



U.S. Department of Energy



Conservatism in DOE's Performance Assessments: Role and Examples

**Presented to:
Nuclear Waste Technical Review Board**

**Presented by:
Dr. Abraham Van Luik
Office of License Application and Strategy
U.S. Department of Energy**

**Dr. Robert Andrews
Bechtel-SAIC Company, LLC**

**November 9, 2005
Las Vegas, NV**

Outline

- **Introduction**
- **Regulatory Requirements**
- **Background – Perspectives on Conservatism**
- **Role of Conservatism in Yucca Mountain Performance Assessment**
- **NWTRB Observations and Recommendations**
- **Example – Engineered Barrier System Transport**
- **Example – Unsaturated Zone Transport**
- **Example – Saturated Zone Transport**
- **Summary**



Introduction

- **The primary purpose of performance assessment is to demonstrate post-closure regulatory compliance**
- **DOE will provide a demonstration of post-closure regulatory compliance that does not underestimate dose**
- **This demands the application of a cautious but reasonable approach in modeling long term performance**
 - **Conservatism has been used in process- and abstraction-level models to simplify analyses and reduce the need for additional information**



Introduction

(Continued)

- **Post-closure performance assessments are inherently complex and need to address a range of uncertainties**
 - Some uncertainty is inherently irreducible
- **There is a continuum of approaches for addressing uncertainty, with two end-members**
 - Using deterministic bounding estimates
 - Utilizing probabilistic statistical modeling techniques that incorporate quantitative representations of uncertainty
- **The DOE has utilized a hybrid approach**
 - Maximize the benefits of bounding approach by simplifying the model and developing cautious but reasonable parameter distributions
 - Maximize the benefits of the probabilistic approach by propagating the relevant uncertainty that is reasonably quantified



Regulatory Requirements

- **Uncertainty in projecting post-closure performance of the Yucca Mountain repository is well recognized**
 - **Proof** that the geologic repository will conform with the objectives for postclosure performance **is not to be had in the ordinary sense of the word because of the uncertainties** inherent in the understanding of the evolution of the geologic setting, biosphere, and engineered barrier system [10 CFR 63.101(a)(2)]
- **Conservatism is an accepted approach for addressing uncertainty**
 - In many regulatory applications, a conservative approach can be used to decrease the need to collect additional information or to justify a simplified modeling approach. **Conservative estimates for the dose to the reasonably maximally exposed individual may be used** to demonstrate that the proposed repository meets U.S. Nuclear Regulatory Commission regulations and provides adequate protection of public health and safety. [NUREG-1804 Section 2.2.1]



Regulatory Requirements

(Continued)

- **When conservatism is used to simplify the analysis or decrease the need to collect additional information, care must be taken to evaluate the effect of this conservatism**
 - The performance assessments and analyses should **focus upon the full range of defensible and reasonable parameter distributions** rather than only upon extreme physical situations and parameter values [10 CFR 63.101(a)(2)]
 - The total system performance assessment is a complex analysis with many parameters, and the **U.S. Department of Energy may use conservative assumptions** to simplify its approaches and data collection needs. **However, a technical basis** that supports the selection of models and parameter ranges or distributions **must be provided** [NUREG 1804, Section 2.2.1]



Regulatory Requirements

(Continued)

- **NRC indicates that the technical bases presented in a Safety Analysis Report may be considered to be unchanged in future analyses if they can be shown to be “conservative or essentially the same”:**
 - **Departure from a method of evaluation described in the Safety Analysis Report (SAR) (as updated) used in establishing the preclosure safety analyses or the performance assessment means:**
 - ◆ **“Changing any of the elements of the method described in the SAR (as updated) **unless the results of the analysis are conservative** or essentially the same. [10 CFR 63.44(a)(2)]**
- **In the Integrated Issue Resolution Status Report the NRC staff discusses the basis for risk insights developed, and notes:**
 - **Generally, **important uncertainties are addressed in a total system performance assessment through a variety of approaches such as parameter ranges** (e.g., range of retardation factors of radionuclides in alluvium) **and conservative modeling** (e.g., assume southerly blowing wind direction for igneous activity). The risk insights provide a basis for focusing on the more important technical issues relative to risk and indicate where staff can benefit most from additional information (e.g., reduction of uncertainty in dose estimates). [NUREG-1762, p. 2-9 to 2-10]**



Background – Perspectives on use of Conservatism –

EPA Technical Support Document August 2005
Docket number OAR-2005-0083-0085

- **Range of conservatisms and their significance has been reviewed by an EPA contractor based on DOE, EPRI and NRC performance assessments**
 - In the 10,000-year engineered system time frame, **under principles of reasonable expectation, there is a framework of assumptions, conservatisms, and data that enables a defensible characterization of performance and uncertainty** using the probabilistic TSPA methods. Collectively, the elements of these assumptions, conservatisms and uncertain values for performance parameters establish a conceptual model of the repository system and a trajectory of expected repository performance that is reasonably predictable and can be explored for overall system performance uncertainty through reasonably based judgments of alternative assumptions, conservatisms, and parameter values. [OAR-2005-0083-0085, p. A-13]



