FIELD SIMULATION OF WASTE IMPOUNDMENT SEEPAGE IN THE VADOSE ZONE: HORIZONTAL SPATIAL VARIABILITY OF THE GEOLOGIC AND HYDROLOGIC PROPERTIES OF AN ALLUVIAL FAN FACIES

by

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ABSTRACT

A long-term field infiltration experiment was conducted on the campus of the New Mexico Institute of Mining and Technology from January 1987 to September 1989. Monitoring of drainage from the experimental plot as well as characterization of the geology and hydrology continued until July of 1990. The experiment site is located in an arroyo directly west of the 12th hole of the N.M.I.M.T. golf course. Runoff events have been diverted from the arroyo by a large dike just to the west of the field site.

Two major geologic facies have been described beneath the field site. The upper facies is quite heterogeneous and stratified, consisting of alluvial sands, silts, and clayey silts intermixed with cobble zones. The underlying facies consists of well-sorted fine to coarse fluvial sands.

The initial goals of the experiment were to investigate the importance of lateral movement of seepage and the capability of models to predict seepage movement in the vadose zone. Subobjectives included evaluating solute transport parameters and developing practical guidelines for characterizing the hydrology and geology of the vadose zone. The current study concentrates on characterizing the horizontal spatial variability of the hydrology and geology at the site using statistical and geostatistical methods.

To achieve the objective, a 41 meter long, 1.5 meter deep "shallow" trench was excavated diagonally through the site using a backhoe. The trench orientation and depth were chosen to run perpendicular to the interpreted water flow direction at a depth in which considerable water was moving. Over an eight month period, 119 disc permeameter measurements of hydraulic conductivity at varying supply pressures were conducted along the floor of the trench. 100cc soil cores were collected after each disc permeameter measurement for laboratory analysis of numerous geologic and hydrologic parameters. Variogram analysis suggests field measured 1.3 cm tension K, laboratory soil core K_s, d10 particle size, and α-values from van Genuchten's soil-water/pressure head analysis are spatially dependent up to 3 meters separation. Further, laboratory K_s is shown to exhibit another scale dependence at 7.0 to 8.0 meters separation. Preliminary analysis suggests the separation distance coincides with moderate scale mapped geology.

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1.0 INTRODUCTION

Surface impoundments (evaporation ponds, mill tailings impoundments) are used in the semi-arid regions of the western United States for the disposal of liquid wastes. They generally cover large areas and are quite shallow in order to maximize evaporation. Yet, until recently, many impoundments were unlined allowing seepage to enter aquifers over long periods of time. Current federal regulations require operators to demonstrate there will be no seepage discharge impacting aquifers from impoundments. Synthetic and clay liners will slow seepage. Underlying materials are unlikely to become saturated.

In the southwestern states, the water table may be 10's of meters below ground surface. Vadose zone processes, therefore, become very important in assessing the potential for groundwater contamination. But, since the vadose zone is often comprised of stratified, partially saturated, geologic materials, its hydraulic properties are difficult to characterize (Larson & Stephens, 1985).

Recent theories suggest that the inherent spatial variability - the natural heterogeneity and anisotropy - in geologic and hydraulic properties can cause infiltration to follow multi-dimensional pathways through the vadose zone. Yeh and Gelhar (1983) have shown theoretically that lateral spreading is enhanced where seepage occurs into dry soils. Stephens and Heerman (1985) used a laboratory sand tank to show this result. In field studies, McCord and Stephens (1986) delineated flowpaths of vadose water on a sandy hillslope. Their results indicated a strong lateral flow component on the hillslope in the absence of apparent sublayers. They proposed that this was possibly due to moisture dependent heterogeneity in the hydraulic conductivity.

Stratification inhibits the downward movement of seepage. In a fine over coarse layered system, water infiltrating the fine layer will be impeded at the fine-coarse interface until the water pressure exceeds the critical value needed for flow through the coarse pores. Miller and Gardner (1962) conducted laboratory column experiments to determine the effects of textural and structural stratification on infiltration. The wetting front was inhibited at a soil interface until the tension lowered enough to allow it to flow into the coarser layer. In laboratory sand tanks, Stephens & Heerman (1985,1988) and Stauffer and Dracos (1986) showed significant horizontal flow along layers under unsaturated conditions.

Lateral flow has also been documented in field studies. Crosby et. al.(1968) conducted a test drilling program in a septic tank drain field area. They found very dry soils at depth and concluded that most of the water moved laterally due to capillarity. Johnson et.al.(1981) monitored water movement beneath a number of landfills in Illinois. Samples collected from porous cup samplers, also known as suction lysimeters, indicated significant lateral flow occurring in the vadose zone. Trautwein & Daniel (1983) conducted moisture content measurements beneath a waste disposal evaporation pond. Previous research had shown the water table to be approximately 119 meter below ground surface with partially saturated materials above. After 20 years of seepage, perched water was detected between 103 m and 42 m below ground surface. The field studies indicated that extensive lateral migration of the perched water had occurred. None of the field investigations describe infiltration under controlled conditions. Lack of important hydrogeologic information such as initial moisture content conditions makes accurate simulations of the observed moisture movement nearly impossible.

In January 1987, a long term field experiment was initiated on the campus of the New Mexico Institute of Mining and Technology in Socorro, New Mexico (fig. 1). Seepage of leachate from a lined impoundment into the unsaturated zone was simulated with a drip irrigation system. Site characterization began in the summer of 1986. Field work continued until August of 1990.

The initial goals of the experiment were to investigate the importance of lateral movement of seepage and the capability of models to predict seepage movement in the vadose zone. Subobjectives, deemed important during the course of the infiltration experiment, include evaluating the solute transport parameters of the site and developing practical

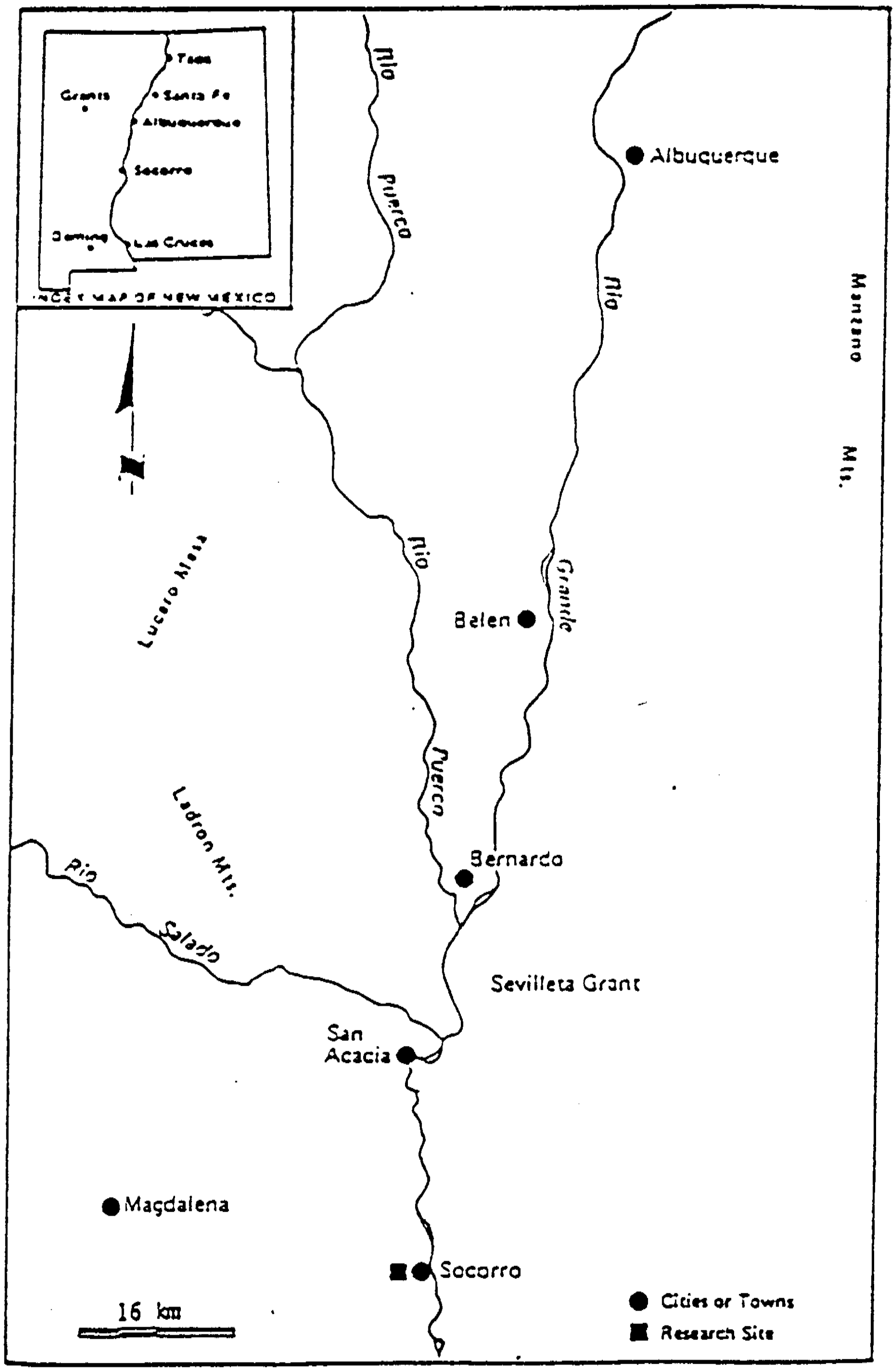


Figure 1. Index Map (Mattson, 1989)

guidelines for characterizing the hydrology and geology of the vadose zone.

The experimental site is situated in an arroyo that has been diverted to stop flooding in Socorro. The site geology consists of two general lithologies. The upper facies (piedmont slope) consists of highly stratified and heterogeneous alluvial fan gravels, sands, and silts with interbedded cobbles and clays. This facies extends to approximately 4 meters below ground surface and overlies ancient Rio Grande fluvial sands (Chamberlain,1980). The sands extend to at least 24 meters below ground surface. Depth to water at the field site was approximately 21 meters as of August 1990. The site was never irrigated prior to the 1987 infiltration experiment, but the adjacent New Mexico Tech Golf Course is irrigated year round. The geologic and hydraulic conditions are similar to many regions of the southwestern United States.

The objective of the current study is to quantify the horizontal spatial variability of the geologic and hydraulic properties of the piedmont slope facies along a 40 meter trench. In order to achieve the objective, tests were conducted in the field and laboratory. Chapter one introduces justification for the current study. Chapter two discusses the disc permeameter used for field measurements as well as relevant spatial variability theory and research. Chapter three describes the experimental site location as well as the infiltration experiment design, construction, and 2.5 years of infiltration monitoring. Chapter four contains descriptions of the site geology. Chapter five describes the field methods employed to conduct 119 disc permeameter measurements along the trench at approximately 0.3 meter intervals as well as the 100 cc ring samples collected for laboratory analysis. Saturated hydraulic conductivity, moisture content - pressure head relationships, particle size distributions, and van Genuchten's α and N parameters were determined in the laboratory. Chapter six presents an analysis of results for the field and laboratory data. Chapter seven presents conclusions.

Three earlier reports are related to the activities at the field site and are the basis for this study. Parsons (1988) describes preliminary characterization of the geologic and hydraulic properties of the site as well as applying a one-dimensional analytical model to the observed moisture movement. Mattson (1989) describes the site design, construction, and applies a two-dimensional analytical model to the observed moisture movement. Flanigan (1989) discusses a solute transport experiment conducted at the site and his resulting observations.

2.0 BACKGROUND

2.1 DISC PERMEAMETER

The disc permeameter (also known as tension infiltrometer) is a compact field instrument for determining insitu hydraulic properties of soils. It was used to determine 119 insitu sorptivities and hydraulic conductivities at preselected supply pressures in this study. Developed by Perroux in 1982, it evolved from the sorptivity tube design of Clothier and White (1981). In addition to sorptivity and hydraulic conductivity, the characteristic mean pore size in which flow is occurring can be determined.

The idea for measuring insitu unsaturated hydraulic properties is not new. Talsma (1969) measured insitu sorptivities but with a device restricting supply pressures to greater than zero. A closed top infiltrometer was designed by Dixon (1975) to study soil macroporosity and roughness at supply pressures between -3 cm and +1 cm of water. However, the device is complicated and may be hard to use in the field (Perroux and White, 1988).

Following the work of Smiles and Harvey (1973), Dirksen (1975) proposed a method to measure sorptivity with a mariotte type device. The method determined the dependence of conductivity on water content or pressure head in the tensiometer range. According to Perroux and White (1988), the simplicity of Dirksen's device makes it attractive for field use.

Using some of Dirksen's permeameter features, Clothier and White (1981) produced a simple field device known as the sorptivity tube. Water flow occurs through a sintered glass plate. Tension is determined by the bubbling pressure of a hypodermic needle which allows air to enter a reservoir. The effective range of supply pressures for the sorptivity tube is from -10 cm to 0 cm of water. Chong and Green (1983) modified the supply plate design of the sorptivity tube. The modification, however, restricts supply pressures to a narrower range (Perroux and White,1988).

Perroux and White (1988) located several limitations in the sorptivity tube design:

1). The limited size of the sintered glass plates available restricted disc sizes to less than 0.1 meter.

2). Air entry through the capillary was insufficient to maintain a constant pressure during the initial stages of infiltration on high sorptivity materials.

3). The hypodermic needle used to regulate supply pressures clog easily under field conditions.

Therefore, they designed the disc permeameter to retain the sorptivity tube simplicity, while increasing its versatility. Other permeameters have been used in field studies. Jarvis and Leed (1987), for example, designed and operated a tension infiltrometer at supply pressures of -0.5, -2, and -9 cm of water. They compared the calculated hydraulic conductivities to the number of conducting macropores counted from a dye experiment.

Perroux and White's permeameter has been used by numerous researchers (Sully and White,1987; Watson and Luxmoore,1986; Perroux and White,1988; Greene and Tongway,1989; etc.). Several researchers have used the disc permeameter to determine transport parameters such as infiltration, macroporosity and mesoporosity on forest watersheds. Watson and Luxmoore (1986) determined that, in general, the larger the total water flux, the larger the macropore contribution to total water flux. Wilson and Luxmoore (1988) analyzed the spatial variability of infiltration under ponded conditions as well as 2, 5, and 14 cm of water tension. Sully and White (1987) described the methodology for measuring topsoil hydraulic properties of sorptivity, hydraulic conductivity, capillary length and characteristic mean pore size with minimal soil disturbance using the disc permeameter. Perroux and White (1987) used the dependence of sorptivity on water supply potential to find the dependence of soil water diffusivity, hydraulic conductivity, and soil water characteristic on water content. Chisholm et.al. (1987) compared the disc permeameter, drip infiltrometer, and disc rainfall simulator for sorptivity measurements. Only the rainfall simulator approximated the situation for natural rain, but the sorptivity measurements for all three devices could be logically explained.

The design, operation, and theory of the disc permeameter used in this study is described by Perroux and White (1988). The paper discusses the effects of the water supply membrane and soil cap materials as well as limitations imposed by restricted air entry. Ankeny et.al. (1988) proposed the design of an automated tension infiltrometer that can be used for tensions ranging from 2 cm to 50 cm and infiltration rates of 1.0×10^{-6} cm/sec to 5.0×10^{-2} cm/sec. This modification allows quick and accurate pressure control at low tension and improved measurement precision as well as automating data collection. More recently, White and Sully (1989) compared disc permeameter measurements of saturated hydraulic conductivity and sorptivity, developed analytical expressions for hydraulic conductivity and sorptivity, and compared them to results calculated from field measurements of time to ponding with a rainfall simulator on gravelly silty clay loam. They found good agreement between the three methods.

Smettem and Clothier (1989) describe a new method for obtaining unsaturated hydraulic conductivity and sorptivity from tension disc permeameter measurements. As sorptivity is often difficult to measure, they extended the ponded twin ring method to unsaturated discs of varying diameters. Long-time quasi steady discharge, at the same water supply potential for all measurements, is needed to determine the hydraulic properties. Time Domain Reflectometry is used to estimate moisture content prior to the first measurement, but apparently not for subsequent measurements. Final moisture content is estimated from a soil-water/pressure head relationship. Comparisons with laboratory methods of determining unsaturated and saturated hydraulic conductivity on two contrasting soils corresponded well with near saturated field results. One soil, however, with large connected pores showed a conductivity change of 3 orders of magnitude as pressure head decreased from -1 to 0 cm water.

White and Perroux (1989) used field sorptivity measurements with the disc permeameter to estimate unsaturated hydraulic conductivities. They derived approximations that relate K(psi) to sorptivity measured over a range of supply pressures. Comparisons with conventionally determined K(psi) for repacked and intact soil samples showed good agreement.

Ankeny et al. (1990a) measured field infiltration rates at selected tensions with a tension infiltrometer to develop new methods of characterizing the effects of wheel traffic and tillage on pore structure as measured by water flow through macropores. In a subsequent paper (Ankeny et al.,1990b), a new field method for determining insitu unsaturated hydraulic conductivity is presented. Unsaturated hydraulic conductivity is determined from consecutive tension infiltration measurements on the same surface. Steady state infiltration rate is the only parameter needed for determining unsaturated hydraulic conductivity. Initial moisture content is not required. They state the method is valuable because it is simple, faster than lab methods, and less disruptive of soil pore structure than other field techniques such as the Guelph Infiltrometer.

2.2 DISC PERMEAMETER MEASUREMENT METHOD

The disc permeameter was used interchangeably in this study for saturated and unsaturated hydraulic conductivity measurements. The methods of operation are similar and are described, briefly, by Perroux and White (1988). Detailed operation procedures are described below and in the CSIRO Disc Permeameter Instruction Manual (1988).

2.2.1 Positive Supply Pressures

Thirty-four measurements were conducted at positive pressures in this study (fig. 2). A thin-walled stainless steel cylinder, having an interior diameter just larger than the disc, is driven several millimeters in the soil. The interior soil is levelled, and the exterior disturbed soil is tamped down. A bentonite or mud seal is placed around the cylinder to limit leakage during infiltration. The permeameter is then placed within the cylinder and adjusted to contain a selected head of water (0.5 cm for this study).

The permeameter is taken from the cylinder and the reservoir filled with water. This is accomplished by closing the air-inlet stopcock, placing the base of the permeameter in

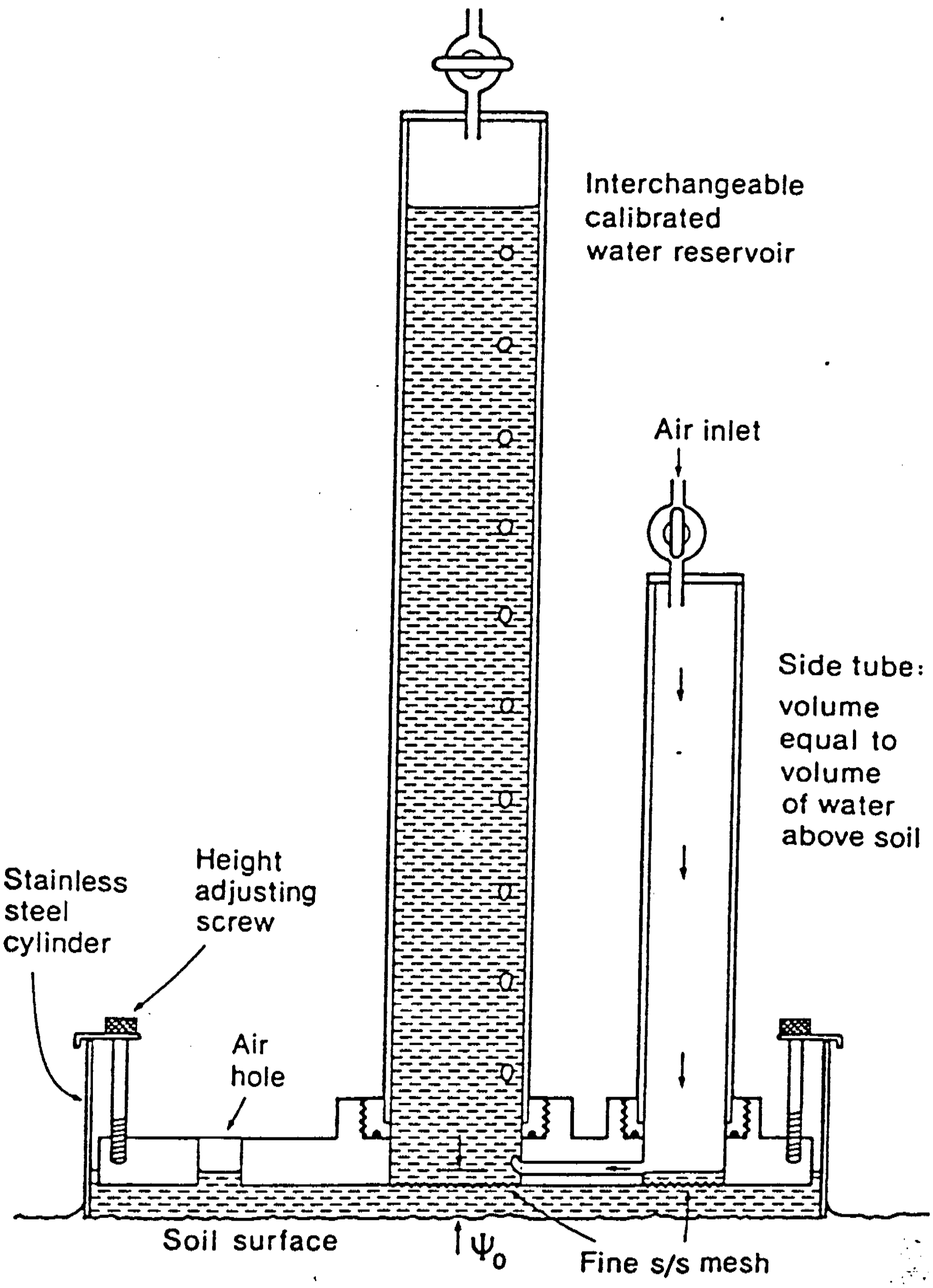


Figure 2. Positive pressure disc permeameter (CSIRO Instruction Manual, 1988)

a tub of water, and evacuating air from the reservoir. A hand vacuum, or good set of lungs, attached to the reservoir stopcock work well to fill the reservoir. Similarly, the side tube is filled to the volume needed for ponded infiltration to occur.

Infiltration is initiated by placing the permeameter within the cylinder and opening the side tube stopcock to deposit water on the soil. Infiltration is recorded versus time. Time begins when the first air bubble appears in the permeameter reservoir. High conductivity materials will require several reservoir volumes before steady state flow is achieved.

2.2.2 Negative Supply Pressures

Eighty-five measurements were conducted at very low tensions. The -1.3 cm tension was employed to exclude flow from cracks formed by evaporation after trench construction (fig. 3). The method is quite similar to that for positive pressures. First, the disc must be soaked in water for several hours prior to measurements to ensure it will remain airtight. The desired tension is fixed by raising or lowering water in the bubbling tower (fig. 3). The supply pressure at the membrane is calculated by $Z = z_2 - z_1$. Z_2 is fixed for each disc and was 0.7mm for our disc. Therefore, z_1, the height of water in the bubbling tower above the air inlet, is used to set the desired supply pressure.

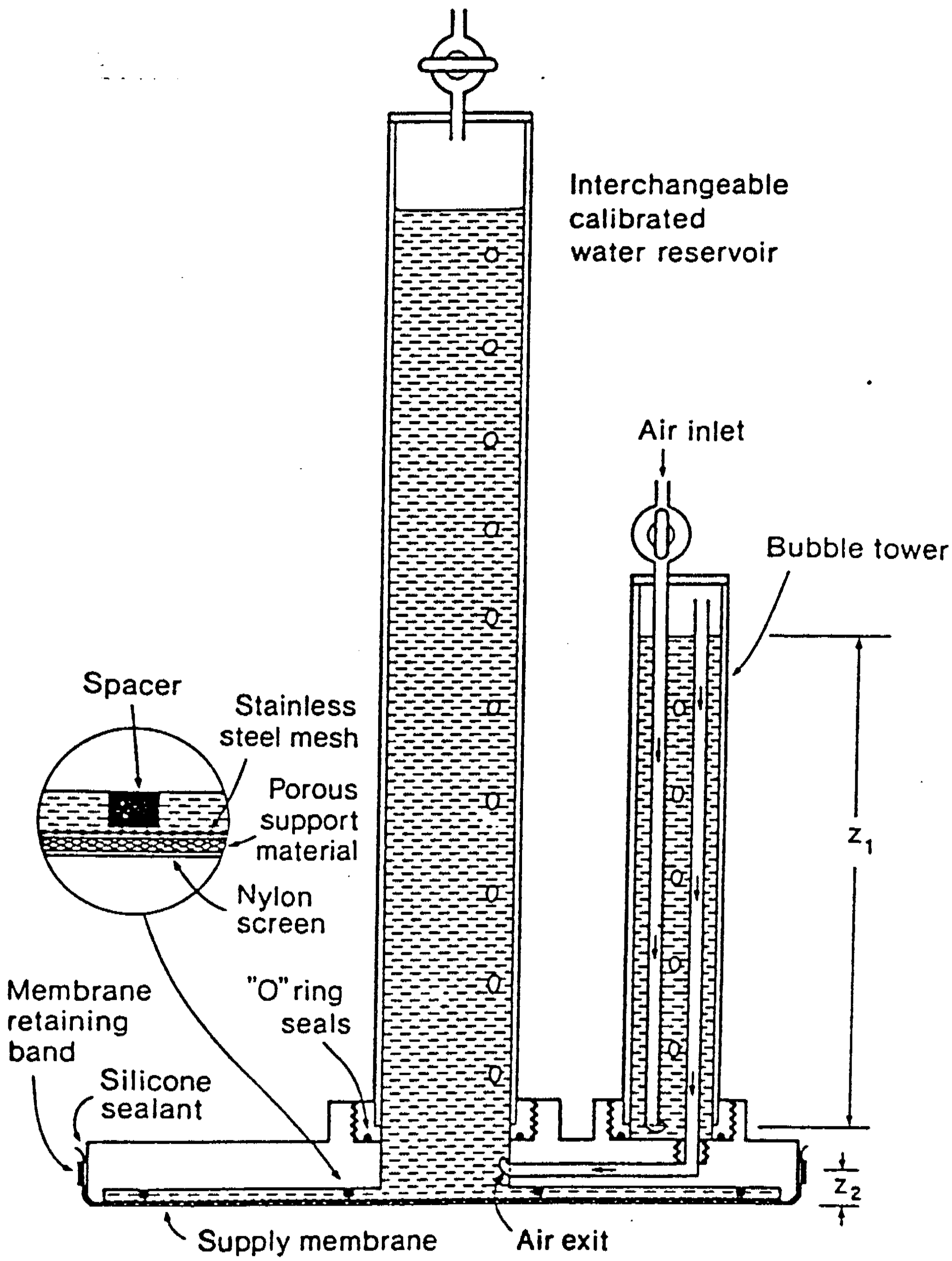


Figure 3. Negative pressure disc permeameter
(CSIRO Instruction Manual, 1988)

The measurement site is prepared by removing vegetation and large rocks, and levelling the soil. A level surface is imperative for good measurements. In many cases, a cap of contact material (normally a fine sand) is needed to ensure a flat measurement surface. The impact of the cap is discussed in White and Perroux (1988) and in the disc calculation section of this study. In any case, the thinnest cap needed for good soil contact with the membrane was used.

The permeameter reservoir is filled as in the positive supply case. The instruction manual (CSIRO,1988) suggests the following steps be conducted before measurements are started:

1). Wet the stopcock to ensure it does not leak.

2). Check the water level in the bubbling tower for the desired supply pressures.

3). Examine the disc for air bubbles. If present, rewet the disc and evacuate the bubbles. Reexamine. If the bubbles continue, the membrane should be changed.

Measurements commence as soon as bubbling begins in the tower after placing the disc firmly on the contact material. Good contact is imperative for meaningful measurements. Infiltration is recorded with time as quickly as possible during early infiltration times. Measurements of consecutive 0.5 cm changes in water level were effective in this study for sorptivity determinations, although not always possible for highly conductive materials. An automated design such as that of Ankeny (1988) would increase accuracy and decrease the labor. Recordings should continue at a lessening pace until steady state flow is achieved. Constant measurements over a 5-10 minute period are necessary for good results.

2.2.3 Calibration

Each permeameter reservoir is different. Therefore, they must be calibrated. Calculated calibrations for the two reservoirs used are:

Reservoir 1: $dV = 17.48 \times (dX) + 2.24$

Reservoir 2: $dV = 17.31 \times (dX) - 0.352$

dV is the volume of water infiltrated for a specified water level drop in the reservoir (mL). dX is the specified drop in water level (cm). 17.48 and 17.31 are associated areas for specified water level changes in each reservoir (cm^2). Assuming essentially pure water at 20 C, cubic centimeters (cm^3) are equivalent to milliliters (mL).

2.2.4 Moisture Contents

Prior to the infiltration measurement, a soil sample (approximately 100-150 g) is collected from the top centimeter of soil near the measurement location for initial moisture content determination. Samples should be collected within 10 to 15 cm of the permeameter. At the end of infiltration a final moisture content sample is taken from the top few millimeters of soil and placed in an air tight container for weighing. For positive supply measurements, sampling for moisture content is conducted as soon as the free water infiltrates the soil surface after removing the permeameter from the ring. Under tension conditions, the cap is quickly scraped from the soil surface, and a sample of soil beneath the cap is taken.

In both cases, samples taken too late or too deep will give incorrect, low values of the change in moisture content from the infiltration event. This is quite frustrating inasmuch as the calculated conductivity is highly dependent on the change in moisture content. Final moisture content samples were also analyzed in the laboratory to determine particle size distributions.

2.3 DISC PERMEAMETER CALCULATIONS

The disc permeameter was used in this study to measure hydraulic conductivity and sorptivity at preselected tensions. The calculation method is detailed in the CSIRO Disc Permeameter Instruction Manual (1989). It is based on Woodings (1968) analysis of multi-dimensional flow from a shallow circular pond or surface disc into homogeneous soils.

For a pond or disc of radius r_o and for water applied at a potential of ψ_o, Wooding (1968) showed the steady state flowrate is calculated by:

$$q = \pi r_o^2 (K_o - K_n) + 4 r_o \Psi_f \quad (1)$$

where K_o = hydraulic conductivity at ψ_o (the supply potential) $[LT^{-1}]$

K_n = hydraulic conductivity at ψ_n (the initial potential) $[LT^{-1}]$

ψ_f = the matric flux potential $[L^2T^{-1}]$

In this situation, the first term on the right represents the contribution of gravity to total flow from the disc. The second term gives the capillarity contribution. The flux potential term (ψ_f) is related to conductivity by:

$$\Psi_f = K_o \lambda_c \quad (2)$$

where λ_c = macroscopic capillary length

For relatively dry materials, $K_n \ll K_o$ and is, therefore, neglected in the following calculations.

Further, the macroscopic capillary length, (λ_c), is related to sorptivity, S_o, and hydraulic conductivity (White and Sully,1987):

$$\lambda_c = \frac{bS_o^2}{(\theta_n - \theta_i) K_o} \quad (3)$$

where θ_i = initial volumetric moisture content

θ_n = final volumetric moisture content

b is a dimensionless constant with a value ranging between 1/2 and $\pi/4$ (White and Sully, 1987). They found b = 0.55 to be a good mean value for field soil hydraulic property determinations.

Using equation (2):

$$q = (\pi r_o K_o) + (4 r_o K_o \lambda_c) \tag{4}$$

and substituting (3) into (1):

$$q = (\pi r_o K_o) + \frac{(4 r_o b S_o^2)}{(\theta_n - \theta_i)} \tag{5}$$

$$\theta_n - \theta_i = \Delta\theta$$

dividing by the disc area, gives the flowrate per unit area:

$$\frac{q}{\pi r_o^2} = K_o + \frac{4 r_o b S_o^2}{\pi r_o \Delta\theta} \tag{6}$$

Rearranging leads to the calculation for hydraulic conductivity at the supply potential.

$$K_o = \frac{q}{\pi r_o^2} - \frac{4 r_o b S_o^2}{\pi r_o^2 \Delta\theta} \tag{7}$$

In the field, sorptivity and steady state flowrate are determined by analyzing the cumulative infiltration versus the square root of time and time, respectively. At early infiltration times, capillarity dominates flow irrespective of the disc size and the system behaves as if it were one dimensional (White and Sully,1987). Philip (1969) determined cumulative infiltration by:

$$\frac{Q}{\pi r_o^2} = S_o t^{1/2} \qquad (8)$$

where Q = total water volume infiltrated [L^3T^{-1}]
t = time from beginning of infiltration [T]
S_o = sorptivity given by the slope of the Cumulative Infiltration vs. $t^{1/2}$ graph. [$LT^{-1/2}$]

Therefore, in order to get an estimate of K_o with the disc permeameter, it is necessary to determine the sorptivity as well as measure the steady state flowrate and the change in moisture content during the infiltration event. Water temperature should be recorded for all measurements.

The characteristic mean pore size of flow can also be calculated from the data collected during an infiltration measurement. The macroscopic capillary length (λ_c) is used to simplify the treatment of multi-dimensional soil-water flows. Philip (1985) states that the macroscopic capillary length is a scaling parameter defined as:

$$\lambda_c = [K(\psi_o) - K(\psi_n)]^{-1} \int_{\psi_n}^{\psi_o} K(\Psi)\, d\Psi \qquad (9)$$

λ_c = K weighted mean potential

This equation can be approximated in the field by two methods. White and Sully (1987) showed, as stated earlier, that:

$$\lambda_c = \frac{bS_o^2}{[(\theta_o - \theta_n) K_o]} \qquad (10)$$

or, paired measurements of sorptivity at positive and negative pressures can be used.

$$\lambda_c \approx \frac{2b\Delta\psi}{[(\frac{S_p}{S_n})^2-1]} \tag{11}$$

$\Delta\psi$ = difference in supply pressures [L]
S_p = positive pressure sorptivity $[LT^{-1/2}]$
S_n = negative pressure sorptivity $[LT^{-1/2}]$

Equation 10 was used exclusively in this study to determine the macroscopic capillary length. White and Sully (1987) further show that the macroscopic capillary length is related to the characteristic mean pore size by:

$$\lambda_m = \frac{\sigma}{\rho g \lambda_c} \tag{12}$$

σ = air/soil-water surface tension $[MT^{-1}]$
ρ = soil-water density $[ML^{-3}]$
g = gravitational acceleration $[LT^{-2}]$

For pure water at 20 C, they reduce equation 12 to:

$$\lambda_m = \frac{7.4}{\lambda_c} \tag{13}$$

For the purposes of this study, the equation 13 was accepted as an adequate approximation for equation 12 . No water temperatures were recorded for the infiltration measurements, but a range of temperatures between 5°C and 30°C is likely. Sensitivity analysis shows that equation 12 ranges only from $7.3/\lambda_c$ at 30° C to $7.6/\lambda_c$ at 0°C. Therefore, since no water temperatures were recorded, equation 13 is used.

2.4 SPATIAL VARIABILITY

Numerous researchers have used geostatistics for the characterization of the spatial variability of geologic and hydraulic properties of soils (Nielsen and Biggar,1973; Caravallo et al.,1976; Smettem,1987; Greenholtz et al., 1988,etc.). Autocorrelation functions and semivariogram analysis have been used extensively in an attempt to uncover structures in the soils tested. Numerous researchers have determined correlation lengths for many soil properties to be significant in hydrological analyses. Byers and Stephens (1983) described d_{10} and saturated hydraulic conductivities correlated up to a meter in the horizontal direction at a medium grained sand experimental site.

Greenholtz et.al.(1988) found wide ranges of dependence along a heavily instrumented 91 meter long transect. Over a 44 day drainage period, correlation ranged from 3 to 32 m for soil wetness, 6 to 34 m for soil water tension, 5 to 35 m for natural log of saturated hydraulic conductivity parameters, and 8 to 24 m for percent sand,silt, and clay at the 0.3 m transect depth. Loaque and Gander (1990) reported the scale of spatial correlation between infiltration measurements for a small rangeland catchment to be less than 20 meters. Yeh et.al.(1986) and Saddiq et.al.(1984) conducted spatial variability analysis of soil water tension along 290 m and 76 m transects, respectively. Correlation distances of at least

6 meters were determined in both studies.

In an extensive field study, Gajem et.al.(1981) analyzed 900 samples from nine transects at a 50 cm depth for varying hydraulic properties. He reported correlation lengths up to 20 times the sample spacing for numerous hydraulic properties including 0.1 bar water content, 15 bar water content and particle size. Viera et.al.(1981) studied the spatial variability of 1280 field measured infiltration rates on Yolo loam. He concluded with geostatistical analysis that only 120 measurements were necessary to obtain the same information as the actual 1280 field measurements.

To my knowledge, few spatial variability field research projects have been conducted at the horizontal sampling intervals finer than this study, that is measurements at approximately 0.3 meter intervals. In my study, spatial correlation for field measured hydraulic conductivity and sorptivity, as well as laboratory determined saturated hydraulic conductivity and various particle size parameters, will be determined. Then, the quantitative data will be related back to the mapped geology. The majority of statistical and all the variogram analyses were preformed using the GEO-EAS package (Geostatistical Enviromental Assessment Software, Englund, 1988). Thirteen programs are documented for analysis ranging from univariate statistics to the production of contour maps from kriging operations. The variogram codes (Prevar and Vario) as well as the univariate statistics code (Stat1) were used extensively in this study (Englund,1988).

2.5 VARIOGRAM THEORY

The variogram satisfies the hypothesis called the "intrinsic hypothesis". Basically, it says that the mean is constant in space, ie. along a transect of data, and the variance is independent of location. The variogram is defined as:

$$\gamma(h) = \frac{1}{2} var[z(x+h) - z(h)] - \frac{1}{2} E[(z(x+h) - z(h))^2] \qquad (14)$$

2γ(h) is the mean squared difference for two points separated by a lag distance h. z(x) is the experimental data value at point x, z(x+h) the experimental data value at a point h distance from x, and h the lag or separation distance. The following equation is used to determine the variogram value γ(h) at a given lag distance (h):

$$\hat{\gamma}(h) - \sum_{i-1}^{N(h)} \frac{[(z(x_i+h) - z(x_i))^2]}{2N(h)} \qquad (15)$$

where N(h) is the number of data pairs separated by the lag distance h. All pairs of data values h distance apart in the random field z(x) are compared.

When studying variograms, several characteristics should be noted to aid in model fitting. The variogram should always pass through the origin because increments are zero at the origin. Then, the variogram will increase as the correlation between observations decreases from the point of interest. Variogram behavior at the origin and infinity characterizes the continuity of the regionalized variable. At the origin four classical types of behavior are noted (Delhomme,1976):

1) Parabolic shape: This is a very regular variable such as head in an observation well with time (fig. 4a,b).

2) Linear shape: This is less regular than the parabolic shape and is characteristic of the thickness of a geologic formation with distance (fig. 4e).

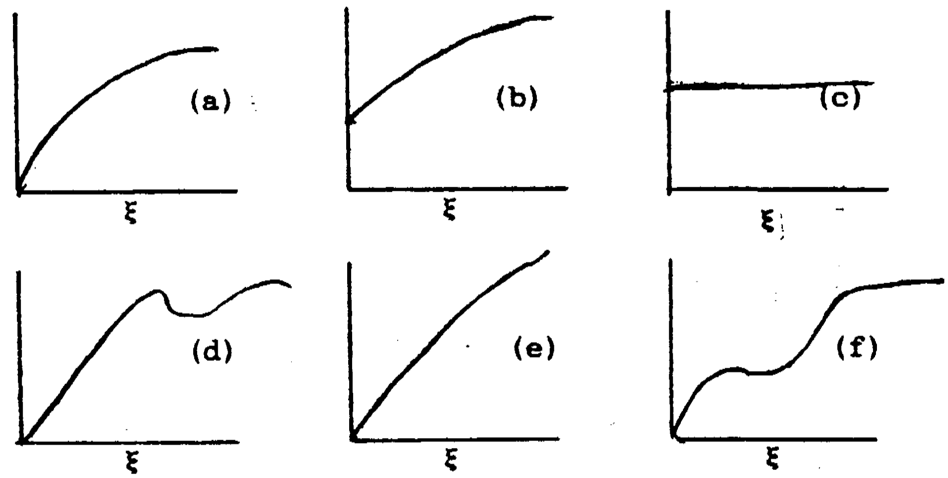
3) Nugget effect: This is a discontinuity at the origin. It suggests that two points - although close in distance - will show a difference about equal to the variance. Nuggets can be found when dealing with ore assay data, rainfall data, or may be caused by error in sampling, handling, and analysis of data (fig. 4b).

4) Pure nugget(white noise): There is no correlation between the data for a given lag distance (h). It is seen with the annual rainfall data at a given location and in cases where the sample spacing may be to large to observe the underlying structure of the soil (fig. 4c).

At infinite lag, the variogram can increase indefinitely or stabilize to a sill - a value equal to the variance of the field data. The range is the distance at which the sill is reached. It shows the extent of a measurement point's influence. There is no correlation beyond the range. Variograms can show periodicity, nested structures, and hole effects. But, most of the fluctuations are caused by sampling - we are attempting to estimate a structure based on a single realization which may consist of a small number of data points.

Figure 4.

Some possible shapes for (isotropic) variograms are shown below:



a). Spherical model variogram
b). Nugget effect
c). Pure nugget (white noise)
d). Exponential variogram with a hole effect
e). Linear variogram (trend in the data)
f). Nested structure

The user should take a serious look at the estimated variogram and the data used to construct it. Does it fit any of the behaviors given ? Is the data normally distributed or transformed to normal ? Is it possible the data contains outliers or a trend ? A theoretical model is then fit to the experimental variogram. Several models are commonly used and fit to the data by hand. These models include the nugget effect, monomial, spherical, exponential, and gaussian. Mathematical descriptions can be found in many geostatistics books (Journel,1974). If the experimental variogram cannot be explained - it is very erratic or rises faster than $(h)^2$ - other avenues not discussed here must be explored.

3.0 SITE DESCRIPTION

The field site is located directly west of the twelfth hole of the New Mexico Tech golf course in Socorro, N.M., about 120 km south of Albuquerque. The environment is semi-arid, receiving approximately 20 cm of precipitation annually (Parsons,1988). Vegetation is sparse consisting of grasses and sage. The site is situated in a east-west trending arroyo directly east of a flood control dike. According to Parsons(1988), the north-south trending dike was constructed in 1963 to divert runoff from the town of Socorro. Therefore, no major runon occurs at the experimental plot. As stated earlier, the site had never previously been irrigated. The depth to the water table (~21 m) is monitored in four 1"(I.D.) P.V.C. observation wells. Mattson (1989) provides a detailed description of the site design and construction. Briefly, the site is situated on fairly level ground in the northeast corner of the Physical Plant boneyard (fig. 5). Initially, a 30 m x 30 m area was cleared to bare soil. Runoff from Socorro Peak is diverted by the flood control dike, but the southern and eastern edges of the site were bermed to limit local runon. Mattson (1989) surveyed a 5 meter interval grid across the site. The grid originates at the southwestern corner of the field site with X in the eastern direction and Y in the northern (fig.6). A trailer, located south of the field site,

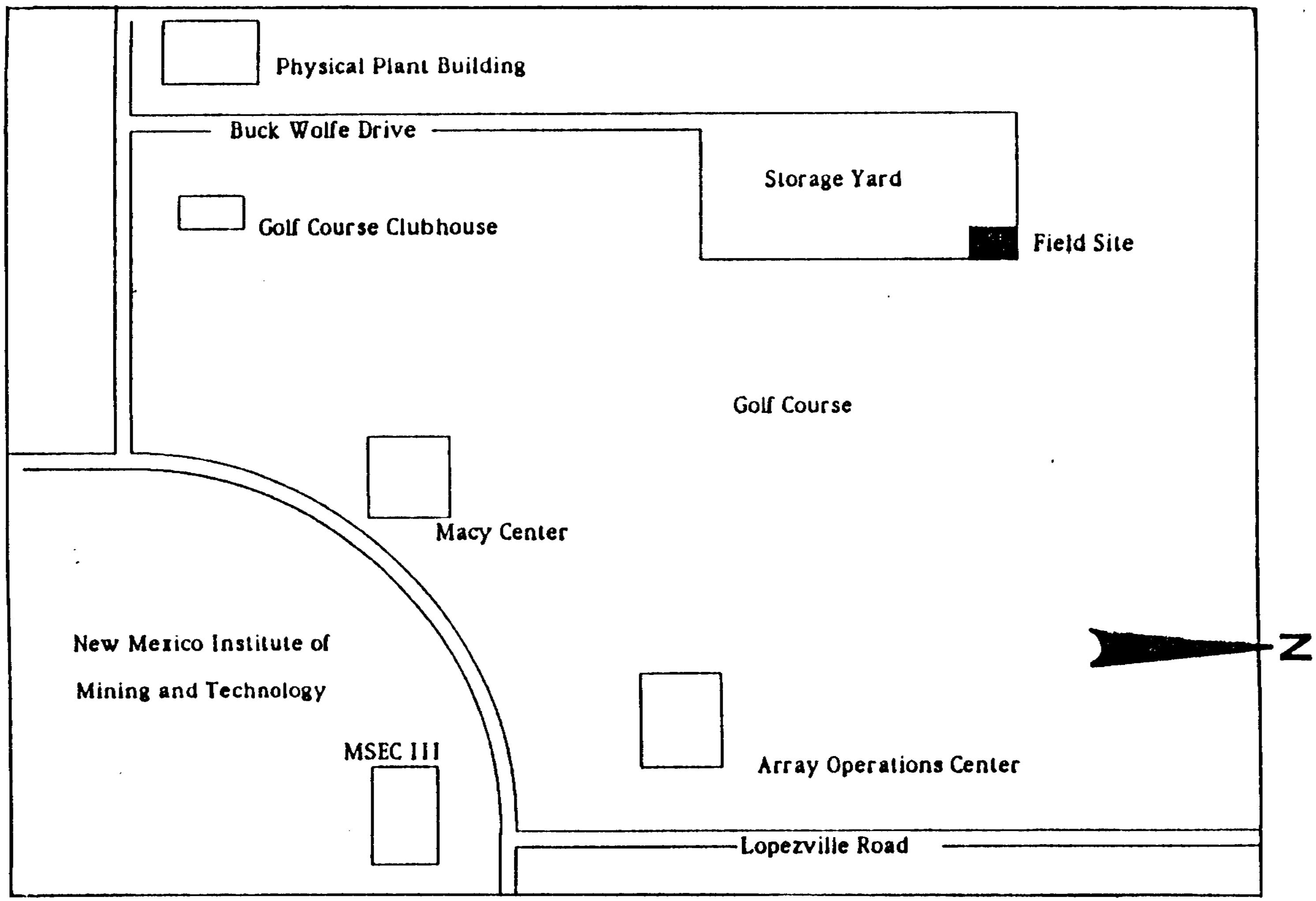


Figure 5. Site location map (not to scale) (Flanigan, 1989)

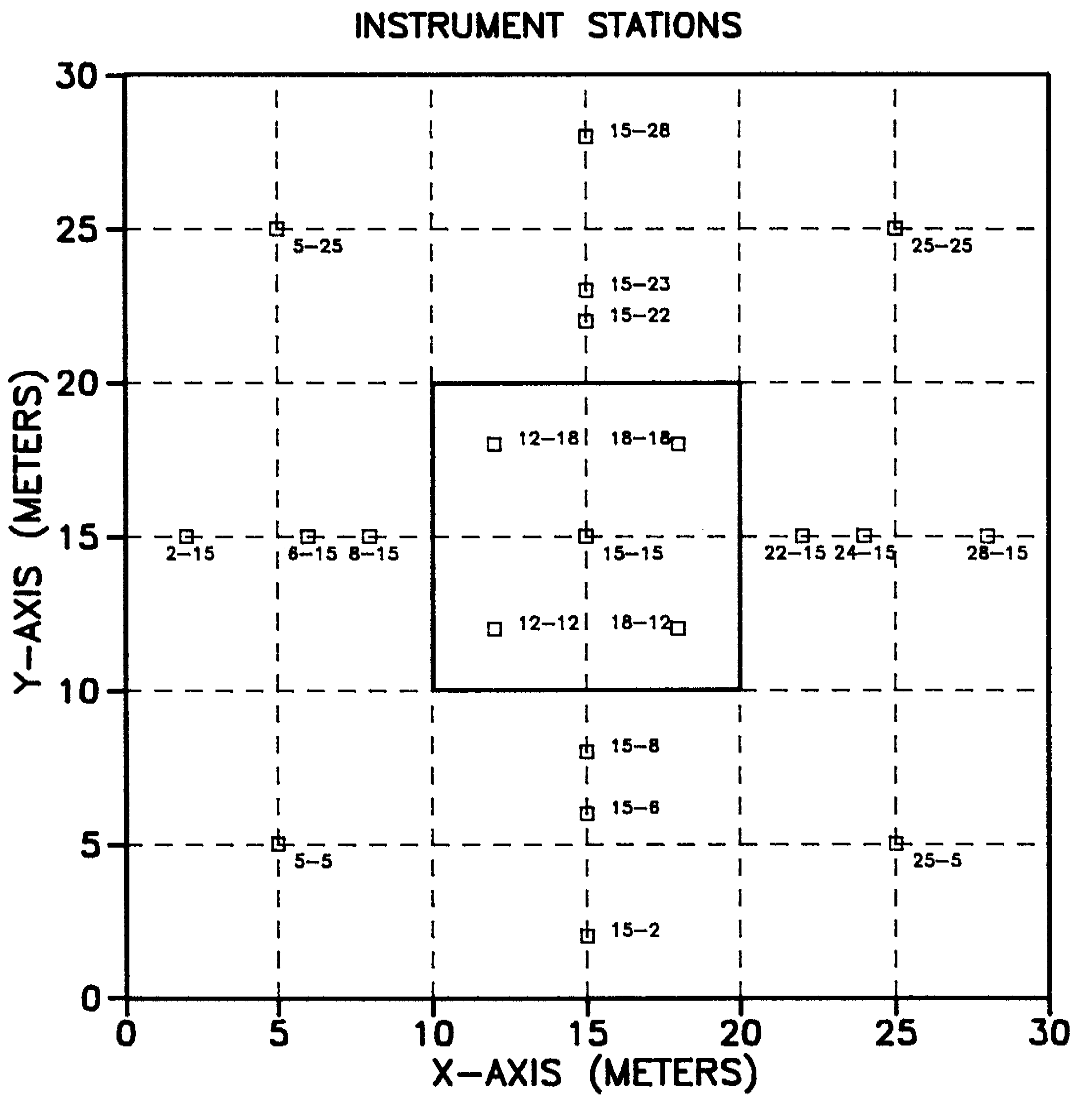


Figure 6. Grid system of the experimental site showing instrument stations. Each station contains a neutron access tube and two nests of tensiometers.

serves as a field office and houses equipment.

Water was applied from January 1987 to September 1990 over a 10.5 m x 10.5 m area at the center of the field site about 60 cm below ground surface. The irrigation system consisted of 21 drip lines (polyethylene, Model No. 164, Agrifirm Irrigation Inc., Fresno, Ca.) with emitters spaced at 50 cm intervals (fig.7). A 1 cm thick layer of fine sand was spread below the emitters to facilitate infiltration. Plastic and hay were placed over the driplines to limit evaporation and serve as insulation, respectively. Then, earthen fill was added to just above ground surface (~60 cm). A second plastic liner to limit natural rainfall infiltration and a thin soil layer completed the irrigation system.

Water was applied by means of a positive displacement pump (Model No. 5-BBV, Sherwood, Detroit, MI.). Water movement through the soil was monitored with a neutron moisture probe (Model No. 503DR, CPN Corp., Martinez, Ca.) and duplicate nests of tensiometers. Pressure heads were measured by inserting a hypodermic needle connected to a pressure transducer system (Tensimeter, Soil Measurement Systems, Tucson, Az.) through a rubber septum at the top of the tensiometer.

