AN EQUATION TO PREDICT RUNOFF FROM SOIL MOISTURE MEASUREMENTS

by

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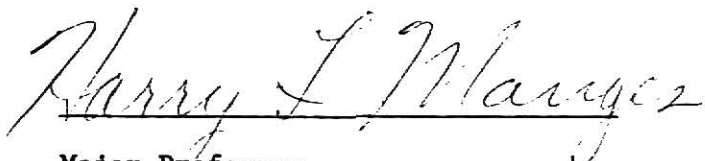

Major Professor

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INTRODUCTION

As the world population increases, industrialization of many developing nations poses serious problems to the modern world. The demand for food and land increases rapidly. In order to increase food supplies the world needs more production of fertilizers, selective seeds, insecticides, and the most important of them all, sufficient water for crop growth.

While arable land is insufficient for the need of almost four billion people on Earth, the water supply, too, is also insufficient for the demand of agricultural and industrial development.

Refinement of present water conservation methods as well as the development of new methods are the responsibility of engineers. In particular, refinement and development of methods for irrigation not only must meet agronomic requirements but must also fulfill the regulation of efficient water usage, and such usage is becoming increasingly important.

There are various irrigation methods, but the most popular one is furrow irrigation. With this method, water is delivered to the head of the furrow; part of the water is infiltrated into the soil; part is temporarily stored on the ground surface. The process continues until the water reaches the end of the furrow, at which time runoff begins.

According to Hauser and Hiler (1975), infiltration is a

major factor governing runoff; however, infiltration is strongly influenced by the soil water content before irrigation.

Unless the runoff can be reused, it is wasted. Investigators like Pope (1973) have studied the problems involved in the use of runoff (tailwater) from irrigation. The reuse system consists of a pump, pipeline, and a structure for collecting the runoff (tailwater). The information on runoff is required for the design of runoff reuse system.

From the observation of irrigation, it is apparent that runoff varies with soil moisture (water) level. The runoff will be high if the soil is wet, and the runoff will be low if the soil is dry before irrigation.

PURPOSE OF STUDY

The purpose of this study was to use a neutron probe to measure the soil moisture content along the soil profile and to examine the runoff from irrigation among three different soil moisture depletion levels.

The principle objective of the study was to develop an equation with soil moisture content as an independent variable for predicting runoff from furrow irrigation. The equation should be in a form such that it can easily be used without requiring the evaluation of the numerous factors that influence runoff.

LITERATURE REVIEW

Soil Moisture Measurement

Soil water measurement is important to the scheduling of irrigation, especially in the semi-arid and arid regions. There are several methods to measure soil moisture content which are presented below.

Gravimetric Method

Determine the soil moisture content by weighing the soil before and after drying in an oven. Usually take about 200 grams of soil and dry in an oven for 24 hours. The moisture percentage on the dry-weight basis is:

$$P_W = \frac{W_W - W_D}{W_D} \quad 100 \qquad (1)$$

Where P_W = the moisture percentage on the dry-weight basis

W_W = the weight of soil before drying

W_D = the weight of soil after drying

A single soil sample can't represent the soil moisture content in large areas. Several samples must be used to obtain a satisfactorily representative indication of soil moisture content.

Another disadvantage is that it takes 24 hours to dry the soil sample. By this method, one can't get a soil moisture con-

tent immediatelly when he wants the information to schedule an irrigation.

Soil Appearance and Feel

This method is used widely by farmers because is is simple and inexpensive. The soil appearance and feel method was developed by U. S. Soil Conservation Service technicians. The method gives an estimate of soil moisture by soil appearance and feel. Accuracy of this method depends on the experience and ability of the irrigators.

Electrical Properties of a Porous Block

Electrical properties of resistance (or conductance), capacitance, and dielectric strength have been used to indicate moisture content. Changes in moisture effect all of these electrical properties. Porous blocks containing desired electrical elements are placed in the soil. The moisture properties of the block changes along with changes in soil moisture content. Only limited successes have been achieved using capacitance or dielectric properties, but practical units have been developed using the resistance or conductance principle.

Tensiometer

A tensiometer consists of a porous cup filled with water and attached to a vacuum gauge or mercury manometer. A hole is bored or dug into the soil to a desired depth, a handful of loose soil is placed into the hole, and the cup pushed firmly into the

soil. Additional soil is placed around the cup and around the tube, whenever necessary, to ensure firm contact with the soil. A connection is soon established between the water inside the cup and the water in the soil outside. As water moves out of the cup because of the suction or tension existing in the soil, the vacuum created in the cup is registered on the gauge. Conversely, an increase of water in the soil will lower the tension, water will go into the tensiometer, and the gauge will read less tension. Fluctations in soil moisture are registered by the tensiometers as long as the tension does not exceed about 0.8 atm. At a greater tension, air enters the closed system through the pores of the cup and the instrument is no longer accurate. The soil moisture tension must be lowered by irrigation or by rainfall and the system filled with water before it will again operate properly.

Hillel (1971) indicated that using soil water tension as an indicator of irrigation needs raised two experimental difficulties:

(1). The distribution of roots is not uniform or constant; therefore, the water tension of the soil corresponds to the root distribution.

(2). The water tension of the soil in contact with the root is always greater than average tension.

Thermal Properties

Heat conductivity of the soil can be used as an index of

soil moisture since the conductivity depends on moisture present in the soil. The thermistor has given the best control because of the influence of temperature or heat conductivity. A permanent porous material with proper pore size distribution must be developed into which a thermally sensitive device can be enbedded without damaging the heating and sensing elements.

Neutron Probe Method

In this method fast neutrons are emitted from a source into the surrounding soil. The fast neutrons are slowed down by water. The resulting slow neutrons which reach the counting tube are recorded. Fast neutrons are not registered by the counter. The greater the water content of the soil, the greater the number of slow neutrons reaching the counting tube. Hydrogen is the principle element which absorbs fast neutrons. There exists a high correlation between the amount of water in the soil and the number of slow neutrons reaching the counting tube. The neutron source and counting device are placed within the hole and lowered to the desired depth. The reading in a unit of time is proportional to the soil moisture content of the soil surrounding the source and counter. Readings are taken at sufficient locations to obtain a representative soil moisture.

Boundary geometry has an influence on the readings. The zone of influence decreases as moisture content increases. Improvements are being made in reducing weight, making the units more dependable, and reducing the radiation exposure hazard.

Since readings can be taken as soon as the instrument is placed in a hole; lag time is negligible, resulting in a fast method of measurement. Also, repeated nondestructive sampling in the same location is feasible. The neutron method is an effective and practical method of measuring soil moisture.

Infiltration of Irrigation Water

Infiltration is a major factor affecting the runoff; however, the infiltration is strongly influenced by the soil moisture content before the storm(Jamison and Thornton, 1961; Holton, 1965). Thus, Hauser and Hiler (1975) indicated the total runoff volume is a function of soil water content before the storm. This relationship can be expressed in a form of the following equation:

$$Q = C + eR^X + fW^Y + g\left(\frac{R}{I}\right)^Z + hI^V \qquad (2)$$

Where Q = daily runoff

R = daily rainfall

W = soil water content before the storm from 0-2 ft. (Hauser states that the 0-2 ft layer of soil is the hydrological active layer.)

I = one-hour maximum rainfall amount for the day

$\frac{R}{I}$ = an index of storm duration

The coefficients of e, f, g, h, and C were determined by standard multiple regression with the least squares technique.

The exponents X, Y, Z, and V were determined by trial and error, because changes of less than 0.5 produced only small changes in equation accuracy.

To determine the total volume of runoff which may come from a watershed during a design flood, one can use the Soil Conservation Service method with the formula given below:

$$Q = \frac{(I - 0.2\,S)^2}{I + 0.8\,S} \qquad (3)$$

Where Q = direct surface runoff in inches of water

I = storm rainfall in inches of water

S = maximum potential difference between rainfall and runoff in inches, starting at the time of the begining of the storm.

Runoff from Irrigation Water

Kincaid and Swanson (1974) stated that the total runoff is a function of rainfall intensity, the soil water depletion in the upper foot of soil, and the total rainfall applied. This can be expressed as the following:

For a very fine sandy loam

$$D_r = -0.18 + 0.12\,I + 0.33\,(D_a - D_p) \qquad (4)$$

For the silt and clay loam

$$D_r = -0.14 + 0.10\,I + 0.41\,(D_a - D_p) \qquad (5)$$

Where D_r = total runoff in inches

D_a = total rainfall applied in inches

I = rainfall intensity in inches per hour

D_p = the soil water depletion (in inches) in the upper foot of soil

In their experiment a portable sprinkler line with part-circle sprinklers spaced 10 feet apart along the line was used to simulate the rainfall, and the simulated rainfall intensity was 3 inches per hour on three or four furrows.

Ohmes (1972) found that the runoff from irrigation is a function of time until it reaches a constant rate. These relationship can be expressed in the following equations:

$$r = RT_r^s \tag{6}$$

and

$$r = R_e \tag{7}$$

Where r = runoff rate

T_r = runoff time from the begining of runoff

R = an empirical constant

s = slope of runoff curve plotted on log-log paper

R_e = the maximum runoff rate

THEORY

The equation of continuity states that the inputs must equal the outputs. For irrigation, inputs consist of only the amount of water fed into the furrow during the irrigation process. Outputs are made up of several components: these components include the volume of water infiltrated into the soil profile, water stored on the ground surface, water lost to evaporation, and water lost to runoff. In equation form, it can be written as:

$$V_E = V_I + V_S + V_{EV} + V_R \qquad (7)$$

Where V_E = the volume of water applied to the field

V_I = the volume of water infiltrated into the soil

V_S = the volume of water stored on the ground surface

V_{EV}= the volume of water lost to evaporation

V_R = the volume of water lost to runoff

During the irrigation process the volume of the surface storage term is significant. This term can be evaluated or estimated as set forth by Wu (1971). At the end of the total time for irrigation surface storage vanishes, adding either to the runoff or becoming soil water. Thus, evaluation of the irrigation process should include surface storage but not necessarily as a separate term. The volume of evaporation during irrigation is insignificant and was neglected.

The infiltration rate can be determined by the infiltration function given by Israelsen and Hansen (1962):

$$I = aT^n \tag{8}$$

and

$$I = aT^n + b \tag{9}$$

Where I = infiltration rate in inches per hour

a = an empirical constant

T = opportunity time for infiltration, in minutes

n = slope of the infiltration curve on log-log paper

b = the basic infiltration rate that will be approached if the irrigation periods last long enough

For this analysis equation 8 will be used. The depth of water D_i which infiltrates into a small unit of length x of the furrow after an opportunity time t, is given by integrating equation 8 between the time limits 0 to t:

$$D_i = \int_0^t I\, dt = \int_0^t aT^n dt = \frac{a}{n+1} t^{n+1} \tag{10}$$

The total volume of water infiltrated into the furrow V_i at a given time t is obtained by integrating depth of water from length 0 to L and then multiplying it by the furrow spacing W in inches:

$$V_i = W\int_0^L D_i dx = W\int_0^L \frac{a}{12\,(n+1)}\, t^{n+1}\, dx \qquad (11)$$

The advance equation $x = dt^V$ was given by Thornton (1960). Then, solving for t:

$$t = \left(\frac{x}{d}\right)^{1/V} \qquad (12)$$

Where t = the time in minutes required for the advance to the point in question

x = the distance the water has advanced in the time t

d = the distance of advance at t equals unity

V = exponent of the logarithmic function

The coefficients d and V are determined by plotting experimental data.

Substituting equation 12 into equation 11, we have

$$V_i = W\int_0^L \frac{a}{12\,(n+1)} \left(\left(\frac{x}{d}\right)^{1/V}\right)^{n+1} dx \qquad (13)$$

After rearranging, equation 13 becomes:

$$V_i = W\int_0^L \frac{a}{12\,(n+1)\,d^{n+1/V}}\, x^{n+1/V} dx \qquad (14)$$

After integration from the head of the furrow to a given length L, we have for the volume of infiltration:

$$V_i = \frac{Wa}{12\ (n+1)d^{n+1/V}(n+1/V)}\ L^{\ n+V+1/V} \qquad (15)$$

For simplification let term n+V+1/V be equal to p. The term $Wa/\ 12(n+1)d^{\ n+1/V}\ (n+1/V)$ can be expressed by a constant called K. Equation 15 can be written as:

$$V_i = KL^p \qquad (16)$$

If one plots K as the ordinate and soil moisture content 0-6, 0-12, 0-18, 0-24, 0-30, and 0-36 inches of soil as the absicca on log-log paper, one will get a linear relationship between them. This expresses K as a function of soil moisture content, and it can be written in the form:

$$K = eS^B \qquad (17)$$

Substitution of equation 17 into equation 16 yields:

$$V_i = eS^BL^p \qquad (18)$$

Substituting equation 18 into equation 7 produces:

$$V_E = eS^BL^p + V_R \qquad (19)$$

In this experiment the volume of water input and the length of the furrow are always constant. Equation 19 can be written as:

$$V_R = V_E - A_1 S^B \qquad (20)$$

Where V_R = the volume of runoff

V_E = the volume of water applied to the field

S = the soil moisture content

A_1 and B are coefficients derived from experimental data, and A_1 is the product of e and L^p.

INVESTIGATION

Equipment and Procedure

This study was made to determine a relationship between runoff and soil moisture level. Varying soil moisture levels were obtained by establishing irrigation treatments at three soil moisture depletion levels. To determine this relationship, it was necessary to determine runoff from plots. The term "Plot" will be used to designate the plot where the access tube was located.

