

Determination of Groundwater Recharge
for Sites in the Great Bend Prairie Region
of Kansas

by

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ABSTRACT

Data from sites representing differing soil types in the Great Bend Prairie region of Kansas were used to calculate groundwater recharge using both Richard's equation and a water balance equation. Each site contains a neutron probe access tube for measuring soil moisture, a water table level recorder, deep piezometers, a precipitation gauge and tensiometers. Local meteorological data was used to calculate evapotranspiration. The data base allows calculation of recharge for up to 4 years per site.

To calculate the unsaturated hydraulic conductivities (K's) needed for using Darcy's equation for unsaturated flow, internal drainage experiments were conducted *in situ*. The moisture and suction head at specified depths were measured while the soil drained. Least squares curve fitting was used to fit and smooth the data, provide coefficients for the fitted models and determine the fitting errors. K was calculated as a function of soil moisture and depth from the resulting coefficients. Fluxes were then obtained from the data base and integrated with respect to time to obtain recharge.

The water balance equation used to obtain recharge equalled the amount of precipitation less the change in soil moisture storage and evapotranspiration. The time intervals used in the water balance equation greatly affected the accuracy of the calculated recharge. Time intervals determined from drainage experiment data were used to help reduce the error caused by arbitrary measurement times. The Darcian flux method worked best for sites of low permeability whereas the water balance method was found to be a better approach for sites of high permeability.

INTRODUCTION

Regulation of groundwater pumpage is a necessary measure for protecting this vital natural resource. The State of Kansas established five Groundwater Management Districts (GMD's) to help control the general use of groundwater. This is no easy task since most of the water used is for irrigation and is spread over the entire region of western Kansas. The ideal regulatory scheme would have the amount of water pumped out balanced by the amount of groundwater recharge. The objective of this thesis is to define the amount of natural groundwater recharge due to infiltration so that the administrators of GMD #5 (Figure 1) can use the information to help regulate groundwater usage in their district. The recharge estimates may then help guide the regulation of groundwater pumping in the study area.

Ideally the study would include all the major natural soil suites in the area, frequent collection of data and installations with enough depth of measurement and spatial distribution (within a site) to obtain quality parameters for estimating recharge. Approximations of data posed problems for some recharge sites because these ideals were not met.

This study was preceded by a successful pilot study in which recharge was calculated for 2 sites over a 19-month period. One of the pilot sites, like the later recharge sites, overlies the Great Bend aquifer of south-central Kansas (part of the High Plains aquifer, Figure 2). The surface geology of the area consists predominantly of unconsolidated Holocene and Pleistocene fluvial deposits (averaging 30 meters thick) overlying Permian or Cretaceous bedrock and underlying thinner eolian deposits at the surface. Large sand dune deposits underlain by discontinuous clay lenses is typical of the near surface conditions in the area. The normal annual precipitation is about 74 cm, varying greatly from year to year (Sophocleous and Perry, 1984).

Figure 1: Location of Study Area

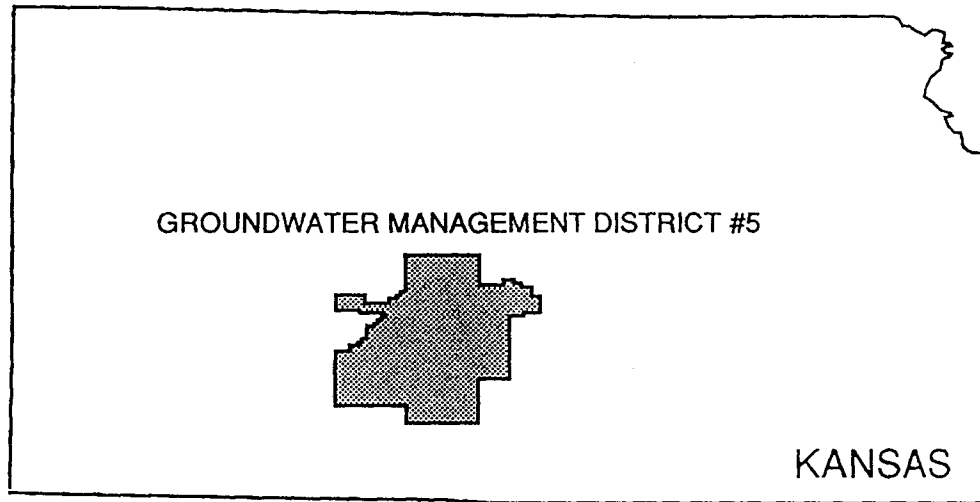
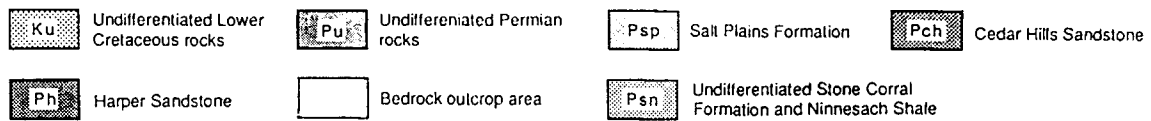
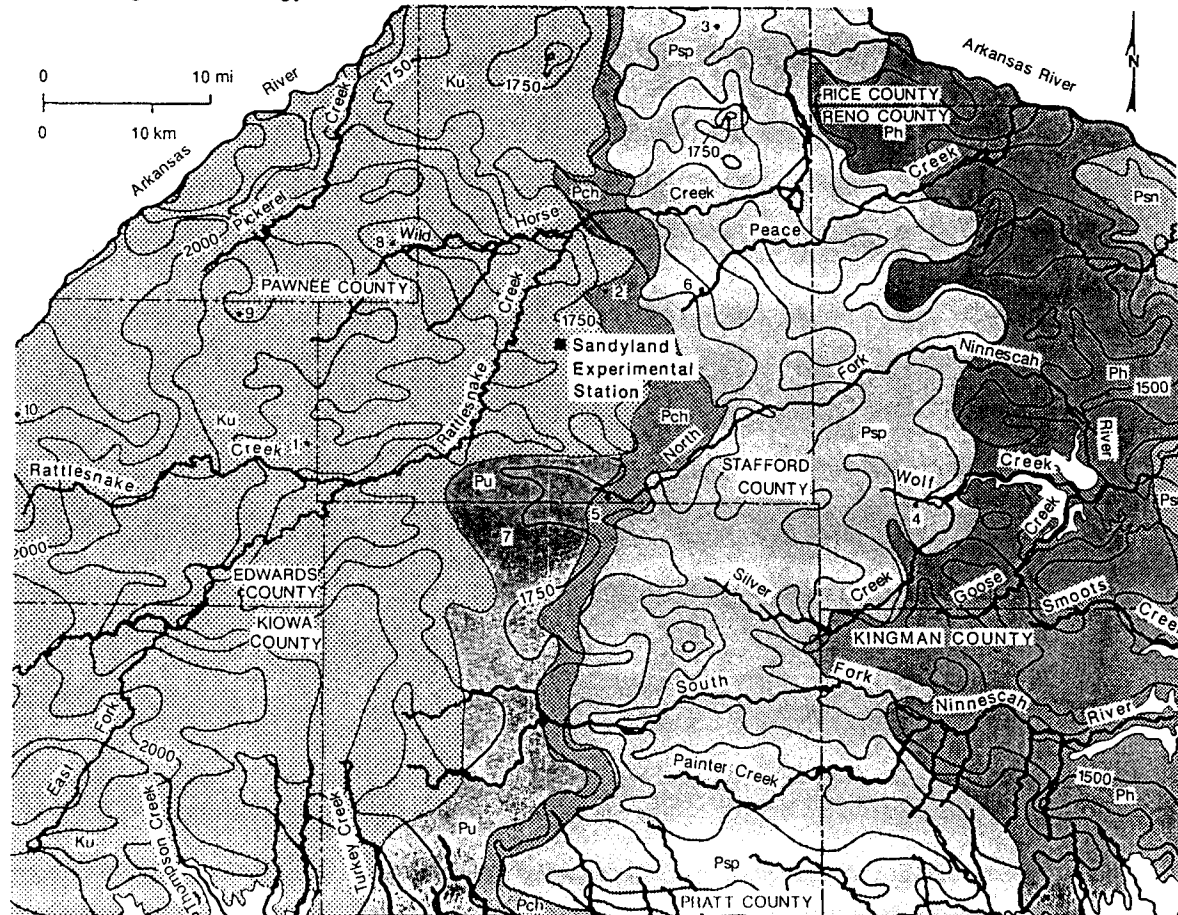


Figure 2: Geology and Bedrock Elevation, Great Bend Prairie, South Central Kansas



In the pilot study, groundwater recharge was calculated using the Darcian approach. The hydraulic conductivity parameter was determined in the laboratory using disturbed core samples compacted to their 'original' bulk densities. The hanging column method and the pressure plate method were used to determine the water characteristic functions for each sample depth. Five different models were selected from the literature to calculate the hydraulic conductivity as a function of the water characteristic curve input (Sophocleous and Perry, 1984). A gradient was determined using the periodic moisture measurements and the water characteristic functions. Hysteresis was not analyzed in detail and the water characteristic functions used were 'average' curves drawn from site-derived data. Darcy's law was then employed to calculate fluxes at each measurement time. Then an estimate of recharge was made by multiplying the flux by the time interval of measurement.

The pilot study concluded that soil layering in the unsaturated zone plays an important role in recharge. The large disparity in recharge between the two pilot sites was caused mainly by the greater thickness of the unsaturated zone in the site that obtained less recharge. The combination of water characteristic curves and saturated conductivities were found to be a simple way of predicting the unsaturated hydraulic conductivity functions.

The 10 recharge sites monitored are all located in GMD #5 (Figure 3). These sites were modelled after the pilot study sites (Sophocleous and Perry, 1984), and ordinarily contain the instrumentation shown in Figure 4. The analog instruments used to record precipitation and changes in water level will be useful for future recharge studies in that more precision can be used.

The sites were set up in characteristic soils of the district to roughly generalize the results of the calculations to the whole of the district. The soil profiles were

Figure 3: Location of the Recharge Sites in GWMD #5

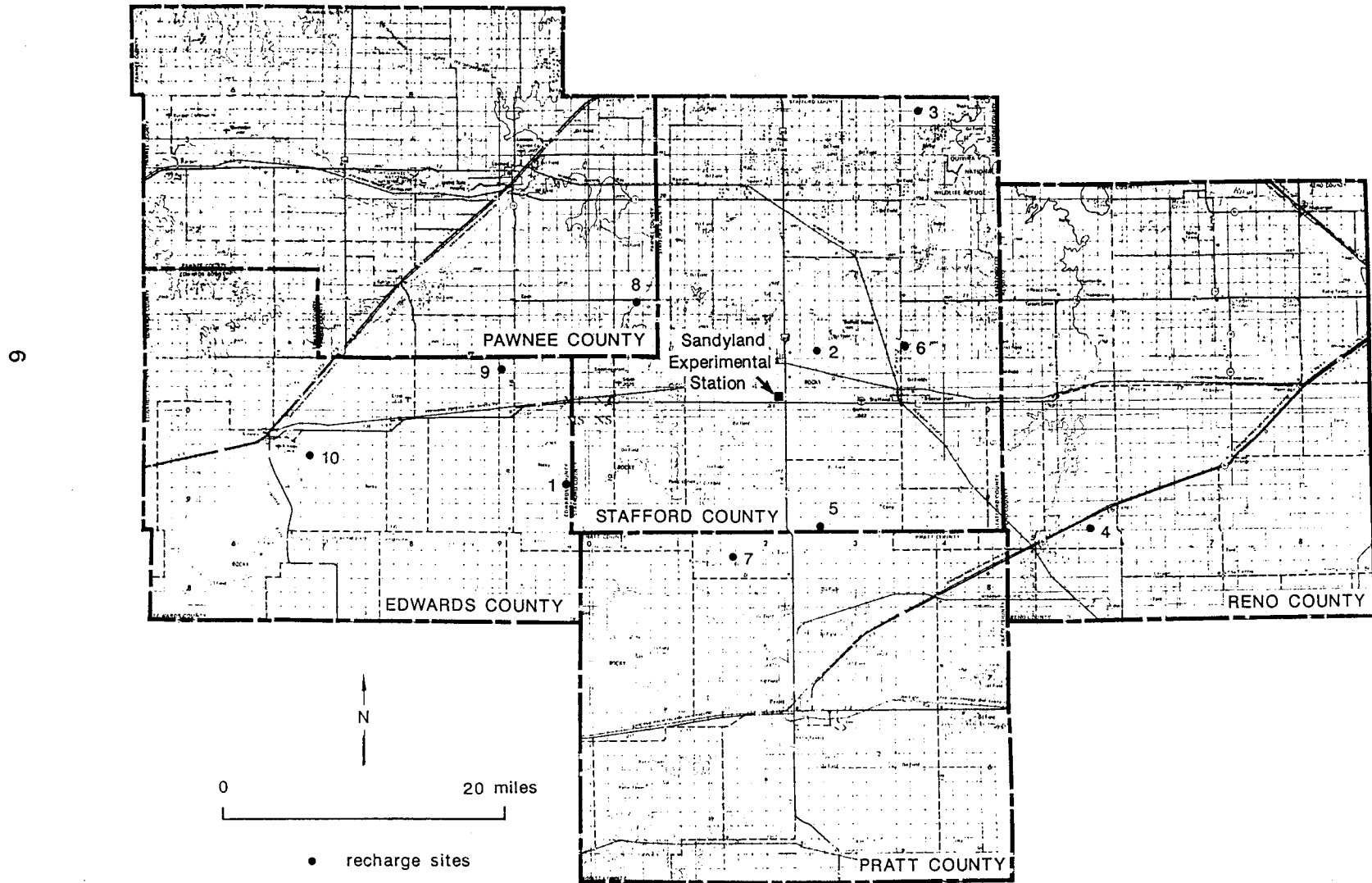
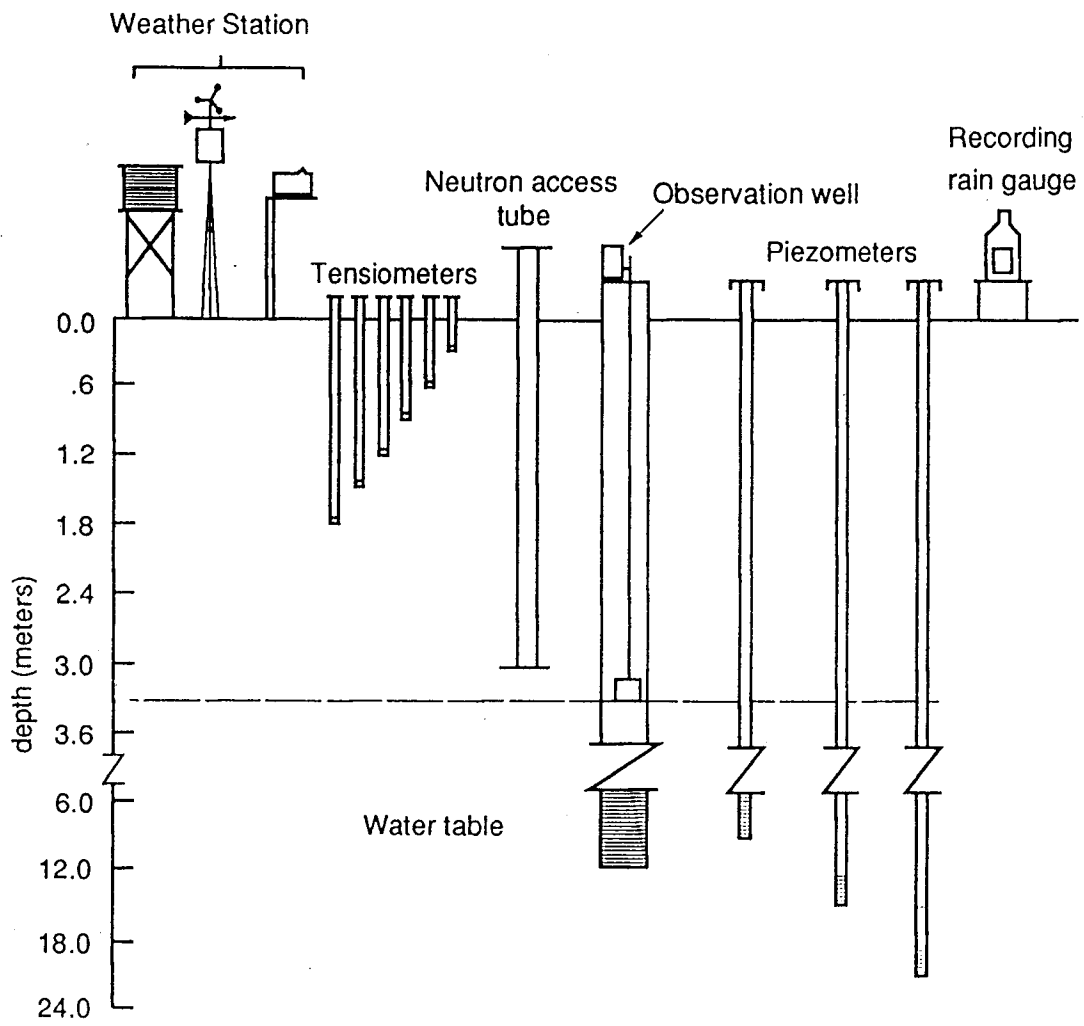


Figure 4: Instrumentation of a Recharge Site



described from samples taken during installation of the neutron access tubes and from classification done by the Soil Conservation Service (sites 5-10) and the Kansas Geological Survey (sites 1-5) (Figure 5). For the present study it was desirable to determine hydraulic conductivity of the unconsolidated sandy deposits in situ, as compacting the soil samples to their original densities can lead to significant errors (for example, the water characteristic is a function of grain orientation as well as soil density).

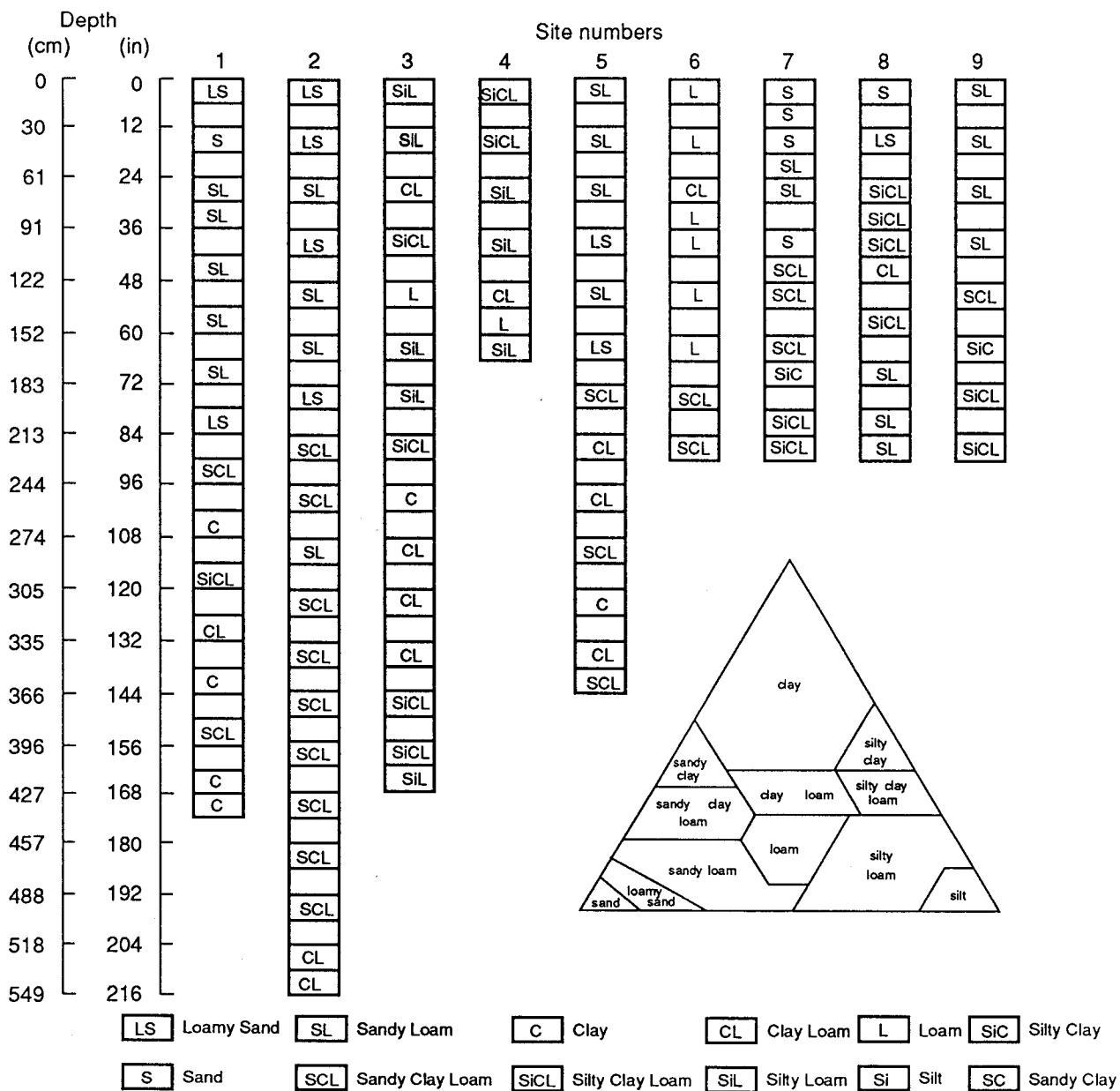
The data base used in this thesis began in 1984 with 5 recharge sites and has been continuously monitored to the present time with the inclusion of 5 more sites in 1987. All sites provided approximately weekly values for soil moisture, soil suction, continuous water table level, at least one deep piezometric head, and a continuous record of precipitation. Several instruments for measuring other meteorological parameters (temperature, solar radiation, humidity, etc.) were added later to facilitate the calculation of evapotranspiration (ET).

Moisture measurements were taken in steel conduit access tubes at 9" intervals to a depth of at least 108" on a weekly basis. Each depth usually received 1 1/2 minutes of measuring time, sometimes more. Two different Cambell Pacific Nuclear neutron probes were used in the collection of moisture data. The errors in measurement are discussed in the error analysis section, although additional errors were sometimes caused by water seepage into and around the access tubes, and gaps in the data were caused by the breakdown of a probe in late 1985.

Continuous precipitation records were obtained using weighing-type precipitation gauges (the charts were on weekly cycles). The most serious error in the measurement of precipitation is that due to wind, about 5% for 20 mph winds (Linsley, 1975).

Stevens continuous water level recorders were used to monitor the water table

Figure 5: Recharge Site Soil Profiles



(charts were usually set on a monthly cycle). Errors in measurement include the float catching on the sides of the piezometer, accidental miscalibration at the beginning/end of the chart, and weak batteries (this slows the clock, compressing the time axis of the chart). Table 1 shows the instrumentation of each site and the year the instrument(s) were installed.

The calculation of groundwater recharge was composed of 3 main parts: 1) the calculation of unsaturated hydraulic conductivity; 2) the calculation of recharge using the hydraulic conductivities in Darcy's equation for unsaturated flow, and 3) calculation of recharge from the water balance method.

To use the Darcy's equation for unsaturated flow it is necessary to determine the unsaturated hydraulic conductivity (here as a function of soil moisture) and the water characteristic function (the relationship between soil moisture and soil suction). Once these two functions are well defined, accurate recharge values can be obtained (using Darcy's Law for unsaturated flow).

The water balance method is related to the law of conservation of mass in that water can enter or leave the soil, can change form, but cannot be created or destroyed (Hillel, 1980 A). Hence the precipitation is balanced with measurements of soil moisture and estimates of evapotranspiration to obtain recharge (surface runoff being considered insignificant). Recharge is verified in both methods by the change in groundwater levels.

Table 1. State of the Data Base

Site #	1	2	3	4	5	6	7	8	9	10
Precipitation	1985-present	1985-present	1985-present	1985-present	1985-present	1987-present	none present	1988-present	1988-present	1988-present
Water Table Level	1985-present	1985-present	1985-present	1985-present	1985-present	1987-present	1987-present	1988-present	1988-present	1988-present
Neutron Readings	1985-present	1985-present	1985-present	1985-present	1985-present	1987-present	1987-present	1988-present	1988-present	1988-present
Tensiometer Readings	1985-present	1985-present	1985-present	1985-present	1985-present	1987-present	1987-present	1988-present	1988-present	1988-present
Piezometers (number of)	1985-present (2)	1985-present (1)	1985-present (2)	1985-present (1)	1985-present (1)	1985-present (2)	1987-present (1)	1987-present (1)	1987-present (1)	1987-present (1)
Weather Station						1987-present	1987-present			

PROCEDURE FOR OBTAINING HYDRAULIC CONDUCTIVITY

THEORY

Of all the methods for determining hydraulic conductivity *in situ*, perhaps the simplest and most widely used is the internal drainage method, well summarized by Hillel et. al, 1973. This method involves the following basic steps:

- 1) a series of tensiometers is installed at various depths, preferably coinciding with soil profile horizons;
- 2) a neutron probe access tube is installed as deeply as possible;
- 3) water is ponded on the surface until steady state conditions are established;
- 4) the plot is covered with a sheet of plastic to prevent any evaporative flux;
- 5) measurements of soil suction and soil moisture are taken as drainage occurs.

These measurements yield instantaneous potential gradients and fluxes for obtaining hydraulic conductivity values. A typical drainage experiment performed at site #5 is shown in Figure 6. Water was ponded inside the plywood hexagon (the impoundment area) which contained two neutron access tubes and a set of tensiometers.

The theoretical basis for obtaining hydraulic conductivity using the internal drainage method is based on Richards equation for vertical flow (Richards, 1931),

$$(1) \quad \frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left[K(\theta) \frac{\partial H}{\partial z} \right],$$

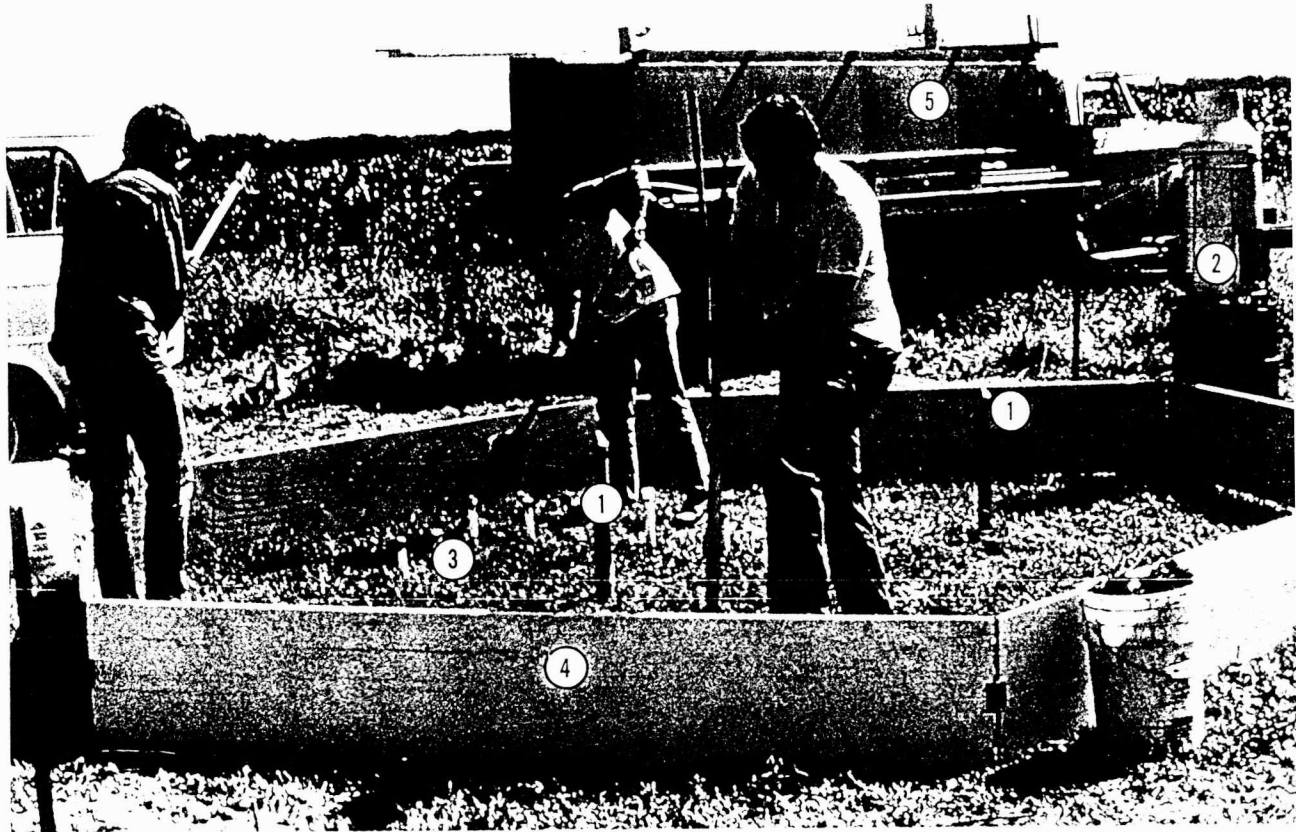
where θ is the volumetric moisture content, t is the time (days), z is depth (cm), H is the hydraulic head (cm H_2O) and K is the unsaturated hydraulic conductivity (cm/day).

Integration of equation (1) yields:

$$(2) \quad \int_0^z \frac{\partial \theta}{\partial t} dz = \left[K(\theta) \frac{\partial H}{\partial z} \right]_{z=z} - \left[K(\theta) \frac{\partial H}{\partial z} \right]_{z=0},$$

where z is the depth to which we measure, and where measurements were taken at depth

Figure 6: Photograph of a Drainage Experiment, Site 5, 1987



1. Neutron Probe Access Tubes
2. Precipitation Gauge
3. Tensiometers
4. Impoundment Area
5. Water Truck

increments dz . The surface water flux is zero because the plot is covered with plastic, cancelling the last term of equation (2).

The total water content (storage) change with time then becomes

$$(3) \quad \left[\frac{\partial W}{\partial t} \right]_z = K(\theta) \left[\frac{\partial H}{\partial z} \right]_z \quad \text{where} \quad W = \int_0^z \theta dz.$$

The drainage method only applies to vertical flow. If there is significant lateral flow, a large error can be introduced as a result (Hillel, 1973). Lateral flow can be monitored using tensiometers outside the impoundment area of the drainage experiment (just above suspect soil layers). Another common assumption made is to set the hydraulic gradient term in equation (3) to unity (e.g., Hillel, 1972), a good approximation in many instances.

Equation (3) was approximated by

$$(5) \quad \left[\frac{\sum_{i=1}^n \theta_{i,t+\Delta t} \cdot \Delta z_i - \sum_{i=1}^n \theta_{i,t} \cdot \Delta z_i}{\Delta t} \right] = K_n(\theta, t) \cdot \left[\frac{H_{n,t} - H_{n-1,t}}{\Delta z} \right],$$

where the left hand term in brackets is the flux, the right hand term is the gradient, n is the number of depth intervals to the soil layer of the hydraulic conductivity calculation and Δz is the distance between two hydraulic head measurements near depth n .

Some researchers use the central difference approximation of the gradient term (e.g., Hanks & Bowers, 1962). However, for non-uniform profiles or large depth increments, the forward difference solution may yield less error in determining K , as used by other researchers (e.g., Hillel, 1973).

MEASUREMENT AND USE OF SOIL MOISTURE

To obtain the flux term of equation (5), a neutron probe is used. A neutron probe consists of a radioactive source of neutrons (Am-Be in this case), a detector for scattered neutrons (both of which are attached to an electric cable) and the digital counter which sits on the top of the access tube from which the probe is lowered. The electric cable is marked off at 6" intervals for the drainage experiments, 9" intervals otherwise. This method takes advantage of the property of hydrogen nuclei for significant scattering and slowing of "fast" neutrons. This process is known as "thermalization", and the hydrogen in water (H₂O) has a marked effect on thermalizing neutrons, creating a "window" of scattered neutrons in the thermal energy range proportional to the water in the soil (Gardner, 1986).

The access tube for the neutron probe was installed in a hole created by alternately sampling and augering. These samples were used to determine their actual moisture contents as described in Appendix III. These moisture contents were then plotted against standardized neutron counts of the probe lowered to each respective sampling depth (the neutron counts are standardized mostly to account for decay of the source since it was calibrated). The resulting "calibration curve" was then used to obtain the moisture content of the soil from standardized neutron counts.

The three main sources of error in determining moisture are : 1) uncertainty in positioning of the neutron probe at a depth, 2) statistical uncertainty in neutron count, and 3) error in calibration of the probe (Wilson, 1974).

The error in positioning the probe at the depth of interest was taken as +/- 5 mm, so that the resulting component of the error in moisture is (Wilson, 1974):

$$(6) \quad \sigma_{e_1} = \frac{|\theta_z - \theta_{z-5}| + |\theta_z - \theta_{z+5}|}{2}$$

where θ_z is the moisture measurement at depth z and $\theta_{z \pm 5}$ is the moisture interpolated to ± 5 mm from the assumed measurement depth z .

The standard error due to random emission of the source of neutrons is dealt with statistically. The soil moisture was obtained from the relationship given by Gardner (1986),

$$(7) \quad \theta = \frac{1}{S} \left[\frac{N_z}{N_{std}} \right],$$

where N_z is the number of neutron counts made at depth z , N_{std} is the standard count measured over a time interval much greater than N_z was, and S is the slope of the calibration curve,

$$(8) \quad S = \frac{\Delta \left[\frac{N_z}{N_{std}} \right]}{\Delta \theta}.$$

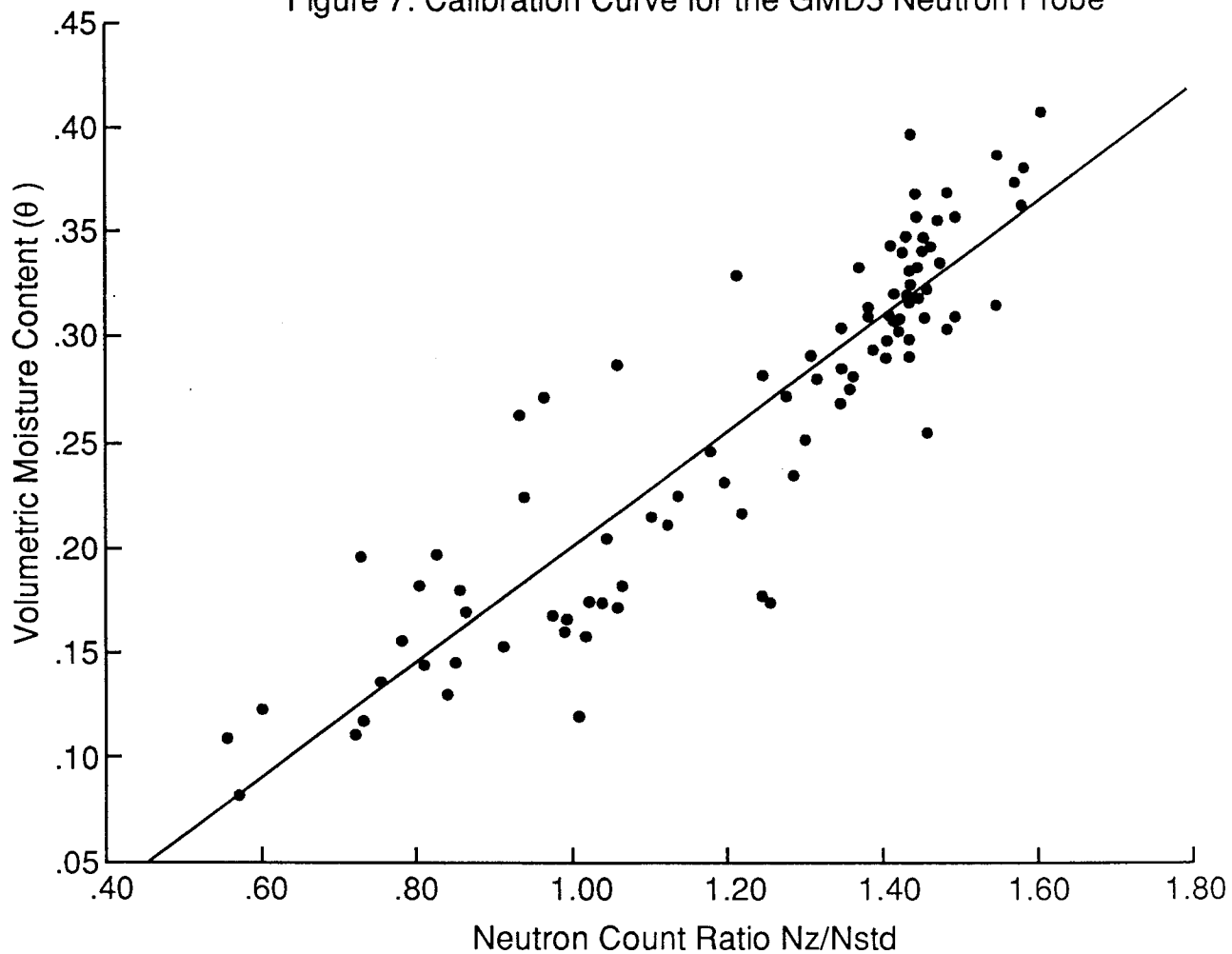
Gardner (1986) gave the 95% certainty water content error due to the error in random counting of returning slow neutrons, as

$$(9) \quad \sigma_{\theta_z} = \sqrt{\frac{\theta}{S N_{std} t}},$$

where t is the time counted at rate N_{std} and N_z .

Like the positioning error, the error in the calibration curve (for determining S) must be considered more subjectively since it depends on field variability of the soils, degree of linearity, and errors in the gravimetric process used to obtain the curve. Since each site yields less than 20 points for calibrating its access tube, and since there are gross soil similarities between the sites, the "fit" of the curve was greatly improved by combining all the sites and using one curve (Figure 7). The standard error in slope is taken to be

Figure 7: Calibration Curve for the GMD5 Neutron Probe



$$(10) \quad \sigma_{\theta_3} = \sqrt{\frac{s^2}{n}},$$

where s is the standard deviation of the least squares fit of the calibration curve and n is the number of sample points used (Steel, 1980).

The first-order approximation of the total error in a quantity is obtained from the errors involved in obtaining the quantity (e.g. Taylor, 1982). Assuming the three errors in calculating soil moisture content are independent, the total error in θ is

$$(11) \quad \sigma_{\theta_z} = \sqrt{\sigma_{\theta_1}^2 + \sigma_{\theta_2}^2 + \sigma_{\theta_3}^2}.$$

A sample of these errors is shown in Table 2. The soil moisture, soil moisture storage and the above-mentioned moisture errors are calculated using FIELDKPROG (Appendix I).

It has been found experimentally that the water content of a given zone of a soil profile decreases with time (drains) according to the drying model

$$(12) \quad W_z(t) = At^{-b}, \quad W_z = \sum_{i=0}^n \theta_z dz$$

where A and b are constants (Richards et al. 1956, Ogata and Richards, 1957).

Smoothed data was generated by using the least squares technique to fit our drainage experiment-derived soil moisture storage data to equation (12). The resulting set of equations were used in the K calculations (equation (5)), to easily extrapolate W 's (and hence K 's) beyond the experiment parameters and to obtain an independent estimate of the error in measuring W_z (i.e. the error in fitting the moisture storage to equation (11) (Figure 8). The error in fitting the data to equation (12) comprised the storage component of the error used in obtaining the error in K discussed later. However, since relatively few points are sometimes involved in estimating this error, the error given

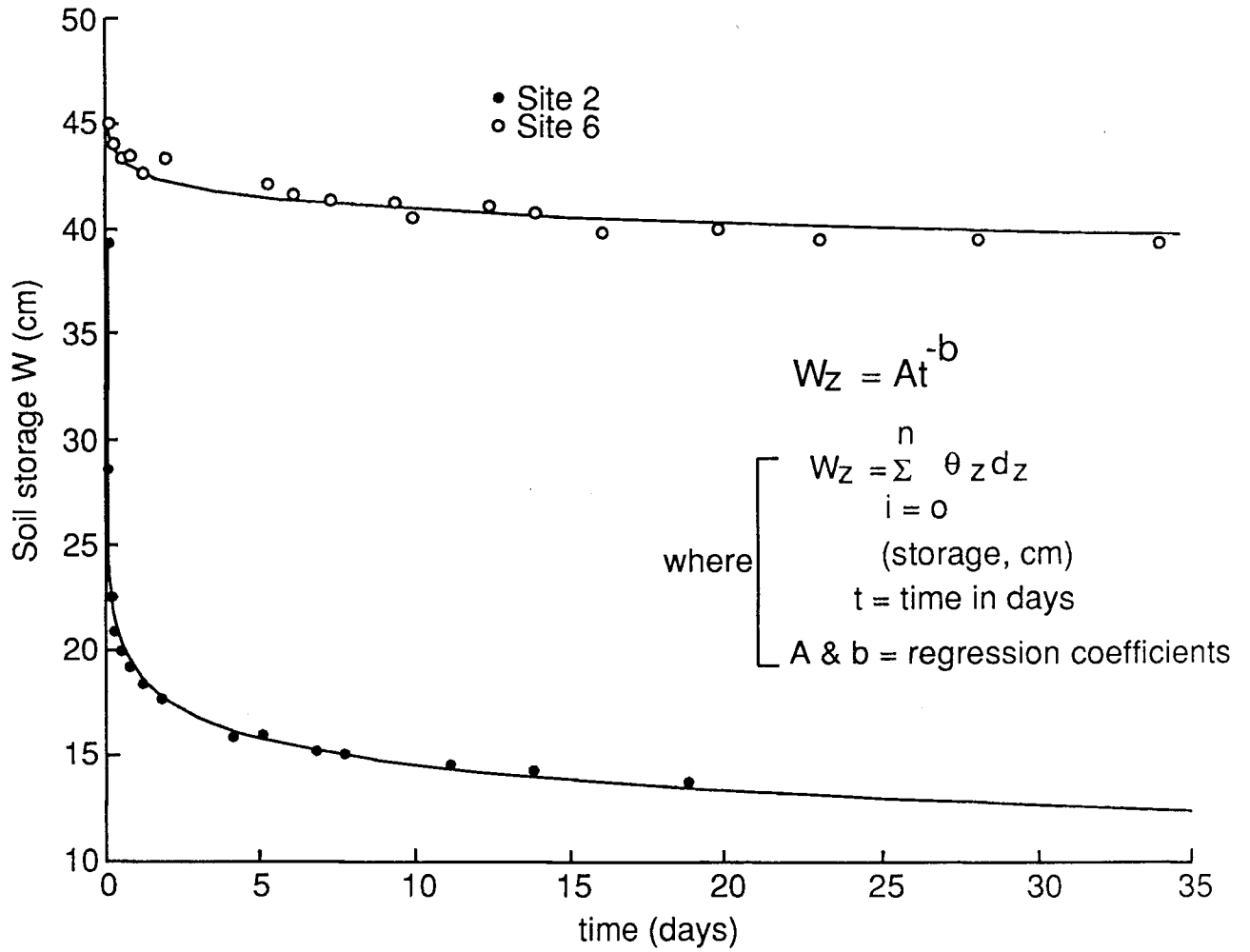
Table 2. Components of Error from using the Neutron Probe

Site #3, August 27, 1987

Calib. error = Error due to the calibration curve.
 Count error = Random counting error.
 Positioning error = Error due to positioning of probe at a certain depth.
 Total error = Errors combined in quadrature.
 % error of Storage = the percent error in value of moisture storage.

DEPTH (cm)	MST	Calib. error	Count error	Position. error	Total error	% error of Storage
30	.3254	.0085	.0036	.0011	.0093	2.8645
46	.3429	.0085	.0033	.0014	.0092	2.6960
61	.3353	.0085	.0033	.0004	.0092	2.7398
76	.3057	.0085	.0033	.0006	.0092	3.0044
91	.3172	.0085	.0032	.0007	.0091	2.8804
106	.3133	.0085	.0032	.0003	.0091	2.9155
122	.3082	.0085	.0032	.0001	.0091	2.9614
137	.2715	.0085	.0032	.0007	.0091	3.3665
152	.2687	.0085	.0030	.0006	.0091	3.3768
168	.2697	.0085	.0030	.0001	.0090	3.3539
183	.2526	.0085	.0030	.0003	.0091	3.5838
198	.2556	.0085	.0029	.0003	.0090	3.5300
213	.2872	.0085	.0029	.0006	.0090	3.1474
229	.3249	.0085	.0031	.0011	.0091	2.8160
244	.3389	.0085	.0033	.0008	.0092	2.7105
259	.3285	.0085	.0033	.0004	.0092	2.7940
274	.3291	.0085	.0033	.0002	.0092	2.7811
290	.3452	.0085	.0033	.0003	.0092	2.6529
305	.3397	.0085	.0034	.0004	.0092	2.7048
320	.3433	.0085	.0033	.0001	.0092	2.6718
335	.3377	.0085	.0033	.0002	.0092	2.7183
350	.3294	.0085	.0033	.0002	.0092	2.7844

Figure 8: Drainage Experiment 91 cm Moisture Storage for Sites 2 and 6, 1987



by equation (11) was calculated and could also be used when necessary. The program used to fit the data to equation (12) is REG1 (Appendix I). A sample of the results of fitting the storage data are given in Table 3 for site #3, 1987.

