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A Research Report for Westinghouse Hanford Company

Status of FY 1988 Soil-Water Balance Studies on the Hanford Site

G. W. Gee
M. L. Rockhold
J. L. Downs

February 1989

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
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EXECUTIVE SUMMARY

Natural recharge (i.e., the amount of water from meteorological sources, such as rainfall or snowmelt, that infiltrates through the vadose zone to the groundwater table) at the Hanford Site is a variable quantity because it depends on soil, plant, and climatic factors that vary in time and space over the Site. Water balance data have been collected at selected locations at the Hanford Site for the past 10 years in an attempt to measure or estimate natural recharge for known soil, plant, and climatic conditions. The data collected include precipitation, neutron probe measured water content (storage), and drainage measurements from lysimeters. The lysimeter studies provided the first quantitative estimates of natural recharge at the Hanford Site.

Data indicate the some soils at the Hanford Site are very susceptible to drainage. Coarse-textured soils (i.e., soils that contain 90% or more sand-sized or larger particles) that are sparsely vegetated or are covered with shallow-rooted grasses are relatively common to the Hanford Site. These coarse soils, when kept bare or vegetated with sparse grass cover (such as cheatgrass or native bluegrass) have shown evidence that a significant portion of the annual precipitation (particularly that portion that occurs during the winter) can be lost as deep drainage and may eventually recharge the unconfined aquifer. In contrast, deep-rooted plants (i.e., shrubs or weedy species that have roots below 1 m) appear to be more effective than shallow-rooted grasses in removing annual precipitation and preventing recharge. At several measurement locations near the 300 North Area of the Hanford Site, where soils are coarse textured and soil surfaces have been kept bare, data from lysimeters indicate that drainage is a significant part of the total water balance. Drainage measurements from twelve bare-surfaced lysimeters in the 300 North Area ranged from 3.1 cm/yr to 5.6 cm/yr, while the total precipitation recorded at the lysimeter location during the past year (July 1987-June 1988) was 12.5 cm. In contrast, no drainage occurred at this same location from a lysimeter that contained deep-rooted vegetation (i.e., tumble mustard). The drainage rates from all 300 North Area lysimeters have decreased during the past year, in response to decreased winter precipitation.

The hydraulic properties of soils at the Grass Site (a location near the 300 North Area) were measured using an unsteady drainage-flux method. Two experiments were run. The first experiment indicated that lateral spreading of water occurred in the layered soil at the test site causing an overestimation of hydraulic conductivities. In the second experiment, lateral spreading was prevented by the use of an impermeable border around the plot. The experimental data from the second experiment were used to estimate the hydraulic conductivity of soil layers at the Grass Site. Data from particle-size analyses were used to predict water retention and hydraulic conductivity. Fractal mathematics were used to estimate parameters needed to predict water release (drainage) characteristics. While the laboratory values were predicted reasonably well, the field-measured water release data showed effects of hysteresis, so laboratory-measured drainage curves do not accurately predict field-measured values. The unsaturated hydraulic conductivity data from the field were found in reasonable agreement with laboratory values for the sandy-textured soils, when appropriate fitting parameters were used. However, order-of-magnitude differences in unsaturated hydraulic conductivity are possible, particularly in the water content range typical of field conditions. Calculations of drainage using estimated hydraulic conductivity values, therefore, may be in error by as much as an order of magnitude.

Future work includes monitoring 300 North Area lysimeters for drainage, installation of small lysimeters at the Grass Site, and measuring the water storage changes at the Grass Site and in the 300 North Area and 200 East lysimeter test sites. Neutron probe monitoring has been reactivated at the 200 East lysimeter site. The neutron probe data from the 200 East lysimeter and adjacent sites will be used to compare water-storage changes in bare versus vegetated soils at this location. Gravel-covered lysimeters have been constructed and placed near the Hanford Meteorological Station and will be monitored over the next several years. Weight change and direct collection of drainage water from the gravel-covered lysimeters will be used to simulate the water storage and drainage that presently occur at tank-farms on the Hanford Site.

ACKNOWLEDGMENTS

This work was funded by the U.S. Department of Energy through the Westinghouse Hanford Waste Management Program Office. We acknowledge the interest and efforts of Kirk Owens of the Waste Management Program Office and Jerry Cammann and Jerry Davis of the Westinghouse Hanford Environmental Technology Group in supporting the publication of this work. We also thank Pacific Northwest Laboratory[a] colleagues who contributed in various ways to this document. Owen Abbey and Randy Kirkham provided instrumentation support and helped with data analysis and interpretation. Chris Kemp and Shannon Goodwin collected neutron probe data, Paula Heller provided laboratory analyses, Mike Kanyid provided tables and graphs from the extensive data base, and Tim Jones and Mike Fayer provided technical review. Scott Tyler of the Desert Research Institute, Reno, Nevada, suggested the use of fractal mathematics to estimate parameters for predicting water retention characteristics. We also acknowledge the support of Tammy Kogan, Debbie Atkin, and the Pacific Northwest Laboratory Text Processing and Technical Communication staff for timely assistance in preparing this document.

(a) Operated for the U.S. Department of Energy by Battelle Memorial Institute.

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1.0 INTRODUCTION

Natural recharge (i.e., input to groundwater from rainfall and snowmelt) occurring below waste storage areas at the Hanford Site is of considerable interest because this recharge provides a possible mechanism for leaching contaminants from waste materials and transporting them to the underlying water reservoir (aquifer). Assessing performance of waste remediation and disposal alternatives requires estimating natural recharge. Natural recharge values are used in calculations that predict the consequence of leaving wastes in place for durations that may be thousands of years (USDOE 1987). Waste management practices and final disposal alternatives may be significantly influenced by knowledge of the rates of natural recharge occurring within the Hanford Site. If natural recharge rates are found to be sufficiently high, particularly near waste storage sites, methods may be required to modify or reduce those rates (e.g., by the use of surface barriers that would limit water infiltration into the wastes) to ensure compliance with applicable regulations.

The purpose of this ongoing study is to quantify the Hanford Site's natural recharge by detailed study of water balance parameters (i.e., precipitation, changes in soil-water storage, evapotranspiration, and drainage), particularly for conditions existing at or near waste burial sites. Previous reports (Gee and Heller 1985; Gee and Jones 1985; Gee 1987) document most of the natural recharge information available before June 1987. This report provides continuity to those studies by describing subsequent work.

The water balance of a given site can be described as a sum of its individual components as shown in the following equation:

$$P = \Delta S + ET + D + R \tag{1.1}$$

where P = precipitation
ΔS = water storage change
ET = evapotranspiration
D = drainage
R = runoff (or runon)

In the absence of runoff, water balance relates precipitation directly to the sum of the water storage changes plus evapotranspiration and drainage. At the Hanford Site, the water balance components (P, ΔS, ET, and D) can vary markedly with time (Figure 1.1). All water balance components are typically expressed in terms of the amount (volume) of water per unit area so that length units (i.e., cm of H_2O) are used throughout the text.

In theory, calculating water balance is one way to evaluate how well water movement and distribution can be accounted for at a waste site. In practice, however, one or more of the water balance terms cannot be measured and must be calculated indirectly. For this reason, measuring the amount of precipitation stored within the soil cannot by itself be used to predict drainage or recharge. For arid sites, drainage or recharge is a difficult parameter to predict (Gee 1987). Work done at the Hanford Site during the past several years has emphasized the use of drainage lysimeters to quantify the drainage component of the water balance (Gee 1987; Gee and Jones 1985)

Drainage-type lysimeters, which are soil-filled containers used to collect and measure drainage, can be used along with water storage (i.e.,

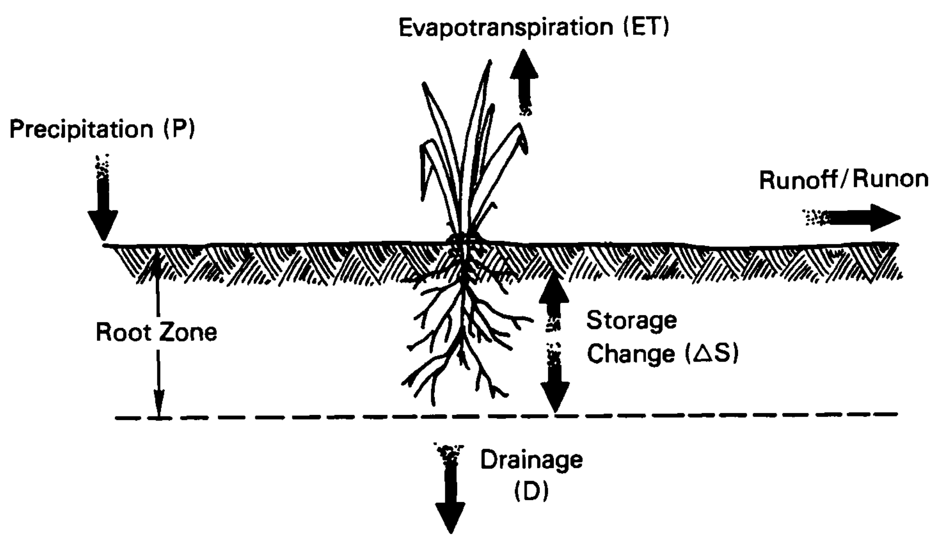

FIGURE 1.1. Parameters for Annual Water Balance at the Hanford Site

neutron probe) data and precipitation records to obtain water balance parameters at a given site and, therefore, can provide detail about water movement for estimates of contaminant migration for that site. Drainage-type lysimeters where installed in 1978 at the Buried Waste Test Facility (BWTF) in the 300 North Area, which is located northwest of the 300 Area proper and southeast of the Fast Flux Test Facility (FFTF) (see Figure 1.2). Additional drainage lysimeters were installed in 1983 and 1984 at the Commercial Waste Test Facility (CWTF) and Gout Waste Test Facility (GWTF) adjacent to the BWTF. Since then, a series of drainage-type lysimeters, referred to as the 622 Area lysimeters (Figure 1.2), has also been installed adjacent to the Hanford Meteorological Station (HMS) to study barrier designs (Kirkham, Gee, and Downs 1987).

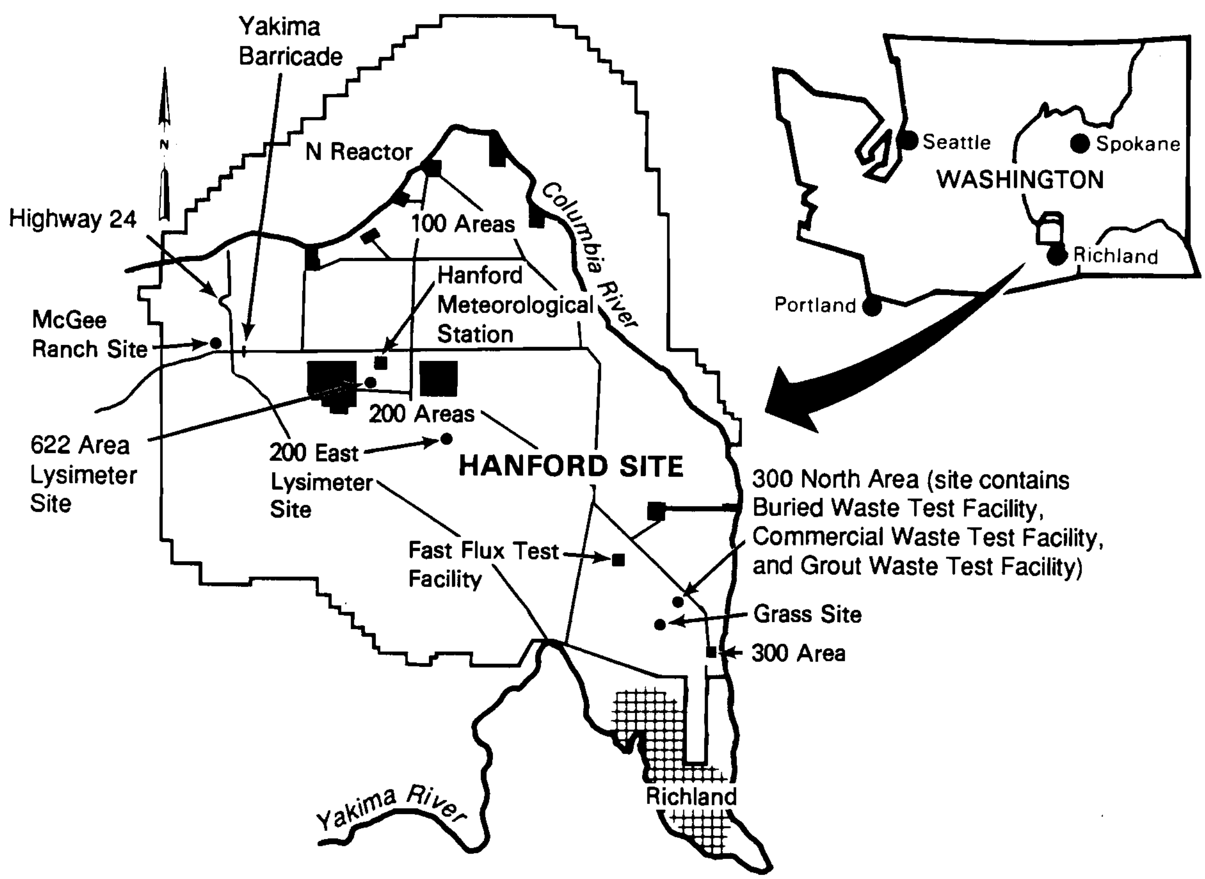

FIGURE 1.2. Hanford Site Map Showing Water Balance Study Areas

The five areas reported in this water balance study are shown in Figure 1.2. Two of the areas, the BWTF and the Grass Site, are located about 3 km apart and are northwest of the 300 Area. The terrain at both sites is quite similar, both are in flat depressions surrounded by stabilized sand dunes. The depth to the water table at both sites is about 15 m. The distinguishing feature of the Grass Site and its immediate surroundings is the lack of shrub-type vegetation (i.e., the vegetative cover is primarily cheatgrass and bluegrass). Before construction of the BWTF, the immediate area was covered by shrubs and grasses. During construction of the BWTF and lysimeter facilities adjacent to it (Gee and Jones 1985), vegetation was disturbed by excavation and now consists of only sparse grass cover. This test area has been fenced, and three sets of lysimeters are located within the fenced area: the BWTF lysimeters, the CWTF lysimeters, and the GWTF lysimeters. All lysimeters are bare surfaced except one, the south weighing lysimeter of the BWTF. For the purpose of this report, this fenced area and the three sets of lysimeters within are referred to as the 300 North Area. The third area, the 200 East lysimeter site, is located about 3 km directly south of the 200 East Area. The fourth area is the area surrounding the HMS and is located adjacent to the 200 West Area. This area is designated as the 622 Area and contains a suite of lysimeters. The fifth area, the McGee Ranch site, is located in the Cold Creek valley northwest of the 200 Areas, across Highway 24 from the Yakima Barricade. The 200 East lysimeter site is 17 km from the McGee Ranch site, with the HMS (622 Area) approximately midway between the two.

The 200 East lysimeter site, the HMS, and the McGee Ranch site are all located on the 200 Area Plateau, which is about 80 m or more above the water table. The vegetation surrounding the 200 Area test locations is diverse, but consists primarily of perennial shrubs (sagebrush and hopsage) and perennial and annual grasses (bluegrass and cheatgrass).

Although the climate is similar at all of these test sites, these locations provide a range of surface soil and plant cover conditions that are typical of much of the Hanford Site.

This report details the water balance parameters measured at these test sites since 1987. Section 2.0 updates the precipitation measurements made in the 200 and 300 Areas. Section 3.0 updates water storage data and provides a discussion of recent measurements at the 200 East lysimeter site, the oldest lysimeter facility at the Hanford Site. Section 4.0 updates information on drainage measurements at the BWTF and describes the installation of gravel-covered lysimeters in the 200 Areas. Section 5.0 describes experiments conducted to obtain field measurements of hydraulic properties. It also describes a proposed method for estimating water retention properties from particle-size analysis using fractal mathematics. Section 6.0 presents a summary of water balance estimates, including annual estimates of potential and actual evapotranspiration for the sites based on measurements reported in previous sections. Limitations of the water balance data set are discussed. Appendices of key data and procedures are also provided. Appendix A identifies data archiving procedures, Appendix B contains precipitation data, Appendix C contains water storage data and the procedure for measuring soil moisture, Appendix D contains drainage data and the procedure for measuring drainage, and Appendix E contains water content, matric potential and hydraulic conductivity data from three field experiments.

2.0 PRECIPITATION

The best documented precipitation records for the Hanford Site are those kept for the Hanford Meteorological Station (HMS) located on the 200 Area Plateau. Precipitation records have also been kept since 1979 for the BWTF and since 1983 for the Grass Site. This section updates precipitation records for these three locations for the 1987-1988 water year (July-June) and discusses real and apparent differences in precipitation among these locations.

2.1 200 AREA PRECIPITATION

Precipitation has been recorded (on at least a daily basis) at the HMS since 1946 (Stone et al. 1983). Precipitation is currently recorded on an hourly basis using a tipping bucket rain gauge. The data are checked against a standard (8-in.-diameter) collection-type (nonrecording) rain gauge. For the past 10 years, winter precipitation as snow has been measured with a heated tipping bucket rain gauge. Before that, winter precipitation was measured either by collecting snow directly in a collection-type rain gauge and subsequently melting it or by recording snow depth in a cleared area adjacent to the station and obtaining the water equivalent by melting snow and converting measured quantity (weights) into an equivalent water depth (i.e., volume/area).

Precipitation data are stored on magnetic tapes and disks and are available from the Atmospheric Sciences Department of Pacific Northwest Laboratory (PNL). These data, along with other climatic data (e.g., temperature, wind speed, humidity, etc.), are currently supplied to the National Oceanic and Atmospheric Administration (NOAA) as the official weather record for the Hanford Site.

Precipitation records for the HMS for January 1, 1986, through August 31, 1988, are shown in Figure 2.1 and Appendix B (Table B.1). The precipitation record for the HMS is assumed to apply to the 200 East Area lysimeter study area as well, because they are in relatively similar terrain

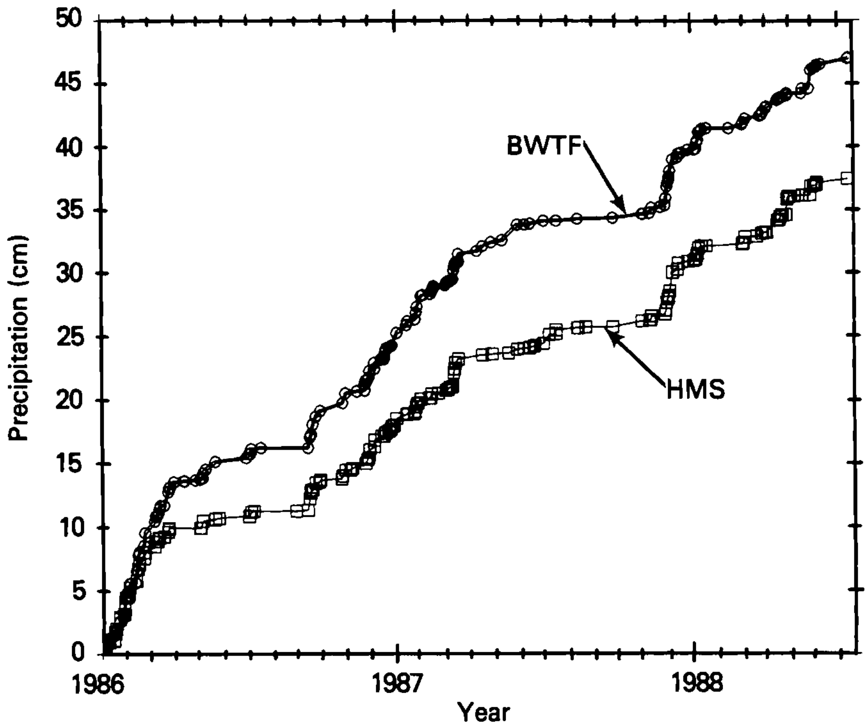

FIGURE 2.1. Precipitation Measured at the Hanford Meteorological Station and Buried Waste Test Facility from January 1987 Through August 1988

and are both located on the 200 Area Plateau. The HMS record indicates that precipitation has been above the long-term average of 16 cm/yr (Stone et al. 1983) for 6 of the past 9 years (1979 through 1987).

However, 2 of the past 3 years have been below the long-term average. In addition, the winter (November through February) precipitation, which normally averages 8.3 cm (Stone et al. 1983) was lower than the average during each of the past 2 years. Precipitation (rain and snow) totals of 5.7 cm and 6.4 cm were measured during the winters of 1986-87 and 1987-88, respectively. In contrast, for the winters of 1982 and 1983, precipitation totals of 13.9 cm and 13.8 cm, respectively, were recorded. Hence, there has been a twofold variation in wintertime precipitation in the past 6 years.

Potential evapotranspiration is lowest in the winter months. Thus, when precipitation is high in winter, the probability for net water infiltration and subsequent recharge is dramatically increased. The effects of variable wintertime precipitation on drainage and recharge at the test sites will be discussed in Section 4.0.

2.2 PRECIPITATION AT THE BWTF AND GRASS SITE

Precipitation has been collected at the BWTF in three different ways since January of 1979: tipping bucket, manual rain gauges (either clear-view type or standard nonrecording type), or weighing lysimeters. A tipping bucket rain gauge with a detection limit of ± 0.025 cm (0.01 inch) of rain was connected to a data-logging device and has been operational most of the time since 1979. Occasionally, the data logger or the tipping bucket rain gauge has been inoperative. In these instances, data from either the manual rain gauges or the weighing lysimeters has been used to supplement the tipping bucket data. For several relatively short durations since 1979, only HMS data were available for the BWTF and Grass Site. Consequently, these values were used to complete the record.

Table 2.1 lists the time periods when each method was used to collect data at the BWTF from January 1986 through June 1988. The type of collection used in the record is clearly identified when entered into the data base. Cumulative precipitation data for the BWTF, as shown in Figure 2.1, is a composite of data obtained by all three methods of data collection. A comparison of the standard rain gauge data for the BWTF and Grass Site is given in Figure 2.2.

During 1988, in an attempt to improve quality control on precipitation measurements at the BWTF site, a review of the BWTF precipitation data reported by Gee (1987) revealed apparent measurement error from the tipping rain gauge for the winter months (January through March) of 1987. Similar discrepancies were noted in the record for 1986. Although the tipping bucket at the BWTF site was propane heated, apparently the heater did not work adequately and the water equivalent of snow was not properly recorded. In addition, there were times when the data logger was not operational (Table 2.1). We have subsequently revised the data by checking the winter records against the HMS data to identify expected precipitation dates, and

TABLE 2.1. Record of Precipitation Measurement Methods at the Buried Waste Test Facility for January 1, 1986, Through July 13, 1988

Time Period: Year	Time Period: Days	Method[a]
1986	1 to 4	WL
	5 to 41	TB
	42 to 51	WL
	52 to 255	TB
	256 to 365	WL
1987	1 to 59	WL
	60 to 229	
	230 to 365	
1988	2 to 4	HMS
	5 to 13	WL
	14 to 100	TB
	101 to 119	SC
	120 to 195	TB

(a) Method:
- WL = weighing lysimeter
- TB = tipping bucket
- HMS = Hanford Meteorological Station data
- SC = standard collection-type gauge.

then using the weighing lysimeter data where available (primarily during times when drainage was not occurring). During above-freezing conditions, the standard (nonrecording) rain gauge was used to provide the precipitation data when the data logger was not operational.

The detection limit of the tipping rain gauge is 0.025 cm (0.01 in.) of water, and the resolution of the weighing lysimeter is 0.002 cm (Kirkham, Gee, and Jones 1984). However, because of known variability in precipitation distribution and difficulties in measuring wintertime snowmelt, the estimated error in the composited precipitation record for the BWTF is likely no less than about 10%. A comparison of the precipitation record for the BWTF (Gee 1987) and the present data (January 1986 through July 1988) indicates that the precipitation for 1986 and 1987 at the BWTF was underestimated by about 20%.

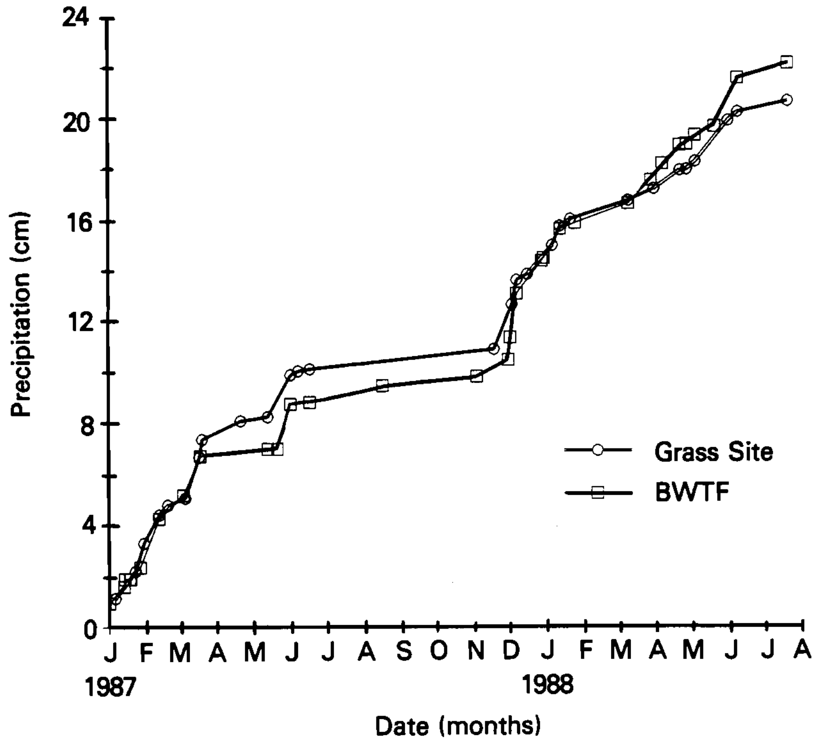

FIGURE 2.2. Comparison of Standard Rain Gauge Data for the Buried Waste Test Facility and Grass Site, January 1987 Through June 1988

In summary, precipitation records are being maintained by the data base from three locations: the HMS, the BWTF, and Grass Site. Since 1986 there appears to be about 20% more precipitation at the BWTF than at the HMS. The BWTF and Grass Site appear to be receiving similar amounts of precipitation. Variability in collection methods, as well as spatial distribution of precipitation, makes the uncertainty in the data no less than ± 10%.

3.0 WATER STORAGE

Neutron probes were used to measure water storage changes at three locations on the Hanford Site. Data were obtained for the Grass Site, the BWTF, and the 200 East lysimeter sites. These data are part of the Hanford Site performance assessment data base. Details of the scope of this data base and the procedures used for data storage and retrieval are provided in Appendix A. The calibration procedure and the protocol for using neutron probes to make soil-water storage measurements are shown in Appendix C.

3.1 GRASS SITE WATER BALANCE

The Grass Site near the 300 Area is being studied because it represents surface conditions (i.e., surface with only sparse grass cover) that may exist at or near waste burial sites after fires or drought conditions. The soil at this site is coarse texture and representative of many soils/surface sediments in the 100 and 200 Area. The vegetative cover of annual and perennial grass (cheatgrass and bluegrass, no shrub growth) on the site has not changed appreciably since testing began in 1983. Changes in water storage at this site are attributed to variations in climate (precipitation) and to changes in water uptake by plants. To document water storage changes, a network of 25 neutron probe access tubes was installed at the site in December of 1982. Figure 3.1 shows a schematic diagram of the Grass Site and the access tubes. These access tubes have been monitored biweekly to a depth of 3.5 m, since January of 1983. Figure 3.2 shows the average soil-water storage at the Grass Site. Data indicate little change in water storage occurred below the 1-m depth from January 1987 to June 1988. This small storage change is attributed to below normal precipitation (see Section 2.0). The maximum average water storage to a depth of 3.5 m during the past year (July 1987 to June 1989) was 20 cm of water, compared to over 32 cm of storage measured in early 1983 for the same site. For the past year, virtually all of the storage change at the Grass Site occurred during the winter months and in the top 1 m of the soil profile. Although essentially no storage change occurred below 1 m during the past year, water could have nevertheless drained from the profile.

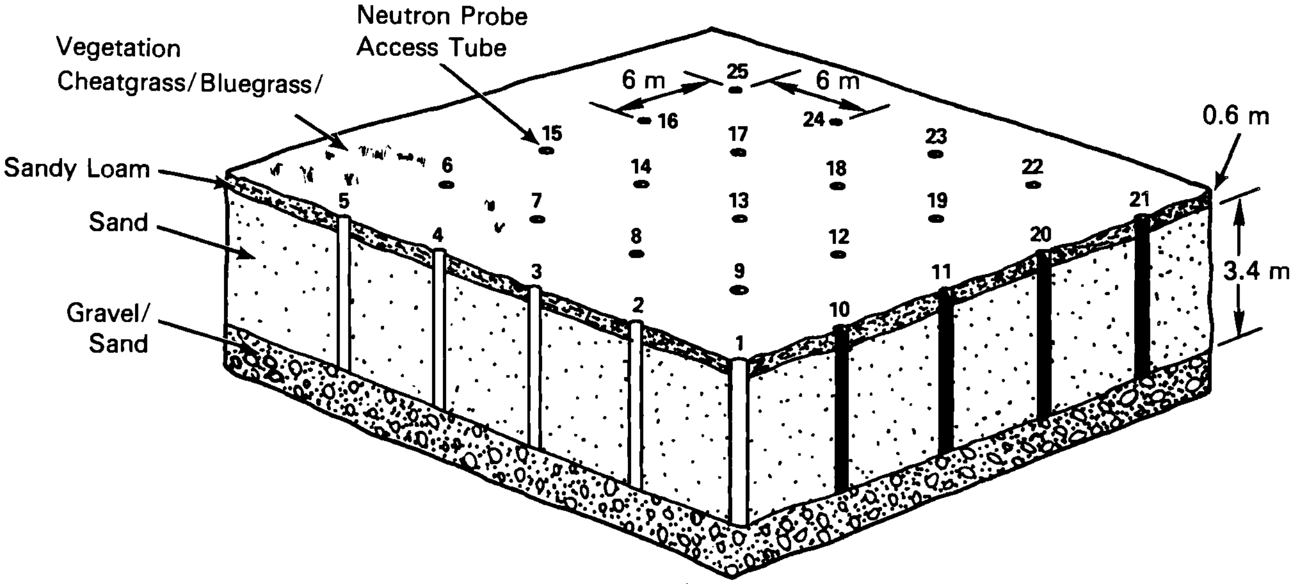

FIGURE 3.1. Schematic View of Neutron Probe Access Tubes at the Grass Site

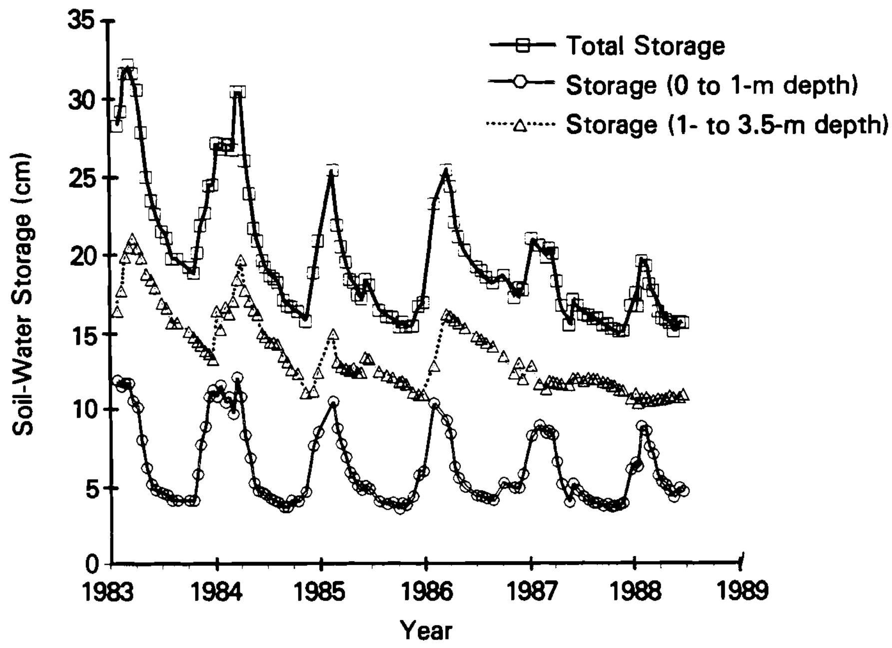

FIGURE 3.2. Soil-Water Storage for the Grass Site for January 1983 to June 1988

Water drainage rates cannot be directly measured using only the water-storage data from the neutron probe access tubes. Water storage data provides only one piece of information needed to assess the overall water balance of a site. Water storage can be used to predict drainage only if the evapotranspiration (water loss from soil and plant surfaces) and precipitation are measured independently. However, if water tensions are known and hydraulic property data are available, estimates of drainage rates can be made using neutron probe data (Rockhold, Fayer, and Gee 1988). Section 5.0 details the hydraulic properties measured for the Grass Site; Section 6.0 provides estimates of drainage using hydraulic conductivity data coupled with water storage and water content data.

In a previous report (Gee 1987), water storage values were obtained by summing water content in the interval between two measured depths and then summing over all depth intervals to obtain the total storage. In this report, a trapezoidal method (Green, Ahuja, and Chong 1986) is used for estimating storage. The trapezoidal method for calculating water storage can be expressed as

$$\int_0^L \theta\,(z,t)dz \approx \theta_1 z_1 + \sum_{i=2}^{n} [(\theta_{i-1} + \theta_i)/2](z_i - z_{i-1}) \qquad (3.1)$$

where L = profile depth
z = soil depth
t = time
dz = depth increment
z_1 and θ_1 = the depth and water content for the first measurement position
θ_i = the soil water content measured at the i^{th} point in the profile starting from the top
n = the number of data points down to depth L.

In comparing methods for calculating water storage for selected dates, there were only a few dates for which the use of different methods resulted in a more than 10% difference in the storage value. Although the storage values did not change significantly, the trapezoidal method was judged to be better documented (Green, Ahuja, and Chong 1986) than the other methods. Consequently, the trapezoidal method will be used to calculate soil-water storage from neutron probe information for all test sites.

To assess whether a few selected neutron probe monitoring points could be used to estimate water storage at the Grass Site, analyses were also made of the variation in water storage data from individual access tubes for the site. The temporal stability of the storage values were tested using a method proposed by Vachaud et al. (1985). Vachaud et al. measured soil water to a depth of 1 m in 17 access tubes using neutron probes at a field site in France. His test data were stable over a 2.5-year period. In other words, the wettest soil profiles were consistently wetter and the driest soil profiles were consistently drier during the entire 2.5-year period (as the field responded to seasonal changes in water content). Vachaud et al. (1985) used a cumulative probability plot to show the time stability of the data. The water storage determined from individual access tubes was ranked according to storage values (low to high); this ranking appeared to persist throughout the year. The persistence of the ranking was interpreted to indicate that it may be possible to reduce large measurement networks (i.e., with many access tubes) to a few representative locations.

Vachand's method was tested using the Grass Site data with relatively poor results. Figures 3.3 and 3.4 are cumulative probability plots of the water storage values for two time periods (October 1983 to April 1984 and January 1988 to April 1988). The curves reflect the probability that storage values will be less than the values shown. The curves provide a convenient way to show the distribution of individual storage values. For both time periods, the ranking of water storage values did not remain consistent, suggesting that values associated with water storage for specific access tubes varied sufficiently to preclude selecting only a few tubes to reflect the storage changes of the overall site. An exception was tube 25. Tube 25 is the access tube where two unsteady drainage-flux experiments were conducted (see Section 5.0). In these two experiments, supplemental water was applied at the soil surface, and the surface was temporarily covered with plastic to

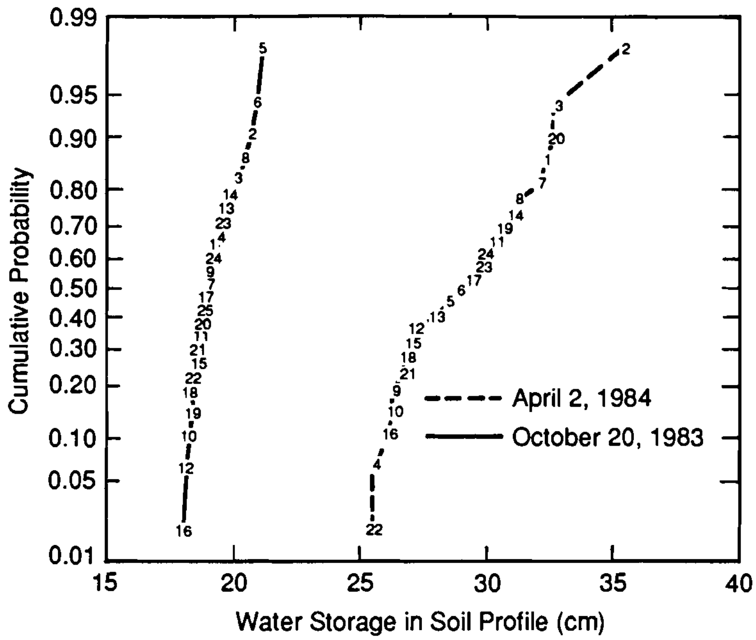

FIGURE 3.3. Cumulative Probability Plot of Water Storage for Individual Neutron Probe Access Tubes on October 20, 1983, and April 2, 1984

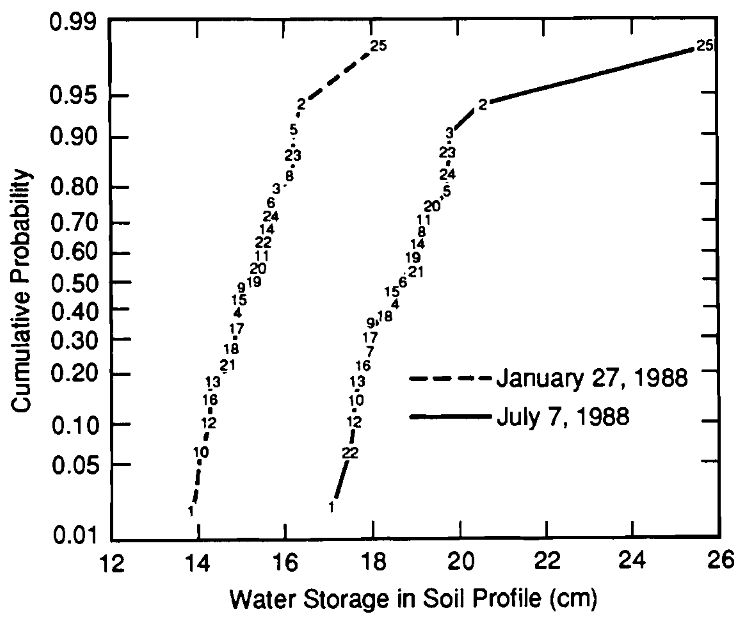

FIGURE 3.4. Cumulative Probability Plot of Water Storage for Individual Neutron Probe Access Tubes on January 27, 1988, and July 7, 1988

prevent evaporation in July 1987 and September 1987. The deliberate wetting and covering of the test plot immediately surrounding the access tube explains why the water content was higher for this tube than for any other tube of the Grass Site. In November 1987, the plot surrounding tube 25 was uncovered to permit evaporation. During the past 10 months (from November 1987 to present), grass (primarily cheatgrass) has begun growing on the plot. The storage changes at tube 25 between January and July 1988, shown in Figure 3.4, reflect the above conditions.

3.2 BURIED WASTE TEST FACILITY

The objective of monitoring water storage at the BWTF is to compare soil-water storage changes for bare and vegetated surfaces under conditions of known drainage documented by lysimeters. The lysimeters at the BWTF are filled with coarse sands typical of sediments underlying the 200 Areas and other waste disposal areas of the Hanford Site.

The water balance of the vegetated lysimeter reflects the water storage and drainage at waste sites covered with vegetation. The water balance of the bare-surface lysimeters reflects conditions of maximized recharge. Such bare-surface conditions may exist at waste burial sites denuded by fire or herbicides. Differences in water balance (i.e., storage and drainage) between the vegetated and nonvegetated (bare) surfaces are attributed to differences in evapotranspiration. The BWTF has a more continuous record of soil-water storage than any other location on the Hanford Site.

Figure 3.5 shows plan and cross-section views of the BWTF facility. The 7.6-m-deep south caisson, the 1.5-m-deep south and north weighing lysimeters are being monitored for water storage on a routine (biweekly) basis. The south caisson and north weighing lysimeter are kept bare. The south weighing lysimeter has been vegetated since March 1983.

