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

Scientific Programs: Update on Ongoing Work - Overview

Presented to:
Nuclear Waste Technical Review Board (NWTRB)

Presented by:
Dr. Mark T. Peters, Manager
Testing & Engineering Support Office Organization
M&O/Los Alamos National Laboratory

Las Vegas, Nevada
January 25-26, 2000

YUCCA MOUNTAIN PROJECT

Overview

- **Climate; Infiltration; UZ Flow Above Repository; Seepage Into Drifts**
  - **ESF Moisture Monitoring Studies**
    - **Alcove 1**
    - **Alcove 4**
    - **Niche Studies**
  - **Cross Drift Studies**
    - **Alcove/Niche Status**
    - **Moisture Monitoring/Bulkhead Studies**
    - **Fracture Mineral Studies**
    - **^{36}Cl Studies**
  - **^{36}Cl Validation Study**
  - **Cooperative Work on Fluid Inclusions**
  - **Stratigraphic Studies**

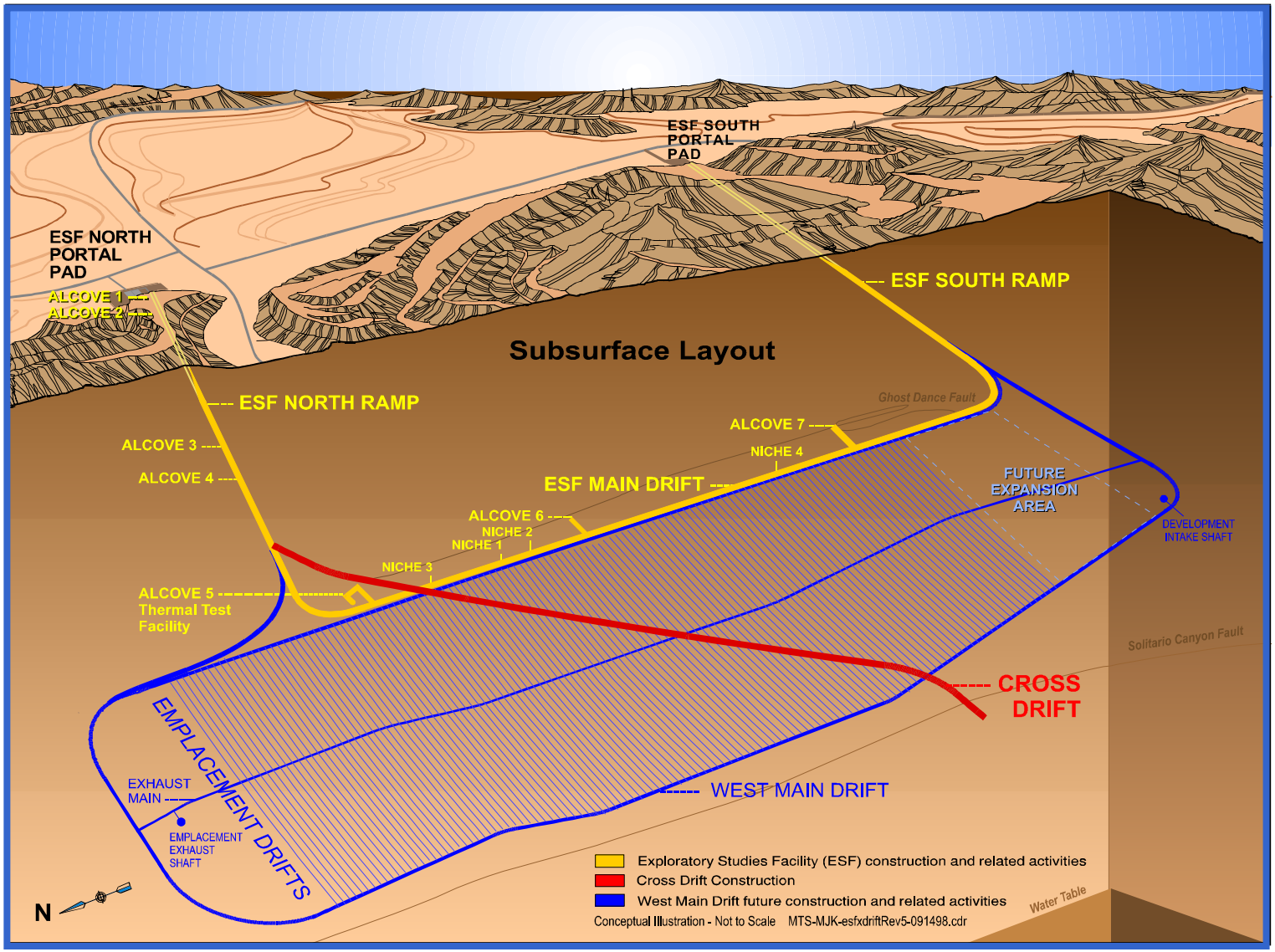
Overview
(Continued)

- **Coupled Processes - Effects on UZ Flow, UZ Transport, and Seepage; Environments on Drip Shield and Waste Package**
  - **Drift Scale Test**
- **SZ Flow and Transport - Advective Pathways and Colloid-Facilitated Transport; Radionuclide Retardation; Dilution of Radionuclide Concentrations**
  - **Saturated Zone Investigations**
    - **Integration of Nye County Results**
    - **Saturated Zone Flow and Transport Model**

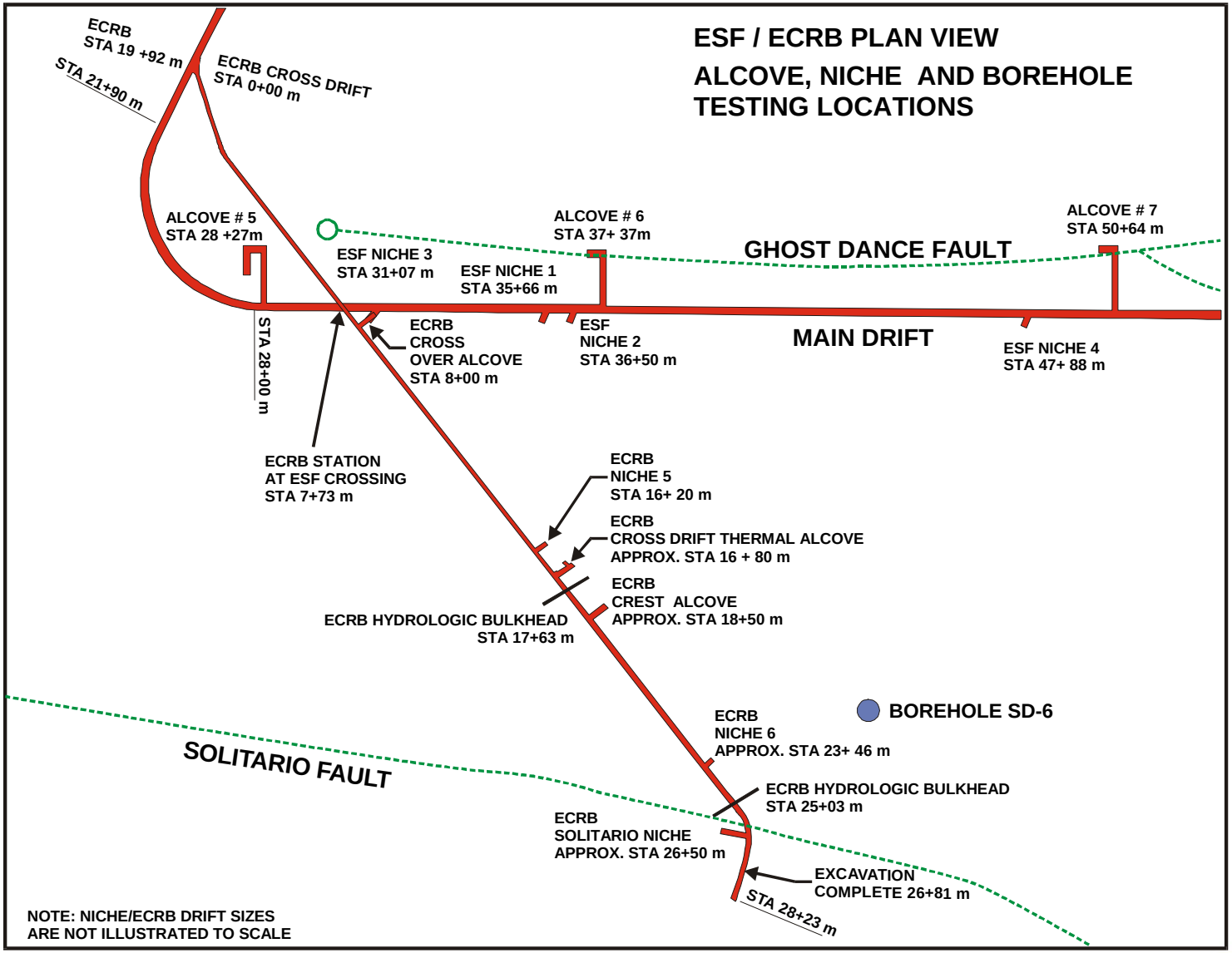
Overview
(Continued)

- **Environments on Drip Shield and Waste Package; Performance of Drip Shield and Waste Package**
  - **Engineered Barrier System Testing**
  - **Waste Package Materials Testing**

Exploratory Studies Facility and Alcoves



Exploratory Studies Facility and Cross Drift



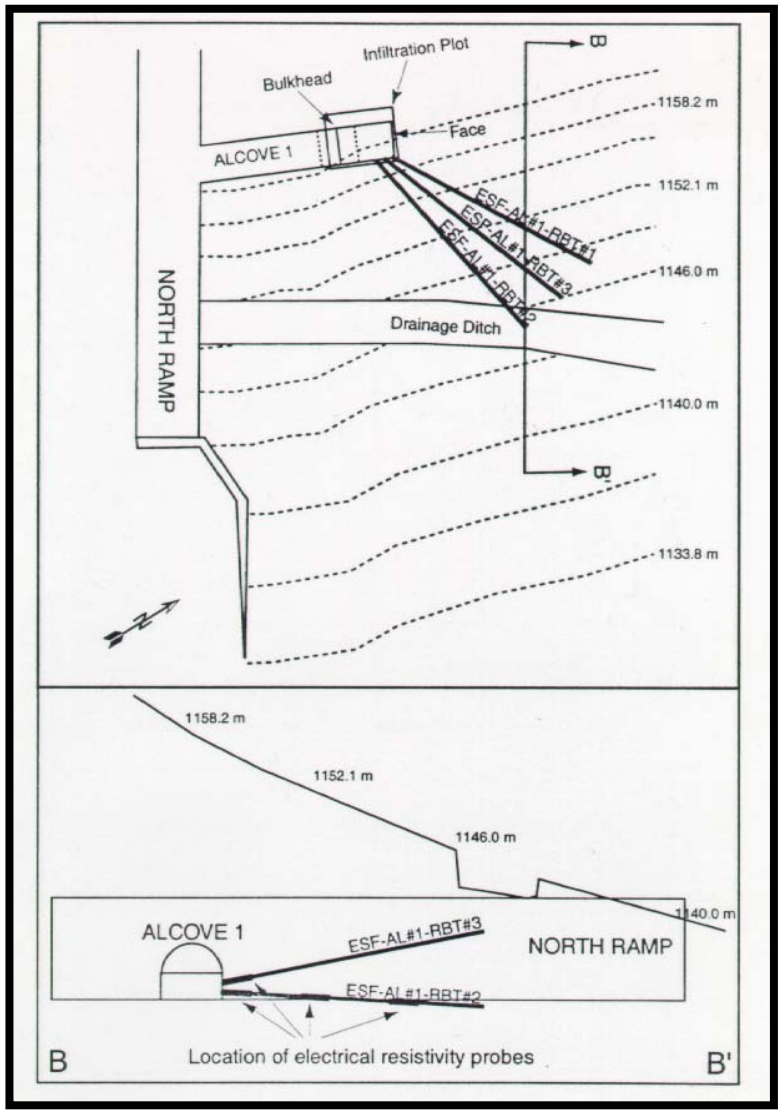
Alcove 1

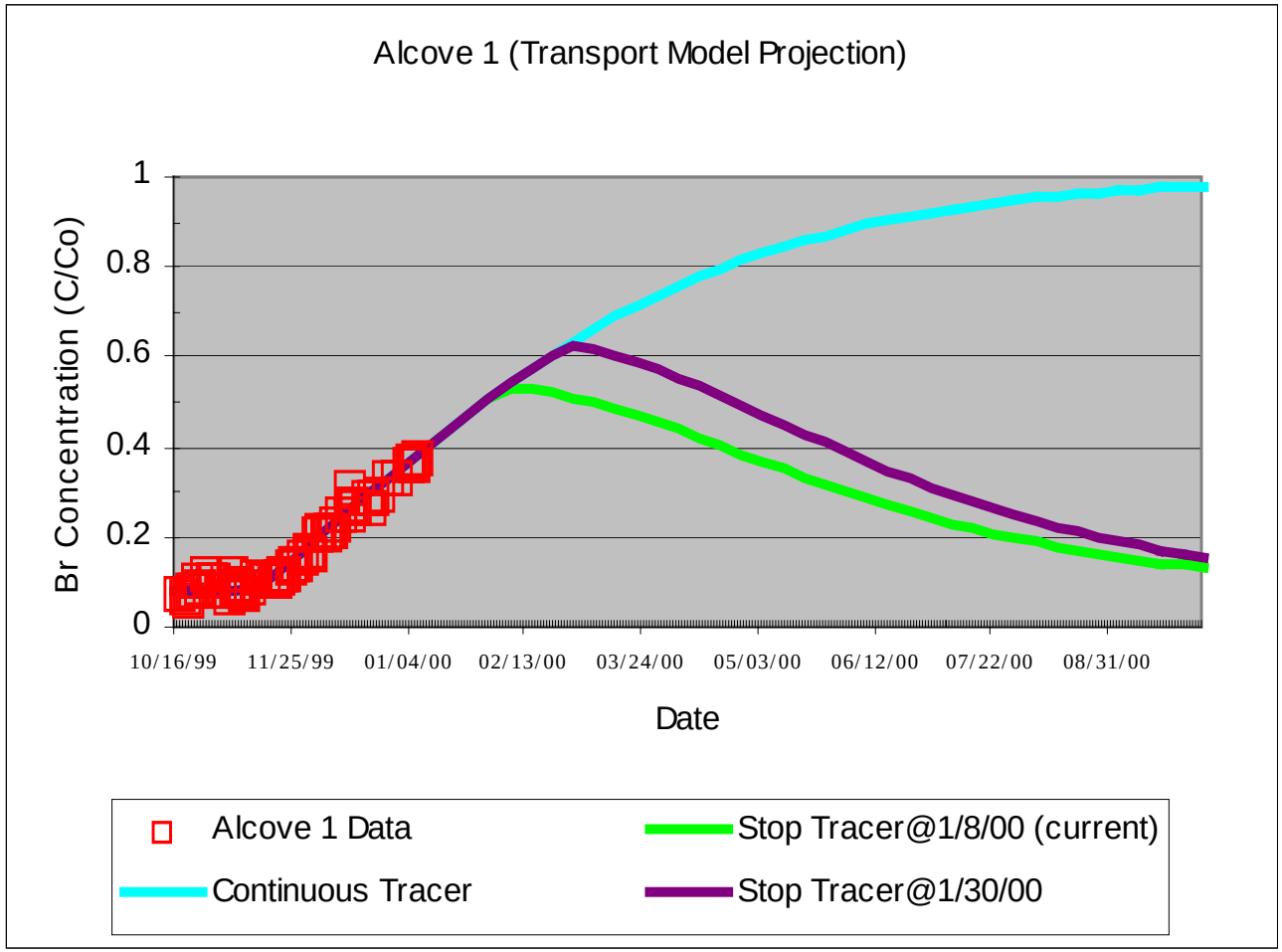
- **Evaluate infiltration and percolation through unsaturated welded tuffs and the climatic effects associated with increased precipitation**
- **Phase 1**
  - **Over 60,000 gallons of water applied**
  - **Seepage in Alcove 1 began after approximately 8.5 weeks (over 30,000 gallons of water applied)**
  - **Approximately 10% of the applied water was recovered in the alcove collection system**

