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

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# Evaluation of Technical Impacts of Sandia National Laboratories Estimates of Infiltration on Unsaturated Zone Hydrology Simulation Results

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

Presented by:
**James Houseworth**
**Technical Staff Member,**
**Lawrence Berkeley National Laboratory**

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**Predecisional—Preliminary**

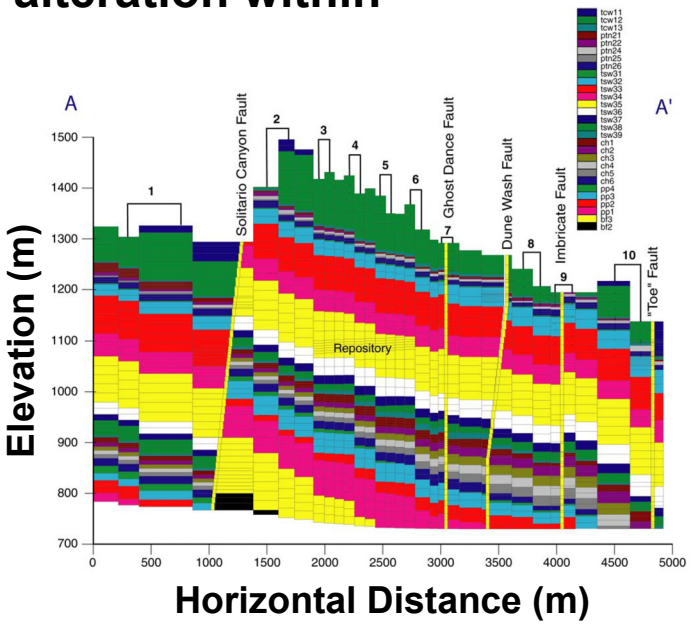
# Outline

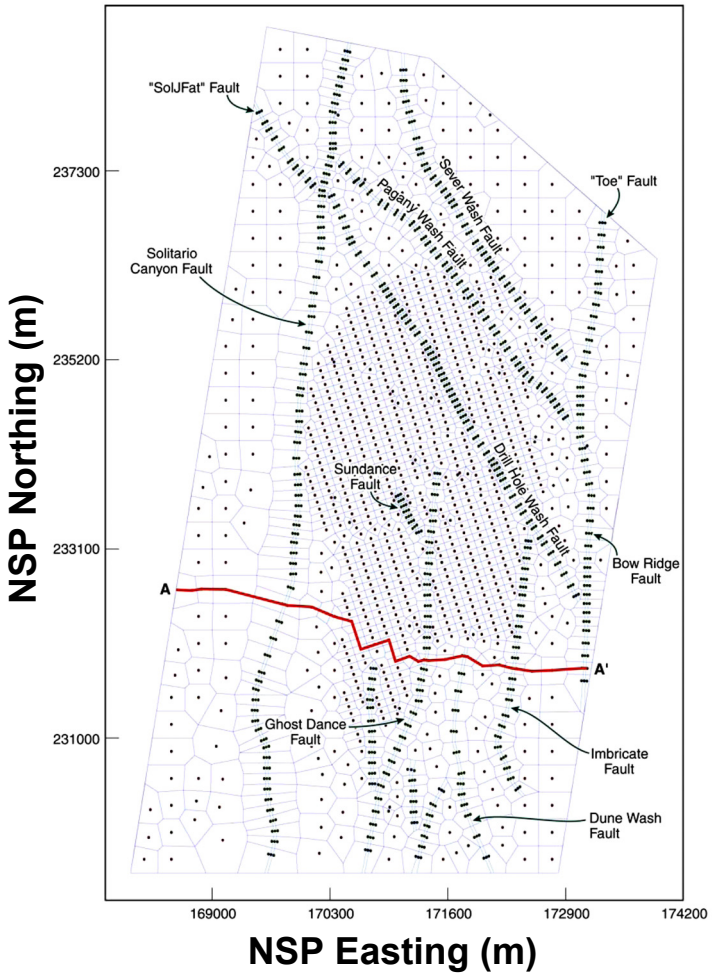
- Overview of unsaturated zone (UZ) flow model
- New infiltration model preliminary results for infiltration and precipitation given present-day climate
- UZ data and sensitivities to infiltration using old infiltration maps
- Evaluation of new, preliminary, infiltration maps for present-day climate
- Summary