Figure 3.6 compares the soil water stored in the top 1.2 m of each of these lysimeters. An annual water storage cycle is clearly seen. Water storage values for all measurement dates, from January 1984 through June 1988, are documented in Appendix C (Tables C.1, C.2, and C.3). During FY 1988, water storage values for late winter were lower in all lysimeters

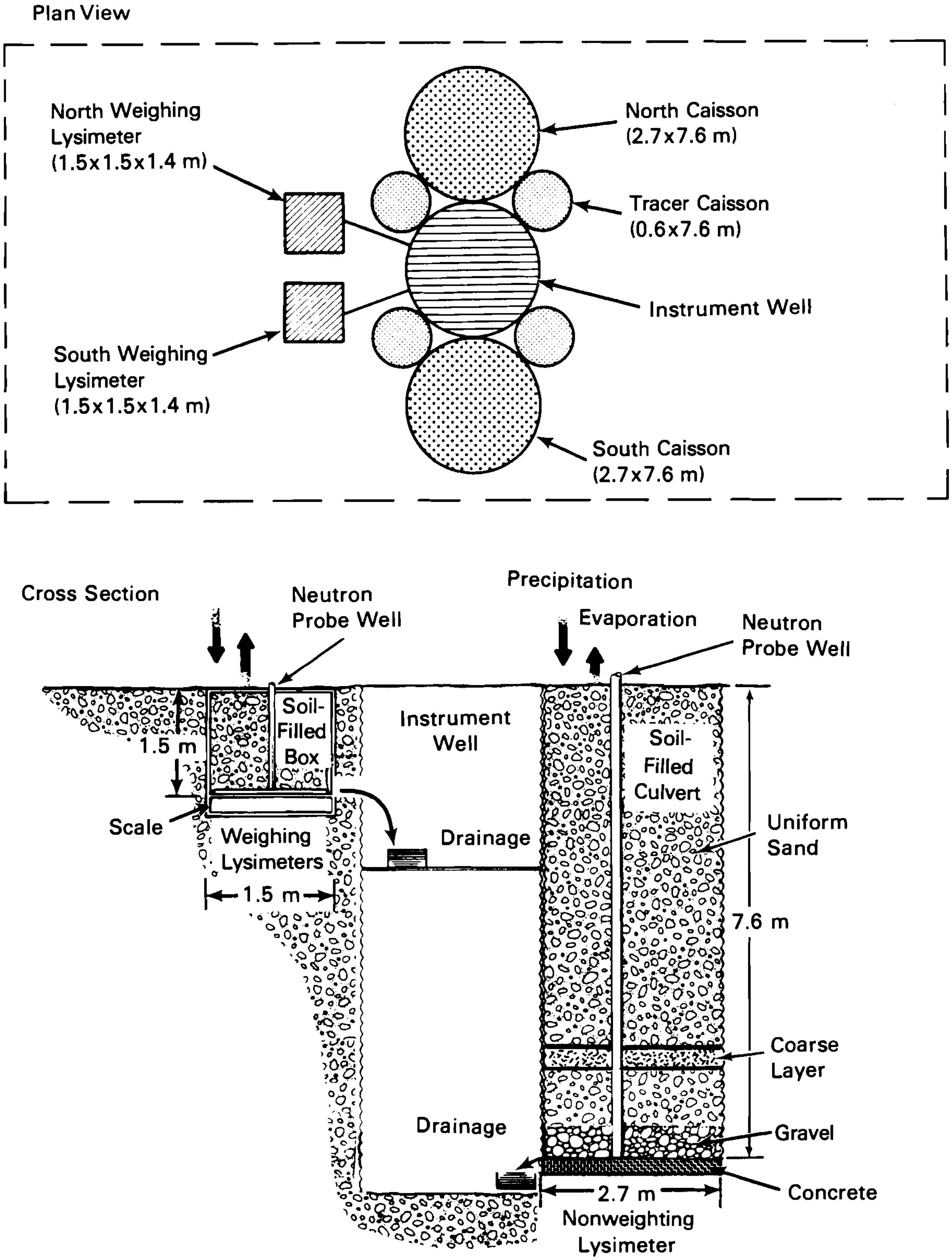

FIGURE 3.5. Plan View and Cross Section of the Buried Waste Test Facility Adjacent to the 300 North Burial Grounds

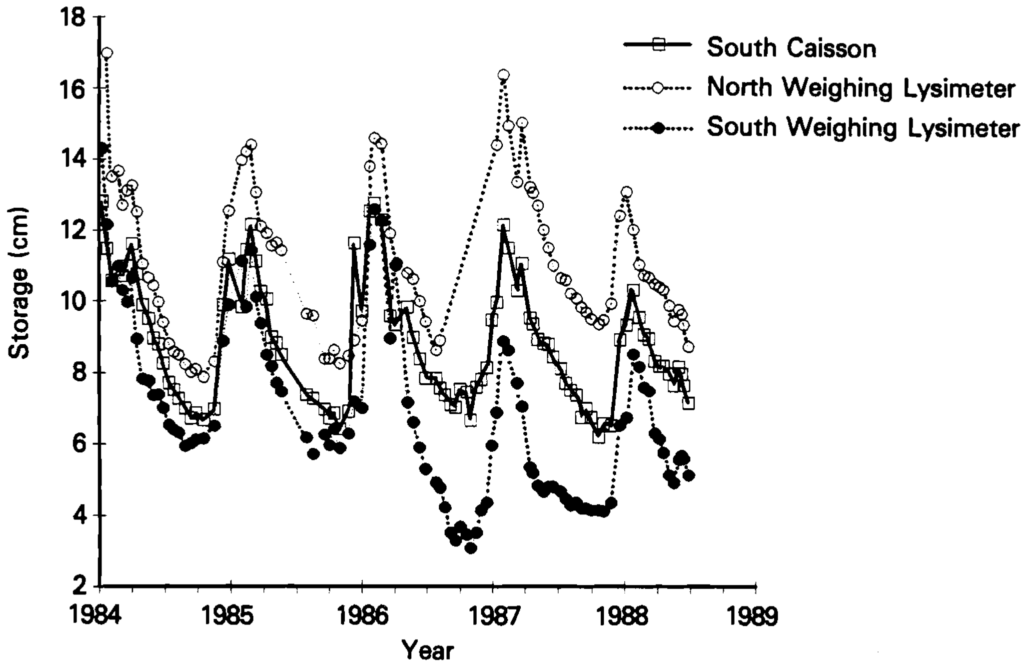

FIGURE 3.6. Water Storage in the Top 1.2-m Depth of the South Caisson, South Weighing Lysimeter, and North Weighing Lysimeter at the Buried Waste Test Facility

than in 1987, reflecting variations in winter precipitation from 1987 to 1988. Water-storage losses have persisted in all lysimeters since early spring (1988). For 1984 through 1988, the south weighing lysimeter consistently stored less water in the top 1.2 m of the soil profile than the other two lysimeters. This result is attributed to vegetative cover on the south weighing lysimeter and bare surfaces (no vegetation) on the other two lysimeters.

Both the south caisson and the north weighing lysimeter have drained during the past year (1987) (see Section 2.0). There has been no drainage from the south weighing lysimeter. The storage changes reflect the composite effect of precipitation, evaporation, and drainage. Water balance calculations using the surface storage data from these lysimeters are presented in Section 6.0.

3.3 THE 200 EAST LYSIMETER SITE

The purpose of renewed monitoring of the 200 East lysimeter site is to thoroughly document current water storage changes at a 200 Area site under controlled surface (bare soil) conditions. Monitoring will permit testing of the hypothesis that removing vegetation from soil surfaces will enhance water storage and possibly lead to drainage at 200 Area waste burial sites. Monitoring planned for this lysimeter site during the next 2 years (1988 through 1989) will consist of at least monthly measurements of water storage in the closed-bottom lysimeter (nonvegetated soil) and in surrounding, undisturbed areas (vegetated soils).

Figure 3.7 shows the plan view of the 200 East lysimeter site and the cross section of the 18.5-m-deep closed-bottom lysimeter. The open-bottom lysimeter, originally emplaced at this site early in 1972, was partially emptied (to a depth of about 6 m) in the spring of 1983. The soil from this excavation, plus additional soil from an excavation immediately surrounding the lysimeter (Figure 3.8), was placed in a large stockpile immediately north of the open-bottom lysimeter. No effective attempt was made to stabilize the soil pile. As a consequence, since 1983, material blown from the pile has accumulated on the surface of the closed-bottom lysimeter. The open-bottom lysimeter is not presently used for soil-water monitoring.

Five neutron probe access tubes are currently being monitored at the 200 East lysimeter site. As shown in Figure 3.7, three of these access tubes are in the closed-bottom lysimeter. The fourth tube is in an area southwest of the lysimeters dominated by sagebrush (*Artemisia tridentata*). The fifth tube is in an area dominated by grass (*Bromus tectorum*), immediately south of the closed-bottom lysimeter. On January 22, 1988, the surface of the closed-bottom lysimeter was observed to be covered to a depth of 40 cm with eolian (windblown) material, apparently from the stockpile located north of the open-bottom lysimeter. Surface vegetation, mostly annual grasses and weeds, was also observed (Figure 3.9).

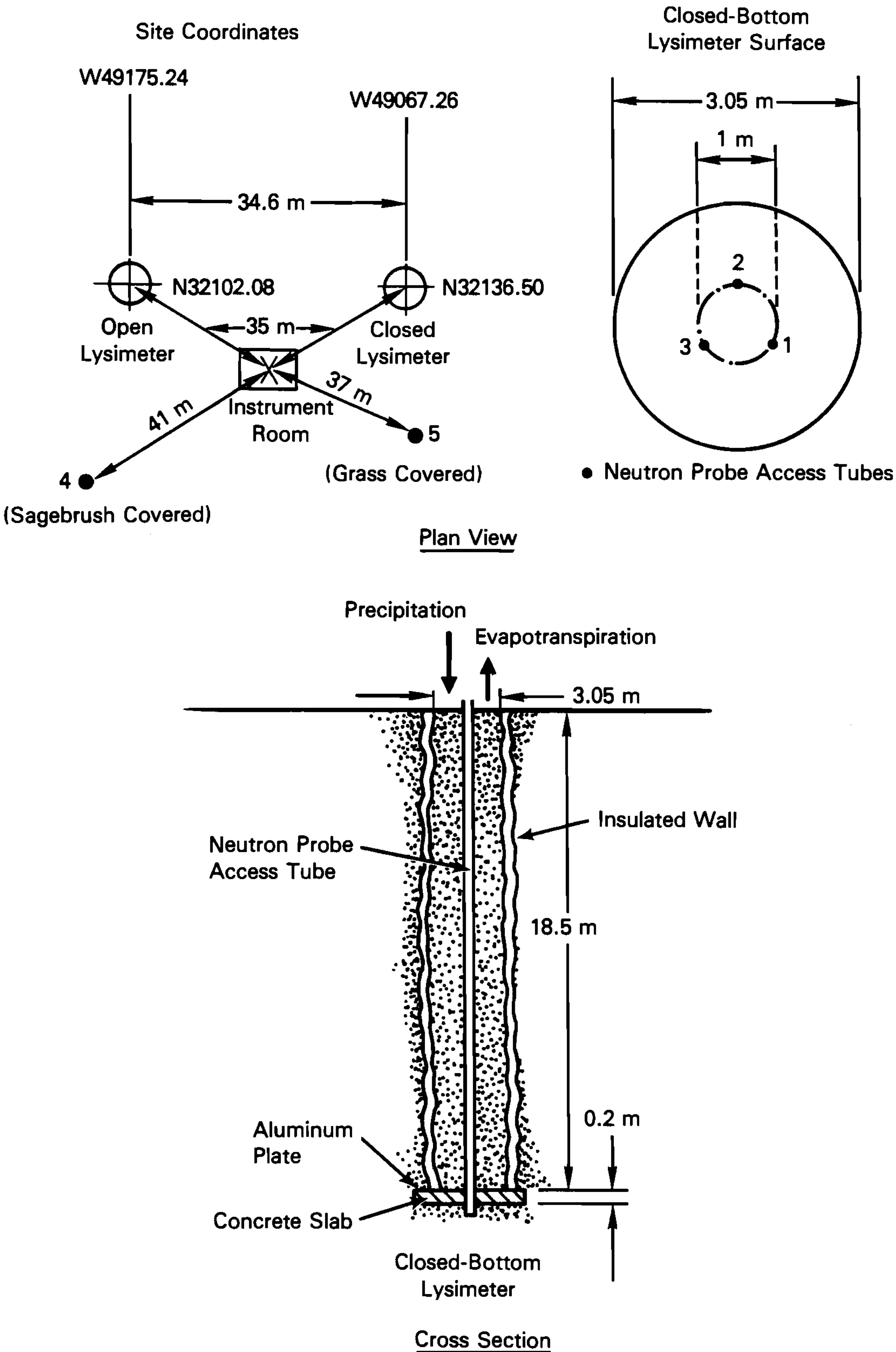

FIGURE 3.7. Plan View and Cross Section of 200 East Area Closed-Bottom Lysimeter

FIGURE 3.8. Excavation Site near the 200 East Open-Bottom Lysimeter on January 22, 1988

FIGURE 3.9. Surface of 200 East Closed-Bottom Lysimeter on January 22, 1988

On February 4, 1988, the surface of the closed-bottom lysimeter was excavated down to the metal rim of the insulated wall (Fig. 3.7) by removing the eolian sand and vegetation. During the excavation, scurf pea (Psoralea lancelota Pursh), a desert lentil with a prolific root system, was found in abundance in and around the lysimeter. All vegetation was removed from the surface of the lysimeter, and monitoring of moisture was initiated using a neutron probe. Since February 1988, the three access tubes in the closed-bottom lysimeter and the fourth and fifth access tubes in the sagebrush (Figure 3.10) and grassy areas (Figure 3.11) have been monitored bimonthly.

Water content profiles of the closed-bottom lysimeter are shown in Figures 3.12 and 3.13. A comparison of water storage measurements for all five access tubes is presented in Figure 3.14. The data show that water- storage changes are significantly less for the lysimeter than for the adjacent undisturbed areas. The effect of vegetation removal on water storage is apparent, with the closed-bottom lysimeter losing less than 1 cm of storage over a 6-month period while more than 3 cm of water was lost from the vegetated (grass and sagebrush covered) sites.

The 200 East lysimeter will continue to be monitored through 1990. Because of vegetation removal, water storage is expected to increase with time in the 200 East closed-bottom lysimeter. The monitoring data are expected to confirm earlier work (Fayer, Gee, and Jones 1986) that suggests the presence of plants on the surface of the 200 East lysimeters is the major reason for differences between storage and drainage data from the 200 East closed-bottom lysimeter monitored in the 300 Area.

Figure 3.12 shows the water content profile as measured to a depth of 18.5 m by the three neutron probes within the closed-bottom lysimeter. Except for measurements at a depth of 18 m, there is reasonable agreement among the three samples; water contents seldom differ by more than ± 0.5 vol% moisture throughout the profile. The peak at 18 m is attributed to the concrete bottom of the closed-bottom lysimeter. Differences in readings for the three tubes are attributed to positioning of the probes and possibly to

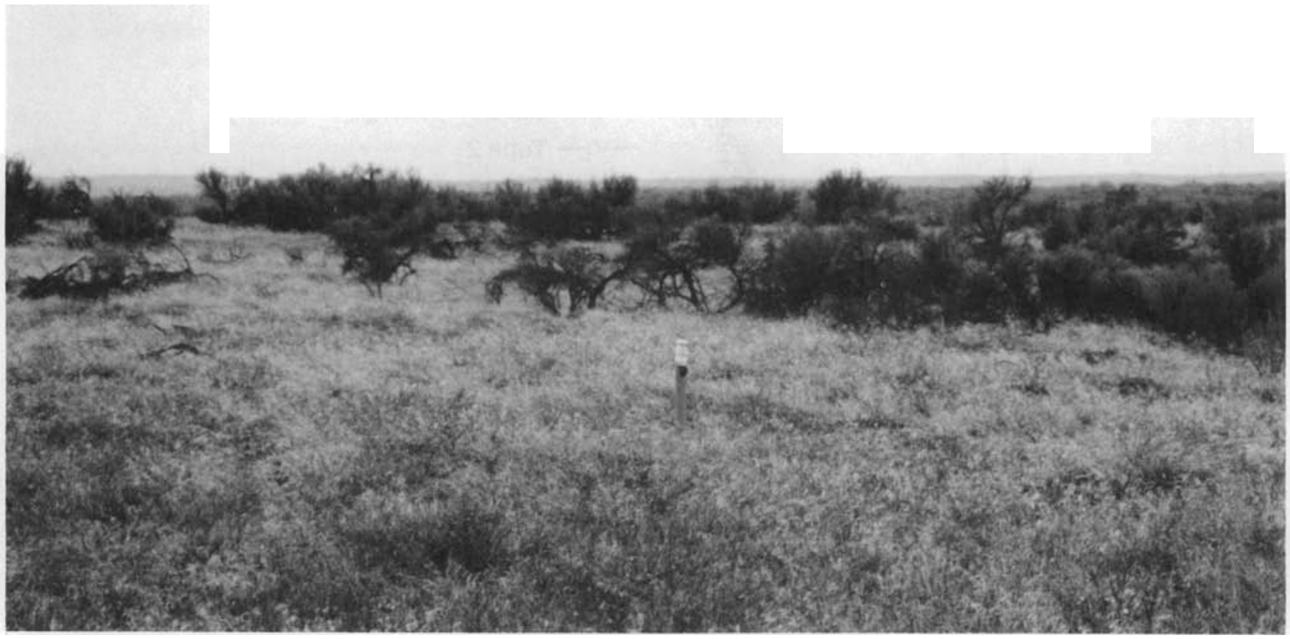

FIGURE 3.10. Access Tube #4 Located in Sagebrush Cover South of the 200 East Closed-Bottom Lysimeter

FIGURE 3.11. Access Tube #5 Located in Grass Cover South of the 200 East Closed-Bottom Lysimeter

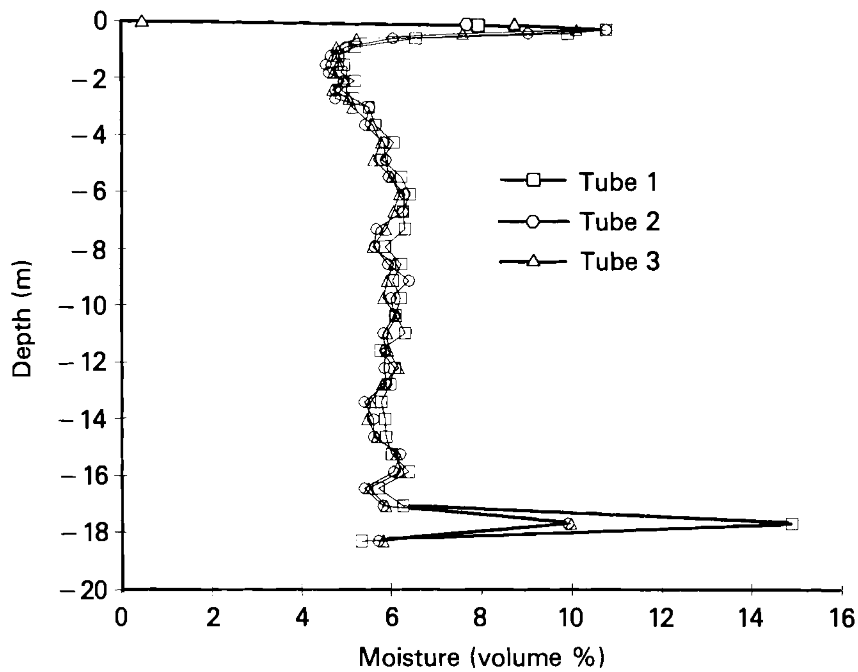

FIGURE 3.12. Water Content Profile at the 200 East Lysimeter Site for February 11, 1988 (all three access tubes were monitored)

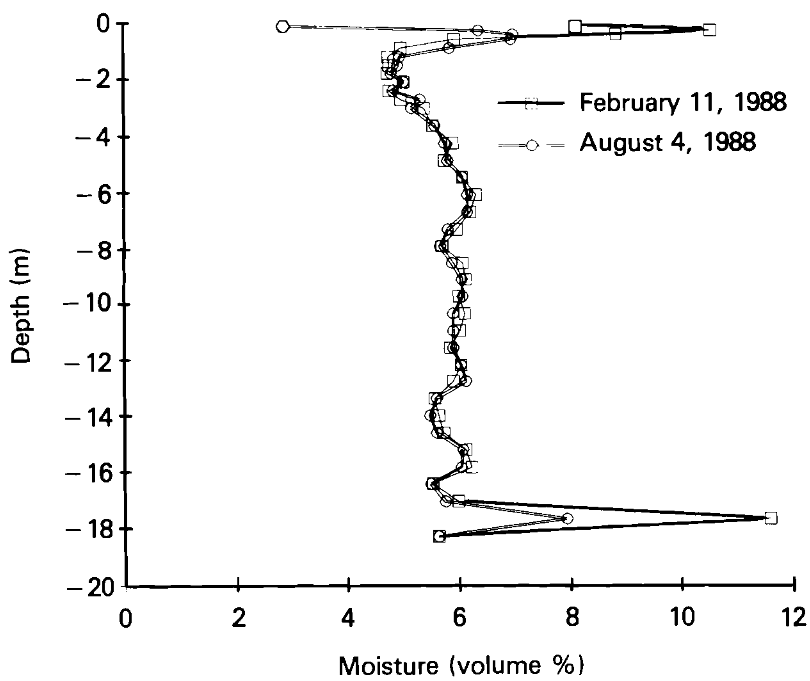

FIGURE 3.13. Water Content Profile at the 200 East Lysimeter Site (average for February 11, 1988, and August 4, 1988)

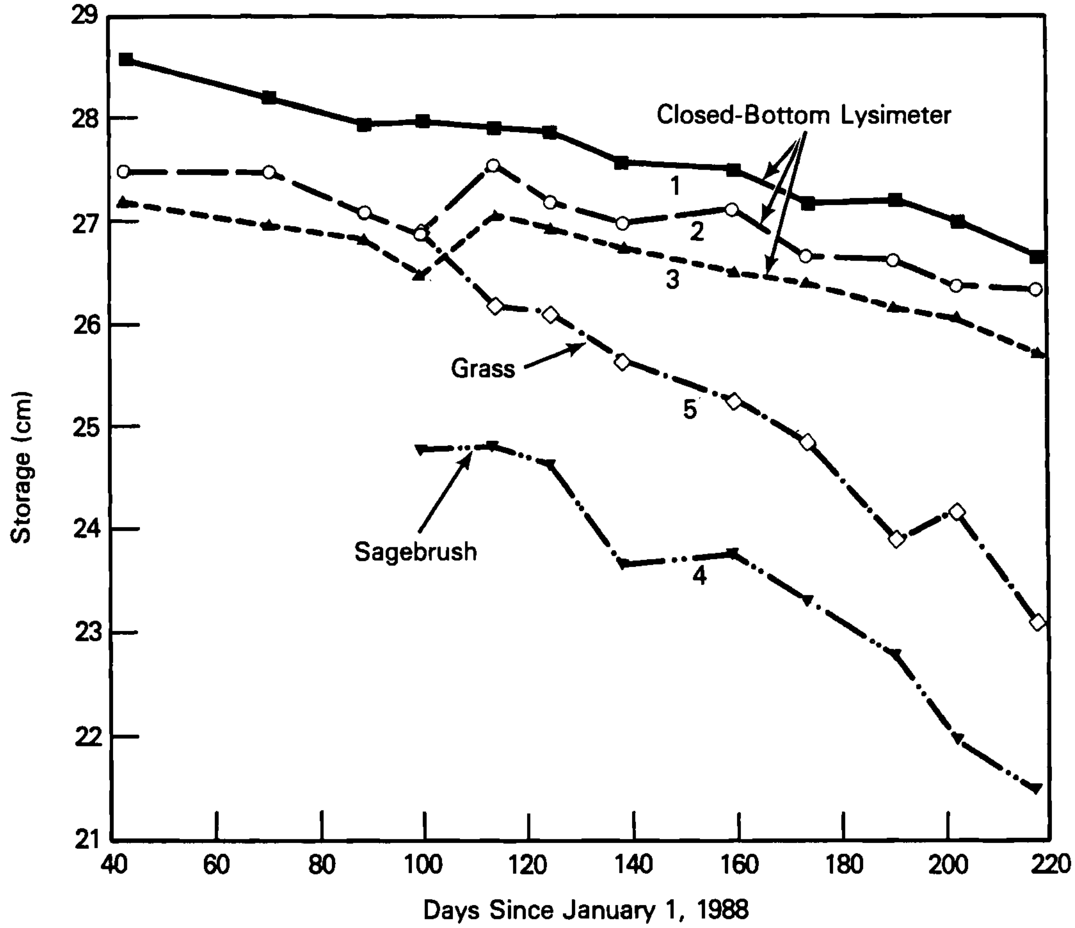

FIGURE 3.14. Soil-Water Storage in the Top 5 m of the Soil Profile as a Function of Time for Closed-Bottom Lysimeter and Adjacent Vegetated Areas at the 200 East Lysimeter Site

differences in the thickness of the concrete. Moisture at the lower depths is measured in 0.6-m increments. The use of smaller increments would help resolve the apparent differences in water storage near the concrete slab at the bottom of the lysimeter.

Future measurements in the lysimeter will be taken over smaller increments (0.3 m or less) in the bottom 1.2 m of the lysimeter to better define total storage and eliminate the uncertainties associated with measurements in and around the concrete bottom.

4.0 DRAINAGE

Drainage was measured directly from lysimeters located in the 300 North Area (see Figure 1.2). In addition, two small gravel-covered lysimeters were constructed and placed at a test facility adjacent to the HMS to quantify the effects of a gravel surface on drainage.

4.1 LYSIMETER DATA

During the past year, drainage measurements were obtained from lysimeters at the BWTF (see Figures 1.1 and 3.5). Appendix D includes the procedure used in collecting data from the BWTF (Figure D.1) and an example data sheet (Figure D.2). Cumulative drainage values from January 1984 through June 1988 for the south caisson, the south weighing lysimeter, and the north weighing lysimeter, are shown in Figures 4.1 and 4.2 and are listed in Appendix D (Tables D.1, D.2, and D.3).

From July 1987 through June 1988, there was no drainage from the south weighing lysimeter, which is covered with vegetation. Drainage occurred from the bare soils in the south caisson and north weighing lysimeter, but at rates lower than observed in previous years. The recent data reflect effects of vegetation and decreased winter precipitation on drainage (see Section 2.0). Table 4.1 summarizes the amount of annual drainage measured in the three BWTF lysimeters since July 1985. For comparison purposes, the average and standard deviation for annual drainage from 10 lysimeters at the adjacent CWTF[a] are also listed.

(a) The CWTF consists of 10 lysimeters (1.8-m dia. by 3.1-m deep), each of which contain a solidified commercial waste container surrounded by soil (Walter, Graham, and Gee 1984; Jones, Serne, and Toste 1988). The facility is used to study the hydrology and geochemistry related to burial of solid wastes under arid climatic conditions. The operation of the facility is currently funded by the Special Waste Form Lysimeter-Arid Task as part of the U.S. Department of Energy (DOE) Low-Level Waste Management Program. The facility is adjacent to and within 20 m of the BWTF. Similarities between the BWTF and CWTF are the climate and soil type. The soils in both facilities have similar textures (>90% sand by weight). All 10 of the CWTF lysimeters have been kept bare (free of vegetation) since installation in 1984.

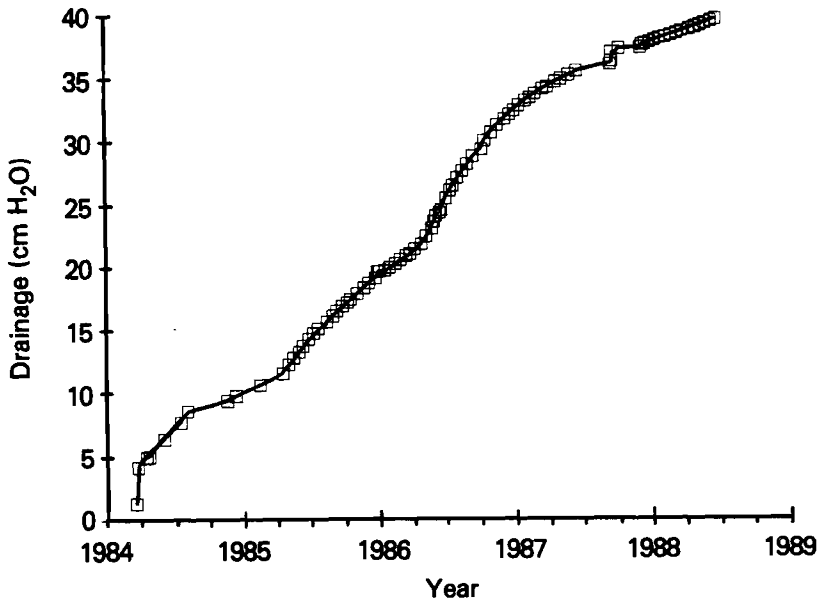

FIGURE 4.1. Cumulative Drainage from the South Caisson at the Buried Waste Test Facility

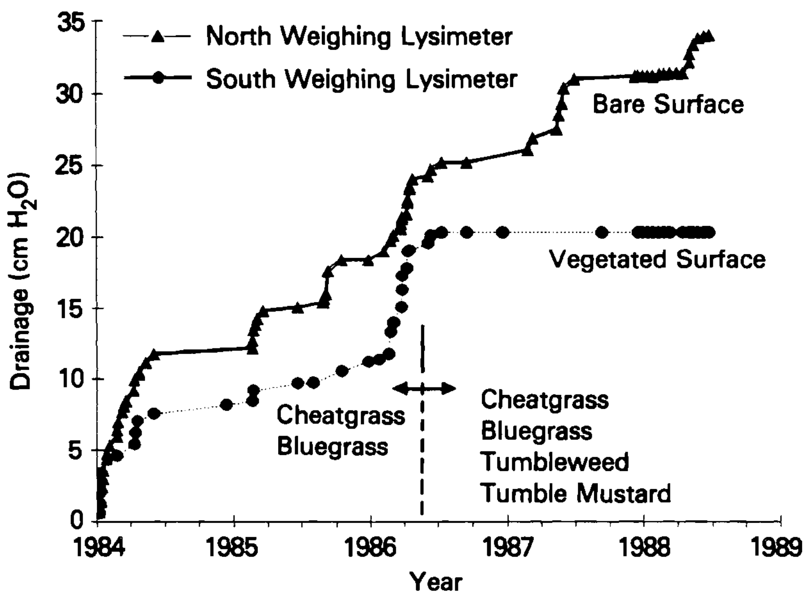

FIGURE 4.2. Cumulative Drainage for the North and South Weighing Lysimeters at the Buried Waste Test Facility

TABLE 4.1. Drainage Data for Three Lysimeters at the Buried Waste Test Facility [South Weighing Lysimeter (SWL), North Weighing Lysimeter (NWL), and South Cassion (SC)] and 10 Lysimeters (averaged values) at the Commercial Waste Test Facility (CWTF)

Year	Lysimeter Drainage, cm H_2O			
(July-June)	SWL	NWL	SC	CWTF
1985-1986	10.6	10.0	11.1	12.3 ± 1.4
1986-1987	0.1	6.0[a]	10.2	4.9 ± 0.8
1987-1988	0.0	3.1	4.0	4.6 ± 0.4

(a) NWL was temporarily decommissioned from August 1986 to January 1987 (i.e., no drainage was collected for this time period).

Twelve bare-soil lysimeters (north weighing lysimeter, south caisson, and 10 lysimeters from the CWTF) exhibited similar high drainage rates (10 to 12 cm/yr) during the 1985 water year (July through June) and consistently lower drainage rates (3 to 5 cm/yr) during the 1987 water year. During 1986, a leak was detected in the north weighing lysimeter; it was excavated (and remained empty for 4 months, August through December 1986), resealed, and refilled in January 1987. The data reported for this lysimeter is biased because of this disruption. The water storage and water contents of the refilled north weighing lysimeter (see Section 3.0, Figure 3.6) were higher than the other two BWTF lysimeters because the north weighing lysimeter was filled in January while the soil contained more moisture (6 to 8 wt%) than the typical "field capacity" (4 to 5 wt%). The excess water in this soil has subsequently drained or evaporated during the past 18 months. Drainage values from the north weighing lysimeter should not reflect the influence of climatic variables.

Drainage from the south caisson, which is the longest drainage lysimeter (7.6 m deep), was over twice that for the CWTF during the 1986 water year. This difference in drainage was likely the result of extra storage water draining from the deeper south caisson. Nevertheless, the data are convincing evidence that drainage occurs in measurable quantities at this location because, when soils are kept bare, coarse-textured soils drain below the surface so readily that drainage occurs even in dry years.

A vegetative cover, primarily cheatgrass and bluegrass (poa), was established on the south weighing lysimeter in March 1983 (Gee 1987). Cheatgrass and bluegrass remained the dominant cover plants until 1986, when a large tumbleweed was allowed to grow on the lysimeter. Tumble mustard, an annual deep-rooted plant, invaded the surface of the lysimeter, germinated, and grew during the summers of 1987 and 1988. Table 4.2 lists the observed surface cover conditions of the south weighing lysimeter since installation in 1979.

Tumbleweed and tumble mustard have relatively deep (generally in excess of 1 m vertical depth) tap roots and grow during summer months, as compared to cheatgrass and bluegrass, which are "cool season" grasses that become dormant in the summer. These differences in plant phenology (i.e., growth

TABLE 4.2. Surface Conditions of South Weighing Lysimeter at the Buried Waste Test Facility. Plant cover[a] and density are listed.

Year	Surface Condition
1979	Bare
1980	Bare
1981	Bare
1982	Bare
1983	Cheatgrass and bluegrass (transplanted, ~40% cover)
1984	Cheatgrass, bluegrass (~50% cover)
1985	Cheatgrass, bluegrass (~50% cover)
1986	Cheatgrass, bluegrass, tumbleweed (~60% cover)
1987	Cheatgrass, bluegrass, tumble mustard (~75% cover)
1988	Cheatgrass, bluegrass, tumble mustard (~60% cover)

(a)

Scientific Name	Common Name
Bromus tectorum	Cheatgrass
Poa sandbergii	Sandberg's bluegrass
Salsola kali	Russian thistle (tumbleweed)
Sisymbrium altissimum	Jim Hill mustard (tumble mustard)

patterns) are probable reasons why water losses from drainage were significantly reduced in the south weighing lysimeter during 1987 and 1988 (Figure 4.1 and Table 4.1). The observed large drainage from the south weighing lysimeter during the 1985-1986 water year is attributed to the release of stored soil water from winter rain accumulations. Water apparently infiltrated the soil profile below the shallow root systems of the cheatgrass and bluegrass during the winter months and could not be removed by capillarity or plant uptake at a rate fast enough to prevent drainage.

As discussed in Section 3.0 (Figure 3.6), the south weighing lysimeter stored significantly less water (in the top 1.2 m) during the past years than did the other two (bare) lysimeters, thus reflecting the influence of water removal in summer months by deep-rooted plants (e.g., tumbleweed and tumble mustard). The lack of drainage is consistent with the lower storage values observed in the south weighing lysimeter.

Because effects of plant cover on drainage from the south weighing lysimeter are based only on a time series of single location, nonreplicated treatments, plant cover effects on drainage (localized recharge) for the entire Hanford Site were not extrapolated. However, the data strongly suggest that where there are shallow-rooted plants, such as cheatgrass and bluegrass, with no tumbleweed or other deep-rooted plants, there is high probability that drainage will occur, particularly when the soil is coarse textured, as it is in the south weighing lysimeter. Evidence that drainage can occur below vegetation at the Hanford Site is documented with the south weighing lysimeter data. Evidence that drainage can be eliminated by the presence of deep-rooted vegetation is also documented for the same location.

Predictive models for recharge that do not account for plant cover and rooting depth variations (either spatially or temporally) will not be successful for the Hanford Site. Vegetation dynamics, as influenced by such things as natural (i.e., fire, drought, etc.) or human disturbances (excavations, weed control, etc.), must be a key component in any reliable estimate for recharge at a specific location. Additional replicated tests that document drainage rates under vegetated conditions would be highly desirable. Tests have been proposed to use small-tube lysimeters at the Grass Site to directly measure drainage rates under conditions where shallow-rooted grasses grow on coarse-textured soils. Details related to small-tube lysimeter design (dimensions etc.) are presented in the following section.

4.2 GRAVEL-COVERED LYSIMETERS

During FY 1988, it was proposed to Westinghouse Hanford Company to study natural recharge at tank farm sites in the 200 Areas. Pacific Northwest Laboratory proposed to install small drainage-type lysimeters at a selected tank farm site and to monitor the lysimeters routinely (at least monthly) for weight change and drainage. The lysimeter data would then be used to estimate current recharge rates at the tank farm site. However, there were some concerns about radiation safety in excavating a site for locating the lysimeters and also in ensuring the accessibility of the lysimeters at the tank farms. Approval was given to construct lysimeters with gravel covers and locate them on the 200 Area Plateau under simulated tank farm conditions, thus minimizing radiation safety concerns and providing ready access to the lysimeters for monitoring. Subsequently, two lysimeters were constructed and located at a site close to the HMS.

Two small-tube (30.5-cm dia.), gravel-covered-type lysimeters were installed at an experimental plot located next to the Field Lysimeter Test Facility (FLTF) and adjacent to the HMS (Kirkham, Gee, and Downs 1987). The dimensions and layering sequence for the gravel-covered lysimeters are shown in Figure 4.3.

Lysimeters were constructed from 1.7-m long, plastic well casing manufactured by Corro-Tec, Inc., of Seattle, Washington. The casing was sealed at the bottom with a plastic insert that was welded to the casing. Each casing was fitted at the bottom with a drainage fitting coupled to a length of flexible plastic Tygon[a] tubing. A clamp was placed at the end of the tubing. Drainage water was collected from the outflow tube and measured. Each column was leak tested by filling the column with water to a depth of approximately 1 m, allowing a minimum of 24 hr to elapse, then checking

(a) Tygon is a registered tradename of U.S. Stoneware Company, Akron, Ohio.

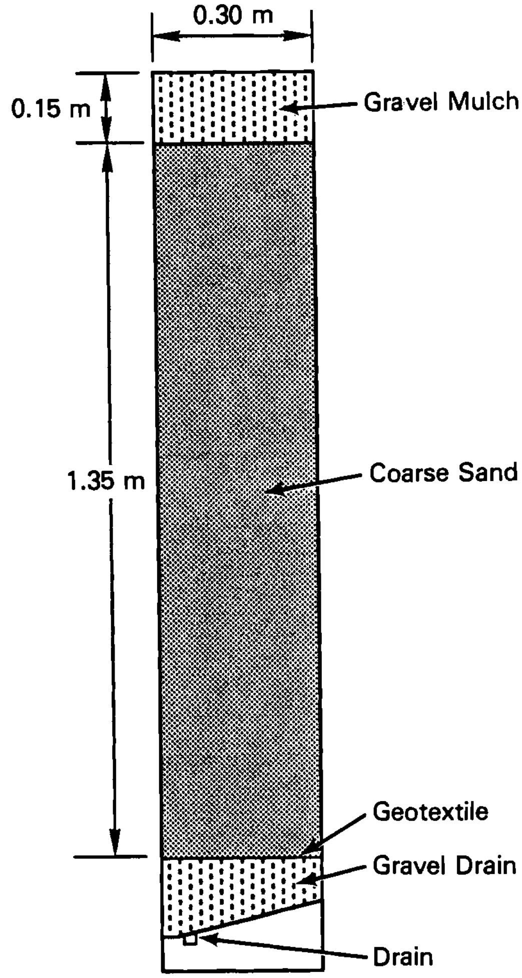

FIGURE 4.3. Schematic of Gravel-Covered Lysimeter Used to Simulate Tank Farm Surface Conditions

bottom seams and the area around the drainage fitting for signs of moisture. No leaks were observed from the welded seams in the bottom of the columns, but some fittings leaked. When leaks were detected, the fittings were readjusted and the leak test repeated until the leaks were stopped. Once the columns were leak free, the water was removed and a piece of heavy-duty screen was placed over the drain hole on the inside of the column to prevent plugging by gravel in the bottom layer.

The column was then filled with layers of gravel, geotextile, and sand, and topped with a layer of gravel (Figure 4.3). The bottom of the lysimeters were filled with ~20 cm of gravel (~8-mm dia) to facilitate collection of any drainage that may occur. The bottom gravel was covered by a geotextile to prevent the sand layer from sifting into the gravel layer. Coarse sand was packed on the geotextile in nine lifts that were 15 cm in length to a height of 135 cm above the geotextile and 15 cm from the top of the column. The average water content of the sand was 5 wt%, and the soil was packed to an average dry bulk density of approximately 1.62 g/cm^3 (1.7 g/cm^3 wet density). Grab samples of each lift were collected for determining moisture. The coarse sand was covered with a 15-cm-thick gravel layer to maximize infiltration. The gravel-covered lysimeters were put in place at the test facility on July 25, 1988. A small (2-ton capacity) crane and a crane scale, sensitive to ± 0.1 kg, were used to position and weigh the lysimeters. Weights of the two lysimeters were documented for 2 days (July 25, 1988, and August 25, 1988) (Table 4.3). Weights will be measured on at least a monthly basis. The weight changes and drainage rates from these two lysimeters will be documented and compared with other lysimeters that are being placed at this same site. The influence of gravel covers and the absence of vegetation on drainage will be documented for soil and climate conditions on the 200 Area Plateau.

TABLE 4.3. Gravel-Covered Lysimeter Weight Changes

	Weight, kg	
Lysimeter	25 July 1988	25 Aug 1988
G-9	230.3	229.8
G-10	229.7	229.2

5.0 HYDRAULIC PROPERTIES

Several efforts have been made to obtain reliable estimates of hydraulic properties of Hanford Site soils for use in water balance calculations using computer codes such as UNSAT-H (Fayer, Gee, and Jones 1986). Field measurements of hydraulic conductivity were started at two locations in FY 1988. In the Fall of 1987, two unsteady drainage flux-method experiments (Green, Ahuja, and Chong 1986) were conducted at the Grass Site and the McGee Ranch. Results of the first set of these experiments are reported by Rockhold, Fayer, and Gee (1988). The results of the second set of experiments are reported here.

In addition to the measurement of hydraulic conductivity at these two sites, water retention characteristics were measured and a fractal technique for parameter estimation was tested. Rockhold, Fayer, and Gee (1988) previously used the Arya and Paris (1981) model to predict water retention characteristics from particle-size distribution and bulk-density data. An estimation method using concepts of fractal mathematics is described in this section and used to estimate parameters in the Arya and Paris (1981) soil-water retention model for the Grass Site and McGee Ranch soils.

5.1 UNSATURATED HYDRAULIC CONDUCTIVITY FOR THE GRASS SITE

Calculations of hydraulic conductivity using the unsteady drainage-flux method are based on a one-dimensional Darcian analysis of transient, in situ soil-water content and hydraulic head profiles during vertical drainage from field plots. The method, as used in this study, consisted of ponding water on the surface of a plot until the soil profile was wetted beyond the maximum depth of interest. The soil surface was then covered with clear plastic and a thin (approximately 3-cm-thick) layer of soil to prevent evaporation and minimize thermal effects. Isothermal conditions were assumed to exist in the profile during drainage. Water contents and hydraulic heads were then monitored as the water in the profiles redistributed and drained. Specific details of measurements taken at the Grass Site and the McGee Ranch, and subsequent hydraulic conductivity calculations, are described by Rockhold, Fayer, and Gee (1988).

Hydraulic head data from the first experiment at the Grass Site indicated that a significant amount of water moved laterally out of the test plot profile [see Figure 5.1(a)]. Therefore, an assumption that all water drains vertically, which is needed to correctly calculate hydraulic conductivities, assuming one-dimensional flow using Richards' equation (Richards 1931), is not valid. Consequently, the experiment was modified to eliminate lateral flow, and rerun.

As reported previously by Rockhold, Fayer, and Gee (1988), the soil profile at the Grass Site is layered, with approximately 45 cm of sandy loam overlying more than 3 m of relatively uniform coarse sand. This textural transition inhibits redistribution of water into the lower layer by restricting the downward flux to the extent that the lower layer cannot become completely saturated. This hydrologic barrier also acts to store water longer in the upper part of the soil profile. Under the conditions of the first experiment, where the surface was covered but only a finite area was wetted, water could apparently be drawn laterally out of the upper part of the soil profile by potential gradients from the drier surrounding soil, rather than draining into the lower part of the soil profile by gravity flow.

In the second experiment at the Grass Site, lateral flow out of the upper profile layer was eliminated by trenching around the perimeter of the plot down to a depth of 60 cm and installing plastic sheeting. The textural transition between the two soil layers occurs between the 45- and 60-cm depths. The distance from the center of the wetted plot to the trench was approximately 1.5 m. Soil was then backfilled and the experiment repeated. Hydraulic conductivities and profile storage changes were calculated using the data from both experiments to quantify the lateral flow effects in the first experiment and to determine the resulting effect on hydraulic conductivity calculations.

Figure 5.1(a) and (b) show the total hydraulic head profiles for the first and second experiments, respectively. Matric head data corresponding to these profiles are listed in Tables D.2 and D.6. Data shown in these figures indicate that lateral flow out of the upper part of the soil profile was effectively eliminated in the second experiment by the plastic sheeting.

