Repository Safety Strategy
Unsaturated Zone Model Validation

Presentation to:
Nuclear Waste Technical Review Board (NWTRB)

Presentation by:
Bo Bodvarsson,
UZ PMR Lead
M&O/LBNL

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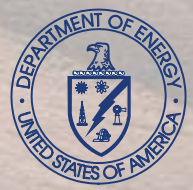


U.S. Department of Energy
Office of Civilian Radioactive Waste Management

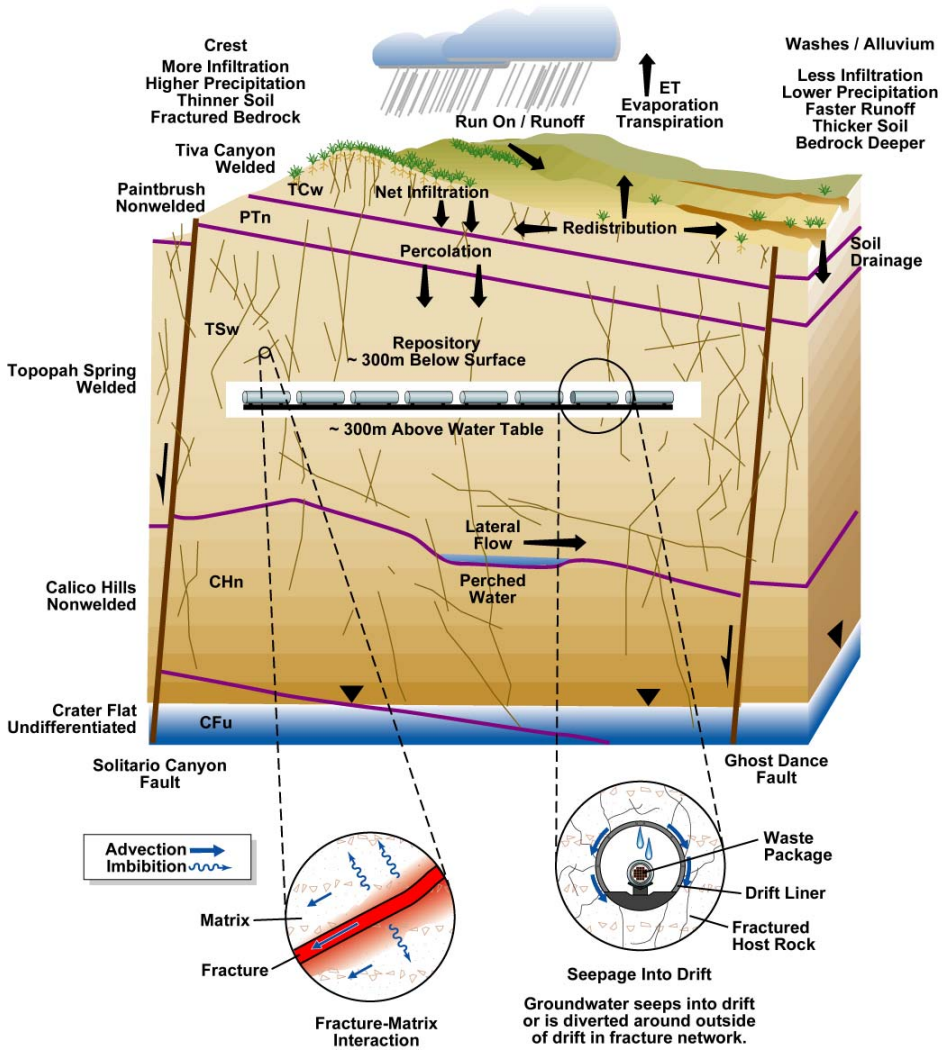
Yucca Mountain Project

Outline

- **UZ Flow and Transport model**
  - **Relation to Principal Factors/Other Factors**
  - **Relation to UZ PMR**
- **Development of the UZ Model**
- **Calibration of the UZ Model**
- **Use of the UZ Model**
- **Uncertainties of the UZ Model**
- **Validation of the UZ Model**

Unsaturated Flow and Transport - Key Processes

- Infiltration
- Fracture/matrix interaction
- Seepage into drifts
- Perched water effects
- Sorption in the Calico Hills