The error in $W_z(t)$ was calculated from

$$(13) \quad \sigma_{W_n(t)} = \left[(\sigma_{\theta_{z_1}} \Delta z_1)^2 + (\sigma_{\theta_{z_2}} \Delta z_2)^2 \dots + (\sigma_{\theta_{z_n}} \Delta z_n)^2 \right],$$

where the small error in the depth term was considered negligible. The error in flux is then

$$(14) \quad \sigma_{flux_n} = \frac{\left[\sigma_{W_n(t)}^2 + \sigma_{W_n(t+\Delta t)}^2 \right]^{1/2}}{\Delta t},$$

where there is no significant error in the time measurement. It is useful to note that as the time intervals decrease, the error increases.

MEASUREMENT AND USE OF SOIL SUCTION

Of the many different instruments and methods available for measuring soil suction, tensiometry has become the most widely used (Hillel, 1980). The "tensiometer" instrument used in this thesis consists of a cup-shaped porous ceramic surface connected to a water-filled plastic tube capped and hermetically sealed with a rubber septum. A series of tensiometers were installed across the study area at ~15 cm intervals (usually) to depths from 15 cm to 255 cm. The water is in dynamic contact with the soil through the ceramic cup, and becomes equilibrated when the suction in the tensiometer equals the soil suction. A pressure transducer needle is inserted into the septum and the suction pressure is displayed on a digital meter electrically connected to the transducer. The actual soil suction is determined by subtracting the height of the water column in the tensiometer from the transducer reading of suction. The water is

Table 3. Linear Regression of Soil Moisture Storage

Site #3, 1987

DEPTH = depth of soil moisture measurement (cm)
 Y-INTCPT = y intercept of the curve linearized in the log domain
 SLOPE = slope of the curve linearized in the log domain
 Std Err = standard error of fitting the model to the data
 CORRCF = correlation coefficient
 SAT.STRGE = saturated soil moisture storage

DEPTH	Y-INTCPT	SLOPE	Std Err	CORRCF	SAT.STRGE
15	1.48069	-.10266	.15707	.97914	5.94800
30	2.42249	-.08638	.35140	.95596	13.38770
46	2.94616	-.05667	.39888	.95633	21.22760
61	3.28163	-.04118	.41130	.95610	28.89290
76	3.51608	-.03254	.41675	.95047	35.88130
91	3.71160	-.02657	.41761	.94728	43.13240
107	3.87503	-.02304	.42764	.94787	50.29530
122	4.00930	-.02130	.45245	.94892	57.34019
137	4.11621	-.02118	.50045	.94921	63.54781
152	4.21064	-.02112	.54921	.94817	69.69020
168	4.29618	-.02102	.59711	.94598	75.85550
183	4.37230	-.02081	.64242	.93916	81.62950
198	4.44415	-.01955	.65464	.93175	87.47220
213	4.51835	-.01788	.64856	.92752	94.03760
229	4.59724	-.01637	.64655	.92427	101.46500
244	4.67199	-.01517	.64646	.92381	109.21130
259	4.73972	-.01380	.63220	.92111	116.72150
274	4.80445	-.01282	.62933	.91802	124.24580

visible through a clear glass portion of the tube protruding above the surface so that a constant water level can be maintained by servicing the tensiometers. The hydraulic head (H) is determined by adding the suction to the depth (below land surface) of the ceramic cup.

The instrument error for measuring soil suction is much more difficult to estimate. The sources of error for this approach include the precision of the digital meter, leakage of air through the rubber septum as the needle is inserted, air bubbles in contact with the porous ceramic cup and non-equilibrium conditions with the surrounding soil during the drainage experiments.

Since tensiometer errors are usually not directly estimable, the instrument error is estimated from the residuals from the model used for the increase of soil suction with time. The increase of soil suction with time for the drainage experiments closely followed a similar drying model to equation (12),

$$(15) \quad \psi = At^{+b},$$

where ψ is the soil suction, and the parameters A and b were found using REG1 as listed in Appendix I.

As many as 4 tensiometers per depth were installed at varying depths within the drainage area. Data from individual tensiometers were first combined for tensiometers at common depths (so that spatial variability was included), then each resulting set of data for each depth was fitted to the model of equation (15) (Figure 9). The residuals from all the tensiometers were then plotted as in Figure 10 (Draper & Smith, 1981). Error bounds were drawn to include 68% of the data (+/- 1 standard deviation). These error bands were used to verify the accuracy of the fitting procedure, but the fitting errors of individual depths were actually used in the K error analysis. Table 4 gives a

Figure 9: Drainage Experiment 91 cm, Soil Suction vs. Time, Sites 2 and 6, 1987

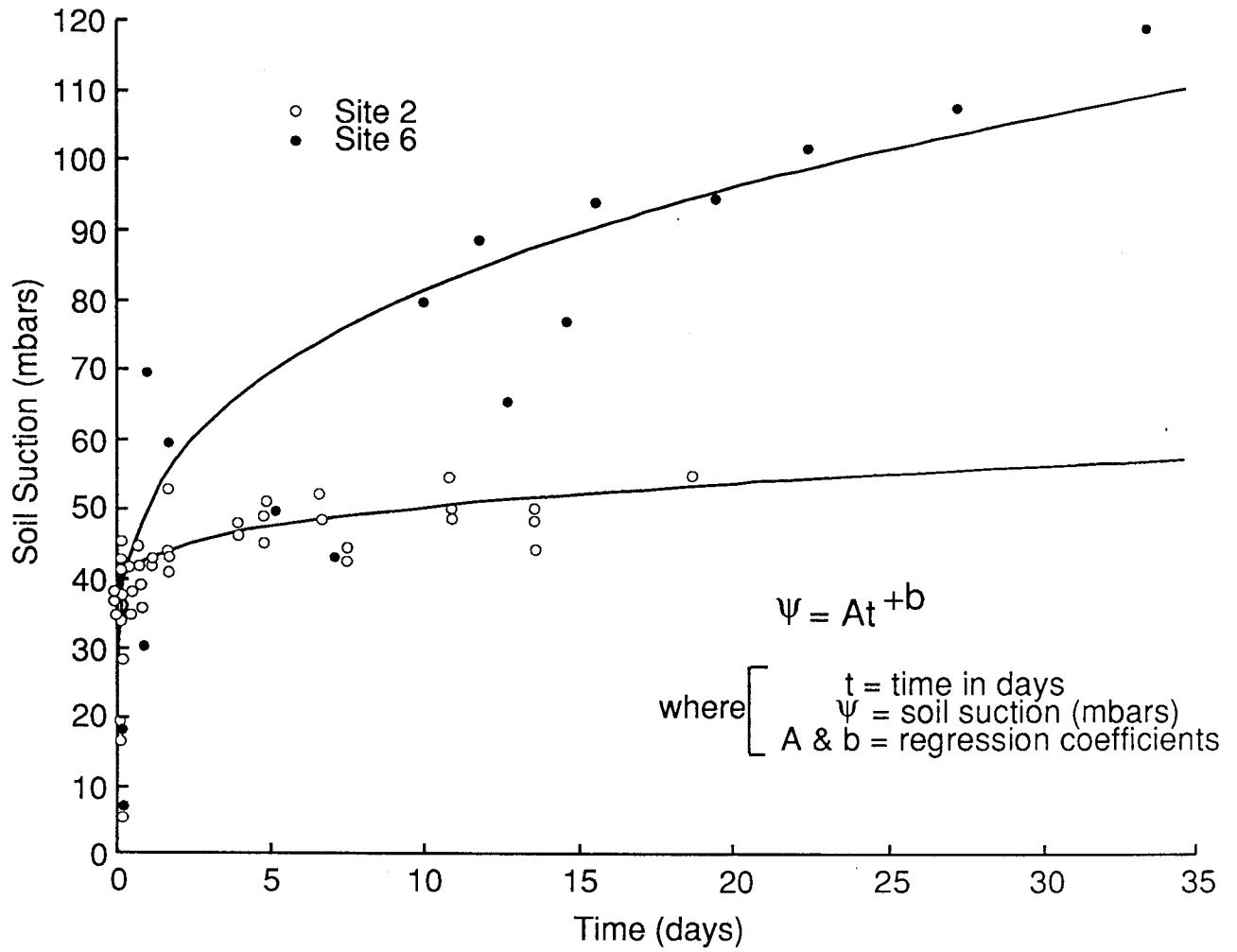
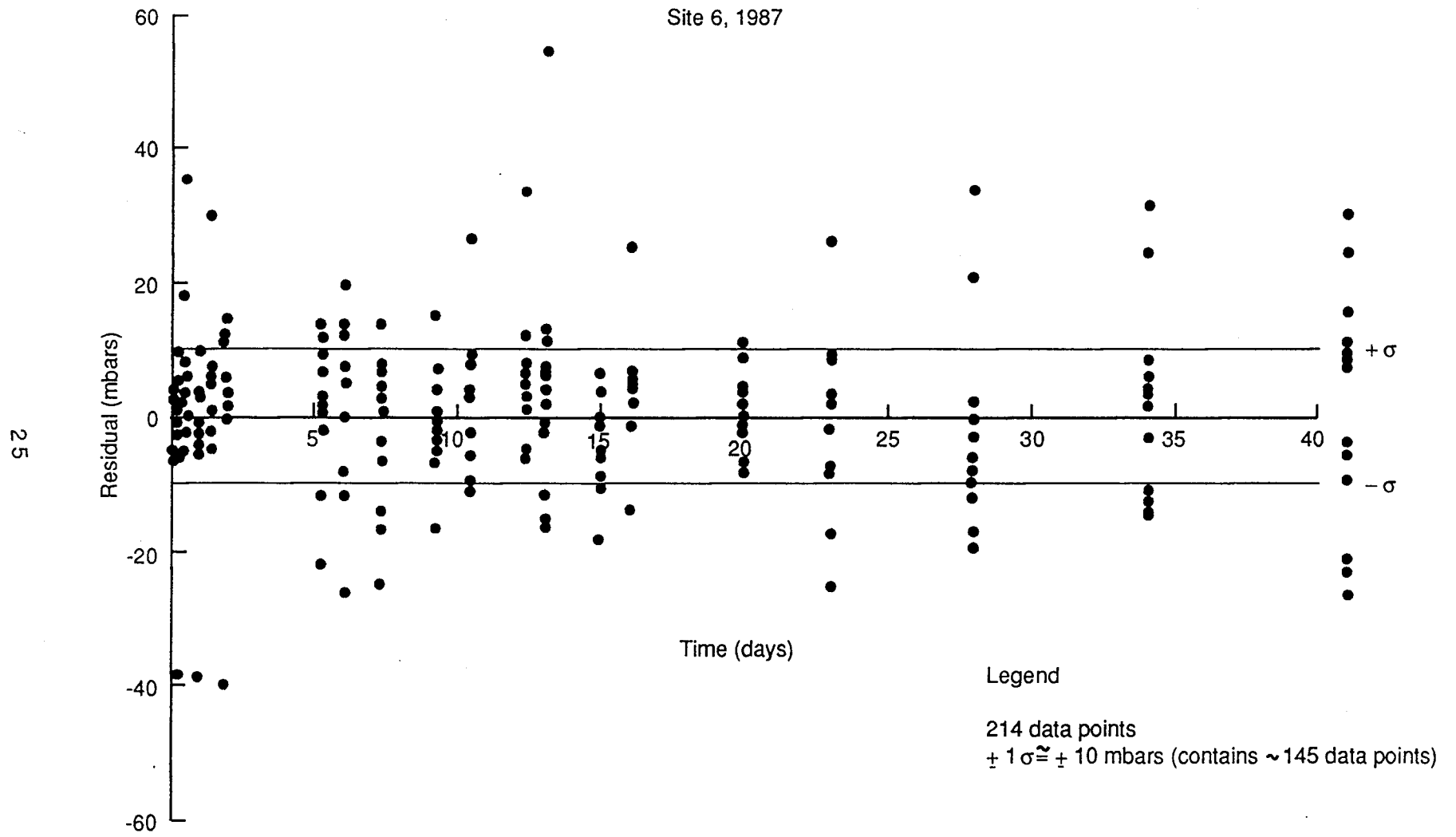


Figure 10: Residuals from Fitting Tensiometer Data Site 6, 1987



sample of the linear regression for tensiometers at Site #3, 1987.

Tensiometers are particularly sensitive to the sources of error attributed to them, and hence a large number of outliers were expected (Figure 8). The explainable outliers due to instrument malfunctions and procedural errors were omitted from the least squares fitting process. The error in placement of the tensiometer at a particular depth was assumed to be relatively negligible. The uncertainty shown in Figure 8 was considered as an estimate of the instrument error in obtaining hydraulic head. The hydraulic heads are obtained and common depths combined using the program TENSIMETERS (Appendix I). The gradient error at a particular time is then

$$(16) \quad \sigma_{\text{gradient}} = \frac{\sqrt{\sigma_{H_1}^2 + \sigma_{H_2}^2}}{\Delta z}$$

where Δz is the distance between the two measurements of head, H_1 and H_2 , and σ_{H_n} is the error in the water characteristic curve at depth n for a particular site, documented in Appendix III. Since the flux error is independent of the gradient error, the error in calculating K from equation (5) is

$$(17) \quad \sigma_K = \pm K \left[\left(\frac{\sigma_{\text{flux}}}{\text{flux}} \right)^2 + \left(\frac{\sigma_{\text{gradient}}}{\text{gradient}} \right)^2 \right]^{\frac{1}{2}}$$

In the case where the θ vs. time drainage curves are steep (near the beginning of the drainage experiments--especially for fast-draining sites such as site #2, Figure 6), the estimation of K is more sensitive to changes in θ than at later times. This results from the numerical procedure used (equation (5)). This makes it difficult to determine accurate saturated K values for sites like site #2, as K is very dependent on the time interval Δt (equation 5) used in the calculation.

Table 4: Linear Regression of Tensiometer Data

Site #3, 1987

DEPTH = depth of soil moisture measurement (cm)
 Y-INTCPT = y intercept of the curve linearized in the log domain
 SLOPE = slope of the curve linearized in the log domain
 Std Err = standard error of fitting the model to the data
 CORRCF = correlation coefficient
 GD. OF FIT = goodness of fit

DEPTH (cm)	Y-INTCPT	SLOPE	Std Err (mbars)	CORRCF	GD. OF FIT
30	3.02307	.24629	3.52303	.88037	.77505
46	2.26904	.42548	2.20992	.88980	.79174
61	2.80479	.31157	2.7972	.80407	.64652
76	3.55887	.11424	2.61706	.36737	.13496
91	2.88465	.30407	2.68107	.77132	.59494
122	3.08342	.24670	3.29736	.90726	.82312
137	3.26858	.11678	3.43775	.34760	.12083
152	3.35446	.21943	3.33036	.87942	.77338
183	2.85303	.22244	2.04117	.75388	.56834

RESULTS

Normally a saturated sandy soil (e.g. site #2) conducts water more rapidly than a clayey soil (e.g. site #3) (Figure 11). The opposite was true after some of the depths became unsaturated, however. This follows theory also, since a sandy soil with large pores which quickly empty (as in site #2) become less conductive as suction increases. In a soil with smaller pores (as in site #3) the pores retain their moisture better and the soil remains closer to its saturated K, even at appreciable suction. Consequently, an unsaturated clayey layer may have a higher K than an unsaturated sandy layer (Hillel, 1971).

Darcy's Law is not valid for all types of flow in porous media. For soils with macropores, deviations from Darcy's law can be expected due to turbulent/near turbulent flow (Hillel, 1971), i.e. the gradient increases faster than the flux at increasing flow velocity. The non-linearity of the K vs θ plots from site #2 could be explained by this idea (Figure 12), especially as we know the site is perforated with highly conductive prairie dog holes. Site #2 displayed a uniformly high K with depth at saturation, but the soil layers became more distinctive as the drainage experiment progressed (Figure 11). After 2 days of drainage the 12 and 18 inch depths maintained a higher K, probably due to their higher clay content.

The steep curves in Figure 12 for site #3 indicate the presence of clay layers that released their moisture very slowly over a wide range in gradient as mentioned above. The slopes of the K vs θ curves (as in Figure 12) correlated well to the soil profile of that site (Figure 5). The K's calculated for a sandy site such as site #2 varied over a much wider range of moisture due to the better drainage. It is also important to consider that site #2 was measured for only 20 days after saturation compared to 80 days for site #3; so a direct comparison of site #3 to site #2 would show even less

Figure 11: Drainage Experiment, Hydraulic Conductivity vs. Depth, Sites 2 and 3

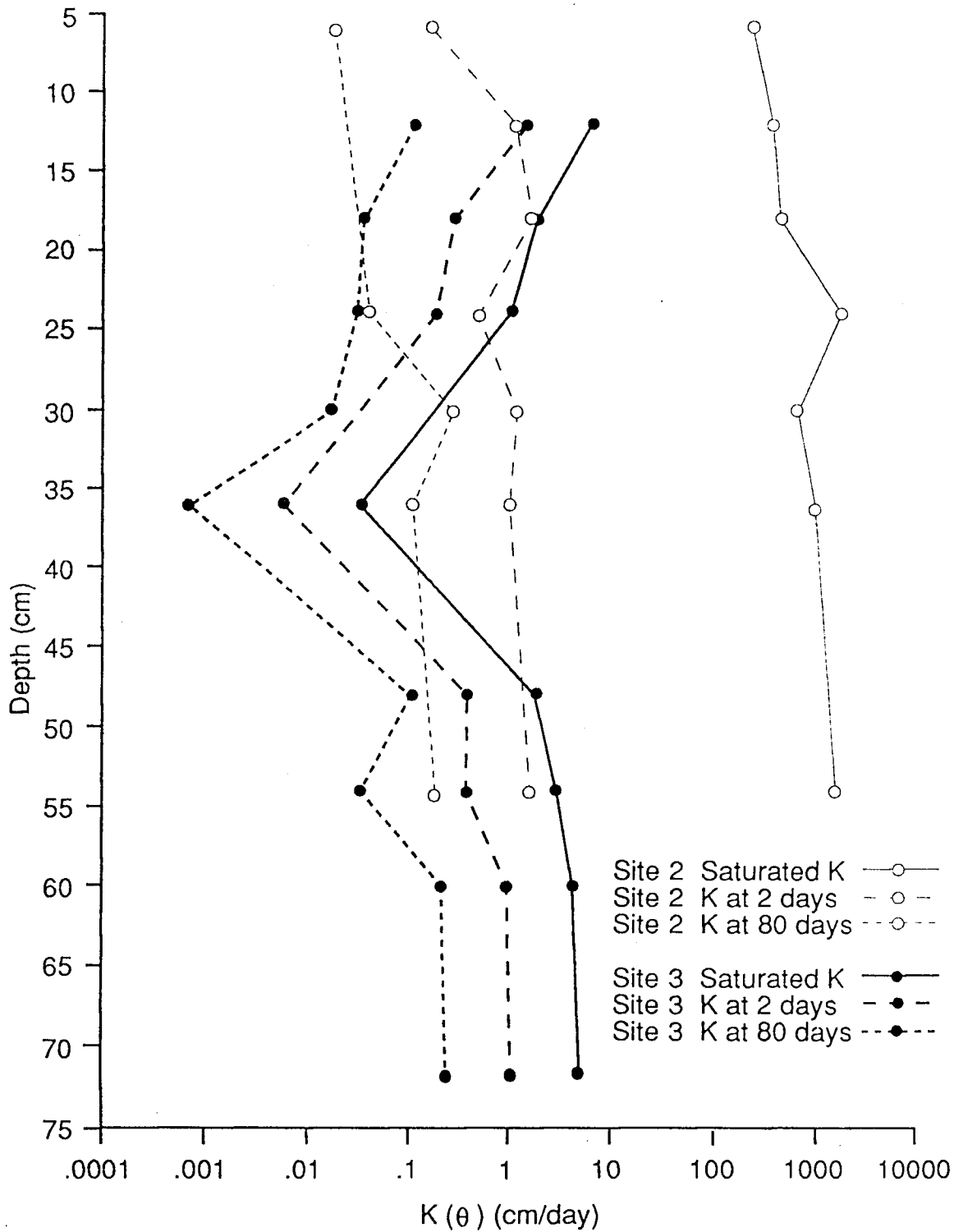
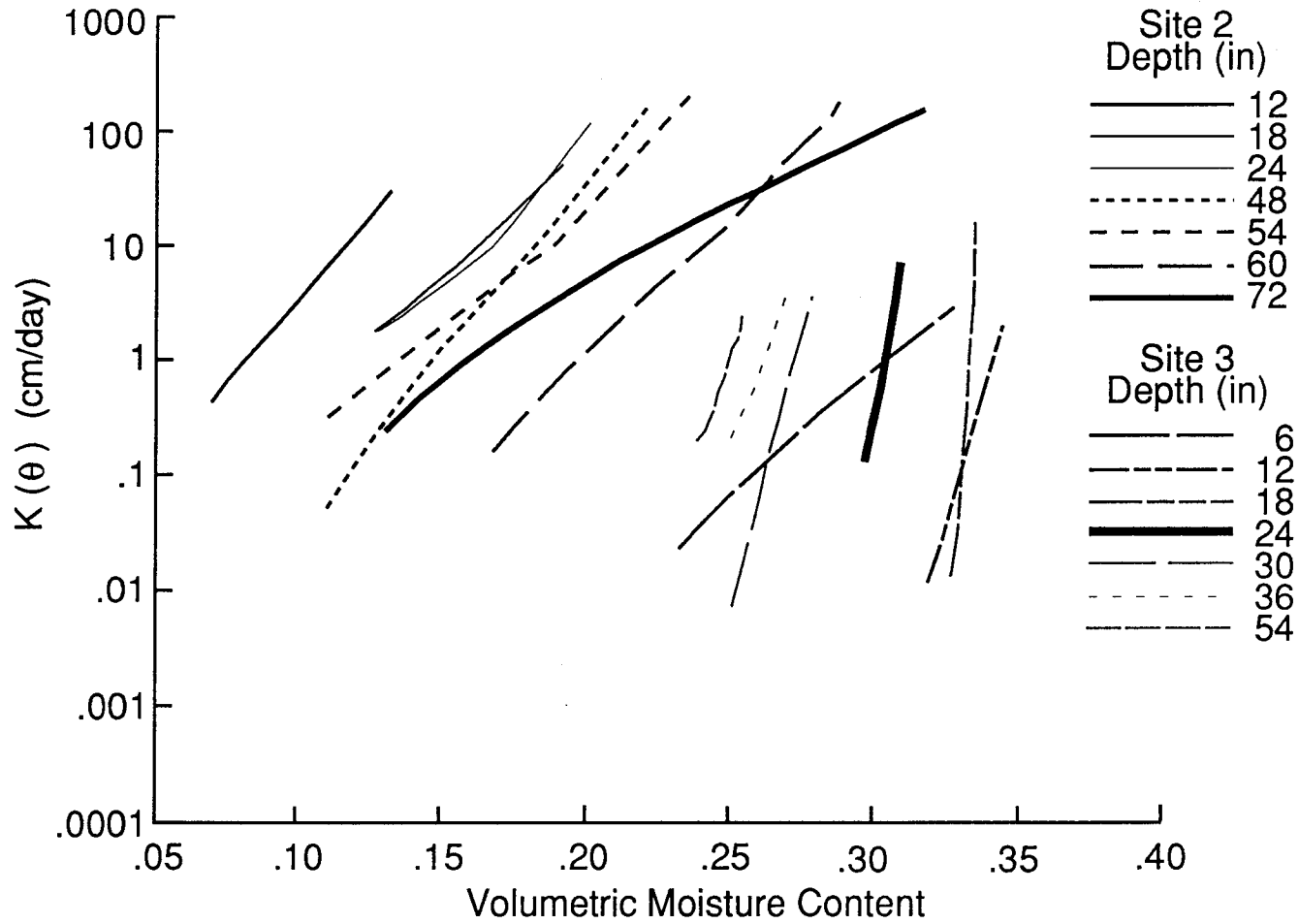


Figure 12: Hydraulic Conductivity Functions, Sites 2 and 3



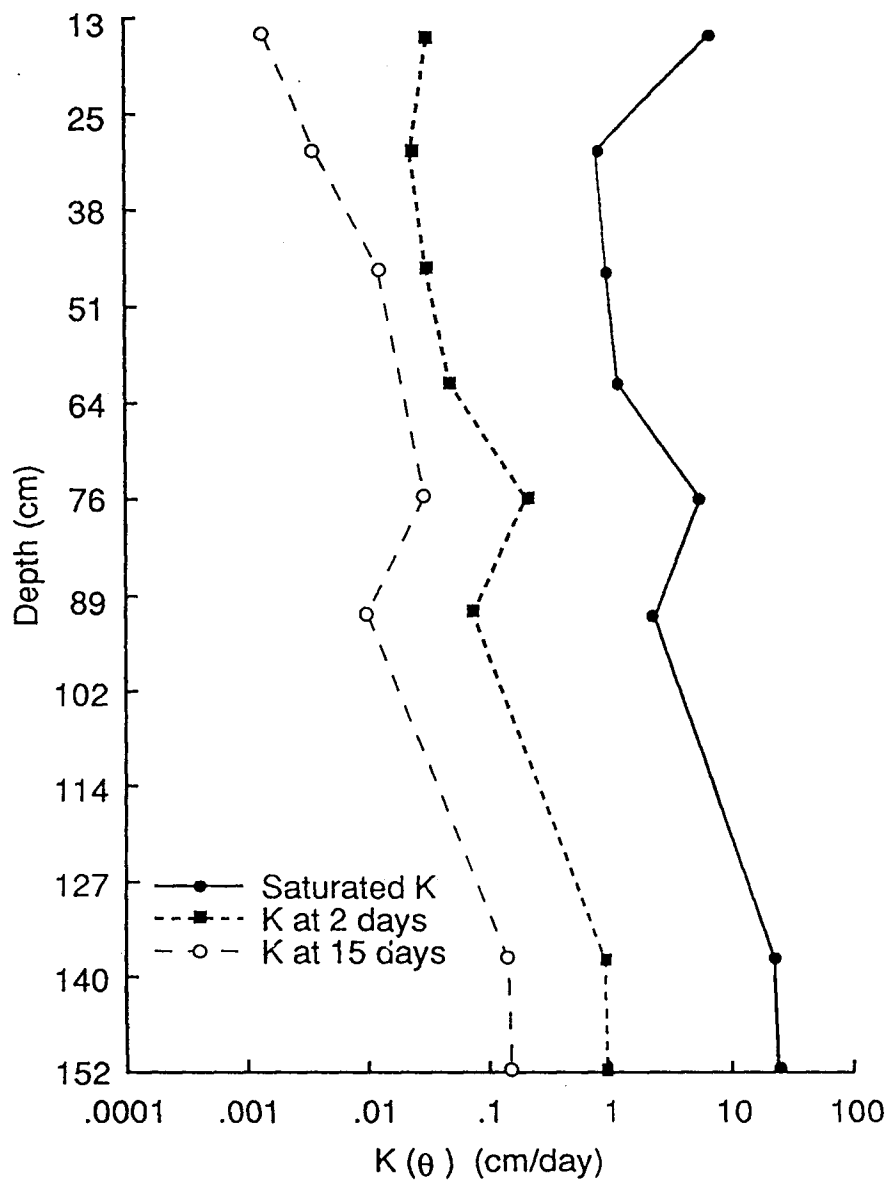
variation in θ over 20 days for site #3 in Figure 12.

Most sites preserved their K profile shape for the duration of the drainage experiments as shown in Figure 13 for site #9. The surface depths tended to have a wider variation in K, most probably due to better drainage. This is consistent with the fact that moistures were usually lowest at the surface depths after termination of a drainage experiment.

Two neutron probe access tubes were spaced 5 feet apart at site #5 in 1986 in order to document the lateral variation in K with moisture content for that case. Hydraulic conductivities were determined using the same gradients for both access tubes. There is excellent agreement of the two sets of $K(\theta)$ functions for the two access tubes (Figure 14), well within the error of measurement. Most of the variation in K occurs close to the surface. This difference can be ascribed to the variation in surface processes (e.g. root distribution and crust formation, Hillel, 1960). This example also indicates that small variations in moisture, evidenced in Table 5, do not change K significantly when the gradient is kept constant (Figure 14). The lateral variation of K is often very large when soil suction is also considered. In addition, a coefficient of variation of 400% for soil samples at 55% saturation has been documented using a similar drainage experiment to determine K (Nielsen et. al, 1973).

When the drainage experiment at site #5 was repeated in 1987, we observed more variation in the resulting $K(\theta)$ functions, though usually well within the error of measurement (Figure 15, see Appendix IV). The antecedant moisture conditions of the two years were very different. The experiment was preceded by very dry ground in 1986 and very wet ground in 1987. Because of this, although some of the K variations could be ascribed to larger amounts of air entrapped in the soil and dry boundary conditions in 1986, much of the variation is probably due to the changing of

Figure 13: Hydraulic Conductivity vs. Depth, Site 9, 1988



**Table 5: Lateral Variation of Moisture Content
from Two Neutron Access Tubes 2 Meters apart,
Drainage Experiment, Site #5, 1986**

July 22 (start of the drainage experiment at saturation)

depth (cm)	moisture content 'new tube'	moisture content 'old tube'
15	.2821	.2942
30	.3030	.3365
46	.3198	.3354
61	.3347	.3250
76	.3378	.2830
91	.3363	.2990
107	.3228	.3171
122	.3191	.3299
137	.3205	.3177
152	.3289	.3250
168	.3482	.3294

August 8 (end of the drainage experiment)

depth (cm)	moisture content 'new tube'	moisture content 'old tube'
15	.2135	.2294
30	.2418	.2568
46	.2719	.2875
61	.2248	.2727
76	.1541	.1787
91	.1552	.1504
107	.1967	.1878
122	.2139	.2173
137	.2054	.1965
152	.1584	.1581
168	.1968	.1922

Figure 14: Lateral Variation in Hydraulic Conductivity,
Site 5, 1986

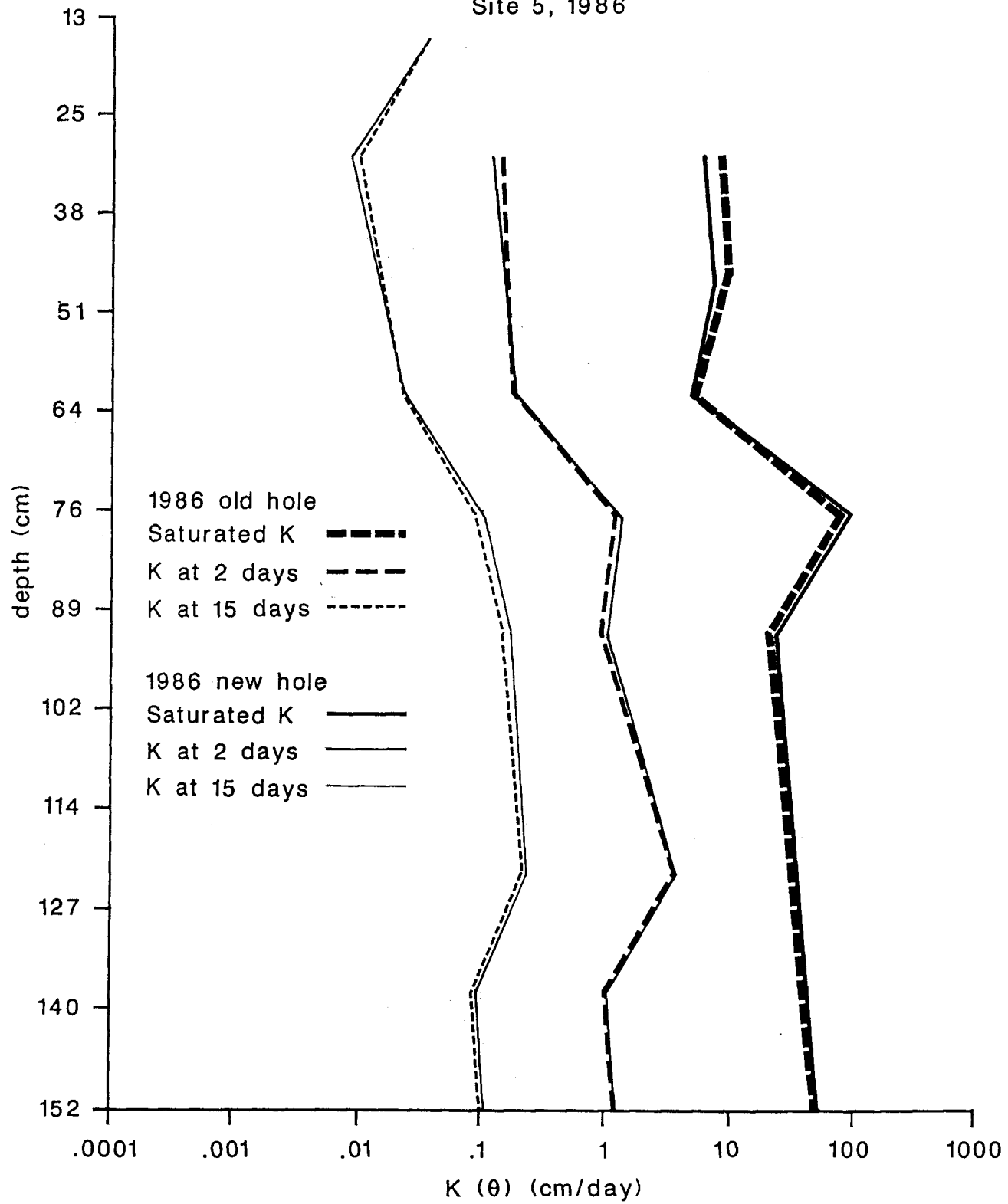
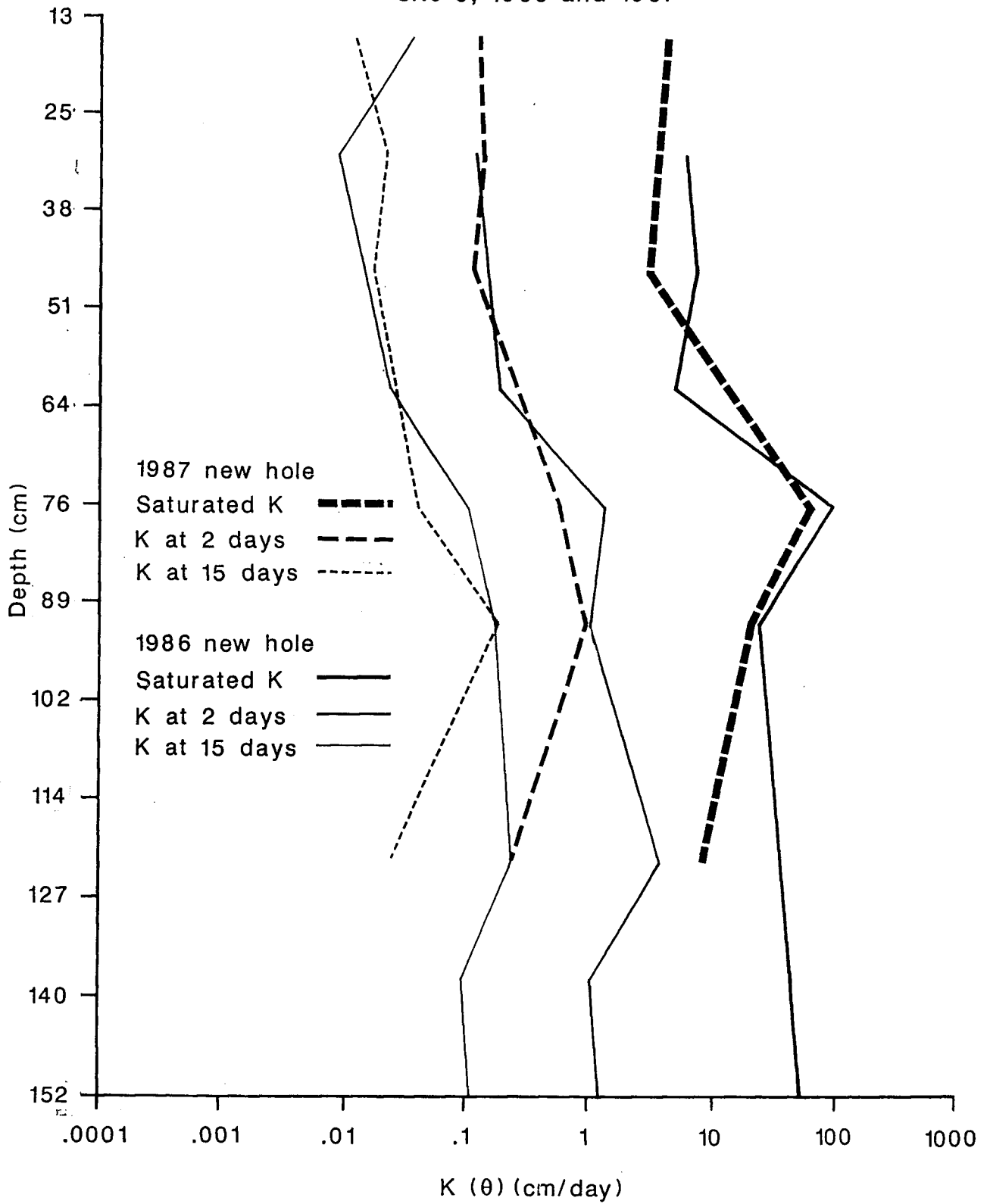


Figure 15: Repeatability of Measuring Hydraulic Conductivity,
Site 5, 1986 and 1987



tensiometers. The repeatability of determining K is therefore mostly a function of the instrument error in the tensiometer data.

In general, while the determination of unsaturated hydraulic conductivity by present methods is not very accurate, and orders of magnitude are sometimes all that can be expected (Freeze & Cherry, 1970), we can better estimate the hydraulic character of the soil from the $K(\theta)$ functions. As discussed in later sections, K is not always the most useful tool in determining recharge rates. The $K(\theta)$ values for the other sites fell between the extremes of sites #2 and #9, and the results of the drainage experiments are given in tabular form in Appendix IV.

The K errors shown in Appendix IV indicate that 100% error is quite common. The proportional error in K tended to increase due to the increasing significance of the error in measuring the change in soil moisture storage. This is consistent with the findings of Fluhler et al. (1976), that when drainage is slower due to drying of the profile, the errors in measured water content changes become dominant in the error in K, and that the proportional error increases with decreasing moisture content.

USE OF UNSATURATED HYDRAULIC CONDUCTIVITY

Two main definitions of groundwater recharge are 1) the amount of water percolating to the water table and 2) the amount of significant increase in the water table. The first definition is used here, and hence includes the recharge needed to maintain a constant water table level. Estimates using the second definition would theoretically be less than the estimates given in this paper.

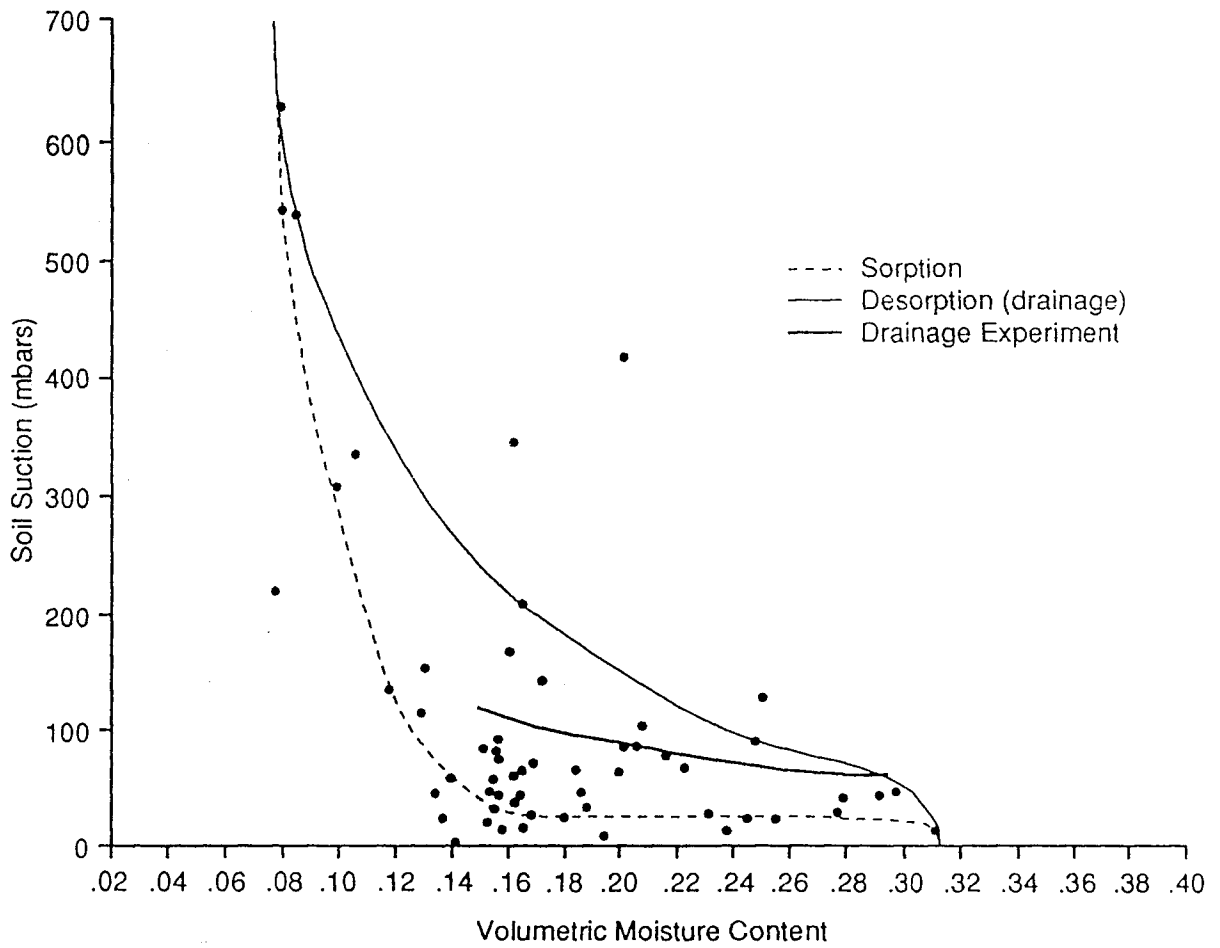
THEORY AND APPLICATION

The calculation of recharge from Richards equation (eq. 1) requires 3 main inputs: a water characteristic function from which hydraulic gradients may be derived given $\theta(z)$ (Sophocleous and Perry, 1984); unsaturated hydraulic conductivity; and measurements of soil parameters (soil moisture and hydraulic head) with time for the period of interest. The accuracy of recharge calculations using the $K(\theta)$ functions depends on the 3 inputs to varying degrees.

a) Gradient Determination.

Direct measurements of soil suction were made on a weekly basis, but since tensiometers are difficult to maintain on such a schedule (accumulation of air bubbles, water leakage etc.), the direct readings frequently do not yield accurate hydraulic gradients. It is also difficult to estimate the error in measurement since a record of the height of the water column in the tensiometers was not deemed practicable and since air leaks/air bubbles create a constantly varying magnitude of error. The direct measurement does, however, avoid hysteresis errors introduced in other methods of obtaining the gradient.

Figure 16: Water Characteristic Curve, 137 cm Depth, Site 5



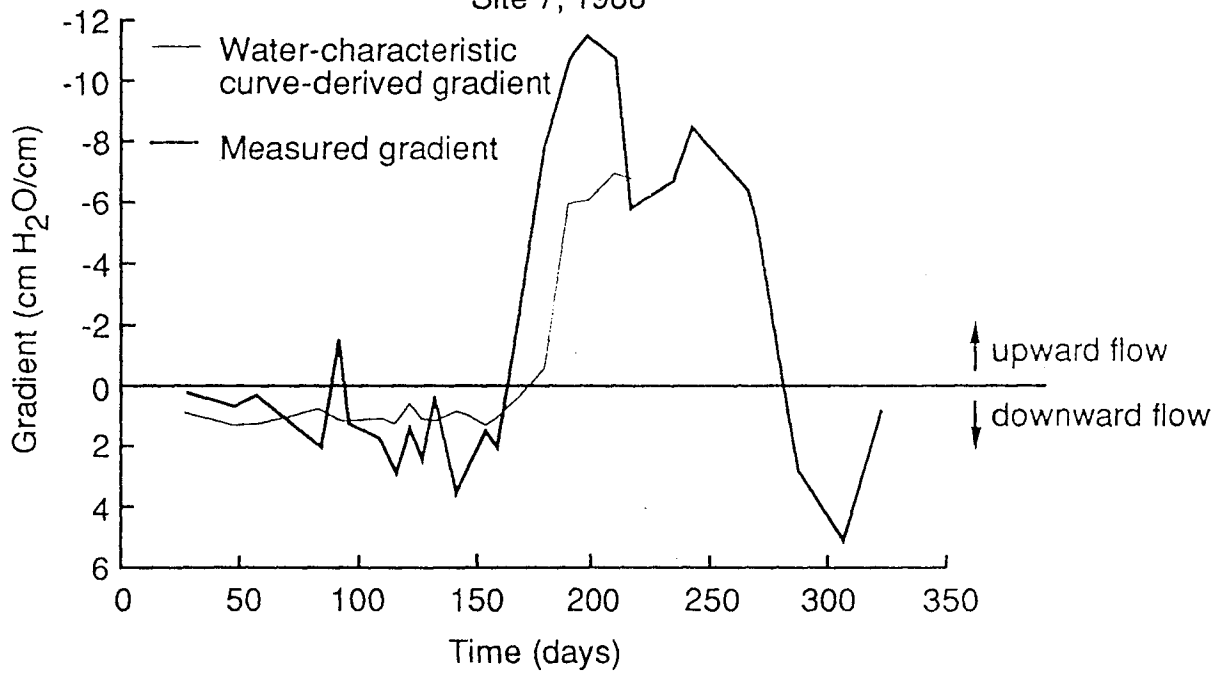
One way to determine the hydraulic gradient is to plot all available $\theta - \psi$ data pairs and observe what is variously termed the water characteristic function (Figure 16). As described in Hillel (1980), the water characteristic function consists of an upper desorption or draining curve observed during drying events, and a lower bound called the sorption curve observed during wetting events. The desorption curve calculated from the drainage experiment at site # 5 is illustrated in Figure 16. Although the curve should follow the desorption curve drawn when using all the data, probably the higher suction values along the desorption curve are due to the inclusion of evapotranspiration. The separation of the two curves is due to the physical phenomenon known as hysteresis, in this case the ψ difference between wetting and drying of a soil. Given θ , this function predicts an average value of ψ for a single depth, considering hysteresis as the error in ψ , i.e. by computing ψ from a water characteristic curve of another depth, we compute the gradient. The measured gradients and the gradients calculated from the water characteristic functions are compared in Figure 17. Large differences sometimes resulted due to poor weekly tensiometer data or poorly defined water characteristic curves, but the water characteristic curve method was more reliable for obtaining gradients.

