DESIGN OF PIPE DRAINAGE SYSTEM FOR GROUND WATER CONTROL

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DEDICATION

This book is dedicated to my family. Most importantly, my parents, Mr and Mrs Fidelis Okwe Ochi; and the youngest of all Eniya (Enny love), as well as, my late Grand father, Chief Ochi Arubi Akete.

CERTIFICATION

I, Ochi LynxLinus , hereby certify that this project was carried out by me and that, it is out of my own research work, under the supervision of my project supervisor, Engr. Nosa A. Egharevba.

All source of information has been appropriately acknowledge.

April 10th, 2000

Engr Nosa A. Egharevba
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Date

Dr. M. G. Yisa
Head of Dept.

Date

APPROVAL

Having supervised and certified this project work, approval is hereby given to it, as it is adequate in quality and has the regulations required in the award of Bachelor of Engineering technology (B.Eng) degree in the school of Engineering and Engineering Technology, Department of Agricultural Engineering, Federal University of Technology,Minna. Niger State.

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Ultimately my greatest thank goes to the Almighty God for given me the strength, courage, wisdom, love and protection. To all those mentioned, my kith and kin, I extend my unstinting thanks and deep appreciation.

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ABSTRACT

This work presents the design of a subsurface drainage system during the period of excess water in the rootzone of the crops considered. The Herringbone system was adopted. The parameters that were derived are pipe depth from surface (80cm), spacing between pipe 25m, pipe angle (36.9^0) diameter of pipe (25mm) drain area ($1890m^2$) and outlet gravity of the drain. A topographical map of the area was used in determining the appropriate contours that were suitable for the pipe layout. This design will be of immense benefit to irrigation planners and most importantly the farmers that cultivate crops in these areas.

CHAPTER ONE

1.0 INTRODUCTION

1.1 DRAINAGE BACKGROUND

Drainage planning involves the preparation of a plan for the solution of a drainage problem. The plan consists of a number of measures to be taken and or work to be constructed. The detailing of such works; being mostly in the domain of engineering is referred to as design.

Drainage is the removal of a volume of excess water in a reasonable time in the soil in order to improve the profitability of farm land. It is primarily concerned with the free ground water found in a directly below the soil layers. Adequate drainage of crop - producing land requires a general lowering of shallow water table and a good understanding of the occurrence, nature and movement of water in the soil, as well as, of the drainage related hydrological processes.

They are periods on most land which excess water occurs and this period of occurrence and of short duration which needs not to be harmful provided the quantity are small. Although, most land has some natural drainage which assist in the removal of certain amount of excess water, but in situations whereby, large quantities of water occurs for prolonged duration at critical periods, an artificial means (drainage) may be feasible.

To establish a basis for planning and design, a great deal of information on the project needs to be collected by means of field investigation. These information required include:

a: Diagnose the drainage in hand and conceive possible solution and;

b: Prepare plan and design.

1.2 AIM AND OBJECTIVES

Adequate drainage aims at improving structures, increase and perpetuates the productivity of soils. Drainage is the first essential in reclamation of water logged saline and alkali soils. If only farm land are considered, drainage benefits irrigation agriculture, and the public in many ways.

Thus, the main aim and objective of this project work is to design a drainage system for an agricultural field, by using corrugated plastic pipes that are capable of draining the excess water (which result from excess rainfall) from the soil of an agricultural field.

In addition, most agricultural crops require a specific period of months of the year of which crops can be grown or planted either by irrigation or during the period of rainfall. Thus, this project aims at estimating the evapo-transpiration, and the months of which the crops can be irrigated or drain.

1.3 PROJECT JUSTIFICATION

This project "Design of pipe drainage system for ground water control" is aimed at:

a: Designing a perfect and suitable drainage system for an agricultural field for the optimum productivity of agricultural crops.

b: To advice farmers on the best period possible for planting of agricultural crops (rice)

c: Also, to advice farmers on the best period for drainage and irrigation for an agricultural crop (rice).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 SUBSURFACE DRAINAGE DESIGN

The design of a subsurface drainage system includes; The layout and arrangement of the drains lines, selection of a suitable outlet, proper depth, and spacing of laterals, determination of the length and size of drains, selection of good quality material of adequate strength, and the design of such accessories as surface inlet and outlet structures.

These systems normally consist of a network of deeply installed filled drains establishing a deep drainage base in the soil, well below the root-zone. In the drains, the soil water potential is effectively zero so that all ground water above the drainage base has higher potential and is under gradient to flow towards and into these drains. Low water table depth, may be maintained by selecting a suitable drain spacing provided the down ward movement of excess water is not impeded, the overlying soil profile will drain to field capacity.

The field drain which is pipe drains is referred to as subsurface, (buried or covered) drain. The method where by pipe drains or ditches are provided is called the horizontal drainage. Ground water drainage is a applicable in soils where the root-zone is underlain by strata of reasonable hydraulic conductivity (k) and or thickness(D) (The K D - value of the strata should be reasonable high); and the excess water on or in the soil is able to infiltrate and perforate through the root zone to the underlying water table at reasonable rates.

2.2 PROBLEMS OF DRAINAGE

Excess water that occur deeper in the soil profile causing water lodging of the root zone due to impeded percolation or high water table has adverse effects on farming land, and this can be classified as follows:

a; **IMPAIRED CROP GROWTH**:- Most crops respire by gaseous exchange in the root zone. The process whereby roots absorbs oxygen (0_2) from the soil atmosphere and release carbon dioxide ($C0_2$) back into it.

limited in water logged soil, the air content of the soil is low because most pores are filled with water. Moreover, the exchange between the remaining air in the soil and the air in the atmosphere i.e. 0_2 moving into soil, $C0_2$ moving out is very restricted by these conditions. In consequence, respiration is restricted by the oxygen deficiency while at the same time, the carbon-dioxide accumulates to toxic levels, directly impairing the root growth and the roots ability to absorbed nutrients.

Root-zone aeration generally becomes inadequate when the effective air-filled pore volume in the main rootzone falls between 5-10%. However, the duration of water logging and its timing in relation to the activity and stages of development, the crop also have a considerable influence. Water logging of the entire rootzone for a period of two to three days can be fatal when it occurs during the seedling stages, whereas a well-developed crop is likely to suffer relatively little damage from a similar incident. Also, a vigorously growing healthy crop is able to withstand water logging better than a poor one.

Crops suffer more from water logging under warm than under cold weather conditions. This is because growth increases at higher temperature, increasing the oxygen consumption and leading to the earlier deficits. In temperature climates, water logged soil often remains cold for too long in spring for a good crop growth, therefore, drainage is largely done to overcome the adverse indirect effect, similar effect may also be expected prolonged water logging during the raining season.

b: **IMPAIRED FARM OPERATIONS**: Excess water on or in the soil adversity affect the soil workability. There are fewer workable days on poorly drained land essential farm operation i.e. seedbed preparation, planting, weeding and spraying and harvesting may be critically delayed. If through necessity these operations are not delayed, but go ahead under unsuitable wet soil conditions, compaction, pudding and smearing of the soil is likely to occur and the soil structure may seriously deteriorate. Besides, affecting future yields, a poor soil structure also hampers the infiltration and percolation of rain water into and through the soil, leading to further reduction in the number of workable days.

The economic significance of the effect of excess water on the farm operations depends on the types of farming, modern mechanized farming for example being much more affected than traditional peasant farming.

c: **FLOODING**: Rivers and coastal plains may be flooded during high river or sea levels, impairing the agricultural use of the land.

d: **SOIL SALINITY**: Inadequate drainage of agricultural of salts in the rootzone which is much preventant in semi-arid climates, especially when the land is irrigated.

e: **EROSION BY RUNOFF**: This problem occurs on the sloping land under intensive rainfall when the land was insufficient retention/detention capacity to prevent the rainfall that has failed to infiltrate from running off at high rates.

2.2.1 SOURCES AND CONTROL OF EXCESS WATER

Direct rainfall constitutes by far the major and most common sources of excess water. However, another major sources of excess water in many cold and moderate climates is snow melt water in the spring. Other sources such as irrigation, seepage, runoff and flood water are mostly of minor importance. The occurrence of excess rainfall applies especially to humid climates. However, it may also occur in semi-arid climates, following the common types of intense, heavy storm or in general during the raining season. The drainage load from rainfall not only depends on the amount of rainfall, but also on the storage capacity of the soil and on the rate of evapo-transpiration. Part of the rainfall may be stored beneficially in the soil profile or be readily evaporated so that only the remaining excess needs to be removed from the land by drainage system.

Controlling of this can best be done by ground water drainage systems in which the excess water is able to infiltrate and percolate through the main root-zone to the sub soil and then moves as ground water flow to the drains.

2.2.2 DRAINAGE REQUIREMENT

The measures taken to improve the drainage conditions of an area depend upon the benefits these are expected to yield when compared with the cost for agricultural drainage project, the benefits and the cost are mostly farm economic quantities. Evaluations of consequences of drainage with particular effects on the environment is considered.