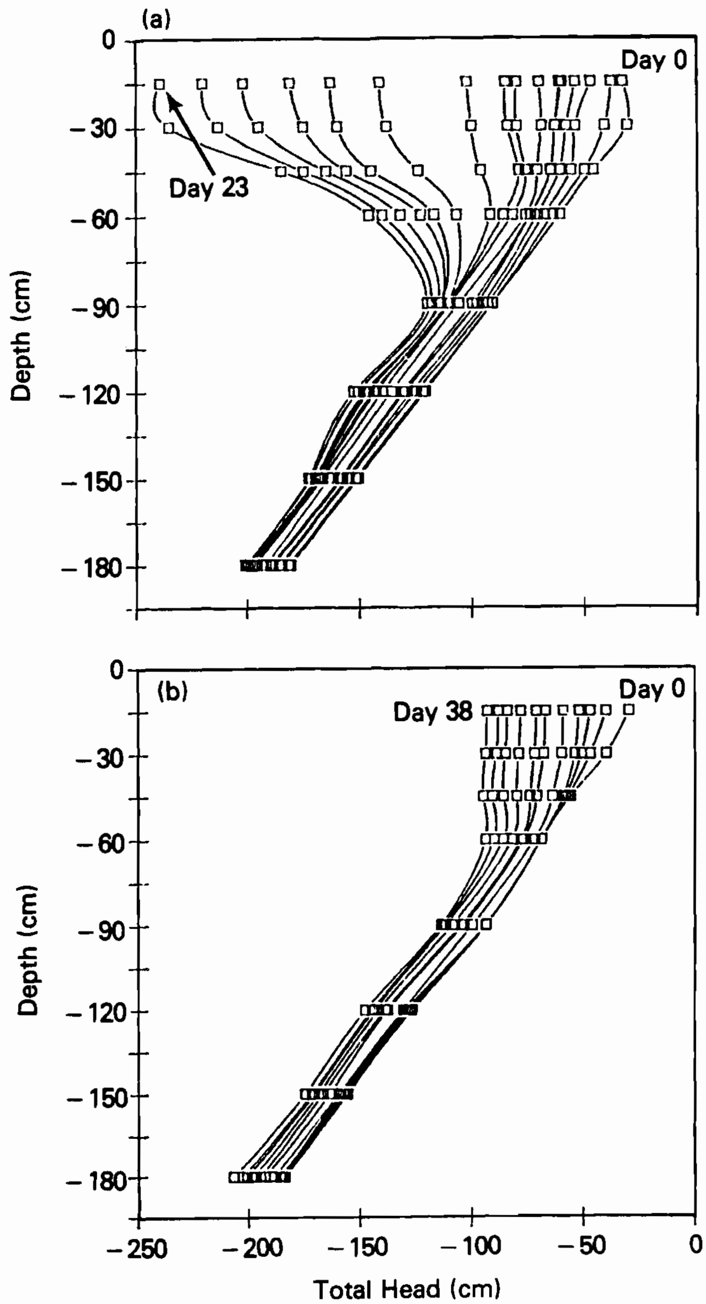

FIGURE 5.1. Total (matric plus gravity) Head Profiles for First and Second Experiments at the Grass Site. (a) Represents first experiment over a period of 23 days, with day 0 plot on right and day 23 plot on left. (b) Represents second experiment over a period of 38 days, with day 0 plot on right and day 38 plot on the left.

In the second experiment, the range over which total head changed above the 60-cm depth was still more than twice as great as the range over which total head changed below the 60-cm depth. This result is likely due to different water retention characteristics of the upper, fine soil relative to the lower, coarse soil.

Figure 5.2(a) and (b) show water content profiles from the first and second experiment, respectively. These data are listed in Tables E.1 and E.5. The water content at the 30-cm depth decreased by 0.083 cm^3/cm^3 in the first experiment (from 0.191 cm^3/cm^3 to 0.108 cm^3/cm^3) during approximately 23 days. This contrasts with the second experiment in which the water content at the 30-cm depth decreased only by 0.045 cm^3/cm^3 (from 0.178 cm^3/cm^3 to 0.133 cm^3/cm^3) during approximately 38 days of drainage. Differences in water content changes at depths below 45 cm are comparable for both experiments. Based on this information and the hydraulic head profiles shown in Figure 5.1(a) and (b), lateral flow of water out of the upper part of the test plot profile in the first experiment appears to have been significant.

Total water storage in the soil profile was calculated for both experiments using a trapezoidal approximation (Green, Ahuja, and Chong 1986), assuming the water content at the surface was equal to the water content at the 15-cm depth. The total water stored in the profile above a depth of 180 cm immediately after ponding was 26.75 cm in the first experiment and 26.09 cm in the second experiment. The total water stored in the profile after approximately 23 days of drainage and redistribution was 12.24 cm and 15.03 cm, for the first and second experiments, respectively. Considering the differences between initial water storage for each experiment, the lateral flow apparently resulted in 3.45 cm more storage loss from the profile in the first experiment than in the second experiment. This value is approximately 24% of the total water storage change during the first experiment.

Water content and hydraulic head profiles were used to calculate hydraulic conductivities with a time-averaging approach, as described by Rockhold, Fayer, and Gee (1988). Calculated hydraulic conductivities for the first and second experiments are listed in Tables E.4 and E.8, respectively.

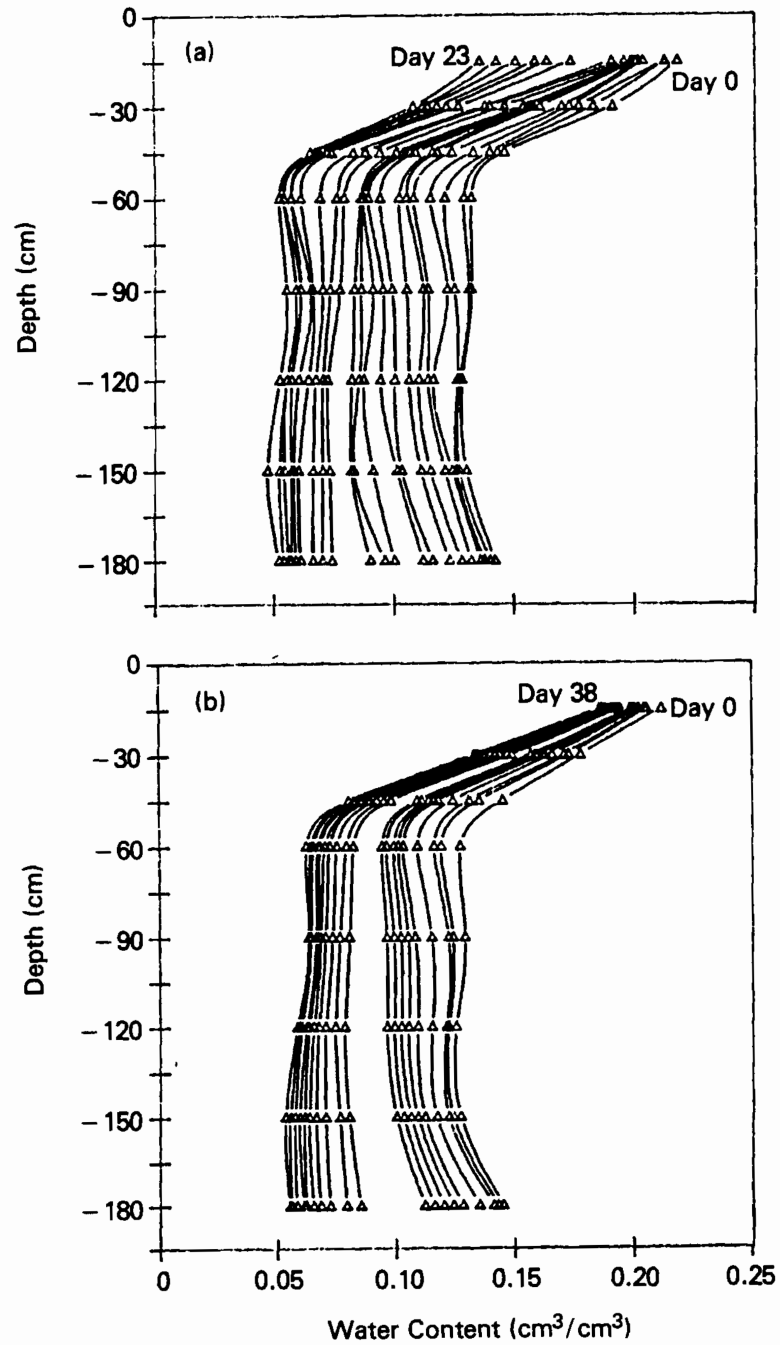

FIGURE 5.2. Water Content Profiles Measured with a Neutron Probe for First and Second Experiments at the Grass Site. (a) Represents first experiment over 23 days, with day 0 plot on right and day 23 on left. (b) Represents second experiment (restricted lateral flow) over a period of 38 days, with day 0 plot on right and day 38 plot on left.

Total head gradients were estimated with a two-sided approximation

$$\partial H/\partial z \approx [h(depth_{z+1},t) - h(depth_{z-1},t)/(depth_{z+1} - depth_{z-1})] - 1$$

where H is the total hydraulic head, h is the matric head at time t, and z is the depth below soil surface.

Figure 5.3(a) and (b) show hydraulic conductivity as a function of volumetric water content for the 30- to 180-cm depths, from the first and second experiments, respectively. Hydraulic conductivities from the upper part of the soil profile are not delineated as well in the first experiment as in the second because the reversal in head gradients (caused by lateral flow) resulted in negative conductivities. In the lower part of the soil profile, calculated hydraulic conductivities are up to one order of magnitude higher for the first experiment than for the second. This result is explained by calculations of hydraulic conductivities that assume storage changes above any given depth in a given time period result from water moving vertically downward. Thus, the higher hydraulic conductivities calculated from data of the first experiment reflect the larger changes in storage that result from lateral flow out of the profile, in addition to vertical flow through the profile, without corresponding changes in head gradients.

Figure 5.4 shows the water retention characteristics from the second experiment at the Grass Site. The data from the lower part of the soil profile (at 60- to 180-cm depths) group together fairly closely compared to the data from the upper part of the soil profile (15- to 45-cm depths). Data from the latter appear to have transitional water retention characteristics, but may actually represent points on scanning curves because they were wet up to different water contents during ponding. Observations from the trench dug around the plot at the study site for the second experiment show the textural transition from the upper soil layer to the coarser lower layer to be relatively abrupt. However, detailed particle-size analyses (see Table 5.1) indicate a textural gradation from the upper to the lower layer, which may explain the differences in water retention characteristics.

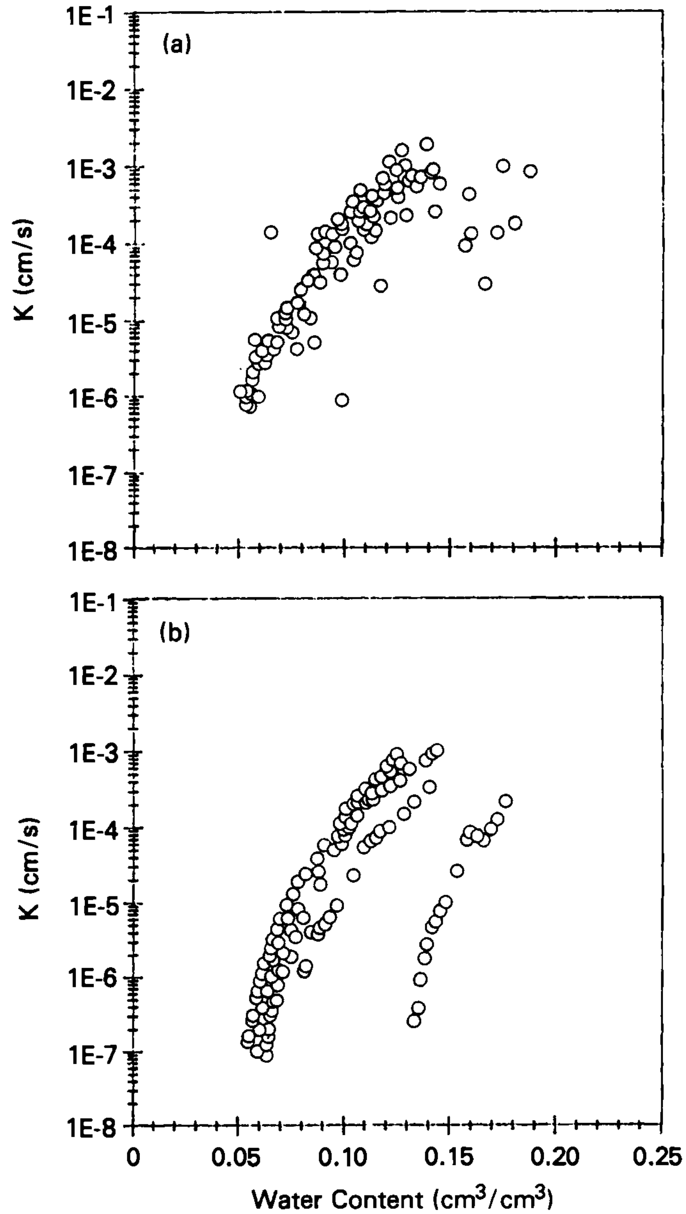

FIGURE 5.3. Comparison of Unsaturated Hydraulic Conductivity as a Function of Water Content for First and Second Experiments at the Grass Site (depth 30 to 180 cm). (a) Represents first experiment and (b) represents second experiment (restricted lateral flow).

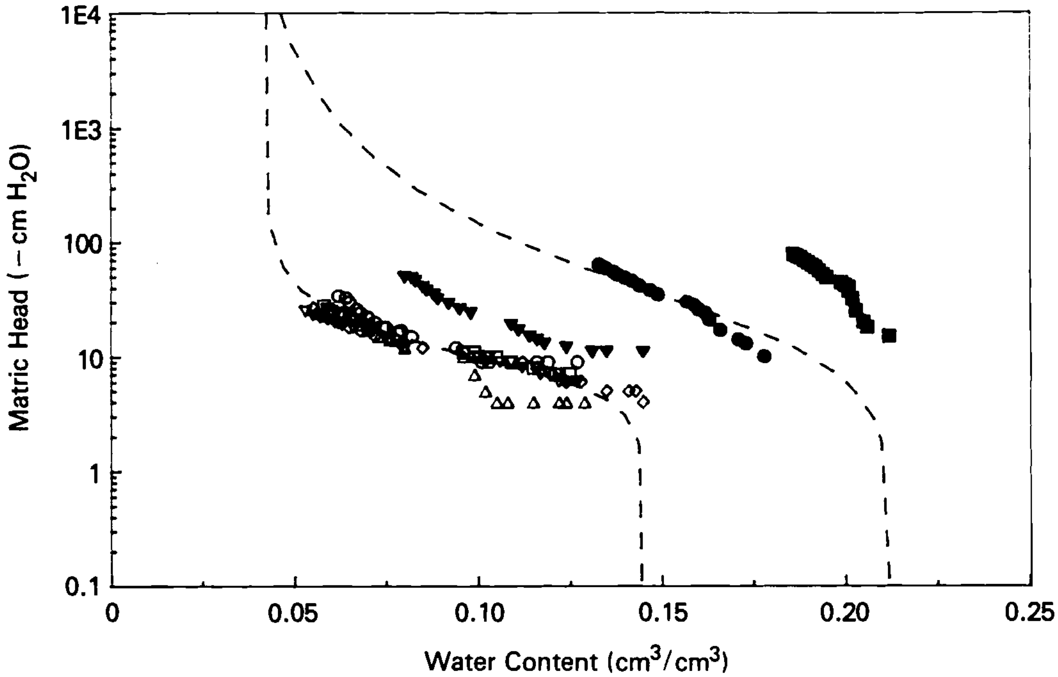

FIGURE 5.4. Water Retention Characteristics (matric head versus water content) for Second Experiment (restricted lateral flow) at the Grass Site. (All depths reported. Upper dashed line represents 30-cm depth; lower dashed line represents 60- to 180-cm depths.)

TABLE 5.1 Grass Site Laboratory Particle-Size and Hydraulic Conductivity Data

Depth (cm)	% Sand	% Silt	% Clay	Kls[a] (cm/s)
0-15	72	22	6	1.25E-4
15-30	77	17	6	6.23E-4
30-40	85	10	5	3.69E-3
40-50	90	6	4	1.67E-3
50-60	96	2	2	2.42E-3
60-80	96	2	2	2.67E-3
80-90	97	1	2	2.68E-3
95	94	4	2	2.01E-3

(a) Laboratory-saturated hydraulic conductivity determined by the falling head method (Klute and Dirksen 1986).

To describe the water retention characteristics and hydraulic conductivity-water content relationships of this layered profile, the van Genuchten (1978) water retention model was fit to the data. These curves are shown in Figure 5.4. The differences between the water retention characteristics and calculated hydraulic conductivities from various depths within the profile necessitated separate curve fittings of data from the upper and lower soil profile. Because of uncertainties regarding the accuracy of hydraulic head approximations at 15 cm and the effects of the textural transition at 45 cm, data from the 30-cm depth were assumed to be the most representative of the upper part of the soil profile. Data from the 60- to 180-cm depths were fitted simultaneously to represent the lower part of the soil profile.

The residual water content values, θ_r, were fixed at the initial (preponding) average water contents (i.e., 0.036 cm^3/cm^3 and 0.042 cm^3/cm^3 for the upper and lower parts of the profile, respectively). The saturated water contents, θ_s, were fixed at the highest water contents obtained during the experiment (i.e., 0.212 cm^3/cm^3 and 0.145 cm^3/cm^3 for the upper and lower parts of the profile, respectively). The saturated hydraulic conductivity, K_s, was fixed for the entire profile at the infiltration rate of 2E-3 cm/s. This value was measured immediately before the start of drainage (i.e., at time zero). This value is approximately two times the field-saturated hydraulic conductivity, K_{fs}, measured in the upper part of the soil profile with a Guelph permeameter (see Table 4.3 of Rockhold, Fayer, and Gee 1988). The field-measured water contents and hydraulic conductivities are not saturated values. For purposes of curve-fitting, however, θ_s and K_s are simply notational distinctions representing the highest values of water content and hydraulic conductivity, respectively, that were obtained during the experiments. The Mualem (1976) conductivity model, as described by Rockhold, Fayer, and Gee (1988), was used with K_s = 2E-3 cm/s and the closed-form solution of the van Genuchten water retention function (van Genuchten 1978) to predict unsaturated hydraulic conductivities for both soil layers. Figure 5.5 shows the resulting hydraulic conductivity curves.

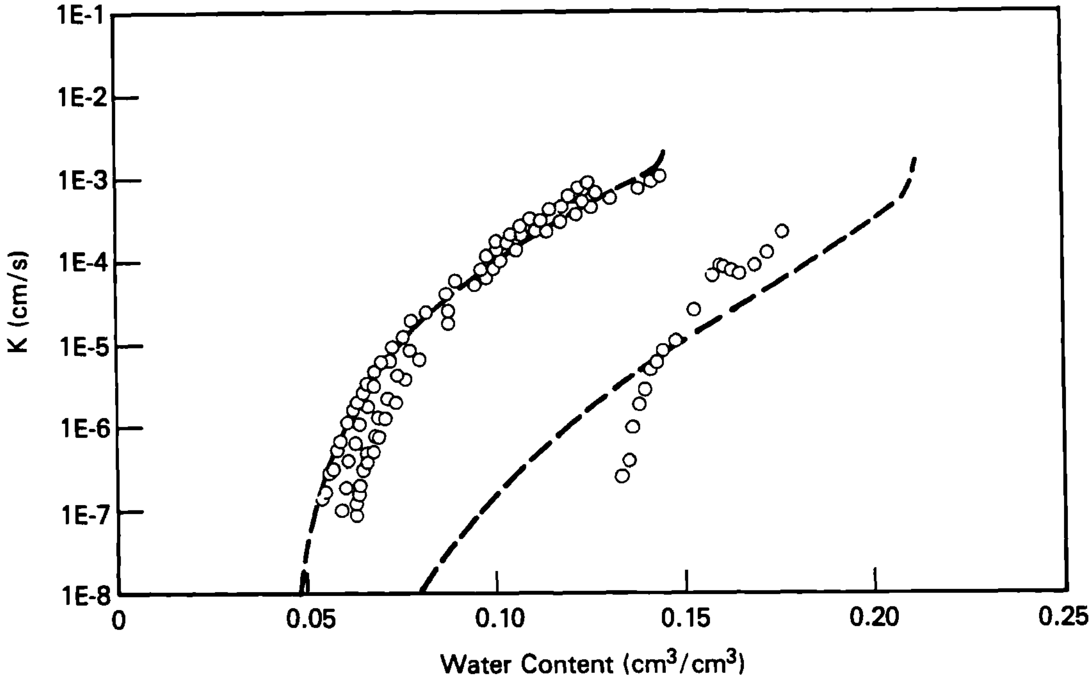

FIGURE 5.5. Calculated Hydraulic Conductivities for Second Experiment (restricted lateral flow) at the Grass Site. (Curve and data on right represent the 30-cm depth. Curve and data on left represent 60- to 180-cm depths.)

The curve representing conductivities predicted for the lower soil layer in Figure 5.5 closely matches the measured conductivities over the range of measured water contents. Predicted conductivities represented by the curve depicting the 30-cm depth are up to five times lower than calculated conductivities at water contents greater than 0.15 cm^3/cm^3, and up to an order of magnitude higher than calculated conductivities at water contents less than 0.15 cm^3/cm^3.

The variations in hydraulic properties within the upper part of the soil profile may be attributed to hysteresis (i.e., nonunique water content versus matric head relationships) and/or textural gradation. Soils with relatively high sand contents, such as those found at the Grass Site, generally show distinctly different (higher) water contents when drained than when wetted to the same matric head values. Laboratory-measured water retention data are most generally related to "primary drying curves" while field-measured water retention data are related to so-called "scanning curves" (Hillel 1982).

Analyses of laboratory data yielded two relatively distinct groups of water retention characteristics. Averaging these characteristics yielded two sets of data representing the 0- to 40-cm layer and the 40- to 95-cm layer at the site (see Table 5.2). Assuming these data are good representations of primary drying characteristics, the van Genuchten (1978) model was fit to the data to determine the primary drying curve for each layer. The resulting data and fitted water retention curves are shown in Figure 5.6.

The first few water retention data points measured after time zero from each depth in the unsteady drainage-flux experiment appear to fall on main wetting curves. As the soil profile drains, these data appear to break off of the wetting curves onto intermediate scanning curves. By assuming that main wetting curves have the same basic shape as main drying curves, and that these curves form a closed loop, a representation of the primary wetting characteristics for each layer was determined. The α parameter determined from fitting the laboratory water retention characteristics with the van Genuchten (1978) model was scaled according to $\alpha h = \alpha' h'$. The term α represents the fitted value for the laboratory data, and h is the value of matric head on the fitted drying curve corresponding to h′, which is measured at the same water content but presumably is on the main wetting curve.

TABLE 5.2. Laboratory-Measured Water Retention Characteristics for the Grass Site

	Water Content, cm^3/cm^3, at Matric Head, -cm								
Depth, cm	0	2	5	10	20	50	100	1000	15300
0-15	0.326	0.324	0.318	0.313	0.296	0.258	0.169	0.094	0.068
15-30	0.273	0.273	0.273	0.265	0.255	0.222	0.163	0.100	0.078
30-40	0.291	0.291	0.291	0.290	0.194	0.161	0.155	0.098	0.070
Mean	0.297	0.296	0.294	0.294	0.248	0.214	0.162	0.097	0.072
40-50	0.388	0.386	0.380	0.352	0.134	0.101	0.074	0.060	0.049
50-60	0.335	0.333	0.327	0.239	0.092	0.077	0.060	0.043	0.039
60-80	0.364	0.364	0.356	0.328	0.086	0.058	0.054	0.042	0.036
80-90	0.407	0.407	0.399	0.335	0.096	0.066	0.040	0.040	0.033
95	0.422	0.422	0.418	0.378	0.096	0.066	0.046	0.040	0.035
Mean	0.383	0.382	0.376	0.326	0.101	0.074	0.055	0.045	0.038

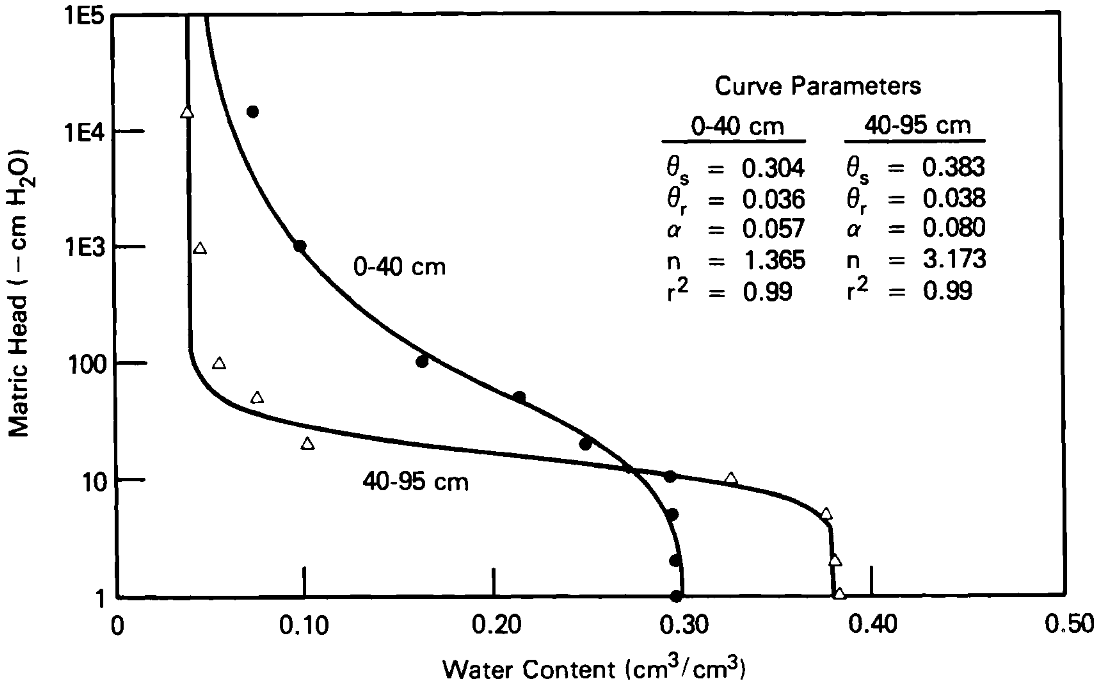

FIGURE 5.6. Water Retention Characteristics Measured in the Laboratory for Grass Site Soil

The α parameters determined by fitting the laboratory data were scaled as described, and the resulting wetting and drying curves are shown in Figures 5.7 and 5.8 with field data from the second unsteady drainage-flux experiment. These figures portray the upper and lower parts of the soil profile, respectively. The drying curves represent fits to average, laboratory-measured water retention data. The hypothetical wetting curves may or may not accurately represent the actual wetting characteristics. Given the available data, however, these curves appear to be reasonable and to bracket the potential hysteretic behavior of the layers in this soil profile.

In conclusion, lateral flow was significant in the first unsteady, drainage-flux experiment at the Grass Site; this is evidenced by total profile water storage changes that were approximately 24% greater in the first experiment than in the second experiment, and calculated hydraulic conductivities for the first experiment, which were up to one order of magnitude greater than those calculated for the second experiment.

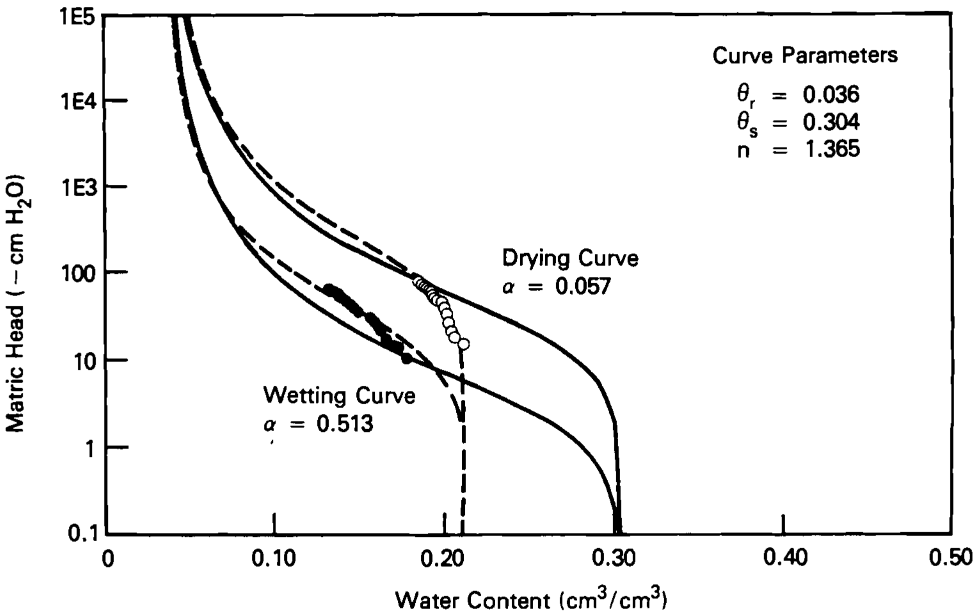

FIGURE 5.7. Field-Measured Water Retention Characteristics from the 30- and 45-cm Depths (upper soil profile) in the Second Experiment at the Grass Site. (Solid lines represent main drying and wetting curves. Dashed lines represent scanning curves.)

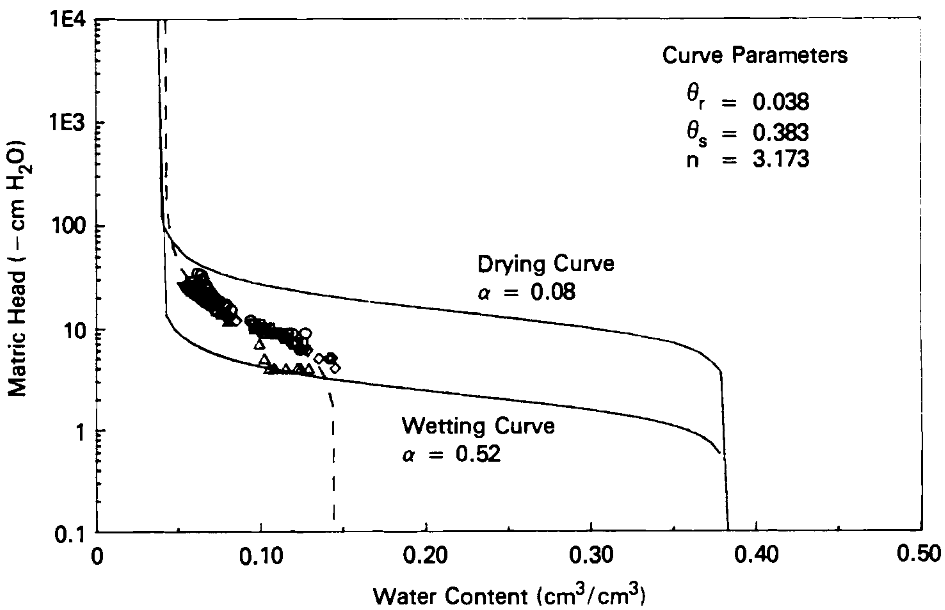

FIGURE 5.8. Field-Measured Water Retention Characteristics from the 60- to 180-cm Depths (lower soil profile) in the Second Experiment at the Grass Site. (Solid lines represent main wetting and drying curves. Dashed line represents scanning curve.)

The water retention data from these experiments also appear to exhibit hysteretic behavior. Assuming the field data to be hysteretic, water retention curves were fit to laboratory-measured water retention data to determine the main drying curves for the two soil layers. The fitted drying curve parameters were then scaled to generate hypothetical wetting curves. These wetting and drying curves approximate the potential hysteretic behavior of the field-measured water retention characteristics from the second experiment. Using such an approach to account for hysteresis effects helps to reconcile the differences between laboratory- and field-measured hydraulic properties. This evidence that hysteresis effects are significant suggests that hysteresis models should be incorporated into existing water balance computer codes such as UNSAT-H (Fayer, Gee, and Jones 1986). Until then, the laboratory drying curve parameters listed in Figures 5.7 and 5.8 should be used for model simulations of the Grass Site, with Ks = 2.0E-3 cm/s.

5.2 UNSATURATED HYDRAULIC CONDUCTIVITY FOR THE MCGEE RANCH

The first unsteady drainage-flux method experiment at the McGee Ranch was also repeated because of uncertainties as to whether or not the 2-m by 2-m plot size was sufficient to create a buffer zone that minimized lateral flow out of the plot profile. In the second experiment at this site, the plot area was expanded to approximately 4 m by 4 m. A trench was not dug around the plot profile and sealed with plastic as in the second experiment at the Grass Site, because no distinct layering of the soil profile was evident at the McGee Ranch.

Measured water retention characteristics and calculated hydraulic conductivities from this second experiment were very similar to those of the first experiment. If lateral flow out of the plot was significant in either experiment, it was not apparent because of the relative uniformity of the soil profile. Therefore, the results of the first unsteady drainage-flux experiment conducted at the McGee Ranch are judged to be valid (Rockhold, Fayer, and Gee 1988). Data from the second experiment at the McGee Ranch are listed in Appendix E of this report.

5.3 WATER RETENTION CHARACTERISTIC PREDICTIONS

The Arya-Paris (1981) model is a capillary pore model that translates particle-size distributions into pore-size distributions. Cumulative pore volumes, corresponding to increasing pore radii, are divided by the sample bulk volume to determine the volumetric water contents. The pore radii are then converted to equivalent matric head values by using the equation of capillarity.

To compute pore volumes and radii, the particle-size distribution is subdivided. The solid mass of each subdivision is assumed to form a matrix with a bulk density equal to that of an undisturbed field sample. An equivalent pore volume for a unit of sample mass is then computed from

$$Vv_i = (W_i/\rho_p)e; \; i = 1,2,.....,n \tag{5.1}$$

and the corresponding pore radius from

$$r_i = R_i \, [4en_i^{(1 - \underline{a})}/6]^{1/2} \tag{5.2}$$

where Vv_i = pore volume
W_i = solid mass
ρ_p = particle density
e = void ratio
r_i = mean pore radius
R_i = particle radius
n_i = number of particles
$\underline{a}$ = constant (pore geometry factor)

The Arya-Paris model approximates a pore length, which corresponds to a given particle-size range, as the number of particles that lie along the pore path times the length contributed by each particle. In a cubic close-packed assemblage of uniform-size spheres, the total pore length is estimated to be equal to $n_i 2R_i$. Because actual soil particles are nonspherical, the model assumes each particle will contribute a length greater than the diameter of an equivalent sphere. The number of particles required to track a pore path is then assumed to equal n_i^a, where a is greater than 1. Thus, the a parameter essentially adjusts the pore radii formulation to account for the nonsphericity of particles and pore tortuosity.

The concept of fractals provides a means of quantifying a variety of scale-invariant processes in nature (Mandelbrot 1982). A power function relationship between number and size is by definition a fractal. Turcotte (1986) has shown that the cumulative particle-size distribution of natural soil materials can be of a fractal nature of the form

$$N = CR^{-D} \tag{5.3}$$

where N is the number of particles larger in radius than R, C is a constant, and D is the fractal dimension. Mandelbrot, Passoja, and Paullay (1984) suggest that the fractal dimension of a transect through a fractal volume can be taken as two less than the dimension of the volume.

Scott Tyler of the Desert Research Institute, Reno, Nevada, suggested application of the concepts of fractal mathematics to independently estimate the a parameter in the Arya and Paris (1981) water retention model. Work by Tyler[a] suggests that the a parameter may be equal to the fractal dimension of a pore trace, representing the tortuosity of the pore trace. Thus, given a particle-size distribution, the fractal dimension of a tortuous pore trace (the a parameter) can be determined by subtracting two from the absolute value of the slope of a log-log plot of particle radii versus cumulative number of particles.

To test this technique for independently determining the a parameter in the Arya and Paris (1981) model, particle-size distribution data were first digitized by PNL from curves representing soils C and F in Figure 1 of Arya and Paris (1981). The a parameters were then determined from these particle-size distributions by plotting mean particle radii (mm) versus cumulative number of particles greater than the radii.

(a) Personal Communication with S. W. Tyler, Desert Research Institute, University of Nevada, Reno, Nevada, 1987.

The $\underline{a}$ parameter determined from this fractal analysis for soil C was 1.227. The best-fit value of the parameter determined by Arya and Paris for this soil was 1.362. Arya and Paris (1981) computed this value by minimizing the sums of the absolute value of the logs of measured matric heads minus the logs of predicted matric heads.

Figure 5.9 shows the cumulative number of particles plotted versus mean particle radius from digitized data representing Arya and Paris soil F. The $\underline{a}$ parameter determined by this analysis was 0.948. Four of the digitized data points were then selectively removed and a first-order regression of the remaining data yielded an $\underline{a}$ parameter of 1.056. This example illustrates the sensitivity of this fractal determination of the $\underline{a}$ parameter to the number and spacing of particle-size-distribution data points. The best-fit value of the $\underline{a}$ parameter determined by Arya and Paris (1981) for soil F was 1.389.

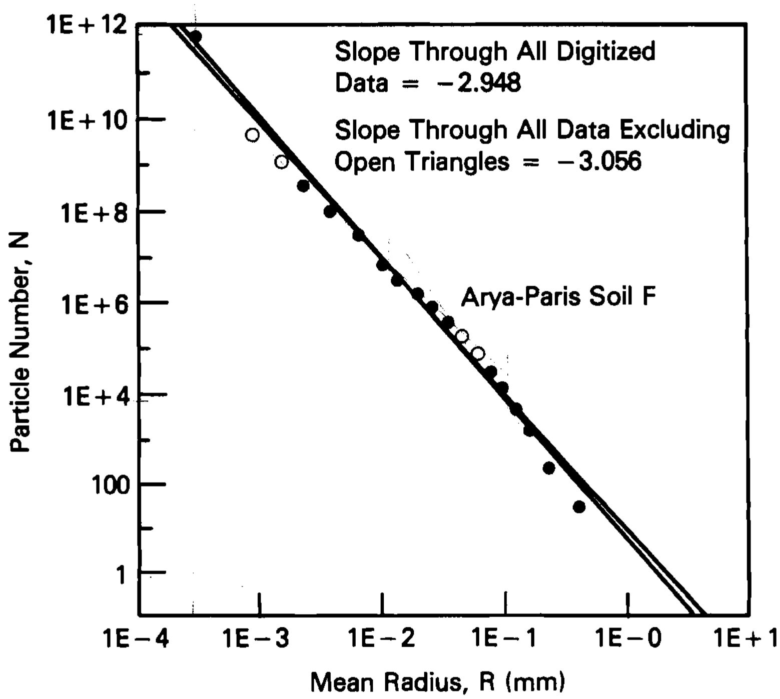

FIGURE 5.9. Computed Slopes for Particle Number Versus Mean Radius for Soil F of Arya and Paris (1981)

Sixteen soil samples were also collected from the FLTF and analyzed by this fractal approach to determine the a parameter. The samples represent a composite of A to C soil horizons that were excavated from the borrow pit at the McGee Ranch. This pit is located adjacent to the unsteady, drainage-flux experiment plot at the site. Particle-size distributions, particle densities, and water retention characteristics were determined for these samples using standard analysis methods (Klute 1986).

All of the samples are classified as silt loams with the exception of two, which are classified as loams. The sand, silt, and clay percentages of the samples ranged from 32-44%, 42-59%, and 7-14%, respectively. Results of the particle-size analyses for these soils are listed in Table 5.3. The average particle density of the samples was 2.72 (± 0.04) g/cm^3.

Water retention characteristics were predicted, using the Arya and Paris (1981) model, from the particle-size distributions of each of the 16 samples, with the fractal analysis to determine the a parameters. A bulk density of 1.37 g/cm^3 and a particle density of 2.72 g/cm^3 were used for all model predictions. The best-fit values of the a parameter, visually determined for the 16 FLTF samples, ranged from 1.10 to 1.25. The a parameters determined for three of the samples by the fractal analyses were outside the visually determined best-fit range (see Table 5.4). These samples were D05-03 (a = 1.081), D13-08 (a = 1.265), and D14-04 (a = 1.328). Using these three a parameters in the Arya and Paris model resulted in predicted water retention characteristics that were not in as close agreement (visually) with the measured data as can be obtained with different values of a. Therefore, the geometric mean value of the 16 a parameters determined by fractal analyses was used for predicting water retention characteristics for all 16 samples using the Arya and Paris model. This mean value is 1.201, with a geometric standard deviation of 0.002. The geometric mean, rather than the arithmetic mean, was used because particle-size distribution data generally show log-normal distributions. The arithmetic mean value of a, however, is 1.203, with a standard deviation of 0.003. The results of these fractal analyses are listed in Table 5.4.

TABLE 5.3. Results of Soil Particle-Size Analysis for the Field Lysimeter Test Facility

Sample ID	% Sand	% Silt	% Clay	Textural Class Name
D02-10	32	59	9	Silt Loam
D02-16	38	53	9	Silt Loam
D04-04	36	57	7	Silt Loam
D04-10	44	49	7	Loam
D05-03	44	42	14	Loam
D07-04	38	52	10	Silt Loam
D08-15	43	50	7	Silt Loam
D09-01	38	52	10	Silt Loam
D09-02	38	52	10	Silt Loam
D09-05	40	47	13	Loam
D10-04	37	53	10	Silt Loam
D11-06	38	52	10	Silt Loam
D11-08	34	59	7	Silt Loam
D12-14	40	53	7	Silt Loam
D13-08	38	52	10	Silt Loam
D14-04	33	56	11	Silt Loam

TABLE 5.4. Fractal Analysis Results of Field Lysimeter Test Facility Soil Particle-Size Distribution Data. Least-squares regressions of mean radius (mm) versus particle number.

Sample ID	Slope	Intercept	r^2	Fractal Dimension, $\underline{a}$
D02-10	-3.244	0.316	0.980	1.244
D02-16	-3.201	0.394	0.980	1.201
D04-04	-3.220	0.360	0.980	1.220
D04-10	-3.166	0.453	0.976	1.166
D05-03	-3.081	0.644	0.988	1.081[a]
D07-04	-3.186	0.441	0.984	1.186
D08-15	-3.151	0.490	0.978	1.151
D09-01	-3.188	0.432	0.982	1.188
D09-02	-3.190	0.433	0.982	1.190
D09-05	-3.175	0.446	0.982	1.175
D10-04	-3.241	0.298	0.976	1.241
D11-06	-3.195	0.409	0.980	1.195
D11-08	-3.238	0.319	0.980	1.238
D12-14	-3.171	0.433	0.976	1.171
D13-08	-3.265	0.265	0.976	1.265[a]
D14-04	-3.328	0.139	0.980	1.328[a]

Geometric Mean $\underline{a}$ = 1.201
Standard Deviation = 0.002

(a) Values are outside the visually determined best-fit range of $\underline{a}$.

Measured water retention characteristics from four of the 16 FLTF soil samples are plotted with predicted values in Figures 5.10 and 5.11. Model predictions match the measured data for all 16 samples within a factor of two of matric head values between water contents of 0.40 cm^3/cm^3 and 0.10 cm^3/cm^3. At water contents between 0.40 cm^3/cm^3 and 0.496 cm^3/cm^3, the predicted values are generally greater than the measured data by as much as a factor of five. The value of 0.496 cm^3/cm^3 is the total porosity calculated for the laboratory samples, which were all packed to a bulk density of 1.37 g/cm^3.

None of the laboratory samples were thoroughly saturated (i.e., they all had water contents that were less than the calculated total porosity). Therefore, it is possible that the predicted water retention characteristics do not match the measured data more closely at higher water contents because the measured data actually represent points on hysteresis loops before reaching the primary drying curve at a water content of about 0.40 cm^3/cm^3. At water contents below about 0.10 cm^3/cm^3, water retention characteristics predicted for this soil by a capillary pore model should not be expected to match measured data as well as at higher water contents, because under these drier soil moisture conditions, water is held primarily in surface films and may not behave in accordance with capillary laws. Overall, the predicted water retention characteristics appear to be good representations of points on main drying curves at water contents between 0.496 cm^3/cm^3 and 0.100 cm^3/cm^3.

Third-order polynomial, least-squares regressions were performed on the predicted water retention characteristics for each sample between matric heads of -50 cm to -3800 cm. The equations of the fitted curves (R-values of 0.99 to 1.00) were then used to calculate matric heads for each sample (at the laboratory-measured water contents) corresponding to matric heads of -100 cm, -150 cm, -510 cm, -1020 cm, and -4080 cm. Predicted and measured matric heads at fixed-water contents are compared in Figure 5.12. A first-order regression of predicted versus measured matric head values resulted in a slope of 0.87, with r^2 equal to 0.956.