Twenty-one monitoring stations are located on the experimental plot. They are identified by the X-Y grid system originating in the southwestern corner. Exact locations of the monitoring stations are provided by Parsons (1988). Each

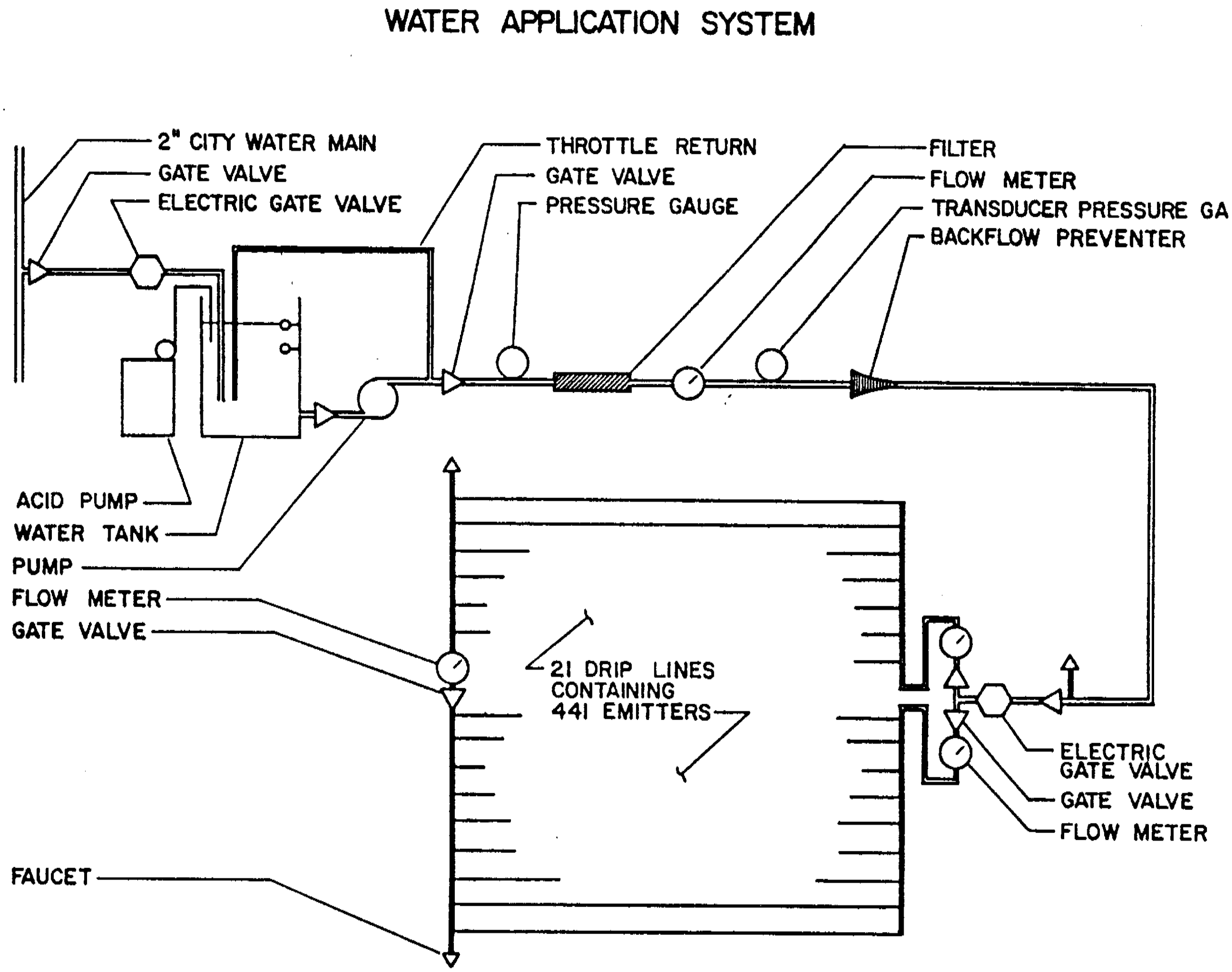


Figure 7. Water application system (Mattson,1989)

monitoring station consists of a neutron access tube and duplicate nests of tensiometers. The neutron access tubes extend to approximately 8 meters below ground surface. The nests contain tensiometers at approximately 50 cm intervals to 4 meters below ground surface.

Porous cup samplers, also known as suction lysimeters in the literature, were installed in two phases. Prior to a bromide tracer test (Flanigan,1989) in the spring of 1988, 14 porous cup samplers were placed " to optimize the amount of area instrumented with the limited number of instruments available" (Flanigan,1989). Four samplers were located approximately 6 meters distant and 6 meters below the driplines on each side of the irrigated plot. Four were installed along the irrigated perimeter and six at various depths and locations within the irrigated plot (fig.8).

Subsequent to a more involved tracer test in July 1989 (Grabka, 1990), a drilling project was undertaken to further characterize the hydrology and install more samplers. Eleven 20.3 cm (8") diameter boreholes were completed to depths ranging from 8 to 22 meters below ground surface (fig.9). The boreholes were sampled with continuous core, shelby tubes, and split spoons samplers depending on the difficulty of soil recovery. Monitoring wells and porous cup samplers were installed at varying depths to 7 meters below the driplines. Further, 20 boreholes were handaugered through the irrigated plot with porous cup samplers emplaced (fig.10). Cobble zones

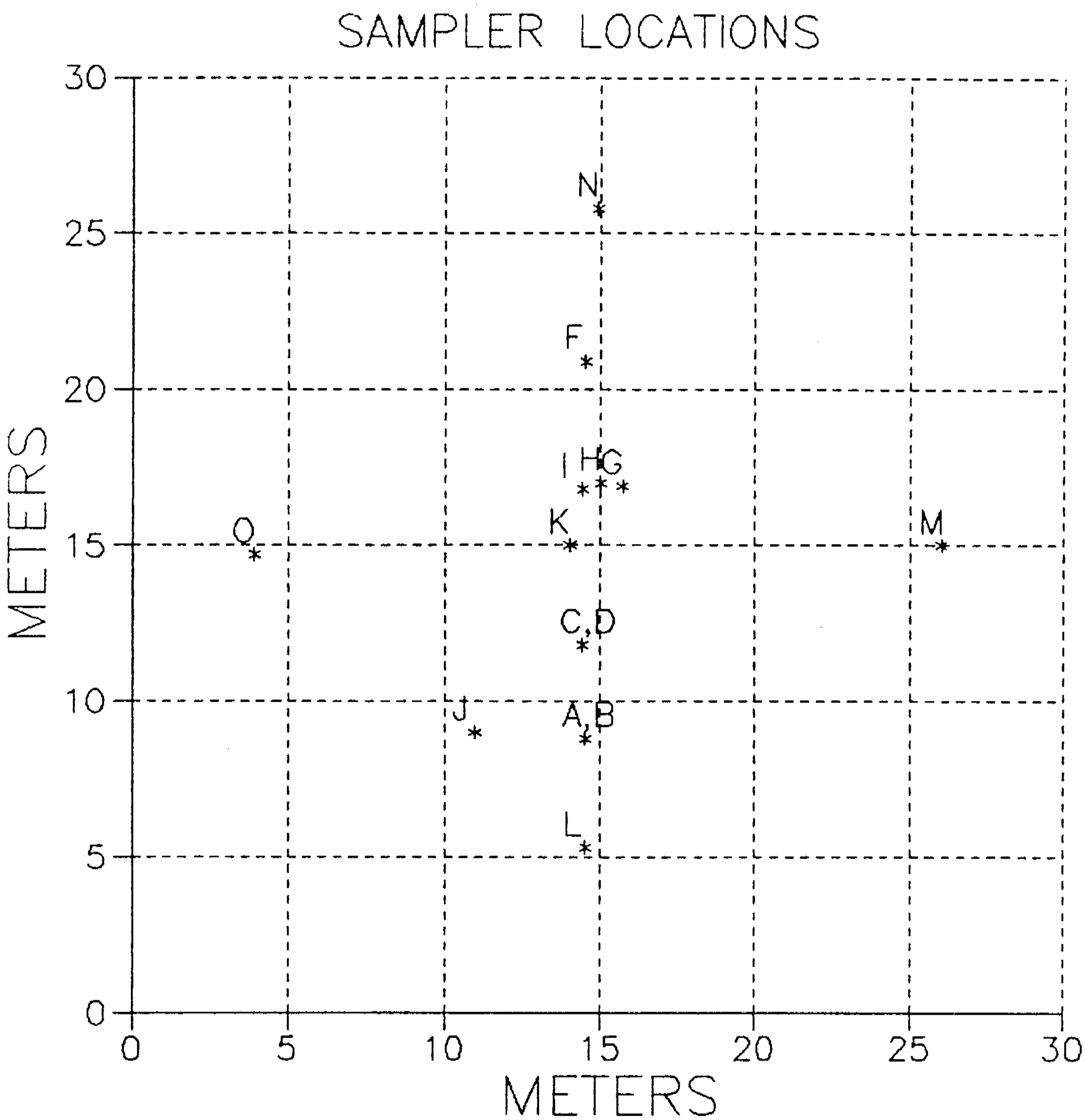


Figure 8. Porous cup sampler locations for the initial tra experiment

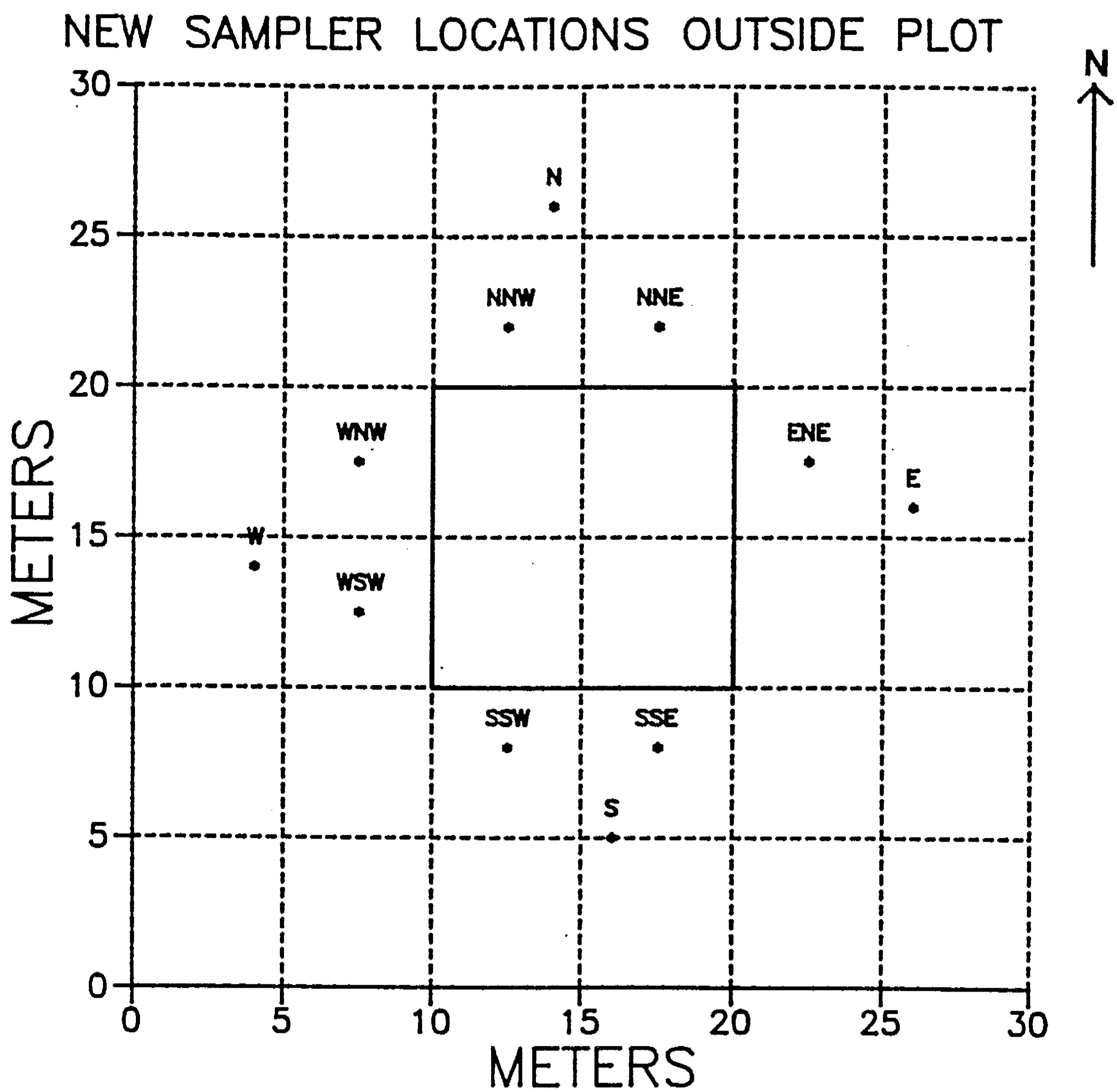


Figure 9. New porous cup sampler locations outside the irrigated plot for the second tracer experiment. Boreholes were logged and instrumented with porous cup samplers.

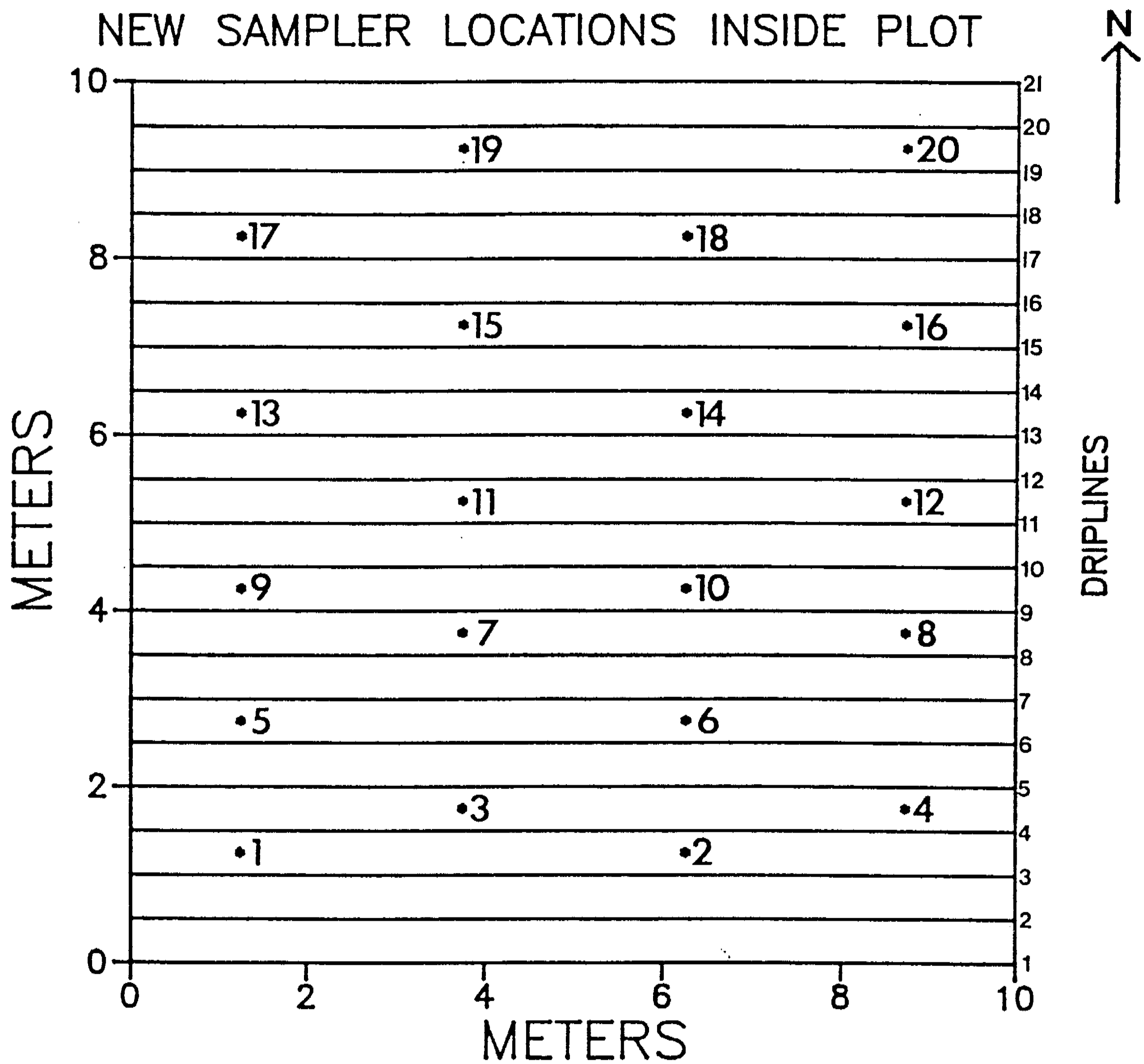


Figure 10. Hand-augered porous cup sampler holes within the irrigated plot.

limited the hand augering to less than 3 meters below the driplines. In September 1989, irrigation was stopped and the subsequent drainage monitored through June 1990.

Total site instrumentation consisted of 21 neutron access tubes, 270 tensiometers, and 84 porous cup samplers. In addition, a computerized data logger (Model No. CR7, Campbell Scientific, Inc., Logan, U.T.) located in the field office recorded precipitation, windspeed, barometric pressure, humidity, and temperature of the soil, tank water, and air hourly. Evaporation was measured weekly in a standard class A pan located on the field site. Further details on site design and construction can be found in Mattson (1989). Flanigan (1989) discusses the first tracer test as well as providing detail on porous cup sampler design, construction, and installation. Grabka (1990) will discuss the second tracer experiment.

4.0 GEOLOGIC FRAMEWORK

Parsons (1988) provides informative detail on the geologic history and the initial characterization of geologic and hydraulic properties of the site. The field site is located in the eastern portion of the Basin and Range Province within the Rio Grande Depression (fig.11). The Rio Grande Depression extends from central Colorado south to Mexican border near El Paso, Texas. Near Socorro, the Rio Grande flows through a series of north-south trending structural basins. These basins are underlain by Tertiary rocks and bordered in most places by highlands of older rocks (Parsons,1988).

Two distinct facies of the Sierra Ladrones Formation, a subdivision of the Santa Fe Group, have been identified beneath the 30 m x 30 m field site. As described by Parsons (1988), the upper facies consists of red-brown silty sands and pebbles interbedded with cobbles. The lower facies consists of clean tan fine sand, to coarse sand and pebbles. Clay lenses exist in both facies. Chamberlain (1980) classified the lower facies as ancient Rio Grande fluvial sand (Tslf) and the upper facies, derived from highlands to the west, as piedmont slope facies (Tslp)(alluvial fan materials).

4.1 GEOLOGIC CROSS-SECTIONS

East-west and north-south trending cross-sections were

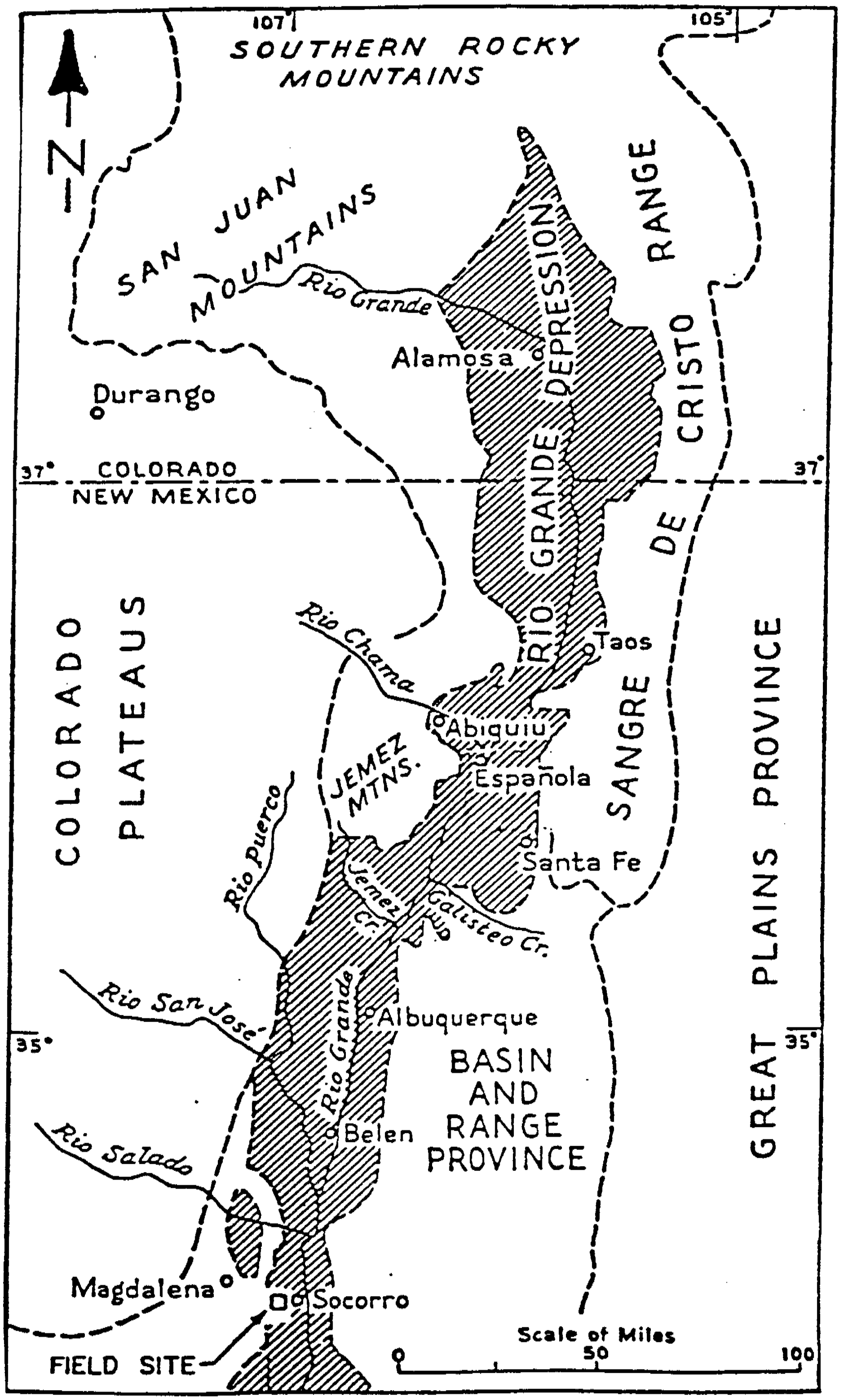


Figure 11. Northern Rio Grande Depression (Parsons, 1988)

interpolated (Parsons,1988) by correlating visual characteristics of soil samples, collected while drilling instrumentation stations, and by cobble zone locations between sampling sites. Figure 12 shows the interpreted geology. It is exaggerated two-fold vertically to exhibit the different layers in greater detail.

The profile is quite stratified with alluvial fan materials (gravels,sands,silts etc.) overlying ancient Rio Grande fluvial sediments. Two major cobble zones, each approximately 0.5 meter in thickness, are found beneath the entire site. Cobble layers of limited lateral extent are found throughout the piedmont slope facies. Cobble size ranges to larger than 30 cm in diameter. Clay lenses of up to 1 meter in thickness and limited lateral extent occur at all depths, but predominate in the fluvial sands.

The piedmont slope facies covers the site to a depth of near 4 meters below datum (m.b.d) through the first major cobble layer. Datum is defined as a plane passing through the tops of the five interior neutron access tubes. They are located approximately 86 cm above the driplines of the irrigated plot. The piedmont slope stratification on the east-west profile suggests a slight eastward inclination. The apparent inclination is presumed to reflect bedding structures from materials derived from highlands directly to the west (Parsons, 1988). Between the two major cobble layers located at 3 to 4 m.b.d. and 4.5 to 5 m. b. d., a transition zone

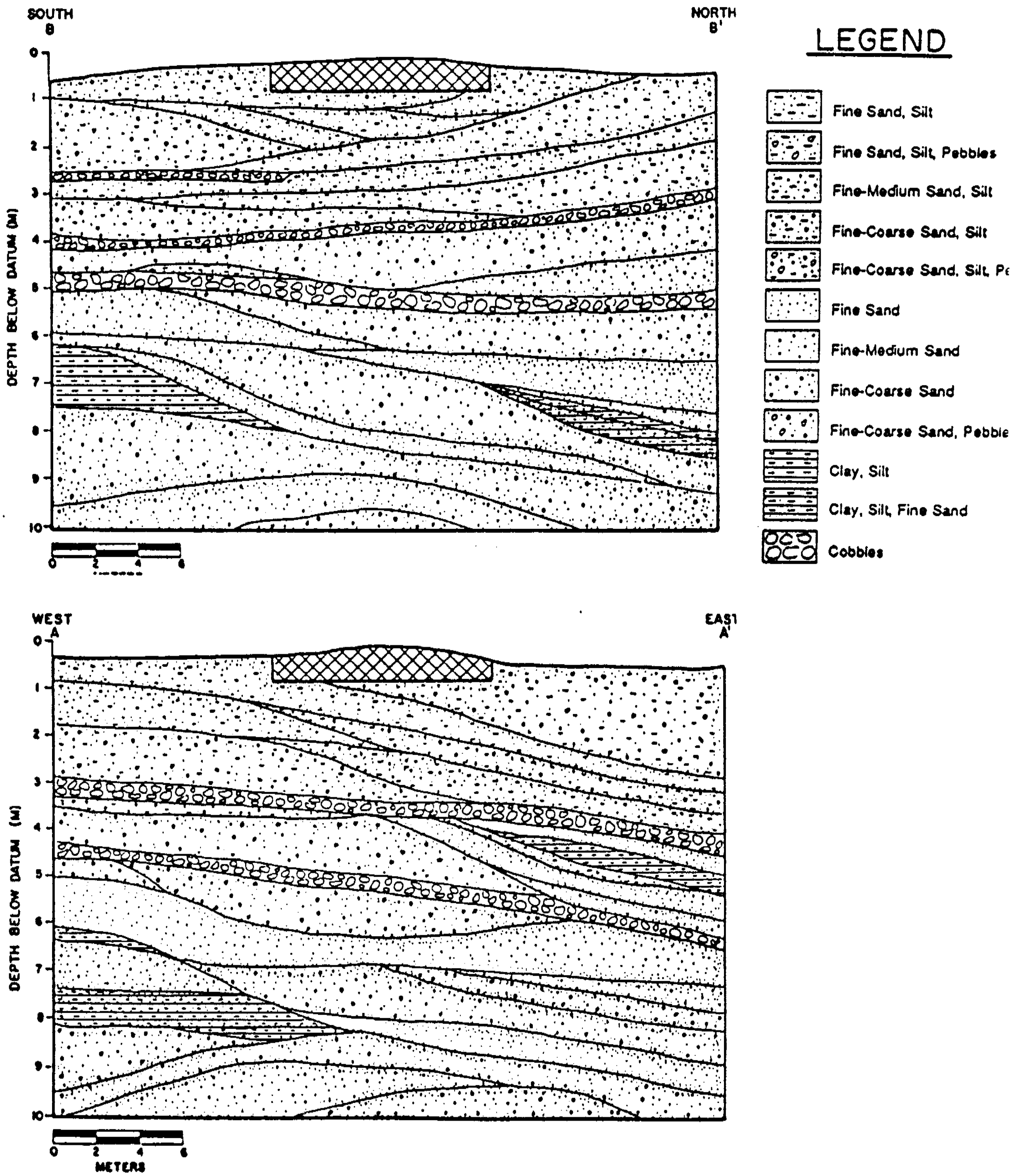


Figure 12. Geologic cross-sections. Hatched areas show drip irrigation system (Parsons, 1988).

exists grading from piedmont slope materials to fluvial sands.

The fluvial sands are found to depths of 24 m.b.d., the limit of drilling. They show sequences of meandering channels consisting of well-sorted, fine sands alternating with fine to coarse sands and pebbles as well as overbank deposits of silts and clays (Parsons,1988). The fluvial facies was probably deposited in a north-south trending ancestral Rio Grande river system (fig.12a). Inclination of beds, as in the piedmont slope facies, is not obvious.

4.2 TRENCH LOCATIONS

Recently, Arnet (1991) described the geology of two trenches excavated at the site for further piedmont slope characterization (fig.13). The trenching was completed in two installments. In October 1989 a backhoe was employed to dig 2/3 of the shallow trench. The interior section through the 10 m x 10 m plot was left intact while drainage monitoring continued. The two outer trench sections were bermed and covered with plastic to limit evaporation and precipitation. In January 1990, the backhoe was again used to complete the shallow trench through the irrigated plot. Final dimensions of the shallow trench are 41 meters in length and approximately 1.5 meter in depth below datum. It was dug perpendicular to the interpreted water flow direction at a depth in which significant water was determined to be moving. The 1.5 meter

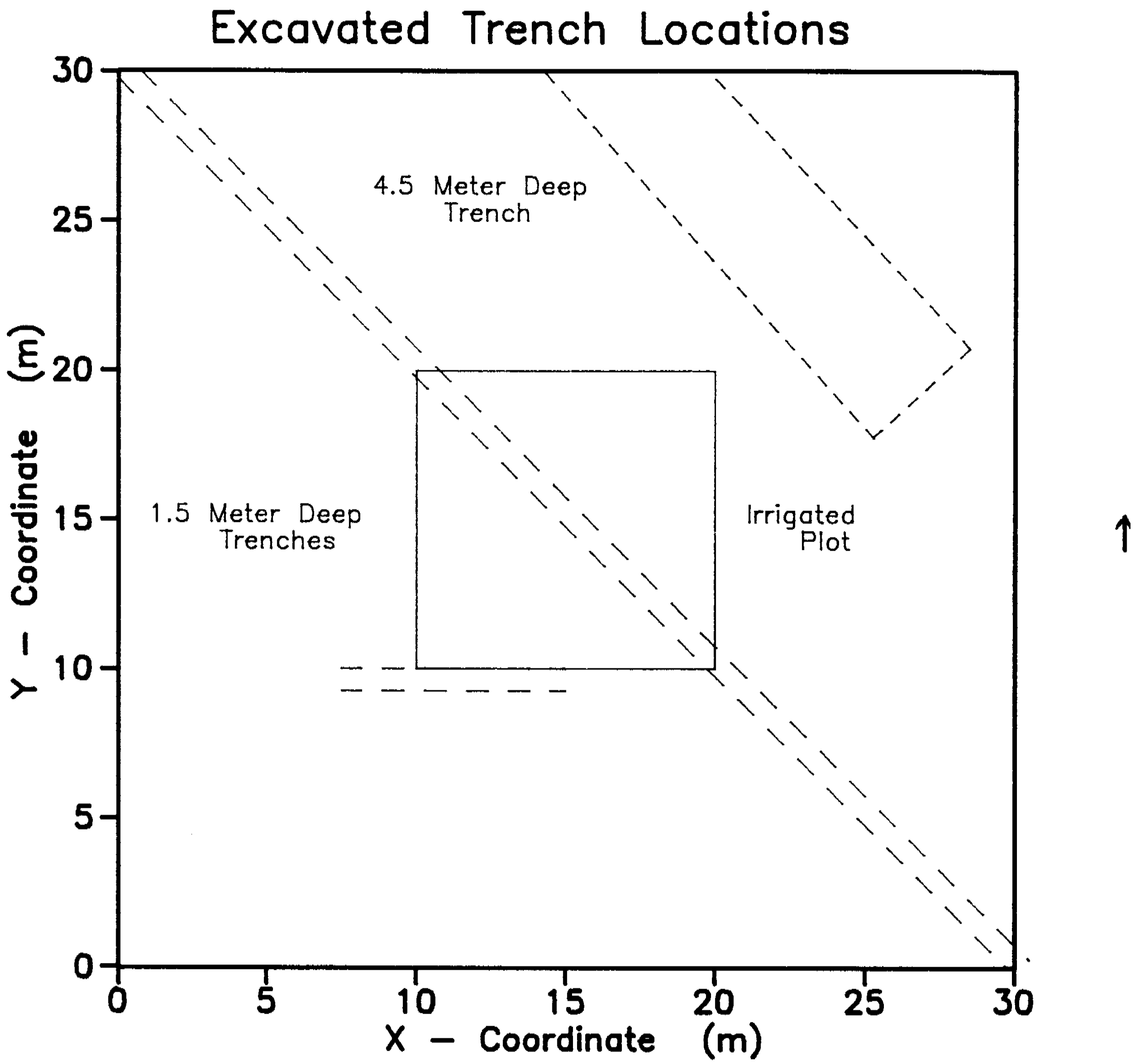


Figure 13. Excavated trench locations. Heavy equipment was used to excavate a number of trenches to varying depth's below ground surface.

depth allowed relatively undisturbed measurements of hydraulic properties without the need for shoring.

Concurrent with the shallow trench completion, a 4.0 meter wide, 15 meter long and 4 meter deep (below datum) trench was excavated with a caterpillar D9 (fig.13). This "deep trench" allowed an enlightening view of the alluvial fan profile. The deep trench is situated in an area where neutron moisture probe measurements indicated lateral movement of vadose water. The trench was also excavated perpendicular to the interpreted flow directions. Depth to the Rio Grande sands is the shallowest encountered on the site. In the trench it was possible to see wetted layers in which the irrigation water flowed.

4.3 DEEP TRENCH GEOLOGY

The western wall of this trench was cleaned of dozer marks using shovels, picks, brooms and brushes. In addition to removing slough, the geologic fabric was accentuated. Approximately 2.5 to 3.0 meters was exposed to the first cobble layer. Digging with pick and shovel resulted in approximately 1 meter of Rio Grande facies material in a 1.5 m x 1.5 m pit at the bottom of the trench. Hand augering in the bottom of the pit yielded an additional meter of Rio Grande materials until augering was halted by the second major cobble layer.

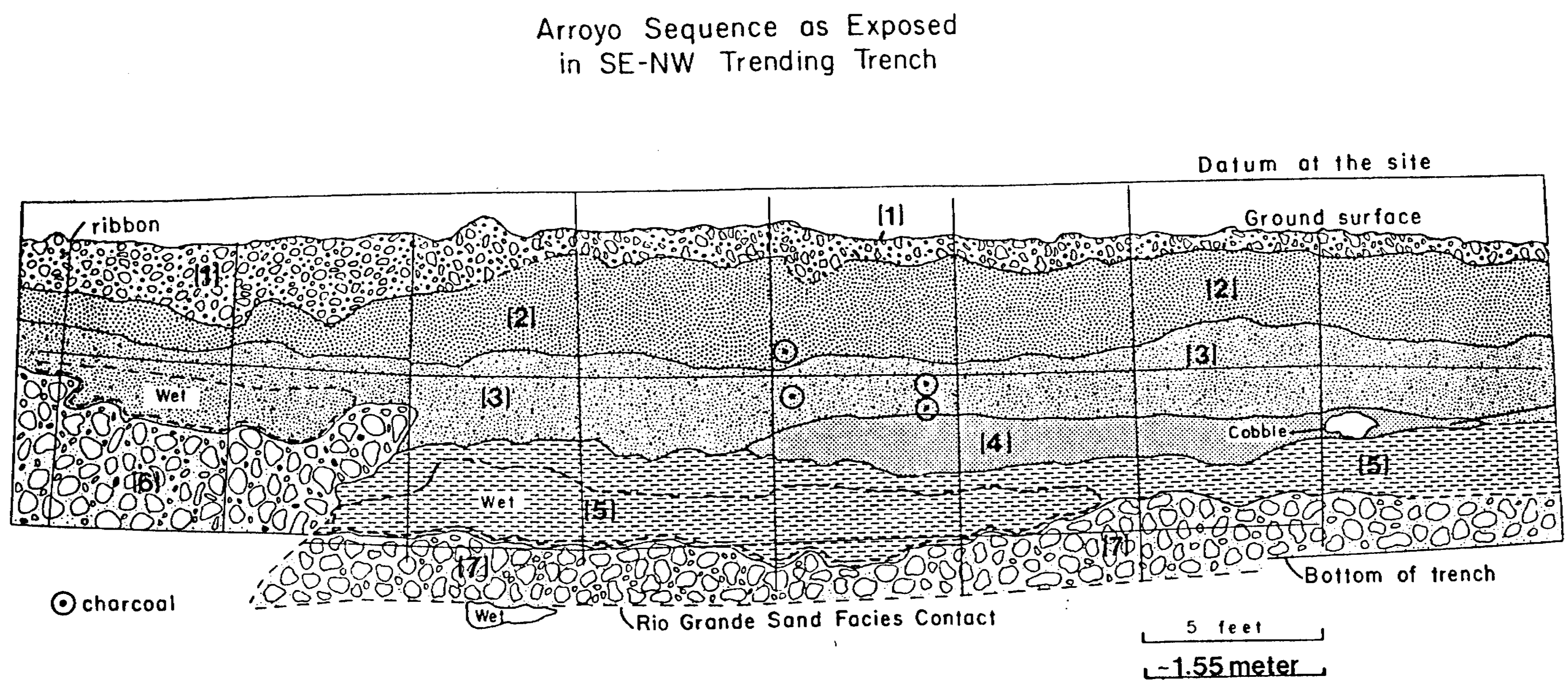


Figure 14. S.E. - N.W. trending "deep" trench geology. Looking at the western wall. Refer to Figure 13 for location. Geologic units as defined in the text are numbered 1 through 7.

A complete description of the deep trench units and their contacts was done by Arnet (1991). Figure 14 shows the deep trench mapped using the classification of W.B. Bull (1963). This classification divides units into mud flow, intermediate, and water laid sediments. The piedmont slope materials fit well in this classification. Arnet (1991) describes the units in Figure 14 as follows:

UNIT 1: Mudflow sediments - this unit is up to 0.6 meter thick and extends across the entire profile. It consists of very recent silty-sands and gravels. Quoting Hawley (1990), Arnet (1991) states the bed is quite a bit younger than underlying units - perhaps less than 200 years old. This is evident by a pronounced discontinuity at the southern end of the trench and by metal pieces found in the bedded gravels.

UNIT 2: Intermediate sediments - The unit is continuous along the profile. It ranges from 0.3 to 1 meter in thickness containing massive silty sands with interbedded sands and gravels in the lower half.

UNIT 3: Mudflow sediments - This massive silty to sandy clay ranges from 0.6 to 1 meter in thickness. It contains up to 30% clay with a few small gravel and sand lenses. Charcoal is scattered throughout the unit. Its texture is bubbly from entrapped air pockets.

Significant moisture retained from the infiltration experiment is found in the clayey sections near the irrigated plot. The unit dries quickly with distance to the north from the irrigated plot (Fig.14).

UNIT 4: Water laid sediments - Finely bedded sands gravels deposited in a relatively high energy environment comprise this 0.5 meter thick unit. Interbedded fine sands and medium to coarse sands, containing black hematite and magnetite stains, lie over gravel lenses. The beds are horizontal at their tops, but arc downward at the bottoms in all likelihood representing the depositional surface.

UNIT 5: Intermediate sediments - This unit is discontinuous at the southern end of the profile where it is truncated by unit 6. Upon excavation, the unit was highly wetted from infiltration (Fig.14). Up to 0.5 meter thick, it consists of silty sand, some clay and small lenses of sand and gravel. Because of its clay content and uniform grain size, the texture appears blocky and smeared. Upper and lower contacts with unit 4 and unit 6 are distinct.

UNIT 6: Mudflow sediments - This debris flow appears to have moved down the mountain front carrying cobbles in a fine to coarse viscous sand and gravel matrix. It truncates unit 5. All contacts are distinct.

UNIT 7: Mudflow sediments - The deepest unit of the piedmont slope facies lies conformably on ancient Rio Grande sands. It is the first major cobble layer as described by Parsons (1988). It consists of bedded sand and gravel layers above approximately 0.25 meters of cobbles suspended in a moist sand matrix. The unit ranges in thickness up to 1 meter, but is quite variable. Its contact with the underlying Rio Grande sands undulates by as much as 0.2 meter vertically in 1 meter horizontal.

The 1 meter of Rio Grande sands, exposed by pick and shovel, is very uniform fine to medium sand with interbedded clay stringers. Hand augering was halted by the second major cobble layer after an additional meter of Rio Grande sediments. These sediments - between the two cobble layers -represent the transition zone between the Piedmont Slope and Rio Grande facies of Parsons (1988) below the field site.

4.4 SHALLOW TRENCH GEOLOGY

Figure 15 shows the fine scale detail of the shallow trench as described by Arnet (1991) using the Unified Soil Classification System. It is also classified using the W.B.

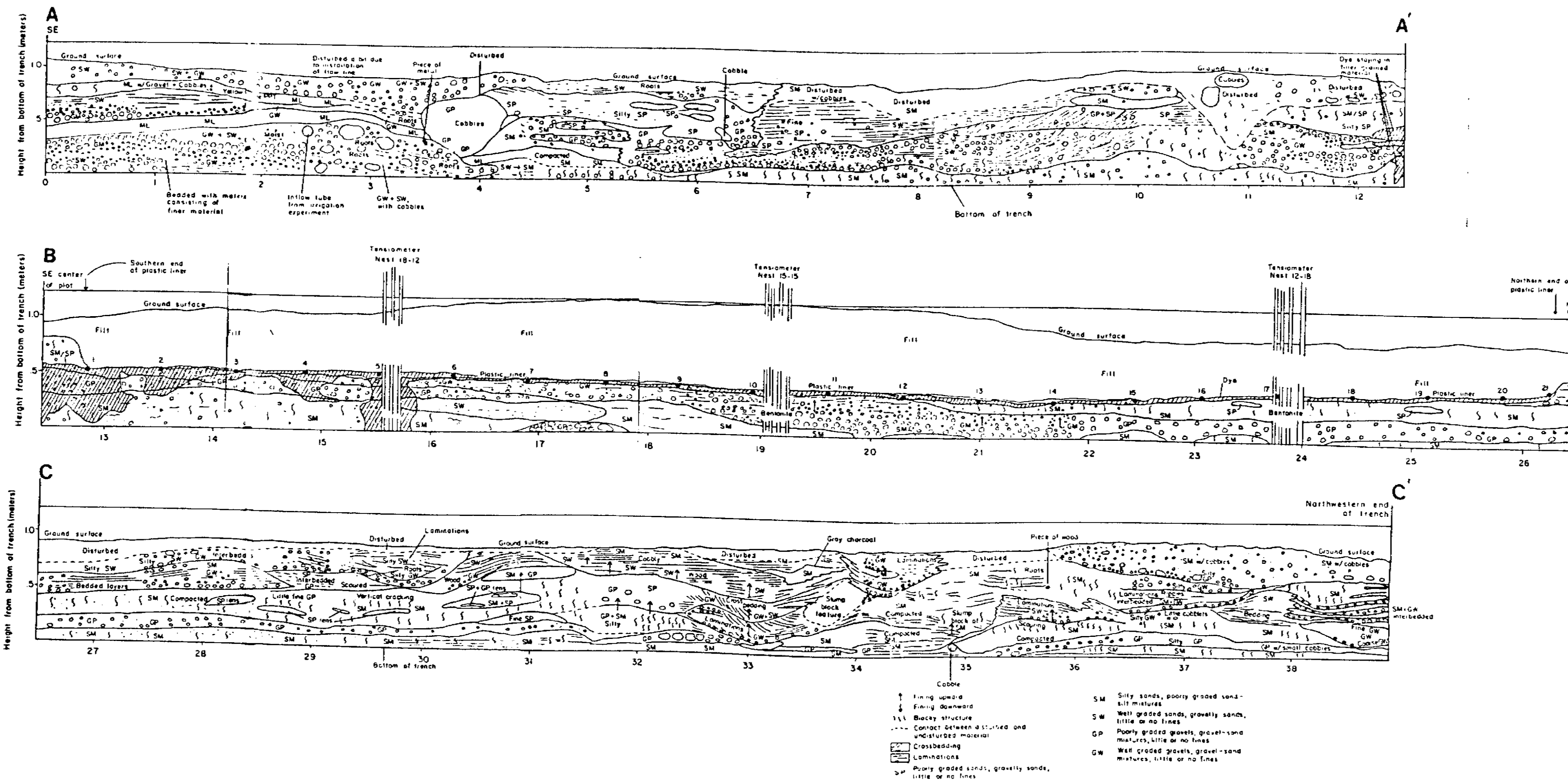


Figure 15. Fine scale geology of the shallow trench. Refer to figure 16 for location of sections A - A', B - B', and C - C'.

Bull system. It is immediately apparent that the units are quite heterogeneous with laminations, fining upward and downward sequences, and crossbedding present throughout the trench. Units 1, 2, and, possibly, 3 are seen in the shallow trench. Water laid unit 1 sediments - bedded gravels and sands - extend from the southeastern corner approximately 3.5 meters to the northwest along the trench. All lengths are as measured from the southeastern corner of the trench moving towards the northwest. It was difficult to sample and measure hydraulic properties of unit 1. In most of the section, undisturbed 100 cc ring samples could not be collected due to the large grain sizes encountered and limited matrix material. Unit 2 extends from 3.5 to approximately 19 meters along the trench. It grades from a silty sand with many pebbles and cobbles in the southeast towards a silty sand in the northwest. Near the center of the irrigated plot, unit 3 is interpreted to appear for 7 to 8 meters (from 19 to 27 meters along the transect). The unit is a silty to sandy clay that appears as if it might have impeded seepage during the infiltration experiment. Unit 3 grades into unit 2 at approximately 27 meters. Unit 2 continues to the end of the trench. Units 4,5,6,and 7 do not appear in the transect. Therefore, insitu saturated hydraulic conductivity measurements were conducted with the disc permeameter along the walls of the deep trench (Arnet,1991). Measured saturated hydraulic conductivities are:

TABLE 1: Saturated Hydraulic Conductivity in the Deep Trench.

UNIT #:	SATURATED HYDRAULIC CONDUCTIVITY (CM/SEC)
4.	5.90×10^{-4}
5.	2.67×10^{-3}
	1.88×10^{-3}
6.	3.31×10^{-4}

The measurements as well as geologic and hydraulic interpretations lead me to believe that units 2,3,4, and 5 were the main water flow units in the piedmont slope facies during infiltration. Units 2 and 5, the intermediate sediments, are geologically quite similar. Units 6 and 7, well-sorted and coarse textured, may have acted as barriers to the seepage. Unit 1 is apparently only seen near the top of the facies at our site and did not contribute to the irrigation event. Yet, it is highly variable in nature ranging from clean gravels to silts and sands. Its hydraulic properties in the vadose zone are also highly variable and, if necessary, should be classified on the small scale. In the southeastern section of the transect, Unit 1 consists of water-laid sediments for a short distance. This short section may have similar hydraulic properties to unit 4 in the deep trench.

My intention in this section has been to describe the geology found in the piedmont slope facies at the site and relate it to the shallow trench. It appears that the main units for vadose zone flow are well represented in the shallow trench. The quantitative data collected in the shallow trench will be used to characterize much of the horizontal spatial variability of the piedmont slope facies.

5.0 HYDROGEOLOGIC CHARACTERIZATION

5.1 MEASUREMENT LOCATIONS

Figure 16 shows the locations of all disc permeameter measurements conducted along the transect. Appendix A presents surveyed measurement locations on the X-Y grid system. Measurements were conducted at approximately 0.3 meter intervals between 1.35 and 1.47 meter below datum. Datum is defined as a plane passing through the irrigated plot at the top of the neutron access tubes.

Due to various reasons the measurements were not conducted along a straight line. For example, the heterogeneous nature of the trench floor necessitated working around large pebbles and cobbles. The non-circular nature of the wetted region around the disc, and sections of the trench dug to deeply by the backhoe, required measurements to be offset from a straight line.

5.2 STATISTICAL TESTS

The Kolmogorov-Smirnoff test (K-S test) was used extensively in the study to evaluate the "goodness of fit" of an empirical distribution to a specified distribution. The specified distributions were usually normal or log-normal. Empirical distributions were also compared to one another to determine

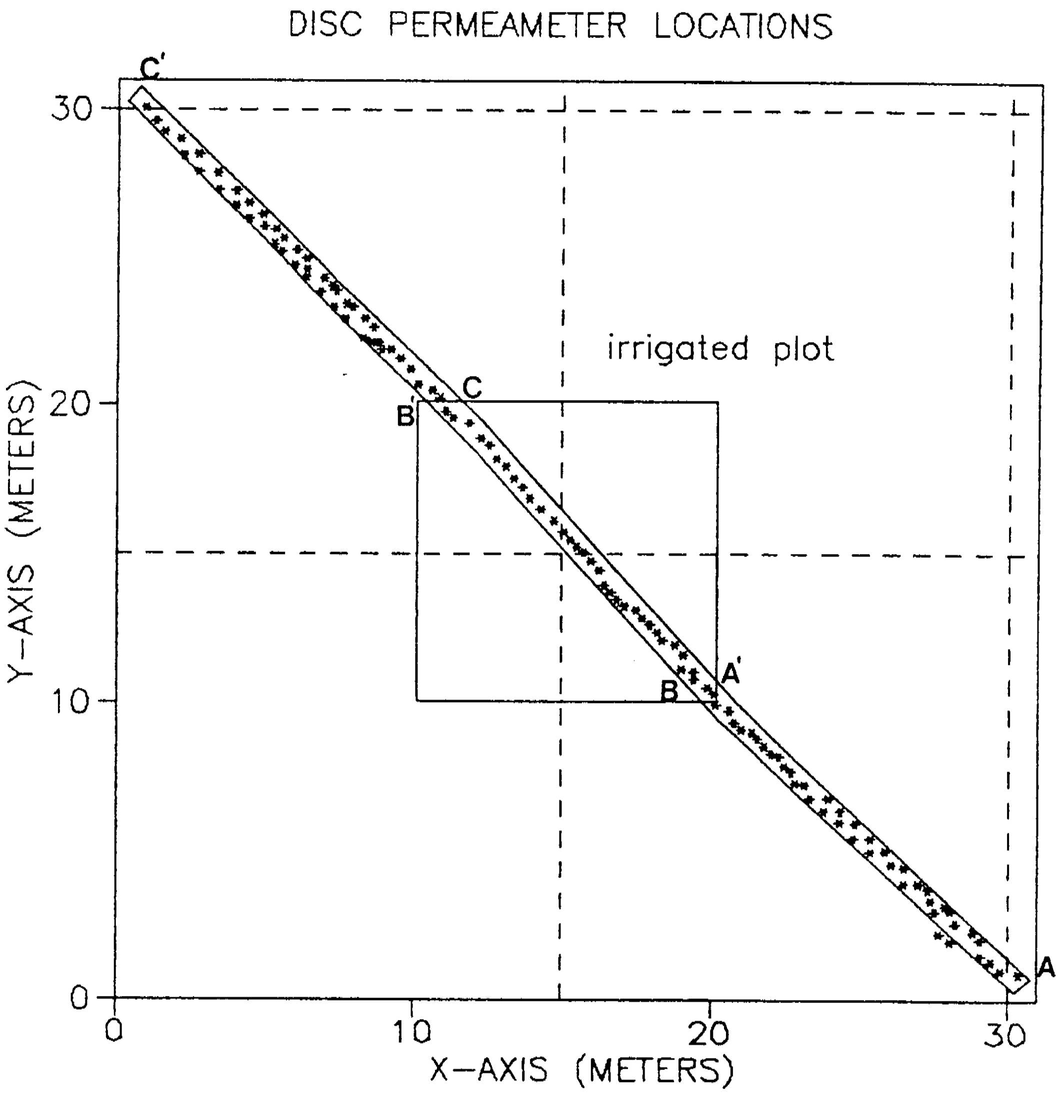


Figure 16. Disc permeameter measurement locations along the shallo trench.

if they stem from similar populations. All the K-S tests were conducted at the 0.05 level of significance. In other words, there is a 1 out of 20 chance of concluding the distributions are different when they are actually the same (Davis, 1986). The K-S test is an alternative to the Chi-Squares test. Observations need not be grouped into arbitrary categories; therefore, the K-S test is more sensitive to deviations in the tails of distributions than the Chi-Squares test (Davis, 1986). Appendix B contains the fortran program used to conduct K-S tests. Appendix C contains the individual K-S test's as well as other statistical information.

The F-test, T-test, and the large sample test of hypothesis for the difference of two mean's (LSTHDTM) were employed to evaluate the statistical relationships of hydrologic properties determined in the field and laboratory. The F-test is used to determine the equality of two data set variances based on the ratio of the variances and sample size (Davis, 1986). If the F-test suggests the variances are not statistically different at the 0.05 level of significance, the T-test is used to test the equality of the two means at the same level of significance.

The T-test is useful for comparing the statistics of two data sets against one another. But, it assumes the data is random, normally distributed, and the two variances are equal. The first assumption is taken as a given, the second is determined using the K-S test, and the third using the F-test.

If the F-test is rejected, a less powerful approximation (LSTHDTM) is employed. The data sets must still be essentially normally distributed, but the variances need not be equal (McClave and Dietrich, 1982).

5.3 LABORATORY ANALYSIS

The 100 cc volumetric ring samples collected from the shallow trench were subjected to various laboratory procedures to determine hydraulic properties. Bulk density (g/cc), porosity (cc/cc), saturated hydraulic conductivity (cm/sec), soil moisture characteristic curve, and particle size distributions were ascertained. Unsaturated hydraulic conductivity relationships were calculated for each core using van Genuchten's (1985) closed form analytical solution. All laboratory and field results are tabulated by disc permeameter (DP) number in appendix D. Seven samples were deleted from the data set due to large soil loss during testing and/or misnumbering of data sheets.