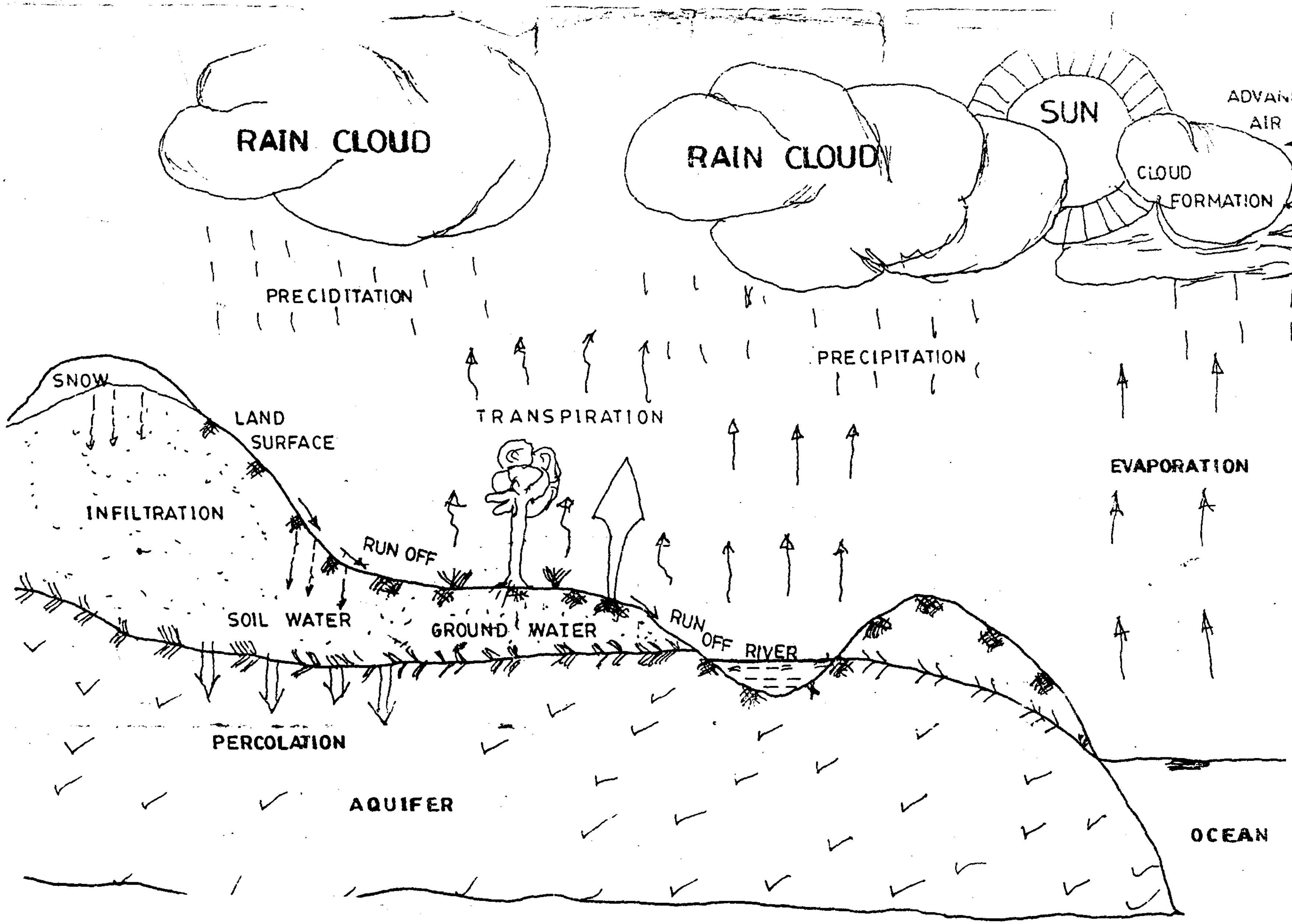
Benefits of agricultural land may arose from the improved crop growth condition created by drainage or from the improved soil workability conditions. Land drainage may be expected to result in better yield at low costs in other words higher net returns to the farmer, and this result should always be considered in relation to the cost of the drainage improvements.

Drainage is of course just one of the factors that determines the returns, others are cropping pattern, fertilizer applications, irrigation, machinery use, management skill e.t.c. The most suitable conmbination of improved drainage and adapted farming in the solution of a drainage problem varies. It should depends mainly on how the cost of better excess water control by improved drainage compare with the cost of adapted farming.

2.3 HYDROGEN CYCLE

The design of agricultural drainage systems requires a good understanding of the occurrence, nature and movement of water in the soil, as well as, of the drainage related hydrological processes. The movement of water from earth to the atmosphere and back to the earth plays a vital role in the existence of plants and animals.

The precipitation reaching the soil surface will partly enter the soil, where it may be retained in the upper layers (soil moisture storage) or percolate through to the deeper layers. The deep percolation eventually reaching the ground water is termed the ground water recharge. Once the storage potential on the soil surface is occupied, the ponded water will move down the slope as overland flow; and collected in the field drains, and then



THE HYDROLOGIC CYCLE

The ground water recharge cause the water table to rise, when it rises above the local ground water drainage base, as formed by the water level, a hydraulic gradient is established which causes ground water flow to this systems. Parts of the infiltrated water finds its way towards the drains as lateral flow above the water table especially in the case of impeded percolation.

Transportation by vegetation and evaporation directly form the soil surface (evapo-transpiration) causes water loss from the soil into the atmosphere by moving air masses. Since air pressure decreases with elevation, the air expands as it is lifted and cooled in accordance with the ideal gas law.

2.4 INFILTRATION, EVAPORATION AND TRANSPIRATION

Three phases of the hydrological cycle of particular interest to agriculture are infiltration evaporation and transpiration.

2.4.1 INFILTRATION

This refers to the entry of water into the soil surface, and it is distinguished from percolation, which is the movement of water through the soil profile. If water is to be conserved in the soil and made available to plants, it must first pass through the soil surface, and if the infiltration rate is high, less water will pass over the soil surface and erosion will be reduced.

The movement of water into the soil by infiltration may be limited by any restriction (based on the minimum value obtained) to the flow of water through the soil profile. Infiltration data are expressed graphically with the rate as the ordinate and the time as the abscissa. The infiltration curve can be expressed by (Horton, 1939) as:

$f = fc + (f_o - f_c)\, e^{-kt}$ 2.1

where;

f = infiltration capacity or the maximum at which soil under a given condition can take water through its surface

f_c = the constant infiltration capacity as it approaches infinity;

f_o = infiltration capacity at the onset of infiltration;

t = time

Also, the infiltration rate (I) of water into the soil is governed by Darcy's law;

$$I = K_0 \frac{h+z-p}{z} \qquad 2.2$$

where,

I = infiltration rate ($m.day^{-1}$)

k_o = Hydraulic conductivity of the soil at moisture content ($m.day^{-1}$)

h = water depth on the soil surface (m)

z = depth to the welting front (m)

p = soil water pressure at the welting front inside the transmission zone (m)

But after prolonged infiltration, z becomes relatively large compared to (h-p) so that the hydraulic gradient approaches unity;

i.e. $\left(\frac{h+z-p}{z} = \frac{z}{z} = 1\right)$

so

$$I_{final} = k_o = \frac{h+z-p}{z} \sim k_{sat} \qquad 2.3$$

2.4.2 Evaporation And Transpiration

Evaporation is the process by which moisture is return to the air from a liquid to a gaseous state. This may occur either from the water surface or from moisture soil particles, and it is important for water conservation.

Transpiration is the process through which water vapour passes into the atmosphere through living tissues of living plants, or in simple form evaporation from plants. For convenience in analysing moisture transfer in this common situation, evaporation and transpiration are combined and referred to as evapo-transpiration.

2.5 Topography

Good topographical map shown the lie of the land: is indispensable in drainage planing and design water movement toward subsurface drains occurs primarily beneath the soil surface. Water always moves from high to lower potential energy levels. Darcy's law states that the quantity of water moving through the soil is a function of the gradient or slope, the cross-sectional area of soil through which the water moves. If the cross-section area is large, and the hydraulic conductivity and gradient are small, a large amount of water can be moved through a soil. But, if the hydraulic conductivity and the gradient is high, and the cross-sectional area is small, a large amount of water can also be moved through a soil. The combination of the three (3) factors in Darcy' law determines the flow quantity.

Some drainage problems arise if the subsurface stratification does not correspond to the surface topography. Eg. In an area with a rolling or undulating soil surface, stratification may all be horizontal. Water moving down through the soil may enter an impermeable horizontal layer, move lateral and create local slide hill seeps and small drainage problems. If the slope of the soil surface is different from the slope of the subsurface layers, the layers may intersect the soil surface at some point, causing seeps over a large area. In soils without contrasting layers that have abrupt changes in the gradient of flow may cause the water table to rise and intersect the soil surface. Changes in slope are logical locations for the placement of intercept for drains. Since water moving in the subsoil is most difficult to control, a careful study be made of both surface and subsurface conditions to determine the effect of topography on drainage requirements.

2.6 CLIMATE

Most drainage problems result from rainfall exceeding the evapo-transpiration during shorter or longer periods. Climate analyses, therefore are able to contribute a great deal to a better understanding and diagnosis of these problems.

The principal influence of climate on drainage requirements is reflected in whether the climate is humid or arid. In humid, the removal of excess surface and subsurface water originating from rainfall is the principle purpose of agricultural drainage. In arid, controlling the water table and preventing an accumulation of salt in the soil's root zone resulting from irrigation water applications are the most important factors. In semi - arid or sub-humid areas, drains may be required for both purposes. During certain periods of the year, excess precipitation may occur that requires rapid removal of excess water from the soil. During other periods of the year, upward movement of saline ground waters into the root zone should be minimised.

The amount of water to be removed is a function of the infiltration characteristics of the soil. Factors related to climate that control the soil surface condition, which controls the part of the rain falling that penetrates into the deep soil layers, rainfall frequency, evapo-transpiration; and irrigation application in excess of evapatranspiration needs.

