DETERMINATION OF THE HYDRAULIC CONDUCTIVITY AND INFILTRATION CAPACITY OF THE FEDRAL UNVERSITY OF TECHNOLOGY OWERRI (FUTO) FARM

BY

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CERTIFICATION

We certify that this project work and write up "The Determination of the Hydraulic Conductivity and Infiltration capacity of the Federal University of Technology Owerri (FUTO) farm by **Nwachukwu Ikechukwu Michael** (B.Eng) **20144914718** is a thesis submitted to the Postgraduate School Federal University Of Technology Owerri. In partial fulfillment of the requirements for the award of Post Graduate Diploma in Agricultural and Bioresources Engineering (Soil and Water Engineering Option)

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DEDICATION

This project is Dedicated to my brother, **late Engr. Chijioke Augustine Nwachukwu**

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I am grateful to my supervisor Dr. C.C. Egwuonwu for his assistance and understanding. My thanks and regards go to all the staff of the Department of Agricultural and Bioresources Engineering. Also to my mother, Mrs Maria U Nwachukwu And my lovely wife, Barr.(Mrs.) Chioma Juliet Nwachukwu.

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ABSTRACT

This thesis describes the in situ methods of the determination of both the hydraulic conductivity and infiltration capacity of the Federal University of Technology, Owerri (FUTO) farm soil. The inverse anger hole method was chosen to determine the hydraulic conductivity due to its simplicity and effectiveness. Cognizance was taken of the factors as presented in the project report that affect the results determined. Also the various methods of determining the two parameters were reviewed. The importance of the data gotten from the use of these methods both in Agricultural and other fields have also been stressed in various sections of the project report. Finally, both tests and results were done and presented under the standard recommended procedures. From these, it was found out that the soil has a basic infiltration rate of about 7.45cm/hr and based on average values the hydraulic conductivity is about 9.2 x 10^{-3} cm/sec and infiltration rate of about 19.70cm/hr. This implies that the soil has a medium value of hydraulic conductivity and a moderately high rate of infiltration, therefore sprinkler irrigation system is recommended.

Keywords: Hydraulic conductivity and infiltration capacity

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The voids in a soil mass are not isolated cavities that hold water like storage reservoirs but are interconnected, small, irregular passage ways through which water can flow in the same way as it flows through other conduits.

Thus any material with voids are interconnected and thus possesses permeability. Thus rock, concrete, soil, and many other materials are both porous and permeable (Peters, 2001),

The term hydraulic conductivity (K) or Coefficient of permeability is used to indicate the easiness or difficulty that a particular fluid will encounter when flowing through a permeable material.

The permeability of a soil mass is important in various fields including agriculture. It is one of the most important characteristics in evaluating drainage problems as well as evaluating the amount of seepage through or beneath dams and levees and flow into water wells.

It also plays an important role in evaluating the uplift or seepage forces beneath hydraulic structures for stability analysis. The devices used for determining the hydraulic conductivity in the laboratory are called permeameters. Also there are several methods for determining the hydraulic conductivity in the field.

On the other hand, when water is supplied to the soil surface, whether by precipitation or irrigation, some of the water penetrates the surface and is absorbed into the soil, while some may fail to penetrate but instead accrue at the surface or flow over it.

Infiltration is the term applied to the process of water entry into the soil generally by downward flow through all or part of the soil surface.

The Infiltration rate is the soil characteristic determining the maximum rate at which water can enter the soil under specific conditions including the presence of water (Micheal, 2001). It is defined as the volume of water passing into a unit area of soil per unit time (or dimensions of velocity). The actual rate at which water is entering the soil at any given time is termed the infiltration velocity. The infiltration capacity of a soil is the infiltration rate which it will allow. The infiltration decreases during irrigation or water application. The rate of decrease is rapid initially and the infiltration rate tends to approach a constant value. The nearly constant rate that develops after some time has elapsed from the start of irrigation is called the basic infiltration rate. Accumulated infiltration also called cumulative infiltration is the total quantity of water that enters the soil in a given time. Infiltration rate and accumulated infiltration are the two parameters commonly used in evaluating the infiltration characteristics of soil.

Infiltration may involve one dimensional, vertical soil water movement such as occurs during sprinkler or flood irrigation, water movement in two dimensions such as flows from an irrigation furrow; or in three dimensions such as from a drip irrigation emitter (Jensen, 2005).

The rate of this process relative to the rate of water supply, determines how much water will enter the root zones, and how much if any will run off. Hence the rate of infiltration affects not only the water economy of plant communities, but also the amount of surface runoff and its attendant danger of soil erosion. Where the rate of infiltration is restricted plants may be denied sufficient moisture while the amount of erosion increases.

Knowledge of the infiltration process as it is affected by the soils properties and transient conditions, and by the mode of water supply is therefore prerequisite for efficient water management.

The term co-efficient of permeability, K, is used for designating flow through in any direction while the infiltration rate relates more to the vertical movement of water. The rate at which water moves in soil is directly proportional to its hydraulic conductivity. Both hydraulic conductivity and the infiltration rate has the same dimensions of velocity and the determination of both can be carried out either in the field or in the laboratory.

1.2 STATEMENT OF PROBLEM

Soil factor is a determining factor in crop production. The soil structure, texture etc are all dependent on the Hydraulic conductivity and infiltration rate. The idea of this work is to have the idea of these and be able to know precisely the type of crops to plant and also Agricultural practice to use for effective crop yield.

1.3 OBJECTIVES

The objectives of this project are:

1, The determination of the hydraulic conductivity of the soil.

2, The determination of the filtration capacity of the farm soil to make data available for future irrigation and water conservation.

1.4 JUSTIFICATION

In general, there are numerous types of problems in connection with engineering projects which will require knowledge of the hydraulic conductivity characteristics of the soil concerned such as computations of seepage through earth dams and losses from irrigation ditches, selection of appropriate irrigation systems, erosion and drainage problems; discharge from wells or the rate of draw down.

This project is therefore chosen to help find a solution to some of these problems which affect the productivity of the college farm.

The values for saturated hydraulic conductivity are used in the design of drainage systems e.g. depth and spacing of under drains for lowering the water table under a road for draining waterlogged agricultural land. It is intended to irrigate the college farm. Hence, knowledge of the soil hydraulic conductivity is essential for computing water conveyance and application efficiencies as well as the design of the drainage system.

In general, soil hydraulic conductivity is a major factor in determining the use to which a soil can be put, stability of roads and building foundations, crop production potential, and growth of trees, shrubs and grasses are all affected to some degree by the ease or difficulty with which the soils drain.

In order words, soil hydraulic conductivity, K, enters all problems involving flow of water through soils such as seepage under dams, the drainage of a sub-grade, backfills and agricultural lands. From the above, it could be seen that the values of, K, determined is also applied to other fields other than agriculture which goes further to justify this project.