Alcove 1
(Continued)

- **Phase 2**
  - **Water application started on 2/19/99**
  - **As of mid-January, approximately 165,000 gallons of water applied (varying application rates)**
  - **Seepage in Alcove 1 began after approximately 3 weeks**
  - **As of mid-January, approximately 11% of the applied water was recovered in the alcove collection system**
  - **Varying concentration of aqueous tracer**

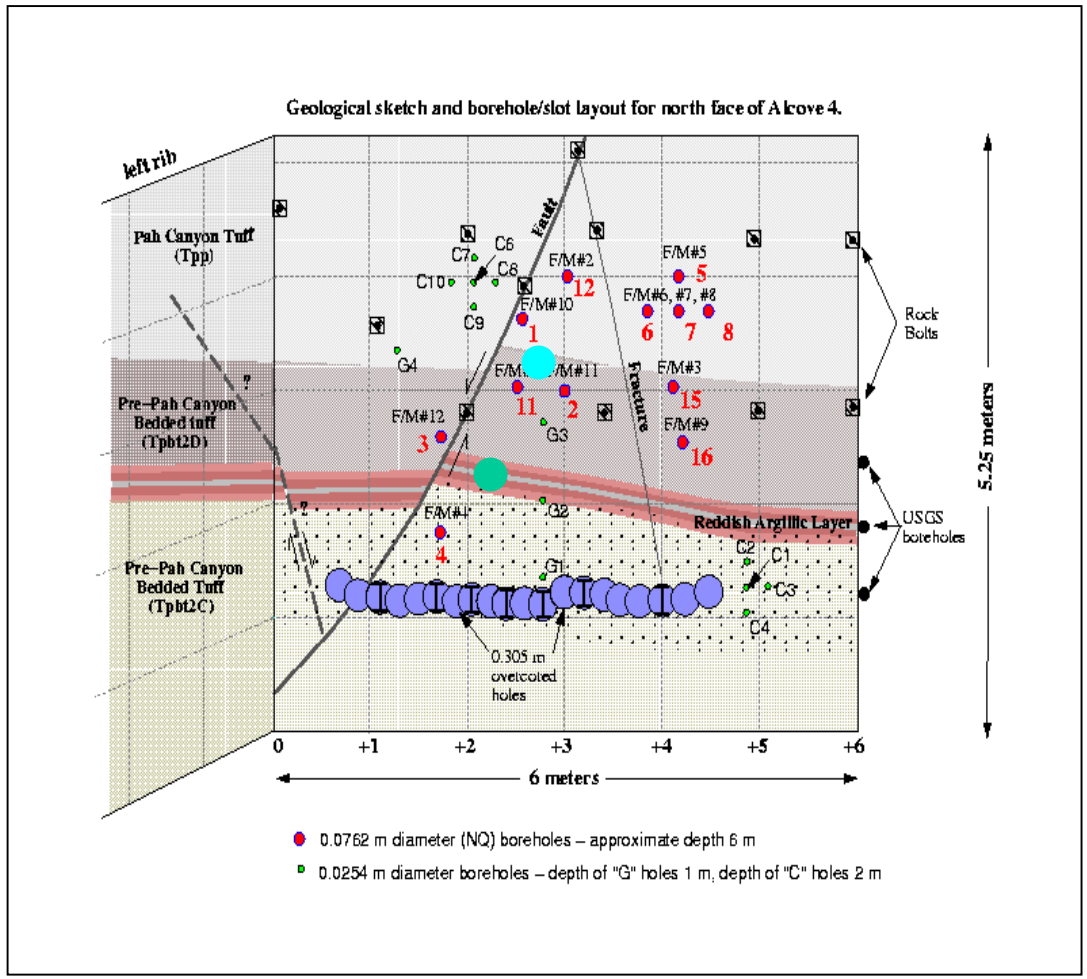
Alcove 1 Illustration




Alcove 1 (Transport Model Projection)
Br Concentration (C/Co)
1
0.8
0.6
0.4
0.2
0
10/16/99
11/25/99
01/04/00
02/13/00
03/24/00
05/03/00
06/12/00
07/22/00
08/31/00
Date
Alcove 1 Data
Stop Tracer@1/8/00 (current)
Continuous Tracer
Stop Tracer@1/30/00

Alcove 4

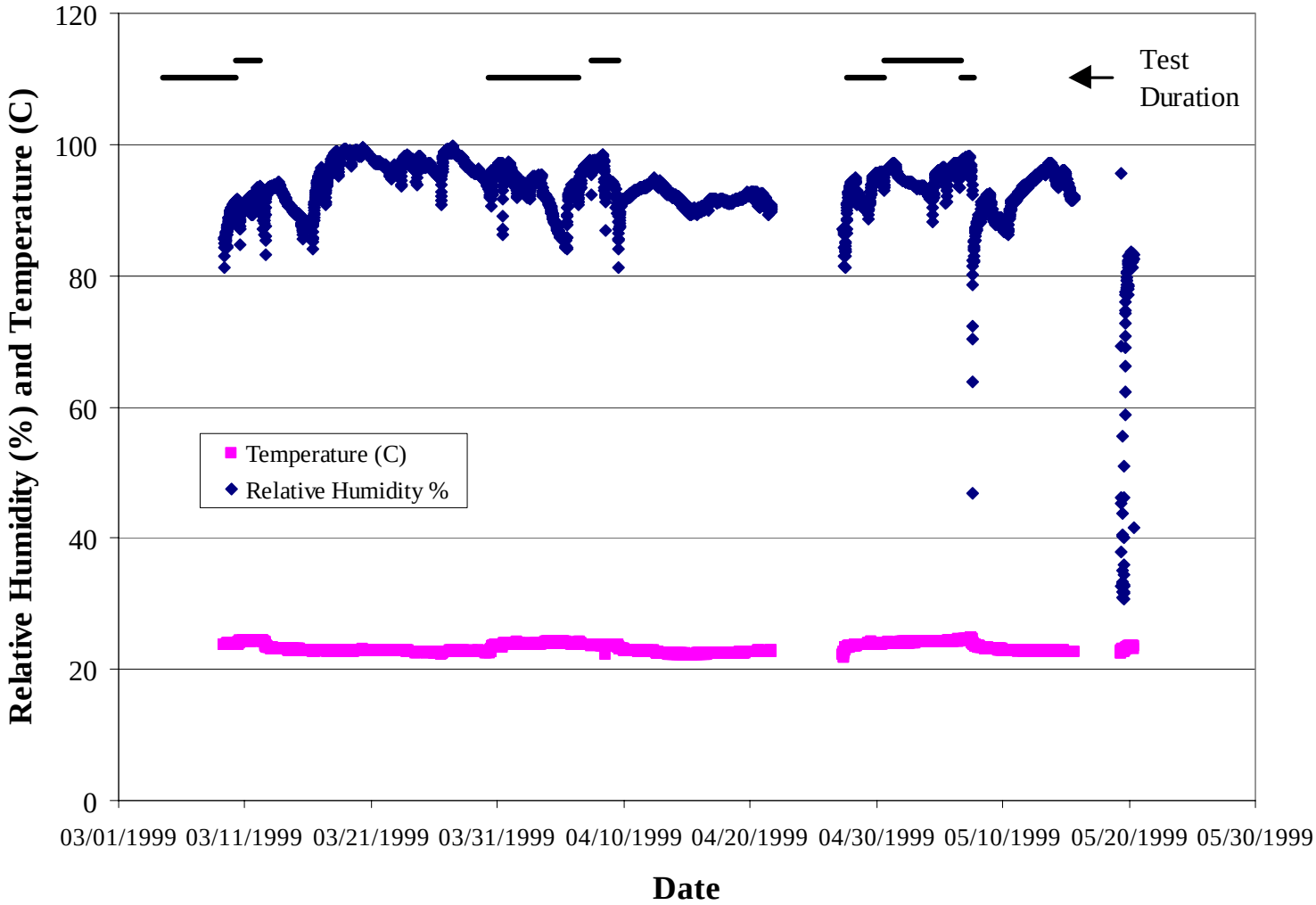
- Flow tests in fault located in the PTn to investigate behavior of fracture/fault pathways in nonwelded tuffs
- Wetting front observed in slot after ~270 liters of water injected into fault
- Fault intake rates decreased from ~150 to ~ 40 m/min.
- Flow velocity along fault estimated to be ~ 0.13 - 1.33 cm/min.



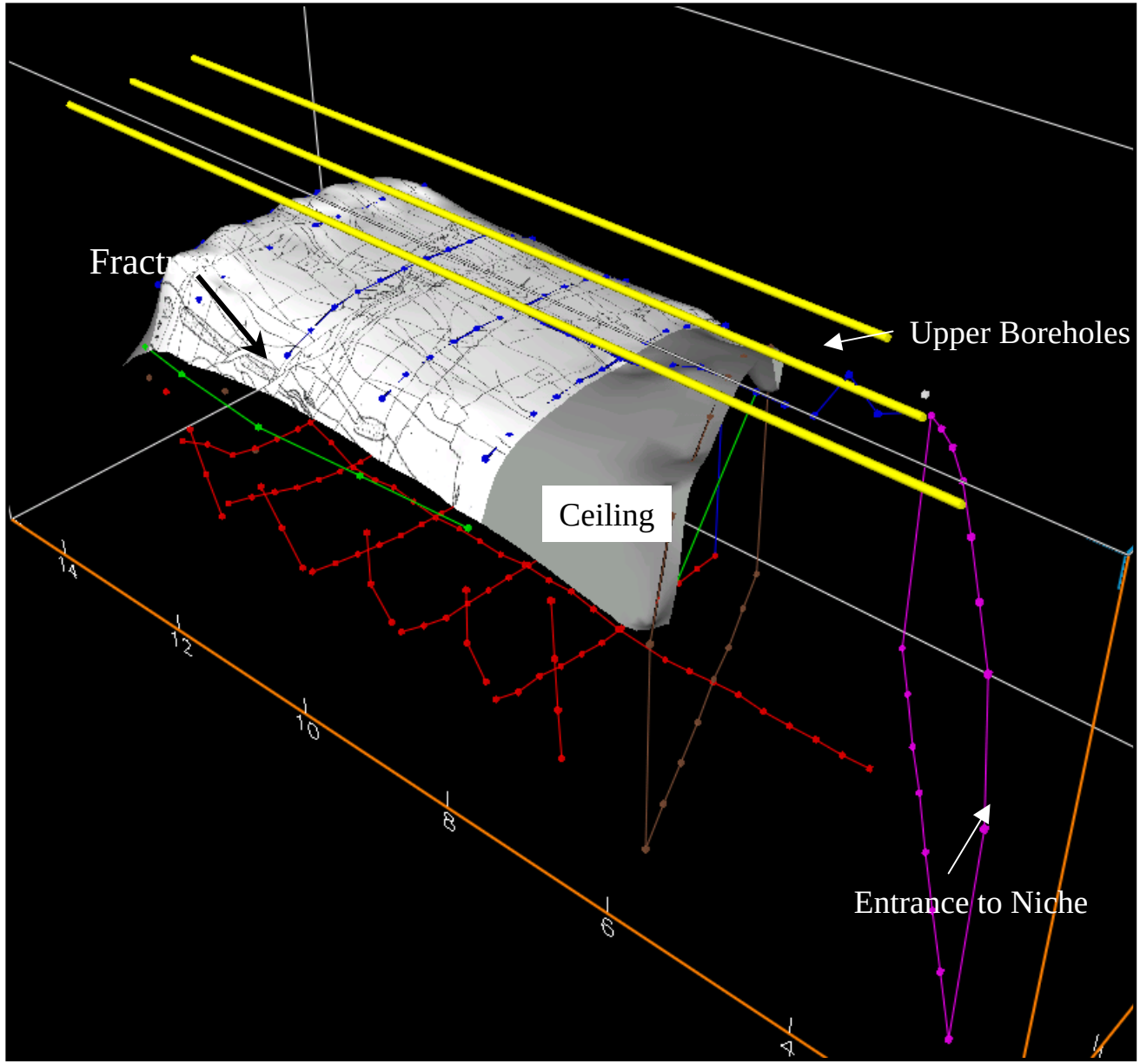
ESF Niche Studies

- **Evaluate drift-scale seepage processes and seepage threshold in potential repository horizon rocks with varying fracture characteristics (Topopah Spring Middle Nonlithophysal Unit)**
- **Niche 3 seepage tests were performed under elevated relative humidity conditions to evaluate how wetting history influences seepage**
- **Niche 4 seepage tests are currently underway, with fractures on niche ceiling extensively mapped and air-permeabilities measured before and after niche excavation, at an intensively fractured zone**