# UZ Flow Model Overview
## Hydrogeologic Variability and Structure

### Features

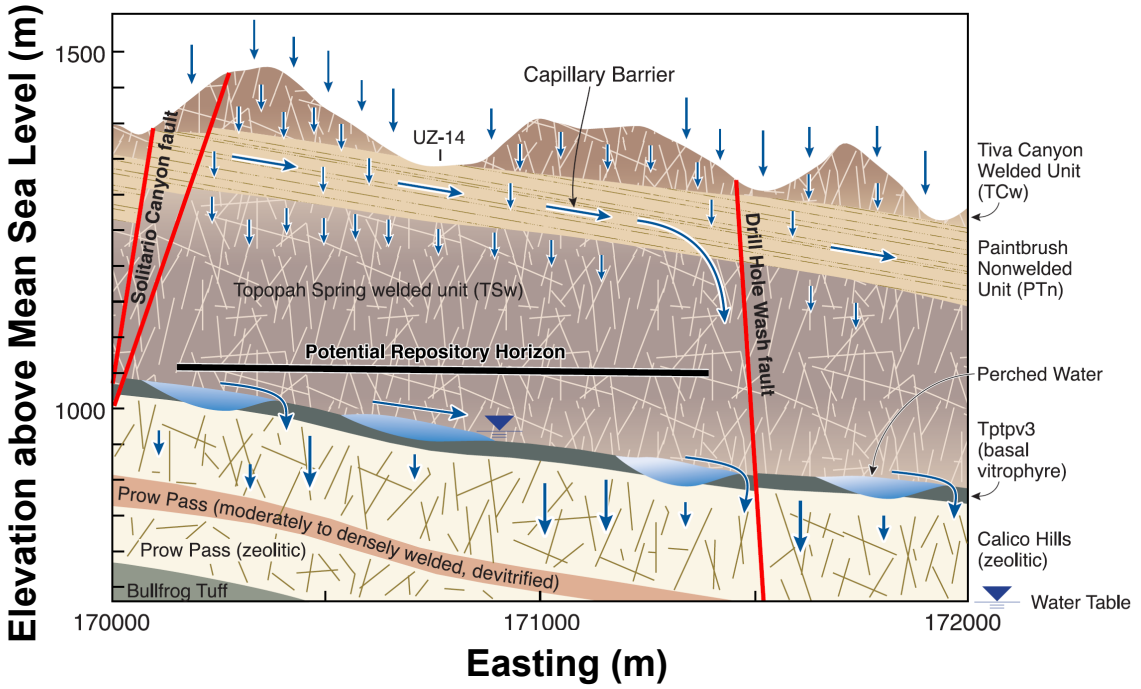
- **3-D mountain-scale model**
  - Major faults represented as discrete features
- **Stratigraphic variability**
  - 30 stratigraphic layers
- **Zeolitic alteration within layers**



# UZ Flow Model Overview
## Hydrologic Processes

- Steady-state flow
- Spatially variable infiltration
- Dual-permeability model
  - Fracture/matrix interactions
  - Small-scale flow focusing
- Lateral flow
  - Capillary and permeability barriers
- Flow in faults
- Perched water