2.7 PHYSICAL PROPERTIES OF SOIL

The soil is a complex mechanical system. And for a soil to be in good physical condition for plant growth, the air water and soil particles must be in the right proportion at all times (Donehuse, 1958). Every centimeter of soil that is expected to support plant life must be; open enough to permit the right amount of rain water or irrigation water to enter the soil, but not so open as to allow excessive loss of water and plant nutrients by deep percolation; sufficient retention of moisture to supply roots with all needed water, but not to create undesirable suspended water tables; well enough aerated to permit all plant root cell to obtain oxygen at all times, but not out nor to the point of preventing a continuous contact of roots with moist soil particles

2.7.1 SOIL MOISTURE CONTENT

In the unsaturated soil above the water table the pores are partly occupied by water and air. The soil water in this zone is commonly referred to as soil moisture. The amount of soil moisture varies greatly with depth and in time. The soil moisture profile as depicted in fig 2.3 would be typical of a soil with a fairly high water-table shortly after a prolonged period of rainfall. In a narrow zone above the water-table, pores fill by capillary rise from the ground water. In the lower part of this capillary zone all pores are filled with water making the soil in this so-called capillary fringe is under negative pressure while the pressure in the ground water is positive. Above the capillary zone, pores fill with water mostly by retaining part of the percolating rain water.

When the groundwater is very deep, the soil may be moist in the upper layers (retained rain) and also in a zone immediately above the watertable (Capillary zone) while, in between the soil may be much drier. The soil moisture content in the upper layer is particularly variable, mainly due to variation in daily weather conditions (especially rainfall variations). Deeper down, variations occur over a longer term, in parallel with seasonal weather variations.

It is important to find the available water capacity for different soil plants or crops to be grown. Three methods includes: Neutron; tensiometers, using electrical properties of a porous block; appearance and feel of soil and Gravimetric determination method . For Gravimetric method, moisture content can be calculated by expressing it as percentage of day weight, (Black 1965).

$$M_d = \frac{W_w - W_d}{W_d} \quad \frac{100}{1} \qquad 2.4$$

Where,

$N_w =$ weight of wet soil
$W_d =$ weight of dry soil
$M_d =$ moisture content expresses as percentage of dry weight.

And

$$M_v = M_d \times A_s \qquad 2.5$$

where,

$M_v =$ Available moisture holding capacity
$A_s =$ Apparent specific gravity of soil

and,

$$A_s = \frac{\text{weight of a given volume of soil}}{\text{weight of equal volume of water}}$$

$$d = \frac{M_v}{100} \times D \qquad 2.6$$

where

$d =$ Available water to plants

$D =$ depth of soil.

combing equations (2.5) and (2.6)

$$d = \frac{M_d}{100} \quad x \quad A_s \quad x \quad D$$

2.7.2. BULK DENSITY

This is define as the ration of the mass of dry particles to the total volume of soil (including particles and pores)

$$D1 = \frac{M_d}{V_t} = \frac{M_s}{V+V_a+V_w} \qquad 2.8$$

where

$D1$ = mass of dried soil

V_t =Total volume

V_a =Volume of air

V_w =volume of water

The term dry bulk density and apparent specific gravity are often used synonymously where as the term specific gravity donates a dimensionless quantity, bulk density is expressed in grams per centimetre cubic or mass per unit volume. The structure, texture and compatibility of the soil influence the apparent specific gravity. It is an important soil physical property considering its influence on the water holding capacity of soils and it`s hydraulic conductivity e.g. when the bulk density of medium to fine - textured sub-soils exceeds about 1.7g/cc, the hydraulic conductivity values will be so low that drainage may become difficult. Total (wet) bulk density is the mass of moist soil per unit volume i.e.

$$D_{bt} = \frac{M_t}{V_t} = \frac{M_s + M_w}{V_s+V_a+V_w} \qquad 2.9$$

where

D_{bt} = wet bulk density

M_t = Total mass of soil

V_t = Total volume of soil

2.7:3 POROSITY

This is defined as the ration of the pores to the total soil volume:

where

g = porosity.

Porosity is an index of the relative volume of pores. It is influence by the textural and structural characteristics of the soil. Michael (1980) The porosity of sandy soil usually ranges from 35 - 50 percent, while that of clay soil ranges from 40 - 60 percent. The more finely divided are the individual soil particles, the greater the porosity.

2.7:4 WATER HOLDING CAPACITY

The moisture content of sample of soil is defined as the amount of water lost when dried at 105^0c, expressed either as the weight of water per unit weight of dry soil or as the volume of water per unit volume of bulk soil. Although useful, such information is not a clear indication of the availability of water for plant growth. The differences exist because the water retention characteristics may be different for different soils. Micheal (1980).

About half of soil volume is pore space, which is occupied by varying amount of air and water, depending on the degree of wetness. Water is held in the pore space in form of films adhering to the soil particles. The smaller pores in the soil are called micro-pores, while the larger ones are macro-pores, and they don't hold water well because the heater films becomes too thick to adhere well to the surrounding soil particles. It is not worthy that drainage takes place within micro-pores.

Hence; $m_v = m_d \times t_s$

2.8 HYDRAULIC CONDUCTIVITY

The hydraulic conductivity of the soil is a very important characteristics in relation to almost any drainage investigations, especially subsurface drainage. The material drainage of the soil and the scope for and costs of improved drainage all depends greatly upon it. K-value of the soil depends mainly on the geometry and distribution of the water-filled spores.

Values are low when water has to follow a tortuous path through fine pores. And this will generally be the case when the soil moisture content is low since under these conditions the water will be mainly present in the fine pores and as film water, forming an irregular hydraulic continuity with many bottle-necks. Differences in the hydraulic conductivity of soils under saturated condition reflects differences in the geometry of the total pore space of the soil.

Temperature also has an influence on k-value, with rising in temperature, water becomes less visions and the k-value increases. In the deeper soil layers, through which most drainage flow takes place, temperature are rather uniform and steady and its influence on k-value may generally be neglected. The hydraulic conductivity of a field soil may vary considerately across an area as well as in depth due to variation, in soil texture and soil structure. In a layered soil k-value will generally differ between layers.

In an unsaturated soil, moisture content is one of the dominant factors influencing permeability. Vaugh (1979). Henry Darcy (1956),s law applies to the movement of soil moisture and the law states that: The rate of water movement through a column of saturated sand is proportional to the different in hydraulic head at the ends of the column, and inversely Daray's law is expressed as:

$$v = k \frac{(h_1 - h_2)}{L} \qquad \text{———} \quad 2.11$$

where

V = velocity of flow, m/day

k = hydraulic conductivity, depending upon the properties of the sand and liquid (m/day)

$h_1 - h_2$ = difference in hydraulic head (m)

L = distance between the points h_1 and h_2 (m).

By definition,

$h_1 - h_2$ = hydraulic gradient (i)

Thus

Often, the quality of flow may be of greatest interest than the velocity. Hence in terms of quantity of flow, Darcy's law may be expressed as follows:

$Q = av = kia$ _______ 2.13

where;

Q = Volume of water discharged in saturated length of time m^3/day $cm^3.sec^{-1}$ or $m^3.day^{-1}$

a = Cross sectional area through which water moves (m^2) or cm^2

The value of k can be obtain from laboratory test of the sample formation by constant head perimeter. Khile and Dirksen(1986).

With a constant head maintained by either continuous inflow or frequent additions of water, steady flow through the soil is obtained. Check figure 2.5 Darcy's law of flow of water in soil is applied for computing perability after measuring volume of flow in unit time across a sectional area (^) at right angles to flow, loss of hydraulic head h_l thus;

$k = \frac{QL}{Ah_l}$ (cm/hr) ___________ 2.14

where;

L = flow length

A = cross sectional area at right angles to flow

h_l = loss of hydraulic head.

2.9 INFILTRATION RATE

The rate at which water can enter soil when not limited by the rate of supply is measured in the field with water either ponded on the surface or falling on it as artificial or natural rain at a rate sufficient to cause run off. It is expressed in (m/s).

Three ways of estimating infiltration characteristics of soil are:

a: Water entry rate into soil as measured in the "field intake rate".

b: Measurements of subsidence of free water in large basin and

c: Estimation of accumulated infiltration from the water front advance data.

The movement of water into the soil by infiltration may be limited by any restination to the flow of water through the soil profile. The major moisture content, condition of soil surface, hydraulic conductivity of the soil profile, texture porosity, degree of swelling of soil colloids and organic matter, vegetation cover, duration of ponding water, irrigation or rainfall and viscosity of the water.

Infiltration rates are generally lower in soils of heavy texture than the soil of light texture. The influence of water depth over soil on infiltration rate was investigated by Horton (1940) and Green and Amph (1911) surface irrigation depth increases initial infiltration slightly, but the head has negligible effect after prolonged irrigation. The high rate of infiltration in the tropics under otherwise comparable soil conditions is due to low viscosity of warm water.

2.10 SOIL TEXTURE

The relative proportion of sand, silt and clay determined the soil texture. Texture is designated by using the names of the predominant size fractions and the word "loam" when ever all three major size fractions occurs in sizeable, proportions. Thus the term "silty clay" describes a soil in which the clay characteristics are outstanding and which also contains a substantial quantity of silt. A silty clay loam is similar to silty clay except that it

contains sand in a sizeable proportion. Sandy soils are classified as coarse textured, loam soils medium textured and clay soils as fine texture. See table 2.1

The least complex textural group is sand, which contains less than in percent silt and clay, such soils form relatively simple capillary system, with a large volume of non-capillary pore space, which ensures good drainage and aeration. Sandy soils are relatively inert chemically, are loose and non cohensive and have low water holding capacity. Clay soils are at the other extreme with reference to the size of particles and complexity. They contain more than 40 percent of clay particles and 45percent sand and silt. The clay particle are usually aggregated together into complex gramiles, because of their clay particle have a much greater surface area than cubes or sphere of similar volume. Their extensive surface enables clay particles to hold more water and minerals than sandy solid.

Loam soils contains more or less equal amounts of sand, silt and clay such soils are considered more favourable for plant growth because they hold more available water and contains than sand and are better aerated and easier to work than clay.

