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

# NUCLEAR WASTE TECHNICAL REVIEW BOARD
# FULL BOARD MEETING

## SUBJECT: A SCIENTIFIC PERSPECTIVE ON UNDERSTANDING CURRENT AND FUTURE INFILTRATION AT YUCCA MOUNTAIN

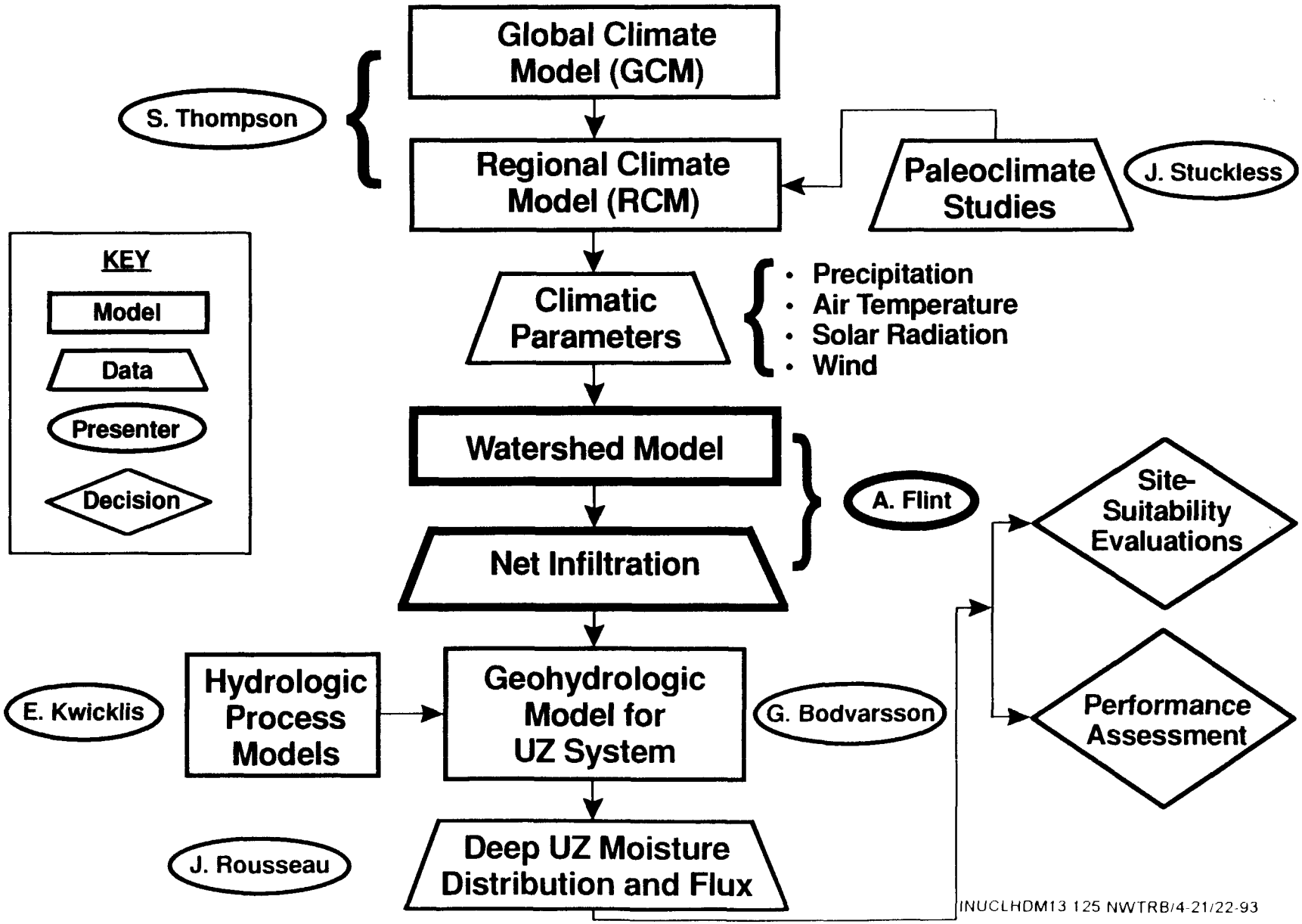

**PRESENTER:** DR. ALAN L. FLINT

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

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


RENO, NEVADA
APRIL 21-22, 1993

# Example Model Hierarchy



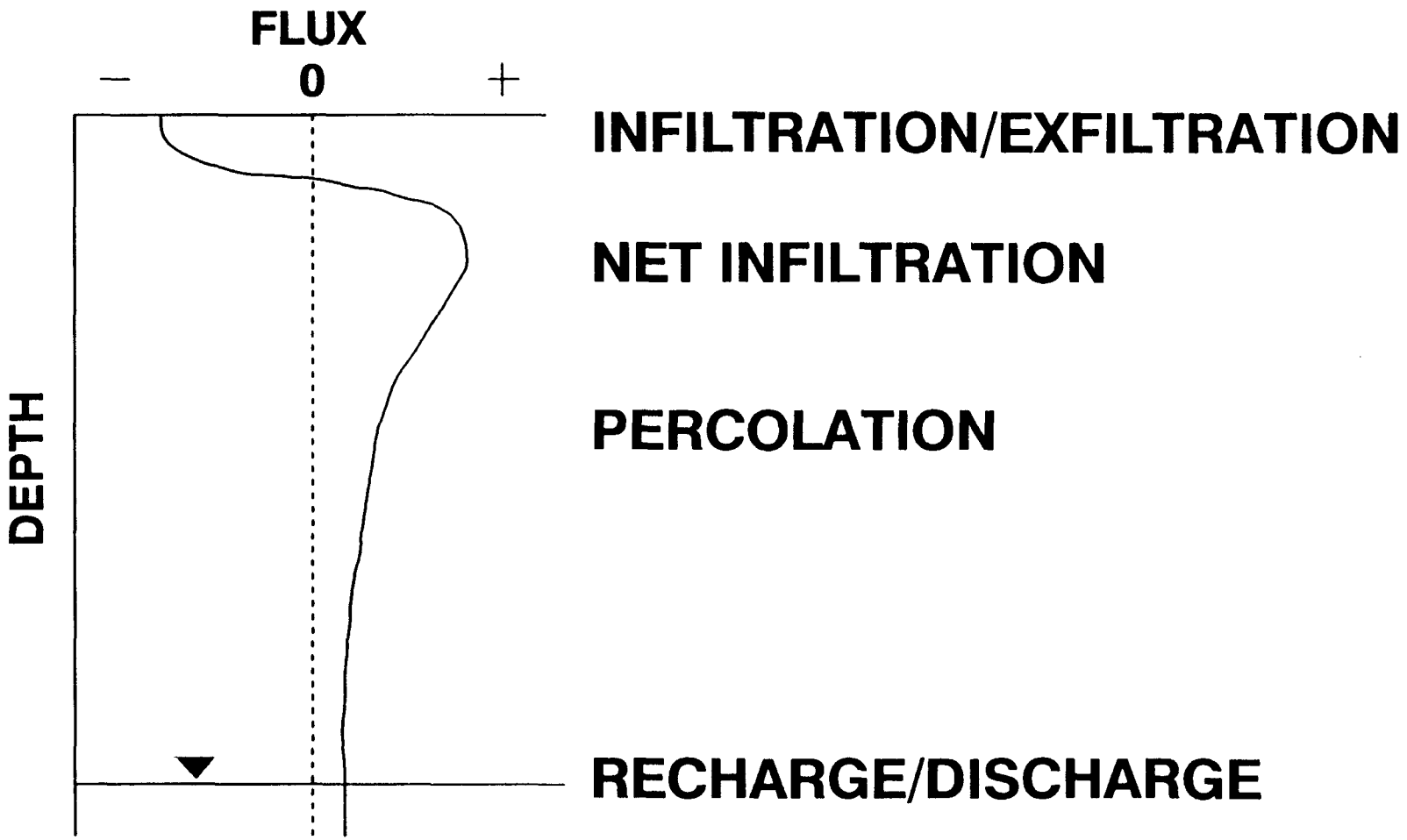
- *Study Objectives*
- *Definitions and Concepts for Infiltration*
- **Research Framework**
  - model development (what information is needed)
  - study activities (how we get the information)
  - setting priorities (in what order we collect information)
- **Current Work**
  - shallow infiltration processes (<15 m)
  - deep infiltration processes (15-100 m)
  - unsaturated zone infiltration processes (site scale)
    - 1-D, 2-D, 3-D surface to the water table
- **Real Time Decision Making**
  - Has study changed?
  - How experiments end
- **Summary**

# Objectives
## (Study Plan 8.3.1.2.2.1)

- To provide an understanding of the past, present and future flow characteristics of the unsaturated zone

- The specific objective of the unsaturated zone infiltration study is to define the upper flux boundary conditions (upper 10 m) for Yucca Mountain under both present day and simulated future wetter climatic conditions, which include the evaluation of the spatial distribution of the infiltration rate over the repository block.

# Definitions and Concepts



- **Study Objectives**
- **Definitions and Concepts for Infiltration**
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  ***model development (what information is needed)***

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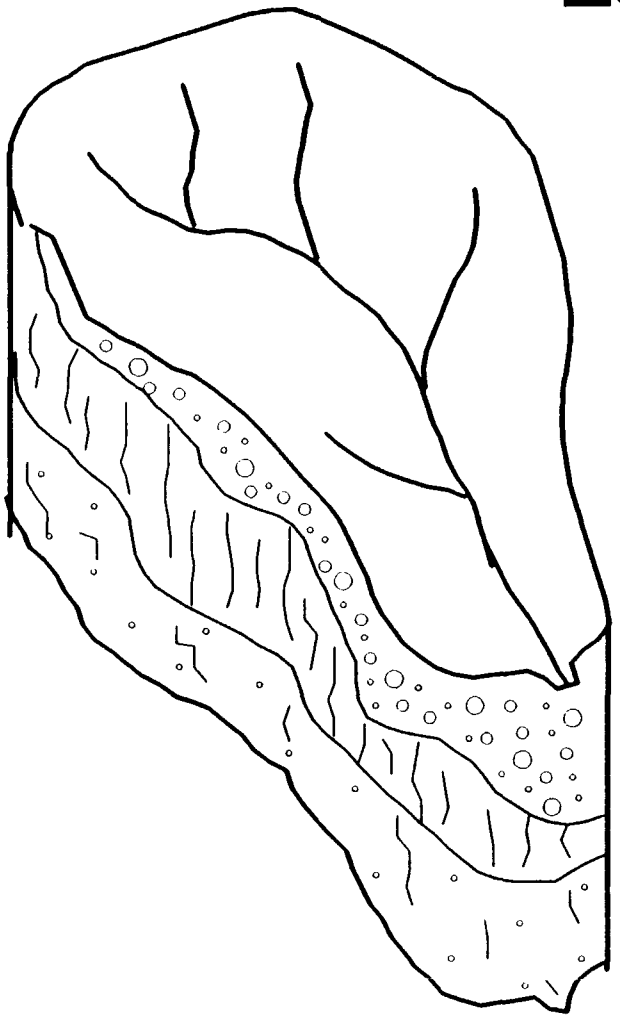
  **Has study changed?**

  **How experiments end**
- **Summary**

# Developing a 3-D Watershed Model Establishes a Framework For Infiltration Studies



## Parameters needed for 3-D model:

- geometry
- soil/rock properties
- boundary conditions
- initial conditions
- infiltration mechanisms and processes

# Activities to Provide Parameters
## Characterization of Unsaturated Zone Infiltration

### Characterization of Hydrologic Properties of Surficial Materials
(Act. 8.3.1.2.2.1.1)

- Parameters Provided
  - geometry
  - soil/rock properties
  - mechanisms
  - initial conditions
- Tests and Analyses
  - sampling, testing, mapping
  - borehole/surface geophysics
  - geostatistical analyses

bulk density, porosity, texture
water content, water potential
fractures
alluvium thickness
surface mapping units
spatial variability

### Characterization of Natural Infiltration
(Act. 8.3.1.2.2.1.2)

- Parameters Provided
  - mechanisms
  - boundary conditions
  - initial conditions
- Tests and Analyses
  - neutron hole logging
  - water budget
  - tritium profiling
  - geostatistical analyses

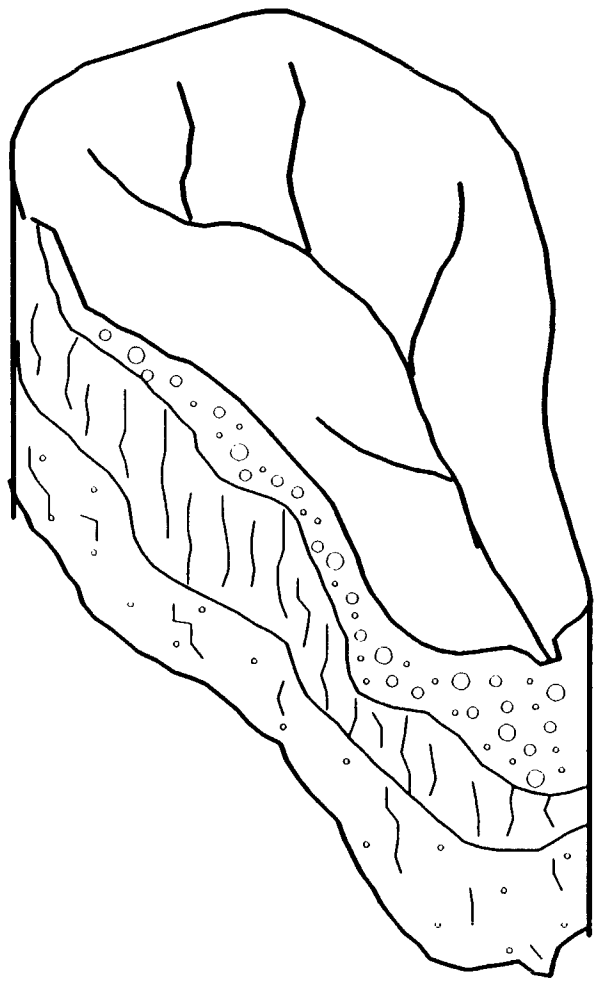
net infiltration/pathways
water content, water potential
rainfall-runoff
evapotranspiration
infiltration rates
spatial variability

### Evaluation of Artificial Infiltration
(Act. 8.3.1.2.2.1.3)

- Parameters Provided
  - soil/rock properties
  - boundary conditions
  - mechanisms
- Tests and Analyses
  - infiltrometers
  - ponding
  - rainfall simulation
  - geostatistical analyses

maximum infiltration rate
saturated conductivity
unsaturated conductivity
flow paths and velocity
rainfall-runoff-
infiltration relations