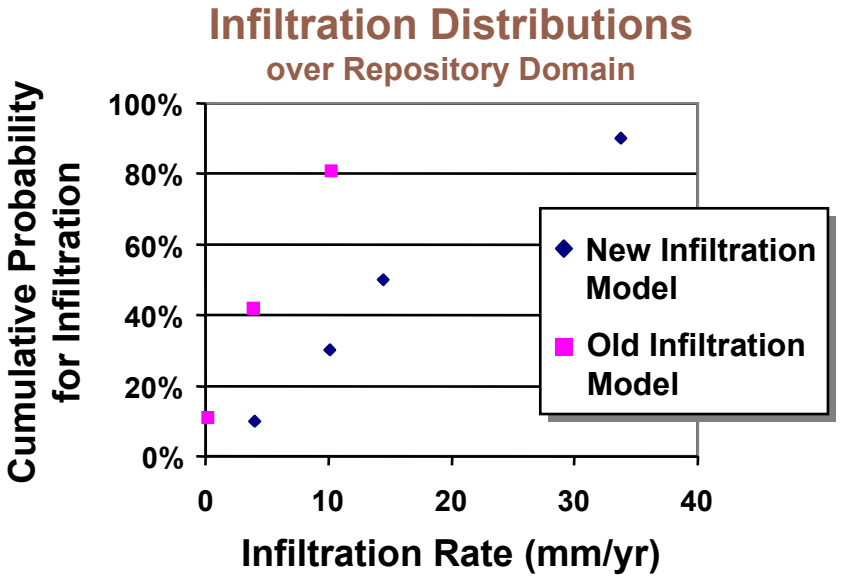


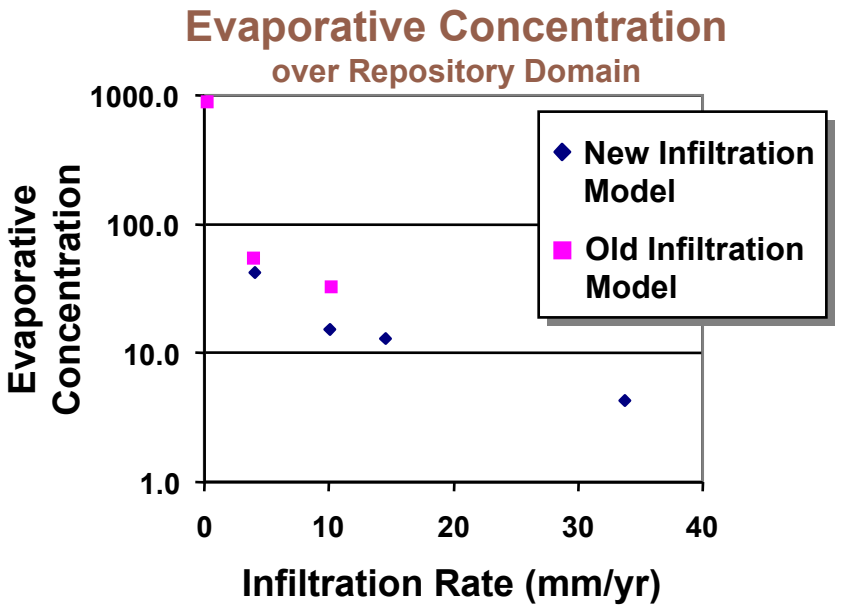

**Flow Distribution using Present-Day Middle, Old Infiltration Map**

| Repository Footprint | Fracture % | Matrix % | Fault % |
|---|---|---|---|
| TCw/PTn Interface | 98.92 | 0.01 | 1.07 |
| Repository | 98.24 | 0.56 | 1.20 |
| Water Table | 18.62 | 46.67 | 34.71 |

# Preliminary Changes in Infiltration and Precipitation

- Average infiltration rates increased roughly a factor of 3
- Evaporative concentration is the ratio of net water arrival (precipitation + runon − runoff) divided by the net infiltration; the average evaporative concentration is reduced by roughly a factor of 6
- Evaporative concentration times the surficial water chloride content gives the chloride content of the infiltrating water

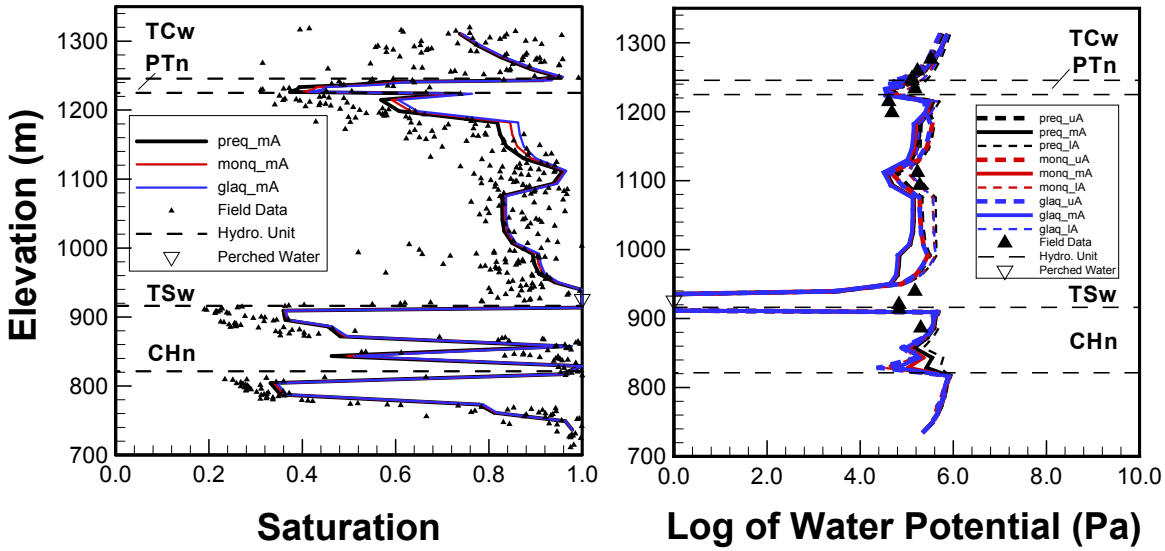


# UZ Data and Sensitivities to Infiltration
## Water Saturation and Water Potential Data

- **1-D calibrations**
  - Calibrations using data from 16 boreholes
  - Matrix permeability, fracture and matrix van Genuchten $\alpha$, and active fracture model parameter ($\gamma$)
- **3-D calibrations**
  - Lateral flow
  - Perched water
- **Low sensitivity to changes in percolation flux**

