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

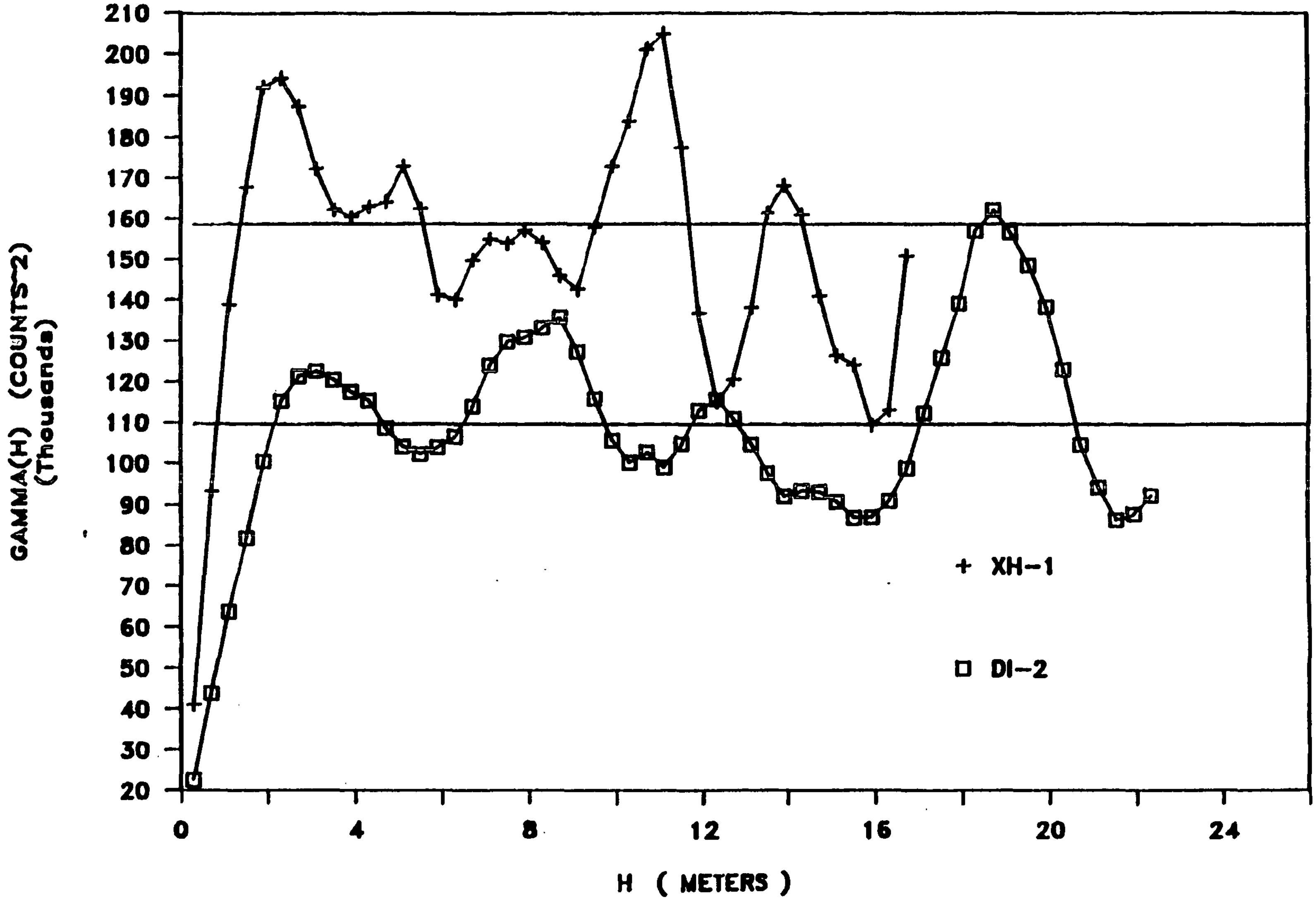
- CHARACTERIZATION OF HYDROLOGIC PROPERTIES OF ROCK MATRIX FOR FLOW MODELS:
  - BULK DENSITY, POROSITY
  - WATER RETENTION
  - UNSATURATED HYDRAULIC CONDUCTIVITY

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

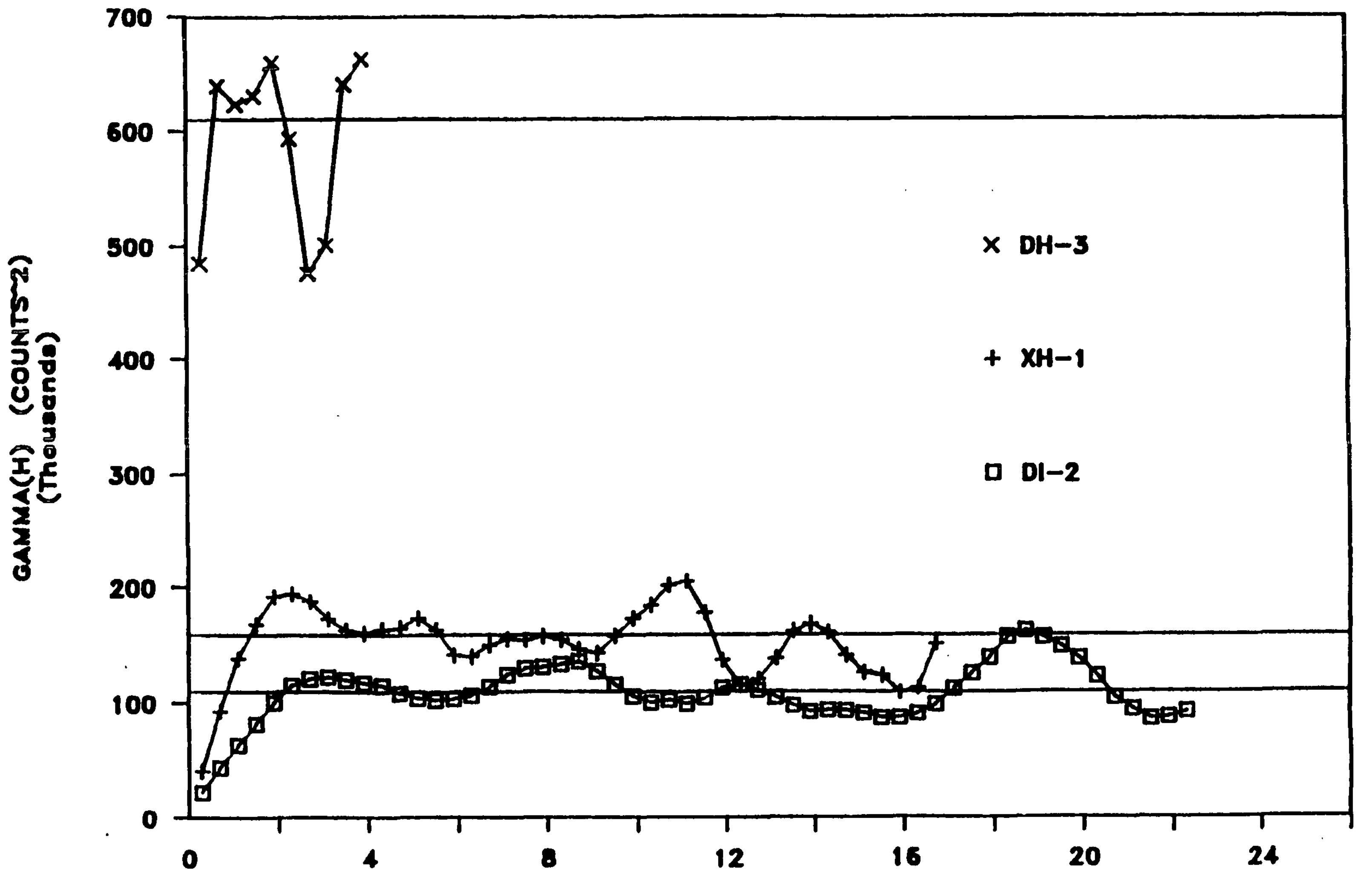
STATISTICAL ANALYSIS

- CLASSICAL STATISTICS
  - BASIS OF INITIAL SAMPLING SCHEME
- GEOSTATISTICS
  - 3-DIMENSIONAL
  - MULTIVARIATE
  - STRUCTURAL ANALYSIS (VARIOGRAPHY)
  - PREDICTION (KRIGING, COKRIGING, ETC.)
  - SIMULATION

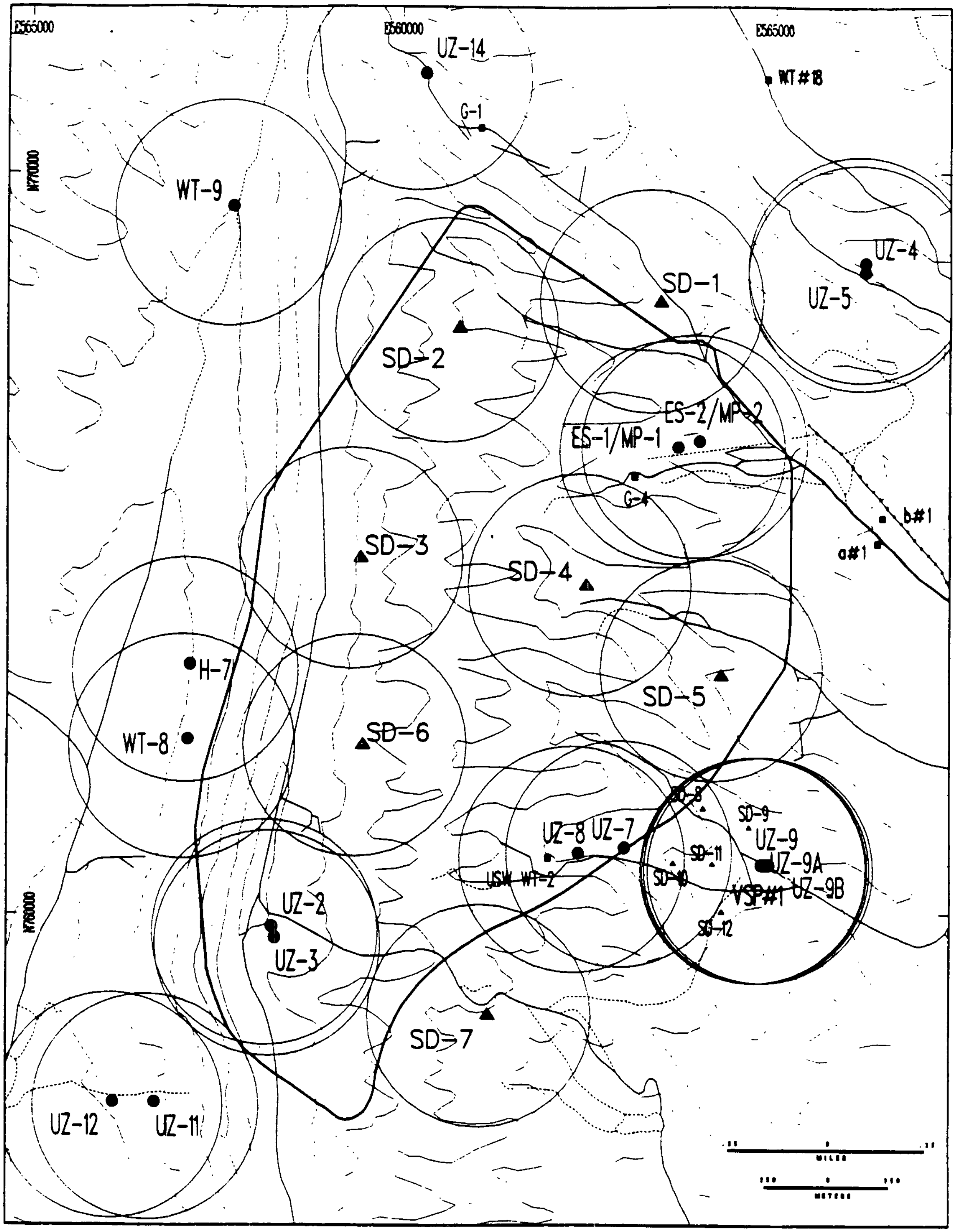
ONE DIMENSIONAL SPATIAL VARIABILITY OF NEUTRON COUNTS IN TWO BOREHOLES IN G-TUNNEL