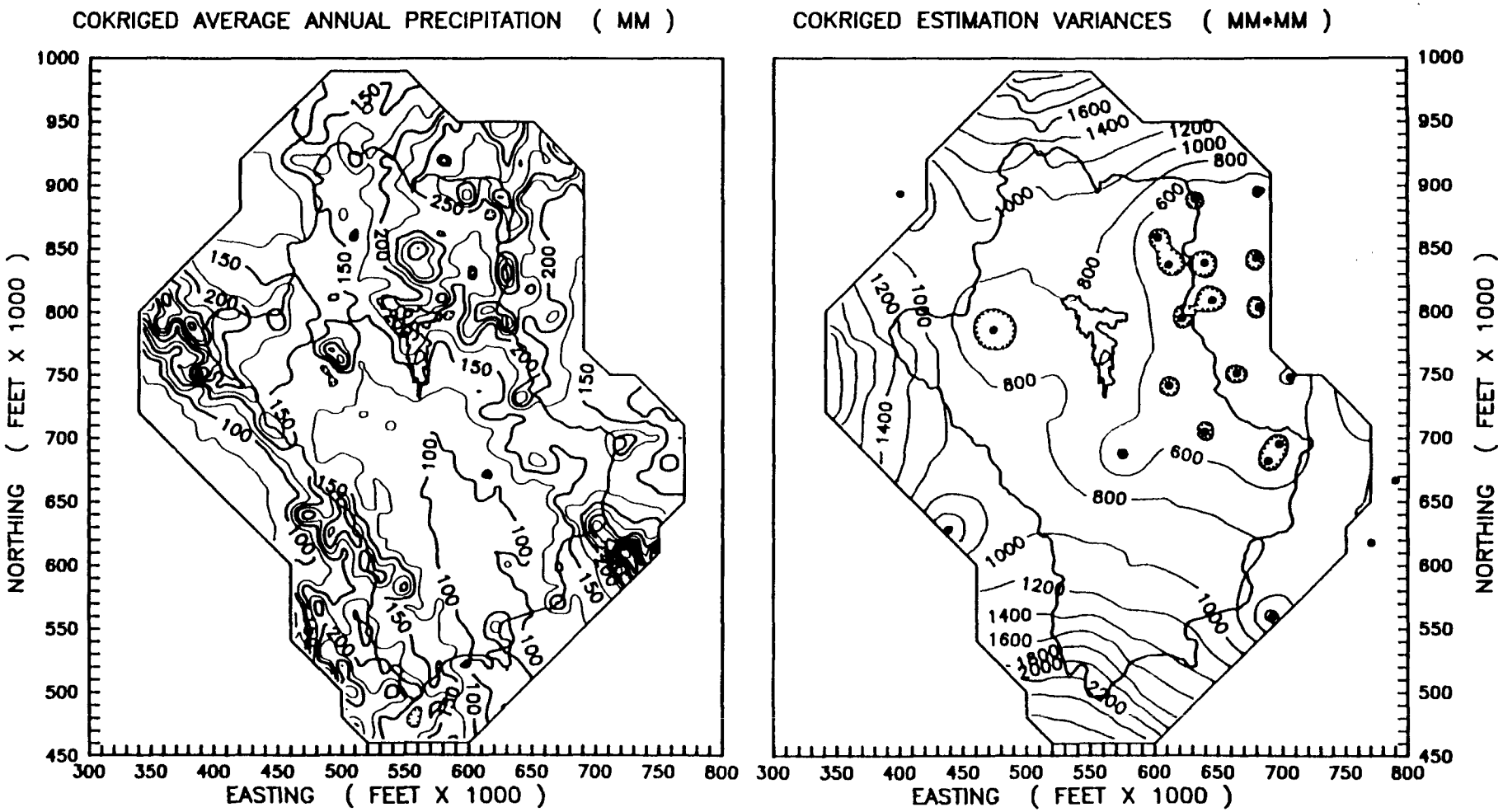
# Activities to Provide Parameters



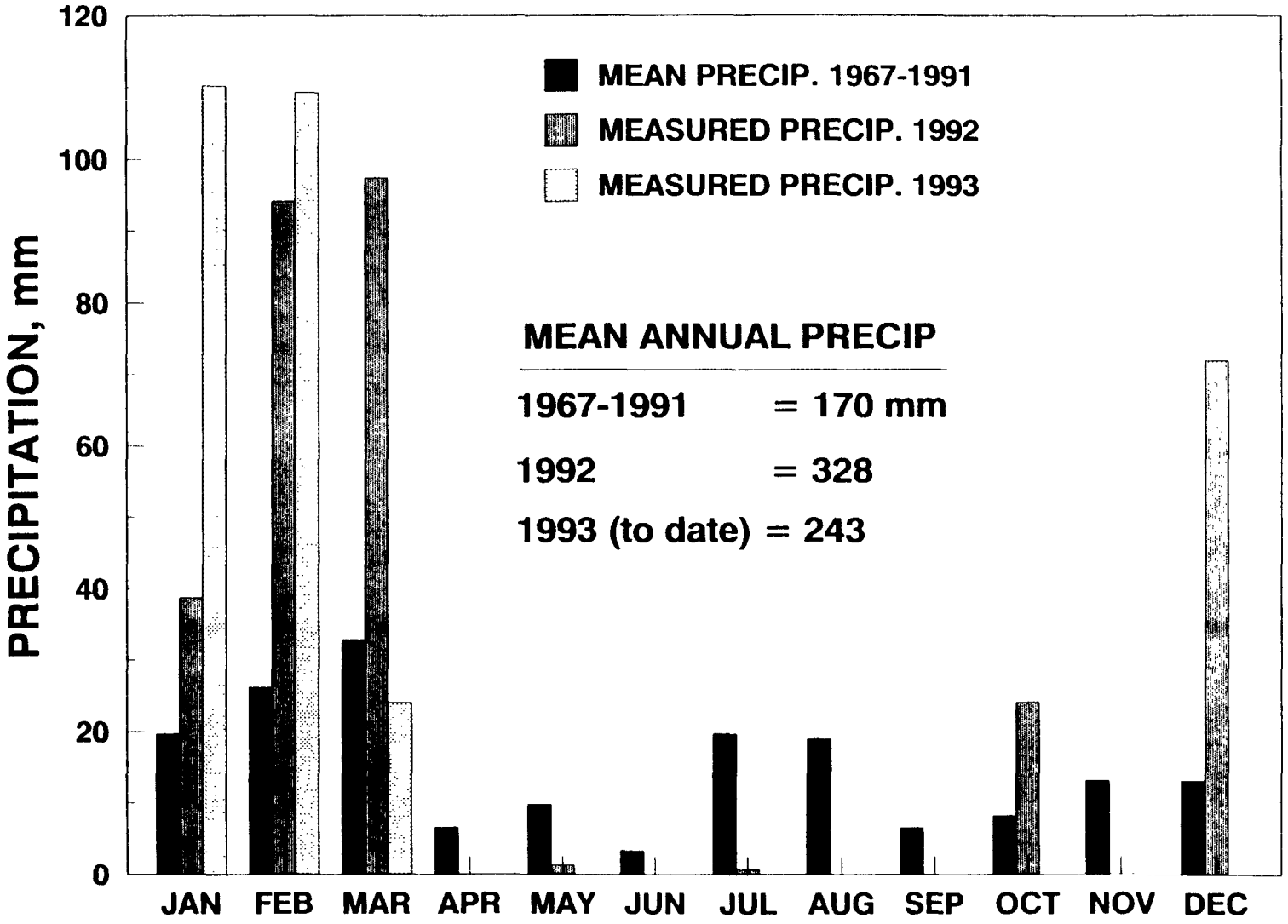
## Characterization of the Meteorology for Regional Hydrology (Activity 8.3.1.2.1.1)

- **Parameters provided:**
  - boundary conditions
- **Tests and Analyses**
  - meteorological data collection processing and storage
  - characterization of precipitation
  - analysis of meteorological data: synoptic, regional, site

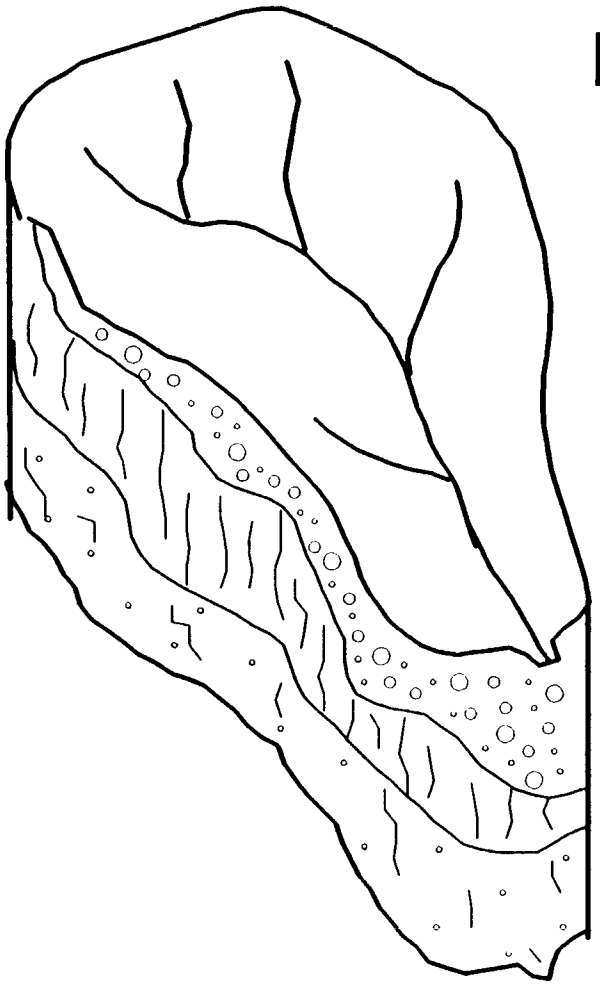
# Cokriged Estimate of Precipitation



# Jackass Flats Precipitation



# Activities to Provide Parameters



## Characterization of Matrix Hydrologic Properties (Activity 8.3.1.2.2.3.2)

- **Parameters provided:**
  - soil/rock properties
  - initial conditions
- **Tests and Analyses**
  - core properties physical and hydrologic
  - develop 3D matrix property model

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# Setting Priorities

- **Issue Hierarchy**
  - SCP, study plans
- **Peer Review/Professional Interaction/PA**
- **Budget**
  - allocation to specific activities controls most priorities
  - drilling/construction support for large scale experiments
- **Balanced Program**
  - importance of activity to a balanced program
  - data needs met by an activity with specific model in mind
- **Window of Opportunity**
  - dynamic system requires constant attention
  - monitoring programs, spontanteous events involve irretrievable data

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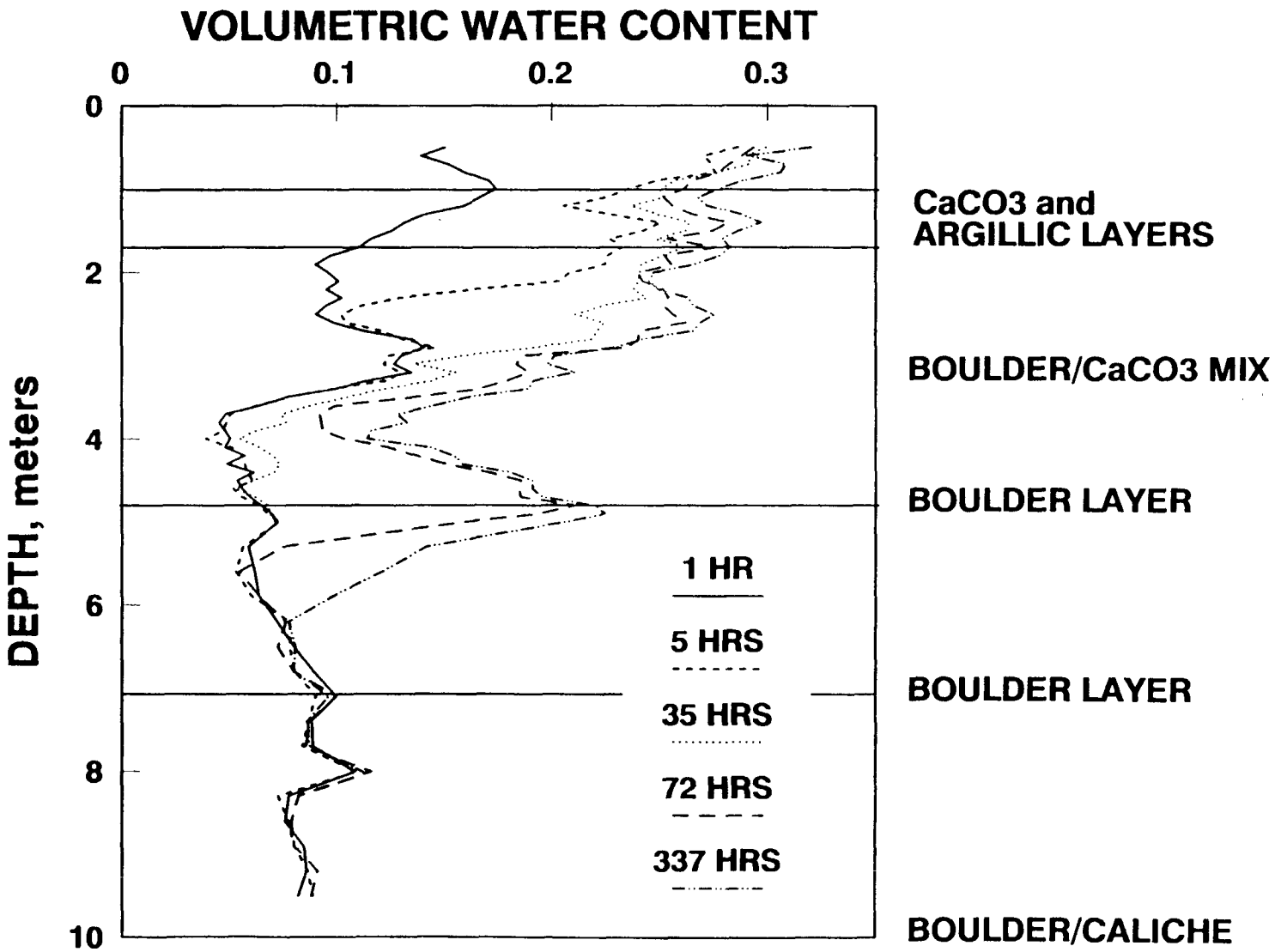
**Photo:**