### 3-D Calibrations for SD-12



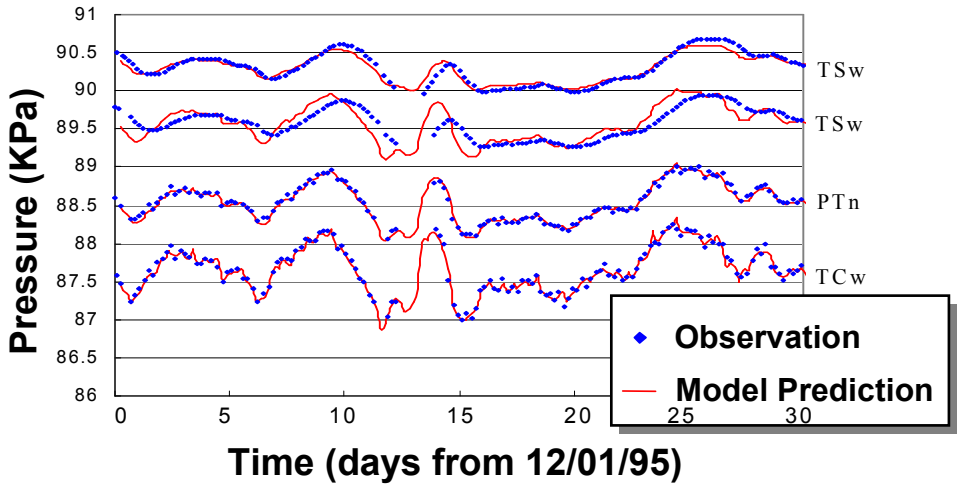

### Average Infiltration Rates from Old Infiltration Maps

| Repository Domain | Infiltration (mm/yr) |
|---|---|
| Present-Day Middle | 3.9 |
| Monsoon Middle | 11.1 |
| Glacial-Transition Middle | 17.6 |

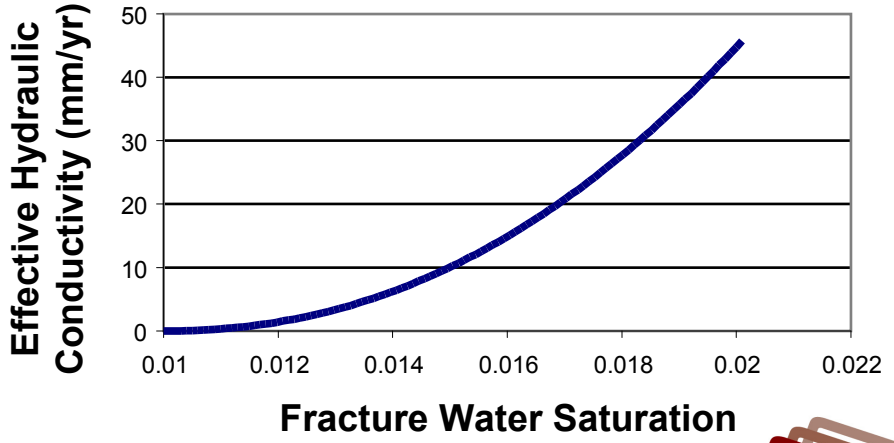
# UZ Data and Sensitivities to Infiltration
## Pneumatic Pressure Data

- **1-D and 3-D calibration of fracture permeability using barometric pressure fluctuations and the old present-day "middle" infiltration map**
- **Low sensitivity to changes in percolation flux over the range of interest (0 to 30 mm/yr); percent change in gas relative permeability less than 2%**