UZ PMR

Major Models and Repository Safety Strategy Factors

Principal Factors

Seepage into drifts
UZ sorption and matrix diffusion

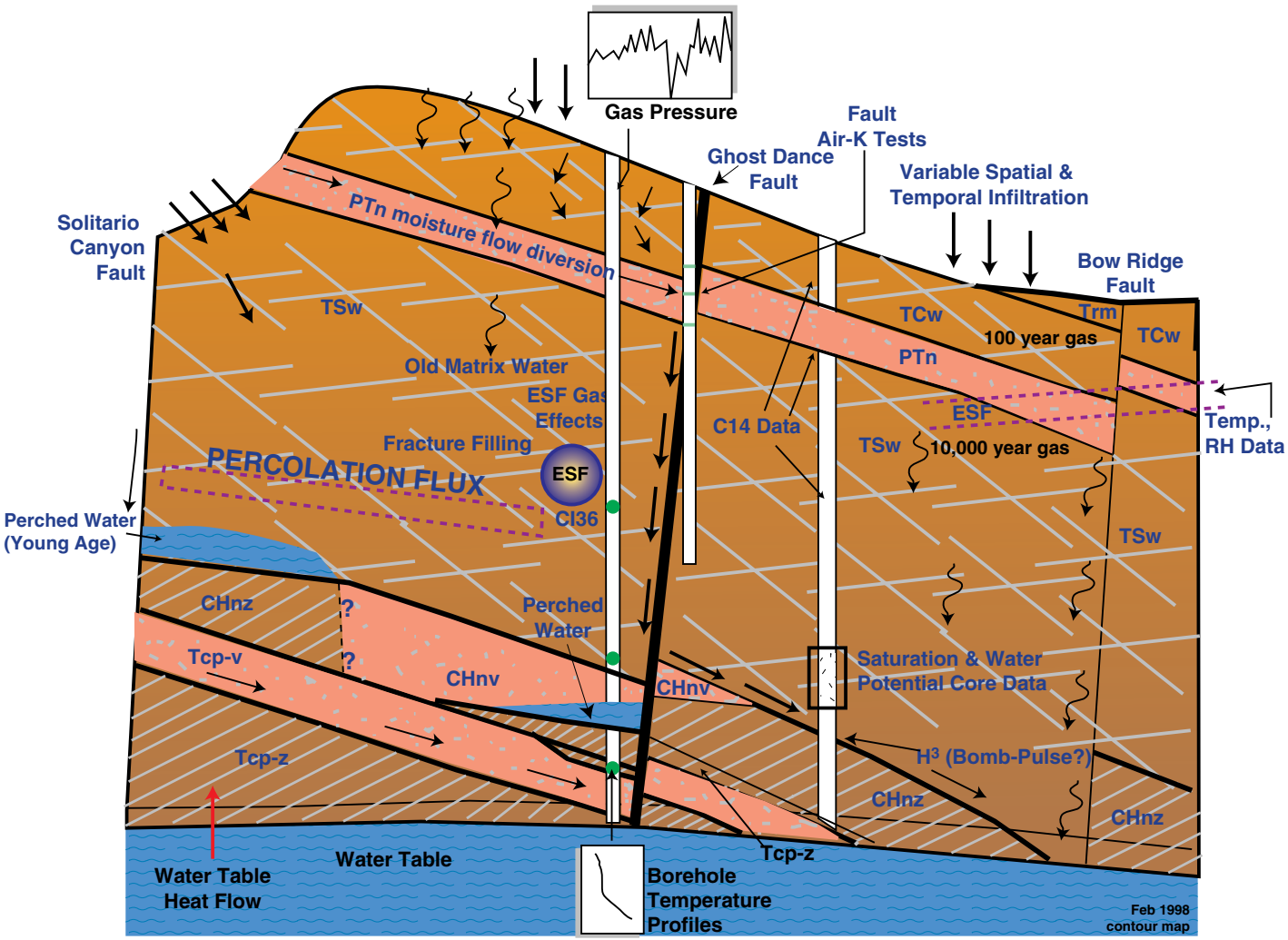
Other Factors

- **Climate**
- **Infiltration**
- **UZ Flow above the repository**
- **Coupled processes**
  - **effects on UZ flow**
- **UZ advective pathways**
- **UZ colloids facilitated transport**
- **Coupled Processes**
  - **effects on UZ transport**

UZ Flow and Transport PMR

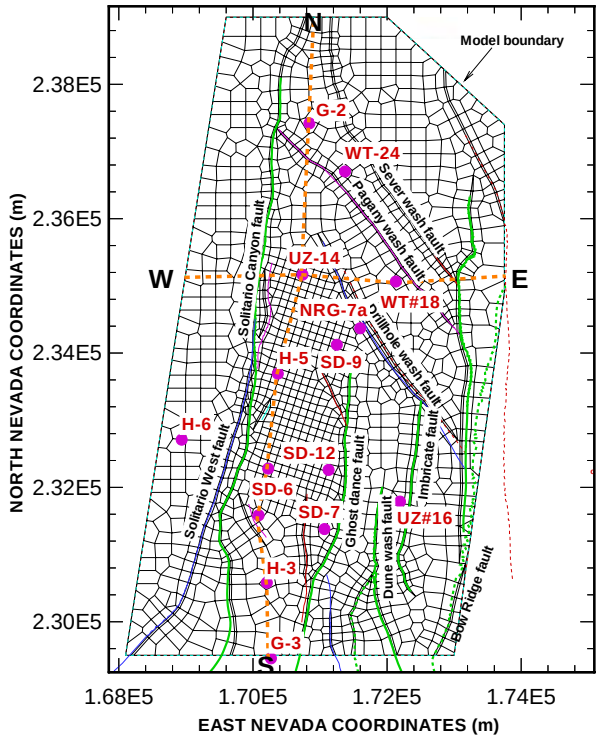
- Properties Model
- Flow and Transport Model
- Seepage Model
- THC model

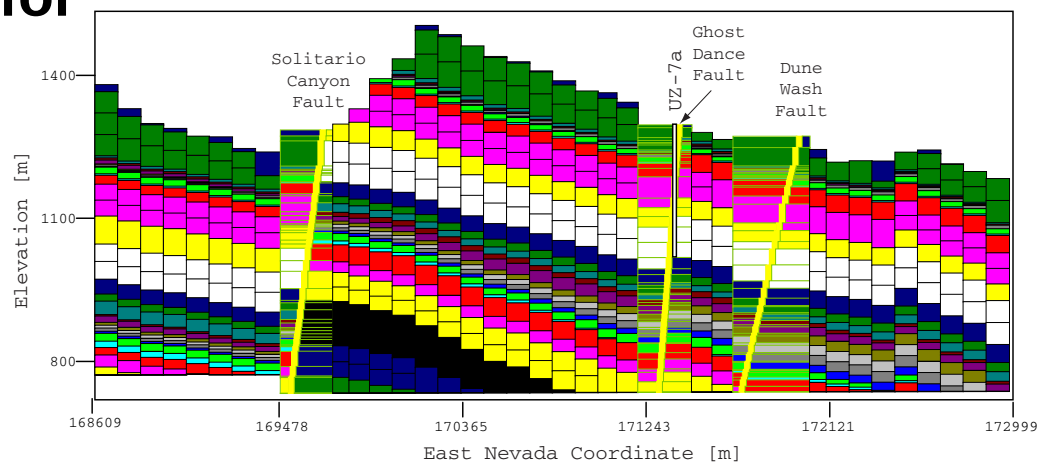
Yucca Mountain Data from the Unsaturated Zone