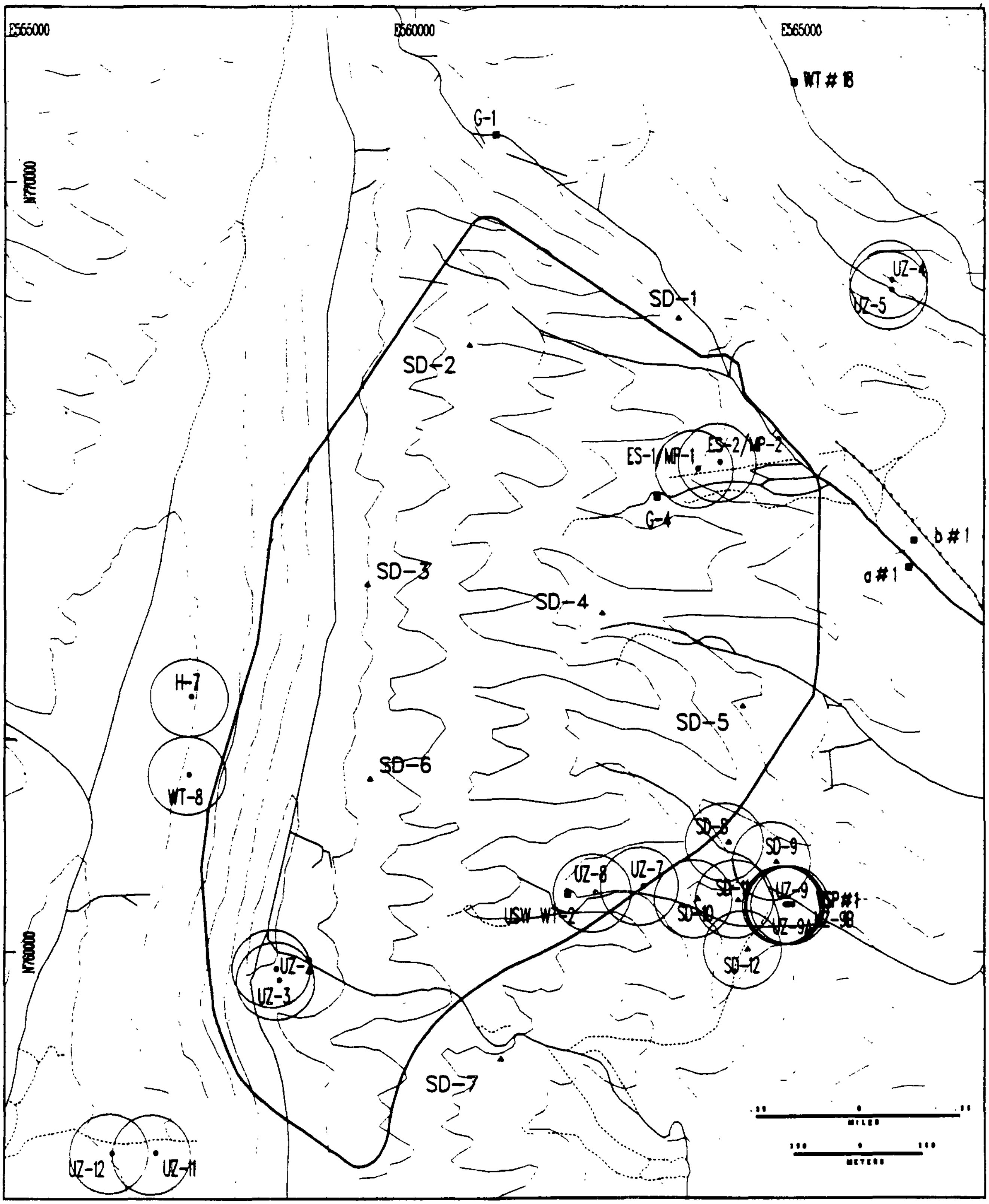
ONE DIMENSIONAL SPATIAL VARIABILITY OF NEUTRON COUNTS IN THREE BOREHOLES IN G-TUNNEL



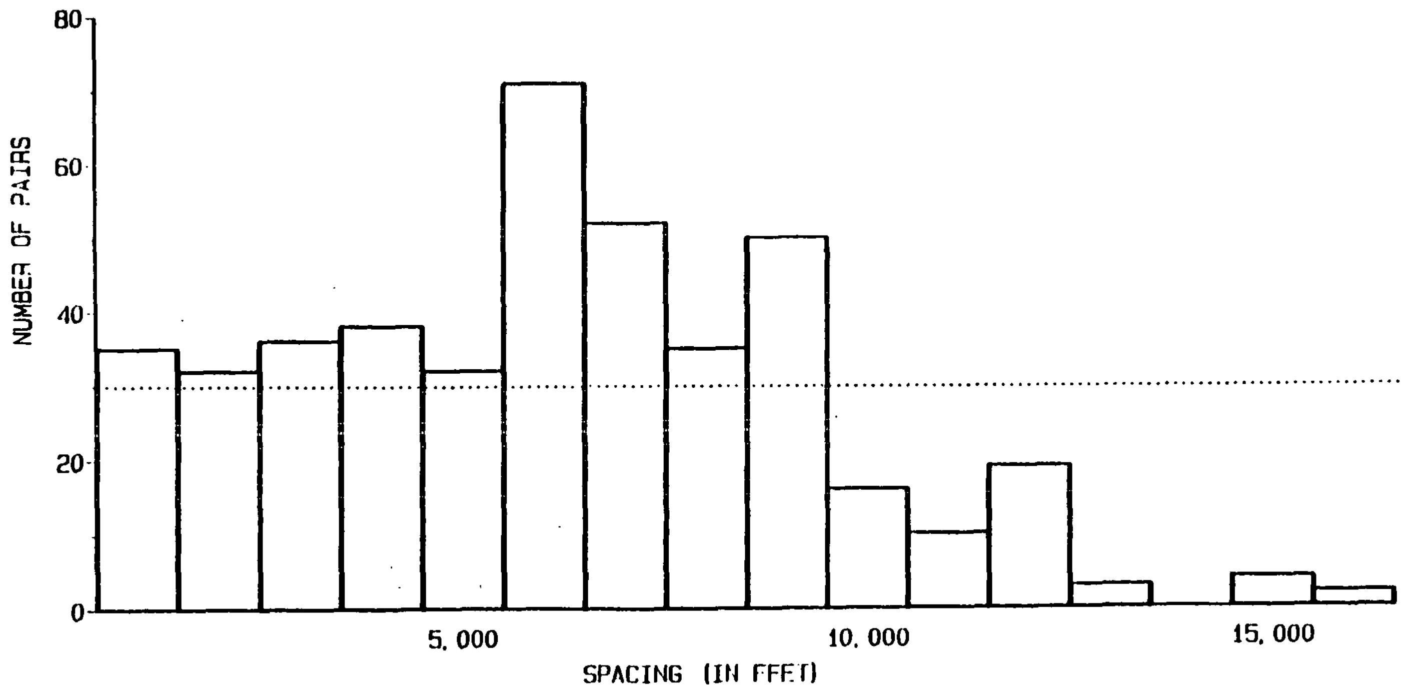
YUCCA MOUNTAIN SYSTEMATIC DRILLING PROGRAM AREAL COVERAGE SCHEME



YUCCA MOUNTAIN SYSTEMATIC DRILLING PROGRAM SMALL SCALE VARIABILITY TEST DRILL HOLE LOCATION



HISTOGRAM OF DATA PAIRS FOR GEOSTATISTICAL ANALYSIS



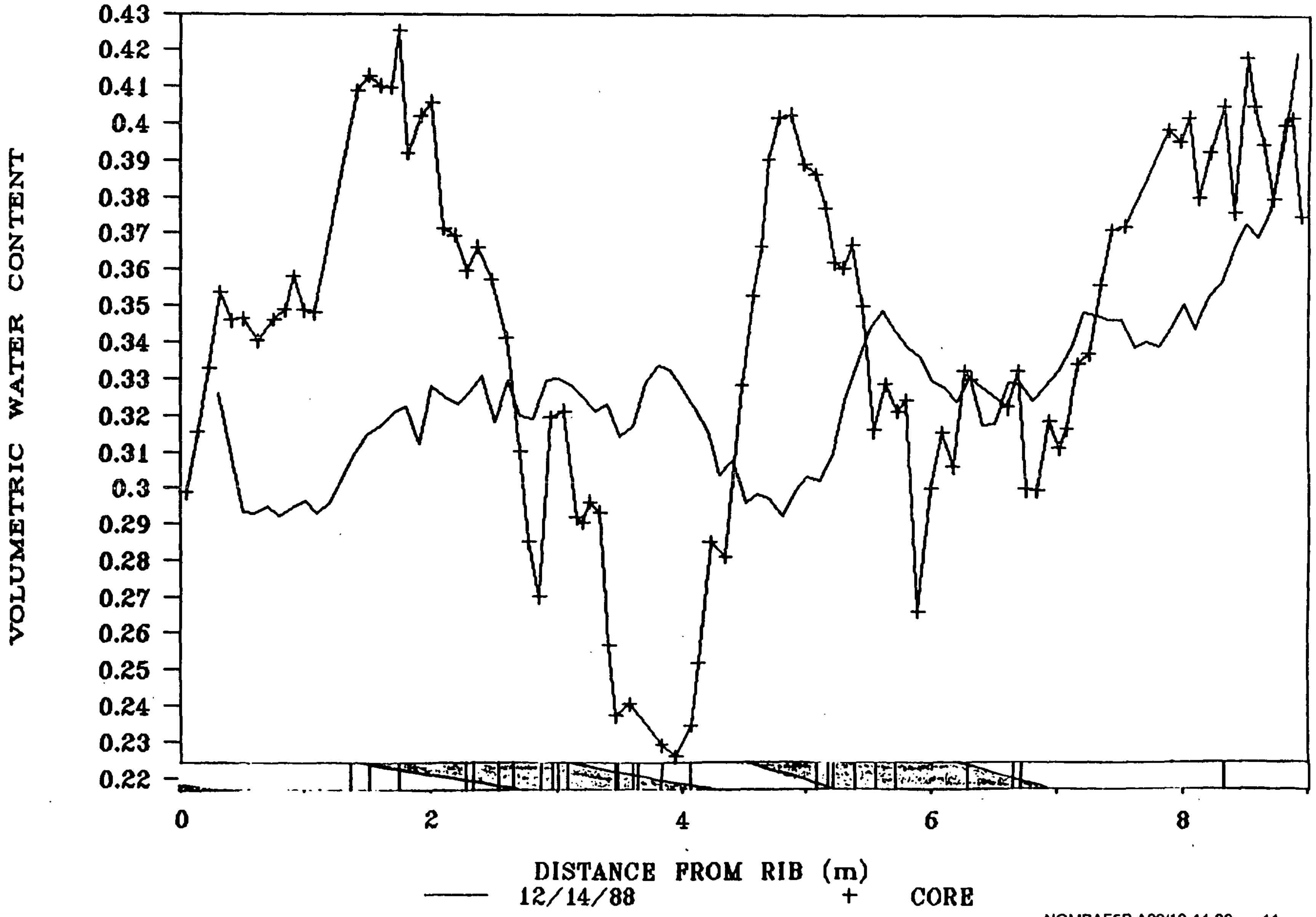
MEASURING AND MODELING MATRIX PROPERTIES

- WATER CONTENT
- WATER POTENTIAL
- PERMEABILITY (GAS AND LIQUID)
  - SATURATED
  - UNSATURATED
  - MODELS
- WATER CHARACTERISTIC CURVES
  - HYSTERESIS
  - MODELS
- RELATED PROPERTIES
  - BULK DENSITY
  - PARTICLE DENSITY
  - POROSITY