Background – International Perspectives on Use of Conservatism

- **International perspectives are consistent with the DOE approach**
 - It was noted by participants that **a mixture of conservative and realistic assumptions in a safety case is inevitable**, and this is recognized by regulators. In those parts of the performance assessment where both types of assumptions are present, the assessment must err on the side of conservatism, but reviewers should be aware that this obscures areas of uncertainty [OECD/NEA 2005]
 - Conservatism of the analyses constitutes an additional qualitative argument for safety, although conservatism in and of itself may also be interpreted as a lack of knowledge, and thus may detract from confidence. **Conservatism is inevitable, and greatly to be preferred to optimism, but should be used and managed judiciously.** [OECD/NEA 2004]



Role of Conservatism in Yucca Mountain Performance Assessment

- **Conservatism has been and continues to be a part of the licensing approach adopted by DOE to:**
 - **Simplify models**
 - **Reduce the need for additional data**
 - **Address alternative conceptual models**
- **Conservative representations are designed to be cautious but reasonable**
- **This approach balances the need to be defensible with the desire to incorporate the full range of possible parameter distributions**



Role of Conservatisms in Yucca Mountain Performance Assessment

(Continued)

- **Post-closure performance assessment rests on a factual basis that provides a defensible prediction of performance; it does not underestimate dose**
- **The performance assessment approach is pragmatic, seeking an accurate representation of the factual basis**
- **Uncertainty is appropriately treated through a cautious approach, involving a reasonable degree of conservatism where warranted**
- **Conservatism is appropriately evaluated through risk-based importance evaluations**
- **Sensitivity studies are being used to enhance system understanding**



NWTRB Observations on Use of Conservatism

- **“The DOE often deals with uncertain features and processes by making conservative estimates of their effects on radionuclide transport. . . The Board identifies some areas where additional work might increase basic understanding, narrow the wide range of predicted radionuclide transport times, and increase confidence in predictions of the performance of the natural barriers.” [May 3, 2004 letter]**
- **DOE’s response [September 10, 2004] indicated:**
 - The most significant uncertainty has been included in the models
 - In some cases conservative approximations have been used
 - Continued evaluation of these processes will be included in the Performance Confirmation Plan
 - Key conservatisms are being evaluated as part of the Science and Technology Program



NWTRB Observations on Use of Conservatism

(Continued)

- “A number of highly conservative assumptions have been used in addressing seismic issues. The DOE may find conservatism attractive because it could provide a way to show regulatory compliance in the face of uncertainty. As stated above, DOE and BSC scientists agree that many of their estimates are highly conservative or physically unrealistic.” [June 27, 2003 letter]
- DOE’s response [October 8, 2003] noted that:
 - Seismic ground motions at annual exceedance probabilities of less than 10^{-6} per year are highly conservative and may be “physically unrealizable”
 - Several different studies are ongoing to bound the very low probability ground motions in order to provide a more realistic set of ground motions
- DOE presented a revised approach considering reasonable bounds on seismic hazard on May 18, 2004, as noted in NWTRB letter [July 28, 2004]
 - We are very pleased to learn . . . that the DOE has initiated a program aimed at deriving more realistic estimates of seismic hazard at the Yucca Mountain site