The experiment was conducted at the Kansas State University Irrigation Experimental Field located near Scandia, Kansas. The experiment consisted of nine plots with each plot containing six furrows spaced 60 inches apart. All nine plots were planted to corn with a row spacing of thirty inches. Furrow lengths on all nine plots were three hundred feet. A layout of the field is shown in Figure 1.

Three soil moisture depletion levels replicated three times were maintained to give a range of soil moisture levels. Table 1 gives the soil moisture depletion levels permitted prior to irrigation for the individual plots.

Water was delivered to the furrows by pipe with adjustable openings. Inflow into each furrow was regulated by adjustment of the openings to obtain a fixed flow rate of water into the field.

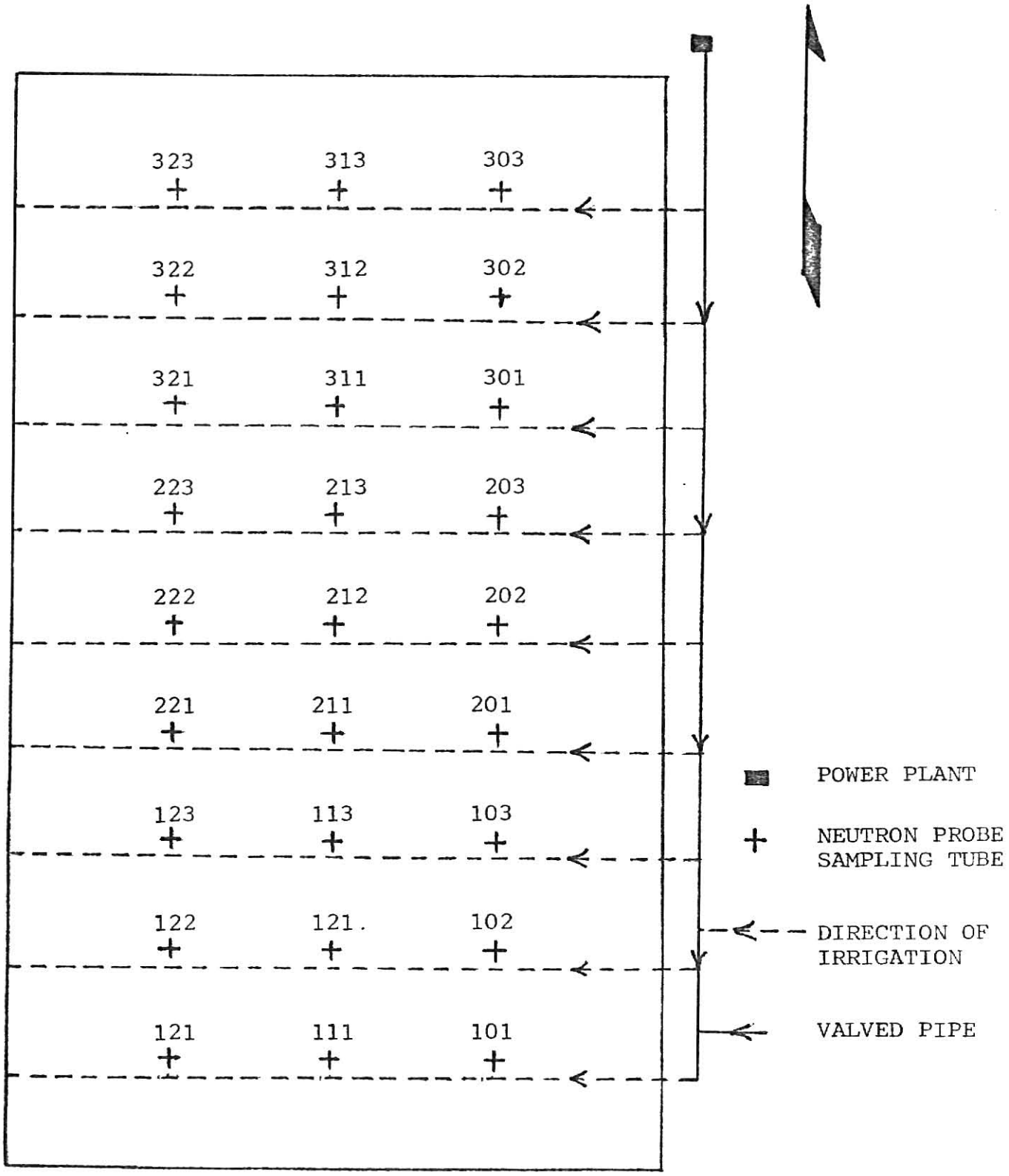


Figure 1. Runoff Plots with Location of Neutron Probe Sampling Tube

Table 1. Soil Moisture Depletion Levels for Runoff Plots

Plot number	Depletion Level percentage	Plot number	Depletion Level percentage
101	60	213	80
102	80	311	40
103	40	312	80
201	60	313	60
202	40	121	60
203	80	122	80
301	40	123	40
302	80	221	60
303	60	222	40
111	60	223	80
112	80	321	40
113	40	322	80
211	60	323	60
212	40		

Valve settings were made prior to the start of irrigation to deliver a predetermined inflow rate into each furrow.

Soil moisture content was measured by both neutron probe and gravimetric methods. The neutron probe, as shown in Figure 2, was a commerical device. From June 2 to June 6, 1975, twenty-seven access tubes for the neutron probe were inserted in the soil to a depth of six feet. On each tube there was a cap to prevent the tube from filling with dust, rainfall and insects.

The neutron probe was calibrated comparing counter readings with soil moisture determined by the gravimetric method. This relationship, which correlates the neutron probe ratio with soil moisture content, is given in Table 2 and by the linear equation:

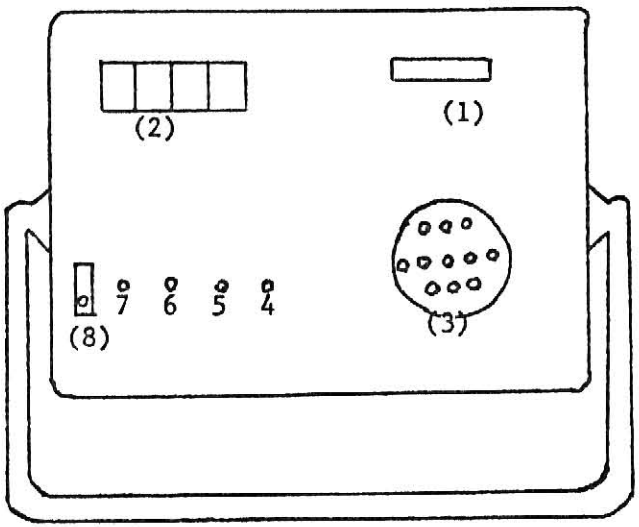
$$Y = -0.7181 + 2.3222\ X \qquad (21)$$

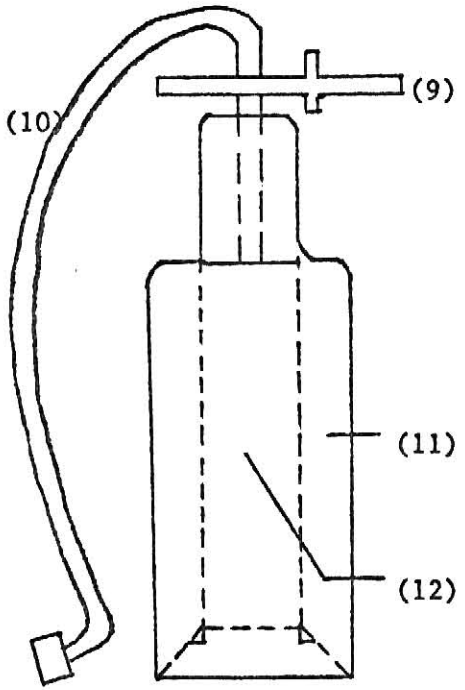
Where Y = soil moisture content, in inches of water per six inch layer

X = neutron probe ratio

Having been taken from the container, the neutron counter machine needs to warm up for at least half an hour and then time selection is to be set to one fourth of a minute. After having attached the test button to the machine, and if the reader shows a reading of 8732, the counting machine is then ready for operation.

The count readings of the neutron probe on the ground was





(1) Battery Indicator

(2) Counting Indicator

(3) Power

(4) Start

(5) Repeat

(6) Timing Control

(7) Buttom for the Counting Indicator

(8) Test Switch

(9) Clamp

(10) Wire

(11) Cave

(12) Neutron Source

Figure 2. Neutron Probe

Table 2. Relationship between Neutron Probe Ratio and Soil Moisture (From Raney, 1975)

Neutron Probe Ratio	Soil Moisture inches of water	Neutron Probe Ratio	Soil Moisture inches of water
0.44	0.30	0.84	1.23
0.45	0.33	0.85	1.26
0.46	0.36	0.87	1.29
0.48	0.39	0.88	1.32
0.49	0.42	0.89	1.35
0.50	0.45	0.91	1.38
0.52	0.48	0.92	1.41
0.53	0.51	0.93	1.44
0.54	0.54	0.94	1.47
0.56	0.57	0.95	1.50
0.57	0.60	0.97	1.53
0.58	0.63	0.98	2.56
0.59	0.66	0.99	1.59
0.61	0.69	1.01	1.62
0.62	0.72	1.02	1.65
0.63	0.75	1.03	1.68
0.65	0.78	1.05	1.71
0.66	0.81	1.06	1.74
0.67	0.84	1.07	1.77
0.68	0.87	1.08	1.80
0.70	0.90	1.10	1.83
0.71	0.93	1.11	1.86
0.72	0.97	1.13	1.89
0.73	0.99	1.14	1.92
0.75	1.02	1.15	1.95
0.76	1.05	1.16	1.98
0.77	1.08	1.17	2.01
0.79	1.11	1.19	2.04
0.80	1.14	1.20	2.07
0.81	1.17	1.21	2.10
0.83	1.20		

taken, and the average of twenty-seven plots was computed as a reference account number for individual days. Readings of neutron count rate are taken at six inch intervals from the depth of twelve inches down to a depth of seventy-two inches for each tube of the twenty-seven plots. These measurements were taken, in most cases, at least twice per week during the irrigation period.

The neutron probe ratio was obtained by dividing the separate neutron probe countings for each plot by the reference account numbers on the same day. From equation 21, one obtains the soil moisture content at every six inch depth of soil with the exception of the first six inches for each plot. The soil moisture contents of the first six inches of soil for each plot were measured by the gravimetric method. The data for each depth and each plot of an individual day are given in the Appendix.

One rain gauge was installed to obtain rainfall information, as shown in Table 3. Consumptive use data, as shown in Table 4, was determined by Rosenthal (1976) at Kansas State University by using climatic data.

Total soil moisture contents of the six feet soil profile of each plot for individual days were obtained by adding the soil moisture content of the first six inch depth by gravimetric method to the soil moisture content of each six inches from

Table 3. Rainfall and Irrigation Data during the 1975 Growing Season

Date	Rainfall inches	Irrigation inches
6/18	1.25	
6/21	0.38	
6/22	1.63	
6/23	0.53	
6/26	0.11	
7/09	0.03	4.62
7/17	0.07	
7/18		4.62
7/20	0.19	
7/24		4.62
7/31		4.62
8/04	2.58	
8/15		4.62
8/29	0.13	

Table 4. Consumptive Use (From Rosenthal, 1976)

Data	Consumptive Use inches
6/17-6/20	0.635
6/21-6/14	1.178
6/25-6/27	0.666
6/28-7/01	1.102
7/02-7/03	0.706
7/04-7/07	1.401
7/08-7/09	0.513
7/10-7/11	0.637
7/12-7/15	1.294
7/16-7/18	1.045
7/19-7/22	1.174
7/23-7/24	0.672
7/25-7/28	1.390
7/29-8/01	0.923
8/02-8/05	1.287
8/06-8/07	0.570
8/08-8/22	4.030
8/23-9/04	1.580

twelve inches down to a depth of seventy-two inches by the neutron probe method. The total soil moisture content of each plot for an individual day plus the infiltration amount from irrigation during the period should be equal to the soil moisture content of each corresponding plot for the next measuring day plus the consumptive use during the time interval. This can be expressed in the following equation:

$$SMC_1 + I = SMC_2 + C.\ U. \qquad (22)$$

Where SMC_1 = the total soil moisture content of each plot for an individual day of measurement

SMC_2 = the total soil moisture content of each corresponding plot for the next measuring day

I = infiltration amount by irrigation during the time interval

C. U.= the consumptive use during the time interval of measurement

Runoff in inches of water can be obtained by substracting the infiltration amount in inches of water from the inflow quantity of irrigation water in inches of water.

DATA ANALYSIS AND RESULTS

The total soil moisture content can be obtained by adding the soil moisture content of the first six inches of soil along the soil profile to the soil moisture content of every six inches from the twelve inch depth down to the depth of seventy-two inches. The total soil moisture content for the various soil moisture depletion levels and individual days are given in Tables 5, 6, and 7.

Consumptive use for each day on the experimental field was given by Rosenthal (1976). Table 4 shows the consumptive use calculated by the computer model during the periods from the measurement to the next measurement.

Plotting the soil moisture content of each six-inch depth of soil as ordinate and the dates of measuring soil moisture content as abscissa on ordinary paper, as shown in Figures 3, 4, and 5, the soil moisture content of depth from twelve inches to thirty-six inches shows great variation exists between dates. On the other hand, the soil moisture content of every six inches of soil from forty-two inches down to seventy-two inches shows that its leveling off to almost a constant, and hence it is not changing from one sampling date to the next.