**Ponding experiment at borehole N-85 at edge of Fortymile Wash**

**Photo:**

**Ponding experiment at borehole N-85, face of profile**

# Ponding Experiment



# Drainage Experiment

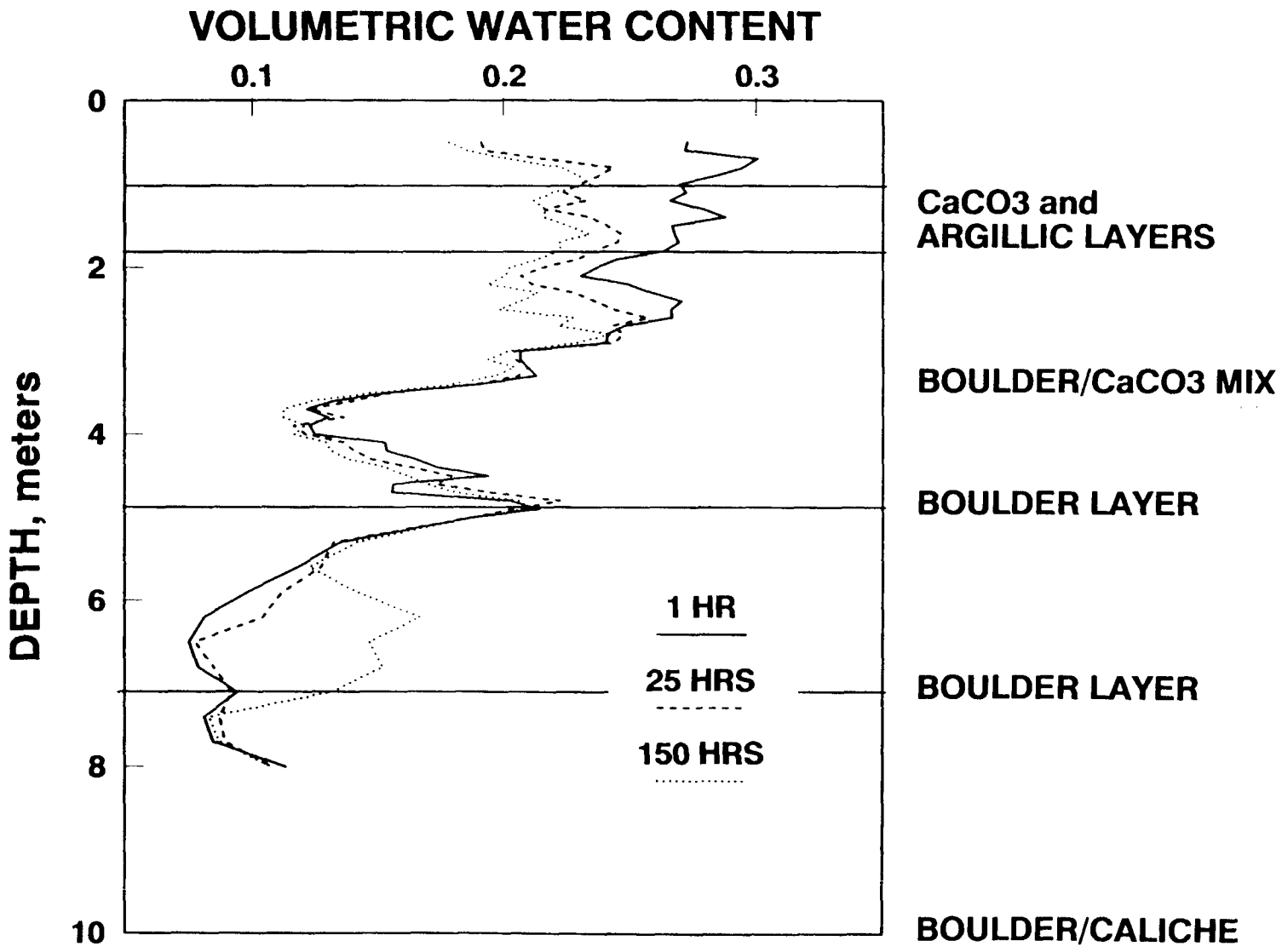


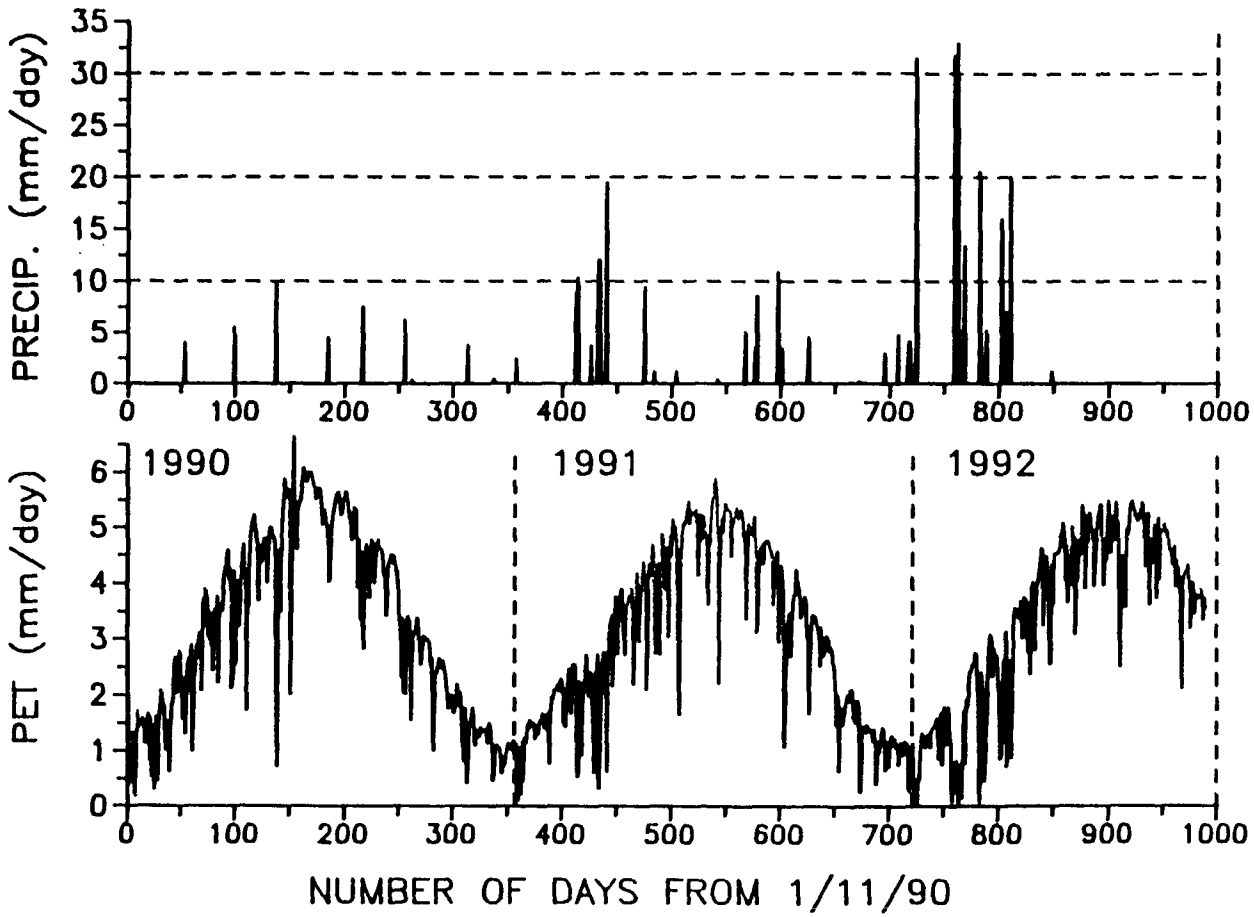
**Photo:**

**Pagany Wash, looking up wash from distance**

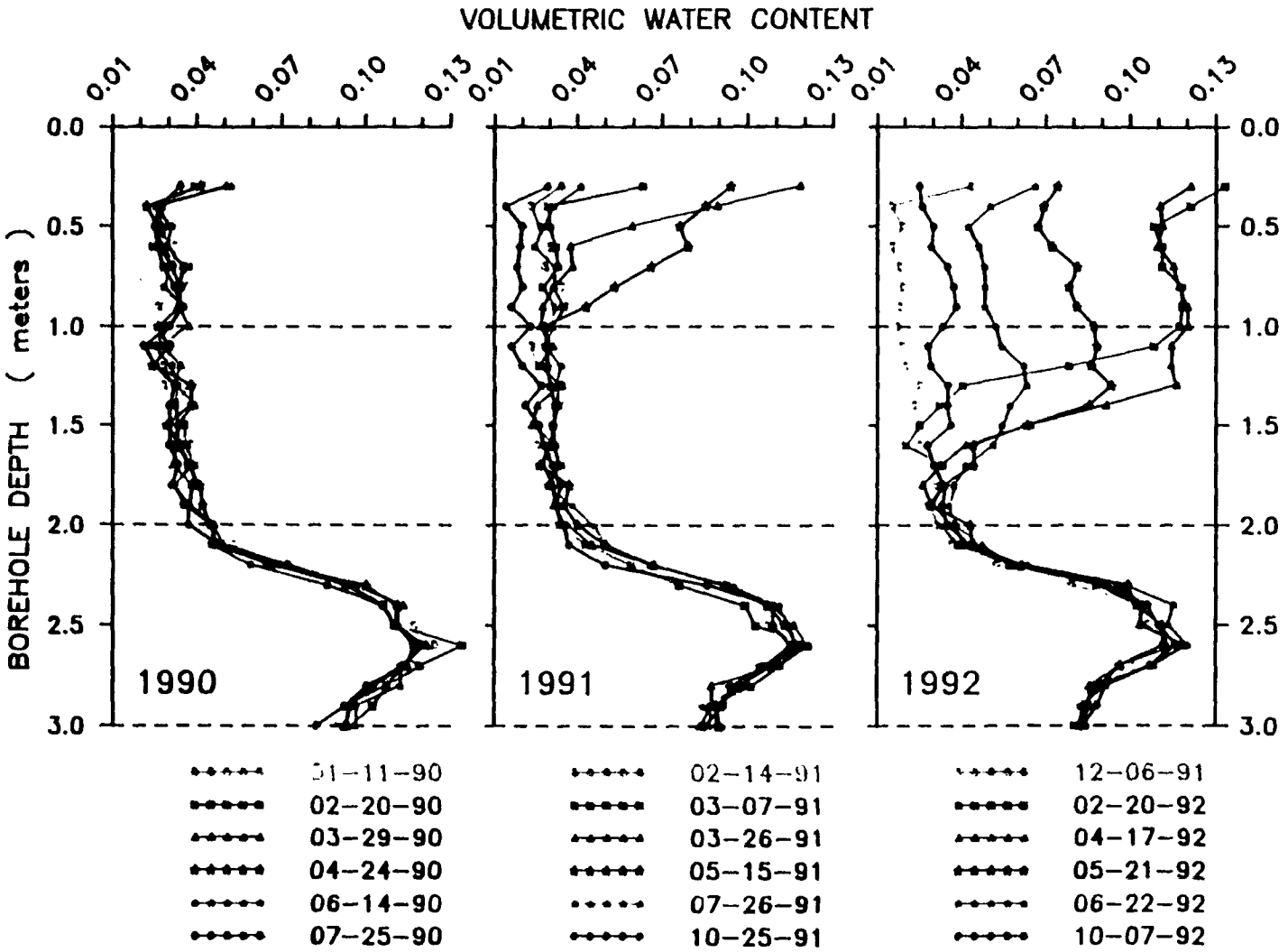
# Photo:

## Pagany Wash cross section

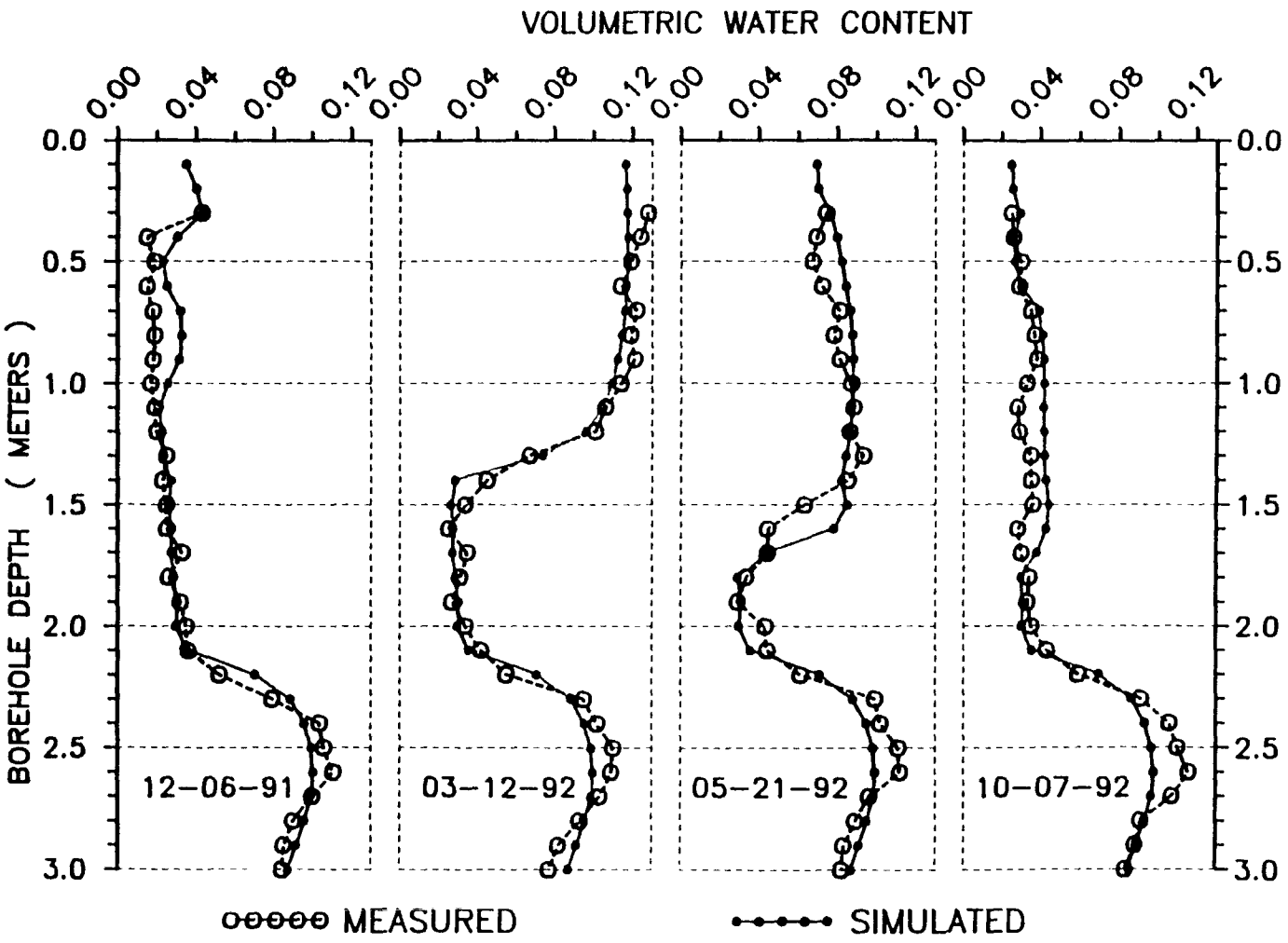
# 1990-1992 Daily Climatic Record at N-7