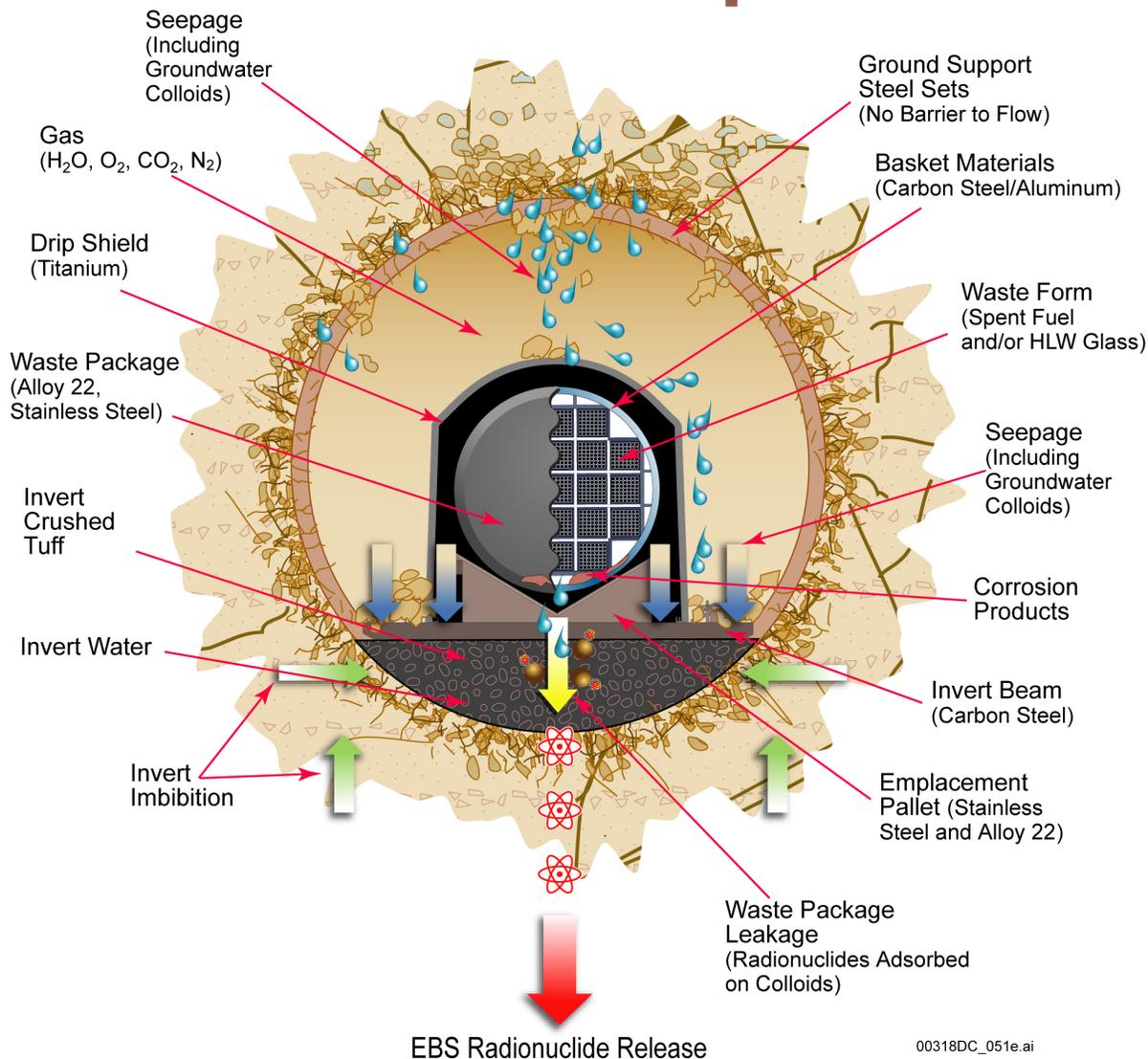


Examples of Conservatism

- **Engineered Barrier System Radionuclide Transport**
- **Unsaturated Zone Radionuclide Transport**
- **Saturated Zone Radionuclide Transport**



General Engineered Barrier System Features and Transport Process



00318DC_051e.ai



Examples of Conservatism

– Engineered Barrier System Transport

- **In-package and invert thermal and hydrologic conditions**
 - **Coupled processes in breached waste packages and the invert result in a range of possible moisture conditions and temperatures**
 - **Moisture conditions conservatively assume water film on waste form and in-package materials**
 - ◆ **No evaporation of water**
 - ◆ **No consumption of water**
 - ◆ **Continuous water film**
 - **Conservatisms enhance alteration of waste forms and diffusive transport**
 - **Current model simplifications reduce information needed to address alternative conceptualizations**



Examples of Conservatism

– Engineered Barrier System Transport

(Continued)

- **In-package and invert chemical conditions**
 - Coupled processes in breached waste packages and the invert result in a range of possible chemical conditions
 - In-package chemical conditions conservatively assume oxidizing environment and range of degradation rates of materials
 - ◆ Enhances waste form degradation
 - ◆ Enhances radionuclide solubility
 - In-drift chemical conditions consider uncertainty in seepage and imbibition water chemistry and their temporal evolution
 - Current model simplifications reduce information needed to address alternative conceptualizations