These figures shows that the soil moisture content of the soil below thirty-six inches doesn't vary with time and has little

Table 5. Total Soil Moisture Content in Inches of Six Feet Depth of Soil for Forty Percent Soil Moisture Depletion Level

Data	Plot Number								
	103	202	301	113	212	311	123	222	321
6/17	19.54	20.51	19.48	20.10	20.84	20.33	21.14	20.35	20.75
6/20	20.86	21.33	20.27	20.82	21.75	21.29	21.64	21.23	21.59
6/24	20.47	20.23	20.17	21.27	21.78	21.26	22.01	21.51	19.99
6/27	20.00	20.60	19.66	21.92	21.06	20.51	21.36	20.92	21.04
7/01	19.01	20.22	19.07	19.50	20.37	20.15	19.41	20.24	20.15
7/03	19.18	20.17	18.63	19.54	20.62	20.40	20.25	29.90	20.01
7/07	17.76	18.87	17.64	18.48	19.39	18.84	18.56	18.21	18.52
7/11	20.18	20.95	19.82	19.95	20.94	21.00	19.31	18.62	19.79
7/15	18.31	20.21	18.55	18.57	19.97	19.88	18.48	18.21	19.04
7/22	18.10	19.26	18.40	18.77	19.25	20.26	18.06	17.45	18.71
7/28	18.32	20.58	19.78	18.48	19.99	20.66	17.96	18.09	18.15
8/01	18.05	20.64	20.22	18.63	19.10	20.40	17.85	17.95	17.63
8/05	17.26	19.07	19.61	17.81	19.50	19.20	18.24	18.75	17.46
8/22	19.36	21.38	20.12	19.81	20.63	20.47	19.85	19.61	18.94
9/04	17.29	18.24	17.72	18.31	18.44	17.83	17.46	16.91	16.76

Table 6. Total Soil Moisture Content in Inches of Six Feet Depth of Soil for Sixty Percent Soil Moisture Depletion Level

Date	Plot Number								
	101	201	303	111	211	313	121	221	323
6/17	20.76	19.58	19.88	20.62	20.95	20.55	21.21	19.89	21.24
6/20	21.34	20.70	20.73	21.05	21.60	21.60	22.11	20.85	22.10
6/24	21.54	20.97	20.60	21.43	21.92	21.44	22.03	21.42	22.38
6/27	20.92	20.09	19.85	20.94	21.31	20.72	21.59	20.46	21.89
7/01	20.36	19.73	19.06	20.31	20.61	20.16	20.77	19.66	21.02
7/03	19.90	19.06	19.03	20.01	21.03	20.21	21.42	19.53	20.91
7/07	18.61	18.08	17.64	18.60	19.84	18.54	18.88	17.92	19.54
7/11	21.00	20.61	19.12	21.27	21.71	19.27	20.78	19.91	20.01
7/15	19.93	19.33	18.45	19.86	20.11	18.73	19.93	18.21	19.53
7/18	18.57	17.58	16.75	18.00	19.00	17.57	18.09	16.31	18.18
7/22	17.84	16.75	16.37	17.43	18.24	17.24	17.40	17.21	18.37
7/28	20.37	19.24	18.29	20.14	20.60	18.23	19.95	18.72	18.69
8/05	19.45	18.84	19.35	20.52	20.42	18.73	19.29	19.23	19.40
8/07	19.43	18.43	18.22	19.13	19.16	19.13	18.30	19.17	18.61
8/22	20.23	20.22	20.14	19.61	21.34	20.34	20.43	20.81	19.30
9/04	18.44	17.49	17.34	18.04	18.87	18.86	19.00	17.48	18.13

Table 7. Total Soil Moisture Content in Inches of Six Feet Depth of Soil for Eighty Percent Soil Moisture Depletion Level

Date	Plot Number								
	102	203	302	112	213	312	122	223	322
6/17	19.57	20.58	20.54	20.50	21.71	21.24	21.27	21.25	20.61
6/20	20.64	21.94	21.38	20.95	21.91	21.12	22.05	21.80	21.48
6/24	20.94	20.66	21.41	21.42	21.61	20.90	22.67	21.73	21.54
6/27	19.95	21.21	20.77	20.70	20.94	20.38	21.39	21.17	21.06
7/01	19.51	20.47	19.80	21.10	20.49	19.60	21.01	20.64	21.14
7/03	19.18	20.77	20.01	20.25	20.50	19.85	19.18	20.31	20.28
7/07	17.84	19.03	18.96	18.89	18.99	18.46	18.92	19.92	18.78
7/09	17.13	18.58	17.94	18.81	18.39	18.27	18.63	18.28	18.20
7/11	16.28	18.20	17.14	17.96	18.22	17.60	17.88	18.29	17.77
7/15	15.83	17.58	16.93	17.50	17.67	17.82	17.75	17.50	17.74
7/22	20.51	20.87	21.01	20.99	19.37	19.04	20.39	17.71	20.66
7/24	19.68	20.75	20.84	21.07	19.45	19.08	20.00	18.49	20.57
7/28	18.52	19.30	19.79	20.05	17.99	18.05	19.01	17.86	18.92
8/05	19.85	20.28	21.03	21.43	19.36	19.83	20.39	18.64	20.73
8/07	20.10	19.80	20.04	20.54	19.08	18.22	19.98	17.60	19.63
8/22	20.01	20.92	21.26	21.29	20.82	21.07	19.81	20.47	20.82
9/04	18.21	18.13	20.00	19.21	18.13	19.20	19.22	17.67	17.66