As regards to soil infiltration capacity, infiltration measurements are usually made to determine the infiltration rate, which is significant in irrigation designs and the type of soil management to be practiced in a given piece of land for optimum crop production.

Knowledge of infiltration capacity is important since it helps in determining the quantity of water to be applied to avoid waste due to deep percolation and danger of erosion due to runoff which might be disastrous to both the crops in the field and human life.

With the hydraulic conductivity and the infiltration capacity values of the school farm obtained, the college farm could now be properly irrigated and this will improve the productivity of the school farm.

Again for surface irrigation, the most efficient furrow or border length depends on the infiltration capacity, (Peters, 2001). Failure to adequately consider the infiltration process may result in poor water application in the field. Many of the soil related factors that control infiltration also govern soil water movement and distribution during and after the infiltration process. Hence, an understanding of infiltration and the factors affecting it is important to the design and operation of efficient irrigation systems

1.5 **SCOPE**

The study focused on the determination of the hydraulic conductivity and infiltration capacity of the soil in Federal University of Technology Owerri (FUTO) farm.

CHAPTER TWO

LITERATURE REVIEW

2.1 HYDRAULIC CONDUCTIVITY

The hydraulic conductivity K, as applied to an aquifer is defined as the rate of flow of water in litres per day through the horizontal cross sectional area of one square of the aquifer under a hydraulic gradient of one meter per meter at the prevailing temperature of water. The rate of flow of ground water in response to a given hydraulic gradient is dependent upon the hydraulic conductivity of the aquifer (Arora, 2010).

David in 2006 through investigations of the flow of water through filter-sands, identified a linear relationship between velocity and hydraulic gradient. Klute (2002) evaluated soil hydraulic conductivity using soil cores and on measurements made in the field where a suitable drain exists and reflects the effect of larger soil volumes, possibly an entire field.

2.1.1 Factors That Affect Permeability

The magnitude of the permeability coefficient depends on the viscosity of the water, and on the size, shape and arrangement of particles, void ratio, and degree of saturation. These factors are further discussed below:

(i) V

iscosity

Viscosity is a function of temperature: the higher the temperature, the lower the viscosity and the higher the permeability. Again, viscosity plays an important part in laminar flow [water particles move in a smooth, orderly procession in the direction of flow, and the energy losses are directly proportional to the velocity. It is characteristic of all soils except coarse gravels] Permeability, K, is measured at 68°F (20°C) which is fairly representative temperature for ground water, At 32°F (0°C) it is 56 percent, and at 104°F (40°C) it is 150 percent of the value at 68°F. When the test temperature differs from 20°C, the coefficient of permeability is corrected to 20°C, by recognizing that the value of K is inversely proportional to viscosity to obtain.

$$K_{20} = K_T \cdot \frac{\mu K_T}{\mu K_{20}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{[2.1]}$$

Where K_T = the coefficient of permeability at any test temperature T.

μ = the viscosity of water.

Appendix 1, gives several values of p versus T.

(ii) Void ratio and unit weight

The void ratio, e, is defined as the ratio of void volume to solid volume in a soil mass. The arrangement of the particles thus affects the void ratio of the soil and since porosity, n, [defined as the ratio of void volume to total volume in a soil mass] of soil and the unit weight Y_w are dependent upon the void ratio, it is clear that alternation of either the void ratio or the unit weight increases or decreases the permeability according to the change in arrangement of the particles. However, since the variation of Y_w is negligible in comparison with that of n, Y_w can be neglected and K computed using equation 2.1.

(iii) Degree of Saturation

The degree of saturation is a major factor because air in voids reduces the cross-sectional area and may block voids completely.

(iv) Gradient

Permeability is virtually zero at low gradients, but increases with increasing gradients.

2.1.1 Methods of Determining Hydraulic Conductivity

Darcy in 1856 through investigations of the flow of water through filter-sands, identified a linear relationship between velocity and hydraulic gradient

$$K = \frac{QL}{At\Delta h} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.2)$$

Where K = the hydraulic conductivity

L = the length of the soil sample

h = hydraulic head difference

A = the cross - sectional area

t = the time for volume of water Q to flow through the sample.

This formula is true as long as laminar flow exists. It has been applied to all soils finer than coarse gravel, as long as the hydraulic gradient is less than 5.

Since then, numerous methods have been developed for measuring the hydraulic conductivity, K, in the field and on disturbed and undisturbed cores that are taken from the field or on reconstituted samples of field soil in the laboratory (Ayers and

Westcot.2013).

2..1.3 Saturated Hydraulic Conductivity

When a water table is present the most commonly used methods are the pumped hole techniques. These include, in order of increasing size of the region sampled for K, the piezometer method, the tube method, the auger hole method , the two-well method and the four-well method

2.1.3.1 Auger hole method

This is probably the most widely used technique for measuring hydraulic conductivity in the field. In this method, an auger hole is drilled to some distance below the water table. After the water level in the hole has reached equilibrium with the field water table, the water level is lowered by quickly pumping or bailing water from the hole. The saturated hydraulic conductivity is then determined from the rate that the water level rises in the hole as,

$$K = C_a\, d_y/d_t \,.\, m/d \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.3)$$

Where C = Constant that depends on the radius for the hole and is obtained from the table of Boast and Kirkham for auger hole underlain by an impermeable material.

a = the depth of the hole below the water table

d = the distance from the bottom of the hole to the impermeable layer.

d_y/d_t = the rate of water rise in the auger hole cm/s

m = The mass of the water

The auger hole method is based on the assumption that there is uniform soil, negligible water table draw down around the auger hole and no water movement in the unsaturated zone above the water table. In order to prevent excessive draw down near the hole the water table should be lowered quickly by bailing or pumping.

Although the diameter of the auger hole is not restricted, sizes between the range of 5 to 15cm are commonly used.

The equation for hydraulic conductivity is:

$$K = \frac{\pi r^2/n \ . \ Y_1/Y_2}{S(t_2-t_1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2.4)$$

Where r = radius of the piezometer

Y_1 = the distance from the water table to water level in the piezometer at time t_1.

Y_2 = the distance from the water table to the water level in the piezometer at time t_2

S = a shape factor which is determined experimentally

Hooghoudt developed a single auger hole method of determining hydraulic conductivity. Improvements to the original Hooghoudt equation were provided by Ernst.

For the case where an impermeable layer is at the bottom of the auger hole, the appropriate Ernst formula :

$$K = \underline{4.17\, r^2 \qquad\qquad} \quad \underline{\Delta Y} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.5)$$

$(D + I0_r)(2\text{-}Y/D)Y \qquad \Delta t$

Where r = the radius of the auger hole,

D = initial depth of water in the auger hole,

ΔY = the rise of water level in the time interval Δt,

Y = the distance from the water table to the average water level in the auger hole during Δt.