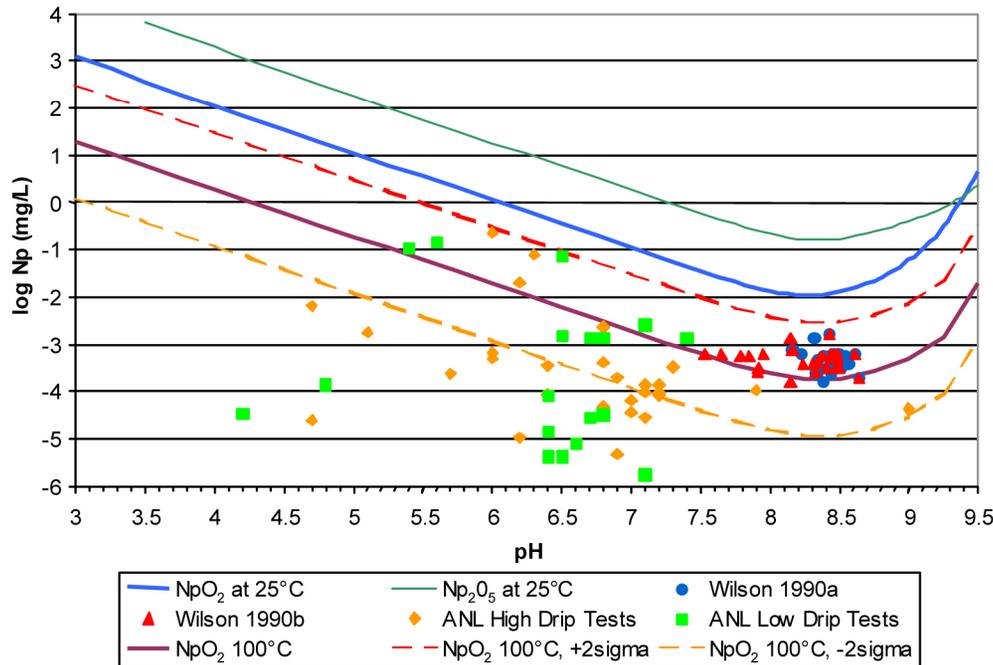


Examples of Conservatism

– Engineered Barrier System Transport

(Continued)

- **Radionuclide solubility**



- **Uncertainty in solubility is a function of uncertainty in environment and uncertainty in model**
- **Solubility models conservatively assume**
 - ◆ **Mineral precipitation control, i.e., no incorporation in secondary uranium phases**
 - ◆ **Solubility at 25°C**
- **Current model simplifications reduce information needed to address alternative conceptualizations**



Examples of Conservatism

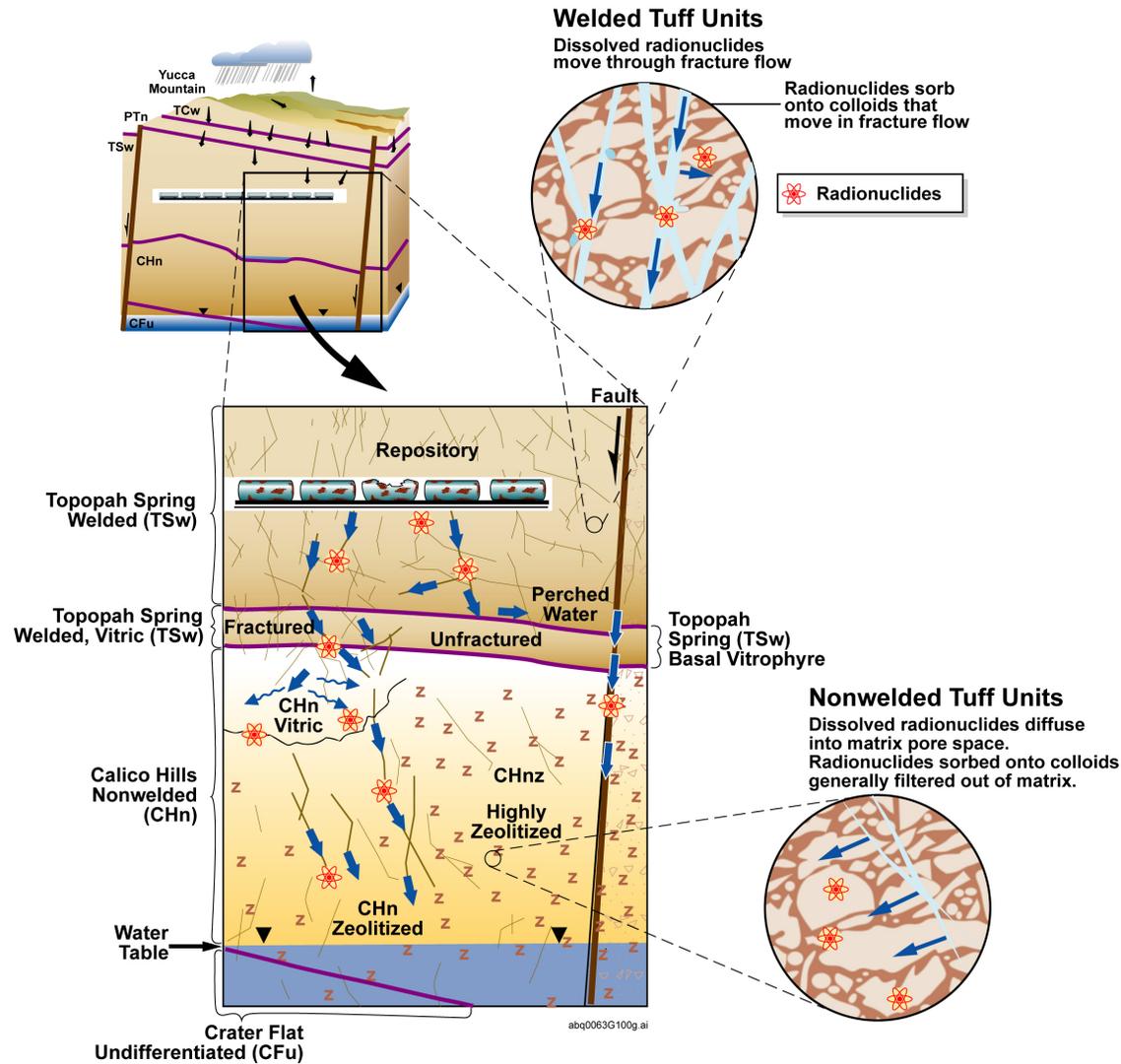
– Engineered Barrier System Transport

(Continued)