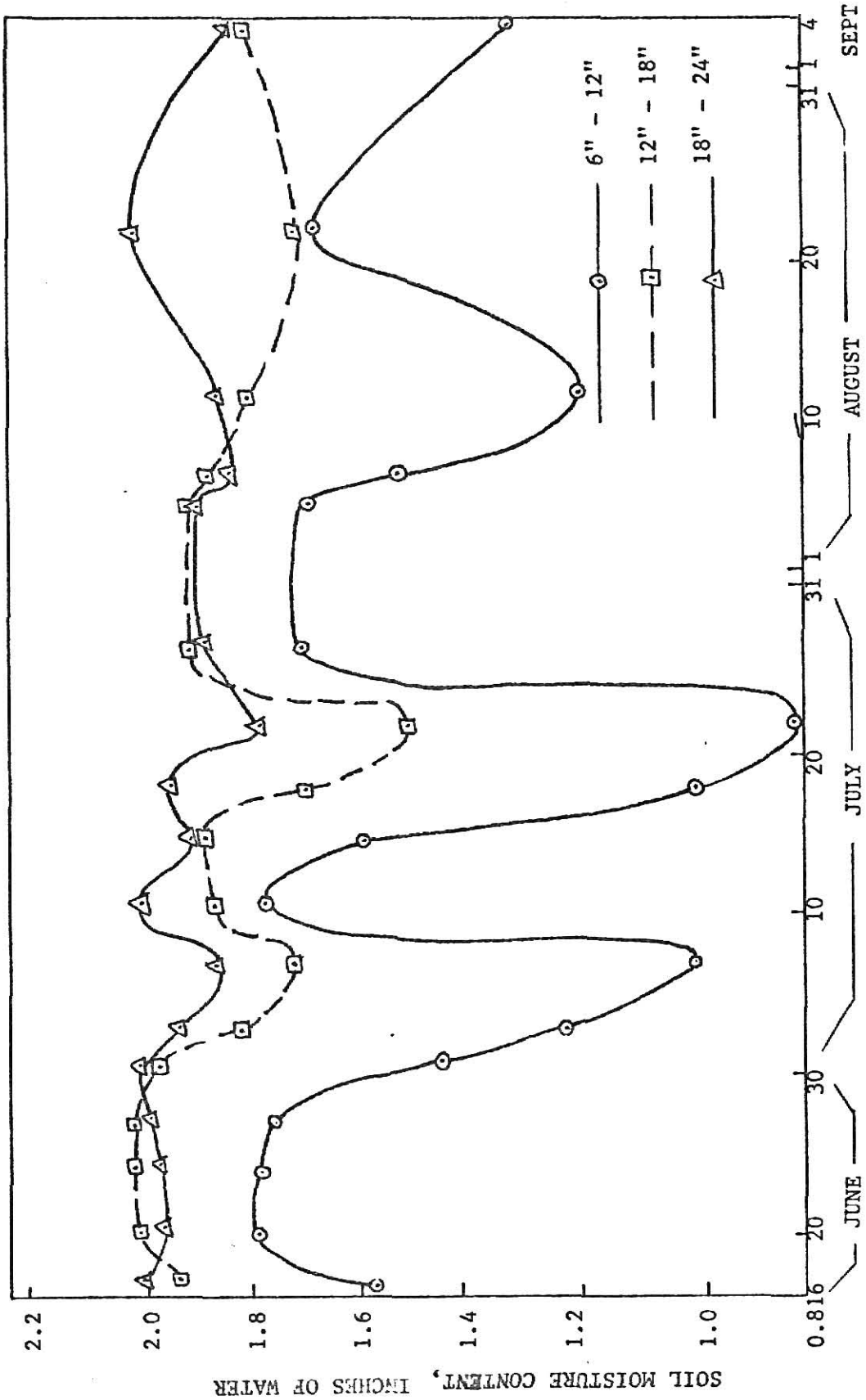


Figure 3. Soil Moisture Content versus Date

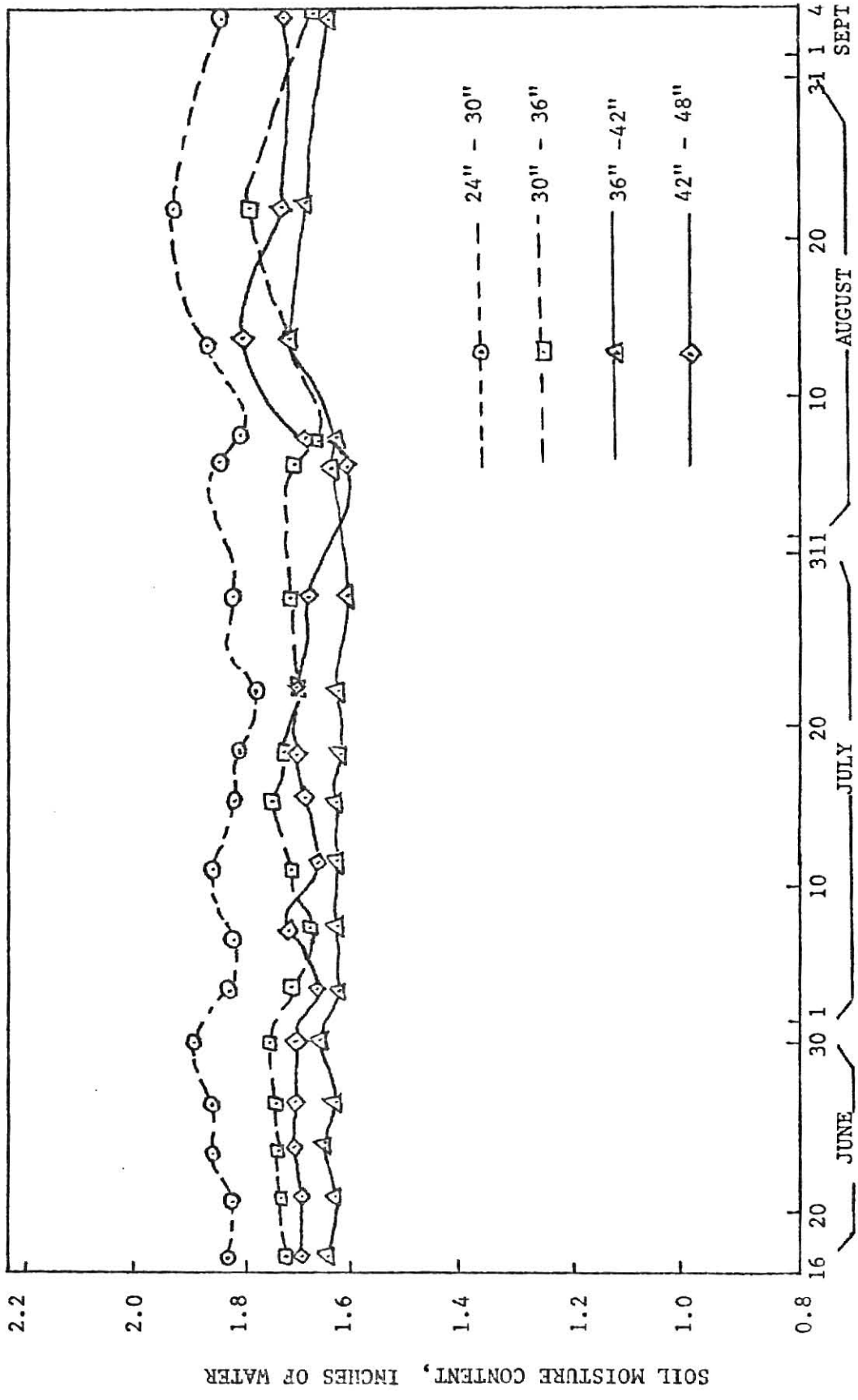


Figure 4. Soil Moisture Content versus Date

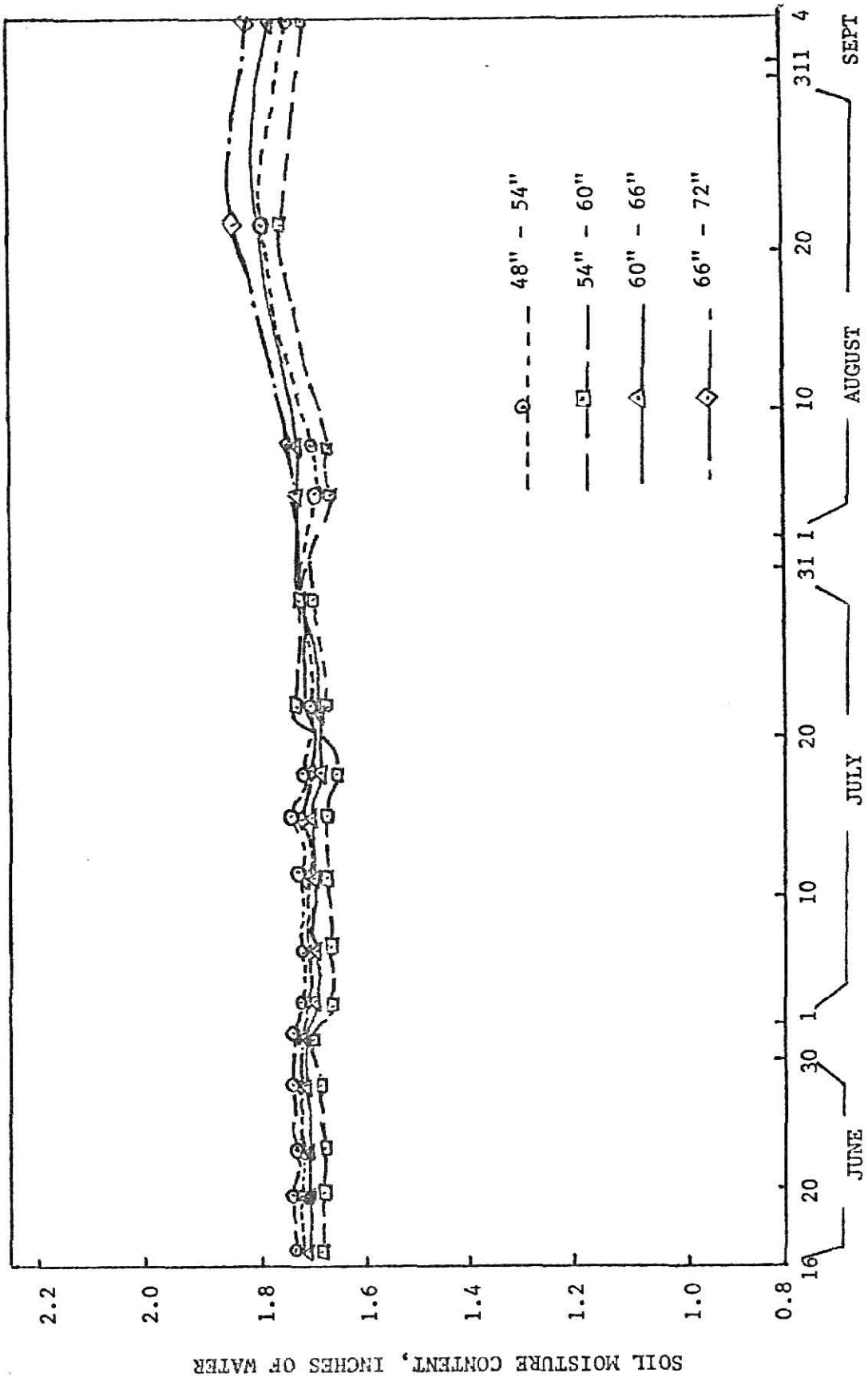


Figure 5. Soil Moisture Content versus Date

affect on either soil infiltration volume or runoff volume.

Infiltration amount in inches of water was obtained by subtracting the soil moisture content of each plot on the day of measurement from the soil moisture content of the corresponding plot on the previous day of measurement plus the consumptive use in inches of water during the period. Runoff in inches of water was obtained by subtracting infiltration amount from irrigation amount. Computed runoff values along with soil moisture content prior to irrigation are given in Tables 8, 9, and 10.

Runoff was compared with soil moisture depletion level for each replication to determine if soil moisture level influenced quantity of runoff. Table 11 gives the results of the statistical analyses for the three replications. In each replication there was a significant difference in runoff between the soil moisture depletion levels at the 0.05 level of significance.

From the facts stated above, runoff is influenced by the soil moisture depletion levels. As stated in the " development of theory", runoff volume is equal to inflow volume minus infiltration volume, as expressed by Equation 20.

In this study, inflow during each irrigation is always kept at 4.62 inches. The length of the furrow in this experiment is 300 feet. Thus, the inflow volume is 4.62 x 300 feet, and the

Table 8. Runoff from Irrigation Water and Soil Moisture Content for Forty Percent Soil Moisture Depletion Level

Soil Moisture Content inches of water	Runoff inches of water
17.76	1.08
18.87	1.42
17.64	1.32
18.48	2.03
19.39	1.95
18.84	1.34
18.56	2.75
18.21	3.09
18.52	2.23
18.31	2.87
20.21	3.61
18.55	2.81
18.57	2.46
18.97	2.38
19.88	2.28
18.48	3.08
18.11	3.32
19.04	2.99
18.10	2.34
19.26	1.24
18.40	1.18
18.77	2.85
19.25	1.82
20.26	2.16
18.06	2.65
17.45	1.92
18.71	3.12

Table 9. Runoff from Irrigation Water and Soil Moisture Content for Sixty Percent Soil Moisture Depletion Level

Soil Moisture Content inches of water	Runoff inches of water
18.61	1.11
18.08	0.97
17.64	2.02
18.60	0.93
19.84	1.63
18.54	2.77
18.88	1.60
17.92	1.60
19.54	3.03
17.84	0.03
16.75	0.07
16.37	0.64
17.43	-0.15
18.24	0.11
17.24	1.57
17.40	0.01
17.21	1.05
18.37	2.24
20.37	3.23
19.24	2.81
18.29	1.35
20.14	2.03
20.69	2.68
18.23	1.91
19.95	3.07
18.72	1.90
18.69	1.70
19.43	2.37
18.43	1.38
18.22	1.25
19.13	2.69
19.16	0.99
18.13	0.87
18.30	0.87
18.17	2.04
18.61	1.27

Table 10. Runoff from Irrigation Water and Soil Moisture Content for Eighty Percent Soil Moisture Depletion Level

Soil Moisture Content inches of water	Runoff inches of water
15.83	-2.21
17.58	0.56
16.93	-1.61
17.50	0.36
17.67	2.15
17.82	2.63
17.75	1.21
17.50	3.64
17.74	0.93
18.52	2.31
19.30	2.66
19.79	2.40
20.05	2.26
17.99	2.27
18.05	2.76
18.01	1.26
17.86	2.86
18.92	1.83
20.10	3.06
19.80	2.05
20.04	1.95
20.54	2.42
18.98	1.33
18.22	0.57
19.58	2.08
17.60	0.96
19.63	2.33

Table 11. Analysis of Variance to Show Differences in Runoff from Varying Soil Moisture Depletion Levels

Source of Variance	D.F.	S.S.	M.S.	F
		Replication 1		
Treatments	2	1.60	0.80	6.02 *
Errors	15	1.99	0.13	
Total	17	3.59		
		Replication 2		
Treatments	2	1.34	0.67	13.40 *
Errors	24	1.30	0.05	
Total	26	3.22		
		Replication 3		
Treatments	2	1.36	0.68	7.56 *
Errors	24	2.16	0.09	
Total	26	3.52		

* Significant at the 0.05 level.

runoff volume is R inches x 300 feet, where R is the runoff in inches. The infiltration volume equation above can be written as:

$$V_i = QS^P \qquad (23)$$

Where $Q = (300)^q K$

By the least squares method, the runoff from irrigation for each depth can be expressed as a function of soil moisture content. In Table 12, the six equations are shown to express the relationship between runoff from irrigation and soil moisture content of the different depths as indicated, and the corresponding correlation coefficients are shown along with each runoff equation.

In these six equations, R is to express the total runoff; S_{0-6} is to express the soil moisture content from ground surface to the depth of six inches, S_{0-12} is to express the soil moisture content from ground surface to the depth of twelve inches, ... etc.

The degrees of freedom for each equation is 53. All t values for these six equations are greater than 2.01, the value needed to show significance at the 0.05 level. It indicated that that these six equations can be confidently used to predict runoff for a given soil moisture content at the different depths.

Table 12. Six Runoff Equations and their corresponding t-test value as well as r-value

Runoff Equations		t	r
$R = 4.62 - 2.581\ S_{0-06}^{-0.485}$	(24)	0.881	0.662
$R = 4.62 - 4.393\ S_{0-12}^{-0.755}$	(25)	0.628	0.740
$R = 4.62 - 7.887\ S_{0-18}^{-0.859}$	(26)	0.926	0.685
$R = 4.62 - 24.46\ S_{0-24}^{-1.335}$	(27)	0.687	0.639
$R = 4.62 - 1465.89\ S_{0-30}^{-3.277}$	(28)	-0.396	0.699
$R = 4.62 - 76973.58\ S_{0-36}^{-4.808}$	(29)	-0.858	0.721

The r values of these six runoff equations are greater than 0.266 at the 0.05 significance level which also shows that these six equations adequately fit the experimental data. The r value for Equation 25 is the highest among these six equations. It is recommended that Equation 25 be used for predicting runoff from irrigation water.

SUMMARY AND CONCLUSION

In furrow irrigation runoff often represents a sizable portion of the water initially applied. Various methods of reducing or reusing runoff water have been devised. Most of the methods requirea knowledge of the amount of runoff produced by an irrigation.

Runoff can be expressed as a function of soil moisture content by the equation:

$$V_R = V_E - A_1 S^B \qquad (20)$$

Detailed soil moisture data were taken from twenty-seven plots. These data were obtained by either the neutron probe method or by the gravimetric method. Twenty-seven access tubes were inserted in the field, and one rain gauge was installed to measure rainfall daily.

During the growing season, the amount of water applied to the field for each irrigation was kept constant at 4.62 inches. The length of furrows was 300 feet. Runoff volume was obtained by subtracting infiltration volume from the inflow volume. Infiltration volume was obtained by subtracting total soil moisture in each plot on the day of measurement from the total soil moisture of the corresponding plot on the previous

day of measurement plus the consumptive use during the period between measurements.

Using the computed runoff and measured soil moisture content the coefficients for Equation 20 were determined for six increments of depth by the method of least squares. Predicted runoff using the resulting coefficients was compared with computed runoff from soil moisture measurements. In each case there were no statistical significant differences at the 0.05 level between predicted and computed runoff. However, the highest correlation between predicted and computed runoff was obtained using soil moisture content of the 0 to 12 inches depth increment.

The results from this study indicate that runoff from irrigation can be adequately predicted from soil moisture content. The best prediction of runoff will result from the use of the soil moisture content of the top twelve inches of the soil profile.

SUGGESTION FOR FURTHER STUDY

This study was limited to evaluating the relationship between runoff from irrigation and soil moisture content. The study was made on one soil type with one furrow length for each irrigation. In addition, runoff was computed from soil moisture measurements and estimated consumptive use.

The following recommendations are made for further research:

1. Runoff should be measured directly to remove errors in measuring soil moisture and in predicting consumptive use.

2. Studies should be made on various furrow lengths to see if length of furrow influences the numerical value of the coefficients in the runoff equations.

3. Studies should be made on various soil types to determine the relationship between the numerical values of the coefficients and soil type in the runoff equation.

4. Studies should be made with various inflow rates to determine the relationship between the numerical values of the coefficients and inflow rates in the runoff equations.