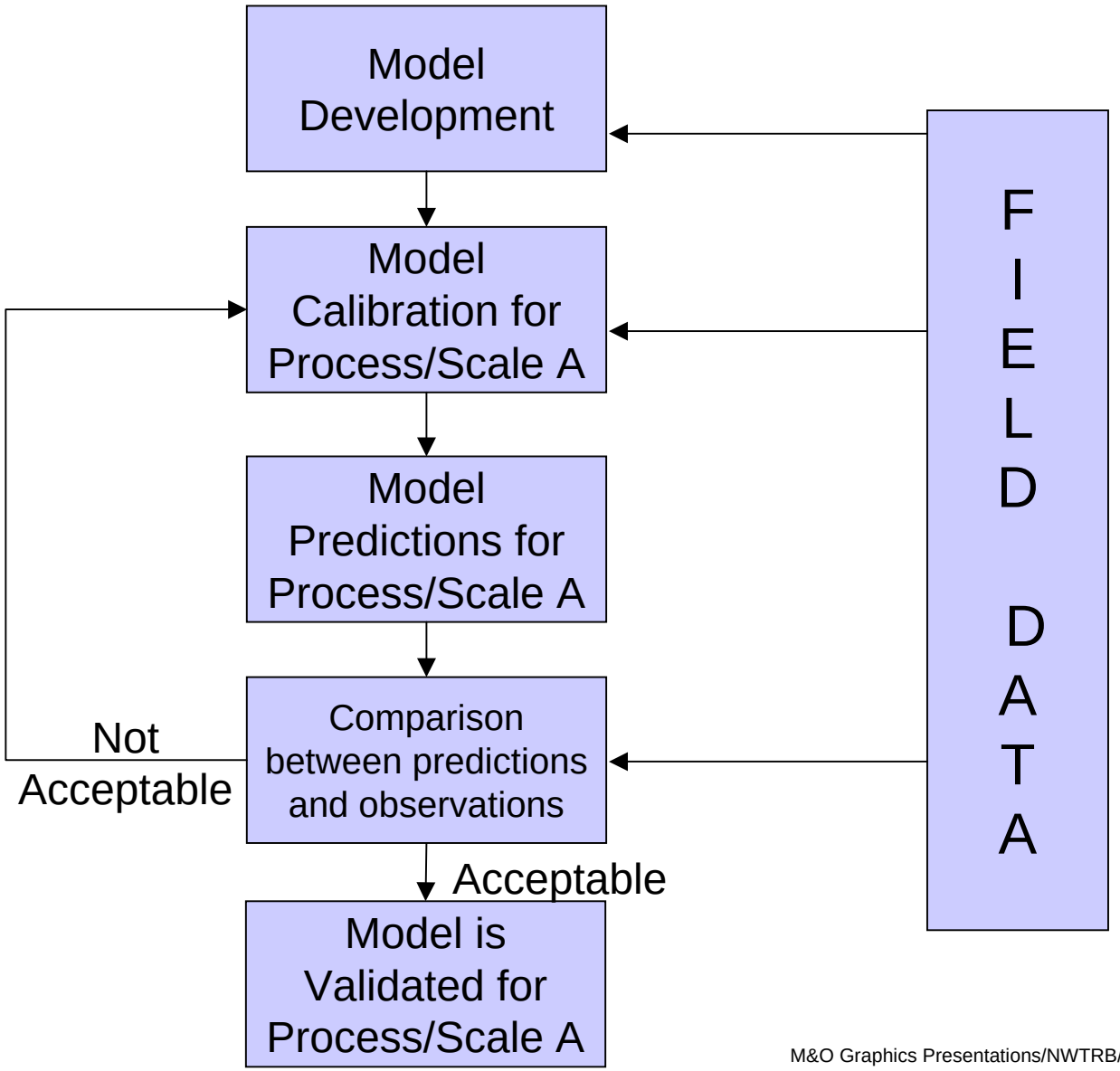
Why is the UZ Flow and Transport Model Needed?

- **To integrate all of the UZ data into a computational framework**
- **To quantify water, gas, tracer/radionuclides and heat transport in the UZ**
- **To provide calibrated UZ flow and transport model to PA for TSPA evaluations**





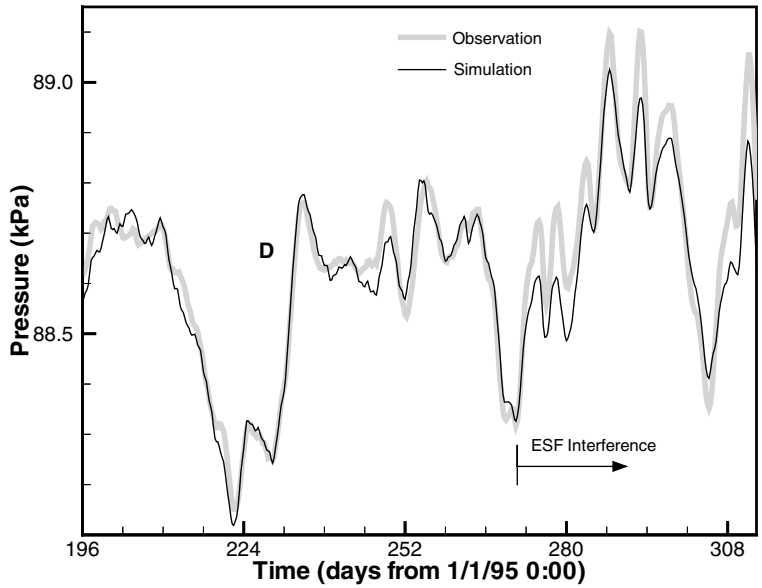
Generic Logic Diagram for Model Calibration/Validation

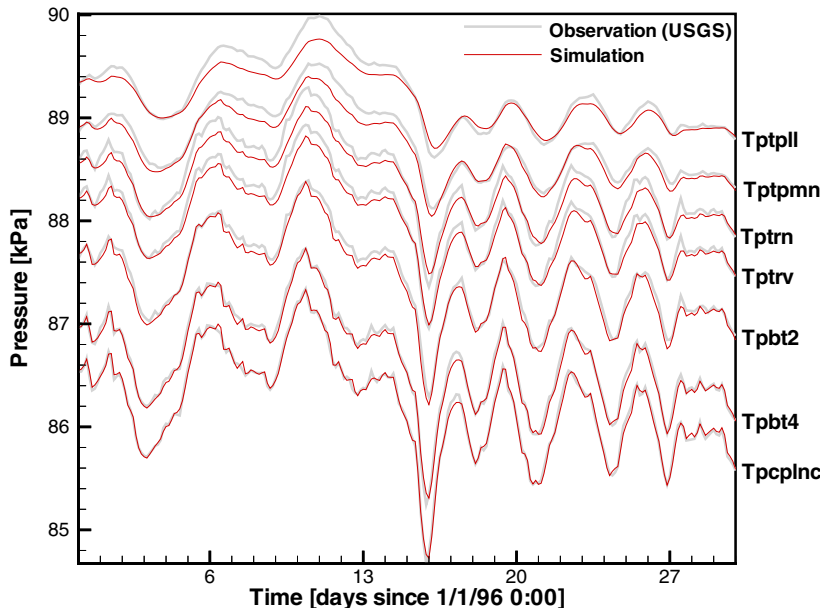


UZ Model Calibrations

Pneumatic Data (Boreholes NRG-7a and UZ-7a)

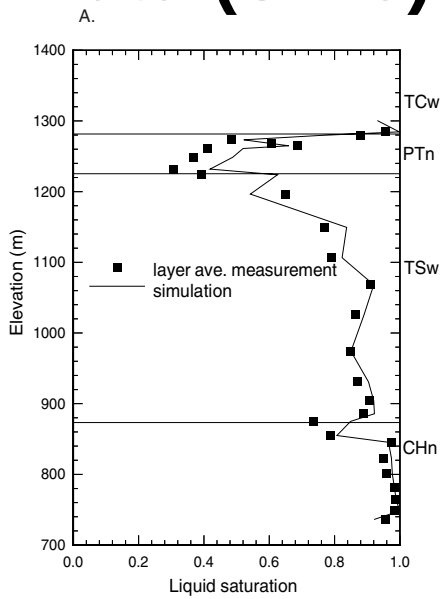
- **Pneumatic data from instrumented boreholes are available from 6 boreholes**
- **The pneumatic data are used to estimate large scale fracture and fault diffusivities**
- **Assuming fracture and fault porosities, the model inversions yield fracture and fault permeabilities.**