Relative Humidity and Temperature Inside Niche 3



Fracture Map of Niche 4 Ceiling



Cross Drift Alcove/Niche Status

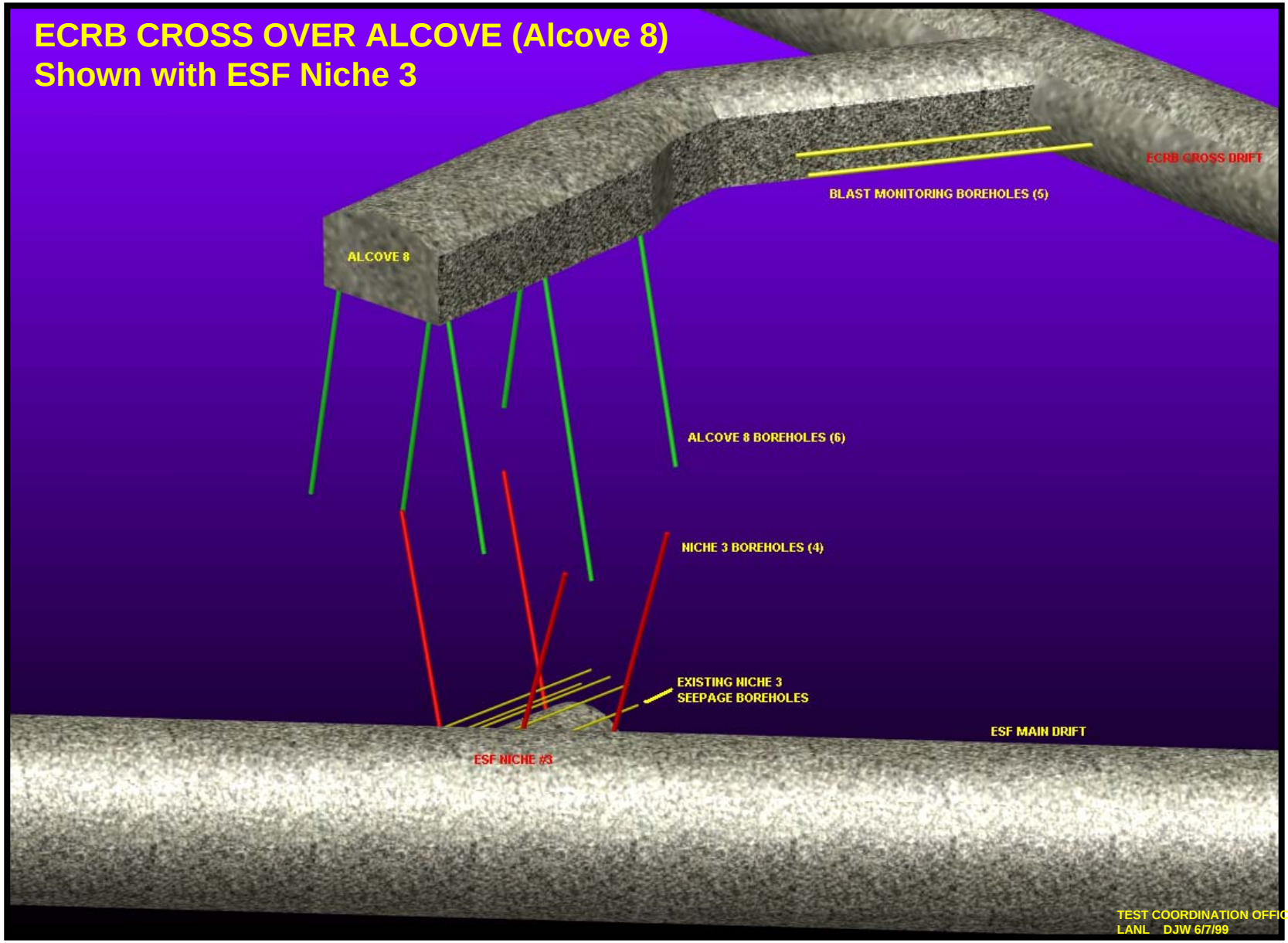
- **Crossover Alcove (Station 8+00 meters)**
  - **Evaluate flow and seepage processes in potential repository horizon rocks at scale of tens of meters**
    - **Blast monitoring boreholes complete and drill and blast excavation began in late FY99 and terminated in early FY00**
    - **Drilling of boreholes from ESF Niche 3 complete**
    - **Remainder of excavation by mechanical miner ongoing**
    - **Testing planned to begin in Spring, 2000**

Cross Drift Alcove/Niche Status

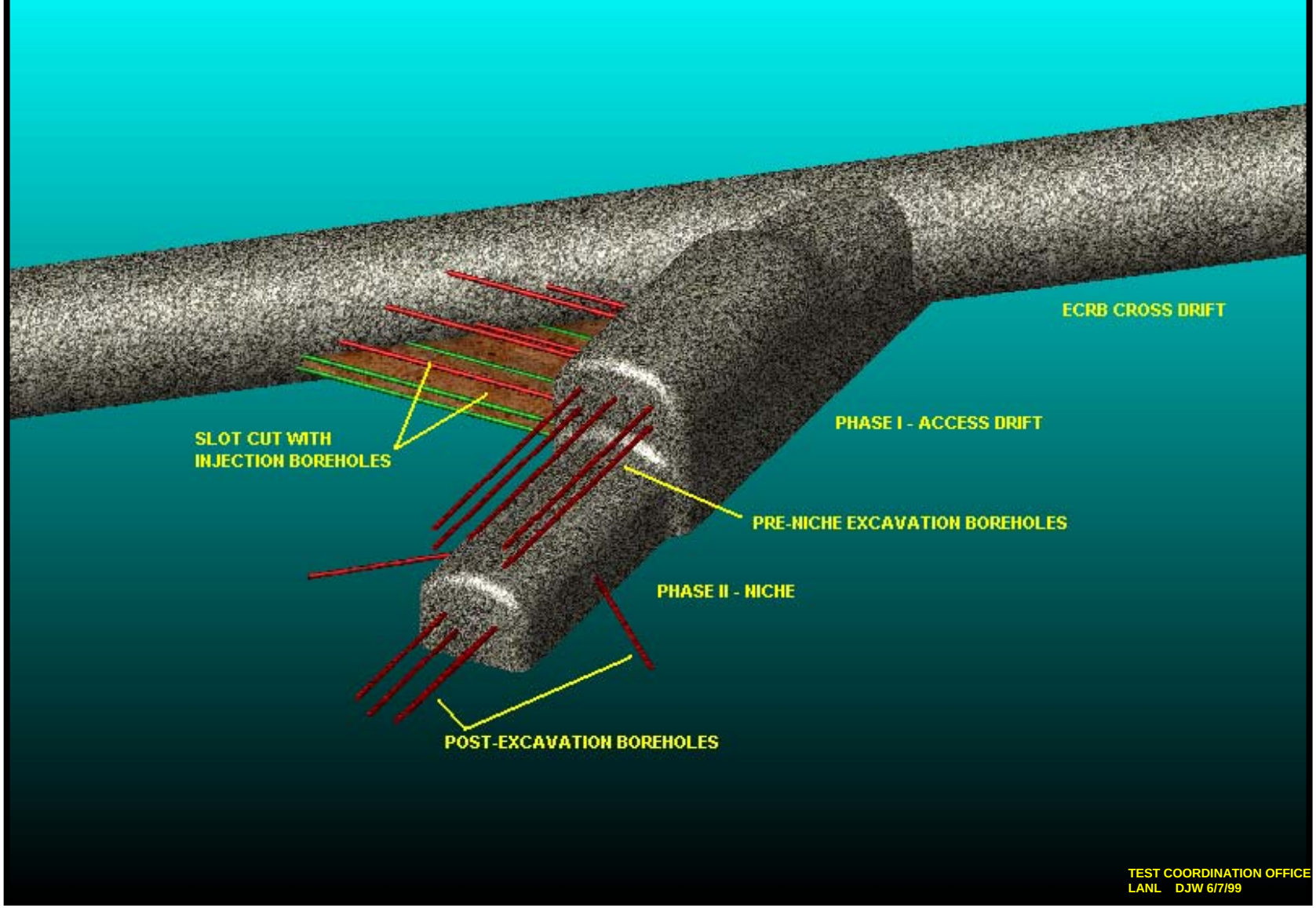
(Continued)

- **Niche 5 (Station 16+20 meters)**
  - **Evaluate drift-scale seepage processes and seepage threshold in potential repository horizon rocks (Topopah Spring Lower Lithophysal Unit)**
    - **Drilling of pre-excavation air permeability boreholes and mechanical excavation of Phase 1 complete**
    - **Pre-excavation air permeability borehole testing complete**
    - **Drilling of Phase 1 boreholes ongoing**
    - **Testing planned to continue in FY00**

ECRB CROSS OVER ALCOVE (Alcove 8)
Shown with ESF Niche 3



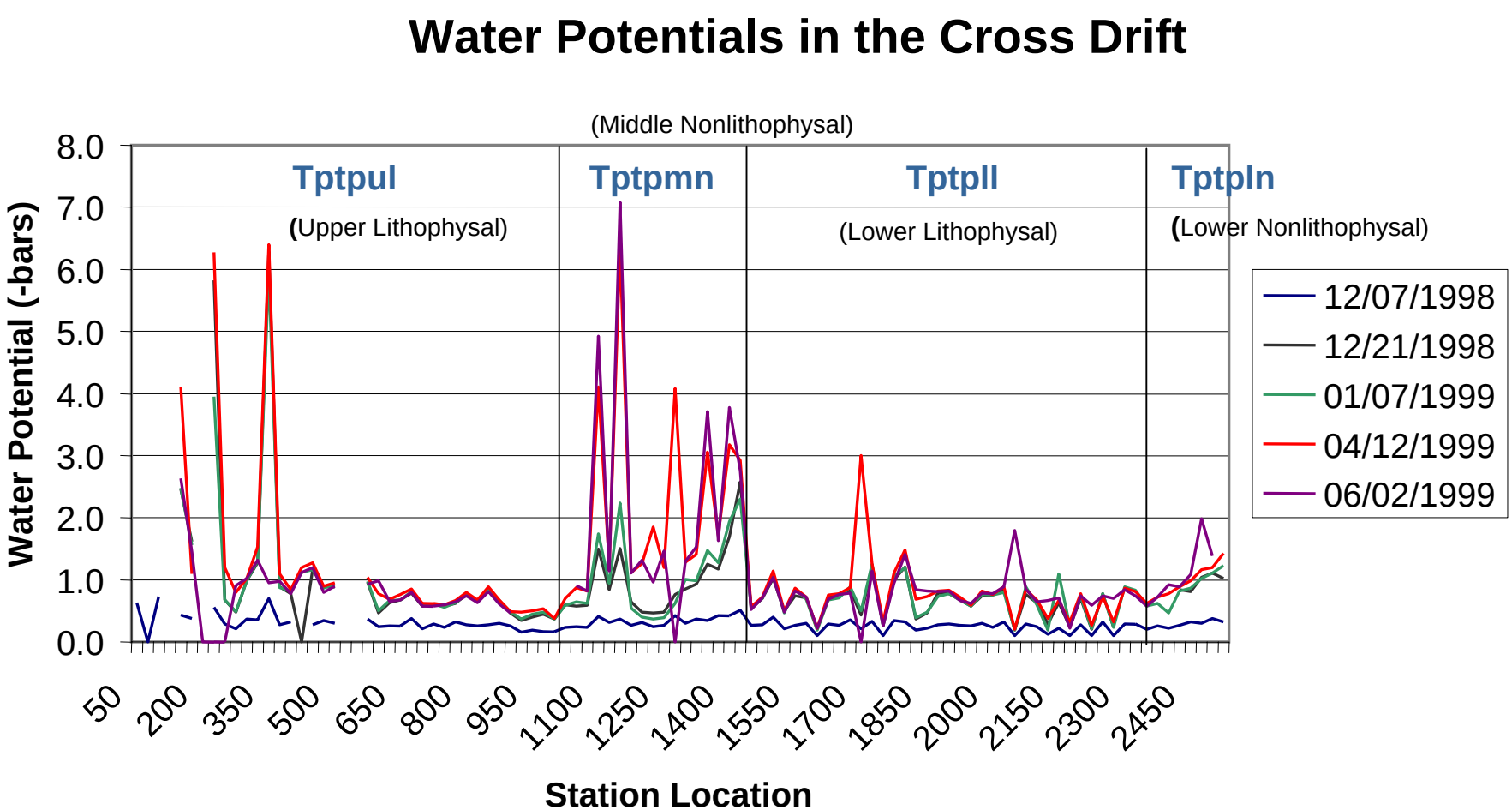
ECRB NICHE 5


ECRB CROSS DRIFT
PHASE I - ACCESS DRIFT
SLOT CUT WITH
INJECTION BOREHOLES
PRE-NICHE EXCAVATION BOREHOLES
PHASE II - NICHE
POST-EXCAVATION BOREHOLES
TEST COORDINATION OFFICE
LANL DJW 6/7/99

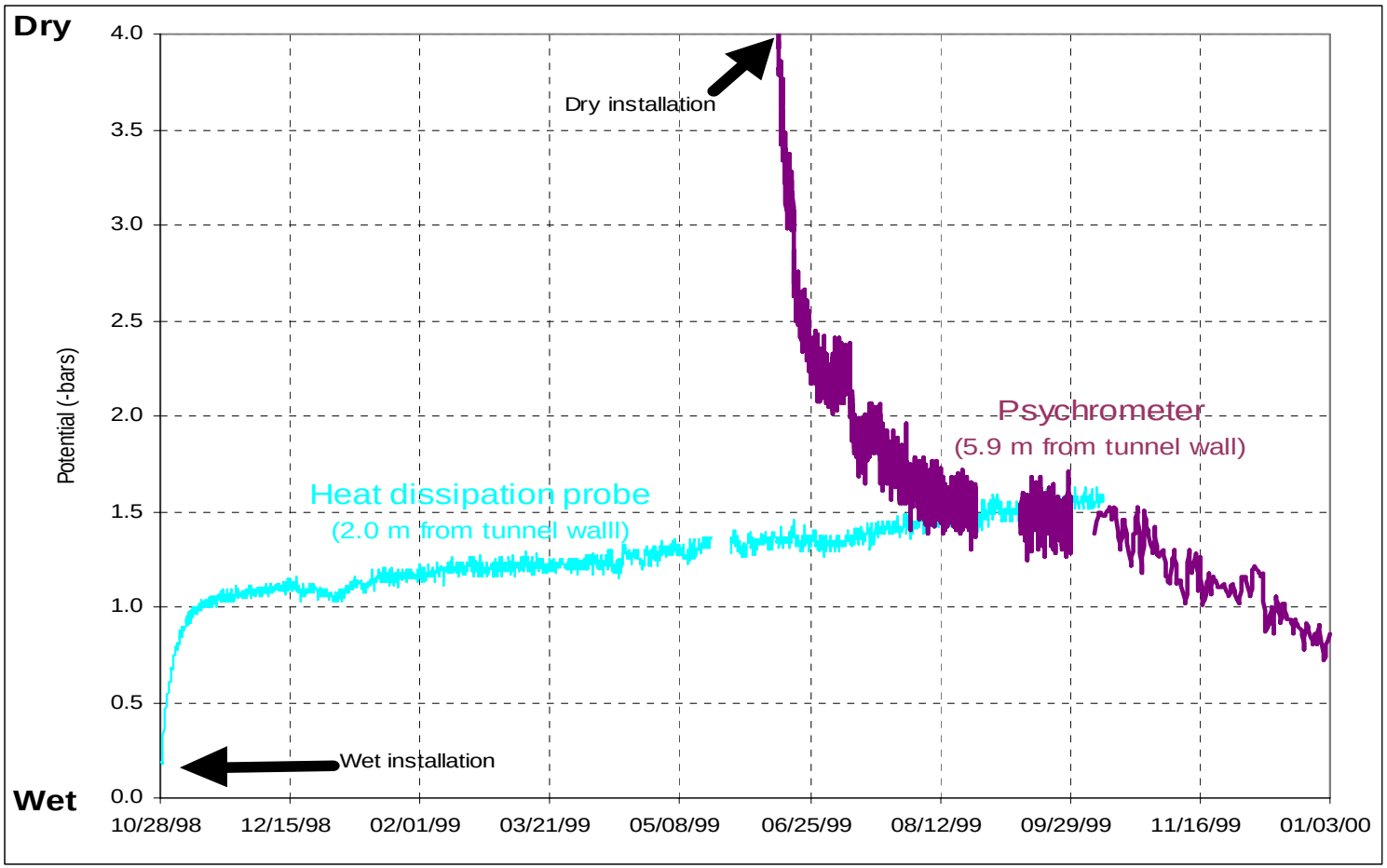
Cross Drift Moisture Monitoring/Bulkhead Studies

- **Evaluate flow and seepage processes in potential repository horizon rocks and Solitario Canyon Fault Zone**
- **Water Potential and Air Permeability - Preliminary Results**
  - **Lower Lithophysal and Lower Nonlithophysal units may have water potential less than ~ 2 bar (based on preliminary thermocouple psychrometer measurements along two 6-m boreholes at CS 20+00 and 25+00, and comparison with heat dissipation probe results)**
  - **Lower Lithophysal unit may be ~ 1.5 orders of magnitude more permeable than Middle Nonlithophysal unit (based on testing of first two boreholes at Niche 5)**

