Update of
Busted Butte Transport Test:
Phase 1 Preliminary Results

Presentation to:
Nuclear Waste Technical Review Board (NWTRB)

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U.S. Department of Energy
Office of Civilian Radioactive Waste Management
The Yucca Mountain Vicinity

Yucca Mountain From Southwest

Busted Butte From Northwest
The Unsaturated Zone Transport Test at Busted Butte

Test Objectives

- Evaluate influence of heterogeneities on flow and transport
- Evaluate other aspects of site, including fracture/matrix interactions and permeability contrast boundaries
- Consider colloid migration in unsaturated zone
- Test use of laboratory sorption data at field scale
- Calibrate and validate site-scale flow and transport model
- Address scaling issues
The Busted Butte Test Plan

- UZ field test designed to proceed in three phases. The first two Phases support the Site Recommendation and License Application.
- Phase I consists of short (2m long) closely spaced injection or injection/collection boreholes to give early results.
- Phase 2 consists of a larger scale and longer duration test which uses radionuclide analogue tracers.
- Phases I and II are being run concurrently.
- Phase III tests will support Performance Confirmation transport testing and it may have a thermal component.
Busted Butte Tracers for Phase I and Phase II

**Phase I:**
- Lithium Bromide
- Potassium Iodide
- Fluorescent polystyrene latex microspheres (two sizes)
- Plutonium Analogs, (colloidal form)
- Sodium Fluorescein
- Pyridone
- 2,4-difluorobenzoic acid
- 2,6-difluorobenzoic acid
- 2,4,5-trifluorobenzoic acid
- 2,3,4,5-tetrafluorobenzoic acid
- Pentafluorobenzoic acid

**Phase II (Same as Phase I plus the additional tracers listed):**
- Neptunium Analogues (Np$^{5+}$):
  - Nickel (II) chloride hexahydrate
  - Cobalt chloride hexahydrate
  - Manganese chloride tetrahydrate
- Plutonium Analogue, (Pu$^{3+}$):
  - Samarium Chloride hexahydrate
- Americium Analogs (Am$^{3+}$):
  - Cerium (III) chloride heptahydrate
- Rhodamine WT
Laboratory Data on Unsaturated Hydrologic Properties

Data collection and interpretation performed by L. E. Flint, U.S. Geologic Survey

<table>
<thead>
<tr>
<th>Sample</th>
<th>Porosity</th>
<th>Bulk Density</th>
<th>Ks (m/s)</th>
<th>alpha (1/bars)</th>
<th>n</th>
<th>air entry (bars)</th>
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<td>Inj1-21.8</td>
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<td>1.00</td>
<td>1.0E-05</td>
<td>18.7</td>
<td>1.2</td>
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<td>Inj3-3.5</td>
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<td>0.12</td>
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<td>Inj3-8.2</td>
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<td>Inj3-23.0</td>
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<td>1.3</td>
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<td>3.0E-06</td>
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<td>1.2</td>
<td>0.10</td>
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</table>
Laboratory Data on Unsaturated Hydrologic Properties

Data collection and interpretation performed by L. E. Flint, U.S. Geologic Survey

Fit to moisture retention curve data

Direct measurements of the unsaturated hydraulic conductivity agree well with the van Genuchten model

Model result compared to conductivity data
Chemical Analyses Performed
June 30, 1999

• ~7000 pads collected
• ~1000 pads extracted for all except metals and microspheres
• Over 10,000 separate analyses (FBAs, bromide, and dyes)
Busted Butte Test Layout
Water is readily imbibed into the rock matrix even when injected directly into the fracture.
Phase IA Mine Back

Busted Butte Unsaturated Zone Transport Test
Phase 1a Mine back (Gilles Bussod in photo)
100 cm depth (second layer, on plane of injection points)
UV illumination, fluorescein dye tracer
February 2, 1999
LANL/SEA
Phase IA Mineback

RESULTS:

• Strong Capillary Flow
• Insignificant Fracture Flow
• Lithologic Contacts = Flow Heterogeneities
Phase IA Results: Matrix Flow in CHn

UZTT-BB-PH1-3: 8 month injection @ 10 ml/h
Phase I Modeling

- Three-dimensional pre-test predictions to aid in the design of the tests
- Two-dimensional heterogeneous simulations used for pre-test predictions - unfractured (Phase IA) and fractured (Phase IB)
- Stochastic models use for pre-test predictions and to understand uncertainty
Transport Field Testing to Confirm Modeling Results

Field Test Results

Numerical Simulation

Fluid saturation during injection
Confirmation of Transport Processes

Field Result
Phase IA

8 mo. Injection @ 1 ml/h
Busted Butte Transport Test: Current Status Phases IA/IB

Tentative Conclusions:
• Long travel times in Calico Hills unit
• Migration of water from fractures into the rock matrix, where sorption can take place

Other Short-Term Expected Results:
• Information on movement of colloids in unsaturated rock
• Data on sorptive retardation in the Calico Hills

Data and analyses from the test will be used as part of the scientific and technical basis for the preparation of the License Application
Site Scale Performance Predictions for the Unsaturated Zone

The Calico Hills formation is predicted to be the main barrier to radionuclide migration, yet its flow and transport characteristics have not been measured until this test.

Breakthrough curve assuming fracture flow from repository to water table

N - nonsorbing  
M - moderately sorbing  
S - strongly sorbing

Breakthrough curve assuming matrix flow in the Calico Hills formation
Phase II Modeling: Predicted Moisture Front
Travel Times to the Water Table

0.1% Arrival

50% Arrival

Easting, m

Northing, m

0.1% Travel Time, years

Easting, m

Northing, m

0.5% Travel Time, years
Phase II Modeling: Fluid and Tracer Front Prediction

Fluid Saturation Difference

Tracer Concentration

Simulation Time: 1 year
# Phase II Pre-Test Predictions of Tracer Breakthrough Times

Table 20. Fluorescein from Upper Injection Boreholes.
(Refer to M&O/YMP file: cons.trc, generated July 9, 1998.)

<table>
<thead>
<tr>
<th>Borehole number</th>
<th>5% breakthrough concentration</th>
<th>50% breakthrough concentration</th>
<th>Normalized concentration at 1 yr</th>
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<td>16</td>
<td>27 days</td>
<td>68 days</td>
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<td>17</td>
<td>48 days</td>
<td>118 days</td>
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<td>118 days</td>
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<td>15</td>
<td>103 days</td>
<td>218 days</td>
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<tr>
<td>13</td>
<td>103 days</td>
<td>218 days</td>
<td>0.90</td>
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<tr>
<td>12</td>
<td>212 days</td>
<td>&gt; 1 yr</td>
<td>0.46</td>
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<tr>
<td>Remaining collection boreholes</td>
<td>&gt; 1 yr</td>
<td>&gt; 1 yr</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Phase II Modeling: Fluid Saturation Distribution Simulation

Initial

After 1 year on injection