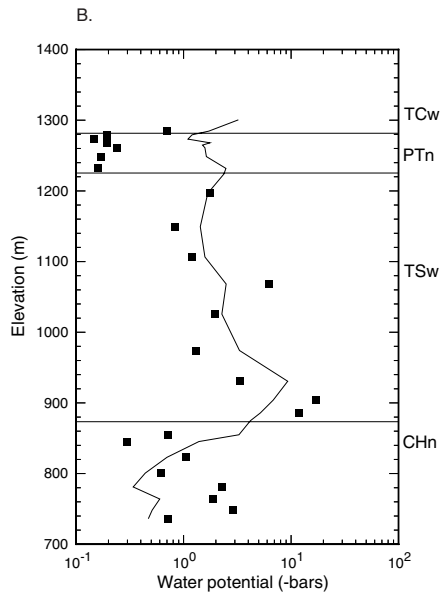




UZ Model Calibrations
Saturation and Water Potential Data (SD-9)

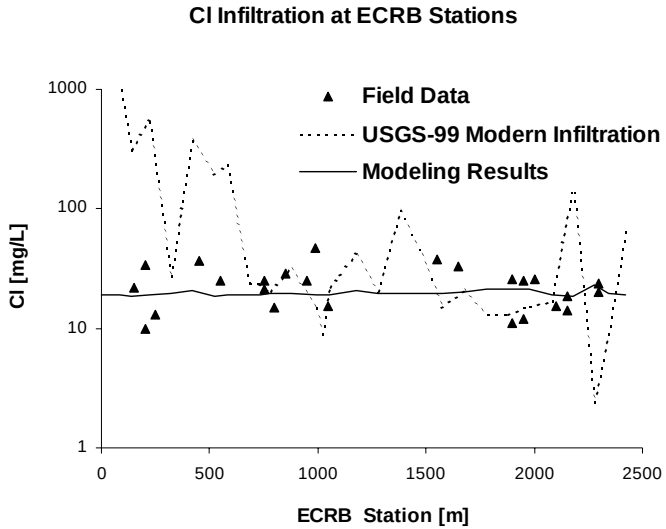
- **Simultaneous calibration against data from 11 boreholes**
- **The saturation calibration helps determine the fracture/matrix interaction factor**
- **The moisture tension calibration help determine the fracture saturations**

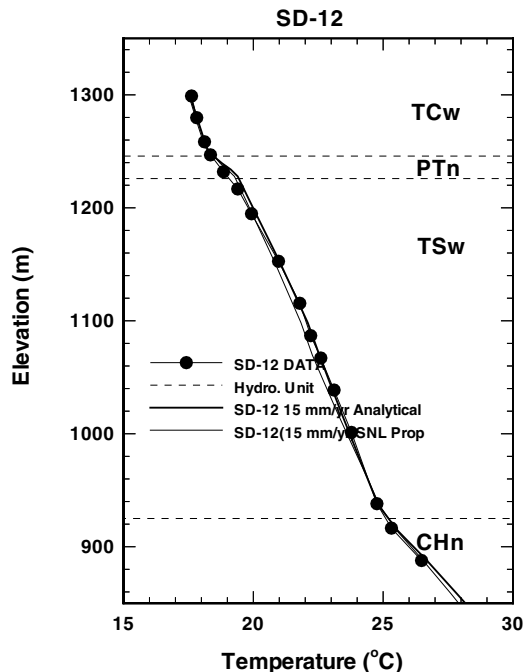




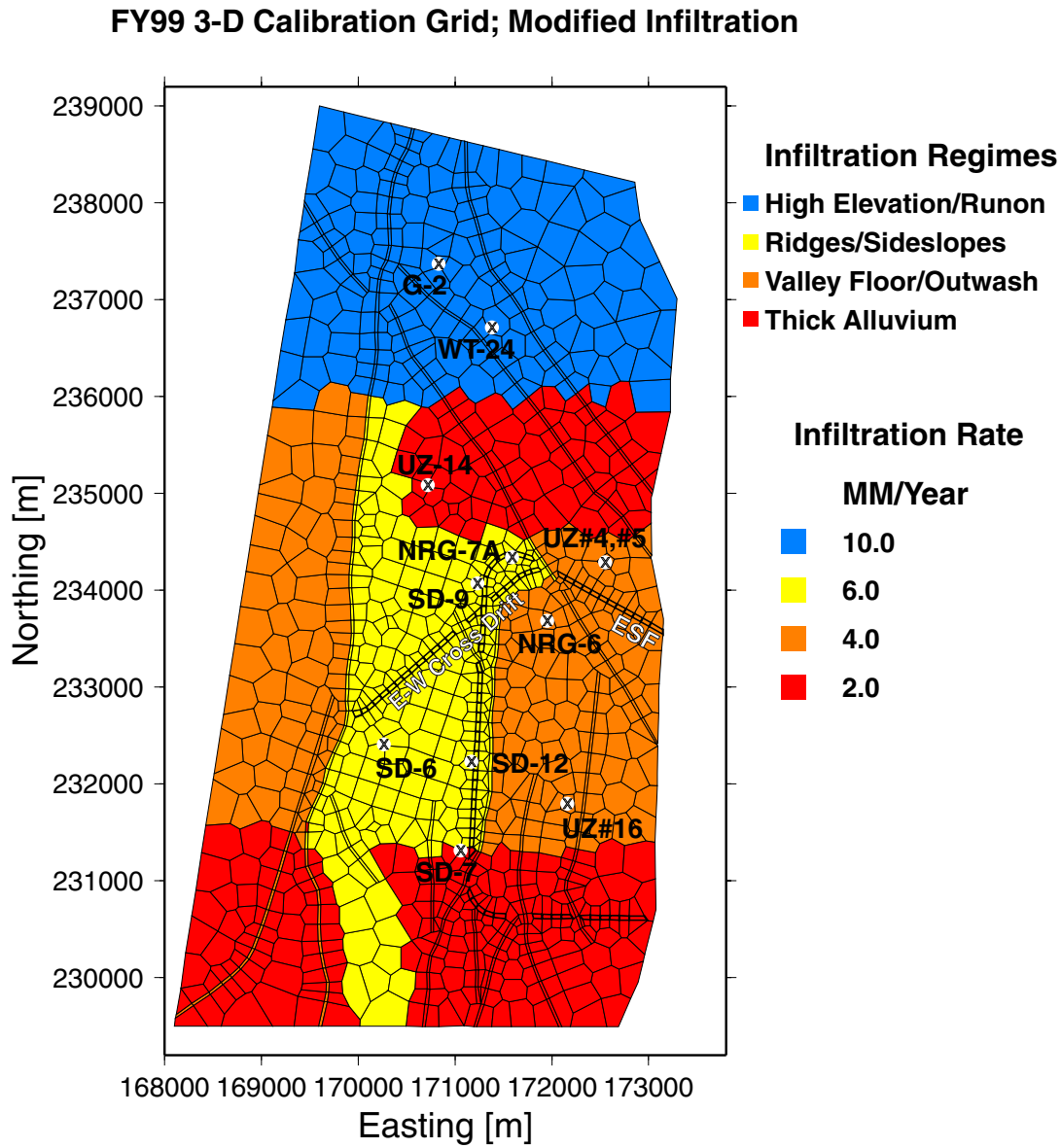
UZ Model Calibrations
Chloride and Temperature Calibration