2.11 TEXTURAL CLASSIFICATION

This has only an approximate relationship to the behaviour of a soil as a medium for plant growth. Textural properties may be modified by organic matter content, one kinds of clay minerals present and kinds of ions associated with them e.g. aggregation effects of organic matter tend to give a fine textured soil high in clay some pore space properties of a coarse textured soil. Similarly, colloidal effects or organic additions to a coarse-textured sandy soil give it some of the moisture and cation retention characteristics of a fine textured soil.

The soil texture forms the basic metric and the geometry of volts created in this soil matric is dependent on the class of soil textured. The soil texture, therefore, influences considerably the other phases (water and air) contained in the spaces in the soil metric. The texture of a soil is more or less constant and does not change with tillage or other practices. Specific surface of soil particles is the proportion of surface of volume of the soil particle. The specific surface of clay is several times larger than silt and sand.

MECHANICAL ANALYSIS

The determination of the relative distribution of the size groups of ultimate soil particles is called mechanical analysis. The process involves the separation of all particles from each other (complete dispension) into ultimate particles, and the measurement of the amount of each size group in the sample. Soil separates are the size groups of minerals particles less than two millimeter (2mm) in diameter or the size groups that ... The diameter and the number and surface area per gram of the seperates are given in table (2.1) below according to United States Department of Agriculture (U S D A) and international soil science society system (I S S S).

S/N	Soil separate	Diameter (mm)	Diameter (mm)	Number of particle per gram	surface area in gram cm
1	very coarse sand	2.00-1.0	-	90	11
2	coarse sand	1.00-0.50	2.00-0.20	720	23
3	medium sand	0.5-0.25	-	5700	45
4	fine sand	0.25-0.10	0.20-0.02	46,000	91
5	very fine sand	0.10-0.05	-	772,000	227
6	silt	0.05-0.002	0.02-0.002	5,776,000	457
7	clay	below 0.002	below 0.002	90,260,853,000	800,00

SOURCE A. Michael (1980)

Table 2.1: soil separates

The corrected hydrometer reading c(g/l) are obtained by subtracting the blank reading Ri (g/I) from the hydrometer readings in the soil suspension R(g/c) and the adding 0.36g/l for every degree above 20^0c

$C = R - R_L + (0.36T)$ _______ 2.15

where;

T = Room temperature minus 20

R = Hydrometer readings in the soil suspension (glc)

R_L = Hydrometer reading in the blank

The percentages by weight of the silt clay and clay fractions are given by

% (silt & clay) = 100 (c_t for salt + clay)/C_o

% (clay) = 100 (c_t for clay)/C_o

% (clay) = 100 (c_t for clay)/C_0

where

C_0 = weight (g) of soil sample on oven-dry basis

% (sand) = 100 - % (silt + clay)

% (silt) = % (silt + clay) - % (clay)

2.12 GROUND WATER, RECHARGE AND FIELD WATER BALANCE

2.12.1 GROUND WATER

Ground water is water beneath the soil surface where voids in the soil are substantially filled with water. Upward movement of ground water by capillary from the water table into the root zone can be a major source of water for plant growth. To be most effective without seriously restricting growth, ground water should be near, but below the out below the depth from which the major portion of the plants water needs are extracted.

If growth is within the normal root zone, plant growth is suppressed. If ground water is too near the surface, the winds ability is economically produce most crops becomes almost zero. However, a water table within the lower portion of the root zone may supply a considerable amount of water and thereby reduce the cost of production. The optimum depth of the water table is that depth which gives the maximum economic return. (Vanghn, Orsonn, Isrealsn and Stringm, 1980).

2.12.2 RECHARGE

Critical shortage of under ground water due to limited natural recharge, small storage capacity, and over use are stimulated effort to recharge ground water reservoirs with surface waters. Flood flows which would otherwise have been lost are diverted and applied to the land, thus providing water to seep into underground reservoir.

Full conservation and use of available water supplies requires an integrated use of surface and subsurface waters in storage facilities. Water percolates into the ground water reservoir to be stored until needed for irrigation. (lotris, 1991)

2.12.3 WATER BALANCE

The water balance of a field is an itemised statement or algebraic summation of all grains losses and charges of storage of water occurring in a given field within a specified boundaries during specified period of time. The task of monitoring and controlling the field water balance is vital to the efficiency management of water and soil. Acknowledge of the water balance is necessary to evaluate the possible method to minimize losses and maximize grain and utilization of water which so often the limiting factor in crop production.

This is expressed as:

(Grains) - (losses) = change in storage (Rathone 1990)

i.e

$$NWR = (P-R_o) + I_R + D_s = E_T + P_c \quad \_\_\_\_ \quad 2.16$$

where;

NWR	=	Net water requirement
R_o	=	Surface run off
E_T	=	Evapo-transpiration
P_c	=	percolation
P	=	Precipitation
D_s	=	change in storage

NOTE: The change in soil water content (Ds) can be obtained from the expression:

$$D_s = (P+I_R) - E_T + P_c + R_o$$

$$= P - R_o - (E_T + P_c)$$

2.13 **PIPE DRAIN SYSTEMS.**

Most ground water drainage for modern farming in temperate climates is done by means of pipe drain systems, which are extensively used or salinity control in irrigated areas. Very little pipe drainage has as yet been installed in the (semi) humid tropics due to partly economic and partly technical reasons.

Pipe lines are the method usually chosen when a drainage system must extend into the interior of a field and are common for subsurface

f pipe drain for drainage include a smooth land surface that permits normal equipment and livestock traffic across the field while the disadvantage is cost.

But today, a great deal of research has been done on the functioning of the pipe drain, the materials used and the installation methods, all of which has added to the sophistication and dependability of the pipe drain system. (Smedema, 1988).

2.14 TYPES AND LAYOUT PATTERNS OF SYSTEMS

The alignment of field drains and the collector drains into which they discharge are mutually dependent, their alignment, however, in the first instance being determined by the topography of the land to be drained. Drains are most effective when they are sited so as to pass through the lowest areas in the land since these are the positions to which water gravitates naturally.

The layout of a drainage system may or may not show a regular pattern. The topography of the area, source of the water, and pattern of wetness are important factors in determining the type of systems which include random, regular and interceptor drain systems.

A: RANDOM (NATURAL) SYSTEM

Random drains are used where small wet areas are separated by higher, drier land. The drains go through one wet area and on to the next, usually through the lowest connecting areas. The layout of the ditches or pipe lines is determined by the location of the wet spots. See (fig. 2.4a). The system is quite flexible as well as economical since the drain line follow natural drains or other low depressions.

B: REGULAR (PARALLEL AND HERRINGBONE) SYSTEM

In regular drains, broad flat areas where several parallel ditches or pipes lines are needed. A variety of pattern are possible, including two basic ones known as parallel grid and herringbone.

In the herringbone system the collector drains are aligned down the main slope and the field drains (laterals) are aligned across the slope, but as at slight angle to the contours, so that the pipes slope downwards towards

In a parallel grid system, the laterals are give slope by increasing the installation depth towards the collector, (see fig. 2.4b).

C: **INTERCEPTOR SYSTEM**

Interceptor drains are placed between the source of the water and the area needing drainage so that the water can be led away. The drain must be deep enough to catch the main flow of water and must sun across that flow. The water being intercepted in humid regions comes from the natural precipitation, whereas in arid regions, it may come from an irrigation canal. (see fig 2.4c).

Note that, in choosing the type of system, decisions regarding drainage system are based on information from the maps or other source. Rolling land with several low wet areas needs a random system, whereas, a large uniformly wet area calls for a regular (parallel or herringbone) system when the interceptor is normally placed near the upper edge of a wet area.(Rycroft, 1988).

2.15 PIPE DRAIN

The different types of pipe drains include the following:

i. clay tile pipe

ii. concrete pipe

iii. plastic (corrugated) pipe

CLAY TILE PIPE

In clay tile pipes, the standard sizes vary between countries. Although typical pipe sections are 30cm long and have internal diameter (ID) equal to 5,6,5,8,10 up to 20cm. Special pipes with collars are available for use in soils in which consolidation is likely to occur. The clay tile is highly resistant to deterioration in aggressive soil conditions. Pipe sections are abulted against each other and water enters through the joints that exist as direct result of the imperfect fit between the ends of the pipe section. (see fig. 2.5a)

CONCRETE PIPE

Here, mostly medium in large size with diameters of 15-20cm of more diameter pipe; water entry occurs through the joints. Pipes made with ordinary (portland) cement are liable to deteriorate in acidic or salty soil, and in this circumstances special resistant cements should be used.

PLASTIC (CORRUGATED) PIPE

This is made from polyethylene (PE) or polyvinyl chloride (pvc). It is very durable but subject to deterioration by long exposure to the ultra-violet radiation of strong sunlight. PVC becomes brittle with freezing temperatures and can be easily fracture.

Corrugated steel pipe with a high structural strength is suitable to withstand high soil loads to cross unstable soils that require the rigidity of a long pipe, and to provide a stable outlet into open ditches. Also, corrugated tubing is light in weight, durable, resistant to soil chemicals, extruded in long lengths, and easy to join and handle in the field. It is especially suitable for installation with a mole plow, and less labour is required. It is also subjected to damage by rodents and its hydraulic roughness is higher than tile. It will float in water and tend to stay curved as in the shipping coil. Corrugated plastic tubing is perforated with three or more rows of opening (0.6-2.0mm wide slots, usually on the grooves of the corrugations) for water entry and may be made with a fabricated porus covering to prevent inflow of fine particles in sandy soils. Also, the perforations may be arranged in any pattern which provides an even distribution around the whole circumference. The open area should be minimally 800mm per m pipe, length standard corrugated drain pipes usually have outside diameters (OD) of 40,50,65,55,100 and 125mm, whereas internal diameter (ID) of 0.9xOD. see fig. 2.5 a shows entry flow patter for clay, concrete pipe and corrugated pipe.