- **Colloid transport**
 - **Colloid formation and stability are a function of chemical conditions**
 - **Generally advective colloidal transport is more significant than diffusive transport**
 - **Diffusive colloidal transport conservatively considers**
 - ◆ **Transport through continuous thin water film**
 - ◆ **No filtration**
 - **Current model simplifications reduce information needed to address alternate conceptualizations**



General Unsaturated Zone Transport Processes



Examples of Conservatism

– Unsaturated Zone Transport

- **Propagation of Future Climate Effects**
 - Assumed to propagate instantaneously through the unsaturated zone resulting in increased fracture flux and an instantaneous rise in the water table
 - Simplifications minimize advective transport times to the water table following radionuclide release from the EBS
 - Simplifications reduce the complexity in predicting time variations



Examples of Conservatism

– Unsaturated Zone Transport

(Continued)

- **Matrix diffusion**
 - **Mass transfer from fractures to matrix**
 - ◆ Increases with increasing fracture-matrix interface area
 - ◆ Increases with effective matrix diffusion coefficient
 - **Both properties are uncertain**
 - ◆ Fracture-matrix interface area dependent on both large and small fractures
 - ◆ Effective matrix diffusion coefficient dependent on radionuclide and tortuosity of flow path through the fractured network
 - **Direct measurement of these properties *in-situ* is difficult**
 - ◆ Measurements in a reasonable time are possible using forced conditions
 - ◆ Uncertainty exists in the representativeness of the results obtained from non-ambient test conditions



Examples of Conservatism

– Unsaturated Zone Transport

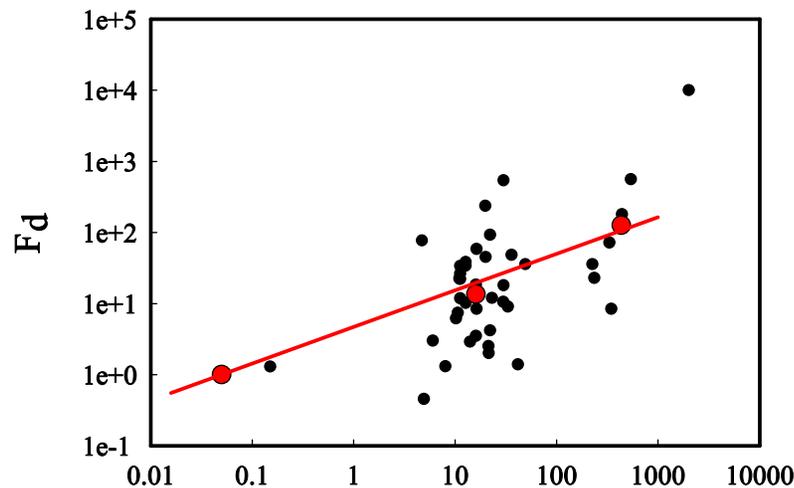
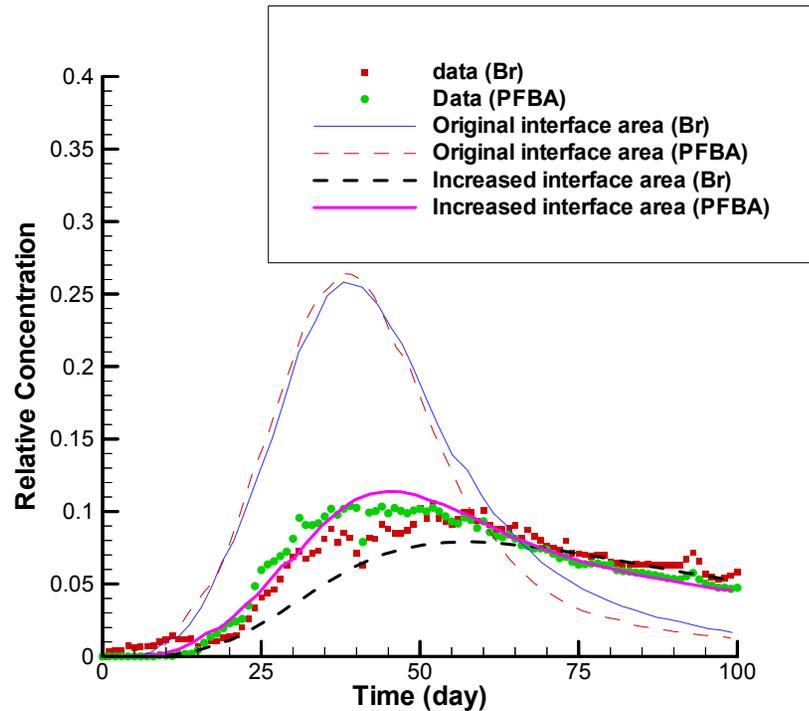
(Continued)