- **Total chloride and temperature data are available for many boreholes, the ESF, and the ECRB**
- **Calibration with all of the chloride data results in a modified infiltration map**
- **In general, the modified infiltration is lower and more uniform than the infiltration maps based on surface based studies**
- **Temperature data also provide important constraints on infiltration rates**



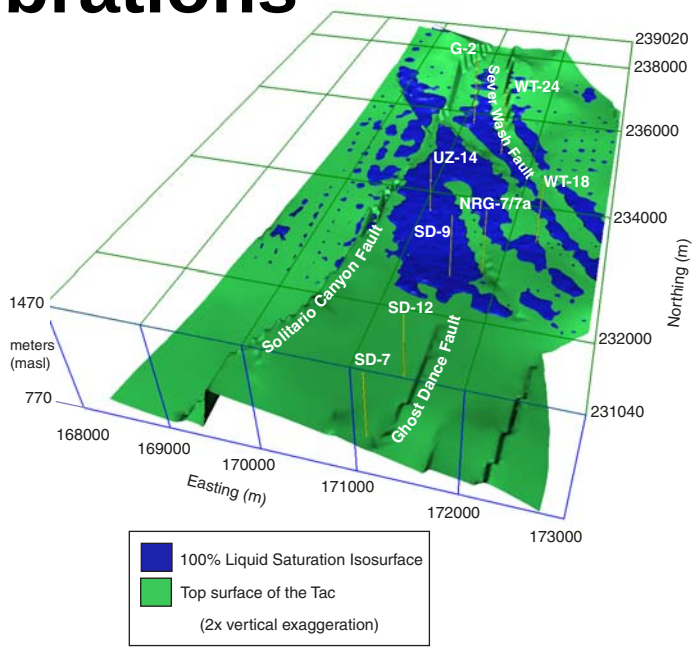


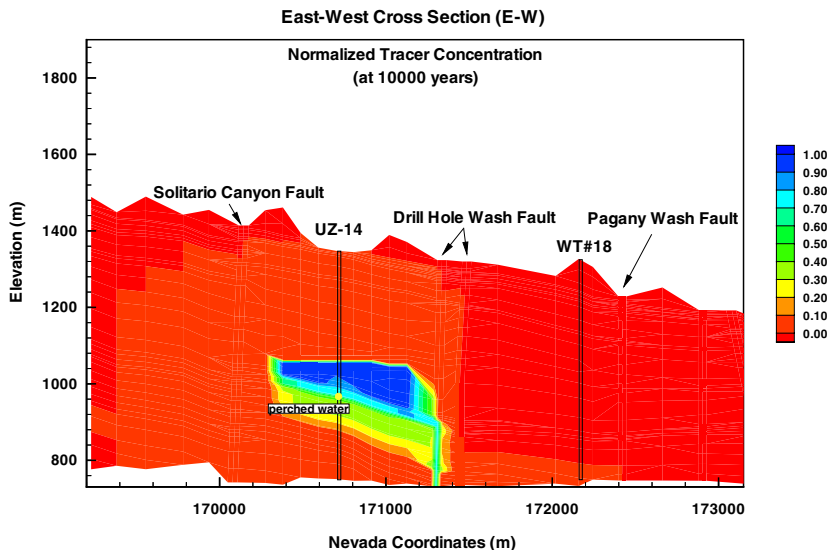
Infiltration Map Based on Chloride Data



UZ Model Calibrations
Perched Water Calibrations

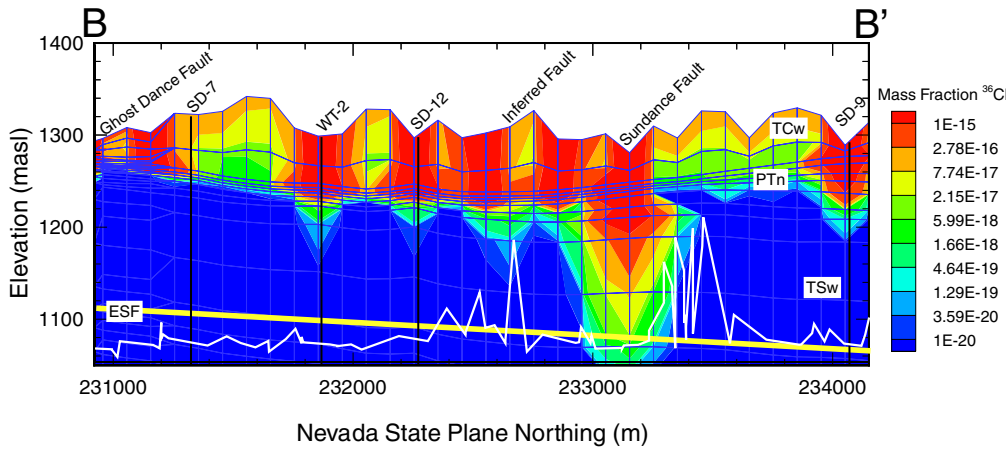
- At least two perched water bodies are found at Yucca Mountain
- Calibration to ages, size, and geochemistry of perched water bodies helps constrain infiltration rates and fracture permeabilities
- The conceptual model for the perched water bodies have significant effects on dilution, matrix diffusion, and sorption in the UZ