2.16 ENTRY LOSSES

Head may be loss as the water flows towards and through the rather limited open areas unto the pipe. This head loss constitutes the entry loss and it follows that, for the same inflow, pipes with a very small entry area will have a much higher head loss than the pipe with a larger area. Entry characteristics of different pipes may be compared using a standard resistance factor (α) which is related to the head loss at entry as (ILRI 1979)

$$h_e = \alpha \frac{Q}{K} \qquad 2.19$$

where;

h_e = head loss at entry .m

α = resistance factor, dimensionless

Q = The inflow rate to the pipe per m length of pipe m .m. .day

K = The hydraulic conductivity of the material enveloping the pipe, m. day

α - range for different material.

clay and concrete α = 0.4-2.0

smooth plastics α = 0.4-0.6

corrugated plastics α = 0.05-0.1

Clay and concrete pipes generally have higher entry resistance than other pipes due to the wide spacing between points at which water is able to enter the pipes. Corrugated plastics pipe offers the least resistance which is at least partly due to the fact that it tends to have a considerably greater slot area than the international standard minimum normally adopted for smooth pipe (Rycroft, 1988)

2.17 PIPE ENVELOPE

A pipe envelope is the material placed around the pipe to serve as:

1. hydraulic function: to reduce the head loss at entry by facilitating the flow of water to the entry points.
2. Filter function: to prevent entry of fines into the pipe, mostly by reducing the velocities of the flow converging onto the entry points, to the extent that very little sediment is actually transported by the water.

Most traditional envelopes provide for a thick layer of highly permeable material around the drain pipe. This has two beneficial effects. Firstly, the head loss at entry is considerably reduced, the resistance factor (α) becoming generally very much less than 0.1. Secondly, the rate of flow of water leaving the soil and entering the surround is several hundred times less than the rate at which it will flow directly from the soil into the slots of a pipe, without a permeable surround. This reduction in velocities lessens the risk of siltation occurring as a direct consequence of erosive flow velocities, and these objectives are generally sufficiently achieved when the envelope has a minimum thickness of 5-10mm and a k-value at least ten times greater than that of the soil (ILRI, 1979). The material that may be considered as fulfilling this condition are coarse sands and graves, organic materials such as peat, litter, coconut fibre, flax, straw or thick synthetic materials such as propylene materials or polystyrene granules.

Soils for which a filter is required are those which are most readily eroded and transported by water investigation indicates that the most critical soils in this respect are uniformly graded coarse silts and fine sands, having median particles sizes in the range 20-100 microns. The entry flow rate are seldom high enough to transport larger sized particles while fine particles less than 2 microns have an inherent stability due to cohesion. Instability can also be caused by the chemical status of a soil (e.g. due to salinity) or it may result from very high erosive forces occurring during irrigation or intense rainfall.

2.18 DRAIN DEPTH AND DRAIN SPACING

A definite relationship exists between depth and spacing of drains. For soils of uniform permeability, the deeper the drains the wider the spacing between drains with the choice of depth and spacing often being an economic consideration (Van Schilfigaarde et al. 1956). The primary consideration in drainage design is to provide adequate root depth above the saturated zone. (Schwarb, soil and water Engineering).

2.18.1 DRAIN DEPTH

The depth of pipe drains should be such as to provide the desired water table depth midway between drain lines. Pipe depths is affected by soil permeability, outlet depth, spacing of laterals, depth to the impermeable layers in the subsoil, and limitations of trending equipment.

Pipe depth, defined as the distance between from the surface to the bottom of the pipe, varies in different soils. Under no conditions should the amount of cover over the top of the pipe be less than 60cm (0.6m). This minimum is necessary to protect the pipe from heavy surface loads and to prevent shifting to the tile. In uniformly permeable mineral soils, the depth of laterals usually varies from 80 to 250cm (0.8-2.5m) unless limited by an compermeable layer, one should design for the maximum depth as this will permit a wide spacing. In deep organic soils after initial settlement has taken place, the minimum depth should not be less than 120cm (1.2m). Where the subsoil is relatively impermeable, the pipe should be placed on or above the impermeable layer. If pipe must be placed below the impermeable layer, the trench should be back-filled with permeable soil.

In humid regions, where the water table will rise to near the surface during heavy rainfall, the rate of drop is the important factor, However, in organic soils the water table may be maintained at a nearly uniform depth, which may be above the pipe. See table 2.2 for a few empirical criteria for drainage depth. In arid region under irrigation, the drainage design criteria are determined more by minimum depth of the water table for optimum crop growth then by the rate of drop. Depths of 200 to 300cm (2.0-3.0m) are common.

s/n	Crop	Depth and Rate of the water table
	Mineral soil	
1	Field	Initial depth 15cm minimum: 30cmld through second 15cm: 20cmld through third 15cm.
2	Field	Drop from surface to 30cm in 24hr and 50cm in 48hr
3	Field	Drop 20cmld
4	Grass	Constant depth 50cm or less
5	Arable	Constant depth 90 to >130cm
	Organic soil (controlle d drainage)	
1	Grasses	maximum depth, 50cm
2	Vegetable (shallow rooted)	Maximum depth, 60cm
3	Field	Maximum depth, 80cm

	rooted)	
4	Cereals, short grass sugar beets	Optimum depth, 80-90cm
5	Truck crops, grass, and sugar cane	Optimum depth, 30-60cm

Table 2.2 Drainage Depth requirement for Humid Areas.

2.18.2 DRAIN SPACING

Spacing between drains depends upon many factors, but the texture and permeability of the soil, and the depth of the drain below soil surface are significant items (Donnan, 1946). Ground water usually moves through coarse textured soil more rapidly than through fine textured soil. Therefore, drains can be spaced farther apart in coarse textured soils.

2.19 **DRAIN SPACING FORMULAR**

The basic design criterion for pipe system for ground water control specifies the recharge (q) that the system should be able to cope with while maintaining a desired water table depth (H). Suitable values for W field drainage base depth (W) is selected based on the local condition of the field. This determine the water table head (h) = W-H, required drain spacing (L) may then be calculated using one of the drain spacingformular.

Drain spacing formular is categorised as either steady state formular or non-steady state formular. Steady state formular are based upon the assumption that a steady constant flow occurs through the soil to the drains. Discharge equals recharge and the head (h) is also constant. In the non-steady state formular, all these parameters very in time.

In most cases, design is based on steady state conditions using one of the many available formular i.e. (Hooghoudt formular). This formular has a wide applicability and a relatively simple structure.

2.19.1 **STEADY STATE (HOOGHOUDT FORMULAR)**

This was developed by Hooghoudt (1940). In this formular, only the insignificant) are considered. Hooghoudt conceived that a parallel open ditch system with the ditch reaching to the impermeable substratum, could generate the same discharge (q) for the same water table head (h) as an identical spaced pipe drain system by reducing the depth (D) to the impermeable substratum. This led him to the idea to treat the horizontal/radial flow to pipe drains (eq2.20) as an equivalent flow to ditches with the impermeable base at a reduced depth (d) describe (eq 2.21) radial flow (horizontal + radial)

$$h = h_h + h_r = \frac{qLh^2}{8kD_h} + q \frac{hI_n}{pk} \frac{aD_r}{u} \quad 2.20$$

equivalent flow (horizontal)

$$h = h_h \text{ (equivalent)} = \frac{qL^2}{8kD_h} \quad 2.21$$

The average thickness of the equivalent horizontal flow zone may be approximated as:

$D_h = d + \frac{h}{2}$ and inserted in eg. 2.21 gives

$$h = \frac{qL^2}{8k(d+h/2)} \quad \text{or } q = \frac{8kh(d+h/2)}{L^2} \quad 2.22$$

thus,

$$q = \frac{8kdh}{L^2} + \frac{4kh^2}{L^2} \quad 2.23$$

eq 2.22&2.23 is refers to as Hooghoudt spacing formular. Per pipe drains.

The equivalent horizontal flow takes place partly below the drainage base (average thickness of this flow zone being a and partly above the drainage base (thickness of this flow being h/2). These two flow components are respectively represented by the first and second terms in (equation 2.23). When the soil above drainage base has a different hydraulic conducting (k_1) than below (k_2). This may be taken into account:

$$q = \frac{8k_2dh}{L^2} + \frac{4k_1h^2}{L^2} \quad 2.24$$

Hooghoudt also found that,

$$d = f(D.L.U) \quad 2.25$$

and prepared a table defining this functional relationship numeral for common sized pipe drains, (Table 2.4). He also derived an expression later for this function, covering a wider range of drain types to be

d = D (for DL1/4L); d = L/8In L[G1]/u(forD > 1/4L) 2.26

In situations where there is no distinct impermeable subtraction the depth D may be equal to the depth at which the k - value has decreased to 1/10 of the (average) k - value of the layer(s) above, provided no ghighly permeable layer occurs within 1-2m below this depth.

NOTE:

The Hooghoudt formular shows that, with all other variable constant, the spacing (L) increases when:

a: K increases, q decreases, D increases and h also decreases (implies increases of W or decrease of H)

b: The drainage flow above the drainage base may be neglected, the Hooghoudt formular is reduced to;

$$L^2 = \frac{8kdh}{q} \quad \text{(simple Hooghoudt formular)} \_\_\_\_\_\_ 2.27$$

CHAPTER THREE

3.0 METHODOLOGY AND PROCEDURE

This chapter focus more on the method by which the project was carried out.