5.3.1 Bulk Density (g/cc)

Dry bulk densities were calculated using (Hillel,1980a):

$$\rho_b = M_s / V_t \qquad (16)$$

ρ_b = bulk density (g/cm^3)

M_s = mass dried soil (g)

V_t = total volume (cm^3)

The samples were dried in a 105°C oven (Fisher, Econotemp, model # 30F) for at least 24 hours and then weighed upon removal to the nearest 0.01 g. Samples with dry volumes less than 100 cm^3 were evaluated to ascertain the actual volume. A uniform sand was loosely pored into the ring and levelled. The sand was transferred to a volumetric cylinder and the deficient volume determined. Parsons (1988) calculated average dry bulk densities for each major soil type at the site. The piedmont slope materials averaged 1.50 g/cm^3, 1.38 g/cm^3 for the clay, and 1.64 g/cm^3 for the fluvial sands. Table 2 compares piedmont slope hydraulic properties for the two sampling episodes. In this study of the piedmont slope facies, dry bulk densities ranged from 1.29 g/cm^3 to 1.75 g/cm^3 with an arithmetic mean of 1.50 g/cm^3 - the same as Parsons (1988). The Kolmogorov-Smirnoff test (K-S test) at the 0.05 level of significance suggests the observations are consonant with the hypothesis they come from a normal distribution (Appendix C). Bulk densities were used for conversion of gravimetric moisture content to volumetric moisture content and in the porosity determinations.

5.3.2 Porosity (cc/cc)

Porosity was determined from the calculated total porosity and from the saturated moisture content. Total porosity is calculated using:

$$n = 1 - \rho_b/\rho_s \qquad (17)$$

TABLE 2: HYDROLOGIC PROPERTIES :

ALLUVIAL FAN MATERIALS (Piedmont Slope Facies)	BULK DENSITY (g/cc)	Nc (%)	S.W.C (%) (cc/cc)	15-B.W.C. (%) (cc/cc)	Ks log (cm/sec)	ALPHA log (1/cm)	N (--)
CURRENT STUDY (1990)							
Mean	1.496	43.5	40.76	14.25	-3.388	-2.745	1.422
Variance	0.011	0.1	39.57	25.08	0.527	0.326	0.049
Coefficient of Variation (%)	7.01	9.08	15.43	35.14	18.904	20.816	15.57
Skewness	-0.296	-0.296	16.92	0.007	3.832	0.666	1.573
Kurtosis	0.25	-0.251	-3.315	-0.413	-0.2713	2.988	6.652
Number of samples (--)	102	102	102	102	100	98	98
PARSONS (1988) (piedmont slope facies)					Ks (cm/sec)	ALPHA (1/cm)	
Arithmetic Mean	1.50	43.4	42.3	12.00	0.027	0.123	1.728
Variance	0.03	38.9	62.8	16.00	0.005	0.101	0.414
Coefficient of Variation (%)	11.3	14.4	18.7	33.30	270.00	258.1	37.2
Number of samples (--)	68	68	67	35	66	62	62
(fluvial sand facies)							
Arithmetic Mean	1.7	36.0	37.1	5.2	0.030	0.087	2.704
Variance	0.01	20.6	54.4	4.9	0.003	0.008	1.906
Coefficient of Variation (%)	7.1	12.6	19.9	42.6	190.0	105.0	51.0
Number of samples (--)	21	21	20	9	15	15	15

Nc = calculated porosity
S.W.C. = saturated water content
15-B.W.C. = 15-Bar water content
Ks = Log of laboratory K saturation
Alpha = van Genuchten fitting parameter
N = van Genuchten fitting parameter

where n is the calculated porosity, and ρ_s the particle density (g/cm^3) (assumed 2.65 g/cm^3). Because particle density can vary with soil type, some error is incorporated in the calculated porosity values. Calculated porosities ranged from 34% to 51% with a mean value of 43.5%.

Saturated moisture contents were estimated by saturating the 100 cc rings in distilled water and weighing prior to pressure plate testing. Again, some error is encountered due to possible entrapped air in the core samples. Saturated moisture content is a direct measure of the water in an individual soil sample. Therefore, in general, saturated moisture contents were used for calculations. However, the porosity of coarse sand and gravel samples was calculated using method 1. Saturated moisture contents were invariably low in these samples as pore water drained before weighing could be conducted. Porosities from the saturated moisture analysis have a mean of 43% and ranged from 30% to 57%. They are compared to the similarly determined results of Parsons (1988) in Table 2. The K-S test at the 0.05 level of significance states the observations of saturated moisture content are not consonant with hypothesis they come from a log-normal distribution, or a normal distribution (Appendix C). The saturated moisture content of eighty-two of 102 samples lies between 38% and 44%. Parsons (1988) showed similar results for saturated water content using fractile diagram analysis, suggesting the distribution may reflect a mixture of more than one population or fit a different type of distribution.

5.3.3 Saturated hydraulic Conductivity

Saturated hydraulic conductivity of the 100 cc ring samples was estimated using a constant head apparatus (Eijelkamp, 6988 BG Lathum, The Netherlands). Sample dimensions are known and steady state flow occurs within several days for most samples. At equilibrium, the samples are assumed saturated, with all entrapped air eliminated. Measurements are taken for several days to ensure equilibrium conditions. Saturated hydraulic conductivity is then easily calculated using Darcy's law.

Some problems were encountered while operating the constant head apparatus. Due to the state of repair of the associated equipment, channeling occurred around several rings. Broken ring screens and dented rings were the largest problems. Soil was lost from several rings before new, heavy duty screens were constructed. Dents in the rings were filled with clear RTV silicone sealant. This eliminated channeling in most cases. Any suspect sample was retested.

Parsons (1988) determined saturated hydraulic conductivities ranging from 2.0×10^{-1} cm/sec in coarse sand to 8.0×10^{-6} cm/sec in the clays. The arithmetic mean for piedmont slope facies was 2.7×10^{-2} cm/sec and 3.0×10^{-2} cm/sec for the underlying fluvial sands (table 2). The current laboratory studies yielded values of saturated hydraulic conductivity ranging from 2.13×10^{-1} cm/sec in the coarse sands near the southeastern end of the shallow trench to 4.24×10^{-7} cm/sec in silts and clays approximately 20 meters along the trench. The Kolmogorov-Smirnoff test at the 0.05 level of significance suggests the observations are consonant with the hypothesis of a log-normal distribution (Appendix C). Hydraulic conductivity has been classified as log-normally distributed in many investigations (Smettem,1987). The logarithmic mean for the current study is 4.09×10^{-4} cm/sec. Comparisons with the data of Parsons (1988) show similar ranges of saturated hydraulic conductivity. The means, however, are different. Parsons (1988) statistical analyses of the hydraulic conductivity is invalid because it involved an arithmetic mean which assumes a normal distribution. The saturated hydraulic conductivities are log normally distributed for both investigations. Studying the fractile diagrams constructed by Parsons (1988), results in an estimated logarithmic mean saturated hydraulic conductivity between 2.0×10^{-4} cm/sec and 3.7×10^{-4} cm/sec for the piedmont slope facies. This estimated mean is within 20% of the current study. It is likely, therefore, that the increased flux of the second tracer experiment, which was equivalent to a hydraulic conductivity of 1.0×10^{-4} cm/sec, resulted in saturated conditions existing in some areas below the irrigated plot.

Saturated hydraulic conductivity values along the first 20 meters of the transect decrease, somewhat step-wise, from the southeast to the northwest by approximately 5 orders of magnitude and then increase towards the northwest (fig 17). Qualitatively, several zones (or layers) of similar hydraulic conductivity are apparent. From 0 to 5 meters along the transect, a high hydraulic conductivity zone exists. Low to moderate hydraulic conductivity zones are present from 5 to 18 meters and 27 to 41 meters, while a low hydraulic conductivity zone outcrops from 18 to 27 meters. These divisions are analyzed in the results and analysis section.

The laboratory saturated hydraulic conductivity realization along the transect reflects the highly stratified and variable nature of the alluvial fan facies. In a number of instances, saturated hydraulic conductivity varies by several orders of magnitude between soil core measurements. Variation of an order of magnitude at the sample spacing is common. It is not apparent if these fluctuations are due to soil heterogeneity or, in part, to the sampling method employed.

While we wish to better understand the soil structure in the horizontal direction, the nearly equal diameter (5.0 cm) and length (5.1 cm) of the soil cores results in vertically averaged hydraulic conductivity if more than one soil layer is sampled. If we examine moving averages of the soil core saturated hydraulic conductivities with distance, however, a smoothed realization is achieved. This realization may help to

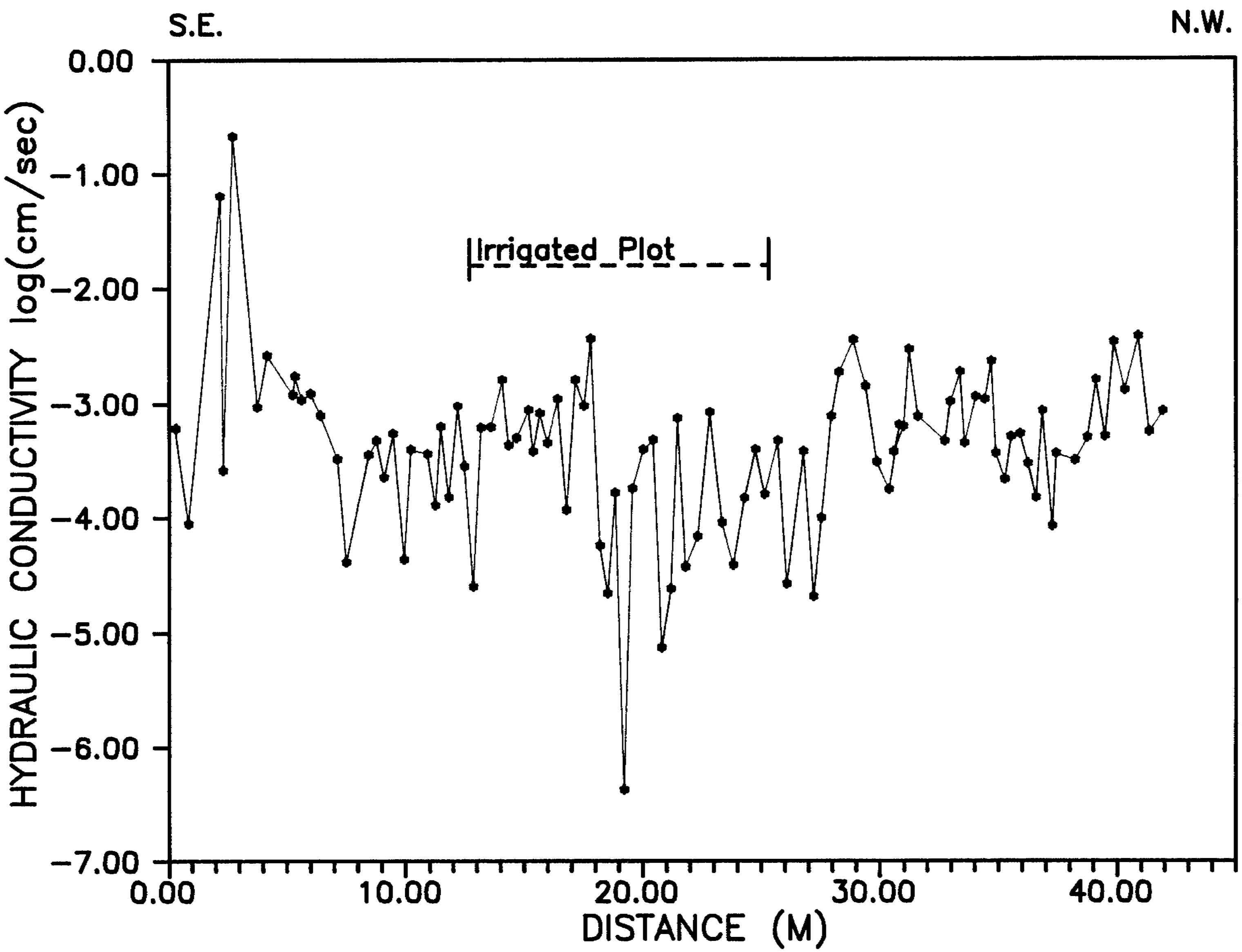


Figure 17. Laboratory saturated hydraulic conductivity along the transect.

elucidate gross horizontal zones of hydraulic conductivity along the transect. It is critical that the moving average procedure, itself, does not obscure the zones of interest.

Variogram analysis provides a means of determining a maximum distance beyond which artificial correlation is introduced by the averaging procedure. Analysis of the unaveraged soil core saturated hydraulic conductivity variogram leads to an estimated spatial dependence (range of correlation) of up to 4.0 meters (fig.18). The variogram is quite scattered about the sill, displaying the large variability in hydraulic conductivity along the transect. The range suggests measurements conducted at greater than 4 meters separation are independent. More importantly, conducting a moving average at ≥ 4 meters will result in artificial correlation. Analysis of the soil core saturated hydraulic conductivity realization along the transect is continued in the analysis of results section.

It must be noted that the variogram in Figure 18 stems from a data set that begins at 4 meters along the transect from the southeast corner. Coarse gravel with little matrix material made undisturbed sampling difficult in some areas. The infrequent sampling in the coarse gravel's, approximately one-half the normal sampling density, caused a nugget effect in variogram analysis of the entire transect. Therefore, to better understand the units directly below the irrigated plot, and because similar texture zones are not recognized in the

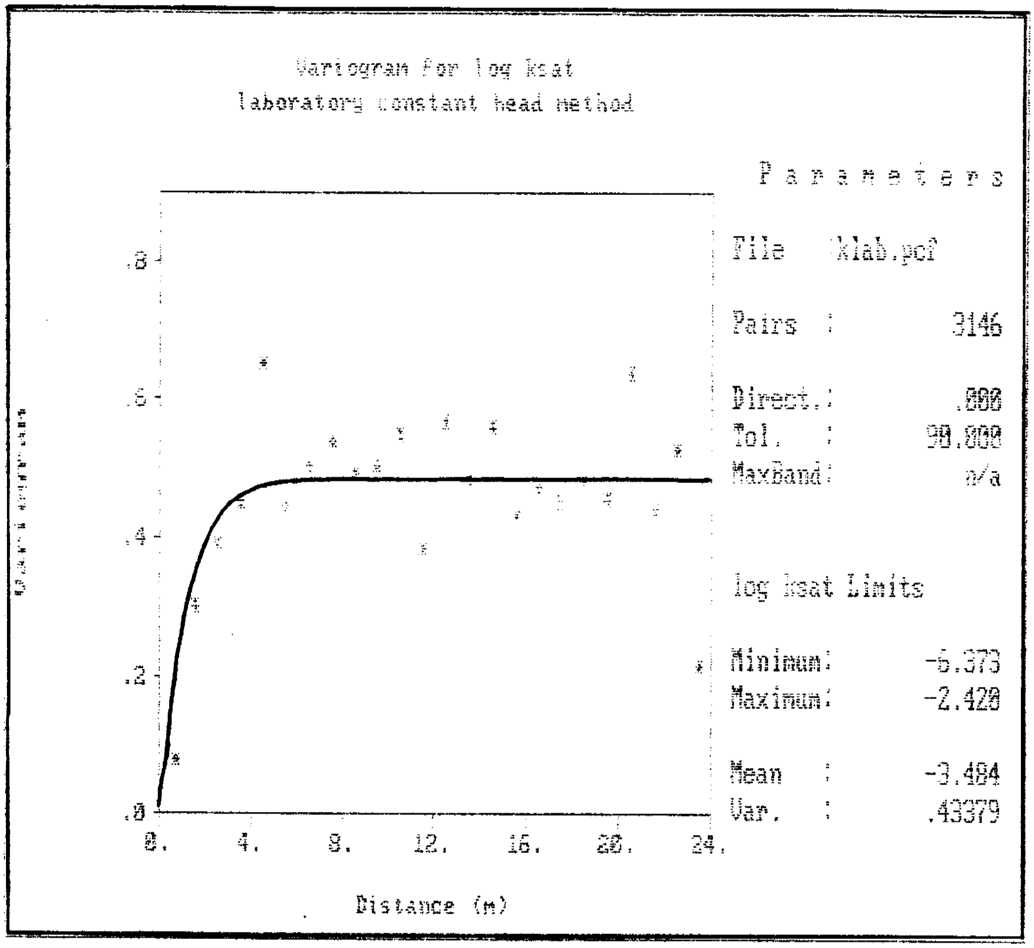


Figure 18. Variogram of log laboratory saturated hydraulic conductivity. An exponential model was fit to the variogram. sill = .485 and range of approximately 3.5 to 4.0 meters.

deep trench, the data in the first 4 meters of the trench from the southeast were dropped from the analysis.

5.3.4 Soil Water Characteristic Curve

The soil moisture retention relationship (θ-Ψ) is measured for each soil core using the hanging column apparatus and 15 bar pressure plate. The hanging columns are used to determine the imbibition curve for each core from negative pressures of approximately 200 cm to zero. An equilibrium period of at least 24 hours is needed between measurements of moisture content at varying pressure. As stated by Parsons (1988), the equilibrium period may not be entirely adequate for the finer samples. Therefore, finer textured samples were allowed as much as 48 hours for equilibrium at the higher negative pressures.

A pressure plate assembly (15 bar ceramic plate extractor, cat. #1500, Soil Moisture Eq. Co., Santa Barbara, Ca.) was used to apply positive pressure to displace water from the samples. Positive pressure was increased in varying increments every 24 hours up to 15 bars of pressure. Most samples were held at 15 bars pressure for two weeks. However, equilibrium was assumed when negligible water was dislodged from the apparatus over a 24 hour period.

I used an air psychrometer (SC-10a, Decagon Device Inc., Pullman, Wa.) to test the assumption that one to two weeks time was sufficient for equilibrium of the soil cores at 15 bars pressure. Fifteen bars gage pressure was applied to three of the finer textured samples. After approximately two weeks, the samples were removed from the pressure plate and placed in a psychrometer chamber to measure soil-water potential. The air psychrometer measured soil-water pressures which ranged from 5 to 8 bars (Appendix E). It appears that the soil-water potential is not in equilibrium with the applied pressure even though negligible water was being eluted from the pressure plate apparatus. It is assumed the moisture content disparity between 5 and 15 bars is slight. As the three soil core samples were fine textured, coarser textured samples are assumed to be closer to equilibrium with the applied pressure.

One hundred and two soil samples were tested in the pressure plate and hanging columns. 15-bar water contents from the pressure plate ranged from near zero in the gravels at the southeastern end of the transect to 24.7% near the northwestern end. The Kolmogorov-Smirnoff test at the 0.05 level of significance indicates the distribution is consonant with that of a normal distribution (Appendix C). Parsons(1988) 15-bar water content distribution was also normal. The arithmetic mean is 14.25% in this study. Selected typical moisture content - pressure head relationships are presented in Figure 19.

5.3.5 Particle Size Analysis

Two sets of grain size data were collected in the field

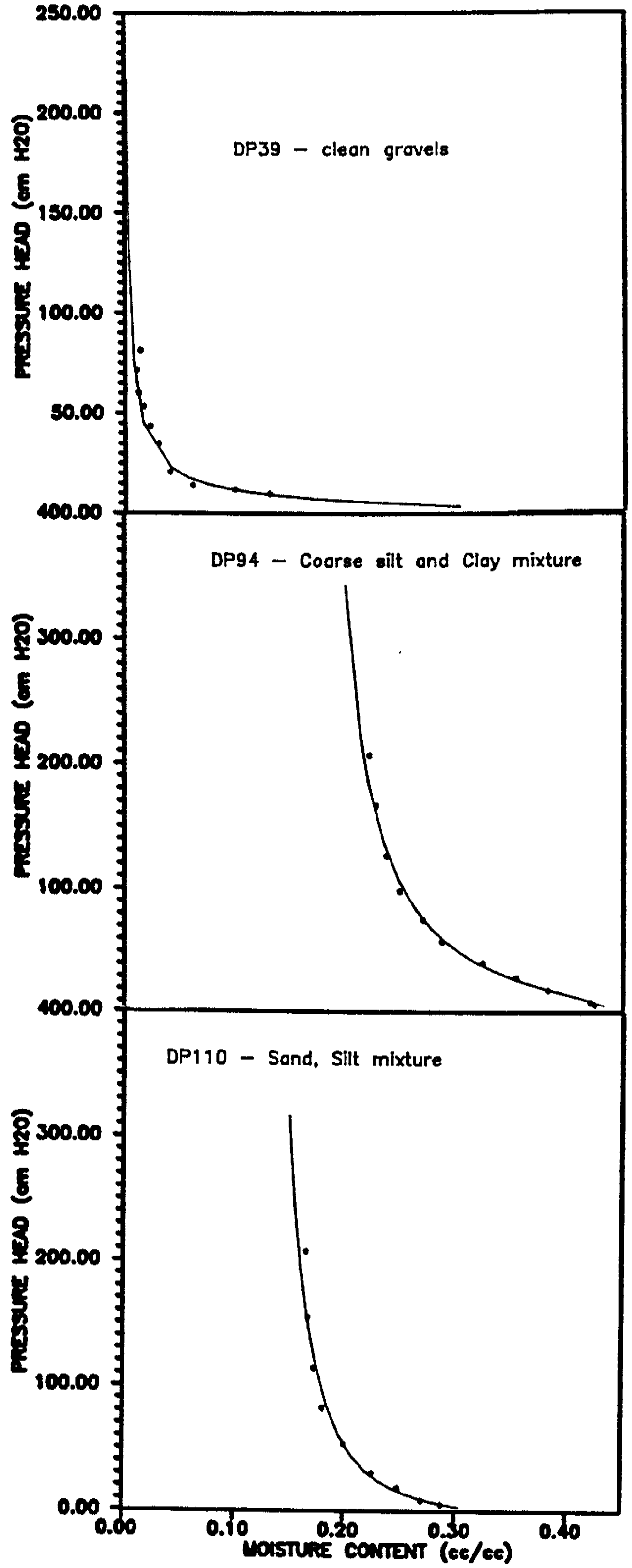


Figure 19. Characteristic moisture content/pressure head relationships along the transect.

and analyzed in the laboratory for particle size distribution. They are the 100cc soil core (S.C.) samples and the final moisture content (F.M.C.) grab samples. The particle size distributions were determined by standard sieve and hydrometer analysis (Day,1965). Particle size parameters measured include d_{10}, d_{30}, d_{50}, d_{60}, and d_{90}, if possible. The coefficient of uniformity (d_{60}/d_{10}) and the coefficient of curvature ($d_{102}/[d_{10}*d_{60}]$) were calculated (Appendix F). The F.M.C. samples are the particle size samples used to determine the final moisture content with the disc permeameter. These samples are scraped from the first centimeter of soil beneath the disc after a measurement is concluded. The S.C. samples contain the grain size data from a 100 cubic centimeter volume of nearly equal diameter (5.0 cm) and length (5.1 cm) from near the center of the disc measurement site. They are collected after the final moisture content grab samples and used for laboratory tests of saturated hydraulic conductivity, etc. Average particle size parameters are presented in Table 3. The d10 particle sizes for the two distributions along the transect are presented in Figure 20.

Both data sets, while exhibiting large differences in d10 size between measurements at several locations, show similar trends along the transect. The d10 size decreases from a fine sand in the southeast to a very fine silt and clay near the center of the transect. From the center towards the northwest, the distributions are less similar. Both have average d10

TABLE 3: PARTICLE SIZE PARAMETERS

ALLUVIAL FAN MATERIALS (piedmont slope facies)	d10 (mm)	d30 (mm)	d50 (mm)	d60 (mm)	d90 (mm)	Cu (--)	Cc (--)
FINAL MOISTURE SAMPLES							
Arithmetic mean	0.089	0.437	0.609	0.747	1.908	23.2	3.009
Variance	0.058	2.154	1.061	1.31	2.381	1074.6	17.552
Standard Deviation	0.242	1.468	1.03	1.145	1.543	32.78	4.19
Coefficient of Variation(%)	272.7	336	169.05	153.16	80.897	141.79	139.23
Skewness	7.83	8.07	3.265	3.395	1.647	5.543	8.84
Kurtosis	69.7	72.73	13.179	14.427	4.376	40.98	45.67
Number of Samples (--)	92	97	98	96	87	90	90
SOIL CORE SAMPLES							
Arithmetic mean	0.049	0.169	0.358	0.526	1.776	18.56	2.492
Variance	0.003	0.015	0.143	0.303	1.887	232.86	4.578
Standard Deviation	0.056	0.123	0.379	0.551	1.374	15.26	2.14
Coefficient of Variation(%)	114.72	72.748	105.703	104.705	77.36	82.2	85.84
Skewness	3.6	3.667	4.357	3.941	2.043	1.36	1.464
Kurtosis	22.71	18.8	26.04	22.63	6.237	4.103	5.239
Number of Samples (--)	102	100	101	101	90	101	100
PARSONS(1988)							
PIEDMONT SLOPE FACIES							
Arithmetic mean	0.067	0.197	0.39	0.566	3.851	59.256	3.115
Variance	0.008	0.098	0.353	0.71	15.342	14161.4	18.253
Coefficient of Variation(%)	134.2	158.7	152.5	149	101.7	200.8	137.2
Number of Samples (--)	59	59	59	59	59	59	59
FLUVIAL SAND FACIES	0.163	0.359	0.803	1.223	4.549	7.071	0.888
Arithmetic mean	0.002	0.066	0.994	2.709	25.112	102.87	0.053
Variance	25.0	71.3	124.1	134.6	110.2	143.4	25.9
Coefficient of Variation(%)	21	21	21	21	21	21	21
Number of Samples (--)							

Cu = coefficient of uniformity (d60/d10)
Cc = coefficient of curvature ((d30^2)/(d60*d10))

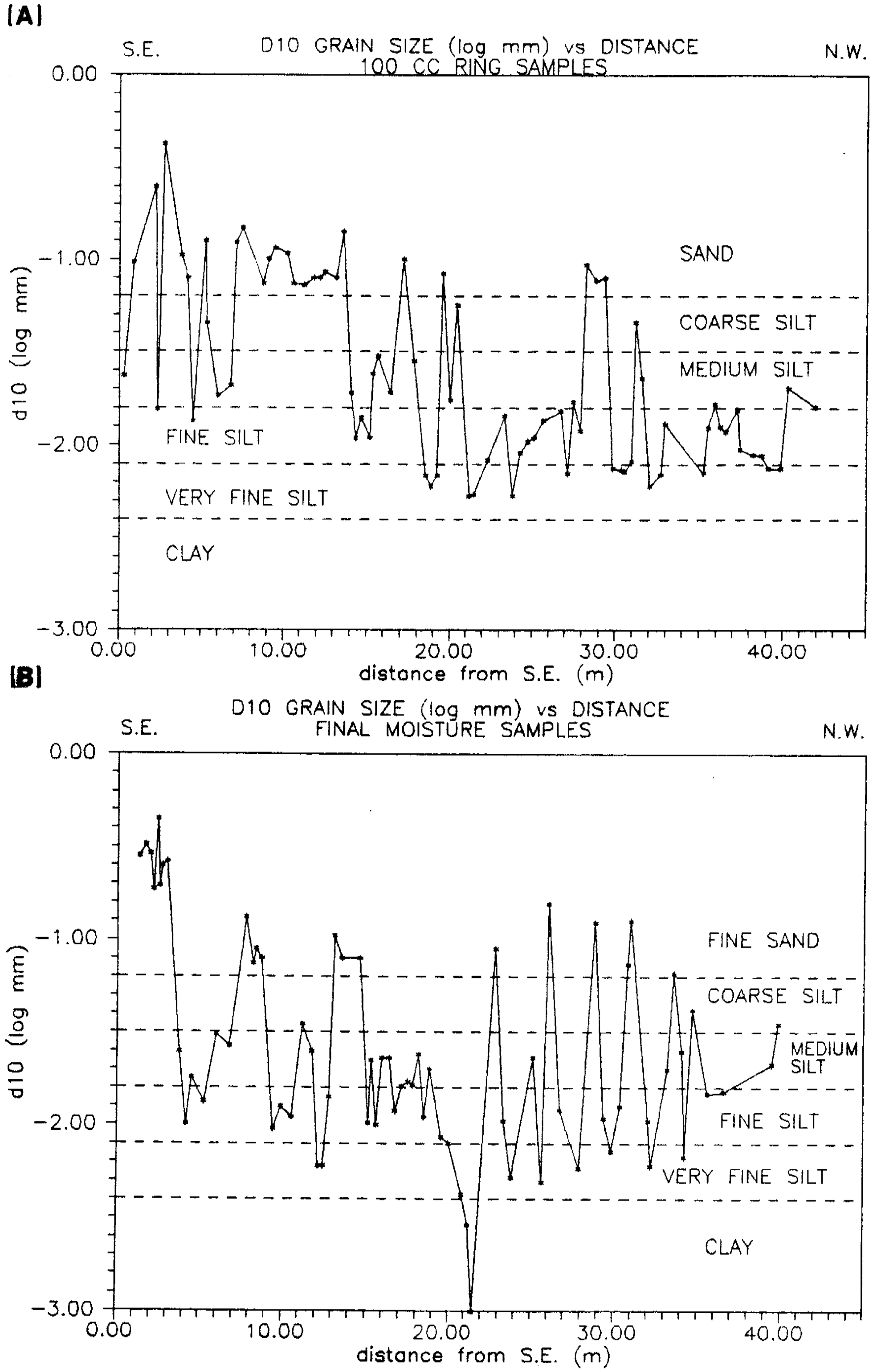


Figure 20. Log d10 particle size for (A) soil core and (B) final moisture content grab samples.

sizes in the fine to medium silt range, but the final moisture d10 sizes are much more variable about the average. They consistently range into the fine sand size. The comparable soil core d10 sizes are mostly fine silts.

The difference in d10 size is greatest from 7 to 14 meters along the transect. The soil core d10's are fine sands while the final moisture d10's range from fine to medium silt. Apparently, layering is fine enough along some parts of the transect, or the trench floor lies near a boundary, that the two methods sample different populations. It appears as if the disc permeameter is influenced most by surface soil layers. Therefore, soil cores are not used as characteristic of the soil beneath the disc permeameter unless sampling is confined to a single layer. Both data sets are log-normally distributed according to the Kolmogorov-Smirnoff test at the 0.05 level of significance (Appendix C). The F-test at the same level of significance contains no evidence to suggest the variances are different. But, the T-test suggests there is a significant difference in the means of the two d10 data sets. The tests and qualitative distribution analysis suggest a bimodal nature to the soil core data (figures 21,22).

An attempt was made to divide the soil core d10's into two distributions according to distance. For example, the data was separated at 14 meters due to grain size difference. The two segments were analyzed. The bimodal nature remained. Other separations were attempted with similar results. According to

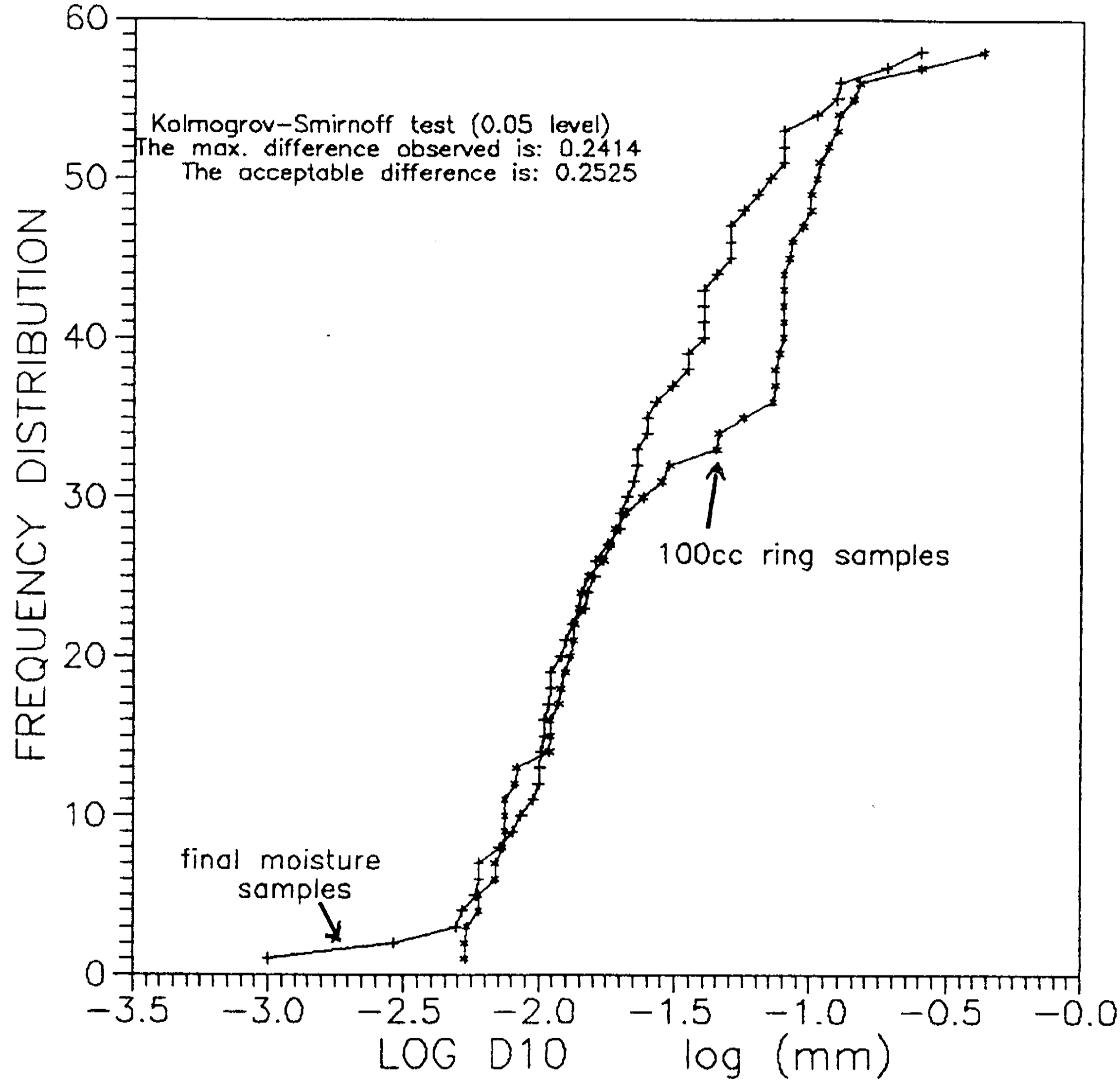


Figure 21. Log d10 particle size distribution comparison of soi: core d10 and final moisture content d10.

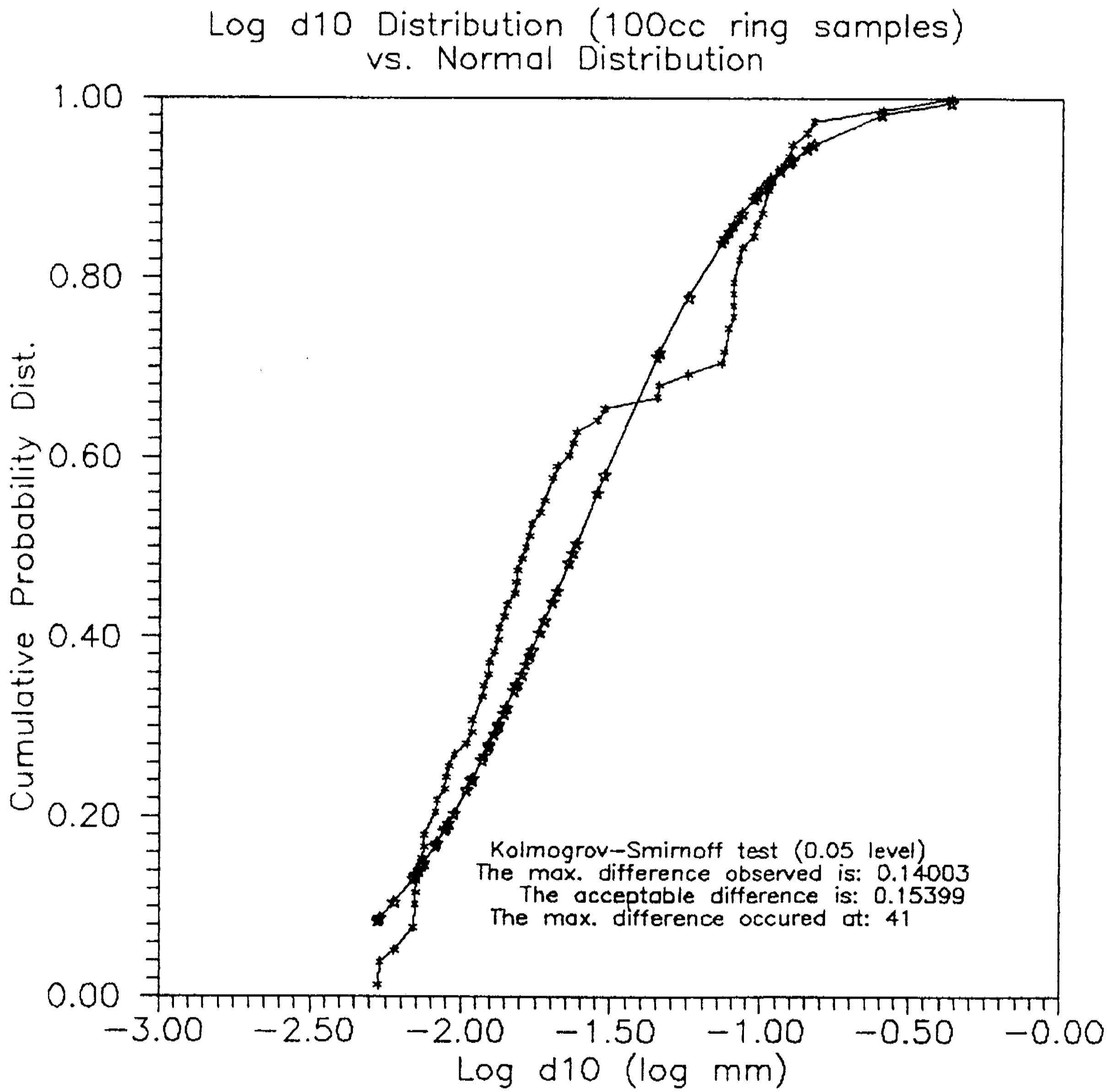


Figure 22. Soil core d10 distribution exhibiting an apparent bimodal nature. One population appears to be a fine sand, the other a fine silt.

the statistical tests, the F.M.C. samples do not exhibit a bimodal nature and, therefore, are not included in the foregoing analysis. The soil core samples are bimodal, but the two distributions cannot separated by distance along the transect.

Variogram results show a range of correlation between 2 and 3 meters for both d10 data sets with little or no nugget (fig.23a,b). A 2-point moving average was conducted in an attempt to smooth the data but yielded inconclusive results. Due to the relatively small range of correlation and missing data, a two point moving average was advisable. Then, artificial correlation from the averaging procedure is avoided. As expected, the averaged graph was quite similar to the unaveraged. No distinct boundaries were apparent.

In summary, the final moisture content d10 sizes vary considerably from 20 to 40 meters along the transect from fine silts to fine sands. The soil core d10 data is more uniform. From 7 to 14 meters, the soil cores appear to sample a layer not seen in the final moisture content data. Perhaps the different volumes sampled by the two methods are responsible for the differing results. Still, in general, both data sets show a decreasing trend in d10 size from 0 to 20 meters and then an increase from 20 to 41 meters.

5.3.6 Parameter Analysis for van Genuchten's code

Van Genuchten's code RETC.F77 (1985) is utilized to

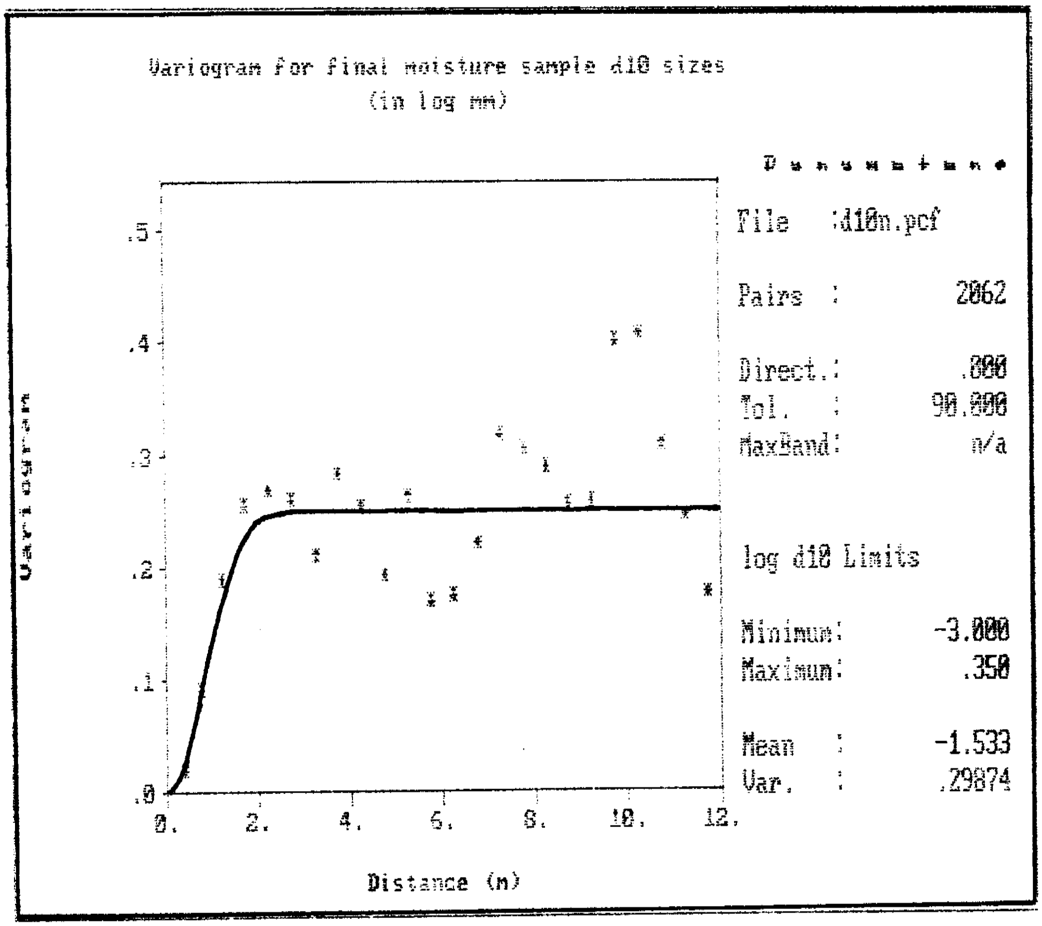


Figure 23a. Variogram analysis of the final moisture content log d1 particle size. A guassian model was fit to the data a a lag spacing of 0.5 meter. The estimated sill is 0.2 with a range of 2 to 3 meters.

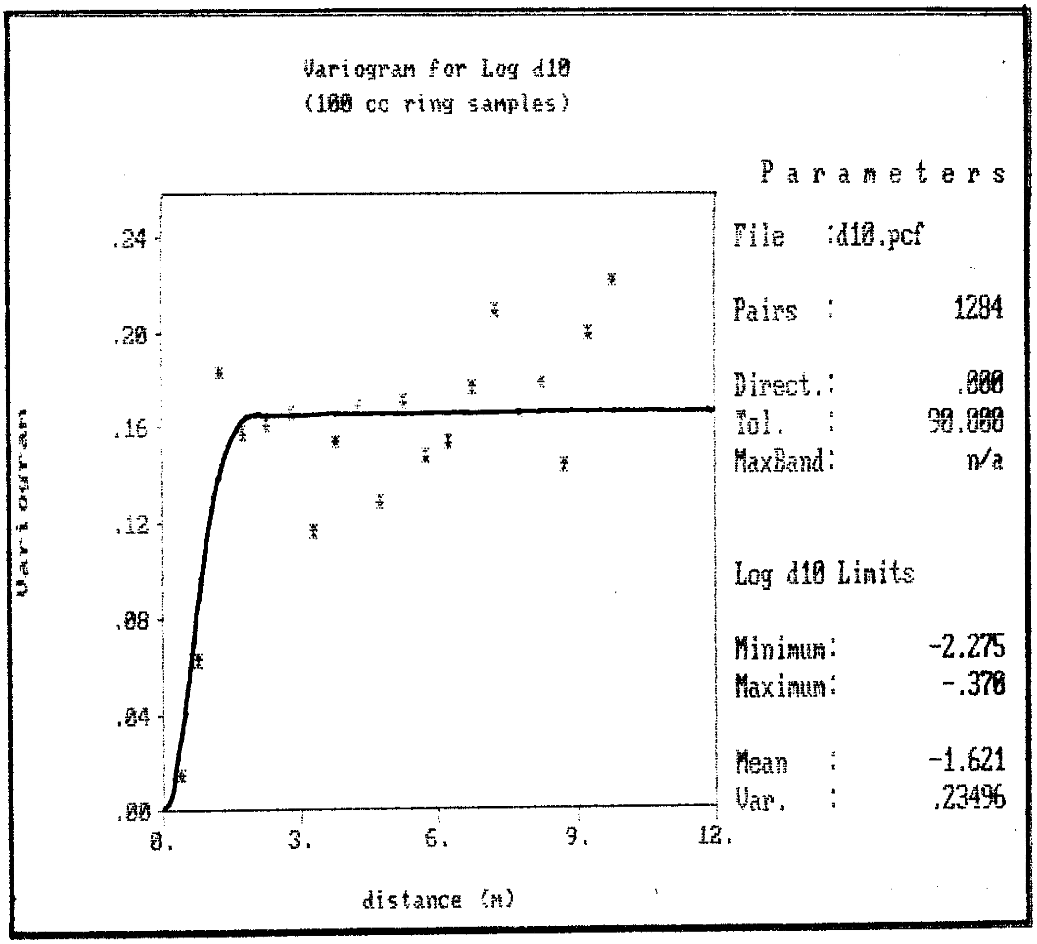


Figure 23b Variogram analysis of the soil core log d10 parti size. Guassian model. Sill of 0.165, range of betw 2.0 and 2.25 meters.

analyze observed soil water retention and hydraulic conductivity data. It can be used to fit several analytical functions to observed retention and unsaturated hydraulic conductivity or diffusivity data. The fitting equations for the soil water retention curve can be described by equations found in van Genuchten (1980). The analytical functions for unsaturated hydraulic conductivity were obtained by using retention functions in conjunction with the predictive hydraulic models of Burdine (1953) and Mualem (1976). The code can be used to predict unsaturated hydraulic conductivity from observed soil water retention data if the saturated hydraulic conductivity is assumed known. It also simultaneously fits analytical functions to observed retention and conductivity data.

As stated earlier, van Genuchten's closed form analytical solution (1980) calculates the relative hydraulic conductivity (K_r) using either the equation by Mualem (1976) or Burdine (1953). Our data was analyzed using only Mualems model. The relative hydraulic conductivity is calculated using the known theta-psi relationship data:

$$K_r(S_e) - S_e^{1/2}\left[\frac{\int_0^{S_e}\frac{1}{\psi(x)}\delta x}{\int_0^{1}\frac{1}{\psi(x)}\delta(x)}\right]^2 \qquad (18)$$

x is a dummy variable, psi is pressure head as a function of the dimensionless water content, S_e.

$$S_e = \frac{(\theta-\theta_r)}{(\theta_s-\theta_r)} \tag{19}$$

S_e = effective saturation (dimensionless)

θ = moisture content (cc/cc)

subscript r = residual volumetric moisture content
s = saturated volumetric moisture content

Equation 18 is solved by relating the effective saturation to the pressure head by:

$$S_e = \left[\frac{1}{1+(\alpha\psi)^N}\right]^m \tag{20}$$

alpha, N, and m are parameters that depend on the shape of the soil water characteristic curve.

The closed form solution combines equation 20 with equation 18:

$$K_r(S_e) = S_e^{1/2}[1-(1-S_e^{1/m})^m]^2 \tag{21}$$

or

$$K_r(\psi) = \frac{\{1-(\alpha\psi)^{N-1}[1+(\alpha\psi)^N]^{-m}\}^2}{[1+(\alpha\psi)^N]^{m/2}} \tag{22}$$

The complete derivation is detailed in van Genuchten (1980).

The model estimates alpha and N by a non-linear least squares regression procedure and calculates K_r by equation 18. The alpha and N values determined from the theta/psi curves are employed to calculate K_r with psi data. The needed input includes θ_s, θ_r, saturated hydraulic conductivity, and the theta/psi relationship. The residual moisture content (θ_r) is assumed to be the 15 bar water content, the maximum operating pressure for the apparatus. This updated version of van Genuchten's 1980 code allows data points to be weighted which is useful in our study because we have no data in the dry range from about 250 cm tension to 15000 cm. This will allow more weight to be given to the hanging column data. As there is some doubt as to the validity of the 15 bar moisture contents (laboratory methods section), the three parameter model (θ_r,θ_s,K_s input) was run only if a good estimate of residual saturation could be determined. In almost all cases, the 15-bar water content was input as the initial value for θ_r in the two parameter model and allowed to vary.

The closed form solution has been found by many workers to produce good agreement between observed and predicted unsaturated hydraulic conductivity in the field and laboratory (van Genuchten,1980;Stephens and Rehfeldt,1985). Van Genuchten (1980) compared observed and calculated conductivity curves for several soils. Three of the soils - a sandstone, and two silt loams - showed good agreement between observed and predicted curves. Predictions for the clay, however, were less accurate. They underestimated conductivity near saturation and overestimated in the dryer ranges. Therefore, van Genuchten (1980) suggests an independent procedure be used to estimate residual moisture content.

Stephens and Rehfeldt (1985) compared the two and three parameter models with field measured theta/psi data. Both models predicted the theta/psi relationship with good agreement. A good visual fit to the theta/psi curve, however, doesn't guarantee an accurate K-psi prediction. Field or laboratory K-psi measurements may be needed to substantiate the prediction under dry conditions. Improved accuracy may be obtained by using θ_r values based upon laboratory measured water content at tensions much larger than experienced in the field. Soil physical characteristics may also be used to estimate the residual moisture content.

A regression of the measured 15-bar water contents and fitted residual moisture contents shows random behavior (fig.24). Perhaps assigning a residual moisture content by soil physical characteristics would yield a better correlation. In any event, according to Parsons (1988), K-psi curves seem to be relatively insensitive to alpha and N values for both the two and three parameter models in the wet region of the curve. Therefore, the two parameter method was deemed appropriate for the stated purpose of determining α and N

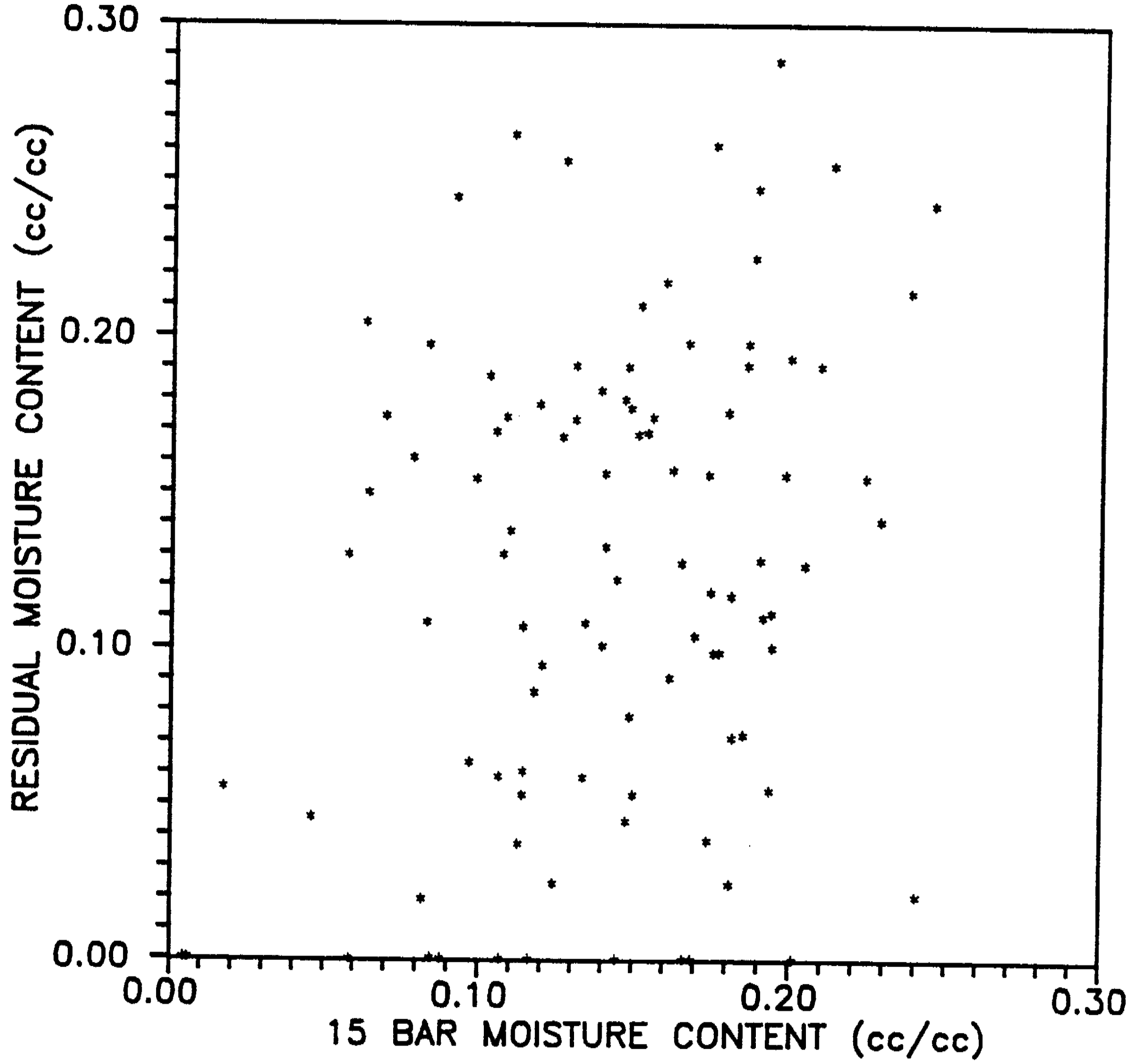


Figure 24. Regression of fitted residual moisture content to measured 15 bar water content.

values.

