U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

SUBJECT: OVERVIEW OF MATRIX PROPERTIES

PRESENTER: DR. ALAN FLINT

PRESENTER'S TITLE AND ORGANIZATION: HYDROLOGIST
U. S. GEOLOGICAL SURVEY
MERCURY, NEVADA

PRESENTER'S TELEPHONE NUMBER: (702) 295-5805

DECEMBER 11-12, 1989
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MATRIX PROPERTY PROGRAM

PROGRAM RESPONSIBLE FOR:

- MEASUREMENT OF STATE VARIABLES OF ROCK MATRIX DESCRIBING IN SITU WATER CONTENT AND WATER POTENTIAL OF YUCCA MOUNTAIN

- CHARACTERIZATION OF HYDROLOGIC PROPERTIES OF ROCK MATRIX FOR FLOW MODELS:
  - BULK DENSITY, POROSITY
  - WATER RETENTION
  - UNSATURATED HYDRAULIC CONDUCTIVITY

- DEVELOPMENT OF 3-D SPATIAL STRUCTURE OF THESE HYDROLOGIC PROPERTIES
STATISTICAL ANALYSIS

- CLASSICAL STATISTICS
  - BASIS OF INITIAL SAMPLING SCHEME

- GEOSTATISTICS
  - 3-DIMENSIONAL
  - MULTIVARIATE
  - STRUCTURAL ANALYSIS (VARIOGRAPHY)
  - PREDICTION (KRIGING, COKRIGING, ETC.)
  - SIMULATION
ONE DIMENSIONAL SPATIAL VARIABILITY OF NEUTRON COUNTS IN TWO BOREHOLES IN G-TUNNEL
ONE DIMENSIONAL SPATIAL VARIABILITY OF NEUTRON COUNTS IN THREE BOREHOLES IN G-TUNNEL
HISTOGRAM OF DATA PAIRS FOR GEOSTATISTICAL ANALYSIS
MEASURING AND MODELING MATRIX PROPERTIES

- WATER CONTENT
- WATER POTENTIAL
- PERMEABILITY (GAS AND LIQUID)
  - SATURATED
  - UNSATURATED
  - MODELS
- WATER CHARACTERISTIC CURVES
  - HYSTERESIS
  - MODELS
- RELATED PROPERTIES
  - BULK DENSITY
  - PARTICLE DENSITY
  - POROSITY
PHOTOGRAPH OF CORE IN LEXAN LINER
PHOTOGRAPH OF
DIFFERENT SIZE CORE SAMPLES
WET DRILLED, NONWELDED

DISTANCE FROM RIB (m)

VOLUMETRIC WATER CONTENT

12/14/88  +  CORE

NOMPAF5P.A22/12-11-89
G-TUNNEL WATER POTENTIALS
NONWELDED TUFF
IMBIBITION MEASUREMENTS TO DETERMINE SORPTIVITY, $s$

\[ s = \frac{0.67}{f} \]

\[ \text{RELATIVE SATURATION} \quad 0.19 \quad \text{and} \quad 0.56 \]

\[ s = 0.67 \quad \text{and} \quad 0.43 \]
SORPTIVITY AT DIFFERENT INITIAL SATURATIONS

- Nonwelded Zeolitized
- Nonwelded Silicified
- Welded
USING SORPTIVITY TO EVALUATE SCALE

- 20% SATURATION
  \[ r^2 = 0.9709 \]

- 80% SATURATION
  \[ r^2 = 0.9354 \]
WATER RETENTION CURVES ON NONWELDED TUFF USING THREE METHODS

CALICO HILLS
NONWELDED, VITRIC

PAINTBRUSH TUFF
NONWELDED

SATURATION

WATER POTENTIAL, bars

SATURATION

WATER POTENTIAL, bars

SPOC
PRESSURE PLATE
CENTRIFUGE
CALICO HILLS
NONWELDED, ZEOLITIZED

WATER POTENTIAL, bars

SATURATION

SPOC
PRESSURE PLATE
CENTRIFUGE
COMPOSITE CURVE
SUBMERSIBLE PRESSURIZED OUTFLOW CELL (SPOC)
WATER RETENTION USING SPOC
HYSTERETIC CURVES