Another method of estimating the hydraulic conductivity of an aquifer is to introduce a tracer into a well and determine its time of arrival at a downstream well [Linsley et al. 2000]. Various tracers such as common salt, dyes and radioactive materials have been used successfully in ground water studies.

2.1.4 **Unsaturated Hydraulic Conductivity**

The measurement of unsaturated hydraulic conductivity is considerably more difficult than measuring saturated hydraulic conductivity. Since the K value is dependent on water content, both the hydraulic gradient and water content must be determined for a range of water contents to adequately define the hydraulic conductivity function.

2.1.4.1 **Laboratory methods**

Soil hydraulic conductivity was evaluated using soil cores and on measurements made in the field where a suitable drain exists and reflects the effect of larger soil volumes, possibly an entire field. The equation below applies to steady flow in an essentially horizontal direction through a block of soil. [James, 2008].

$K = \underline{2LQ}$ ……………………………… (2.6)

$h^2_1 - h^2_2$

Where h_1 and h_2 are the hydraulic heads, K, Q and L remain as defined in equation 2.2

Youngs (2002) determined K by measuring the rate of infiltration into soil columns from water supplied at the surface at a negative pressure. Although the effective conductivity function for a rather large sample was determined and the experimental measurements were simple in nature, the method required separate soil columns for each water content. Also several days were required to determine the conductivity for low water contents.

2.1.4.2 Field methods

In situ method to measure K by infiltrating water through artificial crusts of different hydraulic resistances. The crust may be a porous plate or it may be formed in place by puddling a thin layer at the soil surface. After the crust is formed, water is applied to the surface using a cylindrical infiltrometer and a small constant head is maintained for the duration of the measurement. The effect of the crust resistance is to prevent saturation immediately below the crust. Small tensiometers are used to measure the pressure head at a point just below the crust and at a second point about 3cm below the first. Flow is continued until the pressure heads at the two points approach the same value giving a unit hydraulic gradient and a constant infiltration rate. The hydraulic conductivity corresponding to the measured pressure head is then equal to the steady infiltration rate.

While all these methods have been rigorously developed and thoroughly tested, conductivity often varies widely from point to point in the field and numerous measurements are usually required to obtain field effective values.

Several investigators have tested screens for the retention of soil sample with minimal impediment of water flow. Youngs (2002) in his study of hydraulic conductivity measurements on disturbed soil samples used sand, cotton, glass, wool, filter paper, wire gauze, asbestos and thin fiber glass screens in a permeameter and found them satisfactory although there was a little resistance to water flow, which introduced a small potential drop at the soil boundary.

The desirable size of a permeameter depends on the soil to be tested. Permeameters in the neighborhood of 4 centimeters in diameter and 30cm long have been found satisfactory for many soils.(Finkel,2005)

Appendix 11 can be used as a standard for describing soil permeability and as a rough estimate for different types of soils. A permeability of 1μ per second (10^{-4}cm per sec) is frequently used as the borderlines between pervious and impervious soils. Thus a soil with a permeability less than 1μ per sec. might be considered for a dam core or impervious blanket whereas one with a permeability greater than 1μ per sec. might be considered for a dam shell or pervious fill

2.2. INFILTRATION RATE

Infiltration is the process by which water enters the soil from the ground surface. It first replenishes the soil moisture deficiency. The excess water then moves downwards by the force of gravity. This downward movement under gravity is called percolation (or seepage).Thus percolation is the movement of water within the soil (Calvin et al 2012). The two phenomena infiltration and percolation are interrelated. The infiltration cannot continue for a long time unless percolation removes the water already in the soil, and percolation cannot occur unless there is continuous infiltration. Infiltration is very important in the study of hydrological studies. Infiltration is responsible for subsurface and ground water flow. The supply of ground water reservoir also depends on infiltration. The water that enters the ground provides moiture for the plants, (Arora, 2010). The infiltration rate is used for the computation of the water loss due to infiltration for the determination of the surface runoff.

2.2.1 Factors Affecting Infiltration Rate

The major factors affecting the infiltration of water into the soil are the initial condition or the antecedent moisture content, vegetative cover, hydraulic conductivity of the soil profile, texture, porosity, duration of irrigation or rainfall and viscosity of water. These factors are further discussed below.

(i) The antecedent soil moisture content has considerable influence on the initial rate and total amount of infiltration. The infiltration rates are high for drier initial conditions but that dependence on initial water content decreases with time. If infiltration is allowed to continue indefinitely, the infiltration rate will eventually approach K regardless of the initial water content. Infiltration rates are higher at low initial water contents because of higher hydraulic gradients and more available storage volume. The reduction is in large part due to the fact that moisture causes some of the colloids in the soil to swell, and thereby reduce both the pore space and the rate of water movement (Uehehara and Gillman, 2001).

(ii) The infiltration rate of any soil is limited by any restraint to the flow of water into and through the soil profile.

(iii) Addition of organic matter increases infiltration rate substantially.

(iv) Hydraulic conductivity: The higher the saturated hydraulic conductivity of the soil is, the higher its infiltrability tends to be.

(v) Viscosity of water influences infiltration: The high rates of infiltration in the tropics under otherwise comparable soil conditions is due to the low viscosity of warm water (Brendan, 2009)

(vi) Application rates: Infiltration depends on the rate of application as well as soil conditions for example, if the rainfall or application rate is less than the hydraulic conductivity at residual air saturation for a deep homogeneous soil, infiltration may continue indefinitely at a rate equal to the rainfall rate without ponding at the surface.

The infiltration rate of a soil can be maintained if the system of coarser pores is maintained.

2.2.2 Methods of Determining Infiltration Rate

In the case of infiltration rate, various researchers at different times have studied the infiltration rate of different types of soils under different conditions in various countries.

In general, the water intake rate of tropical soil under their natural vegetative cover is high.(Roth et al 2010). However the removal of vegetation and introduction of mechanized tillage operations result in disturbance and exposure of soil and causes a decline in the infiltration rate. One of the important reasons for high infiltration rates in soils of Western Nigeria is the abundant cavity of the earthworm 'the periodrilus Africanus'.

David (2006) has given expressions for the final infiltration rate for all the three approaches to infiltration. These are shown below (Wayne et al, 2003).

One dimension: $IF = K$ ……………………………………………(2..7)

Two dimension IF: $= K[{}^{1}/_{2} + \frac{1}{\pi} + \frac{k_1(2R_0)}{2K_0(2R_0)}$ ………(2.8)]

Three dimensions: $If = K({}^{3}/_{4} + {}^{1}/_{4}R_0)$ …………………………… (2.9)

Where IF = infiltration rate per unit area of soil surface at steady state.
K = saturated hydraulic conductivity of the soil
K_1 and K_0 = modified Bessel functions

R_0 for a soil which is initially dry is given by

$$R_0 = \frac{Kr_0}{4D^*\theta_1,}$$ ………………………(2.10).