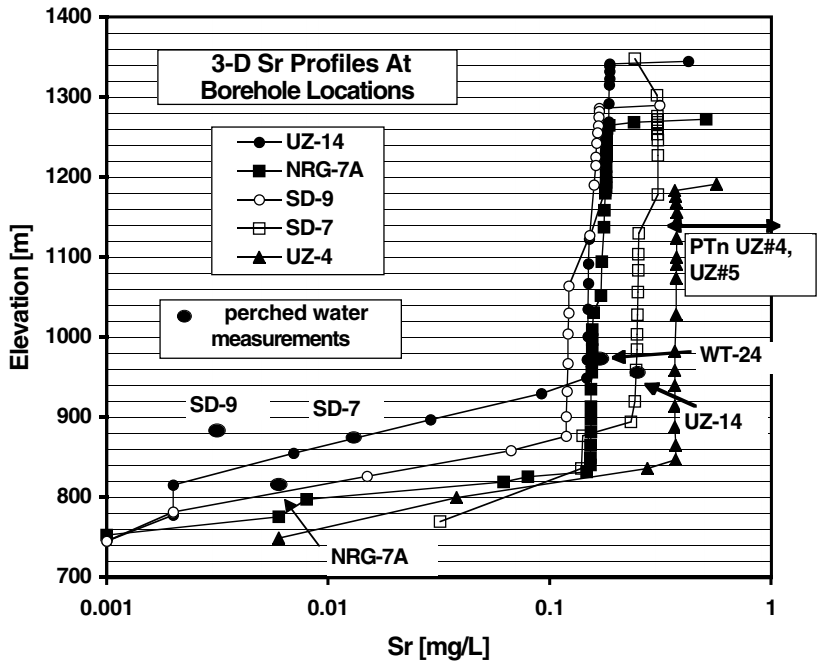




UZ Model Calibration
Cl-36 and Strontium

- **Cl-36 and Strontium data are available from many boreholes, the ESF, and the ECRB**
- **Bombpulse Cl-36 data indicate the presence of fast paths, currently believed to constitute less than 1 % of the flow**
- **Non-bombpulse Cl-36 data can be used to estimate infiltration rates**
- **Calibration with Strontium data helps constrain infiltration rates and identify the presence of zeolitic rocks**





Key UZ Model Uncertainties at Site Recommendation

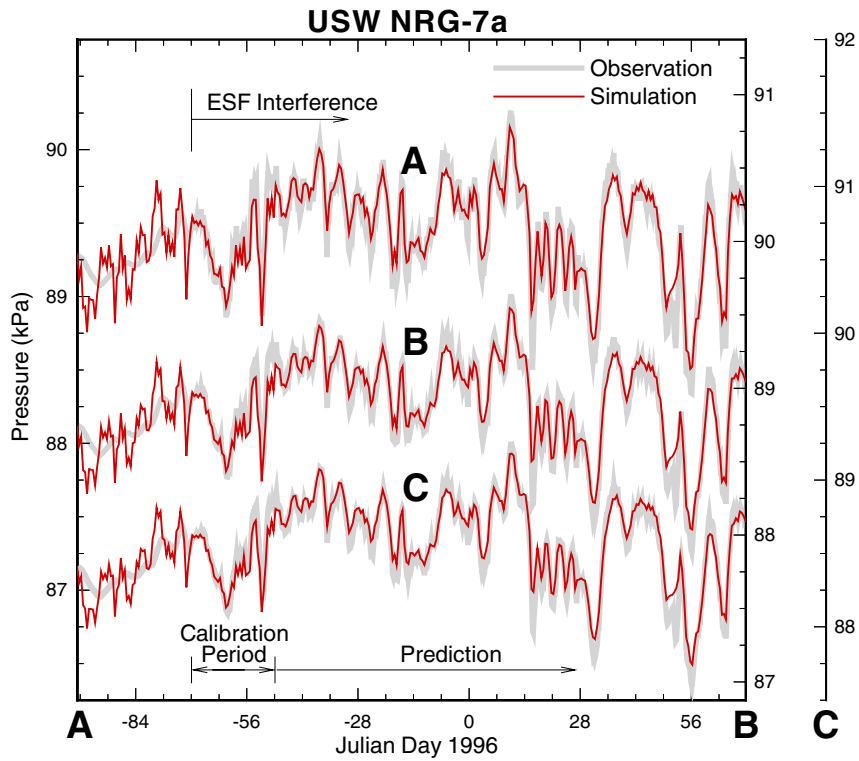
Uncertainties	Plans to address them	Expected Uncertainty	
Infiltration/future climate	Use geochemical and temperature data to constrain past and current infiltration	M	SENSITIVITY STUDIES
Water properties from pneumatic tests	Use pneumatic parameters to match flow and transport data from seepage data from niches, Alcove 1, and Drift to Drift tests	L	
Fracture and fault zone properties/variability	Do systematic testing of hydrological properties in EW cross drift. Perform liquid and pneumatic tests in Solitario Canyon fault zone	M	
Fracture/matrix interaction	Use geochmical data and modeling as well as data for Alcove 1, the Drift to Drift test and Busted Butte to validate active fracture model	H	
Flow patterns from repository to SZ	Evaluate alternative conceptual model for perched water bodies and their impact on transport	H	
Matrix diffusion	Use active fracture model concept, geochemical data and results from Alcove 1 and Drift to Drift test to evaluate matrix diffusion	H	
Fracture and matrix sorption	Use Busted Butte data to validate laboratory measurements of sorption in the vitric Calico Hills	L	
Colloidal transport	Use laboratory measurments and model studies to evaluate importance of colloids. Use natural analogue data and UZ Model to explain fast transport at INEEL and NTS	M	
Thermal effects on UZ flow and transport	Perform modelling sensitivity studies to evaluate importance. Use geothermal systems as analogues to bound THM and THC processes	M	
Detailed flow mechanisms	Develop smaller scale detailed fracture models to evaluate size and spacing distributions of flowing fractures (weeps)	H	

Validation Examples

- **Borehole data**
- **E-W Cross Drift data**
- **Alcove 1 data**
- **Busted Butte data**
- **Drift to Drift test data**
- **Natural Analogue data**

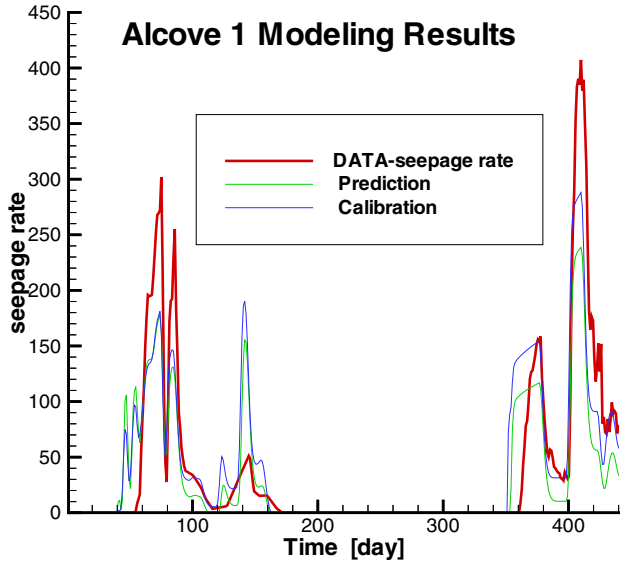
UZ Model Validation
Pneumatic Data: Gas Diffusion/Fracture Permeability