WATER POTENTIAL, bars

0.01

0.1

1

SATURATION

0 20 40 60 80 100

PAINTBRUSH TUFF

CALICO HILLS,
ZEOLITIZED

NOMPAF5P.A22/12-11-89 20
WATER RETENTION USING PSYCHROMETER
WELDED UNITS

SATURATION

WATER POTENTIAL, bars

100

10

1

0.1

0.01

0

0 20 40 60 80 100

TOPOPAH SPRINGS

TIVA CANYON

NOMPAF5 P A22/12/11-69 21
WATER RETENTION USING MERCURY POROSIMETRY

SATURATION

WATER POTENTIAL, bars

TS-WELDED
CH-ZEOLITIZED

0 20 40 60 80 100
UNSATURATED HYDRAULIC CONDUCTIVITY
PAINTBRUSH TUFF NONWELDED

ALL MODELS USED COMPOSITE WATER RETENTION CURVES

UNSATURATED CONDUCTIVITY, cm/s

PERCENT SATURATION

- Measured using centrifuge
- Measured using gas drive
- Marshall
- Van Genuchten
- Burdine
- Brooks and Corey
UNSATURATED HYDRAULIC CONDUCTIVITY
CALICO HILLS, NONWELDED, ZEOLITIZED

ALL MODELS USED COMPOSITE WATER RETENTION CURVES

- OOOOO MEASURED USING CENTRIFUGE
- DOTTED MARSHALL
- THICK VAN GENUCHTEN
- THIN BURDINE
- DASHED BROOKS AND COREY

UNSATURATED CONDUCTIVITY, cm/s

PERCENT SATURATION
G.W.C. vs. Depth

UZ-6s core

Gravimetric Water Content (g/g)

Depth (meters)

Geologic Units
- Qac-ATTU1UM/COTTOwum
- Paintbrush Tuff
- Tpc-Tlva Canyon Member
- Tpy-Yucca Mountain Member
- Tp-Pah Canyon Member
- Tpt-Topopah Spring Member
- BT -Bedded/reworked tuff

Degree of Welding
- N -Non-Welded Tuff
- W -Moderately welded tuff
- D -Densely welded tuff

NOMPAFSP A22/12-11-89 25
Water Potential vs. Depth

UZ-6s core

Depth (meters)

Water Potential (log of kilopascals)
Porosity vs. Depth

UZ-6s core

Geologic Units
- Qac-DTUV/OSSTUVium
- Paintbrush Tuff
- Tpc-Tiva Canyon Member
- Tpy-Yucca Mountain Member
- Tpp-Pah Canyon Member
- Tpt-Topopah Spring Member
- BT-Bedded/reworked tuff

Degree of Welding
- N-Normulated Tuff
- M-Moderately welded tuff
- D-Densely welded tuff

Depth (meters)

Porosity (m³/m³)
RANGE IN CORE PROPERTY VALUES CURRENTLY PUBLISHED
FOR YUCCA MOUNTAIN GEOHYDROLOGIC UNITS

<table>
<thead>
<tr>
<th>GEOHYDROLOGIC UNIT</th>
<th>POROSITY (cm³/cm³)</th>
<th>GRAIN DENSITY (g/cm³)</th>
<th>DRY BULK DENSITY (g/cm³)</th>
<th>SATURATED CONDUCTIVITY (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIVA CANYON w</td>
<td>.08-.12</td>
<td>2.3-2.8</td>
<td>1.4-2.4</td>
<td>1.5E-10-9.7E-10</td>
</tr>
<tr>
<td>PAINTBRUSH TUFF nw</td>
<td>.06-.54</td>
<td>2.2-2.6</td>
<td>1.1-2.4</td>
<td>2.3E-9 -2.4E-4</td>
</tr>
<tr>
<td>TOPOPAH SPRING w</td>
<td>.04-.33</td>
<td>2.4-2.6</td>
<td>1.8-2.4</td>
<td>1.2E-10-2.3E-7</td>
</tr>
<tr>
<td>CALICO HILLS nw</td>
<td>.14-.46</td>
<td>2.2-2.6</td>
<td>1.3-2.0</td>
<td>5.2E-10-2.9E-5</td>
</tr>
<tr>
<td>CRATER FLAT</td>
<td>.19-.38</td>
<td>2.5-2.6</td>
<td>1.6-2.1</td>
<td>2.0E-9 -6.9E-7</td>
</tr>
</tbody>
</table>

References
Anderson (1981)
Rush, Thordarson and Bruckheimer (1983)
Thordarson (1983)
Weeks and Wilson (1987)
Klavetter and Peters (1987)
Flint and Flint (1989)
SUMMARY

- CURRENTLY REFINING METHODS TO MEASURE HYDROLOGIC PROPERTIES

- ONCE ENOUGH DATA IS COLLECTED, THOROUGH ANALYSIS AND MODIFICATIONS WILL DETERMINE THE APPROPRIATENESS OF EACH MODEL IN ORDER TO SIMPLIFY MODEL REQUIREMENTS

- SAMPLING AND TESTING STRATEGY IS BASED ON A GEOSTATISTICAL ANALYSIS WHICH WILL HELP DEFINE UNCERTAINTIES IN THE HYDROLOGIC STRUCTURE