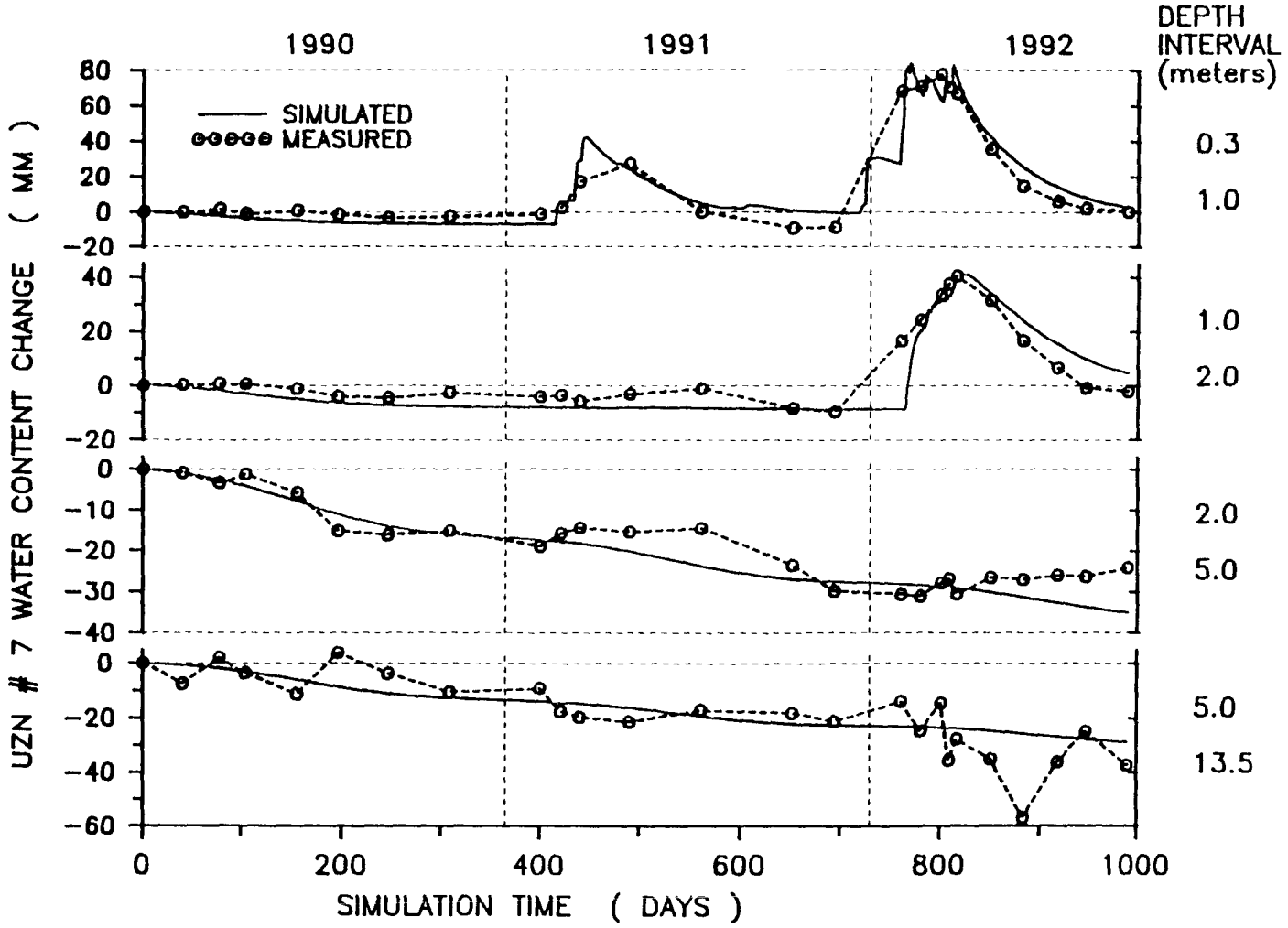
# Measured Neutron Log Profiles in N-7



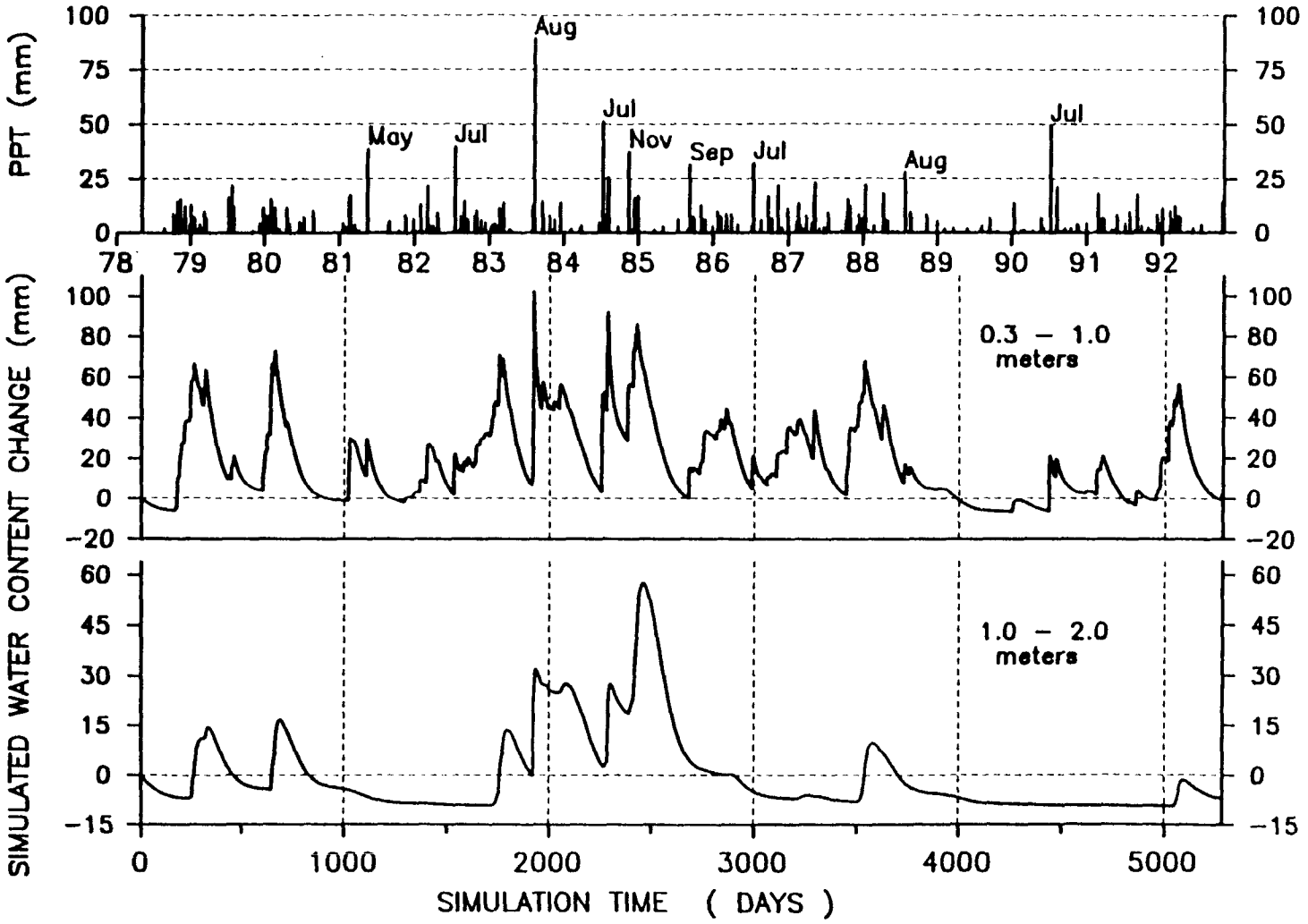
# Measured and Simulated Water Content



# Change in Water Content with Time



# Model Results Using Desert Rock Daily Climatic Record 1978-1992



# Model Results Using Desert Rock Daily Climatic Record Precipitation X 2.5

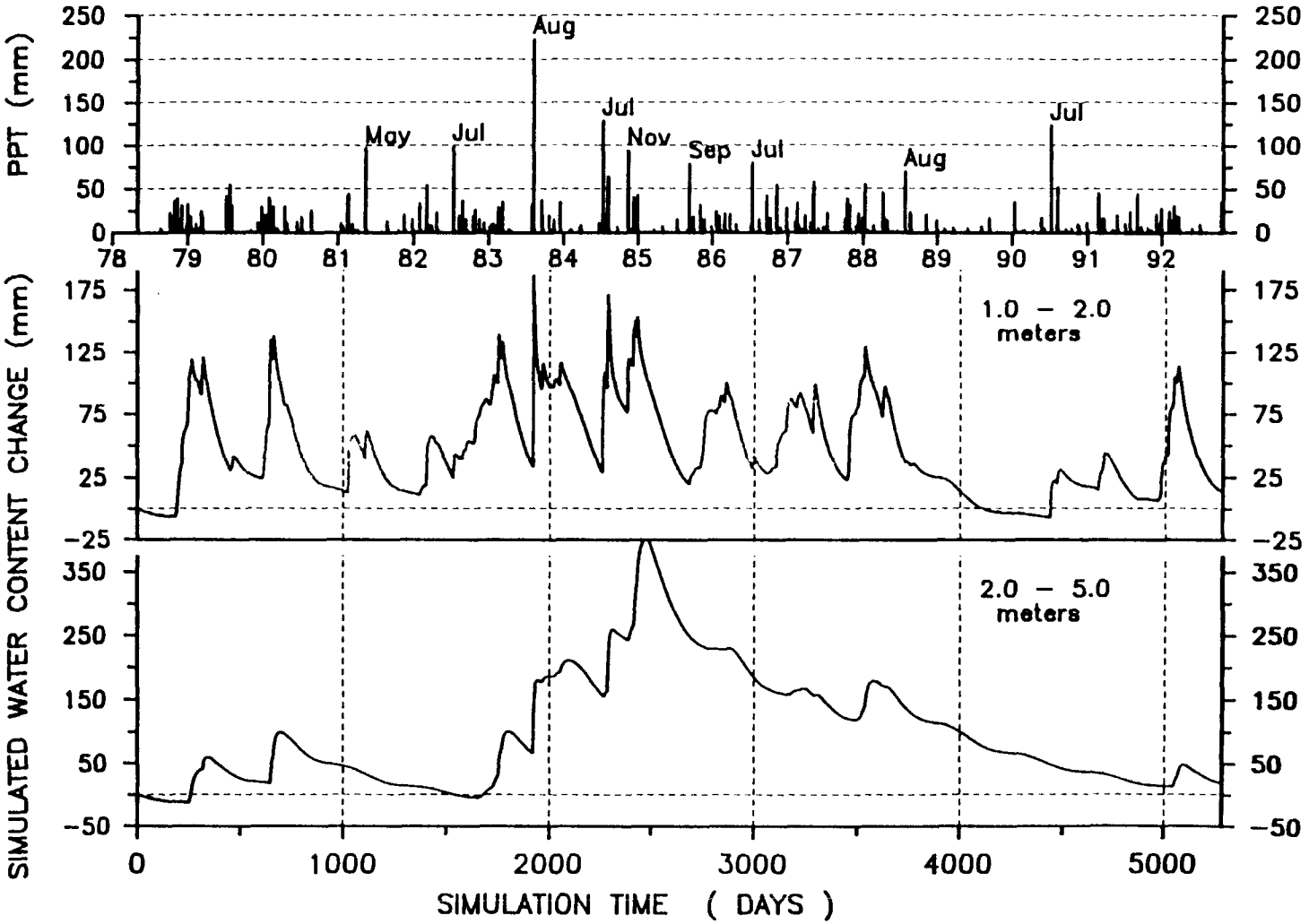
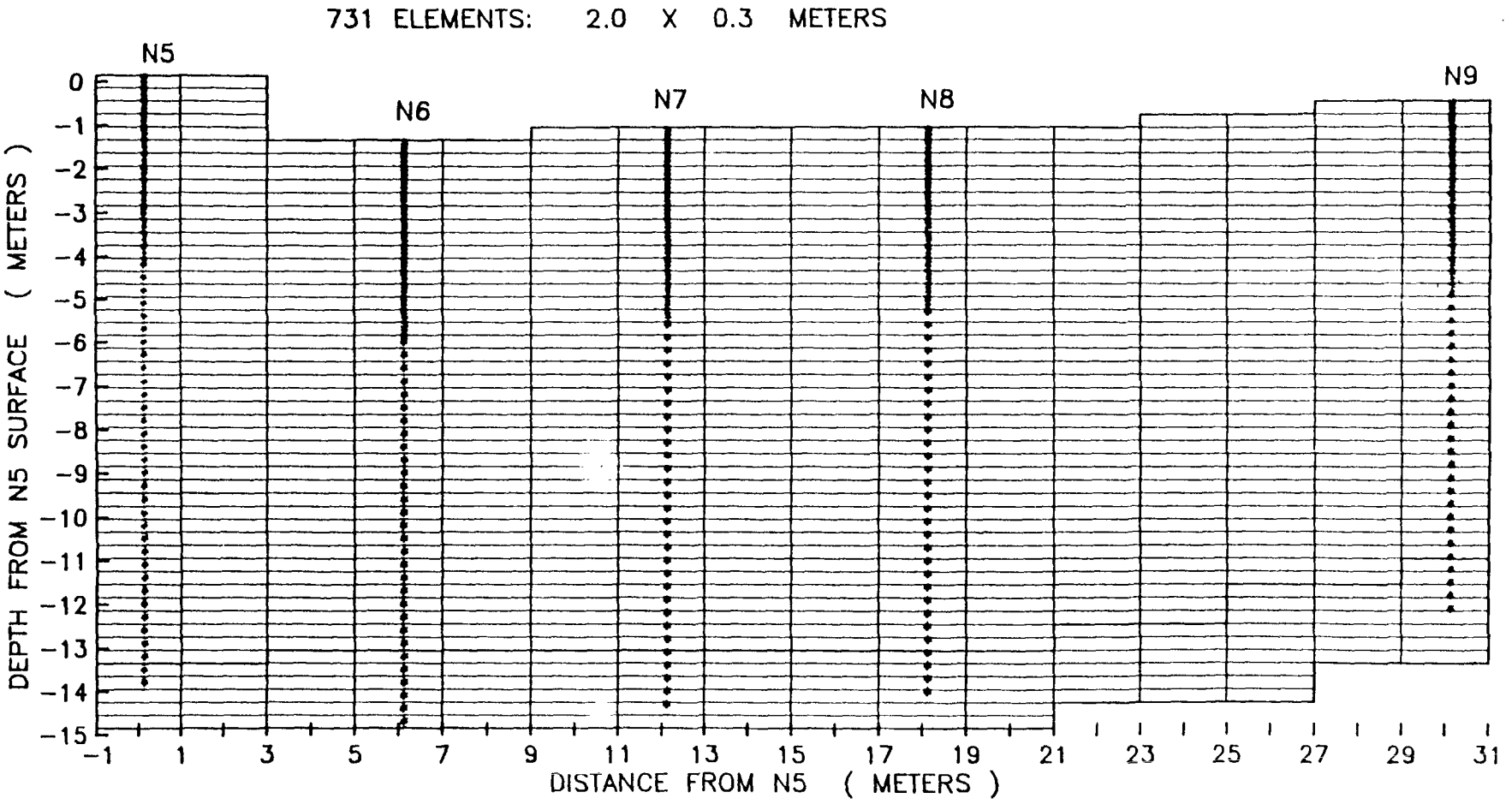