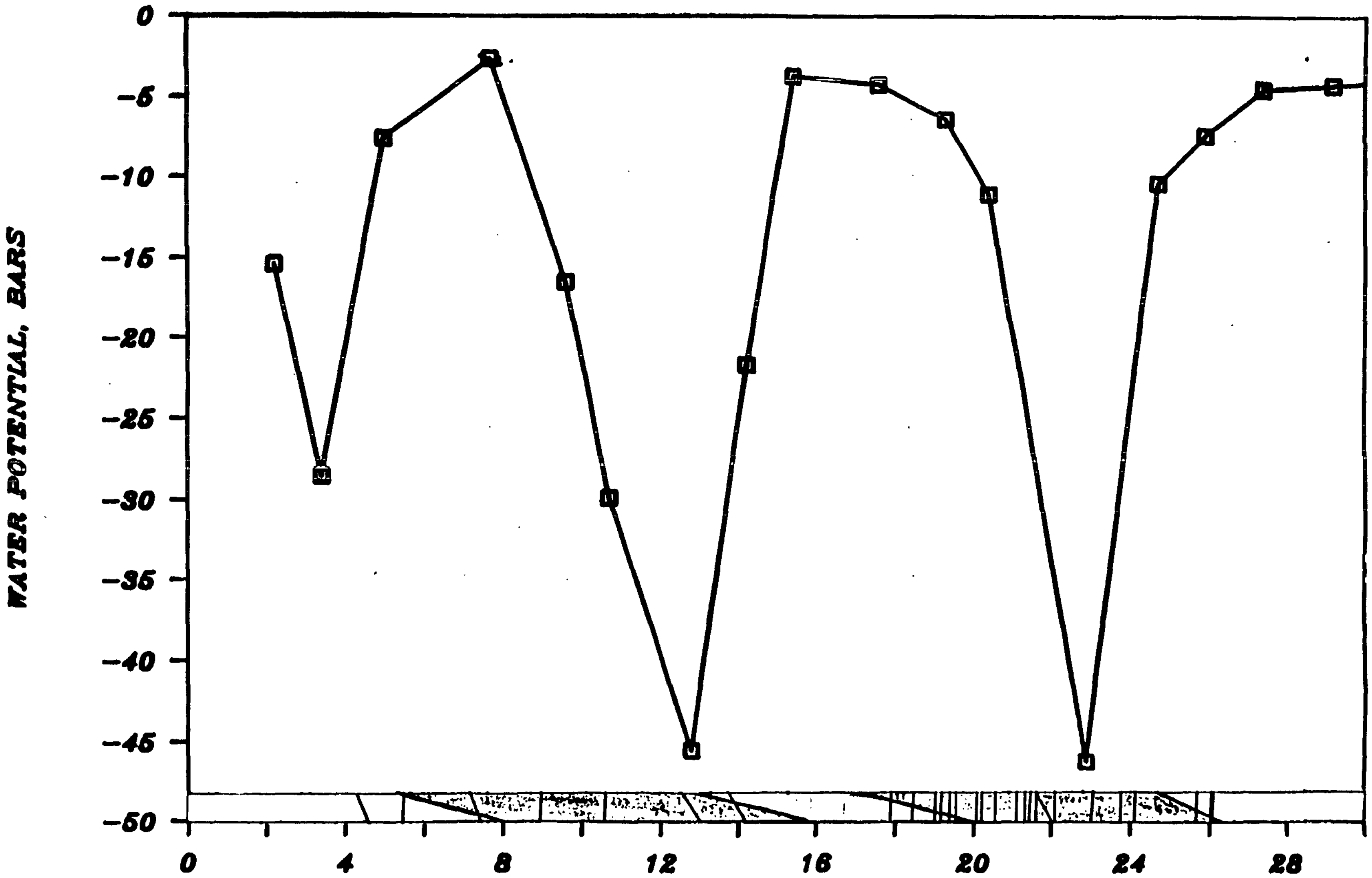
PHOTOGRAPH OF
CORE IN LEXAN LINER

PHOTOGRAPH OF
DIFFERENT SIZE CORE SAMPLES

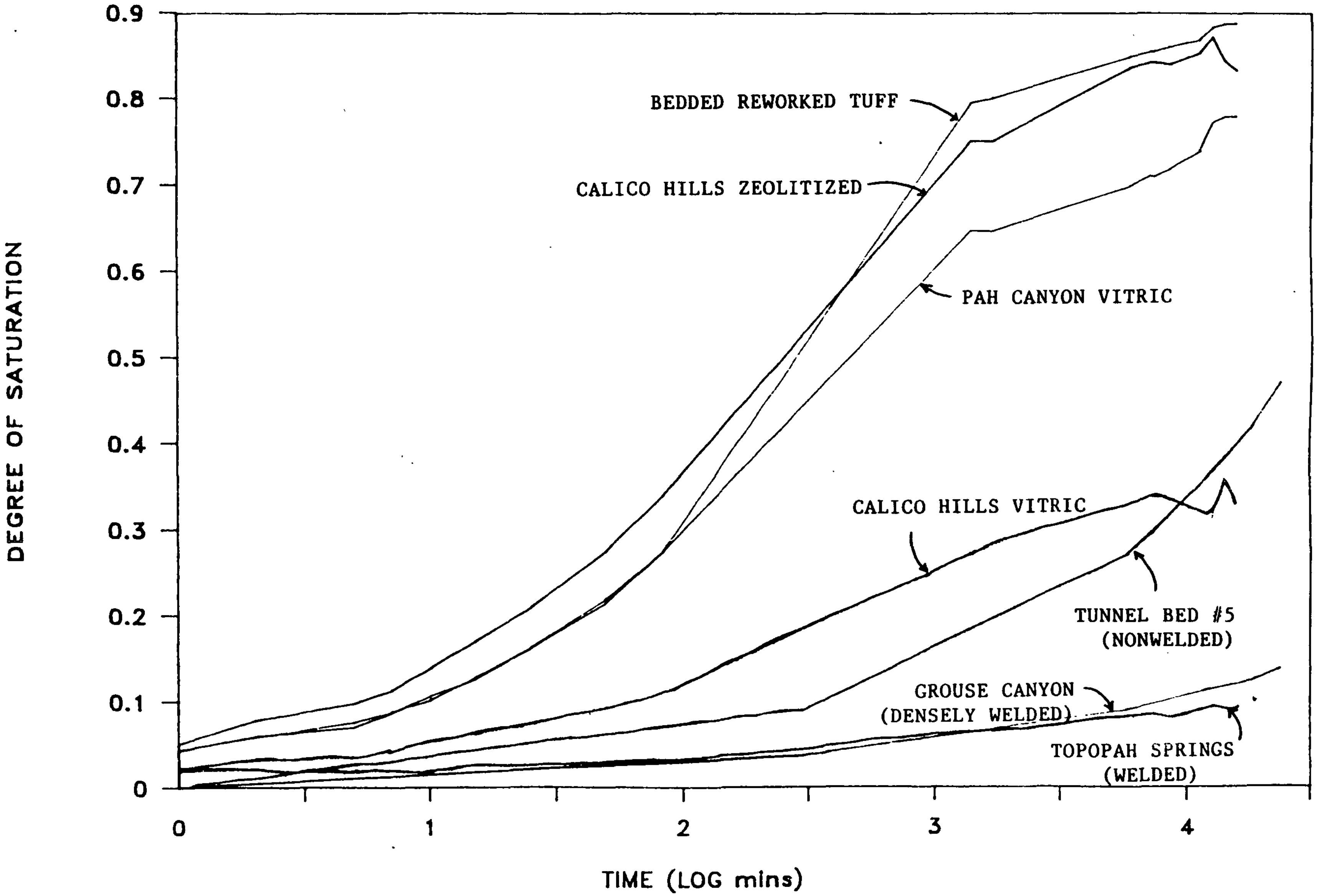
WET DRILLED, NONWELDED



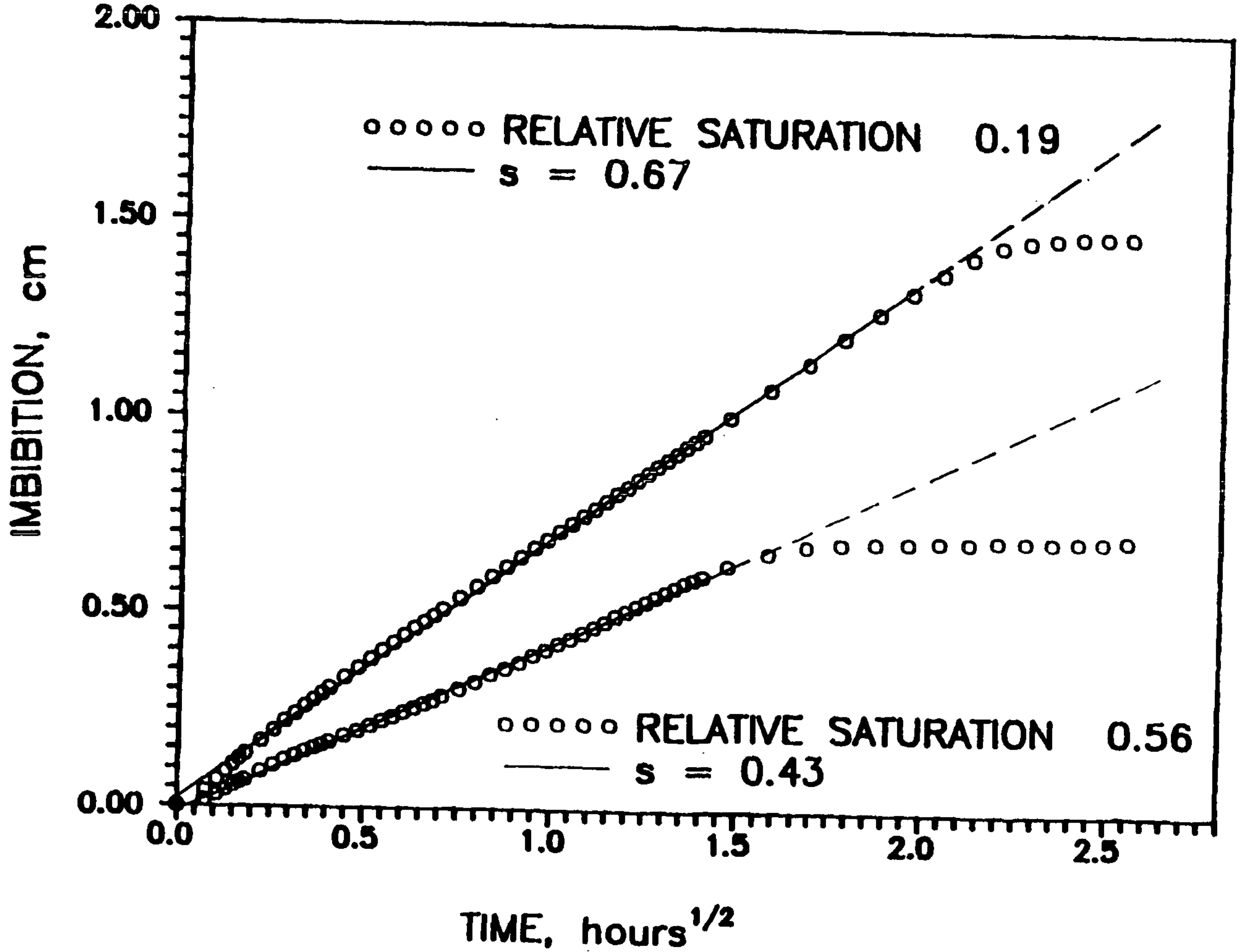
G-TUNNEL WATER POTENTIALS
NONWELDED TUFF