3.1 **SURVEY**

The materials used in marking out squares and peizometer positions was done using pegs, cutlass, range pole, level, staff, measuring tape, and theodolite. The cutlass was used to clear the points of installing pipes and a hard driver anger of length 1.5m and screw diameter of 5cm was used to drill the hole to a one meter (1m) depth. The pipes are conduit pipes of diameter 4.5cm and length of 150cm. Since 100cm below ground surface is the depth of interest. They are radially perforated at 2cm apart across the length of the pipe to allow sufficient and effective inflow of ground water into the pipe to assume its original form and level.

3.2 **DETERMINATION OF SOIL PROPERTIES**

3.2.1 **HYDRAULIC CONDUCTIVITY**

Moisture cans were used to collect samples for moisture content determination at different depth. Retort stands and measuring beakers were also used for the experiment. In addition are core samples which were used to excavate soil sample in an air distributed form from the field to the laboratory. Core samples are column pipes open at both ends with diameter 7.3cm and height 7.5cm. They are used because they allow dimensional flow.

3.2.2 MOISTURE CONTENT, BUCK DENSITY AND POROSITY

Core samples which is 5-8cm in diameter and 6cm height was placed on the soil from (0-20cm) and pressed into the soil by tapping it gently with a mallet until the core was completely filled with soil and gently removed by placing a cutlass under the core sample, so as to prevent the soil in the core from falling off.

After removing the core sample and its contents kept in a polyethene bag immediately to avoid moisture loss or gain by evaporation and

40cm), (40-60cm) and (60-80cm) soil depth. All samples was taken gently in a packet and conveyed to the laboratory, where an electronic machine was used to weighed the can, and its contents. After labelling, samples was placed in an oven at a temperature of 105¯c, for 24 hours and re-weighed. Different in weight of samples was taken moisture content, wet buck density and porosity was worked out.

3.3 ESTIMATION OF STREAM VELOCITY

In this method, (float method). Distances were measured along the side of the stream, the depth and width were also measured using a measuring tape. A piece of wood was placed in the stream flowing water, and allow to flow along the stream within the measured length. A stop watch was used to determined the time taken for the flow. This procedure was repeated for three (3) times, each time changing the location along the stream. The average of the stream was taken and the velocity of the stream was then calculated using the formular.

$Q == AV$

where:

Q = Discharge capacity (m^3/s)

A = cross-sectional are of the land (m_2)

V = velocity (m/s)

3.4 DETERMINATION OF EVAPOTRANSPIRATION

This was determined using climatological data. Owing to the difficult in obtaining accurate direct measurement of an evaporation under field conditions, evapo-transpiration is often predicted on the basis of climatological data either by empirically or by a more theoretical approach. Some of the methods for determining evapo-transpiration is tabulated below in table 3.1:

S/N	METHODS	PARAMETERS
1	Penman	Air temperature, windspear, sunshine hour and relative humidity
2	Blaney-criddle	Air temperature
3	Jensen-Haise	Air temperature and sunshine hour
4	Blaney-Morin-Nigeria	Temperature, relative humidity and sunshine hours

source: Michael (1980)

BLANEY-CRIDDLE

Blaney-criddle (1950) observes that the amount of water consumptively used by the crops during their growing season was closely corrected with mean monthly temperatures and day light hour. This is given as:

$U \quad = \quad 2.54 + P/100$ ________3.2

but $tP/100 \quad = \quad f$

thus;

$U \quad = \quad 25.kf$ _______ 3.3

where;

U = monthly evapo-transpiration in (mm)

K = monthly evapo-transpiration (consumptive use) coefficient.

t = mean monthly temperature (°c)

p = monthly percent of total day time hours of year

f = (tP/100) = monthlyevapo-transpiration factor.

For temperatures in degree centigrade (°c) the equation becomes:

$U \quad = \quad kp\ (0.46tc + 8.13$ _________ 3.4

where t_c = temperature

BLANEY-MORIN-NIGERIA EVAPOTRANSPIRATION MODEL

Blaney and morin (1942) proposed a simple evapotranspiration model which, in a generalized form is as expressed as:

$Et_c \quad = \quad KPT(H-R^m)/100$ _________3.5

where;

Et_c = crop evapotranspiration (in)

K = crop factor

P = ratio of maximum sunshine hours

T = temperature (oF)

R = Relative humidity (%)

H&M = constants.

But in the S.I unit of measurement, the equation takes the form:

Et_p = P (0.45Tx8)(H -R^M/100 ________ 3.6

where: Et_p = potential evapo-transpiration (mm day-1)

T = temperature (^{0}c)

P = sunshine hour

H = empirical constant

R = Relative humidity

Because of some complexity in obtaining some fixed constant variable, the equation was rearranged to

H = $[100Et_p+P(0.45T+8)R^M]/ P(0.45T+8)$_____3.7

Because of some unknown, the above equation (3.7), a regression analysis was performed and the analysis yielded the equation.

Et_p = 0.75class A = $P(0.45T+8)(520-R^{1*31})/100$ ($mmday^{-1}$) __3.8

Preliminary trials showed that this equation (3.8) is satisfactory. It was however, observed that Etp-values for some months (NOV-JAN) were consistently higher than the corresponding measured open-water evaporation.

Further investigation was carried out and the final accepted Blaney-morin equation becomes:

Et_p = $rt(0.45T+8)(520 - R^{1.31})/100$ ______ 3.9

3.5 DETERMINATION OF DRAIN WATER DEPTH

Pipe depth is defined as the distance from the surface to the bottom of the pipe and it varies in different soils. The depth of pipe drain should be such as to provide the desired water-table depth midway between drain lines. Pipe depth is affected by soil permeability, outlet depth, spacing of laterals, depth to the impermeable layer in the subsoil, and limitations of trenching equipment. The depth of the main drain is governed by outlet conditions and topography.

In selecting drain depth, under no conditions should the amount of cover over the top of the pipe be less than 0.6m. This minimum is necessary to protect the pipe from heavy surface loads and to prevent shifting of the tile. In uniformly permeable mineral soils, the depth of laterals usually varies from 80cm to 250cm (0.8-2.5m) unless limited by an impermeable layer. One should design for the maximum depth as this will permit a wide spacing. In deep organic soil the minimum depth should not be less than 120cm (1.2m) where the subsoil is relatively impermeable the pipe should be placed on or above the impermeable layer and if pipe must be placed below the impermeable layer, the trench should be back-filled with permeable soil.

In humid regions where the water table will rise to near the surface during heavy rainfall, the rate of drop is the important factors in organic soil, the water table may be maintained at a nearly uniform depth which may be above the pipe.

3.6 DETERMINATION OF PIPE DRAIN DIAMETER

The design flow for pipe drain is based on entirely different criteria for humid and irrigated conditions. In either case, the drainage coefficient is a convenient term for expressing the flow rate. It is defined as the rate of depth of water to be removed from the drainage area in 24 hours.

In humid areas, the drainage coefficient depend largely on rainfall. It is difficult to corrulate rainfall with drainage coefficient since the distribution of rainfall during the growing seasons and its intensity, must be considered along with evaporation and other losses. Rains of low intensity over a long period of time may produce high rates of outflow from the drains. Thus, the selection of a drainage coefficient is based primarily on experience and judgement. The drainage coefficient should be such as to remove excess water rapidly enough to prevent serious damage to the crops.

The hydraulic capacity of pipe drains diameter can be determined from the manning velocity equation. By equating the design flow to the hydraulic capacity at full flow, the required diameter is expressed as:

$$d = 51.7(D_c \times A \times n)^{0.375}\ 5^{-0.1875} \qquad 3.20$$

where;

d = Inside pipe drain diameter (mm)

D_c = Drainage coefficient (mm/day)

A = Drainage area in (ha)

n = roughness coefficient in manning equation

s = drains slope in (mm)

After computing the required drain size, the next largest commercial size is selected. The roughness coefficient in the manning equation will increase with the misalignment at the pipe joints and with the irregularities of the drain surface, such as roughness of the walls and joints and corrugated in tubing. Design coefficient for corrugated plastic tubing is 0.016.

For practical reasons a minimum tile size is usually specified if the capacity were to match the design flow exactly, the tile should be gradually enlarged starting from the upper end of the line. Local custom, availability of tile, accuracy of installation, and possible failure from sedimentation largely determine from minimum size. In most humid regions wet area, the minimum size recommended is between 70-100mm.

3.7 DETERMINATION OF DRAIN SPACING.

The procedure for the determination of drain spacing with the Hooghoudt formular involves the following steps:

i. Formulation of the basic design criteria(q&H)

ii. Establishment of the field drainage (h = w-H)

iii. Establishment of soil hydraulic conductivity (k)

iv. selecting of drain type (pipe)

v. Determination of the drain spacing (L) by solving the Hooghoudt formular;

Note: The last step solution of the Hooghoudt formular is done by trial and error, since L depends on d and d depends on L the Hooghoudt is of explicit in L which can only be found by trial and error. This was done by assuming a value for L and determining 'd' from table (4.7). Then for L . The calculated value of L is compared with the assumed value, and if they are not the same, then the value of L is modified and is repeated until the calculated and assumed values are equal.

3.8 DRAINAGE OUTLET

The drainage outlet is the most important part of the drainage system and must be selected before any design work can be done on the system. The main drainage outlet is ordinarily along a river or other natural drainage feature in the area sufficiently below the elevation of project land to provide adequate slope for the main drain.

The two principle types of outlets for pipe drains are gravity and pump. Pump outlets may be considered where the water level at the outlet is higher than the bottom of the pipe outlet for any extended period of time. Gravity outlets, by far the most common, include pipe drains constructed water ways, natural channels or well. Outlet ditches should have sufficient capacity to carry surface runoff and drain flow. Where the drains system is connected to other pipe drains, the outlet should have sufficient capacity to carry the additional discharge.