Often the water characteristic curve is not usable at low moistures due to sparse tensiometric data in the high suction region. Fortunately recharge is less important in this region, since a large increase in storage would be needed before recharge could occur.

b) Hydraulic Conductivity

In addition to the inaccuracy of K already mentioned, a source of error from hysteresis is introduced in that $K(\theta)$ is also a function of ψ . This means that at a given

Figure 17: Measured and Calculated Hydraulic Gradient vs. Time, Site 7, 1988

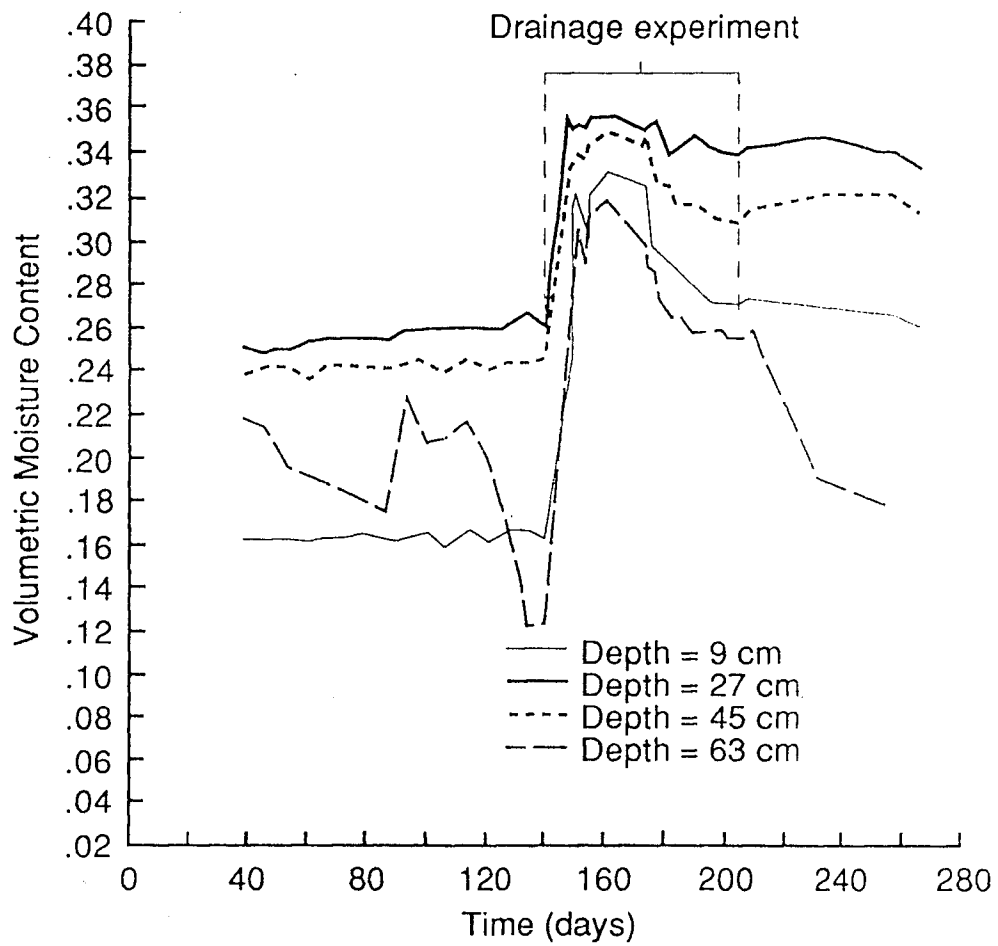


θ there is a range of $K(\theta, \psi)$ possible between the main branches of Figure 16 (Hillel, 1980), whereas the $K(\theta)$ values were all along the desorption curve. However, the relation of K to volumetric wetness $K(\theta)$ is affected by hysteresis much less than is the $K(\psi)$ function (Topp and Miller, 1966). Also, for recharge events that occur during a wet season or for prolonged recharge events, the assumption that we are following the same drying cycle as that of a drainage experiment may not be bad.

An additional difficulty in applying the K functions to natural recharge events arose for the less permeable sites (3, 8 and 9). The process of fully saturating these sites was much longer due to impeding clay layers or a high clay content in general. The resulting soil moisture profiles, as in the other sites, achieved their maximum moistures at the start of the flood experiment, but were very slow to drain. Despite the fact that moisture measurements were made for very long periods of time after the ground surface was sealed from evapotranspiration (80 days, for example), the profile in the upper 2 meters was still at a greater moisture content relative to naturally occurring moisture profiles, such as in site #8 (Figure 18). As a result, the hydraulic conductivity values obtained for these sites could only be applied to the unnaturally high moisture conditions resulting from the drainage experiments themselves.

Extrapolation of the K functions was used if the moistures were close to those at the end of a drainage experiment. However if this extrapolation occurred for a significant time after termination of the flood experiment, we would not know the accuracy of our results at all since extrapolation allows no error analysis. The extrapolated K values would have taken several months or even years to obtain from the hypothetical (extrapolated) drainage experiment from sites 3, 8 and 9. Sites 3, 8 and 9 also 'drained' more rapidly after the plastic was removed from the surface, suggesting significant upward flow. This may indicate that evapotranspiration is a very important

Figure 18: Soil Moisture Content vs. Time, Site 8, 1988



process in releasing soil moisture from these sites. It is therefore difficult to know from a flux calculation at 2 meters depth what fraction of water actually drained all the way to the water table as recharge.

c) Periodic Measurement of Soil Parameters

The complexity and diversity (unpredictable timing, light to high intensity precipitation) of rain events makes it difficult to apply Richard's equation for weekly sampling intervals of soil moisture to rapidly draining soils. Although fluxes can be calculated at the sampling time with the accuracy previously mentioned in parts b) and c), the recharge must be obtained by integrating the fluxes as 'functions' with respect to time. These functions are approximations of the complex behavior of the flux between the weekly sampling periods. The larger the data base is, the more possible it becomes to define the behavior of the flux as a function of time for different conditions. Of course another way to increase the reliability of recharge estimates is to take more frequent measurements, and this is currently being considered for the more permeable sites. In any case, it is very subjective to estimate the dynamic error owing to the sampling intervals in the present data base for each recharge event.

CALCULATION OF GROUNDWATER RECHARGE

The basic model of soil water flow is

$$(18) \quad \frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x} \left[K \frac{\partial H}{\partial x} \right] + \frac{\partial}{\partial y} \left[K \frac{\partial H}{\partial y} \right] + \frac{\partial}{\partial z} \left[K \frac{\partial H}{\partial z} \right] + \frac{\partial K}{\partial z} ,$$

from which the simplified one-dimensional version (equation (1)) was used to determine the weekly fluxes. Some additional assumptions made by using equation (1) are: 1) that the water is continuously connected throughout the flow region; 2) the inertial forces are not as significant as compared to viscous forces (as mentioned before, site #2 was a possible exception near saturation due to rapid drainage), and 3) the water is incompressible (Hillel, 1971). We also assume that 4) there are no biological phenomena (such as roots) influencing the system 5) air freely and instantaneously escapes from the system as water accumulates in it and 6) that the soil does not shrink or swell as the water content changes. The first assumption may not apply for a very dry soil, but otherwise assumptions 1)-3) are reasonable for all conditions (Hillel, 1971). The other assumptions are difficult to model, and are accepted in this thesis in order to obtain estimates of ground water recharge (in the error analysis these errors are considered to be very small). For the relatively sandy recharge sites assumptions 5) and 6) are better approximated.

The calculation of recharge from equation (5) (the discretized form of equation (1)) was done with program QPROG (Appendix I). The program calculates gradients using both the field measurements and interpolation of the digitized water characteristic functions (Appendix III). The water characteristics were always drawn with both desorption and sorption curves, and the procedure used took the average of the two curves for a given θ and considered hysteresis as the standard error. The water

characteristic-derived gradient tends to be smoother with time compared to the direct measurements as was seen in Figure 17. This is partly due to the large error in the tensiometers, but probably is also partly due to real deviations from the water characteristic-derived gradients.

A more complete estimate of the flux would include the drainage in all of the soil layers of the measured profile. Although drainage in the profile can occur with no change in moisture, at least the flux is included which resulted from loss of moisture in the profile. This procedure is just a vertical water balance approach to the soil profile using periodic moisture measurements (Rose et. al, 1965; Van Bavel et al., 1968). The translated flux term then becomes

$$(19) \quad Q_{z+dz}(t) = q_z + \int_z^{z+dz} \frac{\partial \theta}{\partial t} dz,$$

where $Q_z(t)$ is the Darcian flux 'translated' to the depth of measurement $z+dz$, q_z is the Darcian flux and t is the time between measurements.

By connecting the weekly fluxes together in time with straight lines and integrating with respect to time, a good estimate of groundwater recharge can be obtained. The groundwater recharge is given by

$$(20) \quad \int_{t_1}^{t_2} Q(t) dt,$$

where $Q(t) = K \frac{\partial H}{\partial z}$ or the translated flux equation (19), and t_1 and t_2 correspond to weekly measurement times.

When the flux is small the linear integration is a good approximation to the exponential drainage behavior. This is essential for flux calculations interrupted by large time intervals, since the area under the flux-time curve is then greatly affected

by the pairs of fluxes defining the curve segments. The linear drainage model used can be inadequate for highly conductive soils, and the area under the curve can overestimate the recharge if one of the flux endpoints from a segment of the flux-time curve is especially large. A large change in storage may also result from measurements spread far apart in time, resulting in an overestimate of recharge from Q_{z+dz} of equation (19).

When available, the time of the beginning of a significant precipitation event was used instead of the weekly measurement time to calculate flux. The storage measured before the precipitation event was approximated as the storage at the time of precipitation, although it would be more ideal to have the peak moisture storage to begin integrating with. The approximation was especially useful for shortening long time intervals that contained relatively high fluxes.

RESULTS

Only sites where drainage experiments were performed could be used to calculate recharge from Richards equation (sites 2, 3, 5, 6, 7, 8 and 9). Both sites #8 and 9 had K's that did not come into the moisture region of their data base (e.g. Figure 18), so these sites were not used either.

Sites 2 and 5 could benefit greatly from measurements taken at smaller time increments (than the typical weekly ones) during periods of recharge. This data could be attained at a later date and the $K(\theta)$ functions would be quite useful in a full profile model of unsaturated flow such as UNSAT II (Neumann, 1983). Unlike the drainage experiments, continuous and smooth moisture fluctuations are rare for permeable sites except for the most 'ideal' precipitation, antecedant moisture and seasonal conditions. For this study the integration of flux with time was done using straight lines from measurement point to measurement point (see program QPROG, App. I). In Figure 19 the recharge calculations are compiled in this way for Site #2, 1986. The bulk of the recharge shown occurred during the late winter/ early spring and the fall as expected, and shown in the pilot study (Sophocleous and Perry, 1984).

The calculation of recharge in a year when a drainage experiment was performed invariably caused interference in the recharge estimates due to the artificial increase in its moisture profile. For these years a good estimate was obtained by just considering the spring recharge events (before the drainage experiments) since much of the recharge usually occurs early in the year anyway.

The main source of error can be seen in Figure 20 for site #5 in 1988. The integrations can grossly overestimate recharge as previously mentioned when there are long durations between measurement times, The obvious errors of this type were not

Figure 19: 91 - 137 cm, Darcian Flux vs. Time, Site 2, 1986

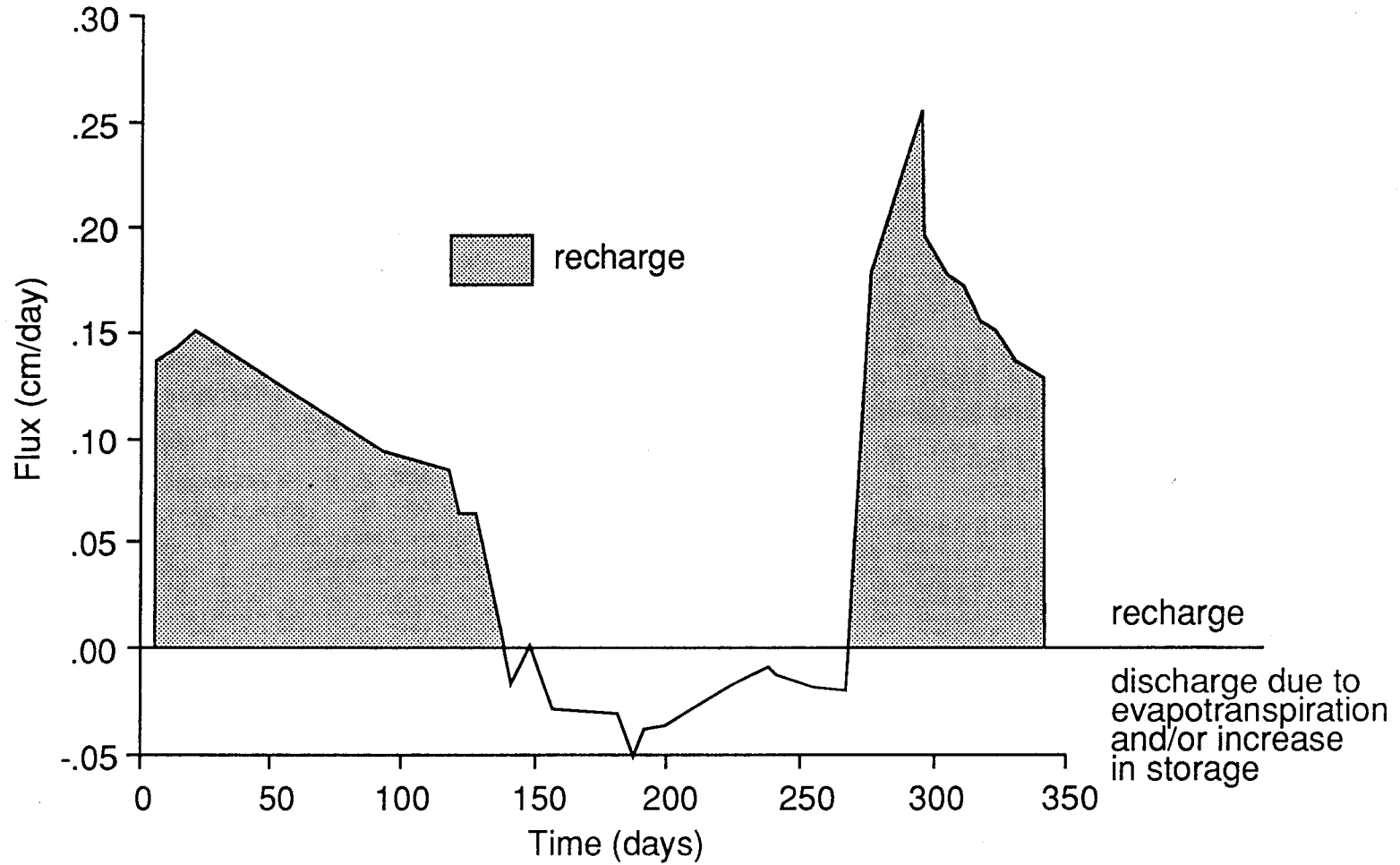
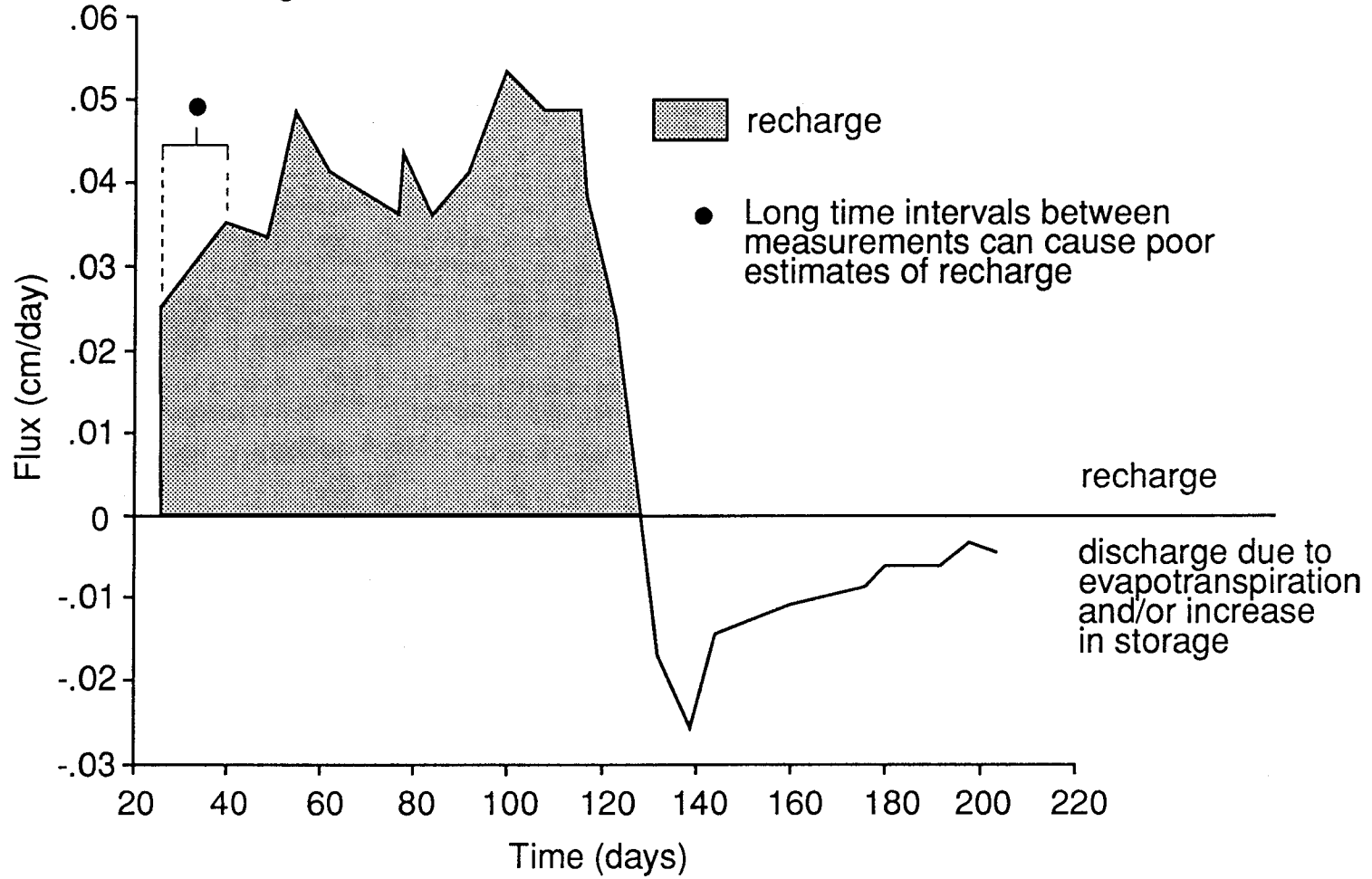


Figure 20: 91 - 152 cm, Darcian Flux vs. Time, Site 5, 1988

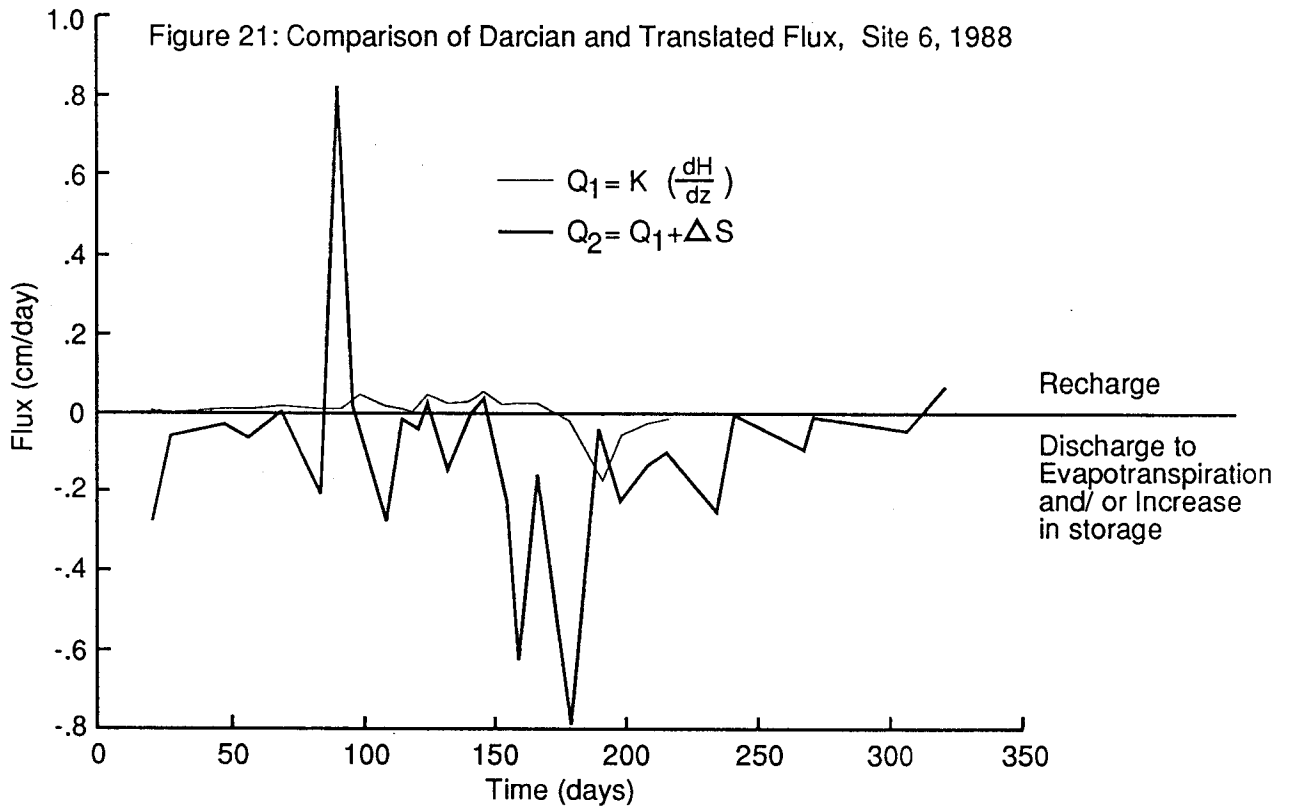


included in the final estimates of recharge, but are included in the results in Appendix II. The sites with more gradual infiltration characteristics were the most amenable to the Darcian calculation of groundwater recharge (sites 3, 6 and 8). However, it was difficult to obtain K's for these sites without extrapolation to the desired moisture content discussed earlier.

Site #2 had the most recharge (at ~1.5 meters) from these calculations. The integrated flux given by equation 20 was approximately 14 cm for 1986, 29 cm for 1987 and 11 cm for 1988 (the decrease in 1988 corresponds to lower precipitation in that year). Both the Darcian and translated flux are plotted in Figure 21 for 1988. Figure 21 indicates the erratic nature of the translated flux term. The translated flux (equation (25)) presented many problems in its use-- primarily due to relatively large time intervals between measurements. Interpretation was also difficult when the soil profile was drying and the direction of flow was not known below 2 meters (as with most sites in 1988), and when large amounts of lateral flow were a possible explanation of soil moisture storage fluctuations (as with the more permeable sites, #2 and 5).

It is probable that at site #3 the recharge occurs in selective areas around the site. The immediate area of site #3 appears to provide only small amounts of steady recharge in the spring. This recharge does not appear to immediately contribute to the resulting fluctuations of water level, and a plot of gradients indicates that downward flow was occurring throughout the spring of 1987, however the K's for most depths remain lower than those obtained after 80 days of the drainage experiments.

Site #5 was disturbed by drainage experiments in both 1986 and 1987. However estimates of recharge for 1988 were 1.5 cm for the Darcian flux, considerably lower than the 11.5 cm of recharge for site #2. The translated flux is theoretically more significant in sites where there is preferential flow, since the flux at an upper layer



may only indicate the moisture that is flowing through the pores surrounding the neutron access tube.

Site #6 had one of the lowest estimates of recharge, about 2 cm for both Darcian and translated fluxes. This indicates that little moisture penetrated the soil and long duration infiltration should be all that can be expected.

WATER BALANCE METHOD

THEORY AND APPLICATION

The field water balance method is an equation of all quantities of water added to, subtracted from, and stored within a given volume of soil during a given period of time (Hillel, 1980 B). The three main components of the balance equation considered here are precipitation (PPT), evapotranspiration (ET) and change in storage (delS). In some sites for some precipitation events there is probably a considerable error due to runoff (e.g. site #3) due to relatively less permeable soil layers at the surface. Recharge is calculated from

$$(21) \quad R = PPT - ET - \text{delS}$$

Other parameters, such as the incorporation of water into plants, capillary flow into the soil profile from below and runoff (Hillel, 1971) were considered qualitatively on a site-by-site basis. The method is paramount for comparative purposes, although errors in calculating recharge using the balance equation may be substantial.

Recharge is computed using the program RECHGE in Appendix I. The program provides calculations using ET, PPT and delS, and tabulates the results of applying the water balance equations for the site for one year of data. The procedure used is to define the time from saturation it would take for the profile to drain to 'field capacity'. This time was never less than 2 days, and is necessary in applying the water balance method. The balance is applied from the time of the main rain to the time defined by the 'field capacity', approximated as 5 days after any rain event for all sites. The two closest storage measurements to these times are used to compute delS.

a) Precipitation

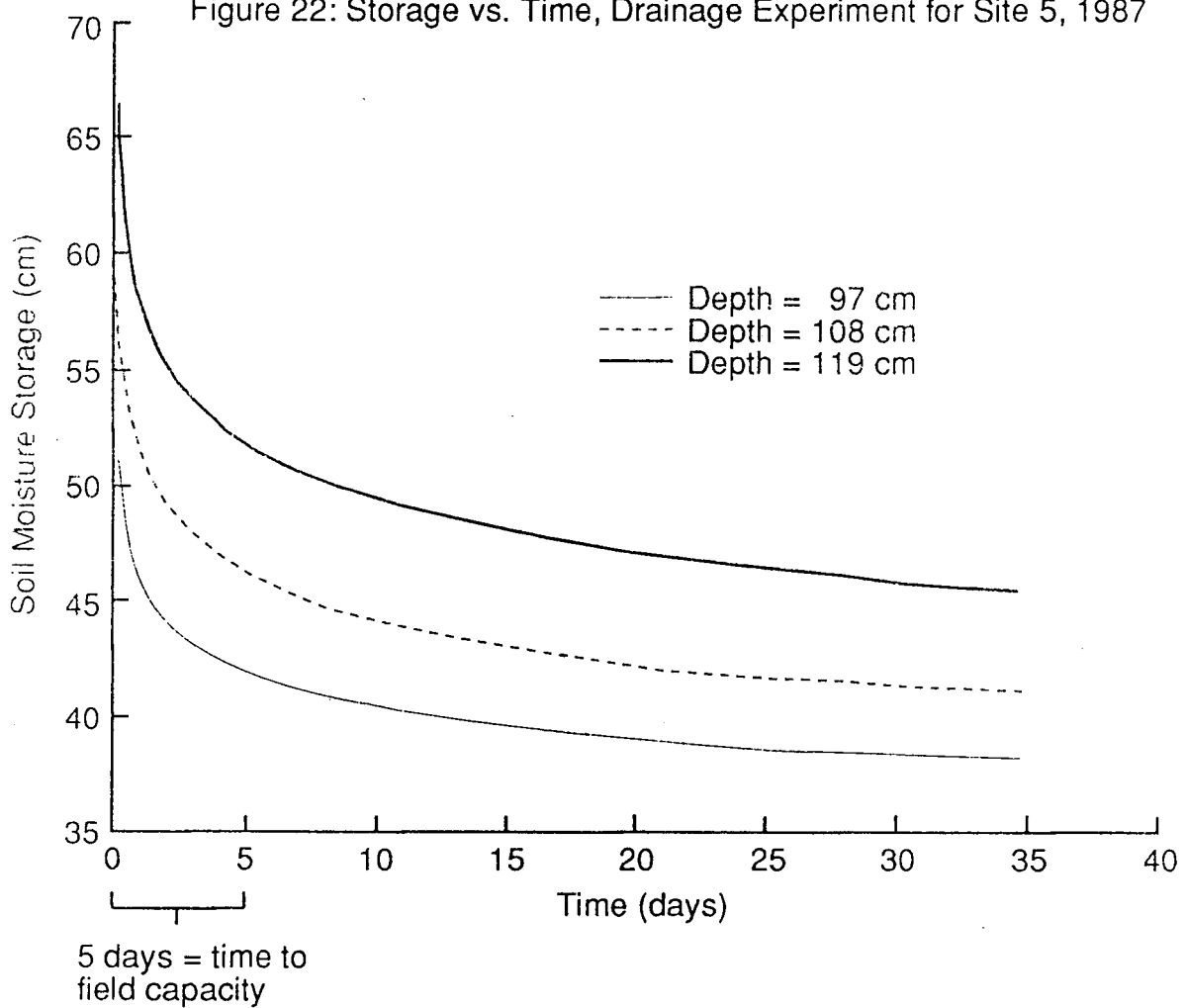
The error in measurement of precipitation at a specific location is typically about 5% (Linsley and Kohler, 1975). The spatial variability of the precipitation is actually less than the rain at certain (measured) locations. Therefore the error in precipitation can be greater than 5% when applying the water balance method over a large area. The main problem with the balance method centers around the complexity of the rain event. In the procedure used here one main event is all that is allowed between measurements and this is not always the case. More accuracy is possible only if the behavior of the profile storage is well defined for the site.

b) Change in Storage

The change in storage term was often the largest component of the water balance equation. Long time intervals and complex precipitation events made it difficult to estimate the storage at the times the balance equation was applied. The time interval used for the water balance equation (determined below) in this study was shorter than the time intervals between measurements of soil moisture storage (usually greater than 6 days). The change in storage was assumed to have occurred over the shorter time interval used, whereas the process actually took longer. Therefore, although the shorter time interval lessened the error in calculating ET, the change in storage term invariably became a large source of error.

The drainage experiments provided us with excellent estimates of the field capacity (Figure 22). Field capacity in our case is the time it takes for the saturated profile to drain until no more significant, or perhaps any, further drainage takes place (Hillel, 1980). This concept is best applied to coarse-textured soils, but in medium to fine-

Figure 22: Storage vs. Time, Drainage Experiment for Site 5, 1987



textured soils, redistribution of soil moisture such as recharge can occur over many days as the K changes more slowly than for sandy soils (Figure 12 shows the most variation in K from sandy site #2, yet it took only 20 days of drainage for this compared to 80 days of drainage for the K's of clayey site #3).

It has been found that soil water content during a rain event rises only to the point where K equals the rainfall rate, then water is transferred downward (Rubin and Steinhardt, 1963). Therefore, the assumption that no infiltration occurs below a threshold value of storage can be a poor approximation. Depending on the conductivity of the site, a relatively lengthy precipitation will pose problems for applying the field capacity concept since recharge can occur slowly below field capacity.

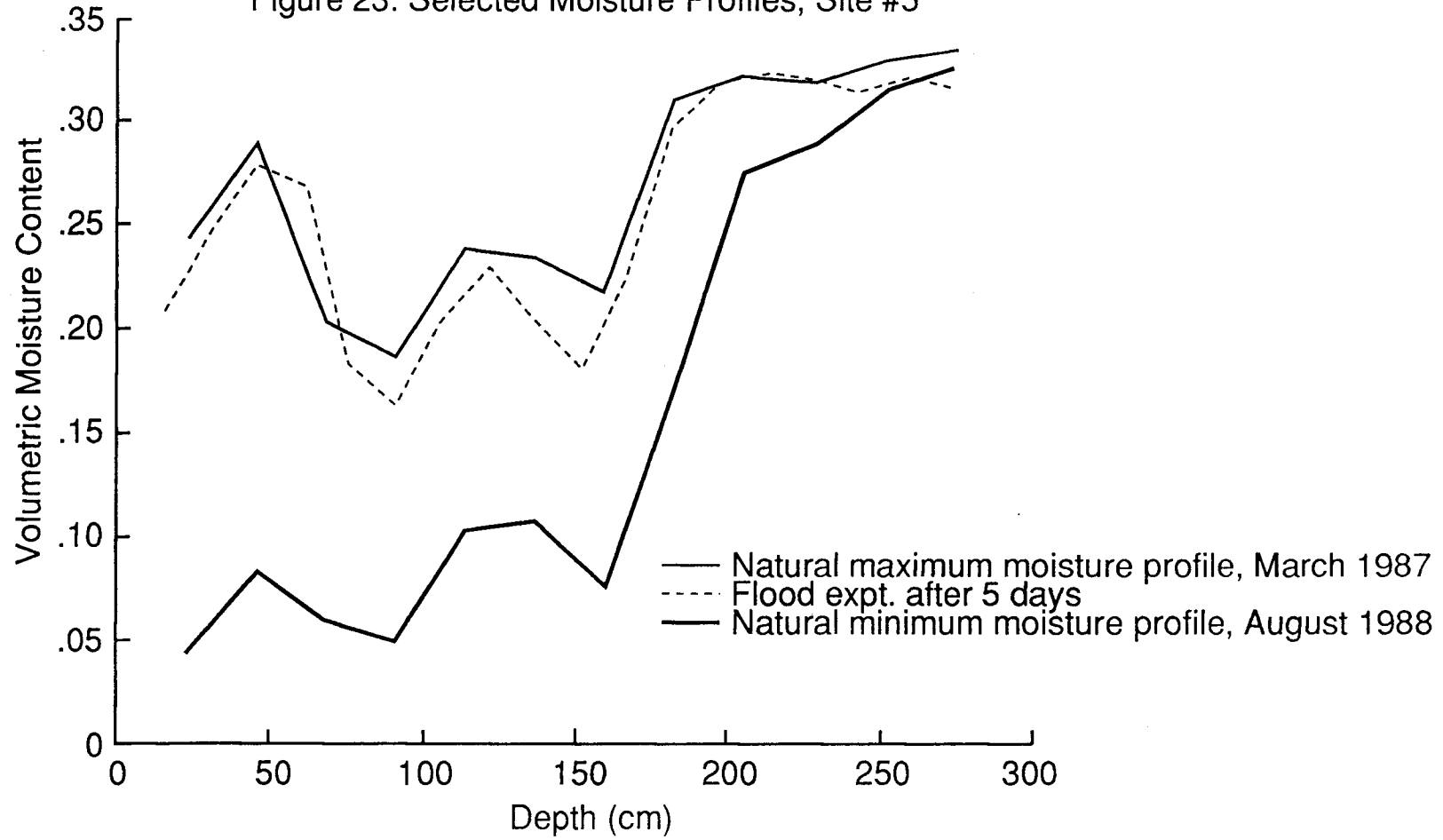
A storage profile corresponding to 'field capacity' was plotted for site #5 between the wet and dry extremes of natural moisture storage (Figure 23). This field capacity profile corresponds to the profile plotted for the 5 days after saturation during the drainage experiments. Hence 5 days after a precipitation event was the time interval used in the water balance equation for that site. Figure 23 indicates the moisture profile dissimilarity between natural conditions and conditions during a drainage experiment. Hence the 'field capacity' storage is not necessarily an accurate method to use in defining the time interval to use for the water balance equation; recharge can occur with a different soil moisture distribution than that of the drainage experiment.

c) Evapotranspiration

The procedure used to calculate the evapotranspiration term of the water balance was adapted from Morton, 1982.

$$(22) ET = 2E_{TW} - E_{T,P}$$

Figure 23: Selected Moisture Profiles, Site #5



where ET is the areal evapotranspiration used in the balance equation, E_{TP} is the potential evapotranspiration and E_{TW} is the wet environment areal evapotranspiration that would occur if the soil-plant surfaces were continuously saturated. This method is termed the complementary relationship.

The procedure above was packaged in a computer program (Morton et. al, 1985) from which we obtained ET. The meteorological data input was taken from the Sandyland Experiment Station located as shown on Figure 3, and the assumption that the Et was the same at every site was made. Due to the unavailability and/or unprocessed form of all required meteorological data at the time of the writing of this thesis, the ET for 1987 was used for 1988 as a first approximation, though this of course can introduce significant additional error. It is also useful to note that the summation of ET is greater than the summation of precipitation for any given year. This emphasizes the 'potential' nature of the ET term, and it is therefore important to apply 'proper' time intervals to the balance equation.

RESULTS

The water balance method was not used for sites #4, 8, 9, and 10. Sites 8-10 were begun recently and do not have a large data base. Site #4 had a very shallow water table (~.6 m) complicating the storage term (measurement depths were inconsistent and shallow).

The water balance method required careful interpretation of the relevant data to obtain good estimates of ground water recharge. Program RECHGE (Appendix I) yields an output that displays the time, moisture storage, precipitation and depth to water for each day. It also calculates the recharge from equation (27) for precipitation events defined by the user. Quite often a negative value for recharge will occur if ET or ΔS exceeds

the precipitation for the time interval recharge was expected, and such cases were considered to be zero recharge. A certain amount of subjectivity occurs, depending on the time interval chosen for the equation, so it is important to try to define a reasonable time interval. The time interval to be used was derived after inspection of storage vs time plots (e.g. Figure 22). The time interval was chosen to include most of the significant drainage during a drainage experiment, but since actual field situations are more complex, this time interval was somewhat subjective.

In Figure 24 we see the excellent correlation between precipitation events and water table rise for the entire data base at site #5. This does not mean, however, that the infiltration measured from the soil profile accounts for the majority of the water table rise. It is always possible that there are more permeable areas in the near vicinity that affect the water table sooner than the area of the recharge site, since the recharge site locations were random in this sense. Consequently, the excellent water level data obtained at each recharge site was difficult to use in determining amounts of percolating recharge that reach the water table. However, the water levels could be used to verify the process of recharge in a gross sense.

Another problem with comparing water level rise to recharge is that percolating water nearing the water table converts to the tension-saturated capillary fringe quickly, resulting in a disproportionate rise in the water level compared to the amount of recharge (O'Brien, 1982 and Gillham, 1984). The problems associated with lateral flow causing water level fluctuations also makes this data difficult to relate to recharge quantitatively.

One way to see the affect of the recharge site soil profile on water table level, and hence the validity of the water balance approach for that site, is to plot the precipitation, change in moisture and depth to water table (Figure 25). There is a

definite contribution to the water table rise approximately 2 days after each major precipitation event resulting from the drainage through the soil profile. The water balance approach works very well at site #2, partly because it is not as directly affected by the moisture storage readings (i.e. PPT and ET are not affected by moisture readings, whereas K and gradient are both determined directly by moisture measurements). For such permeable sites the water balance method is superior to the Darcian approach for our weekly data base.