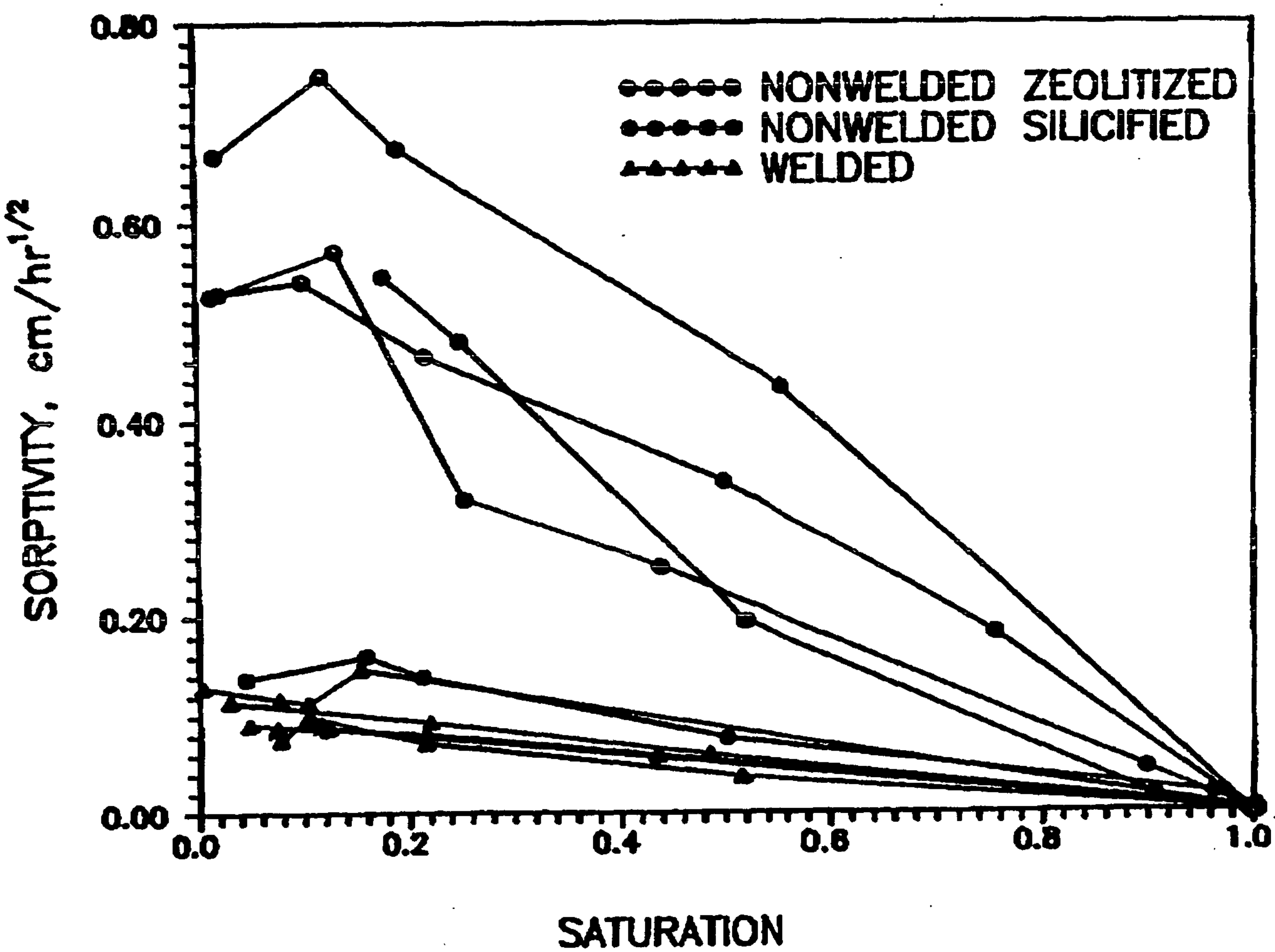
IMBIBITION AND EVAPORATION



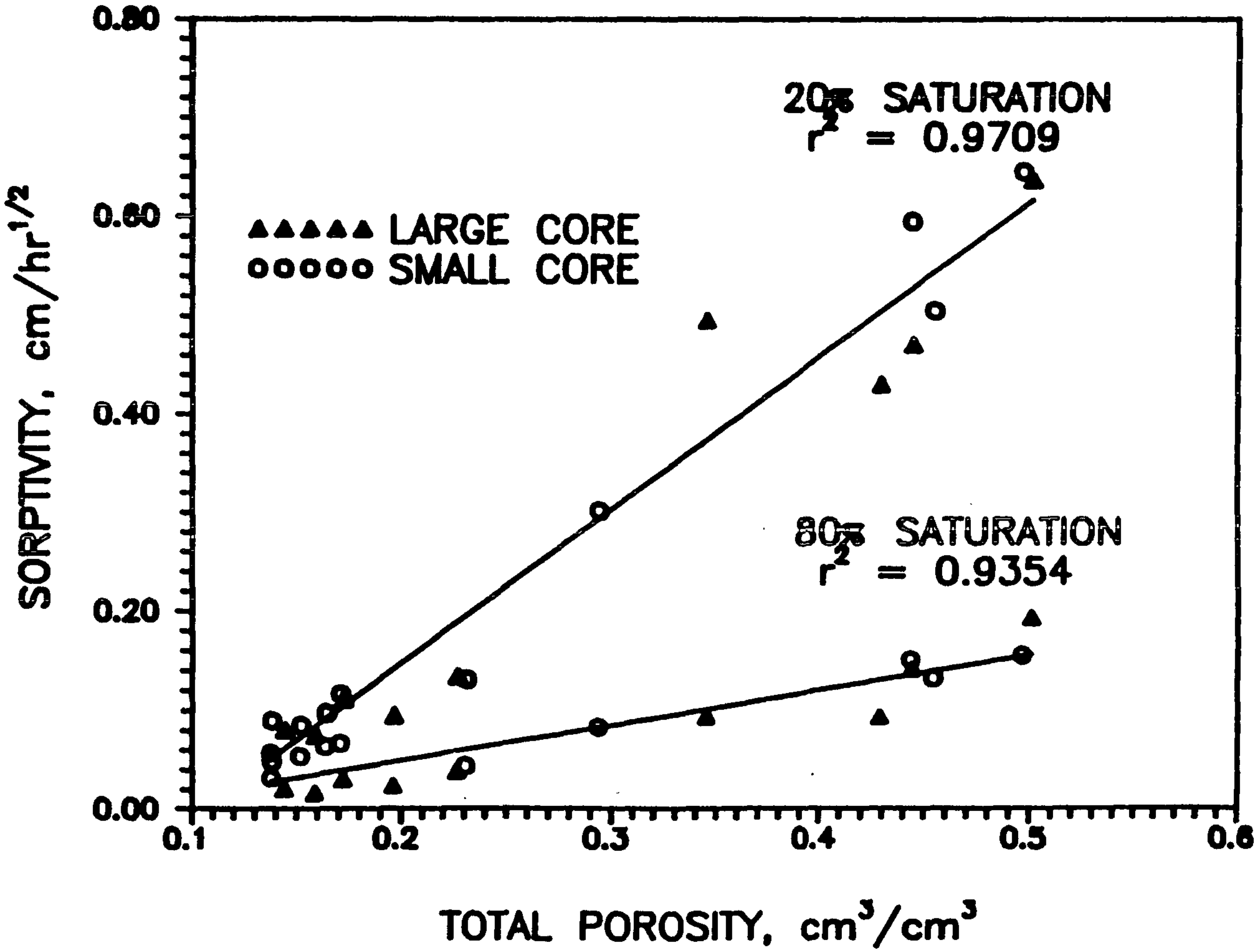
IMBIBITION MEASUREMENTS TO DETERMINE SORPTIVITY, s