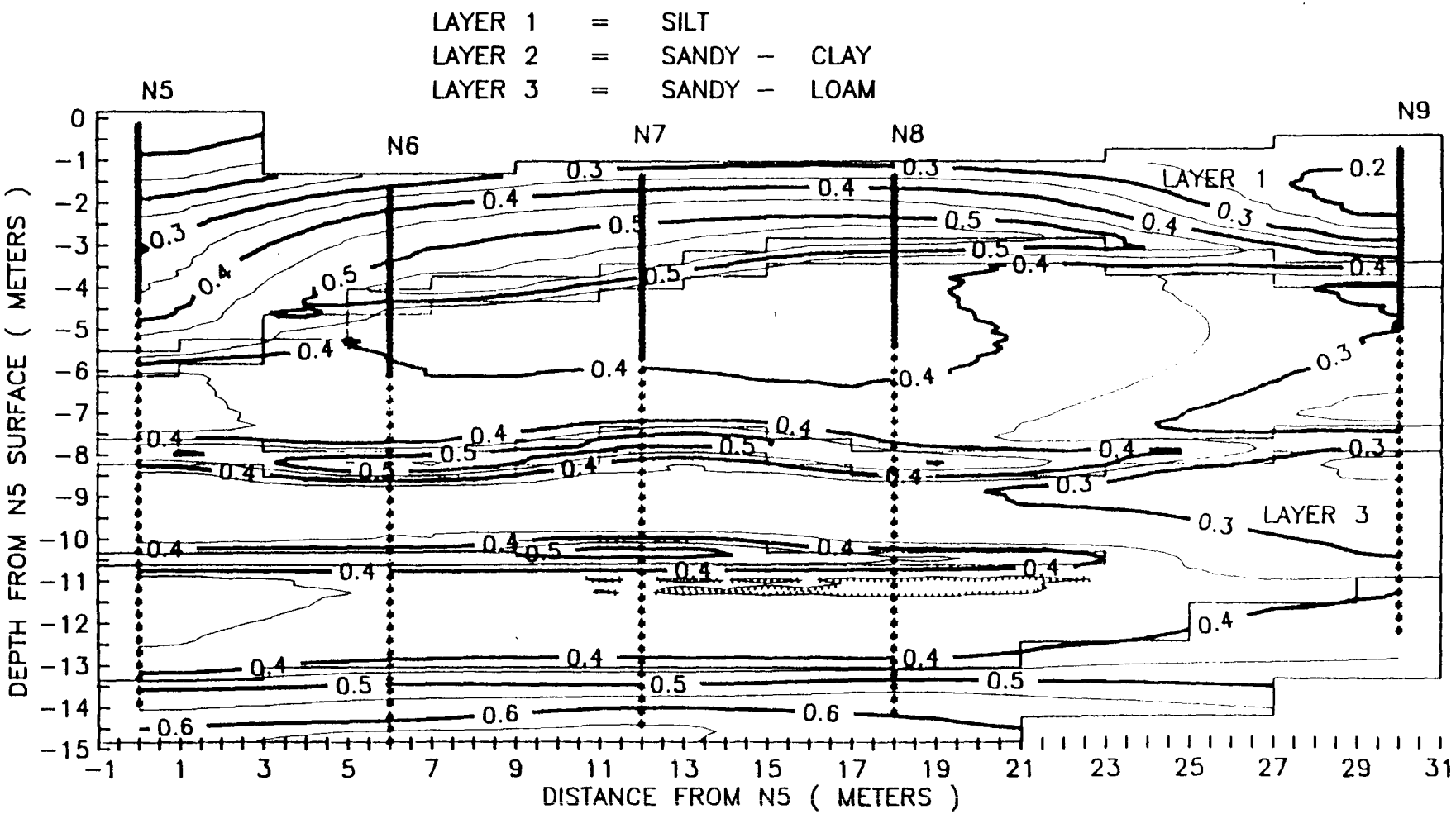
**Photo:**

**Pagany Wash cross section showing 5 boreholes in 2D model**

# Finite Difference Mesh
# Pagany Wash 2D Infiltration Model



# Simulated Water Saturation at 40 Days



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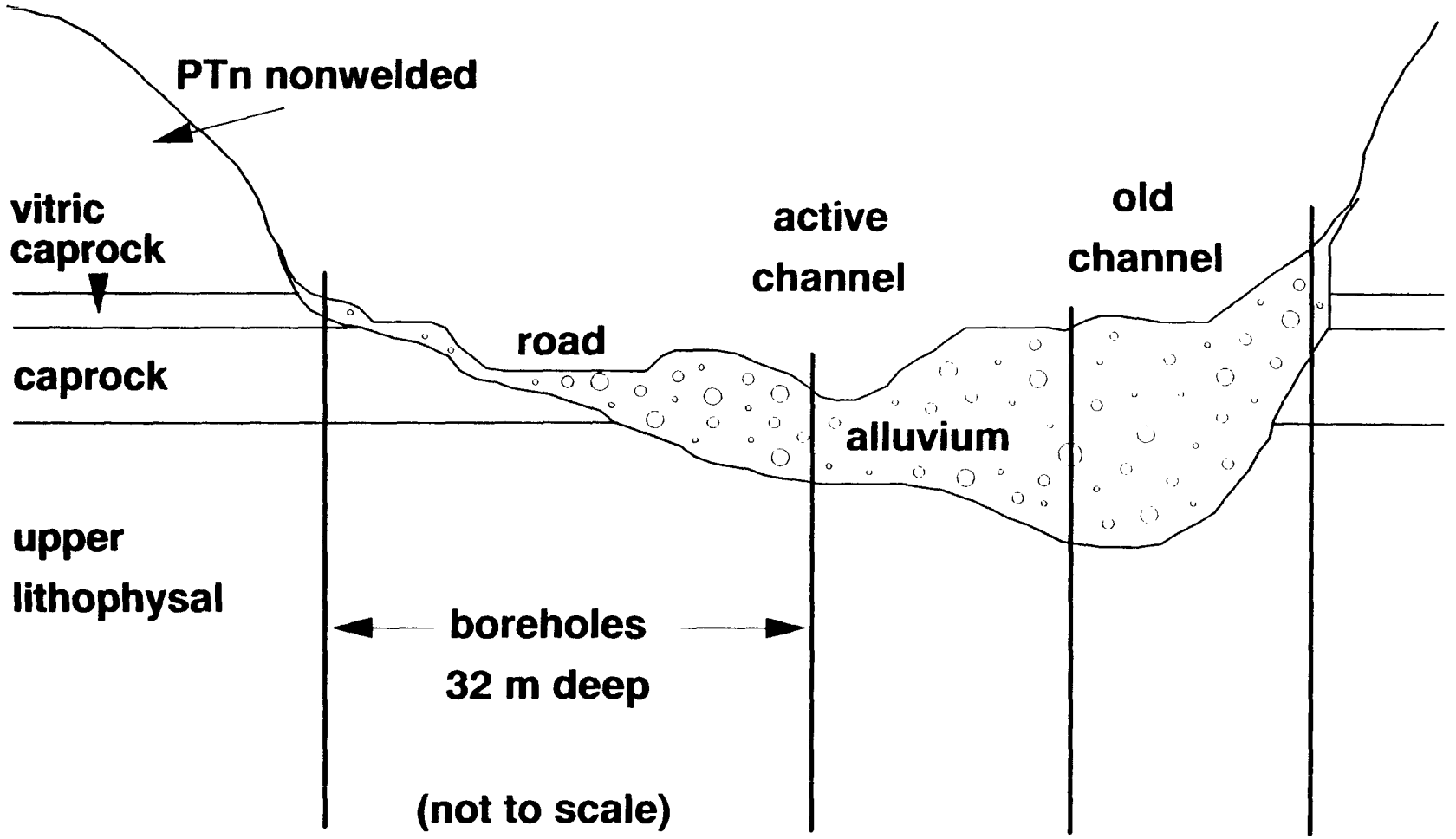
# Photo:

## Abandoned Wash cross section

# Abandoned Wash Idealized Cross Section
## Topopah Spring Member



# Climate Effects in Abandoned Wash

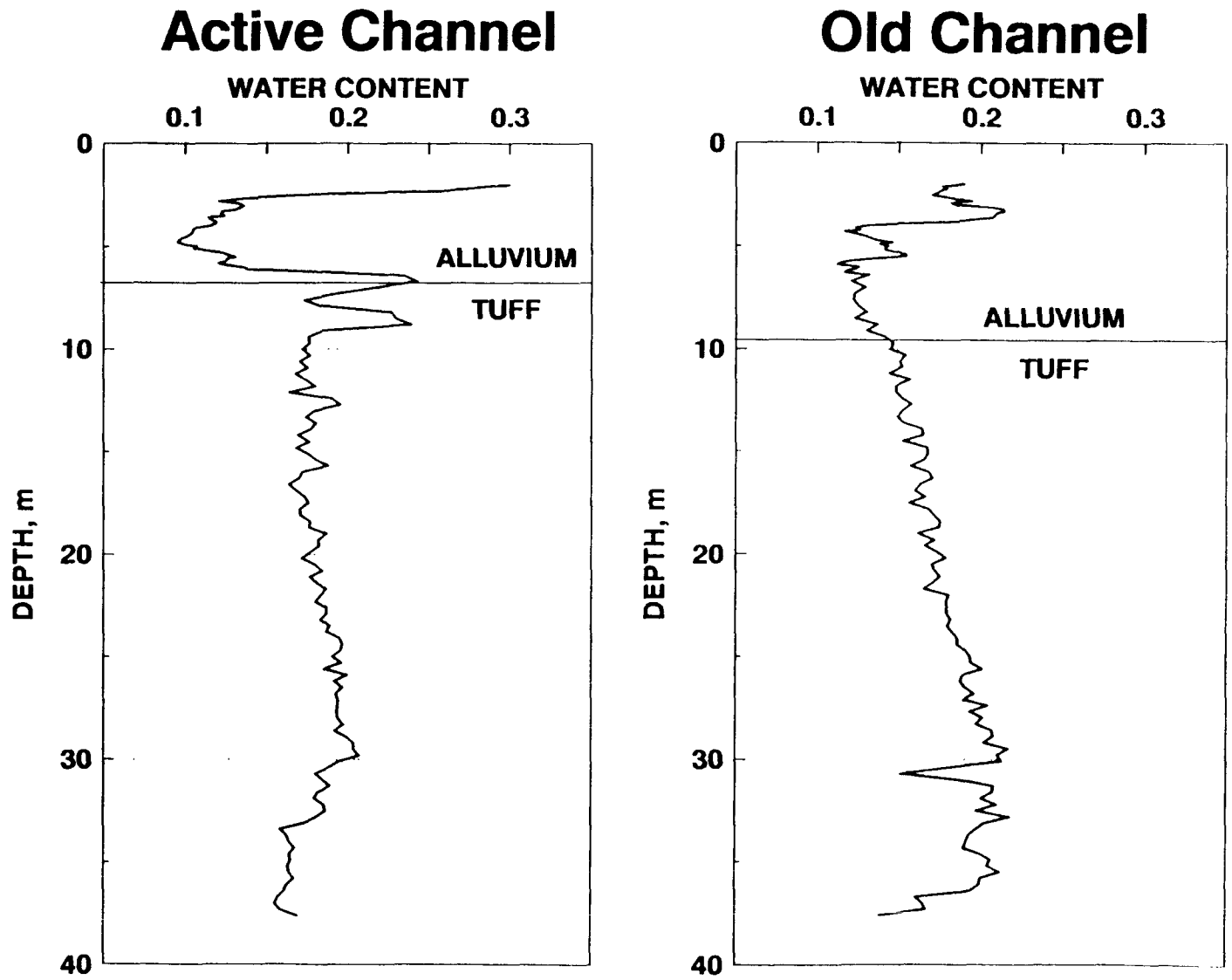


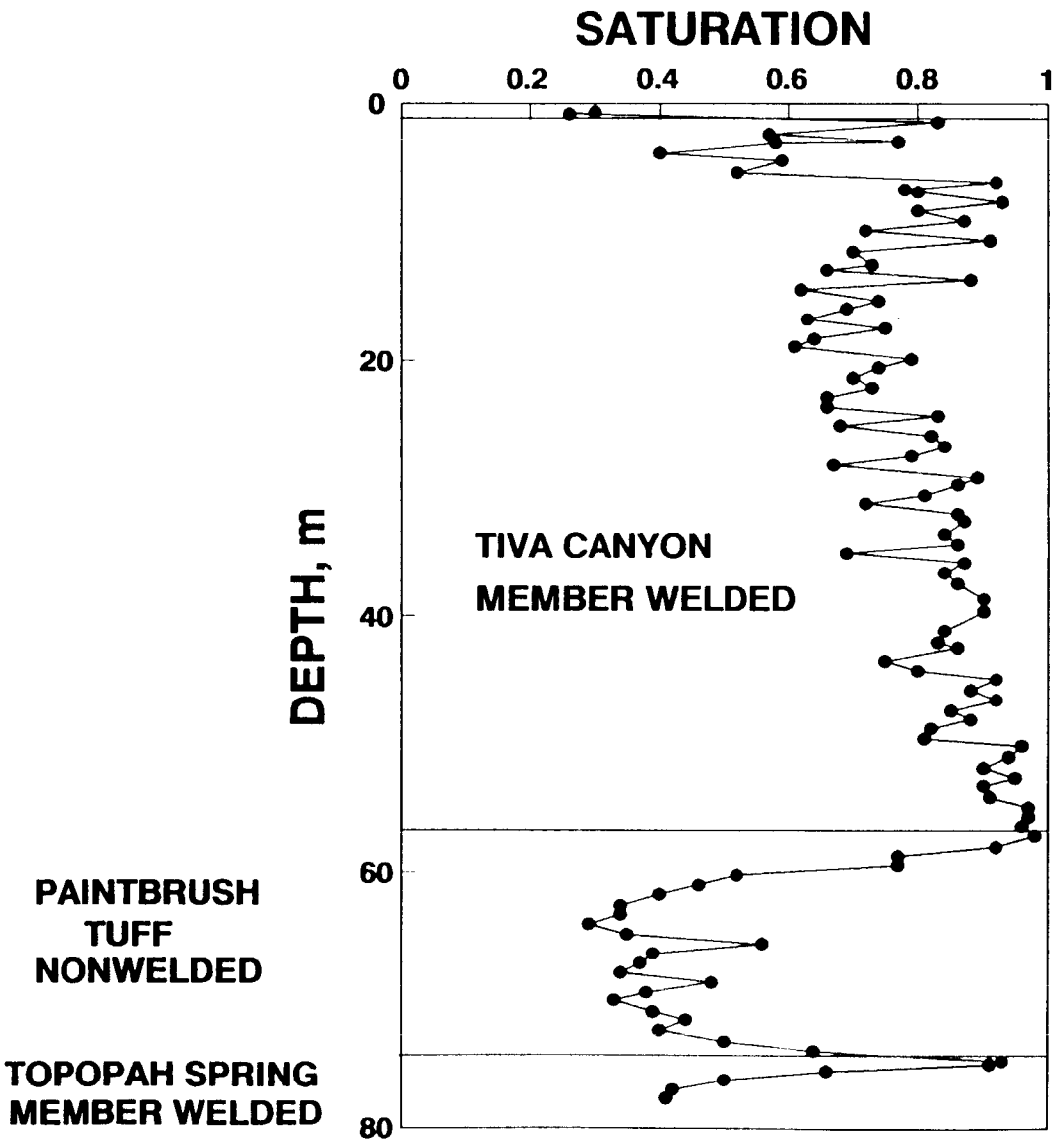
**Photo:**

**Escher print to exemplify modeling: illusion of reality**

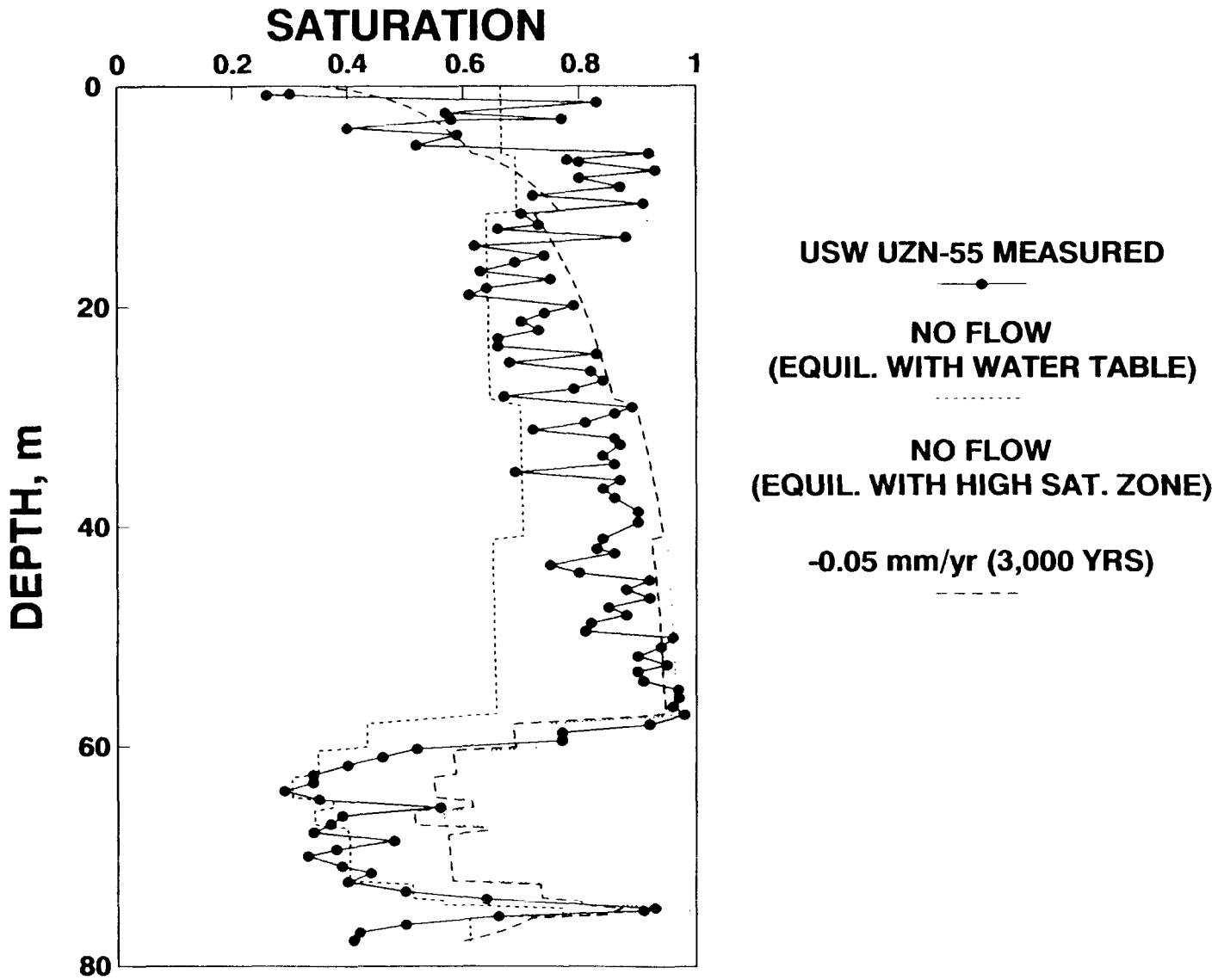
# Photo:

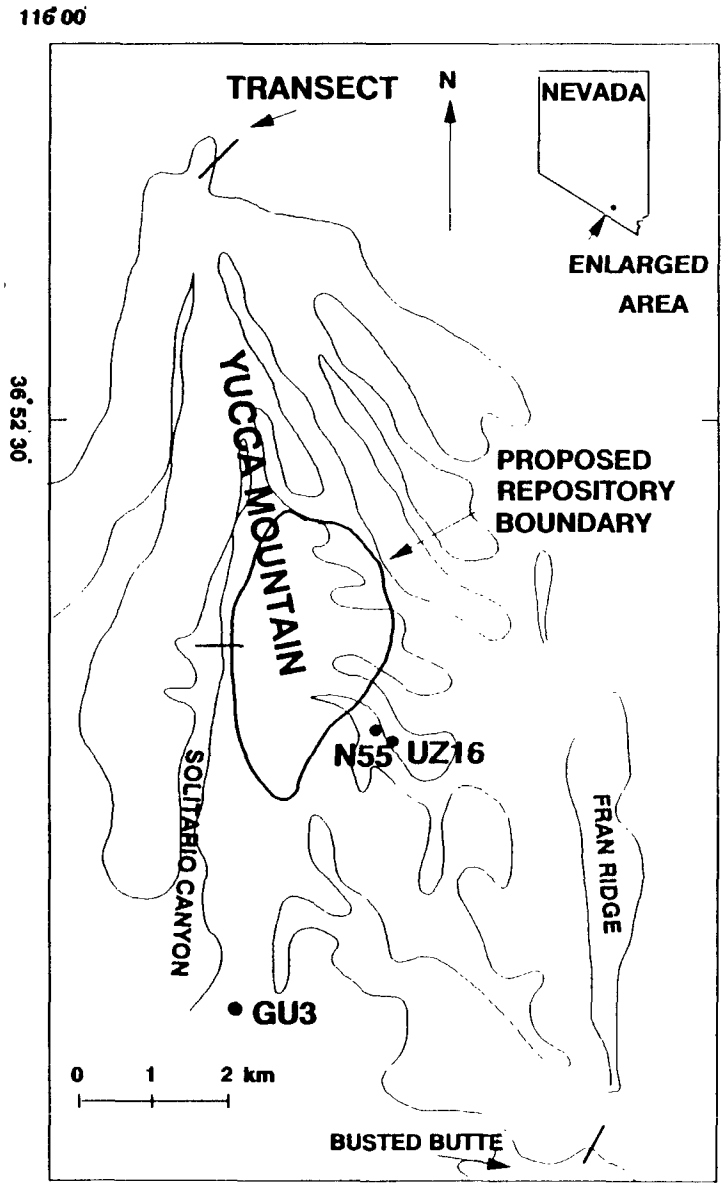
## Borehole N-55 used for 1D model

# N-55 Measured Saturation



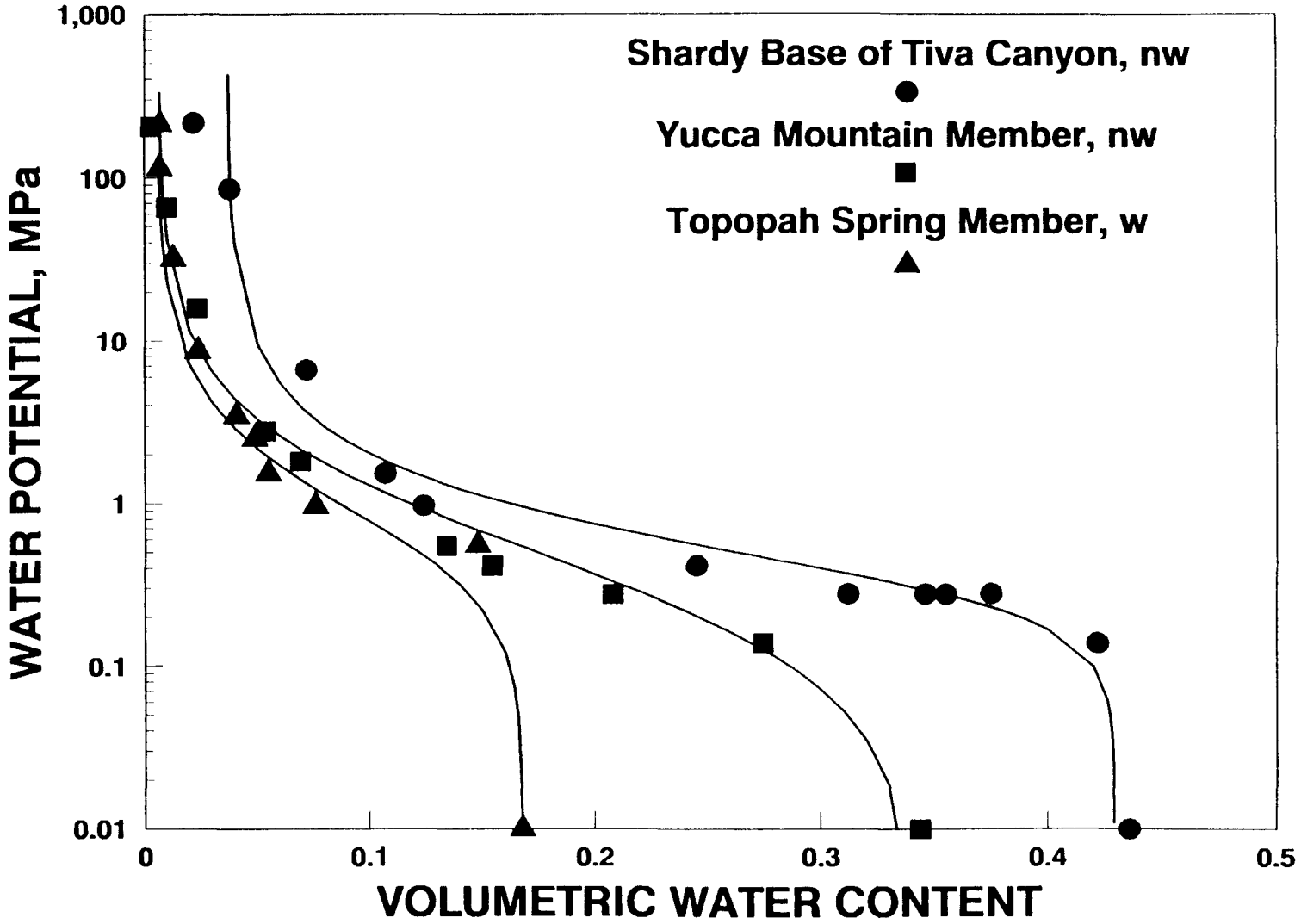
# N-55 Measured Saturation and Model





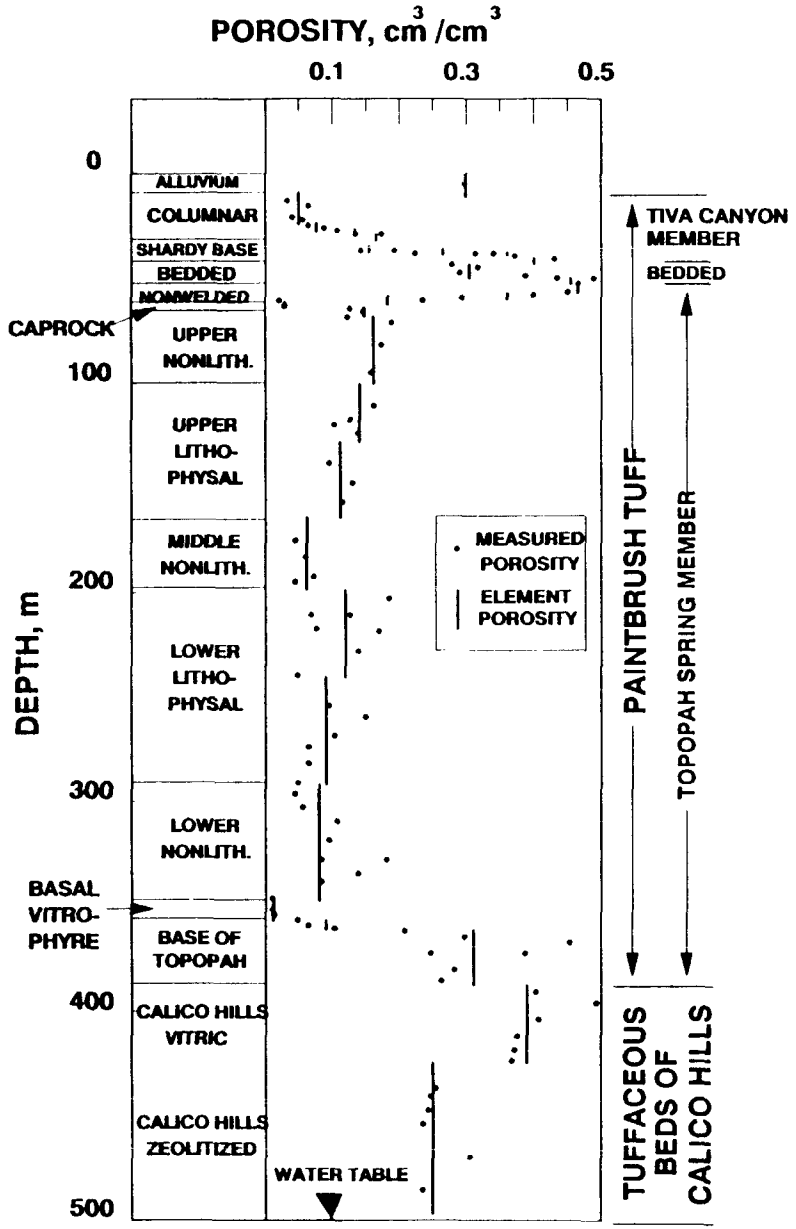

# Map of Yucca Mountain Showing Locations of Transects and Boreholes

# Moisture Retention Curves for Tuff
## Using Chilled-Mirror Psychrometer



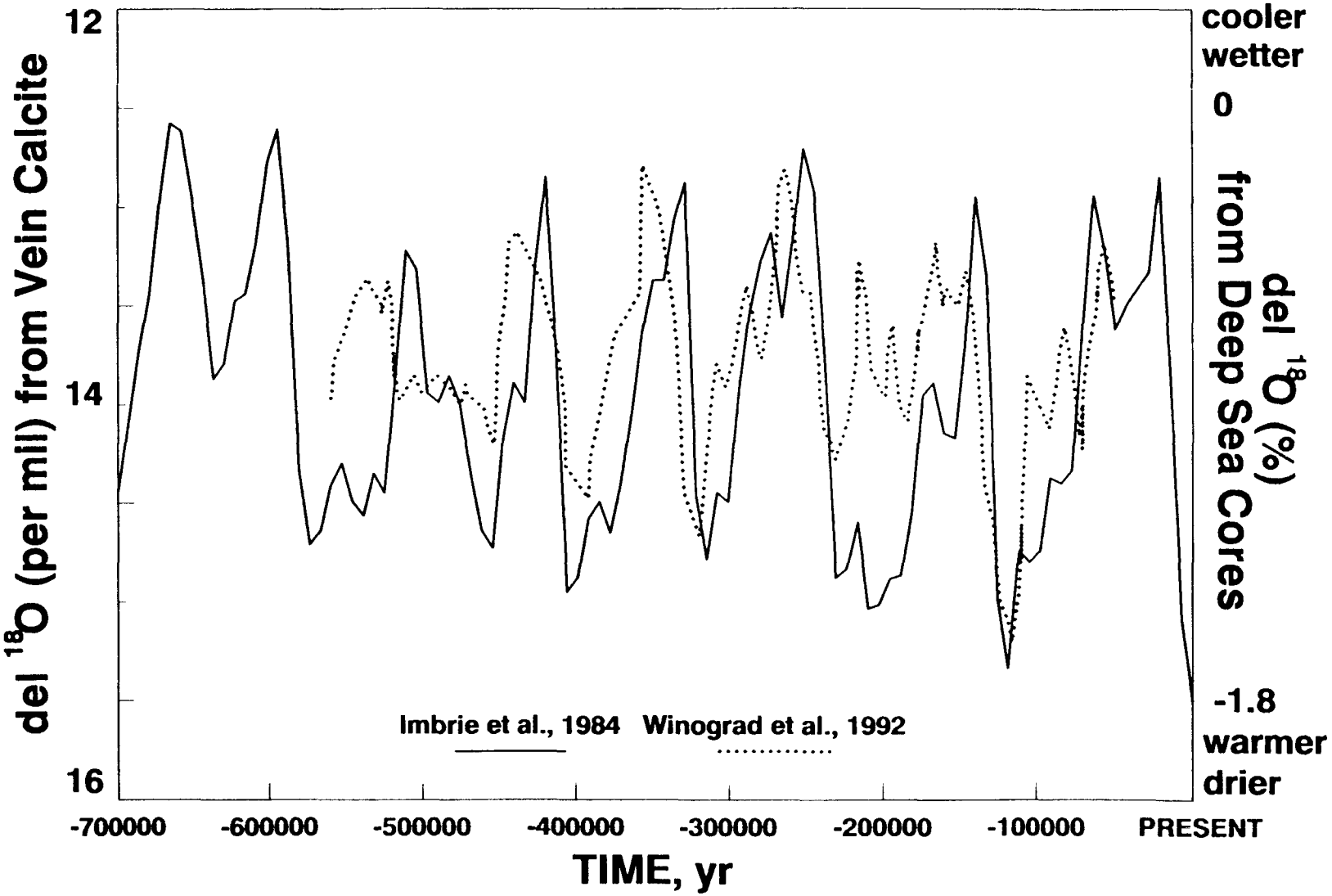
# Properties for UZ16 1D Model

| Model Elements | Depth (m) | Particle Density (g/cm3) | Porosity | Permeability (m2) | van Genuchten Parameters alpha (x10-7) | n | m |
|---|---|---|---|---|---|---|---|
| Alluvium | 0 | 2.48 | 0.300 | $1.0*10^{-12}$ | 20.000 | 1.150 | 0.13 |
| Columnar, w | 9 | 2.48 | 0.070 | $2.1*10^{-18}$ | 0.067 | 1.329 | 0.25 |
| Columnar, mw | 27 | 2.47 | 0.136 | $4.4*10^{-17}$ | 0.067 | 1.326 | 0.25 |
| Columnar, mw | 29 | 2.47 | 0.169 | $2.0*10^{-16}$ | 0.067 | 1.326 | 0.25 |
| Columnar, mw | 31 | 2.47 | 0.148 | $7.6*10^{-17}$ | 0.067 | 1.326 | 0.25 |
| Shardy base, nw | 32 | 2.39 | 0.162 | $1.4*10^{-16}$ | 0.067 | 1.329 | 0.25 |
| Shardy base, nw | 36 | 2.25 | 0.268 | $8.1*10^{-15}$ | 1.000 | 1.220 | 0.18 |
| Shardy base, nw | 38 | 2.34 | 0.366 | $1.3*10^{-13}$ | 2.000 | 1.230 | 0.19 |
| Shardy base, nw | 41 | 2.31 | 0.404 | $2.8*10^{-13}$ | 2.000 | 1.270 | 0.21 |
| Bedded tuff | 43 | 2.35 | 0.305 | $2.9*10^{-14}$ | 2.000 | 1.220 | 0.18 |
| Bedded tuff | 50 | 2.32 | 0.459 | $5.9*10^{-13}$ | 10.000 | 1.180 | 0.15 |
| Topopah nonwelded | 53 | 2.36 | 0.465 | $6.3*10^{-13}$ | 10.000 | 1.150 | 0.13 |
| Topopah nonwelded | 57 | 2.30 | 0.358 | $1.1*10^{-13}$ | 2.000 | 1.150 | 0.13 |
| Topopah nonwelded | 59 | 2.34 | 0.184 | $3.9*10^{-16}$ | 1.000 | 1.150 | 0.13 |
| Caprock, w | 62 | 2.43 | 0.025 | $2.0*10^{-19}$ | 0.067 | 1.200 | 0.17 |
| Upper nonlithophysal, w | 63 | 2.56 | 0.160 | $2.7*10^{-15}$ | 0.125 | 1.300 | 0.23 |
| Upper lithophysal, w | 100 | 2.49 | 0.140 | $5.0*10^{-17}$ | 0.200 | 1.230 | 0.19 |
| Upper lithophysal, w | 128 | 2.49 | 0.110 | $4.0*10^{-18}$ | 0.200 | 1.330 | 0.25 |
| Middle nonlithophysal, w | 164 | 2.49 | 0.060 | $1.2*10^{-18}$ | 0.133 | 1.320 | 0.24 |
| Lower lithophysal, w | 198 | 2.49 | 0.120 | $1.2*10^{-16}$ | 0.133 | 1.320 | 0.24 |
| Lower nonlithophysal, w | 291 | 2.58 | 0.080 | $3.2*10^{-18}$ | 0.067 | 1.320 | 0.25 |
| Basal vitrophyre, w | 347 | 2.37 | 0.013 | $1.1*10^{-19}$ | 0.067 | 1.410 | 0.29 |
| Base Topopah, w | 356 | 2.36 | 0.090 | $7.0*10^{-18}$ | 0.133 | 1.320 | 0.24 |
| Base Topopah, nw | 361 | 2.36 | 0.310 | $1.7*10^{-13}$ | 2.000 | 1.150 | 0.13 |
| Calico Hills vitric, nw | 367 | 2.36 | 0.390 | $3.0*10^{-13}$ | 2.000 | 1.270 | 0.21 |
| Calico Hills zeolitic, nw | 425 | 2.30 | 0.250 | $1.0*10^{-16}$ | 1.100 | 1.230 | 0.19 |
| Lower boundary | 498 | | | | | | |