Calculated α-values are plotted versus distance in Figure 25. The α-values stem from a log normal distribution according to the Kolmogorov-Smirnoff test at the 0.05 level of significance. The logarithmic mean and variance are 0.0625/cm and 1.15/cm (table 2). Again, Parsons determined arithmetic means for log normally distributed data. Fractile diagrams, however, yield a natural log mean of approximately 0.05/cm. The current study α-values have a natural log mean of 0.064/cm and variance of 1.38/cm. The lower mean of Parsons(1988) α-values suggests a higher air-entry and slightly finer soil texture for her soils.

A large α-value should correspond to a coarse grain size and vice versa. This relationship is somewhat consonant with the d10 sizes along the transect. Both the d10 sizes and the alpha values decrease from zero to 20 meter along the transect from the southeast towards the northwest. They also increase slightly after 20 meters and can be quite variable. The hydraulic conductivity and sorptivity data also show similar trends.

Variogram analysis of the α-values results in a nugget which is approximately one-half the sill value (fig.26). A range of approximately 2.0 meters was determined at a lag distance of 0.4 meters which is essentially the sample spacing. All larger lag distances resulted in a pure nugget effect. The range of correlation for the α data along the

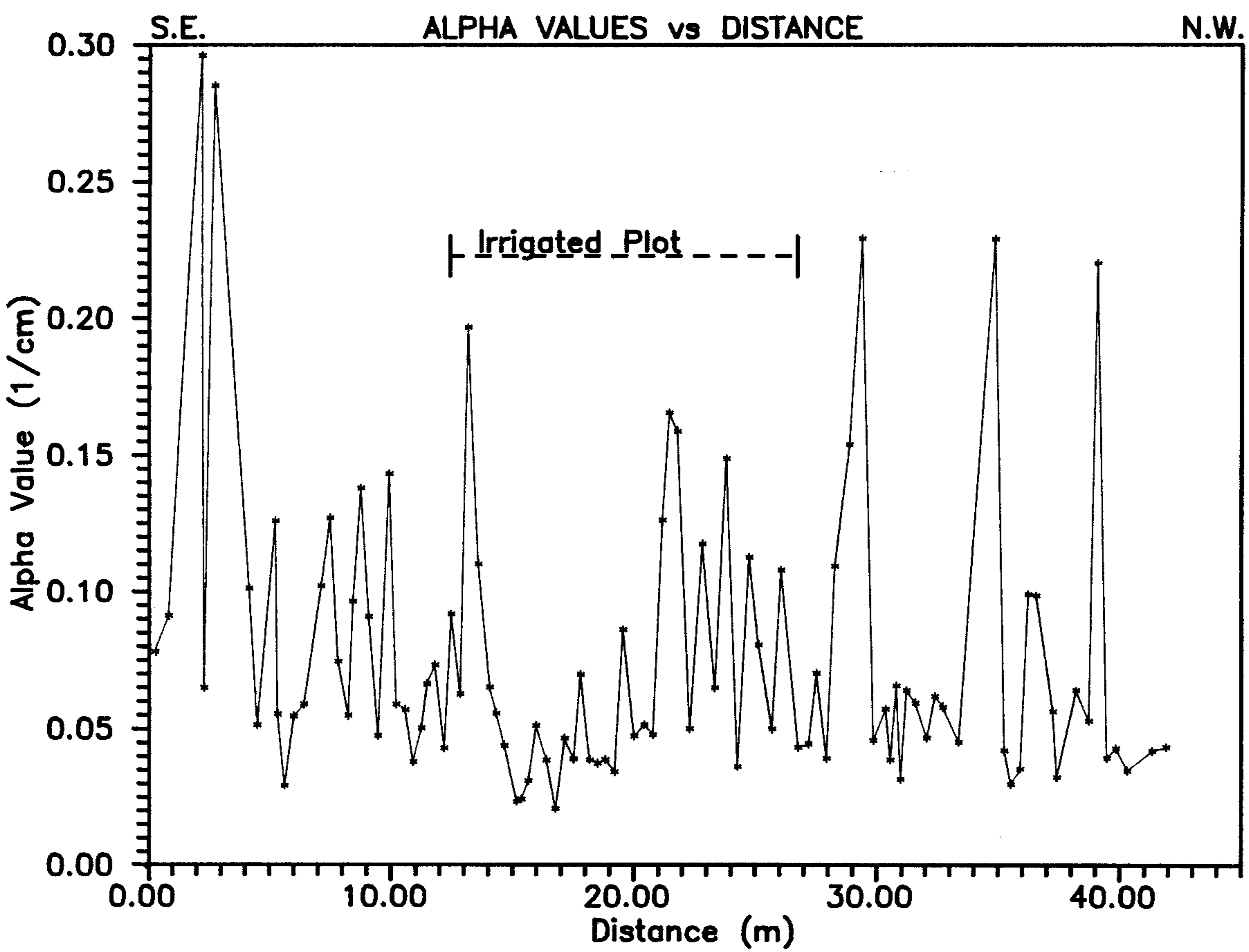


Figure 25. Alpha values calculated from the two parameter fit to van Genuchten's soil-water/pressure head analysis.

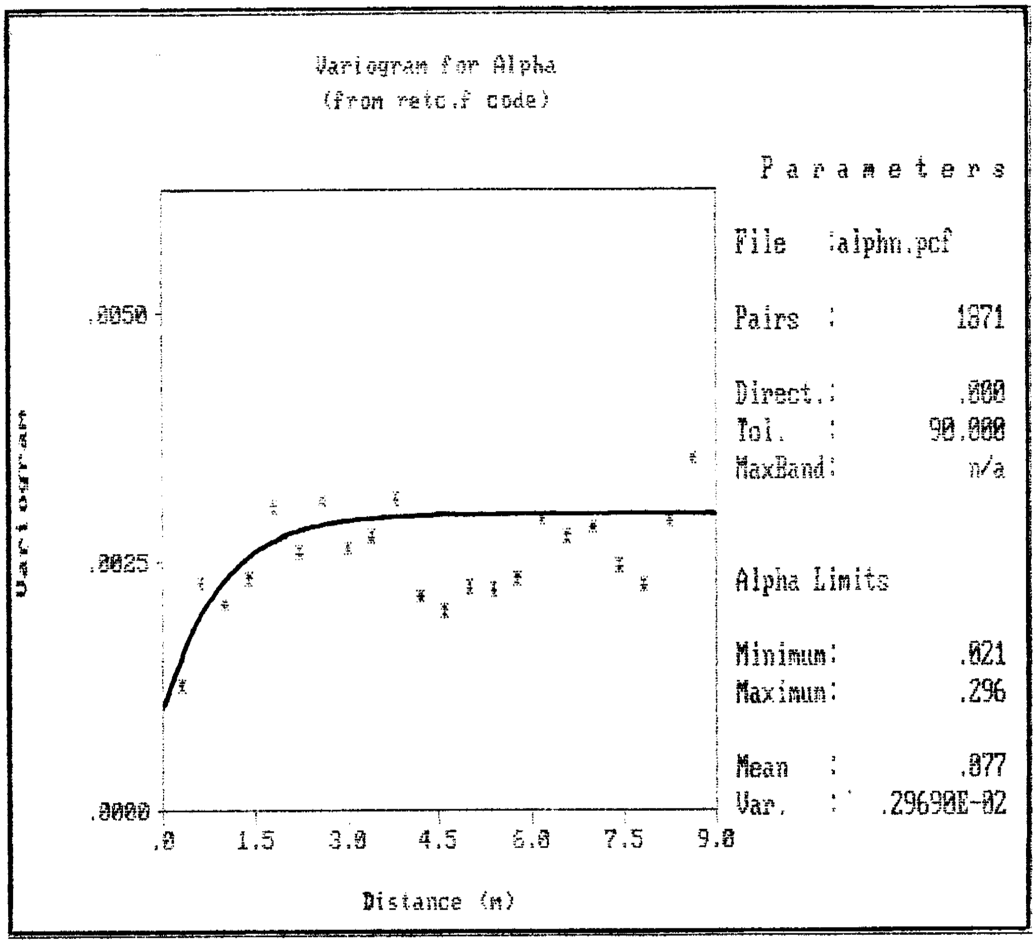


Figure 26. Variogram for Alpha values show an exponential fit wit nugget approximately 50% of the sill. Sill of 0.0028 an range of approximately 2 meters. Note the possible hol effect at 4.0 meter.

transect relates well to the ranges estimated for both d10 sizes and hydraulic conductivity. Therefore, it appears the α-values are related to the soil texture and hydrology.

N values as calculated by van Genuchten's code are plotted in Figure 27. The data is quite uniform along the transect and does not exhibit the trend of the alpha data. The Kolmogorov-Smirnoff test at the 0.05 level of significance shows the data cannot be rejected as normally distributed. The arithmetic mean is 1.422 with a variance of 0.049 (Table 2). This compares to the arithmetic mean of 1.728 and variance of 0.414 for Parsons (1988). This suggests a slightly more uniform soil distribution for her soils than in the current study. Variogram analysis resulted in a pure nugget which suggests the data are randomly distributed (fig.28).

5.4 FIELD MEASUREMENTS

5.4.1 Core Sample Collection

One hundred and eight 100 cc ring samples were collected from the shallow trench. Soil cores were sampled from the center of each disc permeameter location immediately following the measurement. The very dry and brittle nature of the soils restricted the collection of undisturbed dry soil samples. Inevitably, the dry sample would fall apart while attempting to remove the core from the surrounding soil. Therefore, samples were taken after the infiltration events, dried, and

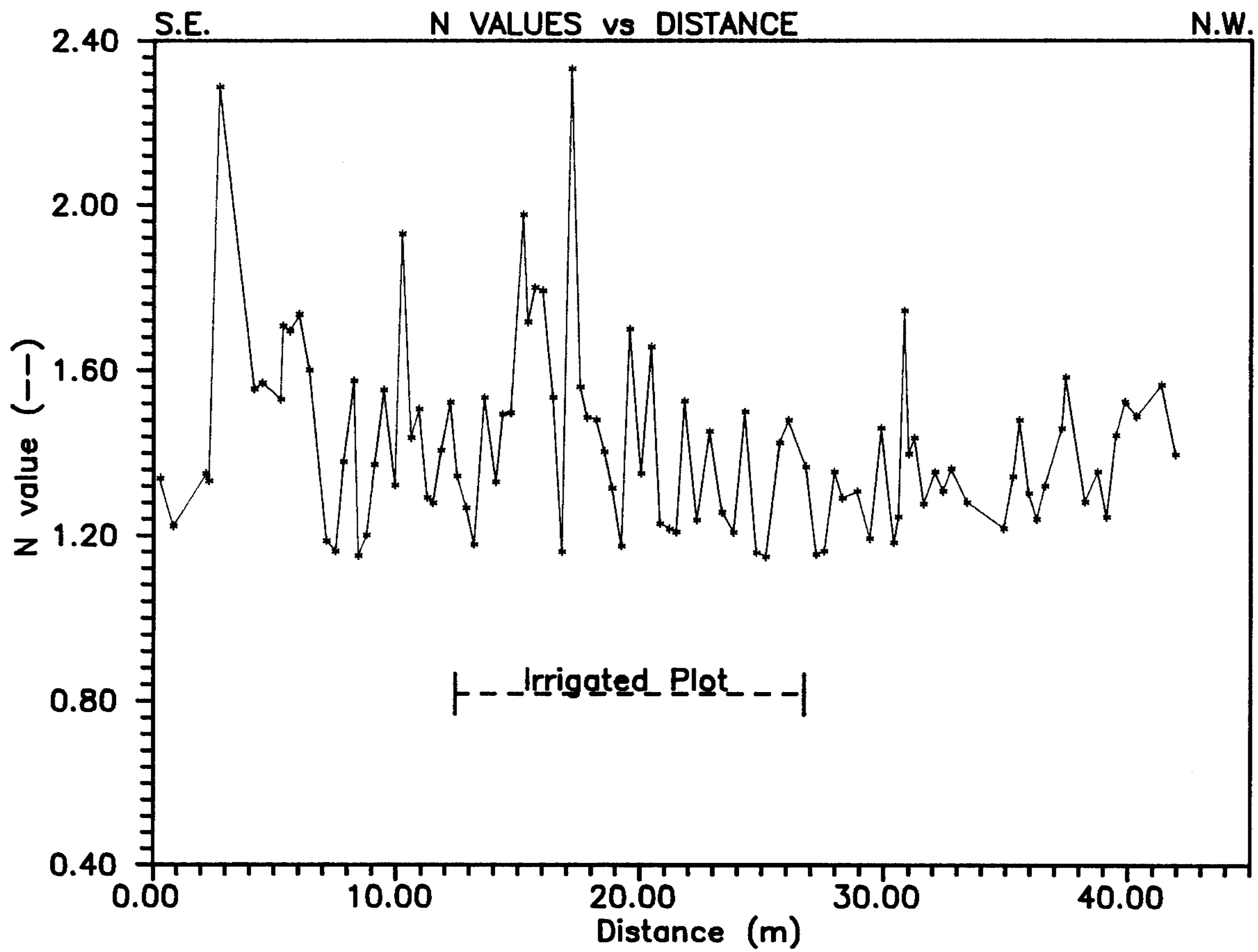


Figure 27. N values calculated using van Genuchten's two parameter model

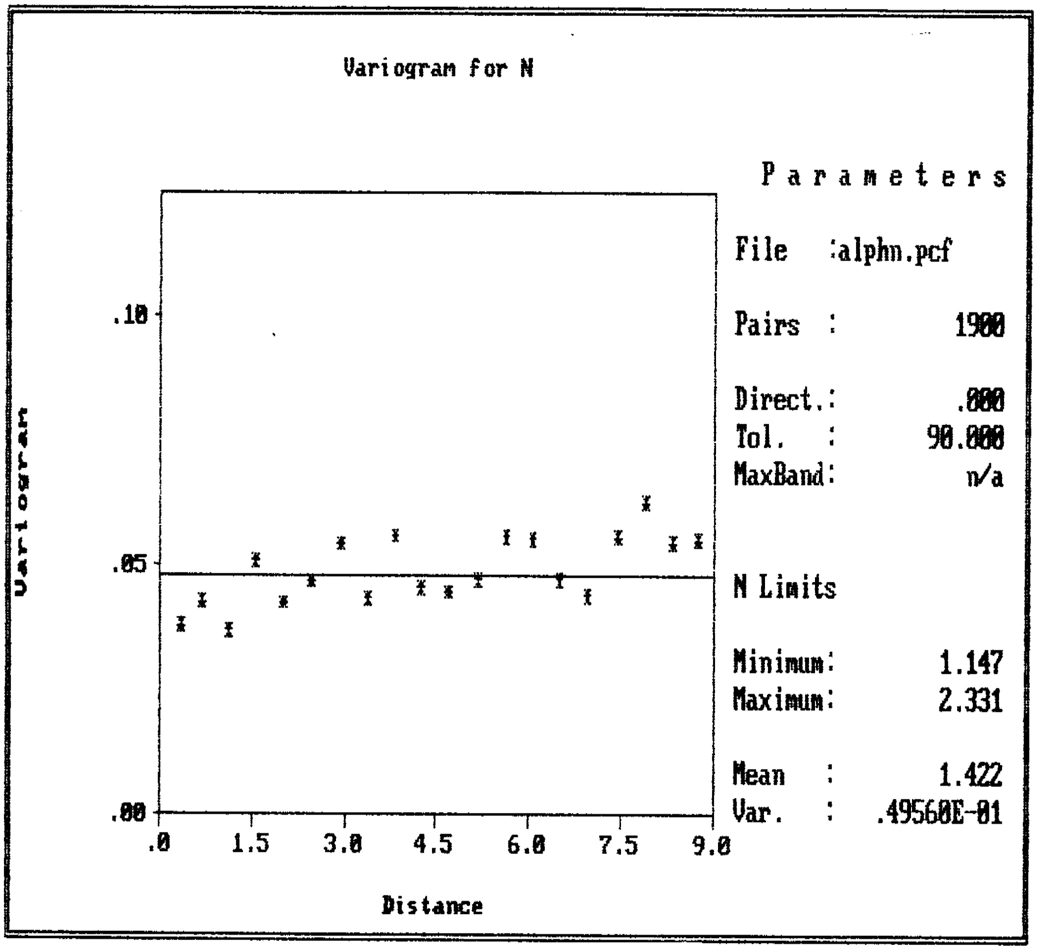


Figure 28. Variogram of N values yields essentially a pure nugget effect. The N data are not spacially dependent at the sample spacing.

deficient volumes estimated for bulk density determinations.

5.4.2 Initial Moisture Content

Grab samples were collected before disc permeameter measurements for initial moisture content determination as stated in the disc permeameter instruction section. They are graphed with distance in Figure 29. The Kolmogorov-Smirnoff test at the 0.05 level of significance suggest they are normally distributed (Appendix C). The mean initial moisture content is 10.1%, with a variance of 0.2% (table 4).

5.4.3 Sorptivity Determinations

Disc permeameter measurements were conducted at 119 locations along the transect at various supply pressures. Sorptivity and steady state flowrate were determined for each measurement. Sorptivity is plotted along the transect in Figure 30. Eighty-one of 119 measurements were conducted at 1.3 cm tension, 20 were at positive pressures and the remainder were at tensions varying from 2.0 to 6.0 cm. All sorptivity values from 5 to 35 meters represent tests at 1.3 cm of tension. The effect of various supply pressures on the sorptivity values is not apparent in studying the data. The positive pressure values do not have larger sorptivities than the tension data or vice versa.

The trend of decreasing sorptivity with increasing soil

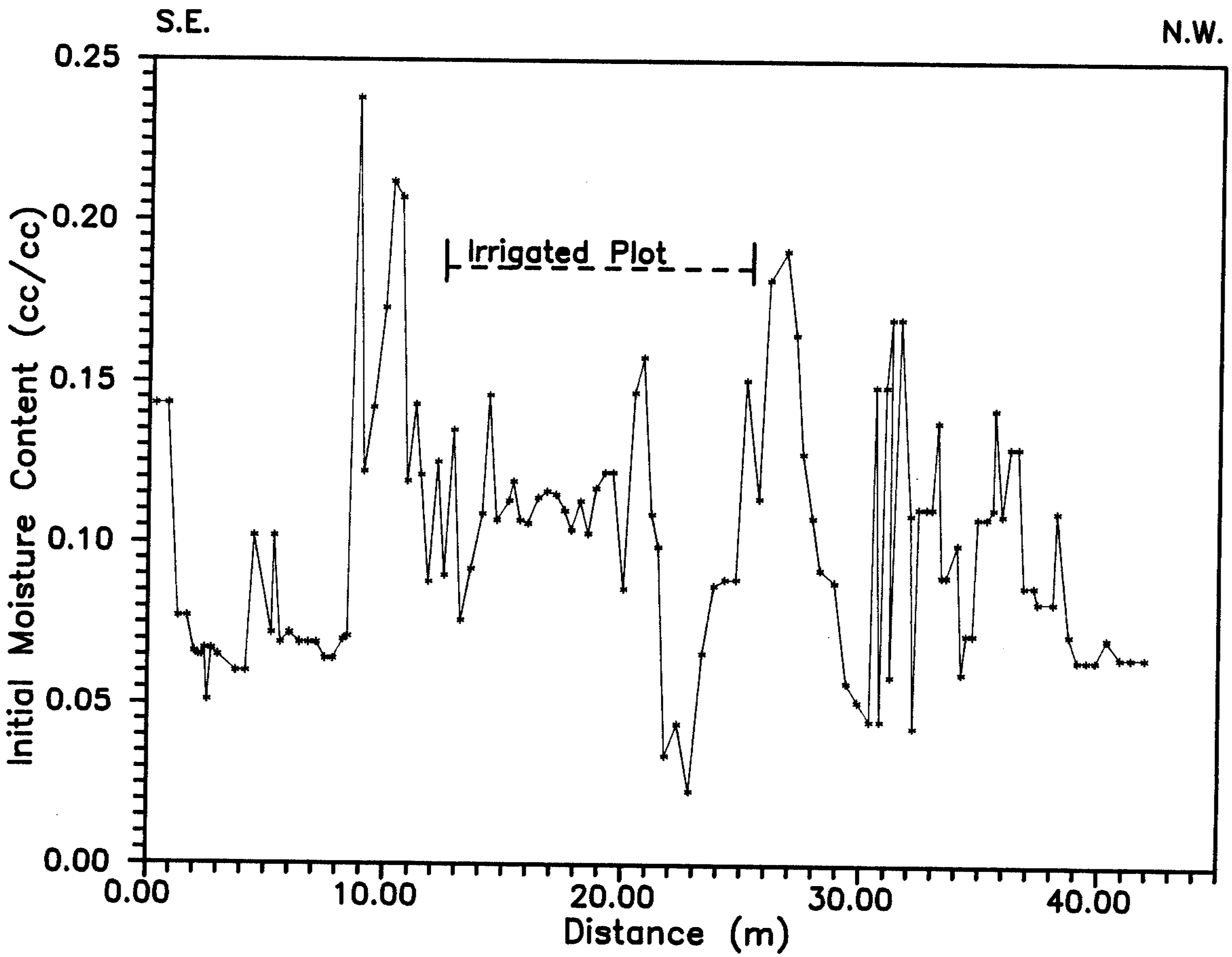


Figure 29. Initial moisture content along the transect. Note the increased

TABLE 4: FIELD MEASURED HYDROLOGIC PROPERTIES
(ALLUVIAL FAN MATERIALS)

	K1.3 log (cm/sec)	SORP log (cm/sqrt(min))	I.M.C. (cc/cc)
Mean	-3.300	-1.135	0.101
Variance	0.219	0.692	0.002
Std. Dev.	0.468	0.832	0.039
% C. V.	14.197	73.295	38.895
Skewness	1.111	-3.74	0.832
Kurtosis	5.797	3.516	3.817
Minimum	-4.223	-4.135	0.023
25th %	-3.557	-1.669	0.069
Median	-3.324	-1.152	0.100
75th%	-3.162	-0.503	0.120
Maximum	-1.523	0.675	0.238
# of samples	81	119	119

K1.3 = 1.3cm tension hydraulic conductivity
Sorp = Sorptivity (unreduced)
I.M.C. = Initial Moisture Contents

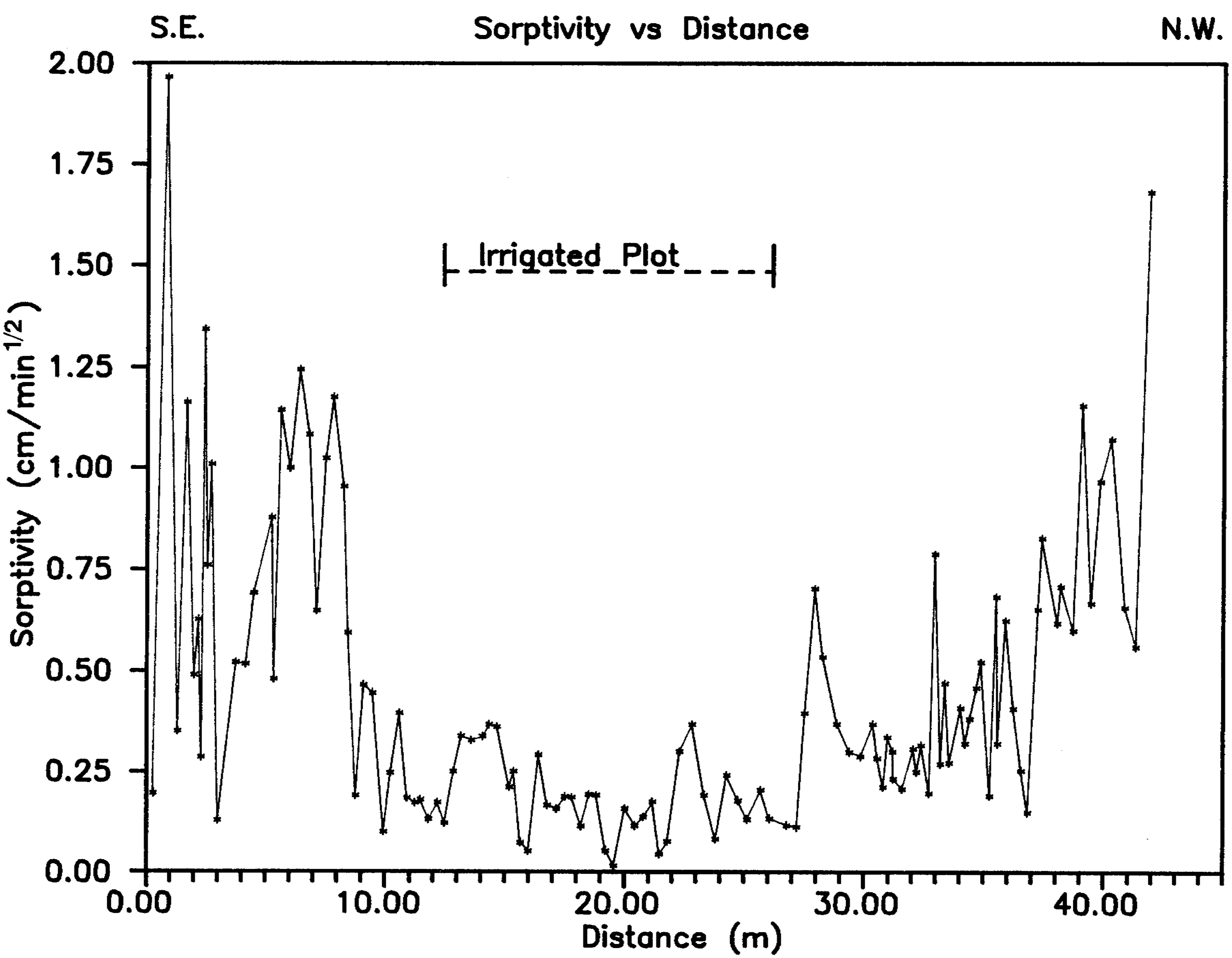


Figure 30. Calculated values of sorptivity along the transect. Note the dependence

moisture content is extremely apparent along the transect. Values of sorptivity measured beneath the irrigated plot or within the region wetted by the irrigation event are lower than comparable data outside the wetted region. This reflects the relatively high moisture content below the irrigated plot even after 6 months of drainage.

In order to better understand the sorptivity data, attempts were made to detrend the data against the change in moisture content during the disc measurement and the initial moisture content of the soil. Both attempts resulted in plots similar to Figure 31. The variability has been decreased by an order of magnitude, but the general trend persists. Obviously, the initial moisture content or change in moisture content during measurement are not the only factors affecting the sorptivity determinations. Studying log reduced sorptivity versus distance (fig.32) yields a qualitative correlation with the log 1.3 cm tension hydraulic conductivity and d10 data. In fact, sorptivity is used to calculate hydraulic conductivity (White and Sully, 1987). It should be relatable to the calculated hydraulic conductivity. The log sorptivities, reduced against change in moisture content, decrease from the southeast to the center of the plot then increase towards the northwest. As discussed in the disc permeameter discussion section, it is possible that the initial moisture content values do not represent the actual conditions of flow. In that case, field determinations of hydraulic conductivity would be

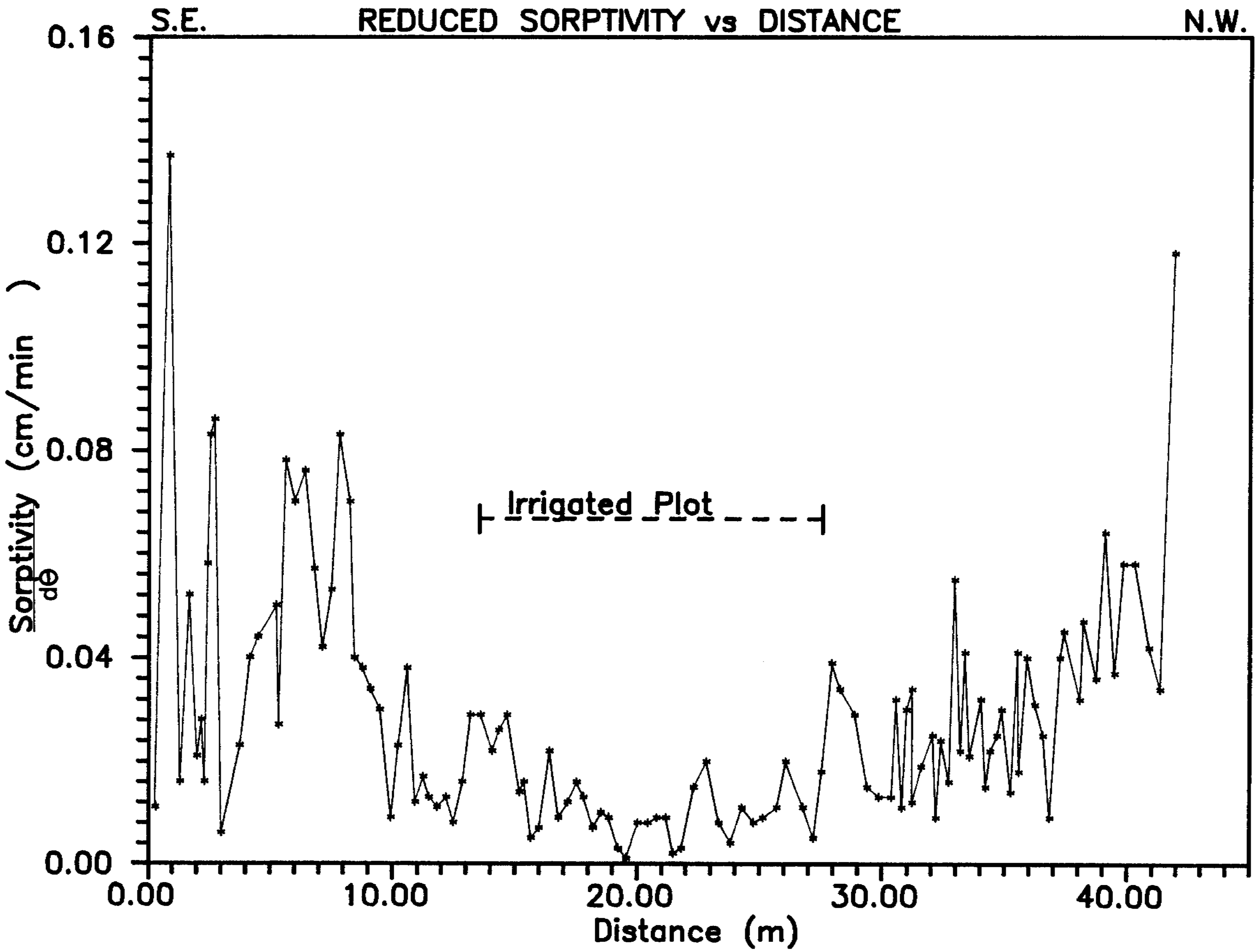


Figure 31. Sorptivity reduced against the change in moisture content during measurement. Variability is greatly decreased but the trend remains

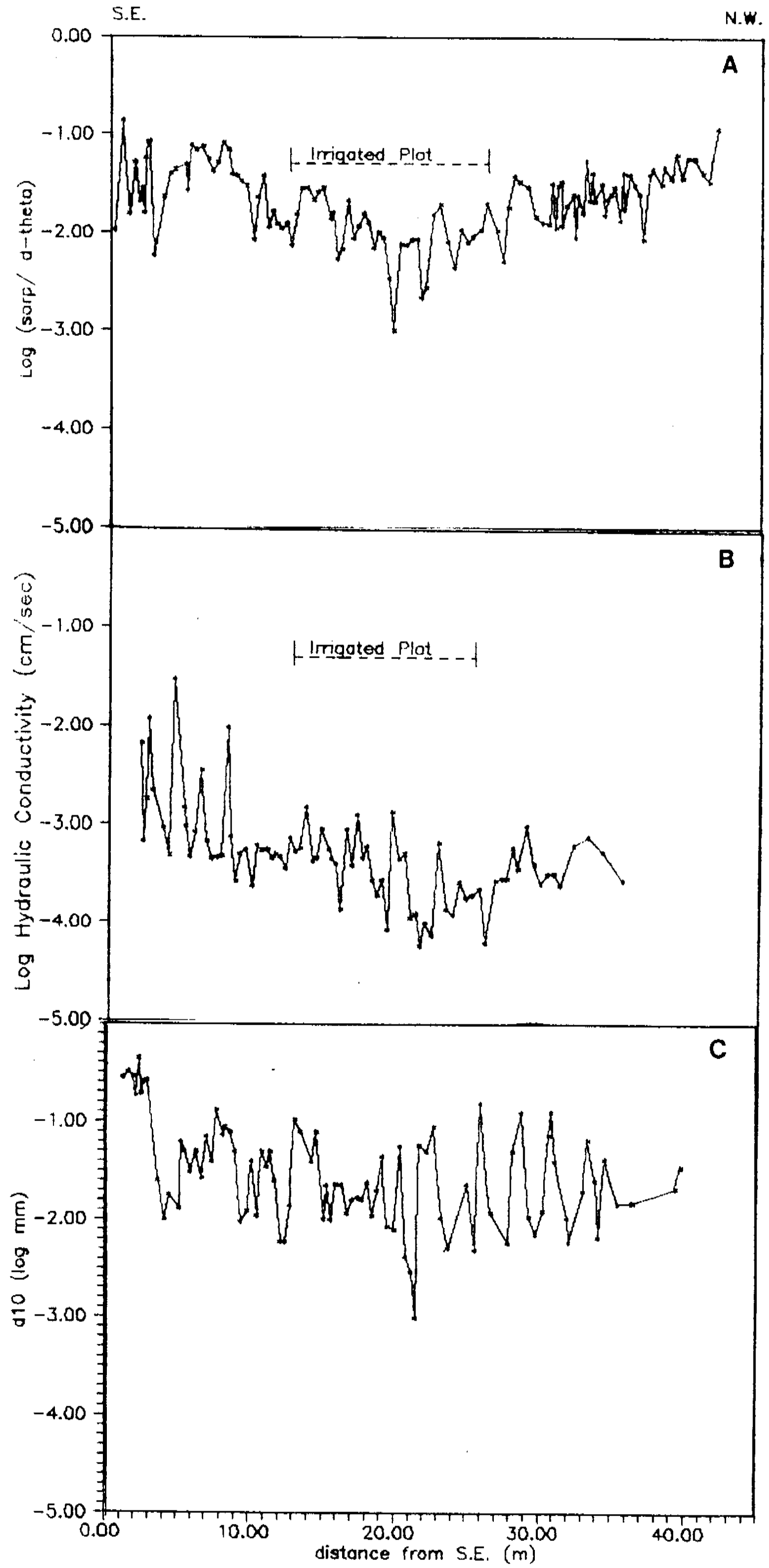


Figure 32. Qualitative comparison of (A) log reduced sorptivity with (B) log 1.3cm tension hydraulic conductivity and (C) log final moisture content sample d10 size.

affected. Comparisons of field and laboratory hydraulic conductivities are very good. Consequently, initial moisture contents are considered to be valid.

The Kolmogorov-Smirnoff test at the 0.05 level of significance resulted in the acceptance of the unreduced sorptivities data as well as the reduced data as log normally distributed (Appendix C). The reduced data set has a mean of 0.021 cm/min$^{1/2}$ and variance of 0.137. The unreduced data has a mean of 0.073 cm/min$^{1/2}$ and variance of 0.692 (Table 4). Variogram analysis of the reduced data showed that the trend has not been eliminated (fig 33). The next effort in this direction would be to detrend the data by fitting a polynomial equation to the trend and examining the remainder (e.g., Johnson, 1987). This is beyond the scope of the study.

5.4.4 1.3 cm Tension Hydraulic Conductivity

Eighty-one of the one hundred nineteen disc permeameter measurements were conducted at 1.3 centimeters of tension for statistical evaluation and comparison with the laboratory saturated hydraulic conductivity data. The 1.3 cm tension data is plotted in Figure 34 versus distance along the transect. The slight tension of the measurements was intended to limit infiltration to pores smaller than evaporation induced cracks in the trench floor while still allowing comparison with the laboratory data. Two centimeters of tension was initially chosen as it limited flow to pores less than 1.5 mm in

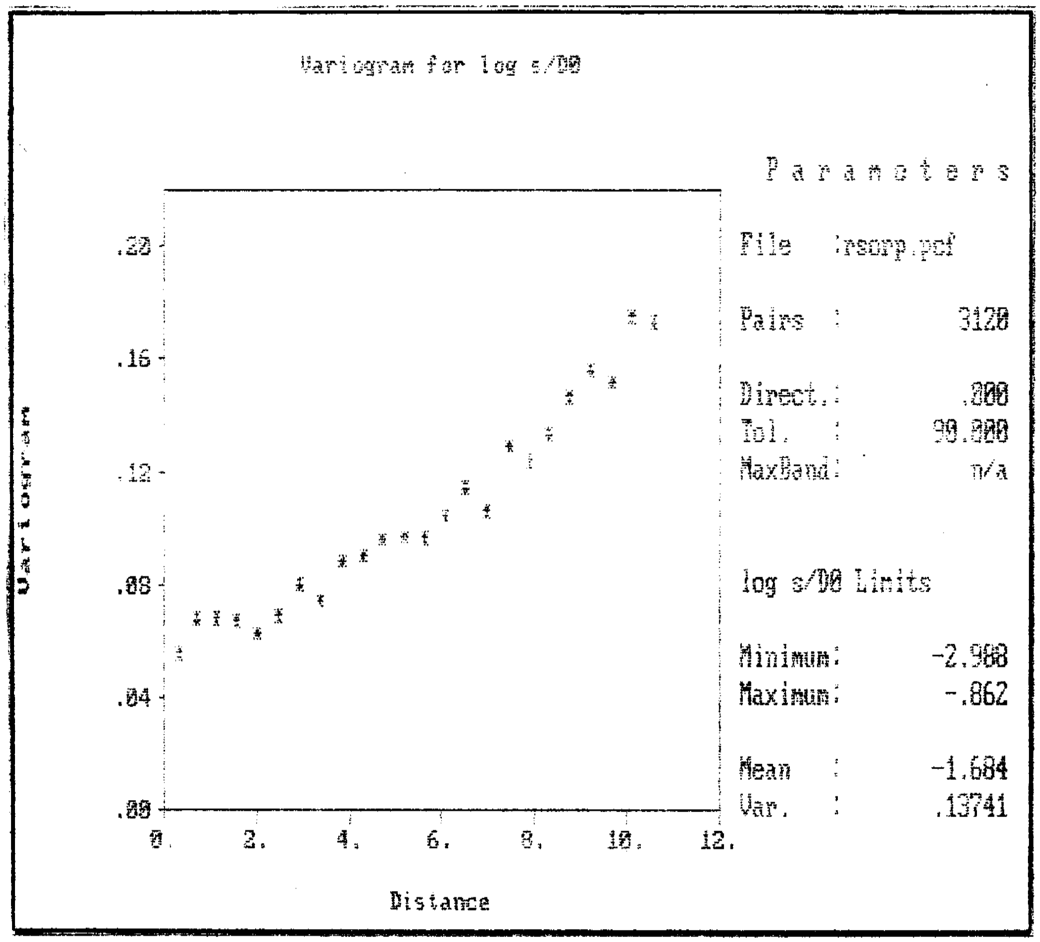


Figure 33. Variogram of the reduced sorptivity data set. The y^2 nature of the variogram shows a trend remains.

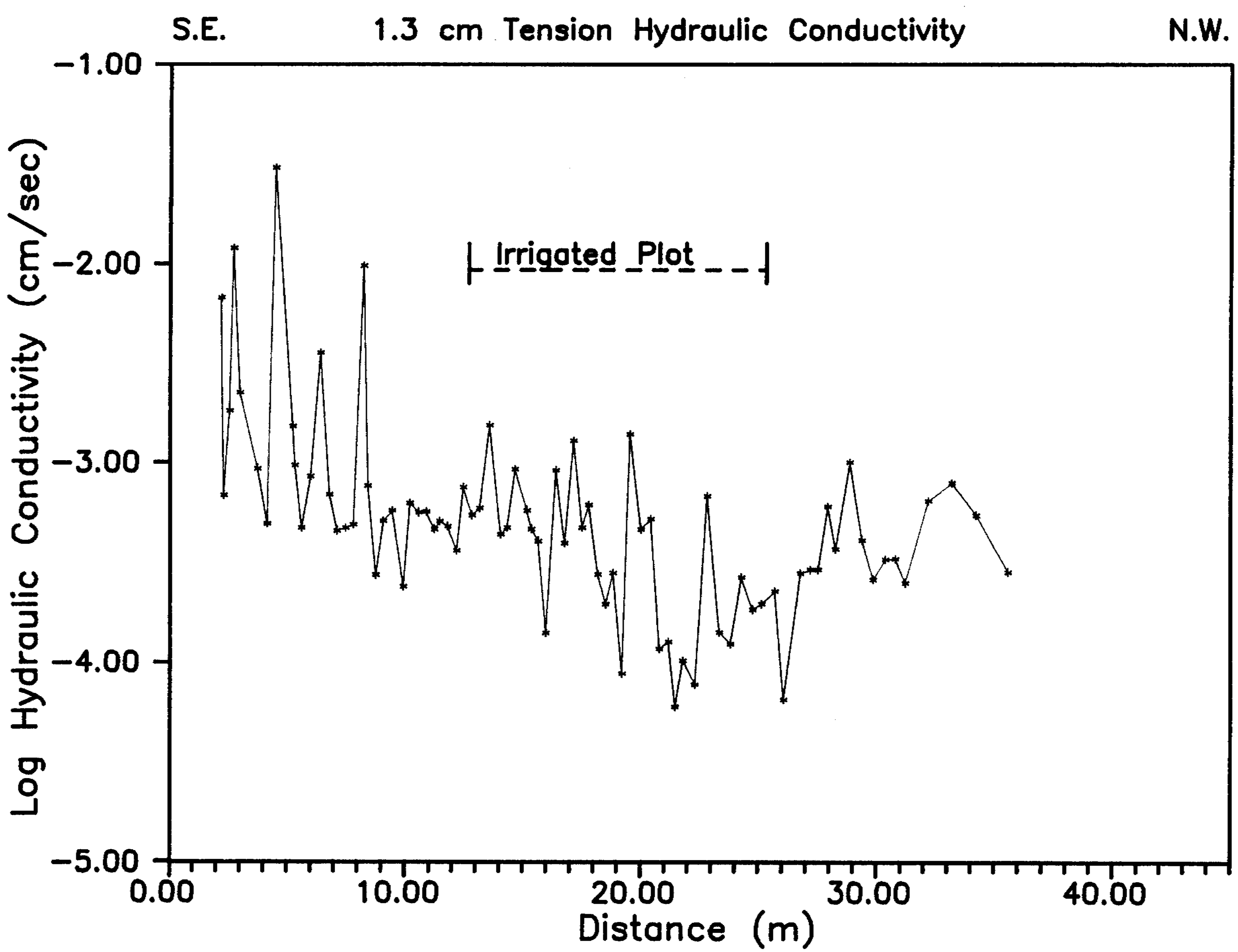


Figure 34. 1.3 cm tension hydraulic conductivity disc permeameter measurements

diameter but still allowed timely measurements. According to Watson and Luxmoore (1986), the pore radii can be calculated using:

$$r = \frac{-2\sigma\cos\alpha}{\rho g h} \approx \frac{-0.15}{h} \quad (23)$$

σ = surface tension of water $[MT^{-2}]$
α = contact angle between the water and the pore wall (assumed zero)
ρ = density of water $[ML^{-3}]$
g = acceleration due to gravity $[LT^{-2}]$
h = pressure of the disc measurement (cm H_2O)

Due to a consistent error in setting the bubbling tower water level, 81 measurements were conducted at 1.3 cm of tension. Infiltration should be limited to pore diameters less than 2.3 mm. This value is assumed to be sufficient to limit flow in most artificial cracks. Both the surface tension and the soil water density are temperature dependent, but, over the range of air temperatures experienced in the field, have little effect on the pore diameter of flow. They tend to cancel each other out.

Studying the log 1.3 cm tension hydraulic conductivity versus distance, hydraulic conductivity is seen to decrease an average of at least one order of magnitude from the southeastern corner of the transect to the 20 meter distance. It, then, increases towards the last 1.3 cm tension measurement at approximately 35 meters distance. As stated earlier, 119 total disc permeameter measurements were conducted in the shallow trench at varying pressures. They cannot be used in statistical analysis or comparisons because of the various supply pressures. A plot of the data, however, does yield a better qualitative understanding of the hydraulic conductivity distribution along the transect (fig.35). Disc measurements of hydraulic conductivity are observed to increase towards the northwestern end of the transect.

At the 0.05 level of significance, the Kolmogorov-Smirnoff test suggests the empirical distribution is consonant with the hypothesis of a log normal distribution (Appendix C). The 1.3 cm tension hydraulic conductivity data have a mean of 5.0×10^{-4} cm/sec and range between 3.88×10^{-5} cm/sec and 6.34×10^{-2} cm/sec (table 4). The 1.3 cm tension hydraulic conductivity is compared with soil core hydraulic conductivity in the analysis of results section. Variogram analysis suggests a range of spatial dependence of less than 2 meters with little or no nugget effect in a very variable data set (fig.36). The 2 meter range states measurements separated by a larger distance are uncorrelated (Geostatistics, 1990). maximize evaporation. Yet, until recently, many impoundments

5.4.5 Characteristic Mean Pore Size

The calculated data for characteristic mean pore size versus distance are graphed in Figure 37. They show little resemblance to the laboratory determined d_{10} sizes. This goes directly against common theory. According to White and Perroux (1987), the capillary length should be small for coarse textured soils and large for fine textured soils. Therefore,

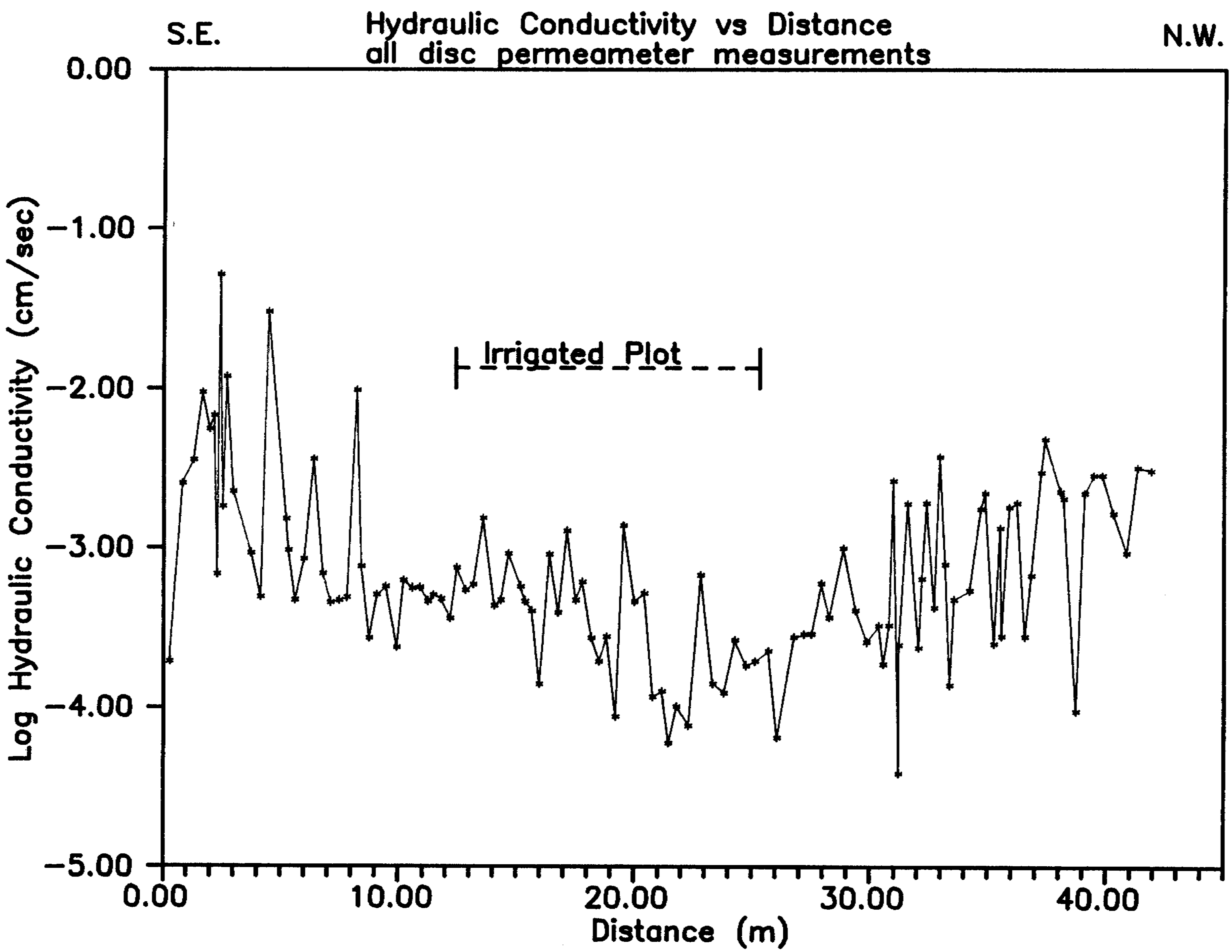


Figure 35. All the disc permeameter measurements at varying supply pressure are plotted. The general trend of increasing hydraulic conductivity from

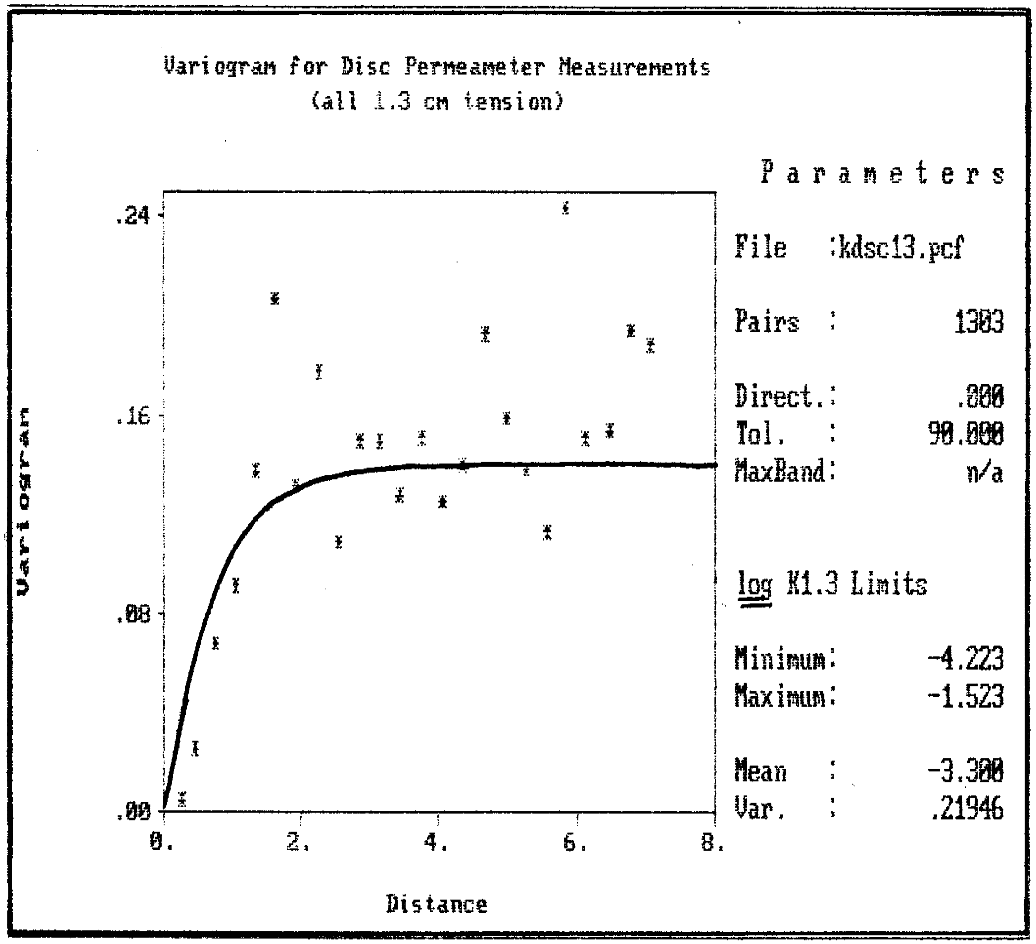


Figure 36. Variogram of 1.3cm tension hydraulic conductivity. guassian model at lag spacing of 0.3 meter,sill of 0.1 and range of approximately 2.2 meter are estimated.