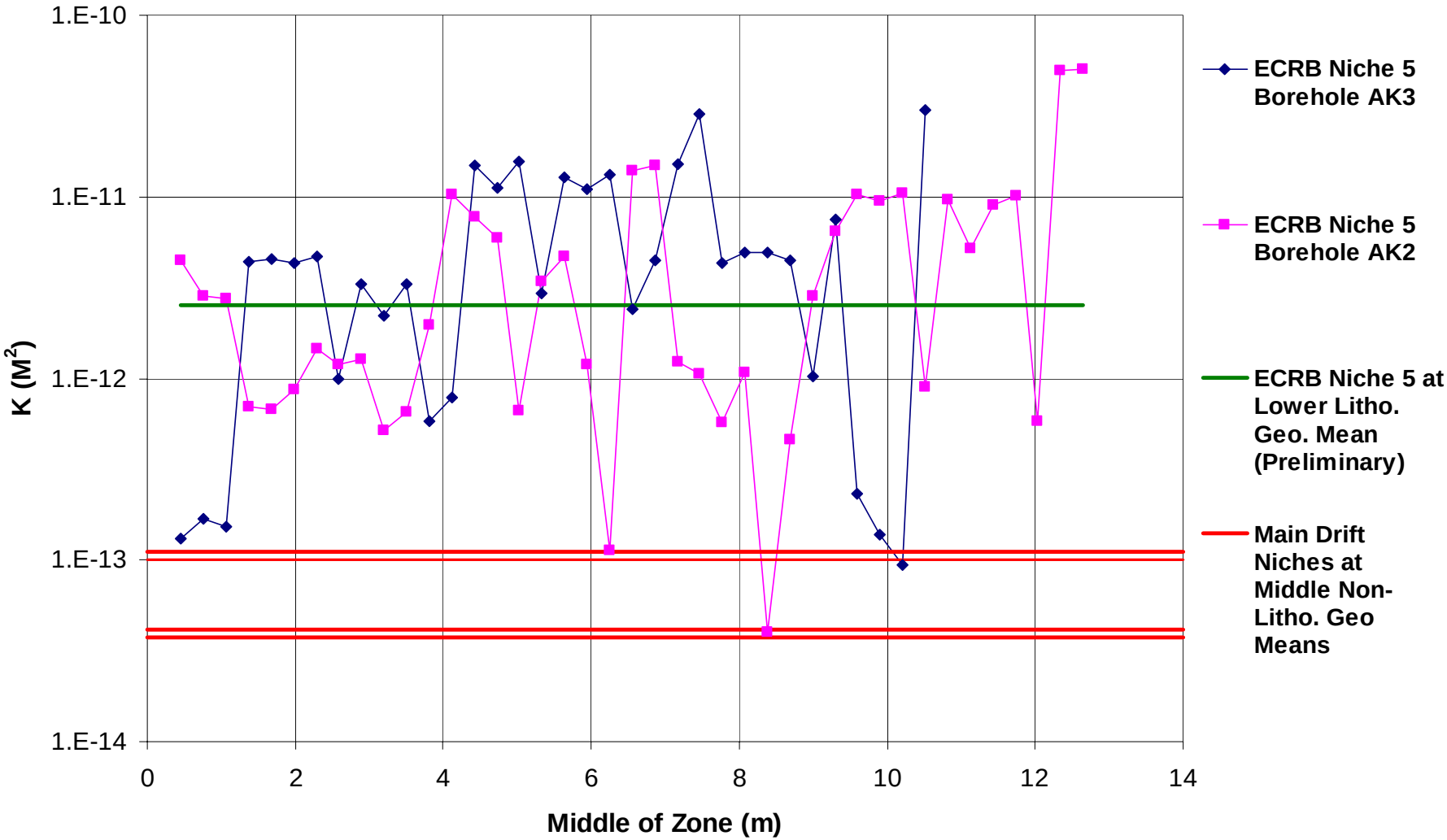
Moisture Monitoring



Water Potential Measurements at Cross Drift CS 25+00



Lower Lithophysal Air Permeability - Preliminary Results

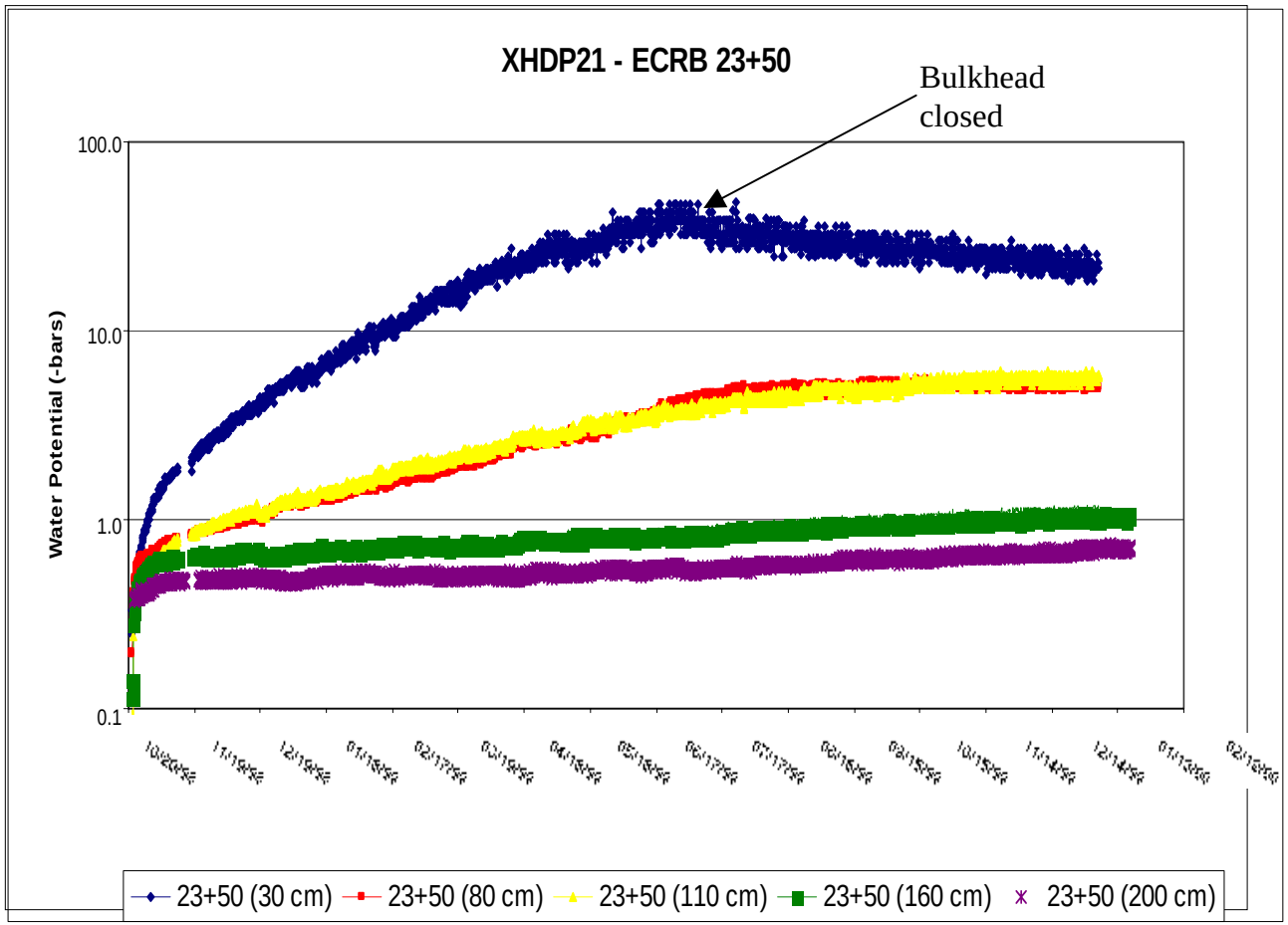


Cross Drift Moisture Monitoring/Bulkhead Studies

(Continued)

- **Bulkhead Studies**
  - **Began in mid June -- bulkheads at Stations 17+63 meters and 25+03 meters**
  - **Systematic hydrologic instrumentation in Topopah Spring Lower Lithophysal and Lower Nonlithophysal Units and Solitario Canyon Fault Zone**
  - **Periodic entry for neutron logging, instrument maintenance, visual observation, and TBM maintenance -- First entry September 1, 1999 and second entry January 13, 2000**
  - **Preliminary Observations**
    - **Rewetting continuing**
    - **No apparent evidence of seepage**

Influence of Bulkhead On Water Potential



- **Shallow depths are wetting**
- **Intermediate depths have stopped drying out**
- **Deep depths are still drying out slightly (after 6 months)**

Cross Drift Moisture Monitoring/Bulkhead Studies

- **Neutron logs and heat dissipation probes indicate that the bulkheads stopped the dryout, and the shallow depths (to 0.5 m) are wetting up**
- **Air temperature is higher than rock temperature and may influence dryout**
- **Extreme variability in rock temperatures with evaporation in fractures and no apparent evaporation adjacent to fractures**

Cross Drift Moisture Monitoring/Bulkhead Studies

(Continued)

- **Estimates of in situ water potential between bulkheads range from -0.45 to -1.6 bars (mean=-0.8 bars)**
- **Estimates of in situ water potential beyond inner bulkhead in fracture zone range from -0.4 to -1.85 bars**

Cross Drift Fracture Mineral Studies

- **Investigate petrographic, petrologic, and geochemical properties of fracture minerals to evaluate long-term percolation flux in potential repository horizon rocks**
- **Conducted preliminary study of opal in Yucca Mountain fracture fillings using USGS-Stanford ion-probe mass spectrometry in Palo Alto**
- **Analyses indicate that *in situ* U-series age determinations are possible at the 30-micron scale**
- **Data are consistent with previous conventional age measurements, which indicated extremely slow rates of deposition**

Cross Drift ^{36}Cl-Cl Studies

- **Evaluate percolation flux in potential repository horizon rocks and provide evidence for any "fast pathways"**
- **Replicate samples revealed bomb-pulse levels in raw material from two locations where bomb-pulse levels were previously observed**
- **Additional data from systematic samples fall within the range of background levels observed in the northern part of the repository area (^{36}Cl/Cl between 480E-15 and 900E-15)**

^{36}Cl Validation

- Validate occurrence of "bomb-pulse" ^{36}Cl at two locations in the ESF -- Sundance Fault zone and Drillhole Wash Fault zone
- Disequilibrium in $^{234}U/^{238}U$ at bulk rock scale for Sundance anomaly core samples indicates long-term water-rock interaction
- No tritium anomalies found in water extracted from 11 core samples from Sundance anomaly (perhaps suggests little interaction between matrix and fracture water)
- Fifteen Cl-36 analyses from the Sundance anomaly will be completed by end of January

Cooperative Work on Fluid Inclusions

- **Cooperative study involving UNLV, DOE (USGS), and State of Nevada to evaluate paleohydrology of Yucca Mountain**
- **New fluid inclusion equipment (microscope and heating stage) installed in USGS laboratory in Denver**
- **Fifty samples have been prepared for examination by USGS**

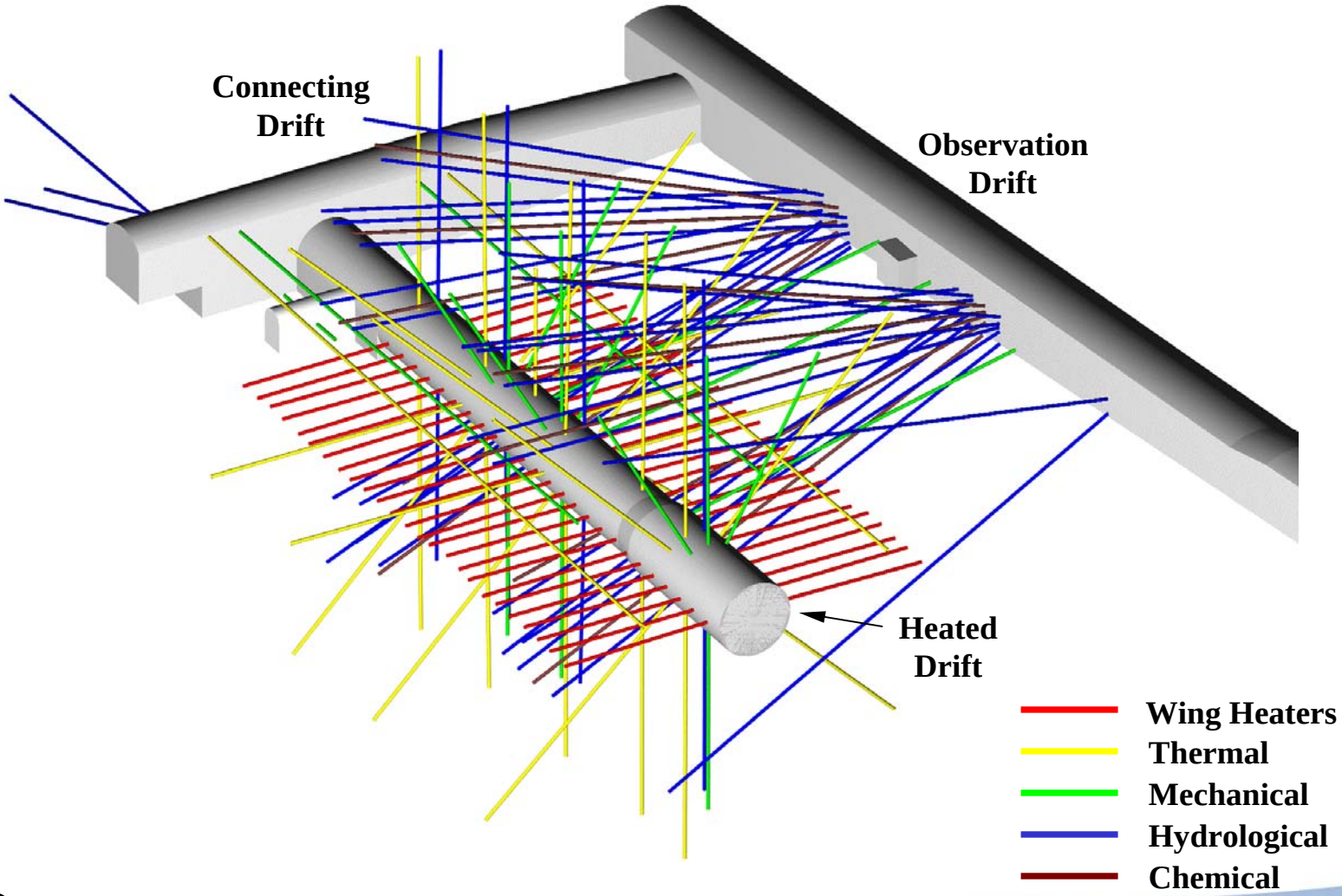
Stratigraphic Studies

- **Stratigraphic Workbooks**
  - **Document, validate, and integrate lithostratigraphic data from surface-based boreholes for use primarily in Geologic Framework Model in support of SR**
    - **Confirmation of contact picks**
    - **Determination of resolution and acceptable window for each contact**
    - **Verification of data supporting contact picks**
    - **All data for each borehole is included in a workbook**
  - **Provide technically-integrated, QA documented, lithostratigraphic database for use in SR**