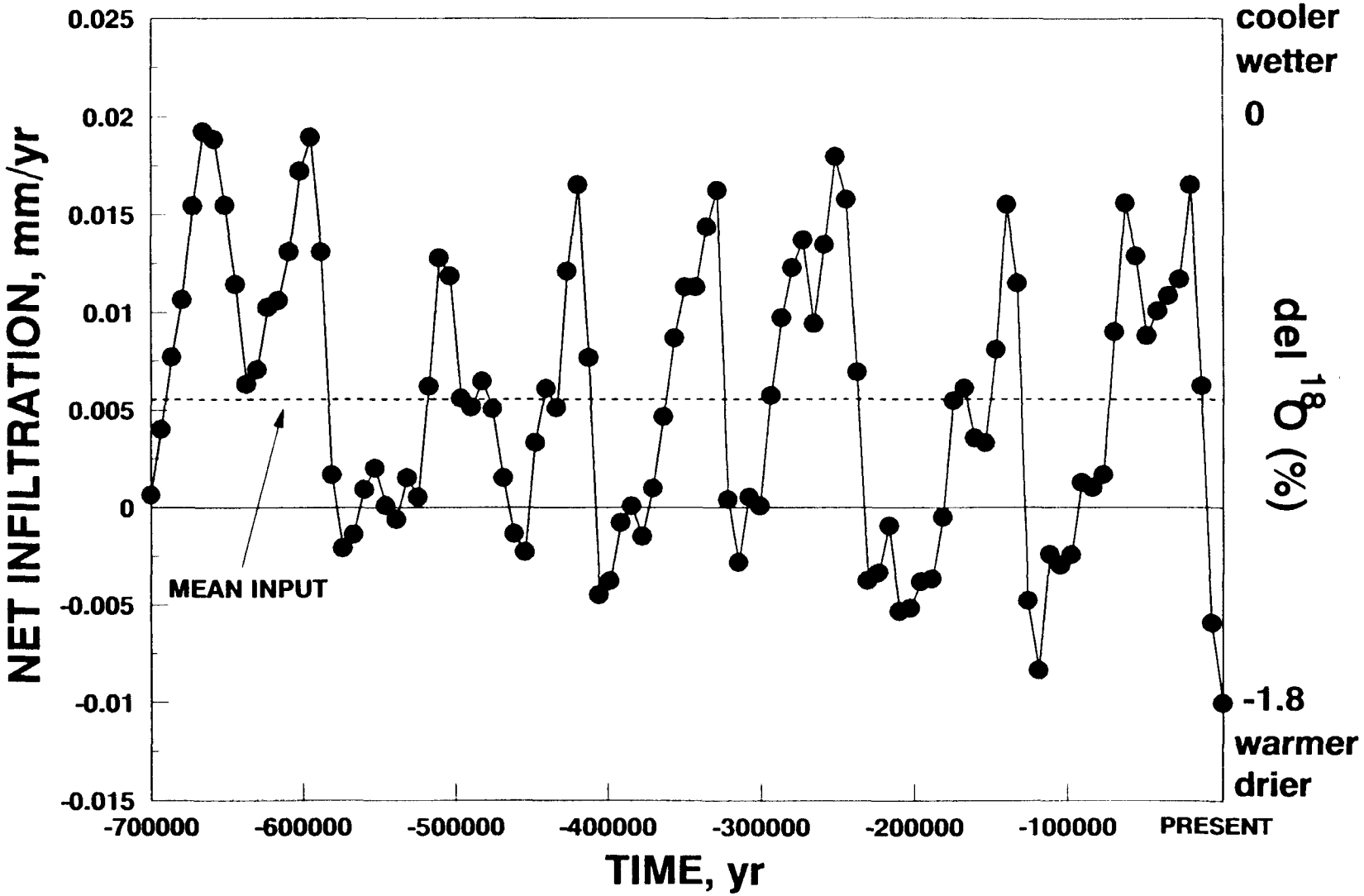



# UZ16 Lithology and Model Inputs

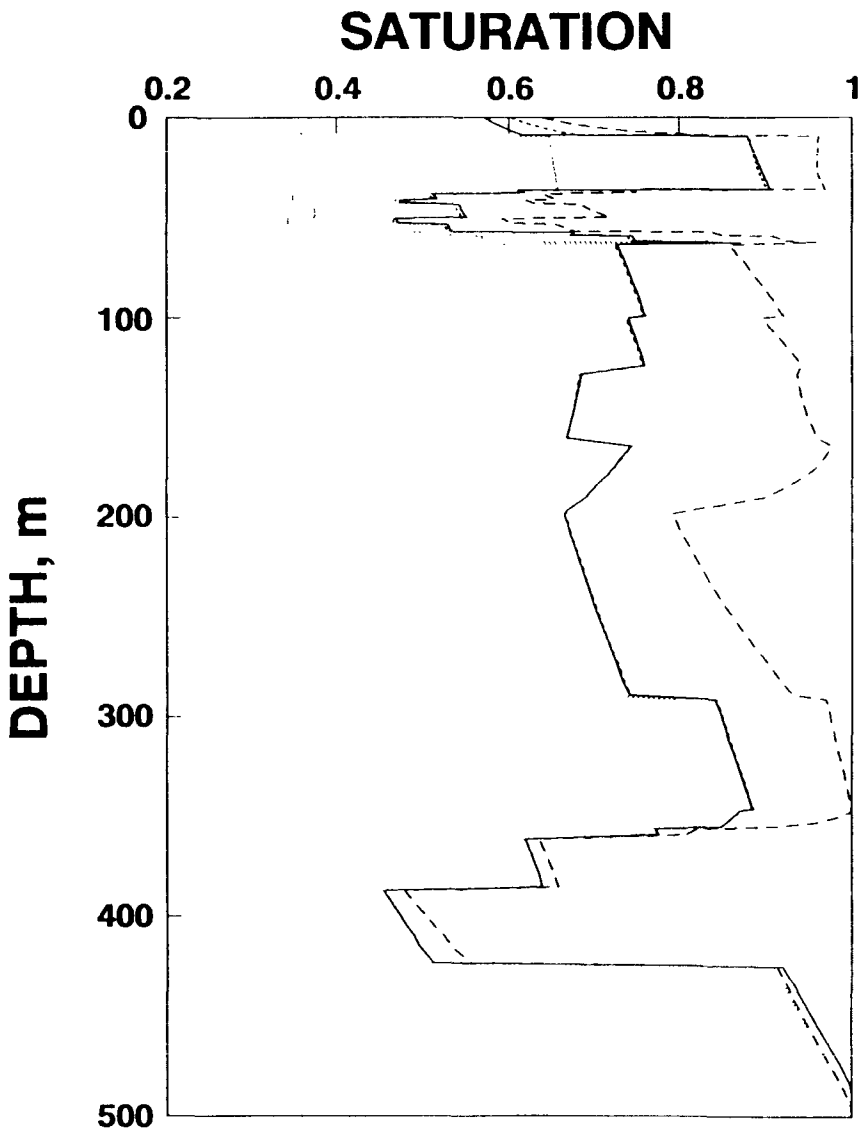
# Past Climate Change



# Cyclic Climate Change



# UZ16 Model



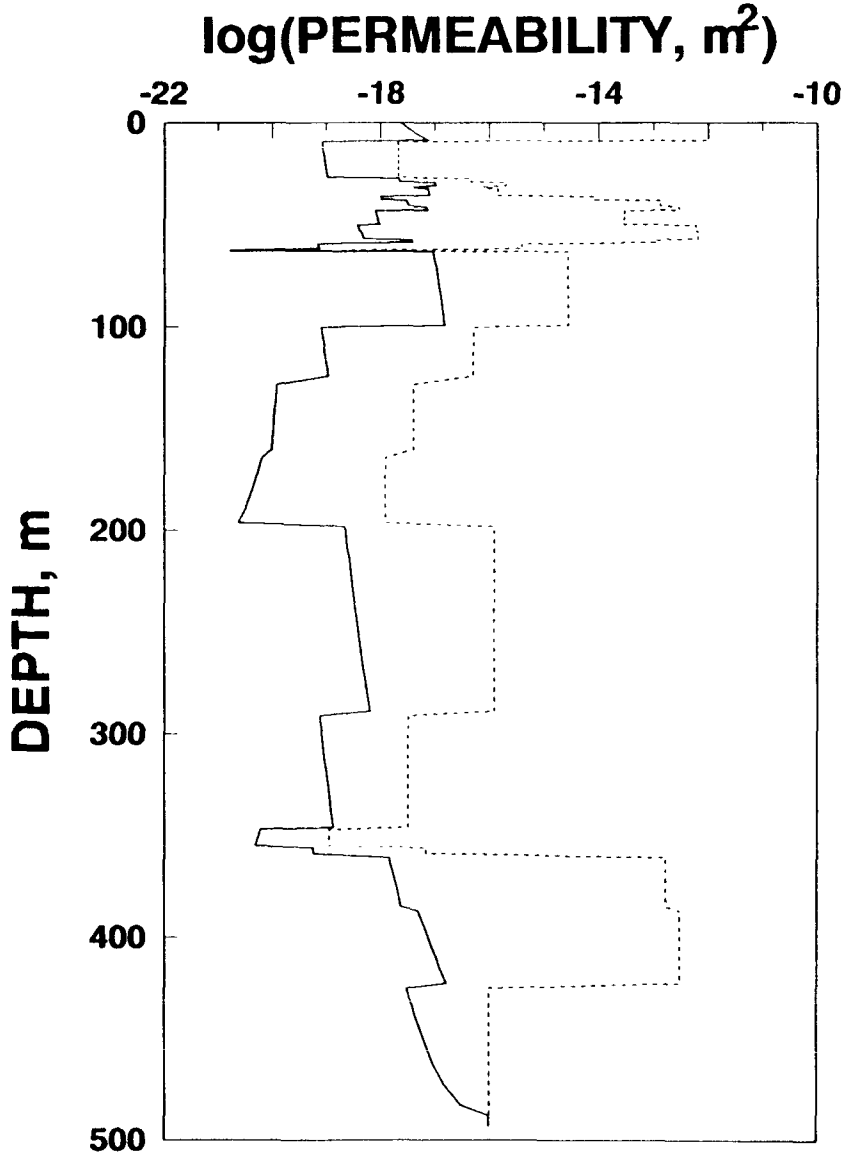

NO FLOW

STEADY STATE (0.1 FLUX)