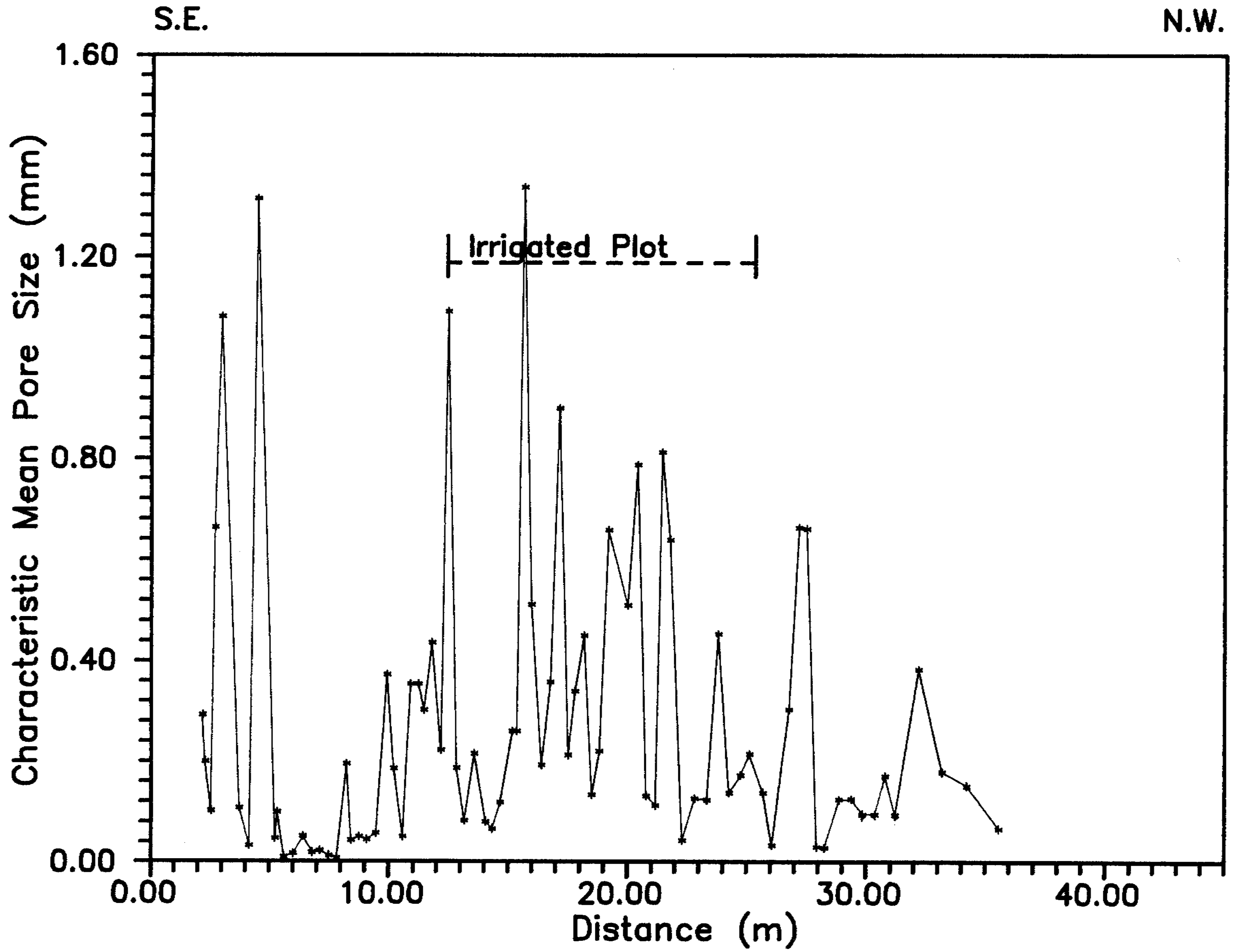


Figure 37. Characteristic mean pore size of flow from the disc permeameter with distance along the transect. The data appears to be invalid through

the characteristic mean pore size should be small for the fine textured materials and large for coarse materials. The characteristic mean pore size does not does not exhibit such a relationship along the transect.

The region of smallest d_{10} size (near 20 m), for example, has relatively large calculated mean pore sizes. Regions with relatively large d_{10} grain sizes, such as from 5 to 10 meters from the southeastern end of the transect, have the smallest calculated pore sizes. As discussed earlier, temperature does not seriously affect the pore size determination. Another parameter must result in the invalid values calculated.

Sorptivity is a prime suspect in producing the invalid characteristic mean pore size values. Because of its dependence on soil moisture content, sorptivities determined through the wetted region of the plot were lower than for comparable soils outside the region. Infiltration in wet soils may approach steady state so quickly as to interfere with the sorptivity determination. The low values of sorptivity, therefore, reflect the initial moisture characteristics of the soil more than the mean pore size of flow. Hydraulic conductivities do not seem to be affected, perhaps because associated steady state flowrates were low.

Other possible explanations of the characteristic mean pore size discrepancies include that the sorptivity equation used is only an approximation; that the laboratory d_{10} sizes may not adequately represent the soil texture; and that the soil sampled does not reflect the soil volume measured by the disc permeameter. The last explanation includes the possibility hydraulic conductivity was measured in the capping material which was placed beneath the disc permeameter and above the soil. But, cap materials were always thin and used sparingly through the irrigated region of the transect. They should not affect flow. The irrigated region of the site and its associated wetted zone extended from approximately 12 to 27 meters along the transect. Due to the given reasons, values of characteristic mean pore size along this section are considered invalid.

6.0 ANALYSIS OF RESULTS

6.1 LABORATORY SATURATED HYDRAULIC CONDUCTIVITY

The laboratory log saturated hydraulic conductivity (LK_S) data is smoothed using a 5-point moving average of the form:

$$V(n) = \sum_{j=o}^{j} \frac{w(n-j)}{5} \tag{24}$$

where n is measurement number being averaged and j is an index (Geostatistics, 1990).For example, in a data set of 10 observations data points 0 to 4 are averaged and assigned an average position. Then, data points 1 to 5 are averaged and assigned an average position. This continues until the last data point is included in the moving average. The purpose of a moving average is to decrease small scale variation (smooth the data) and thereby elucidate structures masked by the small scale variation. A major problem is that correlation is induced by the averaging procedure itself. Therefore, variogram analysis is used to present a quantitative assessment of the natural correlation. An moving average of distance less than the range should not induce artificial correlation greater than the range.

Variogram analysis of the unaveraged lab saturated hydraulic conductivities resulted in a range of approximately 3.5 to 4.0 meters. Little physical significance is assigned to this range as it is likely an average of the different scales of correlation seen along the transect. It is used as the absolute maximum value for the averaging procedure. Moving averages were conducted for various distances up to 2 meters. A 1.5 meter distance (5-point moving average) was chosen as it best exhibits the moderate scale variation in hydraulic conductivity along the transect. It is also less than one-half the calculated range and, therefore, should not add correlation beyond 1/2 the range.

The 5-point moving average of log saturated hydraulic conductivity with distance shows astounding similarity to the moderate scale geology mapped by Arnet (1991) according to the classification of W.B. Bull (fig.38). Boundaries of different mean saturated hydraulic conductivity regions are distinct. The boundaries are quite similar to the qualitative breakdown presented in the unaveraged lab log K_s analysis. Variogram analysis of the averaged data yields a range of 7 to 8 meters which fits well with the moderate scale geology of the shallow trench (fig.39).

The dashed region of the variogram in Figure 39 exhibits a possible hole effect and/or a nested structure. The hole effect suggests similar hydrologic units are separated by 9 to 12 meters along the transect (Geostatistics, 1990). Figure 40, the moving averaged hydraulic conductivity, displays such an effect. Zones of similar hydraulic conductivity at 5 to 19 meters and 28 to 40 meters along the transect, respectively,

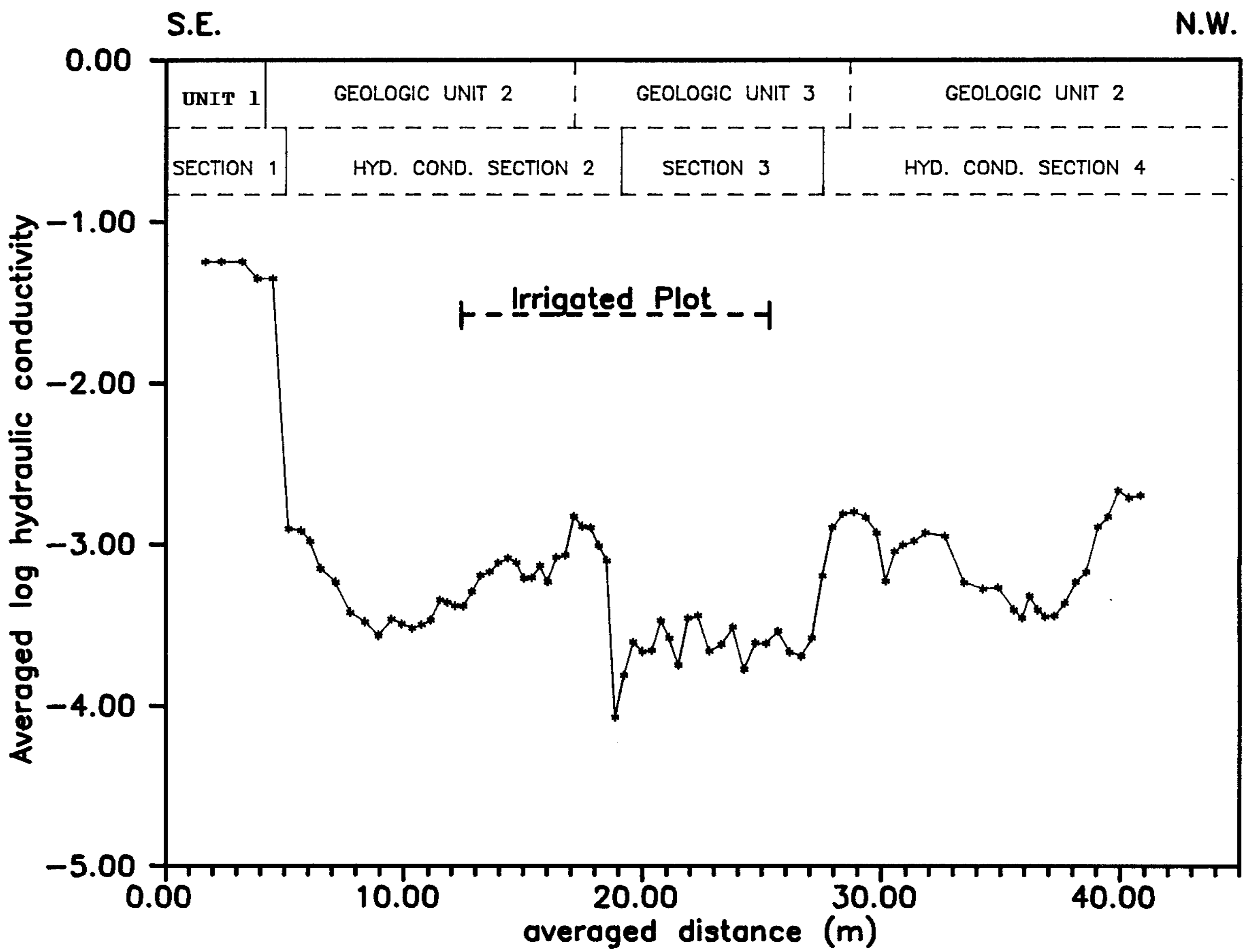


Figure 38. Interpreted boundaries in hydraulic conductivity and geology over the 5-point moving average of laboratory saturated hydraulic

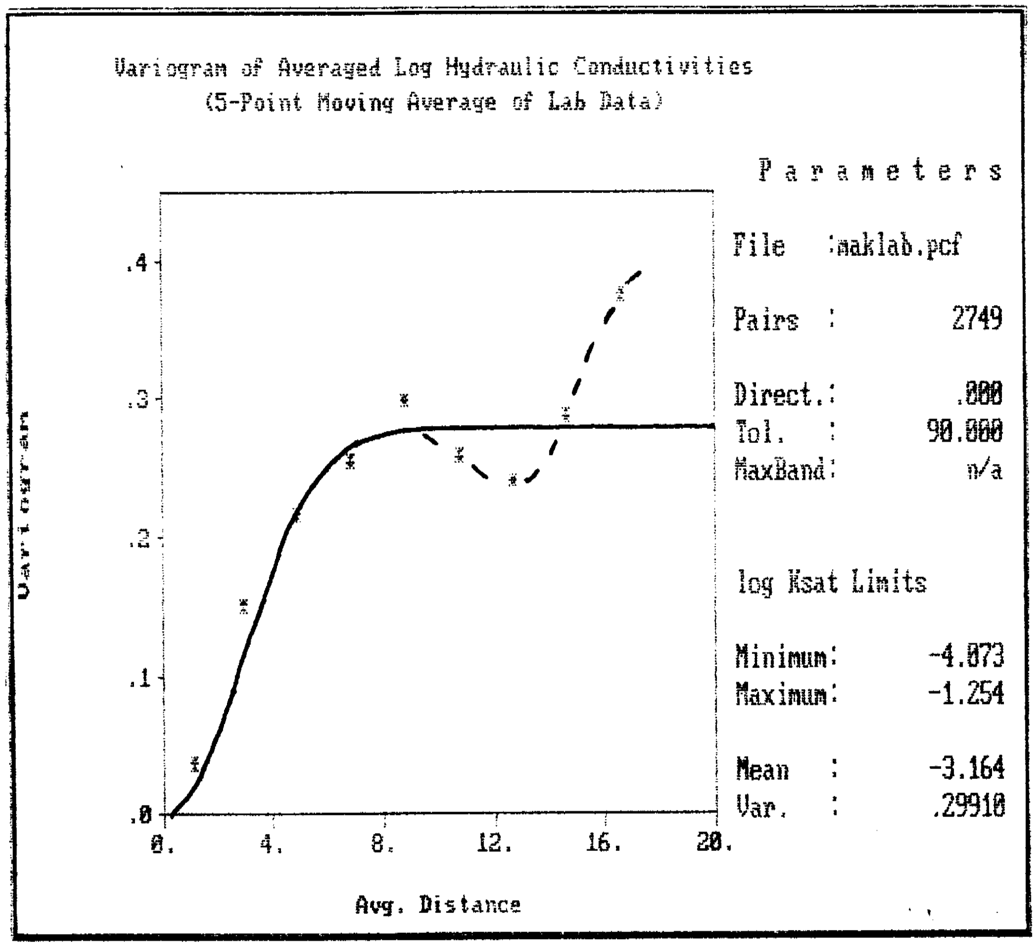


Figure 39. Variogram of the 5-point moving average of laboratory saturated hydraulic conductivity. A guassian fit with sill of 0.28 and range between 7 and 8 meters is estimated. Note the hole effect and possible nested structure with a range near 20 meter.

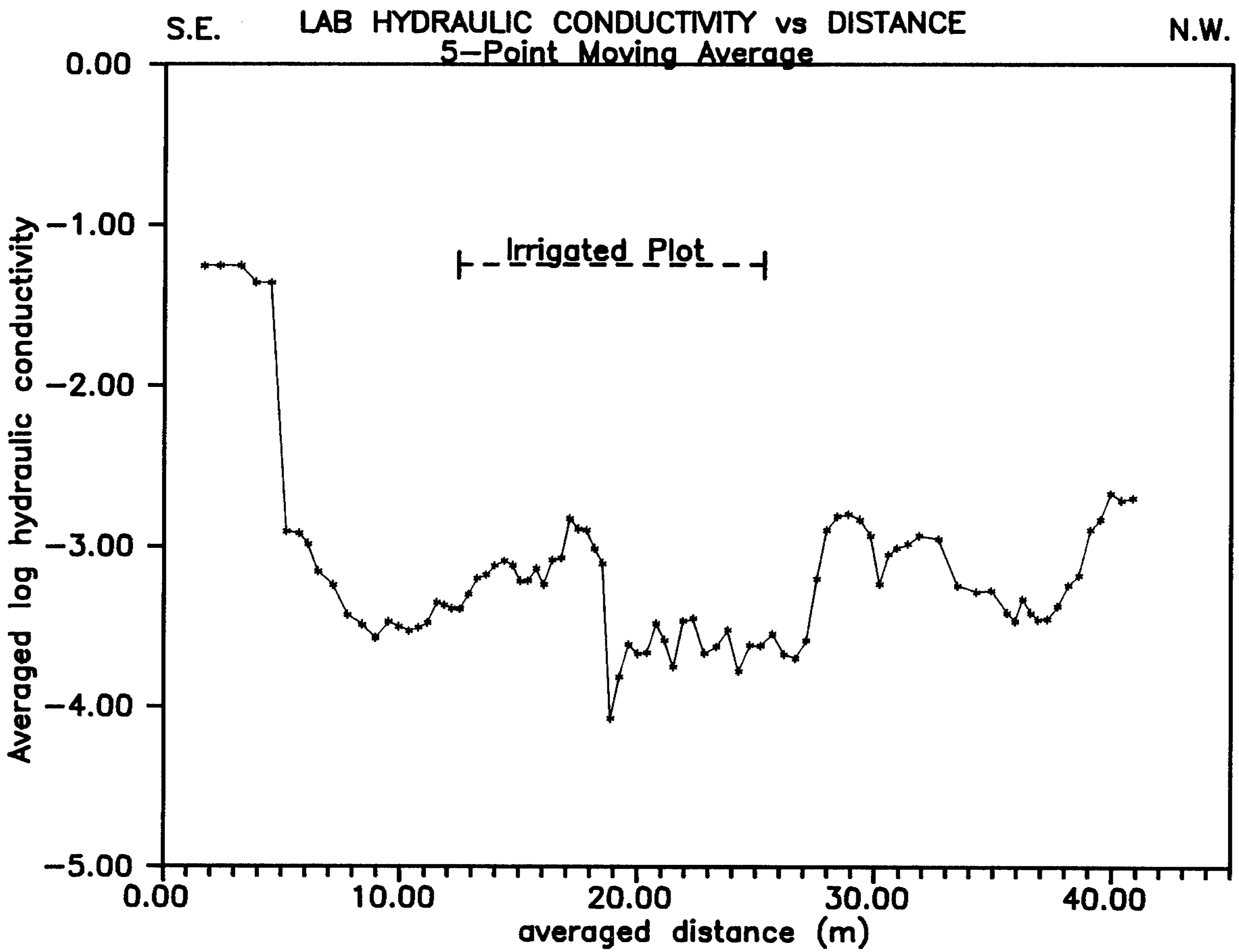


Figure 40. 5-point moving average hydraulic conductivities along the transect.

are separated by a zone of lower hydraulic conductivity for approximately 9 to 10 meters. The nested structure suggests a range of hydrologic correlation of 7 to 8 meters as well as greater than 20 meters.

The strong similarity of the averaged lab log K_s to the geology leads to the designation of four sections along the transect defined by hydrologic and geologic properties (fig.40). Unaveraged data within the boundaries of a section can be analyzed to determine statistical parameters such as the mean, variance and range of correlation. Section 1, extending from 0 to 5 meters, has an average saturated hydraulic conductivity of approximately 5.0×10^{-2} cm/sec. It could not be analyzed with the variogram code because of a lack of data along the section. The data are highly variable with K_s ranging from 2.7×10^{-2} cm/sec in coarse gravels to 2.60×10^{-4} cm/sec in silty-sands (Table 5). Section 1 corresponds to unit 1 of Arnet (1991).

Section two extends from 5 meters along the transect to approximately 18.5 meters (fig.40). It is a moderate hydraulic conductivity section, log normally distributed according to the K-S test at the 0.05 level of significance. The calculated mean is 4.0×10^{-4} cm/sec and ranges between 2.2×10^{-5} cm/sec and 3.65×10^{-3} cm/sec (Table 5). The sediments are classified as intermediate between water-laid and mudflow, corresponding with unit 2 of Arnet (1991). Variogram analysis of the 35 unaveraged K_s in this section yielded a range of between 2.0

TABLE 5: TRANSECT SECTION HYDROLOGIC PROPERTIES
(LAB SATURATED HYDRAULIC CONDUCTIVITY)
(log cm/sec)

	SECTION 1 (0 to 5m)	SECTION 2 (5 to 18m)	SECTION 3 (18 to 27m)	SECTION 4 (27 to 41m)
MEAN	-2.793	-3.397	-4.064	-3.214
VARIANCE	0.724	0.297	0.629	0.191
STD. DEV.	0.851	0.545	0.793	0.436
% C.V.	30.47	16.051	19.521	13.582
SKEWNESS		-0.812	-1.114	0.085
KURTOSIS		2.972	4.39	2.507
MINIMUM		-4.658	-6.373	-4.079
25th %		-3.692	-4.608	-3.506
MEDIAN		-3.300	-3.833	-3.268
75th%		-3.022	-3.407	-2.962
MAXIMUM		-2.438	-3.076	-2.420
# SAMPLES	8	35	21	31

and 2.5 meters, no nugget, and a variable sill (fig.41a). Non-ergodic variogram analysis resulted in a similar range.

Section three contains the lowest saturated hydraulic conductivities along the transect. It is interpreted as the top of geologic unit 3, a mudflow unit. It extends from about 18.5 meters to 27 meters along the transect and contains 21 K_s measurements (fig.40). The K-S test suggests a log normal distribution at the 0.05 level of significance with mean of 8.63×10^{-5} cm/sec (Appendix C). The mean value is lower than the calculated hydraulic conductivity of the second infiltration experiment. Analyzing the distribution of the data shows most of the values to cluster about 1.0×10^{-4} cm/sec with a minimum hydraulic conductivity of 4.24×10^{-7} cm/sec and maximum of 8.40×10^{-4} cm/sec (Table 5).

Inasmuch as the mean flux from the second irrigation was 1.0×10^{-4} cm/sec, it is quite likely that saturation was achieved along this section during the second infiltration event. Variogram analysis of the section is questionable due to the relatively small number of measurements along this section. However, a range of between 2 and 3 meters with no nugget, similar to that of section 2, is suggested (fig. 41b). Non-ergodic variograms showed similar behavior.

From 27 meters to the end of the transect, a sedimentary unit quite similar to that of section 2 is present. Arnet (1991) mapped it as an intermediate unit designated as unit 2.

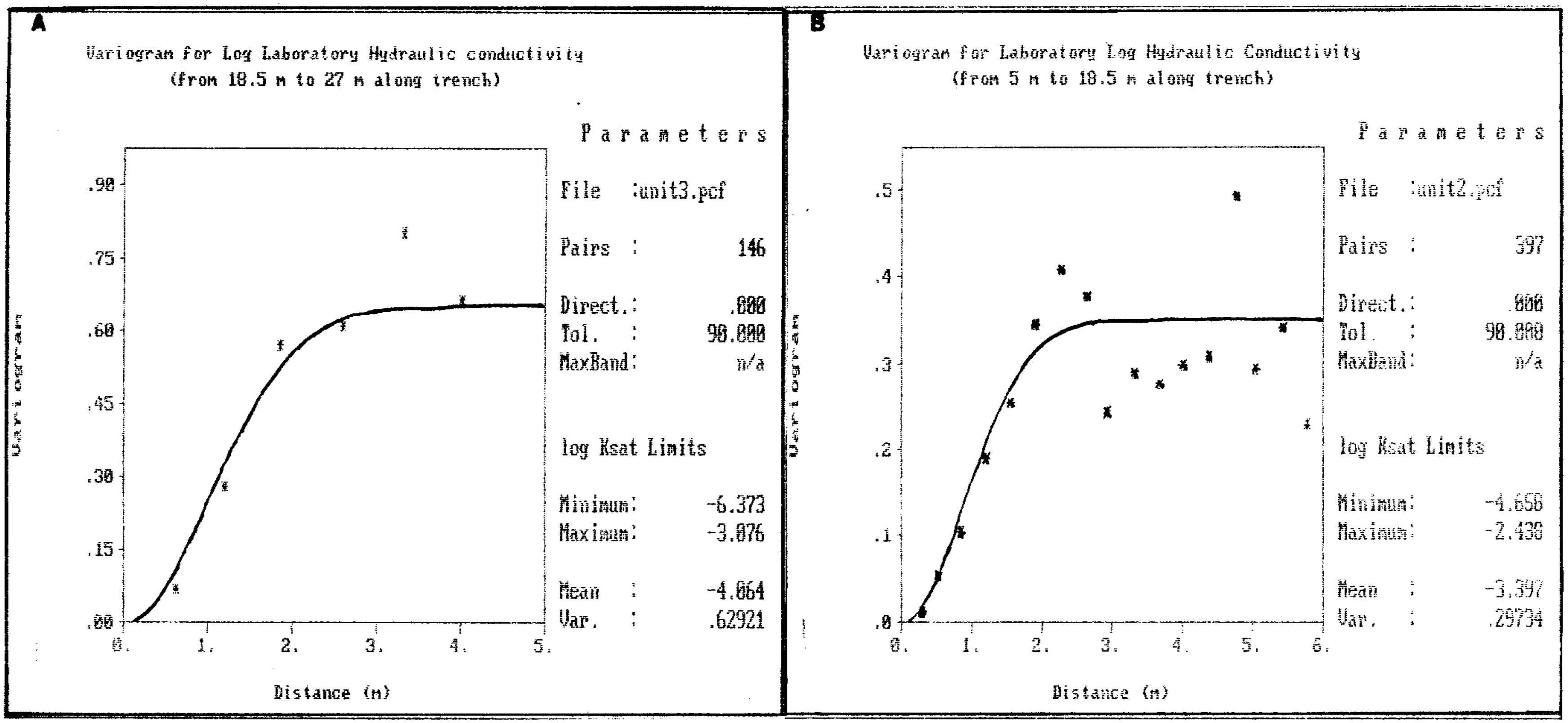


Figure 41. Variogram for saturated hydraulic conductivity of the designated transect sections. (A) Section 2: Guassian model at lag of 0.35 meter, sill of 0.34 and range between 2 and 2.2 meter. (B) Section 3: Guassian model at lag of 0.75 meter, sill of 0.63 and range of approximately 2.5 meter.

The K-S test suggests the hypothesis of a log normal distribution is acceptable at the 0.05 level of significance (Appendix C). The F-test states the variances are equivalent at the 0.05 level of significance. According to the T-test results, there is no evidence to suggest that the two sample sets come from populations having different mean's. The 31 measurements conducted along this section range in K_s from 8.34×10^{-5} cm/sec to 3.80×10^{-3} cm/sec with a mean of 6.11×10^{-4} cm/sec (table 5). Variograms show a range of between 1.5 and 2.0 meters with no nugget (fig.42). Non-ergodic variogram analysis exhibits a similar range. Therefore, section 4 is classified hydrologically as well as geologically to be an extension of unit 2 of Arnet (1991). Section three has a mean hydraulic conductivity over 50% lower than the other two sections. Figure 43 shows a plot of the three section's hydraulic conductivity distributions.

The foregoing discussion makes it clear that the transect properties can be described at a number of scales depending upon the level of interest. The geology has been described at three scales (Parsons,1988; Arnet,1991) These scales of mapping range from the fine scale of the shallow trench; through the more moderate scale of the deep trench and borehole interpretated geology of Parsons; to the large scale of the piedmont slope facies and ancestral Rio Grande facies (Table 6). Table 6 relates the geologic mapping scales to correlation ranges determined by variogram analysis. Four

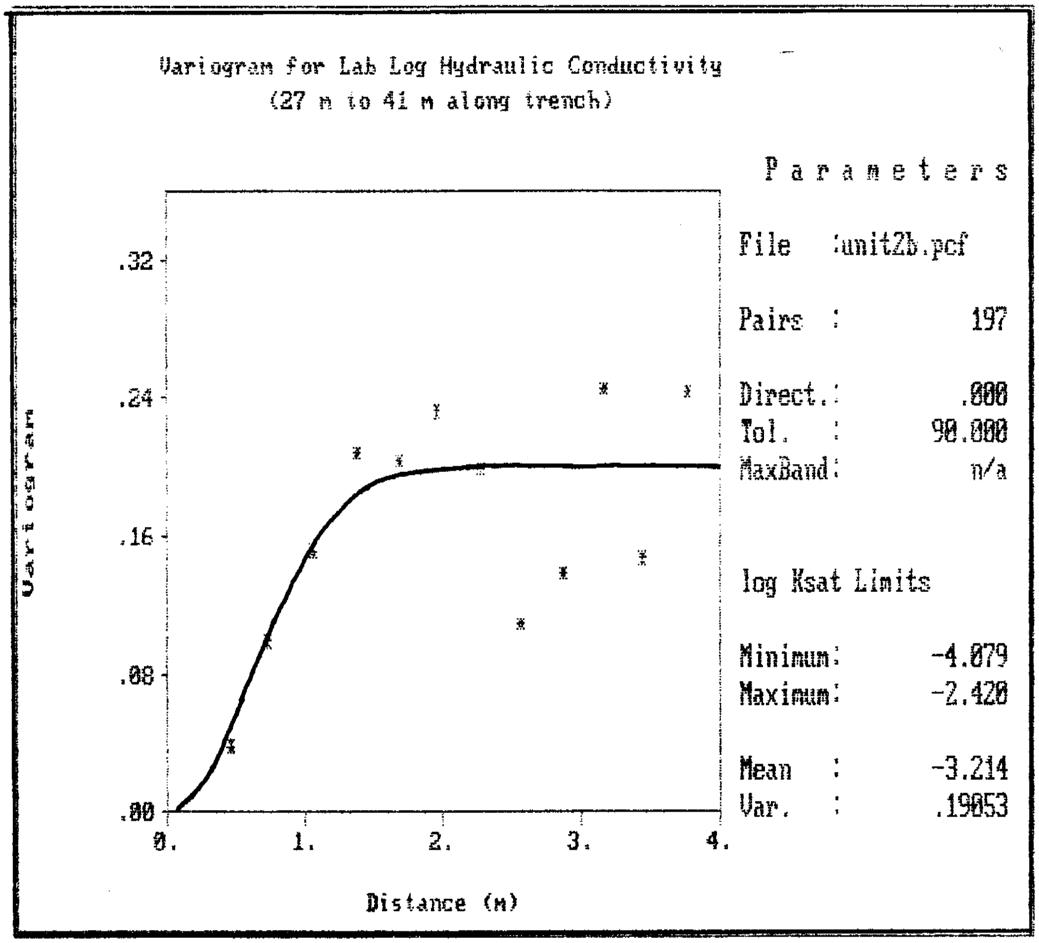


Figure 42. Transect section 4 variogram. A guassian model was fit to the data. The estimated range is approximately 1.5 meter, sill 0.20 at a lag of 0.30 meter.

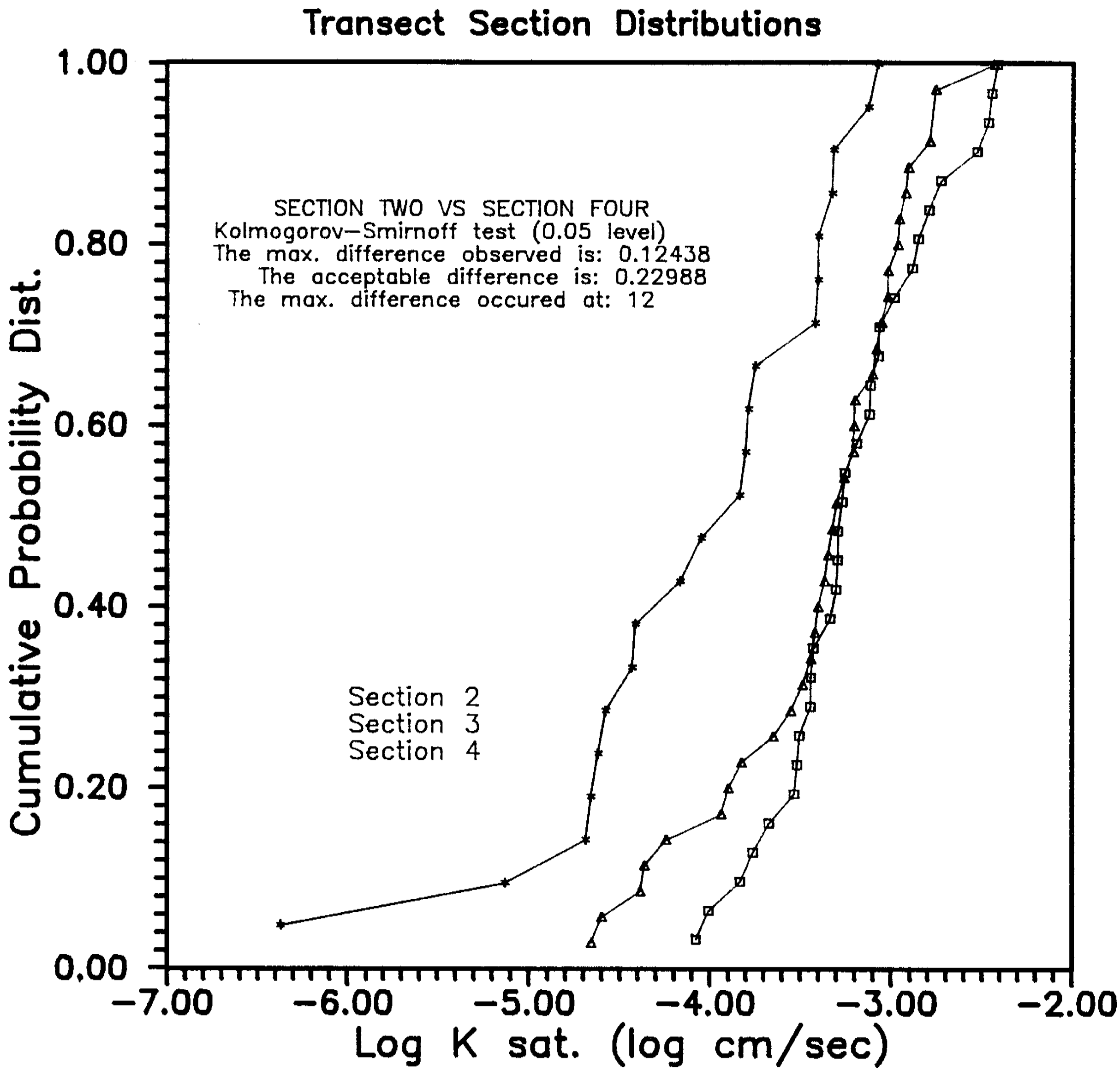


Figure 43. Distributions of log saturated hydraulic conductivity from soil cores for sections 2,3 and 4. It is apparent that sections 2 and 4 have similar distributions.

TABLE 6: Estimated Scales of Measurement for the experimental site

	GEOLOGIC MAPPING SCALES			
	fine scale (0 to 4 m)		moderate scale (4 to 10 m)	large scale (> 10 m)
	INTERPRETED SCALES FROM VARIOGRAM ANALYSIS			
	Vry Small	Small (1 to 4 m)	Moderate (4 to 10 m)	Large (> 10 m)
Lab K		X	X	X
K-1.3		X		
d10-SC		X		
d10-FM		X		
Alpha		X		
	GEOLOGIC INTERPRETATION			
	fining sequences, laminations, crossbedding	small bedding structures	larger bedding structures - contain small bedding structures	Very large beds to facies changes

COMMENTS: M values exhibited a pure nugget
Sorptivity was not entirely detrended

lab K = Laboratory saturated hydraulic conductivity
K-1.3 = Field measured 1.3 cm tension hydraulic conductivity
d10-SC = Soil core d10 particle size
d10-FM = Final moisture content grab sample d10 particle size
Alpha = Alpha values determined in van Genuchten's analysis

scales of measurement are interpreted from the geologic mapping and variogram ranges.

The first is a very small scale which was mapped but not differentiated from a slightly larger scale. It is not observed in the variogram analysis. Perhaps the methods of sampling and measurement obscure this scale. It is physically represented by such structures as fining sequences in grain size and laminations and cross-bedding (fig.38).

The second scale is best represented by the variogram range analyses. Almost all the parameters show correlation at between 1.5 and 3.0 meters separation with the majority clustered about 2.0 meters. Unfortunately, this range of correlation is not easily related to the fine scale mapping of Arnet (1991). The fine scale geologic mapping incorporates both the very small and small variogram interpreted scales.

The third scale is readily apparent in the smoothed realization of the 5-point moving average of saturated hydraulic conductivity (fig.40). It is relatable to the moderate scale interpreted geology of W.B. Bull's classification along the shallow trench. It implies that by establishing boundaries of hydraulic conductivity using W.B. Bull's geologic classification and conducting several quantitative measurements of hydraulic conductivity within the boundaries, conclusions similar to those of this labor intensive study may be drawn.

The fourth scale is hypothesized from the variogram analysis of the smoothed K_S realization (fig.39). It suggests a scale of spatial dependence of at least 20 meters. Unfortunately, no other physical or statistical data exists in this study for spatial dependence at such a scale.

6.2 FIELD AND LABORATORY HYDRAULIC CONDUCTIVITY COMPARISONS

Eighty-one of the disc permeameter measurements of hydraulic conductivity conducted at 1.3 cm of tension are regressed against comparable laboratory saturated hydraulic conductivity (fig.44). A line fit by eye is regressed through the data. This line is more appropriate than a computer generated linear regression because the fit-by-eye gives relatively more weight to outlying data than the mass of measurements in a block near the center of the plot. The mass of log K data pairs ranges from -4.0 to -3.0 on the tension axis and -2.5 to -4.5 on the saturation axis. In general, tension measurements of hydraulic conductivity are slightly higher than saturated values (soil cores) from the disc permeameter test zone. The saturated hydraulic conductivity values throughout the plot are more variable than the tension values. A number of data pairs lie outside the center block and may represented large populations. They can be related to the averaging affects of the disc permeameter as discussed in the laboratory K_S section. For example, in areas of high hydraulic conductivity, the disc permeameter, which averages

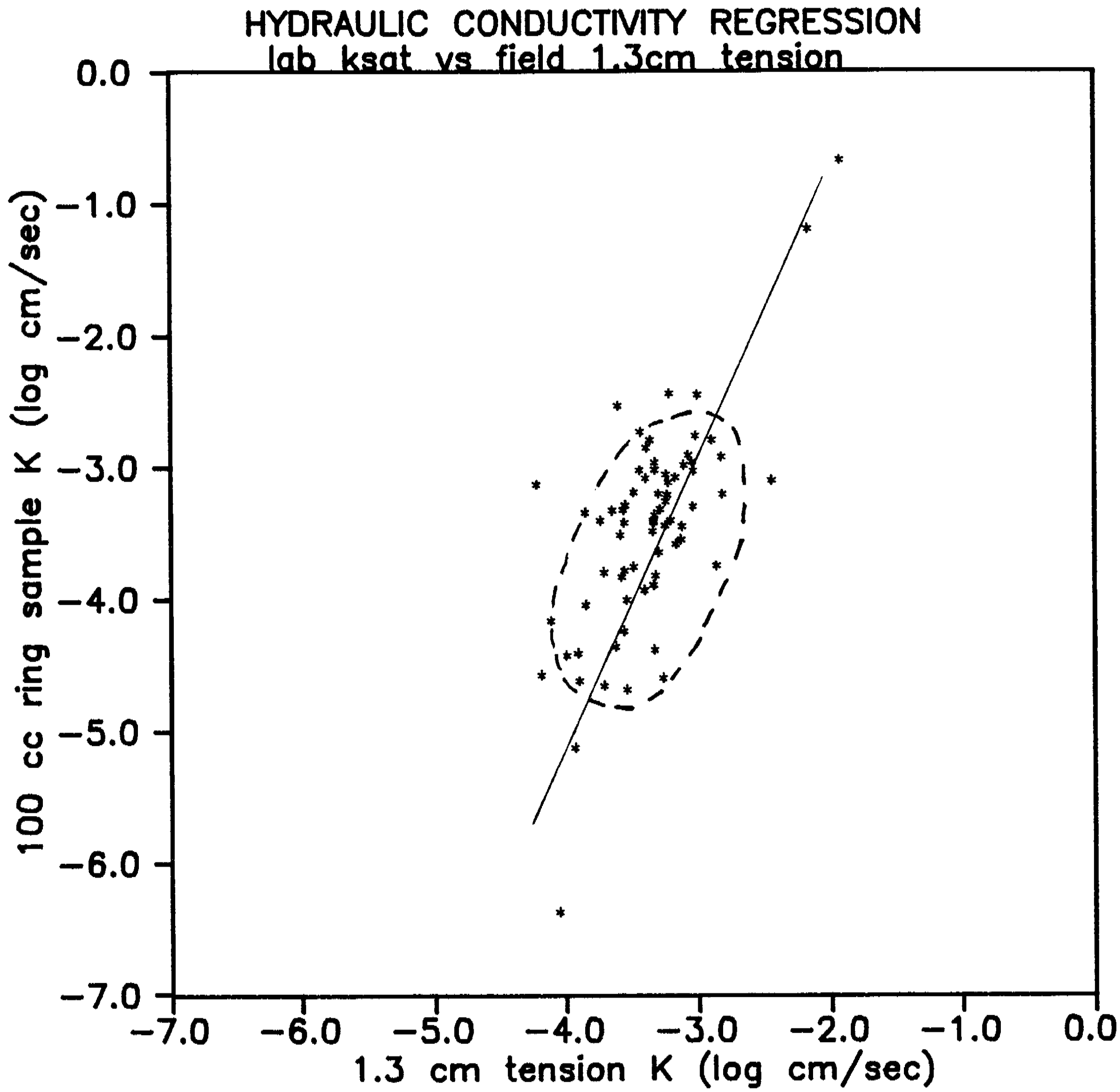


Figure 44. Scatter diagram (regression) of the log laboratory saturated hydraulic conductivity data with the 1.3 cm tension hydraulic conductivity data.

over a larger surface area to thickness ratio than the soil cores, results in a lower hydraulic conductivity. It is essentially an effective horizontal hydraulic conductivity. Also, the soil cores may contain macropores and disturbances such as sidewall channeling which leads to a higher hydraulic conductivity. In low hydraulic conductivity materials the inverse appears to occur. The disc permeameter may average over several soils of varying hydraulic conductivity, resulting in a larger effective K than the soil cores.

Evaluation of the plot of both lab and field hydraulic conductivity determinations with distance along the transect suggests that the disc permeameter at 1.3 cm tension ($K_{1.3}$) produces results which are valid for estimating hydrologic properties at the experimental site (fig.45). The means of the disc permeameter at 1.3 cm tension and soil core (K_s) data sets differ by approximately 10%, with the $K_{1.3}$ mean slightly larger than the lab K_s mean. Due to the different volumes measured by the two methods, the soil cores are about twice as variable as the tension values. In addition, the two distributions show similar trends along the transect, with hydraulic conductivity decreasing towards the center and, then, slowly increasing towards the northwest. The K-S test at the 0.05 level of significance suggests the both the $K_{1.3}$ and lab K_s distributions stem from similar log normal distributions (fig. 46). The F-test at the 0.05 level of significance concludes the variances are not equal for the

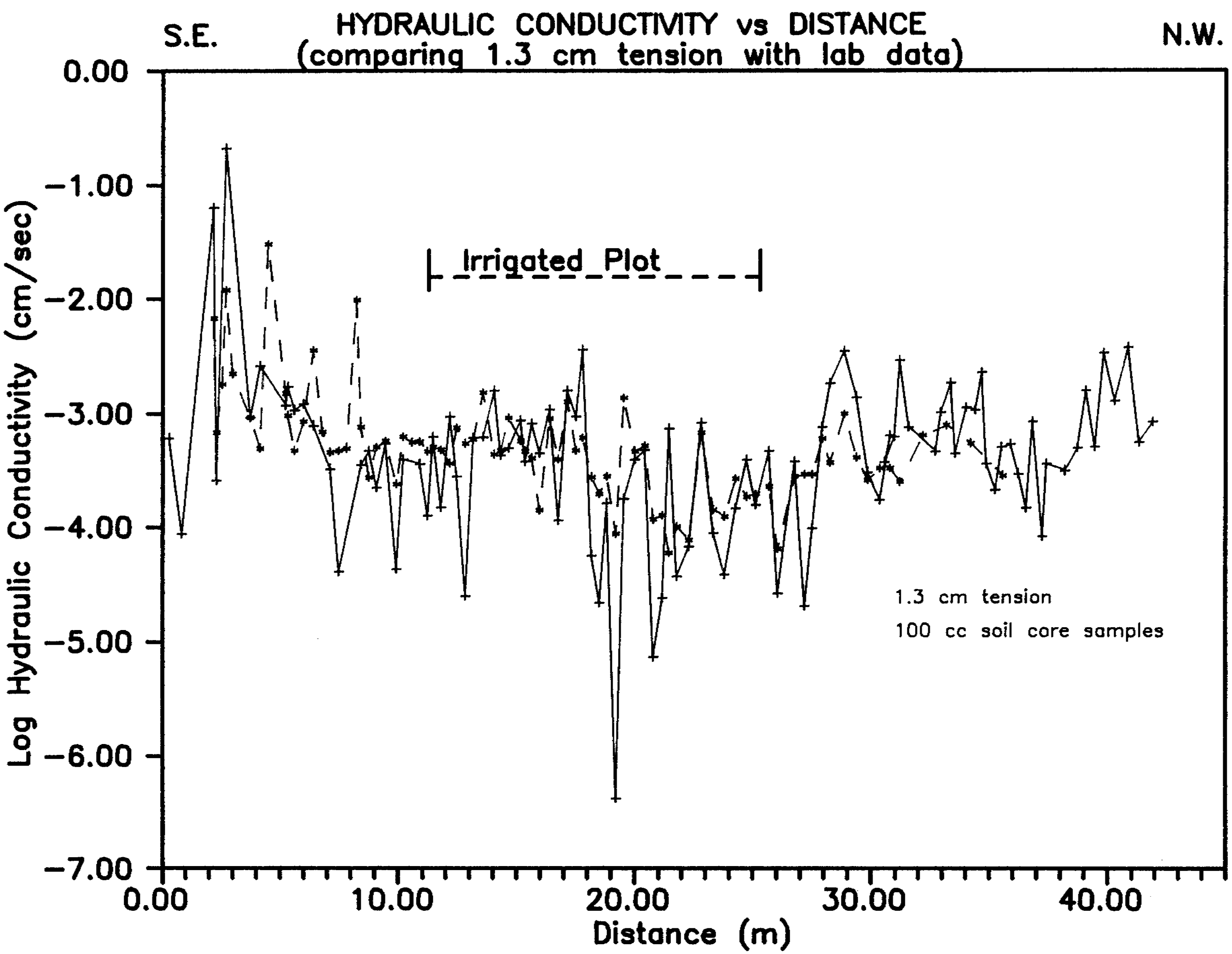


Figure 45. Laboratory saturated hydraulic conductivity and field 1.3cm tension

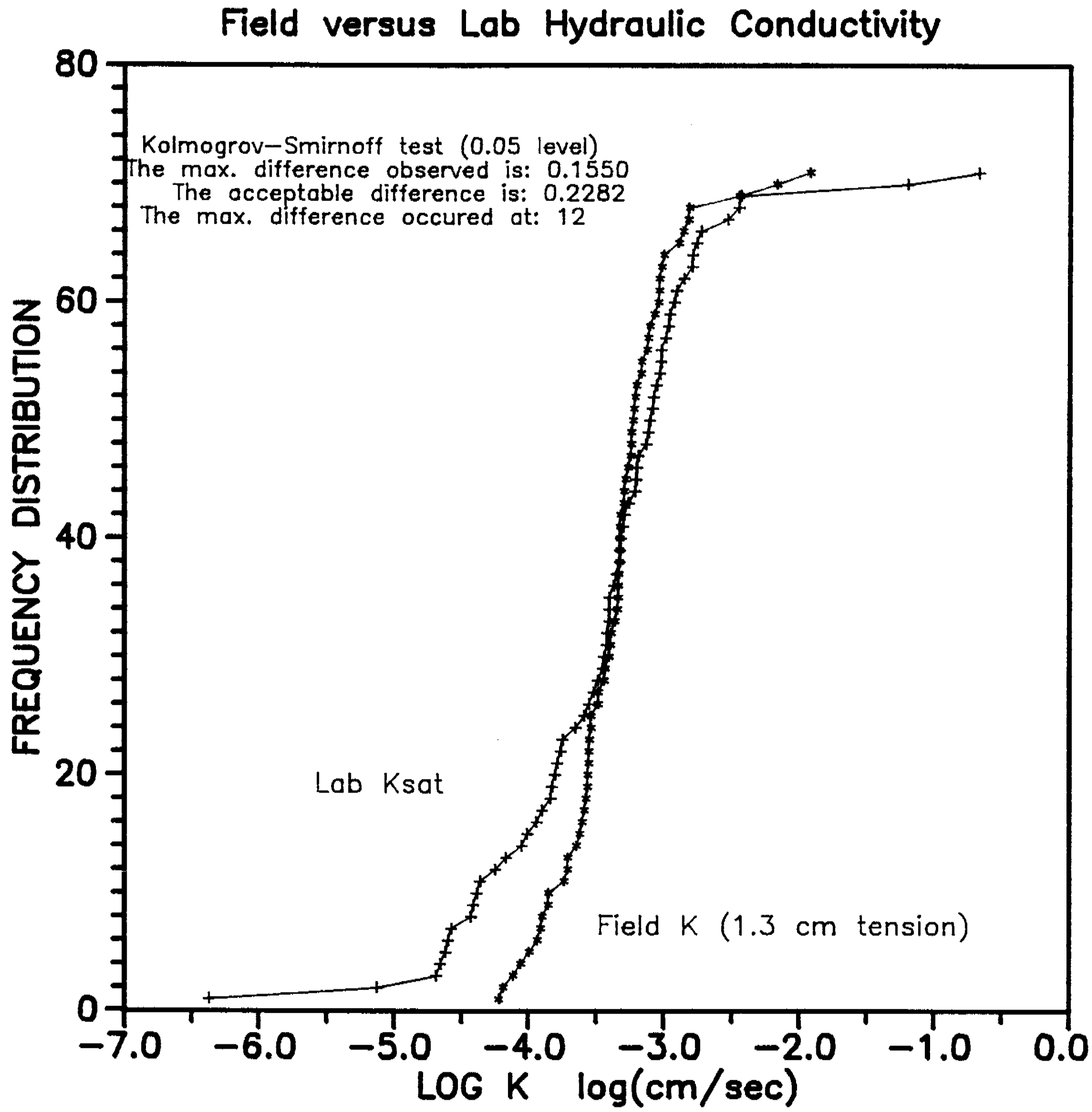


Figure 46. Log laboratory saturated hydraulic conductivity distribution compared with log 1.3 cm tension hydraulic conductivity. They are observed to be similar at the 0.05 level of significance with the Kolmogorov-Smirnoff test.

$K_{1.3}$ and K_s data sets. Therefore, the T-test cannot be used, and the less powerful large scale test of the hypothesis for the difference of two means is employed for analysis. The LSTHDTM suggests there is insufficient evidence at the 0.05 level of significance to indicate a difference between the $K_{1.3}$ and lab K_s mean's. An attempt was made to use the eye-fitted regression of Figure 44 to estimate 1.3 cm tension's from 35 to 41 meters along the transect. The scatter in the data, however, is too large to allow valid estimates of 1.3 cm tension hydraulic conductivity by this method (Gutjahr, pers. comm,1990).