**3-D Calibration for SD-12**

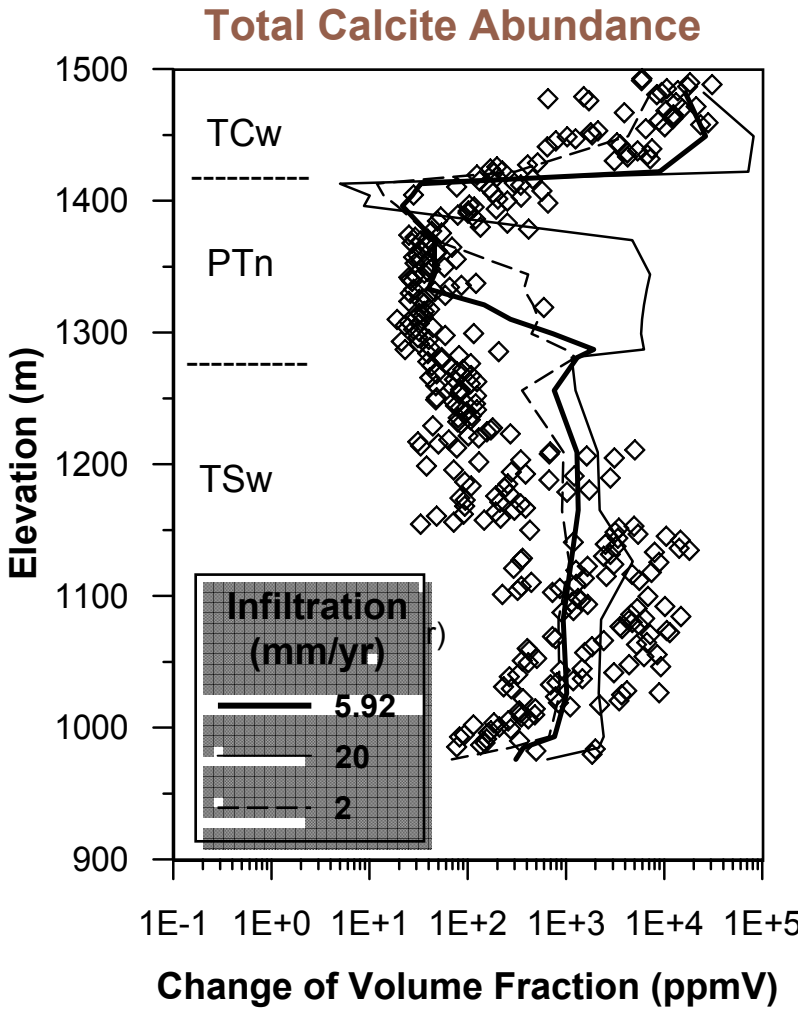



**Effective Fracture Conductivity – TSw35**



# UZ Data and Sensitivities to Infiltration
## Calcite Abundance Data

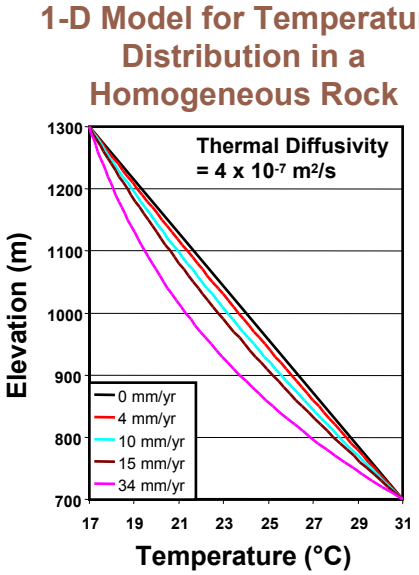
- **Total calcite abundance (ppmV or $10^{-6}$ volume fraction) in deep borehole WT-24**
- **1-D geochemical transport simulations**
- **Over a range of 2 to 20 mm/yr infiltration rates, the simulated abundances generally fall within the range of calcite observed**
- **Limited sensitivity to infiltration rate and poor resolution during the interglacial (present-day) time period**

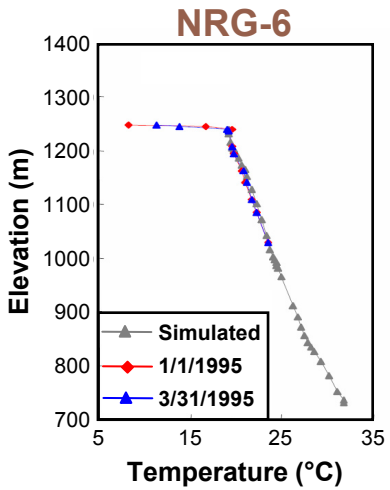


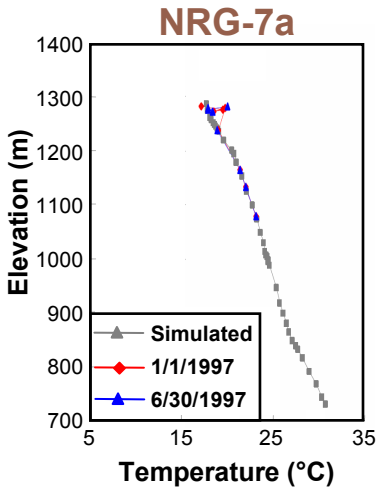
# UZ Data and Sensitivities to Infiltration
## Temperature Data

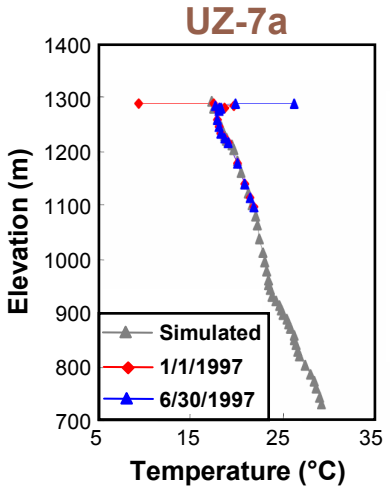
- **The 3-D UZ temperature model matches temperature profiles measured in several boreholes using the present-day "middle" old infiltration map (3.9 mm/yr) and calibrated surface temperatures**

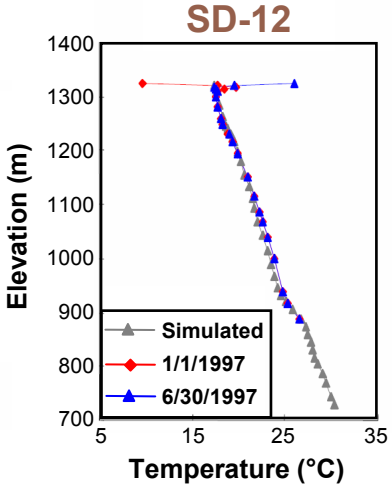
- **Temperature sensitivity to infiltration rate is reduced for low infiltration rates because thermal conduction dominates over advection**