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APPENDIX

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

Table 13. Depth of Soil Moisture in Inches for Each Increment of Soil Depth

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on June 17, 1975											
101	1.556	1.886	1.956	1.847	1.731	1.680	1.692	1.691	1.660	1.672	1.700	1.689
102	1.440	1.566	1.912	2.037	1.908	1.530	1,304	1.429	1.490	1.545	1.656	1.755
103	1.530	1.611	1.898	2.012	1.891	1.322	1.337	1.473	1.587	1.617	1.632	1.628
201	1.330	1.363	1.837	2.042	1.976	1.616	1.422	1.450	1.549	1.634	1.678	1.682
202	1.620	1.451	1.801	2.005	1.980	1.762	1.482	1.556	1.668	1.760	1.689	1.700
203	1.220	1.703	1.908	2.063	1.940	1.672	1.534	1.623	1.715	1.754	1.748	1.698
301	1.460	1.536	1.860	2.003	1.920	1.485	1.393	1.512	1.420	1.588	1.681	1.634
302	1.490	1.768	2.004	1.986	1.771	1.520	1.576	1.665	1.737	1.766	1.450	1.797
303	1.490	1.390	1.745	1.971	2.006	1.856	1.687	1.593	1.536	1.494	1.526	1.587
111	1.320	1.737	2.010	2.179	1.820	1.613	1.623	1.676	1.761	1.748	1.504	1.629
112	1.530	1.551	1.944	2.029	1.747	1.478	1.472	1.620	1.701	1.763	1.821	1.844
113	1.380	1.324	1.845	2.037	1.972	1.659	1.422	1.494	1.598	1.733	1.793	1.839
211	1.500	1.449	1.899	1.996	1.901	1.770	1.635	1.669	1.748	1.808	1.775	1.799
212	1.350	1.681	1.880	1.970	1.879	1.706	1.585	1.671	1.739	1.807	1.709	1.781
213	2.220	1.597	1.964	2.024	1.915	1.748	1.572	1.666	1.737	1.754	1.756	1.760
311	1.510	1.712	1.850	2.012	1.895	1.656	1.484	1.504	1.625	1.665	1.679	1.724
312	1.730	2.421	1.903	1.919	1.640	1.522	1.514	1.560	1.682	1.750	1.776	1.809
313	1.390	1.303	1.824	2.074	2.032	1.853	1.623	1.584	1.659	1.684	1.748	1.780
121	1.350	1.585	1.883	2.037	1.961	1.802	1.662	1.730	1.821	1.817	1.817	1.748
122	1.400	1.398	1.760	1.984	1.974	1.861	1.979	1.796	1.832	1.819	1.841	1.805
123	1.540	1.515	1.775	1.911	2.093	1.897	1.822	1.741	1.709	1.683	1.735	1.716
221	1.540	1.519	1.808	1.976	1.938	1.756	1.453	1.506	1.574	1.659	1.736	1.666
222	1.480	1.599	1.821	1.968	1.920	1.541	1.553	1.572	1.645	1.711	1.766	1.717
223	1.810	1.584	1.810	2.001	1.964	1.747	1.599	1.638	1.741	1.792	1.771	1.693
321	1.670	1.472	1.803	2.012	1.989	1.873	1.695	1.555	1.635	1.674	1.657	1.714
322	1.610	1.613	1.915	1.994	1.891	1.724	1.493	1.622	1.745	1.749	1.493	1.754
323	1.471	1.560	1.916	1.985	1.893	1.788	1.690	1.707	1.790	1.794	1.814	1.829

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on June 20, 1975											
101	2.020	1.761	1.972	1.929	1.811	1.732	1.668	1.703	1.693	1.668	1.684	1.696
102	1.900	1.761	1.937	2.053	1.859	1.576	1.440	1.596	1.544	1.566	1.746	1.666
103	2.200	1.740	1.950	2.030	1.833	1.691	1.388	1.505	1.591	1.628	1.657	1.650
201	2.000	1.587	1.924	2.056	1.970	1.654	1.422	1.502	1.588	1.641	1.665	1.695
202	2.150	1.656	1.936	2.003	1.899	1.644	1.397	1.500	1.599	1.639	1.663	1.684
203	2.120	1.843	2.017	2.073	1.934	1.674	1.576	1.647	1.731	1.773	1.788	1.763
301	1.950	1.617	1.875	2.020	1.865	1.462	1.425	1.616	1.440	1.587	1.697	1.648
302	2.000	1.644	1.818	2.039	1.977	1.762	1.524	1.593	1.695	1.763	1.765	1.800
303	1.650	1.627	1.769	1.948	2.025	1.870	1.705	1.625	1.539	1.491	1.542	1.587
111	1.870	1.831	2.041	1.990	1.827	1.645	1.673	1.701	1.780	1.731	1.516	1.667
112	1.650	1.756	1.955	2.032	1.709	1.498	1.503	1.644	1.713	1.765	1.847	1.877
113	1.930	1.592	1.915	2.051	1.933	1.624	1.461	1.533	1.637	1.745	1.816	1.861
211	2.060	1.628	2.001	2.026	1.866	1.762	1.639	1.667	1.746	1.790	1.792	1.801
212	1.760	1.756	1.985	1.997	1.865	1.719	1.589	1.649	1.752	1.809	1.792	1.772
213	2.140	1.728	2.002	2.059	1.907	1.754	1.604	1.670	1.743	1.775	1.752	1.773
311	1.890	1.796	1.977	2.041	1.893	1.679	1.502	1.519	1.616	1.683	1.697	1.749
312	2.070	1.733	1.946	1.920	1.654	1.562	1.543	1.584	1.701	1.778	1.812	1.815
313	2.110	1.483	1.827	2.058	2.071	1.866	1.639	1.604	1.673	1.755	1.740	1.810
121	1.970	1.578	1.894	2.046	1.963	1.810	1.657	1.749	1.860	1.853	1.832	1.760
122	1.910	1.498	1.806	1.986	1.976	1.892	1.813	1.821	1.848	1.841	1.857	1.803
123	2.110	1.647	1.786	1.962	1.990	1.900	1.839	1.729	1.706	1.700	1.746	1.726
221	2.150	1.603	1.855	1.985	1.935	1.622	1.505	1.535	1.580	1.684	1.751	1.685
222	1.970	1.704	1.825	2.014	1.910	1.586	1.571	1.859	1.675	1.709	1.764	1.737
223	2.160	1.682	1.875	2.044	1.972	1.722	1.626	1.641	1.727	1.770	1.798	1.783
321	2.010	1.629	1.826	2.036	2.000	1.904	1.696	1.569	1.647	1.690	1.683	1.747
322	2.170	1.726	1.952	1.997	1.904	1.710	1.510	1.513	1.647	1.777	1.780	1.798
323	2.080	2.623	1.961	1.978	1.868	1.790	1.675	1.743	1.794	1.811	1.850	1.839

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on June 24, 1975											
101	2.210	1.760	1.986	1.933	1.840	1.728	1.672	1.707	1.676	1.660	1.681	1.691
102	2.230	1.673	1.963	2.075	1.940	1.680	1.430	1.487	1.532	1.547	1.652	1.727
103	1.605	1.985	2.005	1.835	1.423	1.384	1.503	1.599	1.616	1.642	1.626	1.646
201	2.190	1.692	1.943	2.045	1.937	1.629	1.441	1.485	1.572	1.631	1.696	1.712
202	1.880	1.740	1.879	2.024	1.960	1.740	1.491	1.599	1.681	1.704	1.724	1.710
203	2.040	1.846	1.983	2.066	1.945	1.697	1.575	1.637	1.728	1.773	1.784	1.763
301	2.110	1.539	1.789	1.999	1.895	1.548	1.408	1.504	1.444	1.589	1.609	1.649
302	1.970	1.714	1.864	2.007	1.963	1.764	1.527	1.607	1.685	1.772	1.777	1.798
303	2.040	1.612	1.702	1.962	1.985	1.853	1.678	1.623	1.523	1.480	1.546	1.593
111	2.010	1.866	2.059	1.999	1.813	1.656	1.677	1.710	1.783	1.711	1.506	1.644
112	1.860	1.829	2.016	2.024	1.674	1.553	1.561	1.674	1.732	1.793	1.837	1.871
113	1.910	1.764	1.961	2.034	1.920	1.605	1.449	1.568	1.621	1.764	1.821	1.848
211	2.090	1.786	1.963	1.992	1.884	1.738	1.643	1.679	1.757	1.802	1.790	1.792
212	2.040	1.836	1.997	1.965	1.851	1.703	1.602	1.660	1.756	1.807	1.793	1.773
213	1.860	1.812	2.030	2.006	1.876	1.726	1.592	1.663	1.743	1.745	1.777	1.773
311	2.010	1.830	2.019	2.012	1.890	1.645	1.485	1.531	1.612	1.671	1.702	1.751
312	1.970	1.781	1.938	1.918	1.615	1.521	1.531	1.571	1.714	1.764	1.782	1.793
313	2.050	1.544	1.815	2.060	2.012	1.848	1.634	1.600	1.653	1.701	1.744	1.774
121	2.170	1.590	1.720	1.951	2.024	1.953	1.764	1.644	1.756	1.832	1.805	1.668
122	2.200	1.758	1.893	2.040	1.991	1.880	1.803	1.818	1.825	1.815	1.839	1.805
123	2.300	1.704	1.841	1.953	1.984	1.891	1.819	1.710	1.671	1.685	1.731	1.724
221	2.520	1.787	1.926	1.967	1.907	1.588	1.495	1.534	1.577	1.698	1.744	1.678
222	2.330	1.775	1.889	1.981	1.872	1.606	1.558	1.602	1.659	1.735	1.771	1.731
223	2.120	1.764	1.882	2.042	1.935	1.712	1.634	1.656	1.719	1.737	1.788	1.745
321	2.280	1.767	1.885	2.014	1.984	1.893	1.687	1.599	1.649	1.675	1.685	1.715
322	2.100	1.858	2.020	2.002	1.907	1.706	1.496	1.505	1.665	1.757	1.737	1.782
323	2.250	1.841	2.005	1.958	1.852	1.770	1.701	1.736	1.789	1.807	1.829	1.843

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on June 27, 1975											
101	1.590	1.726	1.995	1.962	1.826	1.730	1.659	1.697	1.682	1.668	1.695	1.689
102	1.610	1.507	1.883	2.033	1.928	1.650	1.432	1.474	1.505	1.559	1.655	1.718
103	1.820	1.707	1.920	1.994	1.826	1.413	1.387	1.492	1.587	1.609	1.629	1.620
201	1.670	1.483	1.870	2.062	1.938	1.591	1.417	1.487	1.577	1.639	1.670	1.690
202	1.540	1.591	1.867	2.036	1.959	1.730	1.475	1.607	1.686	1.693	1.709	1.707
203	1.680	1.755	1.961	1.999	1.912	1.643	1.568	1.651	1.739	1.731	1.777	1.730
301	1.810	1.403	1.799	1.985	1.815	1.473	1.417	1.499	1.436	1.616	1.673	1.624
302	1.610	1.514	1.873	1.988	1.936	1.690	1.536	1.608	1.676	1.766	1.759	1.810
303	1.610	1.430	1.595	1.906	1.983	1.886	1.708	1.638	1.531	1.475	1.518	1.566
111	1.710	1.728	2.007	1.998	1.805	1.669	1.668	1.725	1.769	1.733	1.504	1.625
112	1.660	1.680	1.938	2.037	1.708	1.532	1.562	1.663	1.726	1.799	1.827	1.871
113	1.960	1.570	1.908	2.016	1.865	1.577	1.470	1.527	1.627	1.753	1.814	1.833
211	1.700	1.629	1.937	1.996	1.898	1.746	1.627	1.647	1.762	1.791	1.791	1.789
212	1.560	1.702	1.969	1.953	1.824	1.683	1.582	1.679	1.769	1.799	1.771	1.774
213	1.480	1.677	1.987	1.993	1.880	1.685	1.578	1.662	1.737	1.749	1.749	1.866
311	1.560	1.748	1.987	2.004	1.861	1.634	1.498	1.512	1.604	1.679	1.677	1.749
312	1.620	1.693	1.898	1.881	1.608	1.514	1.549	1.564	1.699	1.759	1.785	1.796
313	1.780	1.311	1.745	2.034	1.991	1.805	1.611	1.564	1.668	1.686	1.734	1.783
121	1.670	1.602	1.927	2.040	1.963	1.758	1.636	1.784	1.846	1.833	1.784	1.749
122	1.780	1.617	1.863	1.992	1.971	1.867	1.810	1.787	1.823	1.803	1.827	1.794
123	1.760	1.577	1.756	1.945	1.993	1.899	1.802	1.729	1.688	1.683	1.725	1.705
221	1.860	1.607	1.847	1.962	1.943	1.609	1.475	1.519	1.544	1.681	1.739	1.677
222	1.950	1.712	1.844	1.969	1.878	1.603	1.552	1.593	1.644	1.689	1.752	1.733
223	1.800	1.630	1.801	2.017	1.945	1.727	1.601	1.627	1.720	1.763	1.785	1.755
321	1.790	1.621	1.833	2.002	1.966	1.865	1.687	1.586	1.634	1.678	1.670	1.710
322	1.890	1.692	1.983	1.977	1.878	1.707	1.508	1.522	1.656	1.744	1.729	1.768
323	1.910	1.748	1.974	1.961	1.859	1.763	1.702	1.738	1.782	1.794	1.842	1.820

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on July 1, 1975											
101	1.140	1.476	1.954	1.978	1.852	1.732	1.688	1.713	1.718	1.686	1.703	1.714
102	1.240	1.345	1.818	2.027	1.877	1.610	1.452	1.518	1.552	1.601	1.703	1.777
103	0.890	1.377	1.854	2.033	1.893	1.481	1.396	1.519	1.615	1.632	1.662	1.660
201	0.960	1.656	1.730	2.051	2.005	1.674	1.456	1.510	1.573	1.685	1.704	1.721
202	1.170	1.449	1.761	2.020	1.983	1.763	1.519	1.611	1.716	1.725	1.757	1.741
203	0.990	1.523	1.917	2.077	1.944	1.690	1.602	1.689	1.742	1.783	1.779	1.730
301	1.440	1.147	1.652	1.995	1.866	1.509	1.458	1.524	1.479	1.656	1.716	1.629
302	0.940	1.195	1.686	1.901	1.958	1.798	1.551	1.634	1.708	1.801	1.801	1.824
303	1.100	1.205	1.458	1.844	2.041	1.770	1.747	1.665	1.573	1.488	1.549	1.618
111	1.000	1.338	1.909	2.002	1.855	1.714	1.699	1.739	1.815	1.795	1.788	1.656
112	1.010	1.318	1.845	2.046	1.772	1.572	1.584	1.644	1.748	1.814	1.856	1.907
113	0.800	1.240	1.813	2.009	1.905	1.579	1.270	1.552	1.656	1.779	1.832	1.865
211	0.880	1.518	1.860	2.020	1.940	1.781	1.657	1.705	1.787	1.827	1.821	1.818
212	0.940	1.444	1.886	1.986	1.887	1.697	1.613	1.706	1.779	1.834	1.813	1.787
213	1.080	1.427	1.890	2.015	1.918	1.752	1.624	1.690	1.738	1.778	1.786	1.791
311	1.030	1.623	1.957	2.053	1.915	1.691	1.513	1.536	1.653	1.700	1.708	1.762
312	0.920	1.680	1.827	1.929	1.674	1.575	1.560	1.583	1.713	1.781	1.820	1.831
313	1.350	1.042	1.636	2.043	1.997	1.882	1.664	1.601	1.691	1.711	1.765	1.799
121	0.980	1.307	1.822	2.036	1.978	1.802	1.690	1.796	1.865	1.857	1.839	1.802
122	0.930	1.372	1.755	1.982	1.994	1.912	1.816	1.818	1.871	1.854	1.868	1.840
123	0.300	1.186	1.579	1.904	2.020	1.937	1.843	1.756	1.711	1.699	1.753	1.727
221	1.290	1.152	1.731	1.987	1.990	1.668	1.513	1.562	1.592	1.698	1.769	1.706
222	1.240	1.440	1.722	1.973	1.904	1.637	1.611	1.622	1.689	1.760	1.785	1.755
223	1.460	1.296	1.726	2.009	1.971	1.756	1.648	1.686	1.725	1.772	1.822	1.798
321	1.030	1.335	1.709	1.982	2.014	1.901	1.726	1.610	1.653	1.711	1.718	1.761
322	1.020	1.477	1.880	1.990	1.926	1.749	1.549	1.520	1.664	1.786	1.813	1.768
323	1.170	1.459	1.879	1.980	1.898	1.773	1.710	1.771	1.827	1.822	1.861	1.866