In equation 2.10, r_0 is the radius of the source of water, θ_1, is the water content of the soil at the point of entry of water into the soil and D* = average or weighted mean diffusivity which gives the correct infiltration rate at small times.

Charles (2013) presented analytical solutions for steady state infiltration from a circular ponded surface into a deep, homogeneous soil. It may be concluded from Woodings solutions that a buffer cylinder diameter of 1.25 times that of the infiltration cylinder would be sufficient for coarse soils. For general purposes, a ratio of the buffer cylinder, D, to the infiltration cylinder, d of two or greater ($D/d \geq 2$) is recommended (Straw et al.2012).

Bower (2003) showed that differences in the water level between the infiltration cylinder and buffer area could cause errors in the measurements. To eliminate this source of error, it is recommended mat water be ponded at a shallow depth in both the buffered and the infiltration cylinder.

Parr (2012) published a thorough review of field methods for measuring infiltration capacity (Jensen, 2005). Basically, two types of device have been used - sprinkling infiltrometer (Patterson, 2012) and flooding infiltrometer. From the application point of view, it would be advantageous to use a sprinkling infiltrometer if sprinkler irrigation is to be used while flooding infiltrometer would be more appropriate for soils that are to be furrowed or flood irrigated (Jensen, 2005).

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

The study area considered is the school farm (Federal University of Technology Owerri). It is located at Eziobodo, North - south of Obinze. An area of about 25000 square meters. With longitude and latitude $N5^{0}\ 29^{1}\ 18.08^{11}$ $E7^{0}\ 1^{1}\ 58.68^{11}$. Five different locations were chosen for the study and are designated as A1, A2, A3, A4, A5, A6 and A7.The locations were cleared and pegged for the study.

3.2 MATERIALS

3.2.1 Moisture Content

Dry oven thermostatically controlled, also in the apparatus are moisture cans numbered properly and a sensitive scale balance was made use of.

3.2.2 Infiltration Capacity

Double ring infiltrometer, stop watch, metre rule, mallet, containers with known volume of water, marker

3.2.3 Hydraulic Conductivity

The materials used in determining permeability using inverse auger hole method are were Auger, a stop watch, a measuring tape, cans of water and a standard peg.

3.3 **METHODS**

3.3.1 Determination of Moisture Content

Dry oven thermostatically controlled and being heated continuously at a temperature of 110 $\pm$ ^{0}5C. Also in the apparatus are moisture cans numbered properly. Also a sensitive scale balance was made use of. First a clean dry container was weighed and the weight was taken note of. Next, the moisture soil sample was placed in the container and weighed again, the weight was also recorded. Then the container with the moist sample was placed in the drying oven maintained at a temperature of 110 $\pm$ ^{0}5C. Drying of a moisture content sample over light (15 or 16hrs) is sufficient. Next, the container was removed from the oven and the sample was allowed to cool at room temperature. Finally the container with the dry sample was weighed and the weight recorded.

3.3.2 Determination of Infiltration Capacity

The apparatus used was the cylindrical infilitrometer with buffer cylinder. It consists of two concentric cylinders attached together by mild steel rods.

The dimensions were chosen from the range given-in the review. The inner cylinder (infiltrometer cylinder) was 30cm in diameter and 25cm high. It is in this cylinder that the infiltration rate measurement was taken.

The outer cylinder (the buffer cylinder) is used to provide a buffer area to help reduce the amount of lateral flow during measurement. It is 60cm in diameter and also 25cm high. The two cylinders were constructed of 16 gauge mild flat sheets and welded together by a mild steel sheet measuring 15cm long.

This experiment was carried out at 7 different locations vis: A_1, A_2, $A_{3,}$ A_4, $A_{5,}$ A_6 & A_7. In each case, the land was cleared and the cylinder installed about 12cm using a short wooden plank to prevent damage to the edges of the metal cylinder. Water was collected using a bucket and poured into the infiltration cylinder up to 12cm level mark above the soil. Water was also poured to the same level in the buffer cylinder.

The second's hand of a wrist watch was used to note the instant the addition of water began and the time the water reached 11.2cm mark using the ordinary ruler. The difference between the quantity of water added and the volume of water in the cylinder at the instant it reached 11.2cm level point was taken as the quantity of water that infiltrated during the time interval between the start of filling and the first measurement. Water was added quickly after each measurement in other to maintain a constant average head. Readings were taken before the water records more than 0.8cm. In order words the average depth* of water maintained in the cylinder was 11.2cm, which is approximately equal to the water level expected in the border or basin during irrigation. Soil moisture content being one of the factors that affect infiltration rate was also determined. A sample was collected in 7 areas (A_1 to A_7) and the moisture content was determined in the laboratory using the drying oven.

3.3.3 Determination of Hydraulic Conductivity.

After selecting a site for the study, a hole of diameter 9.0cm and depth 70cm was made using the auger borer. The standard peg was pushed into the ground near the hole. The hole was filled with water and recording started immediately.

Depth or level of water was read using a measuring tape placed into the hole 5 seconds before reading at equal and regular intervals of 30 seconds. The result was then tabulated and shown in tables 4.4 and 4.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

Table 4.1 is The Results of Moisture content from plotA2, Table 4.2 is The Results of Moisture content from plotA7, Table 4.3 is The Mean infiltration rate and elapsed time, Table 4.4 is The Permeability result for the area A2, Table4.5 is The Permeability result for the area A7, Table 4.6 is The Infiltration rate in location A1, Table4.7 is The Infiltration rate in location A2, Table4.8 is The Infiltration rate in location A3), Table4.9 is The Infiltration rate in location A4.