The components of the water balance are plotted in Figure 26 for site #2, 1987. The erratic nature of the storage profile shown can cause problems when there are long

Fig 24: Water Table Level vs. Time, Site 5, 1985-1988

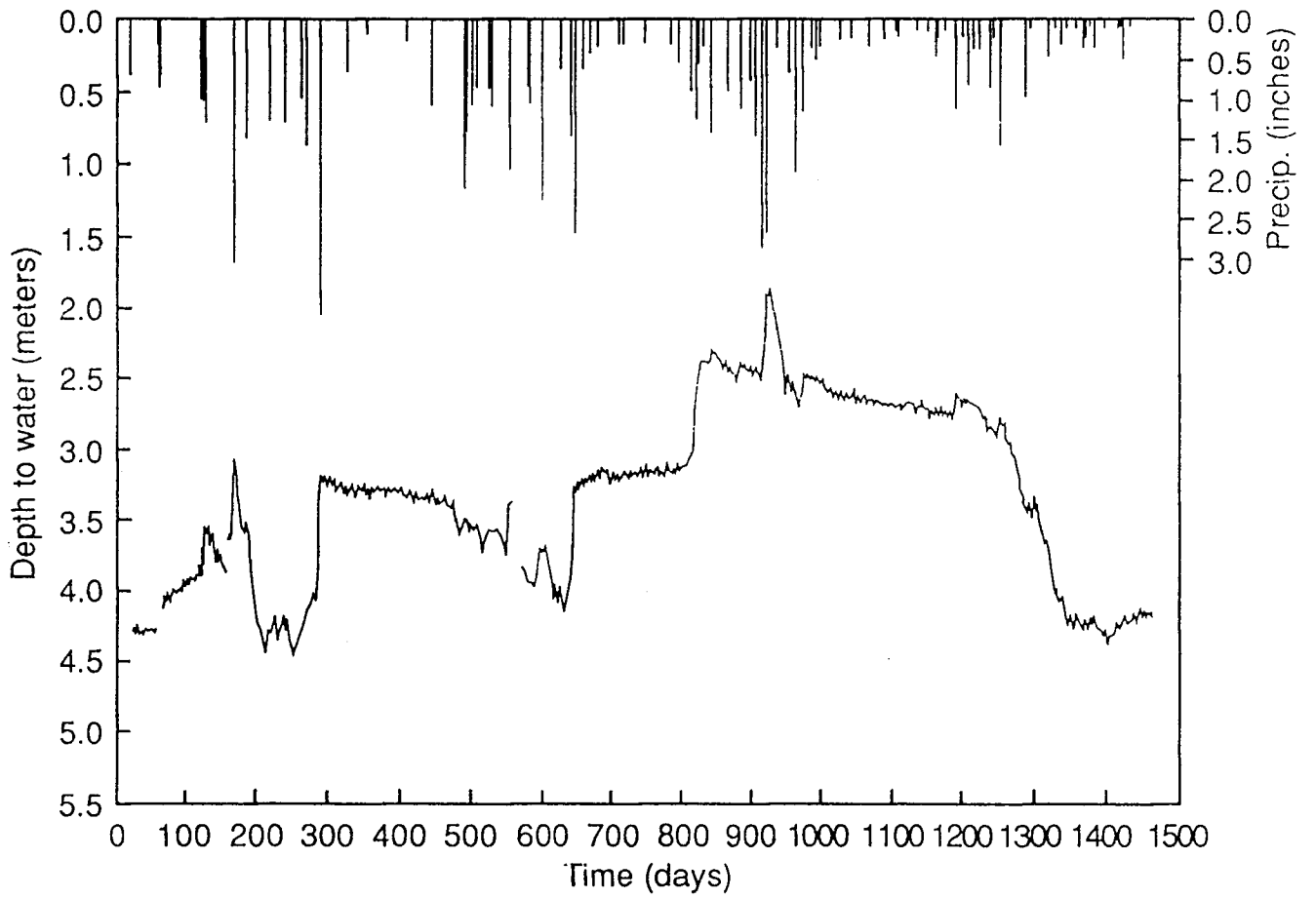
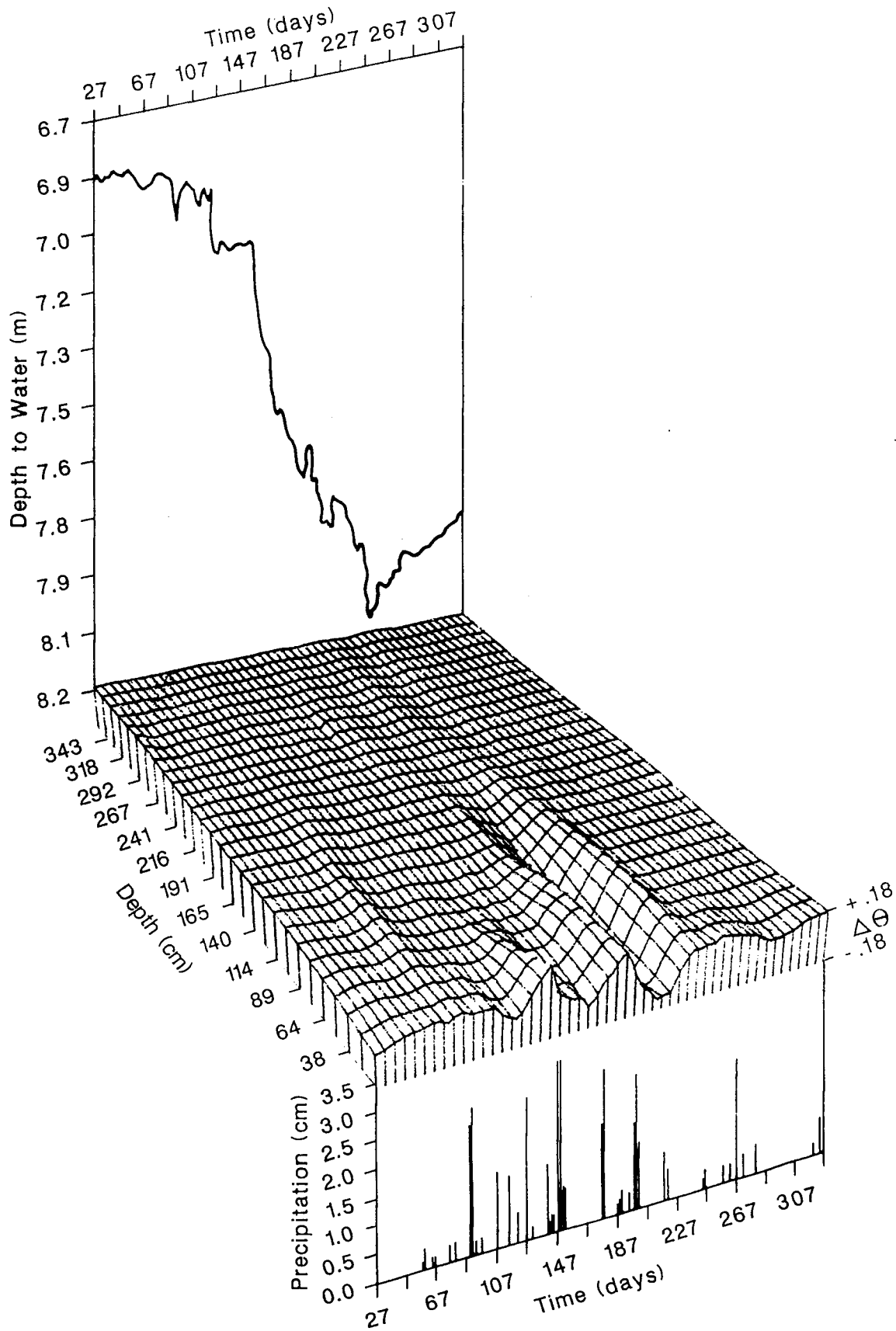


Figure 25: Precipitation, Change in Moisture and Depth to Water Table.
 Site 2, 1988*



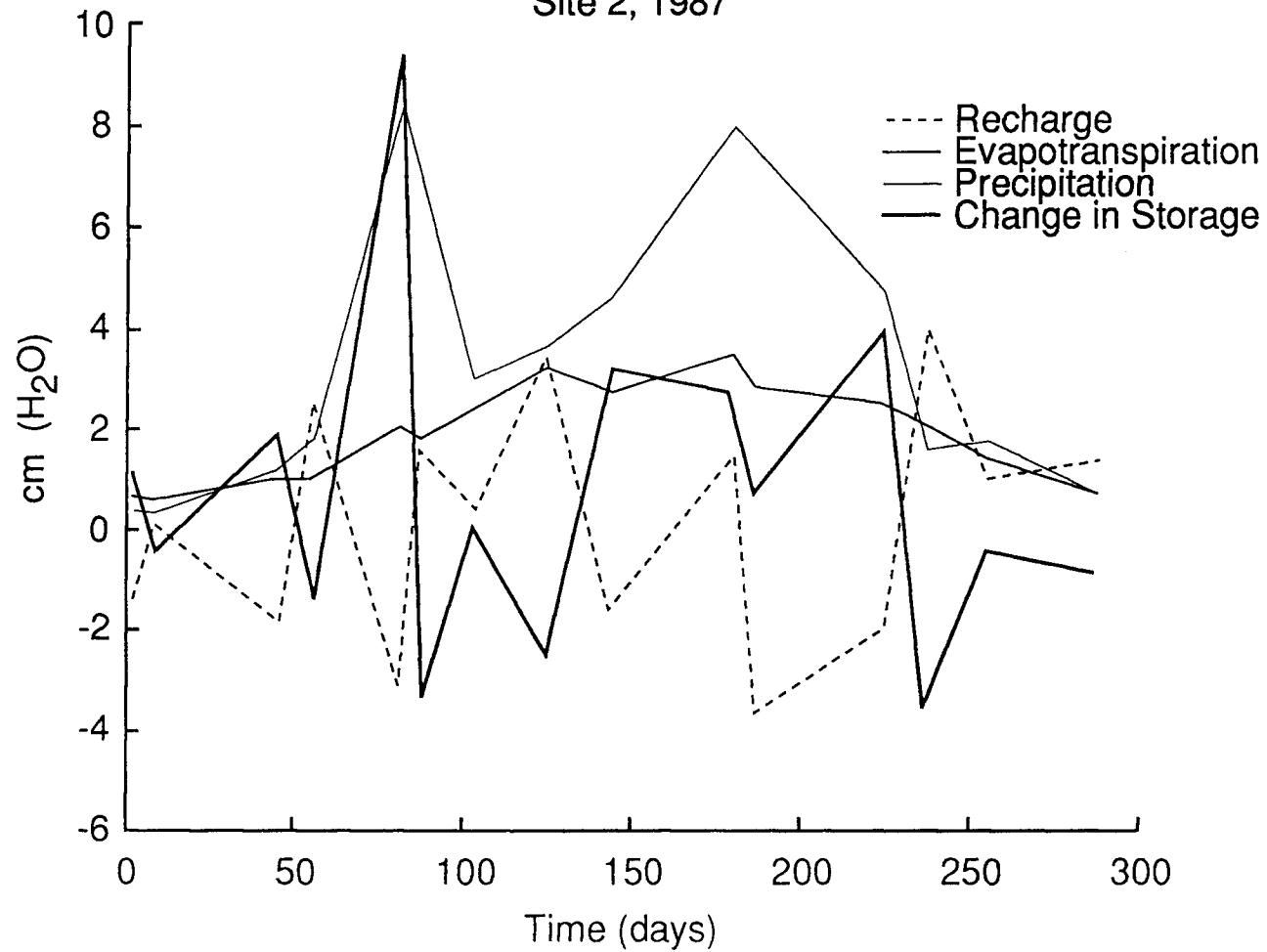
* plot design after Stoertz, M. W., personal comm.

time intervals between measurements. Some of the reasons for this include large changes in moisture in the profile due to lateral flow and upward flow of moisture, violating the water balance equation used here.

The water balance for 1987 (a year of high precipitation) is plotted for sites #1, 2 and 5 in Figure 27. Recharge was greatest at site #1 and 5 (29 and 35 cm resp.). Site #1 has the highest amount of precipitation (at 86 cm) for all sites in 1987 (and the entire data base). The recharge at site #2 is substantially less; its precipitation was 66 cm for 1987. Site #5 was less permeable than site #2, but had more precipitation overall (78 cm). The recharge events correlate roughly, but large discrepancies sometimes occur due to the timing of the change in storage term.

In Figure 28 the water balance plotted for a very dry year (sites #2, 5 and 6, 1988). The recharge is substantially reduced from 1987 in all sites, although substantial events are shown for late 1988. This is because when the soil profiles dry (decreasing soil moisture storage), the change in storage is assumed to drain down to the water table. However in a dry year such as 1988, much of this is likely to flow up from deep roots etc., hence events that are primarily due to the change in storage term for possible upward flow in 1988 were omitted from the final estimates. Furthermore, the ET term would not account for the substantial upward flow over the 5 days it was applied during such dry periods. . . a longer time interval may be more appropriate for these periods. A rough correlation of the estimates of recharge between sites with time can be seen from Figure 28.

Figure 26: Components of the Water Balance Method,
Site 2, 1987*



*discrete water balance components joined with lines
emphasize the variability of each component

Figure 27: Recharge Estimate from the Water Balance Method, Sites 1, 2, and 5, 1987

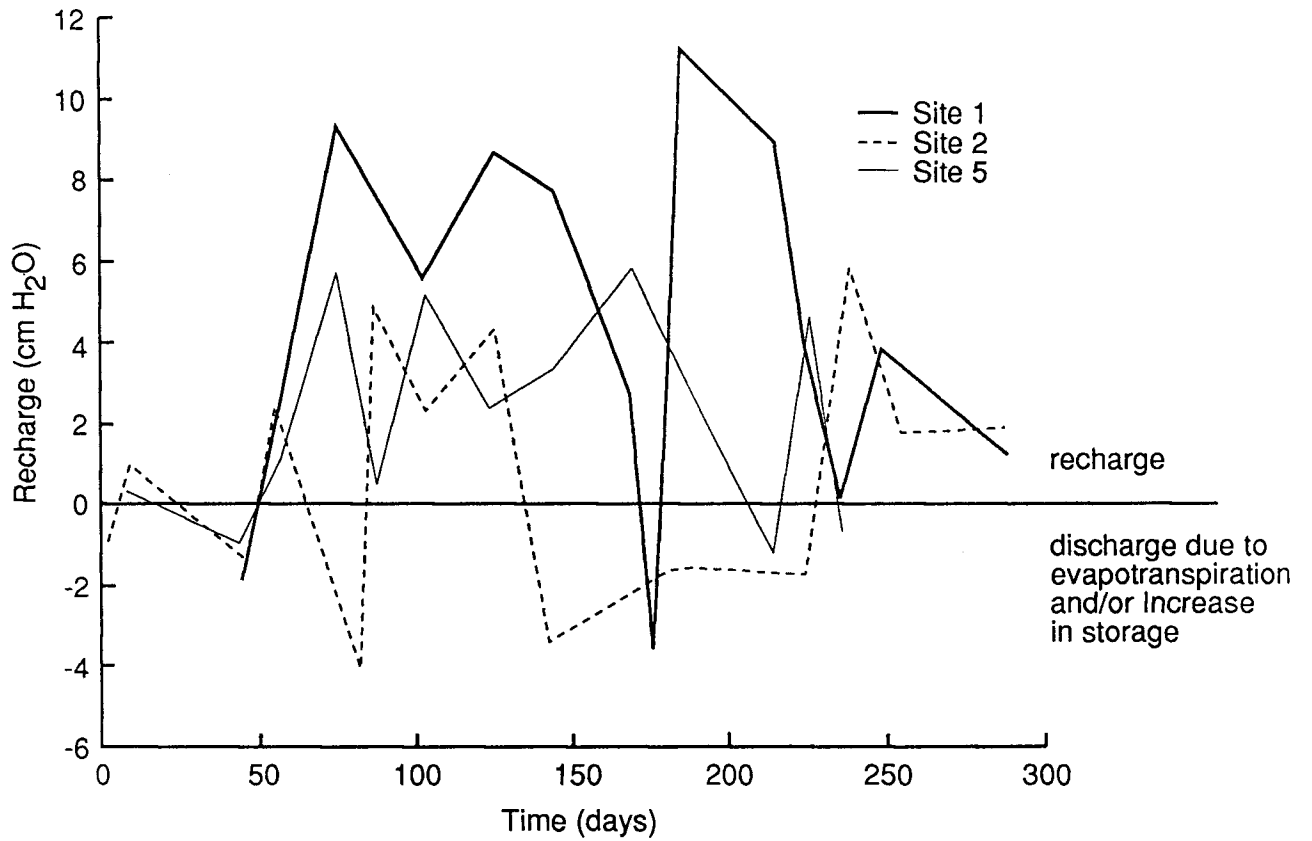
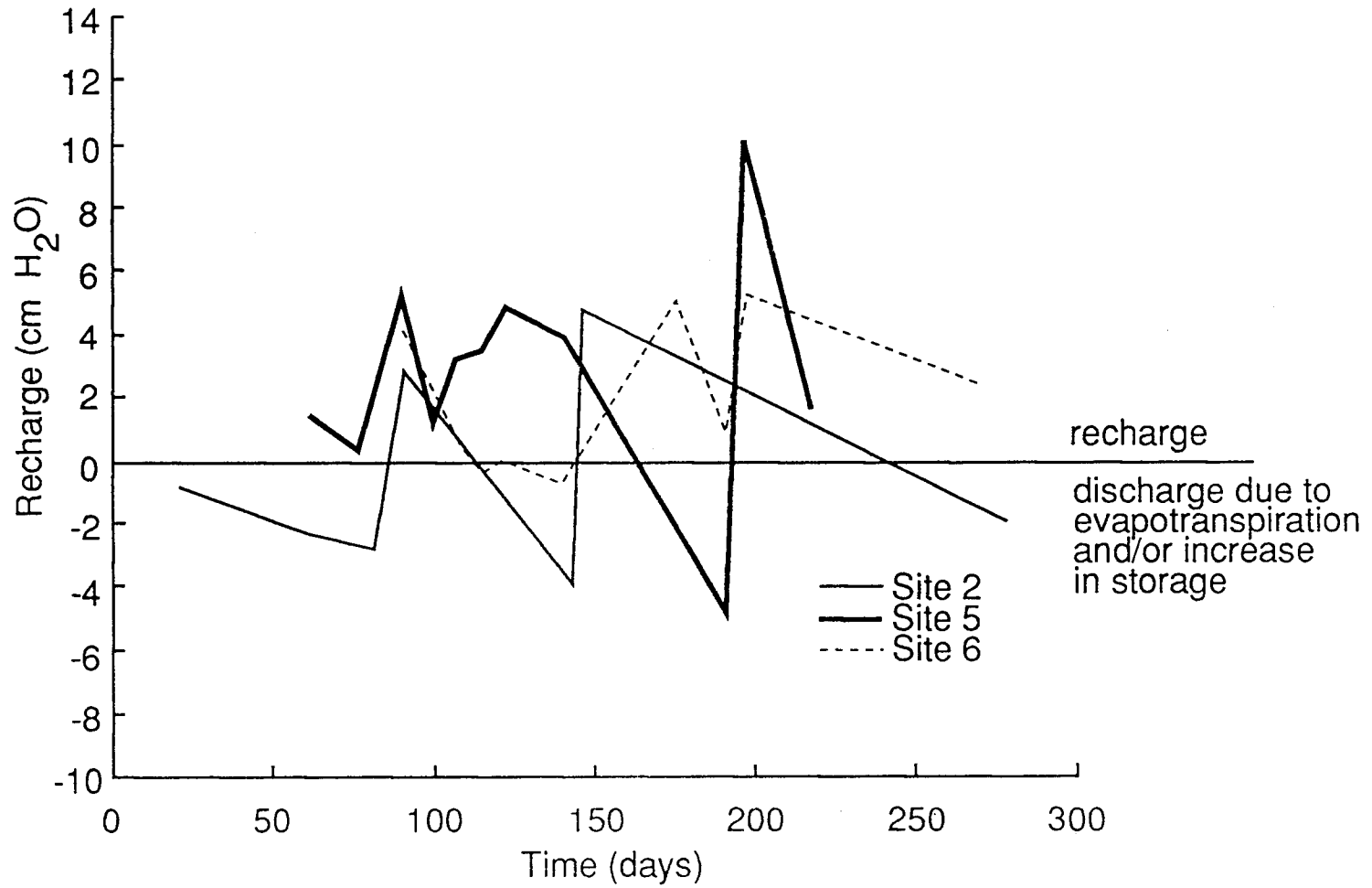


Figure 28: Recharge Estimated from the Water Balance Method, 1988



DISCUSSION

The two methods for calculating groundwater recharge in this thesis had advantages in different situations; the final results are listed in Table 6. The Darcian flux method was superior during periods of low precipitation and for sites with slow percolating recharge (although realistic K's were sometimes difficult to determine for sites with slow drainage). Because it took less time to obtain the $K(\theta)$ functions in the natural range of θ for the more permeable sites, the natural flux at such permeable sites changes very quickly. To apply the flux method accurately for such sites a more detailed data base would be needed than the present one.

The deepest available depth interval was usually used for the Darcian flux calculations to avoid effects of evapotranspiration and to prevent gross lateral flow errors by getting below or into an impeding layer. Due to the difficulties in obtaining accurate water characteristic curves, however, other depth intervals sometimes had to be used.

Site #1 is here assumed to have site #2's characteristics, inferred from their soil profiles (Figure 5). For sites #1 and 2 the water balance method is considered a superior method for calculating groundwater recharge (also a drainage experiment was never performed at site #1, so only the water balance method is used there). The more permeable the site, the harder it is to get a detailed enough data base of discrete soil moisture measurements. However, with the analog measurements of precipitation and water level it is possible to apply the water balance approach and verify its applicability to some degree by plots such as Figure 24.

The Darcian recharge estimates exceeded the water balance estimates for site #2 in 1987 and 1988 because of the use of straight lines to approximate the change in flux

Table 6: Results of Recharge Calculations

site #	depth interval(cm)	Darcian Flux Estimates of Recharge (cm)					
		1986		1987		1988	
		R	R error	R	R error	R	Rerror
1	-----	--	--	--	--	--	--
2	91-137	14	28	29	52	12	20
3	137-152	2	3	7	16	2	12
5	91-152	12	63	21	115	2	9
6	91-137	--	--	6 ^b	6 ^b	2	4
7	137-152	--	--	4 ^b	22 ^b	12	10

Water Balance Estimates of Recharge (cm)

1	11	29	2
2	15	16	6
3	10	16	2
5	19	35	5
6	--	2 ^b	3
7	--	4 ^b	5

Total Precipitation (cm)

1	67.4	86.5	37.9
2	70.6	66.3	36.9
3	57.2	71.4	39.8
5	82.6	78.0	38.0
6	--	3.5 ^b	41.3
7	--	(22.2) ^{a,b}	(38.0) ^a

^a(substituted site #5 precipitation for site #7)

^b(started operating during the summer, 1987)

boldface ; the best estimates of recharge by either method are italicized and boldface. 1987 evapotranspiration estimates were used in 1988 for the water balance method.

from soil moisture measurement to measurement. Such overestimates occur when a moisture measurement was taken during a relatively high drainage period. Therefore, the best recharge estimates at site #2 were taken from the water balance method as 15 cm for 1986, 16 cm for 1987 and 6 cm for 1988.

The Darcian flux method of obtaining recharge was the superior method for site #3, one of the least permeable sites. The error in obtaining recharge was determined by the error in the water characteristic curves used (hysteresis) and the error in K (the errors were combined in quadrature, i.e. the square root of the sum of the squares). Since the flux at site #3 varied very slowly in the data base, straight lines joining the discrete flux calculations from measurement to measurement were a good approximation of the actual variation in flux. The recharge calculations using this method (program QPROG) are presented in Appendix IV. The best estimates of recharge for site #3 consequently came from the Darcian flux method; 2 cm for 1986, 7 cm for 1987 and 2 cm for 1988.

It is useful to note that at site #3 (except for 1988, a very dry year), the water balance estimates of recharge are much higher than the best estimates from the Darcian flux method (10 cm for 1986, 16 cm for 1987). A good explanation of this would be that the precipitation at sites with a shallow clay layer is more likely to go to evapotranspiration and runoff than more permeable sites, and hence the recharge is overestimated with the water balance equation. An increase in the time interval used for the water balance equation would be necessary to obtain the appropriate amount of evapotranspiration (and hence the correct recharge).

The water balance estimates were also higher than the Darcian flux method for 1986 and 1987 at average-permeable site #5. However site #5 also had the largest error from the Darcian flux method, due to the large 'error' (and hysteretic effects) in

its water characteristic curves. For times with relatively high fluxes, the error in calculating recharge from the Darcian flux method consequently became extremely large.

Site #5 also had the most vegetation of all the recharge sites (which helped to cause the large 'hysteresis' errors in its water characteristic curves). Since the Darcian flux method provides the error analysis, and since both methods yield estimates close to each other relative to the errors, the best estimates of recharge are taken from the Darcian flux method as 12 cm for 1986, 21 cm for 1987 and 2 cm for 1988.

Site #6 was relatively impermeable and similar to site #3 in that sense, so the Darcian flux estimates were used as the best recharge estimates, 2 cm for 1988 (site #6 had a partial year of data for 1987). The water balance estimate was slightly higher (3 cm for 1988), perhaps reflecting what would be expected from the discussion of site #3 above.

Site #7 was a fairly permeable site so the water balance calculations were used to obtain the best estimate of recharge, 5 cm for 1988 (site #7 also had a partial data base in 1987). The Darcian flux method has probably overestimated the recharge for this fairly permeable site (10 cm for 1988) for the same reasons mentioned for site #2 above.

CONCLUSIONS

The accuracy of the recharge calculations varied depending on the differing soil type (site). Recharge estimates using either the water balance method or the Darcian flux method were difficult to obtain when the measurement time intervals were large. The Darcian flux method worked best for sites with slow drainage, as fast draining sites caused a large error in the simplified integration procedure used. The water balance method was superior to using the Darcy equation for large time intervals and relatively fast draining profiles provided the change in storage term was well represented (i.e. not a result of a complex precipitation event).

The results presented are accurate enough to yield valuable information on the rates of groundwater recharge in the Great Bend Prairie region of Kansas. The hydraulic conductivity functions can be useful for later studies. For example, by taking detailed measurements of natural recharge events, relatively accurate recharge calculations can be made using the Richards equation with the K's from Appendix II. Additionally, areal recharge estimates can be obtained using the recharge results presented here in conjunction with an appropriate soils map of the Great Bend Prairie region.

REFERENCES

- Draper, N.R., Smith, H. (1981). "Applied Regression Analysis", 2nd ed. Wiley, N.Y.
- Fader, Stuart W., and Stullken, Lloyd E. (1978). Geohydrology of the Great Bend Prairie, South-Central Kansas. Irrigation series 4, map 4.
- Fluhler, H., Ardakani, M.S. and Stolzy, L.H. (1976). Error Propagation in Determining Hydraulic Conductivities from Successive Water Content and Pressure Head Profiles. Soil Sci. Soc. Am. J., vol. 40, pp 830-836.
- Freeze, R.A. and Cherry, J.A. (1979). "Groundwater". Prentice-Hall, N.J.
- Gardner, W. H. (1986). Methods of soil analysis part 1- physical and mineralogical methods, vol. 1, no. 9, 2nd ed., pp 493-544.
- Gillham, R.W. (1984). The capillary fringe and its effect on water-table response. Jour. Hydrol., Vol. 67, no. 1/4, pp. 307-324.
- Hanks, R.J. and Bowers, S.B. (1962). Numerical solution of the moisture flow equation for infiltration into layered soils. Soil Sci. Soc. Amer. Proc. Vol. 26, pp 530-534.
- Hillel, D. (1971). "Soil and Water-Physical Principles and Processes". Academic Press, New York.
- Hillel, D., Krentos, V.D. and Stylianou, Y. (1973). Procedure and Test of an Internal Drainage Method for Measuring Soil Hydraulic Characteristics In situ. Soil Science V 114, no. 5, pp395-400.
- Hillel, D. (1980). "Applications of Soil Physics". Academic Press, New York.
- Hillel, D. (1980). "Fundamentals of Soil Physics". Academic Press, New York.
- Marthaler, H.P., Vogelsanger, F. R. and Wieraenga, P.J. (1983). A Pressure Transducer for Field Tensiometers. Soil Sci. Soc. Am. Jour., Vol. 47, pp 624-627.
- Linsley, R.K., Kohler, M.A. and Paulhus, J.L. (1975). "Hydrology for Engineers". McGraw-Hill, New York (2nd Ed).
- Morton, F. I. (1983). Operational Estimates of Areal Evapotranspiration and Their Significance to the Science and Practice of Hydrology. Jour. Hyd. 66, pp 1-76.
- Neumann, S.P. and Davis, L.A., (1983). Documentation and User's Guide: UNSAT2-Variably Saturated Flow Model, NRC Public Document, Wash. D.C.

- Nielsen, D.R., Biggar, J.W. and Erh, K.T. (1973). Spatial Variability of Field-Measured Soil-Water Properties. *Hilgardia*, Vol. 42, No. 7, pp 215-259.
- O'Brien, A.L. (1982). Rapid water table rise. *Water Resour. Bull.*, Vol. 18, no. 4, pp. 713-715.
- Priestley, C.H.B. and Taylor, R.J., (1972). On the assessment of the surface heat flux and evaporation using large-scale parameters. *Mon. Weather Rev.*, 100: pp 81-92.
- Richards, L.A. (1931). Capillary conduction of liquids in porous mediums. *Physics*, Vol. 1, pp 318-333.
- Rose, C.W., Stern, W.R. and Drummond, J.E., 1965. Determination of hydraulic conductivity as a function of depth and water content for soil in situ. *Aust. J. Soil Res.*, 3: 1-9.
- Rubin, J., (1966). Theory of rainfall uptake by soils initially drier than their field capacity and its applications. *Water Resour. Res.*, Vol. 2, no. 4: pp 739-749.
- Rubin, J. and Steinhardt, R., (1963). Soil-water relations during rain infiltration, I. Theory. *Proc. Soil Sci. Soc. Am.*, 27: pp 246-251.
- Rubin, J., Steinhardt, R. and Reiniger, P., (1964). Soil-water relations during rain infiltration, II. Moisture content profiles during rains of low intensities. *Proc. Soil Sci. Soc. Am.*, 28: 1-5.
- Sophocleous, M.A., (1985). The Role of Specific Yield in Ground-Water Recharge Estimations: A Numerical Study. *Ground Water*, V 23, num. 1, pp 52-58.
- Sophocleous, M.A., and Perry, C., (1984). Experimental Studies in Natural Groundwater-Recharge Dynamics: The Analysis of Observed Recharge Events. *Jour. of Hyd.* 81, 297-332.
- Steel, R.G.D., and Torrie, J.H., (1980). "Principles and Procedures of Statistics". McGraw-Hill, New York.
- Taylor, J.R. (1982). *An Introduction to Error Analysis- The Study of Uncertainties in Physical Measurements*". University Science Books, Mill Valley, California.
- Topp, G.C., and Miller, E.E. (1966). Hysteresis moisture characteristics and hydraulic conductivities for glass-bead media. *Soil Sci. Soc. Amer. Proc.* Vol. 30, pp156-162.

Van Bavel, C.H.M., Stirk, G.B. and Brust, K.J., 1968. Hydraulic properties of a clay loam soil and the field measurement of water uptake by roots: I. Interpretation of water content and pressure profiles. Soil Sci. Soc. Am., Proc., 32: 310-317.

Wilson, R. G. (1974). Method of Measuring Soil Moisture, International Field year for the Great Lakes- Technical Manual Series No. 1, pp 15-16.

APPENDICES

Appendix I.

Computer Programs

a) Program FIELDKPROG

c

c This program calculates soil moisture content given:
c a) neutron counts with depth of 1.5 minutes each
c b) a set of 10 standard counts, of 1.5 minutes each

c

c The two neutron probes used in our measurements are distinguished
c by the order of magnitude difference in their respective standard
c counts. The moisture is calculated based on a calibration curve
c derived from all sites used in our study.

c The error in soil moisture content is calculated from its 3 main
c components (positioning error, error in calibration curve, stat-
c tistical error from counting rate and time of count).

c A strict input format is followed, although allowances
c were made for older data files.

c

c SAMPLE DATA FILE (less the first column containing "c's").

c

c 5507

c 5598

c 5628

c 5627

c 5645 The 10 standard counts.

c 5522

c 5627

c 5648

c 5629

c 5557

cAUG 19 1987 9:15-10:15 Month,day,year,military time

c 6 4744 4663 4744 4730 4931 (see Month Acronyms below)

c 12 4562 4619 4608

c 18 4385 4390 4357 Depth,counts; variable number

c 24 4432 4348 4272 4354 of counts, up to 6.

c 30 3980 3930 3874 3878

c888. Terminates a block of data

c for that measurement; 777.

c is used if > 1 measurement

c on this date.

c

c-----

c Month Acronyms: JAN,FEB,MAR,APR,MAY,JUN,JUL,AUG,SEP,OCT,NOV,DEC

c-----

c

c

PROGRAM FIELDKPROG

```

REAL MST0,MST1,MST2,MSWAIT
REAL RATIO,OLDRATIO,MOIST,AVER,STDAVC,DEPTH,DPTSTO,MSTSTO
INTEGER FCT1,FCT2,FCT3,FCT(20),YEAR,STCT
INTEGER BEGDAY,BEGHR,HR1,HR2,HR,DAY,BEGMIN,FSTDTH
INTEGER JDEPTH(20:100)
CHARACTER*2 IYEAR
CHARACTER*4 FORMT
CHARACTER*5 ADEPTH
CHARACTER*1 OMIT,ADEPTH1,OMWAIT
CHARACTER*3 BEGMTH,MTH
CHARACTER*4 AYEAR,PROBE
CHARACTER*5 MNTH(12)
CHARACTER*8 SRCE1,SRCE2
CHARACTER*9 SOURCE3
CHARACTER*80 LINE
CHARACTER*40 SOURCE,SOURCE1,SOURCE2
CHARACTER*11 TIME
WRITE(*,1)
1  FORMAT(/)
WRITE(*,*)'ENTER FIELDKIN_(old-or-new hole) INPUT FILE: '
READ(*,888)SOURCE2
888  FORMAT(A40)
READ(SOURCE2(5:6),2)IYEAR
READ(SOURCE2(8:8),3)ISITE
AYEAR= '19'//IYEAR
WRITE(*,*)'ENTER DATATIMES_____ OUTPUT FILE: '
READ(*,888)SOURCE
OPEN(14,FILE=SOURCE,IOINTENT='OUTPUT')
OPEN(15,FILE=SOURCE2,IOINTENT='INPUT',PAD='YES',BLANK='ZERO')
OPEN(200,FILE='MSTERR',IOINTENT='OUTPUT')
WRITE(200,543)
543  FORMAT(3X,'TIME',3X,'DEPTH',5X,'CALIB. ER',1X,'Count Er',
& 1X,'Posit. Er',1X,'Total % error of SUMMST')
WRITE(*,*)'ENTER NUMBER OF DEPTHS (for plot files): '
READ(*,*)NN
2  FORMAT(A2)
3  FORMAT(I1)
C  OPEN(55,FILE='STDCNT',IOINTENT='OUTPUT')
SOURCE3 = 'FKOUT11_1'
WRITE(SOURCE3(6:7),'(A2)')IYEAR
WRITE(SOURCE3(9:9),'(I1)')ISITE
OPEN(16,FILE=SOURCE3 ,IOINTENT='OUTPUT')
*
*
*****
*
ITRIG = 2
OMWAIT = ''
L = 6
DO 22 I=1,NN
SRCE1 = 'DEPTH____'
SRCE2 = 'SDPTH____'
IF(L.EQ.6)THEN
WRITE(SRCE1(6:8),'(A3)')6 '

```

```

        WRITE(SRCE2(6:8),'(A3)')'6 '
    ELSEIF(L.LT.99)THEN
        WRITE(SRCE1(6:7),'(I2)')L
        WRITE(SRCE1(8:8),'(A1)')' '
        WRITE(SRCE2(6:7),'(I2)')L
        WRITE(SRCE2(8:8),'(A1)')' '
    ELSE
        WRITE(SRCE1(6:8),'(I3)')L
        WRITE(SRCE2(6:8),'(I3)')L
    ENDIF
    JDEPTH(I+19) = L
    OPEN(I+19,FILE=SRCE1,IOINTENT='OUTPUT')
    WRITE(I+19,9)JDEPTH(I+19),ISITE,AYEAR
9    FORMAT(I3,' in, SITE #,I2,',',A4)
    OPEN(I+99,FILE=SRCE2,IOINTENT='OUTPUT')
    WRITE(I+99,9)JDEPTH(I+19),ISITE,AYEAR
    L = L+6
22   CONTINUE
C
C
C
*
    JJ=1
    J=20
    SUMMST = 0.0000
*
*
*****
*
*
    READ(15,101)BEGMTH,BEGDAY,BEGHR,BEGMIN
101  FORMAT(A3,4X,I2,6X,I2,1X,I2)
    WRITE(16,110)
110  FORMAT(' MNTH',1X,'DAY',3X,'YEAR',2X,'TIME',7X,'DEPTH',5X,
    &'MOIST',5X,'AVERFC',5X,'STDCNT')
C
5   CONTINUE
    WRITE(16,*)'
    WRITE(16,*)'
    STDAVC=0.0
    DO 310 I=1,10
    READ(15,*)STCT
    STDAVC=STCT+STDAVC
C
        IF((STCT/1000).GT.10.)THEN
            PROBE='GMD5'
        ELSE
            PROBE='KGS'
        ENDIF
C
310 CONTINUE
    STDAVC=STDAVC/10.0
C
63  WRITE(16,*)'

```

```

DPTSTO=0.
READ(15,102)MTH,DAY, YEAR, TIME
102 FORMAT(A3,4X,I2,1X,I4,1X,A11)
READ(TIME(1:2),57)HR1
READ(TIME(4:5),57)MIN1
READ(TIME(7:8),57)HR2
READ(TIME(10:11),57)MIN2
57 FORMAT(I2)
*
  IF((HR2.LE.2).AND.(HR1.GT.20))THEN
    HR2=HR2+24
  ENDIF
*
  IF(MIN1.GE.MIN2)THEN
    MIN=(60-MIN1+MIN2)/2 + MIN1
  ELSE
    MIN=(MIN1+MIN2)/2 + MIN1
  ENDIF
  HR= (HR2-HR1)/2 + HR1 + INT(MIN/60)
  IF(HR.GT.24)THEN
    HR=(24-HR)
  ELSEIF(MIN.GT.59)THEN
    MIN= MIN - (INT(MIN/60))*60
  ENDIF
  CALL
MONTH(BEGMTH,MTH,BEGDAY, DAY, BEGHR, HR, BEGMIN, MIN, VTIME)
*
*
  IF(VTIME.GE.0.)THEN
    WRITE(14,14)VTIME
14  FORMAT(F9.4)
  ENDIF
*
*
*
*
C
C
  N=0
  20 READ(15,401)LINE
  JJ=1
  401 FORMAT(A80)
  CALL COUNT(LINE,N)
C
  IF(N.EQ.0)THEN
*
*
992 CONTINUE
  READ(LINE,403)DEPTH, OMIT
403 FORMAT(F4.1,A1)
C
C
  IF(INT(DEPTH).EQ.6)THEN
    FSTDTH = 6

```

```

ELSEIF(INT(DEPTH).EQ.9)THEN
  FSTDTH = 9
ENDIF
C
IF(DEPTH.EQ.777.)THEN
  J=20
  SUMMST = 0.0000
  GO TO 63
ENDIF
IF(DEPTH.EQ.888.)THEN
  J=20
  SUMMST = 0.0000
  GO TO 5
ENDIF
IF(DEPTH.EQ.999.)GO TO 1000
ENDIF
C
C   IF(VTIME.LT.0.)GO TO 20
C
C   READ(LINE,400)ADEPTH,(FCT(K),K=1,N)
C
C 400 FORMAT(A5,6(I5,1X))
C
C
C   JJJ = 1
C   FORMT = '(L_)'
C   OMIT = ''
C   DO 301 KKKK = 1,5
C     IF((ADEPTH(KKKK:KKKK).NE.'
C   ').AND.(ADEPTH(KKKK:KKKK).NE.'@'))THEN
C       WRITE(FORMT(3:3),'(I1)')KKKK-JJJ+1
C       READ(ADEPTH(JJJ:KKKK),FORMT)IDEPTH
C       DEPTH = REAL(IDEPTH)
C       ELSEIF(ADEPTH(KKKK:KKKK).EQ.' ')THEN
C         JJJ = JJJ + 1
C       ELSEIF(ADEPTH(KKKK:KKKK).EQ.'@')THEN
C         OMIT = '@'
C       ENDIF
C 301 CONTINUE
C   IF(OMIT.NE.'@')OMIT=' '
C   FCT1=0
C   ICOUNT=0
C   DO 410 K=1,N
C     FCT1=FCT1+FCT(K)
C 410 CONTINUE
C
C
C   AVER=(FCT1)/N
C   RATIO=AVER/STDAVC
*****
*****
*****
*****
*****

```

```

*
  IF(PROBE.EQ.'GMD5')THEN
* EQUATION A COMBO OF SITES 2,3,5 and 7 EMPLACED ON JULY 20, 1987
  MOIST=-0.0739+.2740*RATIO
  ELSEIF(PROBE.EQ.'KGS')THEN
*
* EQUATION A COMBO OF SITES 2,3,5 and 7 EMPLACED ON JULY 20, 1987
  RATIO= 0.2263 + 1.5791*RATIO
  MOIST=-0.0739 + .2740*RATIO
  ENDIF
C
C
C
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCC
C
C
  IF(INT(DEPTH).EQ.6)THEN
    SUMMST = SUMMST + MOIST*(6*2.54)
  ELSE
    SUMMST = SUMMST + MOIST*(9*2.54)
  ENDIF
*
*
*****
*****
*****
*****
*
C
C
  IF(NINT(DEPTH-DPTSTO).EQ.6)THEN
    IF(VTIME.GE.0.000000)THEN
      WRITE(16,200)MTH,DAY, YEAR, TIME,DEPTH,MOIST,AVER,STDAVC
    ENDIF
200   FORMAT(A5,2X,I2,1X,I4,2X,A11,2X,F6.2,2X,F6.4,3X,F10.2,
&     1X,F10.2)
C
C
      write out a file to test the std counts. .
C
C
      IF(INT(DEPTH).EQ.6)THEN
        IF(OMIT.NE.'@')THEN
          WRITE(55,'(2F10.4,$)')VTIME,AVER/10000
        ELSE
          OMIT = ''
        ENDIF
      ENDIF
C
C
      ELSE
C
C
      *****INTERPOLATE BLOCK*****
C
      III = 1

```

```

111 CONTINUE
    NNN=NINT((DEPTH-DPTSTO)/6.)
    IF(NNN.GE.1)THEN
C
C
        IF(FSTDTH.EQ.6)THEN
            MOIST=(III*6/(DEPTH-DPTSTO))*(MOIST-MSTSTO) + MSTSTO
            DEPTH = DPTSTO + III*6
        ELSE
            MOIST=((INT(DPTSTO/6)+1)*6-DPTSTO)/
&(DEPTH-DPTSTO)*(MOIST-MSTSTO) + MSTSTO
            DEPTH =(INT(DPTSTO/6)+1)*6
        ENDIF
C
        IF(III.LT.NNN)THEN
*
*
            IF(VTIME.GE.0.00000)THEN
                WRITE(16,209)MTH,DAY,YEAR,TIME,DEPTH,MOIST,
&                'INTERPOLATED WRT DEPTH'
                ENDF
209          FORMAT(A5,2X,I2,1X,I4,2X,A11,2X,F6.2,2X,F6.4,26X,A22)
            ELSEIF((III.GE.NNN).AND.(DEPTH/6-INT(DEPTH/6).LE..01))THEN
                IF(VTIME.GE.0.00000)THEN
                    WRITE(16,200)MTH,DAY,YEAR,TIME,DEPTH,MOIST,AVER,STDAVC
                ENDF
            ENDF
        ENDF
    ENDF
*
*
****
*
*
C#####
C  OUTPUT A FILE FOR PLOTTING (MOISTURE VS. TIME), FOR EACH DEPTH
C#####
*
*
****
*
*
        DO WHILE ((JJ.EQ.1).AND.(VTIME.GE.0.0000000))
            IF(INT(DEPTH).EQ.JDEPTH(J))THEN
                IF(OMWAIT.NE.'@')THEN
                    OMWAIT = OMIT
C
C
C          ERROR ANALYSIS
                IF(INT(DEPTH).EQ.6)THEN
                    MST0 = MOIST
                    MST1 = MOIST
                    VTWAIT = VTIME
                    SMWAIT = SUMMST

```

```

        MSWAIT = MOIST
        SUMSQR = 0.0000
    ELSE
        MST2 = MOIST
    CALL ERROR(N,MST0,MST1,MST2,STDAVC,STDERR,E1,E2,E3)
    WRITE(33,'(5F7.4)')MST1,E1,E2,E3,STDERR
    SUMSQR = SUMSQR + (INT(DEPTH*2.54)*STDERR)**2
    SUMERR = SQRT(SUMSQR)
    WRITE(J-1,'(3F10.4)')VTWAIT,MSWAIT,STDERR
    WRITE(J+80-1,'(3F10.4)')VTWAIT,SMWAIT,SUMERR
544  WRITE(200,544)DEPTH,MST1,E1,E2,E3,STDERR,(STDERR/MST1)*100
    FORMAT(7F10.4)
        VTWAIT = VTIME
        SMWAIT = SUMMST
        MSWAIT = MOIST
    ENDIF

    ELSE
        SUMSQR = SUMSQR + (INT(DEPTH*2.54)*STDERR)**2
        SUMERR = SQRT(SUMSQR)
        OMWAIT = OMIT
        VTWAIT = VTIME
        SMWAIT = SUMMST
        MSWAIT = MOIST

    ENDIF
    JJ=2
    ELSE
        IF(J.LE.(NN+19))THEN
            J=J+1
        ELSE
            JJ=2
        ENDIF
    ENDIF
    END DO

*
*
*****
*
*

    DPTSTO=DEPTH
    MSTSTO=MOIST
    IF(NNN.GT.1)THEN
        III = III + 1
        GO TO 111
    ELSE
        III = 999
        GO TO 20
    ENDIF
1000 STOP
    END

C
C
    SUBROUTINE COUNT(LINE,ICOUNT)
    CHARACTER*80 LINE
    ICOUNT=-1

```

```

I=6
5 ICOUNT=ICOUNT+1
N=0
15 IF(N.GE.4)GO TO 50
IF(LINE(I:I).EQ.' ')THEN
N=N+1
I=I+1
GO TO 15
ENDIF
20 IF(LINE(I:I).NE.' ')THEN
I=I+1
GO TO 20
ENDIF
IF(I.LE.80)GO TO 5
50 CONTINUE
RETURN
END

```

```

C
C
SUBROUTINE ERROR(N,MST0,MST1,MST2,STDAVC,STDERR,E1,E2,E3)
REAL MST0,MST1,MST2

```

```

C
C
C
C.... The errors below account for ONE std deviation ...