CHAPTER FOUR

4.0 DESIGN CONSIDERATION OF PIPE DRAINAGE SYSTEM

4.1 **TOPOGRAPHICAL REPORT**

The survey and its result (topographical map) of the experimental area is as shown in figure 4.0 inside the pocket jacket of this project work. Detailed procedure is as explained in Umaru (1999)

4.2 **PHYSICAL PROPERTIES OF THE SOIL**

The physical properties of the soil are as carried out and reported in Idris (1997), Okoje (198). Some of the physical properties from the above named work were used in this project work and has been properly acknowledged and reference are as shown in Appendix A.

4.3 **STREAM SURFACE VELOCITY AND DISCHARGE**

The result of the experiment carried out at the project site discussed in chapter three (3.3) is as shown below in table 4.0.

Readings	Breadth of stream taken (m)	Length of stream measures stream taken (m)	Depth of steam taken (m)	Time taken to flow (see)
1st reading	54.7	30	1.1	2.55
2nd reading	64.1	30	1.3	3.01
3rd reading	70.1	30	1.2	2.49

Table 4.0 Result of experiment.

DESIGN CALCULATION

A: **BREADTH OF STREAM**

Total breadth of stream measured = 54.7+64.1+70.1=188.9m

Average breadth of stream = $\frac{188.9}{3}$ = 62.960m = 63m

B: **LENGTH OF STREAM**

Total length of stream measured = 30+30+30 = 90m

C: **DEPTH OF STREAM**

Total depth of stream measured 1.1+1.3+1=2 3.6

Average depth = 3.6/3 = 1.2m

D: **TIME TAKEN**

Total time taken = 2.55+3.01+2.49 = 8.05

Average time taken = 8.05/3 = 2.68

= 3min.8sec.

= 128sec.

	TOTAL VALUE	MEAN VALUE
BREADTH	188.m	63m
LENGTH	90m	30m
DEPT	3.6m	1.2m
TIME	8.05m	3.08min.

Table 4.1 stream flow value.

From equation 3.1

Q = AV (parameters are as defined ineq 3.1)

A = LxB = 30x60 = $1890m^2$

V = L/t = 30/3.08 = $9.7m^{2/s}$

Q = 1890x9.7 = $18333m^3$/sec.

4.4 **EVAPOTRANSPIRATION**

4.4.1 **BLANEY-CRIDDLE**

From equation 3.4,Blaney Criddles method, where

U = kp(0.46tc+813)-

The value of evapo-transpiration (ET) was calculated and the result is as shown in table (4.1 a & 4.1b),(4.2a & 4.2b) and (4.3a & 4.3b) for 30 years (1965-95) and 15 years (1985-99) and 1 year (1999). Also the graphical representation of these value are as shown in fig 4.1, 4.2, 4.3 for 30 years, 15 years and 1 year respectively. In these graphs the value of ET, and rainfall is plotted against months. This enable the months that needs drainage, as well as irrigation to be known.

4.4.2 **BLANEY-MORIN-NIGERIA**

From equation 3.9,Blaney-morin-Nigeria model. Where:

$Et_p = rt\ (0.45T+8)\ (520-R^{1.31})/100$

The value of evapo-transpiration (ET) was calculated and the result is a shown in table (4A-I &4A-2) (4B-1 & 4B-2) and (4C-1 & 4C-2) for 30 years (1965-95) 15 years (1985-99) and 1year (1999) respectively. Also, the graphical representation of false values are shown in figure 4.4 (graph4) figure 4.5 (graph 5) and figure 4.6 (graph 6) for 30 years, 15 years, and 1 year respectively. In these graph the values of ET and rainfall is plotted against month. This enables the period that needs drainage and irrigation to be known.

4.5 **CLIMATIC DATA**

The climatic data collected and used in this design are as shown in Appendix 4a - 4e of this project work.

4.6 **WATER BUDGET**

4.6.1 **BLANEY-CRIDDLE MODEL**

From table 4.1a and 4.1b and using equation 3.4, the water budget for the period of 30 years (1965-1995) is calculated as in table 4.4.4a and shown in graph one (1) figure 4.1. Also from table 4.2a and 4.2b, and using equation 3.4, the water budget for 15 years (1985-99) is calculated as in table (4.4b) and shown in graph two (2) figure 4.2. In accordance, the water budget for 1 year (1999) is calculated as in table (4.4c) and shown in graph three (3) figure 4.3, using table 4.3a and 4.3b with equation 3.4.

4.6.2 **BLANEY-MORIN-NIGERIA MODEL**

From table 4A-I and 4A-2 and using equation 3.9 the water budget for the period of 30 years (1965-1995) is calculated as shown in table 4D-1. Also, table 44B-1 and 4B-2 and using equation 3.9 the water budget for the period of 15 years is calculate as shown in table 4D-2. In accordance is table 4C-1 and 4C-2, and with equation 3.9 the water budget is calculated as shown in table 4D-3 for 1 year.

4.7 **WATER DEPT DESIGN**

The primary consideration in drainage design is to produce adequate root depth above saturated zones. In selecting the drain depth, the root depth of the crop itself was taken into consideration and found to be 60cm below surface level during the growing period. Also, water table rise to near the surface during heavy rainfall and the rate of drop is another important factor that was taken into consideration before the selecting of the drain depth. This rate of drop is as shown in figure 4.6 (graph 4), and is taken to be 50cm below the ground surface and 100cm at the surface level. From literature, it has been found that for such land (wet land) as in the experimental area, the drainage depth should be between 70-120cm. So based on these factors stated above, and some other factors like outlet dept, spacing of lateral depth (depth at which the pipe drain can be layed) is chosen to be 80cm (0.8m).

4.8 DESIGN OF PIPE DRAIN DIAMETER

water surplus = 5.45mm (obtained from 15 years water budget in table 4.2b and graph 2(figure 4.2)

Taking safety into consideration for the design, water surplus now becomes:

Water surplus = 5.45x1.5 (1.5 =safety factor valued)

= 8.175mm

= 8.18mm

From equation 3.1

Q = AV (parameters are defined ineq. 3.1)

$$V = \frac{8.18\text{x}10^{-3}}{122\text{x}24\text{x}3600} \quad \text{(m/s)}$$

$$= \frac{8.18\text{x}10\text{-}3}{10540800} \quad \text{m/s}$$

$$= 7.7.603217.87\text{x}10^{-10} \quad \text{m/s}$$

$$= 7.70\text{x}10^{-10} \quad \text{m/s}$$

And given that

Area (A) = 1890m^2 (from section 4.3)

then

Q = AV

= $1890m^2 x 7.76x10-10$ m/s

= $1.46664x10-6\ m^3/sec$

= $1.47x10-6\ m^3/sec$

Now, to get the discharge (q) per day, which is also the drainage coefficient.

$$q = \frac{\text{water surplus}}{\text{no of days}}$$

$$= \frac{8.18}{122}$$

= 0.0070491803 mm.day

= 0.07mm. day

Thus,

From equation 3.2

$$d\ \text{design} = 51.7\ (Dc \times A \times n)^{0.375} \times s^{-0.1875}$$

And

Dc = 0.07mm.day

A = $1890m^2$ (0.19ha)

n = 0.016 (manning design constant for corrugated plastic pipe)

s = 0.75 (Idris, (1997)

Substituting into the above equation:

$$d\ \text{design} = 51.7\ (0.07x0.19x0.076)^{0.375}\ xs^{-0.1875}$$

= 51.7(0.0419745699) 1.055421685

= 2.290373002mm

= 0.23cm

Thus, the nearest largest diameter is chosen so:

d design = 25mm

4.9 DESIGN OF DRAIN SPACING

Field drainage base depth (w) = 80cm (0.8m)

Desired water table depth (H) =60cm (0.6m)

water table head (h) =W-H= 0.8-0.6=0.2

From equation 3.6

$$L^2 = \frac{8kdh}{q} \quad \text{(simple Hooghoudt formular)}$$

where;

L = drain spacing (m)

k = soil hydraulic conductivity

d = Reduced depth (m)

h = water table head (m)

q = discharge (mm/day)

And given that,

for 1st trial

Assume length = 20m

d = 0.50 (from table 4.7)

k = 7.52×10^{-4} (Idris, 1997)

h = 0.2

q = 1.47×10^{-6} m^3ls

substituting into simple Hooghoudt formular

$$L^2_{Design} = \frac{8 \times 7.52 \times 10\text{-}4 \times 0.50 \times 0.2}{1.47 \times 10^{-6}}$$

$$L^2_{Design} = \frac{6.016 \times 10^{-4}}{1.47 \times 10^{-6}}$$

$$L^2_{Design} = 409.2517007$$

$$L_{Design} = \sqrt{409.2517007}$$

$$L_{Design} = 20.23m$$

Design not satisfactory because the assume length value is not equal to the calculated length value

for 2nd trial

Assume length = 25m

k = 7.52×10^{-4}

h = 0.2

d = 0.90

q = 1.47×10^{-3}

substituting into simple Hooghoudt formular

$$L^2_{Design} = \frac{8 \times 7.52 \times 10^{-4} \times 0.90 \times 0.2}{1.47 \times 10^{-6}}$$

$$L^2_{Design} = \frac{1.08288 \times 10^{-3}}{1.47 \times 10^{-6}}$$

$$L^2_{Design} = 736.6530612$$

$$L_{Design} = \sqrt{736.6530612}$$

$$L_{Design} = 27.14m$$

Design is satisfactory because the assume length value is equal to the calculated length value.