Fig 4.1 is The graph of average infiltration rate Vs time, Fig 4.2 is The permeability graph of location A7), , Fig 4.3 is The permeability graph of location A2,

TABLE 4.1: Moisture Contents from plot A_2

Evaporating can number	Wt of can	Wt of can + wet sample	Wt of can + Dry sample	Wt of wet Sample	Wt of dry sample	% Mc
93	4.7	41.70	37.18	37.00	32.48	13.92
64	4.67	33.53	29.86	28.86	25.19	14.57
14	4.58	40.54	36.14	35.96	31.56	13.94

TABLE 4.2: Table of result moisture content from plot A_7

Evaporating can number	Wt of can	Wt of can + wet sample	Wt of can + dry sample	Wt of wet sample	Wt of dry sample	% Mc
10	4.63	37.58	34.90	32.95	30.27	8.85
12	4.51	32.18	29.89	27.67	25.38	9.02
50	5.40	37.40	34.99	32.00	29.59	8.15

TABLE 4.3: TABLE 4.3: MEANINFILTRATION RATE AND ELAPSED TIME

Time (sec)	h_r(cm)	D - hj = Ahi(cm)	Ahi + r/2
30	52	58	60.25
60	48	62	64.25
90	40	70	72.25
120	39.5	70.5	72.75
150	39	71	73.25
180	38	72	74.25

Table 4.5 (Permeability result for the area A7),

Time (sec)	h_r(cm)	D - hj = Ahi(cm)	Ahi + r/2
30	52	58	60.25
60	48	62	64.25
90	40	70	72.25
120	39.5	70.5	72.75
150	39	71	73.25
180	38	72	74.25

Water level From reference point before filling (cm)	Water level from reference point after filling (cm)	Depth Of water	Cumulative Infiltration Depth (cm)	Elapsed Time (min)	Average Infiltration Rate of soil (cm/hr)	
-	12.0	-	-	-		A_1can be said to have a basic infiltration rate of 7.62 cm/hr
11.2	12.0	0.8	0.8	0.7	68.57	
11.2	12.0	0.8	1.6	1.5	60.00	
11.2	12.0	0.8	2.4	2.6	43.64	
11.2	12.0	0.8	3.2	4.4	26.67	
11.2	12.0	0.8	4.0	6.8	20.00	
11.2	12.0	0.8	4.8	9.8	16.00	
11.2	12.0	0.8	5.6	13.3	13.71	
11.2	12.0	0.8	6.4	17.4	11.71	
11.2	12.0	0.8	7.2	22.2	10.00	
11.2	12.0	0.8	8.0	27.3	9.41	
11.2	12.0	0.8	8.8	32.8	8.73	
11.2	12.0	0.8	9.6	38.6	8.27	
11.2	12.0	0.8	10.4	44.8	7.74	
11.2	12.0	0.8	11.2	51.1	7.62	
11.2	12.0	0.8	12.0	57.4	7.62	
11.2	12.0	0.8	12.8	63.7	7.62	
11.2	12.0	0.8	13.6	70.0	7.62	

TABLE 4. 6: INFILTRATION RATE IN LOCATION A_1

TABLE 4.7: INFILTRATION RATE IN LOCATION A_2

Water level from reference point before filling (cm)	**Water level From reference point after filling (cm)**	**Depth Of Water**	**Cumulative Infiltration Depth (cm)**	**Elapsed Time (min)**	**Average Infiltration Rate of soil (cm/hr)**	
-	12.0	-	-	-	-	
11.2	12.0	0.8	0.8	0.8	60.00	
11.2	12.0	0.8	1.6	1.8	50.00	
11.2	12.0	0.8	2.4	2.8	45.00	
11.2	12.0	0.8	3.2	4.3	32.00	
11.2	12.0	0.8	4.0	7.4	15.5	The soil has a basic infiltration rate of 7.62 cm/hr
11.2	12.0	0.8	4.8	15.6	14.00	
11.2	12.0	0.8	5.6	20.7	10.01	
11.2	12.0	0.8	6.4	25.8	9.58;	
11.2	12.0	0.8	7.2	31.1	9.40	
11.2	12.0	0.8	8.0	37.2	9.00	
11.2	12.0	0.8	8.8	43.5	7.71	
11.2	12.0	0.8	9.6	49.9	7.49	
11.2	12.0	0.8	10.4	56.4	7.42	
11.2	12.0	0.8	11.2	62.8	7.42	
11.2	12.0	0.8	12.0	69.9	7.42	
11.2	12.0	0.8	12.0	76.4	7.42	
11.2	12.0	0.8	13.6			

TABLE 4.8: INFILTRATION RATE IN LOCATION A_3

Water level from reference point before filling (cm)	**Water level from reference point after filling (cm)**	**Depth Of water**	**Cumulative Infiltration Depth (cm)**	**Elapsed Time (min)**	**Average Infiltration Rate of soil (cm/hr)**	
"	12.0		-	-	-	
11.2	12.0	0.8	0.8	0.7	68.57	
11.2	12.0	0.8	1.6	1.6	53.33	
11.2	12.0	0.8	2.4	3.0	34.29	
11.2	12.0	0.8	3.2	4.8	26.67	
11.2	12.0	0.8	4.0	7.0	21.82	The soil has a
11.2	12.0	0.8	4.8	9.8	17.14	basic
11.2	12.0	0.8	5.6	13.1	14.55	Infiltration rate
11.2	12.0	0.8	6.4	17.1	12.00	of 7.42 cm/hr
11.2	12.0	0.8	7.2	21.2	11.7	
11.2	12.0	0.8	8.0	26.3	9.41	
11.2	12.0	0.8	8.8	32.2	8.27	
11.2	12.0	0.8	9.6	38.2	8.00	
11.2	12.0	0.8	10.4	44.5	7.62	
11.2	12.0	0.8	12.2	51.0	7.38	
11.2	12.0	0.8	12.0	57.6	7.27	
11.2	12.0	0.8	12.8	64.2	7.27	
11.2	12.0	0.8	13.6	70.8	7.27	

TABLE .4 9: INFILTRATION RATE IN LOCATION A_4

Water level from reference point before filling (cm)	Water level from reference point after filling (cm)	Depth Of water	Cumulative Infiltration Depth (cm)	Elapsed Time (min)	Average Infiltration Rate of soil (cm/hr)	
-	12.0	-	-			
11.2	12.0	0.8	0.8	0.8	60.00	
11.2	12.0	0.8	1.6	1.7	53.33	
11.2	12.0	0.8	2.4	2.9	40.00	
11.2	12.0	0.8	3.2	4.5	30.00	
11.2	12.0	0.8	4.0	7.5	16.00	The basic rate of infiltration in the soil in location is 7.38 cm/hr
11.2	12.0	0.8	4.8	10.8	14.55	
11.2	12.0	0.8	5.6	20.4	9.79	
11.2	12.0	0.8	6.4	25.4	9.60	
11.2	12.0	0.8	7.2	30.7	9.06	
11.2	12.0	0.8	8.0	36.8	7.87	
11.2	12.0	0.8	8.8	43.0	7.74	
11.2	12.0	0.8	9.6	49.4	7.50	
11.2	12.0	0.8	10.4	55.9	7.38	
11.2	12.0	0.8	11.2	62.4	7.38	
11.2	12.0	0.8	12.0	68.9	7.38	
11.2	12.0	0.8	12.8	75.4	7.38	-
11.2	12.0	0.8	13.6			