```

```

c
c
C
C CALIBRATION CURVE ERROR
C
C there were N = 96 points used in calib curve; the std dev.
C is StdDev = ((Total SUM of the Squares/(N - 1)) **.5
C where " " " " = .6664
C HENCE StdDev = .08375
C StdErr = .08375/(96)**.5 = .008548
E1 = (.008548)
c E1 = .001

```

```

c
cccccccccccccccccccccccccccccccccccccccccccccccccccccccc

```

```

C
C COUNT ERROR
C
C SLOPE = slope of the calib curve. . . taken from
C Gardner's info on neutron probes.
C

```

```

C
SLOPE = 1/.2740
IF(MST1.LT.0.0000)then
E2 = 0.00000
GO TO 309

```

```

c
c ^^ in other words, neg moistures are not dealt with
c
C
ENDIF

```

```

C

```

```

C      Count Error, 1 std deviation. . . (from Wilson' s paper)
C
309  E2 = (MST1/(SLOPE*STDAVC*(.5*N)))**.500
      CONTINUE
C
C      POSITIONING ERROR
C
C      error due to mis-positioning the probe at said depth;
C      taken as +/- 5mm , as recommended by Wilsons' paper
C
      E3 = ABS((.5/15.24)*(MST0-MST1))
&      + ABS((.5/15.24)*(MST2-MST1))
      E3 = E3/2.000
C
      STDERR = SQRT(E1**2 + E2**2 + E3**2)
      MST0 = MST1
      MST1 = MST2
      RETURN
      END

```

b) PROGRAM REG1

C
C

```
DIMENSION X(2,2),Y(2,1),WK(500)
REAL MST,ier,Mest,MSTSAT
REAL TIME(20)
CHARACTER*30 TITLE
CHARACTER*8 SOURCE,SOURCE1
```

C
C

```
WRITE(*,*)'ENTER SITE #:'
READ(*,'(I1)')ISITE
WRITE(*,*)'ENTER YEAR, 19'
READ(*,'(I2)')IYEAR
```

C
C
C
C

```
WRITE(*,*)'ENTER DESIRED MAXIMUM DEPTH FOR CONSIDERATION
(iN): '
```

```
4 READ(*,4)MAXDPT
   FORMAT(I3)
   WRITE(*,*)'WANT ANY POINTS OMITTED?'
   WRITE(*,*)'(1=yes ,2=No )'
   READ(*,*)LFLAG
   WRITE(*,*)'MOISTURES OR SUMMED MOISTURES? (1 or 2 resp.)'
   READ(*,*)IWHICH
   IF(IWHICH.EQ.1)THEN
     SOURCE1 = 'MREG___#'
     SOURCE = 'DEPTH000'
   ELSE
     SOURCE1 = 'SREG___#'
     SOURCE = 'SDPTH000'
   ENDIF
   WRITE(SOURCE1(5:6),'(I2)')IYEAR
   WRITE(SOURCE1(8:8),'(I1)')ISITE
   OPEN(12,FILE=SOURCE1,IOINTENT='OUTPUT')
   OPEN(100,FILE='test',IOINTENT='OUTPUT')
   WRITE(12,3)
3   FORMAT('DPTH',3X,'Y-INTCPT',7X,'SLOPE',5X,'Std Err ',5X,
   &'CORR CF',5X,'MOIST(sat)')
```

C
C

```
IDCNT=0
DO 444 I=1,NINT(MAXDPT/6.)
  K=1
```

```

IDCNT=IDCNT+6
C
C
WRITE(SOURCE(6:8),4)IDCNT
IF(SOURCE(7:7).EQ.' ')THEN
    SOURCE(6:6)='6'
    SOURCE(7:8)=' '
ELSEIF(SOURCE(6:6).EQ.' ')THEN
    SOURCE(6:7)=SOURCE(7:8)
    SOURCE(8:8)=' '
ENDIF
C
C
C
    OPEN(11,FILE= SOURCE,IOINTENT= 'INPUT',PAD='YES')
20    CONTINUE
    IF(LFLAG.EQ.2)GO TO 933
    WRITE(*,*)'ENTER TIME (iN dec. dys) OF OMISSION FOR
& ',IDCNT,' (iNch.) DEPTH: '
    READ(*,5)TIME(K)
5    FORMAT(F8.4)
    WRITE(*,*) 'ANYMORE ? (1=YES, 2=NO ): '
    READ(*,6)JTEST
6    FORMAT(I1)
    IF(JTEST.EQ.1)THEN
        K=K+1
        GO TO 20
    ENDIF
933    CONTINUE
C
    SUM1=0.000
    SUM2=0.000
    SUM3=0.000
    SUM4=0.000
    SUM5=0.000
    Smerr =0.000
    Smsqr =0.000
    K=1
    N=0
23    READ(11,23)TITLE
    FORMAT(A30)
    DO WHILE(.TRUE.)
61    CONTINUE
    READ(11,60,END=77)TME,MST
60    FORMAT(2F10.4)
    IF(INT(TME*1000).EQ.INT(TIME(K)*1000))THEN
        K=K+1
        GO TO 61
    ELSEIF(INT(TME*1000).EQ.0)THEN
        TME=0.0001
    ELSEIF(TME.LT.0.0000)THEN
        GO TO 61
    ENDIF
    N=N+1

```

```

C
C REGRESSION AREA
C
      Smerr = Smerr + MST
      Smsqr = Smsqr + MST**2.0000
      SUM1 = SUM1 + MST**2.0000
      SUM2 = SUM2 + (MST**2.0000)*(LOG(TME))
      SUM3 = SUM3 + (MST**2.0000)*((LOG(TME))**2.0000)
      SUM4 = SUM4 + (MST**2.0000)*(LOG(MST))
      SUM5 = SUM5 + (MST**2.0000)*(LOG(TME))*(LOG(MST))
END DO
77  CONTINUE
      x(1,1) = SUM1
      x(1,2) = SUM2
      x(2,1) = SUM2
      x(2,2) = SUM3
      y(1,1) = SUM4
      y(2,1) = SUM5

c
c 2x2 matrix inversion
c
c
c call leqt2f(x,1,2,2,y,4,WK,ier)
c
a = y(1,1)
b = y(2,1)
c
c
REWIND (11)
READ(11,23)TITLE
c
c
c correl. coeff. etc.
c
      SUMMSQe = 0.0000000000
      SUMMe = 0.0000000000
      MSTSAT = 0.0000000
DO WHILE (.TRUE.)
66  CONTINUE
      READ(11,60,END=777)TME,MST
C
C      SUBORDINATE PROCESS
C      also fiNd SATURATION MOISTURE
C
      IF(MST.GT.MSTSAT)THEN
          MSTSAT=MST
      ENDIF
C
C
      IF(INT(TME*1000).EQ.INT(TIME(K)*1000))THEN
          K=K+1
          GO TO 66
      ELSEIF(INT(TME*1000).EQ.0)THEN

```

```

        TME=0.0001
        ELSEIF(TME.LT.0.0000)THEN
        GO TO 66
        ENDIF
Mest = (tme**b)*(exp(a))
SUMMSQe = SUMMSQe + Mest**2.0000
SUMMe = SUMMe + Mest
END DO
777  continue
      SST = Smsqr - (SMerr**2.000)/real(N)
      write(100,*)smsqr,'-',smerr,'**2)/',n,'= ',sst
      StdDev = (SST/real((N - 1)))**(.50000)
      StdErr = SQRT(StdDev**2.0000/real(N))
      SSR = SUMMSQe - (SUMMe**2.00000)/real(N)
      write(100,*)summsqe,'-',summe,'**2)/',n,'= ',ssr
      write(100,*)' '
      GOF = SSR/SST
      COCF = SQRT(GOF)
C***
C****
C*****
C*****
C*****
C***** * * * * END REGRESS AREA * * * * *
      IF(IWHICH.EQ.1)THEN
        WRITE(12,55)IDCNT,a,b,StdErr,COCF,MSTSAT
55      FORMAT(I3,2X,5(F10.5,2X))
      ELSE
        WRITE(12,55)IDCNT,a,b,StdErr,COCF,MSTSAT
      ENDIF
444  CONTINUE
      STOP
      END

```

c) Program TENS

```
c
c   This program is for flood experiment data files only;
c   (TENSIN____ files).
c
c
c   The program computes the suction head and total head
c   from the TENSIN____ data files. Up to 6 values per
c   depth are allowed for; time is computed in julian days
c   from conventional time in subroutine MONTH; the heights
c   above land surface are used to account for the total
c   water column.
c
c
cccc Author: Geoff Coble
c
c
cccc The data files must be entered as follows:
c
c   1) all tensiometers used must have a PSI value for
c   all times.
c
c   2) missing readings are entered as '0'.
c
c   3) the negative readings are entered as positive
c   suction for ease . . . IF there are positive
c   readings, then enter as a negative number; they
c   occur infrequently.
c
cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
```

```
c
PROGRAM TENS
CHARACTER*80 HEADING,STRING,SOURCE
CHARACTER*3 ADEPTH,MTH,BEGMTH
CHARACTER*1 OMIT(10)
REAL TOPS(20,10),PSI(10),HEAD(10),JUDY
INTEGER FCT(20,10),DAY,HR1,HR2,BEGHR,BEGDAY,BEGMIN,HR,MIN
INTEGER ID(20),ITNUM(10)
C
WRITE(*,*)'ENTER SITE: '
READ(*,'(I1)')ISITE
WRITE(*,*)'ENTER YEAR: '
READ(*,'(I2)')IYEAR
SOURCE = 'TENSIN____'
WRITE(SOURCE(7:8),'(I2)')IYEAR
WRITE(SOURCE(10:10),'(I1)')ISITE
C
```

```

OPEN(11,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
SOURCE = 'TENSOUT_____'
WRITE(SOURCE(8:9),'(I2)')IYEAR
WRITE(SOURCE(11:11),'(I1)')ISITE
OPEN(12,FILE=SOURCE,IOINTENT='OUTPUT')
IDTH = 0
LLL = 0
LL = 0
IFLAG = 0
C
C read in heights of tensiometers above land surface . . .
C
  IDPTH2 = -1
  READ(11,'(A43,A37)')HEADING,STRING
  DO WHILE (STRING(1:2).NE.'--')
    CALL COUNT(STRING,N)
    READ(HEADING(1:2),'(I2)')IDEPTH
    IF(IDPTH2.EQ.IDEPTH)THEN
      IFLAG2 = 1
      READ(STRING,5)(TOPS(IDEPTH+1,K),K=1,N)
    ELSE
      IFLAG2 = 2
      READ(STRING,5)(TOPS(IDEPTH,K),K=1,N)
    ENDIF
5   FORMAT(4(1X,F5.2))
   READ(11,'(A43,A37)')HEADING,STRING
   IDPTH2 = IDEPTH
  END DO
  READ(11,'(A43,A37)')HEADING,STRING
  READ(HEADING(1:20),2)BEGMTH,BEGDAY,BEGHR,BEGMIN
2   FORMAT(A3,4X,I2,6X,I2,1X,I2)
C
C .....
C
C Test for time string (for a colon); IF so go to 53, and IF
C not, read the depths, call COUNT, then read the tens values
C from the string according to the number from COUNT.
C
C
50 CONTINUE
  READ(11,'(A3,A77)',END=777)ADEPTH,STRING
  NN = 0
  DO WHILE(.TRUE.)
    NN = NN + 1
    IF(STRING(NN:NN).EQ.':')THEN
      IFLAG = IFLAG + 1
      GO TO 53
    ELSEIF(NN.EQ.30)THEN
      GO TO 54
    ENDIF
  END DO
C
54 CONTINUE
  IF(ADEPTH.EQ.' ')GO TO 50

```

```

READ(ADEPTH(1:3),'(F3.1)')DEPTH
IDEPTH = INT(DEPTH*12.00)
CALL COUNT(STRING,N)
C
  IF((IFLAG.EQ.1).AND.(IDEPTH.NE.IDTH))THEN
    LL = LL + 1
    ID(LL)=IDEPTH
    ITNUM(LL)=N
    DO 13 K=1,N
      IF(IDEPTH.EQ.6)THEN
        SOURCE = '_TNS6'
      ELSE
        SOURCE = '_TNS_'
        WRITE(SOURCE(5:6),'(I2)')IDEPTH
      ENDIF
      WRITE(SOURCE(1:1),'(I1)')K
C
      OPEN(K+30+IDEPTH,FILE=SOURCE,IOINTENT='OUTPUT')
      IF(IDEPTH.EQ.6)THEN
        WRITE(SOURCE(6:6),'(A1)')'_ '
      ELSE
        WRITE(SOURCE(7:7),'(A1)')'_ '
      ENDIF
      OPEN(K+170+IDEPTH,FILE=SOURCE,IOINTENT='OUTPUT')
      WRITE(K+30+IDEPTH,*)' '
      WRITE(K+170+IDEPTH,*)' '
      LLL = LLL + 1
13    CONTINUE
C
C OUTSIDE TENSIMETERS AT SAME DEPTH OF PREVIOUS TENSIMETER
ASSUMED.
C
    ELSEIF((IFLAG.EQ.1).AND.(IDEPTH.EQ.IDTH))THEN
      DO 14 K=1,N
        SOURCE = '_TNS_OUT'
        WRITE(SOURCE(5:6),'(I2)')IDEPTH
        WRITE(SOURCE(1:1),'(I1)')K
        OPEN(K+100+IDEPTH,FILE=SOURCE,IOINTENT='OUTPUT')
        WRITE(K+100+IDEPTH,*)' '
14      CONTINUE
      ENDIF
C
      READ(STRING,55)(OMIT(K),FCT(IDEPTH,K),K=1,N)
55      FORMAT(6(A1,I3))
C
      PSISUM = 0.
      HEDSUM = 0.
      DO 100 L=1,N
        IF((OMIT(L).NE.'@').AND.(FCT(IDEPTH,L).NE.0))THEN
          IF(IFLAG2.EQ.1)THEN
            PSI(L) = - TOPS(IDEPTH+1,L) - IDEPTH*2.54 + FCT(IDEPTH,L)
          ELSEIF(IFLAG2.EQ.2)THEN
            PSI(L) = - TOPS(IDEPTH,L) - IDEPTH*2.54 + FCT(IDEPTH,L)
          ENDIF

```

```

HEAD(L) = PSI(L) + IDEPTH*2.54
IF(IDEPTH.NE.IDTH)THEN
  IF(PSI(L).GT.0.000)THEN
    WRITE(L+170+IDEPTH,10)MTH,DAY,HR,MIN,VTIME,PSI(L)
  ENDIF
  WRITE(L+30+IDEPTH,10)MTH,DAY,HR,MIN,VTIME,PSI(L)
10  FORMAT(A3,1X,I2,1X,I2,':',I2,1X,2F12.5)
  ELSE
    WRITE(L+100+IDEPTH,10)MTH,DAY,HR,MIN,VTIME,PSI(L)
  ENDIF
ELSEIF(FCT(IDEPTH,L).EQ.0)THEN
  IF(IDEPTH.NE.IDTH)THEN
    WRITE(L+30+IDEPTH,9)MTH,DAY,HR,MIN,VTIME
9   FORMAT(A3,1X,I2,1X,I2,':',I2,1X,F12.5,3X,'---')
  ELSE
    WRITE(L+100+IDEPTH,9)MTH,DAY,HR,MIN,VTIME
  ENDIF
ENDIF
100 CONTINUE
c
c Block for READING the time using the subroutine MONTH *****
c
c
53  CONTINUE
IF(STRING(16:16).EQ.':')THEN
  READ(STRING(1:21),201)MTH,DAY,HR1,MIN1
201  FORMAT(5X,A3,2X,I2,1X,I2,1X,I2)
  HR2 = HR1 + 1
  MIN2 = MIN1
ELSEIF(STRING(15:15).EQ.':')THEN
  READ(STRING(1:26),202)DAY,IYEAR,HR1,MIN1,HR2,MIN2
  MTH = ADEPTH
202  FORMAT(4X,I2,3X,I2,1X,I2,1X,I2,1X,I2,1X,I2)
  ENDIF
IF((HR2.LE.2).AND.(HR1.GT.20))THEN
  HR2=HR2+24
ENDIF
IF(MIN1.GE.MIN2)THEN
  MIN=(60-MIN1+MIN2)/2 + MIN1
ELSE
  MIN=(MIN1+MIN2)/2 + MIN1
ENDIF
HR= (HR2-HR1)/2 + HR1 + INT(MIN/60)
IF(HR.GT.24)THEN
  HR=(24-HR)
ELSEIF(MIN.GT.59)THEN
  MIN= MIN - (INT(MIN/60))*60
ENDIF
MIN = INT(MIN)
HR = INT(HR)
CALL
MONTH(IYEAR,BEGMTH,MTH,BEGDAY,DAY,BEGHR,HR,BEGMIN,MIN,VTIME
)
c

```

```

IF(.TRUE.)THEN
  IDTH = IDEPTH
  GO TO 50
ENDIF
c
777 CONTINUE
C
C
C ***** CREATE .CLI's *****
C
C TREG.CLI
C -----
c
  OPEN(9,FILE='TREG.CLI',IOINTENT='OUTPUT')
  WRITE(9,'(A12)')'X/M TENSWGT1'
  WRITE(9,'(I1)')ISITE
  WRITE(9,'(I2)')IYEAR
  IF(LL.GT.9)THEN
    WRITE(9,'(I2)')LLL
  ELSE
    WRITE(9,'(I1)')LLL
  ENDIF
  DO 400 K=1,LL
    DO 399 J=1,ITNUM(K)
      SOURCE = ' _TNS___ '
      WRITE(SOURCE(1:1),'(I1)')J
      IF(ID(K).EQ.6)THEN
        WRITE(SOURCE(5:7),'(A3)')'6_ '
      ELSE
        WRITE(SOURCE(5:6),'(I2)')ID(K)
      ENDIF
      WRITE(9,'(A6)')SOURCE
399 CONTINUE
400 CONTINUE
    WRITE(9,'(A1)')'
c
c TRG.CLI
c -----
c
  OPEN(4,FILE='TRG.CLI',IOINTENT='OUTPUT')
  WRITE(4,'(A16)')'X/M TREGPLOTPROG'
  WRITE(4,'(I1)')ISITE
  WRITE(4,'(I2)')IYEAR
  WRITE(*,*)'ENTER MAX TIME: '
  READ(*,'(F6.2)')ZMAXT
  WRITE(4,'(F6.2)')ZMAXT
  IF(LL.GT.9)THEN
    WRITE(4,'(I2)')LL
  ELSE
    WRITE(4,'(I1)')LL
  ENDIF
  DO 332 JI=1,LL
    WRITE(4,'(I1)')ITNUM(JI)
    IF(ID(J).LT.9)THEN

```

```

        WRITE(4,'(I1)')ID(JI)
    ELSE
        WRITE(4,'(I2)')ID(JI)
    ENDIF
332 CONTINUE
    WRITE(4,'(A1)')'
c
c FIG2T.CLI
c -----
c
    OPEN(3,FILE='FIG2T.CLI',IOINTENT='OUTPUT')
    WRITE(3,'(A11)')X/M MAINNEW'
    WRITE(3,'(A1)')'6'
    SOURCE = 'Site #_, 19__'
    WRITE(SOURCE(7:7),'(I1)')ISITE
    WRITE(SOURCE(12:13),'(I2)')IYEAR
    WRITE(3,'(A13)')SOURCE
    WRITE(3,'(A11)')'Time (days)'
    WRITE(3,'(A15)')'Suction (mbars)'
    IF(LL.LT.10)THEN
        WRITE(3,'(I1)')LL
    ELSE
        WRITE(3,'(I2)')LL
    ENDIF
    SOURCE = 'TXAXIS_'
    WRITE(SOURCE(7:7),'(I1)')ISITE
    WRITE(3,'(A7)')SOURCE
    WRITE(3,'(A6)')'PYAXIS'
    WRITE(3,'(A1)')'0'
    WRITE(3,'(A1)')'0'
    DO 89 I=1,LL
        WRITE(3,'(I1)')ITNUM(I)
    DO 300 K=1,ITNUM(I)
        SOURCE = '_TNS__'
        WRITE(SOURCE(1:1),'(I1)')K
        IF(ID(I).EQ.6)THEN
            WRITE(SOURCE(5:7),'(A3)')'6_'
        ELSE
            WRITE(SOURCE(5:6),'(I2)')ID(I)
            WRITE(SOURCE(7:7),'(A1)')'_ '
        ENDIF
        WRITE(3,'(A7)')SOURCE
        WRITE(3,'(A15)')'XY (13X,2F12.5)'
        SOURCE = '_X_'
        WRITE(SOURCE(1:1),'(I1)')K
        IF(I.LT.10)THEN
            WRITE(SOURCE(3:3),'(I1)')I
            WRITE(SOURCE(4:4),'(A1)')' '
        ELSE
            WRITE(SOURCE(3:4),'(I2)')I
        ENDIF
        WRITE(3,'(A4)')SOURCE
300 CONTINUE
c

```

```

      DO 401 K=1,ITNUM(I)
        SOURCE = 'TENS # , Depth= ___ in.'
        WRITE(SOURCE(8:8),'(I1)')K
        WRITE(SOURCE(18:19),'(I2)')ID(I)
        WRITE(3,'(A22)')SOURCE
401    CONTINUE
89    CONTINUE
      WRITE(3,'(A1)')'
C
      STOP
      END
C
cccccccccccccccccccc S U B R O U T I N E "ISIZE" ccccccccccccccccc
C
      SUBROUTINE COUNT(LINE,ICOUNT)
      CHARACTER*80 LINE
      ICOUNT=0
      I=1
5     ICOUNT=ICOUNT+1
      DO WHILE((LINE(I:I).EQ.' ').OR.(LINE(I:I).EQ.'@'))
        I = I + 1
      END DO
C
C STARTS COUNT AT FIRST SPACE SEEN . . .MAKE FIRST CHARACTER A
NON-SPACE
C
6     I = I + 1
      IF(((LINE(I:I).EQ.' ').OR.(LINE(I:I).EQ.'@')).AND.
&(LINE(I:I+5).NE.' '))THEN
        GO TO 5
      ELSEIF(LINE(I:I+5).EQ.' ')THEN
        GO TO 10
      ELSE
        GO TO 6
      ENDIF
10    CONTINUE
      RETURN
      END
C
cccccccccccccccccccc S U B R O U T I N E "MONTH" ccccccccccccccccc
C
C
      SUBROUTINE MONTH(IYEAR,BEGMTH,MTH,BEGDAY,DAY,BEGHR,HR1,
&BEGMIN,MIN1,TME)
      INTEGER BEGDAY,BEGHR,MT,MT1,DAY,DAYS,HR1,BEGMIN,MT2
      CHARACTER*5 MNTH(12),LINE,LINE1,LINE2,LINE3
      CHARACTER*5 SEARCH
      CHARACTER*3 BEGMTH,MTH
      DATA MNTH/'JAN31','FEB28','MAR31','APR30','MAY31','JUN30',
& 'JUL31','AUG31','SEP30','OCT31','NOV30','DEC31'/
      IF((IYEAR.EQ.88).OR.(IYEAR.EQ.92))THEN
        MNTH(2) = 'FEB28'
      ENDIF
      I=0

```

```

SEARCH='MISST'
DAYS = 0.
C
DO WHILE(SEARCH.NE.'FOUND')
  I = I+1
  IF(MNTH(I)(1:3).EQ.BEGMTH)THEN
    SEARCH = 'FOUND'
  ENDIF
END DO
C
IF(MTH.EQ.BEGMTH)THEN
  DAYS=DAY
ELSE
  J = I
  DO WHILE (.TRUE.)
30    CONTINUE
    READ(MNTH(J)(4:5),12)MT
12    FORMAT(I2)
    DAYS = DAYS + MT
    IF(MTH.EQ.MNTH(J+1)(1:3))THEN
      GO TO 34
    ELSE
      J = J+1
      GO TO 30
    ENDIF
  END DO
34  CONTINUE
    DAYS = DAYS + DAY
ENDIF
C
  TME= (DAYS-BEGDAY) + (HR1-BEGHR)/24.+ (MIN1-BEGMIN)/1440.
C
RETURN
END

```

d) Program KPROG

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      UNSATURATED HYDRAULIC CONDUCTIVITY
C
C      This program accepts first order regression curves for moisture,
C      summation of moisture and suction head (vs. time) to calculate
C      a fitted hydraulic conductivity.
C
C      ZK (hydraulic conductivity) is calculated by dividing the flux
C      (Smst1(z,t+1) - Smst(z,t) ) by the gradient,
C      (Head1(z+1,t) - Head(z,t) ).
C
C
C      PROGRAM KPROG
C      REAL Mst,MSTMAX,ZMa,ZMB,MSTMAX2,ZK(200),THETA(200),KERR
C      INTEGER DEPTH
C      CHARACTER*9 SOURCE
C      CHARACTER*30 HEADING,TITLE
C
C      WRITE(*,*)'ENTER SITE #: '
C      READ(*,*)ISITE
C      WRITE(*,*)'ENTER YEAR, 19'
C      READ(*,*)IYEAR
C      SOURCE = 'SREG____'
C      WRITE(SOURCE(5:6),'(I2)')IYEAR
C      WRITE(SOURCE(8:8),'(I1)')ISITE
C      OPEN(11,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
C      SOURCE = 'TREG____'
C      WRITE(SOURCE(5:6),'(I2)')IYEAR
C      WRITE(SOURCE(8:8),'(I1)')ISITE
C      OPEN( 9,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
C      SOURCE = 'MREG____'
C      WRITE(SOURCE(5:6),'(I2)')IYEAR
C      WRITE(SOURCE(8:8),'(I1)')ISITE
C      OPEN(30,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
C      SOURCE = 'TIMES____'
C      WRITE(SOURCE(6:7),'(I2)')IYEAR
C      WRITE(SOURCE(9:9),'(I1)')ISITE
C      OPEN(7,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
C
C      OPEN(8,FILE='tempo',IOINTENT='OUTPUT')
```

```

WRITE(*,*)'ENTER MAXIMUM TIME: '
READ(*,7)TMAX
7  FORMAT(F8.4)
   READ(9,'(A1)')SOURCE
   WRITE(*,*)'
   WRITE(*,*)'The possible depths are: '
   WRITE(*,*)'
   DO WHILE (.TRUE.)
     READ(9,'(4X,A2)',END=707)SOURCE
     WRITE(*,*)'Depth= ',SOURCE
   END DO
707 CONTINUE
   REWIND(9)
   WRITE(*,*)'
C
WRITE(*,*)'ENTER HOW MANY K FUNCTIONS TO CREATE: '
READ(*,*)KNUM
DO 977 KKK=1,KNUM
  REWIND(7)
  REWIND(9)
  REWIND(11)
  REWIND(30)
  READ( 9,3)HEADING
  READ(11,3)HEADING
  READ(30,3)HEADING
  WRITE(*,*)'ENTER DEPTH: '
  READ(*,8) IDPTH
8  FORMAT(I3)
3  FORMAT(A30)
   SOURCE = '  K  '
   WRITE(SOURCE(4:5),'(I2)')IYEAR
   WRITE(SOURCE(7:7),'(I1)')ISITE
C
   IF(IDPTH.EQ.6)THEN
     SOURCE = '6K  '
     WRITE(SOURCE(3:4),'(I2)')IYEAR
     WRITE(SOURCE(6:6),'(I1)')ISITE
     WRITE(SOURCE(7:7),'(A1)')'
   ELSE
     WRITE(SOURCE(1:2),'(I2)')IDPTH
   ENDIF
C
   OPEN(12,FILE=SOURCE,IOINTENT='OUTPUT')
   WRITE(12,211)'Moisture','K(cm/day)','flux(cm/day)','grad(cm/day',
&'K error','flux error','grad error','time(days)'
211 FORMAT(2x,a8,2x,a9,1x,a12,2x,a12,4x,a7,5x,a10,3x,a10,4x,a10)
C
   DO 30 JJJ=1,2
2  CONTINUE
C
   IF(JJJ.EQ.1)THEN
     READ(11,5)DEPTH,a,ZMB,SDS
5  FORMAT(I3,3(2X,F10.5))
     print *,'sds= ',sds

```

```

ELSEIF(JJJ.EQ.2)THEN
  READ(30,111)DEPTH,xc,XB,MSTMAX
111  FORMAT(I3,2F12.5,24X,F12.5)
ENDIF
C
IF(DEPTH.NE.IDPTH)GO TO 2
30  CONTINUE
31  CONTINUE
C
  READ( 9,6)NN,NDEPTH,b,ZTB,SDT
 6   FORMAT(I2,I4,2X,3(F12.5))
  DEPTH = REAL(NDEPTH)
IF(DEPTH.NE.IDPTH)GO TO 31
  READ( 9,6,END=411)NN,NDEPTH2,b2,ZTB2,SDT1
  GO TO 33
C
411  CONTINUE
  BACKSPACE(9)
  BACKSPACE(9)
  BACKSPACE(9)
  READ( 9,6)NN,NDEPTH,b,ZTB,SDT
  READ( 9,6)NN,NDEPTH2,b2,ZTB2,SDT1
C
33  CONTINUE
  dZ = REAL(NDEPTH2 - NDEPTH)
C
C
C
C
C   READ OFF THE FIRST TIME VALUE. . .
C   (use max mst, zero psi for first K);
C   SET TIMES=0 (NOT USED FOR
C   FIRST PASS).
C
  READ(7,'(F10.4)')TIMES
  READ(7,'(F10.4)')TIMES
C
C
  OPEN(33,file='testt',iointent='output')
  ZM = MSTMAX
  T1 = (ZM/EXP(xc))**(1/XB)
  Ta = T1
  N = 0
  ZINC1 = 0.0001
  ZINC2 = 0.006
C
DO WHILE (T1.LE.TMAX)
  N = N + 1
299  CONTINUE
  T1 = (ZM/EXP(xc))**(1/XB)
c
c the higher the moisture, the smaller the time (closer to start of
c drainage experiment)
c
  IF(N.GT.1)THEN

```

```

Ta = ((ZM+ZINC2)/EXP(xc))**(1/XB)
ENDIF
Tb = ((ZM-ZINC2)/EXP(xc))**(1/XB)
c
c The routine below decreases the moisture until the resulting
c time becomes close to TIMES from the actual field measurements.
c
IF(T1.LT.TIMES)THEN
  ZM = ZM - ZINC1
  GO TO 299
ELSE
  READ(7,'(F10.4)',END=979)TIMES
ENDIF
C
C
IF(T1.GT.TMAX)THEN
  GO TO 979
ENDIF
c
cccc SMst1 at time Ta, which is always later than time Tb
c
SMst = (Ta**ZMB)*(EXP(a))
SMst1 = (Tb**ZMB)*(EXP(a))
c
c
IF(N.EQ.1)THEN
  Psi = 0.100
  Psi1 = 0.100
  Head = Psi + NDEPTH*2.54
  Head1 = Psi1 + NDEPTH2*2.54
ELSE
  Psi = (T1**ZTB)*(EXP(b))
  Psi1 = (T1**ZTB2)*(EXP(b2))
  Head = Psi + NDEPTH*2.54
  Head1 = Psi1 + NDEPTH2*2.54
ENDIF
c
grad = (Head1 - Head)/(dZ*2.54)
flux = (SMst1 - SMst)/(Tb - Ta)
  print *, 'grad= ', grad, ' flux= ', flux, ' tb= ', tb
  write(8,999)(' ,SMst1, '-', SMst,')/(' ,Tb, '-', Ta,)' = ', flux
C
  if(grad.lt.(.2))then
    go to 977
  endif
C
C hydraulic conductivity calculated . . .
C
  ZK(N) = -flux/grad
C
  IF((ZK(N-1).LT.ZK(N)).AND.(N.GT.1))THEN
    write(*,*)'PSI CURVES SHOW WATER FLOWS UP...!'
    ZK(N) = -flux
  GO TO 977
C

```

```

        ENDIF
C
    CALL ERROR(ISITE,IYEAR,NDEPTH,NDEPTH2,SDT,SDT1,SDS,
&XK,THETA,Ta,Tb,flux,grad,dZ,KERR,terr,FLUXER,GRADER)
        KERR = KERR * ZK(N)
C
C     Real moisture (not summation) = THETA is needed for
C     the K vs. THETA plots (calculated below)
C
        THETA(N) = (T1**XB)*EXP(xc)
C
C     OUTPUT A __K__ FILE
C
        IF(ZK(N).GT.(.0001))THEN
            WRITE(12,50)THETA(N),ZK(N),-flux,grad,
&
            KERR,FLUXER,GRADER,T1,PSI
50          FORMAT(F9.4,F11.4,7F13.4)
        ENDIF
C
C     write(33,'(4f10.4)'t1,psi,psi1,ZK(N)
C
C shelving . . .
C
999     FORMAT(A1,F7.3,A1,F7.3,A3,F7.4,A1,F7.4,A2,F7.3)
976     CONTINUE
        END DO
979     CONTINUE
977     CONTINUE
        STOP
        END
C
    SUBROUTINE ERROR(ISITE,IYEAR,IDPTH,IDPTH1,SDT,SDT1,SDS,
&XK,THETA,Ta,Tb,FLUX,GRAD,DZ,KERR,terr,FLUXER,GRADER)
    REAL KERR,XK,THETA(200)
    CHARACTER*30 SOURCE
    SOURCE='SDPTH__'
    IF(IDPTH.EQ.6)THEN
        WRITE(SOURCE(6:8),'(A3)')'6 '
    ELSEIF(IDPTH.LE.99)THEN
        WRITE(SOURCE(6:7),'(I2)')IDPTH
        WRITE(SOURCE(8:8),'(A1)')' '
    ELSE
        WRITE(SOURCE(6:8),'(I3)')IDPTH
    ENDIF
    OPEN(51,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
C
C     ERROR BLOCK
C
C
C     ALWAYS READ THE FIRST (LARGEST) ERR FROM SDPTH__ FILES,
C     (is backspaced each time. . .); improvements are to take
C     AVERAGE of kerrs etc.
C

```

```

C (TRY READING STD ERROR FROM SREG, 1-6-89)
C
c READ(51,'(A20)')SOURCE
c READ(51,55)TME,SMST,ERR
c REWIND(51)
c55 FORMAT(3(F10.4))
c SMerr =SQRT(ERR**2 + ERR**2)
c SMerr =SQRT(SDS**2 + SDS**2)
c FLUXER =SMerr/(Tb-Ta)
c
c terr= SQRT((SDT)**2+(SDT1)**2)
c GRADER = (1.96)*(terr/(DZ*2.54))
c
c the flux gets smaller faster than fluxer; hence KERR increased w/ tme
c (SMerr is a constant, while (SMST-SMST1) gets smaller and smaller)
c
c KERR = SQRT((FLUXER/FLUX)**2 + (GRADER/GRAD)**2)
c RETURN
c END

```

e) Program QPROG

c
c Objectives: This program calculates groundwater recharge by
c using K values found from KPROG and Richard's
c equation (simplified form).
c

c
c Diagram of Soil Profile:
c

c
c -----
c upper layer . . . //HEAD1,KA/////////
c -----
c -----
c -----
c -----
c lower layer . . . //////////HEAD2,KB/////////
c -----
c

c
c
c $dH = HEAD2 - HEAD1$
c $dZ = DEPTH2 - DEPTH1$
c KA,KB = Hydraulic conductivities
c

c
c Richard's Equation: $Q = K * (dH/dZ)$
c

c
c This program integrates the flux to obtain the recharge,
c and implements the following special conditions necessary
c to ensure reasonable results:
c

- c
c 1) pre-wetting conditions: certain pre-wetting
c conditions are necessary for a 'significant'
c recharge event to occur when expected.
c
c 2) hysteresis is considered an error here . . .
c
c 3) tables of the exact time of rain events may not
c be needed if the prewetting conditions are
c stringent enough.
c

c
c DEFINITIONS
c

c
c -----
c ISITE Recharge site number.
c

c
c IYEAR The year of the weekly data from that site
c (this is the year the calculations will be made in).
c

c
c IDEPTH1 The depth of the upper layer of the calculation.
c Used to open the proper WCC file, to find the proper
c depth in MOISTOUT file.
c
c IDEPTH2 Same use as IDEPTH1 but for the lower layer of the
c calculation.
c
c DELZ The difference in depth of the upper and lower layers,
c IDEPTH2-IDEPTH1.
c
c D1,D2 These are read from the MOISTOUT file to test for the
c proper depth, IDEPTH1 and IDEPTH2 for the top layer.
c
c DEPTH1 These are read from the MOISTOUT file to test for the
c DEPTH2 proper depth, IDEPTH1 and IDEPTH2 for the bottom layer
c
c AFLAG Prints 'KA EXTRAPOLATED' when needed.
c BFLAG Prints 'KB EXTRAPOLATED' when needed.
c CFLAG Prints 'UNIT GRADIENT USED' when needed.
c IFLAG Used to warn of extrapolated PSI values . . .
c these have proven unreliable, so unit gradient is
c used and CFLAG is printed in the output.
c
c
c SOURCE A multi purpose character string used for opening
c files and reading off titles etc.
c
c STRING Prints an adjustable title to the output.
c
c MOISTA Finds the yearly moisture corresponding to IDEPTH1
c This moisture is used to find the KA value from
c the upper K file opened, and the upper PSI value.
c
c MOISTB Similar to MOISTA; it is the moisture for the lower
c depth layer, and is used to calculate KB and PSI2.
c
c MSTi (Used in the reading statements when finding MOISTA
c and MOISTB).
c
c MOISTB2 Used to shelve the MOISTB value for printing with
c the shelved QBO
c
c
c MST1 Read with K1 and MST2,K2; this is done until the
c yearly moisture value falls between MST1 and MST2
c whereupon KA or KB is interpolated from K1 and K2.
c
c MST2 (see MST1)
c
c PSI1,PSI2 Similar to MST1 and MST2, but read from the WCC file.
c These files were digitized by hand and occur at both
c the top and bottom layer so the gradient can be calc-
c ulated.

c
c PSI Interpolated from PSI1 and PSI2 (the values read from
c the WCC tables).
c
c HEAD1 The hydraulic head found from PSI for MOISTA
c (head as determined from the WCC for the top layer).
c
c HEAD2 The hydraulic head found from PSI for MOISTB.
c (head as determined from the WCC for lower layer).
c
c DELH HEAD2-HEAD1
c
c GRAD The gradient, DELH/DELZ.
c
c
c
c K1,K2 Read in until an interpolation of KA or KB can
c be made.
c
c KA,KB The K's corresponding to the upper and lower layers
c (resp.) of soil used to calculate the flux. These
c K's are interpolated from the tables of K values
c using the weekly moisture data base.
c
c m,b The slope and y-intercept of the last two points in
c the tabular data files for K vs Moisture or Psi vs
c Moisture. This enabled the extrapolation of these
c values (K and Psi) when the yearly moisture value
c fell below the range given in the tables.
c Warning labels AFLAG and BFLAG are printed when
c this is done.
c
c DMAX The maximum depth to which the change in storage
c is calculated for the translated flux method.
c
c SMST,SMST1 These are the storages of the profile (summed depth-
c times-moisture down to DMAX). SMST1 is at a later
c time (about a week later) than SMST.
c
c dsmst The change in storage, SMST - SMST1.
c
c tdsms The cumulative sum of dsmst (for the year IYEAR).
c
c
c DELT The time interval between two measurement times
c (days) in the approximately weekly data base for moisture.
c (for example, SMST was measured DELT days before
c SMST1).
c
c QA,QB These are the fluxes; $QA = GRAD * KA$, $QB = GRAD * KB$.
c
c Q1,Q2 These are the translated fluxes; $Q1 = QA +$
c (cm/day) the change in storage, $(SMST1 - SMST) / DELT$.
c

c 3) CALL the interpolator subroutine with TIME and moisture
c values from 2), obtain the K and the change in head.

c 4) Calculate $q = (\text{Head}) \cdot (K)$.

c 5) Calculate translated q, output q, translated q, TIME.

cc

c BEGIN SOURCE CODE

c
c

```
AFLAG = '      '  
BFLAG = '      '  
CFLAG = '      '  
IFLAG = 0  
RERRS = 0.000  
RERR  = 0.000  
RAS   = 0.000  
RBS   = 0.000  
R1S   = 0.000  
R2S   = 0.000  
WRITE(*,*)'ENTER SITE #: '  
READ(*,*)ISITE  
WRITE(*,*)'ENTER YEAR, 19'  
READ(*,*)IYEAR
```

C
C Special Conditions . . .
C

```
WRITE(*,*)'ENTER MIN STORAGE FOR A RECHARGE EVENT: '  
READ(*, '(F7.3)')SMSTMN  
WRITE(*,*)'ENTER MAXIMUM DEPTH FOR TRANSLATED FLUX: '  
READ(*,*)DMAX
```

C
WRITE(*,*)'ENTER DEPTH (inches) for TOP WCC (for the delH): '
READ(*,*)IDEPTH1
WRITE(*,*)'ENTER DEPTH (inches) for BOTTOM WCC (for delH): '
READ(*,*)IDEPTH2

c
c 1) open input files (K, WCC and MOISTOUT) and output files
c

```
WRITE(*,*)'Enter K file for the TOP of the interval: '  
READ(*, '(A30)')SOURCE  
OPEN(21,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')  
WRITE(*,*)'Enter K file for the BOTTOM of the interval: '  
READ(*, '(A30)')SOURCE  
OPEN(22,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')  
SOURCE= ' __WCC_ '  
WRITE(SOURCE(1:2), '(I2)')IDEPTH1  
WRITE(SOURCE(6:6), '(I1)')ISITE  
OPEN(10,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')  
READ(10, '(A1)')SOURCE  
SOURCE= ' __WCC_ '  
WRITE(SOURCE(1:2), '(I2)')IDEPTH2  
WRITE(SOURCE(6:6), '(I1)')ISITE
```

```

OPEN(11,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
READ(11,'(A1)')SOURCE
SOURCE = ':UDD:GH.SCRATCH:$GEOFF:$MOIST:MOISTOUT ____'
WRITE(SOURCE(39:40),'(I2)')IYEAR
WRITE(SOURCE(42:42),'(I1)')ISITE
OPEN(13,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
SOURCE = 'STORAGE_____'
WRITE(SOURCE(8:9),'(I2)')IYEAR
WRITE(SOURCE(11:11),'(I1)')ISITE
OPEN(90,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
READ(90,'(A1)')SOURCE
SOURCE = 'GRAD_____'
WRITE(SOURCE(5:6),'(I2)')IYEAR
WRITE(SOURCE(8:8),'(I1)')ISITE
OPEN(91,FILE=SOURCE,IOINTENT='INPUT',PAD='YES')
READ(91,'(A1)')SOURCE
SOURCE = 'QOUT_____'
WRITE(SOURCE(5:6),'(I2)')IYEAR
WRITE(SOURCE(8:8),'(I1)')ISITE
OPEN(14,FILE=SOURCE,IOINTENT='OUTPUT')
SOURCE = 'REOUT_____'
WRITE(SOURCE(6:7),'(I2)')IYEAR
WRITE(SOURCE(9:9),'(I1)')ISITE
OPEN(17,FILE=SOURCE,IOINTENT='OUTPUT')
OPEN(30,FILE='GRD',IOINTENT='OUTPUT')
source='routq_____'
WRITE(SOURCE(6:7),'(I2)')IYEAR
WRITE(SOURCE(9:9),'(I1)')ISITE
OPEN(31,FILE=SOURCE,IOINTENT='OUTPUT')
WRITE(31,102)'T(days)', 'DelT(days)', ' Rerror ', 'QB', 'RB', 'RBB'
&,'R2'
102 format(2x,a7,2x,A10,2x,a9,5x,a2,9x,a2,8x,a3,9x,a2)
OPEN(35,FILE='QBTST',IOINTENT='OUTPUT')
OPEN(36,FILE='Q2TST',IOINTENT='OUTPUT')
OPEN(37,FILE='QBBTST',IOINTENT='OUTPUT')
OPEN(38,FILE='KBTST',IOINTENT='OUTPUT')
OPEN(39,FILE='KERR',IOINTENT='OUTPUT')
OPEN(41,FILE='GRAD',IOINTENT='OUTPUT')
OPEN(51,FILE='INTP1',IOINTENT='OUTPUT')
OPEN(52,FILE='INTP2',IOINTENT='OUTPUT')
OPEN(53,FILE='INTP3',IOINTENT='OUTPUT')
OPEN(54,FILE='INTP4',IOINTENT='OUTPUT')
OPEN(61,FILE='INTE1',IOINTENT='OUTPUT')
OPEN(62,FILE='INTE2',IOINTENT='OUTPUT')
OPEN(63,FILE='INTE3',IOINTENT='OUTPUT')
OPEN(64,FILE='INTE4',IOINTENT='OUTPUT')
c
WRITE(14,*)'MAXIMUM DEPTH USED= ',DMAX
WRITE(14,*)'Water Characteristic Used= ',IDEPH1,'-',IDEPH2,
&''''
c STRING = 'TIME Q1(FRD DIF) Q (BCK DIF) Q(trans Q1)
c &Q(trans Q2) GRADIENT STORAGE (___ " down) MAX depth= ____'''
c WRITE(STRING(85:86),'(I2)')IDEPH1
c WRITE(STRING(107:110),'(F4.0)')DMAX

```

```

c   WRITE(14,'(A111)')STRING
    WRITE(14,'(A1)')' '
    WRITE(14,101)'T(days)', 'K(cm/day)', 'Grad1', 'Grad2',
    &'Q(cm/day)', 'Q1(cm/day)', 'Q2(cm/day)', 'Q3(cm/day)', 'R1(cm)',
    &'R2(cm)', 'R1err(cm)'
101
FORMAT(2X,A7,3X,A9,4X,A5,6X,A5,4X,A9,1X,A10,1X,A10,1X,A10,3X,A6,
    &5X,A6,4X,A9)
c
c 2)a Locate a the yearly moisture value for the top of interval
c
    READ(13,'(A1)')SOURCE
    J = 1
10  CONTINUE
    READ(13,24,END=77)D1,T2,MST1
24  FORMAT(F5.0,4X,F7.3,9X,F5.4)
    IF(INT(D1).EQ.IDEPH1)THEN
        MOISTA = MST1
        CONTINUE
    ELSEIF(INT(D1).LT.IDEPH1)THEN
        MST2 = MST1
        D2 = D1
        READ(13,24,END=77)D1,T2,MST1
        IF(INT(D1).GT.IDEPH1)THEN
            CALL INTERP(REAL(IDEPH1),D2,D1,MST2,MST1,MOISTA)
            WRITE(51,502)REAL(IDEPH1),D2,D1,MST2,MST1,MOISTA
        ELSE
            BACKSPACE(13)
            GO TO 10
        ENDIF
    ELSE
        GO TO 10
    ENDIF
c
c 2)b Locate the yearly moisture value for the bottom of interval
c
    BACKSPACE(13)
    BACKSPACE(13)
6   CONTINUE
    READ(13,24,END=77)DEPTH2,T2,MSTi
    IF(INT(DEPTH2).EQ.IDEPH2)THEN
        DEPTH1 = DEPTH2 - 9.00
        MOISTB = MSTi
        CONTINUE
    ELSEIF(INT(DEPTH2).LT.IDEPH2)THEN
        MST2 = MSTi
        DEPTH1 = DEPTH2
        READ(13,24,END=77)DEPTH2,T2,MSTi
        IF(INT(DEPTH2).GT.IDEPH2)THEN
            CALL INTERP(REAL(IDEPH2),DEPTH1,DEPTH2,MST2,MSTi,MOISTB)
            WRITE(52,502)REAL(IDEPH2),DEPTH2,DEPTH1,MST2,MSTi,MOISTB
        ELSE
            BACKSPACE(13)
            GO TO 6
        ENDIF
    ENDIF

```

```

        ENDIF
    ENDIF
C
C POSITION MOISTURE FILE TO NEXT TIME BLOCK . . .
C
    DO WHILE (DEPTH1.LT.DEPTH2)
        DEPTH1 = DEPTH2
        T2 = T
        READ(13,'(F5.0,4X,F7.3,9X,F5.4)',END=77)DEPTH2,T,MSTi
    END DO
C
C NEW ADDITIONS FOR SMSTN, TOR AND GRADRE
C
900  CONTINUE
    READ(90,'(1X,I3,3X,3F7.2)',END=77)JULDY,SMST1,BTOR,ETOR
    PRINT *,'JULDY= ',JULDY,' T2= ',INT(T2)
    IF(JULDY.LT.INT(T2))THEN
        GO TO 900
    ELSEIF(JULDY.EQ.INT(T2))THEN
        TOR = BTOR
        IF(J.EQ.1)SMST = SMST1
        CONTINUE
    ELSE
        IF(J.EQ.1)THEN
            SMST = 0.00
        ELSE
            SMST1= 0.00
        ENDIF
        TOR = 0.00
        BACKSPACE(90)
        BACKSPACE(90)
        BACKSPACE(90)
        PRINT *,'NOT ENOUGH DEPTH FOR STORAGE VALUE . .'
    ENDIF
C
901  CONTINUE
    READ(91,'(I3,5X,I2,1X,I2,F10.2)',END=908)JULDY,ID1,ID2,GRADRE
    IF(JULDY.LT.INT(T2))THEN
        GO TO 901
    ELSEIF(JULDY.EQ.INT(T2))THEN
        IF(ID1.EQ.IDEPH1)THEN
            CONTINUE
        ELSEIF((ID1.LT.IDEPH1)..AND.(ID2.GT.IDEPH1))THEN
            CONTINUE
        ELSE
            GO TO 901
        ENDIF
    ELSE
        ID1 = 0
        ID2 = 0
        GRADRE = 0.00
        PRINT *,'NO GRAD VALUE FOR THIS ONE . .'
    ENDIF
908  CONTINUE

```