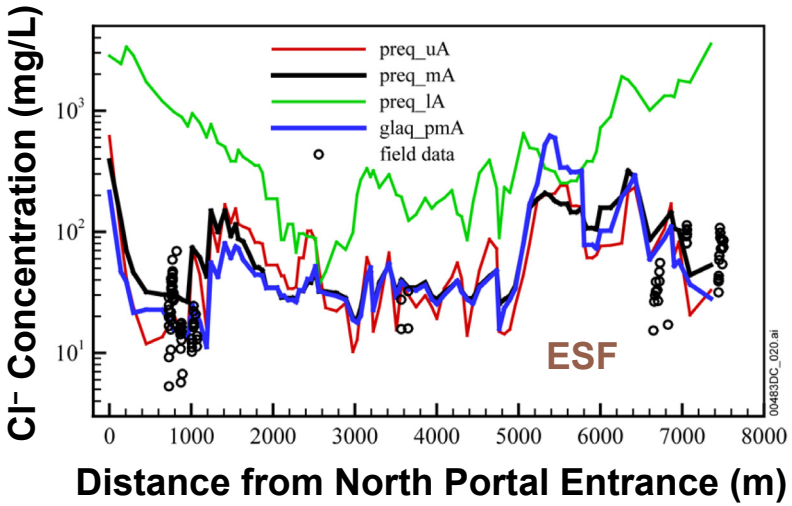



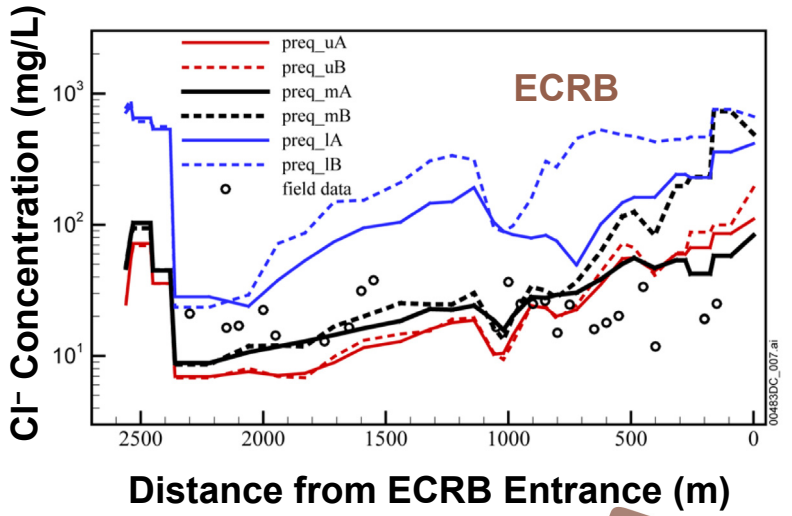
# UZ Data and Sensitivities to Infiltration
## Chloride Concentration Data

- **The 3-D UZ chloride model matches chloride observations in the Exploratory Studies Facility (ESF) and the Enhanced Characterization of the Repository Block (ECRB)**
- **Average chloride concentration is sensitive to the evaporative concentration**




### Average Infiltration Rates and Evaporative Concentration over Repository Domain for Old Infiltration Maps

| Scenario | Infiltration (mm/yr) | Evaporative Concentration |
|---|---|---|
| Present-Day Lower | 0.2 | 885 |
| Present-Day Middle | 3.9 | 55 |
| Present-Day Upper | 10.2 | 33 |
| Glacial-Transition Middle | 17.6 | 23 |



