U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

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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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:

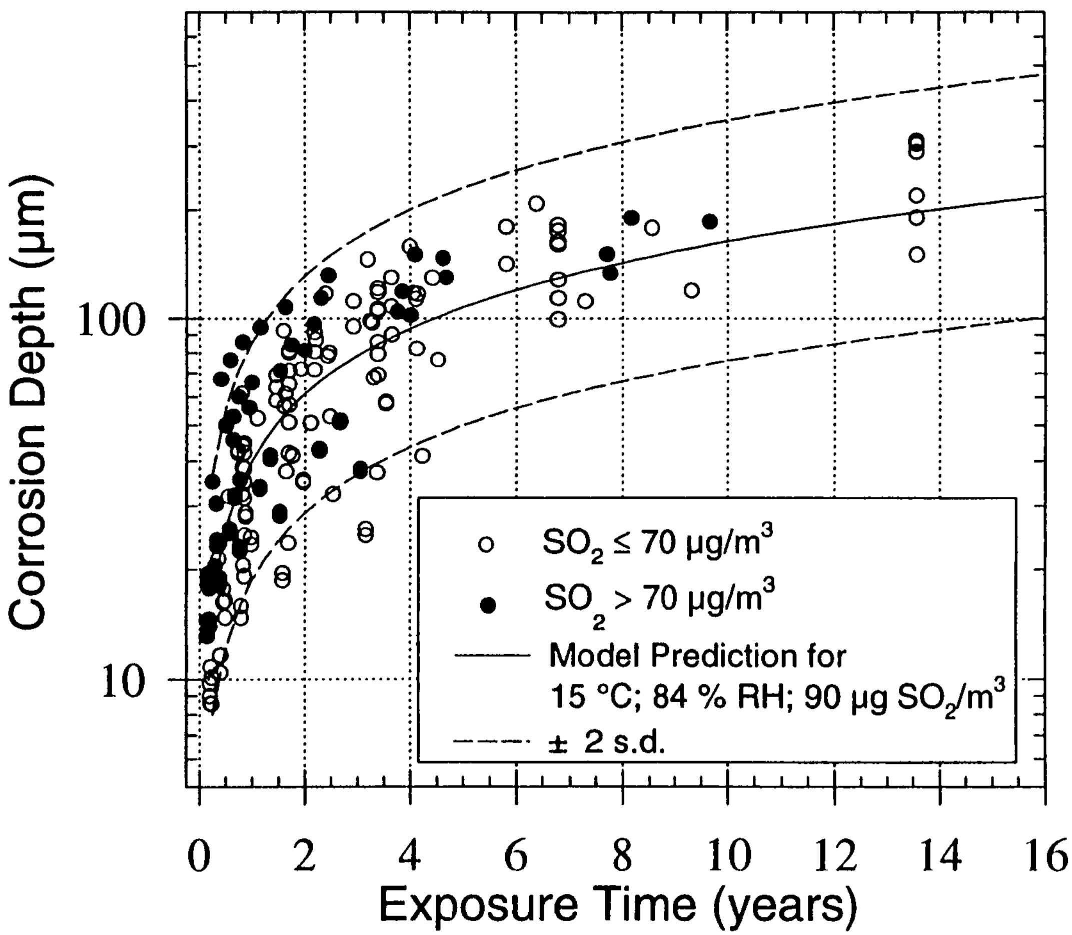
Example of Unsaturated Zone Aqueous Transport Model