```

C
C END NEW ADDITIONS
C
c
c 3) a2. CALL interpolator for KB value corresp. to MOISTB from above
c
      REWIND(22)
      READ(22,'(A1)')SOURCE
      READ(22,'(F9.4,F11.4,26X,F13.5)')MST1,K1,KERR1
11    CONTINUE
c
c Extrapolate a value if end of file, using slope of the last
c two points of the curve
c
      READ(22,'(F9.4,F11.4,26X,F13.5)',END=104)MST2,K2,KERR2
      m = (LOG10(K2) - LOG10(K1))/(MST2 - MST1)
      m2= (LOG10(KERR2) - LOG10(KERR1))/(MST2 - MST1)
      b = LOG10(K2) - m*MST2
      b2= LOG10(KERR2) - m*MST2
      IF(1.EQ.2)THEN
104    CONTINUE
      WRITE(38,501)'EXTRAP (' ,log10(k2),'-',log10(k1),')/(',mst2,'-',
&mst1,')= ',m,' b= ',b
      WRITE(39,501)'EXTRP (' ,log10(KERR2),'-',log10(kERR1),')/(',
&mst2,'-',mst1,')= ',m2,' b2= ',b2
501    FORMAT(A8,F8.4,A1,F8.4,A3,F5.4,A1,F5.4,A3,F12.5,a5,f10.4)
      KB = MOISTB*m + b
      KERR= MOISTB*m2 + b2
      KB = 10**(KB)
      KERR= 10**(KERR)
      BFLAG = ' KB EXTRAPOLATED'
      GO TO 91
      ENDIF
c
c
      IF(MST2.GT.MOISTB)THEN
      MST1 = MST2
      K1 = K2
      KERR1 = KERR2
      GO TO 11
      ELSE
      CALL INTERP(MOISTB,MST1,MST2,K1,K2,KB)
      WRITE(38,502)MOISTB,MST1,MST2,K1,K2,KB
502    FORMAT('INTERP ',6F12.4)
      CALL INTERP(MOISTB,MST1,MST2,KERR1,KERR2,KERR)
      WRITE(38,502)MOISTB,MST1,MST2,KERR1,KERR2,KERR
      ENDIF
91    CONTINUE
c
c 3) b. CALL interpolator for first Psi value, corresp to MOIST
c above; used to calculate change in head (delH)
c
      REWIND(10)
      READ(10,'(A1)')SOURCE

```

```

      READ(10,*)MST1,PSI1D,PSI1S
      PSI1 = (PSI1D+PSI1S)/2.0
      PERR1 = PSI1D - PSI1
13    CONTINUE
c
c Extrapolate a value if end of file, using slope of the last
c two points of the curve
c
      READ(10,*,END=105)MST2,PSI2D,PSI2S
      PSI2 = (PSI2D+PSI2S)/2.0
      PERR2 = PSI2D - PSI2
      PERRA = (PERR1+PERR2)/2.0
      m = (PSI2 - PSI1)/(MST2 - MST1)
      b = PSI2 - m*MST2
105   IF(1.EQ.2)THEN
      CONTINUE
      PSI = MOISTA*m + b
      IFLAG = 1
      HEAD1 = 0.00015
      GO TO 92
      ENDIF
c
c
      IF(MST2.GT.MOISTA)THEN
      MST1 = MST2
      PSI1 = PSI2
      GO TO 13
      ELSE
      CALL INTERP(MOISTA,MST1,MST2,PSI1,PSI2,PSI)
      WRITE(53,502)MOISTA,MST1,MST2,PSI1,PSI2,PSI
      ENDIF
      HEAD1 = PSI + REAL(IDEPTH1)*2.54
      HERR1 = PERRA
9     FORMAT(8(A6,F8.4))
92    CONTINUE
c
c 3) c. CALL interpolator for second Psi value, corresp to MOISTB
c above; used to calculate change in head (delH)
c
      REWIND(11)
      READ(11,'(A1)')SOURCE
      READ(11,*)MST1,PSI1D,PSI1S
      PSI2 = (PSI1D+PSI1S)/2.0
      PERR1 = PSI1D - PSI1
      IF(IFLAG.EQ.1)GO TO 106
14   CONTINUE
c
c Extrapolate a value if end of file, using slope of the last
c two points of the curve
c
      READ(11,*,END=106)MST2,PSI2D,PSI2S
      PSI2 = (PSI2D+PSI2S)/2.0
      PERR2 = PSI2D - PSI2
      PERRB = (PERR1 + PERR2)/2.0

```

```

          m = (PSI2 - PSI1)/(MST2 - MST1)
          b = PSI2 - m*MST2
          IF(1.EQ.2)THEN
106             CONTINUE
C
C
C NEVER EXTRAPOLATE DEEPER DEPTH . . . JUST USE PSI + DEPTH FOR
C UNIT GRADIENT
C
C             IF(IFLAG.EQ.1)THEN
C                 IFLAG = 0
C                 CFLAG = ' UNIT GRADIENT USED'
C                 HEAD2 = 0.0001
C                 GO TO 93
C             ENDIF
c
c
          IF(MST2.GT.MOISTB)THEN
              MST1 = MST2
              PSI1 = PSI2
              GO TO 14
          ELSE
              CALL INTERP(MOISTB,MST1,MST2,PSI1,PSI2,PSI)
              WRITE(54,502)MOISTB,MST1,MST2,PSI1,PSI2,PSI
          ENDIF
          HEAD2 = PSI + REAL(IDEPTH2)*2.54
          HERR2 = PERRB
93             CONTINUE
C
c
c 4) calculate Q1 (procedure 'a') in opening comments)
c
C A POSITIVE GRADIENT INDICATES UPWARD FLOW HERE . . .
C (head at deeper depth Greater than head at shallower depth)
c
C (see KPROG)
c
          DELZ = (IDEPTH2-IDEPTH1)*2.54
          delH = HEAD2 - HEAD1
          GRDERR = SQRT(HERR1**2 + HERR2**2)/DELZ
          GRAD = delH/DELZ
          QB = GRAD*KB
          WRITE(35,504)GRAD,'*',KB,'= ',QB
504          FORMAT(F8.4,A1,F8.4,A2,F8.4)
          QERR = QB*SQRT( (KERR/KB)**2 + (GRDERR/GRAD)**2 )
          QBB = GRADRE*KB
          WRITE(37,504)GRADRE,'*',KB,'= ',QBB
c
c
c 5) Calculate TRANSLATED flux Q2 (procedure 'b') in opening
c comments); write out results.
c
c
          IF(J.EQ.1)THEN

```

```

T1 = T2
J = 2
QBO = QB
QERRO = QERR
QBBO = QBB
c set the second methods' Q to zero for first time . . .
Q2O = 0.0000
GO TO 10
ELSE
PRINT *,'TOR= ',TOR,' T1 = ',T1 , ' T2 = ',T2
IF(INT(TOR).EQ.0)THEN
delT = T2 - T1
ELSE
T1 = TOR
delT = T2 - T1
ENDIF
Q2 = (SMST1 - SMST)/(delT) + QB
WRITE(36,503)('SMST1','-','SMST,')/('DELTA,')+','QB,','Q2
503 FORMAT(A1,F8.4,A1,F8.4,A3,F6.2,A2,F8.3,A1,F8.3)
IF(delT.GT.1.00)THEN
CALL INTEGRATE(T1,T2,QBO,QB,RB)
CALL INTEGRATE(T1,T2,QERRO,QERR,RERR)
CALL INTEGRATE(T1,T2,Q2O,Q2,R2)
WRITE(61,502)T1,T2,QBO,QB,RB
WRITE(62,502)T1,T2,QERRO,QERR,RERR
WRITE(63,502)T1,T2,Q2O,Q2,R2
IF((INT(QBBO*1000).EQ.0).OR.(INT(QBB*1000).EQ.0))THEN
CONTINUE
ELSE
CALL INTEGRATE(T1,T2,QBBO,QBB,RBB)
WRITE(64,502)T1,T2,QBBO,QBB,RBB
ENDIF
c
c Storage condition. . .
c
IF(SMST1.LT.SMSTMN)THEN
RB = 0.00
R2 = 0.00
RBB = 0.00
RERR = 0.00
ELSEIF(SMST1.GE.SMSTMN)THEN
RBS = RB + RBS
R2S = R2 + R2S
RBBS = RBB + RBBS
RERRS = RERRS + RERR
ENDIF
dsmst = SMST1 - SMST
IF(dsmst.ge.0.000)tdsmst = tdsmst + dsmst
WRITE(17,'(3F8.3,A1,8F8.3,3A10,2F7.2)')T1,MOISTB2,QBO,
&'-',T2,MOISTB,QB,Q2,RBS,R2S,SMST,SMST1,AFLAG,BFLAG,CFLAG,
&dsmst,tdsmst
WRITE(30,'(3F12.3)')T1,GRAD,GRADRE
MOISTB2 = MOISTB
QBO = QB

```

```

QBBO = QBB
QERRO = QERR
Q2O = Q2
AFLAG = '      '
BFLAG = '      '
CFLAG = '      '
WRITE(14,100)T1,KB,grad,gradre,QBB-QB,QB,QBB,Q2,
&RB,R2,RERR
100   FORMAT(2X,F7.3,2X,F11.7,2X,F8.4,3X,F8.4,7(2X,F9.5))
      WRITE(31,'(7F11.5)')T1,DELT,rerr,QB,RB,RBB,R2
      PRINT *,'FLUX OBTAINED, TIME = ',T1
      ENDIF
      SMST = SMST1
      T1 = T2
      GO TO 10
    ENDIF
77   CONTINUE
      WRITE(14,'(A1)') '
      WRITE(14,'(A1)') '
      WRITE(14,103)' Total Recharge, R1= ',RBS
      WRITE(14,103)' Total Recharge, R3= ',R2S
      WRITE(14,103)' Total R Error, RERR= ',RERRS
      WRITE(31,103)' Total Recharge, R1= ',RBS
      WRITE(31,103)' Total Recharge, R3= ',R2S
      WRITE(31,103)' Total R Error, RERR= ',RERRS
103   format(a21,f9.4)
c
      STOP
      END
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCC
C
C   Linear interpolator subroutine, for obtaining K and Psi values
C
      SUBROUTINE INTERP(Z,Z1,Z2,V1,V2,V)
c
c   Z   value at which the unknown V corresponds to-
c
c   Z1  value preceding Z, which V1 corresponds to-
c
c   Z2  value following Z, which V2 corresponds to-
c
c   V   interpolated value (result)
c
      V = ((Z-Z2)/(Z1-Z2))*(V1-V2) + V2
      RETURN
      END
C
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCC
C   INTEGRATE SUBROUTINE FOR A LINEAR APPROXIMATION TO THE
C   RECHARGE PROCESS.

```

CC
CCCCCCCCCCCCCCCCCCCC

C
C

SUBROUTINE INTEGRATE(T1,T2,Q1,Q2,RECHARGE)

REAL Zm,T2, T1, Q1, Q2,T,RECHARGE,b

Zm = (Q2-Q1)/(T2-T1)

b = Q1 - Zm*T1

IF((Q1.LT.0).AND.(Q2.LT.0))THEN

RECHARGE = 0.0000

GO TO 20

ELSEIF((Q1.LE.0).AND.(Q2.GE.0))THEN

T = T2 - (-b/Zm)

RECHARGE = ABS(.5*(Zm)*(T)**2)

ELSEIF((Q1.GE.0).AND.(Q2.LE.0))THEN

T = (-b/Zm) - T1

RECHARGE = ABS(.5*(Zm)*(T)**2)

ELSEIF((Q1.GT.0).AND.(Q2.GT.0))THEN

T = T2 - T1

IF(Q1.LE.Q2)THEN

Q = Q1

ELSE

Q = Q2

ENDIF

RECHARGE = ABS(.5*(Zm)*(T)**2) + Q*T

ELSE

PRINT *,'ERROR IN SUBROUTINE INTEGRATE: CASE NOT

CONSIDERED'

ENDIF

20 CONTINUE

RETURN

END

f) Program RECHGE

```
CHARACTER*60
INPUT,INPUT2,OUT1,OUT2,OUT3,OUT4,MONTH,DUMMY,INPUT3
& ,INPUT4
CHARACTER*80 source
INTEGER DAY,INT1,INT2,P,Q
REAL JUDY,JUDY1,JUDY2,JUDY3,INCH1,INCH2,INCH3,START(100),N1,N3
REAL STOPP(100),RCHG(100),PPTSUM(100),JUL,DS(100),ET(100),JULIAN
REAL STOINT1(100),STOINT2(100)
c
c
write(*,*)'enter site #: '
read(*,'(i1)')isite
write(*,*)'enter year, 19'
read(*,'(i2)')iyear
c
source = ':udd:gh.scratch:$geoff:$ppt:ppt_____'
write(source(32:33),'(i2)')iyear
write(source(35:35),'(i1)')isite
OPEN(11,FILE=source,IOINTENT='INPUT',PAD='YES')
c
source = ':UDD:GH.SCRATCH:$GEOFF:$moist:storage_____'
write(source(38:39),'(i2)')iyear
write(source(41:41),'(i1)')isite
OPEN(8,FILE=source,IOINTENT='INPUT',PAD='YES')
c
source = ':UDD:GH.SCRATCH:$GEOFF:$fieldk:storage_____'
write(source(39:40),'(i2)')iyear
write(source(42:42),'(i1)')isite
OPEN(65,FILE=source,IOINTENT='INPUT',PAD='YES')
READ(65,'(A1)')SOURCE
c
source = 'sand__'
write(source(5:6),'(i2)')iyear
OPEN(13,FILE=source,IOINTENT='INPUT',PAD='YES')
c
source = 'rechgeout_____'
write(source(10:11),'(i2)')iyear
write(source(13:13),'(i1)')isite
OPEN(14,FILE=source,IOINTENT='OUTPUT',CARRIAGECONTROL='FORTRAN')
source = 'rout_____'
write(source(5:6),'(i2)')iyear
```



```

IF(JUDY1.LT.START(K))THEN
  ET2=ET1
  GO TO 30
ELSEIF(JUDY1.EQ.START(K))THEN
  ET(K)=0.
  GO TO 51
ELSEIF(JUDY1.GT.START(K))THEN
  ET(K)=((JUDY1-START(K))/5)*ET2
ENDIF
51 CONTINUE
C
  READ(13,27)MONTH,DAY,JUDY3,INCH3,ET3
  ET3 = ET3*2.54
  IF(JUDY3.GT.STOPP(K))THEN
    ET(K)=((STOPP(K)-JUDY1+1)/5)*ET1+ET(K)
    GO TO 71
  ELSEIF(JUDY3.EQ.STOPP(K))THEN
    ET(K)=(ET(K)+ET1)+(.20)*ET3
    GO TO 71
  ELSEIF(JUDY3.LT.STOPP(K))THEN
    ET(K)=ET(K)+ET1
    ET1=ET3
    JUDY1=JUDY3
    GO TO 51
  ENDIF
71 CONTINUE
C
C***
C***
C***
C
C  PRECIPITATION
C
  PPTSUM(K)=0.0
210 CONTINUE
  READ(11,225)JUDY,PPT
  PPT = PPT*2.54
  IF(INT(JUDY).LT.INT(START(K)))THEN
    GO TO 210
  C
  ELSE
211 CONTINUE
  PPTSUM(K)=PPTSUM(K)+PPT
  READ(11,225)JUDY,PPT
  PPT = PPT*2.54
  ENDIF
  IF(INT(JUDY).LE.INT(STOPP(K)))GO TO 211
C
C  RECHARGE=
C
  RCHG(K)=PPTSUM(K)-ET(K)-DS(K)
  RCSUM=RCSUM+RCHG(K)
  WRITE(30,'(5F12.3)')START(K),RCHG(K),ET(K),PPTSUM(K),DS(K)
C

```

```

C
  K=K+1
C
  INT1 = 1
  IF(INT1.EQ.1)GO TO 4
905  CONTINUE
C
C
C  SEPARATE CALCULATION: SUM THE PRECIP FOR WHOLE YEAR
C
  PSUM=0.
  REWIND(11)
903  CONTINUE
  READ(11,225,END=904)JUDY,PPT
  PPT = PPT*2.54
  PSUM=PSUM+PPT
  IF(NINT(JUDY).EQ.365)THEN
  GO TO 904
  ELSE
  GO TO 903
  ENDIF
C
C  *****
C  INPUT/OUTPUT
C  *****
C
904  CONTINUE
  REWIND(11)
  REWIND(13)
  JULIAN=0.
  K=1
  J=1
C
  READ(8,327,END=720)JUDY,DS1
720  CONTINUE
  READ(15,227)DTW
  READ(11,225)JUL,PPT
  PPT = PPT*2.54
  READ(13,27)MONTH,DAY,JUDY2,INCH1,ET1
  ET1 = ET1*2.54
C
777  CONTINUE
  JULIAN=JULIAN+1.
  IF((INT(JULIAN).NE.INT(START(K))).AND.(INT(JULIAN).NE.
&INT(STOPP(J))))THEN
  IF(JULIAN.EQ.JUDY)THEN
  WRITE(14,332)JULIAN,MONTH,DAY,PPT,ET1,DS1,DTW
  WRITE(14,747)
C
  L=1
  ELSE
  WRITE(14,330)JULIAN,MONTH,DAY,PPT,ET1,DTW
  WRITE(14,747)

```

C
C

```
L=0
ENDIF
ELSEIF(INT(JULIAN).EQ.INT(START(K)))THEN
DTWi=DTW
IF(JULIAN.EQ.JUDY)THEN
WRITE(14,333)JULIAN,MONTH,DAY,PPT,ET1,DS1,
&DTW,PPTSUM(K),ET(K),DS(K),RCHG(K)
WRITE(14,747)
```

C
C

```
L=1
K=K+1
ELSE
WRITE(14,334)JULIAN,MONTH,DAY,PPT,ET1,DTW,
&PPTSUM(K),ET(K),DS(K),RCHG(K)
WRITE(14,747)
```

C

```
L=0
K=K+1
ENDIF
ELSEIF(INT(JULIAN).EQ.INT(STOPP(J)))THEN
DTWii=DTWi-DTW
IF(JULIAN.EQ.JUDY)THEN
WRITE(14,335)JULIAN,MONTH,DAY,PPT,ET1,DS1,DTW,DTWi
WRITE(14,747)
```

C
C

```
L=1
J=J+1
ELSE
WRITE(14,350)JULIAN,MONTH,DAY,PPT,ET1,DTW,DTWi
WRITE(14,747)
L=0
J=J+1
ENDIF
ENDIF
```

C
C
C

```
IF(L.EQ.1)THEN
GO TO 410
ELSE
GO TO 420
ENDIF
```

C

```
410 CONTINUE
READ(8,327,END=420)JUDY,DS1
420 CONTINUE
READ(15,227)DTW
READ(11,225)JUL,PPT
PPT = PPT*2.54
READ(13,27,END=721)MONTH,DAY,JUDY2,INCH1,ET1
```

```
ET1 = ET1*2.54
721 CONTINUE
```

```
C
```

```
*
```

```
*****
```

```
* The following block writes out the four days in-between ****  
* ET values....(i.e. only for weekly input). ***
```

```
*
```

```
***
```

```
C
```

```
DO 250 I=1,4  
JULIAN=JULIAN+1.  
IF((INT(JULIAN).NE.INT(START(K))).AND.  
&(INT(JULIAN).NE.INT(STOPP(J))))THEN  
IF(JULIAN.EQ.JUDY)THEN  
WRITE(14,340)JULIAN,PPT,DS1,DTW  
WRITE(14,747)
```

```
C
```

```
C
```

```
L=1  
ELSE  
WRITE(14,341)JULIAN,PPT,DTW  
WRITE(14,747)
```

```
C
```

```
C
```

```
L=0  
ENDIF  
ELSEIF(INT(JULIAN).EQ.INT(START(K)))THEN  
DTWi=DTW  
IF(JULIAN.EQ.JUDY)THEN  
WRITE(14,337)JULIAN,PPT,DS1,DTW,PPTSUM(K),  
&ET(K),DS(K),RCHG(K)  
WRITE(14,747)
```

```
C
```

```
C
```

```
L=1  
K=K+1  
ELSE  
WRITE(14,338)JULIAN,PPT,DTW,PPTSUM(K),ET(K),  
&DS(K),RCHG(K)  
WRITE(14,747)
```

```
C
```

```
C
```

```
L=0  
K=K+1  
ENDIF  
ELSEIF(INT(JULIAN).EQ.INT(STOPP(J)))THEN  
DTWi=DTWi-DTW  
IF(JULIAN.EQ.JUDY)THEN  
WRITE(14,339)JULIAN,PPT,DS1,DTW,DTWi  
WRITE(14,747)
```

```
C
```

```
C
```

```
L=1
```

```

        J=J+1
    ELSE
        WRITE(14,351)JULIAN,PPT,DTW,DTWi
        WRITE(14,747)
        L=0
        J=J+1
    ENDIF
ENDIF
C
C
C
    IF(L.EQ.1)THEN
        GO TO 510
    ELSE
        GO TO 520
    ENDIF
C
510 CONTINUE
    READ(8,327,END=520)JUDY,DS1
520 CONTINUE
    READ(15,227,END=250)DTW
    READ(11,225,END=250)JUL,PPT
    PPT = PPT*2.54
250 CONTINUE
***
*
*
*****
C
    IF(JULIAN.LT.365)GO TO 777
    WRITE(14,952)ISITE,IYEAR
952  FORMAT(///,14X,'SITE #',I1,',19',I2)
    WRITE(14,953)RCSUM
953  FORMAT(/,14X,'CUMULATIVE RECHARGE= ',F7.3)
    WRITE(14,954)PSUM
954  FORMAT(/,14X,'TOTAL PRECIPITATION= ',F7.3)
C
327  FORMAT(F4.0,6X,F7.4)
225  FORMAT(F4.0,1X,F6.3)
227  FORMAT(4X,F6.3)
330  FORMAT(14X,F4.0,8X,A3,4X,I3,4X,F5.3,4X,F6.3,12X,F6.3)
332  FORMAT(14X,F4.0,8X,A3,4X,I3,4X,F5.3,4X,F6.3,2X,F6.3,4X,F6.3)
333  FORMAT('+',79X,'PRECIPITSUM',3X,'EVAPOTRNSUM',3X,'del
STORAGE',
    & 3X,'RECHARGE',/,2X,'START',7X,F4.0,8X,A3,4X,I3,4X,F5.3,4X,F6.3,
    & 2X,F6.3,4X,F6.3,4(3X,F11.3))
334  FORMAT('+',79X,'PRECIPITSUM',3X,'EVAPOTRNSUM',3X,'del
STORAGE',
    & 3X,'RECHARGE',/,2X,'START',7X,F4.0,8X,A3,4X,I3,4X,F5.3,4X,F6.3,
    & 12X,F6.3,4(3X,F11.3))
335  FORMAT(2X,'STOP',8X,F4.0,8X,A3,4X,I3,4X,F5.3,4X,F6.3,5X,F6.3,5X,
    & F6.3,8X,' WT RISE= ',F6.3)
337  FORMAT('+',79X,'PRECIPITSUM',3X,'EVAPOTRNSUM',3X,'del
STORAGE',

```

