NUCLEAR WASTE TECHNICAL REVIEW BOARD
FULL BOARD MEETING

SUBJECT: A FEATURES-BASED DRILLING APPROACH FOR DEEP PERCOLATION STUDIES AT YUCCA MOUNTAIN

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Example Model Hierarchy

Global Climate Model (GCM)

Regional Climate Model (RCM)

Climatic Parameters

Watershed Model

Net Infiltration

Geohydrologic Model for UZ System

Deep UZ Moisture Distribution and Flux

Precipitation
Air Temperature
Solar Radiation
Wind

Paleoclimate Studies

Site-Suitability Evaluations

Performance Assessment

KEY
Model
Data
Presenter
Decision

S. Thompson

J. Stuckless

A. Flint

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G. Bodvarsson

J. Rousseau

4PSUZR5P1.125 NWTRB/4-21/22-93
Presentation Outline

- Purpose and objectives
- Overview of percolation studies
- Borehole siting strategy
- Existing data base
- Setting priorities
- Changes in study
- Preliminary findings and possible interpretations - UZ#16

Achieving study goals
Purpose and Objectives

To characterize current flux in the unsaturated zone at Yucca Mountain, NV, through field and laboratory measurements of

- Matrix hydrologic properties
- In situ permeability
- In situ fluid flow potentials

Uniform flux vs. concentrated flux
Overview of Percolation Studies
UZ Percolation Studies

Data source

UZ borehole & multiple borehole sites

Studies

Chlorine 36 (cuttings)

Hydrogen (core & borehole)

Gaseous phase flow (borehole)

Matrix hydrologic properties (core)

Air permeability testing (borehole)

Fluid flow potentials (borehole)

Vertical seismic profiling (borehole)

Objectives

• Porosity
• Relative permeability
• Moisture retention
• Saturation & water potential

• Fracture & matrix permeability
• Fracture inter-connectedness

• Pneumatic pressure, temperature & water potential
• Flow directions & gradients
• System stability
• Diffusion & saturation permeability

• 3-D subsurface imaging
• Geologic structure
• Fault/fracture system continuity

Scale (temporal and spatial)

Small

Medium to large

Large

Very large
## UZ Percolation Studies

<table>
<thead>
<tr>
<th>Data source</th>
<th>Studies</th>
<th>Objectives</th>
<th>Scale (temporal and spatial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UZ borehole &amp; multiple borehole sites</td>
<td>Chlorine 36 (cuttings)</td>
<td>• Dating of water</td>
<td>0-50 years</td>
</tr>
<tr>
<td></td>
<td>Hydrochemistry (core &amp; borehole)</td>
<td>• Dating of water &amp; gas&lt;br&gt;• Pore-water chemistry&lt;br&gt;• Gas chemistry</td>
<td>$^3$H 0-100 years&lt;br&gt;$^{14}$C 100 - 40,000 years</td>
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<tr>
<td></td>
<td>Gaseous phase flow (borehole)</td>
<td>• Convective gas-flow processes</td>
<td>Large</td>
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</table>
Siting Strategy

“...Target those areas of interest with the greatest potential to provide the evidence needed to assess the suitability of Yucca Mountain as a repository for high-level radioactive waste” (YMP-USGS-SP 8.3.1.2.2.3)
Siting Criteria

- Large-scale structural features
- Surface drainage features
- Topographic features
Features-Based Boreholes
Yucca Mountain, Nevada
Existing Data Base for Deep Percolation Studies
Existing Boreholes in the Vicinity of Yucca Mountain
Existing Dry-Drilled Boreholes in the Vicinity of Yucca Mountain
“All boreholes are not created equal!”
Existing Dry-Drilled Boreholes, Deeper than 500 feet, in the Vicinity of Yucca Mountain

- USW UZ-1 (1269 ft.)
- USW NRG-6 (1100 ft.)
- USW UZ-6s (518 ft.)
- USW UZ-6 (1886 ft.)
- UE-25 UZ-16 (1686 ft.)
Existing Cored, Dry-Drilled Boreholes, Deeper than 500 feet, in the Vicinity of Yucca Mountain
Drilling Sequence and Prioritization
Setting Priorities

- Importance to early site-suitability assessments
- Operational and technical constraints
- Test interference constraints
- Optimize information return
- Funding and resource limitations
Features-Based Boreholes
Yucca Mountain, Nevada

Yucca Crest

1 mile
1 km
Drilling Sequence & Prioritization I

VSP surveys

UZ-16 → UZ-14 → UZ-7 → UZ-9 → UZ-8 → UZ-9a → UZ-9b

- Imbricate Fault
- Drill Hole Wash
- Ghost Dance Fault

- Geophone instrumented
- Hydro-instrumented

Cross-hole tomography UZ-16

Cross-hole tomography UZ-16
Drilling Sequence & Prioritization II

VSP surveys

UZ-6 → UZ-4 → UZ-5 → UZ-11 → UZ-2 → UZ-12 → UZ-3

- Yucca Crest
- Pagany Wash
- Solitario Canyon Fault

Cross-hole tomography UZ-6

Geophone instrumented
Hydro-instrumented
Drilling Sequence & Prioritization III

or select Sandia boreholes (systematic drill holes)

Non-structurally controlled boreholes

Hydro-instrumented
Changes In Study

- Limited changes to date
- Program in its infancy (15% of footage drilled)
- Inclusion of select number of systematic boreholes into testing and measurement program
- Possible elimination of boreholes outside of CPDB with inclusion of systematic boreholes
- Possible reduction in depths and coring requirements at multiple borehole sites
Preliminary Findings
UE-25 UZ#16
Water Levels During the Drilling of UZ-16

- Estimated
- Water level
- Dry-bail run
- Bailed water
- Cores:
  - Unsaturated, dry on surface
  - Unsaturated, wet on surface
  - Saturated
- Reamed sections

Depth, ft

Feb 24 26 28 30 32 34 36
Mar 2 4 6 8 10 12 14 16 18 20 22 24 26

Saturated

Unsaturated

200 gal

1686'

1600

1625

1650

1675
Preliminary Findings

UZ-16 (dry drilled and cored to saturated zone)

- Imbricate faults almost vertical

- Fracture density in Topopah Spring much greater than earlier estimates
  - Range: 50 to 250 per m³
  - Average: 125 per m³ vs 50 per m³ (Montazer & Wilson, 1984)

- Water encountered in fractures in Prow Pass unit in non-saturated matrix environment
Possible Interpretations
UE-25 UZ#16
Potential for Concentrated Recharge through Ghost Dance and Imbricate Fault Zones

Ghost Dance Fault Zone

Imbricate Fault System

2000 feet

4PSUZR5P13 125 NWTRB/4 21/22 93
Conceptualization of Percolation

UZ-16

Alluvium

Topopah Spring

PTn

Unsaturated (≈ 93% sat)

Saturated matrix
Possible Interpretations for Unsaturated Matrix - Fracture Flow at UZ-16

Uniform Flux

• Fracture flow in unsaturated matrix sustained by high-pressure heads and upward flow from the saturated Prow Pass

Concentrated Flux

• Fracture flow in unsaturated matrix sustained by downward fault flow derived from lateral inflow and/or near-surface infiltration
Possible Interpretations for Unsaturated Matrix - Fracture Flow at UZ-16

(Continued)

Perched Water

- Residual water from higher piezometric and/or standing water levels in the Prow Pass

* Matrix may be locally saturated near interconnected fractures and/or near adjacent fault zones
Achieving Study Goals

Answer the question:
Is percolation a

a) Uniform flux problem
b) Concentrated flux problem
c) All of the above
d) None of the above
Photo of LM-300