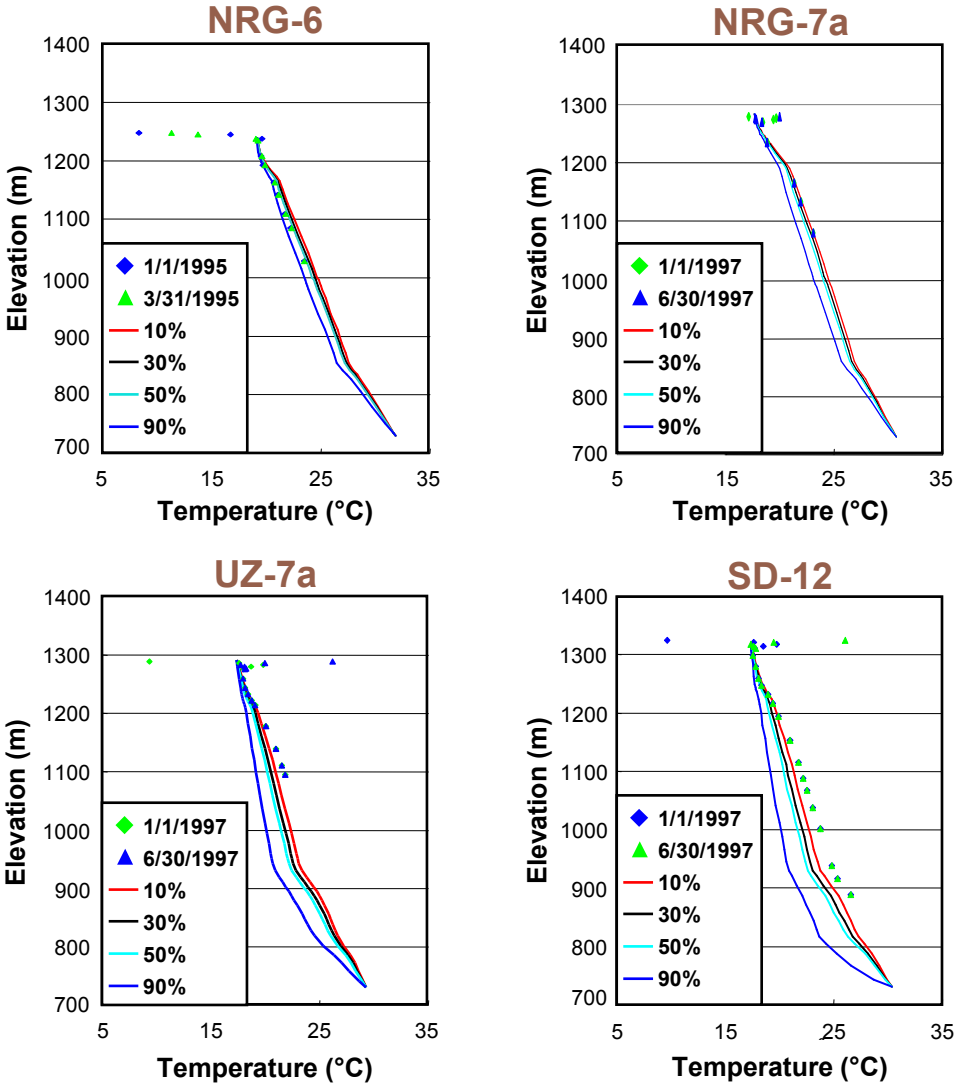
# Effects of New Infiltration Results

## Preliminary Temperature Predictions

- New infiltration rates for present-day climate have little effect for locations with low infiltration flux and/or small changes in infiltration flux
- At locations with sufficiently high infiltration flux, increases in infiltration show reductions in the predicted temperatures

**Preliminary Average Infiltration Rates over Repository Domain for New Infiltration Maps**

| Scenario | Infiltration (mm/yr) |
|---|---|
| pd10 | 4.0 |
| pd30 | 10.1 |
| pd50 | 14.5 |
| pd90 | 33.8 |