```

      & 3X,'RECHARGE',/,2X,'START',7X,F4.0,22X,F5.3,12X,F6.3,4X,F6.3,
      & 4(3X,F11.3))
338   FORMAT('+',79X,'PRECIPITSUM',3X,'EVAPOTRNSUM',3X,'del
STORAGE',
      & 3X,'RECHARGE',/,2X,'START',7X,F4.0,22X,F5.3,22X,F6.3,4(3X,F11.3))
339   FORMAT(2X,'STOP',8X,F4.0,22X,F5.3,13X,F6.3,3X,F6.3,8X,
      & ' WT RISE=',F6.3)
351   FORMAT(2X,'STOP',8X,F4.0,22X,F5.3,22X,F6.3,8X,' WT RISE= ',
      & F6.3)
341   FORMAT(14X,F4.0,22X,F5.3,22X,F6.3)
340   FORMAT(14X,F4.0,22X,F5.3,12X,F6.3,4X,F6.3)
350   FORMAT(2X,'STOP',8X,F4.0,8X,A3,4X,I3,4X,F5.3,4X,F6.3,12X,F6.3,
      & 8X,' WT RISE=',F6.3)
747   FORMAT('+',
1_____')
C
999   STOP
      END

```

APPENDIX II

GRAVIMETRIC METHOD FOR OBTAINING THE NEUTRON CALIBRATION CURVE

Soil samples were taken every 15.2 cm with a 60 cm³ stainless steel sampling bit in the same hole the neutron access tube was installed in soon afterwards. The samples were labeled, placed in plastic zip-lock bags and weighed to .01 gm precision in the field. The samples were then placed in pre-weighed aluminum drying pans and dried in an oven at 150 deg. C for 24 hours.

W_w = sample weight - ziplock bag weight (net wet weight)

W_d = dry sample weight - aluminum pan weight (net dry weight)

The gravimetric water content can then be calculated from

$$(1) \quad w_c = \frac{(W_w - W_d)}{W_d}$$

and the bulk density from

$$(2) \quad \rho_b = \frac{W_d}{60\text{cm}^3}$$

The volumetric water content is given by

$$(3) \quad \theta = \rho_b w_c = \left[\frac{W_w - W_d}{60\text{cm}^3} \right] \quad (\text{Hillel, 1971}).$$

Next the steel access tube was installed in the hole resulting from the sampling, no more than 2 hours after sampling. The neutron probe was then lowered to each sampling depth interval so that neutron counts were made on essentially the same soil samples. The standardized neutron counts were then plotted against θ to obtain the calibration curve (Figure 7).

APPENDIX III : Tabular Input of Program QPROG

Water Characteristic Curve Data

Definitions:

Mst = Volumetric Moisture Content

Drain = Soil Suction (mbars), corresponding to the drainage boundary of the water characteristic envelope

Sorption= Soil Suction (mbars), corresponding to the wetting boundary of the water characteristic envelope

SITE # 2

Depth = 36 in

Moisture	Drainage	Sorption
.345	0.0	0.0
.34	30.0	12.5
.32	31.0	12.7
.30	32.5	12.9
.28	33.5	13.1
.26	35.0	13.3
.24	37.5	15.3
.22	38.0	17.0
.20	42.5	18.0
.18	50.0	20.0
.16	77.5	21.0
.14	120.0	26.0
.12	165.0	42.5
.10	218.0	75.0
.08	288.0	125.0
.06	400.0	250.0

Depth = 54 in

Mst	Drain	Sorption
.324	0.0	0.0
.32	18.8	10.0
.30	19.5	10.5
.28	20.0	10.7
.26	21.5	11.0
.24	22.5	11.2
.22	24.0	11.4
.20	25.0	11.6
.18	27.5	11.8
.16	37.5	12.0
.14	62.5	12.2
.12	105.0	12.5
.10	185.0	37.5
.08	337.5	175.0

SITE # 3

Depth = 12 in

Mst	Drain	Sorption
.33	0.0	0.0
.32	23.0	5.0
.30	25.0	15.0
.28	30.0	20.0
.26	48.0	22.0
.24	60.0	25.0
.22	75.0	33.0
.20	95.0	45.0
.18	135.0	60.0
.16	215.0	78.0

.14	500.0	100.0
.12	665.0	140.0
.10	700.0	205.0

Depth = 18 in

Mst	Drain	Sorption
.35	0.0	0.0
.34	20.0	7.0
.32	45.0	12.0
.30	50.0	13.0
.28	55.0	15.0
.26	60.0	20.0
.24	20.0	34.0
.22	290.0	50.0
.20	450.0	75.0
.18	550.0	115.0
.16	615.0	175.0
.14	675.0	275.0

Depth = 24 in

Mst	Drain	Sorption
.33	0.0	0.0
.32	35.0	7.0
.30	60.0	15.0
.28	380.0	50.0
.26	500.0	110.0
.24	630.0	190.0
.22	675.0	270.0
.20	690.0	365.0
.18	700.0	475.0

Depth = 30 in

Mst	Drain	Sorption
.33	0.0	0.0
.32	40.0	7.0
.30	370.0	100.0
.28	530.0	200.0
.26	550.0	265.0
.24	590.0	293.0
.22	680.0	320.0
.20	800.0	375.0

Depth = 36 in

Mst	Drain	Sorption
.33	0.0	0.0
.32	40.0	4.0
.30	170.0	75.0
.28	265.0	140.0
.26	375.0	185.0
.24	477.0	225.0
.22	560.0	280.0
.20	700.0	420.0

Depth = 54 in

Mst	Drain	Sorption
.29	0.0	0.0
.28	25.0	12.0
.26	110.0	25.0
.24	180.0	50.0
.22	280.0	75.0
.20	425.0	110.0
.18	680.0	200.0
.16	750.0	350.0
.14	800.0	550.0

Depth = 60 in

Mst	Drain	Sorption
.28	0.0	0.0
.27	20.0	7.5
.26	45.0	18.0
.24	103.0	35.0
.22	212.0	65.0
.20	350.0	112.0
.18	530.0	180.0
.16	680.0	312.0
.14	700.0	650.0

Depth = 72 in

Mst	Drain	Sorption
.26	0.0	0.0
.25	44.0	17.0
.24	75.0	22.0
.22	187.0	25.0
.20	350.0	125.0
.18	700.0	700.0

SITE #5

Depth = 36 in

Mst	Drain	Sorption
.34	0.0	0.0
.32	12.1	12.0
.30	16.0	12.1
.28	23.0	12.3
.26	25.0	13.0

.24	29.0	16.0
.22	34.0	18.0
.20	41.0	20.0
.18	50.0	21.0
.16	60.0	23.0
.14	69.0	27.0
.12	91.0	43.0
.10	143.0	91.0
.08	212.0	175.0
.06	350.0	350.0

Depth = 54 in

Mst	Drain	Sorption
.31	0.0	0.0
.30	48.0	25.0
.28	62.5	25.1
.26	77.0	25.2
.24	93.0	25.3
.22	105.0	25.4
.20	125.0	25.5
.18	170.0	25.6
.16	225.0	31.0
.14	283.0	58.0
.12	350.0	125.0
.10	437.0	287.0
.08	625.0	625.0

Depth = 60 in

Mst	Drain	Sorption
.31	0.0	0.0
.30	33.0	13.0
.28	33.5	16.0
.22	34.0	20.0

.20	34.5	20.5
.18	43.0	20.8
.16	58.0	21.5
.14	93.0	25.0
.12	200.0	63.0
.11	350.0	137.0
.10	700.0	700.0

SITE # 6

Depth = 30 in

Mst	Drain	Sorption
.34	0.0	0.0
.33	25.0	2.0
.32	67.1	32.0
.30	307.0	107.1
.28	425.0	170.0
.26	550.0	225.0
.24	637.0	275.0
.22	675.0	342.0
.20	700.0	425.0

Depth = 36 in

Mst	Drain	Sorption
.34	0.0	0.0
.33	50.0	12.0
.32	65.0	20.0
.30	200.0	52.0
.28	400.0	95.0
.26	550.0	180.0
.24	687.0	250.0
.22	750.0	312.0

.20	800.0	412.0
-----	-------	-------

Depth = 54 in

Mst	Drain	Sorption
.30	0.0	0.0
.29	65.0	20.0
.28	150.0	25.0
.26	265.0	60.0
.24	350.0	175.0
.22	450.0	325.0

SITE # 7

Depth = 36 in

Mst	Drain	Sorption
.28	0.0	0.0
.27	27.0	27.0
.26	32.0	27.2
.24	37.0	27.3
.22	45.0	27.4
.20	51.0	27.5
.18	68.0	27.6
.16	100.0	29.0
.14	150.0	37.0
.12	200.0	65.0
.10	275.0	112.0

Depth = 54 in

Mst	Drain	Sorption
.32	0.0	0.0
.31	12.0	5.0
.30	25.0	12.0
.28	90.0	22.0

.26	150.0	25.0
.24	300.0	300.0

Depth = 60 in

Mst	Drain	Sorption
.35	0.0	0.0
.34	7.0	2.0
.32	50.0	12.0
.31	100.0	50.0

APPENDIX IV : Tabular Output of Programs KPROG and QPROG

1) Calculation of K from the drainage experiments (output of KPROG, Appendix II).

Site # 2 . 1987

Depth = 15 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture (cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.1318	31.7031	31.7031	1.0000	21.9940	3.2337	.6862	.0465
.0936	2.3700	1.2625	.5327	6.5935	3.1130	.6862	.2368
.0834	1.2516	.6493	.5188	3.5020	1.6009	.6862	.4100
.0756	.7275	.3686	.5067	2.0465	.9089	.6862	.6541
.0700	.4758	.2365	.4971	1.3444	.5831	.6862	.9432
.0649	.3136	.1529	.4875	.8902	.3769	.6862	1.3518
.0603	.2092	.1000	.4781	.5968	.2466	.6862	1.9177
.0512	.0852	.0389	.4567	.2459	.0959	.6862	4.1759
.0491	.0677	.0305	.4511	.1961	.0753	.6862	5.0965
.0461	.0479	.0212	.4427	.1395	.0523	.6862	6.8791
.0449	.0415	.0182	.4391	.1210	.0449	.6862	7.7988
.0416	.0273	.0117	.4287	.0803	.0289	.6862	11.2138
.0398	.0214	.0091	.4226	.0633	.0223	.6862	13.8405

Depth = 30 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture (cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.1919	56.9609	56.9609	1.0000	32.5067	8.6567	.5501	.0466
.1566	7.6205	3.1250	.4101	22.4695	8.2055	.5501	.2365
.1462	4.6434	1.6635	.3583	14.2558	4.4226	.5501	.4094
.1379	3.1235	.9731	.3115	10.0420	2.6143	.5501	.6531
.1317	2.3373	.6380	.2729	7.8918	1.7283	.5501	.9432
.1259	1.8066	.4220	.2336	6.5148	1.1525	.5501	1.3516

Depth = 46 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2007	125.4317	125.4316	1.0000	49.6320	12.9758	.3819	.0466
.1669	10.4626	4.9351	.4717	28.3555	12.7640	.3819	.2366
.1568	6.5072	2.6467	.4067	18.0714	6.9174	.3819	.4101
.1487	4.4708	1.5588	.3487	12.7657	4.1104	.3819	.6542
.1427	3.4254	1.0334	.3017	10.0757	2.7437	.3819	.9403
.1369	2.7034	.6829	.2526	8.3037	1.8259	.3819	1.3551
.1317	2.2609	.4639	.2052	7.3980	1.2485	.3819	1.9059

Depth = 61 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2203	161.6551	161.6551	1.0000	86.8217	19.1734	.5238	.0466
.1805	9.8132	7.0600	.7194	30.6124	21.4154	.5238	.2369
.1688	4.7850	3.8065	.7955	14.9050	11.5894	.5238	.4093
.1594	2.5928	2.2446	.8657	8.0730	6.8557	.5238	.6532
.1524	1.6054	1.4837	.9242	4.9989	4.5429	.5238	.9422
.1458	1.0015	.9865	.9850	3.1196	3.0278	.5238	1.3521
.1398	.6403	.6696	1.0458	1.9958	2.0600	.5238	1.9050
.1270	.2309	.2762	1.1961	.7214	.8543	.5238	4.1699
.1240	.1792	.2216	1.2362	.5602	.6862	.5238	5.0679
.1194	.1201	.1564	1.3018	.3758	.4852	.5238	6.8989
.1176	.1023	.1359	1.3290	.3202	.4221	.5238	7.8091
.1126	.0646	.0910	1.4093	.2025	.2834	.5238	11.1315
.1096	.0486	.0710	1.4612	.1524	.2213	.5238	13.8753

Depth = 76 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2347	205.5403	205.5403	1.0000	105.0706	26.0842	.4952	.0466
.1897	11.7986	9.4579	.8016	40.7476	32.1369	.4952	.2368
.1766	6.8276	5.1008	.7471	23.6212	17.3200	.4952	.4089
.1661	4.3142	3.0055	.6966	14.9581	10.1992	.4952	.6530
.1584	3.0458	1.9953	.6551	10.5847	6.7681	.4952	.9382
.1510	2.1612	1.3203	.6109	7.5338	4.4765	.4952	1.3519
.1443	1.5745	.8924	.5668	5.5104	3.0243	.4952	1.9118
.1303	.8056	.3698	.4590	2.8625	1.2520	.4952	4.1674
.1270	.6891	.2963	.4300	2.4638	1.0030	.4952	5.0691

.1220	.5471	.2095	.3829	1.9816	.7088	.4952	6.8886
.1200	.5004	.1816	.3629	1.8254	.6144	.4952	7.8153
.1145	.3981	.1211	.3043	1.4939	.4096	.4952	11.1825
.1113	.3546	.0948	.2674	1.3670	.3206	.4952	13.884

Depth = 91 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.2875	192.6427	192.6427	1.0000	56.8343	34.3479	.2351	.0466
.2455	13.7677	11.7664	.8546	45.4621	38.7187	.2351	.2364
.2327	7.4363	6.3450	.8532	24.8838	21.1599	.2351	.4099
.2223	4.3943	3.7446	.8522	14.8715	12.6308	.2351	.6558
.2147	2.9443	2.5068	.8514	10.0520	8.5303	.2351	.9377
.2072	1.9554	1.6634	.8507	6.7350	5.7110	.2351	1.3515
.2004	1.3316	1.1320	.8501	4.6246	3.9189	.2351	1.9046
.1857	.5537	.4701	.8490	1.9597	1.6587	.2351	4.1682
.1822	.4447	.3774	.8488	1.5813	1.3381	.2351	5.0688
.1769	.3164	.2685	.8485	1.1335	.9589	.2351	6.8661
.1747	.2739	.2324	.8484	.9843	.8326	.2351	7.8088
.1687	.1831	.1553	.8482	.6636	.5612	.2351	11.1848
.1652	.1437	.1219	.8481	.5238	.4429	.2351	13.8752

Depth = 137 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.3173	172.1266	172.1266	1.0000	108.5644	100.7439	.2351	.0465
.2456	23.0718	19.7180	.8546	124.1473	105.9621	.2351	.2365
.2253	12.5500	10.7083	.8533	65.9541	56.1981	.2351	.4090
.2093	7.4617	6.3586	.8522	38.4266	32.6990	.2351	.6530
.1977	4.9888	4.2475	.8514	25.2932	21.5029	.2351	.9378
.1866	3.3171	2.8219	.8507	16.5535	14.0605	.2351	1.3535
.1768	2.2660	1.9264	.8501	11.1417	9.4566	.2351	1.9065
.1563	.9484	.8052	.8490	4.5082	3.8209	.2351	4.1696
.1516	.7643	.6487	.8488	3.6025	3.0525	.2351	5.0617
.1445	.5444	.4620	.8485	2.5327	2.1452	.2351	6.8640
.1416	.4717	.4002	.8484	2.1822	1.8480	.2351	7.8070
.1339	.3176	.2694	.8482	1.4468	1.2249	.2351	11.1350
.1293	.2480	.2103	.8481	1.1189	.9472	.2351	13.9028

Site # 3, 1987

Depth = 30 cm

	K	flux	grad	K	flux	grad	time
Moisture (cm/day)	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3271	3.0018	3.0018	1.0000	17.5592	17.4856	.5349	.3408
.3271	3.1321	3.1321	.3668	10.1979	9.1177	.5349	.3408
.3226	2.5730	2.5730	.3517	8.4628	7.5039	.5349	.4084
.3017	.9943	.9943	.2871	3.4620	2.9248	.5349	.9796
.2985	.8546	.8546	.2787	3.0046	2.5174	.5349	1.1261
.2960	.7584	.7584	.2725	2.6866	2.2365	.5349	1.2569
.2938	.6822	.6822	.2675	2.4323	2.0137	.5349	1.3855
.2859	.4633	.4633	.2528	1.6866	1.3723	.5349	1.9782
.2813	.3680	.3680	.2473	1.3516	1.0923	.5349	2.4451
.2762	.2838	.2838	.2447	1.0478	.8444	.5349	3.1053
.2707	.2133	.2133	.2471	.7862	.6363	.5349	4.0385
.2661	.1673	.1673	.2541	.6115	.5000	.5349	5.0520
.2625	.1379	.1379	.2635	.4987	.4128	.5349	6.0359
.2594	.1165	.1165	.2748	.4164	.3493	.5349	7.0493
.2474	.0594	.0594	.3543	.2006	.1794	.5349	13.0885
.2455	.0533	.0533	.3734	.1781	.1609	.5349	14.4754
.2410	.0410	.0410	.4279	.1342	.1241	.5349	18.4331
.2383	.0349	.0349	.4676	.1132	.1059	.5349	21.3561
.2346	.0280	.0280	.5317	.0895	.0849	.5349	26.2005
.2326	.0248	.0248	.5716	.0788	.0753	.5349	29.3014
.2304	.0216	.0216	.6202	.0685	.0659	.5349	33.1748
.2243	.0188	.0148	.7850	.0589	.0452	.5349	47.1038
.2219	.0147	.0127	.8637	.0459	.0388	.5349	54.2118

Depth = 46 cm

	K	flux	grad	K	flux	grad	time
Moisture (cm/day)	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3437	2.7268	2.7268	1.0000	3.7390	3.5238	.4585	.3409
.3437	2.3856	3.2777	1.3740	1.7239	2.1009	.4585	.3409
.3427	1.9277	2.6749	1.3876	1.3990	1.7284	.4585	.4132
.3382	.7341	1.0637	1.4489	.5439	.7126	.4585	.9882

.3375	.6313	.9205	1.4581	.4694	.6202	.4585	1.1330
.3369	.5547	.8131	1.4658	.4137	.5504	.4585	1.2742
.3364	.4979	.7330	1.4721	.3723	.4983	.4585	1.4053
.3346	.3376	.5042	1.4935	.2549	.3478	.4585	2.0022
.3336	.2720	.4091	1.5042	.2066	.2846	.4585	2.4393
.3323	.2055	.3116	1.5164	.1572	.2190	.4585	3.1560
.3310	.1553	.2370	1.5262	.1198	.1684	.4585	4.0874
.3299	.1226	.1879	1.5321	.0953	.1347	.4585	5.0912
.3290	.1012	.1553	1.5350	.0791	.1122	.4585	6.0967
.3282	.0853	.1310	1.5359	.0671	.0953	.4585	7.1590
.3252	.0454	.0690	1.5207	.0365	.0515	.4585	13.1208
.3247	.0409	.0620	1.5147	.0331	.0465	.4585	14.5228
.3235	.0320	.0479	1.4950	.0262	.0362	.4585	18.5411
.3228	.0278	.0412	1.4799	.0229	.0313	.4585	21.3896
.3218	.0228	.0332	1.4528	.0189	.0255	.4585	26.2484
.3212	.0203	.0291	1.4331	.0170	.0225	.4585	29.6876
.3206	.0181	.0256	1.4105	.0152	.0198	.4585	33.5853
.3189	.0133	.0176	1.3293	.0114	.0139	.4585	47.6962
.3182	.0118	.0151	1.2872	.0102	.0120	.4585	55.1375

Depth = 61 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3344	18.2888	18.2888	1.0000	9.1805	1.7614	.4926	.0638
.3327	1.2872	2.9133	2.2634	.3413	.4413	.4926	.2599
.3321	.7671	1.7333	2.2595	.2049	.2675	.4926	.4272
.3311	.3276	.7279	2.2219	.0894	.1159	.4926	.9807
.3309	.2770	.6118	2.2087	.0761	.0980	.4926	.1584
.3308	.2548	.5609	2.2012	.0702	.0901	.4926	1.2590
.3306	.2157	.4713	2.1846	.0599	.0762	.4926	1.4873
.3302	.1552	.3327	2.1439	.0438	.0545	.4926	2.0762
.3300	.1319	.2795	2.1195	.0376	.0461	.4926	2.4534
.3297	.1036	.2151	2.0772	.0300	.0358	.4926	3.1521
.3294	.0817	.1656	2.0275	.0241	.0278	.4926	4.0507
.3291	.0647	.1274	1.9698	.0195	.0216	.4926	5.2067
.3289	.0555	.1070	1.9265	.0171	.0182	.4926	6.1560
.3287	.0478	.0898	1.8789	.0150	.0154	.4926	7.2792
.3280	.0290	.0486	1.6754	.0099	.0085	.4926	13.0974
.3278	.0254	.0408	1.6055	.0090	.0072	.4926	15.4943
.3275	.0210	.0314	1.4894	.0079	.0056	.4926	19.9405
.3274	.0198	.0287	1.4475	.0076	.0051	.4926	21.6909
.3271	.0168	.0221	1.3119	.0070	.0040	.4926	27.9237

.3270	.0160	.0202	1.2631	.0069	.0037	.4926	30.3785
.3269	.0153	.0185	1.2125	.0068	.0034	.4926	33.0493
.3264	.0128	.0119	.9293	.0072	.0022	.4926	50.3881
.3263	.0126	.0109	.8663	.0075	.0020	.4926	54.8267

Depth = 122 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3090	7.4222	7.4222	1.0000	7.1471	5.5141	.6126	.1132
.3068	3.1145	4.5159	1.4499	1.7561	1.6861	.6126	.2461
.3053	1.8684	2.6186	1.4015	1.0770	.9840	.6126	.4192
.3029	.8420	1.0888	1.2931	.5112	.4134	.6126	.9888
.3025	.7397	.9400	1.2707	.4542	.3575	.6126	1.1415
.3022	.6718	.8418	1.2530	.4163	.3206	.6126	1.2715
.3019	.6106	.7537	1.2345	.3821	.2874	.6126	1.4165
.3009	.4468	.5212	1.1664	.2904	.1996	.6126	2.0317
.3003	.3725	.4174	1.1207	.2488	.1603	.6126	2.5240
.2997	.3121	.3342	1.0709	.2152	.1287	.6126	3.1371
.2990	.2558	.2577	1.0073	.1843	.0995	.6126	4.0451
.2984	.2174	.2061	.9478	.1638	.0798	.6126	5.0323
.2979	.1912	.1710	.8944	.1505	.0664	.6126	6.0387
.2974	.1694	.1419	.8374	.1404	.0552	.6126	7.2487
.2957	.1223	.0750	.6133	.1312	.0294	.6126	13.5181
.2955	.1192	.0696	.5835	.1336	.0273	.6126	14.5500
.2948	.1129	.0534	.4734	.1526	.0210	.6126	18.8295
.2944	.0459	.0459	.4061	.0716	.0181	.6126	21.8245
.2939	.0380	.0380	.3170	.0750	.0150	.6126	26.2542
.2936	.0340	.0340	.2609	.0808	.0134	.6126	29.3371

Depth = 137 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2799	4.5965	4.5965	1.0000	7.4029	6.8409	.6156	.2415
.2798	5.3239	5.3239	.9173	5.3346	3.9615	.6156	.2458
.2769	3.1595	3.1351	.9923	3.0617	2.3340	.6156	.4127
.2721	1.1194	1.2888	1.1514	1.0266	.9604	.6156	.9847
.2713	.9381	1.1096	1.1828	.8528	.8270	.6156	1.1400
.2707	.8212	.9915	1.2074	.7416	.7390	.6156	1.2727
.2702	.7346	.9025	1.2287	.6598	.6728	.6156	1.3953
.2683	.4793	.6305	1.3155	.4220	.4702	.6156	1.9819

.2671	.3649	.5020	1.3757	.3174	.3745	.6156	2.4769
.2658	.2709	.3917	1.4459	.2327	.2923	.6156	3.1571
.2645	.2006	.3053	1.5219	.1703	.2279	.6156	4.0289
.2633	.1517	.2423	1.5973	.1274	.1809	.6156	5.0513
.2623	.1200	.1997	1.6644	.1000	.1491	.6156	6.1038
.2615	.0993	.1710	1.7210	.0822	.1277	.6156	7.1052
.2583	.0463	.0914	1.9758	.0375	.0683	.6156	13.1077
.2578	.0410	.0828	2.0201	.0331	.0619	.6156	14.4337
.2565	.0299	.0641	2.1413	.0240	.0479	.6156	18.5599
.2557	.0246	.0547	2.2206	.0196	.0409	.6156	21.6794
.2547	.0193	.0448	2.3250	.0153	.0335	.6156	26.3444
.2541	.0166	.0397	2.3905	.0131	.0297	.6156	29.6231
.2535	.0143	.0352	2.4584	.0113	.0263	.6156	33.3191
.2517	.0092	.0245	2.6766	.0072	.0183	.6156	47.4911
.2510	.0077	.0213	2.7677	.0060	.0159	.6156	54.5467

Depth = 152 cm

	K	flux	grad	K	flux	grad	time
Moisture (cm/day)	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2799	4.5965	4.5965	1.0000	7.4029	6.8409	.6156	.2415
.2798	5.3239	5.3239	.9173	5.3346	3.9615	.6156	.2458
.2769	3.1595	3.1351	.9923	3.0617	2.3340	.6156	.4127
.2721	1.1194	1.2888	1.1514	1.0266	.9604	.6156	.9847
.2713	.9381	1.1096	1.1828	.8528	.8270	.6156	1.1400
.2707	.8212	.9915	1.2074	.7416	.7390	.6156	1.2727
.2702	.7346	.9025	1.2287	.6598	.6728	.6156	1.3953
.2683	.4793	.6305	1.3155	.4220	.4702	.6156	1.9819
.2671	.3649	.5020	1.3757	.3174	.3745	.6156	2.4769
.2658	.2709	.3917	1.4459	.2327	.2923	.6156	3.1571
.2645	.2006	.3053	1.5219	.1703	.2279	.6156	4.0289
.2633	.1517	.2423	1.5973	.1274	.1809	.6156	5.0513
.2623	.1200	.1997	1.6644	.1000	.1491	.6156	6.1038
.2615	.0993	.1710	1.7210	.0822	.1277	.6156	7.1052
.2583	.0463	.0914	1.9758	.0375	.0683	.6156	13.1077
.2578	.0410	.0828	2.0201	.0331	.0619	.6156	14.4337
.2565	.0299	.0641	2.1413	.0240	.0479	.6156	18.5599
.2557	.0246	.0547	2.2206	.0196	.0409	.6156	21.6794
.2547	.0193	.0448	2.3250	.0153	.0335	.6156	26.3444
.2541	.0166	.0397	2.3905	.0131	.0297	.6156	29.6231
.2535	.0143	.0352	2.4584	.0113	.0263	.6156	33.3191
.2517	.0092	.0245	2.6766	.0072	.0183	.6156	47.4911
.2510	.0077	.0213	2.7677	.0060	.0159	.6156	54.5467

Depth = 183 cm

	K	flux	grad	K	flux	grad	time
Moisture (cm/day)	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2575	2.8067	2.8067	1.0000	3.6144	3.5450	.2512	.4749
.2575	3.4134	3.4134	.6843	2.4922	2.1544	.2512	.4749
.2575	3.4134	3.4134	.6843	2.4922	2.1544	.2512	.4749
.2541	2.5533	1.6094	.6303	1.9087	1.0178	.2512	.9912
.2535	2.2717	1.4079	.6198	1.7069	.8908	.2512	1.1298
.2530	2.0617	1.2591	.6107	1.5561	.7969	.2512	1.2602
.2525	1.8718	1.1258	.6015	1.4196	.7127	.2512	1.4060
.2509	1.3781	.7858	.5702	1.0636	.4979	.2512	1.9990
.2500	1.1629	.6412	.5514	.9078	.4065	.2512	2.4389
.2489	.9476	.4997	.5273	.7518	.3170	.2512	3.1131
.2477	.7613	.3801	.4993	.6167	.2414	.2512	4.0678
.2467	.6370	.3024	.4747	.5267	.1921	.2512	5.0887
.2459	.5543	.2516	.4540	.4671	.1599	.2512	6.0909
.2452	.4921	.2141	.4352	.4226	.1362	.2512	7.1319
.2425	.3218	.1145	.3557	.3060	.0729	.2512	13.1635
.2421	.3040	.1043	.3430	.2951	.0664	.2512	14.4230
.2410	.2630	.0806	.3064	.2731	.0514	.2512	18.5576
.2403	.2424	.0684	.2820	.2655	.0436	.2512	21.7995
.2395	.2237	.0566	.2530	.2640	.0361	.2512	26.2184
.2390	.2147	.0503	.2342	.2680	.0321	.2512	29.4337
.2385	.2078	.0447	.2149	.2768	.0285	.2512	33.0510

Site # 5, 1986

Depth = 30 cm

	K	flux	grad	K	flux	grad	time
Moisture (cm/day)	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3059	9.1622	9.1622	1.0000	6.0574	3.2205	.5599	.1338
.2844	.9771	1.1031	1.1290	2.8411	3.1607	.5599	.5047
.2762	.4898	.6287	1.2836	1.4194	1.8012	.5599	.8598
.2719	.3372	.4650	1.3790	.9758	1.3323	.5599	1.1442

.2679	.2367	.3498	1.4778	.6840	1.0021	.5599	1.4988
.2642	.1696	.2677	1.5790	.4895	.7670	.5599	1.9308
.2608	.1242	.2087	1.6811	.3581	.5980	.5599	2.4445
.2588	.1031	.1800	1.7455	.2973	.5158	.5599	2.8124.2
487	.0394	.0838	2.1287	.1132	.2400	.5599	5.8068
.2450	.0273	.0628	2.2971	.0786	.1799	.5599	7.6294
.2383	.0139	.0369	2.6483	.0400	.1056	.5599	12.6418

Depth = 46 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.3149	13.0067	13.0067	1.0000	9.1623	3.8336	.6398	.1341
.3022	2.5201	1.4991	.5949	5.0965	2.5674	.6398	.5092
.2973	2.3932	.8615	.3600	5.9285	1.4865	.6398	.8650
.2947	.6397	.6397	.2184	2.1769	1.1083	.6398	1.1499

Depth = 61 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.3038	16.3627	16.3627	1.0000	9.9974	5.1984	.5219	.1337
.2899	.8233	1.9668	2.3888	1.5520	3.6824	.5219	.5063
.2845	.4733	1.1264	2.3801	.8955	2.1169	.5219	.8642
.2817	.3537	.8401	2.3751	.6706	1.5821	.5219	1.1448
.2790	.2664	.6314	2.3700	.5061	1.1914	.5219	1.5054
.2765	.2045	.4835	2.3650	.3891	.9140	.5219	1.9444
.2743	.1617	.3816	2.3604	.3081	.7224	.5219	2.4401
.2729	.1391	.3278	2.3574	.2654	.6214	.5219	2.8222
.2660	.0655	.1534	2.3410	.1257	.2923	.5219	5.8452
.2635	.0497	.1160	2.3345	.0955	.2213	.5219	7.6453
.2589	.0296	.0688	2.3216	.0571	.1318	.5219	12.6140

Depth = 76 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>

.2419	24.5377	24.5377	1.0000	14.1603	7.9978	.4762	.1339
.2166	8.4143	2.7753	.3298	29.9661	9.0349	.4762	.5068
.2073	4.0582	1.5930	.3925	13.8792	5.0939	.4762	.8602
.2024	2.7475	1.1769	.4284	9.2214	3.7271	.4762	1.1476
.1980	1.9277	.8912	.4623	6.3679	2.7972	.4762	1.4957
.1938	1.3687	.6795	.4964	4.4563	2.1141	.4762	1.9367
.1901	1.0084	.5324	.5280	3.2432	1.6436	.4762	2.4432
.1879	.8395	.4595	.5474	2.6805	1.4118	.4762	2.8112
.1769	.3279	.2142	.6531	1.0118	.6421	.4762	5.8165
.1730	.2327	.1616	.6944	.7093	.4799	.4762	7.6094
.1659	.1226	.0951	.7752	.3659	.2776	.4762	12.6100

Depth = 91 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2475	31.6616	31.6616	1.0000	14.4043	12.5682	.2223	.1335
.2098	3.6620	3.9463	1.0776	17.0231	18.3266	.2223	.5058
.1964	2.2004	2.2456	1.0205	9.8860	10.0769	.2223	.8609
.1896	1.6802	1.6619	.9891	7.4123	7.3222	.2223	1.1436
.1833	1.2992	1.2452	.9584	5.6326	5.3907	.2223	1.5016
.1777	1.0275	.9552	.9297	4.3839	4.0693	.2223	1.9281
.1726	.8255	.7448	.9023	3.4699	3.1253	.2223	2.4381
.1696	.7241	.6412	.8855	3.0163	2.6661	.2223	2.8082
.1550	.3729	.2971	.7968	1.4834	1.1790	.2223	5.8008
.1499	.2927	.2232	.7626	1.1447	.8706	.2223	7.5962
.1407	.1867	.1299	.6961	.7069	.4903	.2223	12.6558

Depth = 137 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2850	48.5135	48.5135	1.0000	33.9183	23.7903	.4983	.1335
.2522	5.9757	6.9154	1.1572	24.4556	28.1440	.4983	.5048
.2402	3.1673	3.9232	1.2387	12.7949	15.7700	.4983	.8579
.2339	2.2383	2.8804	1.2869	8.9779	11.4995	.4983	1.1455
.2282	1.6206	2.1621	1.3342	6.4577	8.5776	.4983	1.4981
.2229	1.1908	1.6452	1.3816	4.7156	6.4879	.4983	1.9345
.2182	.9001	1.2841	1.4267	3.5442	5.0364	.4983	2.4392
.2154	.7595	1.1051	1.4550	2.9803	4.3199	.4983	2.8071

.2015	.3152	.5088	1.6142	1.2152	1.9553	.4983	5.7998
.1965	.2261	.3799	1.6801	.8660	1.4505	.4983	7.6230
.1876	.1224	.2216	1.8108	.4630	.8362	.4983	12.6213

Depth = 152 cm

	K	flux	grad	K	flux	grad	time
Moisture (cm/day)	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2999	47.1441	47.1441	1.0000	47.9154	41.7605	.4983	.1333
.2538	7.2463	8.3851	1.1572	40.1526	46.3223	.4983	.5045
.2374	3.8180	4.7303	1.2390	20.5846	25.4326	.4983	.8594
.2290	2.6995	3.4739	1.2869	14.3404	18.4050	.4983	1.1454
.2214	1.9495	2.6012	1.3343	10.2143	13.5942	.4983	1.4992
.2145	1.4358	1.9830	1.3811	7.4258	10.2309	.4983	1.9298
.2083	1.0810	1.5422	1.4266	5.5241	7.8624	.4983	2.4384
.2047	.9130	1.3282	1.4547	4.6325	6.7233	.4983	2.8021
.1868	.3754	.6062	1.6147	1.8346	2.9565	.4983	5.8130
.1806	.2702	.4539	1.6796	1.3025	2.1835	.4983	7.6087
.1695	.1455	.2635	1.8107	.6834	1.2354	.4983	12.6184

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Depth = 15 cm

	K	flux	grad	K	flux	grad	time
Moisture (cm/day)	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2436	3.1063	3.1063	1.0000	1.4824	.8264	.3962	.0744
.2368	2.0300	.7367	.3629	3.1236	.7987	.3962	.1682
.2321	1.1132	.4051	.3640	1.7102	.4392	.3962	.2996
.2254	.4522	.1691	.3739	.6855	.1833	.3962	.6967
.2236	.3515	.1331	.3787	.5297	.1443	.3962	.8777
.2220	.2800	.1074	.3837	.4192	.1165	.3962	1.0795
.2198	.2036	.0798	.3921	.3017	.0865	.3962	1.4382
.2175	.1448	.0583	.4028	.2120	.0632	.3962	1.9472
.2162	.1190	.0488	.4098	.1729	.0529	.3962	2.3143
.2139	.0836	.0355	.4241	.1196	.0384	.3962	3.1494
.2109	.0521	.0233	.4465	.0730	.0252	.3962	4.7309
.2093	.0402	.0185	.4605	.0557	.0201	.3962	5.8914
.2082	.0336	.0158	.4710	.0461	.0172	.3962	6.8572

.2072	.0285	.0137	.4812	.0388	.0149	.3962	7.8773
.2041	.0169	.0087	.5170	.0225	.0095	.3962	12.1612
.2027	.0133	.0071	.5355	.0175	.0077	.3962	14.8283

Depth = 30 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2809	4.8965	4.8965	1.0000	4.1465	3.5152	.4492	.0742
.2739	1.7086	1.8651	1.0916	2.0295	2.0784	.4492	.1685
.2691	.9615	1.0300	1.0712	1.1456	1.1487	.4492	.2994
.2622	.4168	.4305	1.0331	.4994	.4807	.4492	.6967
.2603	.3305	.3372	1.0204	.3968	.3767	.4492	.8825
.2587	.2717	.2742	1.0089	.3268	.3063	.4492	1.0784
.2564	.2050	.2031	.9909	.2472	.2270	.4492	1.4418
.2541	.1545	.1501	.9712	.1870	.1678	.4492	1.9326
.2527	.1301	.1247	.9582	.1578	.1394	.4492	2.3129
.2504	.0980	.0917	.9352	.1194	.1026	.4492	3.1137
.2472	.0662	.0595	.8995	.0811	.0667	.4492	4.7306
.2456	.0544	.0479	.8798	.0670	.0536	.4492	5.8427
.2444	.0470	.0406	.8641	.0580	.0455	.4492	6.8514
.2434	.0416	.0354	.8505	.0515	.0396	.4492	7.8285
.2401	.0279	.0224	.8015	.0350	.0251	.4492	12.2024
.2386	.0233	.0181	.7771	.0294	.0203	.4492	14.9605

Depth = 46 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3003	5.8766	5.8766	1.0000	5.6088	5.4111	.2512	.0748
.2954	1.4400	2.6694	1.8538	1.1827	2.1625	.2512	.1671
.2919	.8060	1.4668	1.8199	.6649	1.1931	.2512	.2992
.2869	.3493	.6158	1.7631	.2900	.5038	.2512	.6959
.2855	.2760	.4816	1.7451	.2296	.3947	.2512	.8838
.2843	.2254	.3898	1.7290	.1879	.3198	.2512	1.0858
.2826	.1691	.2884	1.7050	.1413	.2371	.2512	1.4555
.2809	.1268	.2130	1.6793	.1062	.1755	.2512	1.9545
.2799	.1070	.1780	1.6635	.0897	.1469	.2512	2.3266
.2782	.0802	.1311	1.6353	.0674	.1084	.2512	3.1333
.2758	.0533	.0848	1.5924	.0450	.0703	.2512	4.7847

.2746	.0434	.0681	1.5695	.0367	.0566	.2512	5.9208
.2738	.0379	.0588	1.5538	.0321	.0489	.2512	6.8280
.2730	.0330	.0508	1.5375	.0280	.0423	.2512	7.8774
.2705	.0216	.0320	1.4837	.0184	.0267	.2512	12.3482
.2694	.0179	.0261	1.4585	.0153	.0218	.2512	15.0686

Depth = 91 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.2399	31.8695	31.8695	1.0000	16.0076	14.1794	.2331	.0738
.2222	10.9299	8.9398	.8179	28.7889	23.4089	.2331	.1668
.2103	6.2186	4.8437	.7789	15.9456	12.3352	.2331	.2996
.1943	2.8012	2.0070	.7165	6.9139	4.9105	.2331	.6951
.1901	2.2551	1.5737	.6978	5.5079	3.8075	.2331	.8769
.1865	1.8677	1.2719	.6810	4.5208	3.0478	.2331	1.0747
.1814	1.4246	.9341	.6557	3.4039	2.2070	.2331	1.4432
.1765	1.0937	.6886	.6296	2.5806	1.6046	.2331	1.9311
.1736	.9337	.5726	.6133	2.1865	1.3231	.2331	2.3032
.1687	.7127	.4163	.5841	1.6479	.9480	.2331	3.1231
.1622	.4960	.2688	.5419	1.1276	.6000	.2331	4.7431
.1591	.4167	.2168	.5202	.9399	.4793	.2331	5.8237
.1567	.3640	.1830	.5028	.8163	.4015	.2331	6.8455
.1547	.3253	.1586	.4877	.7259	.3457	.2331	7.8477
.1484	.2286	.0998	.4368	.5028	.2131	.2331	12.2119
.1457	.1969	.0814	.4133	.4309	.1720	.2331	14.8456

Depth = 122 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.2854	27.3659	27.3659	1.0000	121.7685	117.8010	1.1266	.0814
.2727	4.3863	13.5784	3.0957	9.5021	28.9973	1.1266	.1673
.2628	2.2695	7.3389	3.2337	4.8776	15.5642	1.1266	.3003
.2492	.8795	3.0315	3.4467	1.8690	6.3651	1.1266	.6961
.2456	.6782	2.3794	3.5082	1.4369	4.9827	1.1266	.8762
.2425	.5406	1.9263	3.5630	1.1421	4.0236	1.1266	1.0713
.2380	.3869	1.4104	3.6459	.8141	2.9358	1.1266	1.4408
.2336	.2771	1.0339	3.7309	.5809	2.1446	1.1266	1.9356
.2311	.2286	.8644	3.7811	.4781	1.7894	1.1266	2.2948

.2266	.1608	.6232	3.8750	.3350	1.2853	1.1266	3.1323
.2207	.1003	.4018	4.0056	.2078	.8245	1.1266	4.7548
.2178	.0792	.3224	4.0731	.1635	.6599	1.1266	5.8616
.2157	.0665	.2744	4.1234	.1372	.5606	1.1266	6.8327
.2139	.0573	.2387	4.1676	.1178	.4869	1.1266	7.8013
.2079	.0344	.1486	4.3219	.0704	.3016	1.1266	12.2366
.2053	.0274	.1206	4.3924	.0560	.2440	1.1266	14.9326

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Depth = 30 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3687	3.9886	3.9886	1.0000	19.7512	19.6315	.5445	.1509
.3610	2.6679	2.6679	.6418	6.9423	6.5629	.5445	.2340
.3515	2.6001	1.4933	.5743	6.8487	3.6697	.5445	.4074
.3374	1.3741	.6126	.4458	3.7671	1.5036	.5445	.9541
.3318	1.1115	.4256	.3829	3.1516	1.0440	.5445	1.3512
.3260	.9383	.2899	.3090	2.8329	.7109	.5445	1.9496

Depth = 46 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3602	2.6695	2.6695	1.0000	3.4157	3.1903	.4571	.2038
.3596	2.8656	2.8656	.5216	3.0374	1.7085	.4571	.2364
.3574	1.6304	1.6304	.4783	1.8427	.9836	.4571	.4079
.3540	.6774	.6774	.4114	.8600	.4161	.4571	.9541
.3526	.4707	.4707	.3852	.6300	.2913	.4571	1.3571
.3511	.3181	.3181	.3588	.4512	.1985	.4571	1.9825
.3472	.1140	.1140	.3065	.1848	.0726	.4571	5.3517
.3466	.0972	.0972	.3017	.1599	.0622	.4571	6.2412
.3459	.0807	.0807	.2975	.1344	.0518	.4571	7.4702
.3450	.0636	.0636	.2948	.1067	.0410	.4571	9.4172
.3447	.0587	.0587	.2947	.0986	.0379	.4571	10.1744
.3439	.0474	.0474	.2964	.0793	.0308	.4571	12.5091
.3434	.0415	.0415	.2991	.0689	.0270	.4571	14.2365
.3429	.0363	.0363	.3033	.0596	.0237	.4571	16.2055
.3420	.0285	.0285	.3146	.0454	.0187	.4571	20.4709

.3415	.0249	.0249	.3234	.0388	.0164	.4571	23.3145
.3408	.0206	.0206	.3389	.0310	.0136	.4571	27.9801

Depth = 61 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3433	14.3011	14.3011	1.0000	12.6445	2.9569	.8596	.0680
.3404	1.4502	2.7467	1.8940	.8243	.9399	.8596	.2409
.3392	.7871	1.5996	2.0321	.4300	.5528	.8596	.4077
.3372	.2799	.6468	2.3103	.1433	.2273	.8596	.9845
.3364	.1842	.4496	2.4410	.0919	.1590	.8596	1.4026
.3356	.1208	.3122	2.5844	.0589	.1112	.8596	2.0002
.3334	.0373	.1141	3.0539	.0171	.0414	.8596	5.3313
.3330	.0301	.0949	3.1526	.0137	.0345	.8596	6.3760
.3327	.0256	.0827	3.2296	.0116	.0302	.8596	7.2928
.3321	.0185	.0627	3.3915	.0082	.0230	.8596	9.5442
.3320	.0175	.0599	3.4196	.0078	.0220	.8596	9.9824
.3315	.0133	.0475	3.5647	.0059	.0175	.8596	12.4969
.3312	.0113	.0414	3.6557	.0050	.0153	.8596	14.3026
.3309	.0096	.0360	3.7498	.0042	.0133	.8596	16.3710
.3304	.0073	.0286	3.9136	.0032	.0106	.8596	20.5100
.3301	.0062	.0249	4.0163	.0027	.0093	.8596	23.4840
.3297	.0050	.0207	4.1585	.0021	.0077	.8596	28.1359

Depth = 76 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3256	13.9963	13.9963	1.0000	18.1694	4.8184	1.2517	.0678
.3216	1.7593	3.2607	1.8534	1.4600	1.5724	1.2517	.2359
.3198	.9579	1.8270	1.9073	.7820	.8872	1.2517	.4154
.3171	.3848	.7615	1.9788	.3081	.3738	1.2517	.9766
.3160	.2657	.5320	2.0025	.2115	.2622	1.2517	1.3863
.3149	.1836	.3712	2.0216	.1456	.1838	1.2517	1.9704
.3118	.0656	.1337	2.0396	.0519	.0670	1.2517	5.3426
.3113	.0556	.1133	2.0359	.0442	.0569	1.2517	6.2810
.3108	.0473	.0960	2.0298	.0376	.0483	1.2517	7.3861
.3100	.0365	.0736	2.0146	.0292	.0371	1.2517	9.5779
.3098	.0342	.0688	2.0096	.0275	.0348	1.2517	10.2219

.3092	.0283	.0563	1.9918	.0228	.0285	1.2517	12.4285
.3088	.0249	.0493	1.9773	.0202	.0250	1.2517	14.1612
.3084	.0220	.0431	1.9605	.0179	.0219	1.2517	16.1382
.3077	.0177	.0341	1.9252	.0146	.0174	1.2517	20.2934
.3073	.0157	.0298	1.9013	.0131	.0152	1.2517	23.1374
.3067	.0131	.0244	1.8599	.0111	.0125	1.2517	28.1768

Depth = 91 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3256	7.1617	7.1617	1.0000	7.0347	6.4434	.3942	.0884
.3226	3.5167	3.4181	.9720	2.1387	1.5490	.3942	.2408
.3210	2.0597	1.9727	.9578	1.2649	.8992	.3942	.4125
.3185	.8945	.8310	.9290	.5598	.3823	.3942	.9614
.3175	.6416	.5869	.9147	.4053	.2710	.3942	1.3513
.3164	.4458	.3999	.8969	.2848	.1854	.3942	1.9675
.3135	.1726	.1444	.8371	.1146	.0677	.3942	5.3306
.3131	.1516	.1254	.8272	.1014	.0589	.3942	6.1205
.3125	.1250	.1015	.8113	.0846	.0477	.3942	7.5329
.3118	.1000	.0792	.7914	.0686	.0373	.3942	9.6024
.3116	.0939	.0738	.7855	.0647	.0348	.3942	10.2931
.3110	.0777	.0596	.7667	.0543	.0282	.3942	12.6809
.3107	.0708	.0536	.7568	.0498	.0254	.3942	14.0773
.3103	.0625	.0465	.7430	.0445	.0220	.3942	16.1838
.3096	.0504	.0362	.7175	.0367	.0172	.3942	20.6656
.3092	.0447	.0314	.7019	.0329	.0149	.3942	23.7697
.3087	.0385	.0262	.6815	.0289	.0125	.3942	28.3207

Depth = 137 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2935	15.4365	15.4365	1.0000	15.9669	14.7618	.3942	.0683
.2879	5.0039	4.8651	.9723	3.9267	3.2687	.3942	.2378
.2855	2.9212	2.7986	.9580	2.3044	1.8835	.3942	.4090
.2818	1.2721	1.1822	.9294	1.0140	.7978	.3942	.9523
.2802	.8881	.8116	.9139	.7119	.5484	.3942	1.3770
.2787	.6344	.5693	.8974	.5117	.3851	.3942	1.9496
.2744	.2435	.2038	.8370	.2011	.1383	.3942	5.3382

.2738	.2133	.1764	.8268	.1770	.1197	.3942	6.1514
.2730	.1790	.1454	.8124	.1494	.0988	.3942	7.4352
.2720	.1439	.1141	.7930	.1212	.0776	.3942	9.4305
.2717	.1348	.1061	.7869	.1138	.0721	.3942	10.1293
.2708	.1110	.0852	.7676	.0946	.0580	.3942	12.5581
.2703	.0997	.0754	.7562	.0855	.0513	.3942	14.1553
.2697	.0877	.0651	.7420	.0758	.0443	.3942	16.3469
.2688	.0726	.0522	.7194	.0634	.0356	.3942	20.2989
.2682	.0640	.0450	.7034	.0565	.0307	.3942	23.4606
.2674	.0543	.0370	.6808	.0486	.0252	.3942	28.4698

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Depth = 30 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2851	5.2870	5.2870	1.0000	10.9357	10.6214	.4923	.0292
.2773	.4784	.9063	1.8943	.4995	.9164	.4923	.2041
.2727	.1407	.2741	1.9473	.1473	.2784	.4923	.6598
.2715	.1021	.2000	1.9581	.1070	.2033	.4923	.8990
.2690	.0523	.1032	1.9748	.0548	.1052	.4923	1.7200
.2671	.0314	.0622	1.9811	.0330	.0635	.4923	2.8278
.2657	.0215	.0427	1.9813	.0227	.0437	.4923	4.0882
.2649	.0174	.0344	1.9794	.0183	.0352	.4923	5.0510
.2616	.0072	.0140	1.9535	.0076	.0144	.4923	12.1684
.2611	.0063	.0122	1.9466	.0067	.0126	.4923	13.9159
.2598	.0045	.0086	1.9242	.0047	.0088	.4923	19.7493
.2579	.0027	.0051	1.8787	.0029	.0052	.4923	33.0476
.2569	.0021	.0038	1.8477	.0022	.0040	.4923	43.3991

Depth = 46 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3136	9.2769	9.2769	1.0000	30.1346	29.4711	.6779	.0327
.3015	.8951	1.6594	1.8538	1.4539	2.6261	.6779	.2026
.2939	.2561	.4962	1.9375	.4141	.7834	.6779	.6616
.2919	.1832	.3593	1.9608	.2960	.5668	.6779	.9079

.2880	.0947	.1902	2.0077	.1527	.2997	.6779	1.6935
.2849	.0557	.1140	2.0464	.0896	.1794	.6779	2.7966
.2826	.0374	.0777	2.0759	.0601	.1222	.6779	4.0718
.2814	.0304	.0636	2.0916	.0488	.0999	.6779	4.9595
.2761	.0120	.0259	2.1631	.0191	.0406	.6779	11.9721
.2752	.0102	.0222	2.1755	.0163	.0348	.6779	13.9280
.2731	.0070	.0154	2.2050	.0112	.0242	.6779	19.8644
.2701	.0041	.0091	2.2481	.0065	.0143	.6779	33.1446
.2686	.0031	.0070	2.2699	.0049	.0110	.6779	42.9052

Depth = 61 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3107	76.0191	76.0191	1.0000	93.9164	60.2964	.9472	.0083
.2903	2.9826	2.3463	.7867	5.6462	3.4274	.9472	.2022
.2830	.8133	.6922	.8511	1.4920	1.0095	.9472	.6687
.2812	.5851	.5098	.8713	1.0640	.7432	.9472	.9022
.2774	.2884	.2656	.9208	.5143	.3868	.9472	1.7092
.2745	.1662	.1605	.9655	.2917	.2336	.9472	2.7997
.2723	.1087	.1091	1.0039	.1885	.1587	.9472	4.0852
.2711	.0860	.0883	1.0267	.1481	.1284	.9472	5.0267
.2661	.0318	.0362	1.1370	.0533	.0525	.9472	12.0481
.2653	.0271	.0313	1.1572	.0451	.0455	.9472	13.8779
.2633	.0180	.0218	1.2112	.0297	.0316	.9472	19.7990
.2605	.0101	.0130	1.2956	.0164	.0189	.9472	32.7097
.2590	.0074	.0099	1.3455	.0119	.0143	.9472	42.8987

Depth = 76 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2660	114.6140	114.6140	1.0000	196.6779	168.8491	.8800	.0083
.2224	2.9081	3.7511	1.2899	8.5636	10.7452	.8800	.2024
.2081	.8910	1.1119	1.2479	2.5424	3.0743	.8800	.6617
.2045	.6551	.8080	1.2334	1.8542	2.2131	.8800	.9030
.1974	.3531	.4233	1.1989	.9837	1.1376	.8800	1.6949
.1920	.2185	.2548	1.1664	.6015	.6747	.8800	2.7785
.1880	.1523	.1733	1.1383	.4157	.4539	.8800	4.0434
.1858	.1247	.1398	1.1212	.3388	.3636	.8800	4.9870

.1769	.0549	.0569	1.0376	.1466	.1442	.8800	11.9600
.1754	.0477	.0487	1.0209	.1272	.1229	.8800	13.9199
.1719	.0344	.0337	.9787	.0913	.0841	.8800	19.9356
.1671	.0220	.0201	.9122	.0581	.0493	.8800	33.0227
.1646	.0174	.0152	.8732	.0460	.0371	.8800	43.1995

Depth = 91 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2874	68.5895	68.5895	1.0000	589.8962	589.7493	.1921	.0175
.2409	12.6903	5.7257	.4512	50.0151	22.4341	.1921	.2030
.2213	4.3357	1.6945	.3908	16.3734	6.3447	.1921	.6590
.2164	3.2846	1.2291	.3742	12.2670	4.5466	.1921	.8991
.2068	1.8873	.6409	.3396	6.8970	2.3140	.1921	1.6876
.1995	1.2289	.3827	.3114	4.4175	1.3554	.1921	2.7787
.1942	.8971	.2601	.2899	3.1873	.9078	.1921	4.0375
.1913	.7545	.2096	.2777	2.6645	.7257	.1921	4.9749
.1796	.3755	.0847	.2256	1.2972	.2836	.1921	11.9436
.1776	.3337	.0721	.2162	1.1494	.2401	.1921	13.9517

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Depth = 30 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3083	1.4094	1.4094	1.0000	1.1803	.9289	.5166	.2541
.3000	.2399	.2310	.9627	.4282	.3931	.5166	.9902
.2956	.1164	.1088	.9351	.2084	.1854	.5166	2.0678
.2918	.0619	.0563	.9098	.1112	.0960	.5166	3.9403
.2874	.0295	.0260	.8784	.0534	.0443	.5166	8.4016
.2865	.0254	.0221	.8717	.0459	.0378	.5166	9.8230
.2833	.0147	.0125	.8471	.0267	.0213	.5166	17.1926
.2816	.0110	.0092	.8335	.0200	.0157	.5166	23.2063
.2799	.0082	.0067	.8195	.0150	.0115	.5166	31.3803

Depth = 61 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3540	1.4257	1.4257	1.0000	.7848	.3080	.5063	.2675
.3522	.3605	.2175	.6033	.3321	.0826	.5063	1.0347
.3512	.1386	.1012	.7300	.1098	.0387	.5063	2.1999
.3504	.0634	.0548	.8635	.0445	.0210	.5063	4.0285
.3494	.0235	.0254	1.0817	.0142	.0098	.5063	8.5988
.3492	.0192	.0218	1.1335	.0113	.0084	.5063	10.0093
.3485	.0095	.0127	1.3395	.0051	.0049	.5063	17.0450
.3481	.0063	.0093	1.4767	.0033	.0036	.5063	23.1163
.3477	.0042	.0068	1.6300	.0021	.0027	.5063	31.3609

Depth = 76 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3473	2.8150	2.8150	1.0000	1.7862	.5211	.6069	.2677
.3449	.1030	.2879	2.7957	.0583	.1504	.6069	1.0267
.3436	.0514	.1372	2.6715	.0294	.0720	.6069	2.1346
.3425	.0289	.0731	2.5326	.0167	.0385	.6069	3.9742
.3412	.0150	.0347	2.3180	.0088	.0183	.6069	8.3057
.3409	.0129	.0292	2.2593	.0077	.0154	.6069	9.8496
.3399	.0081	.0164	2.0342	.0049	.0087	.6069	17.4068
.3394	.0065	.0123	1.9026	.0040	.0065	.6069	23.1549
.3388	.0050	.0087	1.7256	.0032	.0046	.6069	32.6279

Depth = 91 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3416	1.6452	1.6452	1.0000	1.1108	.8788	.4130	.2573
.3385	.1754	.3549	2.0237	.1207	.2333	.4130	1.0221
.3369	.0806	.1719	2.1321	.0554	.1133	.4130	2.0934
.3355	.0407	.0909	2.2332	.0279	.0600	.4130	3.9309
.3338	.0177	.0418	2.3642	.0121	.0276	.4130	8.4784
.3334	.0145	.0348	2.3965	.0099	.0230	.4130	10.1650
.3322	.0080	.0200	2.4965	.0055	.0133	.4130	17.5411

.3316	.0060	.0152	2.5485	.0041	.0101	.4130	23.0597
.3309	.0042	.0110	2.6108	.0029	.0073	.4130	31.7482

Depth = 122 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3328	4.0477	4.0477	1.0000	4.9456	2.5364	1.0489	.2553
.3242	.7364	.6285	.8535	1.6073	1.1336	1.0489	.9992
.3197	.2557	.3007	1.1762	.5120	.5392	1.0489	2.0703
.3158	.1041	.1574	1.5118	.1993	.2808	1.0489	3.9251
.3113	.0374	.0739	1.9753	.0692	.1309	1.0489	8.2931
.3102	.0291	.0613	2.1027	.0536	.1085	1.0489	9.9734
.3070	.0141	.0355	2.5084	.0256	.0625	1.0489	17.1222
.3052	.0094	.0260	2.7617	.0169	.0457	1.0489	23.2631
.3035	.0064	.0194	3.0188	.0115	.0340	1.0489	31.1245

Depth = 137 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3191	4.7154	4.7154	1.0000	6.0296	3.0915	1.0978	.2547
.3108	.5610	.7661	1.3656	1.0699	1.3249	1.0978	.9946
.3064	.3027	.3632	1.2000	.5897	.6247	1.0978	2.0783
.3027	.1875	.1923	1.0258	.3785	.3292	1.0978	3.8944
.2983	.1163	.0894	.7684	.2584	.1521	1.0978	8.3012