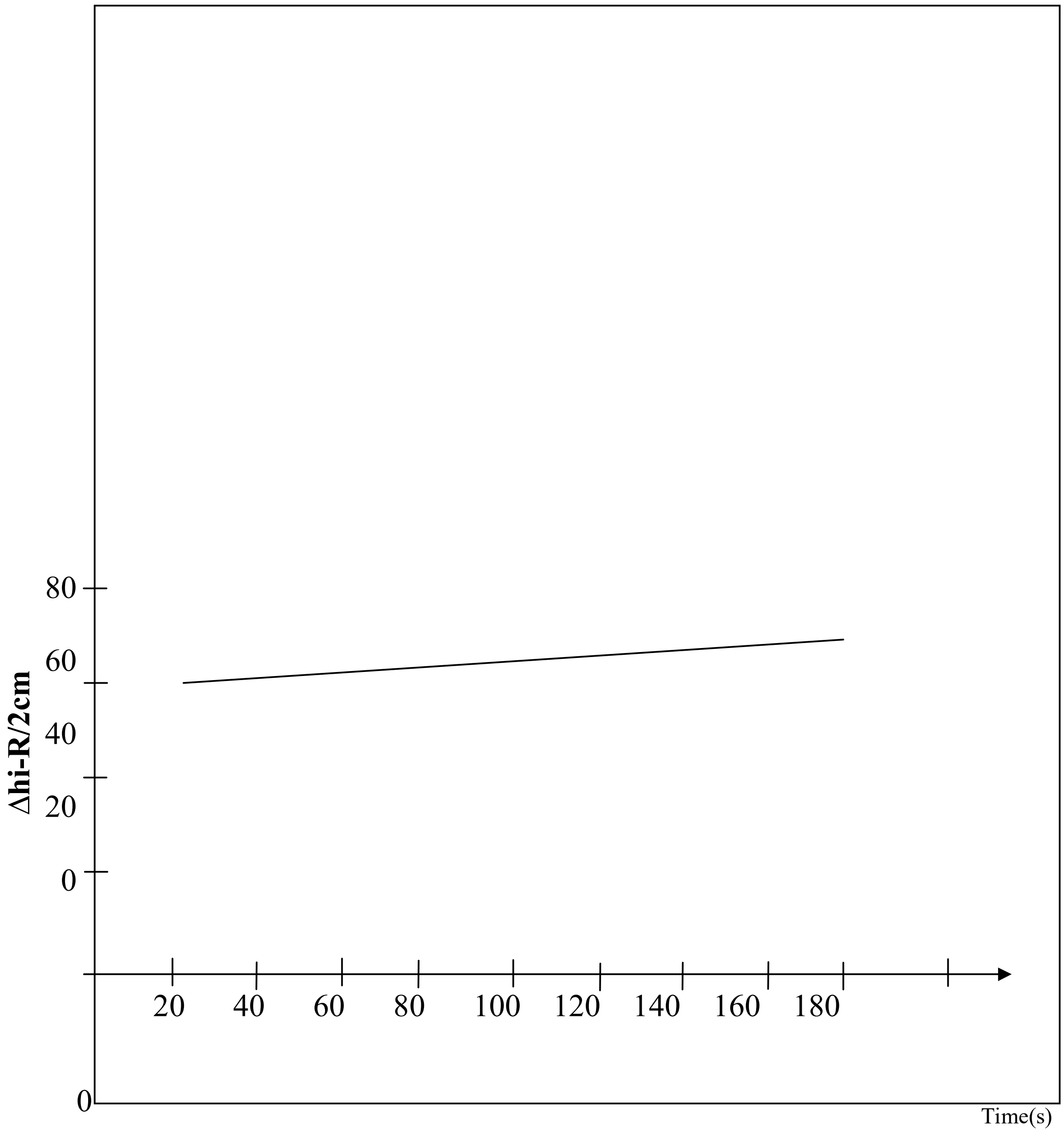

Figure 4.2: Permeability graph for plot A7

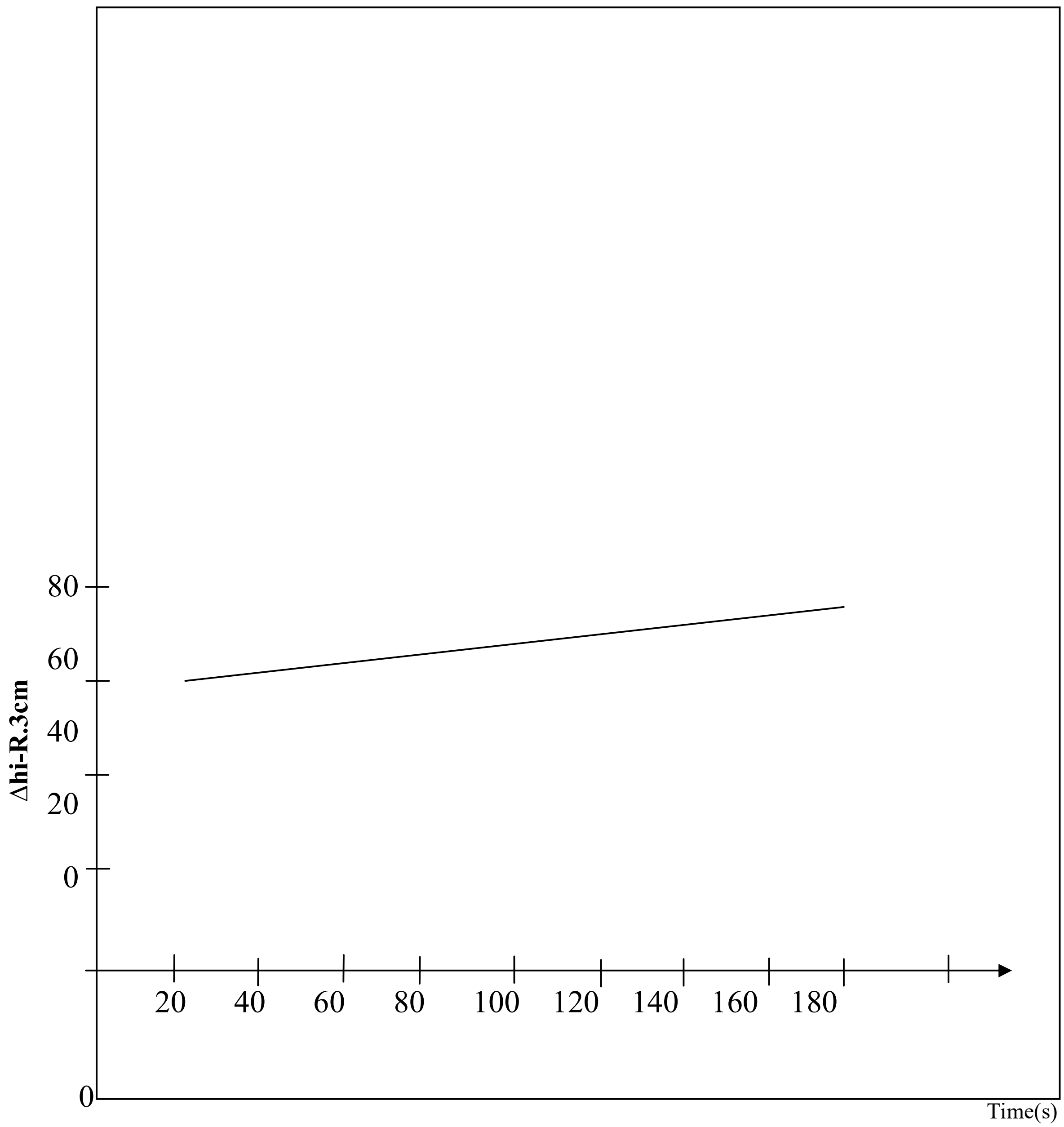

Figure 4.3: Permeability graph for plot A2

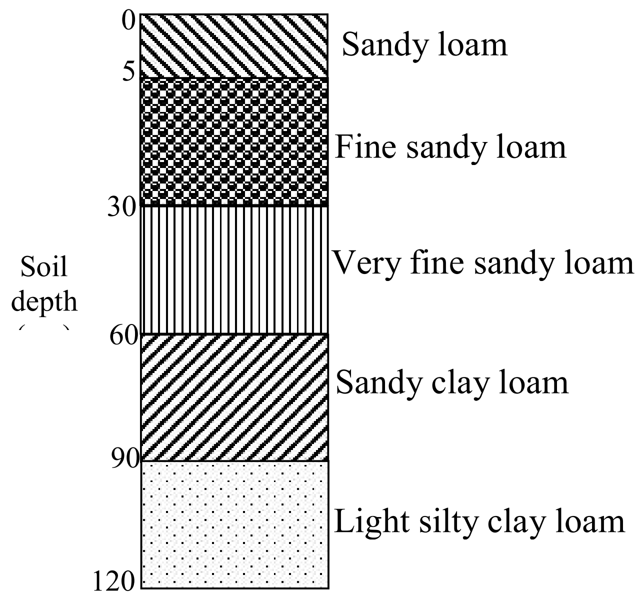

Figure 4.4: Soil Profile analysis

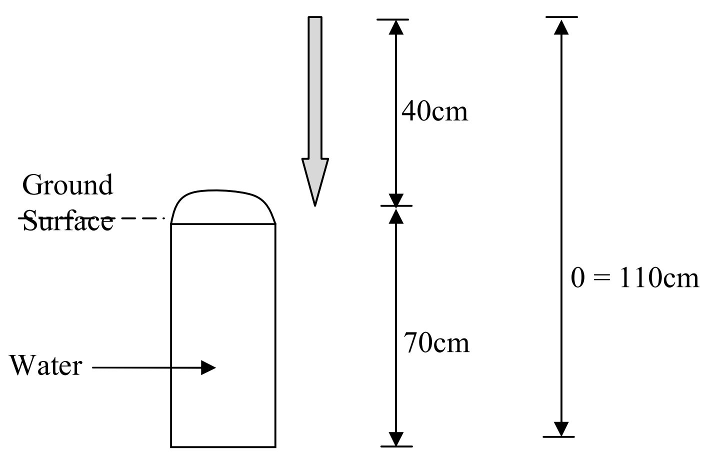

Figure 4.5: Set up for permeability measurement

4.2 DISCUSSION

4.2.1 Infiltration Capacity

The results of the infiltration test of the school farm have been presented in tables 4.6, to4. 9. From the table, it can be seen that the values of the infiltration rate of the farm soil was high during the initial point but decreased with time. This decrease can be attributed to increase in the degree of saturation. Primarily however, the decrease in the infiltration rate results from the inevitable decrease in the matric suction gradient (constituting one of the forces drawing water into the soil), which occurs as infiltration, proceeds.

From figure 4.1 (graph), the basic infiltration rate of the school farm soil is about 7.45cm/hr. But on the average, the college farm soil has an infiltration rate of 19.70cm/hr. This indicates that the farm soil has a moderately high infiltration rate.

The infiltration measurements were made in different places in the farm, some where crops are growing and others on bare soil. It was found out that the infiltration rate in the bare soil area was higher than for the covered area. This high rate could be attributed to the fact that it was more porous than for the covered area.

The accuracy or the validity of the data obtained in this study can be said to be the same with that obtained in other places. For instance, the plot of accumulated infiltration rate versus elapsed time (figure 4.1) is similar to that determined by Michael, (1981).

4.2.1 Hydraulic Conductivity

The results of the hydraulic conductivity test of the school farm are presented in tables 4.4 and 4.5. The school farm in general is sandy loam. From the tables, it could be seen that the hydraulic conductivity for the 2 areas chosen varied which means that the hydraulic conductivity in A2 was confirmed to be higher than that of A7 due to the nearness of A7 to the river.