- **Current representation of site-scale matrix diffusion process considers**
 - **Geometric relationship of fracture-matrix interface area based on the most permeable fracture system**
 - **Effective diffusion coefficient based on laboratory experiments**



Examples of Conservatism – Unsaturated Zone Transport

(Continued)



(Liu et. al, 2004) Test Scale L (m)

- Alcove 8-Niche 3 fault test results indicate that fracture-matrix interface area is potentially greater than indicated by a geometric relationship
 - Similar conclusions possible with Alcove 8-Niche 3 large plot test
- Ratio (F_d) of effective matrix diffusion coefficient to laboratory-scale matrix diffusion coefficient appears scale dependent



Examples of Conservatism

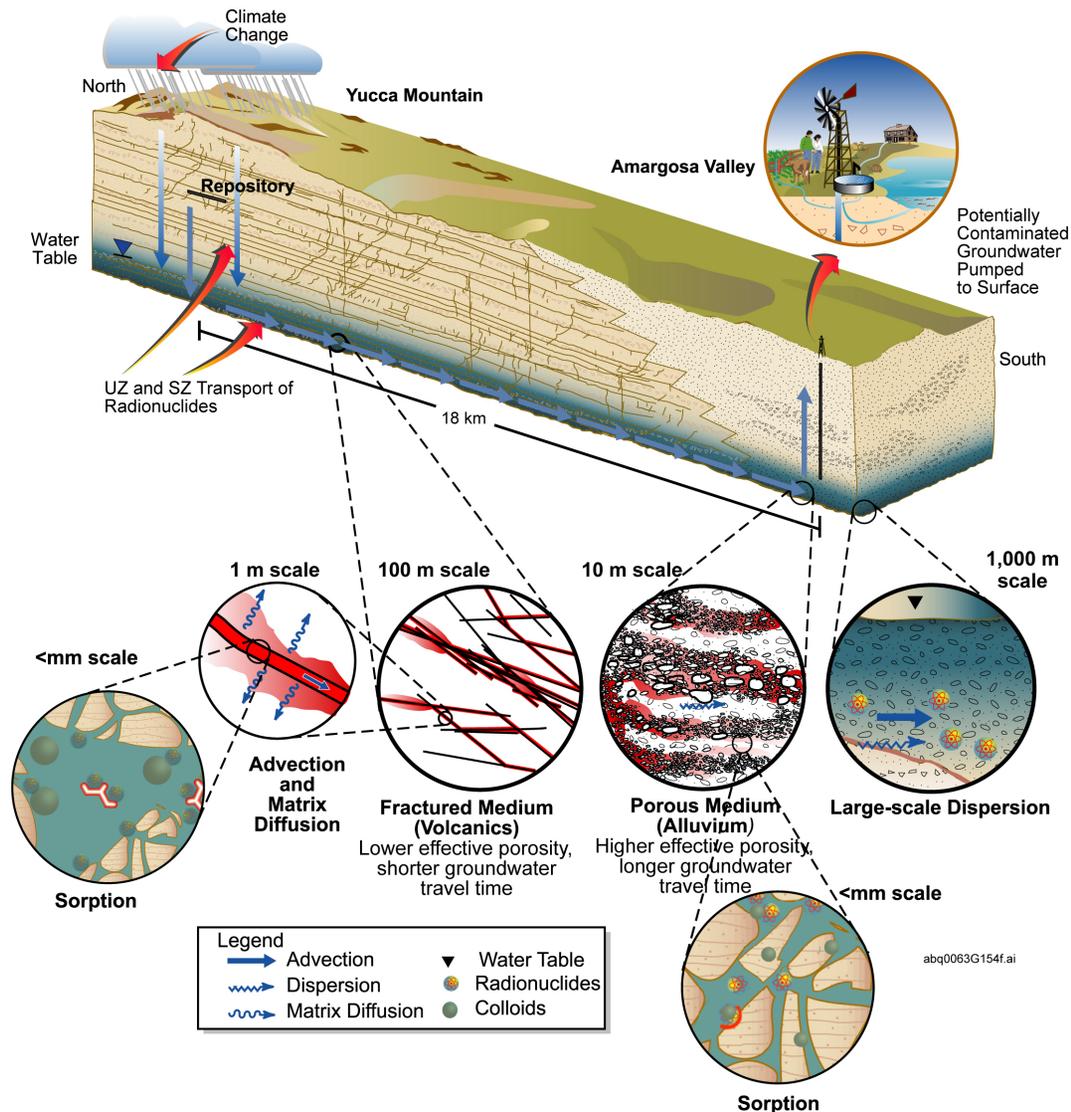
– Unsaturated Zone Transport

(Continued)