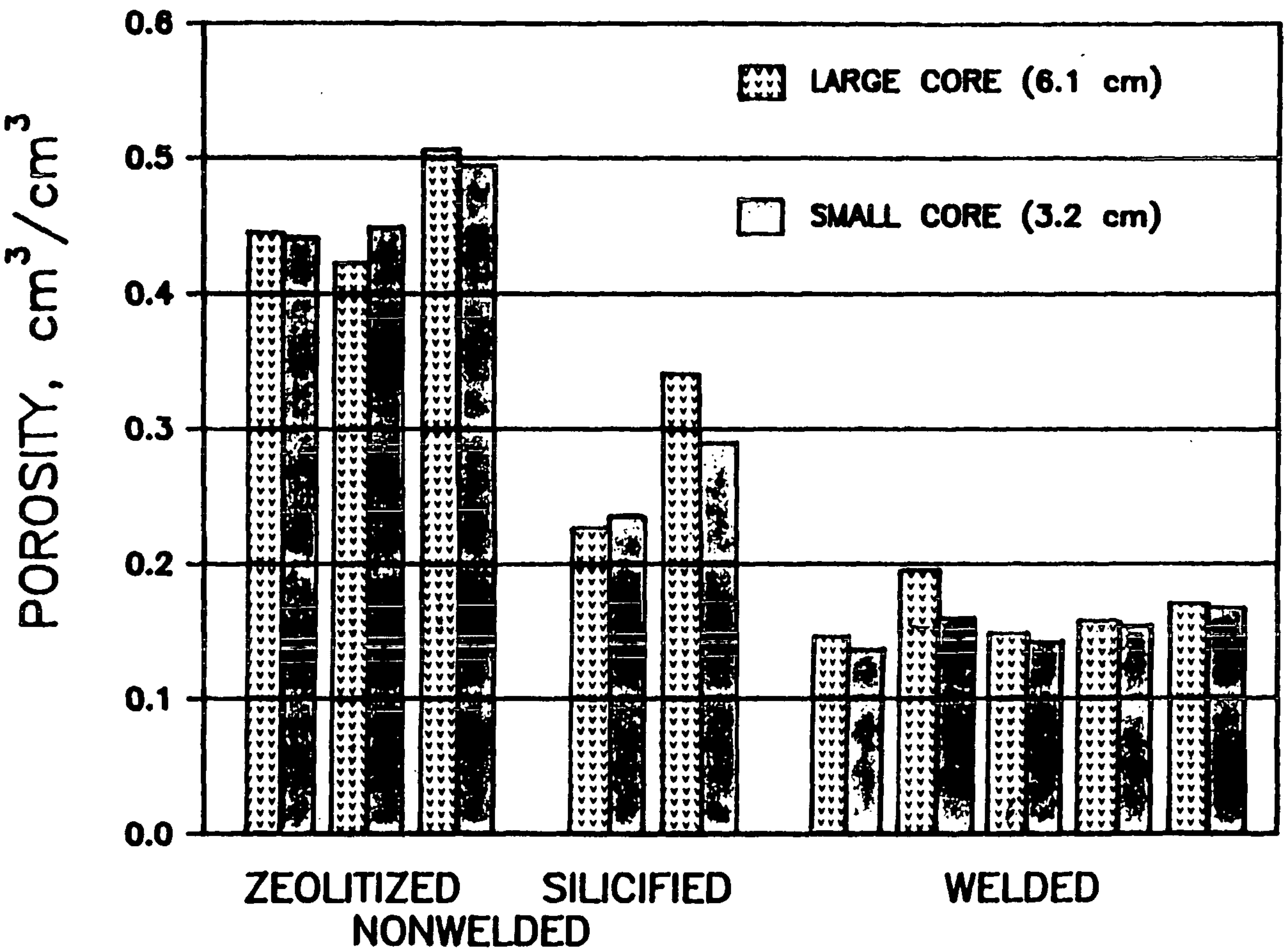


SORPTIVITY AT DIFFERENT INITIAL SATURATIONS



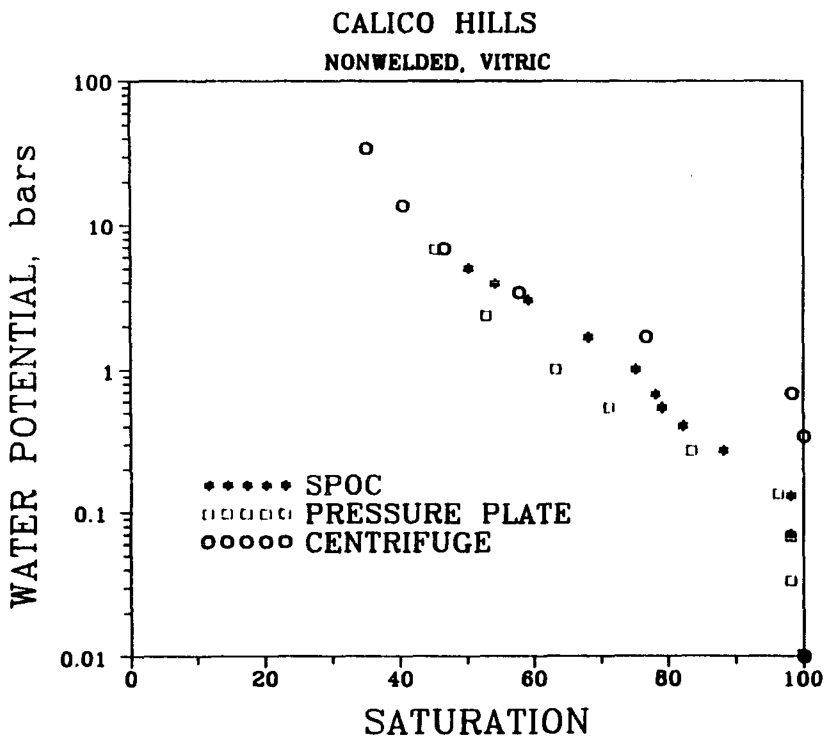
USING SORPTIVITY TO EVALUATE SCALE

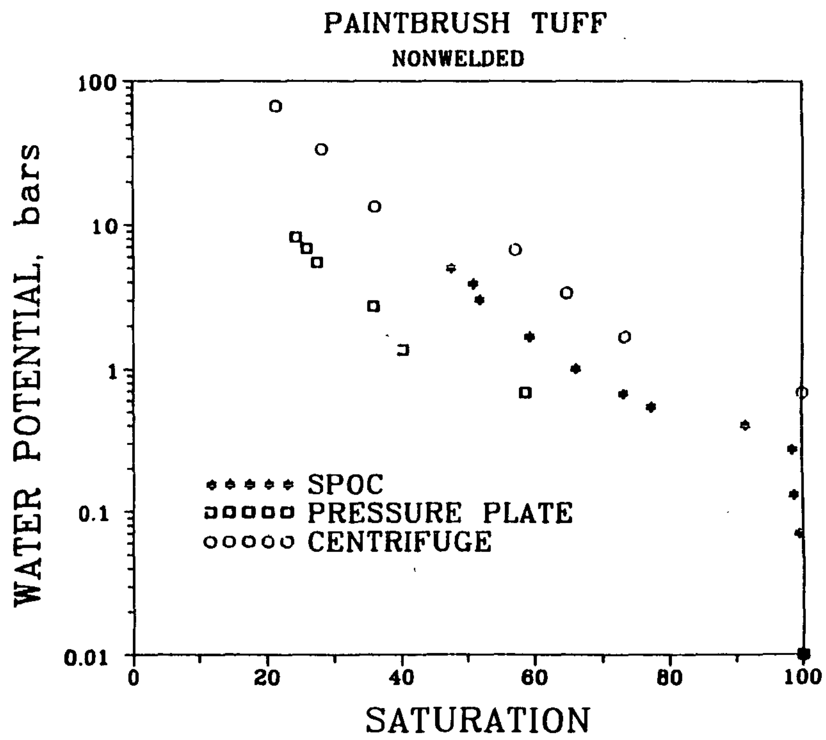


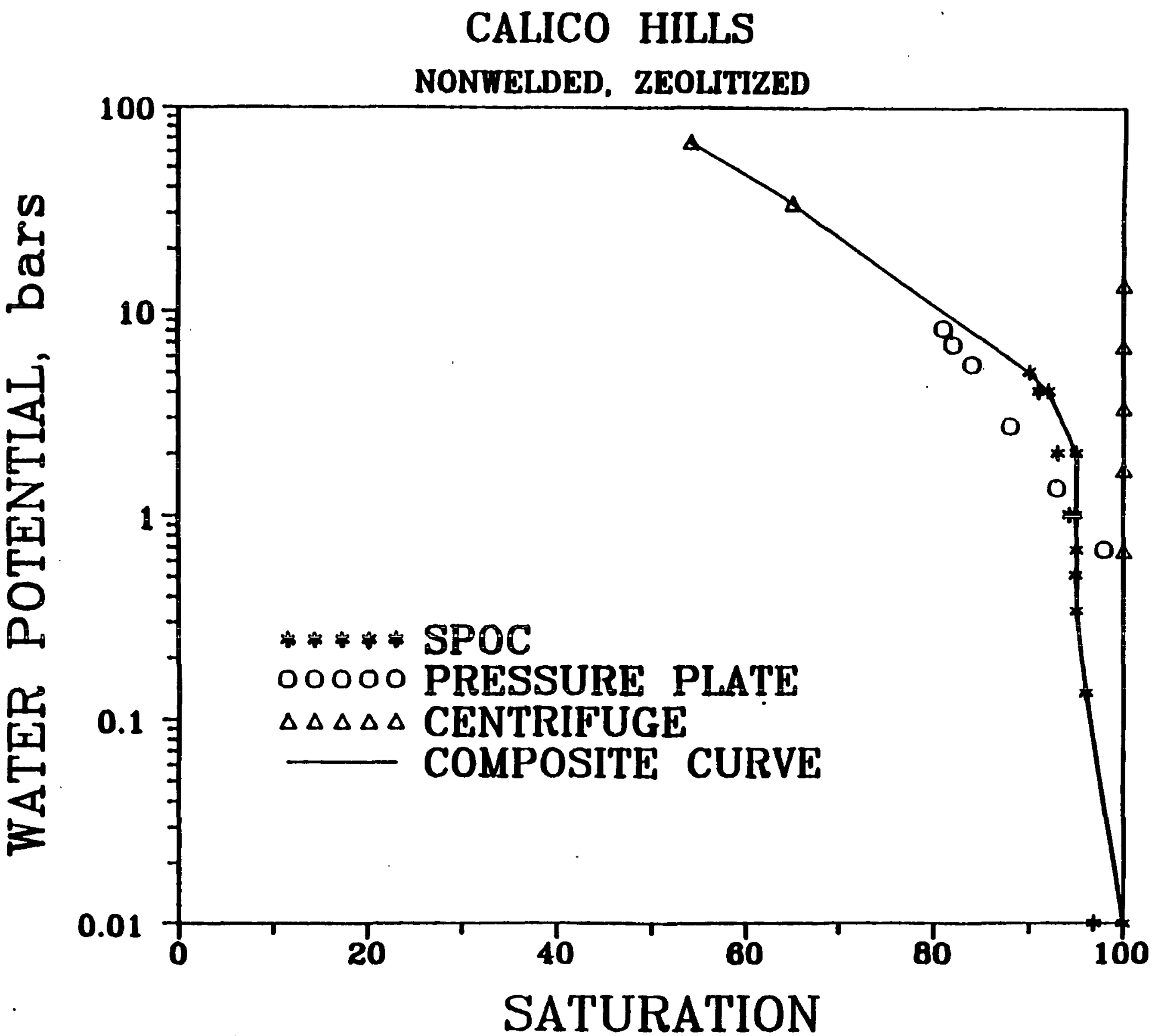


POROSITY, cm³/cm³
0.6
0.5
0.4
0.3
0.2
0.1
0.0
LARGE CORE (6.1 cm)
SMALL CORE (3.2 cm)
ZEOLITIZED
SILICIFIED
NONWELDED
WELDED

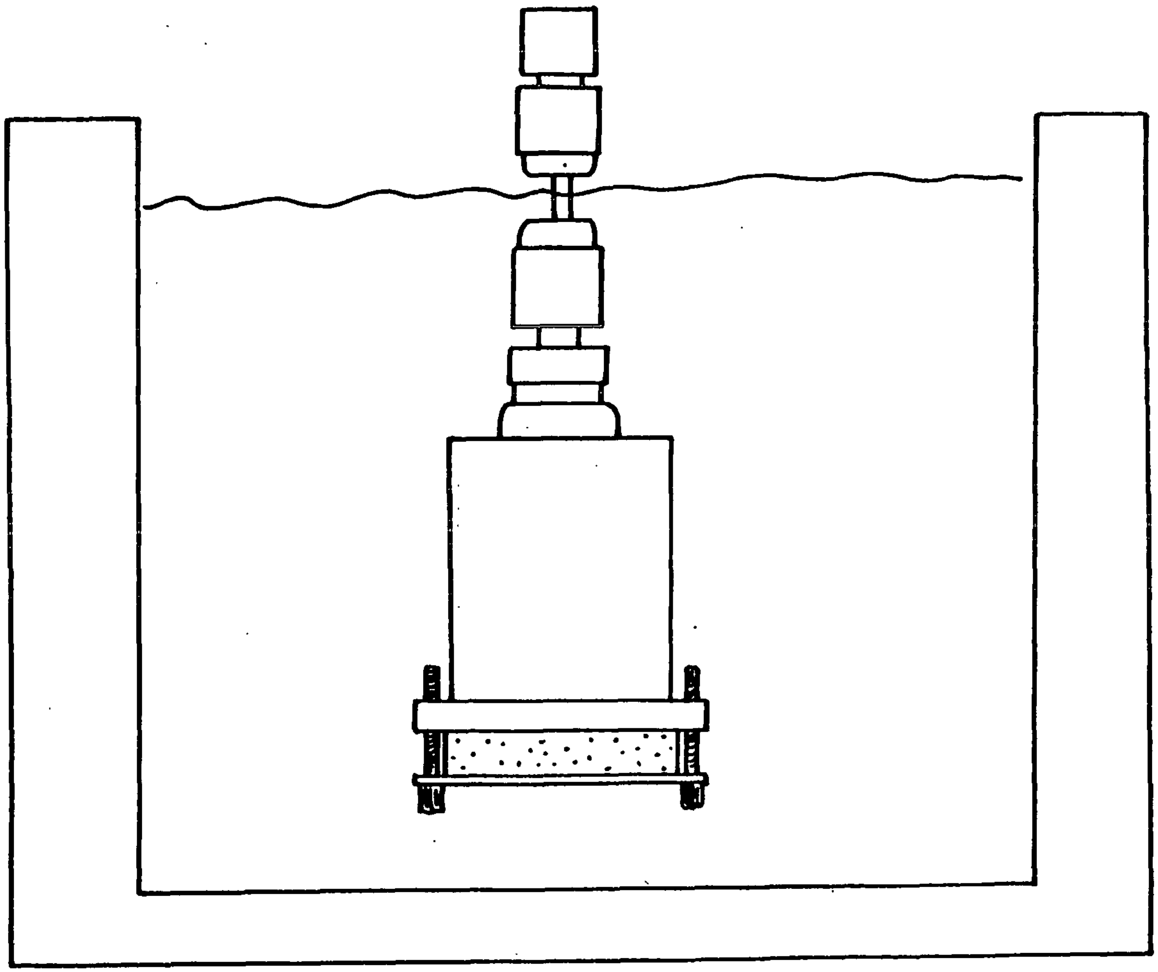
WATER RETENTION CURVES ON NONWELDED TUFF USING THREE METHODS