6.3 DISC PERMEAMETER DISCUSSION

Laboratory values of saturated hydraulic conductivity are plotted along with field hydraulic conductivities measured at the same locations along the transect in Figure 45. The laboratory data are more variable than the field data. A comparison of the laboratory values of saturated hydraulic conductivity and field hydraulic conductivity measured 1.3 cm tension shown in Figure 44 resulted in the majority of the data pairs concentrated in an ellipsoid bounded by an order of magnitude on the tension hydraulic conductivity axis and two orders of magnitude on the saturated hydraulic conductivity axis. Outside the ellipsoid, field hydraulic conductivities are larger than the comparable laboratory saturated hydraulic conductivities for fine textured soils. In coarse textured soils, the opposite behavior is observed. Averaging caused by the disc permeameter's large surface area is a likely explanation for the differences at both ends of the scale. For example, in fine textured soils, a soil core samples a smaller horizontal area and greater soil thickness than the disc permeameter resulting in a low effective vertical hydraulic conductivity determination. The disc permeameter, on the other hand, may sample the fine textured unit as well as surrounding higher conductivity materials, resulting in a effective horizontal hydraulic conductivity that is larger than the soil core value. Low hydraulic conductivity soils are more likely to contain macropores not sampled by the soil core than higher hydraulic conductivity materials. Also, low hydraulic conductivity soils may swell in the soil core preventing sidewall channeling. This may not occur in sandy soils. Soil cores of coarse soils may have hydraulic conductivities greater than the field values. Therefore, the disc permeameter will yield values of hydraulic conductivity that are smoothed, less varied, as compared to the soil cores.

6.3.1 Measurement Limitations

A number of limitations were encountered during use of the disc permeameter. In its present form it is limited to hydraulic conductivity determinations ranging from approximately 1.0×10^{-2} cm/sec to approximately 1.0×10^{-5}

cm/sec. The accuracy of measurements is greatly reduced for coarse textured, high hydraulic conductivity materials. Bubbling, caused by air entry into the reservoir, is so great and the water level drops so quickly that the data contains significant scatter. Determinations of sorptivity are then especially difficult. Although measurements can be conducted with fair results, an automated device (Ankeny et al.,1988) would result in less scatter and, therefore, better results.

In fine textured, low hydraulic conductivity materials, care must be taken to limit outside influences on the disc permeameter. Below 1.0×10^{-4} cm/sec, direct exposure of the disc permeameter reservoir and wetted soil region around the permeameter base to the sun can increase flow from the instrument. Increasing flowrate with time occurred in a number of disc permeameter measurements on fine textured materials. The exposure of the permeameter reservoir to intense sunlight, as is common in the southwestern United States in the spring and summer, caused heating and expansion of air within the reservoir perhaps inducing flow from the disc.

Sun exposure to the wetted region about the permeameter base results in evaporation. The effect is of major importance in this study for measurements of hydraulic conductivity in fine textured soils. Evaporation can induce a gradient from the soil surface towards the disc base, thereby inducing flow from the reservoir. One or both of the effects could have resulted in the increased flow. To limit the problem, the disc permeameter and measurement areas were shielded from the sun with good result to calculated hydraulic conductivities of 6.0×10^{-5} cm/sec.

In coarse to medium textured soils (gravels to silty-sands), flow from the disc can reach steady state in 1 to 10 minutes (fig.47). In fine textured materials (silts and clays), however, the disc permeameter measurement must be conducted for longer time periods to ensure steady state flow. Even after significant time (20 to 30 minutes), the wetted region about the disc may be of larger lateral extent than thickness. Capillary forces may still have considerable effect on the flowrate. Because the measurements would be disrupted, no quantitative data of this phenomena was recorded. Instead, extra measurement time was allotted for the wetted region to expand and steady state to occur. For hydraulic conductivity determinations below 5.0×10^{-5} cm/sec, 3 to 4 hours should be allowed for reasonable hydraulic conductivity determinations.

6.3.2 Capping Material

For most disc permeameter measurements a capping material, normally a fine sand, is needed to ensure good contact of the disc base with the soil surface. Perroux and White (1987) state that the best capping material "is one whose hydraulic properties are identical to the underlying soil". This is not always possible. Therefore, they suggest the appropriate cap material should have both a high

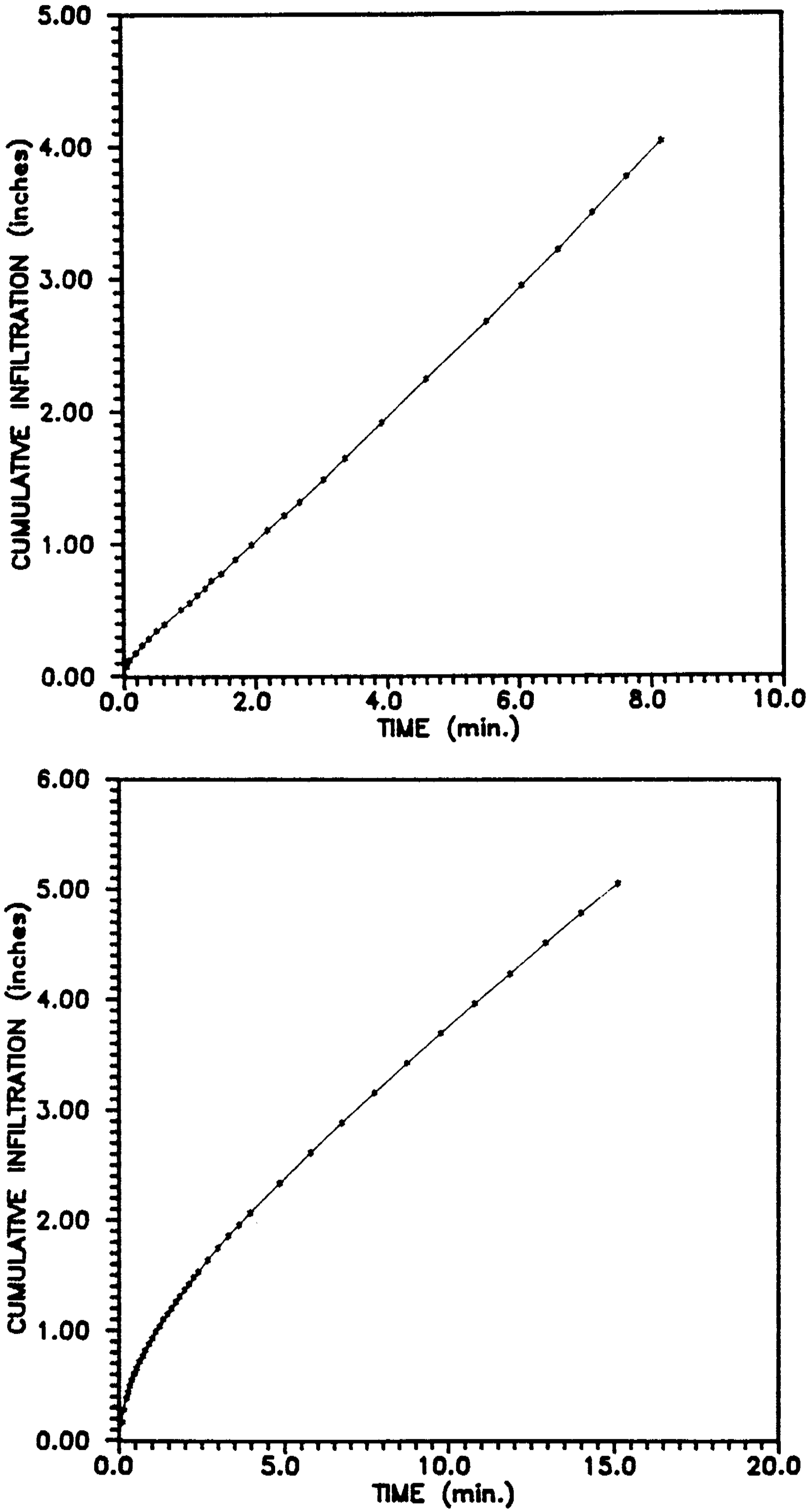


Figure 47. Steady state flowrate. (A) DP39 - in gravels, steady state may be reached in less than 1 minute. (B) DP52 - in sands and silts, steady state is reached in approximately 5 minutes.

sorptivity and conductivity, but a weak dependence upon the supply pressure. Figure 48 shows the effects of a cap on the sorptivity determination of several disc permeameter measurements.

1). If the cap is too thick, the hydraulic conductivity determined may reflect the characteristics of the capping material or an average of the cap and underlying soils. In any event, the value determined is not representative of the soil. This is especially true for tension measurements. At high tensions, the volume of measurement may be smaller than for a tension near zero. A large cap (> 5 mm) can result in large error as described above. Therefore, cap size should be as thin as possible.

2). If the cap is too thin, good contact between the soil and disc may be questionable. The area of flow is then in question, as are the subsequent hydraulic conductivity determinations. Good contact must be assured in the field because the problem is not readily apparent when analyzing the graph's.

A "good" cap thickness is dependent upon the type of soil being measured. Clayey soils, for example, are often blocky in nature when dry. It is difficult to achieve a flat surface in such a soil. Using soil extracted during levelling of the measurement site as a cap, filling depressions and small holes, is better than applying a fine sand cap. Even though the pore structure has been destroyed, the cap material is

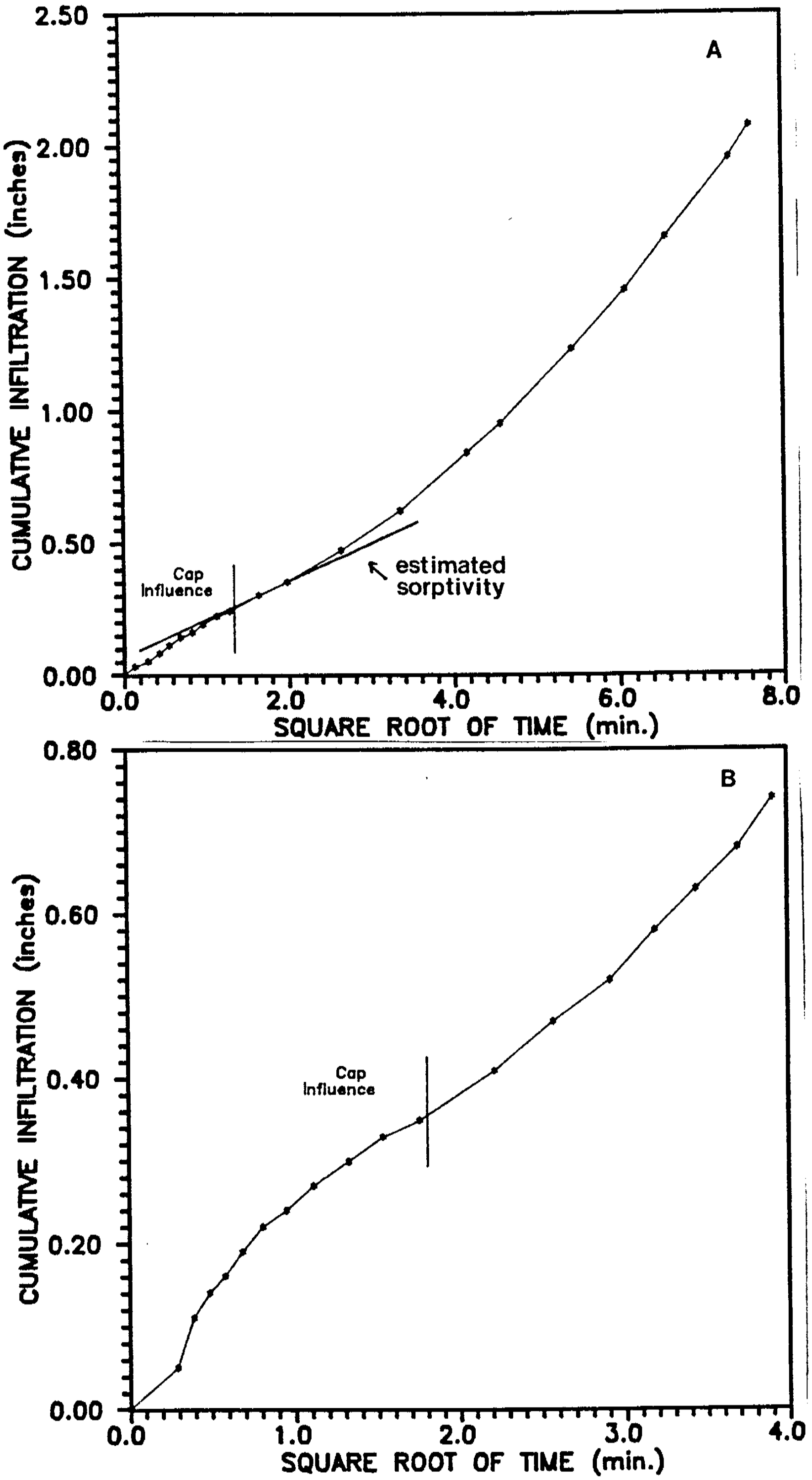


Figure 48. Cap material effects on estimated sorptivity. (A) DP33 and (B) DP35 are in gravelly soils. As sorptivity is estimated from the first few minutes of infiltration, a reasonable estimate is not possible for (B) due to cap material interference.

similar to the underlying soils. Sandy soils usually do not require a cap. Gravels, however, often need a cap to achieve a level measurement surface. Again, the thinnest cap needed for a level surface is best. Otherwise, the cap hydraulic conductivity, which may be relatively lower than the gravels, will control flow at low tensions.

The largest problem encountered with capping material in this study occurred in the intermediate sediments between water-laid and mudflow. These sediments consist of intermixed sands and gravels in a fine silt matrix. It is exceedingly difficult to construct a level surface that has good contact between the disc and soil without a cap. In all these measurements, the thinnest sand cap possible for a level surface was used. Fine sands of the Rio Grande facies were used as cap material in this study. Mean particle size for this material was determined by Parsons (1988) and is tabulated in Table 2.

6.3.3 Moisture Content Effects

In Wooding's (1968) analysis of flow from a circular disc the hydraulic conductivity of a soil at the initial supply potential (K_i) is subtracted from that of the hydraulic conductivity measured at the supply potential (K_n). Disc permeameter theory states that for relatively dry materials $K_i << K_n$ and is neglected in further derivations ((White and Sully, 1987). In several regions of the transect initial moisture contents exceeded 20%. Although the trench section extending through the irrigated plot was allowed several weeks to dry after excavation before any disc measurements were performed, a dichotomy in moisture content was apparent 1 to 2 cm below the surface. The dry surface seemed to impair further drying of the underlying materials. Therefore, initial moisture content samples may not represent the actual conditions in which flow is occurring. Due to the high initial moisture contents just below the surface, the initial hydraulic conductivity may not be significantly less than the supply hydraulic conductivity.

The stratification of moisture content appears to be the main reason for the large decrease in sorptivities as determined through the wetted region. Associated steady state flowrates, however, are also lower. Therefore, the calculated hydraulic conductivities appear valid, but the impact on the characteristic mean pore size is less certain.

6.3.4 Heterogeneous Soils

The disc permeameter theory is based on the analysis of flow from a circular disc into a homogeneous, isotropic porous medium (CSIRO instruction manual, 1988). Soils in our study area (fig. 38) are quite heterogeneous and anisotropic at the scale of disc measurement. Still, the heterogeneity and anisotropy had little apparent effect on the calculated hydraulic conductivities as compared to the laboratory saturated hydraulic conductivities(fig.45). As stated earlier, the disc permeameter seems to integrate soil units, resulting in effective hydraulic conductivity determinations. If the purpose of the measurements is characterizing variation on the order of ten's of centimeters, the disc permeameter should not be used. The effects of using the disc permeameter in an area of fine over coarse materials was seen by Arnet(1991) in the deep trench at the experimental site. Water collected in a fine to silty sand above a cobble layer. The steady state flowrate decreased as pressure increased in the fine sand above the cobbles. Using the late time infiltration data as the steady state flowrate resulted in a negative calculated hydraulic conductivity. It is not known if the water was obstructed from flow through the cobbles due to a decreased flow volume or a higher matric pressure in the cobble layer. Such an occurrence is not apparent for any of the shallow trench measurements.

7.0 CONCLUSIONS

1). The horizontal spatial variability of hydraulic conductivity can be characterized at a number of scales at the field site, ranging from 1.5 to 2.5 meters to greater than 20 meters.

2). Qualitative geologic data can be used to define geologic and hydrologic boundaries, which when used in conjunction with quantitative methods comprises a less time consuming and more cost effective method of characterizing the horizontal spatial variability.

3). Log reduced sorptivity, 1.3 cm tension hydraulic conductivity ($K_{1.3}$), d_{10}, and van Genuchten's α-values exhibit similar ranges of correlation (2 m to 3 m) to the small scale hydrologic analysis.

4). Field and laboratory hydraulic conductivities are log-normally distributed. Van Genuchten's Alpha parameter is log-normally distributed while N is normal. 15 bar water content and bulk density are normally distributed.

5).Comparisons with Parsons (1988) show that the mean's of the saturated hydraulic conductivity distributions differ by less than 20% and ranges are similar. Calculated porosity and saturated water content mean's and ranges show excellent agreement. The 15-bar water content distributions as well as Alpha and N distributions, however, are not well correlated.

6). The disc permeameter is a reasonable device for estimating effective horizontal hydraulic conductivity in relatively dry soils over at least 3 orders of magnitude ranging from 1.0 x 10^{-2} cm/sec to approximately 1.0 x 10^{-5} cm/sec.

8.0 RECOMMENDATIONS

Several analyses that are beyond the scope of the current study should be considered for future analysis of the data. The sorptivity data set should be detrended using a fitted polynomial equation to better understand its behavior along the transect. Residual moisture content should be estimated by soil texture, instead of 15-bar water content, and employed in van Genuchten's three parameter analysis to determine the difference in alpha and N for the two methods. Kriging as well as conditional simulation should be employed to further investigate the validity of using geologic data in conjunction with limited hydrologic measurements to characterize hydrologic variation. Lastly, the characteristic mean pore size should be further evaluated to better understand its sensitivity to heterogeneities in moisture content and geology.

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Appendix **A**: Disc Permeameter Measurement Locations

D.P. # from S.E. corner	Distance from Southeast corner Feet	Meters	100 cc Ring
33	0.92	0.28	yes
34	2.76	0.84	yes
35	4.30	1.31	no
36	5.54	1.69	no
37	6.59	2.01	no
38	8.01	2.44	no
39	8.92	2.72	yes
40	9.84	3.00	no
41	7.58	2.31	yes
42	7.19	2.19	yes
43	8.40	2.56	no
44	12.30	3.75	yes
45	13.68	4.17	yes
46	14.76	4.50	yes
47	17.52	5.34	yes
48	17.22	5.25	yes
49	18.44	5.62	yes
50	19.69	6.00	yes
51	21.06	6.42	yes
52	22.31	6.80	yes
53	23.38	7.13	yes
54	24.61	7.50	yes
55	25.69	7.83	yes
56	27.07	8.25	yes
57	27.69	8.44	yes
58	28.77	8.77	yes
59	29.82	9.09	yes
60	31.07	9.47	yes
61	32.61	9.94	yes
62	33.53	10.22	yes
63	34.74	10.59	yes
64	35.83	10.92	yes
65	36.91	11.25	yes
66	37.66	11.48	yes
67	38.75	11.81	yes
68	39.99	12.19	yes
72	40.91	12.47	yes
73	42.13	12.84	yes
74	43.21	13.17	yes
75	44.59	13.59	yes
76	46.13	14.06	yes
77	47.05	14.34	yes
78	48.13	14.67	yes
79	49.84	15.19	yes

Appendix **A** : Disc Permeameter Measurement Locations

D.P. # from S.E. corner	Distance from Southeast corner Feet	Meters	100 cc Ring
80	50.44	15.38	yes
81	51.38	15.66	yes
82	52.43	15.98	yes
83	53.84	16.41	yes
84	55.05	16.78	yes
85	56.30	17.16	yes
86	57.51	17.53	yes
87	58.43	17.81	yes
88	59.68	18.19	yes
89	60.76	18.52	yes
90	61.81	18.84	yes
91	63.06	19.22	yes
92	64.14	19.55	yes
93	65.68	20.02	yes
94	67.06	20.44	yes
95	68.24	20.80	yes
96	69.52	21.19	yes
97	70.44	21.47	yes
98	71.52	21.80	yes
99	73.20	22.31	yes
100	74.90	22.83	yes
101	76.57	23.34	yes
102	78.12	23.81	yes
103	79.66	24.28	yes
104	81.20	24.75	yes
105	82.43	25.13	yes
106	84.28	25.69	yes
107	85.50	26.06	yes
108	87.83	26.77	yes
71	89.21	27.19	yes
70	90.29	27.52	yes
69	91.67	27.94	yes
109	92.75	28.27	yes
110	94.73	28.88	yes
111	96.42	29.39	yes
112	97.97	29.86	yes
113	99.66	30.38	yes
114	101.05	30.80	yes
32	100.26	30.56	yes
31	101.64	30.98	yes
30	102.43	31.22	yes
29	103.64	31.59	yes
28	105.18	32.06	yes
27	106.27	32.39	yes

Appendix A: Disc Permeameter Measurement Locations

D.P. # from S.E. corner	Distance from Southeast corner Feet	Meters	100 cc Ring
26	107.35	32.72	yes
25	108.10	32.95	yes
24	109.50	33.38	yes
23	110.10	33.56	yes
22	111.65	34.03	yes
21	112.89	34.41	yes
20	113.81	34.69	yes
19	114.42	34.88	yes
18	115.65	35.25	yes
17	116.57	35.53	yes
16	117.81	35.91	yes
15	118.86	36.23	yes
14	119.95	36.56	yes
13	120.87	36.84	yes
12	122.21	37.25	yes
11	122.74	37.41	yes
10	124.87	38.06	no
9	125.33	38.20	yes
8	127.03	38.72	yes
7	128.25	39.09	yes
6	129.49	39.47	yes
5	130.71	39.84	yes
4	132.25	40.31	yes
3	134.10	40.88	yes
2	135.63	41.34	yes
1	137.50	41.91	yes
115	102.43	31.22	no
116	105.64	32.20	no
117	108.89	33.19	no
118	112.27	34.22	no
119	116.73	35.58	no

```
c       APPENDIX  B: Kolmogorov-Smirnoff Test
c
c       This program was written by M. Davis and edited by
c       R. Schmidt-Petersen for use in determining if an
c       empirical data set is normally or log-normally
c       distributed using the kolmogorov-Smirnoff test.

        character indat*30,outdat*30
        dimension edf(500),cdf(500)
        dimension flow(750)
        common/block/n,arrin(500),indx(500),irank(500)


        write(*,*)'INPUT DATA FILE containing the data'
        read(*,'(a)')indat
        write(*,*) 'INPUT DATA FILE to write dist. fcn. to'
        read(*,'(a)')outdat

        open (unit=20,file=indat,status='old')
        open (unit=30,file=outdat,status='new')
        write(*,*) 'number of data points'
        read(*,*)n
        do 9  i = 1,n
        read(20,*)arrin(i)
        write(*,*)arrin(i)
9       continue
c  The data is then ranked so the emperical distribution function c
c   be calculated
        call rank

c  The ranked data is then used to calculate the dist. func.
        do 10 j=1,n
           write(*,*)irank(j),indx(j),arrin(indx(j))
           rir=irank(j)
           rn=n
           edf(j)=rir/rn
           write(30,*)arrin(indx(j)),edf(j)
10      continue

        call moment(arrin,n,ave,adev,sdev,var,skew,curt)

        write(30,*)'n=',n,' the mean is:',ave
        write(30,*)' and the variance is:',var
        write(30,*)'n=',n,'the kurtosis is:',curt
        write(30,*)' and the skewness is:',skew
        write(*,*)' Would you like to plot up the normal dist fcn?'
        write(*,*)'1=yes'
        write(*,*)'2=no'
        read(*,*)iopt

        if(iopt.eq.1) then
           do 60 k=1,n
               v=(arrin(indx(k))-ave)/(sdev)
               if (v.lt.0.) then
                  av=abs(v)
                  cdf(k)=1.-f(av)
                  write(*,*)'v is neg',v,ccdf
                  pause
                else
                  cdf(k)=f(v)
```

```
                  endif
                  write(30,*)arrin(indx(k)),cdf(k)
60           continue
        write(30,*)'  '
        else
            goto 900
        endif

        write(*,*)'Would you like to perform a K-S Test?'
        write(*,*)'1=yes'
        write(*,*)'2=no'

        read(*,*)iopt2
        if (iopt2.eq.1) then
           do 65 j=1,n
                diff=abs(edf(j)-cdf(j))
                if(diff.gt.rmax) then
                   rmax=diff
                   jmax=j
                endif
                write(*,*)rmax
65         continue
        rn=n
        tks=1.36/sqrt(rn)
        else
           goto 900
        endif
        write(30,*)'The maximum difference observed is:',rmax
        write(30,*)'The acceptable difference is:',tks
        write(30,*)'The max diff occured at:',jmax
900     end


        subroutine moment(data,n,ave,adev,sdev,var,skew,curt)

        dimension data(n)
        if(n.le.1)pause 'N must be at least 2'
        s=0.
        do 11 j=1,n
           s=s+data(j)
11      continue
        ave=s/n
        adev=0.
        var=0.
        skew=0.
        curt=0.
        do 12 j=1,n
           s=data(j)-ave
           adev=adev+abs(s)
           p=s*s
           var=var+p
           p=p*s
           skew=skew+p
           p=p*s
           curt=curt+p
12      continue
        adev=adev/n
        var=var/(n-1)
        sdev=sqrt(var)
        if(var.ne.0)then
```

```
          skew=skew/(n*sdev**3)
          curt=curt/(n*var**2)-3.
        else
          pause 'no skew or kurtosis when zero variance'
        endif
        return
        end

        subroutine rank

        common/block/n,arrin(500),indx(500),irank(500)

        call index

        irank(1)=1
        do 45 j=2,n
           if(arrin(indx(j)).eq.arrin(indx(j-1)))then
                icount=icount+1
                irank(j)=j-icount
           else
                irank(j)=j
           endif
           icount=0
45      continue
        return

        end


        subroutine index
        common/block/n,arrin(500),indx(500),irank(500)

        do 11 j=1,n
           indx(j)=j
11      continue

        l=n/2+1
        ir=n
        write(*,*)'n=',n
10      continue
            if(l.gt.1)then
                l=l-1
                indxt=indx(l)
                q=arrin(indxt)
            else
                indxt=indx(ir)
                q=arrin(indxt)
                indx(ir)=indx(1)
                ir=ir-1
                if(ir.eq.1)then
                   indx(1)=indxt
                   return
                endif
            endif
        i=l
        j=l+l
20      if(j.le.ir)then
           if(j.lt.ir)then
              if(arrin(indx(j)).lt.arrin(indx(j+1)))j=j+1
           endif
```

```
         if(q.lt.arrin(indx(j)))then
             indx(i)=indx(j)
             i=j
             j=j+j
         else
             j=ir+1
         endif
      goto 20
      endif
      indx(i)=indxt
      goto10
      end

      real function f(v)

      dimension b(5)
      data b/.319381530,-0.356563782,1.781477937,-1.821255978,
   *         1.330274429/
      pi=acos(-1.)
      t=1./(1.+0.2316419*v)
      sr2pi=sqrt(2.*pi)
      z=(1./sr2pi)*exp(-v**2/2)
      f=1.-z*(b(1)*t+b(2)*t**2+b(3)*t**3+b(4)*t**4+b(5)*t**5)
      return
      end
```

APPENDIX C: KOLMOGOROV-SMIRNOFF RESULTS AND GRAPHS

1.) Bulk density

2.) Saturated water content

3.) Laboratory saturated hydraulic conductivity

4.) 15-bar water content

5.) d10 - final moisture samples

6.) Alpha values

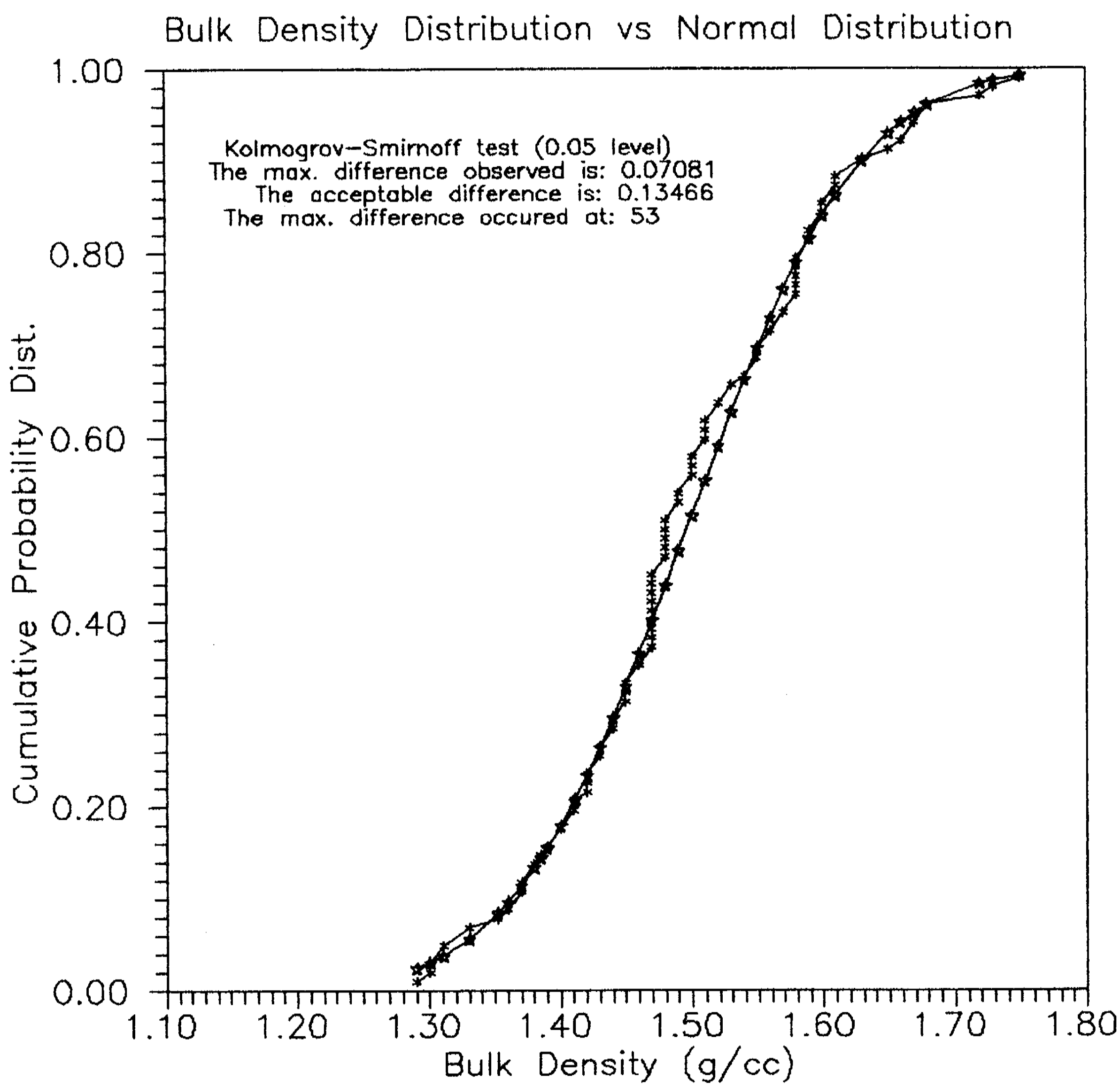
7.) N values

8.) Initial Moisture Content

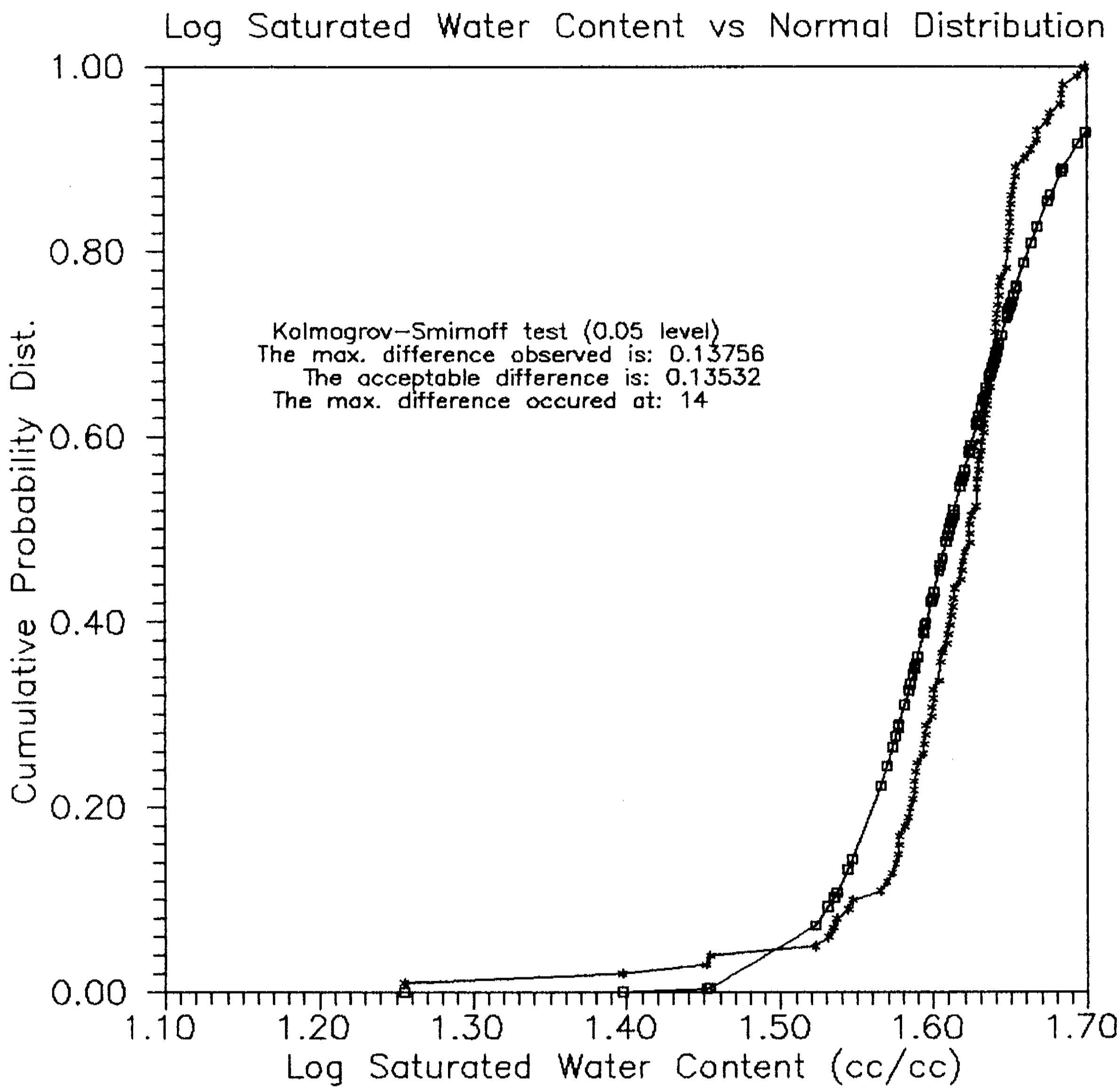
9.) Sorptivity

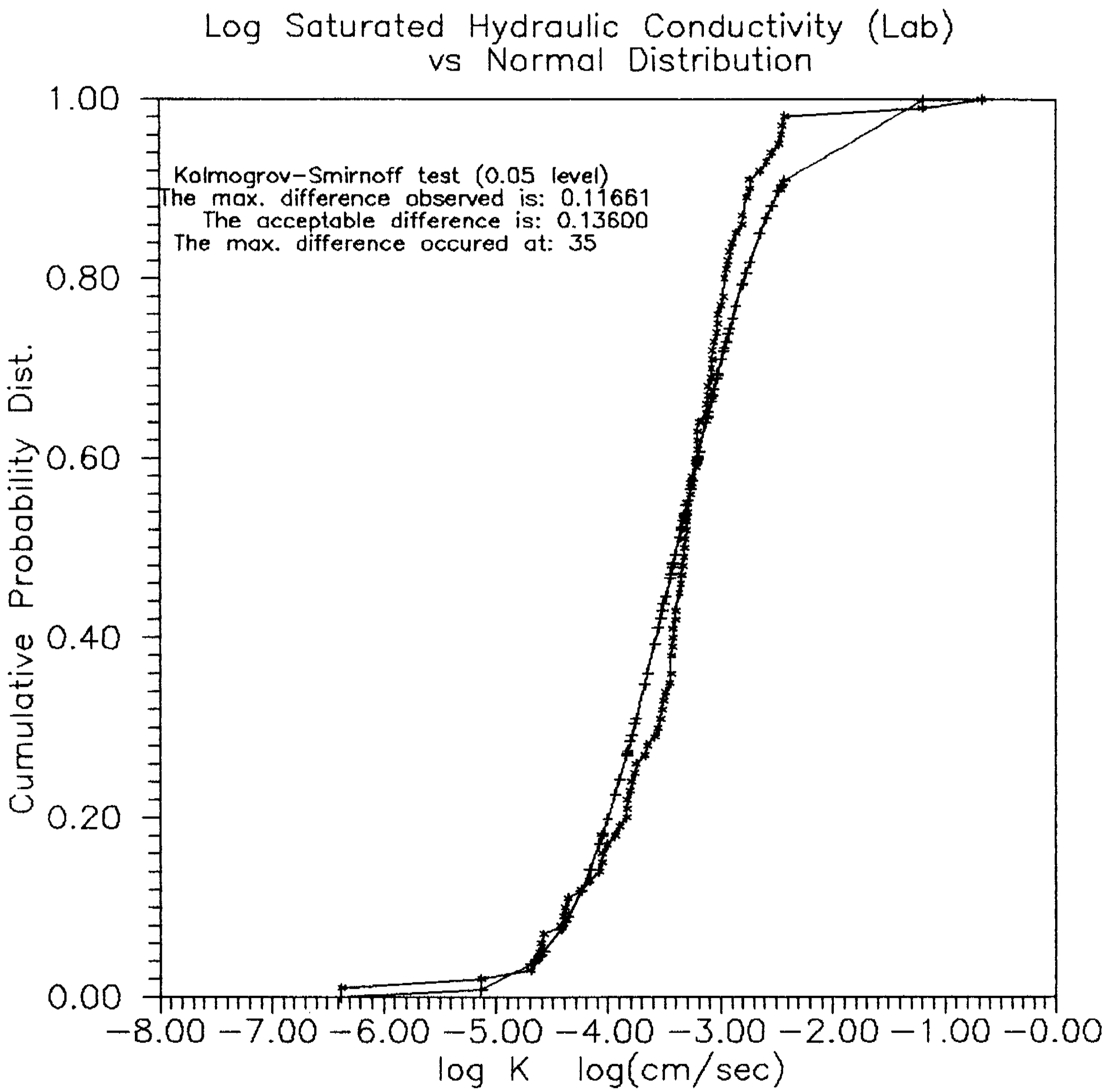
10.) Reduced sorptivity

11.) 1.3 cm tension hydraulic conductivity

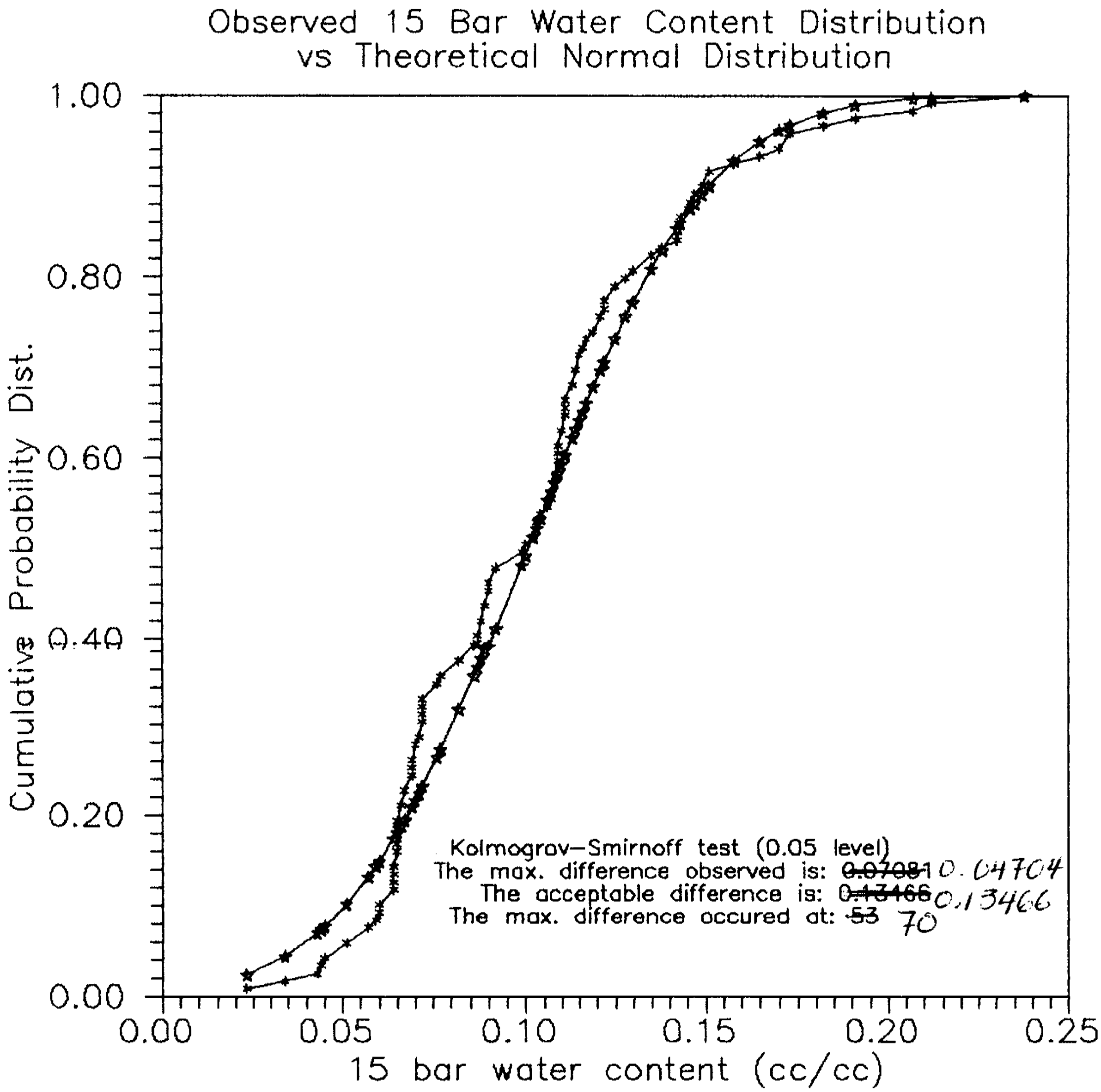


Bulk Density Distribution vs Normal Distribution
Kolmogrov–Smirnoff test (0.05 level)
The max. difference observed is: 0.07081
The acceptable difference is: 0.13466
The max. difference occured at: 53
Cumulative Probability Dist.
Bulk Density (g/cc)
1.00
0.80
0.60
0.40
0.20
0.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80

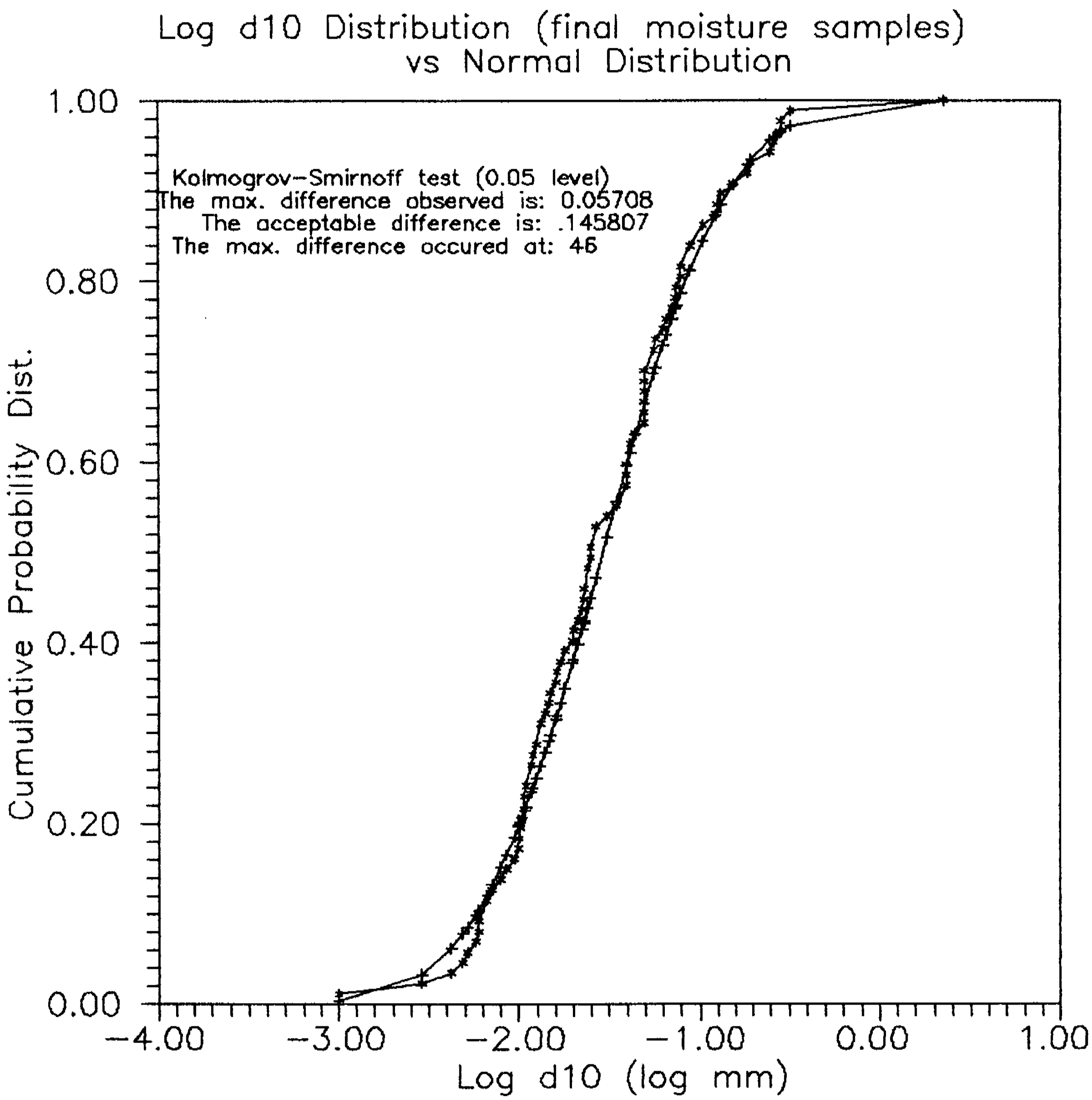

Log Saturated Water Content vs Normal Distribution
Cumulative Probability Dist.
1.00
0.80
0.60
0.40
0.20
0.00
Kolmogrov-Smirnoff test (0.05 level)
The max. difference observed is: 0.13756
The acceptable difference is: 0.13532
The max. difference occured at: 14
1.10
1.20
1.30
1.40
1.50
1.60
1.70
Log Saturated Water Content (cc/cc)



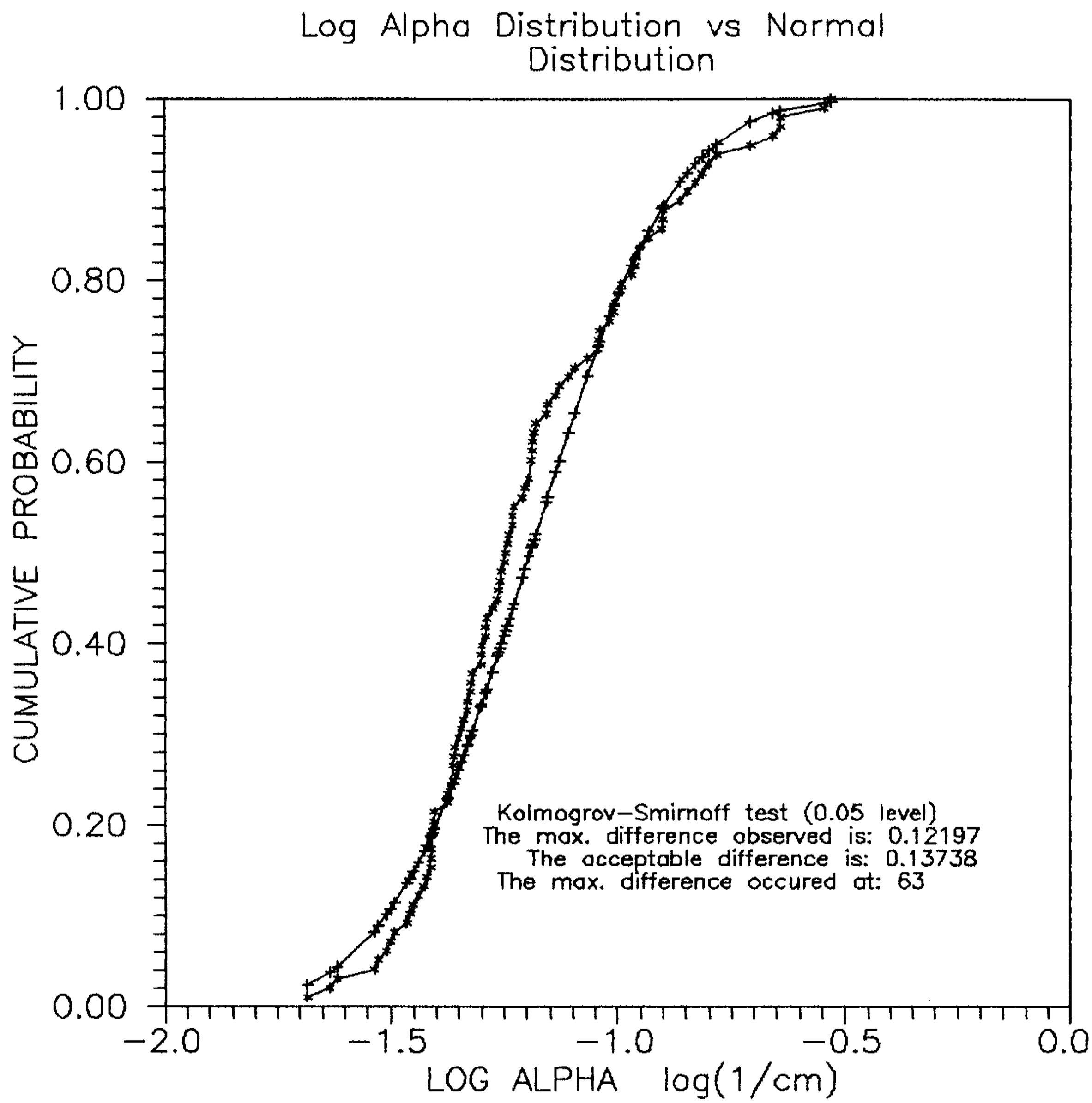
Log Saturated Hydraulic Conductivity (Lab)
vs Normal Distribution
Kolmogrov-Smirnoff test (0.05 level)
The max. difference observed is: 0.11661
The acceptable difference is: 0.13600
The max. difference occured at: 35
Cumulative Probability Dist.
0.00
0.20
0.40
0.60
0.80
1.00
−8.00 −7.00 −6.00 −5.00 −4.00 −3.00 −2.00 −1.00 −0.00
log K log(cm/sec)