According to the classification given under typical values in Appendix 2.. The school farm soil would be called one of medium permeability. Again it will be noticed that the type of graph obtained is a straight line graph. Also the variability's that limit the validity of the field test were guarded against. The meter rule was inserted into the hole five seconds before taking readings because slight variation in the starting time resulted in slight seepage difference in various readings. Also, the auger hole was made nearly vertical because slanting the rule in the process of taking reading of stop clock causes error

4.2.3 General Comments

The results obtained from these tests will be of immense assistance in improving the crop productivity potential of the school farm. It will play a very important role in evaluating drainage problems and in determining which type of irrigation system to be adopted and if dam construction is required, the type of fill and also in computing the conveyance efficiencies of the different irrigation systems.

Since the permeability value is medium, the loss of water to the deeper horizons of the soil won't be rapid when there is continuous application on the surface. This study has shown that the farm could be successfully irrigated effectively by the sprinkler method.

A specific example on how to use the K to solve a drainage problem in the school farm is illustrated below; in this case, Q, K, and A are farm and soil characteristics where Q is the rate at which water is to leave the farm, A is the area of the farm that contributes water to the drainage system be it pumped well or tile drain or open ditch.

$$\frac{H}{L} = C(d)\sqrt{Q/Ak} \text{ ---------------------------------(4.1)}$$

Where H height of the highest part of the water - table above the drain level.

L = half distance of separation between adjacent drain lines.

d = depth to the impermeable floor below the drain

The value of C(d) depends on the depth of the drains above the impermeable floor very approximately, C(d) varies from 1 when d is zero, to 0.5 when d is large.