- 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

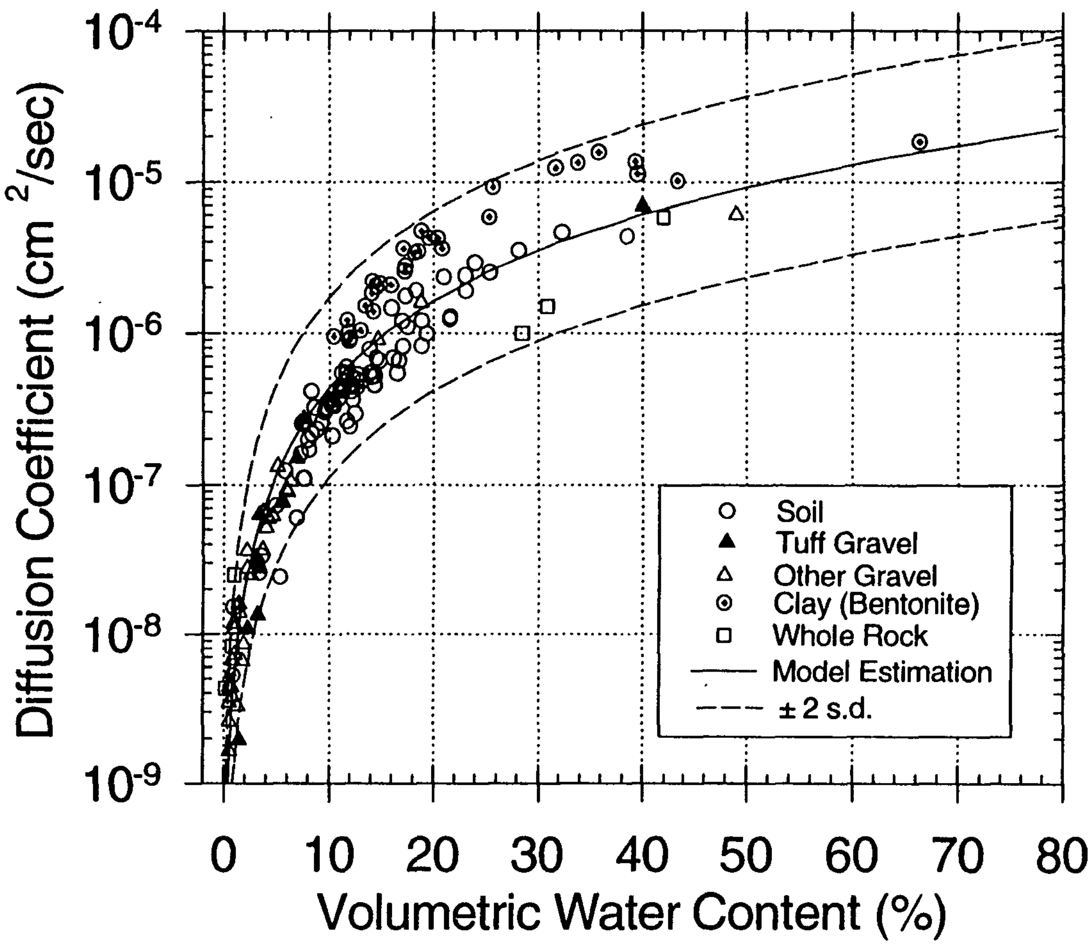
General Corrosion Depth Versus Time of Corrosion-Allowance Material in Humid-Air and the Model Fit



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

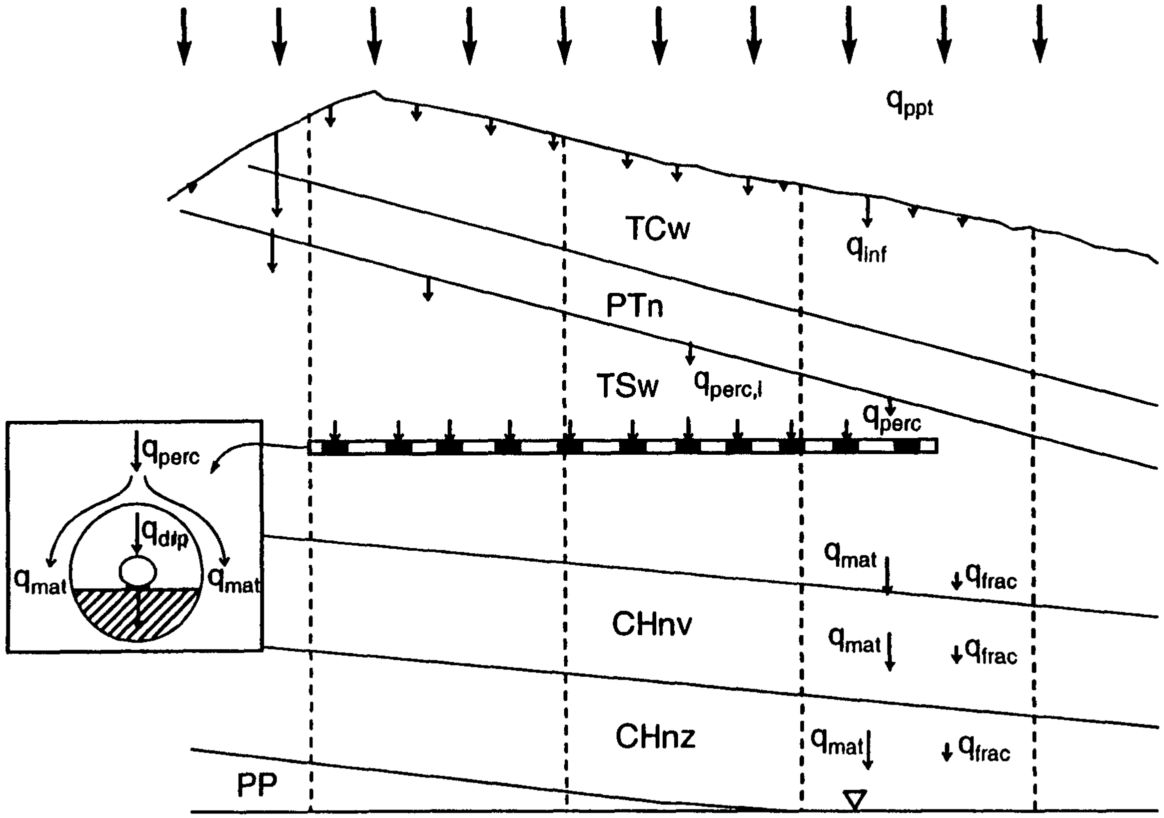
Diffusion Coefficient Versus Water Content: Observations and Model Fit