PRESENT

-25,000 YRS

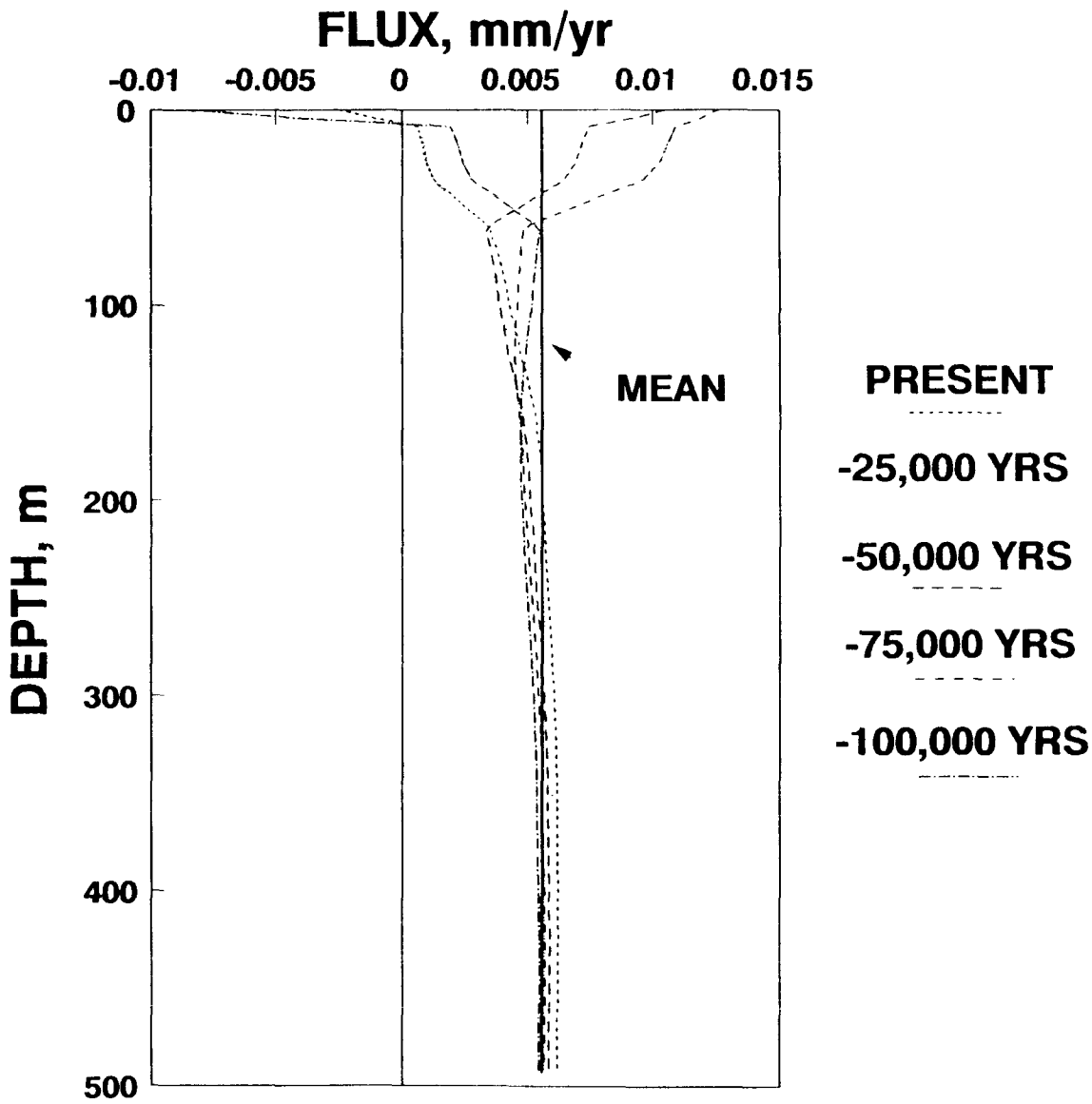
# UZ16 Model



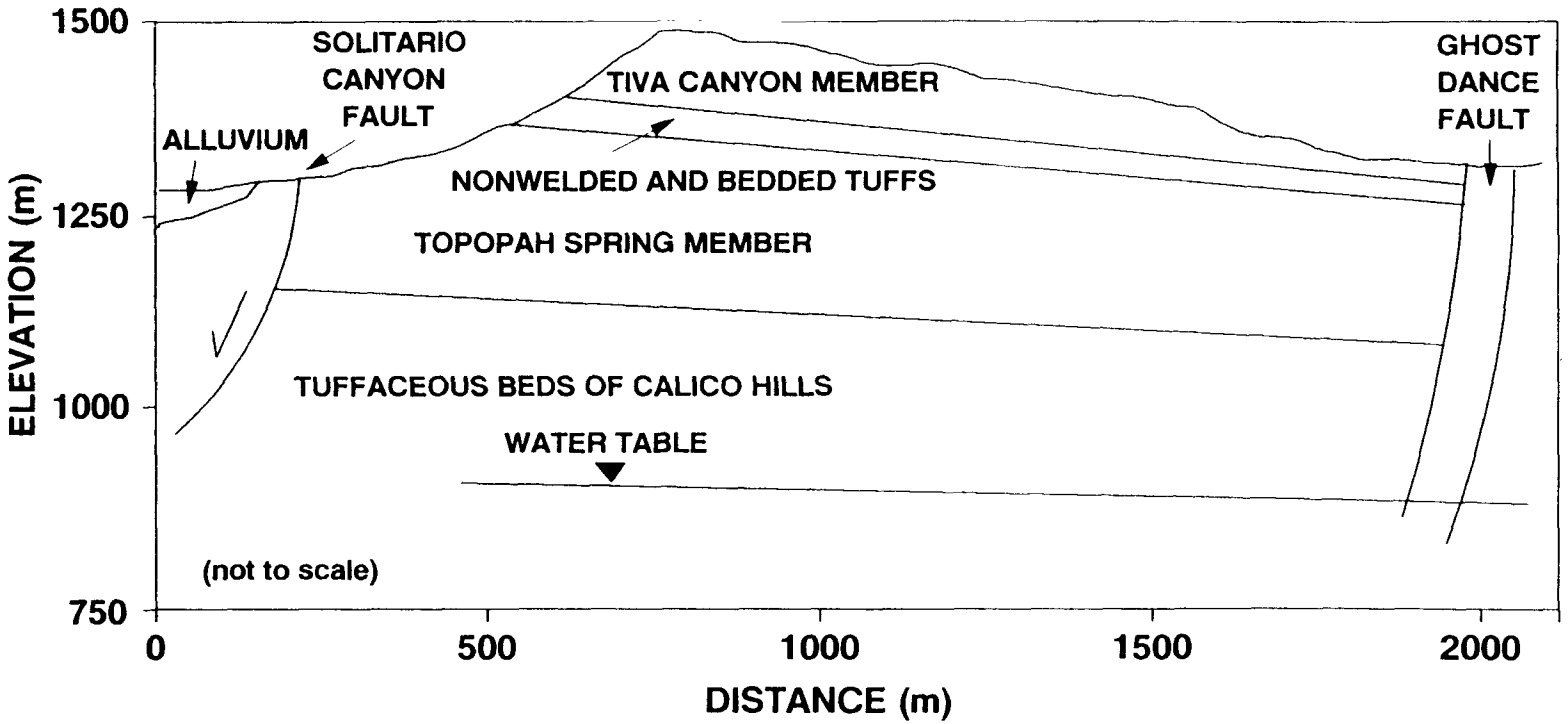

SATURATED PERMEABILITY

RELATIVE PERMEABILITY

# UZ16 Model


FLUX, mm/yr
-0.01
-0.005
0
0.005
0.01
0.015
0
100
200
300
400
500
DEPTH, m
MEAN
PRESENT
-25,000 YRS
-50,000 YRS
-75,000 YRS
-100,000 YRS

# Cross Section of Yucca Mountain




[Adapted from Scott and Bonk (1984)]

# 2D Model of Yucca Mountain

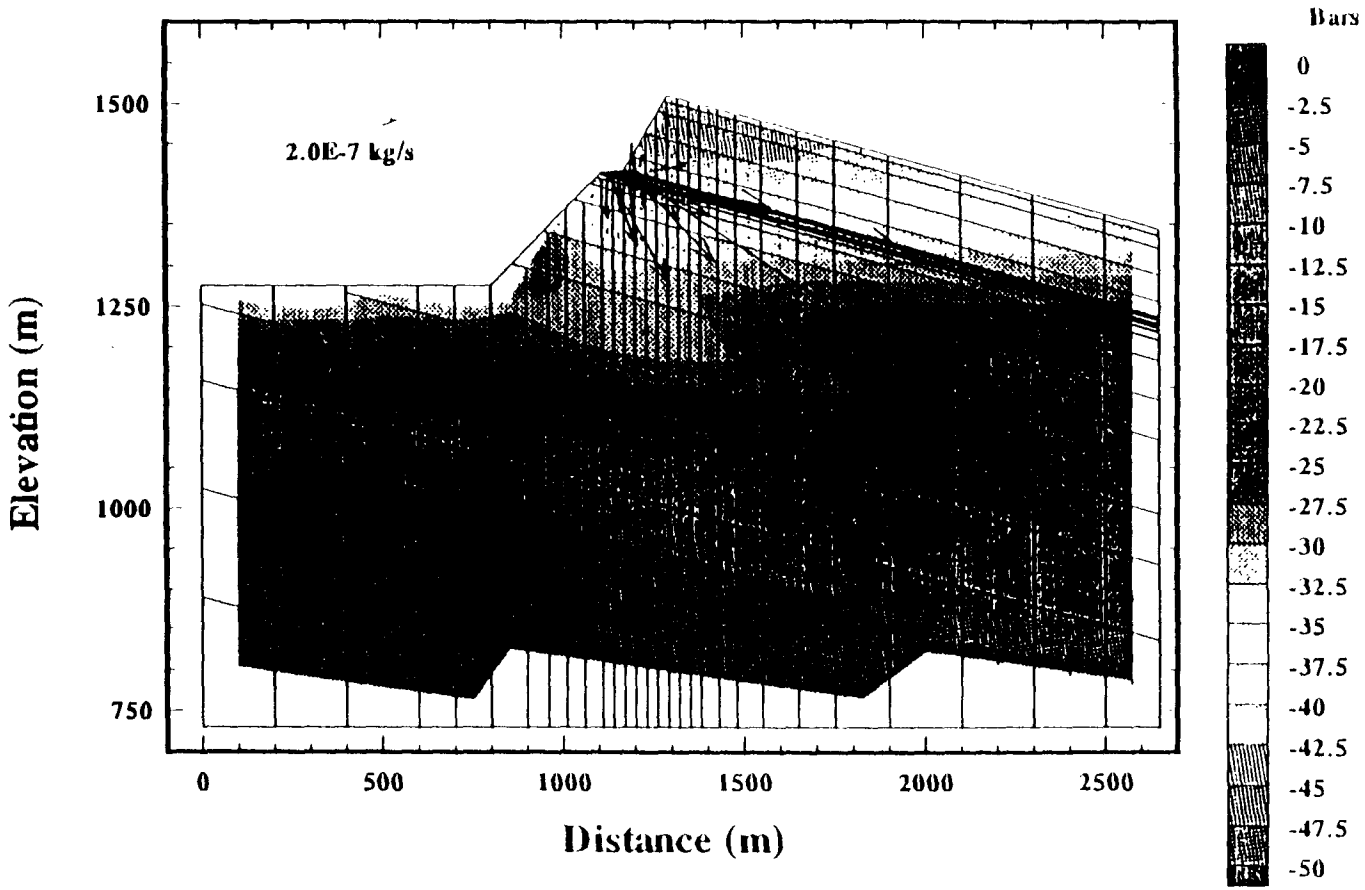
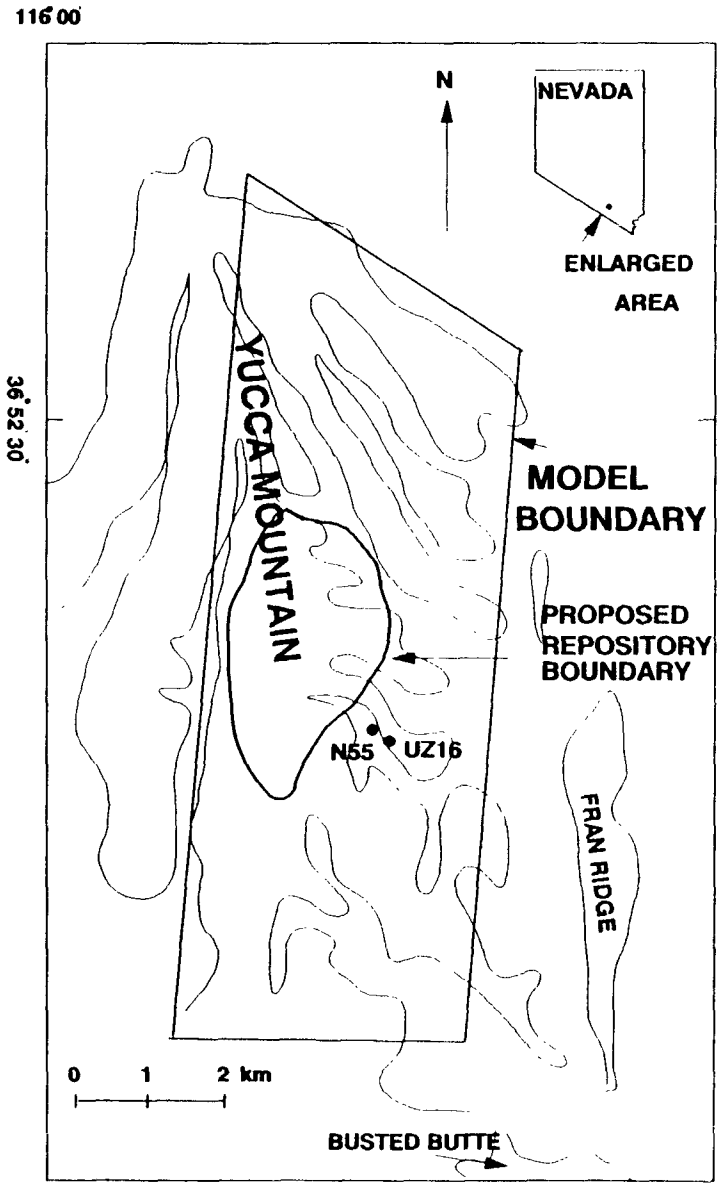
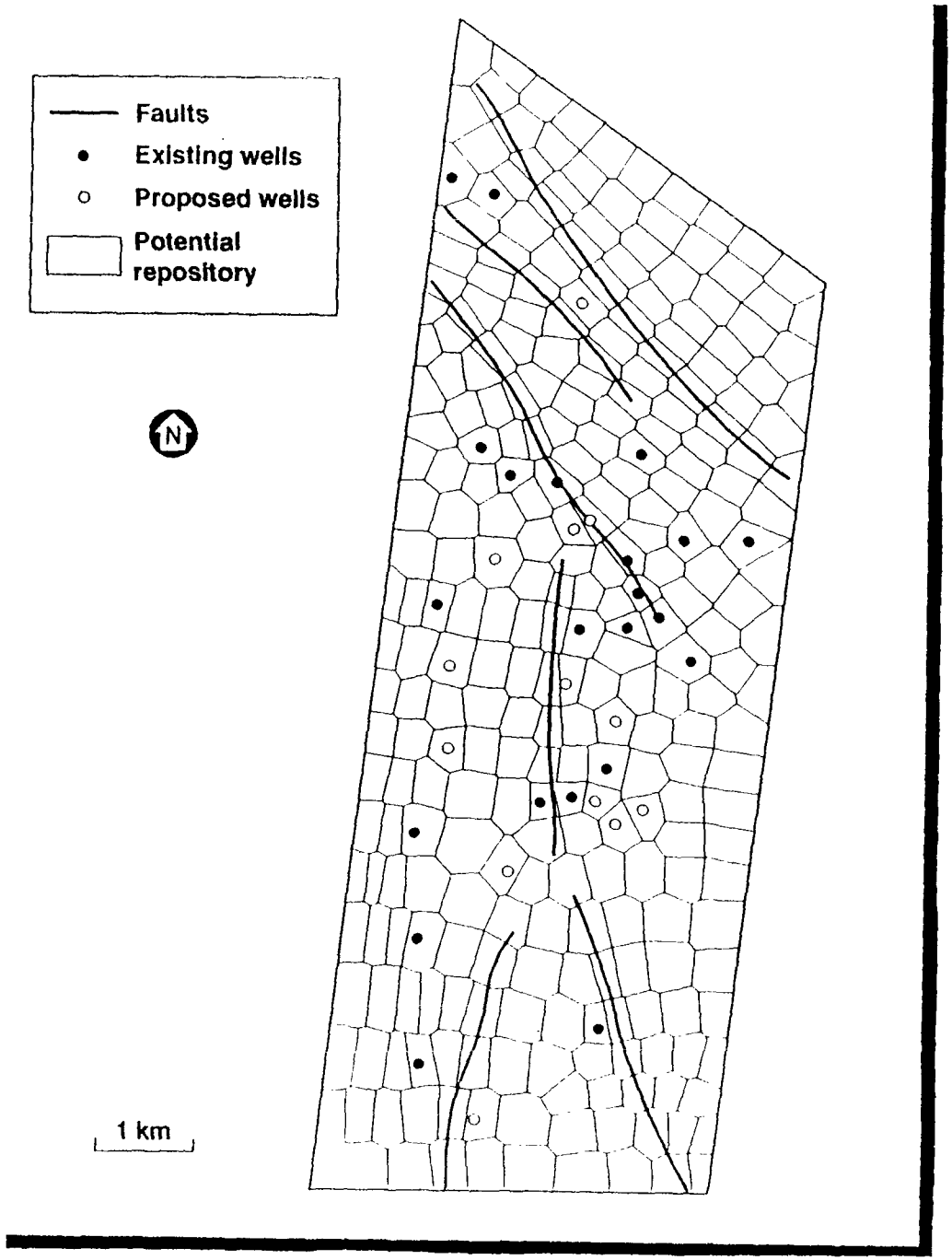



Figure 33. Capillary pressure distribution after 50 years of 10.0 mm/yr infiltration into the bedded unit outcrops in Solitario Canyon




# Map of Yucca Mountain With 3D Site Scale Model Boundary




# LBL/USGS
# 3D Site Scale Model

- **Study Objectives**
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    - 1-D, 2-D, 3-D surface to the water table
- ***Real Time Decision Making***
  - *Has study changed?*
  - *How experiments end*
- ***Summary***

# Has the Study Changed?

- Deeper drilling of neutron holes to examine role of PTn
- More experimentation/model interaction
- Accelerated mapping to feed modeling efforts
- Initial stochastic view has become increasingly deterministic

**For example:**

**Artificial Infiltration field testing program has changed due to increased knowledge and understanding**

| | Number of tests | |
|---|---|---|
| | originally planned | currently planned |
| **Rainfall simulation** | | |
| Small plot | 23 | 7 |
| Large plot | 15 | 3 |
| **Ponding** | 49 | 7 |

# How Do We Execute Changes?

- On the spot field changes -> "Drill it deeper"
- Study plans were written to allow experimentation/modification

**Photo:**

**Book Cover: Searching for Certainty**

**by John L. Casti**

**Photo:**

**Book Cover: How Experiments End**
**by Peter Galison**

# When Do Experiments End?

- When the money runs out
- When the time is up
- When the deliverables are complete

# Why Experiments End?

- The science and performance assessment are satisfied that it can predict or explain the results of an experiment or observation, i.e. that adequate confidence has been developed in the models of the results

- The model results are insensitive to additional or more detailed data

# Summary

## How Do We Solve This "Black Box" Issue?

- Establish well thought out, comprehensive plan for site characterization
- Set priorities for critical paths for understanding the site through measurements, observations, and models
- Carry out studies, analyse data, and run models
- Redirect research and model activities to meet objective as redefined by results

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