumptions based on reasonable judgment must be employed
Philosophy of Use of Judgment in TSPA Analyses

- Use judgment to define
  - which models to incorporate in the analyses
  - what parameter ranges to use
  - how to incorporate spatial variability in properties
- Ensure that judgments and assumptions are as reasonably conservative as possible
- Acknowledge that judgments and assumptions made are uncertain
- Evaluate the significance of the uncertain judgments and assumptions
- Prioritize information needs by degree of significance and uncertainty of the conceptual models and parameters
Evolution of Conceptual Assumptions in TSPA:
Example of Waste Package Degradation Model

- **TSPA-1991**
  - assume degradation is time-varying function starting at 300 years and uniform over the next 5000 years
  - “failure” implies complete loss of containment
- **TSPA-1993**
  - degradation based on temperature-dependent aqueous corrosion of corrosion-allowance and corrosion-resistant materials; temperature derived from repository-scale thermo-hydrologic model
  - “failure” implies complete loss of containment
- **TSPA-1995**
  - degradation based on temperature- and humidity-dependent humid air and aqueous corrosion of corrosion-allowance material and cathodic protection of corrosion-resistant material; humidity and temperature determined by alternative drift-scale thermo-hydrologic models
  - “failure” defined by first pit, but effective area for diffusive transport depends on number of pits versus time
Evolution of Conceptual Assumptions in TSPA:
Example of Drift-Scale Flow and Transport Model

- **TSPA-1991**
  - unsaturated zone (UZ) percolation flux assumed to intercept repository drifts and waste packages

- **TSPA-1993**
  - UZ percolation flux distributed log-normally at repository horizon, only advective release if flux > saturated conductivity of Topopah Spring welded (TSw) unit
  - diffusive release based on water content of rock adjacent to drift

- **TSPA-1995**
  - UZ percolation flux distributed log-normally at repository horizon, only advective release if flux > saturated conductivity of TSw
  - diffusive release based on in-drift saturations derived from alternative thermo-hydrologic models
  - alternative drift-scale flow and transport models evaluated in sensitivity analyses
Evolution of Conceptual Assumptions in TSPA: Example of Unsaturated Zone Aqueous Transport Model

- **TSPA-1991**
  - matrix-dominated flow and transport

- **TSPA-1993**
  - matrix- or fracture-dominated transport with high matrix diffusion (effectively matrix-dominated)
  - fracture transport with no matrix diffusion (Weeps model)

- **TSPA-1995**
  - sensitivity to matrix diffusion (TSPA-1993) evaluated as part of Calico Hills Systems Study
  - fracture transport with variable fracture-matrix interaction (sensitivity to fracture-matrix coupling evaluated)
Examples of Judgment Used in TSPA-1995:
Waste Package Degradation

- Alternate drift-scale thermo-hydrologic models with different backfill thermal conductivities
- Relative humidity and temperature criterion for initiation of humid air and aqueous corrosion
- Corrosion degradation rates with pitting factor for humid air and aqueous corrosion of corrosion-allowance material
- Incorporation of variability in corrosion degradation rates from package to package and from pit to pit
- Percent of corrosion-allowance material degraded prior to initiation of corrosion of corrosion-resistant material (cathodic protection)
- Pitting corrosion rates of corrosion-resistant material
General Corrosion Depth Versus Time of Corrosion-Allowance Material in Humid-Air and the Model Fit

- Corrosion Depth (µm)
- Exposure Time (years)

- C:
  - SO₂ ≤ 70 µg/m³
  - SO₂ > 70 µg/m³
- Model Prediction for 15 °C; 84 % RH; 90 µg SO₂/m³
- ± 2 s.d.
Examples of Judgment Used in TSPA-1995: Radionuclide Mobilization and EBS Release

• Cladding degraded congruently with waste package
• Waste form surface covered by thin water film
• Aqueous dissolution rates derived from flow-through laboratory observations with uncertainty
• Solubility limits based on laboratory observations with uncertainty
• Alternative drift-scale aqueous advective release models
  – flux at “drips” intersects pits on waste package
  – flux at “drips” does not enter waste package
  – flux at “drips” does not enter drift
• Diffusive release model uses laboratory-derived saturation-dependent diffusion coefficients
Diffusion Coefficient Versus Water Content: Observations and Model Fit

![Graph showing diffusion coefficient versus volumetric water content. The graph includes data points for different types of materials: Soil, Tuff Gravel, Other Gravel, Clay (Bentonite), and Whole Rock. The graph also shows model estimation and ±2 s.d. lines.](image-url)
Examples of Judgment Used in TSPA-1995: Geosphere Flow and Transport

- Range of percolation flux values investigated
- Fracture and matrix flux distributions based on UZ flow model with non-equilibrium effects
- Alternative representations of fracture-matrix coupling in UZ transport
- Retardation values based on laboratory tests
- Aqueous flux distribution in saturated zone based on preliminary hydrologic model
- Dilution in saturated zone limited to constrained flow area
Schematic of Unsaturated Zone Flow Models

\[ \text{q}_{\text{ppt}} \]

\[ \text{TCw} \]

\[ \text{PTn} \]

\[ \text{TSw} \]

\[ \text{q}_{\text{perc,l}} \]

\[ \frac{\text{CHnv}}{\text{q}_{\text{mat}}} \]

\[ \text{CHnz} \]

\[ \text{PP} \]

\[ \text{q}_{\text{frac}} \]
Unsaturated Zone Flow Alternative Conceptual Models Affecting Performance

- Precipitation ($q_{ppt}$) variability in time and space
- Infiltration ($q_{inf}$) uncertainty and variability
- Percolation flux ($q_{perc}$) uncertainty
- Drift-scale percolation flux distribution ($q_{perc,i}$) at repository horizon
- Percolation flux distribution between drips ($q_{drip,i}$) and matrix ($q_{mat,i}$) at the intersection with the drifts
- Alternative models of $q_{drip,i}$ within drifts
- Percolation flux distribution between fractures ($q_{frac}$) and matrix ($q_{mat}$) beneath the repository
Sensitivity of 1,000,000-year Total Peak Dose to Infiltration Rate Distribution, $q_{inf}$

(83 MTU/acre, gravel backfill, climatic variation of $q_{inf}$)

**Entire $q_{inf}$ range (0.01 - 2.0 mm/yr)**
Summary and Conclusions

- Present state of process-level models has necessitated the use of conceptual and parameter assumptions in TSPAs

- Assumptions require judgment

- Aim is to make judgments reasonable, transparent and/or conservative

- Sensitivity analysis is used to identify those models and parameters where judgment has a significant impact

- Additional testing, synthesis of information and process-level modeling aims at enhancing representativeness of judgments made in the analysis

- Given that uncertainty remains, judgment will be required; the significance of which must be evaluated