	Depth of Soil in Inches											
Plot No.	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
101	1.560	1.216	1.835	1.903	1.779	1.683	1.639	1.656	1.645	1.630	1.686	1.663
102	1.560	1.101	1.652	1.971	1.886	1.619	1.445	1.459	1.530	1.565	1.680	1.731
103	1.590	1.277	1.789	1.958	1.839	1.443	1.370	1.489	1.575	1.599	1.628	1.627
201	1.590	0.834	1.584	1.999	1.958	1.658	1.434	1.474	1.572	1.619	1.661	1.683
202	1.590	1.234	1.724	1.979	1.952	1.761	1.505	1.613	1.680	1.699	1.730	1.700
203	1.590	1.311	1.832	2.035	1.926	1.688	1.566	1.749	1.738	1.794	1.779	1.760
301	1.560	0.852	1.483	1.918	1.885	1.570	1.469	1.502	1.462	1.561	1.716	1.652
302	1.605	0.994	1.535	1.943	1.982	1.757	1.544	1.601	1.685	1.767	1.777	1.811
303	1.650	0.973	1.367	1.794	1.992	1.848	1.713	1.634	1.526	1.474	1.513	1.591
111	1.605	1.133	1.779	1.918	1.813	1.672	1.663	1.762	1.767	1.729	1.526	1.635
112	1.605	1.136	1.782	1.996	1.720	1.562	1.576	1.668	1.713	1.787	1.842	1.883
113	1.605	0.860	1.649	1.943	1.904	1.655	1.452	1.520	1.605	1.739	1.794	1.856
211	1.620	1.414	1.868	1.978	1.892	1.739	1.646	1.685	1.788	1.789	1.802	1.799
212	1.620	1.280	1.825	1.934	1.837	1.707	1.619	1.688	1.751	1.808	1.785	1.763
213	1.620	1.226	1.778	1.959	1.909	1.710	1.613	1.660	1.746	1.754	1.769	1.761
311	1.650	1.522	1.917	1.996	1.881	1.677	1.510	1.528	1.618	1.685	1.677	1.731
312	1.680	1.190	1.737	1.890	1.621	1.559	1.520	1.584	1.726	1.754	1.805	1.796
313	1.590	0.843	1.982	1.963	1.842	1.622	1.601	1.666	1.703	1.762	1.812	1.822
121	1.605	1.711	1.983	1.938	1.801	1.679	1.752	1.847	1.851	1.835	1.759	1.760
122	1.605	1.214	1.568	1.905	1.959	1.872	1.796	1.796	1.826	1.832	1.821	1.811
123	1.605	1.477	1.871	1.966	1.900	1.823	1.725	1.686	1.668	1.744	1.728	1.056
221	1.620	1.014	1.607	1.934	1.946	1.637	1.486	1.576	1.594	1.693	1.744	1.676
222	1.590	1.229	1.624	1.922	1.869	1.608	1.560	1.599	1.664	1.715	1.782	1.740
223	1.620	1.080	1.579	1.988	1.929	1.759	1.636	1.657	1.732	1.752	1.800	1.782
321	1.590	1.091	1.554	1.913	1.957	1.871	1.713	1.591	1.649	1.681	1.686	1.712
322	1.590	1.396	1.844	1.964	1.879	1.707	1.537	1.517	1.650	1.749	1.748	1.794
323	1.620	1.295	1.815	1.917	1.838	1.758	1.692	1.728	1.803	1.807	1.819	1.817

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
101	0.770	0.961	1.685	1.830	1.770	1.655	1.626	1.685	1.650	1.637	1.658	1.688
102	0.897	.7850	1.401	1.955	1.802	1.572	1.465	1.514	1.537	1.588	2.678	1.743
103	0.712	0.920	1.599	1.869	1.816	1.443	1.398	1.500	1.589	1.623	1.644	1.642
201	0.663	.9804	1.439	1.850	1.926	1.641	1.457	1.507	1.573	1.645	1.707	1.785
202	0.897	0.863	1.444	1.901	1.928	1.751	1.523	1.600	1.705	1.785	1.738	1.730
203	0.608	0.885	1.636	1.996	1.925	1.671	1.576	1.654	1.762	1.787	1.793	1.760
301	0.858	0.809	1.443	1.833	1.805	1.478	1.457	1.525	1.458	1.622	1.697	1.661
302	0.756	1.140	1.329	1.809	1.910	1.718	1.562	1.625	1.705	1.772	1.794	1.831
303	0.764	0.773	1.196	1.673	1.875	1.815	1.728	1.641	1.544	1.510	1.527	1.587
111	0.679	0.942	1.588	1.774	1.804	1.684	1.692	1.731	1.783	1.740	1.525	1.655
112	0.764	1.590	1.587	1.857	1.960	1.587	1.581	1.663	1.726	1.808	1.851	1.903
113	0.780	0.812	1.564	1.820	1.794	1.593	1.466	1.534	1.659	1.771	1.817	1.868
211	0.967	0.953	1.933	1.885	1.777	1.651	1.689	1.780	1.821	1.824	1.828	1.825
212	0.881	1.009	1.613	1.811	1.816	1.718	1.647	1.702	1.786	1.818	1.799	1.792
213	0.702	0.938	1.616	1.827	1.836	1.713	1.602	1.690	1.752	1.761	1.767	1.784
311	0.632	1.042	1.777	1.953	1.886	1.672	1.511	1.528	1.660	1.689	1.719	1.768
312	0.686	0.871	1.586	1.850	1.647	1.562	1.556	1.592	1.712	1.777	1.813	1.799
313	0.601	0.660	1.451	1.856	1.920	1.839	1.648	1.607	1.672	1.717	1.759	1.809
121	0.585	0.597	1.385	1.849	1.929	1.823	1.672	1.733	1.825	1.857	1.850	1.769
122	0.663	0.705	1.162	1.677	1.879	1.853	1.821	1.814	1.829	1.831	1.877	1.807
123	0.702	0.755	1.212	1.644	1.895	1.884	1.817	1.712	1.708	1.706	1.773	1.743
221	0.889	0.695	1.296	1.723	1.887	1.602	1.505	1.565	1.586	1.702	1.768	1.700
222	0.718	0.834	1.280	1.776	1.850	1.614	1.588	1.611	1.683	1.739	1.781	1.734
223	0.983	0.739	1.318	1.844	1.895	1.715	1.656	1.677	1.719	1.772	1.809	1.802
321	0.835	0.785	1.381	1.739	1.851	1.822	1.711	1.611	1.664	1.678	1.686	1.755
322	0.663	0.938	1.637	1.847	1.842	1.720	1.558	1.550	1.680	1.769	1.781	1.802
323	0.749	0.963	1.644	1.797	1.821	1.760	1.698	1.775	1.794	1.815	1.869	1.852

Plot No.	Depth of Soil in inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on July 9, 1975											
101	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
102	0.647	1.342	1.737	1.742	1.563	1.424	1.425	1.530	1.569	1.678	1.732	1.789
103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
201	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
202	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
203	0.686	0.760	1.434	1.929	1.865	1.620	1.572	1.669	1.739	1.767	1.786	1.756
301	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
302	0.811	0.575	1.114	1.680	1.839	1.747	1.556	1.605	1.688	1.761	1.768	1.799
303	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
111	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
112	0.796	0.740	1.473	1.786	1.664	1.560	1.663	1.701	1.796	1.831	1.892	1.903
113	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
211	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
212	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
213	0.468	0.909	1.536	1.751	1.793	1.699	1.580	1.651	1.733	1.767	1.750	1.755
311	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
312	0.741	0.841	1.520	1.758	1.628	1.549	1.563	1.594	1.699	1.748	1.817	1.817
121	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
122	0.616	0.645	1.141	1.606	1.842	1.835	1.806	1.805	1.848	1.814	1.843	1.822
123	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
221	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
223	0.593	0.717	1.263	1.792	1.849	1.707	1.635	1.641	1.733	1.760	1.797	1.798
321	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
322	0.593	0.776	1.563	1.756	1.777	1.688	1.544	1.539	1.639	1.759	1.771	1.800
323	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on July 11, 1975											
101	1.890	1.788	1.937	1.976	1.818	1.685	1.613	1.637	1.670	1.650	1.652	1.681
102	0.540	0.302	1.233	1.643	1.689	1.547	1.405	1.467	1.514	1.538	1.639	1.707
103	1.970	1.635	1.782	1.789	1.691	1.999	1.406	1.476	1.562	1.576	1.610	1.605
201	1.870	1.714	1.925	2.002	1.885	1.621	1.520	1.524	1.576	1.643	1.666	1.675
202	1.840	1.782	1.914	2.014	1.810	1.690	1.528	1.604	1.682	1.692	1.698	1.695
203	0.480	0.784	1.406	1.837	1.852	1.608	1.547	1.629	1.712	1.740	1.744	1.748
301	1.810	1.765	1.873	1.893	1.762	1.477	1.431	1.493	1.432	1.007	1.657	1.618
302	0.470	0.520	1.146	1.638	1.799	1.694	1.525	1.562	1.660	1.735	1.604	1.785
303	1.570	1.532	1.505	1.671	1.876	1.768	1.671	1.606	1.515	1.447	1.509	1.562
111	2.000	1.814	1.966	1.926	1.822	1.701	1.676	1.697	1.728	1.716	1.490	1.630
112	0.630	0.712	1.441	1.717	1.599	1.530	1.561	1.643	1.695	1.759	1.824	1.846
113	1.780	1.534	1.744	1.770	1.739	1.747	1.567	1.445	1.512	1.603	1.733	1.780
211	1.910	1.730	1.942	1.996	1.875	1.782	1.684	1.690	1.740	1.784	1.773	1.802
212	1.740	1.739	1.882	1.826	1.778	1.699	1.600	1.763	1.714	1.782	1.746	1.761
213	0.660	0.792	1.519	1.769	1.749	1.615	1.580	1.662	1.734	1.727	1.755	1.758
311	1.780	1.851	1.999	1.983	1.856	1.688	1.554	1.539	1.614	1.662	1.725	1.747
312	0.450	0.821	1.493	1.686	1.565	1.525	1.521	1.589	1.691	1.734	1.770	1.759
313	1.800	0.809	1.343	1.736	1.827	1.731	1.601	1.567	1.662	1.669	1.740	1.782
121	1.350	1.552	1.802	1.928	1.882	1.736	1.643	1.730	1.810	1.802	1.797	1.743
122	0.500	0.504	1.057	1.534	1.738	1.804	1.756	1.779	1.827	1.787	1.821	1.777
123	1.050	1.352	1.404	1.562	1.832	1.840	1.794	1.705	1.671	1.646	1.722	1.728
221	1.820	1.541	1.609	1.808	1.820	1.607	1.502	1.544	1.593	1.662	1.727	1.680
222	1.390	1.008	1.280	1.696	1.727	1.580	1.573	1.577	1.638	1.708	1.748	1.691
223	0.670	1.093	1.134	1.701	1.796	1.675	1.619	1.644	1.699	1.722	1.775	1.758
321	1.250	1.490	1.689	1.810	1.846	1.812	1.668	1.569	1.630	1.651	1.658	1.690
322	0.570	0.746	1.462	1.700	1.703	1.672	1.531	1.493	1.658	1.730	1.744	1.762
323	1.200	1.415	1.698	1.735	1.752	1.696	1.660	1.718	1.754	1.780	1.802	1.799