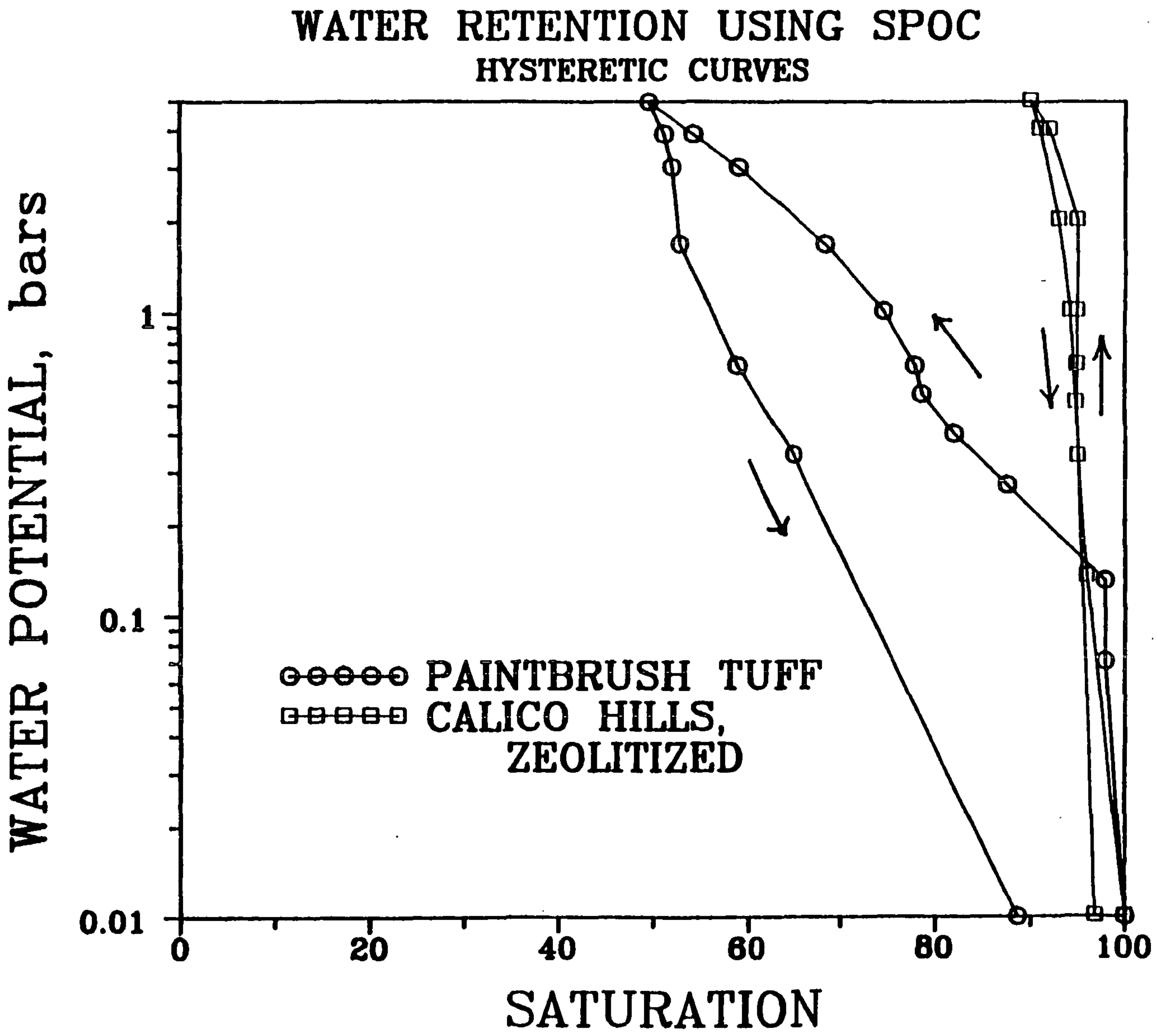




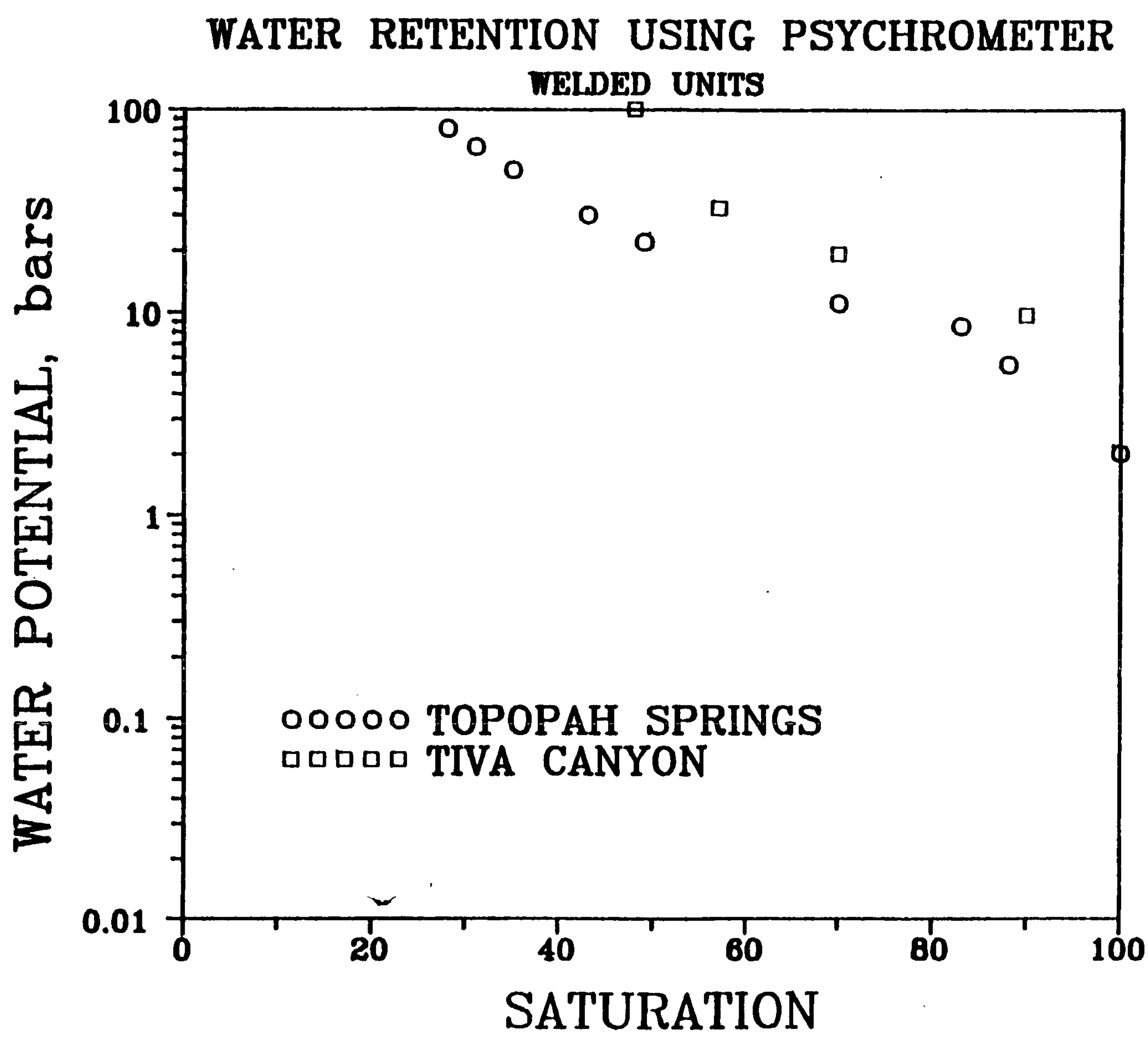

CALICO HILLS
NONWELDED, ZEOLITIZED
WATER POTENTIAL, bars
100
10
1
0.1
0.01
0
20
40
60
80
100
SATURATION
SPOC
PRESSURE PLATE
CENTRIFUGE
COMPOSITE CURVE

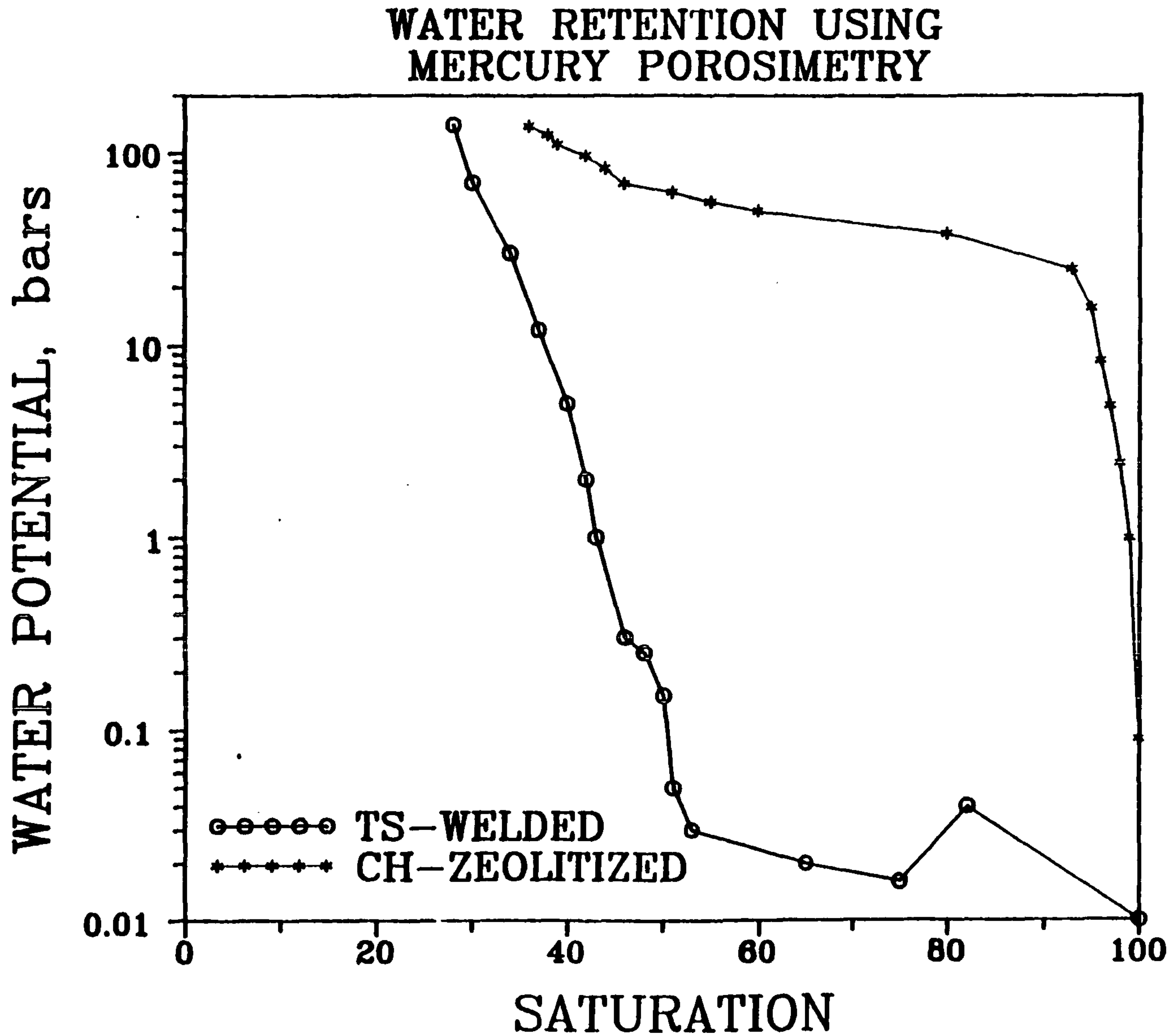
SUBMERSIBLE PRESSURIZED OUTFLOW CELL (SPOC)





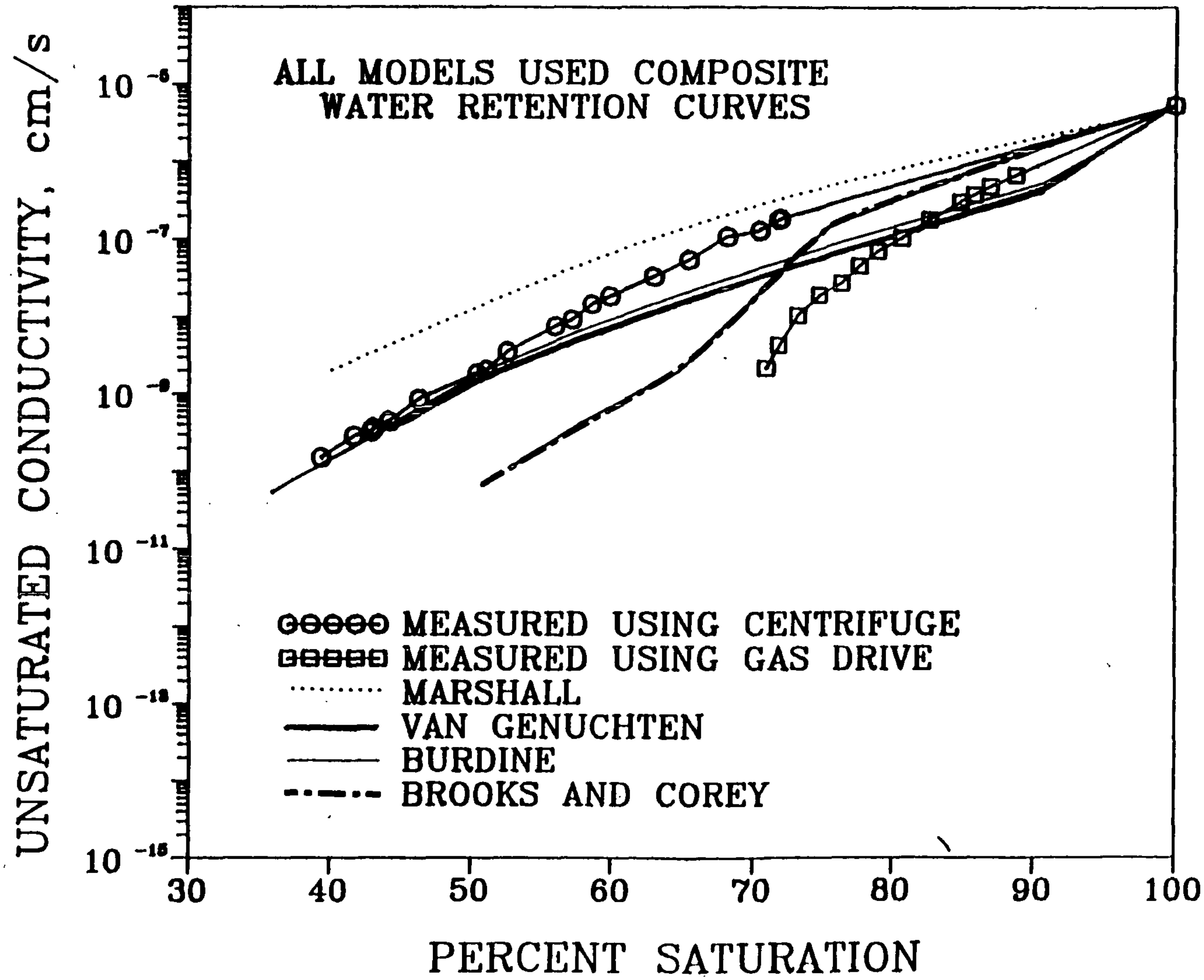
WATER RETENTION USING SPOC
HYSTERETIC CURVES
WATER POTENTIAL, bars
1
0.1
0.01
0
20
40
60
80
100
SATURATION
PAINTBRUSH TUFF
CALICO HILLS, ZEOLITIZED