Drift Scale Test:

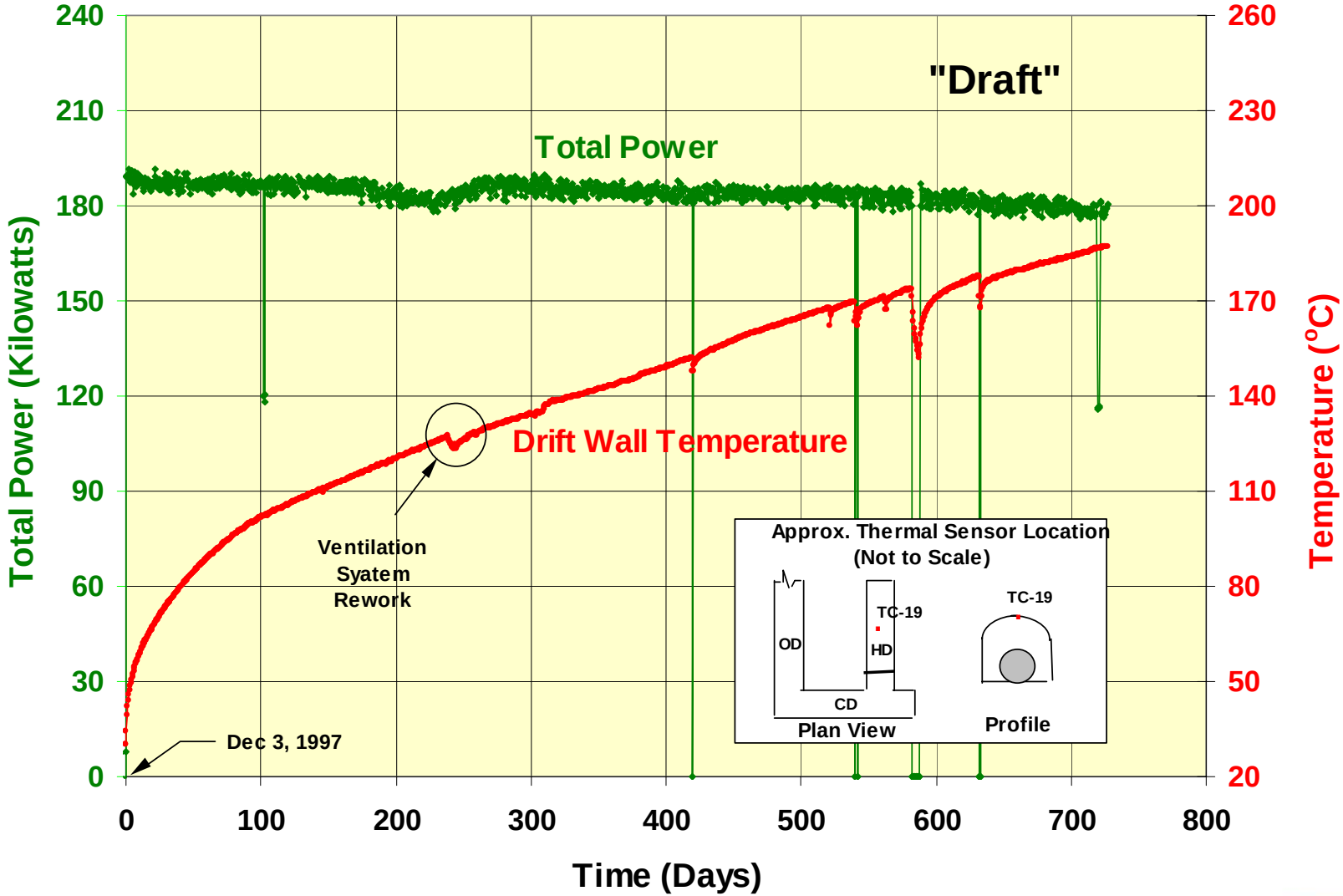
As-Built Borehole Perspective

Evaluate thermally-coupled processes in repository horizon rocks at the field-scale



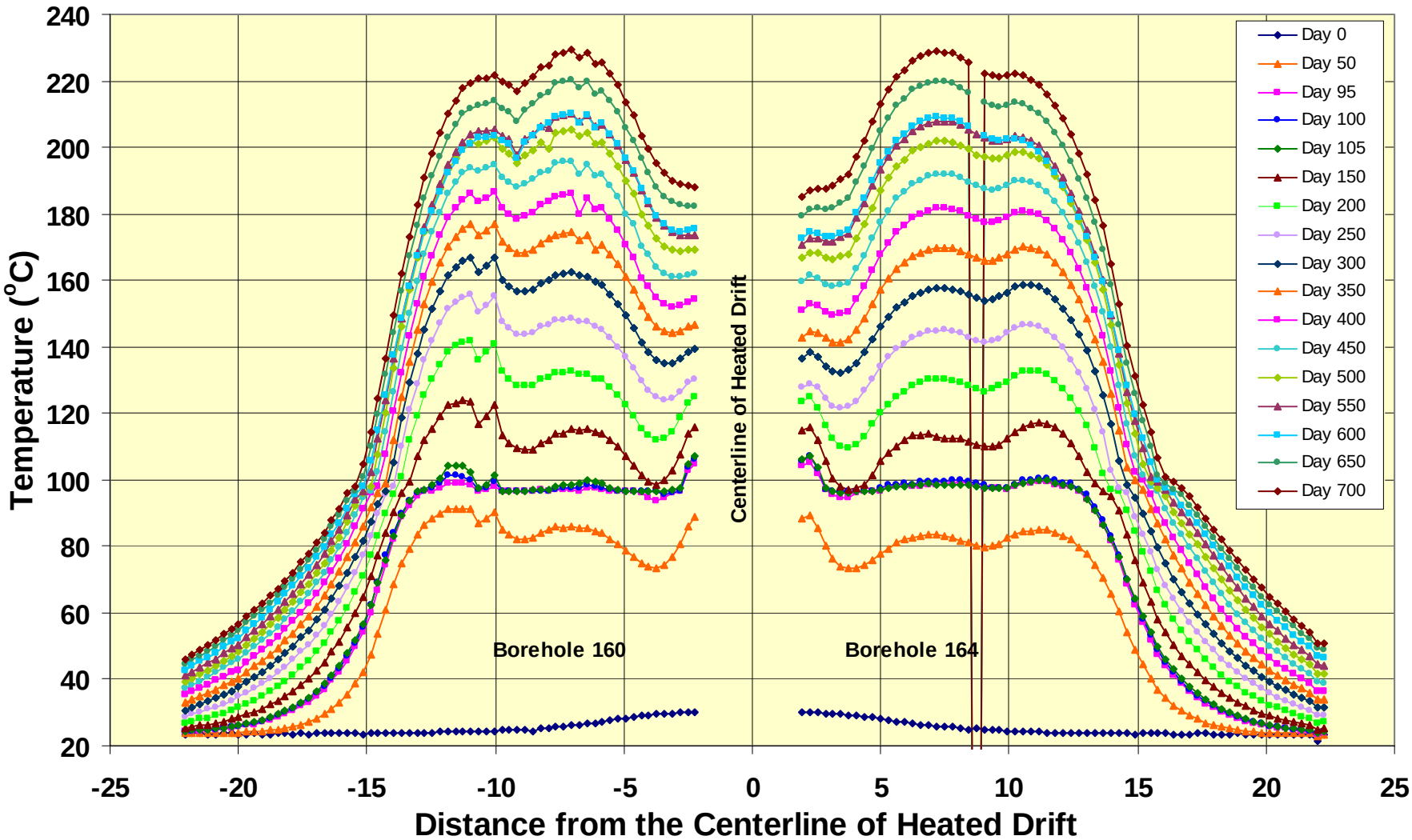
Drift Scale Test

Total Power and Drift Wall Temperature



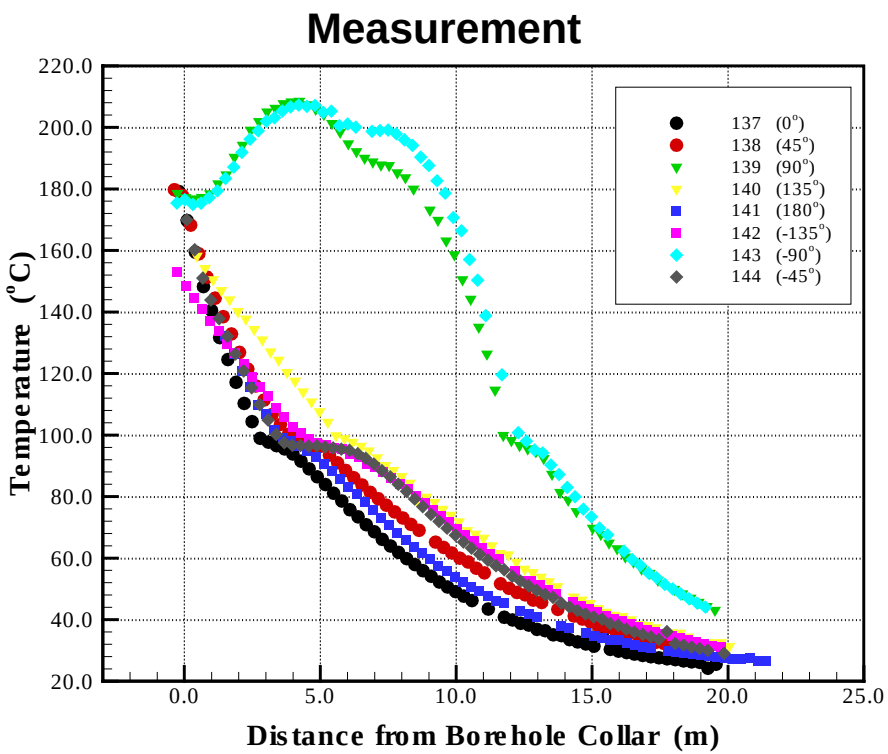
Drift Scale Test

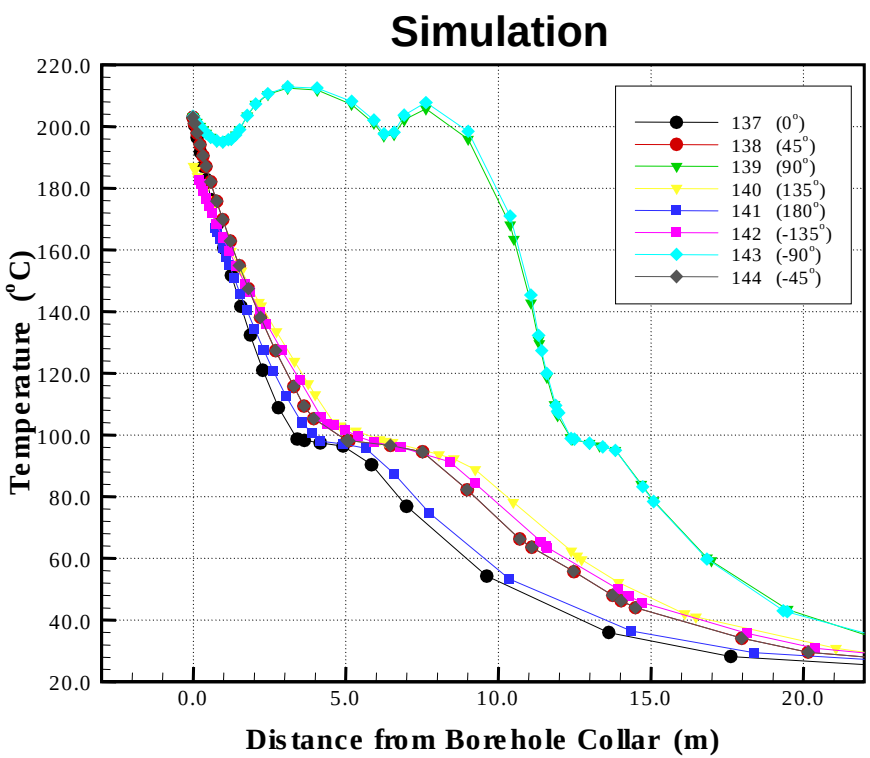
Parallel to the Wing Heaters at Mid-length of the Heated Drift



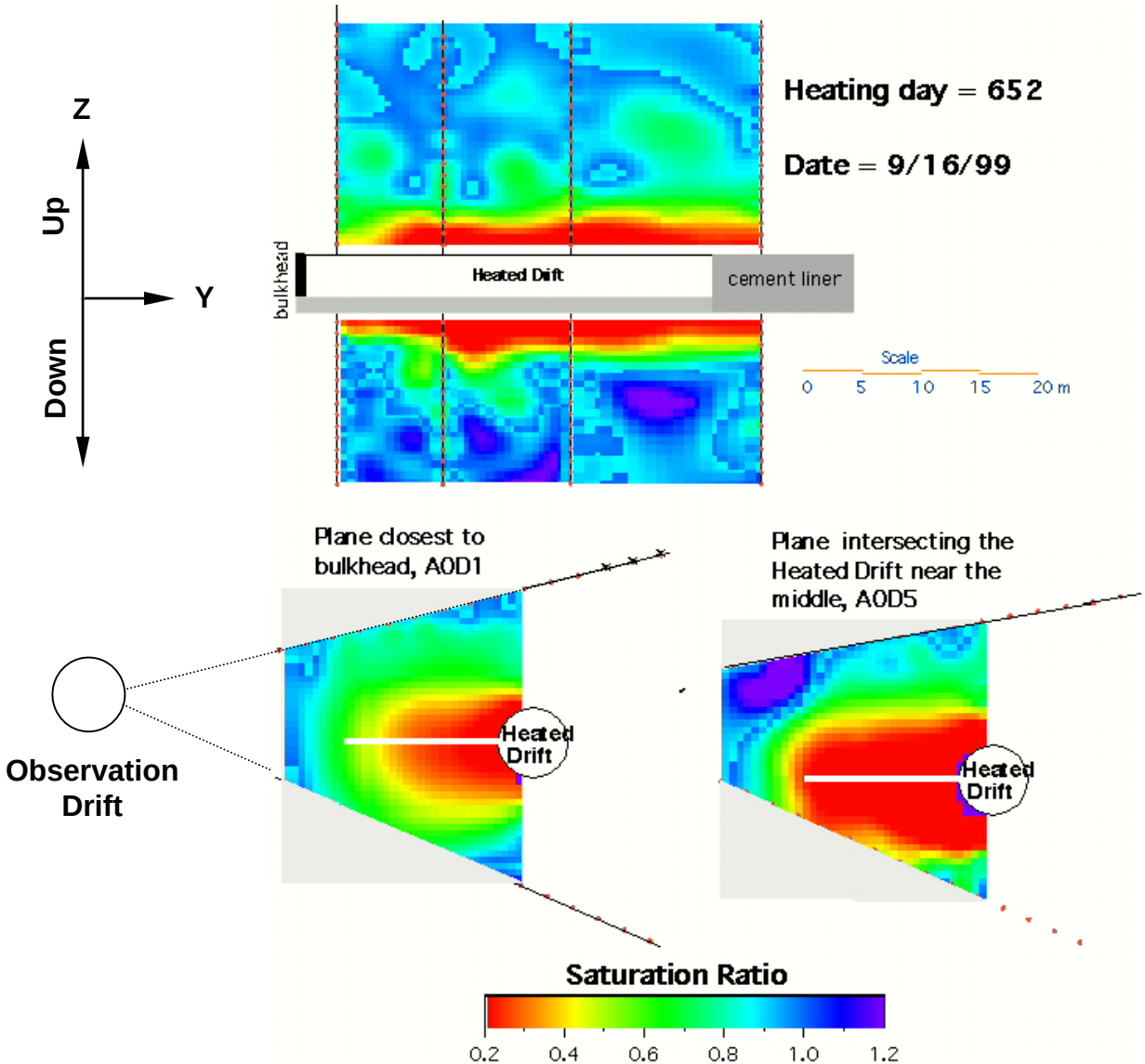
Drift Scale Test:

Temperature Measurements Vs. Simulations (DKM-TT99) at 21 Months of Heating





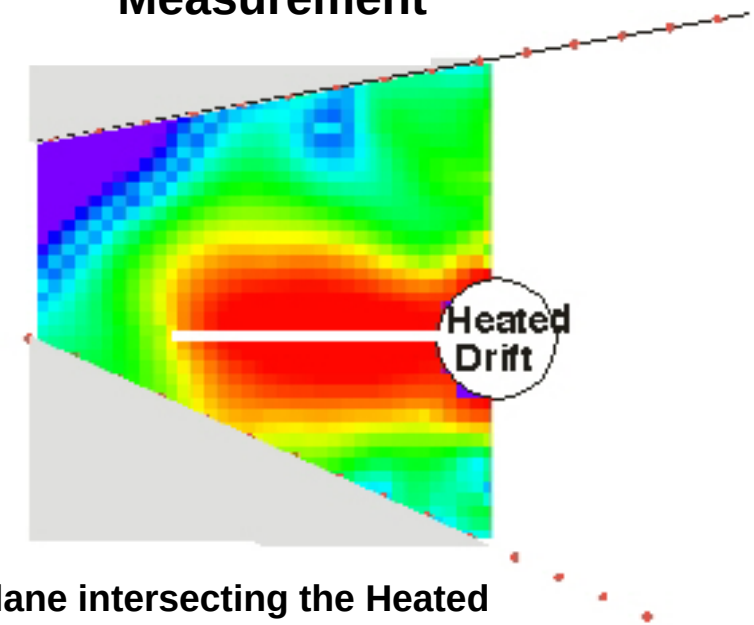
Drift Scale Test:
Electrical Resistivity Tomography



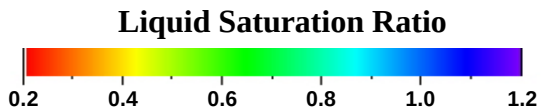
Drift Scale Test

Comparison of Measured and Simulated Matrix Liquid Saturation after 1 Year of Heating

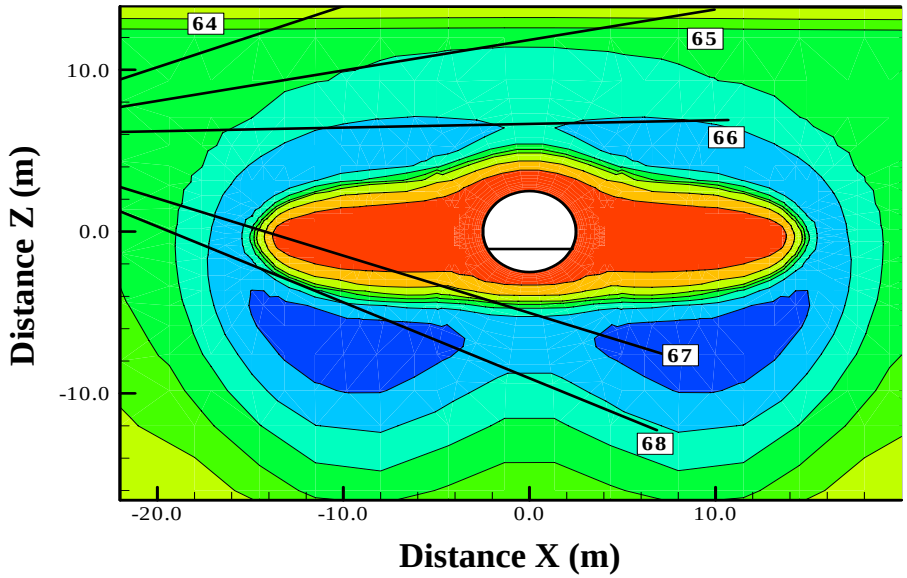
Measurement

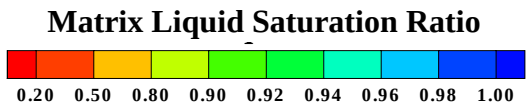


Plane intersecting the Heated Drift near the middle AOD



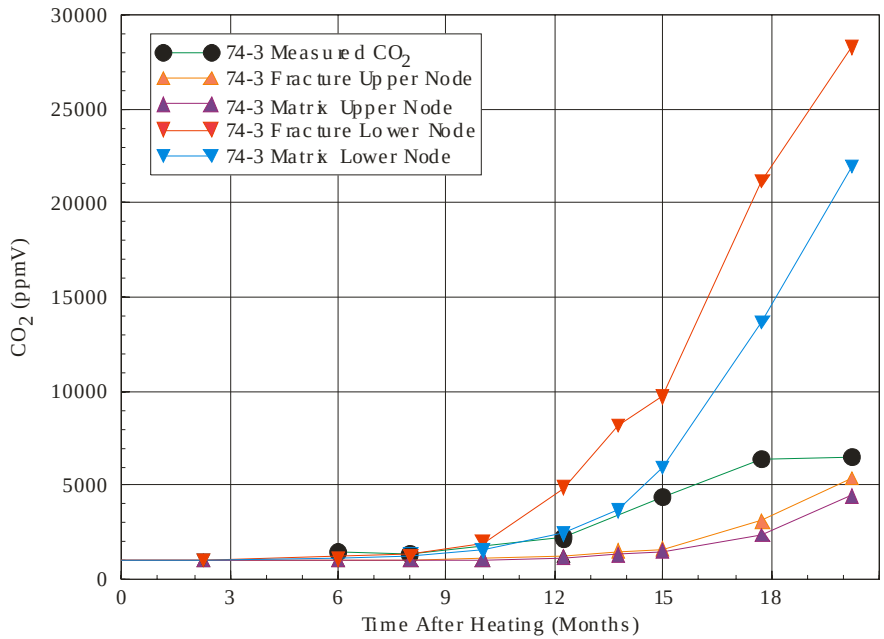
Simulation (DKM)

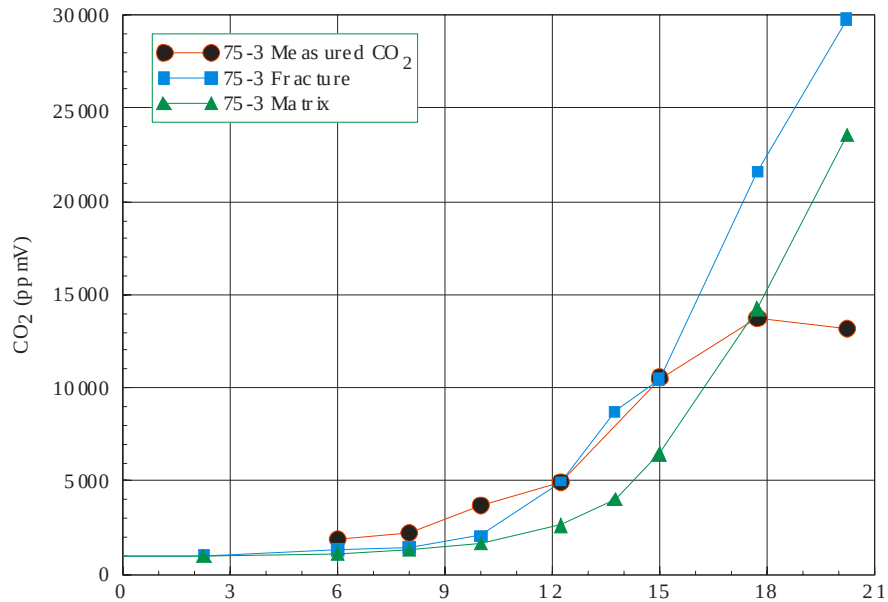




Drift Scale Test

Comparison of Modeled CO_2 Concentrations in Fractures and Matrix over Time to Measured Concentrations in Boreholes





Saturated Zone Investigations

- **Evaluate flow and transport processes in the saturated zone in the Yucca Mountain area**
- **Integration of Nye County Data**
  - **DOE is incorporating data from the Nye County Early Warning Drilling Program into the site-scale saturated zone flow and transport model, including:**
    - » **Lithologic data into the hydrogeologic framework model**
    - » **Water-level data for flow field calibration**
    - » **Hydraulic testing data for flow and transport model**
    - » **Laboratory sorption measurements (^{237}Np, ^{129}I, and ^{99}Tc) on alluvium for process model and TSPA**
    - » **Hydrochemistry data for flow field calibration**
    - » **Eh/pH data for use in flow and transport model**

Saturated Zone Investigations

(Continued)

- **Saturated Zone Flow and Transport Model**
  - **Improved process model capability for SR**
    - **Ability to handle any source size**
    - **Grid size does not impact the source size or introduce numerical dispersion**

Engineered Barrier System Testing

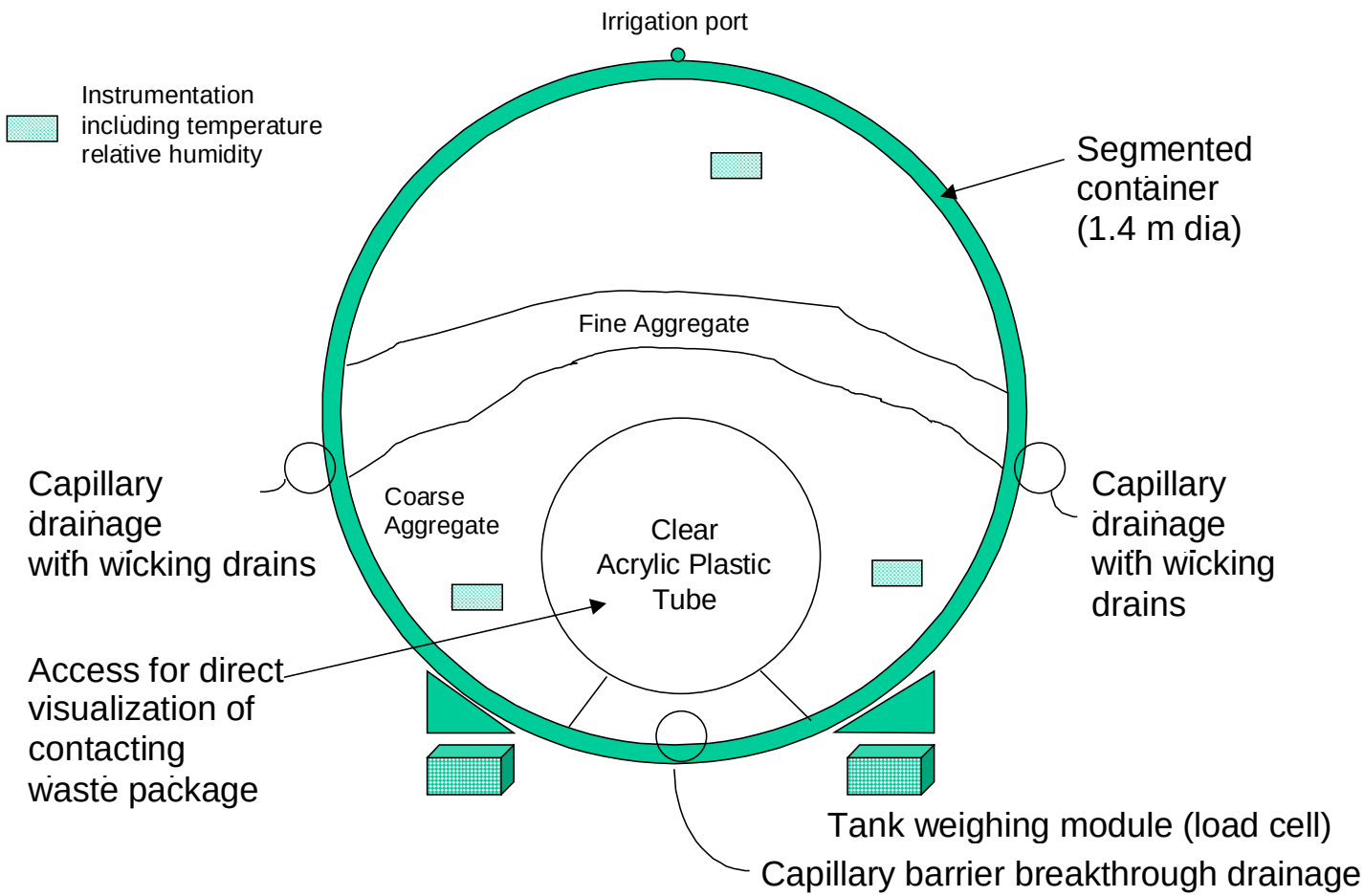
- **Support the YMP Design Selection Process**
- **Evaluate or demonstrate various engineered barrier alternative configurations**
  - **Capillary Barrier**
  - **Standard Backfill**
  - **Drip Shield**
  - **Combinations**
  - **Ambient and Thermal**

Engineered Barrier System Testing

(Continued)

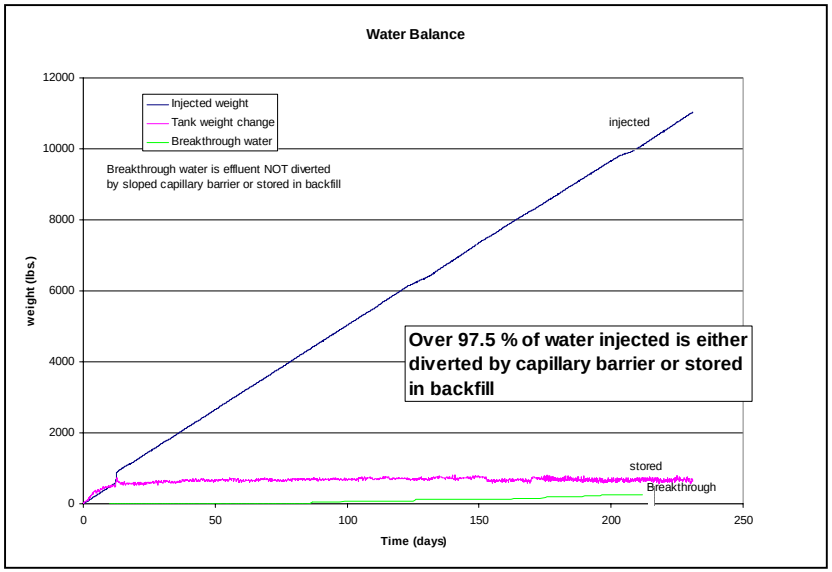
- **Provide data for model evaluation**
- **Pilot-Scale Testing**
  - **Test Canister #1 - Richard's Barrier at ambient temperature**
  - **Test Canister #2 - Single-Layer Backfill at ambient temperature**
  - **Test Canister #3 - Drip Shield with Invert (no backfill) at elevated temperature**
  - **Test Canister #4 - Drip Shield with Invert and Backfill at elevated temperature**