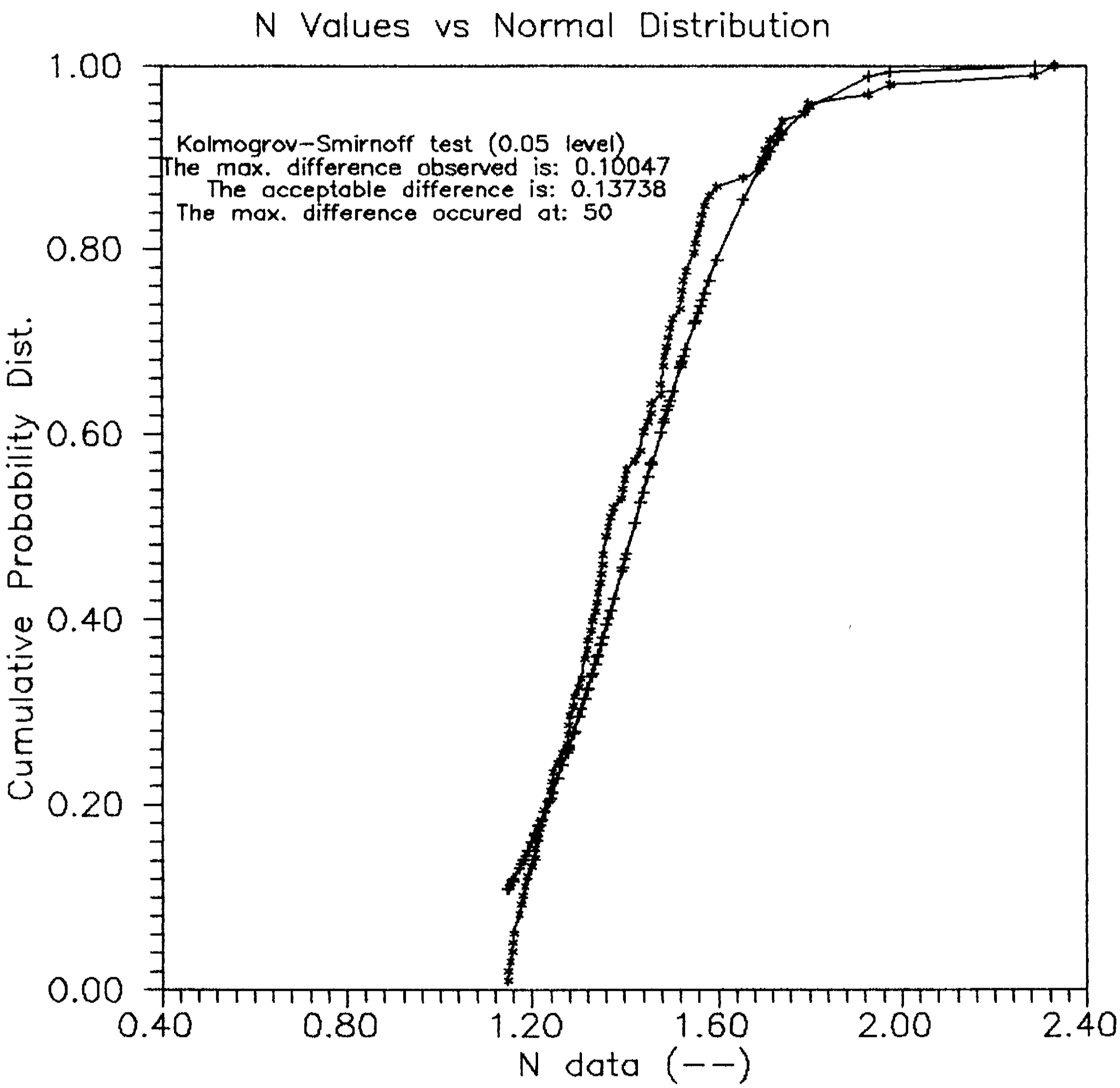


Observed 15 Bar Water Content Distribution
vs Theoretical Normal Distribution
Cumulative Probability Dist.
1.00
0.80
0.60
0.40
0.20
0.00
0.00
0.05
0.10
0.15
0.20
0.25
15 bar water content (cc/cc)
Kolmogrov–Smirnoff test (0.05 level)
The max. difference observed is: 0.07081 0.04704
The acceptable difference is: 0.13466 0.13466
The max. difference occured at: 53 70

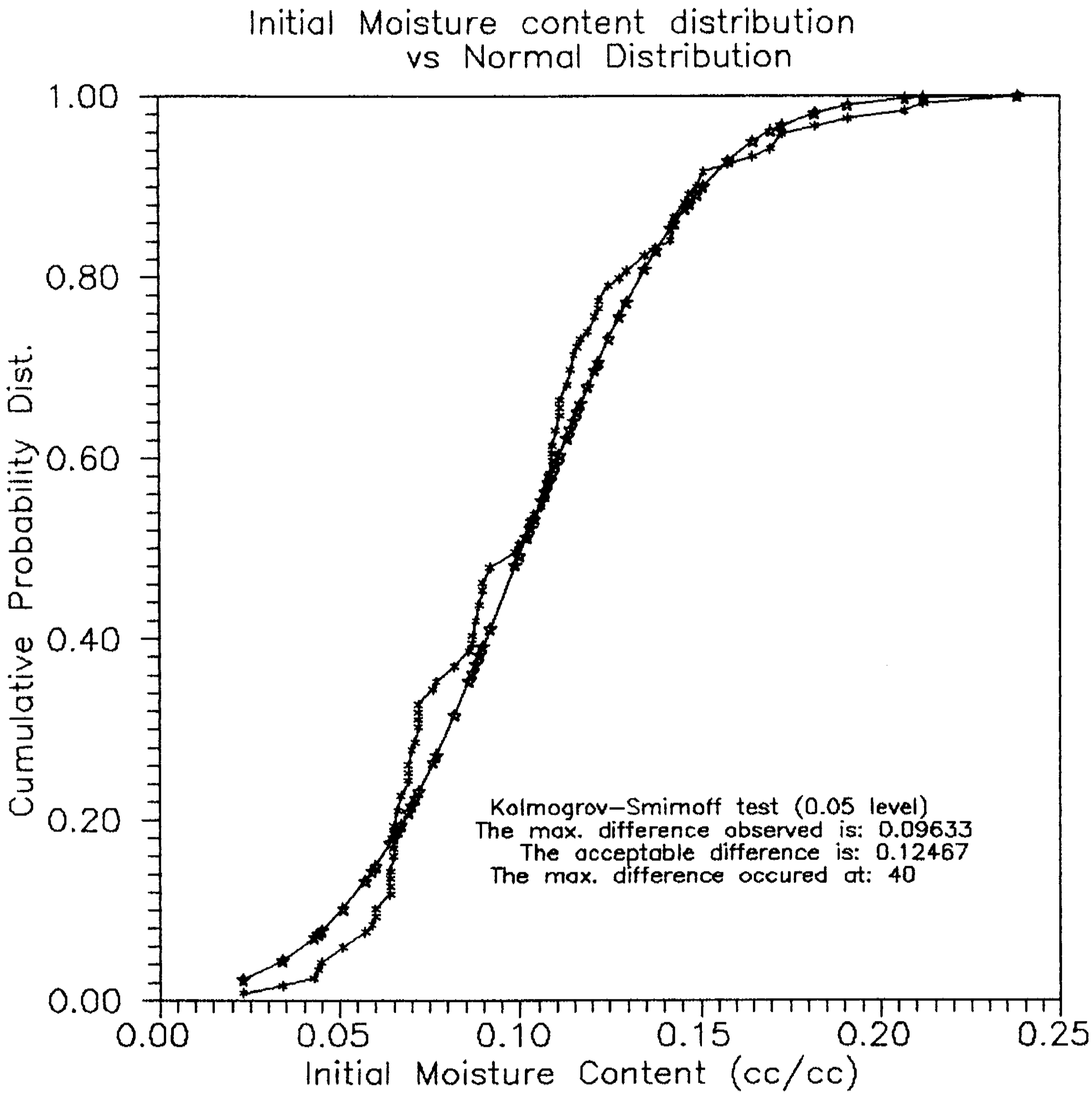


Log d10 Distribution (final moisture samples)
vs Normal Distribution
Kolmogrov-Smirnoff test (0.05 level)
The max. difference observed is: 0.05708
The acceptable difference is: .145807
The max. difference occured at: 46
Cumulative Probability Dist.
0.00
0.20
0.40
0.60
0.80
1.00
-4.00
-3.00
-2.00
-1.00
0.00
1.00
Log d10 (log mm)

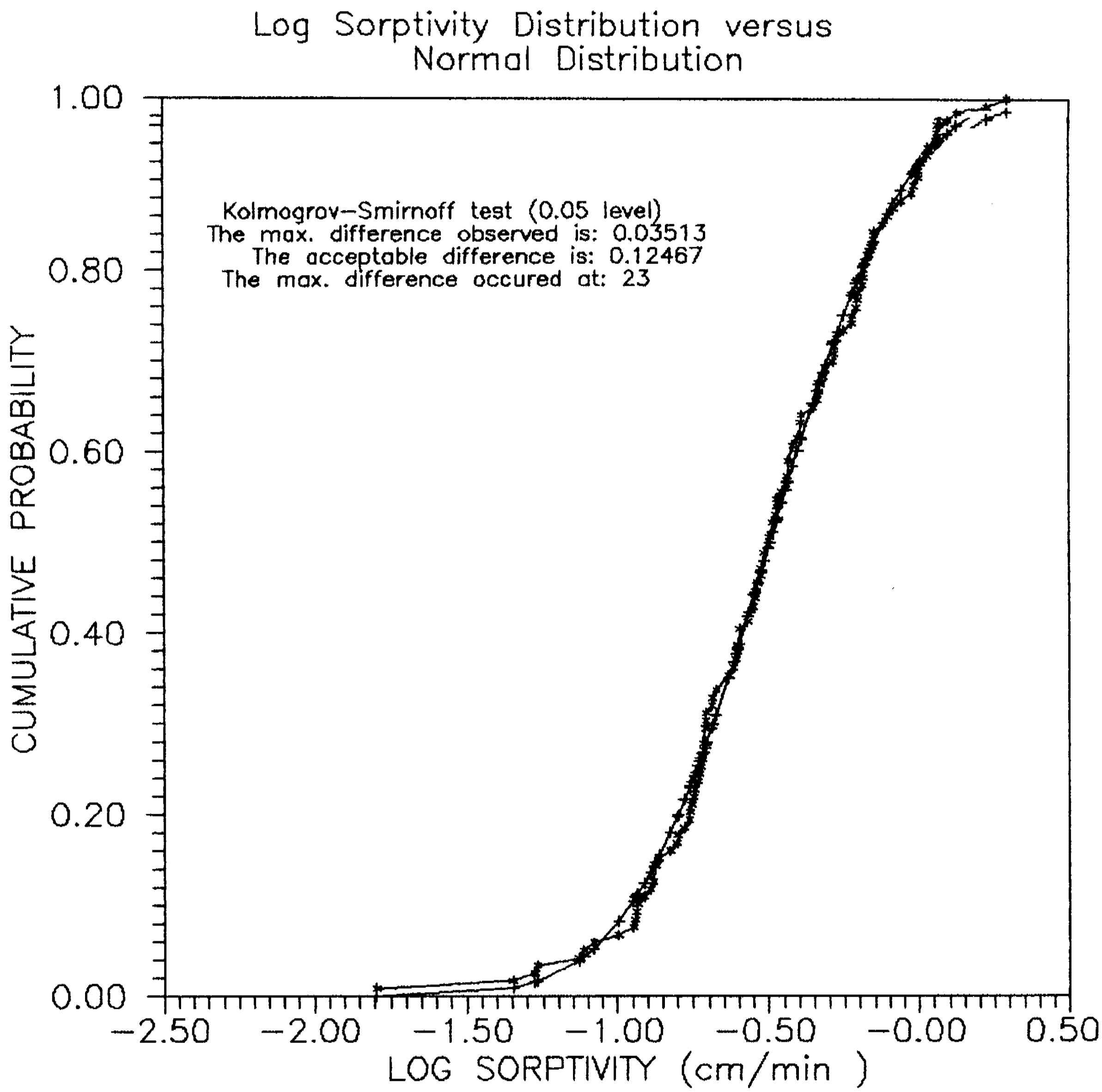

Log Alpha Distribution vs Normal Distribution
1.00
0.80
0.60
0.40
0.20
0.00
CUMULATIVE PROBABILITY
-2.0
-1.5
-1.0
-0.5
0.0
LOG ALPHA log(1/cm)
Kolmogrov-Smirnoff test (0.05 level)
The max. difference observed is: 0.12197
The acceptable difference is: 0.13738
The max. difference occured at: 63



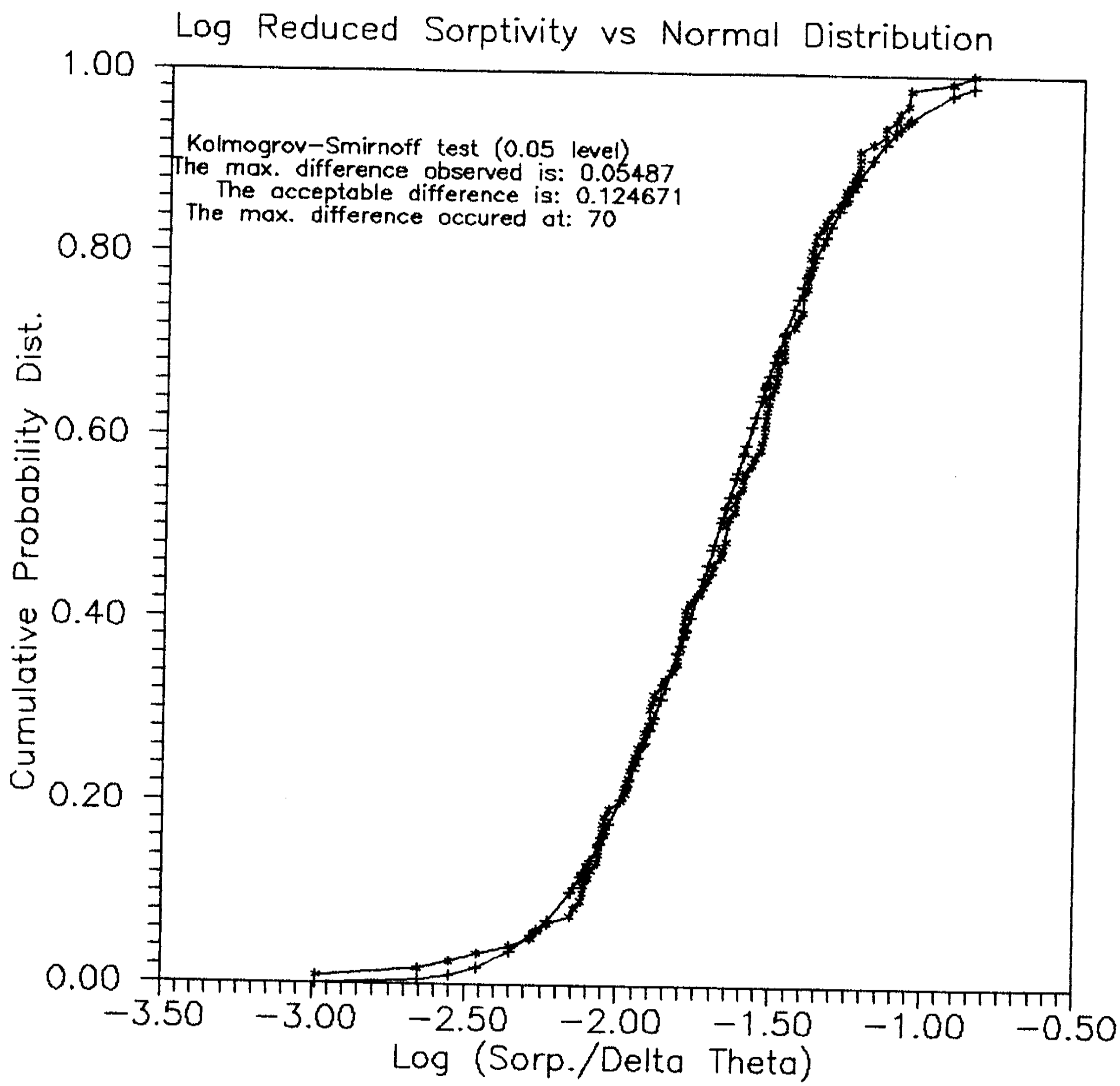
N Values vs Normal Distribution
Kolmogrov-Smirnoff test (0.05 level)
The max. difference observed is: 0.10047
The acceptable difference is: 0.13738
The max. difference occured at: 50
Cumulative Probability Dist.
N data (--)
0.00
0.20
0.40
0.60
0.80
1.00
0.40
0.80
1.20
1.60
2.00
2.40

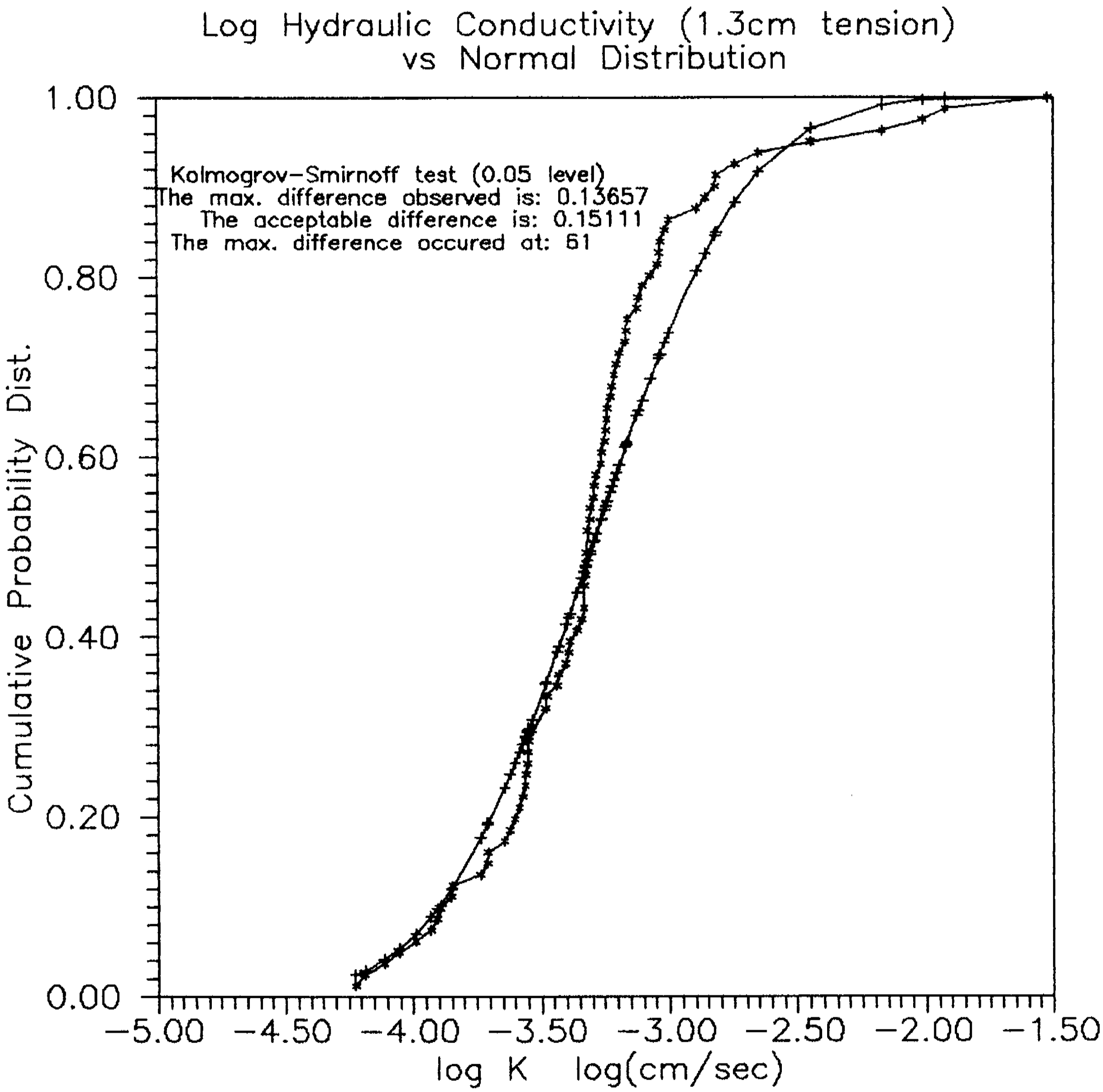


Initial Moisture content distribution
vs Normal Distribution
1.00
0.80
0.60
0.40
0.20
0.00
Cumulative Probability Dist.
0.00
0.05
0.10
0.15
0.20
0.25
Initial Moisture Content (cc/cc)
Kolmogrov–Smirnoff test (0.05 level)
The max. difference observed is: 0.09633
The acceptable difference is: 0.12467
The max. difference occured at: 40



Log Sorptivity Distribution versus
Normal Distribution
1.00
0.80
0.60
0.40
0.20
0.00
CUMULATIVE PROBABILITY
Kolmogrov–Smirnoff test (0.05 level)
The max. difference observed is: 0.03513
The acceptable difference is: 0.12467
The max. difference occured at: 23
−2.50
−2.00
−1.50
−1.00
−0.50
−0.00
0.50
LOG SORPTIVITY (cm/min)


Log Reduced Sorptivity vs Normal Distribution
Kolmogrov-Smirnoff test (0.05 level)
The max. difference observed is: 0.05487
The acceptable difference is: 0.124671
The max. difference occured at: 70
Cumulative Probability Dist.
Log (Sorp./Delta Theta)
1.00
0.80
0.60
0.40
0.20
0.00
-3.50
-3.00
-2.50
-2.00
-1.50
-1.00
-0.50



Log Hydraulic Conductivity (1.3cm tension)
vs Normal Distribution
Kolmogrov-Smirnoff test (0.05 level)
The max. difference observed is: 0.13657
The acceptable difference is: 0.15111
The max. difference occured at: 61
Cumulative Probability Dist.
1.00
0.80
0.60
0.40
0.20
0.00
-5.00
-4.50
-4.00
-3.50
-3.00
-2.50
-2.00
-1.50
log K log(cm/sec)

APPENDIX D: Field and Laboratory Hydraulic and Geologic Properties determined in the study

1) Samples are tabulated according to disc permeameter measurement number.
2) Locations are presented on the site X-Y grid.
3) Field measured hydraulic conductivities are tabulated with the measurement supply pressure presented in the headings section directly above the tabulated hydraulic conductivity value.

===

B.D. = Bulk Density
Nc = Porosity calculated from the bulk density data
SWC = Saturated Water Content
15-bar W.C. = 15 bar Water Content
d10-ring = 100cc soil core d10 grain size
d10-fm = final moisture content grab sample d10 grain size
Psi = Hanging column tension in cm
Theta = Volumetric moisture content at a given Psi
Alpha and N = Curve fitting parameters from van Genuchten's RETC.f code.

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 1 Location:(meters)

X: 0.95

Y: 30.05

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.065	0.303	1.68	0.00301

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring & fm (mm)	(mm)	K sat (cm/sec)
1.5	0.434	0.4212	0.1138	0.015995		0.00085

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5	0.4072
11.4	0.3849
19.9	0.3636
30.7	0.3401
49	0.3114
73.2	0.2731
97.6	0.2475
128.6	0.2294
166.6	0.2187
206.2	0.2113

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0434	1.395

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 1 Location:(meter)

X: 0.95

Y: 30.05

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.065	0.303	1.68	0.00301

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.5	0.434	0.4212	0.1138	0.015995		0.00065

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 2 Location:(meters)

X: 1.3

Y: 29.6

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.065	0.341	0.56	0.00317

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.45	0.4528	0.4308	0.0782	0.066069		0.000559

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.9	0.4197
11.7	0.4023
16.7	0.3879
29.2	0.3622
50.7	0.3262
77.1	0.2902
97.4	0.2738
132.7	0.2573
171.5	0.2486
211	0.243

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.042	1.564

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 3 Location:(meter)

X: 1.6

Y: 29.25

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.065	0.327	0.657	0.000932

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
						0.0038

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 4 Location:(meter)
X: 2.15
Y: 29

Field Data:

****

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.071	0.378	1.071	0.00164

Laboratory Data:

****

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.49	0.4377	0.4201	0.1201	0.020183		0.0013

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Drainage	
181.1	0.2448
130.2	0.249
107.8	0.2698
77.4	0.301
52.7	0.3344
36.9	0.3646
22.9	0.3896
7.7	0.4292
4.7	0.4448

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0347	1.487

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 3 Location:(meters)

X: 2.25

Y: 28.45

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.064	0.341	0.966	0.00283

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC * (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.48	0.4415	0.5098	0.1071	0.007498	0.034994	0.0034

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.9	0.4759
4.7	0.4669
13.8	0.4364
28.8	0.4002
41.4	0.3686
66.7	0.3189
98.5	0.285
134.8	0.2624
169	0.2545
206	0.2488

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0429	1.523

* - swc from hanging column data

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 6 Location:(meters)

X: 2.75

Y: 28.48

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.064	0.363	0.667	0.00283

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.5	0.434	0.462	1.5	0.057543	0.021183	0.000512

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.5	0.4601
10.1	0.4381
20.7	0.4201
30.9	0.4051
56.4	0.3711
97.8	0.3321
156.3	0.3121
174.7	0.3071
210.5	0.3031

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0394	1.442

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 7 Location:(meter)

X: 2.75

Y: 27.9

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.064	0.365	1.155	0.00219

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.43	0.4604	0.3775	0.1125	0.007498		0.0016

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
184.9	0.1645
154.2	0.1645
115.7	0.169
66.1	0.1805
47.3	0.2155
23.8	0.2415
6.4	0.2785
3	0.3205

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.2199	1.244

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 8 Location:(meter)

X: 3.37

Y: 27.85

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.072	0.349	0.6	0.000095

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.47	0.4453	0.3925	0.1396	0.00881		0.0005

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Drainage	
275	0.219
249	0.221
206	0.229
157.4	0.237
119.5	0.249
93.7	0.264
71.4	0.2805
54.3	0.298
31.8	0.328
20.6	0.35
6.3	0.378
3.9	0.39

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.053	1.354

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 9 Location:(meter)

X: 3.4

Y: 27.3

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.11	0.36	0.708	0.00203

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.39	0.4755	0.4558	0.1695	0.008912		0.000314

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.5	0.482
7.1	0.463
13.5	0.438
21.6	0.42
35.5	0.3955
57.5	0.363
78.4	0.343
99.2	0.3255
127.2	0.311
165	0.304
208.5	0.29

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0639	1.281

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 10 Location:(meter)

X: 4

Y: 27.25

Field Data:

****

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.082	0.406	0.618	0.00224

Laboratory Data:

****

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 11 Location:(meters)

X: 3.95

Y: 26.75

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.082	0.385	0.827	0.00476

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.411	0.4675	0.4461	0.1857	0.009506		0.000361

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.9	0.4448
14.7	0.4198
20.1	0.4078
32	0.3908
51.4	0.3648
72.5	0.3358
94.3	0.3158
134.5	0.2958
174.1	0.2868
213	0.2798

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0323	1.583

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 12 Location:(meter)

X: 4.4

Y: 26.85

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.087	0.357	0.652	0.00295

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.47	0.4453	0.4205	5.179	0.015417		0.000083

Hanging Column Data: van Genuchten analysis:

Psi (cm)	Theta (cc/cc)	Psi (cm)	Theta (cc/cc)	Alpha (1/cm)	N (--)
Drainage		Imbibition		0.0563	1.459
2.5	0.3849	5.7	0.3779		
20.9	0.3679	23	0.3499		
32	0.3569	42.3	0.3179		
50.3	0.3309	59.6	0.2949		
65	0.3189	95.5	0.2729		
99	0.2919	120.7	0.2649		
123.3	0.2799	159.4	0.2539		
168	0.2649	203.8	0.2489		
208.6	0.2529	252.9	0.2449		
250.4	0.2454				
252.9	0.2449				

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 13 Location:(meter)

X: 4.4

Y: 26.3

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.087	0.375	0.15	0.000675

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
				0.074131		0.000856

Hanging Column Data: van Genuchten analysis:

Psi (cm)	Theta (cc/cc)	Psi (cm)	Theta (cc/cc)	Alpha (1/cm)	N (--)
Drainage		Imbibition			
2.5	0.3928	7.5	0.3638		
23.8	0.3728	25.2	0.3198		
35.1	0.3418	42.3	0.2678		
53.5	0.3358	59	0.2548		
68.1	0.2998	93.2	0.2518		
99.5	0.2778	121.5	0.2498		
126.6	0.2678	159.9	0.2478		
167.5	0.2628	203.8	0.2468		
209.8	0.2578	250.65	0.2478		
250.75	0.2528				

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 14 Location:(meter)

X: 4.87

Y: 26.45

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (5.2 cm tension) (cm/sec)
0.13	0.3	0.253	0.000282

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.5	0.434	0.4997	0.2447	0.011803	0.014996	0.000148

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
279.5	0.3248
246.5	0.3258
211.4	0.3308
167.7	0.3358
125	0.3428
96.5	0.3518
69.2	0.3638
51.6	0.3768
33.4	0.3958
20.3	0.4178
6.2	0.4508
3.7	0.4578

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0984	1.32

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 15 Location:(meter)

X: 4.92

Y: 26.05

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm tension) (cm/sec)
0.13	0.347	0.407	0.0019

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.43	0.4604	0.4834	0.0967	0.012502		0.000294

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
214.5	0.2321
186.8	0.2396
149.6	0.2451
112.8	0.2561
82.4	0.2701
42.8	0.3041
27.8	0.3291
16.5	0.3521
6.5	0.3811

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0989	1.239

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 16 Location:(meters)

X: 5.3

Y: 25.95

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm tension) (cm/sec)
0.109	0.369	0.624	0.00179

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.3	0.5094	0.4404	0.2012	0.016519		0.000539

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5	0.4415
14.5	0.4206
24.6	0.3998
46.1	0.3602
69.7	0.317
97.9	0.3279
135	0.2633
167	0.2571
207.3	0.2508

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0354	1.302

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 17 Location:(meter)

X: 5.6

Y: 25.65

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm tension) (cm/sec)
0.111	0.387	0.683	0.00133

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.31	0.5057	0.4822	0.0629	0.012416		0.00051

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
213.7	0.2464
188.3	0.2545
151.7	0.2637
113.6	0.2821
78.5	0.3148
51.7	0.3526
30.5	0.3853
15.9	0.4093
6.1	0.4384

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0297	1.479

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 18 Location:(meters)

X: 5.5

Y: 25.2

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (5.4 cm tension) (cm/sec)
0.108	0.341	0.191	0.000254

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC * (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.37	0.483	0.54	0.1749	0.007079		0.000214

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.2	0.5309
14.5	0.5089
28.5	0.4879
43.8	0.4709
69.8	0.4449
101.6	0.4229
139.2	0.4049
178.2	0.3989
216.2	0.3939

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0421	1.342

* - swc from hanging column data

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 19 Location:(meters)

X: 6.05

Y: 25.25

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.108	0.401	0.522	0.00219

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.6	0.3962	0.4019	0.1869	0.066069		0.000362

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.9	0.3436
6.3	0.3291
13.6	0.3054
28.2	0.2816
39.8	0.2682
67.2	0.2444
99.3	0.2258
138.2	0.2176
170.4	0.2083
210.5	0.2041

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.2286	1.219

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 20 Location:(meter)

X: 3.95

Y: 24.75

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.072	0.375	0.459	0.00175

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.42	0.4642	0.4037	0.1205	0.056234	0.041686	0.00232

Hanging Column Data: van Genuchten analysis:

Psi (cm)	Theta (cc/cc)	Psi (cm)	Theta (cc/cc)	Alpha (1/cm)	N (--)
Drainage		Imbibition			
2.5	40.37	235.4	22.2		
19.6	38.5	204.3	22.5		
35.7	35.1	163.8	23		
59.7	31.5	124.3	24.1		
97.8	27.6	95.3	25.5		
149.4	24.4	60.1	28.5		
187.2	23.6	46.7	31.2		
235.4	22.2	28.3	34.5		
		8.1	39.4		

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 21 Location:(meter)

X: 6.38

Y: 24.95

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.072	0.357		

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 22 Location:(meter)

X: 6.4

Y: 24.35

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.1	0.314		

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.44	0.4566	0.4649	0.0845		0.025003	0.00114

Hanging Column Data: van Genuchten analysis:

Psi (cm)	Theta (cc/cc)	Psi (cm)	Theta (cc/cc)	Alpha (1/cm)	N (--)
Drainage		Imbibition		0.0456	1.221
2.5	0.4492	5.4	0.4397		
19.3	0.4287	23.7	0.4047		
33.9	0.4087	43.3	0.3807		
54.7	0.3797	63	0.3577		
72.7	0.3647	97.5	0.3247		
97.5	0.3472	121.4	0.3067		
130	0.3297	160.7	0.2897		
168.5	0.3107	202.2	0.2797		
209.9	0.2857	251.8	0.2737		
249.3	0.2737				
251.8	0.2737				

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 23 Location:(meter)

X: 7

Y: 24.3

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (5.7 cm tension) (cm/sec)
0.09	0.303	0.273	0.000479

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
					0.066069	

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

Disc Permeameter Measurement Hydrolcgic Properties

D.P.#: 24 Location:(meters)

X: 6.85

Y: 23.85

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (5.7 cm tension) (cm/sec)
0.09	0.282	0.47	0.000139

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.39	0.4755	0.4821	0.0584			0.00187

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.9	0.4336
9.4	0.4153
15	0.402
28.8	0.3796
53.1	0.344
73.8	0.3094
97.7	0.2839
129.5	0.2625
168.1	0.2503
208.2	0.2422

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0452	1.28

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 25   Location:(meter)

X: 7.4

Y: 23.9

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.111	0.35	0.788	0.0037

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.48	0.4415	0.4362	0.1448	0.013001		0.00103

Hanging Column Data:

Psi	Theta

No hanging column data

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 26 Location:(meters)

X: 7.31

Y: 23.35

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (5.3 cm tension) (cm/sec)
0.111	0.313	0.197	0.000428

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring & fm (mm) (mm)	K sat (cm/sec)
1.31	0.5057	0.3907	0.1475	0.006998	0.000464

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.5	0.481
13.9	0.452
23.2	0.431
44	0.398
71.2	0.3655
100	0.344
135.7	0.328
173.8	0.321
215.1	0.316

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0579	1.362

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 27 Location:(meters)

X: 7.75

Y: 23.45

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.111	0.333	0.316	0.0019

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.49	0.4377	0.4099	0.1023	0.050118		

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.8	0.4349
12	0.4189
19	0.4049
31	0.3889
50.1	0.3679
72.9	0.3449
95.9	0.3319
138.5	0.3189
177.9	0.3124
217.6	0.3079

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0618	1.307

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 28   Location:(meter)

X: 7.7

Y: 22.95

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (4.3 cm tension) (cm/sec)
0.109	0.316	0.307	0.00024

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	d10 - fm (mm)	K sat (cm/sec)
1.47	0.4453	0.4439	0.0984	0.005997	0.010495	

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
217.9	0.2707
189.5	0.2782
152.6	0.2842
113.4	0.2962
78	0.3152
51.6	0.3392
28.3	0.3672
17.2	0.3842
6	0.4092

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0467	1.354

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 29   Location:(meters)

X: 8.35

Y: 22.95

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm tension) (cm/sec)
0.17	0.351	0.207	0.00189

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.42	0.4642	0.4648	0.1755	0.022803		0.00076

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.9	0.4194
16.2	0.3944
24	0.3804
42.7	0.3544
68.9	0.3234
98.6	0.2994
136	0.2824
175.5	0.2764
214.2	0.2724

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0593	1.276

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 30   Location: (meters)

X: 8.3

Y: 22.31

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (4.4 cm tension) (cm/sec)
0.17	0.285	0.233	0.000038

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC * (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.36	0.4868	0.5279	0.1304	0.045394		0.00294

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.1	0.5059
10.6	0.4809
17.6	0.4579
29.8	0.4249
43	0.3989
67.9	0.3599
98.4	0.3319
146.2	0.3119
180.2	0.3069
216.5	0.3029

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0639	1.436

* swc estimated from hanging column data

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 31 Location:(meter)

X: 8.55

Y: 22.15

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.149	0.335	0.336	0.00261

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.45	0.4528	0.4606	0.1901	0.008203		0.000627

Hanging Column Data: van Genuchten analysis:

Psi (cm)	Theta (cc/cc)	Psi (cm)	Theta (cc/cc)	Alpha (1/cm)	N (--)
Drainage		Imbibition		0.0316	1.397
2.5	0.4374	6	0.4449		
19.5	0.4219	23.2	0.4119		
38.7	0.4019	43.3	0.3899		
60.2	0.3769	63.6	0.3649		
76.8	0.3639	96.9	0.3269		
100.7	0.3489	122.9	0.3079		
130.9	0.3289	163.3	0.2919		
171.4	0.3029	203	0.2829		
215.1	0.2869	254.75	0.2779		
252.25	0.2779				
254.75	0.2779				

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 32 Location:(meters)

X: 8.9

Y: 21.9

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (4.4 cm tension) (cm/sec)
0.149	0.296	0.284	0.000189

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.51	0.4302	0.4462	0.1066	0.007194		0.000374

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.8	0.4107
9.4	0.3977
17.6	0.3817
28.7	0.3647
47.5	0.3427
72.8	0.3137
97.9	0.2952
131.5	0.2827
170.1	0.2747
209.8	0.2327

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0388	1.245

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 33 Location:(meters)

X: 30.38

Y: 0.009

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (4.5 cm tension) (cm/sec)
0.143	0.453	0.196	0.000194

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.29	0.5132	0.4389	0.108	0.023496		0.00061

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.6	0.4967
14.1	0.4507
24.8	0.4227
46	0.3897
71.5	0.3607
96.8	0.3407
133.8	0.3217
171.2	0.3137
209.8	0.3087

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0779	1.337

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 34 Location:(meters)

X: 29.79

Y: 1

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.143	0.381	1.965	0.00252

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.59	0.4	0.2496	0.0043	0.095499		0.000088

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.9	0.2662
14.1	0.2462
22.4	0.2317
33.2	0.2182
68.9	0.1902
107.8	0.1702
157.6	0.1552
201.2	0.1522

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.091	1.221

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 35 Location:(meter)

X: 29.44

Y: 1.31

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.8 cm tension) (cm/sec)
0.077	0.449	0.276	0.00353

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
No ring - coarse gravels					0.281838	

Hanging Column Data:

Psi	Theta

** No ring collected

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 36 Location:(meter)

X: 29.1

Y: 1.5

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.5 cm pressure) (cm/sec)
0.077	0.45	1.163	0.00945

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
No ring - coarse gravels					0.323593	

Hanging Column Data:

Psi	Theta

** No ring collected

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 37 Location:(meter)

X: 29.1

Y: 2.05

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.066	0.453	0.49	0.00553

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
No ring - coarse gravels					0.288403	

Hanging Column Data:

Psi	Theta

** No ring collected

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 38 Location:(meter)

X: 28.87

Y: 2.33

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (.3 cm tension) (cm/sec)
0.067	0.453	1.343	0.0512

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
No ring - coarse gravels					2.238721	

Hanging Column Data:

Psi	Theta

** No ring collected

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 39 Location:(meters)

X: 28.125

Y: 1.98

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.067	0.263	0.507	0.0119

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.352	0.4898	0.3336	0.0059	0.426579	0.251188	0.0119

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
9.1	0.1302
11.5	0.0982
13.8	0.0602
20.3	0.0402
34.5	0.0302
43.2	0.0227
53.1	0.0172
59.9	0.0122
71.2	0.0112
81	0.0142

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.285	2.287

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 40 Location:(meter)

X: 28.3

Y: 2.6

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.065	0.43	0.129	0.00224

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
No ring - coarse gravels					0.263026	

Hanging Column Data:

Psi	Theta

** No ring collected

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 41 Location:(meter)

X: 28.11

Y: 3.05

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.065	0.361	0.286	0.000684

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.43	0.4604	0.438	0.1773	0.015488		0.00026

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.3	0.3946
17.2	0.3633
27	0.3381
52	0.3048
70.5	0.2857
94	0.2655
125.5	0.2514
177	0.2383
224.9	0.2323

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0648	1.331

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 42 Location:(meters)

X: 27.75

Y: 2.25

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.065	0.434	0.627	0.00674

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.4	0.4717	0.2828	0.0877	0.251188	0.186208	0.0634

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.8	0.3443
4.6	0.3343
7.7	0.3153
8.7	0.2863
10.7	0.2703
13.4	0.2513
17.3	0.2213
29.3	0.1853
42.5	0.1633
58.1	0.1543
73.6	0.1513
93	0.1498

Van Genuchten analysis:

Alpha (1/cm)	N (--)
1.349	0.2959

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 43 Location:(meter)

X: 27.6

Y: 3

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.051	0.203	0.76	0.00181

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
No ring - coarse gravels					0.194984	

Hanging Column Data:

Psi	Theta

** No ring collected

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 44 Location:(meter)

X: 27.94

Y: 3.18

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.06	0.43	0.521	0.000924

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.51	0.4302	0.3888	0.127	0.104712	0.025003	0.000934

Hanging Column Data:

Psi	Theta

** No ring collected

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 45 Location:(meter)

X: 27.45

Y: 3.37

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.06	0.275	0.517	0.000495

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.44	0.4566	0.4261	0.1095	0.079432	0.275422	0.00263

Hanging Column Data: van Genuchten analysis:

Psi (cm)	Theta (cc/cc)	Psi (cm)	Theta (cc/cc)	Alpha (1/cm)	N (--)
Drainage		Imbibition		0.1011	1.553
2.5	0.4015	8.9	0.3665		
18.9	0.3795	26.4	0.2985		
32.1	0.331	45.1	0.2585		
48.2	0.2825	61.6	0.2385		
68.5	0.2555	95.1	0.2165		
100.1	0.2325	121.2	0.2075		
132.8	0.2185	163.9	0.1975		
172.8	0.2075	204.4	0.1915		
216.2	0.1965	251.5	0.1885		
251.6	0.1905				

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 46 Location:(meters)

X: 27.375

Y: 3.74

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.102	0.362	0.692	0.03

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.36	0.4868	0.4364	0.1046	0.013396	0.017988	

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.6	0.4403
12.7	0.4188
17.9	0.4043
33.3	0.3668
53.7	0.3258
79.9	0.2908
97.6	0.2768
131.1	0.2638
170.5	0.2558
209.8	0.2498

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0513	1.568

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 47 Location:(meters)

X: 27.05

Y: 3.94

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.102	0.397	0.48	0.000962

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.33	0.4981	0.4247	0.1098	0.044668	0.063095	0.00173

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.7	0.4681
14	0.4311
23	0.4091
38.5	0.3771
66.3	0.3446
97.8	0.3241
134.3	0.3121
171.4	0.3071
214.6	0.3031

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0552	1.705

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 48 Location:(meter)

X: 26.55

Y: 3.94

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.072	0.364	0.878	0.00151

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.52	0.4264	0.4362	0.0577	0.125892	0.013212	0.00119

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
220.3	0.1707
190.6	0.1781
153.4	0.1834
114.3	0.1919
81.8	0.2036
43.9	0.2291
28.4	0.2535
18.2	0.28
8.3	0.3268
5.5	0.348

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1256	1.528

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 49 Location:(meter)

X: 26.55

Y: 4.48

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.069	0.313	1.144	0.000473

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.385	0.4774	0.4504	0.1485	0.050118	0.050118	0.00108

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Drainage	
272.5	0.245
246.2	0.247
204.8	0.255
157.4	0.265
116.5	0.281
94.1	0.298
70	0.325
89	0.317
63.7	0.338
41.3	0.375
22.9	0.405
6	0.435
3	0.447

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0291	1.693

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 50 Location:(meter)

X: 26.1

Y: 4.6

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.072	0.31	1	0.000849

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.37	0.483	0.4345	0.0628	0.018323	0.030831	0.00123

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
218.5	0.2483
187	0.2563
149.6	0.2643
113	0.2783
78.9	0.2953
44	0.3233
30.6	0.3853
17	0.4193
6.2	0.4563

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0545	1.733

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 51 Location:(meter)

X: 25.9

Y: 5.05

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.069	0.341	1.244	0.00357

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.38	0.4792	0.3846	0.1266	0.035481	0.050118	0.000787

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
240	0.3048
200.5	0.3088
159.8	0.3168
118.2	0.3268
87	0.3398
65.7	0.3558
42.9	0.3818
27	0.4108
17.2	0.4348
7.2	0.4698
4.1	0.4818

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0588	1.599

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 52 Location:(meter)

X: 25.4

Y: 5

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.069	0.388	1.083	0.000691

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
					0.026791	

Hanging Column Data:

Psi	Theta

** No ring collected

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 53 Location:(meter)

X: 25.4

Y: 5.45

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.069	0.324	0.649	0.000457

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.55	0.4151	0.3524	0.0458	0.123026	0.070794	0.000326

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
225.1	0.2178
187.4	0.2238
152.5	0.2278
117.7	0.2348
78.5	0.2488
53.5	0.2648
31.8	0.2858
19	0.3048
6.3	0.3268

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.102	1.186

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 54 Location:(meter)

X: 24.85

Y: 5.45

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.064	0.388	1.024	0.000472

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.75	0.3396	0.2843	0.0173	0.14791	0.03981	0.000041

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
230.8	0.2001
198.1	0.2061
154.3	0.2096
119.6	0.2161
74	0.2271
43.5	0.2421
27	0.2551
15.3	0.2711
5	0.2881

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1267	1.16

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 55 Location:(meter)

X: 24.9

Y: 5.97

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.064	0.299	1.176	0.000491

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.4	0.4717	0.378	0.1406	0.089125	0.131825	

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
217.5	0.2319
190.6	0.2391
153.2	0.2431
113.7	0.28
78.6	0.2672
55.2	0.2866
30.6	0.3342
18.1	0.3689
5.6	0.3945

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0744	1.378

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 56 Location:(meters)

X: 24.375

Y: 5.99

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.07	0.296	0.954	0.00975

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.47	0.4453	0.4072	0.0641	0.044668	0.074989	

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.9	0.3918
11.4	0.3698
18.8	0.3498
30.9	0.3208
51.6	0.2848
71.9	0.2628
97.2	0.2398
126.9	0.2288
167.1	0.2198
242.5	0.2138

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0548	1.573

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 57 Location: (meter)

X: 24.41

Y: 6.37

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.071	0.32	0.594	0.000763

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.49	0.4377	0.4467	0.0818	0.064565	0.026791	0.000356

Hanging Column Data: van Genuchten analysis:

Psi (cm)	Theta (cc/cc)	Psi (cm)	Theta (cc/cc)	Alpha (1/cm)	N (--)
Drainage		Imbibition		0.0963	1.149
2.5	0.4022	2.5	0.3642		
20.8	0.3852	23.2	0.3482		
35.8	0.3612	42.6	0.3162		
50.1	0.3362	60.1	0.2942		
62.9	0.3232	95.7	0.2762		
92.9	0.2982	122.1	0.2662		
123.7	0.2862	160.8	0.2562		
167.5	0.2722	202.8	0.2532		
209.5	0.2602	251.1	0.2512		
248.6	0.2522				
251.1	0.2512				

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 58 Location:(meter)

X: 23.85

Y: 6.37

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.238	0.321	0.191	0.000274

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.6	0.3962	0.4366	0.1937	0.074131	0.079432	0.000475

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.8	0.375
16.4	0.355
24.2	0.341
51.2	0.313
69.9	0.3
91.5	0.287
125.4	0.277
176.1	0.269
229.1	0.2655

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1377	1.2

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 58 Location:(meters)

X: 23.85

Y: 6.37

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.238	0.321	0.191	0.000274

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.6	0.3962	0.4366	0.1937	0.074131	0.079432	0.000475

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
2.7	0.394
12.3	0.366
22.1	0.348
34.1	0.332
60.6	0.304
96.6	0.2865
141.4	0.275
176	0.27
217.2	0.268

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1377	1.2

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 59 Location:(meters)

X: 24

Y: 6.8

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.122	0.352	0.466	0.000511

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.51	0.4302	0.4352	0.1539	0.1	0.03981	0.000225

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.8	0.3883
12.9	0.3678
17.4	0.3553
31	0.3283
51.6	0.3033
79.5	0.2813
99.6	0.2713
135.1	0.2623
176	0.2593
215.2	0.2523

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0907	1.371

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 60 Location:(meter)

X: 23.4

Y: 6.8

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.142	0.389	0.445	0.000574

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.68	0.366	0.3426	0.1139	0.114815	0.009506	0.00055

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.2	0.2964
16.5	0.2804
24.5	0.2634
50	0.2334
67.9	0.2204
90.9	0.2054
123.6	0.1944
174.2	0.1854
229.2	0.1804

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0475	1.551

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 60 Location:(meter)

X: 23.4

Y: 6.8

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.142	0.389	0.445	0.000574

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.68	0.366	0.3426	0.1139	0.114815	0.131825	0.00055

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Drainage	
237.5	0.1788
195.9	0.1808
157.1	0.1858
117.3	0.1898
87.9	0.1958
68.4	0.2028
43.8	0.2158
25.5	0.2308
16	0.2478
5.9	0.2668
3.9	0.2778

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0475	1.551

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 61 Location:(meter)

X: 23.2

Y: 7.25

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.173	0.369	0.101	0.00024

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.67	0.3698	0.4247	0.1596	0.070794	0.012502	0.000043

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
246.1	0.2943
204.4	0.2863
172.4	0.2903
131.6	0.2933
96.5	0.2983
74.4	0.3073
44.5	0.3293
27.7	0.3533
17.5	0.3703
5.6	0.3933
3.8	0.4013

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.143	1.321

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 62 Location:(meter)

X: 22.875

Y: 7.31

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.212	0.387	0.247	0.000626

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.66	0.3736	0.387	0.1387	0.107151	0.03981	0.000396

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
236	0.1868
202.2	0.1908
161.6	0.1938
114.1	0.2018
90	0.2098
54	0.2298
35.5	0.2508
22.1	0.2798
7.6	0.3298
4.8	0.3408

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0588	1.928

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 63 Location:(meter)

X: 22.75

Y: 7.69

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.207	0.378	0.396	0.000561

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.66	0.3736	0.387	0.1387	0.074131	0.01099	

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
246.1	0.247
204.6	0.25
163	0.255
132.5	0.26
97.9	0.268
74.8	0.281
51.3	0.299
33.6	0.322
19.8	0.341
3.8	0.362
2.2	0.375

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0568	1.436

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 64 Location:(meter)

X: 22.5

Y: 7.875

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.119	0.383	0.185	0.000567

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.59	0.4	0.426	0.1557	0.044668	0.050118	0.000361

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
238.2	0.2612
201.6	0.2662
158.2	0.2762
118.4	0.2882
85.4	0.3072
67.4	0.3252
44.6	0.3552
26.6	0.3822
16.6	0.3992
5.7	0.4222
3	0.4312

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.3799	1.505

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 65 Location:(meter)

X: 22.31

Y: 8.2

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.143	0.314	0.173	0.000465

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (rg) (mm)	d10 (fm) (mm)	K sat (cm/sec)
1.75	0.3396	0.3399	0.1137	0.072443	0.034994	0.000127

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
246.3	0.2135
207.5	0.214
168.3	0.218
131.5	0.223
94	0.228
72.4	0.234
43.5	0.244
25	0.26
17.8	0.2725
7.8	0.319
4.8	0.337

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.502	1.291

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 65 Location:(meter)

X: 22.31

Y: 8.2

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.143	0.314	0.173	0.000465

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.75	0.3396	0.3399	0.1137	0.072443	0.034994	0.000127

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
226.6	0.2477
197.7	0.2577
153.4	0.2667
117.6	0.2777
75.9	0.2967
50.5	0.3177
29.3	0.3437
15.5	0.3647
6.2	0.3877

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.502	1.291

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 66 Location:(meters)

X: 22.05

Y: 8.3

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.121	0.362	0.181	0.000509

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.61	0.3925	0.4249	0.124	0.075857	0.050118	0.00063

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.1	0.3712
11.2	0.3523
15.5	0.3385
29.7	0.312
49.6	0.2823
78	0.2486
97.6	0.2343
134.2	0.219
172.9	0.2098
211.3	0.2047

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0662	1.278

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 67 Location:(meters)

X: 21.8

Y: 8.55

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.088	0.284	0.132	0.000481

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.55	0.4151	0.4147	0.1403	0.079432	0.025003	0.00015

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.7	0.3929
11.4	0.3769
16.3	0.3599
31.3	0.3309
49.3	0.3059
76.8	0.2779
100	0.2649
137.1	0.2529
176	0.2479
216	0.2449

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0731	1.405

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 68 Location:(meters)

X: 21.56

Y: 8.81

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.125	0.354	0.174	0.000364

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC * (cc/cc)	15-bar WC (cc/cc)	d10-ring (mm)	& fm (mm)	K sat (cm/sec)
1.54	0.4189	0.431	0.0913	0.079432	0.005997	0.00095

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.4	0.429
9.6	0.414
14.2	0.405
29.6	0.385
50.1	0.362
79.5	0.336
98.2	0.325
136.5	0.318
176.1	0.308
216	0.304

Van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0429	1.521

*- swc from hanging column data

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 69 Location:(meter)

X: 10.85

Y: 20.25

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.108	0.412	0.703	0.000603

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.46	0.4491	0.4448	0.1477	0.011994	0.005807	0.000768

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
215.7	0.1964
189.6	0.2044
153.8	0.2114
119.4	0.2219
77.1	0.2494
49.4	0.2834
29.5	0.3144
15.8	0.3314
5	0.3574

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0393	1.354

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 70 Location:(meter)

X: 11.06

Y: 19.8

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.128	0.486	0.396	0.000292

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.53	0.4226	0.4799	0.2102	0.016982		0.000098

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3	0.4661
8	0.4461
13	0.4311
23.5	0.4141
37.3	0.3951
59.8	0.3691
84.8	0.3501
102.4	0.3381
130.1	0.3271
170.8	0.3181
210.8	0.3091