The basic infiltration rate found to be about 7.45cm/hr means that any irrigation system designed should supply this amount of water to the crops for maximum use to avoid waste and runoff due to excess, while the average value guides the person designing the system. The hydraulic conductivity found to be about 9.2 x $10^{'3}$ Cm/sec .shows that soil could be used for a pervious fill in the case of dam constructions.

CHAPTER FIVE

CONCLUSION

5.1 CONCLUSION

On the significance and implications of the data from these tests, an excess of water limits agricultural production just as a deficiency does; the design of a suitable drainage system depends on the properties of the soil, the characteristics of the site and the root zone of the crop, and precedes the economic assessment as to whether to drain a site, and irrigation practices are based on a knowledge of the infiltration rates, hydraulic conductivity and also on the soil water properties. The infiltration rate depends on the K as well as the moisture content. And since the basic objectives of this project will help find solution on how to improve crop yield in the farm as well as put more areas into cultivation by making data available on these aspects and having found them and with the design of suitable irrigation system for the school farm possible, the farm could be modernized and irrigated for improved crop production potential.

This project could be considered successful since the objectives have been achieved. The results showed that the crop production potential of the farm could be improved successfully. The project has also made data available for solving drainage problems that might arise in the course of mechanizing the farm and putting it under irrigation. It has also made data available for the maximum amount of water to be applied by any irrigation system chosen without waste and danger due to erosion as a result of runoff.

5.2 Recommendations

I limited my study choosing only five locations in the FUTO farm. I recommend that more locations should be considered, at least ten locations to have a more precise results.

From these, it was found that the soil has a basic infiltration rate of about 7.45cm / hr and based on average values the hydraulic conductivity is about 9.2x cm/sec and infiltration rate of about 19.70cm/hr. This implies that the soil has a medium value of hydraulic conductivity and a moderately high rate of infiltration, therefore sprinkler irrigation system is recommended.

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VISCOSITY OF WATER

(VALUES ARE MILLIPOISES)

(Lambe, 1951)

Appendix 1

°c	0	1	2	3	4	5	6	7	8	9
0	**17.94**	**17.32**	**16.74**	**16.19**	**15.68**	**15.19**	**14.73**	**14.29**	**13.87**	**13.48**
10	**13.10**	**12.74**	**12.39**	**12.06**	**11.75**	**11.45**	**11.16**	**10.88**	**10.60**	**10.34**
20	**10.09**	**9.84**	**9.61**	**9.38**	**9.16**	**8.95**	**8.75**	**8.55**	**8.36**	**8.18**
30	**8.00**	**7.83**	**7.67**	**7.51**	**7.36**	**7.31**	**7.06**	**6.95**	**6.97**	**6.66**
40	**6.54**	**6.42**	**6.30**	**6.18**	**6.08**	**5.97**	**5.87**	**5.77**	**5.68**	**5.58**
50	**5.29**	**5.40**	**5.32**	**5.24**	**5.15**	**5.07**	**4.99**	**4.9*2**	**4.84**	**4.77**
60	**4.70**	**4.63**	**4.56**	**4.50**	**4.43**	**4.38**	**4.31**	**4.24**	**4.19**	**4.13**
70	**4.07**	**4.02**	**3.96**	**3.91**	**3.86**	**3.81**	**3.71**	**3.71**	**3.66**	**3.62**
80	**3.57**	**3.53**	**3.48**	**3.44**	**3.40**	**3.36**	**3.32**	**3.28**	**3.24**	**3.20**
90	**3.17**	**3.13**	**3.10**	**3.06**	**3.03**	**2.99**	**2.96**	**2.93**	**2.90**	**2.87**
100	**2.84**	**2.82**	**2.79**	**2.76**	**2.73**	**2.70**	**2.67**	**2.64**	**2.62**	**2.59**

1 dyne sec per sq. cm = 1 poise

1 gram sec. per sq. cm = 980.7 poises

1 pound sec. per sq. ft = 478.69 poises

1 poise = 1000 millipoises

Appendix 2

RELATIVE VALUES OF PERMEABILITY FOR GIVEN OIL TYPES. (Sowers and Sowers 1970)

Relative Permeability	Values of K cm/sec	Typical Soil
Very permeable	Over 1×10^{-1}	Coarse gravel
Medium permeability	$1 \times 10^{-1} - 1 \times 10^{-3}$	Sand, fine sand
Low permeability	$1 \times 10^{-3} - 1 \times 10^{-5}$	Silty sand, dirty sand
Very low permeability	$1 \times 10^{-5} - 1 \times 10^{-7}$	Silt, fine sand-stone
Impervious	less than 1×10^{-7}	

Appendix 3

CALCULATIONS

The moisture content of the soil is calculated as follows:

$$M = \frac{W_1 - W_2}{W_2 - W_3} \times 100$$

Where M = Moisture content %
W_1 = Weight of container + moist soil sample (g)
W_2 = Weight of container + oven dry soil (g)
W_3 = Weight of container (g)

From Plot A_7

Can 10

W_1 = 37.58
W_2 = 34.90
W_3 = 4.63

$$= \frac{W_1 - W_2}{W_2 - W_3} \times 100$$

$$= \frac{37.58 - 34.90}{34.90 - 4.60} \times 100$$

$$= \frac{2.68}{30.27} \times 100$$

$$= 8.85\%$$

Can 12

W_1 = 32.18
W_2 = 29.89
W_3 = 4.51

$$= \frac{32.18 - 29.89}{29.89 - 4.51} \times 100$$

$$= 9.02\%$$

Can 50

W_1 = 34.40
W_2 = 34.99
W_3 = 5.40

$$= \frac{34.40 - 34.99}{34.99 - 5.44} \times 100$$

$$= 8.15\%$$

$$\text{Average} = \frac{8.85 + 9.02 + 8.15}{3}$$

$$= \quad 8.67\%$$

From Plot A_2 (Can 93)

$$W_1 = 41.7g$$

$$W_2 = 37.18g$$

$$W_3 = 4.70g$$

$$= \frac{41.70 - 37.18}{37.18 - 4.7} \times 100$$

$$= \frac{4.52}{32.48} \times 100$$

$$= 13.92\%$$

Can 64

$$= \frac{33.53 - 29.86}{29.86 - 4.67} \times 100$$

$$= \frac{3.67}{25.19} \times 100$$

$$= 14.57\%$$

Can 14

$$= \frac{40.54 - 36.14}{36.14 - 4.58} \times 100$$

$$= \frac{4.4}{31.56} \times 100$$

$$= 13.94\%$$

Average $= \frac{13.92 + 14.57 + 13.94}{3}$

$$= 14.14\%$$

Mean basic rate of Infiltration

$$= \frac{7.62 + 7.42 + 7.27 + 7.38}{4}$$

$$= \frac{29.69}{4}$$

$$= 7.42cm/hr$$