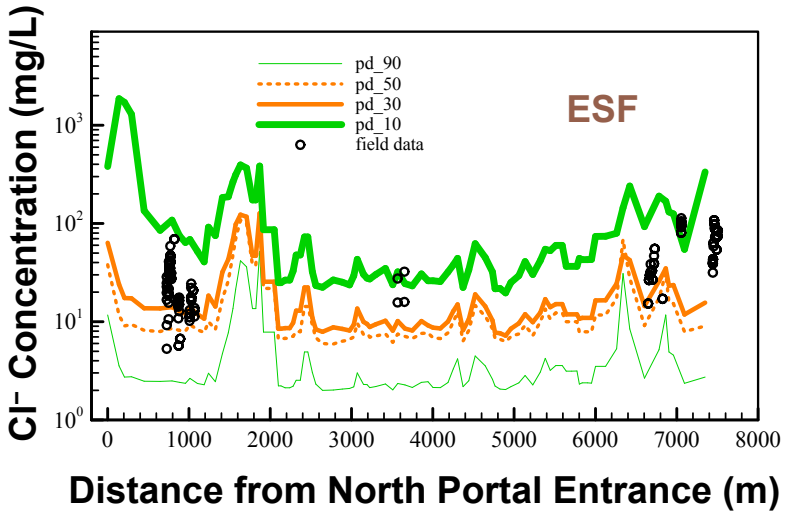
# Effects of New Infiltration Results

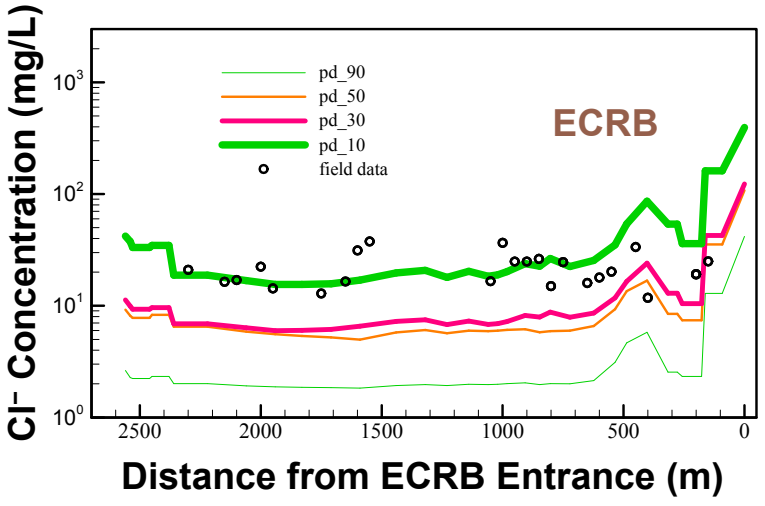
## Preliminary Chloride Predictions

- **Reductions in the evaporative concentration for the new infiltration model lead to lower levels of predicted chloride concentrations**
- **Reductions in predicted chloride concentration appear to be more universal than reductions in temperature using the new infiltration model because of the uniform sensitivity over all infiltration rates to reduced evaporative concentration**

**Preliminary Average Infiltration Rates and Evaporative Concentration over Repository Domain for New Infiltration Maps**

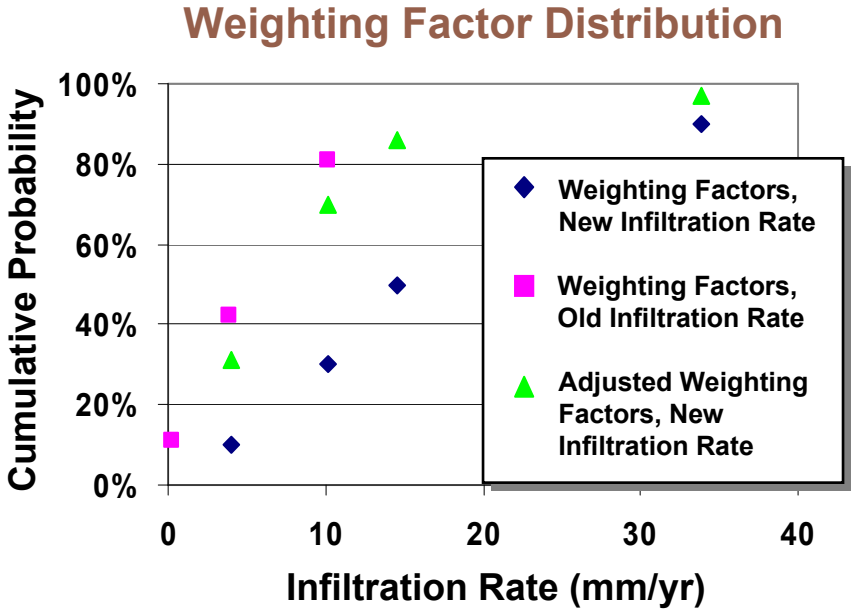
| Scenario | Infiltration (mm/yr) | Evaporative Concentration |
|---|---|---|
| pd10 | 4.0 | 42 |
| pd30 | 10.1 | 15 |
| pd50 | 14.5 | 13 |
| pd90 | 33.8 | 4 |



# Integration of UZ and Infiltration Model Preliminary Results

- **UZ model predictions for temperature and chloride, using median results from the new infiltration model, deviate from observations of temperature and chloride**
- **To integrate the UZ flow and infiltration models for use in TSPA, use Generalized Likelihood Uncertainty Estimate (GLUE) methodology to incorporate UZ results into the weighting factors for UZ flow fields**
  - **Determine the prior weights ($P_i$)**
  - **Calculate the likelihood values based on chloride data ($L_{ci}$) and temperature data ($L_{ti}$) and UZ model predictions**
  - **Calculate the final weighting factors $P_i^f$**




$$P_i^f = \frac{P_i L_{ci} L_{ti}}{\sum_{i=1}^{4} P_i L_{ci} L_{ti}}$$

# Summary

- **UZ flow model is a 3-D mountain-scale process model calibrated and validated against hydrologic, pneumatic, thermal, and geochemical data**
- **Preliminary UZ model results**
  - **Water saturation, water potential, and pneumatic pressure have low sensitivity to infiltration flux**
  - **Calcite deposition has limited sensitivity to infiltration rate and poor resolution for the time period associated with present-day climate**
  - **Temperature profiles along boreholes are sensitive to infiltration at locations with sufficiently high infiltration rates**
  - **Average chloride concentrations are sensitive to the evaporative concentration**

# Summary (continued)

- Preliminary UZ model results for temperature and chloride, using the median new infiltration rate for present-day climate, deviate from the observed data
- The UZ flow and infiltration models are integrated using prior uncertainty information from the infiltration model plus the residuals between UZ model predictions and UZ observations for temperature and chloride; this is accomplished using the GLUE methodology to develop weighting factors for flow fields used in TSPA
- The integration of UZ flow and infiltration models through the weighting factors provides an improved treatment of uncertainty while maintaining consistency with observations