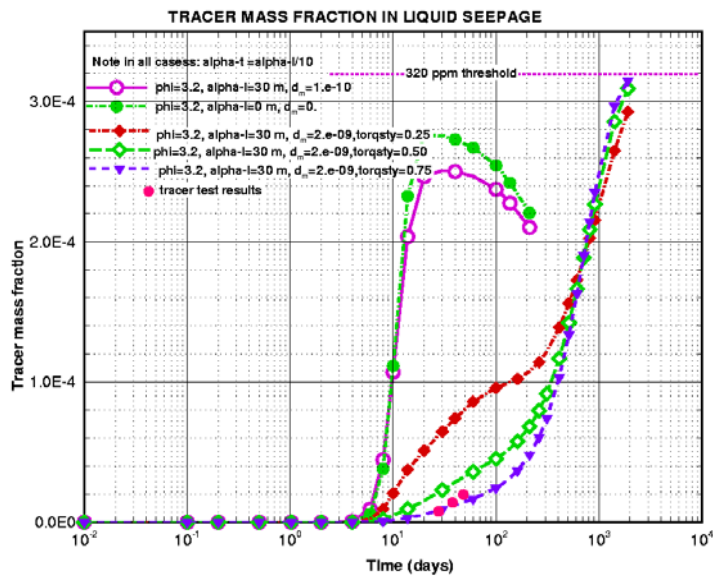
- **Blind predictions of gas pressure variations were made in instrumented boreholes using variations in atmospheric pressure**
- **Excellent matches were obtained between predictions and subsequent observations for all boreholes**



UZ Model Validation
Alcove 1 Test: Seepage and Matrix Diffusion

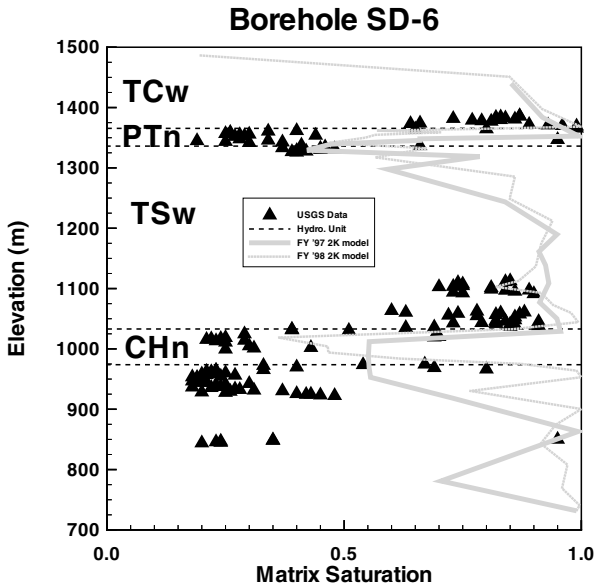
- The Alcove 1 flow and transport test consisted of infiltration above Alcove 1 and measurements of seepage and tracer concentration in the Alcove
- The seepage data allow for calibration with the seepage model. Calibration of pulse 1 allowed for predictions for pulse II
- The tracer test data allowed for predictions of fracture/matrix interaction and matrix diffusion
- The model results indicate that 50% of the fractures flowed and that matrix diffusion was very effective in retarding the tracer

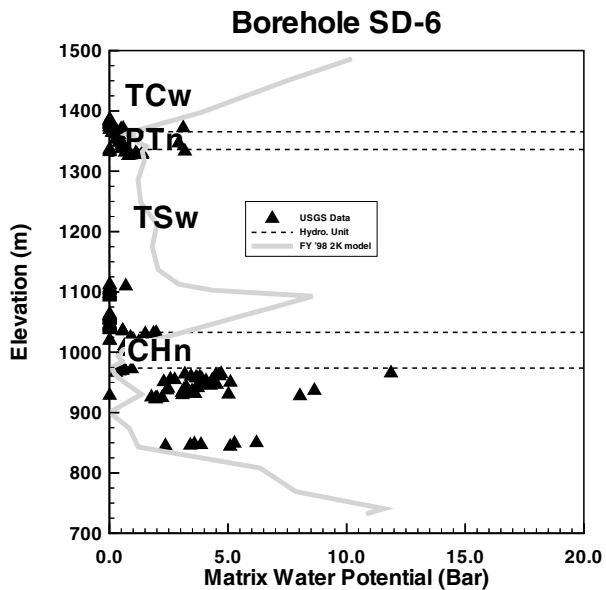




UZ Model Validation
Borehole SD-6: Matrix and Fracture Saturations

- **Predictions of saturations, moisture tension, temperature and gas pressure have been made for recently drilled boreholes**
- **Matrix saturation is generally well predicted for all hydrogeologic units**
- **Moisture tension predictions are less in agreement with observed data, partly due to measurement errors**