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on July 15, 1975											
101	1.110	1.546	1.888	1.910	1.777	1.704	1.619	1.669	1.663	1.657	1.710	1.673
102	0.340	0.433	1.118	1.557	1.584	1.496	1.395	1.483	1.489	1.584	1.642	1.713
103	1.140	1.249	1.683	1.793	1.770	1.449	1.500	1.384	1.594	1.616	1.502	1.628
201	0.930	1.348	1.766	1.991	1.923	1.656	1.532	1.543	1.594	1.657	1.574	1.701
202	1.060	1.584	1.794	1.997	1.918	1.758	1.564	1.632	1.712	1.730	1.726	1.735
203	0.310	0.597	1.276	1.703	1.783	1.633	1.566	1.646	1.751	1.776	1.780	1.775
301	0.890	1.365	1.698	1.897	1.805	1.560	1.421	1.530	1.451	1.578	1.713	1.637
302	0.220	0.464	1.067	1.616	1.714	1.664	1.457	1.603	1.691	1.764	1.792	1.790
303	1.090	1.271	1.416	1.647	1.797	1.786	1.699	1.622	1.532	1.485	1.532	1.576
111	0.930	1.590	1.852	1.884	1.817	1.708	1.682	1.734	1.782	1.712	1.510	1.653
112	0.280	0.330	1.374	1.665	1.571	1.551	1.570	1.667	1.700	1.787	1.824	1.879
113	0.710	1.054	1.655	1.793	1.750	1.560	1.464	1.530	1.620	1.773	1.805	1.853
211	0.660	1.370	1.796	1.946	1.899	1.768	1.709	1.707	1.717	1.787	1.829	1.806
212	0.690	1.468	1.791	1.807	1.791	1.738	1.626	1.675	1.802	1.812	1.811	0.959
213	0.410	0.715	1.397	1.623	1.646	1.634	1.581	1.653	1.744	1.759	1.733	1.772
311	0.630	1.662	1.931	2.015	1.920	1.713	1.593	1.576	1.654	1.685	1.741	1.771
312	0.520	0.814	1.573	1.639	1.572	1.526	1.535	1.592	1.691	1.756	1.796	1.808
313	1.070	0.713	1.383	1.765	1.841	1.797	1.622	1.582	1.684	1.701	1.758	1.816
121	0.980	1.084	1.620	1.873	1.888	1.755	1.669	1.778	1.841	1.844	1.323	1.775
122	0.530	0.472	0.999	1.439	1.663	1.775	1.760	1.804	1.835	1.808	1.845	1.820
123	0.620	0.917	1.240	1.628	1.821	1.851	1.803	1.723	1.708	1.669	1.755	1.737
221	0.970	0.889	1.341	1.720	1.801	1.606	1.535	1.566	1.615	1.719	1.750	1.696
222	0.910	0.855	1.230	1.689	1.747	1.593	1.587	1.595	1.680	1.747	1.752	1.724
223	0.460	0.572	1.129	1.649	1.698	1.644	1.649	1.660	1.727	1.749	1.797	1.771
321	1.020	1.034	1.506	1.780	1.802	1.978	1.691	1.597	1.675	1.692	1.703	1.747
322	0.570	0.665	1.440	1.645	1.663	1.629	1.566	1.533	1.683	1.762	1.777	1.804
323	0.850	1.103	1.645	1.747	1.758	1.717	1.689	1.729	1.807	1.812	1.838	1.839

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on July 18, 1975											
101	0.760	1.082	1.686	1.856	1.756	1.652	1.588	1.644	1.653	1.613	1.640	1.639
102	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
201	0.530	0.866	1.484	1.782	1.802	1.625	1.477	1.517	1.567	1.614	1.663	1.656
202	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
203	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
301	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
302	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
303	0.460	0.929	1.154	1.567	1.720	1.713	1.642	1.586	1.501	1.423	1.497	1.550
111	0.530	1.034	1.569	1.850	1.671	1.679	1.654	1.684	1.741	1.667	1.477	1.628
112	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
113	.....	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....
211	0.590	0.939	1.580	1.805	1.761	1.714	1.659	1.875	1.744	1.747	1.772	1.794
212	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
213	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
311	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
312	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
313	0.650	0.609	1.325	1.686	1.736	1.686	1.574	1.551	1.644	1.626	1.711	1.772
121	0.550	0.660	1.379	1.688	1.728	1.648	1.607	1.726	1.816	1.793	1.769	1.729
122	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
123	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
221	0.520	0.518	1.061	1.496	1.615	1.504	1.474	1.523	1.570	1.649	1.711	1.667
222	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
223	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
321	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
322	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
323	0.450	0.845	1.549	1.636	1.664	1.629	1.629	1.677	1.737	1.777	1.790	1.801

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on July 22, 1975											
101	0.610	0.807	1.521	1.717	1.710	1.625	1.594	1.627	1.633	1.683	1.655	1.660
102	2.030	1.627	1.906	1.955	1.856	1.705	1.549	1.469	1.505	1.548	1.632	1.772
103	1.110	1.323	1.619	1.735	1.641	1.391	1.384	1.506	1.561	1.601	1.617	1.615
201	0.530	0.601	1.247	1.610	1.641	1.567	1.488	1.515	1.560	1.631	1.678	1.686
202	0.850	1.408	1.647	1.846	1.830	1.678	1.537	1.606	1.712	1.719	1.707	1.724
203	1.420	1.739	1.932	2.019	1.901	1.774	1.605	1.634	1.706	1.739	1.756	1.747
301	1.140	1.341	1.636	1.783	1.735	1.535	1.435	1.498	1.421	1.593	1.706	1.617
302	1.430	1.638	1.879	1.973	1.901	1.787	1.704	1.764	1.700	1.744	1.774	1.803
303	0.580	0.599	1.047	1.557	1.705	1.621	1.602	1.610	1.515	1.456	1.504	1.578
111	0.570	0.788	1.520	1.574	1.620	1.645	1.695	1.751	1.705	1.487	1.651	1.425
112	1.250	1.767	1.972	1.991	1.876	1.696	1.615	1.662	1.727	1.768	1.823	1.845
113	1.030	1.248	1.602	1.761	1.667	1.475	1.460	1.513	1.627	1.730	1.815	1.837
211	0.610	0.778	1.412	1.578	1.674	1.659	1.637	1.695	1.760	1.790	1.770	1.785
212	0.790	1.310	1.701	1.759	1.797	1.639	1.581	1.654	1.739	1.803	1.786	1.776
213	1.280	1.538	1.636	1.608	1.591	1.560	1.634	1.636	1.727	1.752	1.755	1.760
311	1.180	1.759	1.969	1.951	1.852	1.678	1.574	1.552	1.626	1.685	1.704	1.754
312	1.410	1.449	1.498	1.579	1.531	1.517	1.532	1.541	1.674	1.744	1.792	1.780
313	0.620	0.494	1.146	1.639	1.671	1.657	1.604	1.562	1.657	1.682	1.733	1.780
121	0.610	0.484	1.135	1.527	1.628	1.620	1.564	1.710	1.792	1.811	1.805	1.715
122	1.180	1.406	1.694	1.839	1.825	1.758	1.743	1.749	1.821	1.785	1.796	1.791
123	0.660	0.970	1.247	1.563	1.697	1.743	1.753	1.687	1.669	1.649	1.723	1.695
221	0.950	0.651	1.220	1.529	1.639	1.520	1.487	1.538	1.566	1.682	1.730	1.700
222	0.800	0.760	1.196	1.605	1.625	1.534	1.554	1.564	1.645	1.724	1.753	1.711
223	0.550	0.864	1.187	1.633	1.623	1.619	1.604	1.635	1.715	1.745	1.779	1.765
321	1.070	1.042	1.473	1.731	1.735	1.729	1.647	1.585	1.647	1.655	1.678	1.720
322	1.270	1.661	1.950	1.901	1.773	1.706	1.686	1.660	1.707	1.765	1.748	1.809
323	0.520	0.934	1.596	1.630	1.593	1.580	1.634	1.715	1.750	1.802	1.817	1.800

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on July 24, 1975											
101	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
102	1.605	1.455	1.940	1.776	1.664	1.506	1.485	1.524	1.530	1.644	1.703	1.831
103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
201	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
202	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
203	1.605	1.590	1.891	1.972	1.875	1.677	1.559	1.644	1.701	1.739	1.749	1.746
301	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
302	1.605	1.553	1.801	1.944	1.880	1.780	1.664	1.624	1.697	1.749	1.751	1.787
303	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
111	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
112	1.620	1.681	1.911	1.971	1.817	1.659	1.605	1.672	1.703	1.759	1.806	1.870
113	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
211	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
212	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
213	1.590	1.405	1.614	1.591	1.578	1.521	1.614	1.698	1.743	1.742	1.614	1.743
311	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
312	1.620	1.324	1.476	1.558	1.534	1.521	1.517	1.568	1.678	1.732	1.779	1.771
313	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
121	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
122	1.590	.9932	1.490	1.736	1.801	1.749	1.737	1.755	1.794	1.787	1.794	1.772
123	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
221	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
222	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
223	1.605	.7631	1.172	1.592	1.596	1.601	1.625	1.688	1.727	1.771	1.736	1.579
321	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
322	1.590	1.499	1.902	1.865	1.765	1.704	1.645	1.652	1.681	1.745	1.750	1.774
323	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on July 28, 1975											
101	1.660	1.695	1.930	1.199	1.757	1.644	1.563	1.622	1.630	1.633	1.658	1.655
102	1.080	1.143	1.647	1.868	1.760	1.603	1.506	1.498	1.498	1.492	1.655	1.709
103	1.620	1.037	1.575	1.741	1.616	1.389	1.399	1.525	1.570	1.607	1.644	1.610
201	1.750	1.466	1.747	1.691	1.598	1.542	1.485	1.512	1.568	1.663	1.664	1.683
202	1.440	1.597	1.814	1.953	1.908	1.725	1.607	1.643	1.703	1.721	1.747	1.722
203	.9600	1.131	1.640	1.843	1.941	1.650	1.579	1.639	1.720	1.773	1.767	1.756
301	1.430	1.455	1.760	1.944	1.830	1.693	1.672	1.612	1.465	1.590	1.716	1.615
302	.8700	1.616	1.564	1.838	1.845	1.756	1.649	1.616	1.705	1.763	1.785	1.786
303	1.440	1.238	1.360	1.605	1.680	1.601	1.570	1.591	1.555	1.527	1.536	1.583
111	1.240	1.665	1.952	1.884	1.795	1.704	1.671	1.664	1.743	1.698	1.483	1.640
112	1.130	1.284	1.800	1.940	1.768	1.673	1.615	1.658	1.712	1.760	1.826	1.864
113	.9700	1.307	1.427	1.742	1.694	1.509	1.395	1.501	1.592	1.726	1.797	1.818
211	1.550	1.448	1.880	1.909	1.792	1.703	1.613	1.667	1.750	1.809	1.767	1.805
212	1.530	1.351	1.736	1.745	1.653	1.624	1.594	1.662	1.760	1.785	1.787	1.756
213	1.100	.4485	1.534	1.615	1.600	1.556	1.535	1.643	1.721	1.728	1.737	1.750
311	1.460	1.704	1.938	1.949	1.960	1.715	1.627	1.584	1.653	1.706	1.726	1.738
312	.9200	.9705	1.468	1.570	1.523	1.516	1.532	1.550	1.699	1.765	1.775	1.770
313	1.200	.9551	1.385	1.600	1.626	1.611	1.571	1.547	1.646	1.666	1.744	1.778
121	1.550	1.300	1.630	1.782	1.714	1.597	1.548	1.732	1.803	1.809	1.775	1.711
122	.8800	.5524	1.080	1.555	1.681	1.672	1.688	1.729	1.800	1.799	1.788	1.780
123	1.260	.7453	1.098	1.484	1.682	1.653	1.667	1.660	1.648	1.656	1.712	1.690
221	1.220	1.282	1.590	1.743	1.694	1.516	1.486	1.526	1.578	1.689	1.720	1.677
222	1.210	.9288	1.314	1.655	1.594	1.508	1.514	1.553	1.658	1.707	1.736	1.712
223	1.250	.5835	1.174	1.634	1.572	1.524	1.569	1.611	1.697	1.744	1.766	1.735
321	1.040	.8492	1.386	1.712	1.684	1.636	1.600	1.577	1.643	1.659	1.665	1.706
322	1.060	.9871	1.679	1.753	1.680	1.646	1.627	1.640	1.687	1.638	1.746	1.772
323	1.060	1.061	1.581	1.576	1.557	1.494	1.581	1.694	1.739	1.778	1.801	1.771