.2973	.1069	.0750	.7012	.2470	.1274	1.0978	9.8746
.2942	.0922	.0433	.4696	.2661	.0733	1.0978	16.9755
.2925	.0320	.0320	.3263	.1204	.0540	1.0978	22.9041

Depth = 152 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3106	6.4252	6.4252	1.0000	5.2865	3.8254	.5679	.2567
.3004	1.1987	.9397	.7840	2.6722	1.9813	.5679	.9944
.2950	.5733	.4457	.7774	1.2697	.9319	.5679	2.0754

.2904	.3024	.2336	.7723	.6659	.4847	.5679	3.9258
.2851	.1428	.1095	.7671	.3122	.2253	.5679	8.2867
.2839	.1202	.0921	.7661	.2624	.1891	.5679	9.8328
.2801	.0693	.0529	.7631	.1506	.1080	.5679	16.9840
.2780	.0510	.0388	.7617	.1104	.0789	.5679	23.0462
.2759	.0374	.0284	.7606	.0807	.0576	.5679	31.3449

Depth = 183 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.3138	9.1343	9.1343	1.0000	7.0481	4.7717	.5679	.2560
.3045	1.6086	1.2611	.7840	3.2564	2.3839	.5679	.9940
.2996	.7717	.6000	.7775	1.5565	1.1280	.5679	2.0658
.2954	.4069	.3143	.7724	.8182	.5882	.5679	3.9045
.2905	.1905	.1461	.7671	.3815	.2719	.5679	8.3013
.2894	.1603	.1228	.7660	.3208	.2283	.5679	9.8502
.2859	.0922	.0703	.7631	.1839	.1302	.5679	17.0505
.2840	.0680	.0518	.7618	.1355	.0957	.5679	23.0314
.2821	.0501	.0381	.7606	.0996	.0702	.5679	31.1733

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Depth = 15 cm

	K	flux	grad	K	flux	grad	time
<u>Moisture</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>(cm/day)</u>	<u>error</u>	<u>error</u>	<u>error</u>	<u>(days)</u>
.2948	.0571	.0571	1.0000	.0287	.0147	.4314	.9593
.2942	.0194	.0194	.2972	.0307	.0123	.4314	1.3020
.2934	.0128	.0128	.3893	.0164	.0081	.4314	1.9585
.2926	.0085	.0085	.5032	.0091	.0054	.4314	2.9494
.2906	.0033	.0030	.9108	.0026	.0019	.4314	8.2489
.2902	.0024	.0024	1.0184	.0018	.0016	.4314	10.1414
.2895	.0014	.0017	1.2324	.0010	.0011	.4314	14.5670
.2886	.0007	.0011	1.5625	.0005	.0007	.4314	23.2350
.2882	.0005	.0009	1.7320	.0003	.0005	.4314	28.6065
.2878	.0004	.0007	1.9170	.0002	.0004	.4314	35.2299
.2874	.0003	.0006	2.1191	.0002	.0004	.4314	43.4000
.2870	.0002	.0005	2.3395	.0001	.0003	.4314	53.4796
.2868	.0002	.0004	2.4571	.0001	.0003	.4314	59.3724

.2866 .0001 .0004 2.5799 .0001 .0002 .4314 65.9202

Depth = 30 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3192	.2904	.2904	1.0000	.2127	.0704	.6911	.9465
.3181	.0402	.0851	2.1178	.0387	.0772	.6911	1.2759
.3165	.0258	.0548	2.1215	.0249	.0496	.6911	1.9738
.3151	.0176	.0372	2.1131	.0169	.0337	.6911	2.8966
.3113	.0064	.0129	2.0135	.0062	.0116	.6911	8.2753
.3106	.0053	.0106	1.9790	.0052	.0095	.6911	10.0548
.3094	.0040	.0075	1.9046	.0038	.0068	.6911	14.0549
.3077	.0026	.0047	1.7606	.0026	.0042	.6911	22.6389
.3069	.0022	.0037	1.6744	.0022	.0033	.6911	28.3580
.3061	.0019	.0029	1.5746	.0019	.0027	.6911	35.5430
.3054	.0016	.0024	1.4749	.0017	.0022	.6911	43.3290
.3048	.0015	.0020	1.3795	.0015	.0018	.6911	51.3658
.3044	.0014	.0018	1.3103	.0014	.0016	.6911	57.5465
.3039	.0013	.0016	1.2171	.0014	.0014	.6911	66.3423

Depth = 46 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3213	.2015	.2015	1.0000	.2086	.0468	1.0087	.9528

Depth = 61 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3003	.3199	.3199	1.0000	.3370	.0804	1.0231	.9630
.2997	.0721	.1397	1.9364	.0532	.0720	1.0231	1.2568
.2987	.0489	.0891	1.8237	.0372	.0459	1.0231	1.9615
.2978	.0351	.0594	1.6901	.0279	.0306	1.0231	2.9317
.2955	.0180	.0209	1.1623	.0184	.0108	1.0231	8.2330
.2950	.0166	.0167	1.0018	.0190	.0086	1.0231	10.3159

.2943	.0163	.0121	.7425	.0240	.0062	1.0231	14.1552
.2933	.0077	.0077	.2903	.0273	.0040	1.0231	22.2731

Depth = 76 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2777	.7050	.7050	1.0000	.5130	.1258	.7054	.9506
.2768	.3526	.1996	.5660	.4919	.1250	.7054	1.2828
.2755	.2302	.1286	.5588	.3244	.0805	.7054	1.9814
.2743	.1550	.0856	.5524	.2203	.0535	.7054	2.9652
.2712	.0552	.0296	.5374	.0802	.0185	.7054	8.4708
.2706	.0451	.0241	.5349	.0658	.0150	.7054	10.3933
.2697	.0333	.0177	.5312	.0488	.0110	.7054	14.1375
.2683	.0207	.0109	.5261	.0306	.0068	.7054	22.8621
.2677	.0168	.0088	.5241	.0250	.0055	.7054	28.1133
.2670	.0132	.0069	.5221	.0197	.0043	.7054	35.8037
.2665	.0111	.0058	.5207	.0166	.0036	.7054	42.5703
.2659	.0091	.0047	.5193	.0135	.0029	.7054	52.4214
.2656	.0082	.0042	.5186	.0122	.0026	.7054	58.1818
.2652	.0071	.0037	.5178	.0106	.0023	.7054	66.8706

Depth = 91 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.2875	.9492	.9492	1.0000	.5609	.1707	.5629	.9407
.2865	.1383	.2546	1.8411	.1048	.1765	.5629	1.2753
.2851	.0889	.1653	1.8591	.0672	.1144	.5629	1.9564
.2838	.0589	.1104	1.8758	.0444	.0764	.5629	2.9163
.2804	.0198	.0381	1.9198	.0149	.0263	.5629	8.3573
.2798	.0164	.0315	1.9275	.0123	.0217	.5629	10.0770
.2787	.0115	.0223	1.9417	.0086	.0153	.5629	14.2157
.2772	.0071	.0138	1.9609	.0053	.0095	.5629	22.7771
.2765	.0056	.0111	1.9698	.0042	.0076	.5629	28.4064
.2758	.0045	.0088	1.9786	.0033	.0061	.5629	35.4472
.2752	.0037	.0073	1.9862	.0027	.0050	.5629	42.8748
.2746	.0030	.0060	1.9937	.0022	.0041	.5629	51.8804
.2743	.0027	.0055	1.9974	.0020	.0038	.5629	57.0783
.2739	.0024	.0048	2.0023	.0018	.0033	.5629	64.8384

Depth = 137 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3207	3.7457	3.7457	1.0000	2.4983	.7082	.6396	.9378
.3179	1.7040	.8055	.4727	3.8900	1.4809	.6396	1.2634
.3138	1.1327	.5141	.4539	2.6151	.9402	.6396	1.9639
.3103	.7957	.3488	.4383	1.8565	.6349	.6396	2.8752
.3008	.2971	.1190	.4004	.7144	.2138	.6396	8.2720
.2990	.2451	.0967	.3943	.5927	.1733	.6396	10.1437
.2962	.1809	.0698	.3858	.4409	.1247	.6396	13.9659
.2922	.1160	.0436	.3761	.2852	.0775	.6396	22.1691
.2902	.0923	.0344	.3725	.2277	.0609	.6396	27.9977
.2882	.0732	.0271	.3700	.1808	.0478	.6396	35.4157
.2867	.0613	.0226	.3688	.1515	.0398	.6396	42.2881
.2851	.0505	.0186	.3684	.1249	.0327	.6396	51.1470
.2842	.0453	.0167	.3686	.1118	.0293	.6396	56.9492
.2831	.0395	.0146	.3692	.0975	.0256	.6396	64.9722

Depth = 152 cm

	K	flux	grad	K	flux	grad	time
Moisture	(cm/day)	(cm/day)	(cm/day)	error	error	error	(days)
.3412	2.2631	2.2631	1.0000	1.6024	.6873	.6396	.9418
.3397	1.8335	.8658	.4722	3.0515	.8374	.6396	1.2768
.3376	1.2333	.5599	.4540	2.1085	.5421	.6396	1.9595
.3357	.8595	.3765	.4380	1.5063	.3649	.6396	2.8937
.3306	.3207	.1283	.4002	.5998	.1247	.6396	8.3307
.3297	.2685	.1060	.3946	.5076	.1030	.6396	10.0568
.3281	.1952	.0753	.3856	.3754	.0732	.6396	14.0731
.3259	.1248	.0469	.3759	.2446	.0457	.6396	22.3982
.3248	.0993	.0370	.3724	.1961	.0360	.6396	28.2901
.3237	.0787	.0291	.3699	.1563	.0284	.6396	35.7604
.3229	.0664	.0245	.3688	.1321	.0239	.6396	42.4261
.3220	.0546	.0201	.3684	.1087	.0196	.6396	51.4471
.3215	.0489	.0180	.3686	.0974	.0176	.6396	57.2767
.3209	.0428	.0158	.3692	.0852	.0154	.6396	65.1649

QPROG OUTPUT

Abbreviated output of program QPROG.

Definitions:

- T = time in days.
 DelT = time interval between measurements of soil moisture (days).
 Rerror = error in calculation of RB (cm)
 QB = Darcian flux (cm/day).
 RB = Darcian flux integrated with respect to time using water characteristic curve derived gradient (recharge in cm).
 RBB = Darcian flux integrated with respect to time using measured gradient (cm).
 R2 = translated recharge using RB and the change in storage for the soil profile (cm).

Site #2, 1986

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 91 cm-137 cm

T(days)	DelT(days)	Rerror	QB	RB	RBB	R2
6.00000	8.00000	2.06089	.13690	1.06509	0.00000	.72258
14.00000	7.00000	1.89867	.14368	.98200	0.00000	1.29013
* 21.00000	10.00000	2.85178	.15123	1.47451	0.00000	1.82594
* 90.78999	23.21001	5.50843	.09491	2.85641	0.00000	1.33008
117.00000	5.00000	.86540	.08567	.45145	0.00000	.48678
122.00000	7.00000	1.02618	.06610	.53120	0.00000	.54601
127.50000	7.50000	.95720	.06493	.49136	0.00000	.00000
135.00000	7.00000	.65262	.02176	.30342	0.00000	.00000
142.00000	8.00000	.12245	-.01481	.05179	0.00000	.02829
148.00000	9.00000	.08033	.00376	.00343	0.00000	1.33714
157.00000	7.00000	.06095	-.02672	.00163	0.00000	.31156
164.00000	7.00000	.00000	.00000	.00000	0.00000	.00000
171.00000	7.00000	.00000	.00000	.00000	0.00000	.00000
181.33000	2.67000	.00000	-.02784	.00000	0.00000	4.22502
187.83000	4.17000	.00000	-.04717	.00000	0.00000	8.88079
192.00000	7.00000	.00000	-.03526	.00000	0.00000	1.83255
199.00000	7.00000	.00000	-.03381	.00000	0.00000	.00000
217.00000	8.00000	.00000	.00000	.00000	.00081	.00369
225.00000	9.00000	.00000	-.01358	.00000	.02669	2.85390
238.71001	2.28999	.00000	-.00563	.00000	.00765	2.48681
241.00000	7.00000	.00000	-.00880	.00000	.02021	5.13122
255.00000	7.00000	.00000	-.01375	.00000	.03237	.37994
267.00000	7.00000	.00000	-.01600	.00000	.04082	1.35590
275.41992	11.58008	1.88573	.18301	.97448	.55903	4.62027
294.33008	1.66992	.72420	.25953	.36951	.22913	1.42690
296.00000	8.00000	3.64590	.19981	1.83735	1.28018	4.39381
304.00000	6.00000	2.26014	.18191	1.14515	.74190	.32685
310.00000	7.00000	2.47448	.17684	1.25561	.74190	.77144
317.00000	8.00000	2.64296	.15929	1.34449	.74190	.66449
325.00000	5.00000	1.51967	.15194	.77807	.74190	.51308

330.00000	8.00000	2.29250	.14174	1.17472	.74190	.82073
340.33008	9.66992	2.59876	.13383	1.33238	.74190	1.99519

Total Recharge, R1= 18.4240
 Total Recharge, R3= 50.5611
 Total R Error, RERR= 17.7052

Site #2, 1987

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 91 cm-137 cm

T(days)	DeIT(days)	Rerror	QB	RB	RBB	R2
2.25000	4.75000	1.26156	.13980	.65542	0.00000	.53203
8.66000	5.34000	1.43831	.13922	.74497	0.00000	1.50481
14.00000	6.00000	1.59171	.13627	.82647	0.00000	1.29258
20.00000	8.00000	2.16112	.14522	1.12597	0.00000	.98596
28.00000	7.00000	1.95757	.14625	1.02012	0.00000	.87512
35.00000	7.00000	1.92833	.14190	1.00852	0.00000	.35352
45.71001	3.28999	.93030	.15339	.48576	0.00000	1.10751
55.25000	5.75000	1.87994	.18638	.97684	0.00000	3.48867
84.00000	7.00000	4.72140	.62228	2.83029	0.00000	2.43529
* 106.00000	11.00000	8.15585	.25014	4.79827	0.00000	1.09756
* 117.00000	11.00000	4.78674	.19230	2.43339	0.00000	1.90339
* 134.00000	15.00000	5.20477	.16004	2.64252	0.00000	5.12478
* 149.00000	11.00000	3.29225	.14554	1.68067	0.00000	1.40095
160.00000	9.00000	2.55629	.14738	1.31811	0.00000	2.22107
* 189.00000	14.51401	.00000	.07099	.00000	.00000	.00000
206.54300	2.25600	.00000	.79196	.00000	.00000	.00000
209.69800	1.80000	.00000	.64168	.00000	.00000	.00000
212.42400	3.34100	.00000	.53828	.00000	.00000	.00000
215.76500	2.71201	.00000	.45846	.00000	.00000	.00000
218.47701	5.09999	.00000	.39235	.00000	.00000	.00000
232.00000	7.00000	4.29824	.37361	2.68088	.00000	2.35088
239.00000	7.00000	4.61648	.46003	2.91774	2.73226	1.92774
253.00000	6.00000	3.71845	.33138	2.37423	2.73226	1.72352
259.00000	7.00000	3.49448	.31026	2.24576	2.73226	1.22159
280.00000	9.00000	3.46542	.14151	2.03301	2.73226	.70372
289.00000	5.00000	1.42307	.14077	.70571	2.73226	.29293
294.00000	8.00000	2.11755	.12426	1.06012	2.73226	.36911
302.00000	6.00000	1.40556	.11090	.70546	2.73226	.39421

308.00000	7.00000	1.49055	.10232	.74627	1.26543	.14959
* 315.00000	12.00000	2.31505	.09121	1.16121	1.26543	.00000
327.00000	9.00000	1.55876	.08326	.78512	1.26543	1.56277
336.00000	8.00000	1.44387	.09914	.72959	.41584	1.51570
344.00000	6.00000	1.17195	.10027	.59823	.43161	.39448
350.00000	7.00000	1.35642	.10019	.70162	.43161	1.11328
Total Recharge, R1=		41.9923				
Total Recharge, R3=		38.0428				
Total R Error, RERR=		75.7420				

Site #2, 1988

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 91 cm-137 cm

T(days)	DelT(days)	Rerror	QB	RB	RBB	R2
* 21.21001	25.78999	8.11841	.17868	4.18223	0.00000	15.68404
* 47.00000	9.00000	3.21315	.18196	1.62286	0.00000	6.12212
62.58000	6.42000	2.19259	.16041	1.09902	0.00000	.82775
81.00000	8.00000	2.46485	.14539	1.22322	0.00000	.62630
91.00000	6.00000	4.10005	.67041	2.44740	0.00000	4.55490
97.00000	6.00000	.00000	.39182	.00000	.00000	.00000
103.00000	7.00000	5.93811	.67633	3.73853	.00000	8.66719
110.00000	8.00000	.00000	.24643	.00000	.00000	.00000
118.00000	6.00000	3.34857	.46511	2.13464	.00000	9.48534
* 124.00000	9.00000	4.66159	.15063	2.77084	.00000	22.69058
133.00000	7.00000	.00000	.09449	.00000	.00000	.00000
141.25000	3.75000	.96443	.16482	.48621	.00000	7.48401
151.50000	3.50000	.45554	-.00860	.27412	.00000	12.24205
155.00000	5.00000	.08314	.03063	.05977	.00000	.99098
160.00000	8.00000	.00000	.00000	.00000	.00000	.00000
168.00000	6.00000	.00000	.00000	.00000	.00000	.00000
174.00000	6.00000	.00000	.00000	.00000	.00000	.00000
180.00000	8.00000	.00000	.00000	.00000	.00000	.00000
188.00000	8.00000	.00000	.00000	.00000	.00000	.00000
196.00000	7.00000	.00000	-.03295	.00000	.00000	.00000
203.00000	13.00000	.00000	.00000	.00000	.00000	4.81023
216.00000	19.00000	.00000	.00000	.00000	.00000	.00000
235.00000	7.00000	.00000	.00000	.00000	.00000	.00000
242.00000	21.00000	.00000	.00000	.00000	.00000	.00000
267.25000	2.75000	.00000	.00000	.00000	.00000	.00000
270.00000	17.00000	.00000	.00000	.00000	.00000	.00000
287.00000	19.00000	.00000	.00000	.00000	.00000	.00000
306.00000	15.00000	.00000	.00000	.00000	.00000	.00000
321.00000	6.00000	.00000	.00000	.00000	.00000	.00000
Total Recharge, R1=		20.0388				
Total Recharge, R3=		94.1855				
Total R Error, RERR=		35.5404				

Site #3, 1986

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 137 cm-152 cm

T(days)	DeIT(days)	Rerror	QB	RB	RBB	R2
6.00000	8.00000	.00000	-.00004	.00000	0.00000	.19485
14.00000	7.00000	.06197	.00394	.01367	0.00000	.34929
21.00000	10.00000	.39855	.00665	.05297	0.00000	.30369
* 31.00000	83.00000	3.75149	.05512	2.56357	0.00000	1.16807
117.00000	5.00000	.21980	.05412	.27310	0.00000	.19153
129.00000	6.00000	.25080	.04454	.29596	0.00000	.07779
135.00000	7.00000	.28445	.04549	.31508	0.00000	.00000
148.00000	2.00000	.08480	.04096	.08645	0.00000	.63855
153.00000	4.00000	.16751	.04306	.16803	0.00000	1.83802
157.00000	7.00000	.27062	.03692	.27992	0.00000	.34106
164.00000	7.00000	.25527	.03508	.25201	0.00000	.00000
174.00000	4.00000	.13480	.03623	.14262	0.00000	.00000
178.00000	6.00000	.21105	.02728	.19052	0.00000	.00000
187.00000	5.00000	.17666	.01190	.09795	0.00000	.02103
192.00000	7.00000	.05962	-.00089	.03875	0.00000	.01992
199.00000	7.00000	.00000	-.00042	.00000	0.00000	.00000
206.00000	11.00000	.00000	.00191	.00000	.00000	.00000
213.00000	12.00000	.04198	-.02611	.00078	.00000	6.11430
234.00000	7.00000	.00000	.00000	.00000	.00000	7.48477
241.00000	7.00000	.00000	.00000	.00000	.00000	.00000
255.00000	7.00000	.00000	.00000	.00000	.00000	.10256
272.00000	2.00000	.00000	.00000	.00000	.00000	.00946
274.00000	13.00000	.00000	.00000	.00000	.00000	.14614
287.00000	9.00000	.00000	.00000	.00000	.00000	.50808
296.00000	8.00000	.00000	.00000	.00000	.00000	.12503
304.00000	6.00000	.00000	.00000	.00000	.00000	.01343
310.00000	7.00000	.00000	.00000	.00000	.00000	.01576
317.00000	8.00000	.00000	.00000	.00000	.00000	.00000
325.00000	5.00000	.00000	.00000	.00000	.00000	.00000
330.00000	8.00000	.00000	.00000	.00000	.00000	.00000
338.00000	12.00000	.00000	.00000	.00000	.00000	.28403
Total Recharge, R1=		4.7714				
Total Recharge, R3=		19.9474				
Total R Error, RERR=		6.3694				

Site #3, 1987

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 137 cm-152 cm

T(days)	DelT(days)	Rerror	QB	RB	RBB	R2
2.00000	5.00000	.00000	.00000	.00000	0.00000	.15000
7.00000	7.00000	.00000	.00000	.00000	0.00000	.40500
14.00000	6.00000	.00000	.00000	.00000	0.00000	.21214
20.00000	8.00000	.00000	.00000	.00000	0.00000	.13000
28.00000	7.00000	.00000	.00000	.00000	0.00000	.03094
35.00000	7.00000	.00000	.00000	.00000	0.00000	.00000
42.00000	7.00000	.00000	.00000	.00000	0.00000	.11838
49.00000	12.00000	.00000	.00000	.00000	0.00000	.86143
61.00000	9.00000	.00000	.00000	.00000	0.00000	.26010
81.00000	3.00000	.00000	.00000	.00000	0.00000	1.91182
84.00000	7.00000	.03548	.01769	.06193	0.00000	5.09860
103.00000	3.00000	.09262	.15216	.25478	0.00000	.89335
* 106.00000	11.00000	.89673	.21996	2.04667	.09587	3.44666
125.00000	3.00000	.36079	.18293	.60434	.04549	.64116
128.00000	7.00000	.86667	.15583	1.18566	.10926	1.02567
146.00000	3.00000	.36351	.14682	.45397	.04583	.49040
* 149.00000	11.00000	1.24570	.12450	1.49222	.14189	1.27760
161.00000	8.00000	.77187	.11157	.94427	.08629	.33930
169.00000	7.00000	.74159	.10781	.76784	.07398	.40061
180.00000	3.00000	.35018	.08874	.29483	.02809	.38979
185.00000	4.00000	.39412	.07486	.32721	.03162	1.71055
* 189.00000	19.00000	1.57999	.05522	1.23574	.10268	4.32021
* 208.00000	11.00000	.72065	.01692	.39672	.03619	.00000
219.00000	4.00000	.21699	.00420	.04223	.00896	.00000
223.00000	7.45100	.00000	-.00868	.00000	.00000	.00000
224.00000	8.43600	.00000	-.12870	.00000	.09311	10.15149
232.43600	2.35600	.00000	.07762	.00000	.00000	.00000
235.47900	1.98399	.00000	2.44330	.00000	.00000	.00000
237.46300	1.91200	.00000	-3.09278	.00000	.00000	.00000
243.39600	1.00700	.00000	-.97713	.00000	.00000	.00000
245.39900	1.01801	.00000	-.38986	.00000	.32148	19.03571
246.41701	6.01099	.00000	-.37809	.00000	.00000	.00000
252.42799	1.36000	.00000	-.21966	.00000	.00000	.00000
253.78799	3.94809	.00000	-.07098	.00000	.00000	.00000
257.73608	2.95190	.00000	-.18415	.00000	.00000	.00000
260.68799	4.74512	.00000	-.15551	.00000	.00000	.00000
265.43311	3.19482	.00000	-.25520	.00000	.00000	.00000
268.62793	3.79419	.00000	-.28202	.00000	.19667	18.18813
272.42212	9.03979	2.76037	.32748	.79534	.92200	45.57330
281.46191	5.00513	1.64163	-.08734	.64703	.48448	.46437

286.46704	6.92896	.00000	-.11107	.00000	.26653	.00000
293.39600	6.33203	.00000	-.18248	.00000	.24624	.00000
* 299.72803	14.80786	1.08629	.06355	.12154	.69685	.00130
314.53589	8.46411	3.14478	.00106	.27345	.43797	.01631
323.00000	6.00000	2.57765	.02209	.06945	.29009	.00970
329.00000	8.00000	.85691	-.01174	.05769	.38364	.09973
337.00000	7.00000	.00000	-.00511	.00000	.31915	.01720
344.00000	7.00000	.00000	-.01962	.00000	.31465	.00000
351.00000	6.00000	.57305	.04416	.09172	.27208	.00655
Total Recharge, R1= 12.1646						
Total Recharge, R3= 117.6775						
Total R Error, RERR= 21.2776						

Site #3, 1988

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 137 cm-152 cm

T(days)	DelT(days)	Rerror	CB	RB	RBB	R2
* 27.00000	21.00000	.00000	.03500	.00000	.00000	.00000
48.00000	9.00000	.00000	-.01846	.00000	.00000	.00000
57.00000	12.00000	.00000	-.03283	.00000	.00000	23.53265
69.00000	15.00000	.00000	-.00120	.00000	.00000	29.60478
84.00000	5.00000	.00000	-.01769	.00000	.00000	.00155
91.00000	5.00000	.00000	-.01150	.00000	.00000	1.86511
96.00000	8.00000	.00000	-.01372	.00000	.00000	3.04131
104.00000	6.00000	.53111	.01684	.02783	.00000	.00000
115.00000	2.00000	.17867	-.03552	.00541	.00000	.01010
117.00000	6.00000	.35352	.03416	.05024	.00000	.17593
123.00000	9.00000	2.66925	.11199	.65766	.00000	.55515
132.00000	8.00000	2.38850	.02577	.55104	.00000	.24344
140.00000	7.00000	.00000	.04438	.00000	.00000	.00000
152.00000	2.00000	.55818	.05869	.10307	.00000	19.60138
154.00000	5.00000	1.69797	.01285	.17886	.00000	62.65160
159.00000	8.00000	.77492	-.00115	.04721	.00000	.00000
167.00000	7.00000	.46583	.05715	.19607	.00000	.00000
178.00000	3.00000	.99840	.00737	.09678	.00000	.00000
181.00000	9.00000	.79493	-.01147	.01297	.00000	.00000
190.00000	6.00000	.00000	-.00010	.00000	.00000	.00000
197.00000	12.00000	.00000	-.05617	.00000	.00000	.00000
209.00000	7.00000	.00000	-.07663	.00000	.00000	.00000
217.00000	18.00000	.00000	-.01744	.00000	.00000	.00000
235.00000	4.00000	.00000	-.00907	.00000	.00000	.00000
263.00000	7.00000	.01075	.00055	.00011	.00000	.00029
270.00000	18.00000	.05136	-.02701	.00010	.00000	.00430
288.00000	20.00000	.00000	-.02700	.00000	.00000	.00000
308.00000	14.00000	.00000	.00000	.00000	.00000	.00000

322.00000 8.00000 .00000 -.02530 .00000 .00000 .08129
 Total Recharge, R1= 1.9274
 Total Recharge, R3= 141.3689
 Total R Error, RERR= 11.4734

Site #5, 1986

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 91 cm-152 cm

T(days)	DelT(days)	Rerror	QB	RB	RBB	R2
6.00000	8.00000	5.89265	.15843	1.24196	0.00000	.77374
14.00000	7.00000	5.35736	.16357	1.12701	0.00000	1.36952
21.00000	10.00000	.00000	.16273	.00000	.00000	.00000
* 31.00000	83.00000	.00000	.00558	.00000	.00000	.00000
114.00000	8.00000	.00000	-.00927	.00000	.00000	.00000
122.00000	7.00000	.00000	-.01867	.00000	.00000	.00000
129.00000	6.00000	.00000	-.01314	.00000	.00000	.00000
147.50000	1.50000	.00000	-.00276	.00000	.00709	2.14817
152.50000	4.50000	.00474	.00075	.00036	.01601	4.04048
158.00000	6.00000	.06645	.00218	.00879	.01601	4.85712
174.13000	3.87000	.14282	.00934	.02229	.01601	.04500
181.67000	2.33000	.14621	.01059	.02322	.01113	.63436
187.08000	4.92000	.28573	.00788	.04545	.04989	2.01109
194.00000	5.00000	.14856	.00147	.02337	.03653	.00000
199.00000	3.47900	.00000	.01416	.00000	.00000	.00000
* 202.47900	1.39400	.00000	7.82579	.00000	.00000	.00000
* 203.75000	2.52400	29.23112	2.76156	13.36125	59.22095	51.12625
* 206.63901	3.00000	.00000	.91176	.00000	.00000	.00000
* 211.43401	5.00299	16.18777	.36139	3.18477	3.92459	2.83978
* 216.43700	4.00101	.00000	.29143	.00000	.00000	.00000
* 220.43800	4.56200	.00000	.03111	.00000	.00000	.00000
* 226.00000	8.00000	7.68495	.34786	1.51587	.00000	1.28087
234.00000	7.00000	8.62177	.15578	1.76272	.00000	.67067
241.00000	7.00000	4.33091	.10577	.91541	.00000	.00000
253.67000	1.33000	.64132	.06885	.11612	.00000	.00000
259.33008	2.66992	1.29451	.07332	.18979	.00000	.22560
265.75000	8.25000	4.28894	.11514	.77740	.00000	2.92519
275.00000	12.00000	8.43224	.18094	1.77645	.00000	3.41782
294.33008	1.66992	1.27657	.14015	.26810	.00000	.13863
296.00000	8.00000	5.07545	.12853	1.07474	.00000	.01094
307.33008	2.66992	1.40551	.09596	.29969	.00000	.00238
310.00000	7.00000	3.34423	.07467	.59720	.00000	.00000
317.00000	8.00000	4.31879	.08337	.63214	.00000	.24791
325.00000	5.00000	2.86283	.08375	.41778	.00000	.34716
335.16992	2.83008	1.38804	.06018	.20366	.00000	.01065

340.83008 9.16992 3.92890 .06639 .58032 .00000 .21728
 Total Recharge, R1= 30.1658
 Total Recharge, R3= 105.6667
 Total R Error, RERR= 116.3584

Site #5, 1987

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 91 cm-152 cm

T(days)	DeIT(days)	Rerror	QB	RB	RBB	R2
2.00000	5.00000	2.35452	.06795	.34659	0.00000	.17487
8.67000	5.33000	2.33985	.06161	.34525	0.00000	.26558
14.00000	6.00000	2.52500	.06280	.37322	0.00000	.28753
20.00000	8.00000	3.47451	.06543	.51293	0.00000	.47127
28.00000	7.00000	2.95655	.05949	.43725	0.00000	.09987
35.00000	7.00000	2.87660	.06232	.42636	0.00000	.34697
45.67000	3.33000	1.43569	.06517	.21228	0.00000	.58645
57.25000	3.75000	1.76607	.07402	.26099	0.00000	1.33378
61.00000	9.00000	4.81181	.12115	.87828	0.00000	2.92027
* 75.67000	8.33000	43.62614	1.88079	8.33808	0.00000	12.13542
86.96001	4.03999	24.35300	.43187	4.67157	0.00000	4.80654
103.25000	1.75000	2.98439	.26055	.60587	0.00000	.25026
105.00000	6.00000	8.87443	.34340	1.81187	0.00000	1.38908
111.00000	6.00000	7.76184	.18537	1.58633	0.00000	.03622
124.25000	3.75000	2.89522	.13806	.60644	0.00000	.60518
128.00000	7.00000	4.06477	.10825	.86207	1.42887	.58927
143.33000	3.67000	1.77499	.06754	.32257	.55524	.00000
* 147.00000	15.00000	6.82600	.06605	1.00189	1.74320	.00000
169.00000	7.00000	2.16466	.02553	.32053	1.39882	.00000
180.13000	2.87000	.49679	.02732	.07585	.44899	1.63174
183.00000	6.00000	.00000	.48976	.00000	.00000	.00000
189.00000	6.74400	.00000	.58291	.00000	.00000	.00000
199.70300	1.61800	.00000	.95542	.00000	.00000	.00000
201.32100	1.09000	.00000	.74163	.00000	.00000	.00000
204.39000	4.34900	.00000	.25040	.00000	.00000	.00000
208.73900	2.67101	.00000	.21399	.00000	.00000	.00000
215.75000	1.86800	1.83497	.19283	.37997	.13791	35.10997
224.71001	4.28999	3.67545	.16477	.76706	.44781	81.45206
235.50000	1.50000	.93083	.09813	.19718	.44781	.20527
237.00000	7.00000	4.76806	.18883	1.00437	.44781	.52668
244.00000	8.00000	6.49481	.15107	1.35960	.44781	1.17757
252.00000	7.00000	4.53455	.08410	.82309	.44781	.00000
259.00000	7.00000	3.59202	.06602	.52544	.44781	.00000
* 266.00000	13.00000	4.63854	.03971	.68727	.44781	.00000
279.00000	10.00000	2.37818	.03184	.35776	.44781	.00000

289.00000	5.00000	1.01860	.02965	.15372	.44781	.00000
294.00000	6.00000	1.05077	.02344	.15924	.44781	.00000
300.00000	8.00000	1.07115	.01742	.16342	.44781	.00000
308.00000	7.00000	.74707	.01534	.11465	.17686	.00000
315.00000	9.00000	.82325	.01291	.12710	.17686	.00000
324.00000	12.00000	.97898	.01237	.15168	.17686	.01538
336.00000	7.00000	.54658	.01188	.08488	.00000	.08696
343.00000	8.00000	.56937	.01023	.08843	.00000	.02640
351.00000	5.00000	.34082	.01101	.05310	.00000	1.53943

Total Recharge, R1= 31.1942
Total Recharge, R3= 148.0701
Total R Error, RERR= 170.3568

Site #5, 1988

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 91 cm-152 cm

T(days)	DeIT(days)	Rerror	CB	RB	RBB	R2
26.00000	14.00000	1.07730	.01321	.17050	.02305	16.73244
40.00000	9.00000	.82814	.01604	.13158	.02305	10.96373
49.00000	6.00000	.63597	.01763	.10099	.02305	.05606
55.00000	6.00000	.71051	.01983	.11236	.02305	.06023
62.17000	5.83000	.71544	.01888	.11282	.02305	.31541
76.50000	1.50000	.17547	.01811	.02774	.02305	.00525
78.00000	6.00000	.69290	.01845	.10969	.02305	.00000
84.00000	5.00000	.54875	.01635	.08701	.02305	.00000
91.73000	4.27000	.45709	.01754	.07235	.02305	2.23376
100.00000	3.00000	.37396	.02178	.05897	.02305	1.39945
108.13000	2.87000	.39519	.02161	.06227	.02305	.00000
115.67000	1.33000	.17850	.02071	.02815	.02305	.00000
117.00000	7.00000	.81606	.01602	.12857	.02305	.00000
123.33000	8.67000	.69223	.00909	.10887	.02305	.00000
132.00000	7.00000	.07516	-.01547	.01178	.02305	.00000
139.00000	5.00000	.00000	-.03017	.00000	.00000	.00000
144.00000	16.00000	.00000	-.01930	.00000	.00000	3.27445
160.00000	8.00000	.00000	-.00953	.00000	.00000	5.77990
168.00000	8.00000	.00000	-.01064	.00000	.00000	.00000
176.00000	4.00000	.00000	-.00628	.00000	.00000	.00000
180.00000	8.00000	.00813	.00124	.00082	.00000	.00000
191.50000	3.50000	.00996	-.00044	.00161	.00000	.03132
198.13000	4.87000	.14394	.01100	.02575	.00000	3.23268
203.00000	11.00000	.79021	.01311	.13256	.00000	5.00875
217.78999	18.21001	.00000	.00000	.00000	.00000	.00000
236.00000	6.00000	.00000	.00000	.00000	.00000	.00000
242.00000	21.00000	.00000	.00000	.00000	.00000	.00000
263.00000	7.00000	.00000	.00000	.00000	.00000	.00000
270.00000	17.00000	.00000	.00000	.00000	.00000	.00000

287.00000	19.00000	.00000	.00000	.00000	.00000	.00000
306.00000	15.00000	.00000	.00000	.00000	.00000	.00000
324.12988	2.87012	.00000	.00000	.00000	.00000	.00000
Total Recharge, R1=		1.4844				
Total Recharge, R3=		49.0934				
Total R Error, RERR=		9.3249				

Site #6, 1987

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 91 cm-137 cm

T(days)	DelT(days)	Rerror	QB	RB	RBB	R2
188.00000	8.00000	.00060	.00003	.00000	0.00000	.00000
196.00000	12.00000	.00291	-.00031	.00002	0.00000	.00000
208.00000	11.00000	.00000	-.00454	.00000	0.00000	.01068
219.00000	4.00000	.00000	-.00550	.00000	.00518	.00619
223.00000	7.00000	.00000	-.01329	.00000	.00518	1.99730
230.00000	9.00000	.00000	-.00511	.00000	.00518	3.08001
239.00000	7.00000	.00000	-.00311	.00000	.00518	.00000
246.00000	5.77600	.00000	.00024	.00000	.00000	.00000
254.39600	3.98706	.00000	2.87171	.00000	.00000	.00000
261.36694	3.31006	.00000	1.47724	.00000	.00000	.00000
265.52100	1.18408	1.16234	.49655	1.16857	.68941	31.78926
266.70508	2.01196	.00000	.39867	.00000	.00000	.00000
269.36792	2.40308	.00000	.25005	.00000	.00000	.00000
273.38696	2.09912	.46704	.16623	.43691	.37053	.00000
275.48608	3.89893	.66706	.14017	.59732	.46905	.16001
279.38501	3.07104	.27869	.06349	.31274	.25485	.10423
282.45605	4.93384	.17584	.07052	.33060	.25655	.00782
287.38989	6.07520	.18919	.06835	.42182	.26027	.20984
293.46509	7.01392	.50265	.10593	.61119	.43549	.47651
303.00000	11.63892	1.07687	.03967	.84731	.88490	.40858
314.63892	8.74609	.58897	.05066	.39500	.50168	.02853
331.00000	4.43799	.23215	.02514	.16820	.18312	.33969
335.43799	8.56201	.37298	.02511	.21513	.58364	.29123
344.00000	6.00000	.26138	.01723	.12701	.58364	.00000
Total Recharge, R1=		5.6318				
Total Recharge, R3=		38.9099				
Total R Error, RERR=		5.9787				

Site #6, 1988

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 91 cm-137 cm

T(days)	DeIT(days)	Rerror	QB	RB	RBB	R2
20.00000	7.00000	.10683	.00868	.08323	.02095	26.15039
27.00000	20.00000	.25735	.00652	.15199	.13804	74.24854
47.00000	9.00000	.12449	.01049	.07656	.03137	.00000
56.00000	13.00000	.20168	.01099	.13965	.05879	.00000
69.00000	15.00000	.25465	.01096	.16467	.10533	.00000
84.00000	5.00000	.08404	.00747	.04609	.07516	.11721
91.17000	4.83000	.06542	.00783	.03696	.03288	1.53822
96.00000	7.00000	.11712	.01724	.08776	.04749	1.91842
108.75000	1.25000	.02668	.01283	.01880	.02584	.00000
115.67000	1.33000	.02484	.01257	.01689	.03406	.00000
120.50000	4.50000	.08218	.00813	.04657	.09978	.00000
125.00000	7.00000	.21111	.02614	.11994	.25369	.00000
132.00000	8.00000	.32894	.02485	.20394	.27583	.00000
141.50000	4.50000	.19295	.02294	.10752	.23295	.00266
146.00000	9.00000	.36445	.02159	.20040	.69947	.33541
155.00000	4.00000	.13069	.02448	.09215	.17812	.02226
159.00000	8.00000	.30204	.02968	.21665	.31548	.00000
167.00000	7.00000	.54725	.02273	.18342	.06390	.00000
178.75000	2.25000	.09425	-.01149	.01698	.00000	.00000
190.00000	6.00000	.00000	-.15846	.00000	.00000	.00000
198.08000	10.92000	.00000	-.04340	.00000	.00000	.00000
209.00000	7.00000	.00000	-.01869	.00000	.00000	.00000
216.00000	19.00000	.00000	-.00296	.00000	.00000	.00000
235.00000	7.00000	.00000	.00000	.00000	.00000	.00000
242.00000	17.00000	.00000	.00000	.00000	.00000	.00000
267.29004	2.70996	.00000	.00000	.00000	.00000	.01832
270.00000	17.00000	.00000	.00000	.00000	.00000	.20319
287.00000	19.00000	.00000	.00000	.00000	.00000	.00169
306.00000	16.00000	.00000	.00000	.00000	.00000	.00000
322.00000	5.00000	.00000	.00000	.00000	.00000	.01195

Total Recharge, R1= 2.0102
Total Recharge, R3= 104.5682
Total R Error, RERR= 3.5170

Site #7, 1987

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 137 cm-152 cm

T(days)	DelT(days)	Rerror	QB	RB	RBB	R2
224.00000	5.00000	4.26891	.25574	.68474	1.75791	.54435
237.00000	7.00000	11.34959	.29604	1.93123	4.67369	2.56323
244.00000	7.00000	3.91700	-.09961	.77528	4.43161	1.38942
252.00000	7.00000	.04495	.00160	.00009	1.94788	.00000
259.00000	7.00000	.28353	-.00825	.00091	.30884	.05922
266.00000	13.67212	.00000	-.02020	.00000	.00000	.00000
283.40088	1.08301	.00000	.69394	.00000	.00000	.00000
284.48389	1.25610	.00000	2.44989	.00000	.00000	.00000
286.67310	6.98682	.00000	-1.27391	.00000	.00000	.00000
293.65991	1.91309	.00000	-.51026	.00000	2.37335	12.54951
295.57300	5.87793	.05763	.03222	.00562	1.57742	52.36034
301.45093	12.94800	1.52011	.02177	.34955	.62597	.01858
314.39893	10.19507	.47889	.00197	.12099	.19721	.00000
324.59399	10.06201	.05513	-.00512	.00274	.06842	.00000
334.65601	16.34399	.00000	-.02691	.00000	.55973	.00000
351.00000	5.00000	.09678	.04059	.06101	.25828	.19004

Total Recharge, R1= 3.9322
 Total Recharge, R3= 69.6747
 Total R Error, RERR= 22.0725

Site #7, 1988

Maximum depth used for translated flux = 274 cm

Water Characteristic Curve interval = 137 cm-152 cm

T(days)	DelT(days)	Rerror	QB	RB	RBB	R2
27.00000	13.00000	.00000	-.00514	.00000	.00000	24.89661
40.00000	8.00000	.00000	-.00588	.00000	.00000	15.32746
48.00000	7.00000	.00000	-.00517	.00000	.00000	.00007
55.00000	6.00000	.00000	-.00473	.00000	.00000	.00000
61.00000	7.00000	.00000	-.00549	.00000	.00000	11.34501
68.00000	10.00000	.00000	-.01626	.00000	.00000	34.82031
78.00000	11.00000	.00000	-.00977	.00000	.00000	.14283
91.00000	5.00000	.14005	.02734	.05034	.00000	1.76845
96.00000	7.00000	2.00429	.29117	1.11477	.00000	2.64277
108.00000	3.00000	.86244	.02946	.48094	.00000	.22879
111.00000	7.00000	.88036	.02295	.18342	.00000	.48508
118.00000	7.00000	.20209	-.23712	.00709	.00000	.05856
125.00000	7.00000	1.05324	.12635	.15372	.00000	.21349
132.00000	7.00000	2.01224	.00283	.45213	.00000	.43811
141.00000	5.00000	.00972	-.08572	.00023	.00000	.68874

152.00000	3.00000	1.13671	2.69319	3.91519	.00000	5.22521
* 155.00000	5.00000	4.49216	1.11130	9.51122	.00000	9.83123
160.00000	8.00000	.87632	-.02454	4.34915	.00000	2.26780
168.00000	12.00000	.00000	-.17229	.00000	.00000	.00000
180.00000	8.00000	.00000	-.00852	.00000	.00000	.00000
188.00000	7.00000	.00000	-.00125	.00000	.00000	.00000
199.00000	3.00000	.00000	-.00142	.00000	.00000	1.73697
202.00000	13.00000	.00000	-.00014	.00000	.00000	5.76612
215.00000	16.00000	.00000	-.00017	.00000	.00000	.40166
231.00000	11.00000	.00000	-.00283	.00000	.00000	4.60099
* 242.00000	22.00000	25.51012	.59416	6.50479	.00000	14.15464
* 264.00000	9.00000	13.54330	.77414	6.15734	.00000	6.11643
280.00000	7.00000	.95233	-.76756	1.36049	.00000	1.16437
287.00000	19.00000	.00000	-.12362	.00000	.00000	.00000
306.00000	15.00000	.00000	-.02565	.00000	.00000	.00000
324.00000	4.00000	.00000	-.02355	.00000	.00000	.68288
Total Recharge, R1= 34.2408						
Total Recharge, R3= 145.0045						
Total R Error, RERR= 53.6754						

* Problems associated with long time intervals between measurements and unusually high flux measurements at permeable sites that cause overestimates of recharge (due to the linear integration procedure) and drainage experiments. These quantities were not included in the estimates of recharge given in Table 4.

RECHGE OUTPUT

Definitions:

Time: Time of the rain event.
Recharge: Recharge calculated from the water balance equation.
ET: Evapotranspiration.
PPT: Precipitation.
delS: Change in soil moisture storage.

Abbreviated Results from program RECHGE

Site #1, 1986

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
91.000	-5.015	2.428	1.143	3.730
116.000	5.792	2.855	5.207	-3.440
148.000	-2.551	2.957	6.096	5.690
152.000	-.304	2.195	.660	-1.230
158.000	-.358	2.692	.584	-1.750
175.000	.690	3.048	2.438	-1.300
187.000	1.827	3.383	2.540	-2.670
221.000	2.764	3.241	14.275	8.270
225.000	-1.704	3.444	.000	-1.740
265.000	.707	2.144	3.531	.680
284.000	-.487	1.778	1.651	.360

Site #1, 1987

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
44.000	-2.348	.986	.787	2.150
57.000	1.771	1.128	2.159	-.740
75.000	8.464	1.732	5.766	-4.430
102.000	4.195	2.154	2.489	-3.860
125.000	6.993	3.231	5.004	-5.220

144.000	6.496	2.743	4.089	-5.150
169.000	1.032	3.434	3.556	-.910
175.000	-.874	3.597	7.493	4.770
180.000	1.261	4.181	7.442	2.000
185.000	2.767	4.003	.000	-6.770
215.000	7.623	2.601	6.604	-3.620
224.000	2.515	2.621	2.286	-2.850
235.000	-.101	1.966	3.175	1.310
248.000	3.697	1.585	2.972	-2.310
288.000	.804	.808	1.702	.090

Site #1, 1988

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
18.000	2.307	.960	1.397	-1.870
91.000	.038	3.810	3.378	-.470
108.000	-3.438	5.075	1.397	-.240
141.000	-3.120	3.693	2.083	1.510
152.000	-.940	5.801	2.921	-1.940
198.000	-6.095	6.294	5.029	4.830
267.000	.962	3.800	3.912	-.850

Site #2, 1986

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
90.790	.011	2.391	3.302	.900
117.000	1.872	2.997	3.099	-1.770
127.500	.559	3.094	1.473	-2.180
148.000	3.240	2.957	3.277	-2.920
181.330	1.565	4.024	9.779	4.190
187.830	1.287	4.200	.178	-5.310
225.830	.304	3.143	3.607	.160
238.710	4.137	2.605	6.121	-.620
260.000	1.082	2.581	4.953	1.290
267.000	-5.138	2.052	1.524	4.610
275.420	-1.037	2.178	2.591	1.450
294.330	2.023	1.595	1.778	-1.840

Site #2, 1987

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
2.250	-1.426	.667	.381	1.140
8.660	.129	.545	.305	-.370
45.710	-1.812	1.055	1.143	1.900
55.250	2.485	1.010	1.854	-1.640
81.920	-3.000	2.049	8.509	9.460
86.910	1.611	1.809	.000	-3.420
103.160	.447	2.415	2.972	.110
125.000	3.431	3.231	3.632	-3.030
143.330	-1.536	2.794	4.648	3.390
180.170	1.539	3.552	8.001	2.910
186.660	-3.576	2.896	.000	.680
224.710	-1.931	2.577	4.826	4.180
237.830	4.047	2.104	1.651	-4.500
255.000	1.095	1.473	1.778	-.790
288.000	1.461	.808	.889	-1.380

Site #2, 1988

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
21.210	-.948	1.288	.000	-.340
62.580	-2.467	2.902	.635	.200
80.000	-3.046	4.171	.305	-.820
91.000	2.528	3.810	5.258	-1.080
141.250	-4.595	3.854	1.880	2.620
151.500	3.688	4.244	4.572	-3.360
267.250	-1.368	3.768	2.540	.140

Site #3, 1986

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
117.000	1.306	2.997	3.683	-.620
128.000	-1.048	3.170	1.422	-.700
148.000	4.019	2.957	7.315	.340
153.000	-.415	2.479	1.524	-.540
174.000	-.881	4.023	2.362	-.780
187.000	3.517	3.749	6.096	-1.170
213.000	.698	3.581	4.089	-.190
233.000	.925	3.078	3.734	-.270
254.000	1.971	2.337	4.597	.290
272.000	.451	1.808	3.150	.890

Site #3, 1987

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
81.000	6.044	2.017	8.941	.880
103.000	1.613	2.316	3.429	-.500
125.000	.246	3.231	2.667	-.810
146.000	1.937	2.713	2.540	-2.110
161.000	.372	3.520	3.023	-.870
180.000	3.162	3.531	8.712	2.020
185.000	3.140	2.896	1.956	-4.080
224.000	2.905	2.520	5.994	.570

Site #3, 1988

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
91.000	1.951	3.810	5.461	-.300
115.000	-4.243	5.806	1.473	-.090
152.000	-2.296	5.801	3.175	-.330
178.000	-2.011	6.706	2.184	-2.510
197.000	1.901	6.126	5.207	-2.820
217.000	2.843	6.472	8.255	-1.060
267.000	-2.052	3.800	1.778	.030

Site #5, 1986

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
121.000	-3.995	3.475	.000	.520
147.500	-5.590	2.972	3.912	6.530
152.500	-3.327	2.337	.000	.990
158.000	2.389	2.692	1.041	-4.040
174.130	-3.632	2.889	1.727	2.470
181.670	4.794	2.490	5.613	-1.670
187.080	2.823	1.962	.635	-4.150
194.000	-21.324	1.819	1.905	21.410
203.750	5.088	2.648	4.496	-3.240
213.000	1.203	3.170	3.683	-.690
225.460	2.004	4.308	5.842	-.470
253.670	-1.671	2.355	1.524	.840

259.330	-4.318	2.618	.000	1.700
265.750	-.025	2.949	3.734	.810
275.000	4.179	3.119	6.858	-.440
294.330	.798	1.900	1.829	-.870
307.330	.917	1.174	1.321	-.770
335.170	-.159	.623	1.194	.730

Site #5, 1987

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
8.670	.146	.672	.838	.020
45.670	-1.547	1.053	1.067	1.560
57.250	.502	1.139	1.981	.340
75.670	4.741	1.756	2.997	-3.500
86.960	-.739	2.234	1.956	.460
103.250	3.745	2.357	3.632	-2.470
124.250	3.359	3.139	4.318	-2.180
143.330	5.623	2.794	5.867	-2.550
168.830	4.142	3.441	4.623	-2.960
180.130	9.724	3.649	14.783	1.410
215.750	-2.637	2.616	1.829	1.850
224.710	3.383	2.643	4.826	-1.200
235.500	2.694	1.913	6.147	1.540

Site #5, 1988

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
62.170	1.037	1.267	1.524	-.780
76.500	-.593	1.821	.508	-.720
91.730	4.028	2.316	4.724	-1.620
100.000	-.263	2.316	.533	-1.520
108.130	2.010	2.278	2.108	-2.180
115.670	1.760	1.569	.838	-2.490
123.330	3.313	1.436	.889	-3.860
141.000	2.696	2.362	2.718	-2.340
191.500	-6.230	3.010	2.540	5.760
198.130	9.956	2.820	7.366	-5.410
217.790	.617	2.423	1.270	-1.770

Site #6, 1987

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
303.000	1.256	.792	1.778	-.270
331.000	1.173	.696	.559	-1.310

Site #6, 1988

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
91.170	3.095	2.316	5.461	.050
108.750	-1.100	2.995	1.854	-.040
115.670	-.902	2.784	1.702	-.180
120.500	-1.564	2.416	.762	-.090
141.500	-1.814	2.934	1.219	.100
*178.750	3.213	3.372	3.175	-3.410
*191.540	.179	3.013	3.912	.720
*198.080	4.643	2.818	6.680	-.780
*267.290	2.228	1.093	3.200	-.120

Site #7, 1987

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
216.000	-.709	2.550	1.651	-.190
224.000	3.735	2.621	4.826	-1.530
238.000	.593	2.118	4.242	1.530
252.000	.097	1.687	2.134	.350

Site #7, 1988

Time(days)	Recharge(cm)	ET(cm)	PPT(cm)	delS(cm)
91.000	2.618	2.316	4.724	-.210
108.000	-1.118	2.957	2.108	.270
141.000	-.844	2.972	2.718	.590
152.000	1.645	3.343	4.267	-.720
*199.000	5.137	3.353	6.350	-2.140
280.000	1.057	.422	.889	-.590

* indicates a dry profile relatively unaffected by a rain event and/or complications resulting from a drainage experiment.