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



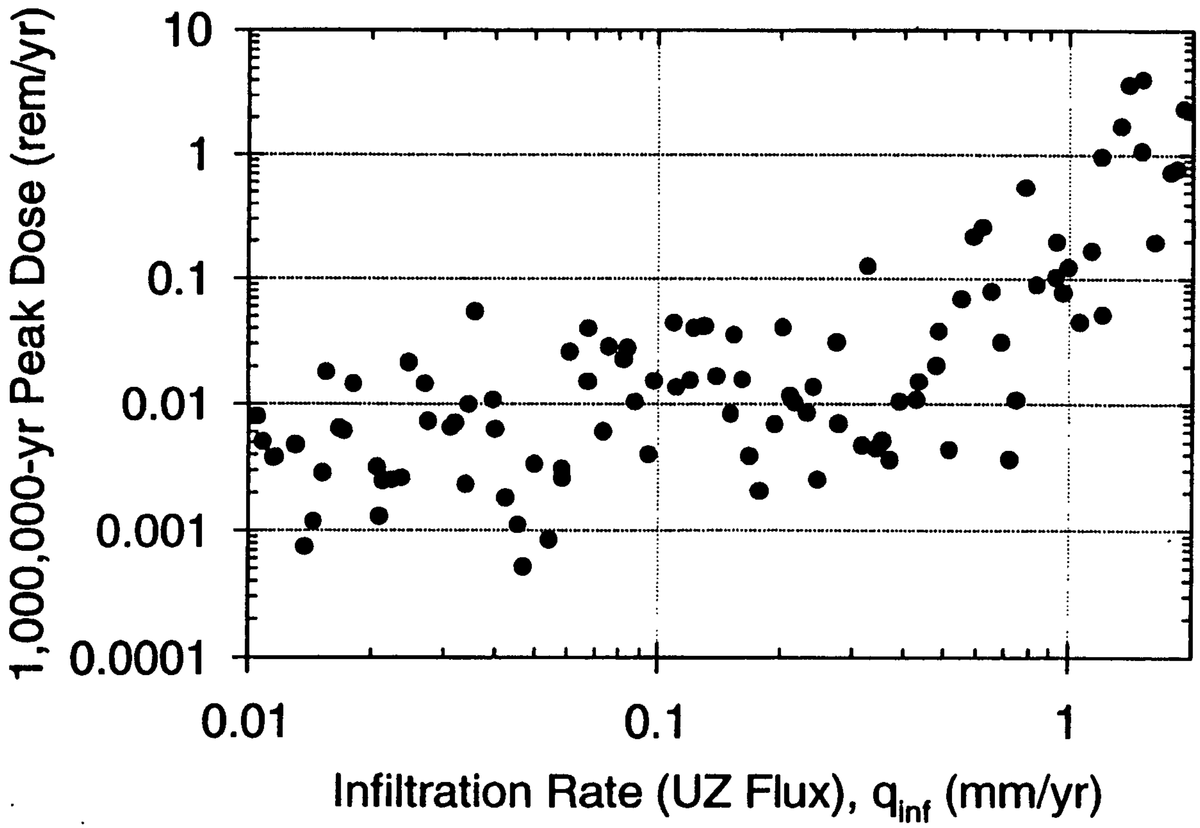
Unsaturated Zone Flow Alternative Conceptual Models Affecting Performance

- 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})

<u>Entire</u> 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