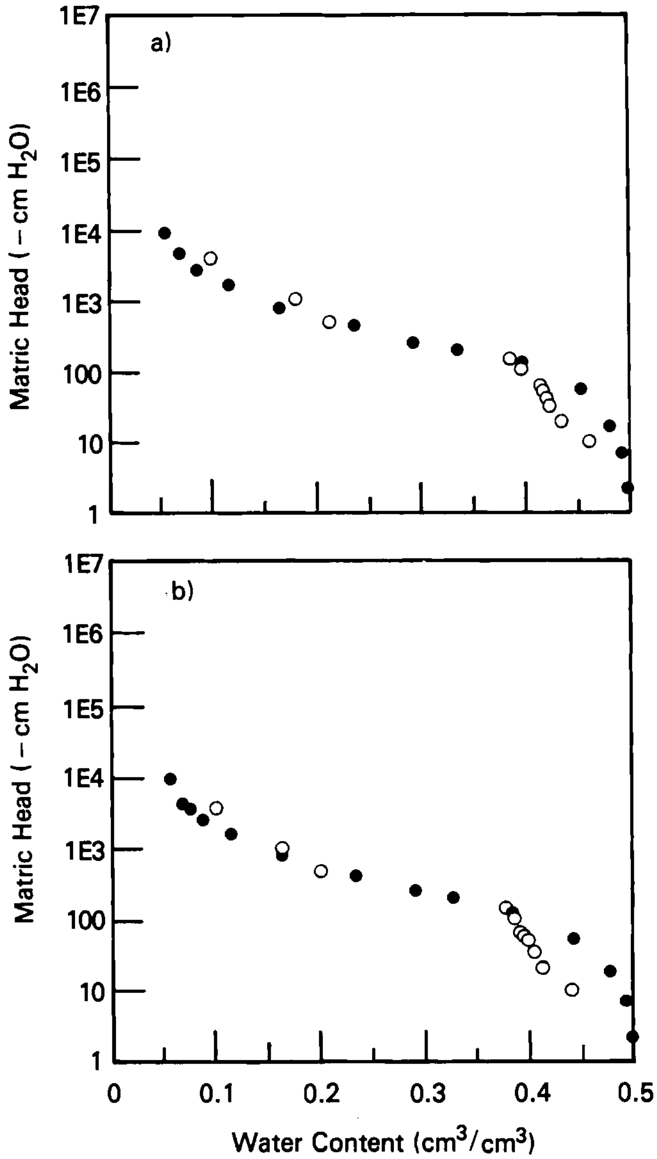

FIGURE 5.10. Soil-Water Retention Characteristics for the McGee Ranch. a) Represents sample FLTF D10-04; b) represents sample FLTF D11-06. [Solid circles are predicted from the Arya and Paris (1981) model. Open circles are measured data.]

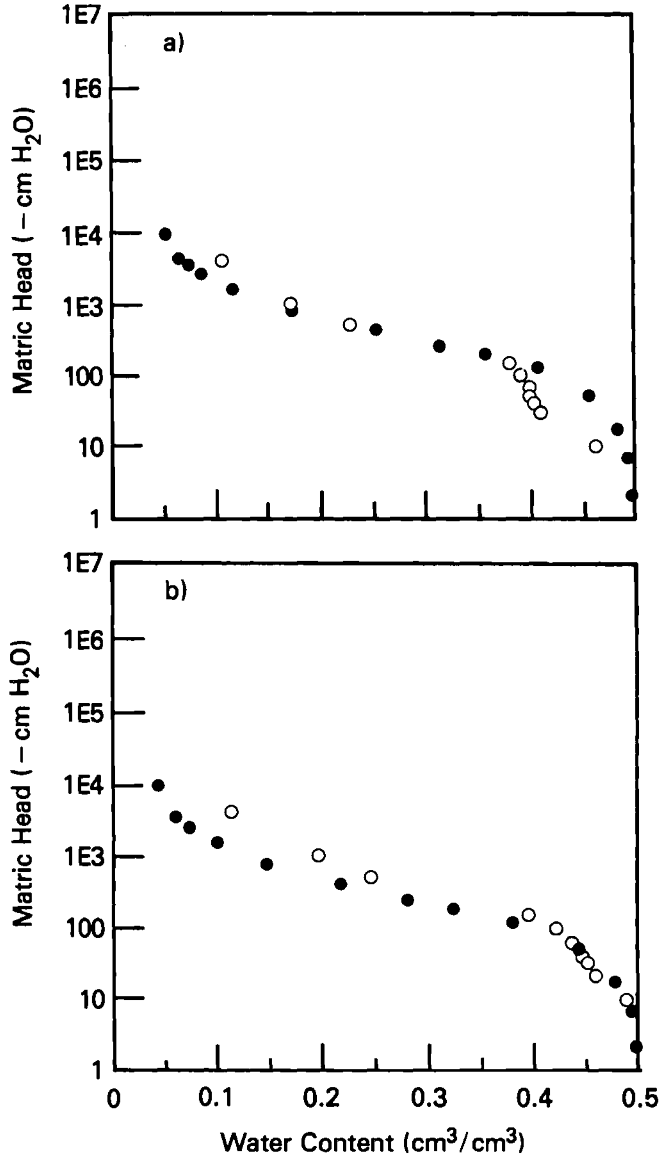

FIGURE 5.11. Soil-Water Retention Characteristics for the McGee Ranch. a) Represents sample FLTF D11-08; b) represents sample FLTF D12-14. [Solid circles are predicted from the Arya and Paris (1981) Model. Open circles are measured data.]

Figure 5.12 shows that the measured and predicted values are in close agreement at matric heads of -100 cm and -510 cm, and are reasonable at -1000 cm. The range in variation of the predicted matric head values is about the same as that for the five measured matric head values shown, suggesting that the variability in the predictions stems from differences in

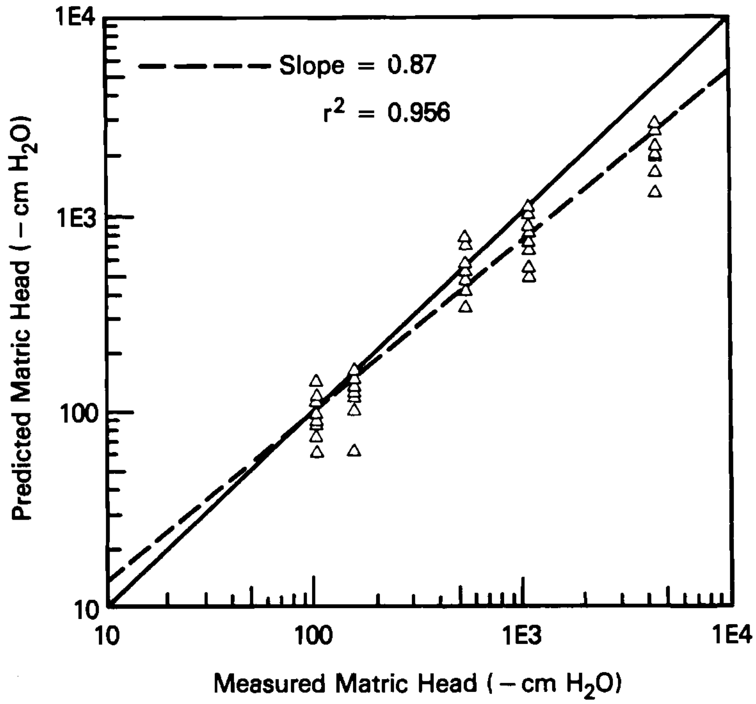

FIGURE 5.12. Predicted Versus Measured Matric Head Values for 16 McGee Ranch (FLTF) Soils for a Range of -100 cm to -5000 cm of Matric Head

the particle-size distributions of the samples. This variation may also be due in part to the use of the geometric mean a rather than individual a's for each sample.

Fractal analysis was also performed on particle-size distribution data from the upper and lower parts of the soil profile at the Grass Site. Figure 5.13 shows the regressions of particle number versus mean radius for these data. The a parameters determined from these analyses are 0.718 and 0.463 for the upper and lower parts of the soil profile, respectively.

According to Tyler[a] a small fractal dimension indicates a fairly straight flow path, while a fractal dimension greater than 1.5 yields tortuous pore channel representations which are unrealistic. Tyler also suggests that fractal dimensions of pore traces that are less than one do not

(a) Personal Communication with S. W. Tyler, Desert Research Institute, University of Nevada, Reno, Nevada, 1987.

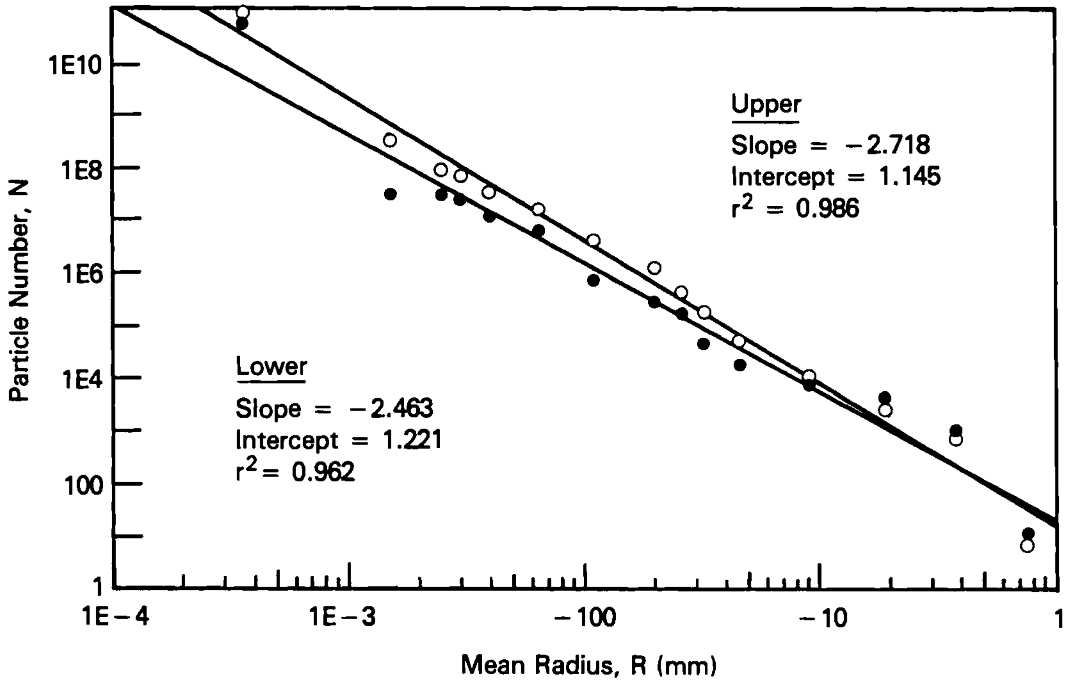

FIGURE 5.13. Particle Number Versus Mean Radius for Grass Site Soils. (Lower curve represents 60-cm depth. Upper curve represents 20-cm depth.)

show scale-invariant similarity, and that use of the fractal model is not appropriate in such cases. Therefore, the a parameters used in the Arya and Paris (1981) model for the Grass Site were determined by visual fit to the mean laboratory-measured water retention data. The laboratory data, rather than the field data, were used because the laboratory data appeared to be more representative of main drying characteristics.

Figure 5.14 shows the water retention curves fit to laboratory data and the water retention characteristics predicted by the Arya and Paris (1981) model for the Grass Site. Mean particle-size distribution data from the upper and lower parts of the soil profile at the Grass Site were used to generate these predicted characteristics. The best-fit values of a were visually determined from these data and are 1.5 and 1.3 for the upper and lower parts of the soil profile, respectively.

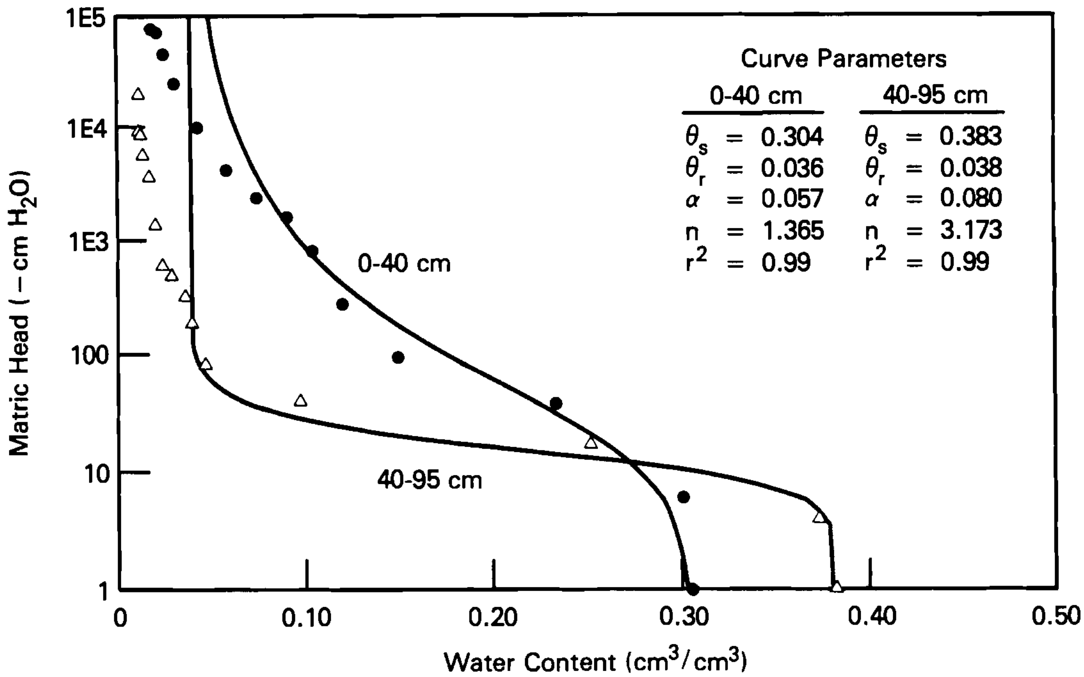

FIGURE 5.14. Water Retention Curves and Curve-Fitting Parameters for the Grass Site. (Solid lines represent laboratory data. Points represent characteristics predicted from the Arya and Paris model.)

Predicted water retention characteristics are in agreement with the curve representing the mean laboratory water retention characteristics for the upper part of the soil profile within a factor of two for water contents from 0.304 cm^3/cm^3 to about 0.080 cm^3/cm^3. At water contents from 0.080 cm^3/cm^3 to the residual water content of 0.036 cm^3/cm^3, the predicted characteristics underestimate matric head by up to an order of magnitude. Predicted water retention characteristics for the lower part of the soil profile match the mean laboratory-measured water retention characteristics within a factor of two from 0.383 cm^3/cm^3 to the residual water content of 0.038 cm^3/cm^3.

Fractal analysis was also used to estimate the a parameter for the BWTF soil. The same composite particle-size distribution from samples 18A and 18B that was used previously in the study by Rockhold, Fayer, and Gee (1988), was used to estimate the a parameter by fractal analysis. Figure 5.15 shows the

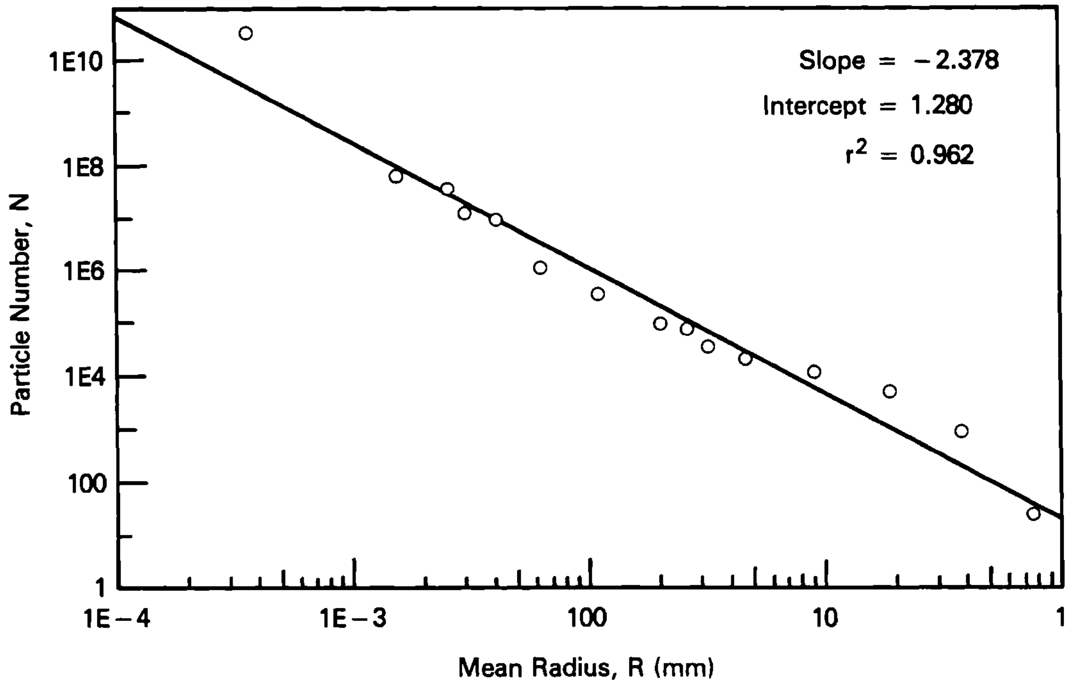

FIGURE 5.15. Particle Number Versus Mean Radius for Sandy Soil at the Buried Waste Test Facility

log-log plot from these data of particle number versus mean radius. The a parameter determined from this analysis is 0.378. This low value indicates that, like the Grass Site soil, the BWTF sand does not show scale-invariant similarity and, thus, the fractal model is not appropriate to use. The visually determined best-fit a for this soil, taken from previous work by Rockhold, Fayer, and Gee (1988), is 1.18.

In conclusion, the Arya and Paris (1981) model provides reasonable estimates of water retention characteristics for the range of matric heads (from 0 to -1000 cm) where capillary flow dominates for the soils from the Grass Site, McGee Ranch, and BWTF. Determination of the a parameter using fractal analysis was successful for the McGee Ranch silt loam soil, but was not successful for the sandy loam and sands from the Grass Site and BWTF. The a parameters generated from these analyses for the Grass Site and BWTF soils were less than one, indicating that these soil materials do not show scale-invariant similarities. In such cases[a], this particular fractal model is inappropriate.

Tyler[a] also noted that this fractal analysis yields estimates of a that are less than one for one of the sandy soils of his study. It is currently unclear whether this nonfractal behavior is generally typical for coarser-textured soils. The fractal determination of the a parameter is also highly sensitive to the number of and spacing of particle-size distribution data points. Therefore, it was necessary to determine the a parameters in the Arya and Paris (1981) model for soils from the Grass Site and BWTF by visually fitting predicted water retention characteristics to measured data. Variations of the fractal model used could potentially be developed for estimating the a parameter for these coarser-textured soils.

5.4 HYDRAULIC PROPERTY SUMMARY

The parameters in Table 5.5 summarize the hydraulic properties of the Grass Site and McGee Ranch soils.

Field-measured saturated hydraulic conductivities were in close agreement with laboratory-measured saturated hydraulic conductivities. Unsaturated hydraulic conductivities calculated from field data for two experiments varied by up to one order of magnitude, depending on initial and boundary conditions.

Field-measured water retention characteristics showed considerable differences from laboratory-measured data. These differences were attributed to hysteresis effects, which were effectively bracketed by scaling the main drying curves determined from laboratory data to generate hypothetical wetting curves.

Water retention characteristics predicted from particle-size and bulk density data using a capillary pore model matched laboratory-measured values within a factor of two of the matric head over the range of field-measured water contents. The fractal parameter estimation technique tested for

(a) Personal Communication with S. W. Tyler, Desert Research Institute, University of Nevada, Reno, Nevada, 1987.

estimating a parameter in the capillary pore model was successful for only one of the three soils tested.

TABLE 5.5 Curve-Fitting Parameters for the van Genuchten (1978) Water Retention and Mualem (1976) Predictive Conductivity Models

Data Set	θ_r	θ_s	α	m	n	K_s
Grass Site Laboratory Data, Upper Profile						
Drying Curve	0.036	0.304	0.057	(b)	1.365	2.0E-3
Wetting Curve[(a)]	0.036	0.304	0.513	(b)	1.365	2.0E-3
Lower Profile						
Drying Curve	0.038	0.383	0.080	(b)	3.173	2.0E-3
Wetting Curve[(a)]	0.038	0.383	0.520	(b)	3.173	2.0E-3
Grass Site Field Data (Second Experiment)						
Upper Profile (30-cm depth)	0.036	0.212	0.065	(b)	1.438	2.0E-3
Lower Profile (60 to 180 cm)	0.042	0.145	0.123	(b)	2.484	2.0E-3
McGee Ranch (FLTF) Laboratory Data	0.005	0.496	0.016	(b)	1.372	9.9E-4
Field Data[(c)]	0.000	0.409	0.006	(b)	2.356	1.2E-3

(a) Hypothetical wetting curves generated by scaling the α parameter determined from laboratory data so that the wetting curves bracket the field-measured water retention characteristics.
(b) Mualem-based restruction, $m = 1 - 1/n$.
(c) From the first experiment conducted at the McGee Ranch (Rockhold, Fayer, and Gee 1988).

6.0 SITE WATER BALANCE CONSIDERATIONS

Table 6.1 lists water balance parameters for selected locations at the Hanford Site for the year July 1987 through June 1988. In calculating the annual evapotranspiration and the annual drainage (except where measured directly), we have assumed there has been no runoff since the soils at the test locations cited are generally coarse-textured and water infiltration rates exceeded precipitation and snowmelt rates during the test period. Table 6.2 shows the ratio of actual evapotranspiration to predicted potential evapotranspiration calculated from the neutron probe and weighing lysimeter data for the BWTF.

Figure 6.1 shows the monthly rainfall distribution for a 68-year period at the Hanford Site (based on historical data for 1912 through 1980 from the HMS). The data clearly show that wintertime precipitation dominates the Hanford Site and is likely responsible for net infiltration of water at locations where the soil is coarse textured and plant cover is sparse and/or shallow rooted. Figure 6.2 shows the monthly potential evapotranspiration for the past 10 years (1978 through 1987) calculated using a standard Penman-type calculation, which requires knowledge of daily temperature, radiation, and wind speed (Fayer, Gee, and Jones 1986, and reference therein to Doorenbos and Priutt methods for calculations of potential evapotranspiration). Figure 6.3 compares calculated potential evapotranspiration and precipitation for the HMS, for 1978 through 1987. Figure 6.4 shows the correlation between potential evapotranspiration (PET) and precipitation for the same period. The coefficient of determination (r^2 value) between PET and precipitation is 0.005, suggesting that these two variables are not correlated.

The data from Tables 6.1 and 6.2 also illustrate that estimates of potential evapotranspiration (as computed from climate variables alone) are virtually useless in predicting actual evapotranspiration and drainage at the Hanford Site. This is because when soil or plant surfaces are dry, as is the case much of the time at the Hanford Site, they no longer evaporate water to the atmosphere at the potential rate. For coarse, bare soils, the soil

TABLE 6.1. Water Balance Parameters for July 1987 Through June 1988

Location	Surface Condition	Precipitation, cm/yr	Storage Change, cm/yr	Drainage, cm/yr	Evapotranspiration, cm/yr
BWTF					
South caisson	Bare	12.5	-1.9	3.1	10.3
North weighing caisson	Bare	12.5	-1.9	4.1	9.3
South weighing caisson	Vegetated	12.5	0.5	0	12.0
CWTF					
10 lysimeters	Bare	12.5	-1.9	4.6	9.8
Grass Site	Vegetated	11.5	0.5	(2.0)[a]	10.0

(a) Estimated from Buried Waste Test Facility observations.

TABLE 6.2. Ratio of Actual Evapotranspiration (ET) to Predicted Potential Evapotranspiration (PET)[a] for July 1987 Through June 1988

Location	ET/PET
BWTF	
South caisson	0.06
North weighing lysimeter	0.05
South weighing lysimeter	0.07
CWFT	
10 lysimeters	0.06
Grass Site	0.06

(a) PET for all 300 North Area locations is assumed to be the same as at the Hanford Meteorological Station and equal to 163.2 cm.

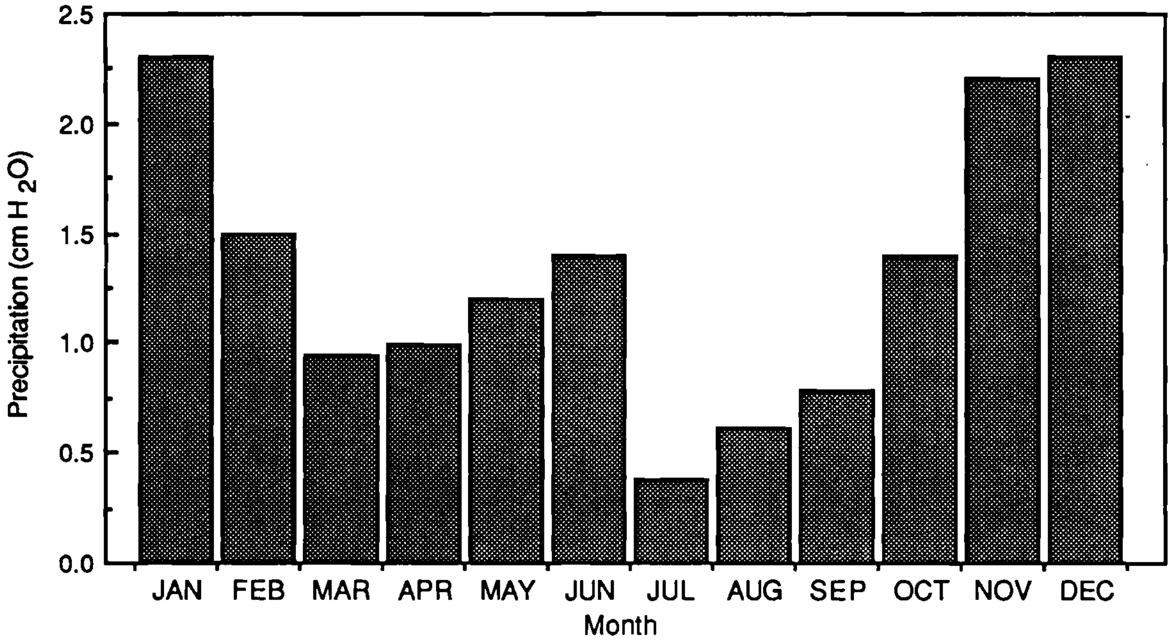

FIGURE 6.1. Monthly Rainfall Distributions Determined from Long-Term Averages (1912 through 1980) at the Hanford Site (after Stone et al. 1983)

surface dries relatively quickly and tends to form an armor or highly resistive layer that prevents rapid water losses except immediately after rainfalls. During the summer, the actual evapotranspiration is only a small fraction of the potential rate. Because most precipitation at the Hanford Site occurs during winter when the potential evaporation is lowest, the chance for water to be stored and eventually drain is markedly increased. Coarse (e.g., sandy or gravelly) soils having water storage capacities of only a few centimeters of water in the top meter of the soil profile are more susceptible to drainage than fine-textured (e.g., silty or clayey) soils that often have storage capacities exceeding the annual precipitation by several times (e.g., 40 to 60 cm of water).

The actual storage capacity of the soil is a function not only of the soil texture, but of plant cover and the distribution of precipitation. If deep-rooted plants are present, the effective storage capacity of the soil is increased because plant roots will intercept much, if not all, of the infiltrating water before it moves below the root zone. Thus, the presence of

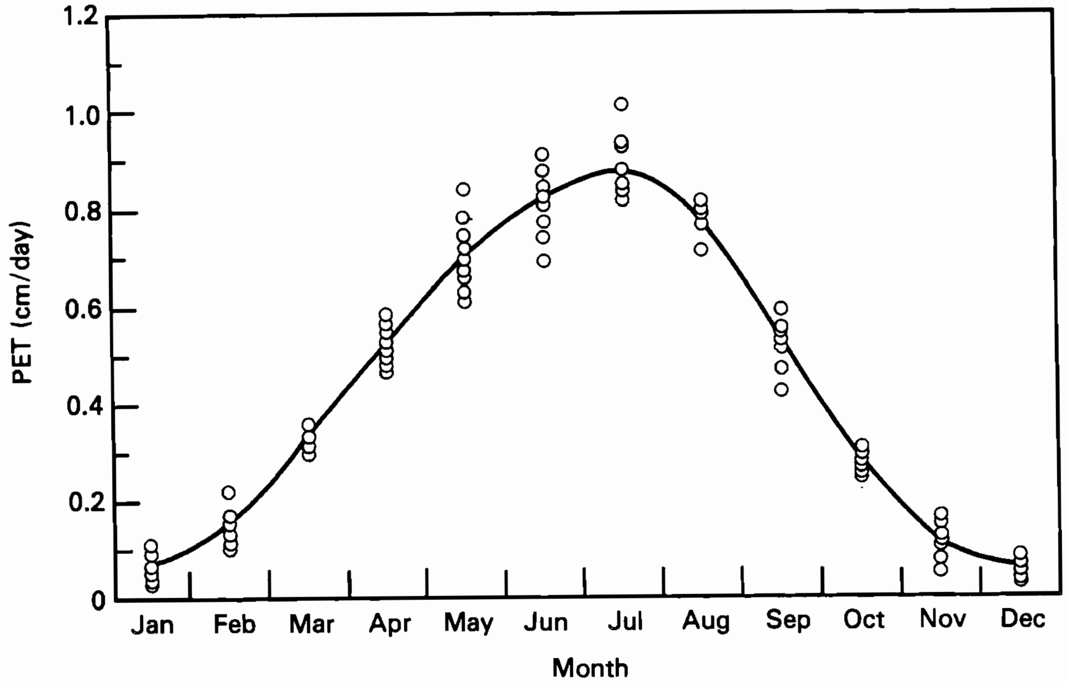

FIGURE 6.2. Average Daily Potential Evapotranspiration (PET) at the Hanford Meteorological Station Determined for Each Month of the Year Using the Penman Model for 1978 Through 1987

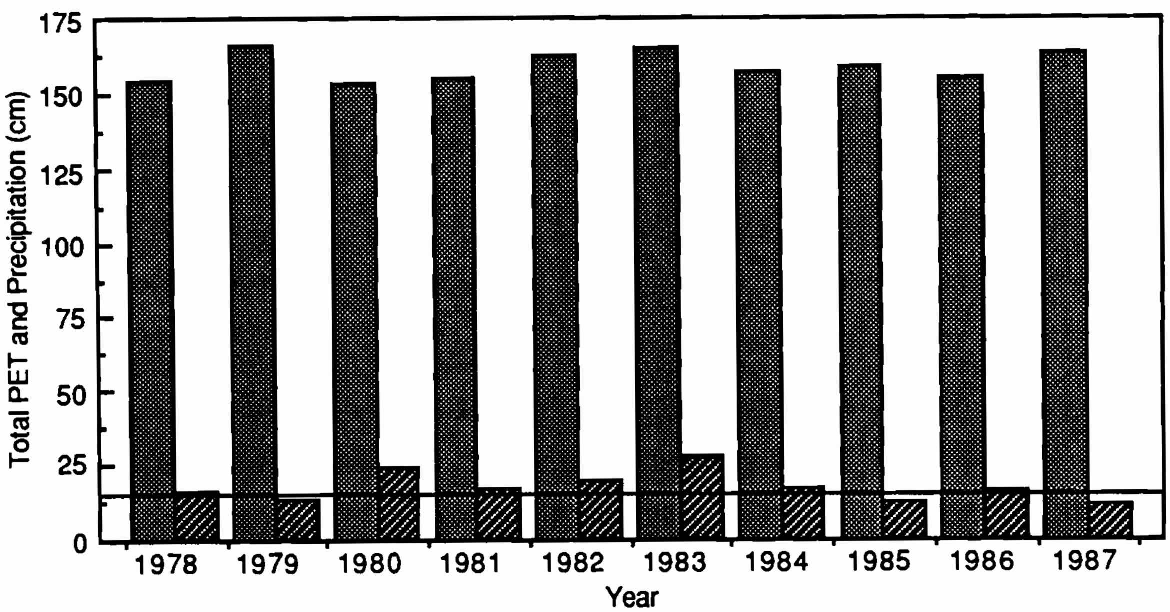

FIGURE 6.3. Total Potential Evapotranspiration (PET) and Precipitation (crosshatch) at the Hanford Meteorological Station for 1978 Through 1987. The solid line represents the long-term average (16 cm/yr) precipitation for the Hanford Site.

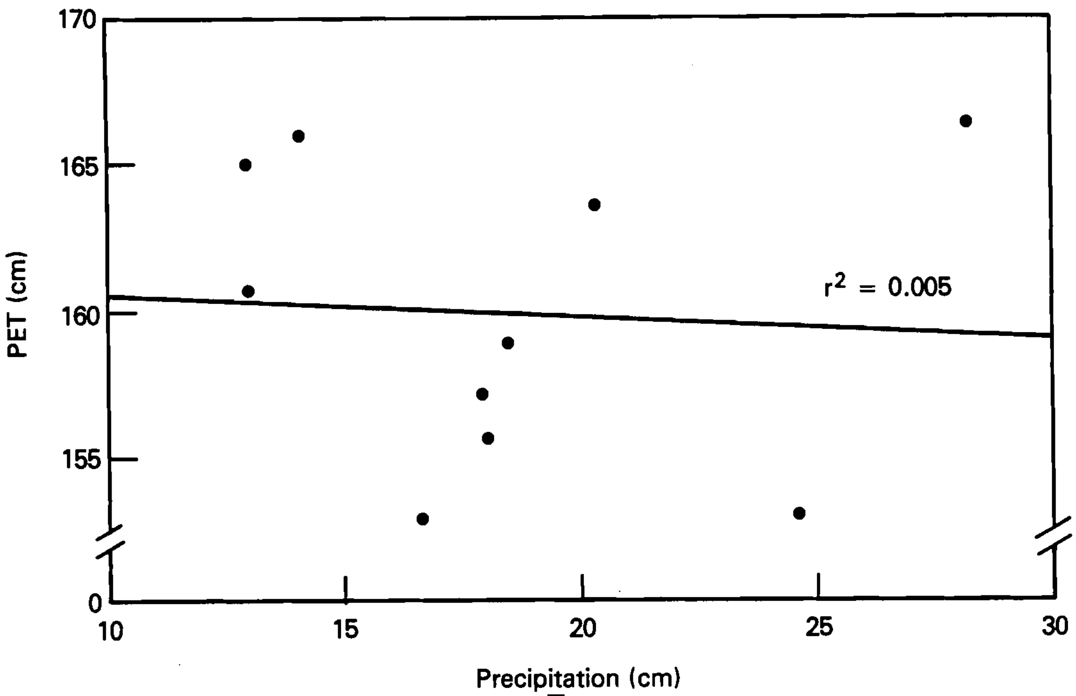

FIGURE 6.4. Correlation Between Potential Evapotranspiration (PET) and Precipitation for 1978 Through 1987

plants can significantly increase the storage capacity of both coarse and fine-textured soils. In a semiarid climate, as exists at the Hanford Site, a coarse soil with plant cover may in some years have adequate storage capacity to prevent drainage and in other years not. For example, change of vegetation from deep-rooted sagebrush to shallow-rooted cheatgrass, which often occurs after a fire, can dramatically change the storage capacity of a soil. If the grass root depth is only a few tens of centimeters and winter precipitation penetrates to depths of a meter or more, then the chances of deep drainage occurring are greatly enhanced. Such conditions (i.e., grass cover, lack of deep-rooted plants, coarse soils) have been present at the Grass Site for the past 5 years or more.

The distribution of precipitation, as well as its quantity, determine if the storage capacity of a soil will be exceeded in any given year. If the wintertime precipitation were doubled or if a large snowfall occurred by rapid snowmelting, the storage capacity of most coarse-textured soils at the Hanford Site would be exceeded and drainage would likely occur.

It is clear from the previous discussion that the storage capacity of a soil is a dynamic property. Estimates of the storage capacity of a given soil must be made on a site-specific basis and must include information about the plant cover and the distribution of precipitation. Models used to predict the water balance of a site must address these factors to be successful. The UNSAT-H model (Fayer, Gee, and Jones 1986) includes all of the key parameters (soil hydraulic properties, plant characteristics, and climatic variables) and has been used successfully to assess the dynamic nature of water balance parameters for selected conditions at the Hanford Site.

In summary, the following observations made related to Hanford Site water balance can be made.

1. Lysimeter measurements have quantified drainage rates ranging from 0 to more than 10 cm/yr. The range is a primary function of surface cover (from deep-rooted vegetation to bare soil) conditions. Drainage measured from July 1987 to June 1988 in BWTF and CWTF lysimeters located north of the 300 Area was influenced by present- and previous-year (below normal) precipitation; bare-soil drainage from July 1987 through June 1988 ranged from 3 cm/yr to 5 cm/yr. Previous-year drainage values exceeded 10 cm/yr as a consequence of higher wintertime precipitation.

2. Water storage changes from July 1987 through June 1988 for all lysimeter sites and the Grass Site were relatively small (ranging from 4 cm to 5 cm total storage) compared to previous years' records (more than 8 cm). The smaller water storage changes are also attributed to lower precipitation.

3. Water storage measurements at the 200 East lysimeter site show that bare surface conditions have significantly reduced summertime water storage losses compared to water storage losses from vegetated surfaces.

4. Potential evapotranspiration is not a reliable estimate of actual evaporation or evapotranspiration at the Hanford Site. There was no correlation between potential evapotranspiration and variation in precipitation for the past 10 years (1978 to 1988). Reliable

estimates of actual evapotranspiration cannot be obtained directly from estimates of precipitation or potential evapotranspiration. These estimates are best made by quantifying drainage rates, precipitation, and soil-water storage changes.

5. There is still relatively large uncertainty in predicting natural recharge for specific conditions at the Hanford Site. Additional lysimeter tests and continued monitoring of the present lysimeter facilities appear to offer the best approach to quantifying natural recharge over the expected range of conditions that exist at the Hanford Site.

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APPENDIX A

DATA ARCHIVING PROCEDURES

APPENDIX A

DATA ARCHIVING PROCEDURES

DATA BASE OBJECTIVES

Pacific Northwest Laboratory (PNL) is working under direction from the Westinghouse Hanford Company, Environmental Technology Group, to collect, analyze, and store data needed for performance assessment activities. The information and computer-encoded mathematical models needed to assess performance of proposed waste remediation and disposal options will be assembled in a quality-assured and consistent manner for retrieval and analysis. Major concerns that must be addressed include ensuring that 1) data are archived and documented adequately, 2) data are accessible through the Hanford Site computer network, and 3) the Hanford Site Performance Assessment (HSPA) data base is compatible with other Hanford Site data bases.

The data are currently stored and accessed using RS/1 software.[a] RS/1 is a data analysis system with graphical, statistical, and data management capabilities. The software is user friendly and can be operated both on the VAX[b] and IBM[c] PC/AT computer systems. Most data now reside in the HSPA MicroVAX[b], which has the advantages of large storage capacity and multiuser capabilities. Accessing the data using RS/1 on the IBM PC/AT offers the advantages of fast response time for data entry as a single user and, most importantly, compatibility with data collection software. Data are easily transferred from RS/1 on the IBM PC/AT to final storage on the VAX computer system. The organization of the data in this system and the current procedures for storage and retrieval are described in this report.

(a) RS/1 (The Research System) is a registered tradename of BBN Research Systems, Sunnyvale, California.
(b) VAX and MicroVAX are registered tradenames of the Digital Equipment Corporation (DEC), Maynard, Massachusetts.
(c) IBM is a registered tradename of the International Business Machines Corp., Boca Raton, Florida.

STANDARD INTERFACE TO OTHER HANFORD SITE DATA BASES

To make credible assessments of performance of waste remediation and disposal systems for the Hanford Site, all relevant data must be accessible. In addition to the HSPA data base, other data bases exist for a variety of Hanford Site data (e.g., the Hanford Site Protective Barriers Program data base, Hanford Site groundwater monitoring data base, Hanford Site compliance data base, and the Westinghouse Hanford Company ROCSAN data base (containing granulometric data).

It is not realistic to assume that any one data base contains and adequately documents all required data. Thus, either "switchboard" software must be developed to enable the HSPA data base to interface with, and access, information from the other data bases, or the HSPA data base must be compatible with an existing data base management system.

Of considerable interest to all Hanford Site environmental data management systems is the development of a new data base management system that will provide a geographically based retrieval system. A Geographic U.S. Information System (GIS) for Hanford, Pasco Basin, and/or Yakima Firing Range data is being developed at PNL, with funding provided by the U.S. Department of Defense. Among other features, this GIS will use a standard software interface to access different data bases. A comprehensive approach appears to provide the most cost-effective way for performance assessment personnel to interface with other data bases. During the next several years, the activities of the GIS development will be reviewed, and plans will be made to implement features of the GIS into the HSPA data base.

CURRENT DATA MANAGEMENT AND PROCEDURES

The objective of the HSPA data base is to provide the means to centralize, critically review, store, and retrieve reliable and consistent data to support various waste remediation and disposal studies at the Hanford Site. Several types of data have been, and are currently being, collected to support the calibration and validation of groundwater pathway models. Data stored in the HSPA data base are listed in Table A.1 according to type of data, method of collection, and location of data collection.

TABLE A.1. Types of Data Collected for the HSPA Data Base

Type of Data	Method of Collection	BWTF	Grass Site
Soil Moisture	Neutron probe or gravimetric	X	X
Drainage	Physical measurement	X	
Precipitation	Tipping bucket[a]	X	X
	Weighing Lysimeter[a]	X	
	Collection-type (non-recording)	X	X
Soil Water Potential	Tensiometers	X	X
Soil Temperature	Thermocouples[a]	X	X
Wind Speed and Direction	Anemometer[a]	X	X
Air Temperature	Thermistor[a]	X	X
Relative Humidity	Humidity transducer[a]	X	
Saturated Vapor Pressure	Calculated from temperature and relative humidity[a]	X	
Solar Radiation	Pyranometer[a]	X	X
Phenology	Observations	X	X
Vegetative Cover	Observations	X	X
Evaporation or Evapotranspiration Rates	Lysimeter weight changes	X	

(a) Connected to data logger.

Work on the HSPA data base currently involves collection of water balance data from the Buried Waste Test Facility (BWTF) and the Grass Site. Numerous reports also document the hydraulic conductivity and water retention data previously gathered for Hanford Site sediments (Enfield, Hsieh, and Warrick 1973; Hsieh, Brownell, and Reisenauer 1973; Hsieh and Enfield 1974; Cass, Campbell, and Jones 1981; Gee and Campbell 1980; Gee et al. 1981; Gee and Kirkham 1984; Sisson and Lu 1984; and Heller, Gee, and Myers 1985). In addition, in situ hydraulic conductivity data have been collected at the BWTF and Grass Site and adjacent to the 200 Areas at the McGee Ranch site. These data are incorporated into the data base as needed. Relevant computer codes are archived (at this time, only UNSAT-H Version 1.0).

This appendix discusses the current procedures and software for collection, storage, and archiving of performance assessment data and outlines plans and procedures for data management using the HSPA MicroVAX.