- **Recent data tend to support a potential scale dependency of this process**
- **Uncertainty exists in the quantification of this potential scale dependency of matrix diffusion**
- **Further evaluation of the matrix diffusion process is being considered by the Science and Technology Program**
- **Additional complexity of alternate transport models needs to consider additional information over the network of small fractures and the range of possible fluxes**



General Saturated Zone Transport Processes



Examples of Conservatism

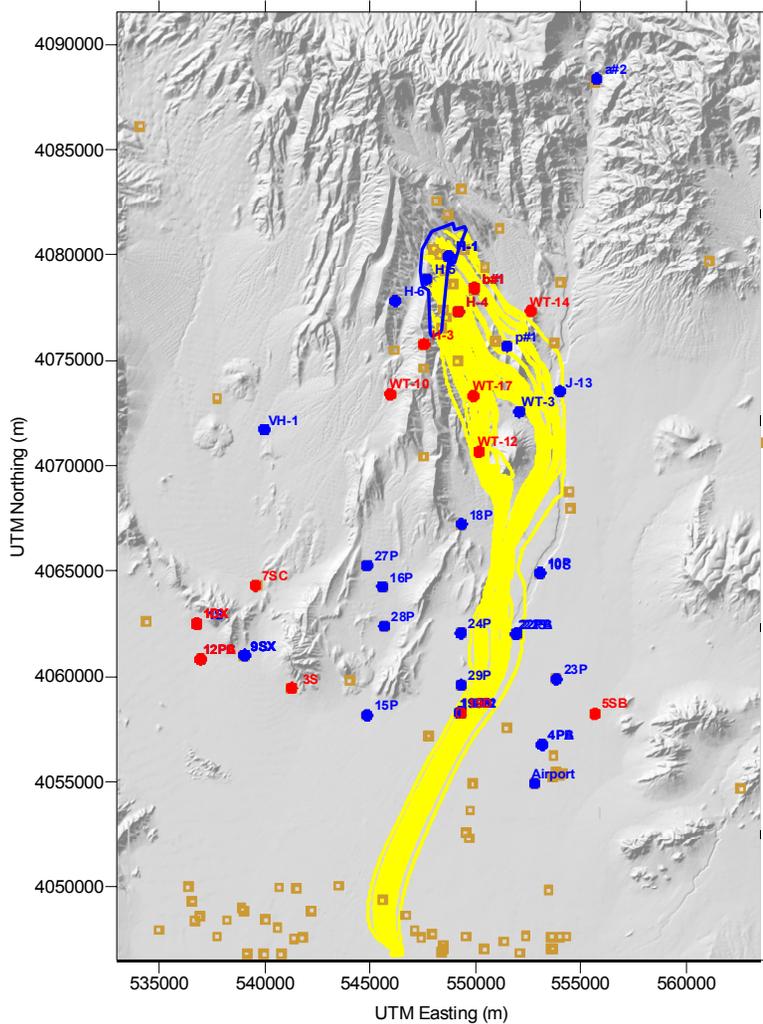
– Saturated Zone Transport

- **Propagation of Future Climate Effects**
 - Climate change represented as an instantaneous rise in the water table and increased flux in the saturated zone
 - Maximum water table rise chosen to bound range of possible water table rises
- **Lack of Permanent Colloid Filtration**
 - Colloid transport considers retardation processes but not permanent filtration
- **Potential Reducing Conditions**
 - A range of potential redox conditions exist in the saturated zone
 - Oxidizing conditions are conservative from radionuclide solubility and retardation perspectives which affect radionuclide transport



Examples of Conservatism – Saturated Zone Transport

(Continued)