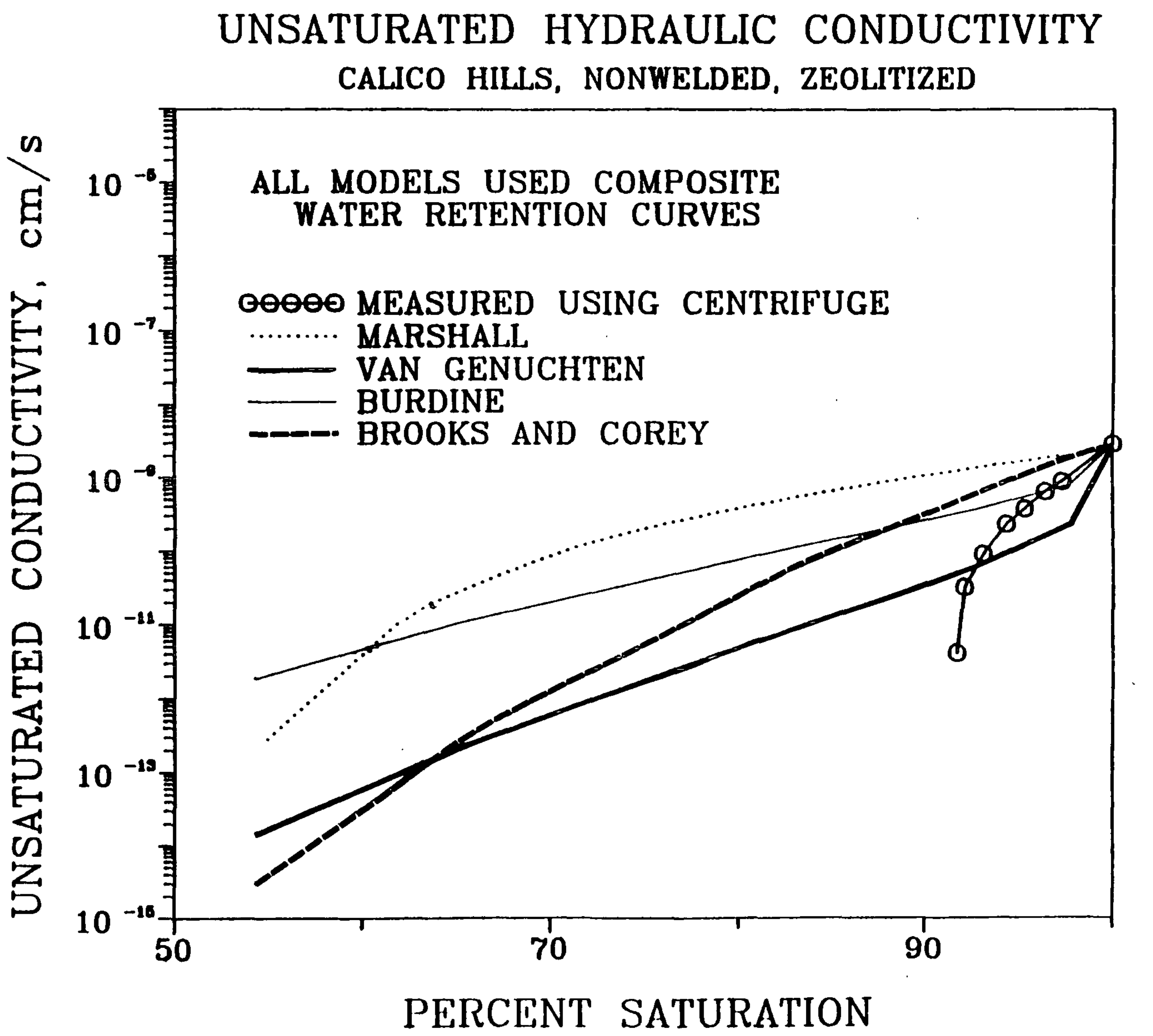

WATER RETENTION USING PSYCHROMETER
WELDED UNITS
WATER POTENTIAL, bars
100
10
1
0.1
0.01
0
20
40
60
80
100
SATURATION
TOPOPAH SPRINGS
TIVA CANYON

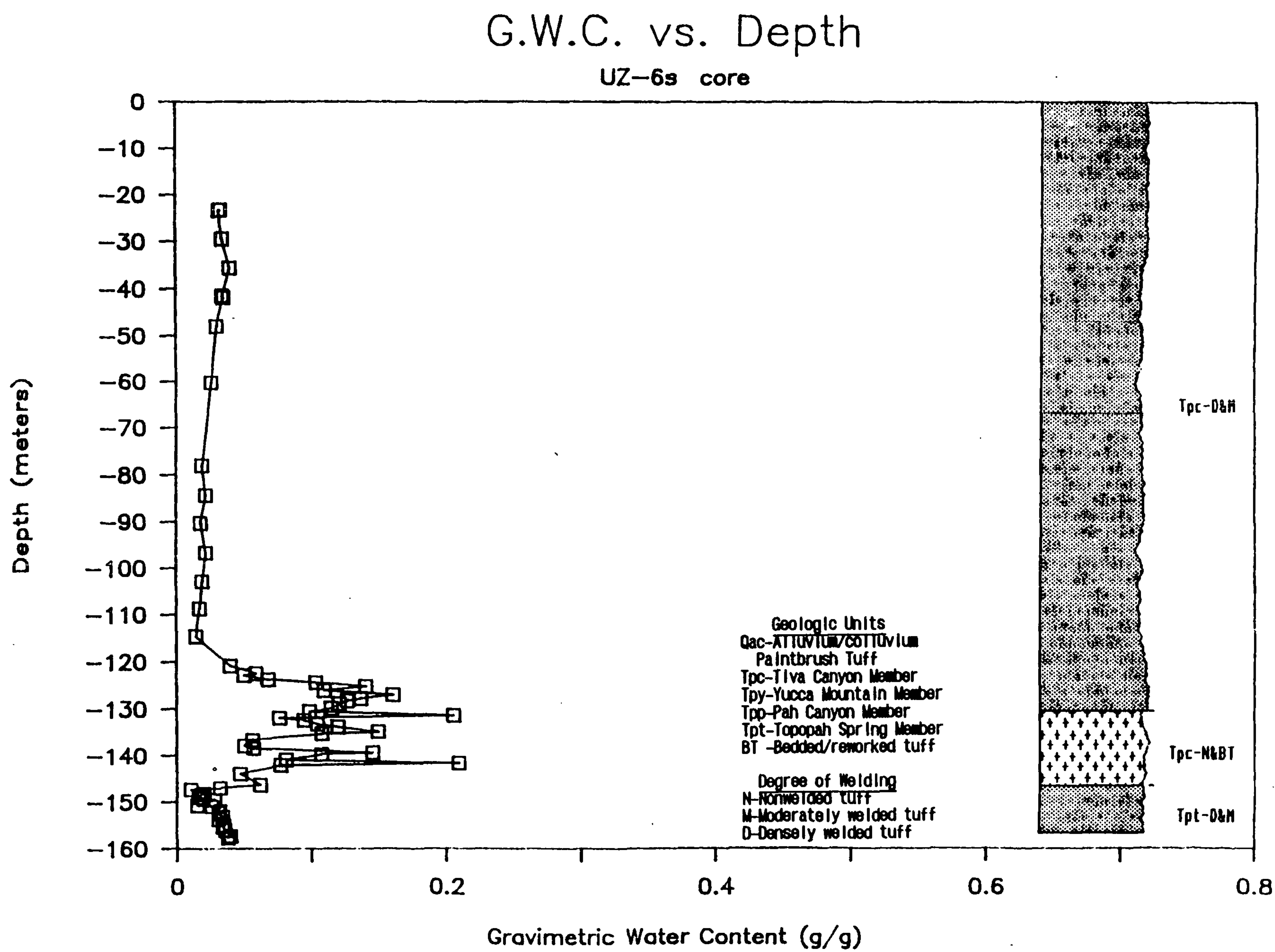

WATER RETENTION USING
MERCURY POROSIMETRY
WATER POTENTIAL, bars
100
10
1
0.1
0.01
0
20
40
60
80
100
SATURATION
TS-WELDED
CH-ZEOLITIZED