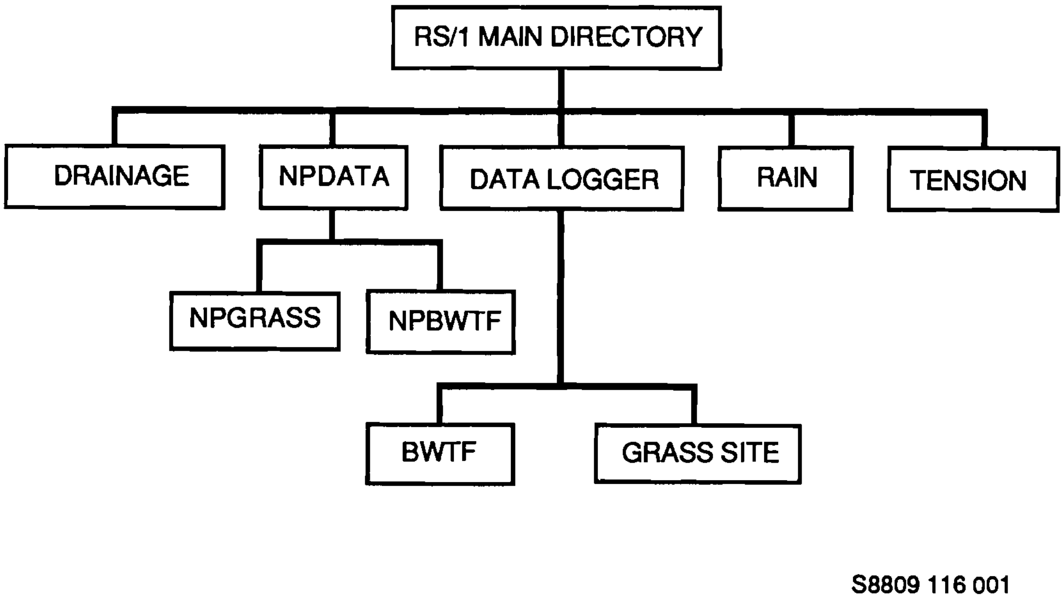
DATA BASE DESIGN

Performance assessment data are stored and accessed using a statistical analysis system that operates on both the IBM PC/AT and VAX computer systems. This flexibility is important because the software used for automated data collection and for editing data files operates on IBM systems; data collected in this manner can be processed directly into RS/1 by the IBM PC/AT. The software, RS/1, is specifically designed for information handling. Within the data base, information is stored in hierarchical directories, as shown in Figure A.1. Data are stored according to data type and geographical location.

Data collected are transferred directly from the IBM PC/AT data collection station to the HSPA MicroVAX. The framework for data collection, processing, quality assurance, storage, and access is shown in Figure A.2, and is discussed in detail in the following sections.

Procedures for Incorporating Neutron Probe Data

Soil moisture data are collected using neutron probes at various study areas on the Hanford Site. As discussed in the main body of the report, measurements of soil water using the neutron probe have been taken periodically in the 300 Area BWTF since 1978, at the Grass Site since 1983, and at the 200 East lysimeter site since February of 1988. Descriptions of these sites are provided in Section 2.0. The neutron probe field measurements



THE MAIN DIRECTORY CONTAINS A LISTING OF ALL OTHER DIRECTORIES AS WELL AS THE INDIVIDUAL USER DIRECTORIES
THE DRAINAGE DIRECTORY CONTAINS DRAINAGE DATA FOR THE BWTF SITE ONLY AT THIS TIME
THE NPDATA DIRECTORY CONTAINS THE SUMMARY TABLES FOR NEUTRON PROBE DATA COLLECTED AT THE BWIF AND GRASS SITES
THE NPGRASS DIRECTORY CONTAINS RAW NEUTRON PROBE COUNT AND PERCENT MOISTURE DATA FOR THE GRASS SITES
THE NPBWTF DIRECTORY CONTAINS RAW COUNT AND PERCENT MOISTURE DATA FOR THE BWTF SITE
THE DATA LOGGER DATA CONTAINS DIRECTORIES FOR EACH OF THE SITES WHERE DATA LOGGERS AUTOMATICALLY COLLECT DATA FOR A NUMBER OF SENSORS
THE BWTF DIRECTORY CONTAINS THE FILES OF DATA LOGGER DATA FOR THE BWTF SITE ORGANIZED BY CALENDAR YEAR
THE GRASS SITE DIRECTORY CONTAINS THE FILES OF DATA LOGGER DATA FOR THE GRASS SITE ORGANIZED BY CALENDAR YEAR
THE RAIN DIRECTORY CONTAINS SUMMARIES OF THE RAIN DATA CONTAINED IN THE BWTF AND GRASS-SITE DIRECTORIES
THE TENSION DIRECTORY CONTAINS SOIL WATER POTENTIAL DATA COLLECTED AT BOTH THE GRASS SITE AND BWTF

FIGURE A.1. Directory and File Organization for Water Balance Data in the RS/1 Data Base

are recorded in the project notebook and stored on a digital readout unit (data logger) connected to the probe. The information on the digital readout unit is transmitted to an IBM PC/AT in PNL facilities. The file is then edited to a specific format and transmitted to the HSPA MicroVAX system. This method of data transfer avoids errors that might be generated during manual data entry. The raw data files for the current year are stored on

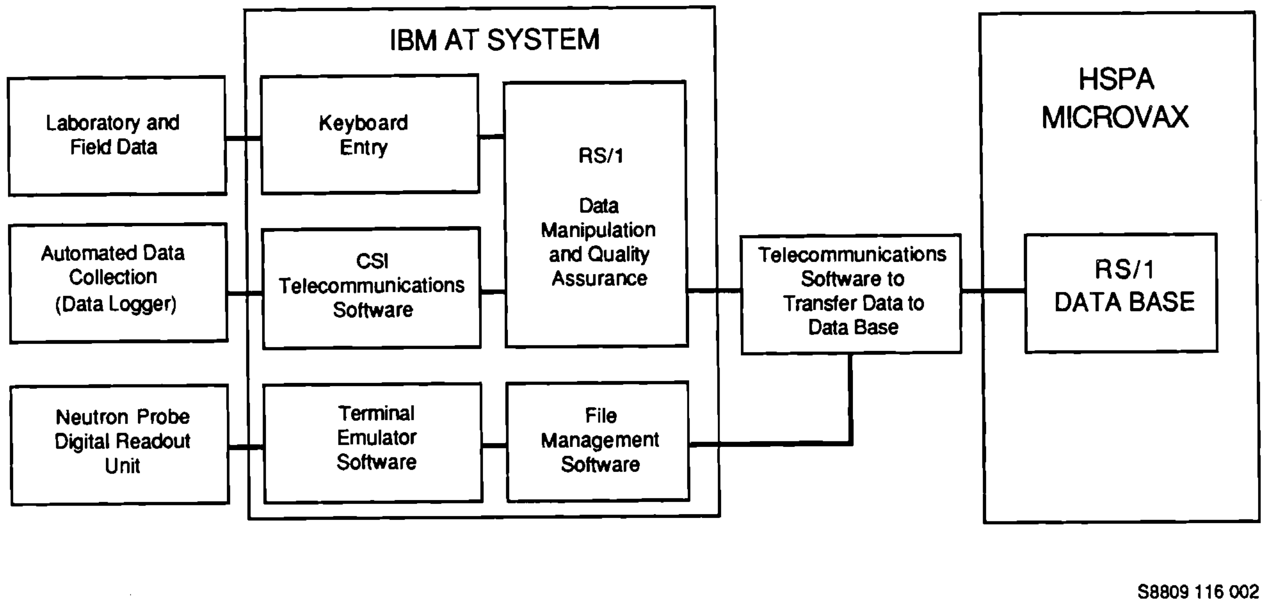


FIGURE A.2. Framework for Collecting, Processing, Storing, and Accessing Water Balance Data

backup floppy disks and on the VAX system in addition to being documented in the project notebook. Using RS/1 procedures (simple computer programs written in the RS/1 command language), the raw data are read into tables and analyzed to obtain percent moisture and total centimeters of water storage at each depth. Averages of these values are then calculated and entered into summary tables that reflect total storage in the soil profile.

Within the data base, the neutron probe data for the current calendar year are organized first by site and then chronologically. Neutron probe data for a specific site are entered in a directory for that site. The file names of the tables in the RS/1 directories for neutron probe data indicate the calendar date on which the data were collected and include a prefix letter indicating the site at which the data were collected and a suffix letter indicating whether the table contains raw counts (A) or percent moisture (C). Examples of these formats are shown in Figures A.3 and A.4. Tables containing summaries of the data collected from each site are stored in a first-level directory (the 'NPDATA' directory) for easier access by all users.

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Neutron Probe Data for the Grass Site on May 20, 1987

0 01-JUL-87 BNW 51374 P. 75-76	1 ST. MEAN STANDARD	2 END MEAN STANDARD	3 DEPTH	4 HOLE 1	5 HOLE 2
1 Probe:	11820.0	11864.00	-15	5131	3406
2 503_DR			-30	7077	5339
3 H33I15140	0.8	0.87	-45	5427	5339
4 Time:			-60	4580	4802
5 16 sec.			-75	4296	4700
6 Taken by:			-90	4483	4475
7 LD SANT			-105	4634	4431
8 Entered by:			-120	4195	4509
9 SM GOODWIN			-135	4232	4445
10 by Computer			-150	4015	4452
11 Processed by:			-165	3871	4599
12 MAKTABL3B			-195	4215	4361
13 Slope:			-225	4276	4526
14 21.28			-255	4054	4448
15 Offset:			-285	4272	4555
16 -3.28			-315	4172	4616
17 MSF->	11842.0		-345	4778	4819

0 01-JUL-87 BNW 51374 P. 75-76	6 HOLE 3	7 HOLE 4	8 HOLE 5	9 HOLE 6	10 HOLE 7
1 Probe:	3350	3003		2783	2504
2 503_DR	5072	3989	4097	4168	4467
3 H33I15140	4635	3897	5266	3900	4495
4 Time:	4497	4153	4695	4003	4214
5 16 sec.	4444	4332	4441	4270	3988
6 Taken by:	4505	4341	4458	4180	4498
7 LD SANT	4116	4303	4694	4462	4709
8 Entered by:	4202	4558	4515	4607	4538
9 SM GOODWIN	4328	4517	4739	4908	4685
10 by Computer	4240	4284	5274	4676	5036
11 Processed by:	4294	4391	5010	4472	4932
12 MAKTABL3B	4308	4215	4571	4352	4332
13 Slope:	4076	4113	4792	4092	4072
14 21.28	4290	4045	4347	4239	4092
15 Offset:	4886	4290	4553	4443	4385
16 -3.28	4472	4420	4805	4874	4331
17 MSF->	5052	5668	6200	6099	4287

FIGURE A.3. Example of Neutron Probe Raw Count Data Stored Using RS/1 Format

Neutron Probe Data for the Grass Site on May 20, 1987

0 01-JUL-87 BNW 51374 P. 75-76		11 HOLE 8	12 HOLE 9	13 HOLE 10	14 HOLE 11	15 HOLE 12
1 Probe:		4099	3504	3310	3330	3277
2 503_DR		5690	4627	5135	4995	4942
3 H33115140		4840	4239	4593	4853	4256
4 Time:		4501	4067	4227	4475	4056
5 16 sec.		4582	4118	4119	4272	3980
6 Taken by:		4637	4165	4276	4274	4169
7 LD SANT		4766	4107	4238	4122	4201
8 Entered by:		4710	4006	4147	4335	4414
9 SM GOODWIN		4711	4306	3991	4335	4312
10 by Computer		4663	4218	3909	4148	4033
11 Processed by:		4578	4472	3840	4167	4208
12 MAKTABL3B		4995	4452	3959	4111	3779
13 Slope:		4617	4485	4284	4222	3869
14	21.28	4362	4083	4163	4461	4090
15 Offset:		4147	4256	4140	4407	4245
16	-3.28	4175	4711	4316	4416	4366
17 MSF->		4562	4699	4715	4513	5081

0 01-JUL-87 BNW 51374 P. 75-76		16 HOLE 13	17 HOLE 14	18 HOLE 15	19 HOLE 16	20 HOLE 17
1 Probe:		3482	3692	3762	3237	3850
2 503_DR		4735	5161	5318	4848	5184
3 H33115140		4327	4808	4521	4303	4562
4 Time:		4260	4492	4173	4056	4105
5 16 sec.		3995	4434	4201	3901	4169
6 Taken by:		4074	4371	4130	3928	4215
7 LD SANT		4066	4192	4210	3897	4117
8 Entered by:		4469	4217	4187	3965	4057
9 SM GOODWIN		4590	4181	4553	4189	4168
10 by Computer		4376	4222	4772	4081	4092
11 Processed by:		4473	4486	4461	4078	4207
12 MAKTABL3B		4661	4770	4117	4245	4635
13 Slope:		4436	4034	4097	4179	4265
14	21.28	4339	4053	4108	4099	4136
15 Offset:		4521	4316	4315	4054	4459
16	-3.28	4542	4365	4179	4308	4420
17 MSF->		5163	4743	4656	4720	4896

FIGURE A.3. (contd)

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Neutron Probe Data for the Grass Site on May 20, 1987

0 01-JUL-87 BNW 51374 P. 75-76		21 HOLE 18	22 HOLE 19	23 HOLE 20	24 HOLE 21	25 HOLE 22
1 Probe:		3852				
2 503_DR		5403				
3 H33T15140		4449				
4 Time:		4073				
5 16 sec.		4104				
6 Taken by:		4073				
7 LD SANT		4040				
8 Entered by:		4316				
9 SM GOODWIN		4307				
10 by Computer		4235	4069			
11 Processed by:		4172	3991			
12 MAKTABL3B		3876	3676			
13 Slope:		4211	3735			
14	21.28	4256	4063			
15 Offset:		4359	4658			
16	-3.28	4289	4292			
17 MSF->		4537	4876			

0 01-JUL-87 BNW 51374 P. 75-76		26 HOLE 23	27 HOLE 24	28 HOLE 25
1 Probe:				
2 503_DR				
3 H33T15140				
4 Time:				
5 16 sec.				
6 Taken by:				
7 LD SANT				
8 Entered by:				
9 SM GOODWIN				
10 by Computer				
11 Processed by:				
12 MAKTABL3B				
13 Slope:				
14	21.28			
15 Offset:				
16	-3.28			
17 MSF->				

FIGURE A.3. (contd)

G20MAY87C 17R x 34C 15-SEP-87 10:26 Page 1

Neutron Probe Data for the Grass Site on May 20, 1987

0 01-JUL-87 BNW 51374 P. 75-76		1 ST. MEAN STANDARD	2 END MEAN STANDARD	3 DEPTH	4 HOLE 1	5 HOLE 2
1 Probe:		11820.0	11864.00	-15	5.940375	2.840561
2 503_DR				-30	9.437325	6.314150
3 H33115140		0.8	0.87	-45	6.472285	6.314150
4 Time:				-60	4.950231	5.349164
5 16 sec.				-75	4.439885	5.165871
6 Taken by:				-90	4.775923	4.761547
7 LD SANT				-105	5.047269	4.682479
8 Entered by:				-120	4.258389	4.822645
9 SM GOODWIN				-135	4.324878	4.707637
10 by Computer				-150	3.934930	4.720216
11 Processed by:				-165	3.676163	4.984374
12 MAKTABL3B				-195	4.294329	4.556690
13 Slope:				-225	4.403945	4.853194
14	21.28			-255	4.005013	4.713028
15 Offset:				-285	4.396757	4.905307
16	-3.28			-315	4.217058	5.014923
17 MSF->		11842.0		-345	5.306036	5.379713

0 01-JUL-87 BNW 51374 P. 75-76		6 HOLE 3	7 HOLE 4	8 HOLE 5	9 HOLE 6	10 HOLE 7
1 Probe:		2.739929	2.116372		1.721034	1.219672
2 503_DR		5.834352	3.888208	4.082283	4.209870	4.747171
3 H33115140		5.049066	3.722885	6.182969	3.728276	4.797487
4 Time:		4.801081	4.182915	5.156886	3.913366	4.292532
5 16 sec.		4.705840	4.504577	4.700449	4.393163	3.886411
6 Taken by:		4.815457	4.520750	4.730998	4.231434	4.802878
7 LD SANT		4.116426	4.452464	5.155089	4.738186	5.182044
8 Entered by:		4.270968	4.910698	4.833427	4.998750	4.874758
9 SM GOODWIN		4.497389	4.837021	5.235953	5.539645	5.138916
10 by Computer		4.339254	4.418321	6.197345	5.122743	5.769661
11 Processed by:		4.436291	4.610600	5.722939	4.756156	5.582773
12 MAKTABL3B		4.461449	4.294329	4.934058	4.540517	4.504577
13 Slope:		4.044547	4.111035	5.331194	4.073298	4.037359
14	21.28	4.429103	3.988840	4.531532	4.337457	4.073298
15 Offset:		5.500111	4.429103	4.901713	4.704043	4.599818
16	-3.28	4.756156	4.662712	5.354555	5.478548	4.502780
17 MSF->		5.798412	6.905361	7.861361	7.679865	4.423712

FIGURE A.4. Example of Processed Neutron Probe Data Stored Using RS/1 Format

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Neutron Probe Data for the Grass Site on May 20, 1987

0 01-JUL-87 BNW 51374 P. 75-76		11 HOLE 8	12 HOLE 9	13 HOLE 10	14 HOLE 11	15 HOLE 12
1 Probe:		4.085877	3.016666	2.668049	2.703989	2.608749
2 503_DR		6.944894	5.034690	5.947563	5.695984	5.600743
3 H33115140		5.417450	4.337457	4.973592	5.440811	4.368005
4 Time:		4.808269	4.028374	4.315893	4.761547	4.008607
5 16 sec.		4.953825	4.120020	4.121817	4.396757	3.872035
6 Taken by:		5.052660	4.204479	4.403945	4.400351	4.211667
7 LD SANT		5.284472	4.100253	4.335660	4.127208	4.269171
8 Entered by:		5.183841	3.918757	4.172133	4.509968	4.651930
9 SM GOODWIN		5.185638	4.457855	3.891802	4.509968	4.468637
10 by Computer		5.099382	4.299720	3.744449	4.173930	3.967276
11 Processed by:		4.946637	4.756156	3.620456	4.208073	4.281750
12 MAKTABL3B		5.695984	4.720216	3.834298	4.107441	3.510839
13 Slope:		5.016720	4.779517	4.418321	4.306908	3.672569
14	21.28	4.558487	4.057125	4.200885	4.736389	4.069704
15 Offset:		4.172133	4.368005	4.159554	4.639351	4.348238
16	-3.28	4.222449	5.185638	4.475825	4.655524	4.565675
17 MSF->		4.917885	5.164074	5.192826	4.829833	5.850525

0 01-JUL-87 BNW 51374 P. 75-76		16 HOLE 13	17 HOLE 14	18 HOLE 15	19 HOLE 16	20 HOLE 17
1 Probe:		2.977132	3.354501	3.480290	2.536869	3.638426
2 503_DR		5.228765	5.994285	6.276413	5.431826	6.035616
3 H33115140		4.495592	5.359946	4.844209	4.452464	4.917885
4 Time:		4.375193	4.792096	4.218855	4.008607	4.096659
5 16 sec.		3.898990	4.687870	4.269171	3.730073	4.211667
6 Taken by:		4.040953	4.574660	4.141584	3.778591	4.294329
7 LD SANT		4.026577	4.252998	4.285344	3.722885	4.118223
8 Entered by:		4.750765	4.297923	4.244013	3.845080	4.010404
9 SM GOODWIN		4.968201	4.233231	4.901713	4.247607	4.209870
10 by Computer		4.583645	4.306908	5.295254	4.053531	4.073298
11 Processed by:		4.757953	4.781314	4.736389	4.048141	4.279953
12 MAKTABL3B		5.095788	5.291660	4.118223	4.348238	5.049066
13 Slope:		4.691464	3.969073	4.082283	4.229637	4.384178
14	21.28	4.517156	4.003216	4.102050	4.085877	4.152366
15 Offset:		4.844209	4.475825	4.474028	4.005013	4.732795
16	-3.28	4.881946	4.563878	4.229637	4.461449	4.662712
17 MSF->		5.997879	5.243141	5.086803	5.201811	5.518081

FIGURE A.4. (contd)

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Neutron Probe Data for the Grass Site on May 20, 1987

0 01-JUL-87 BNW 51374 P. 75-76		30 STANDARD DEV GRASS PLOT	31 MOISTURE (cm) GRASS PLOT	32 ROWMEAN ROTOTILLED
1 Probe:		0.716877	0.444642	3.546180
2 503_DR		0.738794	0.861098	6.291987
3 H33115140		0.608993	0.762539	4.898718
4 Time:		0.457499	0.671547	4.412930
5 16 sec.		0.431403	0.652679	4.244013
6 Taken by:		0.358726	0.666560	4.349436
7 LD SANT		0.485079	0.660130	4.604011
8 Entered by:		0.398414	0.665482	4.669301
9 SM GOODWIN		0.404216	0.687277	4.944241
10 by Computer		0.715761	0.684025	4.547106
11 Processed by:		0.588576	0.684941	4.396757
12 MAKTABL3B		0.668948	1.322873	4.643544
13 Slope:		0.504975	1.296888	4.389569
14	21.28	0.258855	1.282045	4.286542
15 Offset:		0.390559	1.378508	4.648336
16	-3.28	0.325416	1.390224	4.859184
17 MSF->		0.778644	1.616466	6.327927

0 01-JUL-87 BNW 51374 P. 75-76		33 STANDARD DEV ROTOTILLED	34 MOISTURE (cm) ROTOTILLED
1 Probe:		2.166465	0.531927
2 503_DR		2.771173	0.943798
3 H33115140		1.415726	0.734808
4 Time:		0.519462	0.661940
5 16 sec.		0.299710	0.636602
6 Taken by:		0.381430	0.652415
7 LD SANT		0.523408	0.690602
8 Entered by:		0.376843	0.700395
9 SM GOODWIN		0.607738	0.741636
10 by Computer		0.594749	0.682066
11 Processed by:		0.624054	0.659514
12 MAKTABL3B		0.410543	1.393063
13 Slope:		0.309334	1.316871
14	21.28	0.259840	1.285963
15 Offset:		0.228868	1.394501
16	-3.28	0.631053	1.457755
17 MSF->		1.220846	1.898378

FIGURE A.4. (contd)

Procedures for Automated Data Collection and Storage

Most data collected at the BWTF and the Grass Site are automatically collected using CSI (Campbell Scientific, Inc., Logan, Utah) data loggers. The programs controlling data collection are generated and edited using CSI software that operates on the IBM PC/AT. The data logger program controls which sensors are interrogated, time interval, and date(s) of the measurement. An example of a program for a data logger and short descriptions of the software programs are given in this appendix. The data are output to a cassette tape recorder and transmitted daily via telephone and modem to the IBM PC/AT in PNL's laboratory. The data are sorted daily and then transmitted to the HSPA MicroVAX, where they are entered into RS/1. Data from key sensors are then plotted and the quality of the data inspected before it is added to the HSPA RS/1 data base.

These data sets include scale readings from the weighing lysimeters, rainfall, soil temperatures, ambient temperature, wind speed, solar radiation, and relative humidity, as described in Table A.1. The information collected at the BWTF from 1983 have been read into the RS/1 software and analyzed. Raw data files for 1983 to 1985 are stored on the user-mountable hard disk. Processed data are stored in RS/1 directories for each site. Within the directory for each site, data are organized according to calendar year. The file names of the RS/1 tables reflect where the data were collected, the calendar year, and whether the data are hourly or daily averages.

Micrometeorological data collected from the Grass Site since September 1986 are similarly transmitted by telephone and read into the RS/1 software on the HSPA MicroVAX.

Procedures for Incorporating Field and Laboratory Data

Several types of data (see Table A.1) are collected manually in the field or result from laboratory analyses:

- Drainage data are collected manually from the north and south weighing lysimeters and south caisson at the BWTF. These data are manually entered into RS/1 and processed using RS/1 procedures to obtain cumulative values of drainage during the monitoring period.

- Soil-water potential is measured in the field at the BWTF and at the Grass Site. These data are entered manually into RS/1 for analysis.
- Plant-water potential is measured in the field at the BWTF and at the Grass Site. These data are entered manually into RS/1 for analysis.
- Plant-water relations data measured in the field, estimates of canopy cover, and phenology observations for the Grass Site are entered and stored on the HSPA MicroVAX.
- Soil hydraulic conductivity data are manually entered and stored using RS/1 software.
- Data on particle size, density, and gravimetric moisture from laboratory analyses are also entered and stored in tables using RS/1 software.

Procedures for Incorporating Hanford Site Meteorological Station Data

Meteorological data of interest are obtained from the HMS. Precipitation data are read into RS/1 software from these files and stored as tables for comparison with micrometeorological data collected at the field study sites.

Code Documentation and Entry into Archive

UNSAT-H Version 1.0 (Fayer, Gee, and Jones 1986) was archived on tape and on a user-mountable hard disk as follows: 1) on a 3/4-in. 1600 BPS VAX tape in a locked cabinet in PNL's Sigma V Building computer room, 2) on a 3/4-in. BPI VAX tape in M. J. Fayer's office (room 2607, Sigma V, Pacific Northwest Laboratory, Richland, Washington), 3) on a user-mountable hard disk labeled 'TARDIS' in the Sigma V computer room, and 4) as a working copy on the PNL ZVAX.

Version 1.0 of UNSAT-H was updated in 1987 to include additional options for computing functions affecting hydraulic conductivity and recompiled and archived as Version 1.1 in accordance with QA procedures. Version 2.0 will be completed and available by October 1988. UNSAT2 (Davis and Neuman 1983) has been used on an interim basis for protective barrier analysis (Fayer et al. 1985).

IBM PC-COMPATIBLE SOFTWARE FOR ACCESSING DATA LOGGERS

Automated collection of field data is accomplished using CSI data loggers. Programs entered into the data loggers for data collection and processing are documented. An example of a program generated for the BWTF site using the CSI software, EDLOG, is given in Figure A.5 (page A.16). The EDLOG program operates on the IBM PC/AT and allows us to label and document sensors on the program itself. Other CSI software is used with IBM PCs to automatically access data from field sites over telephone lines or radio links, to monitor data from the sensors in real time, or to download new programs to the data logger or upload an old program to check for validity. CSI's PC205 telecommunications software includes:

- TELECOM[a]--interrogates CSI data loggers and retrieves and stores the data. The program can be used in either an attended or unattended mode.
- TERM[a]--works as a terminal emulator to establish communications with a data logger. The program is used to monitor the data from the data logger in real time, or to download, retrieve, or alter data-logger programs.
- PC206[a]--software supports the telecommunications software and allows development and editing of data-logger programs through use of the EDLOG program.

(a) TELECOM, TERM, and PC206 are tradenames of Campbell Scientific, Inc., Logan, Utah.

```
Program:BWTF 05/12/88 JLD OA
Flag Usage:
Input Channel Usage:
Excitation Channel Usage:
Continuous Analog Output Usage:
Control Port Usage:
Pulse Input Channel Usage:
Output Array Definitions:

*      1          Table 1 Programs
  01: 10          Sec. Execution Interval

01:  P78          Resolution
  01: 1           High Resolution

02:  P3           Pulse
  01: 1           Rep
  02: 2           IN Card
  03: 1           Pulse Input Chan
  04: 2           Switch Closure
  05: 1           Loc [:RAINGAGE ]
  06: 1           Mult
  07: 0           Offset

03:  P3           Pulse
  01: 1           Rep
  02: 2           IN Card
  03: 2           Pulse Input Chan
  04: 2           Switch Closure
  05: 2           Loc [:WINDSPEED]
  06: .1789       Mult
  07: 1           Offset

04:  P9           Full BR w/Compensation
  01: 2           Reps
  02: 8           5000 mV slow EX Range
  03: 1           1500 uV slow BR Range
  04: 1           IN Card
  05: 1           IN Chan
  06: 1           EX Card
  07: 1           EX Chan
  08: 1           Meas/EX
  09: 1000        mV Excitation
  10: 3           Loc [:NWL       ]
  11: 1           Mult
  12: -1          Offset
05:  P6           Full Bridge
  01: 1           Rep
  02: 2           5000 uV slow Range
  03: 1           IN Card
  04: 5           IN Chan
  05: 1           EX Card
  06: 3           EX Chan
  07: 1           Meas/EX
  08: 2000        mV Excitation
  09: 5           Loc [:SSC       ]
  10: 1           Mult
  11: 0           Offset
```

FIGURE A.5. Example of a Program Generated for the Buried Waste Test Facility Using the Campbell Scientific, Inc. Software

```
06:  P6         Full Bridge
  01: 1         Rep
  02: 3         15 mV slow Range
  03: 1         IN Card
  04: 10        IN Chan
  05: 1         EX Card
  06: 6         EX Chan
  07: 1         Meas/EX
  08: 2000      mV Excitation
  09: 6         Loc [:NSC      ]
  10: 1         Mult
  11: 0         Offset

07:  P10        Battery Voltage
  01: 24        Loc [:BATT VOLT]

08:  P17        Panel Temperature
  01: 2         IN Card
  02: 7         Loc [:PANEL T  ]

09:  P14        Thermocouple Temp (DIFF)
  01: 16        Reps
  02: 4         50 mV slow Range
  03: 1         IN Card
  04: 11        IN Chan
  05: 1         Type T (Copper-Constantan)
  06: 7         Ref Temp Loc PANEL T
  07: 8         Loc [:SWL T    ]
  08: 1         Mult
  09: 0         Offset

10:  P4         Excite,Delay,Volt(SE)
  01: 1         Rep
  02: 7         1500 mV slow Range
  03: 1         IN Card
  04: 13        IN Chan
  05: 1         EX Card
  06: 5         EX Chan
  07: 1         Meas/EX
  08: 5         Delay (units .01sec)
  09: 500       mV Excitation
  10: 25        Loc [:WIND DIR ]
  11: .72       Mult
  12: 0         Offset

11:  P2         Volt (DIFF)
  01: 2         Reps
  02: 6         500 mV slow Range
  03: 1         IN Card
  04: 8         IN Chan
  05: 26        Loc [:SOLAR UP ]
  06: 1         Mult
  07: 0         Offset

12:  P11        Temp 107 Probe
  01: 1         Rep
  02: 1         IN Card
  03: 11        IN Chan
  04: 1         EX Card
  05: 4         EX Chan
  06: 28        Loc [:AIR TEMP ]
  07: 1         Mult
  08: 0         Offset
```

FIGURE A.5. (contd)

```
13:  P12       RH 207 Probe
  01: 1        Rep
  02: 1        IN Card
  03: 12       IN Chan
  04: 1        EX Card
  05: 4        EX Chan
  06: 1        Meas/Temp
  07: 28       Temperature Loc AIR TEMP
  08: 29       Loc [:C REL HUM]
  09: 1        Mult
  10: 0        Offset

14:  P30       Z=F
  01: 1000     F
  02: 30       Z Loc :

15:  P14       Thermocouple Temp (DIFF)
  01: 2        Reps
  02: 1        1500 uV slow Range
  03: 2        IN Card
  04: 13       IN Chan
  05: 1        Type T (Copper-Constantan)
  06: 7        Ref Temp Loc PANEL T
  07: 31       Loc [:DRY BULB ]
  08: 1        Mult
  09: 0        Offset

16:  P30       Z=F
  01: 98.882   F
  02: 39       Z Loc :

17:  P56       Saturation Vapor Pressure
  01: 31       Temperature Loc DRY BULB
  02: 33       Loc [:SVP      ]

18:  P57       Wet/Dry Bulb Temp to VP
  01: 39       Pressure Loc
  02: 31       Dry Bulb Temp Loc DRY BULB
  03: 32       Wet Bulb Temp Loc
  04: 34       Loc [:VP       ]

19:  P38       Z=X/Y
  01: 34       X Loc VP
  02: 33       Y Loc SVP
  03: 35       Z Loc [:REL HUMVP]

20:  P         End Table 1


*     2        Table 2 Programs
  01: 10       Sec. Execution Interval

01:  P78       Resolution
  01: 1        High Resolution

02:  P92       If time is
  01: 0        minutes into a
  02: 60       minute interval
  03: 10       Set flag 0 (output)

03:  P80       Year
```

FIGURE A.5. (contd)

```
04:  P77       Real Time
  01: 110      Day,Hour-Minute

05:  P72       Totalize
  01: 1        Rep
  02: 1        Loc RAINGAGE

06:  P71       Average
  01: 23       Reps
  02: 2        Loc WINDSPEED

07:  P76       Wind Vector
  01: 1        Rep
  02: 0        Polar Sensor (speed and direc)
  03: 2        Wind Speed/East Loc WINDSPEED
  04: 25       Wind Direction/North Loc WIND DIR

08:  P71       Average
  01: 10       Reps
  02: 26       Loc SOLAR UP

09:  P92       If time is
  01: 0        minutes into a
  02: 1440     minute interval
  03: 10       Set flag 0 (output)

10:  P80       Year

11:  P77       Real Time
  01: 100      Julian Day

12:  P72       Totalize
  01: 1        Rep
  02: 1        Loc RAINGAGE

13:  P71       Average
  01: 23       Reps
  02: 1        Loc RAINGAGE

14:  P71       Average
  01: 10       Reps
  02: 26       Loc SOLAR UP

15:  P92       If time is
  01: 540      minutes into a
  02: 1440     minute interval
  03: 30       Then Do

16:  P89       If X<=>F
  01: 24       X Loc BATT VOLT
  02: 3        >=
  03: 11.5     F
  04: 30       Then Do

17:  P30       Z=F
  01: 5000     F
  02: 40       Z Loc :

18:  P21       Analog Out
  01: 1        EX Card
  02: 1        CAO Chan
  03: 40       mv Loc

19:  P95       End
```

FIGURE A.5. (contd)

```
20:  P95         End

21:  P92         If time is
  01: 960        minutes into a
  02: 1440       minute interval
  03: 30         Then Do

22:  P30         Z=F
  01: 0          F
  02: 40         Z Loc :

23:  P21         Analog Out
  01: 1          EX Card
  02: 1          CAO Chan
  03: 40         mv Loc

24:  P95         End

25:  P91         If Flag
  01: 11         1 is set
  02: 1          Call Subroutine 1

26:  P           End Table 2


*     3          Table 3 Subroutines

01:  P85         Beginning of Subroutine
  01: 1          Subroutine Number

02:  P92         If time is
  01: 0          minutes into a
  02: 2          minute interval
  03: 10         Set flag 0 (output)

03:  P80         Year

04:  P77         Real Time
  01: 110        Day,Hour-Minute

05:  P71         Average
  01: 2          Reps
  02: 3          Loc NWL

06:  P95         End

07:  P           End Table 3


*     4          Mode 4 Output Options
  01: 10         (Tape ON ) (Printer OFF)
  02: 2          Printer 9600 Baud


*     A          Mode 10 Memory Allocation
  01: 64         Input Locations
  02: 90         Intermediate Locations


*     C          Mode 12 Security
  01: 0          Security Disabled
  02: 0          Security Code
```