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on August 1, 1975											
101	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
102	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
103	1.730	1.022	1.531	1.659	1.563	1.346	1.363	1.477	1.550	1.592	1.612	1.581
201	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
202	1.560	1.694	1.849	1.960	1.864	1.720	1.581	1.634	1.671	1.698	1.706	1.698
203	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
301	1.660	1.626	1.794	1.899	1.797	1.670	1.670	1.698	1.525	1.612	1.699	1.627
302	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
303	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
111	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
112	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
113	1.690	1.076	1.423	1.704	1.641	1.416	1.344	1.467	1.588	1.705	1.762	1.818
211	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
212	1.180	1.348	1.641	1.700	1.600	1.527	1.517	1.653	1.711	1.711	1.763	1.744
213	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
311	1.490	1.715	1.913	1.898	1.798	1.680	1.590	1.586	1.648	1.672	1.692	1.722
312	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
313	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
121	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
122	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
123	1.030	1.045	1.139	1.545	1.635	1.599	1.628	1.613	1.609	1.636	1.710	1.665
221	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
222	1.290	1.040	1.259	1.586	1.560	1.507	1.472	1.503	1.633	1.685	1.711	1.697
223	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
321	.8300	.9409	1.393	1.647	1.600	1.581	1.515	1.531	1.633	1.622	1.648	1.692
322	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
323	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on August 5, 1975											
101	1.050	1.646	1.900	1.884	1.739	1.621	1.561	1.586	1.600	1.579	1.641	1.644
102	1.650	1.584	1.887	1.955	1.788	1.669	1.521	1.467	1.474	1.526	1.633	1.694
103	1.206	.8839	1.461	1.686	1.592	1.369	1.343	1.456	1.539	1.568	1.603	1.598
201	1.260	1.480	1.798	1.773	1.664	1.497	1.445	1.485	1.529	1.609	1.656	1.665
202	1.104	1.431	1.685	1.365	1.785	1.681	1.563	1.630	1.707	1.699	1.704	1.721
203	1.440	1.589	1.868	1.927	1.813	1.633	1.526	1.609	1.691	1.717	1.739	1.724
301	1.620	1.224	1.625	1.893	1.771	1.663	1.761	1.626	1.522	1.646	1.704	1.643
302	1.878	1.570	1.807	1.941	1.864	1.779	1.635	1.614	1.670	1.731	1.760	1.783
303	1.896	1.497	1.675	1,729	1.624	1.551	1.555	1.565	1.563	1.513	1.529	1.604
111	1.605	1.599	1.881	1.818	1.725	1.617	1.628	1.666	1.758	1.698	1.471	1.613
112	1.872	1.712	1.936	1.995	1.857	1.730	1.599	1.642	1.682	1.762	1.809	1.834
113	1.248	.7480	1.388	1.696	1.660	1.433	1.321	1.451	1.590	1.704	1.765	1.811
211	1.914	1.364	1.776	1.797	1.697	1.605	1.595	1.657	1.714	1.773	1.764	1.764
212	1.614	1.069	1.595	1.683	1.604	1.745	1.521	1.626	1.734	1.783	1.765	1.761
213	1.314	1.504	1.775	1.662	1.576	1.519	1.498	1.608	1.725	1.717	1.727	1.741
311	.9300	1.441	1.769	1.821	1.729	1.626	1.558	1.572	1.647	1.690	1.685	1.733
312	1.608	1.354	1.477	1.531	1.527	1.488	1.500	1.547	1.669	1.723	1.748	1.753
313	1.614	1.165	1.380	1.589	1.587	1.594	1.556	1.531	1.605	1.656	1.701	1.754
121	1.290	1.209	1.599	1.772	1.694	1.539	1.502	1.685	1.785	1.770	1.761	1.687
122	1.644	1.297	1.649	1.824	1.781	1.713	1.666	1.710	1.765	1.759	1.792	1.763
123	1.476	.9325	1.188	1.607	1.646	1.565	1.612	1.593	1.603	1.629	1.713	1.674
221	1.818	1.415	1.672	1.767	1.622	1.463	1.433	1.487	1.550	1.630	1.717	1.656
222	1.974	1.058	1.324	1.603	1.569	1.495	1.477	1.505	1.636	1.703	1.732	1.680
223	2.052	.9864	1.144	1.561	1.545	1.470	1.505	1.576	1.658	1.720	1.697	1.723
321	1.320	.6246	1.229	1.616	1.594	1.528	1.456	1.505	1.605	1.642	1.642	1.696
322	1.806	1.575	1.884	1.880	1.731	1.663	1.609	1.628	1.702	1.745	1.737	1.766

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on August 7, 1975											
101	1.404	1.533	1.872	1.850	1.670	1.549	1.531	1.577	1.606	1.590	1.622	1.627
102	2.292	1.442	1.815	1.935	1.791	1.618	1.471	1.454	1.480	1.509	1.609	1.694
103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
201	1.218	1.226	1.662	1.763	1.638	1.484	1.448	1.493	1.550	1.606	1.673	1.664
202	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
203	1.368	1.360	1.761	1.893	1.793	1.582	1.522	1.619	1.709	1.722	1.737	1.741
301	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
302	1.386	1.347	1.694	1.888	1.848	1.727	1.636	1.601	1.657	1.750	1.737	1.765
303	1.146	1.333	1.591	1.720	1.642	1.556	1.524	1.585	1.522	1.490	1.523	1.586
111	1.224	1.327	1.768	1.769	1.681	1.599	1.625	1.657	1.731	1.648	1.468	1.641
112	1.242	1.589	1.913	1.969	1.821	1.703	1.587	1.635	1.689	1.752	1.798	1.842
113	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
211	1.014	1.136	1.635	1.825	1.711	1.594	1.560	1.623	1.734	1.781	1.759	1.781
212	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
213	1.218	1.306	1.716	1.655	1.566	1.501	1.496	1.632	1.703	1.731	1.723	1.730
311	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
312	.9900	1.207	1.479	1.551	1.510	1.515	1.499	1.552	1.679	1.746	1.747	1.751
313	1.266	.9287	1.344	1.597	1.597	1.594	1.534	1.532	1.618	1.651	1.697	1.777
121	.7740	.9504	1.470	1.736	1.692	1.541	1.478	1.622	1.763	1.785	1.777	1.713
122	1.116	1.227	1.542	1.739	1.754	1.762	1.652	1.695	1.803	1.791	1.813	1.772
123	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
221	1.098	1.195	1.552	1.718	1.650	1.458	1.433	1.493	1.545	1.661	1.702	1.660
222	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
223	1.044	.8723	1.156	1.575	1.532	1.458	1.479	1.593	1.671	1.726	1.782	1.718
321	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
322	1.098	1.346	1.780	1.840	1.732	1.640	1.613	1.616	1.679	1.755	1.742	1.786
323	1.044	1.167	1.612	1.577	1.506	1.418	1.525	1.684	1.736	1.780	1.785	1.782

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on August 22, 1975											
101	1.430	1.680	1.710	1.950	1.815	1.695	1.605	1.650	1.680	1.620	1.680	1.710
102	1.340	1.680	1.950	2.070	1.875	1.650	1.800	1.500	1.560	1.605	1.710	1.770
103	1.240	1.530	1.920	1.890	1.695	1.440	1.440	1.530	1.650	1.680	1.695	1.650
201	1.450	1.365	1.803	2.025	1.950	1.695	1.530	1.560	1.620	1.650	1.740	1.800
202	1.440	1.650	1.830	2.025	1.920	1.820	1.740	1.770	1.800	1.800	1.770	1.800
203	1.610	1.530	1.860	2.010	1.860	1.615	1.515	1.680	1.800	1.815	1.815	1.815
301	1.050	1.170	1.695	1.980	1.830	1.710	1.710	1.830	1.740	1.800	1.800	1.800
302	1.620	1.470	1.830	1.950	1.930	1.815	1.710	1.695	1.740	1.815	1.830	1.860
303	1.550	1.515	1.740	1.920	1.830	1.710	1.650	1.650	1.650	1.605	1.620	1.695
111	1.220	1.515	1.875	1.875	1.740	1.620	1.605	1.650	1.710	1.680	1.470	1.650
112	1.430	1.695	1.950	2.010	1.830	1.740	1.650	1.650	1.710	1.815	1.815	1.890
113	1.220	1.290	1.815	1.950	1.800	1.560	1.470	1.530	1.650	1.800	1.830	1.890
211	1.820	1.515	1.920	1.950	1.860	1.695	1.605	1.680	1.815	1.830	1.830	1.830
212	1.310	1.650	1.875	1.875	1.710	1.590	1.560	1.695	1.815	1.875	1.860	1.815
213	1.320	1.530	1.950	2.025	1.860	1.605	1.560	1.695	1.815	1.815	1.815	1.830
311	1.160	1.710	1.950	1.950	1.830	1.650	1.590	1.620	1.650	1.770	1.770	1.815
312	1.870	1.680	1.680	1.890	1.830	1.680	1.620	1.590	1.620	1.770	1.815	1.770
313	1.330	1.380	1.860	2.025	1.860	1.710	1.590	1.590	1.710	1.740	1.800	1.830
121	1.350	1.470	1.875	2.025	1.890	1.710	1.500	1.650	1.860	1.830	1.830	1.815
122	1.670	1.410	1.710	1.890	1.860	1.740	1.650	1.710	1.830	1.875	1.860	1.860
123	1.620	1.260	1.615	1.860	1.830	1.695	1.620	1.530	1.590	1.650	1.800	1.770
221	1.130	1.395	1.740	1.920	1.830	1.620	1.440	1.470	1.590	1.720	1.740	1.710
222	1.710	1.440	1.590	1.680	1.650	1.560	1.515	1.530	1.640	1.740	1.800	1.740
223	1.300	1.395	1.695	1.740	1.740	1.650	1.590	1.560	1.695	1.770	1.800	1.815
321	1.060	1.200	1.605	1.770	1.620	1.560	1.470	1.695	1.710	1.740	1.800	1.710
322	1.370	1.440	1.875	1.920	1.800	1.650	1.605	1.590	1.740	1.815	1.830	1.830
323	1.280	1.740	1.980	1.860	1.620	1.470	1.500	1.695	1.815	1.815	1.875	1.860

Plot No.	Depth of Soil in Inches											
	00-06	06-12	12-18	18-24	24-30	30-36	36-42	42-48	48-54	54-60	60-66	66-72
	Sampled on Sept.,4, 1975											
101	.8100	1.350	1.800	1.680	1.800	1.530	1.515	1.560	1.590	1.560	1.620	1.620
102	1.110	1.350	1.740	1.830	1.680	1.470	1.350	1.380	1.470	1.515	1.620	1.695
103	.7900	1.080	1.695	1.710	1.520	1.350	1.320	1.470	1.560	1.590	1.615	2.590
201	.7500	1.230	1.440	1.695	1.680	1.440	1.250	1.440	1.515	1.620	1.650	1.680
202	.7600	1.050	1.500	1.740	1.650	1.590	1.530	1.650	1.650	1.710	1.710	1.695
203	.6800	1.275	1.500	1.740	1.620	1.470	1.395	1.560	1.695	1.710	1.740	1.740
301	.6900	1.290	1.410	1.710	1.605	1.500	1.515	1.560	1.515	1.605	1.695	1.620
302	1.340	1.350	1.695	1.770	1.710	1.620	1.560	1.590	1.650	1.770	1.770	1.770
303	.7200	.8400	1.470	1.800	1.695	1.605	1.530	1.515	1.470	1.500	1.590	1.650
111	.8300	1.020	1.605	1.650	1.590	1.500	1.515	1.620	1.710	1.680	1.695	1.620
112	1.170	1.080	1.680	1.800	1.695	1.620	1.530	1.605	1.680	1.800	1.815	1.860
113	1.605	.8850	1.515	1.710	1.605	1.380	1.260	1.380	1.590	1.740	1.815	1.815
211	.7800	1.515	1.605	1.695	1.605	1.500	1.470	1.620	1.710	1.860	1.740	1.770
212	.7400	1.140	1.680	1.710	1.590	1.470	1.500	1.620	1.710	1.800	1.740	1.740
213	.8800	.9000	1.560	1.770	1.680	1.470	1.410	1.605	1.695	1.710	1.710	1.750
311	.8900	1.005	1.605	1.680	1.605	1.470	1.395	1.470	1.620	1.680	1.695	1.710
312	1.020	1.275	1,710	1.950	1.605	1.560	1.515	1.560	1.695	1.740	1.770	1.800
313	1.150	1.275	1.500	1.830	1.740	1.620	1.470	1.515	1.620	1.680	1.710	1.770
121	.8900	1.470	1.520	1.860	1.740	1.530	1.395	1.590	1.770	1.740	1.710	1.770
122	1.000	1.050	1.185	1.605	1.650	1.560	1.515	1.605	1.740	1.740	1.800	1.770
123	.7000	.8100	1.695	1.680	1.710	1.590	1.515	1.410	1.440	1.530	1.695	1.680
221	1.130	.7500	1.380	1.650	1.695	1.650	1.395	1.395	1.500	1.620	1.695	1.620
222	.6900	.8400	1.290	1.605	1.590	1.500	1.440	1.395	1.515	1.650	1.710	1.695
223	1.290	.7500	1.275	1.650	1.605	1.530	1.470	1.410	1.530	1.680	1.770	1.710
321	.7200	.7650	1.395	1.620	1.560	1.500	1.380	1.350	1.530	1.620	1.620	1.605
322	.8100	.9300	1.605	1.650	1.560	1.440	1.410	1.500	1.520	1.710	1.740	1.770
323	.8900	1.110	1.710	1.710	1.515	1.320	1.395	1.395	1.710	1.770	1.800	1.800

AN EQUATION TO PREDICT RUNOFF FROM SOIL MOISTURE MEASUREMENTS

by

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ABSTRACT

There are various irrigation methods, but the most popular one is furrow irrigation. Runoff often represents a sizeable portion of the water applied. Various methods have been devised to reduce or to reuse runoff; otherwise, it is wasted. It was the purpose of this study to obtain a simple relationship that can be used to determine runoff from furrow irrigation.

A mathematical relationship was developed to predict runoff from furrow irrigation. The independent variables are inflow to the furrow and soil moisture content. The equation has the form:

$$R = V_E - KS^P$$

Where R = runoff in inches of water

V_E = the water applied to the field

S = soil moisture content, in inches of water

P = slope of runoff curve on log-log paper

K = coefficient obtained from experimental data

Field studies were conducted to determine runoff and soil moisture content. Soil moisture was measured to a depth of six inches by the gravimetric method and from six to seventy-two inches with a neutron probe. At the same time, consumptive use was estimated by a computer program operated by personnel of the Evapotranspiration Labortory. Runoff was computed using soil moisture measurements and estimated consumptive use.

Coefficient for the runoff were determined from the field

data using soil moisture contents for depths of 0-6, 0-12, 0-18, 0-24, 0-30, and 0-36 inches. In each case runoff predicted from the equation using calculated coefficients was not statistically significantly different at the 0.05 level from runoff computed from soil moisture contents. However, the highest correlation between predicted and computed runoff was obtained using soil moisture from 0-12 inches.