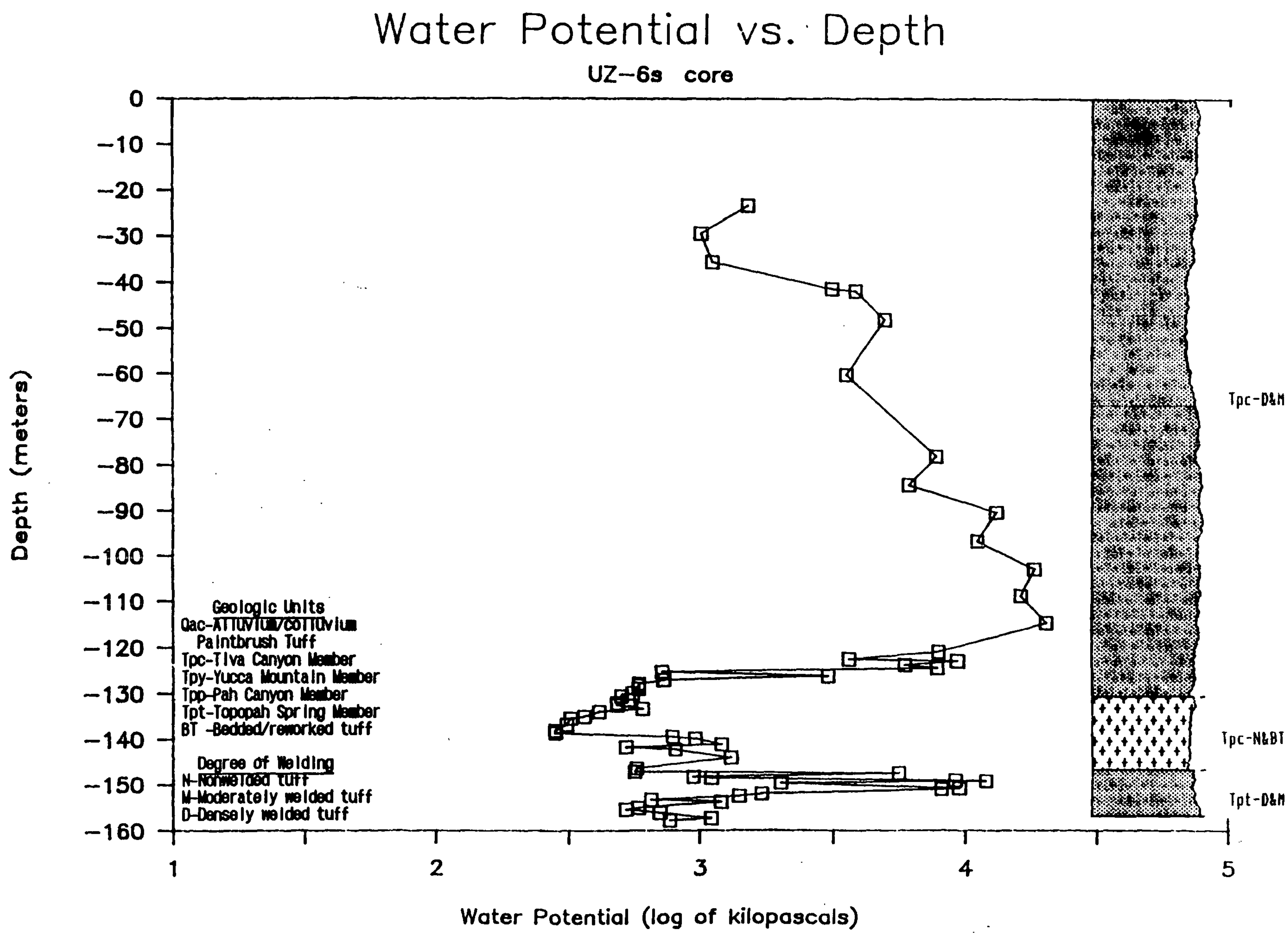
UNSATURATED HYDRAULIC CONDUCTIVITY

PAINTBRUSH TUFF NONWELDED



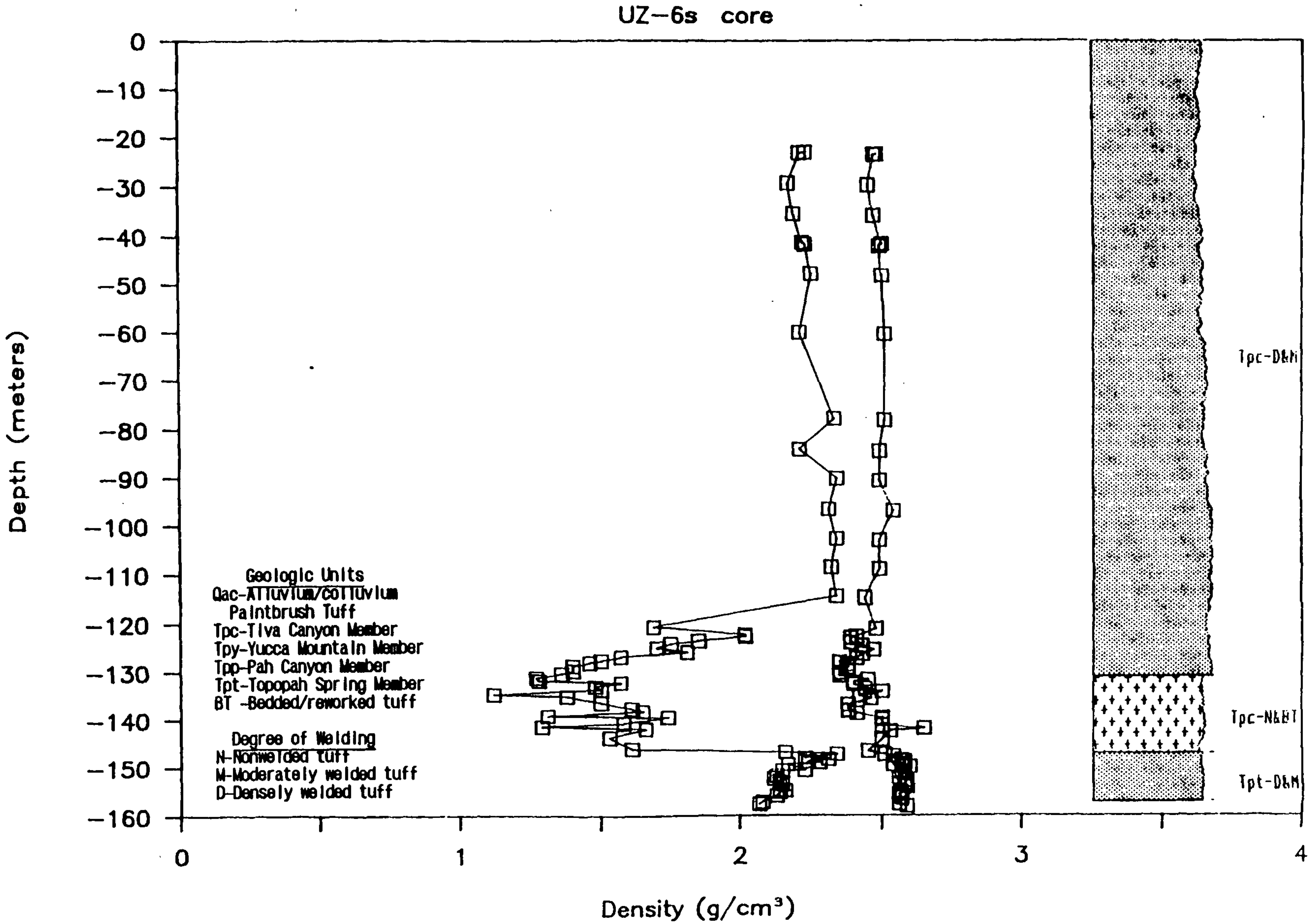

UNSATURATED HYDRAULIC CONDUCTIVITY
CALICO HILLS, NONWELDED, ZEOLITIZED
ALL MODELS USED COMPOSITE
WATER RETENTION CURVES
MEASURED USING CENTRIFUGE
MARSHALL
VAN GENUCHTEN
BURDINE
BROOKS AND COREY
UNSATURATED CONDUCTIVITY, cm/s
PERCENT SATURATION
10 ⁻⁵
10 ⁻⁷
10 ⁻⁹
10 ⁻¹¹
10 ⁻¹³
10 ⁻¹⁵
50
70
90

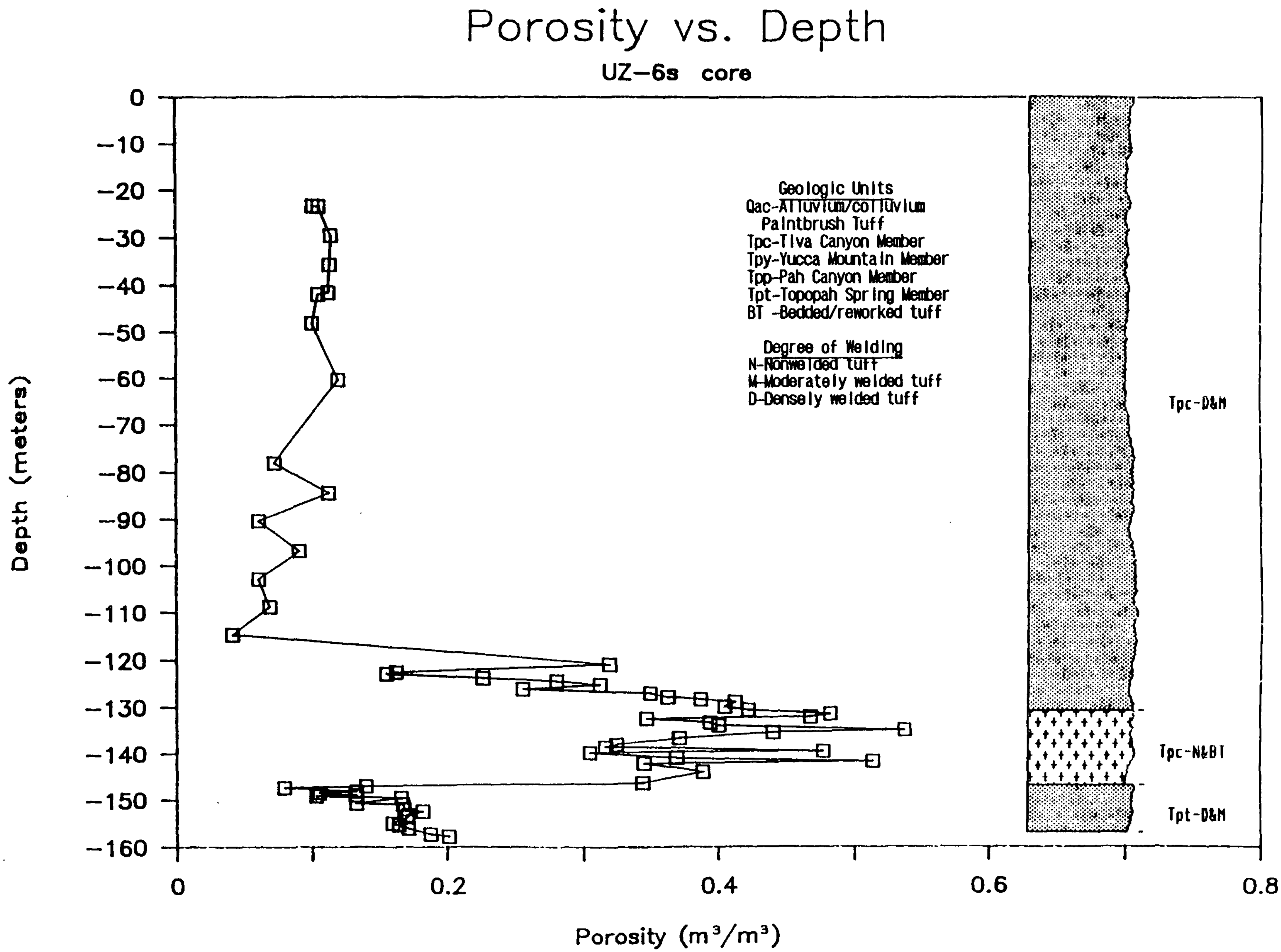

G.W.C. vs. Depth
UZ-6s core
Depth (meters)
Gravimetric Water Content (g/g)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
0
0.2
0.4
0.6
0.8
Geologic Units
Qac-Alluvium/colluvium
Paintbrush Tuff
Tpc-Tiva Canyon Member
Tpy-Yucca Mountain Member
Tpp-Pah Canyon Member
Tpt-Topopah Spring Member
BT -Bedded/reworked tuff
Degree of Welding
N-Nonwelded tuff
M-Moderately welded tuff
D-Densely welded tuff
Tpc-D&M
Tpc-N&BT
Tpt-D&M



Water Potential vs. Depth
UZ-6s core
Depth (meters)
Water Potential (log of kilopascals)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
1
2
3
4
5
Geologic Units
Qac-Alluvium/colluvium
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-Nonwelded tuff
M-Moderately welded tuff
D-Densely welded tuff
Tpc-D&M
Tpc-N&BT
Tpt-D&M

Bulk & Grain Density vs. Depth





Porosity vs. Depth
UZ-6s core
Geologic Units
Qac-Alluvium/colluvium
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-Nonwelded tuff
M-Moderately welded tuff
D-Densely welded tuff
Tpc-D&M
Tpc-N&BT
Tpt-D&M
Depth (meters)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
0
0.2
0.4
0.6
0.8
Porosity (m³/m³)

RANGE IN CORE PROPERTY VALUES CURRENTLY PUBLISHED FOR YUCCA MOUNTAIN GEOHYDROLOGIC UNITS

GEOHYDROLOGIC UNIT	POROSITY (cm^3/cm^3)	GRAIN DENSITY (g/cm^3)	DRY BULK DENSITY (g/cm^3)	SATURATED CONDUCTIVITY (cm/s)
TIVA CANYON w	.08-.12	2.3-2.8	1.4-2.4	1.5E-10-9.7E-10
PAINTBRUSH TUFF nw	.06-.54	2.2-2.6	1.1-2.4	2.3E-9 -2.4E-4
TOPOPAH SPRING w	.04-.33	2.4-2.6	1.8-2.4	1.2E-10-2.3E-7
CALICO HILLS nw	.14-.46	2.2-2.6	1.3-2.0	5.2E-10-2.9E-5
CRATER FLAT	.19-.38	2.5-2.6	1.6-2.1	2.0E-9 -6.9E-7

References
Anderson (1981)
Rush, Thordarson and Bruckheimer (1983)
Thordarson (1983)
Montazer and Wilson (1984)
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