FIGURE A.5. (contd)

```
Page 7    Input Location Assignments (with comments):

(Key: T=Table Number    E=Entry Number    L=Location  Number)

 T: E: L:
 1: 2: 1:  Loc [:RAINGAGE ]
 1: 3: 2:  Loc [:WINDSPEED]
 1: 4: 3:  Loc [:NWL      ]
 1: 5: 5:  Loc [:SSC      ]
 1: 6: 6:  Loc [:NSC      ]
 1: 8: 7:  Loc [:PANEL T  ]
 1: 9: 8:  Loc [:SWL T    ]
 1: 7:24:  Loc [:BATT VOLT]
 1:10:25:  Loc [:WIND DIR ]
 1:11:26:  Loc [:SOLAR UP ]
 1:12:28:  Loc [:AIR TEMP ]
 1:13:29:  Loc [:C REL HUM]
 1:14:30:  Z Loc :
 1:15:31:  Loc [:DRY BULB ]
 1:17:33:  Loc [:SVP      ]
 1:18:34:  Loc [:VP       ]
 1:19:35:  Z Loc [:REL HUMVP]
 1:16:39:  Z Loc :
 2:17:40:  Z Loc :
 2:22:40:  Z Loc :
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FIGURE A.5. (contd)

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APPENDIX B

PRECIPITATION DATA

TABLE B.1. Precipitation Data from the Hanford Meteorological Station from January 1986 to July 1988

	0 DATE	1 PRECIP (CM)	2 CUMULATIVE ANNUAL (CM)	3 CUMULATIVE TOTAL (CM)
1	01-JAN-86	0.0254	0.0254	0.0254
2	02-JAN-86	0.1016	0.1270	0.1270
3	04-JAN-86	0.0254	0.1524	0.1524
4	05-JAN-86	0.4826	0.6350	0.6350
5	09-JAN-86	0.2794	0.9144	0.9144
6	15-JAN-86	0.1524	1.0668	1.0668
7	16-JAN-86	0.5080	1.5748	1.5748
8	17-JAN-86	0.2286	1.8034	1.8034
9	18-JAN-86	0.1778	1.9812	1.9812
10	22-JAN-86	0.7874	2.7686	2.7686
11	23-JAN-86	0.1524	2.9210	2.9210
12	27-JAN-86	0.2032	3.1242	3.1242
13	28-JAN-86	0.3810	3.5052	3.5052
14	29-JAN-86	0.5588	4.0640	4.0640
15	30-JAN-86	0.3810	4.4450	4.4450
16	01-FEB-86	0.0762	4.5212	4.5212
17	02-FEB-86	0.1270	4.6482	4.6482
18	04-FEB-86	0.5588	5.2070	5.2070
19	12-FEB-86	0.5334	5.7404	5.7404
20	14-FEB-86	0.9398	6.6802	6.6802
21	15-FEB-86	0.3556	7.0358	7.0358
22	21-FEB-86	0.5080	7.5438	7.5438
23	23-FEB-86	0.4064	7.9502	7.9502
24	07-MAR-86	0.5334	8.4836	8.4836
25	08-MAR-86	0.3302	8.8138	8.8138
26	10-MAR-86	0.0508	8.8646	8.8646
27	12-MAR-86	0.2286	9.0932	9.0932
28	13-MAR-86	0.0762	9.1694	9.1694
29	18-MAR-86	0.0254	9.1948	9.1948
30	23-MAR-86	0.4064	9.6012	9.6012
31	24-MAR-86	0.2540	9.8552	9.8552
32	25-MAR-86	0.0254	9.8806	9.8806
33	02-MAY-86	0.0254	9.9060	9.9060
34	03-MAY-86	0.0254	9.9314	9.9314
35	06-MAY-86	0.5334	10.4648	10.4648
36	21-MAY-86	0.1016	10.5664	10.5664
37	26-MAY-86	0.0762	10.6426	10.6426
38	02-JUL-86	0.1778	10.8204	10.8204
39	04-JUL-86	0.3302	11.1506	11.1506
40	08-JUL-86	0.0254	11.1760	11.1760
41	29-AUG-86	0.0508	11.2268	11.2268
42	13-SEP-86	0.0762	11.3030	11.3030
43	15-SEP-86	0.8890	12.1920	12.1920
44	16-SEP-86	0.4826	12.6746	12.6746
45	17-SEP-86	0.1524	12.8270	12.8270
46	19-SEP-86	0.1016	12.9286	12.9286
47	23-SEP-86	0.5334	13.4620	13.4620
48	27-SEP-86	0.0254	13.4874	13.4874
49	29-SEP-86	0.1778	13.6652	13.6652
50	25-OCT-86	0.0762	13.7414	13.7414
51	26-OCT-86	0.2032	13.9446	13.9446
52	29-OCT-86	0.4572	14.4018	14.4018
53	05-NOV-86	0.0508	14.4526	14.4526
54	07-NOV-86	0.1270	14.5796	14.5796
55	24-NOV-86	0.4318	15.0114	15.0114
56	26-NOV-86	0.2794	15.2908	15.2908
57	27-NOV-86	0.1778	15.4686	15.4686
58	28-NOV-86	0.5842	16.0528	16.0528
59	04-DEC-86	0.2032	16.2560	16.2560
60	05-DEC-86	0.5588	16.8148	16.8148
61	13-DEC-86	0.3048	17.1196	17.1196
62	17-DEC-86	0.0254	17.1450	17.1450
63	18-DEC-86	0.2032	17.3482	17.3482
64	19-DEC-86	0.1016	17.4498	17.4498
65	22-DEC-86	0.0762	17.5260	17.5260
66	24-DEC-86	0.0762	17.6022	17.6022
67	25-DEC-86	0.0508	17.6530	17.6530
68	26-DEC-86	0.2540	17.9070	17.9070
69	27-DEC-86	0.0254	17.9324	17.9324
70	28-DEC-86	0.0762	18.0086	18.0086
71	01-JAN-87	0.5080	0.5080	18.5166
72	13-JAN-87	0.3048	0.8128	18.8214
73	14-JAN-87	0.0508	0.8636	18.8722
74	23-JAN-87	0.0254	0.8890	18.8976
75	24-JAN-87	0.1524	1.0414	19.0500
76	25-JAN-87	0.4064	1.4478	19.4564
77	26-JAN-87	0.2032	1.6510	19.6596
78	27-JAN-87	0.0508	1.7018	19.7104
79	31-JAN-87	0.3302	2.0320	20.0406
80	11-FEB-87	0.0762	2.1082	20.1168
81	12-FEB-87	0.0254	2.1336	20.1422
82	13-FEB-87	0.2794	2.4130	20.4216
83	22-FEB-87	0.1016	2.5146	20.5232
84	03-MAR-87	0.2032	2.7178	20.7264
85	05-MAR-87	0.0508	2.7686	20.7772
86	06-MAR-87	0.0508	2.8194	20.8280
87	08-MAR-87	0.1016	2.9210	20.9296
88	10-MAR-87	0.0254	2.9464	20.9550
89	11-MAR-87	0.1270	3.0734	21.0820
90	12-MAR-87	1.0668	4.1402	22.1488
91	14-MAR-87	0.2794	4.4196	22.4282
92	15-MAR-87	0.4572	4.8768	22.8854
93	19-MAR-87	0.3048	5.1816	23.1902
94	17-APR-87	0.3048	5.4864	23.4950
95	30-APR-87	0.0508	5.5372	23.5458
96	20-MAY-87	0.0762	5.6134	23.6220
97	30-MAY-87	0.3556	5.9690	23.9776
98	08-JUN-87	0.0254	5.9944	24.0030
99	14-JUN-87	0.0254	6.0198	24.0284
100	15-JUN-87	0.0762	6.0960	24.1046
101	20-JUN-87	0.0762	6.1722	24.1808
102	21-JUN-87	0.0762	6.2484	24.2570

TABLE B.1 (contd)

0 DATE	1 PRECIP (CM)	2 CUMULATIVE ANNUAL (CM)	3 CUMULATIVE TOTAL (CM)
103 02-JUL-87	0.1524	6.4008	24.4094
104 09-JUL-87	0.6858	7.0866	25.0952
105 17-JUL-87	0.1270	7.2136	25.2222
106 18-JUL-87	0.3048	7.5184	25.5270
107 13-AUG-87	0.1016	7.6200	25.6286
108 14-AUG-87	0.0254	7.6454	25.6540
109 24-AUG-87	0.0508	7.6962	25.7048
110 26-SEP-87	0.0254	7.7216	25.7302
111 01-NOV-87	0.4572	8.1788	26.1874
112 11-NOV-87	0.0508	8.2296	26.2382
113 12-NOV-87	0.0508	8.2804	26.2890
114 13-NOV-87	0.2540	8.5344	26.5430
115 30-NOV-87	0.2032	8.7376	26.7462
116 01-DEC-87	0.2794	9.0170	27.0256
117 02-DEC-87	0.6604	9.6774	27.6860
118 03-DEC-87	0.3048	9.9822	27.9908
119 04-DEC-87	0.0508	10.0330	28.0416
120 05-DEC-87	0.1778	10.2108	28.2194
121 06-DEC-87	0.3810	10.5918	28.6004
122 09-DEC-87	1.3970	11.9888	29.9974
123 15-DEC-87	0.2286	12.2174	30.2260
124 16-DEC-87	0.4826	12.7000	30.7086
125 28-DEC-87	0.2032	12.9032	30.9118
126 04-JAN-88	0.0508	0.0508	30.9626
127 07-JAN-88	0.0508	0.1016	31.0134
128 08-JAN-88	0.3302	0.4318	31.3436
129 09-JAN-88	0.1778	0.6096	31.5214
130 10-JAN-88	0.4064	1.0160	31.9278
131 14-JAN-88	0.1778	1.1938	32.1056
132 20-JAN-88	0.0254	1.2192	32.1310
133 04-MAR-88	0.1524	1.3716	32.2834
134 06-MAR-88	0.0254	1.3970	32.3088
135 08-MAR-88	0.4826	1.8796	32.7914
136 22-MAR-88	0.0762	1.9558	32.8676
137 28-MAR-88	0.2286	2.1844	33.0962
138 29-MAR-88	0.0254	2.2098	33.1216
139 02-APR-88	0.0254	2.2352	33.1470
140 03-APR-88	0.0508	2.2860	33.1978
141 17-APR-88	0.9144	3.2004	34.1122
142 19-APR-88	0.0762	3.2766	34.1884
143 20-APR-88	0.2032	3.4798	34.3916
144 22-APR-88	0.1778	3.6576	34.5694
145 27-APR-88	0.0254	3.6830	34.5948
146 28-APR-88	1.2192	4.9022	35.8140
147 30-APR-88	0.1524	5.0546	35.9664
148 02-MAY-88	0.0254	5.0800	35.9918
149 08-MAY-88	0.0254	5.1054	36.0172
150 18-MAY-88	0.0508	5.1562	36.0680
151 27-MAY-88	0.0254	5.1816	36.0934
152 28-MAY-88	0.7112	5.8928	36.8046
153 01-JUN-88	0.0508	5.9436	36.8554
154 02-JUN-88	0.0254	5.9690	36.8808
155 04-JUN-88	0.0254	5.9944	36.9062
156 05-JUN-88	0.1778	6.1722	37.0840
157 13-JUL-88	0.3302	6.5024	37.4142

TABLE B.2. Precipitation Data for the Buried Waste Test Facility from January 1986 to July 1988

	0 DATE	1 PRECIP (CM)	2 CUMULATIVE ANNUAL (CM)	3 CUMULATIVE TOTAL (CM)
1	01-JAN-86	0.10	0.1000	0.1000
2	02-JAN-86	0.28	0.3800	0.3800
3	05-JAN-86	0.41	0.7864	0.7864
4	08-JAN-86	0.14	0.9264	0.9264
5	09-JAN-86	0.28	1.2064	1.2064
6	15-JAN-86	0.23	1.4350	1.4350
7	16-JAN-86	0.36	1.7906	1.7906
8	17-JAN-86	0.13	1.9176	1.9176
9	18-JAN-86	0.03	1.9430	1.9430
10	19-JAN-86	0.03	1.9684	1.9684
11	22-JAN-86	0.56	2.5272	2.5272
12	23-JAN-86	0.05	2.5780	2.5780
13	27-JAN-86	0.33	2.9082	2.9082
14	28-JAN-86	0.30	3.2130	3.2130
15	29-JAN-86	0.58	3.7972	3.7972
16	30-JAN-86	0.76	4.5592	4.5592
17	01-FEB-86	0.03	4.5846	4.5846
18	02-FEB-86	0.36	4.9402	4.9402
19	03-FEB-86	0.05	4.9910	4.9910
20	04-FEB-86	0.53	5.5244	5.5244
21	05-FEB-86	0.03	5.5498	5.5498
22	11-FEB-86	0.03	5.5798	5.5798
23	12-FEB-86	0.93	6.5098	6.5098
24	13-FEB-86	0.02	6.5298	6.5298
25	14-FEB-86	1.19	7.7198	7.7198
26	15-FEB-86	0.28	7.9998	7.9998
27	21-FEB-86	0.56	8.5586	8.5586
28	23-FEB-86	0.94	9.4984	9.4984
29	07-MAR-86	0.91	10.4128	10.4128
30	08-MAR-86	0.38	10.7938	10.7938
31	09-MAR-86	0.05	10.8446	10.8446
32	10-MAR-86	0.10	10.9462	10.9462
33	12-MAR-86	0.08	11.0224	11.0224
34	13-MAR-86	0.46	11.4796	11.4796
35	14-MAR-86	0.18	11.6574	11.6574
36	18-MAR-86	0.03	11.6828	11.6828
37	23-MAR-86	1.07	12.7496	12.7496
38	24-MAR-86	0.28	13.0290	13.0290
39	26-MAR-86	0.13	13.1560	13.1560
40	30-MAR-86	0.38	13.5370	13.5370
41	12-APR-86	0.05	13.5878	13.5878
42	13-APR-86	0.03	13.6132	13.6132
43	26-APR-86	0.05	13.6640	13.6640
44	02-MAY-86	0.08	13.7402	13.7402
45	03-MAY-86	0.05	13.7910	13.7910
46	05-MAY-86	0.03	13.8164	13.8164
47	06-MAY-86	0.38	14.1974	14.1974
48	09-MAY-86	0.36	14.5530	14.5530
49	21-MAY-86	0.56	15.1118	15.1118
50	28-JUN-86	0.30	15.4166	15.4166
51	02-JUL-86	0.30	15.7214	15.7214
52	03-JUL-86	0.03	15.7468	15.7468
53	04-JUL-86	0.38	16.1278	16.1278
54	16-JUL-86	0.08	16.2040	16.2040
55	13-SEP-86	0.04	16.2440	16.2440
56	15-SEP-86	0.83	17.0740	17.0740
57	16-SEP-86	0.10	17.1740	17.1740
58	17-SEP-86	0.08	17.2540	17.2540
59	19-SEP-86	0.78	18.0340	18.0340
60	23-SEP-86	0.62	18.6540	18.6540
61	29-SEP-86	0.44	19.0940	19.0940
62	26-OCT-86	0.65	19.7440	19.7440
63	29-OCT-86	0.80	20.5440	20.5440
64	13-NOV-86	0.09	20.6340	20.6340
65	22-NOV-86	0.09	20.7240	20.7240
66	23-NOV-86	0.45	21.1740	21.1740
67	24-NOV-86	0.32	21.4940	21.4940
68	26-NOV-86	0.11	21.6040	21.6040
69	27-NOV-86	0.16	21.7640	21.7640
70	28-NOV-86	0.51	22.2740	22.2740
71	04-DEC-86	0.15	22.4240	22.4240
72	05-DEC-86	0.44	22.8640	22.8640
73	13-DEC-86	0.32	23.1840	23.1840
74	16-DEC-86	0.02	23.2040	23.2040
75	17-DEC-86	0.18	23.3840	23.3840
76	18-DEC-86	0.38	23.7640	23.7640
77	19-DEC-86	0.28	24.0440	24.0440
78	22-DEC-86	0.06	24.1040	24.1040
79	23-DEC-86	0.03	24.1340	24.1340
80	24-DEC-86	0.04	24.1740	24.1740
81	26-DEC-86	0.13	24.3040	24.3040
82	01-JAN-87	0.99	0.9900	25.2940
83	13-JAN-87	0.58	1.5700	25.8740
84	14-JAN-87	0.28	1.8500	26.1540
85	24-JAN-87	0.21	2.0600	26.3640
86	25-JAN-87	0.53	2.5900	26.8940
87	26-JAN-87	0.48	3.0700	27.3740
88	31-JAN-87	0.83	3.9000	28.2040
89	02-FEB-87	0.07	3.9700	28.2740
90	12-FEB-87	0.03	4.0000	28.3040
91	13-FEB-87	0.30	4.3000	28.6040
92	14-FEB-87	0.09	4.3900	28.6940
93	15-FEB-87	0.09	4.4800	28.7840
94	16-FEB-87	0.14	4.6200	28.9240
95	02-MAR-87	0.13	4.7470	29.0510
96	03-MAR-87	0.15	4.8994	29.2034
97	04-MAR-87	0.03	4.9248	29.2288
98	05-MAR-87	0.05	4.9756	29.2796
99	06-MAR-87	0.05	5.0264	29.3304
100	08-MAR-87	0.03	5.0518	29.3558
101	09-MAR-87	0.03	5.0772	29.3812
102	11-MAR-87	0.10	5.1788	29.4828

TABLE B.2. (contd)

0 DATE	1 PRECIP (CM)	2 CUMULATIVE ANNUAL (CM)	3 CUMULATIVE TOTAL (CM)
103 12-MAR-87	0.74	5.9154	30.2194
104 13-MAR-87	0.08	5.9916	30.2956
105 14-MAR-87	0.25	6.2456	30.5496
106 15-MAR-87	0.25	6.4996	30.8036
107 17-MAR-87	0.03	6.5250	30.8290
108 18-MAR-87	0.03	6.5504	30.8544
109 19-MAR-87	0.61	7.1600	31.4640
110 10-APR-87	0.23	7.3886	31.6926
111 17-APR-87	0.38	7.7696	32.0736
112 28-APR-87	0.36	8.1252	32.4292
113 12-MAY-87	0.15	8.2776	32.5816
114 30-MAY-87	1.19	9.4714	33.7754
115 08-JUN-87	0.05	9.5222	33.8262
116 15-JUN-87	0.05	9.5730	33.8770
117 02-JUL-87	0.23	9.8016	34.1056
118 18-JUL-87	0.03	9.8270	34.1310
119 13-AUG-87	0.15	9.9794	34.2834
120 26-SEP-87	0.03	10.0094	34.3134
121 01-NOV-87	0.30	10.3094	34.6134
122 02-NOV-87	0.03	10.3394	34.6434
123 11-NOV-87	0.05	10.3894	34.6934
124 13-NOV-87	0.41	10.7994	35.1034
125 24-NOV-87	0.05	10.8494	35.1534
126 30-NOV-87	0.20	11.0494	35.3534
127 01-DEC-87	0.51	11.5594	35.8634
128 02-DEC-87	0.93	12.4894	36.7934
129 03-DEC-87	0.31	12.7994	37.1034
130 04-DEC-87	0.21	13.0094	37.3134
131 05-DEC-87	0.27	13.2794	37.5834
132 06-DEC-87	0.44	13.7194	38.0234
133 09-DEC-87	0.93	14.6494	38.9534
134 15-DEC-87	0.12	14.7694	39.0734
135 16-DEC-87	0.34	15.1094	39.4134
136 20-DEC-87	0.08	15.1894	39.4934
137 28-DEC-87	0.19	15.3794	39.6834
138 04-JAN-88	0.05	0.0508	39.7342
139 07-JAN-88	0.07	0.1208	39.8042
140 08-JAN-88	0.44	0.5608	40.2442
141 09-JAN-88	0.26	0.8208	40.5042
142 10-JAN-88	0.61	1.4308	41.1142
143 13-JAN-88	0.07	1.5008	41.1842
144 14-JAN-88	0.15	1.6532	41.3366
145 20-JAN-88	0.03	1.6786	41.3620
146 17-FEB-88	0.05	1.7294	41.4128
147 04-MAR-88	0.33	2.0596	41.7430
148 05-MAR-88	0.10	2.1612	41.8446
149 08-MAR-88	0.33	2.4914	42.1748
150 26-MAR-88	0.20	2.6946	42.3780
151 28-MAR-88	0.10	2.7962	42.4796
152 29-MAR-88	0.23	3.0248	42.7082
153 02-APR-88	0.28	3.3042	42.9876
154 03-APR-88	0.08	3.3804	43.0638
155 17-APR-88	0.56	3.9404	43.6238
156 18-APR-88	0.05	3.9904	43.6738
157 19-APR-88	0.12	4.1104	43.7938
158 22-APR-88	0.03	4.1404	43.8238
159 28-APR-88	0.15	4.2904	43.9738
160 29-APR-88	0.18	4.4682	44.1516
161 16-MAY-88	0.03	4.4936	44.1770
162 18-MAY-88	0.36	4.8492	44.5326
163 26-MAY-88	0.03	4.8746	44.5580
164 28-MAY-88	1.47	6.3478	46.0312
165 01-JUN-88	0.13	6.4748	46.1582
166 03-JUN-88	0.05	6.5256	46.2090
167 05-JUN-88	0.18	6.7034	46.3868
168 09-JUN-88	0.05	6.7542	46.4376
169 13-JUL-88	0.51	7.2622	46.9456
170 14-JUL-88	0.03	7.2876	46.9710

APPENDIX C

WATER STORAGE PROCEDURES AND DATA

TITLE: MEASUREMENT OF SOIL MOISTURE USING THE NEUTRON PROBE

1.0 APPLICABILITY

This procedure describes the use of the 503-DR Hydroprobe Neutron Depth moisture Gauge in measuring soil moisture in the field. The 503-DR measures subsurface moisture in soil and other materials by using a probe containing a source of high energy neutrons and a slow (thermal) neutron detector. Impact of the fast neutrons with hydrogen present in the water in the soil slows some of the neutrons and deflects them back for detection. The measurement of the number of slow neutrons detected is displayed directly on a digital readout unit attached to the source shield assembly. The digital readout unit operates on NICAD batteries and should be charged before being used. For further information concerning the 503DR, see the operators manual on file in the field lab, Room 1519, Sigma V.

2.0 DEFINITIONS

None. For further technical information, see the operators manual in Room 1519 of Sigma V.

3.0 RESPONSIBLE STAFF

Neutron Probe Operator.

Concurrence [signature]	Date 4/28/88	Approved [signature]		Date 5/9/88
Prepared by JL Downs [signature]	Date 4/28/88	QAD Concurrence [signature]		Date 5/6/88
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FIGURE C.1. Technical Procedure for Soil Moisture Measurement Using the Neutron Probe

4.0 PROCEDURE

4.1 Equipment and Training

- 503-DR Hydroprobe (serial no. 53115140), Neutron Depth Moisture Gauge or equivalent
- Project notebook (Laboratory Record Book, LRB)
- Appropriate cable for the site to be measured (see LRB)
- Radiation Safety Training

4.2 Setting the Format, Time, and Units

The FORMAT key allows the user to specify the number of wells to be monitored and the number of depths to be measured at each well. Whenever the format is changed, any data on the unit are lost. Therefore, before setting the format, check to make sure that any data taken previously has been 'dumped' or telecommunicated from the digital readout unit to a floppy disk.

The steps to set the format are as follows:

4.2.1 Press the FORMAT button on the readout unit. Press STEP until Depth--appears. Key in the number of depths that will be measured for each well and press the ENTER button.

4.2.2 The readout unit will then read SET FMT? Press ENTER to set the format.

Set the counting time on the readout unit by first pressing the TIME key. Next press the STEP key until the appropriate time shows on the screen and then press the ENTER button.

FIGURE C.1. (contd)

Location	Time	Depths
300 Grass Site	16s	17
BWTF Lysimeters	16s	25
200E Lysimeter	16s	38
CWLA	32s	20
Grout Lysimeters	32s	28

The units are set in the same manner as the time. First press the UNIT key on the readout unit. Then press the STEP key until the correct units are displayed (i.e., COUNT LN) and press the ENTER key.

4.3 Mean Standard Count

The neutron probe must be tested in a reference standard at the beginning and end of each day of use. The reference standard may be any invariable medium that will absorb energy from fast neutrons to allow them to react with the detector while they are within its range. The neutron probe shield is used as a standard. Thirty-two measurements must be made in the reference standard. The mean value of the thirty-two measurements is the mean standard count.

4.3.1 Attach the digital readout unit to the hydroprobe and connect the cable from the probe to the readout unit.

4.3.2 Place the probe in the proper position in the indentation on the probe case. Take 32 readings. The 503-DR probe does this automatically:

4.3.2a Press STD on the readout unit. The unit will display the last standard count taken. Press STEP to display the previous chi value. Press STEP again to display the previous mean standard count.

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FIGURE C.1. (contd)

4.3.2b Press STD again; the readout unit will inquire, NEW STD? Press ENTER; the probe will then begin taking 32 consecutive 8-second counts to compute the mean standard count. Stand at least 10 feet from the probe during this time to minimize any effects on the mean standard count. When the probe is finished record the mean standard count, the previous mean standard count, the Chi value, and the serial number of the probe in the LRB.

4.3.3 Evaluate the function of the neutron probe by computing the Chi statistic, R. This calculation is performed automatically by the 503-DR probe if the STD option is used. (If the mean standard count is determined manually, the R value can be calculated using the equations at the end of this step.)

If $0.75 \leq R \leq 1.25$, the probe is working properly.

If $R > 1.25$, the detector is not counting some of the neutrons.

If $R < 0.75$, the detector is counting pulses other than neutrons.

If the Chi value (R) is too high or too low, repeat the test up to 4 times. If the average of the 4 tests is outside the range 0.75 to 1.25, return the probe electronics to the factory for repair.

Equations for manually calculating R:

$$\text{Mean standard count (MSC)} = \frac{\sum_{i=1}^{n} X_i}{n}$$

where n is the total number of readings
and X represents an individual reading

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FIGURE C.1. (contd)

$$\text{Standard Deviation (S)} = \left[\frac{\sum_{i=1}^{n} (X_i - MSC)^2}{n-1} \right]^{1/2}$$

$$\text{Chi Statistic (R)} = S/MSC^{1/2}$$

NOTES:

The range 0.75 to 1.25 is based on a sample size of 32 and a probability interval of 0.95. The range should be recalculated if a different sample size is used.

The 503-DR displays 'S' with the current Standard Count, 'P' with the previous Standard Count and 'Chi' with the ratio, R.

The DR automatically adjusts all readings to a 16-second reading equivalent. Even the automatic calibration makes this adjustment after taking 32 eight-second readings and computing the Chi value. Therefore, if probe calibration is done manually, select the 16-second time interval because any other time interval will yield an incorrect Chi value.

4.4 Measurement

4.4.1 Place the probe on top of the access port. Record in the LRB the time, access port identification, and the depths to be measured.

4.4.2 Lower the probe to the deepest depth and secure the stop on the top of the probe.

4.4.3 Press LOG on the keypad on the readout unit.

4.4.4 Key in the appropriate I.D. number and press ENTER. (The I.D. number consists of a location code and the well number; for example, 991 where 99 is the location code and 1 is the well number.)

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FIGURE C.1. (contd)

Location codes:

BWTF	55
300 N Grass site	99
CWLA	66
200 East Lysimeter	22

(Grout Access tubes are not logged and stored)

4.4.5 STEP through the K Data query. The unit will then read TAKE _#_, where the number refers to the deepest depth that you set in the FORMAT statement.

4.4.6 Press START. The probe will then take the count and display the value on the readout unit.

4.4.7 Record the value in the laboratory notebook alongside the corresponding depth. Press ENTER to store the value in the digital readout unit. The readout unit will then read TAKE _#_, indicating the probe is ready to read the next depth.

4.4.8 Move the cable to the next depth to be measured, and repeat steps 6 and 7 until all measurements for a well are logged. After entering the value for DEPTH 1, the readout unit will query DATA OK?

4.4.9 If data were taken satisfactorily, press ENTER and go on to log the next well. If a mistake was made in taking the readings, press the STEP key to return to that depth and retake that count. Then press STEP to reach the DATA OK? query and press ENTER.

4.4.10 When data collection is completed, bring the digital readout unit to Sigma V/1519. Download the data to the HSPA MicroVAX per instructions from the data base steward.

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FIGURE C.1. (contd)

TABLE C.1. Water Storage in the South Caisson at the Buried Waste Test Facility, January 1984 Through June 1988

DEPTH (FT)	09-JAN-84	23-JAN-84	06-FEB-84	24-FEB-84	05-MAR-84	20-MAR-84	02-APR-84	16-APR-84	02-MAY-84	16-MAY-84
-0.75	2.23	1.97	1.65	2.08	1.77	1.98	1.79	1.63	1.43	1.25
-1.00	0.77	0.64	0.57	0.69	0.62	0.66	0.62	0.57	0.50	0.47
-2.00	3.31	2.71	2.55	2.65	2.69	2.71	2.77	2.60	2.33	2.32
-3.00	3.42	3.08	2.90	2.72	2.90	2.88	3.17	2.95	2.81	2.73
-4.00	3.10	3.10	2.92	2.76	2.76	2.76	3.26	3.01	2.85	2.74
-5.00	2.84	3.02	2.87	2.76	2.66	2.63	3.14	2.93	2.74	2.70
-6.00	2.69	3.13	3.06	2.92	2.90	2.86	3.03	3.10	2.89	2.91
-7.00	2.41	2.88	3.07	2.98	2.98	2.88	2.90	3.10	2.92	3.01
-8.00	2.43	2.58	2.94	3.04	3.04	2.94	2.96	3.00	3.02	3.03
-9.00	2.68	2.65	2.98	3.20	3.25	3.22	3.20	3.18	3.21	3.24
-10.00	2.82	2.79	2.94	3.26	3.29	3.32	3.30	3.27	3.24	3.38
-11.00	2.90	2.88	2.92	3.20	3.26	3.30	3.32	3.33	3.31	3.35
-12.00	3.02	2.98	3.00	3.12	3.29	3.39	3.47	3.46	3.41	3.44
-13.00	3.02	2.98	2.98	3.01	3.19	3.36	3.47	3.42	3.32	3.46
-14.00	3.10	3.07	3.07	3.04	3.16	3.30	3.49	3.43	3.30	3.51
-15.00	3.07	3.07	3.06	3.02	3.06	3.10	3.33	3.38	3.28	3.46
-16.00	3.00	3.02	3.01	2.93	2.95	2.98	3.13	3.26	3.29	3.42
-17.00	3.12	3.12	3.10	3.05	3.01	3.14	3.14	3.18	3.32	3.48
-18.00	3.23	3.22	3.20	3.22	3.18	3.24	3.22	3.20	3.25	3.35
-19.00	3.32	3.31	3.30	3.31	3.32	3.34	3.32	3.32	3.27	3.27
-20.00	3.07	3.08	3.06	3.04	3.03	3.10	3.05	3.04	3.04	3.05
-21.00	2.36	2.37	2.34	2.34	2.37	2.35	2.33	2.36	2.33	2.34
-22.00	2.45	2.46	2.44	2.44	2.49	2.45	2.45	2.50	2.45	2.43
-23.00	3.23	3.24	3.24	3.21	3.24	3.20	3.15	3.15	3.11	3.09
-24.00	3.48	3.46	3.48	3.41	3.50	3.38	3.29	2.96	3.20	2.78
STORAGE 1.2m	12.82	11.50	10.59	10.90	10.74	10.99	11.62	10.77	9.91	9.52
TOTAL STORAGE	71.07	70.83	70.66	71.39	71.91	72.47	74.30	73.34	71.82	72.22

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL 0 FOR THE SOUTH CAISSON

TABLE C.1. (contd)

DEPTH (FT)	31-MAY-84	12-JUN-84	25-JUN-84	12-JUL-84	26-JUL-84	08-AUG-84	28-AUG-84	12-SEP-84	25-SEP-84	17-OCT-84
-0.75	1.23	1.22	1.08	0.87	0.76	0.74	0.68	0.62	0.79	0.82
-1.00	0.43	0.43	0.39	0.34	0.31	0.29	0.27	0.25	0.29	0.29
-2.00	2.17	2.11	1.95	1.86	1.82	1.72	1.65	1.59	1.59	1.54
-3.00	2.60	2.55	2.41	2.34	2.33	2.25	2.21	2.14	2.09	1.99
-4.00	2.54	2.51	2.42	2.33	2.30	2.28	2.20	2.14	2.11	2.02
-5.00	2.55	2.50	2.42	2.35	2.27	2.27	2.20	2.16	2.15	2.04
-6.00	2.81	2.80	2.69	2.62	2.53	2.52	2.49	2.38	2.39	2.32
-7.00	2.89	2.90	2.77	2.66	2.60	2.91	2.59	2.54	2.45	2.43
-8.00	2.97	2.98	2.85	2.74	2.69	3.01	2.63	2.63	2.59	2.48
-9.00	3.17	3.18	3.10	2.97	2.95	2.96	2.84	2.82	2.85	2.78
-10.00	3.30	3.29	3.19	3.06	3.02	3.06	3.01	2.96	2.93	2.94
-11.00	3.36	3.35	3.25	3.12	3.06	3.11	3.10	3.04	2.98	2.95
-12.00	3.44	3.41	3.38	3.21	3.15	3.19	3.19	3.15	3.06	3.09
-13.00	3.47	3.36	3.30	3.23	3.16	3.18	3.14	3.15	3.03	3.10
-14.00	3.51	3.39	3.30	3.26	3.23	3.25	3.15	3.15	3.19	3.11
-15.00	3.47	3.38	3.32	3.20	3.20	3.16	3.13	3.09	3.16	3.06
-16.00	3.37	3.38	3.24	3.19	3.21	3.13	3.13	3.10	3.04	3.01
-17.00	3.45	3.49	3.31	3.36	3.35	3.31	3.26	3.19	3.19	3.14
-18.00	3.54	3.52	3.44	3.43	3.37	3.31	3.33	3.30	3.28	3.22
-19.00	3.56	3.54	3.49	3.47	3.38	3.42	3.38	3.43	3.30	3.29
-20.00	3.20	3.32	3.22	3.17	3.15	3.25	3.13	3.14	3.07	3.11
-21.00	2.38	2.57	2.55	2.46	2.51	2.54	2.50	2.45	2.40	2.46
-22.00	2.43	2.48	2.55	2.55	2.63	2.62	2.58	2.51	2.47	2.53
-23.00	3.09	3.05	3.06	3.08	3.20	3.17	3.14	3.05	3.02	3.06
-24.00	3.21	2.64	2.70	2.85	2.65	2.58	2.78	2.68	2.61	2.75
STORAGE 1.2m	8.98	8.81	8.26	7.72	7.53	7.28	7.01	6.74	6.87	6.67
TOTAL STORAGE	72.15	71.34	69.41	67.72	66.84	67.22	65.71	64.68	64.04	63.52

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL 0 FOR THE SOUTH CAISSON

TABLE C.1. (contd)

DEPTH (FT)	15-NOV-84	11-DEC-84	27-DEC-84	3Ø-JAN-85	12-FEB-85	27-FEB-85	12-MAR-85	25-MAR-85	1Ø-APR-85	23-APR-85
-Ø.75	1.25	1.91	2.38	1.98	2.62	1.84	1.73	1.51	1.38	1.21
-1.ØØ	Ø.39	Ø.63	Ø.76	Ø.51	Ø.78	Ø.62	Ø.6Ø	Ø.53	Ø.49	Ø.43
-2.ØØ	1.63	2.6Ø	2.81	2.Ø8	2.71	2.77	2.69	2.46	2.34	2.1Ø
-3.ØØ	1.86	2.63	2.82	2.78	2.77	3.36	3.Ø6	2.87	2.76	2.58
-4.ØØ	1.83	2.14	2.42	2.48	2.58	3.58	3.Ø6	2.91	3.Ø9	2.67
-5.ØØ	1.88	1.91	2.Ø4	2.15	2.29	3.41	3.ØØ	2.86	3.Ø7	2.65
-6.ØØ	2.17	2.19	2.29	2.37	2.4Ø	2.95	3.14	3.Ø5	2.98	2.89
-7.ØØ	2.28	2.29	2.4Ø	2.42	2.41	2.4Ø	2.78	2.98	3.Ø5	2.94
-8.ØØ	2.38	2.32	2.49	2.43	2.44	2.43	2.46	2.69	2.94	2.94
-9.ØØ	2.61	2.55	2.74	2.71	2.71	2.73	2.65	2.74	2.88	3.Ø8
-1Ø.ØØ	2.77	2.7Ø	2.88	2.87	2.87	2.88	2.82	2.87	2.89	3.Ø1
-11.ØØ	2.91	2.79	2.95	2.85	2.98	2.96	2.93	2.93	2.98	2.92
-12.ØØ	2.98	2.98	3.Ø6	2.94	3.11	3.11	3.Ø6	3.Ø5	3.11	3.Ø4
-13.ØØ	2.97	2.96	3.Ø4	3.Ø3	3.1Ø	3.Ø9	2.98	3.Ø7	3.12	3.Ø9
-14.ØØ	3.Ø9	2.98	3.1Ø	3.2Ø	3.19	3.14	3.Ø2	3.11	3.2Ø	3.15
-15.ØØ	3.Ø4	2.97	3.Ø9	3.21	3.11	3.1Ø	3.Ø3	3.Ø4	3.17	3.12
-16.ØØ	2.93	2.91	3.Ø5	3.11	3.Ø7	3.Ø3	2.97	3.ØØ	3.Ø8	3.Ø9
-17.ØØ	3.Ø5	3.ØØ	3.14	3.18	3.22	3.18	3.Ø7	3.11	3.2Ø	3.19
-18.ØØ	3.15	3.Ø8	3.24	3.26	3.28	3.31	3.16	3.19	3.31	3.26
-19.ØØ	3.2Ø	3.17	3.36	3.34	3.42	3.41	3.24	3.26	3.38	3.31
-2Ø.ØØ	2.98	2.98	3.Ø7	2.78	3.15	3.1Ø	3.ØØ	3.Ø1	3.Ø7	3.Ø6
-21.ØØ	2.32	2.29	2.35	2.26	2.41	2.32	2.32	2.34	2.33	2.38