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0702	1.160

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 71 Location:(meter)

X: 11.3

Y: 19.57

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.165	0.524	0.113	0.000292

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.61	0.3925	0.4292	0.116	0.007014		0.000020

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.9	0.4114
12.9	0.4015
25.8	0.3891
47.6	0.3708
63.5	0.357
91.1	0.3353
132.1	0.3195
179.7	0.3076
236	0.2987

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0445	1.153

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 72 Location:(meter)

X: 21.375

Y: 9

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.4 cm tension) (cm/sec)
0.09	0.361	0.123	0.000752

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.65	0.3774	0.3761	0.1175	0.085113	0.005997	0.000281

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
7.3	0.3409
15.3	0.3149
26.3	0.2889
47.1	0.2569
64.2	0.2399
92.5	0.2209
132.4	0.2059
178.1	0.1969
230.6	0.1899

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0916	1.343

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 73 Location: (meter)

X: 21

Y: 9.1

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.135	0.402	0.251	0.000544

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.67	0.3698	0.3778	0.1443	0.063095	0.013995	0.000025

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.6	0.3435
16.5	0.3272
27.3	0.3129
54.5	0.2885
69.7	0.2773
94.7	0.262
130	0.2528
180.5	0.2436
231.6	0.2416

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0626	1.266

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 74 Location:(meter)

X: 20.75

Y: 9.35

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.4 cm tension) (cm/sec)
0.076	0.273	0.339	0.000592

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.56	0.4113	0.3812	0.1499	0.079432	0.104712	0.000618

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4	0.3524
10.8	0.3239
23.8	0.3027
44.7	0.2774
65.8	0.2584
90	0.2404
129	0.2351
176	0.234

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1965	1.177

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 75 Location:(meter)

X: 20.6

Y: 9.75

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.092	0.279	0.328	0.00153

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.73	0.3472	0.344	0.134	0.141253	0.079432	0.000624

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
218.5	0.143
187.8	0.1505
152.8	0.1538
113.6	0.1591
79.5	0.1688
55.5	0.1817
33.7	0.2054
17.2	0.2376
7	0.2753

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.11	1.533

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 76 Location:(meter)

X: 20.15

Y: 9.94

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.109	0.367	0.338	0.000438

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring & fm (mm) (mm)	K sat (cm/sec)
1.51	0.4302	0.4723	0.1876	0.01901	0.00161

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.4	0.4476
12.5	0.4466
24.5	0.4199
46.8	0.385
69.4	0.3727
93.8	0.3522
128.5	0.3419
177	0.3419

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0651	1.329

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 77   Location:(meter)

X: 20.06

Y: 10.31

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.146	0.377	0.368	0.000474

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.48	0.4415	0.4941	0.1993	0.010914	0.03981	0.000430

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.5	0.4528
7.1	0.4418
18.1	0.4148
26.7	0.3948
50.4	0.3548
64.2	0.3358
93.1	0.3008
125.5	0.2888
175.2	0.2818
228.6	0.2808

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0556	1.493

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 78 Location:(meter)

X: 19.85

Y: 10.52

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.107	0.314	0.362	0.00092

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.47	0.4453	0.4485	0.1652	0.013995	0.079432	0.000501

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.2	0.4621
5.5	0.4517
15.5	0.4194
26.5	0.3923
39.8	0.3631
56.1	0.3319
74.8	0.3058
96.5	0.2829
128.1	0.2652
167.7	0.2538
197.5	0.2475

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0438	1.496

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 79 Location:(meter)

X: 19.4

Y: 10.8

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.113	0.364	0.212	0.000576

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.42	0.4642	0.45	0.0694	0.01099	0.010209	0.000879

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
218.5	0.2324
191.2	0.2434
153.8	0.2534
115.8	0.2734
84.2	0.3044
49.3	0.3724
32	0.4084
16.7	0.4354
5.3	0.4644

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0233	1.975

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 80 Location:(meter)

X: 19.4

Y: 11.06

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.119	0.375	0.251	0.000466

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.47	0.4453	0.4387	0.1447	0.02421	0.022387	0.00038

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.3	0.418
14.5	0.4
26.8	0.3805
42.1	0.36
58.2	0.335
76.5	0.306
97.5	0.283
129.8	0.261
168.4	0.2505
199.7	0.244

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0242	1.715

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 81 Location:(meter)

X: 19

Y: 11.15

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.107	0.33	0.074	0.000405

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC * (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.57	0.4075	0.44	0.1466	0.029991	0.01	0.000826

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.9	0.434
10.7	0.417
21.5	0.397
36.7	0.368
58.2	0.325
81	0.292
100.1	0.274
126.5	0.26
166.5	0.25
198	0.244

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.031	1.798

* - swc from hanging column data

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 82 Location:(meter)

X: 19.05

Y: 11.62

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.106	0.232	0.053	0.000141

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.3	0.5094	0.4104	0.1186	0.044668	0.023014	0.000451

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.5	0.4084
8	0.3904
14.7	0.3654
24.3	0.3344
37	0.3044
58.2	0.2704
75.9	0.2534
95.4	0.2404
121.9	0.2314
154.9	0.2234
183.3	0.2184

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0512	1.790

Disc Permeameter Measurement Hydrologic Properties

D.P.#: B3 Location:(meter)

X: 18.8

Y: 11.95

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.114	0.337	0.292	0.000909

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.3	0.5094	0.3742	0.106	0.01901	0.022908	0.0011

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.5	0.4042
7.5	0.3912
15.4	0.3672
26.5	0.3432
38.8	0.3162
57	0.2732
74.3	0.2462
98.1	0.2192
127	0.2022
164.5	0.1902
208.7	0.1812

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0386	1.533

Disc Permeameter Measurement Hydrologic Properties

D.P.#: B4 Location:(meter)

X: 18.375

Y: 12.1

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.116	0.427	0.167	0.000396

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.58	0.4038	0.4457	0.1463	0.050118	0.011803	0.000116

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
12.5	0.383
26.8	0.379
43	0.371
64.2	0.361
92.9	0.35
133.4	0.333
202.3	0.312
241.7	0.308
253	0.301

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0207	1.159

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 85 Location:(meter)

X: 18.18

Y: 12.37

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.115	0.332	0.158	0.00128

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.52	0.4264	0.3937	0.1263	0.1	0.015995	0.00161

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.7	0.3672
7.5	0.3572
17.9	0.3272
26.6	0.2842
46.8	0.2342
63	0.2152
91.8	0.1952
130.2	0.1852
174.4	0.1792
226.6	0.1792

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0466	2.331

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 86 Location:(meter)

X: 17.95

Y: 12.62

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.11	0.307	0.189	0.000474

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.37	0.483	0.4274	0.1692	0.056234	0.017021	0.000953

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.3	0.4392
6.6	0.4302
13.5	0.4092
23.9	0.3862
36.8	0.3612
55.7	0.3252
73	0.3032
96.4	0.2772
126.9	0.2622
166.6	0.2522
204.6	0.2442

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.039	1.559

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 87 Location:(meter)

X: 17.7

Y: 12.85

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.104	0.344	0.187	0.000614

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.45	0.4528	0.4309	0.1509	0.028379	0.016218	0.00365

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.9	0.3832
14.3	0.3622
26.7	0.3322
46.5	0.3002
62.3	0.2822
90.6	0.2602
129.6	0.2462
173.6	0.2372
268.8	0.2322

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0697	1.485

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 88 Location:(meter)

X: 17.5

Y: 13.12

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.113	0.38	0.115	0.000276

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.47	0.4453	0.4439	0.2236	0.03981	0.024099	0.000056

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
6	0.434
11.9	0.413
23.4	0.392
35.6	0.372
58.9	0.335
80.5	0.312
100.3	0.295
132	0.281
176.1	0.269
215.5	0.26

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0387	1.479

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 89 Location:(meter)

X: 17.1

Y: 13.25

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.103	0.419	0.194	0.000196

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.57	0.4075	0.4273	0.2374	0.006902	0.01099	0.000022

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.7	0.4302
15.3	0.4152
22.3	0.4062
37.1	0.3902
59	0.3662
78.7	0.3522
99.9	0.3382
135.6	0.3262
179	0.3182
222.5	0.3112

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0374	1.402

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 90   Location:(meter)

X: 16.87

Y: 13.48

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.117	0.475	0.192	0.000281

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC * (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.44	0.4566	0.47	0.2043	0.005997	0.019998	0.000164

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.7	0.4625
12.6	0.4395
24.3	0.4205
36.8	0.4035
54.1	0.3805
72.7	0.3625
98.7	0.34
126.2	0.3255
169.6	0.3135
206.2	0.3055

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0388	1.314

* - swc from hanging column data

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 91   Location: (meter)

X: 16.65

Y: 13.7

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.122	0.384	0.054	0.000087

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.58	0.4038	0.4741	0.2404	0.006902	0.044668	4.27E-07

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3	0.4266
13	0.4196
28	0.4076
39.7	0.4006
57.2	0.3916
79.5	0.3726
104.7	0.3526
135.8	0.3386
176.2	0.3276
216.6	0.3196

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0343	1.173

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 92 Location:(meter)

X: 16.45

Y: 13.95

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.122	0.381	0.016	0.00138

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.48	0.4415	0.4328	0.2122	0.083176	0.008609	0.000179

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.5	0.3954
8	0.3804
16.9	0.3604
25.1	0.3434
50.9	0.3094
67.8	0.2964
92.5	0.2844
123.9	0.2794
177.1	0.2774
231.4	0.2834

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.086	1.698

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 93 Location:(meter)

X: 16.27

Y: 14.45

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.086	0.429	0.159	0.000465

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.42	0.4642	0.4471	0.2284	0.017298	0.007998	0.000396

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
6.7	0.4443
12.7	0.4263
29.5	0.3993
52	0.3693
64.1	0.3503
90.6	0.3213
130.3	0.3003
179	0.2883
234.1	0.2873

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0473	1.35

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 94 Location:(meter)

X: 16.00

Y: 14.75

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.147	0.398	0.116	0.000522

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 (mm)	- ring & fm (mm)	K sat (cm/sec)
1.58	0.4038	0.3986	0.1622	0.056234	0.056234	0.000481

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.3	0.4239
6.5	0.4199
16.8	0.3809
26.7	0.3529
38.7	0.3229
55.7	0.2859
73.7	0.2689
96.7	0.2479
125	0.2359
165.4	0.2269
205.7	0.2209

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0515	1.656

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 95   Location:(meter)

X: 15.75

Y: 15.05

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.158	0.423	0.138	0.000117

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - (mm)	ring & fm (mm)	K sat (cm/sec)
1.6	0.3962	0.4027	0.194	0.066069	0.004197	0.000007

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.6	0.4078
12.5	0.3928
21.7	0.3818
36.4	0.3668
57.4	0.3428
80	0.3268
99.6	0.3148
130.7	0.3038
169.4	0.2968
209.4	0.2903

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0479	1.228

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 96 Location:(meter)

X: 15.5

Y: 15.25

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.109	0.446	0.176	0.000127

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.41	0.4679	0.4111	0.191	0.005308	0.003897	0.000024

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
3.5	0.366
13.9	0.3423
29.9	0.3186
58	0.2928
82.2	0.2768
106.6	0.2649
149	0.2556
213.5	0.2494

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.126	1.215

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 97 Location:(meter)

X: 15.3

Y: 15.48

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.099	0.439	0.045	0.000059

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.46	0.4491	0.4334	0.1814	0.005395	0.001	0.000743

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.2	0.3716
14.8	0.3416
29.2	0.3166
59.3	0.2806
84	0.2636
106.7	0.2516
149.3	0.2426
206.8	0.2376

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1653	1.208

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 98 Location:(meter)

X: 15.05

Y: 15.75

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.034	0.494	0.077	0.000102

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.72	0.3509	0.386	0.1944	0.050118	0.057543	0.000037

Hanging Column Data:

Psi	Theta
Imbibition	
8.3	0.3679
14.2	0.3379
19.6	0.3349
33	0.3299
63.4	0.3219
92.4	0.3149
126.5	0.3089
173.3	0.3049
216.9	0.2989

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1585	1.525

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 99   Location:(meter)
X: 14.75
Y: 16.12

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.044	0.369	0.3	0.000077

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.58	0.4038	0.4301	0.1808	0.008298	0.050118	0.000068

Hanging Column Data:

Psi	Theta
Imbibition	
3.5	0.4126
11.9	0.3946
21.6	0.3796
48.8	0.3466
73.8	0.3086
102.1	0.2886
123.1	0.2756
161.4	0.2656
217.6	0.2606

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0501	1.237

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 100 Location:(meter)

X: 14.3

Y: 16.5

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.023	0.333	0.368	0.000679

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.63	0.3849	0.3871	0.1855	0.050118	0.089125	0.000839

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
7	0.3372
13.3	0.3182
28.8	0.2912
55	0.2642
80	0.2532
105.6	0.2442
149.4	0.2382
216.9	0.2342

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1173	1.452

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 101 Location:(meter)

X: 13.95

Y: 16.87

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.066	0.461	0.192	0.000142

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.56	0.4113	0.3972	0.1809	0.014288	0.010495	0.000089

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.1	0.3914
14.5	0.3764
28.9	0.3524
55.6	0.3224
81.7	0.3034
107.7	0.2874
151.5	0.2764
218.7	0.2694

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0649	1.256

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 102 Location:(meter)

X: 13.69

Y: 17.25

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.087	0.398	0.083	0.000124

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.55	0.4151	0.4063	0.2089	0.005308	0.005199	0.000038

Hanging Column Data:

Psi	Theta
Imbibition	
4.5	0.4023
10.3	0.3768
19.5	0.3603
45.5	0.3418
69.3	0.3303
100.5	0.3193
123	0.3113
161.8	0.3043
216	0.3003

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1486	1.207

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 103 Location:(meter)

X: 13.4

Y: 17.55

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.089	0.46	0.242	0.000268

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.59	0.4	0.4156	0.1979	0.009099		0.000147

Hanging Column Data:

Psi	Theta
Imbibition	
4.5	0.4088
12.9	0.3878
25.6	0.3678
51.5	0.3303
80.2	0.2988
106.9	0.2828
126.4	0.2648
164.2	0.2588
220.5	0.2508

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0363	1.499

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 104 Location:(meter)

X: 13.125

Y: 17.95

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.089	0.46	0.179	0.000184

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring & fm (mm) (mm)	K sat (cm/sec)
1.48	0.4415	0.3939	0.1663	0.010495	0.000395

Hanging Column Data:

Psi	Theta
Imbibition	
4.4	0.4131
6.2	0.4086
9.5	0.4006
15.95	0.3856
49.5	0.3396
69.7	0.3141
96.9	0.2966
127.1	0.2866
167.7	0.2756
215.1	0.2711

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1125	1.157

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 105 Location:(meter)

X: 12.82

Y: 18.2

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.151	0.385	0.132	0.000197

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.5	0.434	0.3976	0.1739	0.01099	0.023014	0.000158

Hanging Column Data:

Psi	Theta
Imbibition	
4.55	0.422
6.7	0.412
10.3	0.4005
13.85	0.393
50.1	0.362
68.6	0.344
96.3	0.3255
125.5	0.314
165.2	0.3025
214.8	0.2955

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0805	1.147

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 106 Location:(meter)

X: 12.56

Y: 18.65

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.114	0.427	0.205	0.000228

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.47	0.1737	0.4082	0.4453	0.013489	0.004897	0.000472

Hanging Column Data:

Psi	Theta
Imbibition	
3.5	0.3961
12.8	0.3761
25.2	0.3531
51	0.3191
82.3	0.2871
105.2	0.2741
125.5	0.2651
162.5	0.2561
217.8	0.2521

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0500	1.424

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 107 Location:(meter)

X: 12.25

Y: 18.9

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.182	0.294	0.134	0.000064

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.48	0.4415		0.1883	0.063095	0.154881	0.000026

Hanging Column Data:

Psi	Theta
Imbibition	
7.65	0.3952
8.1	0.3887
13.25	0.3757
15.3	0.3577
51.6	0.3237
65.5	0.3137
94.7	0.3037
124.6	0.2977
163.1	0.2887
213	0.2847

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1078	1.479

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 108 Location:(meter)

X: 11.87

Y: 19.4

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.191	0.374	0.117	0.00028

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.58	0.4038	0.4092	0.1744	0.015135	0.011994	0.000381

Hanging Column Data:

Psi	Theta
Imbibition	
3.25	0.412
12.3	0.389
22.9	0.3705
47.5	0.337
72.1	0.307
103	0.284
125.9	0.271
163.9	0.261
211.5	0.256

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0433	1.366

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 109 Location:(meter)

X: 10.6

Y: 20.5

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.092	0.357	0.535	0.00037

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.58	0.4038	0.3709	0.1335	0.093325	0.050118	0.00186

Hanging Column Data:

Psi	Theta
Imbibition	
4.5	0.3122
13.4	0.2792
23	0.2582
45.9	0.2302
70.5	0.2062
100.8	0.1922
124.3	0.1842
163.3	0.1762
211.3	0.1722

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1092	1.290

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 110 Location:(meter)

X: 10.125

Y: 20.7

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.088	0.297	0.369	0.000998

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - (mm)	ring & fm (mm)	K sat (cm/sec)
1.61	0.3925	0.3501	0.1487	0.076736	0.123026	0.00355

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
4.5	0.2876
7.9	0.2697
18	0.2485
29.5	0.2253
52.7	0.1999
81.8	0.1803
113.8	0.1724
154.8	0.1671
207.3	0.165

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.1537	1.307

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 111 Location:(meter)

X: 9.85

Y: 21.25

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.057	0.394	0.299	0.00041

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.47	0.4453	0.3929	0.1616	0.079432	0.010814	0.0014

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
7	0.341
14.9	0.324
29.9	0.301
57.1	0.276
83.9	0.26
107.4	0.249
150.2	0.24
217.4	0.235

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.2288	1.192

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 112 Location:(meter)

X: 9.5

Y: 21.6

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.051	0.425	0.288	0.00026

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.45	0.4528	0.4173	0.167	0.007498	0.007194	0.000305

Hanging Column Data:

Psi	Theta
Imbibition	
5.1	0.4464
5.8	0.4414
9.8	0.4307
14.4	0.4175
46.6	0.3677
67.8	0.3402
98	0.3179
127.5	0.3067
166.4	0.2945
213.3	0.2894

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0458	1.46

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 113 Location:(meter)

X: 9.2

Y: 21.9

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.045	0.534	0.369	0.000329

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 - ring (mm)	& fm (mm)	K sat (cm/sec)
1.54	0.4189	0.4019	0.1934	0.007396	0.012502	0.000174

Hanging Column Data:

Psi (cm)	Theta (cc/cc)
Imbibition	
5.7	0.4002
13.1	0.3897
28.5	0.3697
55.2	0.3437
79.9	0.3232
106.5	0.3067
149.5	0.2947
217.5	0.2877

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0572	1.182

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 114 Location:(meter)

X: 8.8

Y: 22.15

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.045	0.355	0.212	0.00033

Laboratory Data:

B.D. (g/cc)	Nc (cc/cc)	SWC (cc/cc)	15-bar WC (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
1.47	0.4453	0.3674	0.1514	0.063095	0.074131	0.000646

Hanging Column Data:

Psi	Theta
Imbibition	
4	0.3893
13.1	0.3563
23.9	0.3343
46.7	0.2853
71	0.2663
101.3	0.2558
125.5	0.2483
165	0.2433
214.7	0.2383

van Genuchten analysis:

Alpha (1/cm)	N (--)
0.0656	1.742

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 115 Location:(meter)

X: 8.63

Y: 22.65

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.059	0.473	0.299	0.00025

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
					0.03981	

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 116   Location:(meter)

X: 7.93

Y: 23.35

Field Data:

****

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.043	0.5	0.249	0.000643

Laboratory Data:

****

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 (mm)	-ring & fm (mm)	K sat (cm/sec)
					0.005997	

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 117 Location:(meter)

X: 7.25

Y: 24.05

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.138	0.347	0.273	0.000788

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 (mm)	-ring & fm (mm)	K sat (cm/sec)
					0.019815	

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 118 Location:(meter)

X: 6.4

Y: 24.6

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.06	0.402	0.316	0.000546

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 -ring (mm)	& fm (mm)	K sat (cm/sec)
					0.006698	

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

Disc Permeameter Measurement Hydrologic Properties

D.P.#: 119 Location:(meter)

X: 5.25

Y: 25.45

Field Data:

Initial Moisture content: (cc/cc)	Final Moisture Content (cc/cc)	Sorptivity (cm/sqrt(min))	Hyd. Cond. (1.3 cm tension) (cm/sec)
0.142	0.447	0.325	0.000283

Laboratory Data:

B.D. (g/cc)	15-b WC (cc/cc)	SWC (cc/cc)	Nc (cc/cc)	d10 (mm)	-ring & fm (mm)	K sat (cm/sec)
					0.014655	

Hanging Column Data:

Psi	Theta

No Ring collected or evaluated in the laboratory

APPENDIX E: THERMOCOUPLE PSYCHROMETER MEASUREMENTS

Three fine to very fine textured 100cc soil core samples were tested in a thermocouple psychrometer (SC-10a, Decagon Devices Inc., Pullman, Wa.) for soil-water pressure after two weeks residence at 15 bars in a pressure plate apparatus. The assumption of equilibrium for the samples at 15 bars after approximately two weeks in the pressure plate was tested. Less than 0.5 ml water had been eluted from the pressure plate apparatus, containing 12 soil cores, over the last 24 hour period suggesting near equilibrium conditions existed.

THEORY

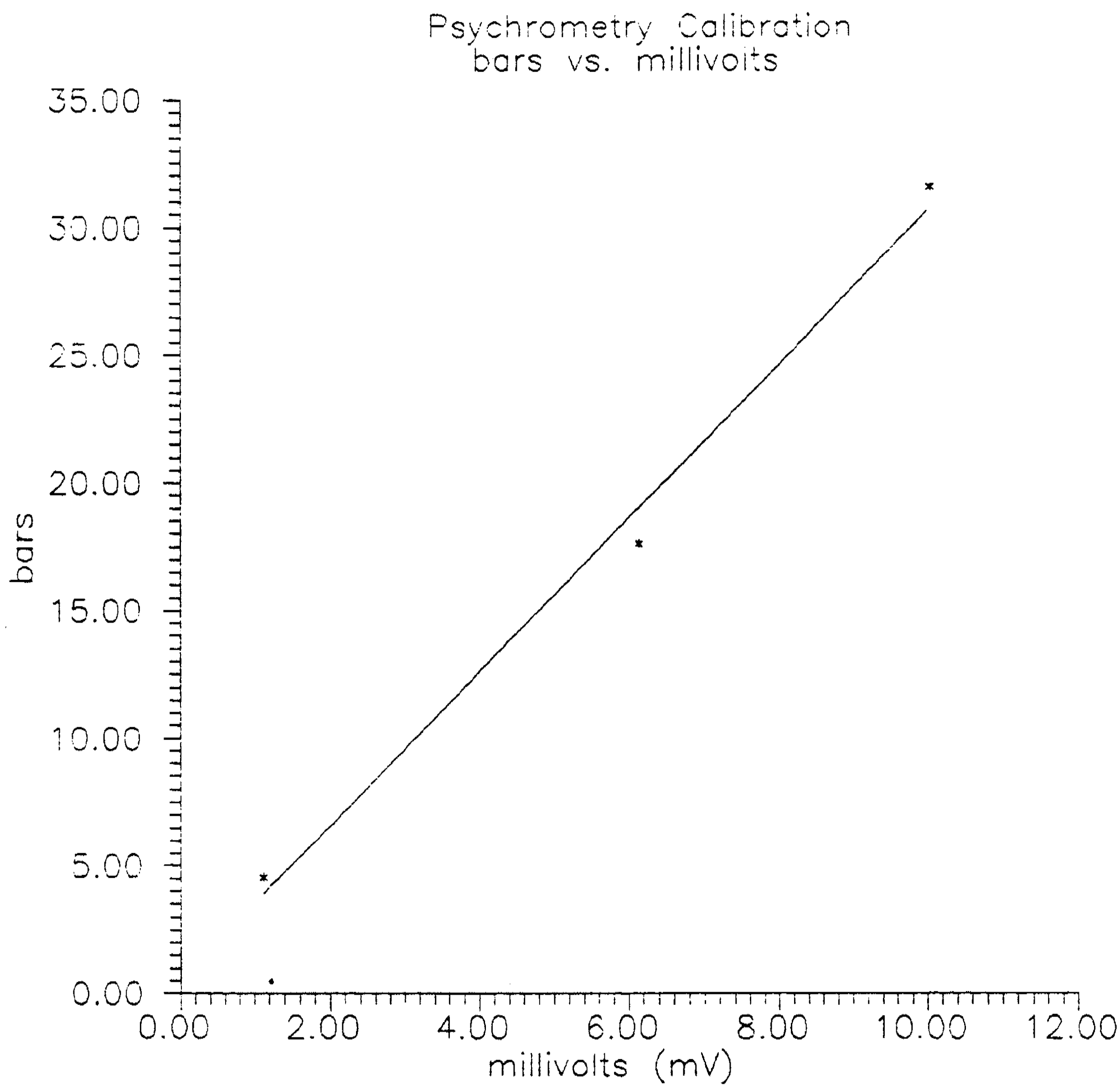
Under equilibrium conditions, the soil moisture potential is equal to the vapor potential in ambient air (Hillel, 1980a) Further, assuming thermal equilibrium and neglecting gravity effects, the vapor potential is equal to the sum of the matric and osmotic potentials. Therefore, it is possible to make a realistic estimate of a soil sample's tension status from an equilibrium measurement of the vapor potential of the atmosphere above the sample.

The thermocouple psychrometer estimates the vapor potential by measuring the equilibrium relative humidity of the atmosphere above a soil sample. This is accomplished by determining the difference between wet and dry bulb temperatures (Hillel, 1980a). The relative humidity is recorded as a microvolt value which is then related to the sample tension by a laboratory calibration. This study used three $MgCl_2$ solutions of varying concentration to determine a relationship of microvolts to bars pressure (fig.1). The calibration has an r^2 of just greater than 0.99. The SC-10a Thermocouple Psychrometer Operator's Manual and Methods of Soil Analysis (1986) contain complete instructions for calibration and operation of the instrument.

OPERATION

The SC-10a contains 10 sample chambers for measurement of soil samples in stainless steel sample cups. The chambers are numbered 0 thru 9. Normally, Chamber 0 will contain a sample cup filled to the top of the insert with distilled water. Chambers 1 thru 3 hold calibrating solutions, while 4 thru 9 contain the soil samples of interest. Chambers 1 thru 9 should only be filled to the halfway point (approximately .5 cm in depth) with solutions or soil. This protects the ceramic bead at the tip of the psychrometer from damage and allows a meaningful measurement of vapor potential.

After loading the samples in the SC-10a, wait approximately one-half hour for equilibrium of temperature and water in the sample chamber to be achieved. Start the procedure by first measuring the calibration solutions, then proceed to the samples of interest and, finally, return to the calibration solutions.


Psychrometry Calibration
bars vs. millivolts
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
bars
0.00
2.00
4.00
6.00
8.00
10.00
12.00
millivolts (mV)

PROCEDURE

1) Rotate the thermocouple to chamber 0. Immerse the ceramic bead on the thermocouple in the distilled water. This is accomplished by raising the sample container by means of a lever. The lever must click into place for reliable measurements.

2) Lower the sample container, rotate the thermocouple to the first measurement chamber and raise the sample container. Take readings of microvolts with time at 15 second intervals for at least 5 minutes (fig.2).

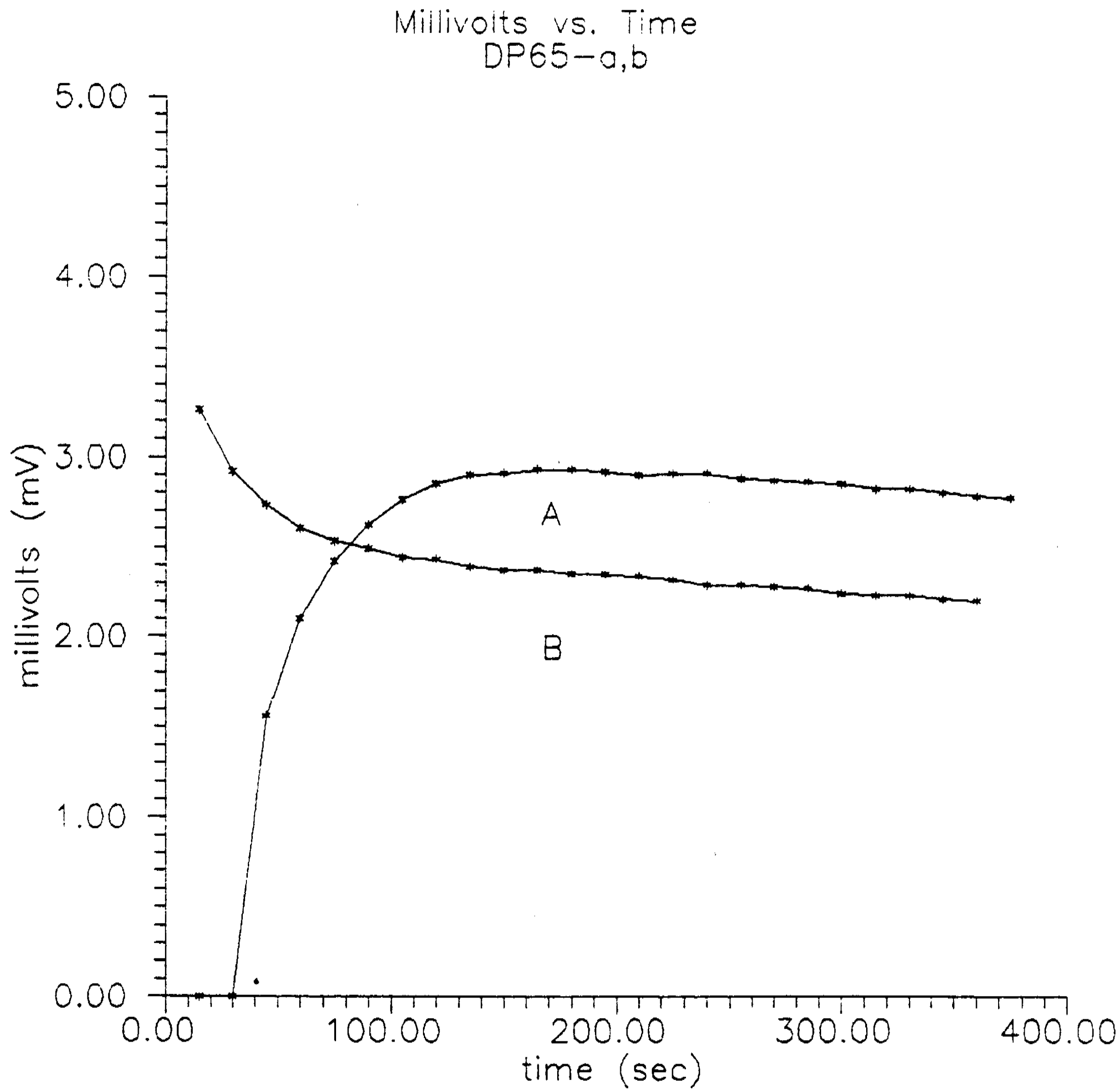
3) Before each measurement, re-immerse the ceramic bead in the distilled water.

4) Use the $MgCl_2$ solution readings to calculate a linear regression for the microvolts to bars pressure relationship (fig.).

5) From the linear regression, determine the soil-water tension of the soil core samples.

RESULTS

Duplicate samples taken from opposite ends of the soil cores were tested in the psychrometer. The average of the two was assumed representative of the of the soil-water tension for each soil core. Measured values and averages are tabulated (in bars):


Millivolts vs. Time
DP65-a,b
5.00
4.00
3.00
2.00
1.00
0.00
millivolts (mV)
A
B
0.00
100.00
200.00
300.00
400.00
time (sec)

	DP15	DP65	DP79	STD. ERR.
A.	8.83	7.11	7.78	1.76
B.	7.17	3.35	4.46	1.76
AVG.	8.00	5.23	6.12	1.76

The average values ranged from 5.23 to 8.00 bars, much lower than the assumed 15 bar value. As very little water was being eluted from the pressure plate apparatus, it is assumed the moisture content difference between 5 and 15 bars is slight. Coarser textured samples should be much closer to 15 bars. Still, since the measured values are so much lower than the assumed 15 bars, these assumptions may be invalid. Therefore, The 15 bar pressure plate values are only used as initial guesses in van Genuchten's analysis and allowed to vary during a run. It is apparent that residence times of greater than 1 month may be needed to assure 15 bar equilibrium of fine textures soils in the pressure plate.

APPENDIX **F:** A & B: Grain size data

Appendix **A:** Grain size from sieve and hydrometer analysis
100 cc soil core samples

SAMPLE #	d10 (mm)	d30 (mm)	d50 (mm)	d60 (mm)	d90 (mm)	Cu (--)	Cc (--)
DP1	0.015995	0.095499	0.194984	0.316227		19.770	1.803
DP2	0.066069	0.125892	0.199526	0.251188	0.651138	3.802	0.955
DP3							
DP4	0.020183	0.081283	0.151356	0.199526	0.812830	9.886	1.641
DP5	0.007498	0.107151	0.194984	0.269153	1.047128	35.892	5.689
DP6	0.057543	0.114815	0.204173	0.301995	1.122018	5.248	0.759
DP7	0.007498	0.114815	0.199526	0.269153	1.023292	35.892	6.531
DP8	0.008810	0.114815	0.199526	0.275422	1.023292	31.261	5.433
DP9	0.008912	0.083176	0.177827	0.257039	1.047128	28.840	3.020
DP10							
DP11	0.009506	0.089125	0.162181	0.234422	1	24.660	3.565
DP12	0.015417	0.125892	0.223872	0.295120	0.933254	19.143	3.483
DP13	0.074131	0.199526	0.407380	0.660693	3.630780	8.913	0.813
DP14	0.011803	0.107151	0.213796	0.316227	1	26.792	3.076
DP15	0.012502	0.141253	0.263026	0.380189	1.202264	30.409	4.198
DP16	0.016519	0.083176	0.123026	0.144543	0.323593	8.750	2.897
DP17	0.012416		0.120226	0.158489	0.794328	12.764	
DP18	0.007079	0.091201	0.199526	0.316227	1.174897	44.668	3.715
DP19	0.066069	0.194984	0.501187	0.831763	6.025595	12.589	0.692
DP20	0.056234	0.128824	0.234422	0.309029	1	5.495	0.955
DP21							
DP22							
DP23							
DP24							
DP25	0.013001	0.102329	0.169824	0.208929	0.794328	16.069	3.855
DP26	0.006998	0.089125	0.165958	0.234422	1.071519	33.497	4.842
DP27	0.050118	0.154881	0.346736	0.524807	2.238721	10.471	0.912
DP28	0.005997	0.107151	0.208929	0.316227	1.174897	52.723	6.053
DP29	0.022803	0.104712	0.199526	0.288403	1	12.647	1.667
DP30	0.045394	0.117489	0.208929	0.288403	0.977237	6.353	1.054
DP31	0.008203	0.102329	0.181970	0.257039	1.737800	31.333	4.966
DP32	0.007194	0.1	0.199526	0.288403	1.122018	40.087	4.819
DP33	0.023496	0.093325	0.141253	0.173780	0.891250	7.396	2.133
DP34	0.095499	0.363078	2.951209	4.168693		43.652	0.331
DP35							
DP36							
DP37							
DP38							
DP39	0.426579	0.912010	1.584893	1.995262	6.165950	4.677	0.977
DP40							

d10-d90 = % particle size finer by weight than the size indicated
Cu = coefficient of uniformity (d60/d10)
Cc = coefficient of curvature ((d30^2)/(d60*d10))

Appendix **A:** Grain size from sieve and hydrometer analysis
100 cc soil core samples

SAMPLE #	d10 (mm)	d30 (mm)	d50 (mm)	d60 (mm)	d90 (mm)	Cu (--)	Cc (--)
DP41	0.015488	0.112201	0.194984	0.251188	1.071519	16.218	3.236
DP42	0.251188	0.645654	1.258925	1.659586	4.570881	6.607	1.000
DP43							
DP44	0.104712	0.269153	0.501187	0.707945	1.202264	6.761	0.977
DP45	0.079432	0.169824	0.275422	0.316227	0.851138	3.981	1.148
DP46	0.013396	0.112201	0.173780	0.213796	0.630957	15.959	4.395
DP47	0.044668	0.134896	0.251188	0.331131	1	7.413	1.230
DP48	0.125892	0.426579	0.741310	0.977237	3.311311	7.762	1.479
DP49	0.050118	0.120226	0.190546	0.251188	0.707945	5.012	1.148
DP50	0.018323	0.125892	0.204173	0.281838	1.071519	15.382	3.069
DP51	0.035481	0.131825	0.234422	0.301995	0.812830	8.511	1.622
DP52	0.020892	0.1	0.204173	0.316227	1.584893	15.136	1.514
DP53	0.123026	0.363078	0.794328	1.202264		9.772	0.891
DP54	0.147910	0.630957	1.819700	2.630267		17.783	1.023
DP55	0.089125	0.169824	0.257039	0.316227	1.096478	3.548	1.023
DP56	0.044668	0.141253	0.251188	0.316227	1	7.079	1.413
DP57	0.064565	0.128824	0.229086	0.309029	1.174897	4.786	0.832
DP58	0.074131	0.165958	0.323593	0.446683	1.698243	6.026	0.832
DP59	0.1	0.199526	0.389045	0.549540	2.089296	5.495	0.724
DP60	0.114815	0.295120	0.794328	1.548816		13.490	0.490
DP61	0.070794	0.158489	0.316227	0.467735	2.344228	6.607	0.759
DP62	0.107151	0.245470	0.380189	0.512861	3.235936	4.786	1.096
DP63	0.074131	0.162181	0.338844	0.501187		6.761	0.708
DP64	0.044668	0.125892	0.223872	0.316227	1.548816	7.079	1.122
DP65	0.072443	0.190546	0.407380	0.776247		10.715	0.646
DP66	0.075857	0.165958	0.323593	0.478630	6.309573	6.310	0.759
DP67	0.079432	0.162181	0.363078	0.501187	1.819700	6.310	0.661
DP68	0.079432	0.218776	0.537031	0.891250		11.220	0.676
DP69	0.011994	0.123026	0.204173	0.281838	1.318256	23.496	4.477
DP70	0.016982	0.131825	0.309029	0.446683	1.659586	26.303	2.291
DP71	0.007014	0.107151	0.177827	0.251188	1	35.810	6.516
DP72	0.085113	0.199526	0.389045	0.602559	5.754399	7.079	0.776
DP73	0.063095	0.173780	0.407380	0.691830	4.168693	10.965	0.692
DP74	0.079432	0.213796	0.870963	1.584893		19.953	0.363
DP75	0.141253	0.467735	0.977237	1.513561		10.715	1.023
DP76	0.019010	0.1	0.162181	0.208929	1.122018	10.990	2.518
DP77	0.010914	0.093325	0.158489	0.199526	0.891250	18.281	3.999
DP78	0.013995	0.107151	0.169824	0.204173	1.412537	14.588	4.018
DP79	0.010990						
DP80	0.024210	0.095499	0.162181	0.218776	1.174897	9.036	1.722
DP81	0.029991	0.123026	0.199526	0.301995	1.412537	10.069	1.671
DP82	0.044668	0.131825	0.251188	0.331131	1.096478	7.413	1.175
DP83	0.019010	0.109647	0.181970	0.239883	1.174897	12.618	2.636
DP84	0.050118	0.125892	0.181970	0.316227	1.778279	6.310	1.000
DP85	0.1	0.199526	0.295120	0.338844	1.023292	3.388	1.175
DP86	0.056234	0.128824	0.213796	0.309029	1.318256	5.495	0.955
DP87	0.028379	0.177827	0.363078	0.524807	1.949844	18.493	2.123
DP88	0.039810	0.128824	0.186208	0.323593	1.288249	8.128	1.288
DP89	0.006902	0.131825	0.269153	0.380189	1.258925	55.081	6.622

Appendix **A:** Grain size from sieve and hydrometer analysis
100 cc soil core samples

SAMPLE #	d10 (mm)	d30 (mm)	d50 (mm)	d60 (mm)	d90 (mm)	Cu (--)	Cc (--)
DP90	0.005997	0.104712	0.234422	0.398107	1.621810	66.374	4.592
DP91	0.006902	0.1	0.234422	0.436515	1.778279	63.241	3.319
DP92	0.083176	0.245470	0.575439	0.912010	4.168693	10.965	0.794
DP93	0.017298	0.123026	0.239883	0.363078	1.819700	20.989	2.410
DP94	0.056234	0.158489	0.263026	0.323593	1.047128	5.754	1.380
DP95	0.066069	0.158489	0.398107	0.831763	4.786300	12.589	0.457
DP96	0.005308	0.117489	0.218776	0.323593	1.202264	60.954	8.035
DP97	0.005395	0.138038	0.234422	0.309029	1.096478	57.280	11.429
DP98	0.050118	0.138038	0.251188	0.334965	1.584893	6.683	1.135
DP99	0.008298	0.125892	0.223872	0.298538	1.047128	35.975	6.397
DP100	0.050118	0.162181	0.354813	0.524807	2.089296	10.471	1.000
DP101	0.014288	0.134896	0.269153	0.398107	1.584893	27.861	3.199
DP102	0.005308	0.1	0.169824	0.223872	0.841395	42.170	8.414
DP103	0.009099	0.125892	0.218776	0.295120	1.047128	32.434	5.902
DP104	0.010495	0.114815	0.190546	0.263026	1	25.061	4.775
DP105	0.010990	0.125892	0.239883	0.363078	1.396368	33.037	3.972
DP106	0.013489	0.125892	0.218776	0.319889	1.428893	23.714	3.673
DP107	0.063095	0.158489	0.323593	0.501187	4.265795	7.943	0.794
DP108	0.015135	0.125892	0.257039	0.384591	1.698243	25.410	2.723
DP109	0.093325	0.254097	0.724435	1.180320		12.647	0.586
DP110	0.076736	0.229086	0.512861	0.794328	3.162277	10.351	0.861
DP111	0.079432	0.251188	0.660693	1.071519	5.888436	13.490	0.741
DP112	0.007498	0.108392	0.186208	0.275422	1.202264	36.728	5.689
DP113	0.007396	0.101157	0.229086	0.380189	1.513561	51.404	3.639
DP114	0.063095	0.165958	0.323593	0.446683	1.412537	7.079	0.977

Appendix **B**: Grain size from sieve and hydrometer analysis
final moisture content grab samples

SAMPLE #	d10 (mm)	d30 (mm)	d50 (mm)	d60 (mm)	d90 (mm)	Cu (--)	Cc (--)
DP1-0n							
DP2-0n							
DP3-0i		0.091201	0.154881	0.199526	0.691830		
DP4-0i		0.107151	0.218776	0.301995	0.933254		
DP5-0n	0.034994	0.102329	0.190546	0.275422	0.891250	7.870	1.086
DP6-0n	0.021183	0.147910	0.245470	0.346736	1.096478	16.368	2.979
DP7-0n							
DP8-0n							
DP9-0n							
DP10-0n							
DP11-0n							
DP12-0n							
DP13-0n							
DP14-0n	0.014996	0.104712	0.269153	0.478630	4.677351	31.915	1.528
DP14-0n	0.213796	1.122018	4.466835				
DP15-0n							
DP16-0n							
DP17-0n							
DP18-0n							
DP19-0n							
DP20-0n	0.041686	0.074989	0.151356	0.213796	0.891250	5.129	0.631
DP21-0n							
DP22-0i	0.025003		0.114815	0.154881	0.524807	6.194	
DP23-0i	0.066069	0.120226	0.199526	0.309029	1.096478	4.677	0.708
DP24-0n							
DP25-0n							
DP26-0n							
DP27-0n							
DP28-0i	0.010495	0.095499	0.173780	0.234422	0.831763	22.336	3.707
DP29-0n							
DP30-0n							
DP31-0i	0.125892	0.338844	0.776247	1.995262	6.165950	15.849	0.457
DP32-0n							
DP33-0n							
DP34-0n							
DP35-0i	0.281838	0.933254	2.754228	3.981071		14.125	0.776
DP36-0n	0.323593	0.776247	1.445439	1.905460	5.011872	5.888	0.977
DP37-0nA	0.288403	1.479108	3.801893	5.128613		17.783	1.479
DP38-0nB	2.238721	3.630780	5.623413				
DP39-0n	0.251188	0.575439	0.977237	1.348962	5.011872	5.370	0.977
DP39-0nA	0.251188	0.457088	0.794328	1.096478	5.248074	4.365	0.759
DP40-0i	0.389045	2.454708	4.365158	6.165950		15.849	2.512
DP40-0n	0.263026	2.511886	4.466835	6.025595		22.909	3.981
DP41-0n							
DP42-0i	0.275422	0.660693	1.258925	1.737800	5.495408	6.310	0.912
DP42-0nA	0.186208	0.407380	0.691830	0.870963	2.818382	4.677	1.023
DP43-0n	0.194984	0.660693	2.754228	4.466835		22.909	0.501
DP43-0i	0.162181	0.501187	1.096478	1.584893	5.248074	9.772	0.977
DP44-0n	0.025003	0.079432	0.151356	0.208929	0.724435	8.356	1.208
DP45-0n	0.010092	0.125892	0.234422	0.316227	1	31.333	4.966
DP46-0n	0.017988	0.141253	0.239883	0.288403	0.691830	16.032	3.846
DP47-0n	0.063095	0.138038	0.251188	0.346736	0.933254	5.495	0.871
DP48-0n	0.013212	0.114815	0.223872	0.309029	0.933254	23.388	3.228
DP49-0n	0.050118	0.131825	0.234422	0.309029	0.954992	6.166	1.122

Appendix **B:** Grain size from sieve and hydrometer analysis
final moisture content grab samples

SAMPLE #	d10 (mm)	d30 (mm)	d50 (mm)	d60 (mm)	d90 (mm)	Cu (--)	Cc (--)
DP50-0n	0.030831	0.177627	0.354813	0.501187	1.819700	16.255	2.046
DP51-0n	0.050118	0.181970	0.316227	0.416869	1.479108	8.318	1.585
DP52-0n	0.026791	0.173780	0.316227	0.426579	1.698243	15.922	2.642
DP53-0n	0.070794	0.213796	0.398107	0.549540	1.737800	7.762	1.175
DP54-0n	0.039810	0.177827	0.389045	0.512861	1.995262	12.882	1.549
DP55-0n	0.131825	0.346736	0.676082	0.933254	6.309573	7.079	0.977
DP56-0n	0.074989	0.218776	0.457088	0.691830	5.011872	9.226	0.923
DP57-0n	0.089125	0.275422	0.446683	0.794328	3.548133	8.913	1.072
DP58-0n	0.079432	0.223872	0.422668	0.630957	2.691534	7.943	1.000
DP59-0n	0.050118	0.162181	0.323593	0.467735	2.137962	9.333	1.122
DP60-0n	0.009506	0.158489	0.354813	0.562341	3.235936	59.156	4.699
DP61-0n	0.012502	0.134896	0.288403	0.416869	1.819700	33.343	3.491
DP62-0n	0.039810	0.144543	0.269153	0.380189	1.621810	9.550	1.380
DP63-0n	0.010990	0.141253	0.269153	0.380189	1.584893	34.594	4.775
DP64-0n	0.050118	0.125892	0.213796	0.323593	1.548816	6.457	0.977
DP65-0n	0.034994	0.194984	0.501187	0.831763		23.768	1.306
DP66-0n	0.050118	0.151356	0.301995	0.416869	2.187761	8.318	1.096
DP67-0n	0.025003	0.169824	0.389045	0.616595	6.165950	24.660	1.871
DP68-0n	0.005997	0.123026	0.223872	0.316227	1.348962	52.723	7.980
DP69-0n	0.005807	0.120226	0.190546	0.251188	1	43.251	9.908
DP70-0n							
DP71-0n		13.80384	0.177827	0.263026	1.445439		
DP72-0n	0.005997	0.125892	0.239883	0.354813	1.380384	59.156	7.447
DP73-0n	0.013995	0.112201	0.199526	0.309029	1.584893	22.080	2.911
DP74-0n	0.104712	0.602559	1.778279	2.570395		24.547	1.349
DP75-0n	0.079432	0.245470	0.645654	1		12.589	0.759
DP76-0n		0.107151	0.173780	0.208929	1		
DP77-0n	0.039810	0.125892	0.194984	0.239883	0.676082	6.026	1.660
DP78-0n	0.079432	0.144543	0.234422	0.301995	0.912010	3.802	0.871
DP79-0n	0.010209	0.091201	0.162181	0.213796	1.174897	20.941	3.811
DP80-0n	0.022387	0.079432	0.123026	0.151356	0.724435	6.761	1.862
DP81-0n	0.01	0.125892	0.208929	0.309029	0.912010	30.903	5.129
DP82-0n	0.023014	0.120226	0.177827	0.338844	1.862087	14.723	1.854
DP83-0n	0.022908	0.085113	0.138038	0.186208	0.741310	8.128	1.698
DP84-0n	0.011803	0.087096	0.147910	0.194984	0.831763	16.520	3.296
DP85-0n	0.015995	0.117489	0.190546	0.239883	0.912010	14.997	3.597
DP86-0n	0.017021	0.112201	0.186208	0.245470	1	14.421	3.013
DP87-0n	0.016218	0.109647	0.181970	0.251188	1.023292	15.488	2.951
DP88-0n	0.024099	0.1	0.173780	0.239883	1.258925	9.954	1.730
DP89-0n	0.010990	0.125892	0.245470	0.346736	1.174897	31.550	4.159
DP90-0n	0.019998	0.083176	0.190546	0.316227	1.412537	15.812	1.094
DP91-0n	0.044668	0.141253	0.316227	0.501187	1.995262	11.220	0.891
DP92-0n	0.008609	0.131825	0.251188	0.363078	1.148153	42.170	5.559
DP93-0n	0.007998	0.109647	0.165958	0.218776	1.071519	27.353	6.871
DP94-0n	0.056234	0.123026	0.218776	0.281838	1	5.012	0.955
DP95-0n	0.004197	0.123026	0.301995	0.501187	1.698243	119.399	7.194
DP96-0n	0.002897	0.087096	0.169824	0.251188	1.122018	86.696	10.423
DP97-0n	0.001	0.1	0.194984	0.275422	1.071519	275.423	36.308
DP98-0n	0.057543	0.120226	0.213796	0.323593	1.412537	5.623	0.776
DP99-0n	0.050118	0.158489	0.331131	0.524807	2.630267	10.471	0.955

Appendix B: Grain size from sieve and hydrometer analysis
final moisture content grab samples

SAMPLE #	d10 (mm)	d30 (mm)	d50 (mm)	d60 (mm)	d90 (mm)	Cu (--)	Cc (--)
DP100-0n	0.089125	0.257039	0.630957	0.891250	5.623413	10.000	0.832
DP101-0n	0.010495	0.087096	0.173780	0.251188	0.954992	23.933	2.877
DP102-0n	0.005199	0.112201	0.208929	0.316227	1.380384	60.814	7.656
DP103-0n		0.083176	0.141253	0.181970	0.676082		
DP104-0n		0.087096	0.177827	0.281838	1.174897		
DP105-0n	0.023014	0.097723	0.177827	0.251188	1	10.914	1.652
DP106-0n	0.004897	0.089125	0.158489	0.213796	0.870963	43.652	7.586
DP107-0n	0.154881	0.501187	1.096478	1.584893	4.677351	10.233	1.023
DP108-0n	0.011994	0.107151	0.199526	0.316227	1.202264	26.363	3.027
DP109-0n	0.050118	0.158489	0.281838	0.371535	1	7.413	1.349
DP110-0n	0.123026	0.398107	0.912010	1.380384		11.220	0.933
DP111-0n	0.010814	0.141253	0.301995	0.416869	1.380384	38.548	4.426
DP112-0n	0.007194	0.104712	0.199526	0.316227	1.258925	43.954	4.819
DP113-0n	0.012502	0.087096	0.173780	0.257039	1.096478	20.559	2.360
DP114-0n	0.074131	0.223872	0.512861	0.758577	3.981071	10.233	0.891
DP115-0n	0.039810	0.147910	0.301995	0.407380	1.584893	10.233	1.349
DP116-0n	0.005997	0.081283	0.154881	0.213796	1.096478	35.645	5.152
DP117-0n	0.019815	0.107151	0.190546	0.275422	0.977237	13.900	2.104
DP118-0n	0.006698	0.093325	0.199526	0.316227	1.122018	47.206	4.111
DP119-0n	0.014655	0.104712	0.158489	0.199526	0.912010	13.614	3.750