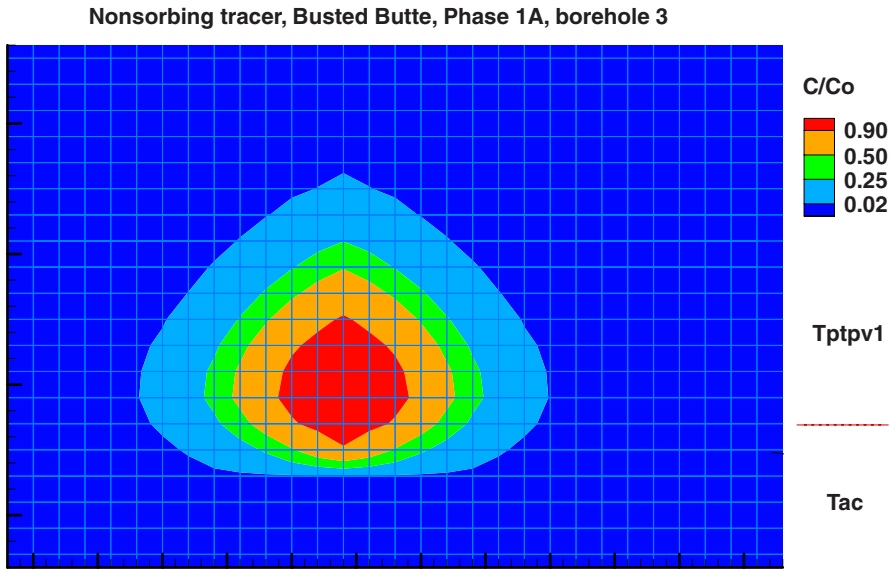


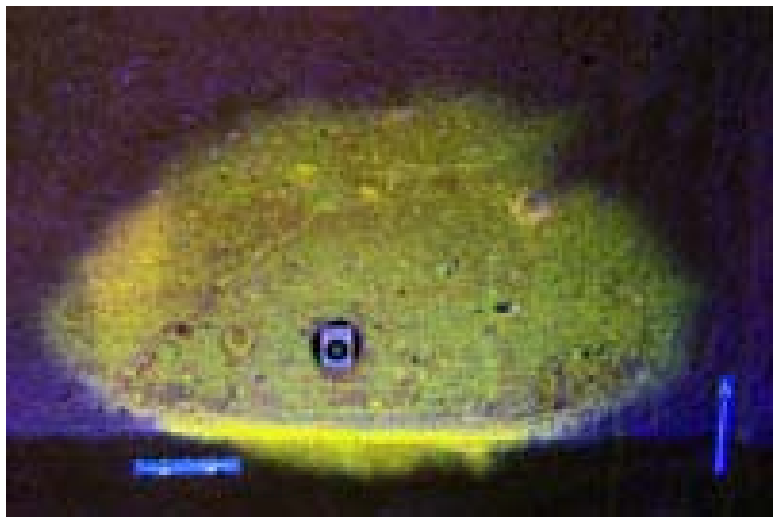


UZ Model Validation

Busted Butte: Capillary Driven Flow in Vitric Calico Hills

- **Transport tests are being conducted in the unwelded Calico Hills at Busted Butte**
- **Tracer data from phase 1A agree well with predictions made by the UZ model using both FY97 and FY99 property sets**

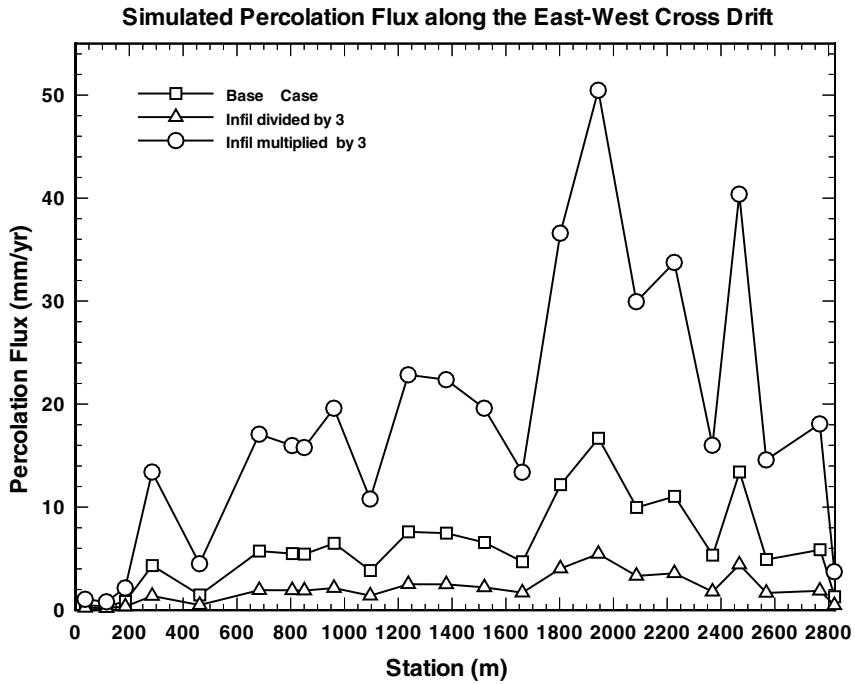


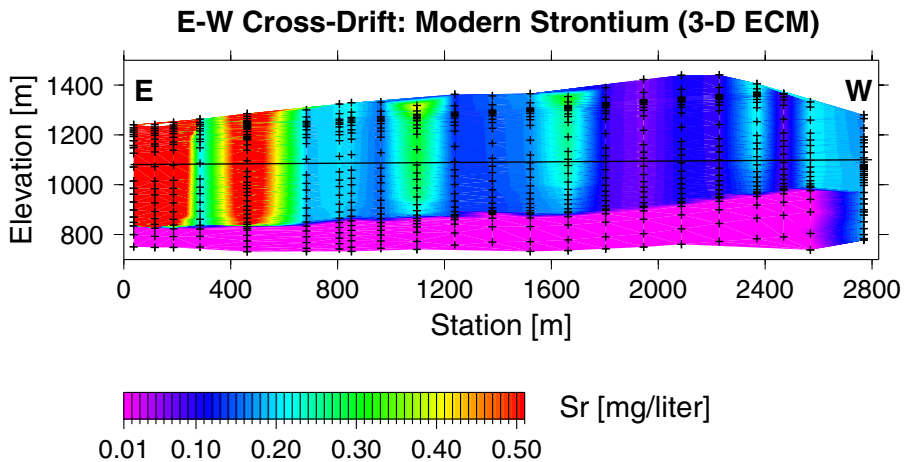


UZ Model Validation

E-W Cross Drift: Percolation Flux and Strontium Calculations

- Predictions were made of percolation flux and Strontium concentrations in the E-W cross drift
- The percolation flux predictions were based on current estimates of infiltration. Total Chloride data from the cross drift suggest that the infiltration rates used are generally too high
- Strontium concentration data from the E-W cross drift are not yet available





External Peer Review of the UZ Model

- **UZ Expert Elicitation 1997**
- **UZ Transport Peer Review 1999**
- **TSPA Peer Review 1997-1999**
- **NRC/IRSR Review Comments**
- **NWTRB/ACNW/etc.**

Summary

- **The UZ model is reasonably well calibrated against all available data**
- **Uncertainties vary significantly in the different components of the model**
- **Current field activities should increase confidence and reduce uncertainties in the various components of the UZ model**

Summary

- **Model calibrations and validation activities yield confidence in model predictions of some processes such as gas flow, bulk water flow and transport through the Calico Hills vitric**
- **Less data are available for calibration and validation of other important processes, such as matrix diffusion and transport through Calico Hills zeolitic**
- **The UZ model uncertainty will continue to decrease due to additional calibrations and validations using Yucca Mountain and natural analogue data**