-22.ØØ	2.43	2.35	2.52	2.69	2.55	2.49	2.41	2.45	2.44	2.46
-23.ØØ	3.Ø4	2.94	3.15	2.73	3.22	3.14	3.Ø2	3.12	3.Ø6	3.Ø1
-24.ØØ	2.62	2.52	2.67	2.91	2.91	2.65	2.63	2.85	2.87	2.6Ø
STORAGE 1.2m	6.97	9.91	11.19	9.84	11.47	12.18	11.14	1Ø.29	1Ø.Ø7	8.99
TOTAL STORAGE	61.78	63.8Ø	67.82	66.28	69.34	71.Ø2	68.84	69.Ø1	7Ø.19	68.19

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL Ø FOR THE SOUTH CAISSON

TABLE C.1. (contd)

DEPTH (FT)	Ø8-MAY-85	21-MAY-85	3Ø-JUL-85	16-AUG-85	18-SEP-85	Ø1-OCT-85	15-OCT-85	3Ø-OCT-85	25-NOV-85	1Ø-DEC-85
-Ø.75	1.14	1.Ø6	Ø.64	Ø.59	Ø.8Ø	Ø.73	Ø.87	Ø.6Ø	1.1Ø	2.Ø2
-1.ØØ	Ø.4Ø	Ø.38	Ø.27	Ø.33	Ø.29	Ø.28	Ø.32	Ø.26	Ø.36	Ø.67
-2.ØØ	2.Ø7	2.Ø2	1.8Ø	1.93	1.6Ø	1.62	1.62	1.59	1.63	2.89
-3.ØØ	2.61	2.53	2.38	2.2Ø	2.1Ø	2.Ø5	2.Ø4	2.Ø1	1.91	3.33
-4.ØØ	2.59	2.52	2.31	2.23	2.17	2.Ø4	2.Ø3	1.98	1.91	2.74
-5.ØØ	2.59	2.76	2.29	2.27	2.35	2.11	2.Ø7	2.Ø5	1.96	2.Ø1
-6.ØØ	2.89	3.Ø6	2.62	2.59	2.59	2.38	2.42	2.37	2.27	2.26
-7.ØØ	2.91	2.91	2.79	2.67	2.59	2.47	2.52	2.47	2.37	2.38
-8.ØØ	2.97	2.9Ø	2.84	2.73	2.68	2.54	2.58	2.63	2.46	2.41
-9.ØØ	3.16	3.Ø7	3.Ø8	2.99	2.9Ø	2.9Ø	2.83	2.93	2.69	2.66
-1Ø.ØØ	3.11	3.18	3.17	3.Ø8	3.ØØ	3.Ø6	2.99	2.98	2.82	2.85
-11.ØØ	3.Ø3	3.2Ø	3.17	3.Ø9	3.12	3.Ø1	3.Ø2	3.Ø1	2.91	2.92
-12.ØØ	3.Ø9	3.22	3.29	3.21	3.2Ø	3.Ø7	3.13	3.Ø9	3.Ø1	3.Ø1
-13.ØØ	3.Ø9	3.13	3.27	3.22	3.13	3.Ø7	3.13	3.1Ø	3.Ø5	3.Ø3
-14.ØØ	3.19	3.17	3.3Ø	3.27	3.25	3.18	3.15	3.18	3.12	3.Ø9
-15.ØØ	3.13	3.15	3.22	3.25	3.19	3.17	3.17	3.11	3.Ø7	3.Ø8
-16.ØØ	3.Ø4	3.15	3.13	3.2Ø	3.17	3.Ø9	3.14	3.Ø9	3.Ø2	2.99
-17.ØØ	3.18	3.27	3.19	3.27	3.3Ø	3.19	3.23	3.2Ø	3.12	3.Ø7
-18.ØØ	3.27	3.33	3.28	3.27	3.29	3.24	3.32	3.28	3.18	3.19
-19.ØØ	3.38	3.35	3.41	3.31	3.36	3.31	3.4Ø	3.34	3.24	3.27
-2Ø.ØØ	3.11	3.Ø7	3.Ø8	3.Ø2	3.Ø7	3.Ø7	3.13	3.Ø9	3.Ø5	3.Ø5
-21.ØØ	2.42	2.43	2.46	2.33	2.32	2.39	2.42	2.38	2.37	2.33
-22.ØØ	2.58	2.58	2.63	2.47	2.49	2.6Ø	2.58	2.47	2.44	2.36
-23.ØØ	3.Ø8	3.15	3.2Ø	3.13	3.13	3.18	3.14	3.12	3.Ø5	3.ØØ
-24.ØØ	2.62	2.67	2.74	2.71	2.71	2.72	2.59	2.73	2.55	2.51
STORAGE 1.2m	8.82	8.52	7.39	7.27	6.97	6.73	6.88	6.44	6.91	11.65
TOTAL STORAGE	68.69	69.25	67.57	66.37	65.81	64.47	64.83	64.Ø6	62.66	67.13

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL Ø FOR THE SOUTH CAISSON

TABLE C.1. (contd)

DEPTH (FT)	31-DEC-85	23-JAN-86	Ø5-FEB-86	24-FEB-86	19-MAR-86	Ø4-APR-86	Ø8-MAY-86	23-MAY-86	1Ø-JUN-86	27-JUN-86
-Ø.75	1.88	2.32	2.32	2.35	1.59	1.49	1.44	1.28	1.Ø2	Ø.9Ø
-1.ØØ	Ø.58	Ø.77	Ø.76	Ø.79	Ø.54	Ø.52	Ø.56	Ø.44	Ø.37	Ø.34
-2.ØØ	2.23	3.Ø1	3.16	3.23	2.38	2.38	2.7Ø	2.15	1.96	1.91
-3.ØØ	2.57	3.17	3.31	3.1Ø	2.58	2.55	2.65	2.57	2.52	2.37
-4.ØØ	2.5Ø	3.3Ø	3.23	2.86	2.5Ø	2.4Ø	2.5Ø	2.56	2.53	2.34
-5.ØØ	2.14	3.35	3.Ø7	2.8Ø	2.44	2.36	2.63	2.57	2.48	2.34
-6.ØØ	2.23	3.24	3.Ø5	3.Ø1	2.63	2.48	2.79	2.79	2.69	2.56
-7.ØØ	2.34	2.83	2.99	3.12	2.69	2.49	2.9Ø	2.89	2.8Ø	2.68
-8.ØØ	2.4Ø	2.64	2.92	3.Ø8	2.69	2.58	2.98	2.96	2.88	2.81
-9.ØØ	2.67	2.7Ø	3.17	3.27	2.89	2.85	3.25	3.19	3.Ø9	3.Ø5
-1Ø.ØØ	2.81	2.77	3.32	3.44	3.ØØ	2.97	3.42	3.36	3.24	3.18
-11.ØØ	2.86	2.8Ø	3.37	3.47	3.Ø4	3.Ø1	3.44	3.47	3.32	3.22
-12.ØØ	3.Ø1	2.9Ø	3.36	3.5Ø	3.1Ø	3.Ø8	3.54	3.53	3.44	3.31
-13.ØØ	2.98	2.94	3.14	3.46	3.Ø7	3.Ø5	3.52	3.49	3.38	3.33
-14.ØØ	3.Ø3	3.Ø5	3.Ø5	3.47	3.16	3.Ø7	3.56	3.59	3.41	3.38
-15.ØØ	3.Ø4	3.Ø4	2.96	3.38	3.Ø6	3.Ø1	3.5Ø	3.5Ø	3.41	3.36
-16.ØØ	2.95	2.99	2.95	3.36	2.97	2.94	3.49	3.48	3.36	3.3Ø
-17.ØØ	3.Ø2	3.Ø8	3.1Ø	3.4Ø	3.12	3.Ø5	3.63	3.66	3.5Ø	3.45
-18.ØØ	3.14	3.14	3.2Ø	3.35	3.19	3.17	3.7Ø	3.71	3.61	3.59
-19.ØØ	3.23	3.22	3.3Ø	3.31	3.21	3.18	3.78	3.73	3.63	3.66
-2Ø.ØØ	3.Ø5	2.99	3.Ø3	2.99	2.88	2.85	3.49	3.48	3.37	3.39
-21.ØØ	2.39	2.32	2.31	2.29	2.Ø2	2.15	2.76	2.78	2.76	2.66
-22.ØØ	2.44	2.45	2.47	2.41	2.Ø9	2.21	2.84	2.89	2.79	2.77
-23.ØØ	3.Ø6	3.Ø6	3.1Ø	3.Ø8	2.73	2.68	3.34	3.46	3.29	3.3Ø
-24.ØØ	2.49	2.53	2.59	2.66	2.27	2.2Ø	2.73	2.88	2.8Ø	2.85
STORAGE 1.2m	9.75	12.56	12.78	12.32	9.6Ø	9.35	9.85	9.ØØ	8.41	7.86
TOTAL STORAGE	65.Ø3	7Ø.6Ø	73.2Ø	75.15	65.84	64.73	75.14	74.39	71.63	7Ø.Ø3

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL Ø FOR THE SOUTH CAISSON

TABLE C.1. (contd)

DEPTH (FT)	28-JUL-86	07-AUG-86	21-AUG-86	05-SEP-86	18-SEP-86	03-OCT-86	20-OCT-86	31-OCT-86	17-NOV-86	01-DEC-86
-0.75	0.89	0.83	0.77	0.69	0.80	1.13	1.02	1.04	1.09	1.55
-1.00	0.33	0.32	0.29	0.27	0.29	0.38	0.37	0.35	0.43	0.48
-2.00	1.86	1.79	1.75	1.70	1.65	1.76	1.84	1.57	2.04	1.89
-3.00	2.41	2.32	2.31	2.26	2.15	2.16	2.13	1.87	1.98	1.99
-4.00	2.37	2.31	2.27	2.21	2.13	2.13	2.12	1.84	2.08	1.92
-5.00	2.34	2.33	2.28	2.24	2.22	2.16	2.23	1.89	2.37	2.02
-6.00	2.66	2.58	2.56	2.52	2.54	2.46	2.48	2.47	2.37	2.33
-7.00	2.71	2.65	2.62	2.59	2.59	2.60	2.53	2.51	2.45	2.40
-8.00	2.73	2.71	2.71	2.72	2.67	2.65	2.66	2.30	2.73	2.52
-9.00	2.94	2.95	2.97	2.94	2.92	2.85	2.95	2.61	2.90	2.81
-10.00	3.09	3.11	3.06	3.04	3.01	3.07	3.12	2.74	2.99	2.88
-11.00	3.19	3.18	3.15	3.15	3.03	3.14	3.16	2.76	3.07	2.96
-12.00	3.30	3.27	3.29	3.26	3.15	3.21	3.31	2.92	3.03	3.14
-13.00	3.36	3.24	3.30	3.26	3.23	3.25	3.31	2.91	3.14	3.13
-14.00	3.44	3.33	3.38	3.34	3.32	3.34	3.32	2.94	3.14	3.17
-15.00	3.41	3.33	3.43	3.31	3.26	3.29	3.33	2.96	3.08	3.14
-16.00	3.36	3.32	3.36	3.28	3.20	3.23	3.27	2.90	3.18	3.12
-17.00	3.46	3.45	3.44	3.34	3.41	3.34	3.44	2.99	3.31	3.28
-18.00	3.58	3.54	3.56	3.40	3.52	3.47	3.57	3.11	3.45	3.35
-19.00	3.62	3.60	3.58	3.56	3.51	3.54	3.58	3.20	3.16	3.39
-20.00	3.35	3.30	3.24	3.26	3.24	3.29	3.32	2.92	2.40	3.11
-21.00	2.68	2.59	2.56	2.58	2.59	2.59	2.62	2.24	2.59	2.41
-22.00	2.74	2.72	2.71	2.74	2.71	2.69	2.71	2.40	3.23	2.62
-23.00	3.33	3.31	3.28	3.24	3.29	3.26	3.30	2.95	2.70	3.28
-24.00	2.95	2.77	2.85	2.89	2.86	2.68	2.89	2.97	2.05	2.82
STORAGE 1.2m	7.86	7.58	7.40	7.13	7.02	7.56	7.48	6.67	7.62	7.83
TOTAL STORAGE	70.08	68.86	68.73	67.79	67.29	67.68	68.57	61.37	64.98	65.72

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL 0 FOR THE SOUTH CAISSON

TABLE C.1. (contd)

DEPTH (FT)	15-DEC-86	30-DEC-86	13-JAN-87	30-JAN-87	13-FEB-87	10-MAR-87	23-MAR-87	14-APR-87	21-APR-87	05-MAY-87
-0.75	1.69	2.06	1.79	2.22	1.82	1.56	1.91	1.08	1.37	0.93
-1.00	0.56	0.71	0.62	0.75	0.62	0.54	0.66	0.44	0.48	0.39
-2.00	2.04	2.60	2.80	3.28	2.79	2.50	2.76	2.40	2.24	2.21
-3.00	1.96	2.20	2.72	3.36	3.18	2.85	2.90	2.83	2.66	2.71
-4.00	1.91	1.93	2.07	2.57	3.11	2.87	2.85	2.79	2.66	2.71
-5.00	1.98	1.97	1.91	2.06	2.50	2.82	2.76	2.71	2.57	2.65
-6.00	2.34	2.29	2.23	2.27	2.26	2.74	2.88	2.90	2.79	2.88
-7.00	2.42	2.38	2.34	2.30	2.34	2.44	2.64	2.82	2.75	2.89
-8.00	2.42	2.45	2.41	2.42	2.37	2.40	2.43	2.59	2.56	2.80
-9.00	2.66	2.69	2.68	2.66	2.61	2.63	2.66	2.65	2.58	2.82
-10.00	2.76	2.83	2.79	2.76	2.72	2.76	2.81	2.77	2.59	2.79
-11.00	2.84	2.90	2.84	2.86	2.81	2.83	2.86	2.82	2.65	2.80
-12.00	3.01	2.98	2.96	2.90	2.97	2.93	2.90	2.89	2.73	2.90
-13.00	3.02	3.01	2.95	2.88	3.02	2.88	2.92	2.86	2.78	2.94
-14.00	3.10	3.12	3.01	3.06	3.13	2.99	3.07	2.96	2.94	3.02
-15.00	3.09	3.07	3.01	3.08	3.08	3.08	3.08	2.95	2.88	2.96
-16.00	3.02	3.06	2.99	3.03	2.98	3.03	3.05	2.92	2.81	2.88
-17.00	3.13	3.20	3.14	3.11	3.07	3.11	3.08	3.06	2.94	3.00
-18.00	3.26	3.30	3.24	3.20	3.23	3.18	3.15	3.09	3.05	3.11
-19.00	3.36	3.38	3.31	3.27	3.32	3.32	3.28	3.24	3.15	3.19
-20.00	3.10	3.07	3.00	3.01	2.98	3.05	3.02	3.00	2.84	2.91
-21.00	2.37	2.35	2.31	2.36	2.34	2.34	2.31	2.22	2.16	2.21
-22.00	2.50	2.57	2.47	2.51	2.61	2.54	2.46	2.41	2.35	2.41
-23.00	3.16	3.18	3.12	3.14	3.24	3.16	3.14	3.09	2.96	3.10
-24.00	2.73	2.64	2.81	2.67	2.70	2.70	2.70	2.57	2.50	2.64
STORAGE 1.2m	8.16	9.50	10.00	12.18	11.53	10.33	11.09	9.55	9.39	8.95
TOTAL STORAGE	64.42	65.94	65.51	67.74	67.81	67.29	68.26	66.08	63.95	65.84

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL 0 FOR THE SOUTH CAISSON

TABLE C.1. (contd)

DEPTH (FT)	20-MAY-87	03-JUN-87	18-JUN-87	08-JUL-87	23-JUL-87	04-AUG-87	20-AUG-87	03-SEP-87	18-SEP-87	30-SEP-87
-0.75	1.10	1.22	1.09	0.94	0.87	0.77	0.74	0.64	0.65	0.71
-1.00	0.39	0.42	0.39	0.35	0.32	0.30	0.29	0.25	0.27	0.27
-2.00	2.08	2.09	1.99	1.93	1.79	1.81	1.75	1.61	1.71	1.57
-3.00	2.62	2.52	2.49	2.46	2.32	2.34	2.32	2.12	2.20	2.09
-4.00	2.64	2.56	2.49	2.46	2.40	2.32	2.28	2.14	2.16	2.12
-5.00	2.65	2.64	2.51	2.52	2.45	2.36	2.33	2.30	2.26	2.23
-6.00	2.83	2.91	2.80	2.81	2.70	2.67	2.67	2.62	2.56	2.56
-7.00	2.85	2.88	2.86	2.85	2.80	2.77	2.77	2.66	2.63	2.66
-8.00	2.87	2.85	2.92	2.92	2.88	2.83	2.86	2.78	2.74	2.72
-9.00	2.92	2.99	3.08	3.12	3.08	3.06	3.06	3.07	2.98	2.97
-10.00	2.79	2.90	3.03	3.10	3.15	3.20	3.19	3.19	3.10	3.11
-11.00	2.73	2.81	2.88	2.95	3.07	3.15	3.22	3.18	3.16	3.14
-12.00	2.78	2.81	2.88	2.88	3.01	3.06	3.19	3.25	3.23	3.21
-13.00	2.76	2.82	2.86	2.84	2.89	2.94	3.01	3.14	3.17	3.21
-14.00	2.92	2.98	2.95	2.95	2.95	2.97	2.98	3.04	3.11	3.21
-15.00	2.95	2.97	2.92	2.97	2.95	3.47	2.93	2.94	2.97	3.01
-16.00	2.90	2.91	2.87	2.89	2.82	3.41	2.86	2.81	2.85	2.86
-17.00	2.98	3.03	2.99	2.98	2.92	2.99	2.95	2.94	2.93	2.94
-18.00	3.14	3.14	3.09	3.14	3.08	3.14	3.04	3.04	3.02	3.03
-19.00	3.27	3.27	3.23	3.31	3.20	3.22	3.17	3.10	3.09	3.15
-20.00	2.89	2.88	2.89	2.93	2.90	2.88	2.88	2.82	2.82	2.87
-21.00	2.18	2.15	2.19	2.18	2.18	2.12	2.17	2.14	2.18	2.17
-22.00	2.41	2.43	2.45	2.44	2.39	2.34	2.42	2.33	2.32	2.40
-23.00	3.09	3.06	3.11	3.12	3.10	3.06	3.10	3.08	3.01	3.09
-24.00	2.62	2.61	2.60	2.68	2.76	2.65	2.78	2.89	2.65	2.62
STORAGE 1.2m	8.83	8.82	8.46	8.13	7.71	7.53	7.38	6.76	6.99	6.76
TOTAL STORAGE	65.36	65.86	65.55	65.74	65.00	65.84	64.98	64.08	63.75	63.93

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL 0 FOR THE SOUTH CAISSON

<u>TABLE C.1</u>. (contd)

DEPTH (FT)	21-OCT-87	04-NOV-87	24-NOV-87	18-DEC-87	06-JAN-88	26-JAN-88	12-FEB-88	23-FEB-88	09-MAR-88	25-MAR-88
-0.75	0.40	0.70	0.78	1.88	1.60	1.44	1.28	1.08	1.21	0.90
-1.00	0.21	0.27	0.29	0.63	0.55	0.51	0.44	0.39	0.41	0.34
-2.00	1.57	1.55	1.59	2.45	2.48	2.44	2.16	2.04	1.97	1.87
-3.00	2.03	2.00	1.97	2.15	2.56	3.00	2.75	2.70	2.60	2.53
-4.00	2.00	2.06	1.91	1.85	2.17	2.95	2.95	2.87	2.80	2.71
-5.00	2.14	2.15	2.03	1.95	2.08	2.26	2.58	2.61	2.59	2.57
-6.00	2.48	2.47	2.37	2.23	2.39	2.05	2.27	2.41	2.60	2.62
-7.00	2.55	2.59	2.48	2.34	2.47	2.24	2.29	2.32	2.52	2.54
-8.00	2.64	2.67	2.58	2.43	2.58	2.33	2.35	2.34	2.40	2.37
-9.00	2.95	2.88	2.83	2.67	2.85	2.59	2.59	2.54	2.59	2.53
-10.00	3.11	3.02	2.95	2.79	2.98	2.86	2.85	2.78	2.82	2.75
-11.00	3.20	3.10	3.03	2.86	3.09	2.85	2.90	2.88	2.89	2.83
-12.00	3.27	3.19	3.19	3.00	3.20	3.01	3.00	3.01	3.01	2.96
-13.00	3.21	3.19	3.24	3.05	3.19	3.09	3.01	3.03	3.07	3.00
-14.00	3.23	3.21	3.27	3.09	3.25	3.11	3.04	3.05	3.13	3.04
-15.00	3.00	3.09	3.15	2.97	3.20	3.09	3.04	3.05	3.10	3.05
-16.00	2.78	2.93	3.02	2.89	3.12	3.02	2.98	3.01	3.04	3.06
-17.00	2.92	2.95	2.99	2.93	3.23	3.11	3.05	3.13	3.14	3.15
-18.00	3.06	3.01	2.98	2.92	3.25	3.08	3.06	3.10	3.13	3.15
-19.00	3.14	3.11	3.09	2.96	3.23	3.05	3.05	3.04	3.14	3.21
-20.00	2.83	2.85	2.81	2.75	2.98	3.04	3.01	3.10	3.10	3.19
-21.00	2.14	2.11	2.07	2.06	2.17	2.24	2.24	2.28	2.27	2.32
-22.00	2.34	2.23	2.29	2.20	2.30	2.03	2.03	2.06	2.09	2.15
-23.00	3.05	2.94	3.00	2.90	3.03	2.69	2.67	2.75	2.72	2.84
-24.00	2.57	2.50	2.52	2.48	2.55	2.62	2.53	2.61	2.59	2.59
STORAGE 1.2m	6.21	6.59	6.54	8.95	9.35	10.33	9.58	9.08	8.98	8.34
TOTAL STORAGE	62.80	62.78	62.44	62.40	66.51	64.67	64.13	64.19	64.90	64.26

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL 0 FOR THE SOUTH CAISSON

TABLE C.1. (contd)

DEPTH (FT)	07-APR-88	19-APR-88	05-MAY-88	17-MAY-88	31-MAY-88	08-JUN-88	14-JUN-88	27-JUN-88
-0.75	0.94	1.00	0.86	0.75	1.14	0.97	0.83	0.58
-1.00	0.34	0.36	0.32	0.29	0.39	0.36	0.31	0.24
-2.00	1.78	1.77	1.77	1.69	1.81	1.80	1.73	1.57
-3.00	2.48	2.43	2.46	2.38	2.32	2.33	2.37	2.31
-4.00	2.67	2.66	2.58	2.55	2.51	2.53	2.44	2.46
-5.00	2.53	2.51	2.46	2.41	2.39	2.49	2.30	2.32
-6.00	2.69	2.67	2.68	2.61	2.59	2.65	2.55	2.49
-7.00	2.74	2.72	2.81	2.74	2.79	2.76	2.72	2.67
-8.00	2.57	2.56	2.66	2.68	2.74	2.76	2.76	2.70
-9.00	2.59	2.64	2.72	2.71	2.77	2.76	2.81	2.80
-10.00	2.78	2.80	2.88	2.79	2.84	2.82	2.81	2.88
-11.00	2.91	2.88	2.91	2.87	2.80	2.86	2.84	2.87
-12.00	3.01	3.04	3.05	3.00	2.93	2.97	3.00	2.99
-13.00	2.99	3.09	3.07	2.98	2.95	3.01	3.04	3.00
-14.00	3.01	3.11	3.07	3.05	2.97	3.10	3.04	2.99
-15.00	2.98	3.05	3.05	3.04	2.98	3.06	2.98	3.06
-16.00	2.98	2.99	3.06	2.97	2.98	2.99	2.98	3.05
-17.00	3.08	3.12	3.19	3.14	3.13	3.13	3.13	3.11
-18.00	3.05	3.11	3.15	3.21	3.08	3.15	3.14	3.09
-19.00	3.14	3.17	3.14	3.23	3.16	3.21	3.20	3.15
-20.00	3.14	3.22	3.21	3.18	3.19	3.20	3.23	3.22
-21.00	2.30	2.34	2.35	2.33	2.27	2.39	2.39	2.35
-22.00	2.10	2.12	2.14	2.15	2.12	2.19	2.19	2.15
-23.00	2.74	2.79	2.82	2.83	2.82	2.81	2.89	2.83
-24.00	2.62	2.66	2.62	2.65	2.64	2.65	2.71	2.69
STORAGE 1.2m	8.21	8.22	7.99	7.66	8.17	7.98	7.67	7.16
TOTAL STORAGE	64.15	64.81	65.01	64.22	64.30	64.93	64.39	63.55

TRAPEZOIDAL AVERAGING OF PERCENT MOISTURE DATA MULTIPLIED BY DEPTH INCREMENTS IN COL 0 FOR THE SOUTH CAISSON

TABLE C.2. Water Storage in the South Weighing Lysimeter at the Buried Waste Test Facility, January 1984 Through June 1988

DEPTH (FT)	09-JAN-84	23-JAN-84	06-FEB-84	24-FEB-84	05-MAR-84	20-MAR-84	02-APR-84	16-APR-84	02-MAY-84	16-MAY-84
-0.75	3.16	2.55	1.82	2.25	1.70	1.65	1.54	1.07	0.87	0.80
-1.00	0.99	0.80	0.61	0.73	0.58	0.55	0.54	0.39	0.34	0.32
-2.00	3.46	2.81	2.48	2.66	2.52	2.32	2.52	2.06	1.83	1.79
-3.00	3.21	2.75	2.55	2.50	2.59	2.49	2.77	2.48	2.22	2.22
-4.00	3.47	3.26	3.08	2.86	2.93	2.98	3.29	2.95	2.57	2.63
STORAGE 1.2m	14.30	12.18	10.55	10.99	10.33	9.99	10.67	8.96	7.82	7.76

DEPTH (FT)	31-MAY-84	12-JUN-84	25-JUN-84	12-JUL-84	26-JUL-84	08-AUG-84	28-AUG-84	12-SEP-84	25-SEP-84	17-OCT-84
-0.75	0.73	0.82	0.70	0.56	0.52	0.46	0.43	0.42	0.64	0.61
-1.00	0.29	0.32	0.28	0.24	0.22	0.20	0.19	0.19	0.24	0.24
-2.00	1.66	1.70	1.60	1.47	1.42	1.35	1.29	1.31	1.29	1.34
-3.00	2.11	2.05	2.01	1.89	1.88	1.85	1.76	1.76	1.69	1.71
-4.00	2.56	2.49	2.41	2.37	2.37	2.44	2.26	2.33	2.27	2.26
STORAGE 1.2m	7.35	7.38	7.00	6.53	6.40	6.31	5.93	6.01	6.14	6.16

DEPTH (FT)	15-NOV-84	11-DEC-84	27-DEC-84	30-JAN-85	12-FEB-85	27-FEB-85	12-MAR-85	25-MAR-85	10-APR-85	23-APR-85
-0.75	0.98	1.85	2.21	2.82	1.97	1.87	1.59	1.28	0.86	0.82
-1.00	0.32	0.59	0.67	0.76	0.66	0.63	0.55	0.45	0.35	0.32
-2.00	1.41	2.26	2.37	2.31	2.44	2.82	2.39	2.13	1.93	1.81
-3.00	1.65	2.06	2.26	2.38	2.28	3.02	2.57	2.48	2.32	2.23
-4.00	2.16	2.14	2.39	2.88	2.51	3.09	3.02	3.05	3.05	3.00
STORAGE 1.2m	6.51	8.90	9.90	11.14	9.85	11.44	10.11	9.38	8.51	8.17

DEPTH (FT)	08-MAY-85	21-MAY-85	30-JUL-85	16-AUG-85	18-SEP-85	01-OCT-85	15-OCT-85	30-OCT-85	25-NOV-85	10-DEC-85
-0.75	0.67	0.60	0.40	0.32	0.58	0.56	0.76	0.43	0.99	1.52
-1.00	0.28	0.26	0.19	0.17	0.23	0.22	0.26	0.22	0.32	0.45
-2.00	1.67	1.58	1.28	1.24	1.36	1.27	1.34	1.38	1.35	1.56
-3.00	2.11	2.05	1.83	1.67	1.76	1.69	1.79	1.70	1.60	1.61
-4.00	2.99	2.99	2.48	2.32	2.32	2.23	2.30	2.15	2.04	2.05
STORAGE 1.2m	7.72	7.48	6.18	5.73	6.25	5.96	6.44	5.88	6.30	7.19

TABLE C.2. (contd)

DEPTH (FT)	31-DEC-85	23-JAN-86	05-FEB-86	24-FEB-86	19-MAR-86	04-APR-86	08-MAY-86	23-MAY-86	10-JUN-86	27-JUN-86
-0.75	1.38	2.45	2.42	2.17	1.46	1.50	0.71	0.67	0.45	0.40
-1.00	0.42	0.80	0.79	0.74	0.48	0.53	0.28	0.25	0.20	0.16
-2.00	1.55	2.97	3.03	3.05	2.00	2.46	1.64	1.48	1.31	1.09
-3.00	1.64	2.70	2.96	3.01	2.14	2.83	2.08	1.91	1.77	1.59
-4.00	2.00	2.68	3.40	3.32	2.90	3.70	2.45	2.30	2.19	2.06
STORAGE 1.2m	7.00	11.61	12.61	12.29	8.98	11.03	7.16	6.61	5.92	5.30

DEPTH (FT)	28-JUL-86	07-AUG-86	21-AUG-86	05-SEP-86	18-SEP-86	03-OCT-86	20-OCT-86	31-OCT-86	17-NOV-86	01-DEC-86
-0.75	0.36	0.37	0.37	0.34	0.43	0.62	0.57	0.63	0.69	1.00
-1.00	0.16	0.16	0.16	0.14	0.16	0.21	0.20	0.20	0.23	0.31
-2.00	1.06	1.02	0.99	0.90	0.86	0.95	0.89	0.80	0.91	1.06
-3.00	1.48	1.44	1.29	1.09	0.98	0.98	0.93	0.76	0.88	0.93
-4.00	1.87	1.81	1.42	1.06	0.89	0.95	0.91	0.70	0.83	0.86
STORAGE 1.2m	4.92	4.80	4.23	3.54	3.32	3.71	3.49	3.09	3.54	4.16

DEPTH (FT)	16-DEC-86	30-DEC-86	13-JAN-87	30-JAN-87	13-FEB-87	10-MAR-87	23-MAR-87	14-APR-87	21-APR-87	05-MAY-87
-0.75	1.17	1.85	1.68	2.22	1.81	1.28	0.98	0.22	0.50	0.23
-1.00	0.37	0.61	0.56	0.73	0.60	0.44	0.36	0.16	0.19	0.15
-2.00	1.16	1.71	2.23	2.82	2.42	2.03	1.84	1.38	1.19	1.15
-3.00	0.87	0.94	1.57	2.03	2.27	2.13	2.02	1.81	1.61	1.57
-4.00	0.81	0.85	0.86	1.09	1.55	1.83	1.87	1.79	1.70	1.74
STORAGE 1.2m	4.37	5.96	6.90	8.90	8.65	7.71	7.07	5.36	5.20	4.84

DEPTH (FT)	20-MAY-87	03-JUN-87	18-JUN-87	08-JUL-87	23-JUL-87	04-AUG-87	20-AUG-87	03-SEP-87	16-SEP-87	30-SEP-87
-0.75	0.36	0.59	0.51	0.45	0.39	0.37	0.34	0.30	0.31	0.30
-1.00	0.16	0.21	0.21	0.18	0.16	0.15	0.14	0.14	0.14	0.14
-2.00	1.09	1.11	1.16	1.11	1.04	0.99	0.99	0.98	1.00	0.98
-3.00	1.46	1.40	1.40	1.42	1.39	1.32	1.37	1.34	1.32	1.30
-4.00	1.61	1.52	1.53	1.52	1.52	1.47	1.53	1.46	1.44	1.45
STORAGE 1.2m	4.68	4.83	4.81	4.68	4.50	4.30	4.38	4.22	4.21	4.17

TABLE C.2. (contd)

DEPTH (FT)	21-OCT-87	Ø4-NOV-87	24-NOV-87	18-DEC-87	Ø6-JAN-88	26-JAN-88	12-FEB-88	23-FEB-88	Ø9-MAR-88	25-MAR-88
-Ø.75	Ø.33	Ø.33	Ø.46	1.74	1.6Ø	2.Ø4	1.8Ø	1.48	1.46	Ø.87
-1.ØØ	Ø.14	Ø.14	Ø.18	Ø.54	Ø.51	Ø.66	Ø.57	Ø.49	Ø.47	Ø.32
-2.ØØ	1.ØØ	Ø.97	1.Ø5	1.68	1.75	2.49	2.18	2.Ø1	1.86	1.6Ø
-3.ØØ	1.31	1.27	1.29	1.28	1.48	1.95	1.99	1.93	1.88	1.78
-4.ØØ	1.39	1.41	1.39	1.3Ø	1.43	1.41	1.64	1.7Ø	1.83	1.75
STORAGE 1.2m	4.16	4.13	4.37	6.56	6.77	8.56	8.18	7.6Ø	7.49	6.32

DEPTH (FT)	Ø7-APR-88	19-APR-88	Ø5-MAY-88	17-MAY-88	31-MAY-88	Ø8-JUN-88	14-JUN-88	27-JUN-88
-Ø.75	Ø.77	Ø.65	Ø.38	Ø.26	Ø.8Ø	Ø.83	Ø.74	Ø.49
-1.ØØ	Ø.27	Ø.24	Ø.16	Ø.13	Ø.27	Ø.29	Ø.26	Ø.19
-2.ØØ	1.51	1.38	1.22	1.14	1.27	1.36	1.35	1.23
-3.ØØ	1.82	1.72	1.65	1.65	1.54	1.53	1.58	1.56
-4.ØØ	1.79	1.78	1.74	1.76	1.7Ø	1.68	1.69	1.68
STORAGE 1.2m	6.17	5.78	5.16	4.93	5.58	5.69	5.61	5.15

TABLE C.3. Water Storage in the North Weighing Lysimeter at the Buried Waste Test Facility, January 1984 Through June 1988

DEPTH (FT)	09-JAN-84	23-JAN-84	06-FEB-84	24-FEB-84	05-MAR-84	20-MAR-84	02-APR-84	16-APR-84	02-MAY-84	16-MAY-84
-0.75	3.54	3.43	1.75	2.17	1.82	2.21	1.85	1.73	1.54	1.40
-1.00	1.26	1.25	0.61	0.73	0.64	0.73	0.65	0.62	0.54	0.51
-2.00	4.60	4.24	2.92	2.97	2.98	3.00	2.99	2.83	2.53	2.50
-3.00	3.63	3.26	3.41	3.13	3.23	3.14	3.49	3.20	3.01	2.92
-4.00	4.75	4.81	4.82	4.68	4.05	4.04	4.29	4.15	3.43	3.35
STORAGE 1.2m	17.78	16.99	13.53	13.68	12.73	13.12	13.27	12.54	11.05	10.67

DEPTH (FT)	31-MAY-84	12-JUN-84	25-JUN-84	12-JUL-84	26-JUL-84	08-AUG-84	28-AUG-84	12-SEP-84	25-SEP-84	17-OCT-84
-0.75	1.40	1.33	1.15	0.97	0.83	0.78	0.72	0.64	0.83	0.80
-1.00	0.50	0.49	0.43	0.38	0.35	0.31	0.29	0.27	0.31	0.31
-2.00	2.39	2.40	2.20	2.06	1.94	1.87	1.73	1.68	1.68	1.62
-3.00	2.81	2.78	2.64	2.45	2.45	2.50	2.42	2.35	2.26	2.20
-4.00	3.33	2.98	3.00	2.96	3.03	3.05	3.08	3.08	3.02	2.96
STORAGE 1.2m	10.44	9.98	9.43	8.82	8.59	8.51	8.24	8.01	8.10	7.89

DEPTH (FT)	15-NOV-84	11-DEC-84	27-DEC-84	30-JAN-85	12-FEB-85	27-FEB-85	12-MAR-85	25-MAR-85	10-APR-85	23-APR-85
-0.75	1.25	2.05	2.43	3.52	3.50	1.91	1.75	1.50	1.38	1.30
-1.00	0.41	0.64	0.79	0.93	1.00	0.68	0.62	0.54	0.50	0.48
-2.00	1.65	2.66	2.97	2.87	3.02	3.24	2.87	2.66	2.50	2.37
-3.00	2.08	2.80	2.97	3.06	2.93	3.80	3.36	3.18	3.14	3.02
-4.00	2.91	2.97	3.39	3.60	3.77	4.80	4.47	4.22	4.41	4.42
STORAGE 1.2m	8.31	11.11	12.55	13.98	14.23	14.42	13.07	12.11	11.93	11.58

DEPTH (FT)	08-MAY-85	21-MAY-85	30-JUL-85	16-AUG-85	18-SEP-85	01-OCT-85	15-OCT-85	30-OCT-85	25-NOV-85	10-DEC-85
-0.75	1.40	1.32	0.69	0.70	0.73	0.87	0.95	0.64	1.09	1.46
-1.00	0.52	0.47	0.30	0.30	0.28	0.31	0.33	0.29	0.37	0.46
-2.00	2.45	2.31	1.91	1.85	1.72	1.68	1.74	1.75	1.78	1.82
-3.00	2.96	2.95	2.67	2.66	2.45	2.33	2.39	2.38	2.25	2.18
-4.00	4.32	4.38	4.09	4.08	3.22	3.20	3.24	3.22	2.98	2.99
STORAGE 1.2m	11.65	11.44	9.67	9.60	8.41	8.40	8.65	8.27	8.48	8.91

TABLE C.3. (contd)

DEPTH (FT)	31-DEC-85	23-JAN-86	05-FEB-86	24-FEB-86	19-MAR-86	07-APR-86	08-MAY-86	23-MAY-86	10-JUN-86	27-JUN-86
-0.75	1.56	2.75	2.49	2.38	1.75	1.54	1.42	1.38	1.22	1.03
-1.00	0.50	0.90	0.82	0.80	0.60	0.54	0.49	0.50	0.44	0.39
-2.00	2.05	3.28	3.36	3.39	2.64	2.46	2.34	2.33	2.16	2.07
-3.00	2.29	2.93	3.62	3.59	2.94	2.83	2.89	2.78	2.67	2.62
-4.00	3.07	3.95	4.32	4.29	4.00	3.70	3.67	3.65	3.52	3.33
STORAGE 1.2m	9.48	13.81	14.61	14.46	11.93	11.07	10.81	10.64	10.01	9.43

DEPTH (FT)	28-JUL-86	07-AUG-86	13-JAN-87	30-JAN-87	13-FEB-87	10-MAR-87	23-MAR-87	14-APR-87	21-APR-87	05-MAY-87
-0.75	1.02	0.88	2.38	2.51	2.22	2.11	2.42	1.38	1.77	1.24
-1.00	0.38	0.35	0.84	0.88	0.75	0.72	0.84	0.57	0.62	0.52
-2.00	1.69	1.94	3.71	4.17	3.36	2.91	3.56	3.04	2.81	2.80
-3.00	2.26	2.52	3.79	4.54	3.84	3.27	3.60	3.39	3.16	3.22
-4.00	3.29	3.22	3.68	4.30	4.78	4.36	4.63	4.87	4.72	4.93
STORAGE 1.2m	8.64	8.92	14.41	16.39	14.96	13.37	15.05	13.25	13.08	12.72

DEPTH (FT)	20-MAY-87	03-JUN-87	18-JUN-87	08-JUL-87	23-JUL-87	04-AUG-87	20-AUG-87	03-SEP-87	16-SEP-87	30-SEP-87
-0.75	1.46	1.66	1.38	1.24	1.19	1.08	1.10	0.95	1.04	1.03
-1.00	0.53	0.57	0.51	0.46	0.45	0.41	0.41	0.38	0.39	0.39
-2.00	2.63	2.58	2.56	2.42	2.44	2.24	2.21	2.19	2.15	2.13
-3.00	3.13	2.94	2.96	2.89	2.91	2.82	2.77	2.78	2.71	2.66
-4.00	4.28	3.79	3.61	3.66	3.63	3.69	3.61	3.53	3.41	3.30
STORAGE 1.2m	12.03	11.53	11.01	10.67	10.63	10.23	10.10	9.84	9.70	9.52

DEPTH (FT)	21-OCT-87	04-NOV-87	24-NOV-87	18-DEC-87	06-JAN-88	26-JAN-88	12-FEB-88	23-FEB-88	09-MAR-88	25-MAR-88
-0.75	1.01	1.07	1.08	2.01	2.40	1.77	1.55	1.38	1.52	1.36
-1.00	0.39	0.41	0.42	0.70	0.78	0.62	0.55	0.51	0.53	0.49
-2.00	2.13	2.17	2.16	3.07	3.02	2.93	2.59	2.54	2.48	2.44
-3.00	2.65	2.65	2.83	3.21	3.14	3.29	3.02	2.94	2.88	2.90
-4.00	3.22	3.17	3.48	3.48	3.78	3.41	3.34	3.38	3.28	3.33
STORAGE 1.2m	9.39	9.48	9.96	12.46	13.12	12.03	11.05	10.75	10.70	10.52

TABLE C.3. (contd)

DEPTH (FT)	07-APR-88	19-APR-88	05-MAY-88	17-MAY-88	31-MAY-88	08-JUN-88	14-JUN-88	27-JUN-88
-0.75	1.29	1.31	1.08	0.95	1.39	1.26	1.10	0.80
-1.00	0.48	0.48	0.42	0.37	0.50	0.46	0.42	0.32
-2.00	2.46	2.42	2.37	2.20	2.35	2.31	2.28	2.07
-3.00	2.90	2.81	2.87	2.82	2.67	2.73	2.70	2.73
-4.00	3.29	3.31	3.16	3.12	2.88	2.91	2.86	2.85
STORAGE 1.2m	10.42	10.33	9.90	9.45	9.78	9.67	9.37	8.77

APPENDIX D

DRAINAGE MEASUREMENT PROCEDURE AND DATA

PROCEDURE FORM

Technical Procedure No. HSPA 2

TITLE: DRAINAGE MEASUREMENTS AT THE BURIED WASTE TEST FACILITY (BWTF)

1.0 APPLICABILITY

This procedure describes drainage measurements at the Buried Waste Test Facility (BWTF) located adjacent to the 300 North Burial Ground about 6km northwest of the 300 Area at the Hanford site. Figures 1 and 2 show the location, plan view and cross sectional view of the BWTF.

2.0 DEFINITIONS

Lysimeters refers to a device (container of soil material) that limits water movement to one dimension, allows surface evaporation (and plant transpiration) and drainage to occur from the soil. The two types of lysimeters in use at the BWTF are drainage and weighing. The SC drainage lysimeter encloses a soil column 2.7-m in diameter and 7.6-m deep. Drainage water is removed from this lysimeter by pumping the free water that collects in the gravel pack located at the bottom of the SC lysimeter. The weighing lysimeters, NWL and SWL, enclose a soil block approximately 1.5m x 1.5m x 1.5m. Drainage water is removed from these lysimeters by applying subatmospheric pressure to suction candles located at the bottom of the lysimeters.

Drainage means water collected from the lysimeters other than that obtained during deliberate water input (i.e., leak testing may occur periodically throughout the life time of the facility). Water collected from the drain ports of the lysimeters over the course of the test period constitutes drainage water.

3.0 RESPONSIBLE STAFF

Field Personnel, or Project Manager.

Concurrence	Date	Approved	Date
Michael J. Fayer	23 May 1988	[illegible signature]	5/27/88
Prepared by GW Gee [signature]	Date 5/17/88	QAD Concurrence DR Dahl	Date 5/27/88

Procedure No.	Revision No.	Effective Date	Page	of
HSPA 2	1.0	06/06/88	1	8

FIGURE D.1. Procedure for Measuring Drainage at the Buried Waste Test Facility

4.0 PROCEDURE

4.1 MATERIALS

4.1.1 Carboy containers - 20 to 40L. Large enough to handle up to 20L of drainage.

4.1.2 Scales - Laboratory platform type. Resolution of ±1 g with capacity of 25 kg.

4.1.3 Pumps. Figure 3 shows the schematic of pumps used to draw water from the lysimeters.

4.2 SCHEDULE

Three lysimeters are being sampled, the NWL, SWL, and SC as described in Figure 2. Sampling of drainage is done periodically, on an as-needed basis. During periods of active drainage, an adequate sampling period is twice per month. When lysimeters are draining slowly (e.g., less than one liter per sampling), a sampling period of once every three months may be an adequate schedule. As an example, the South Weighing Lysimeter (SWL) has not drained for almost two years. Thus the actual sampling schedule is dependent upon the amounts of drainage occurring.

4.3 PROCEDURE

The procedure for collection of drainage water is described as follows:

4.3.1 Check for drainage in the carboys located at the bottom of the North Weighing Lysimeter (NWL), the South Weighing Lysimeter (SWL), and the South Caisson (SC). If over 1L has drained (in at least a two-week period), either replace the carboy with an empty one or transfer the drainage water into a tared container and bring back into the laboratory for weighing.

4.3.2 Weigh the carboy and water on a calibrated scale to the nearest gram. Remove the water and weigh the carboy empty. Record the date, who made the measurement, what was measured, what M&TE scale

FIGURE D.1. (contd)

was used, and the drainage data on the data sheet prepared for drainage measurements (see Exhibit 1) and place in a laboratory record book.

4.3.3 Note any unusual conditions observed in the field during measurements (e.g., pumps not working etc.). Record unusual events in the laboratory record book.

4.3.4 Discard water. The drainage water is similar to the soil solution reported in Gee and Campbell (1979, Table 1). The drainage water is nonradioactive and nonhazardous therefore a routine chemical analysis of the water is not performed. The data are being collected for water balance purposes only.

4.4 ACCEPTANCE CRITERIA