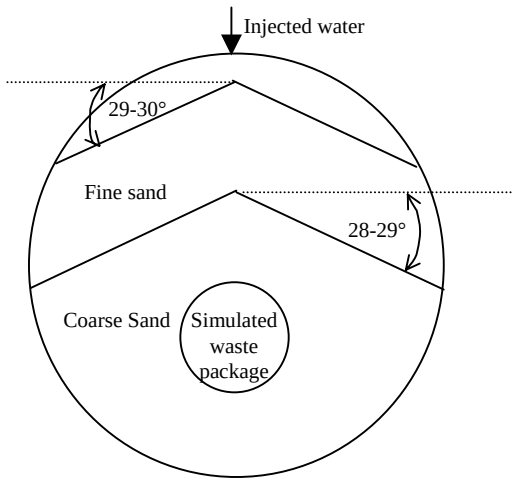
Test Canister #1



Cross-section view of ambient capillary barrier 1/4 scale configuration

Engineered Barrier System Testing





- **Canister #1 (capillary barrier) diversion effectiveness**
- **Over 97.5% of the injected water is diverted by the capillary barrier or stored in backfill**
- **Breakthrough water is collected in wick drains located at bottom sides and front of the canister**
- **Coarse backfill continues to "wet" due to greater amount of "fines" than expected**

Engineered Barrier System Testing

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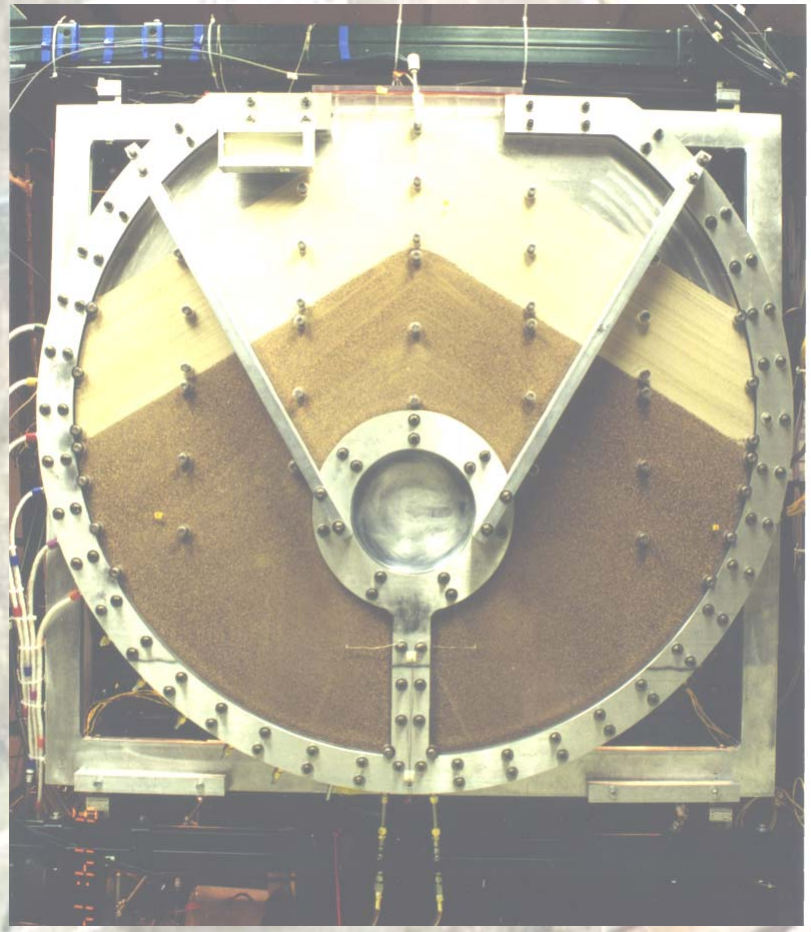


Laboratory Testing

"Mimic cell" constructed at same scale as pilot tests

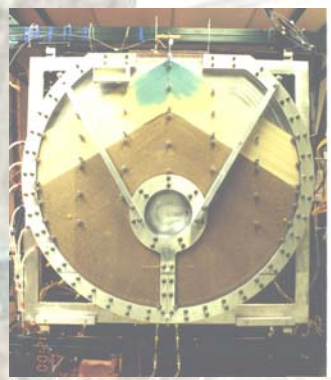
Tests used to evaluate conceptual models and to provide data and visual observations of flow processes that can't be seen in pilot scale tests

No wicks on right side of cell

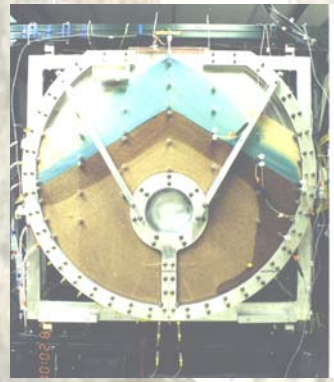
Wicks in both fine and coarse soil on left

Engineered Barrier System Testing

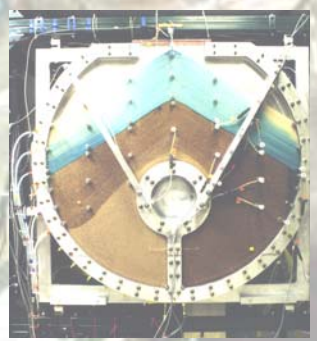
(Continued)



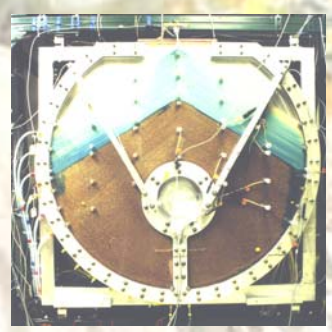
4 days



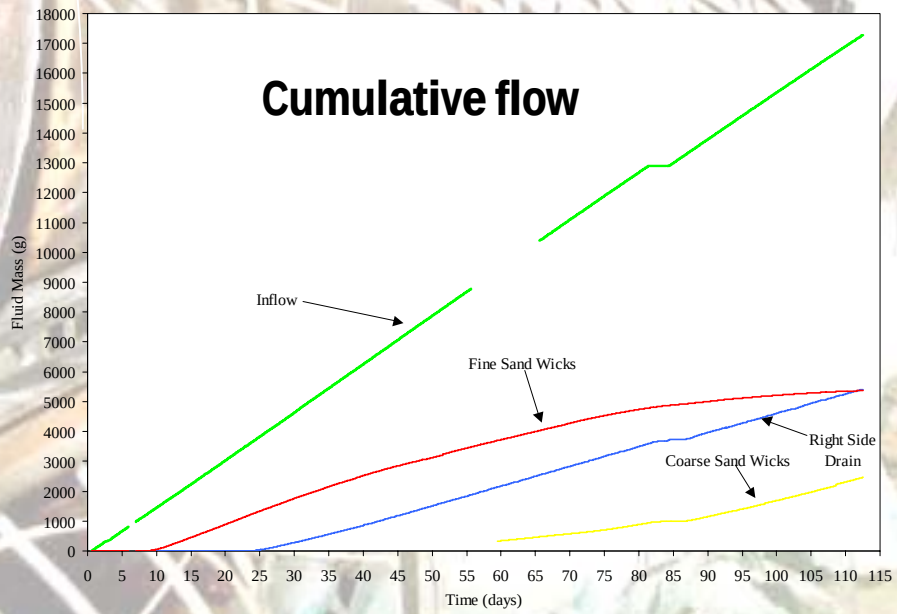
19 days



49 days



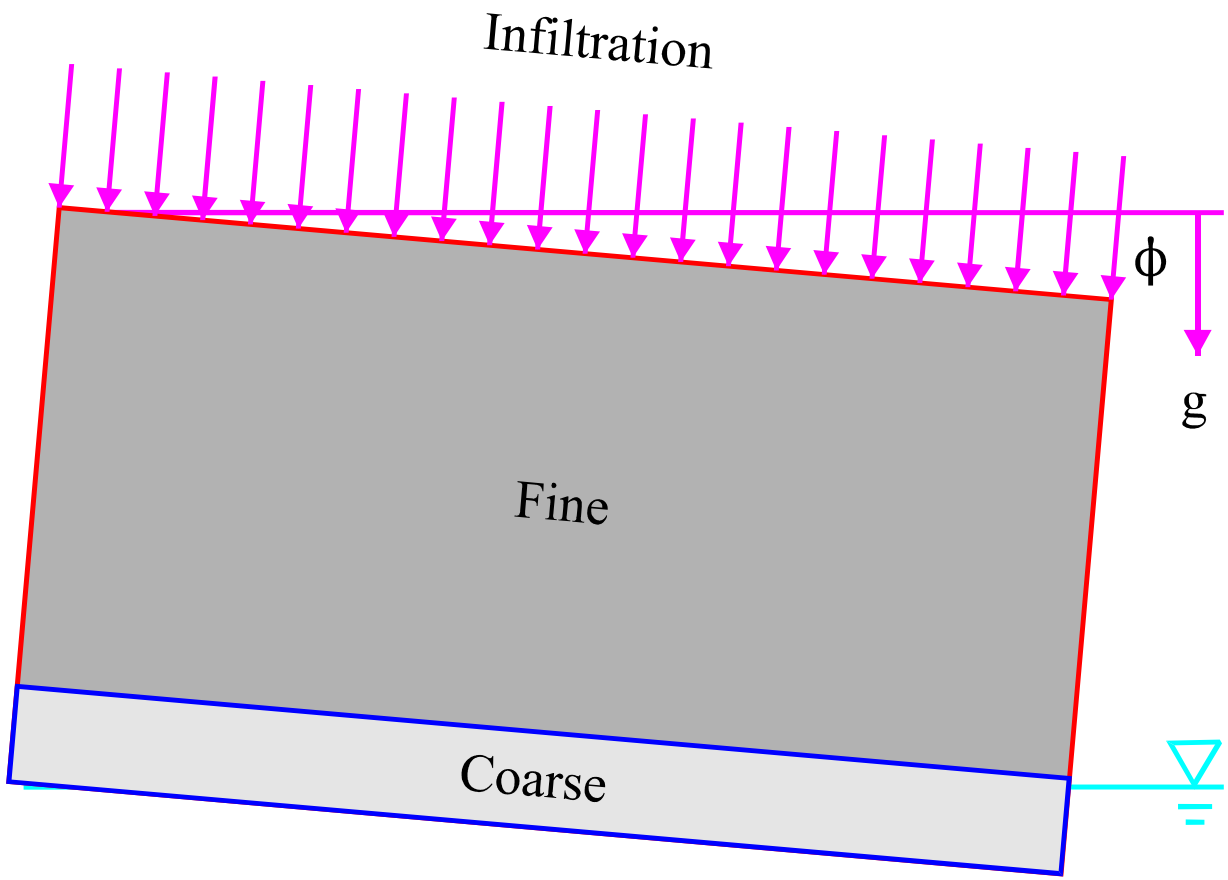
82 days



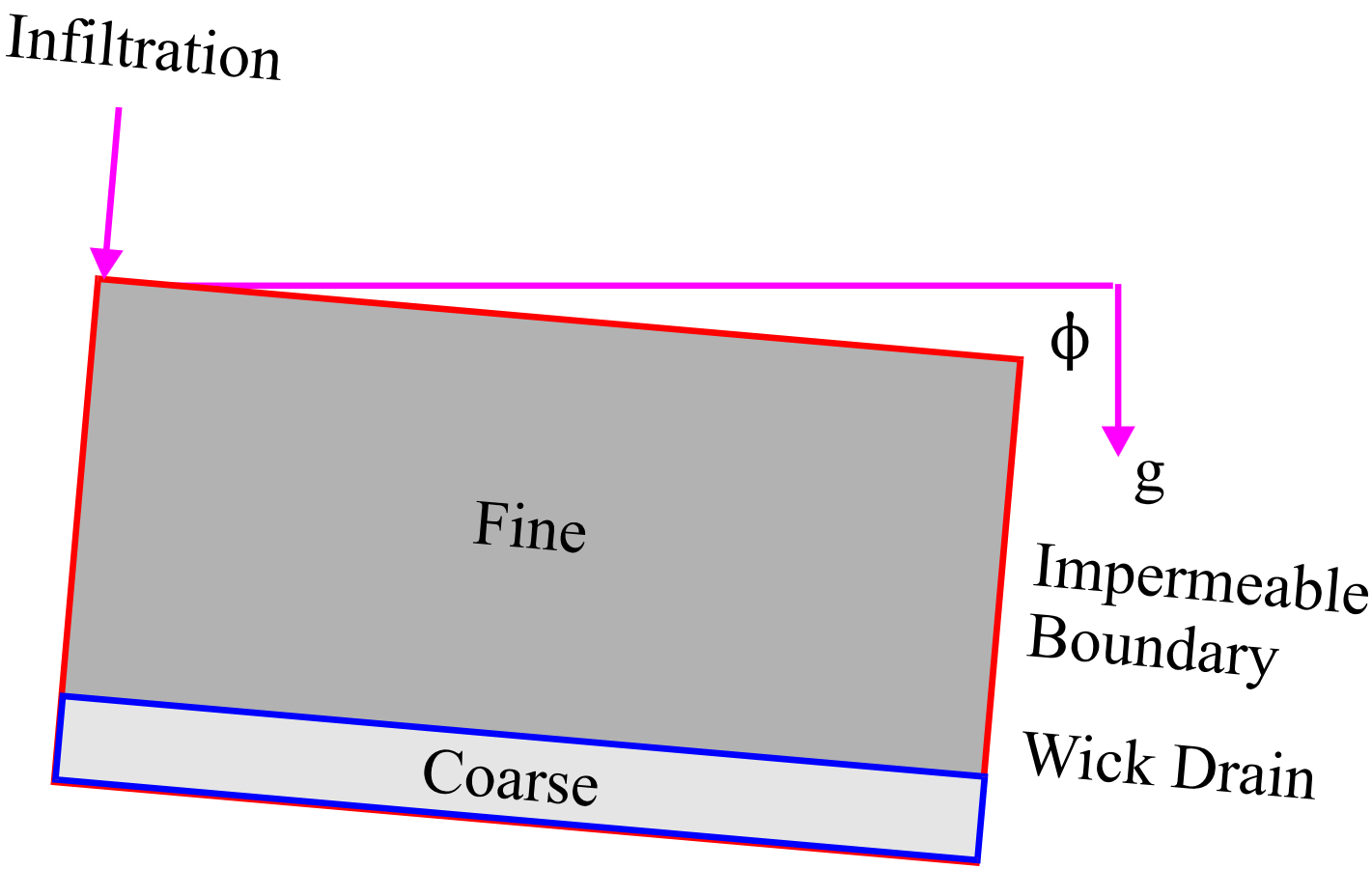
Capillary Barrier

- **The EBS Capillary Barrier System is Much Different Than a "Typical" Capillary Barrier**
  - **Single Infiltration Point vs. Uniform Infiltration**
  - **Finite Boundary vs. "Long" Barrier - Wick BC**
- **Ross' Equation for Capillary Barriers Not Appropriate Performance Evaluation Tool**