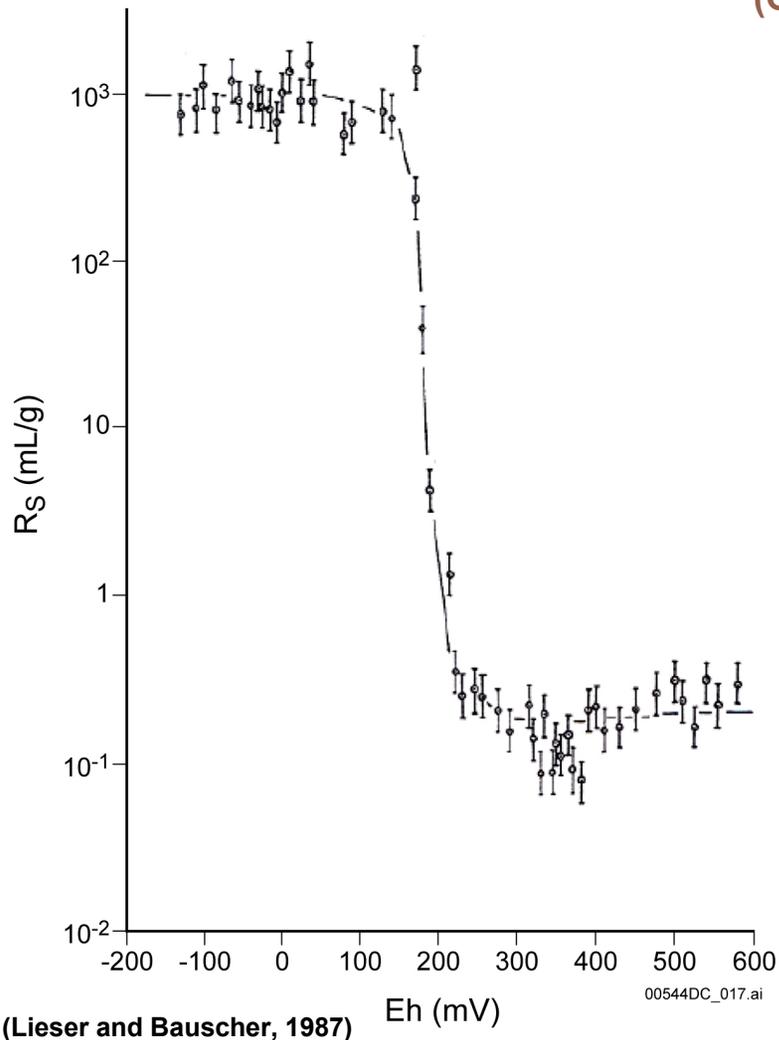


- **Blue indicates oxidizing conditions**
 - *In situ* dissolved oxygen > 1.0 mg/L
 - Iron concentrations > 0.1 mg/L
 - Generally these correspond to Eh > 200 mV
- **Red indicates reducing conditions**
- **Brown indicates indeterminate or not measured conditions**



Examples of Conservatism – Saturated Zone Transport

(Continued)



- **Technetium sorption coefficient (R_s) is increased by about a factor of 10,000 in reducing conditions**



Examples of Conservatism

– Saturated Zone Transport

(Continued)

- **Significant retardation in the saturated zone would occur if the conditions along the likely flow paths were reducing**
- **Uncertainty exists in the location and extent of reducing conditions**
- **Even if these conditions were determined to exist along likely present-day flow paths, the effects of climate change may change the conditions and flow paths such that desorption or redissolution processes may have to be considered**
- **Reasonable caution precluded including this retardation process in the saturated zone transport model**



Summary

- **The primary purpose of performance assessment is to demonstrate post-closure regulatory compliance; system understanding is addressed through subsystem and process-level sensitivity studies**
- **DOE will provide a demonstration of post-closure performance that does not underestimate dose**
- **Accordingly, DOE's assessments of post-closure performance are consistent with the 'cautious, but reasonable' approach articulated by the NAS, EPA and NRC**
- **Relevant observations related to processes should be reasonably explained by the models**
 - **The effects of conservatism are evaluated at the process, subsystem and total system levels, using sensitivity analyses**



Summary

(Continued)

- **Some external comments have indicated a desire to parallel conservative compliance assessments with a “realistic” non-conservative assessment to allow evaluating the “safety margin”**
 - **DOE has evaluated aspects of safety margin with a range of sensitivity analyses at process and subsystem levels**
 - **DOE has considered approaches for developing less-conservative assessments in certain areas**
 - ◆ **Identifying less conservative representations may require additional data or modeling complexity**
 - ◆ **Importance analyses are to be used to guide the need for such efforts**
- **However, it should be kept in mind that, as the NRC has written in its statement of considerations accompanying 10 CFR 63:**
 - **... “the performance assessment evaluates “potential” doses, not “actual” doses. For example, [the specification of the reasonably maximally exposed individual] ... is considered appropriately conservative for evaluating performance but most likely is not an “accurate” prediction of what will happen during the next 10,000 years”. (66 FR 55748)**



Summary

(Continued)

- **The role of conservatism in conducting performance assessments to be used in regulatory decision-making is acknowledged by regulators**
 - **DOE continues to use appropriate conservatisms to reasonably enhance the confidence in the technical basis for the post-closure performance assessment**
- **Given the complexity of these assessments, there is a need to carefully evaluate the conservatisms to ensure no unintended optimisms (including potential risk dilution) result**
 - **DOE continues to evaluate the range of conservatisms to ensure no unintended risk dilution has occurred**



Summary

(Continued)

- **Based on recent analyses and data, some of DOE's models have been modified to remove selected conservatisms**
- **The goal is analyses that rely on data that can be defended, and that allow us to have confidence in the performance assessment at this point in time**
- **DOE's Science and Technology Program continues to develop data to evaluate and potentially reduce conservatisms in post-closure models**
 - **This information will be evaluated and may be included in future revisions of models**
- **It is expected that selected reductions in performance-assessment conservatism may be made in future years**
 - **Planning of performance assessment work for FY 06 and beyond is in progress**