4.4.1 If no drainage is collected for the test period, check to find out 1) whether the drainage pumps (vacuum pumps) are pulling at least 100 cm H_2O and 2) that no water is standing at the bottom of the neutron probe access tube. If one or both conditions is false, repair or replace drainage line or pump or both to ensure adequate collection of all drainage water.

4.4.2 Drainage water should be weighed to the nearest gram (± 1 g). Precision of drainage in terms of an equivalent depth of water is better than ± 0.004 cm H_2O.

5.0 REFERENCES

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HSPA 2	1.0	06/06/88	3 8

FIGURE D.1. (contd)

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Phillips, S. J., A. C. Campbell, M. D. Campbell, G. W. Gee, H. H. Hoober, and K. O. Schwarzmiller. 1979. A Field Test Facility for Monitoring Water/Radionuclide Transport Through Partially Saturated Geologic Media: Design Construction and Preliminary Description. PNL-3226, Pacific Northwest Laboratory, Richland, Washington.

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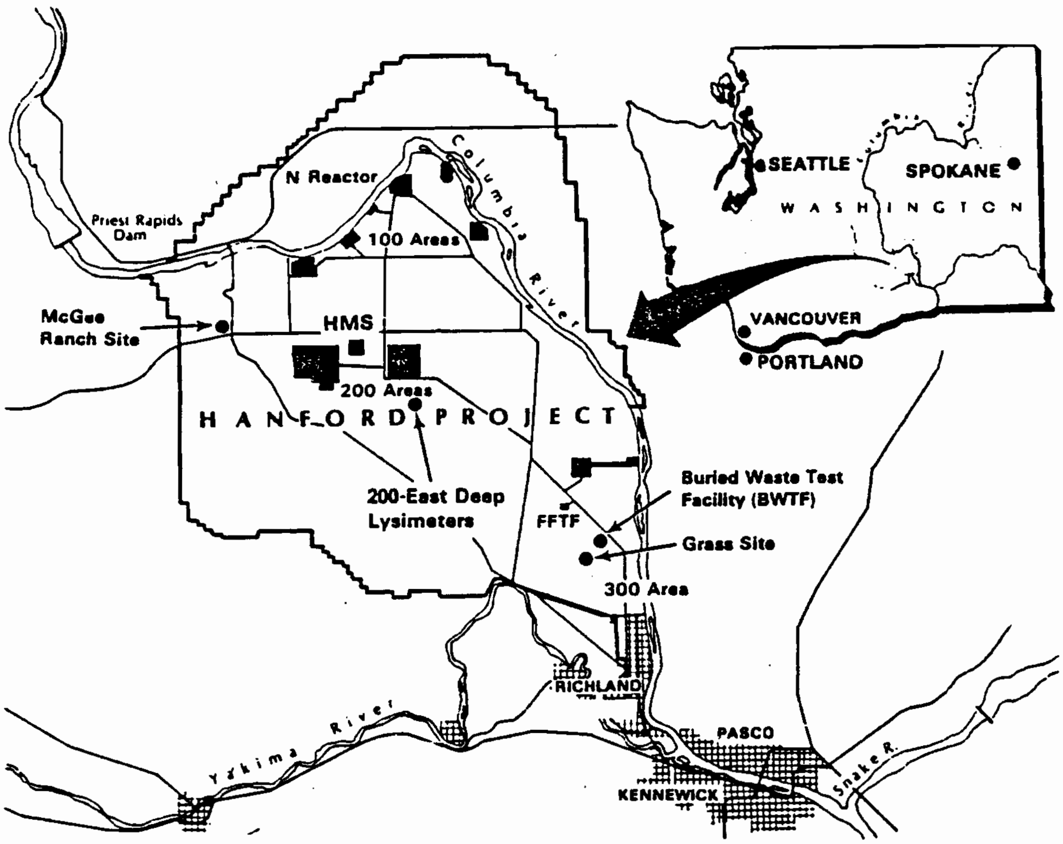
HSPA 2	1.0	06/06/88	4	8

FIGURE D.1. (contd)



Fiqure 1. Location of Buried Waste Test Facility Relative to other Lysimeter and Field Site Location's at the Hanford Site.

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FIGURE D.1. (contd)

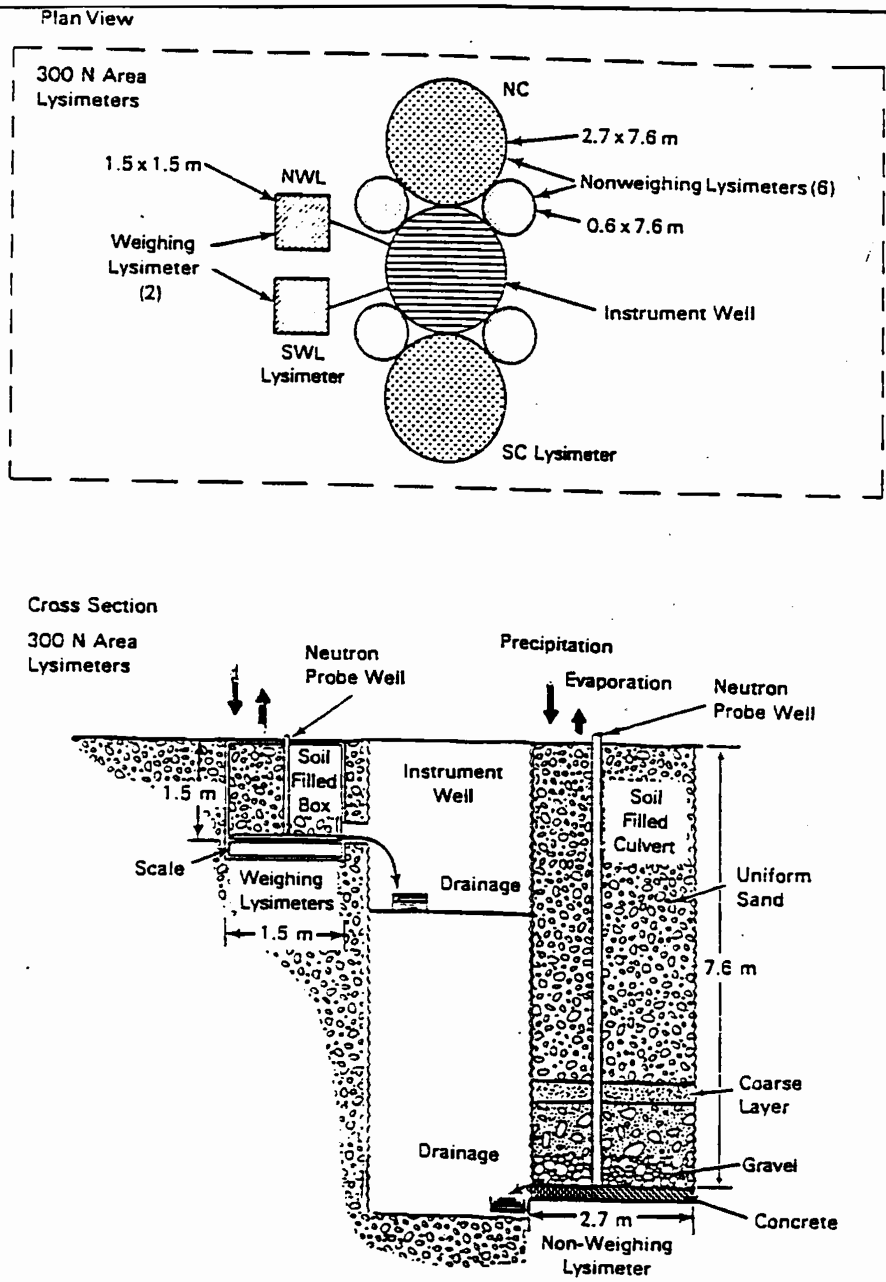

Figure 2. Plan View and Cross Section of the Buried Waste Test Facility Adjacent to the 300 N Burial Grounds.

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FIGURE D.1. (contd)

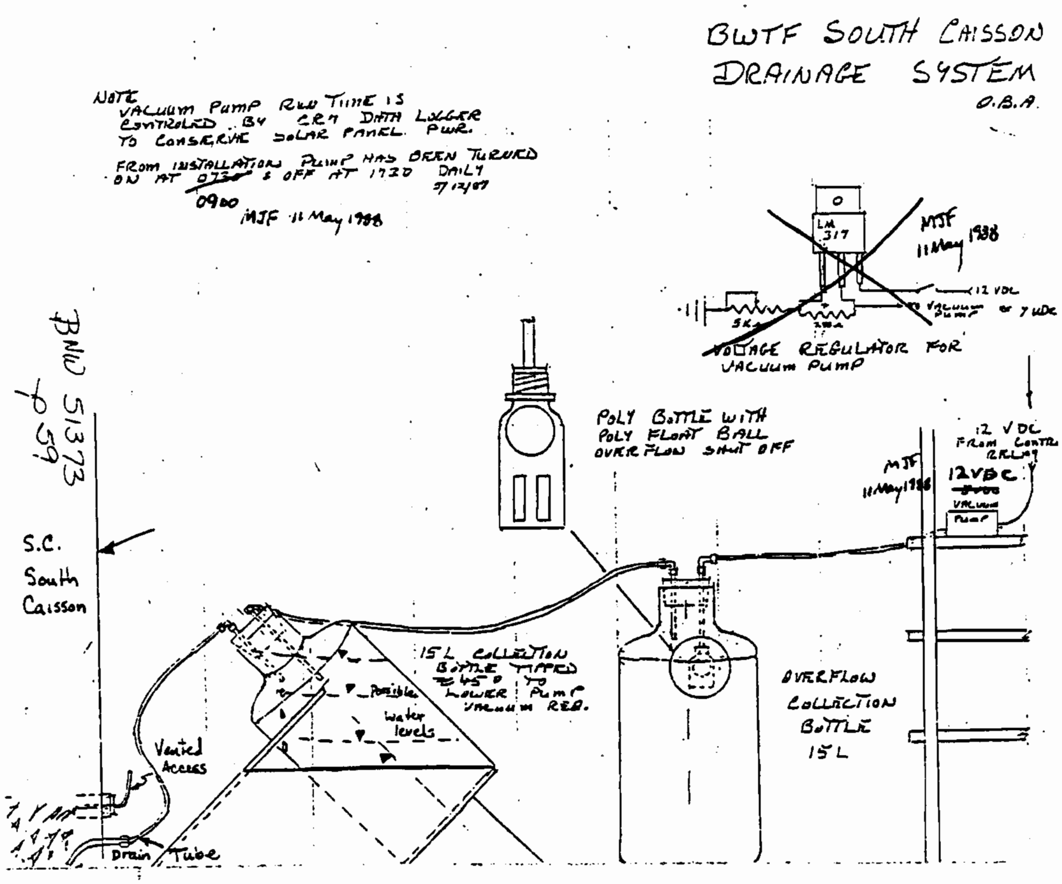

Figure 3. Drainage System for BWTF - SC Lysimeter.

Procedure No.	Revision No.	Effective Date	Page	of
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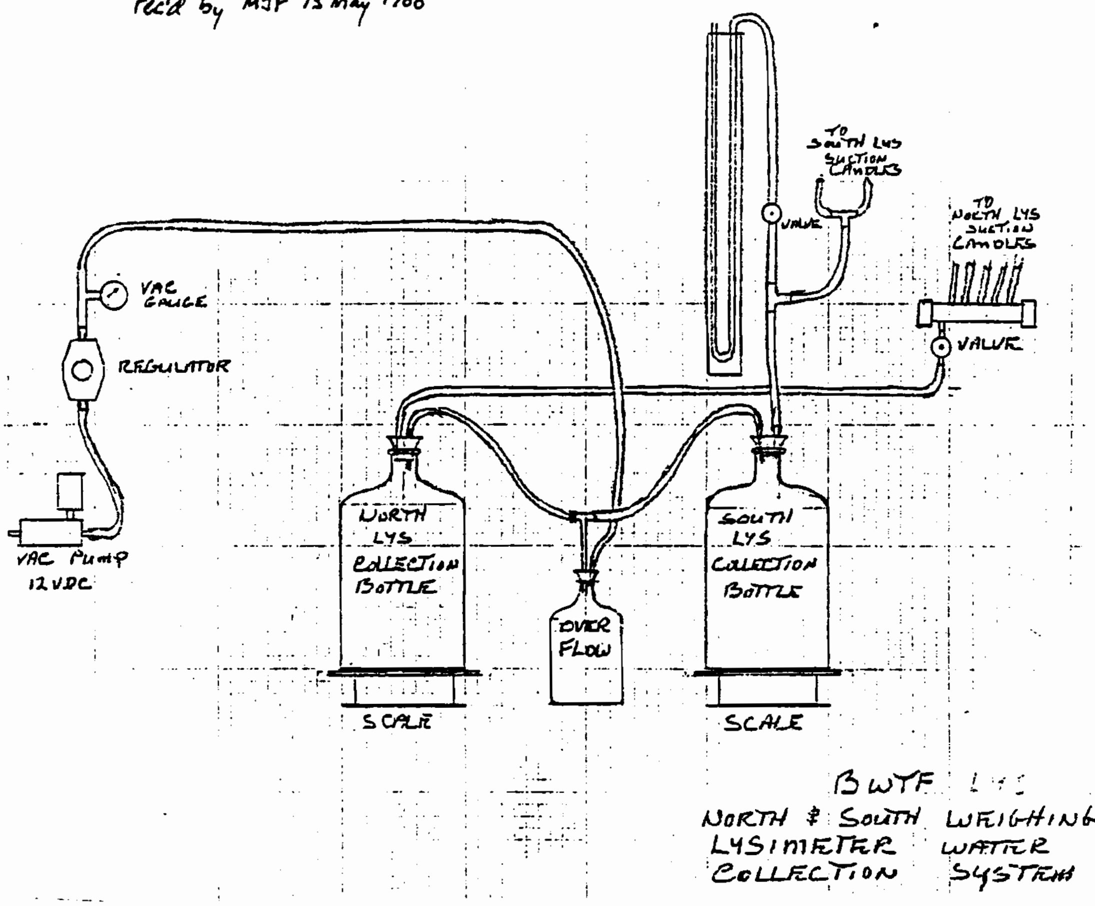
FIGURE D.1. (contd)

drawn by O. Abbey
rec'd by MJF 13 May 1988



Procedure No.	Revision No.	Effective Date	Page of
HSPA 2	1.0	06/06/88	8 8

FIGURE D.1. (contd)

TABLE D.1. South Cassion Drainage

SOUTH CASSION DRAINAGE

NOTE 1/2/86	DATE	DAY OF YEAR	DAYS SINCE 01-JAN-81	DRAINAGE (G)	EQUIVALENT WATER (CM)	CUMULATIVE CM ANNUAL DRAINAGE	CUMULATIVE DRAINAGE (CM)
	19-MAR-84	79	1174	79516	1.31	1.31	8.68
	23-MAR-84	83	1178	173708	2.87	4.19	11.55
	16-APR-84	107	1202	43590	0.72	4.91	12.28
	24-APR-84	115	1210	7785	0.13	5.04	12.40
	04-JUN-84	156	1251	82476	1.36	6.40	13.77
	17-JUL-84	199	1294	81210	1.34	7.74	15.11
	06-AUG-84	219	1314	52252	0.86	8.61	15.97
	19-NOV-84	324	1419	48745	0.81	9.41	16.78
	12-DEC-84	347	1442	22767	0.38	9.79	17.16
	15-FEB-85	46	1507	51567	0.85	0.85	18.01
	18-APR-85	108	1569	56593	0.94	1.79	18.95
	03-MAY-85	123	1584	43000	0.71	2.50	19.66
	16-MAY-85	136	1597	31123	0.51	3.01	20.17
	30-MAY-85	150	1611	28963	0.48	3.49	20.65
	11-JUN-85	162	1623	27226	0.45	3.94	21.10
	27-JUN-85	178	1639	32877	0.54	4.49	21.64
	09-JUL-85	190	1651	26505	0.44	4.92	22.08
	23-JUL-85	204	1665	24995	0.41	5.34	22.50
	13-AUG-85	225	1686	31300	0.52	5.86	23.01
	29-AUG-85	241	1702	30073	0.50	6.35	23.51
	09-SEP-85	252	1713	22790	0.38	6.73	23.89
	23-SEP-85	266	1727	20651	0.34	7.07	24.23
	07-OCT-85	280	1741	21365	0.35	7.42	24.58
	14-OCT-85	287	1748	12954	0.21	7.64	24.80
	01-NOV-85	305	1766	27161	0.45	8.09	25.24
	20-NOV-85	324	1785	27998	0.46	8.55	25.71
	03-DEC-85	337	1798	22203	0.37	8.92	26.07
	20-DEC-85	354	1815	22880	0.38	9.30	26.45
	26-DEC-85	360	1821	33940	0.56	9.86	27.01
	30-DEC-85	364	1825	0	0.00	9.86	27.01
	15-JAN-86	15	1841	5800	0.10	0.10	27.11
	28-JAN-86	28	1854	12180	0.20	0.30	27.31
	13-FEB-86	44	1870	20634	0.34	0.64	27.65
	26-FEB-86	57	1883	16150	0.27	0.91	27.92
	14-MAR-86	73	1899	17940	0.30	1.20	28.22
	25-MAR-86	84	1910	12420	0.21	1.41	28.42
	07-APR-86	97	1923	20260	0.33	1.74	28.76
	24-APR-86	114	1940	26940	0.45	2.19	29.20
	06-MAY-86	126	1952	33680	0.56	2.74	29.76
	21-MAY-86	141	1967	41230	0.68	3.43	30.44
	28-MAY-86	148	1974	30830	0.51	3.94	30.95
	02-JUN-86	153	1979	28780	0.48	4.41	31.43
	11-JUN-86	162	1988	14748	0.24	4.66	31.67
	17-JUN-86	168	1994	12763	0.21	4.87	31.88
	30-JUN-86	181	2007	56600	0.94	5.80	32.82
	10-JUL-86	191	2017	36260	0.60	6.40	33.42
	18-JUL-86	199	2025	21705	0.36	6.76	33.78
	30-JUL-86	211	2037	38800	0.64	7.40	34.42
	13-AUG-86	225	2051	34955	0.58	7.98	35.00
	25-AUG-86	237	2063	31270	0.52	8.50	35.51
	09-SEP-86	252	2078	34300	0.57	9.07	36.08
	03-OCT-86	276	2102	34770	0.57	9.64	36.65
	10-OCT-86	283	2109	41211	0.68	10.32	37.34

THE COLUMN AREA IS 60478 SQUARE CM.

TABLE D.1. (contd)

SOUTH CASSION DRAINAGE

NOTE 1/2/86	DATE	DAY OF YEAR	DAYS SINCE 01-JAN-81	DRAINAGE (G)	EQUIVALENT WATER (CM)	CUMULATIVE CM ANNUAL DRAINAGE	CUMULATIVE DRAINAGE (CM)
	29-OCT-86	302	2128	40104	0.66	10.98	38.00
	13-NOV-86	317	2143	33975	0.56	11.55	38.56
	04-DEC-86	338	2164	30890	0.51	12.06	39.07
	16-DEC-86	350	2176	23674	0.39	12.45	39.46
	29-DEC-86	363	2189	15107	0.25	12.70	39.71
	13-JAN-87	13	2204	25468	0.42	0.42	40.13
	30-JAN-87	30	2221	21705	0.36	0.78	40.49
	11-FEB-87	42	2233	15510	0.26	1.04	40.75
	24-FEB-87	55	2246	18637	0.31	1.34	41.06
	18-MAR-87	77	2268	20901	0.35	1.69	41.40
	31-MAR-87	90	2281	19860	0.33	2.02	41.57
	20-APR-87	110	2301	22810	0.38	2.40	41.94
	05-MAY-87	125	2316	17516	0.29	2.69	42.23
	26-MAY-87	146	2337	18450	0.31	2.99	42.54
	17-JUN-87	168	2349	19300	0.32	3.31	42.86
	15-SEP-87	258	2449	22470	0.37	3.68	43.39
	16-SEP-87	259	2450	12000	0.20	3.88	43.59
	17-SEP-87	260	2451	42940	0.71	4.59	44.30
	08-OCT-87	281	2472	18830	0.31	4.90	44.61
	03-DEC-87	337	2528	5057	0.08	4.98	44.70
	09-DEC-87	343	2534	10046	0.17	5.15	44.86
	16-DEC-87	350	2541	6890	0.11	5.26	44.98
	30-DEC-87	364	2555	10077	0.17	5.43	45.14
	12-JAN-88	12	2568	7560	0.13	0.13	45.27
	25-JAN-88	25	2581	8896	0.15	0.27	45.42
	08-FEB-88	39	2595	7759	0.13	0.40	45.54
	23-FEB-88	54	2610	8530	0.14	0.54	45.69
	09-MAR-88	69	2625	8698	0.14	0.69	45.83
	23-MAR-88	83	2639	10620	0.18	0.86	46.00
	13-APR-88	104	2660	9262	0.15	1.01	46.16
	27-APR-88	118	2674	8260	0.14	1.15	46.29
	11-MAY-88	132	2688	8270	0.14	1.29	46.43
	25-MAY-88	146	2702	9910	0.16	1.45	46.60
	08-JUN-88	160	2716	10357	0.17	1.62	46.77
	22-JUN-88	174	2730	9419	0.16	1.78	46.92

THE COLUMN AREA IS 60478 SQUARE CM.

TABLE D.2. South Weighing Lysimeter Drainage

SOUTH WEIGHING LYSIMETER DRAINAGE

DATE	DAY OF YEAR	DAYS SINCE 01-JAN-81	DRAINAGE WATER (g)	EQUIVALENT WATER (cm)	CUMULATIVE ANNUAL (cm)	CUMULATIVE TOTAL (cm)
06-JAN-84	6	1467	14650	0.63	0.63	10.05
09-JAN-84	9	1470	13887	0.60	1.24	10.65
10-JAN-84	10	1471	18163	0.79	2.02	11.44
11-JAN-84	11	1472	16733	0.72	2.75	12.17
12-JAN-84	12	1473	14464	0.63	3.37	12.79
23-FEB-84	54	1515	28504	1.23	4.61	14.03
10-APR-84	101	1562	18493	0.80	5.41	14.83
12-APR-84	103	1564	18831	0.82	6.22	15.64
18-APR-84	109	1570	18558	0.80	7.02	16.44
01-JUN-84	153	1614	11986	0.52	7.54	16.96
12-DEC-84	347	1808	14910	0.65	8.19	17.61
20-FEB-85	51	1878	5602	0.24	0.24	17.85
21-FEB-85	52	1879	17058	0.74	0.98	18.59
20-JUN-85	171	1998	11290	0.49	1.47	19.08
02-AUG-85	214	2041	1867	0.08	1.55	19.16
14-OCT-85	287	2114	18650	0.81	2.36	19.97
26-DEC-85	360	2187	14712	0.64	2.99	20.60
24-JAN-86	24	2216	3332	0.14	0.14	20.75
18-FEB-86	49	2241	9573	0.41	0.56	21.16
24-FEB-86	55	2247	35363	1.53	2.09	22.69
04-MAR-86	63	2255	15550	0.67	2.76	23.36
25-MAR-86	84	2276	24866	1.08	3.84	24.44
26-MAR-86	85	2277	28314	1.23	5.06	25.67
27-MAR-86	86	2278	23008	1.00	6.06	26.66
08-APR-86	98	2290	13220	0.57	6.63	27.23
10-APR-86	100	2292	27091	1.17	7.80	28.41
16-APR-86	106	2298	4082	0.18	7.98	28.58
05-JUN-86	156	2348	11017	0.48	8.46	29.06
13-JUN-86	164	2356	12500	0.54	9.00	29.60
09-JUL-86	190	2382	4528	0.20	9.20	29.80
15-SEP-86	258	2450	0	0.00	9.20	29.80
19-DEC-86	353	2545	0	0.00	9.20	29.80
11-SEP-87	254	2811	0	0.00	0.00	29.80
16-DEC-87	350	2907	0	0.00	0.00	29.80
30-DEC-87	364	2921	0	0.00	0.00	29.80
12-JAN-88	12	2934	0	0.00	0.00	29.80
25-JAN-88	25	2947	0	0.00	0.00	29.80
08-FEB-88	39	2961	0	0.00	0.00	29.80
23-FEB-88	54	2976	0	0.00	0.00	29.80
09-MAR-88	69	2991	0	0.00	0.00	29.80
13-APR-88	104	3026	0	0.00	0.00	29.80
30-APR-88	121	3043	0	0.00	0.00	29.80
02-MAY-88	123	3045	0	0.00	0.00	29.80
11-MAY-88	132	3054	0	0.00	0.00	29.80
25-MAY-88	146	3068	0	0.00	0.00	29.80
08-JUN-88	160	3082	0	0.00	0.00	29.80
22-JUN-88	174	3096	0	0.00	0.00	29.80

THE AREA OF THE LYSIMETER USED IN COLUMN 5 IS 152 cm SQUARED.

TABLE D.3. North Weighing Lysimeter Drainage

NORTH WEIGHING LYSIMETER DRAINAGE

DATE	DAY OF YEAR	DAYS SINCE 01-JAN-81	DRAINAGE WATER (g)	EQUIVALENT WATER (cm)	CUMULATIVE ANNUAL (cm)	CUMULATIVE TOTAL (cm)
06-JAN-84	6	1832	7261	0.31	0.31	44.29
11-JAN-84	11	1837	10736	0.72	1.04	45.01
13-JAN-84	13	1839	23932	1.04	2.07	46.06
16-JAN-84	16	1842	11058	0.48	2.55	46.53
17-JAN-84	17	1843	14506	0.63	3.18	47.16
26-JAN-84	26	1852	18663	0.81	3.99	47.96
27-JAN-84	27	1853	8388	0.36	4.35	48.33
03-FEB-84	34	1860	12963	0.56	4.91	48.89
23-FEB-84	54	1880	15206	0.66	5.57	49.55
24-FEB-84	55	1881	11204	0.48	6.06	50.03
27-FEB-84	58	1884	11586	0.50	6.56	50.53
07-MAR-84	67	1893	17667	0.76	7.32	51.30
14-MAR-84	74	1900	8612	0.37	7.69	51.67
19-MAR-84	79	1905	8391	0.36	8.06	52.03
09-APR-84	100	1926	17313	0.75	8.81	52.78
10-APR-84	101	1927	15977	0.69	9.50	53.47
23-APR-84	114	1940	10174	0.44	9.94	53.91
24-APR-84	115	1941	3723	0.16	10.10	54.08
11-MAY-84	132	1958	15434	0.67	10.77	54.74
01-JUN-84	153	1979	12898	0.56	11.33	55.30
19-FEB-85	50	2242	10382	0.45	0.45	55.75
20-FEB-85	51	2243	11468	0.50	0.95	56.25
21-FEB-85	52	2244	18195	0.79	1.73	57.04
27-FEB-85	58	2250	8145	0.35	2.09	57.39
04-MAR-85	63	2255	10725	0.46	2.55	57.85
19-MAR-85	78	2270	12081	0.52	3.07	58.37
20-JUN-85	171	2363	5567	0.24	3.31	58.62
28-AUG-85	240	2432	7945	0.34	3.66	58.96
29-AUG-85	241	2433	6900	0.30	3.96	59.26
03-SEP-85	246	2438	6857	0.30	4.25	59.56
09-SEP-85	252	2444	37670	1.63	5.88	61.19
14-OCT-85	287	2479	19156	0.83	6.71	62.01
26-DEC-85	360	2552	375	0.02	6.73	62.03
06-FEB-86	37	2594	12678	0.55	0.55	62.58
24-FEB-86	55	2612	18893	0.82	1.37	63.40
04-MAR-86	63	2620	7850	0.34	1.71	63.74
24-MAR-86	83	2640	11015	0.48	2.18	64.21
25-MAR-86	84	2641	7351	0.32	2.50	64.53
26-MAR-86	85	2642	8847	0.38	2.88	64.91
27-MAR-86	86	2643	2294	0.10	2.98	65.01
08-APR-86	98	2655	5566	0.24	3.22	65.26
10-APR-86	100	2657	17902	0.77	4.00	66.03
11-APR-86	101	2658	4781	0.21	4.21	66.24
16-APR-86	106	2663	17693	0.77	4.97	67.00
17-APR-86	107	2664	2812	0.12	5.09	67.12
25-APR-86	115	2672	12604	0.55	5.64	67.67
05-JUN-86	156	2713	4742	0.21	5.84	67.88
13-JUN-86	164	2721	11433	0.49	6.34	68.37
09-JUL-86	190	2747	9835	0.43	6.76	68.80
15-SEP-86	258	2815	0	0.00	6.76	68.80
24-FEB-87	55	2977	20349	0.88	0.88	69.68
11-MAR-87	70	2992	19418	0.84	1.72	70.52
14-MAY-87	134	3056	12830	0.56	2.28	71.07

THE LYSIMETER AREA USED IN COLUMN 5 IS 152 cm SQUARED.

TABLE D.3. (contd)

NORTH WEIGHING LYSIMETER DRAINAGE

DATE	DAY OF YEAR	DAYS SINCE 01-JAN-81	DRAINAGE WATER (g)	EQUIVALENT WATER (cm)	CUMULATIVE ANNUAL (cm)	CUMULATIVE TOTAL (cm)
19-MAY-87	139	3061	23720	1.03	3.30	72.10
26-MAY-87	146	3068	19258	0.83	4.14	72.93
01-JUN-87	152	3074	25330	1.10	5.23	74.03
30-JUN-87	181	3103	14130	0.61	5.84	74.64
08-DEC-87	342	3264	4603	0.20	6.04	74.84
16-DEC-87	350	3272	0	0.00	6.04	74.84
30-DEC-87	364	3286	0	0.00	6.04	74.84
12-JAN-88	12	3299	0	0.00	0.00	74.84
25-JAN-88	25	3312	0	0.00	0.00	74.84
11-FEB-88	42	3329	3294	0.14	0.14	74.98
23-FEB-88	54	3341	0	0.00	0.14	74.98
09-MAR-88	69	3356	742	0.03	0.17	75.01
28-MAR-88	88	3375	0	0.00	0.17	75.01
13-APR-88	104	3391	0	0.00	0.17	75.01
30-APR-88	121	3408	16876	0.73	0.91	75.74
02-MAY-88	123	3410	13577	0.59	1.49	76.33
11-MAY-88	132	3419	15471	0.67	2.16	77.00
25-MAY-88	146	3433	9911	0.43	2.59	77.43
08-JUN-88	160	3447	4086	0.18	2.77	77.61
22-JUN-88	174	3461	845	0.04	2.80	77.64

THE LYSIMETER AREA USED IN COLUMN 5 IS 152 cm SQUARED.

	DRAINAGE DATA - BURIED WASTE TEST FACILITY									
	BOTTLE 1			BOTTLE 2						
DATE	WATER + TARE (kg)	TARE (kg)	WATER (kg)	WATER + TARE (kg)	TARE (kg)	WATER (kg)	TOTAL WATER (kg)	INITIALS	COMMENTS (include lysimeter identification)

FIGURE D.2. Data Sheet for Drainage Record at the Burial Waste Test Facility

APPENDIX E

HYDRAULIC PROPERTIES DATA

APPENDIX E

HYDRAULIC PROPERTIES DATA

TABLE E.1. Water Content Data (cm^3/cm^3) from Grass Site (first experiment)

Time, s	Water Content, cm^3/cm^3, at Depth, cm: 15	30	45	60	90	120	150	180
0.00E+0	0.2178	0.1907	0.1462	0.1320	0.1317	0.1278	0.1303	0.1422
4.84E+2	0.2126	0.1825	0.1434	0.1290	0.1306	0.1271	0.1274	0.1404
1.08E+3	0.2125	0.1766	0.1397	0.1207	0.1250	0.1263	0.1259	0.1376
1.68E+3	0.2036	0.1733	0.1333	0.1155	0.1221	0.1165	0.1241	0.1356
2.88E+3	0.2024	0.1700	0.1241	0.1079	0.1138	0.1137	0.1211	0.1317
4.08E+3	0.2020	0.1612	0.1184	0.1049	0.1122	0.1097	0.1153	0.1284
5.28E+3	0.2015	0.1585	0.1160	0.1023	0.1050	0.1062	0.1108	0.1226
7.08E+3	0.2010	0.1579	0.1087	0.0936	0.0986	0.0996	0.1033	0.1159
8.88E+3	0.2005	0.1570	0.1066	0.0888	0.0952	0.0940	0.1011	0.1118
1.31E+4	0.2002	0.1560	0.1049	0.0870	0.0913	0.0871	0.0914	0.1005
1.67E+4	0.1999	0.1543	0.1042	0.0868	0.0863	0.0846	0.0833	0.0958
1.97E+4	0.1997	0.1539	0.1013	0.0864	0.0830	0.0820	0.0819	0.0902
6.89E+4	0.1995	0.1463	0.0940	0.0794	0.0772	0.0718	0.0727	0.0738
9.93E+4	0.1957	0.1400	0.0945	0.0755	0.0734	0.0699	0.0702	0.0699
1.87E+5	0.1911	0.1379	0.0829	0.0687	0.0700	0.0669	0.0662	0.0662
4.27E+5	0.1743	0.1275	0.0741	0.0609	0.0660	0.0645	0.0598	0.0611
6.18E+5	0.1642	0.1223	0.0715	0.0574	0.0655	0.0604	0.0582	0.0587
7.67E+5	0.1587	0.1178	0.0695	0.0570	0.0613	0.0569	0.0574	0.0575
1.03E+6	0.1505	0.1141	0.0676	0.0542	0.0606	0.0551	0.0542	0.0563
1.38E+6	0.1432	0.1116	0.0675	0.0538	0.0587	0.0545	0.0522	0.0544
1.98E+6	0.1358	0.1084	0.0653	0.0522	0.0547	0.0517	0.0475	0.0523

TABLE E.2. Matric Head Data from the Grass Site (first experiment)

Time, s	Matric Head, cm, at Depth, cm							
	15	30	45	60	90	120	150	180
0.00E+0	-18	-1	-1	-1	-1	-1	-1	-1
4.84E+2	-20	-6	-3	-2	-1	-1	-1	-1
1.08E+3	-23	-11	-5	-4	-1	-2	-2	-2
1.68E+3	-26	-17	-6	-5	-2	-3	-3	-3
2.88E+3	-32	-24	-11	-8	-3	-5	-5	-5
4.08E+3	-39	-28	-16	-11	-5	-7	-6	-6
5.28E+3	-44	-32	-20	-13	-6	-9	-7	-7
7.08E+3	-45	-33	-20	-14	-8	-10	-8	-9
8.88E+3	-46	-33	-20	-14	-10	-11	-9	-10
1.31E+4	-52	-38	-24	-16	-14	-14	-12	-12
1.67E+4	-54	-39	-26	-16	-16	-16	-14	-12
1.97E+4	-55	-39	-26	-16	-16	-16	-14	-12
6.89E+4	-65	-50	-31	-22	-20	-20	-17	-17
9.93E+4	-70	-54	-34	-26	-20	-20	-17	-17
1.87E+5	-87	-70	-51	-32	-21	-23	-18	-17
4.27E+5	-126	-108	-79	-47	-21	-24	-18	-18
6.18E+5	-148	-130	-100	-57	-24	-26	-19	-19
7.67E+5	-166	-145	-111	-63	-24	-27	-19	-20
1.03E+6	-187	-165	-120	-72	-25	-28	-20	-20
1.38E+6	-205	-183	-130	-80	-28	-31	-22	-21
1.98E+6	-224	-205	-140	-86	-30	-33	-23	-21

TABLE E.3. Time-Averaged Water Content from the 300 Area Grass Site (first experiment)

Time, s	Water Content, cm^3/cm^3, at Depth, cm							
	15	30	45	60	90	120	150	180
2.59E+2	0.215	0.187	0.145	0.131	0.131	0.127	0.129	0.141
7.78E+2	0.213	0.180	0.142	0.125	0.128	0.127	0.127	0.139
1.38E+3	0.208	0.175	0.137	0.118	0.124	0.121	0.125	0.137
2.25E+3	0.203	0.172	0.129	0.112	0.118	0.115	0.123	0.134
3.46E+3	0.202	0.166	0.121	0.106	0.113	0.112	0.118	0.130
4.67E+3	0.202	0.160	0.117	0.104	0.109	0.108	0.113	0.126
6.22E+3	0.201	0.158	0.112	0.098	0.102	0.103	0.107	0.119
7.95E+3	0.201	0.157	0.108	0.091	0.097	0.097	0.102	0.114
1.10E+4	0.200	0.157	0.106	0.088	0.093	0.091	0.096	0.106
1.49E+4	0.200	0.155	0.105	0.087	0.089	0.086	0.087	0.098
1.82E+4	0.200	0.154	0.103	0.087	0.085	0.083	0.083	0.093
4.43E+4	0.200	0.150	0.098	0.083	0.080	0.077	0.077	0.082
8.41E+4	0.198	0.143	0.094	0.077	0.075	0.071	0.071	0.072
1.43E+5	0.193	0.139	0.089	0.072	0.072	0.068	0.068	0.068
3.07E+5	0.183	0.133	0.079	0.065	0.068	0.066	0.063	0.064
5.23E+5	0.169	0.125	0.073	0.059	0.066	0.062	0.059	0.060
6.92E+5	0.161	0.120	0.071	0.057	0.063	0.059	0.058	0.058
8.98E+5	0.155	0.116	0.069	0.056	0.061	0.056	0.056	0.057
1.21E+6	0.147	0.113	0.068	0.054	0.060	0.055	0.053	0.055
1.68E+6	0.140	0.110	0.066	0.053	0.057	0.053	0.050	0.053

TABLE E.4. Hydraulic Conductivity from the Grass Site (first experiment)

Time, s	Hydraulic Conductivity, cm/sec, at Depth, cm						
	30	45	60	90	120	150	180
2.59E+2	8.51E-4	5.78E-4	6.44E-4	7.63E-4	8.12E-4	9.24E-4	1.07E-3
7.78E+2	1.87E-4	2.43E-4	3.75E-4	7.17E-4	8.53E-4	9.18E-4	1.03E-3
1.38E+3	1.03E-3	7.31E-4	7.08E-4	8.78E-4	1.15E-3	1.46E-3	1.56E-3
2.25E+3	1.36E-4	2.27E-4	2.61E-4	4.43E-4	5.50E-4	6.36E-4	7.22E-4
3.46E+3	2.34E-4	3.40E-4	2.63E-4	2.81E-4	3.27E-4	4.61E-4	5.71E-4
4.67E+3	1.21E-4	1.45E-4	1.24E-4	2.27E-4	3.40E-4	4.57E-4	5.74E-4
6.22E+3	4.78E-5	1.14E-4	1.53E-4	2.51E-4	3.40E-4	4.73E-4	5.70E-4
7.95E+3	6.65E-5	6.12E-5	6.76E-5	1.27E-4	1.96E-4	2.63E-4	3.01E-4
1.10E+4	3.38E-5	2.58E-5	1.85E-5	3.62E-5	7.50E-5	1.36E-4	2.03E-4
1.49E+4	8.12E-5	4.16E-5	1.58E-5	3.45E-5	6.74E-5	1.15E-4	1.68E-4
1.82E+4	5.00E-5	4.61E-5	2.44E-5	3.75E-5	6.94E-5	9.33E-5	1.31E-4
4.43E+4	-2.5E-5	2.35E-5	7.44E-6	9.77E-6	1.51E-5	2.17E-5	2.92E-5
8.41E+4	-2.6E-5	8.70E-5	9.19E-6	1.12E-5	1.39E-5	1.62E-5	1.86E-5
1.43E+5	-6.8E-6	-2.5E-5	8.03E-6	6.68E-6	7.31E-6	8.80E-6	9.62E-6
3.07E+5	-5.0E-6	-3.8E-6	1.36E-4	5.12E-6	4.38E-6	5.23E-6	5.52E-6
5.22E+5	-2.4E-6	-1.4E-6	-4.0E-6	4.10E-6	2.80E-6	3.43E-6	3.38E-6
6.92E+5	-1.5E-6	-8.7E-7	-1.9E-6	4.46E-6	2.99E-6	3.60E-6	3.32E-6
8.98E+5	-7.8E-7	-5.0E-7	-1.1E-6	3.90E-6	1.57E-6	1.98E-6	1.95E-6
1.21E+6	-3.8E-7	-2.6E-7	-5.0E-7	3.06E-6	8.75E-7	1.07E-6	1.09E-6
1.68E+6	-1.9E-7	-1.4E-7	-3.2E-7	3.82E-6	8.33E-7	1.14E-6	1.16E-6

TABLE E.5. Water Content Data from the Grass Site (second experiment)

Time, s	Water Content, cm^3/cm^3, at Depth, cm							
	15	30	45	60	90	120	150	180
0.00E+0	0.2119	0.1784	0.1454	0.1274	0.1287	0.1252	0.1268	0.1451
8.99E+2	0.2064	0.1728	0.1351	0.1191	0.1244	0.1224	0.1240	0.1425
1.32E+3	0.2053	0.1709	0.1315	0.1160	0.1220	0.1206	0.1224	0.1408
2.76E+3	0.2032	0.1665	0.1237	0.1087	0.1146	0.1146	0.1172	0.1348
4.50E+3	0.2018	0.1633	0.1183	0.1034	0.1081	0.1087	0.1119	0.1280
5.70E+3	0.2011	0.1617	0.1158	0.1009	0.1048	0.1054	0.1089	0.1240
7.02E+3	0.2006	0.1603	0.1137	0.0987	0.1018	0.1024	0.1061	0.1202
8.70E+3	0.2000	0.1589	0.1115	0.0965	0.0988	0.0992	0.1030	0.1160
1.08E+4	0.1994	0.1575	0.1094	0.0943	0.0958	0.0960	0.0999	0.1117
4.68E+4	0.1955	0.1489	0.0977	0.0818	0.0798	0.0780	0.0805	0.0851
7.38E+4	0.1944	0.1466	0.0948	0.0786	0.0763	0.0739	0.0756	0.0789
1.35E+5	0.1929	0.1438	0.0915	0.0749	0.0726	0.0696	0.0700	0.0722
2.23E+5	0.1918	0.1416	0.0890	0.0722	0.0700	0.0666	0.0660	0.0677
3.23E+5	0.1909	0.1401	0.0875	0.0704	0.0685	0.0649	0.0635	0.0649
5.03E+5	0.1900	0.1384	0.0857	0.0685	0.0669	0.0630	0.0608	0.0621
6.77E+5	0.1894	0.1374	0.0847	0.0673	0.0660	0.0620	0.0593	0.0605
1.20E+6	0.1882	0.1355	0.0829	0.0652	0.0645	0.0603	0.0566	0.0579
1.97E+6	0.1872	0.1340	0.0816	0.0636	0.0635	0.0591	0.0546	0.0561
3.24E+6	0.1862	0.1326	0.0804	0.0622	0.0627	0.0582	0.0529	0.0546

TABLE E.6. Matric Head Data from the Grass Site (second experiment)

Time, s	Matric Head, cm, at Depth, cm 15	30	45	60	90	120	150	180
0.00E+0	-15	-10	-11	-9	-4	-7	-6	-4
8.99E+2	-18	-13	-11	-9	-4	-7	-6	-5
1.32E+3	-20	-14	-11	-9	-4	-7	-6	-5
2.76E+3	-25	-17	-12	-9	-4	-8	-7	-5
4.50E+3	-32	-21	-13	-9	-4	-9	-8	-6
5.70E+3	-37	-24	-14	-9	-4	-10	-9	-6
7.02E+3	-40	-26	-15	-10	-5	-10	-9	-7
8.70E+3	-42	-28	-17	-11	-7	-11	-10	-8
1.08E+4	-44	-30	-19	-12	-10	-11	-10	-9
4.68E+4	-49	-35	-24	-15	-12	-16	-12	-12
7.38E+4	-52	-38	-26	-17	-14	-18	-14	-13
1.35E+5	-56	-42	-29	-18	-15	-19	-17	-15
2.23E+5	-60	-46	-32	-20	-17	-21	-18	-17
3.23E+5	-63	-49	-35	-22	-19	-22	-19	-18
5.03E+5	-66	-52	-38	-24	-21	-23	-20	-20
6.77E+5	-69	-55	-41	-26	-22	-24	-21	-21
1.20E+6	-73	-59	-46	-30	-23	-25	-22	-23
1.97E+6	-75	-61	-49	-33	-24	-26	-23	-24
3.2EE+6	-78	-64	-50	-34	-24	-28	-25	-27

TABLE E.7. Time-Averaged Water Content from the Grass Site (second experiment)

Time, s	Water Content, cm^3/cm^3, at Depth, cm 15	30	45	60	90	120	150	180
4.32E+2	0.209	0.176	0.140	0.123	0.127	0.124	0.125	0.144
1.12E+3	0.206	0.172	0.133	0.118	0.123	0.121	0.123	0.142
2.07E+3	0.204	0.169	0.128	0.112	0.118	0.118	0.120	0.138
3.63E+3	0.203	0.165	0.121	0.106	0.111	0.112	0.115	0.131
5.10E+3	0.201	0.163	0.117	0.102	0.106	0.107	0.110	0.126
6.39E+3	0.201	0.161	0.115	0.100	0.103	0.104	0.107	0.122
7.86E+3	0.200	0.160	0.113	0.098	0.100	0.101	0.105	0.118
9.76E+3	0.200	0.158	0.110	0.095	0.097	0.098	0.101	0.114
2.88E+4	0.197	0.153	0.104	0.088	0.088	0.087	0.090	0.098
6.03E+4	0.195	0.148	0.096	0.080	0.078	0.076	0.078	0.082
1.04E+5	0.194	0.145	0.093	0.077	0.074	0.072	0.073	0.076
1.79E+5	0.192	0.143	0.090	0.074	0.071	0.068	0.068	0.070
2.73E+5	0.191	0.141	0.088	0.071	0.069	0.066	0.065	0.066
4.13E+5	0.190	0.139	0.087	0.069	0.068	0.064	0.062	0.064
5.90E+5	0.190	0.138	0.085	0.068	0.066	0.063	0.060	0.061
9.37E+5	0.189	0.136	0.084	0.066	0.065	0.061	0.058	0.059
1.59E+6	0.188	0.135	0.082	0.064	0.064	0.060	0.056	0.057
2.61E+6	0.187	0.133	0.081	0.063	0.063	0.059	0.054	0.055

TABLE E.8. Hydraulic Conductivity Data from the Grass Site (second experiment)

Time, s	Hydraulic Conductivity, cm/s, at Depth, cm						
	30	45	60	90	120	150	180
4.32E+2	2.26E-4	3.46E-4	5.59E-4	7.06E-4	7.75E-4	9.34E-4	1.04E-3
1.12E+3	1.26E-4	2.23E-4	3.65E-4	5.20E-4	6.31E-4	7.99E-4	9.20E-4
2.07E+3	8.83E-5	1.53E-4	2.38E-4	3.61E-4	4.73E-4	6.36E-4	7.65E-4
3.63E+3	6.81E-5	1.03E-4	1.41E-4	2.18E-4	3.05E-4	4.41E-4	5.60E-4
5.10E+3	7.70E-5	8.86E-5	1.01E-4	1.51E-4	2.18E-4	3.33E-4	4.37E-4
6.39E+3	8.28E-5	7.56E-5	7.86E-5	1.20E-4	1.76E-4	2.71E-4	3.61E-4
7.86E+3	8.55E-5	6.73E-5	6.41E-5	9.62E-5	1.43E-4	2.18E-4	2.92E-4
9.76E+3	6.86E-5	5.74E-5	4.98E-5	7.71E-5	1.18E-4	1.73E-4	2.30E-4
2.88E+4	2.54E-5	2.31E-5	1.76E-5	2.54E-5	3.95E-5	5.80E-5	7.55E-5
6.03E+4	1.04E-5	9.47E-6	6.40E-6	8.28E-6	1.26E-5	1.91E-5	2.42E-5
1.04E+5	7.71E-6	6.60E-6	3.53E-6	4.26E-6	6.20E-6	9.45E-6	1.24E-5
1.79E+5	5.59E-6	5.19E-6	1.93E-6	2.17E-6	3.08E-6	4.65E-6	6.08E-6
2.73E+5	4.76E-6	4.66E-6	1.21E-6	1.28E-6	1.76E-6	2.58E-6	3.32E-6
4.13E+5	2.75E-6	3.94E-6	7.62E-7	7.80E-7	1.07E-6	1.54E-6	1.94E-6
5.90E+5	1.81E-6	4.14E-6	5.03E-7	4.95E-7	6.57E-7	9.07E-7	1.13E-6
9.37E+5	9.53E-7	3.99E-6	3.55E-7	3.11E-7	3.92E-7	5.35E-7	6.55E-7
1.58E+6	3.72E-7	1.41E-6	2.11E-7	1.65E-7	1.94E-7	2.62E-7	3.16E-7
2.61E+6	2.60E-7	1.24E-6	1.31E-7	9.27E-8	1.03E-7	1.37E-7	1.63E-7

TABLE E.9. Water Content Data from the McGee Ranch (second experiment)

Time, s	Water Content, cm, at Depth, cm				
	15	30	45	60	90
0.00E+0	0.3813	0.4073	0.4089	0.4103	0.4044
4.50E+3	0.3700	0.3981	0.4005	0.4042	0.4037
5.28E+3	0.3677	0.3960	0.3988	0.4030	0.4035
5.82E+3	0.3660	0.3945	0.3977	0.4022	0.4034
7.62E+3	0.3604	0.3894	0.3941	0.3994	0.4029
8.40E+3	0.3580	0.3871	0.3925	0.3982	0.4026
9.42E+3	0.3550	0.3842	0.3905	0.3967	0.4023
1.05E+4	0.3518	0.3811	0.3884	0.3950	0.4020
1.23E+4	0.3467	0.3760	0.3849	0.3923	0.4013
1.45E+4	0.3409	0.3701	0.3810	0.3892	0.4005
1.65E+4	0.3357	0.3647	0.3775	0.3863	0.3997
1.83E+4	0.3314	0.3601	0.3745	0.3838	0.3990
2.00E+4	0.3276	0.3561	0.3718	0.3818	0.3983
7.71E+4	0.2613	0.2795	0.3163	0.3309	0.3677
9.75E+4	0.2502	0.2662	0.3051	0.3198	0.3567
1.76E+5	0.2248	0.2361	0.2769	0.2913	0.3206
3.56E+5	0.1995	0.2067	0.2446	0.2578	0.2691
5.31E+5	0.1876	0.1931	0.2276	0.2400	0.2408
1.05E+6	0.1706	0.1742	0.2009	0.2117	0.1993
1.81E+6	0.1595	0.1623	0.1816	0.1912	0.1730
2.76E+6	0.1524	0.1548	0.1680	0.1768	0.1566

TABLE E.10. Matric Head Data from the McGee Ranch (second experiment)

Time, s	Matric Head, cm, at Depth, cm 15	30	45	60	90
0.00E+0	-34	-35	-24	-17	-10
4.50E+3	-59	-56	-50	-41	-19
5.28E+3	-63	-60	-54	-45	-24
5.82E+3	-66	-63	-58	-48	-27
7.62E+3	-76	-71	-68	-58	-38
8.40E+3	-81	-75	-73	-62	-43
9.42E+3	-85	-79	-77	-66	-48
1.05E+4	-88	-83	-80	-69	-53
1.23E+4	-93	-90	-85	-74	-61
1.45E+4	-101	-96	-91	-80	-66
1.65E+4	-107	-101	-97	-85	-71
1.83E+4	-109	-103	-100	-87	-74
2.00E+4	-110	-106	-103	-90	-77
7.71E+4	-151	-148	-147	-133	-115
9.75E+4	-160	-156	-155	-141	-123
1.76E+4	-186	-180	-180	-166	-147
3.56E+5	-226	-212	-214	-200	-183
5.31E+5	-250	-235	-234	-220	-204
1.05E+6	-292	-278	-276	-262	-247
1.81E+6	-326	-312	-310	-298	-288
2.76E+6	-358	-344	-346	-338	-327

TABLE E.11. Time-Averaged Water Content Data from the McGee Ranch (second experiment)

	Water Content, cm^3/cm^3, at Depth, cm				
Time, s	15	30	45	60	90
2.25E+3	0.376	0.403	0.405	0.407	0.404
4.92E+3	0.369	0.397	0.400	0.404	0.404
5.53E+3	0.367	0.395	0.398	0.403	0.403
6.74E+3	0.363	0.392	0.396	0.401	0.403
8.04E+3	0.359	0.388	0.393	0.399	0.403
8.90E+3	0.356	0.386	0.392	0.397	0.402
9.94E+3	0.353	0.383	0.389	0.396	0.402
1.14E+4	0.349	0.379	0.387	0.394	0.402
1.34E+4	0.344	0.373	0.383	0.391	0.401
1.55E+4	0.338	0.367	0.379	0.388	0.400
1.74E+4	0.334	0.362	0.376	0.385	0.399
1.91E+4	0.330	0.358	0.373	0.383	0.399
4.86E+4	0.294	0.318	0.344	0.356	0.383
8.73E+4	0.256	0.273	0.311	0.325	0.362
1.37E+5	0.237	0.251	0.291	0.306	0.339
2.66E+5	0.212	0.221	0.261	0.275	0.295
4.43E+5	0.194	0.200	0.236	0.249	0.255
7.90E+5	0.179	0.184	0.214	0.226	0.220
1.43E+5	0.165	0.168	0.191	0.201	0.186
2.29E+5	0.156	0.159	0.175	0.184	0.165

TABLE E.12. Hydraulic Conductivity Data from the McGee Ranch (second experiment)

	Hydraulic Conductivity, cm/s, at Depth, cm				
Time, s	15	30	45	60	90
2.25E+3	4.03E-5	1.05E-4	2.25E-4	4.51E-4	8.07E-4
4.92E+3	5.55E-5	1.24E-4	2.47E-4	4.70E-4	6.30E-4
5.53E+3	5.86E-5	1.27E-4	2.54E-4	4.75E-4	5.92E-4
6.74E+3	6.37E-5	1.25E-4	2.39E-4	4.79E-4	5.75E-4
8.04E+3	7.31E-5	1.25E-4	2.28E-4	4.69E-4	5.29E-4
8.90E+3	7.36E-5	1.19E-4	2.18E-4	4.34E-4	4.59E-4
9.94E+3	7.02E-5	1.20E-4	2.26E-4	3.99E-4	4.12E-4
1.14E+4	5.78E-5	1.16E-4	2.41E-4	3.37E-4	3.38E-4
1.34E+4	5.49E-5	1.16E-4	2.46E-4	3.06E-4	3.02E-4
1.55E+4	6.04E-5	1.16E-4	2.36E-4	3.08E-4	3.01E-4
1.74E+4	5.98E-5	1.07E-4	2.24E-4	3.02E-4	2.81E-4
1.91E+4	5.10E-5	9.40E-5	2.12E-4	2.84E-4	2.54E-4
4.86E+4	2.27E-5	4.43E-5	1.11E-4	1.90E-4	1.84E-4
8.73E+4	1.06E-5	2.02E-5	5.23E-5	1.19E-4	1.26E-4
1.37E+5	7.32E-6	1.25E-5	3.06E-5	7.65E-5	8.78E-5
2.66E+5	6.31E-6	6.26E-6	1.23E-5	3.35E-5	4.19E-5
4.43E+5	3.07E-5	3.97E-6	6.24E-6	1.53E-5	1.97E-5
7.90E+5	1.47E-5	2.16E-6	3.45E-6	7.15E-6	9.27E-6
1.43E+6	3.27E-6	9.52E-7	1.50E-6	2.64E-6	3.53E-6
2.29E+6	1.68E-6	4.26E-7	5.91E-7	1.13E-6	1.70E-6

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