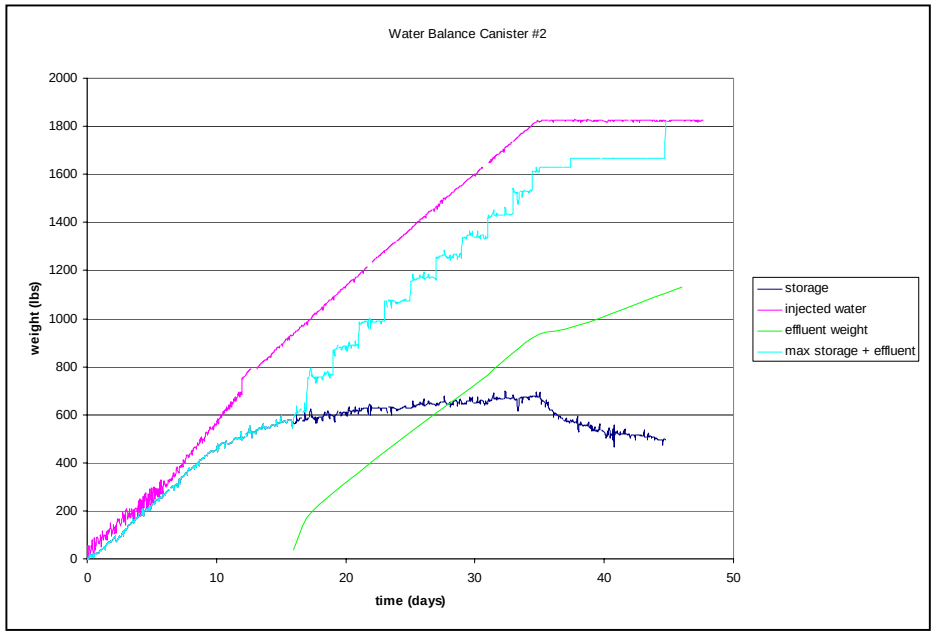
“Typical” Capillary Barrier



EBS Capillary Barrier



Engineered Barrier System Testing

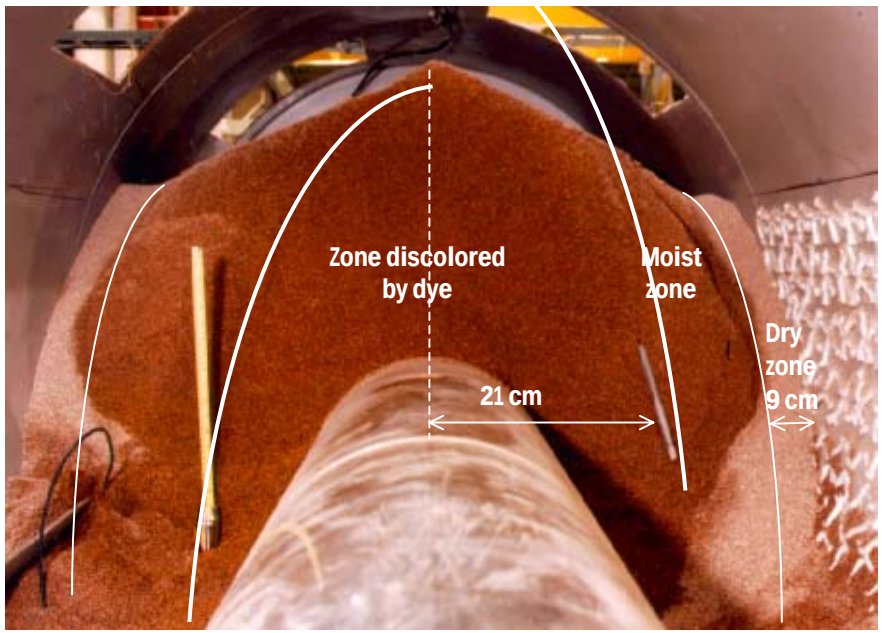


Canister #2 (Plain Backfill) water balance

- Water was observed at the top of the simulated waste package within three days after startup and began to appear at drainage wicks at seven days
- Nearly all the injected water is accounted for in the water balance (within 5 lbs.)
- Plain backfill of the particle sizes used in the EBS testing does not provide hydrologic protection to the simulated waste package

Engineered Barrier System Testing

(Continued)



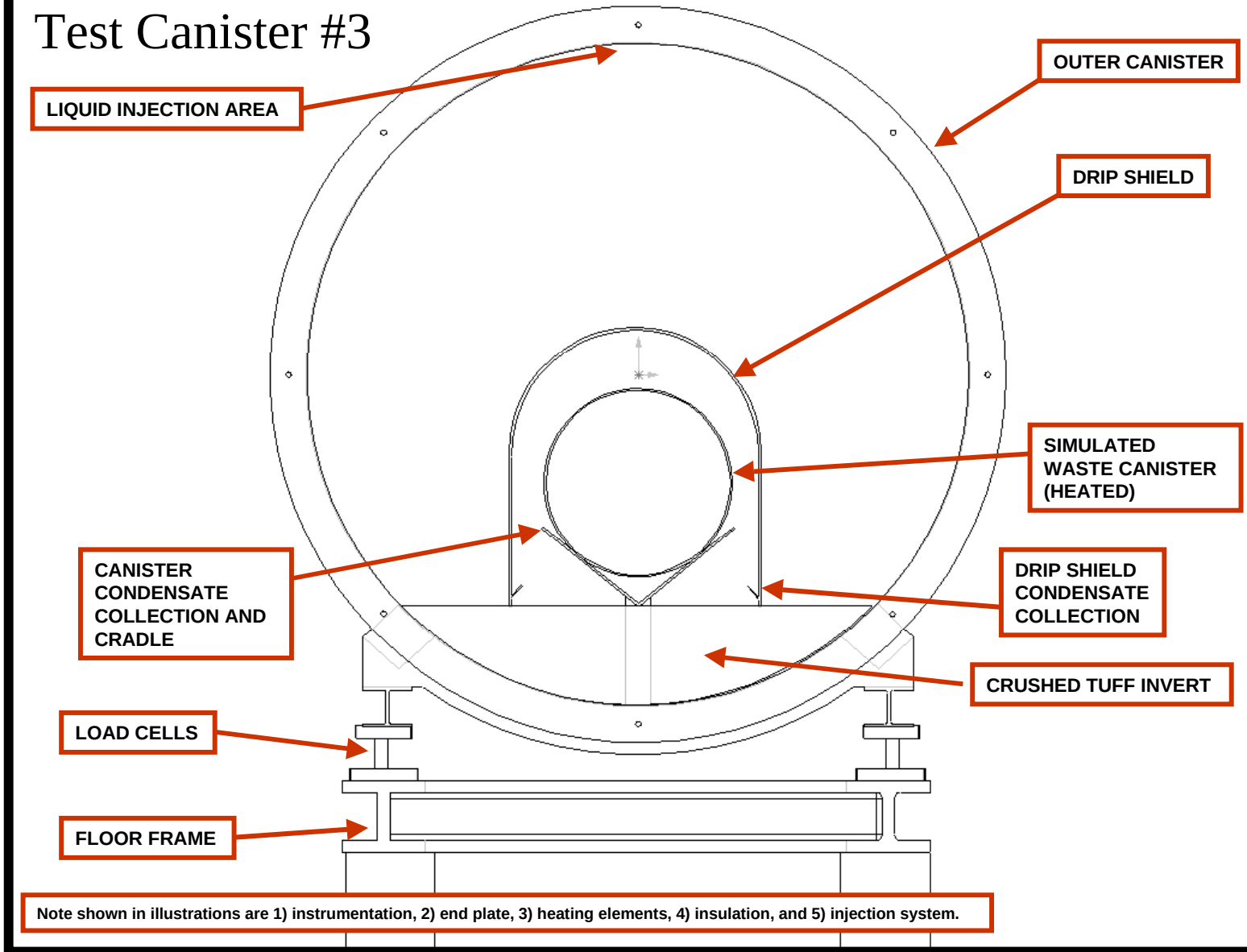
Canister #2
(plain backfill) post-test

- **Post test excavation shows that the dyed water moved downward by gravity and spread laterally around the simulated waste package**
- **Region near the edges of the canister remained dry although the entire coarse backfill continued to "wet" due to capillarity caused by presence of "fines"**

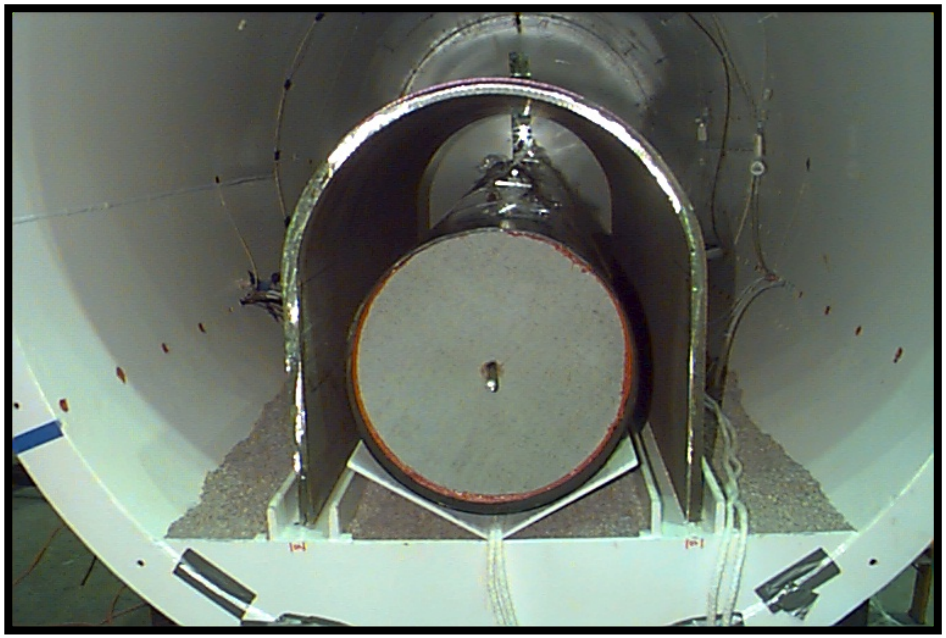
Preliminary Conclusions

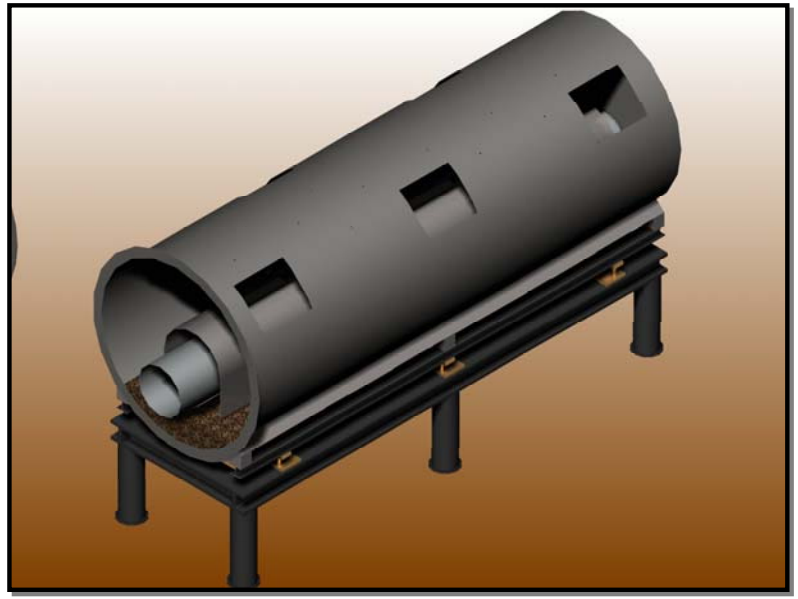
- **Simple Pre-Test Model Gives “Reasonable” Results**
- **Capillary Barrier Diverts Water Toward the Drift Wall**
- **Standard Backfill Has No Diversion Capability**
- **Performance of Capillary Barrier Dependent on Wick Boundary Condition (Leakage, Diversion)**
- **Much Different Than Standard Capillary Barrier**

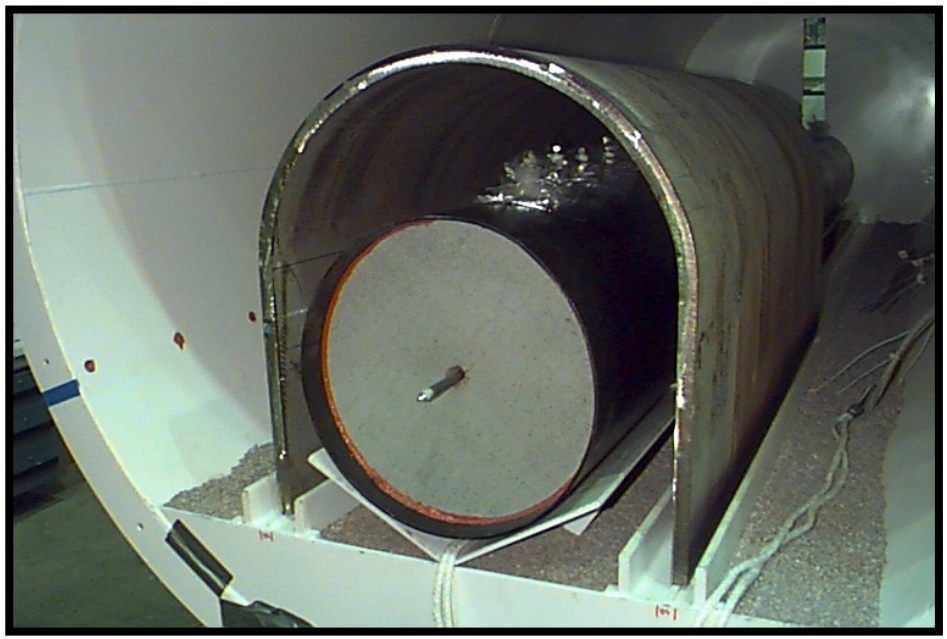
Test Canister #3



Note shown in illustrations are 1) instrumentation, 2) end plate, 3) heating elements, 4) insulation, and 5) injection system.







Engineered Barrier System Testing

- **Test Canister #3**
  - **Preliminary Results**
    - **Inner surface of drip shield was contacted by moisture near drip shield joints, but no dripping occurred.**
    - **Surface of the mock waste package did not come in contact with moisture**
    - **Salt deposits visible on the outer surface of the drip shield and invert**
    - **Carbon steel coupons on outer surface of drip shield were visibly corroded**
    - **Ti coupons on outer surface of drip shield had an oxide film**
    - **Coupons between drip shield and mock waste package did not show any obvious change**

Waste Package Materials Testing

- **Objective is to confirm corrosion rates and mechanisms of candidate waste package and drip shield materials**
- **Both long-term and short-term testing is underway to address key materials degradation issues**
- **Test environments include range of expected water chemistries, including concentrated and near saturated J-13 solutions from dripping onto hot packages**

Waste Package Materials Testing
(Continued)

- **Localized corrosion testing is emphasizing cyclic polarization, crevice corrosion testing, hydrogen pickup, and microbiologically-influenced corrosion**
- **Long-term stability of passive films on Alloy 22, titanium Grade 7, and stainless steel is being evaluated using microstructural examination with the Atomic Force Microscope**

Waste Package Materials Testing
(Continued)

- **Stress Corrosion cracking of all candidate alloys and hydrogen induced cracking of titanium alloys are being extensively evaluated utilizing a variety of crack initiation and growth tests**
- **Testing of (small scale mockup) welded samples is underway to evaluate stress mitigation methods, including induction annealing and laser peening**
- **Long-term thermal stability of Alloy 22 is being evaluated for the impact of the generation of ordered and precipitated intermetallic phases on corrosion for both welded and aged specimens**