3rd trial

Assume length $=$ 25m

$k = 7.52x10^{-4}$

$h = 0.2$

$d = 0.75$

$q = 1.47x10^{-3}$

Substituting into simple Hooghout formular

$$L^2_{Design} = \frac{8x7.52x10^{-4}x0.75x0.2}{1.47x10^{-6}}$$

$$L^2_{Design} = \frac{9.024x10^{-4}}{1.47x10^{-6}}$$

$$613.877551$$

$$L^2_{Design} = \sqrt{613.877551}$$

$$= 24.77655244$$

$$L^2_{Design} = 25m$$

Design is satisfactory because the assume length value is equal to the calculated length value.

4.10 REQUIRED NUMBER OF PIPE

Given that

water surplus $= 8.18x10^{-3}$ m

area of land $= 1890m^2$

Total no. to be drained $= 1890\ m^2\ x8.18x10^{-3}$

$= 15.4602\ m^3$

$= 15.46\ m^3$

Also,

Length of pipe $=$ 100m(standard commercial length)

Diameter of pipe $=$ 25mm($25x10^{-3}$ m)

Volume of pipe $= 25x10^{-3}\ x100$

$= 2.5\ m^3$

Required number of pipe to drain

$$= \frac{\text{total volume of area}}{\text{total volume of pipe}}$$

$$= \frac{}{2.5}$$

= 6.18408

= 7 pipes

To find the time taken of the water to be drain.

Quantity of water (water surplus, = 818mm)

no of days = 122

Amount of water to be drain/day

$$= \frac{8.18}{122}$$

= 0.0670491803

= 0.07mm/day

Amount of water to be drain in 1 hour

$$= \frac{0.07}{24}$$

$= 2.92 \times 10^{-3}$ mm/hr

Amount of water to be drain in 1 minute

$$= \frac{0.07}{24 \times 60}$$

$= 4.86 \times 10^{-5}$ mm/min.

Amount of water to be drain in 1 sec

$$= \frac{0.07}{24 \times 60 \times 60}$$

$= 8.10 \times 10^{-7}$ mm/sec.

4.11 FRICTIONAL LOSS

In designing an underground pipe drain system, the head loss due to friction in the pipe and other factors are taken into consideration.

Friction head exists on both the suction and the discharge side of pipe and varies with the rate of flow of the water. Pipe size, condition of the interior of the pipe and the material of which the pipe is made.

The formular for friction loss determination is given by Darcy-Wisbach

$$h_f = \frac{4flv^2}{2gd}$$

where;

h_f = loss of pressure in pipe (head-loss)

f = friction factor

L = length of pipe (m)

V = velocity of flow (m^3/s)

d = pipe diameter (m)

And, given that:

f = 0.005 for new pipe) Michael (1978)

L = 100m (standard commercial length of pipe)

V = 7.76x 10^{-10} m/s

d = $25x10^{-3}$ m

Substituting this into the equation

$$= \frac{4flv^2}{2gd} = \frac{4x0.005x100x7.76x10^{-10}x7.76x10^{-10}}{2x9.81x2.5x10^{-3}} m$$

$$h_f = \frac{1.204352x10^{-18}}{0.04905} \text{ /';[p-0 m}$$

$$= 2.46x10^{-17}m$$

Note: This value will now be the frictional loss in the pipe.

4.12 **PIPE ANGLE**

Slope = 0.75 (Idris, 1997)

pipe spacing = 25m

Slope length = ?

Given that,

slope = 0.75 =$\tan^{-1}$ 0.75 = 36.87^0

thus,

pipe angle = 36.9^0

To find slope length,

$$\cos q = \frac{25}{x}, \quad x = \frac{25}{\cos q} = \frac{25}{\cos q 36.9^0}$$

BC = 31.9m

To calculate for AB

$AB^2 = (31.3^2 - 25^2)^{1/2)} = (979.69-625)^{1/2} = 18.8m$

AB = 18.8m

Thus,

AB = 18.8m

BC = 31.3m (slope length)

Pipe angle = 36.9^0

4.13 MAIN DRAINAGE OUTLET DESIGN

The main drainage outlet design consideration in this project work is by gravity (natural drainage). This is because of nature of the land shape that is slopy in nature. The contour map of the experimental area is as shown in figure 4.0 inside the pocket book (inside backcover). The lateral drain pipe collects the excess water from either direction of the field to the mains (natural flow). This is why the Herringbone layout system is selected for this design. This system is adopted to areas that have a concave surface or a narrow drain with the land slopping to it from either direction. The main line is laid out nearly normal to the slope and follow the low area despite the large amount of double drainage (Land drained both by the laterals and the main or submains). The herringbone layout system is as shown in figure 2.4.

4.14 DRAINAGE PIPE MAINTENANCE

Sometimes, a drainage system becomes inadequate either because the soil conditions changes or a new crop with stricter requirement is grown or planned, or due to irregular maintenance of the system.

Drainage ditches and pipes needs to be kept clean and free of excess vegetation and debris. Sometimes enough sediment accumulates in them to require removal. Field ditches may fill up as high as the land alongside them in a few years time. They must then be completely re-excavated. Thus regular maintenance is essential to keep any ditches functioning properly.

Grass growing on ditches bank is usually desirable for erosion control, but reeds and lattials in the water slow the flow and raise the water levėl, making the ditch less effective. Some ditches become clogged with vegetation that they loose all effectiveness, several techniques including moving, burning, use of herbicides and hand removal of vegetation should be or can be used to limit the amount of growth in ditches.

Pipe lines also needs maintenance though less frequently than ditches. Sometimes the pipe outlet is covered by debris or by high water in a outlet ditch. The covered outlet may cause water to deposit sediment capacity. Also, pressure builds up in the line and water may flow out into misalignment allows soil to enter and block the line, similar problems result when a heavy load crushes one or more pipes.

During the first year after installation, drain lines should be carefully watched to detect evidences of failure. Sinkholes over the line indicate a broken pipe or two wide a crack or opening surface water should be diverted across the trench, since this water may enter the drain or enrolled the bank fill and wash out the pipe. Sediment basin, should be cleaned at regular intervals. Surface inlets must be kept free of weed growth and sediment around the entrance.

Ultimately, adequate maintenance provide insurance for good crops production. Damage to pipe drains and the resulting development of poor drainage conditions and crop damage is one of the most costly result of lack of mainenance. The availability and cost of manual labour is a major factor in selecing the method of maintenance. The economy and feasibility of methods needs to be determined locally. These considerations and the feasibiliy of establishing maintenance methods as discussed before should be inclued in working out a maintenance plan.

4.15 COST

S/N	TYPE OF COST (COMPONENT COST)	AMOUNT (MILLION)
1	MACHINERY COST	100,000.00
2	MATERIAL COST	75,000.00
3	TRANSPORTATION COST	20,000.00
4	LABOUR COST	50,000.00
5	OVERHEAD COST	60,000.00
TOTAL		305,000.00

Table 4.15): Rough estimated cost of Drainage system.

Landlrainage is generally undertaken either to bring into production or to increae the productivity of existing cultivated land. It represent a capital invetment intended to result in future benefits and the viability of the drainageproject may and should be assessed like any other investment

Cost of pipe drainage systems vary from project to project and are valid for a limited period only. Therefore, emphasis is placed upon methods of cost calculation and on the structure of the total and component cost.

Some of the key factors to be considered for pipe drainage include: cost of machinery, cost of material, cost of construction, labour cost, overhead cost (including design and supervision), transportation cost.

4.15.1MACHINERY COST

This include all the purchase cost of the important drainage machinery and the implement that are needed for the construction. The cost of these machinery and equipment depends on the owners choice of machines and equipment type, size as well as availability, fuel consumption, oil and lubrication, maintenance and repair should also be considered.

4.15.2 MATERIAL COST

This includes the purchase cost of all the materials that are required. This cost is based on local selection and availability of the materials needed.

4.15.3 TRANSPORTATION COST

This includes the movement of machines, implement and materials from the place of purchase to the project site.

4.15.4 LABOUR COST

This involves salary cost of all the people involved in the project such as: operator, assistant operator and labourer.

4.15.5 OVERHEAD COST

This involves all the cost for design and supervising the project, as well as other miscellaneous.

Note: The figures given in table 5.0 are rough estimates. The actual cost of the project depends on a proper market survey of all the things required for t the project.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the step by step method and procedure carried out, a perfect drainage design has been achieved. Drainage and irrigation period (May-Oct. for drainage and Nov-April for irrigation) has also been specified. The proper layout pattern and arrangement of the drain spacing (25m), depth (0.8m), diameter (25mm) has also been fully analysed and achieved. Topographical map of the study location has also been achieved. The summary of this result is as shown in table 5.1.

Table 5.1 Summary of drainage parameters.

s/n	Design Parameter	Design Consideration Figures
1	Drain diameter	25mm
2	Drain spacing	25 meter
3	Drain depth	80cm
4	Drain Area	$1890m^2$
5	Outlet	By gravity
6	No of pipe	7
7	Frictional losses	$2.46x10^{-17}m$
8	Pipe angle	36.9^0
9	Total cost	=N=305million

Note: Total cost (=N= 305 million, includes Design, materials and installation.)

5.2 RECOMMENDATION.

It is highly recommended that, the maintenance of the drain pipe at periodic time should be done. This will ensure proper functioning of the drain pipes. Although, this methods and procedure used in this design is due to available data, other methods and procedure could be used in the of drainage system provided the required data are available. Also

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Table 4.1a. Summary of 30 years meteorological data (1961995) of the study location (Emiluge Baddegi)

Months	Rainfall (mm)	Relative humidity (%)	Air temperature (°c)	Sunshine hour (%)
JAN	1.0	59.1	25.0	7.0
FEB	2.0	52.9	26.7	7.3
MAR	21.0	61.6	30.9	6.7
APR	57.0	70.6	30.2	7.3
MAY	130.2	77.4	27.8	7.4
JUN	173.5	81.7	27.4	4.9
JUL	214.7	84.5	27.4	5.2
AUG	228.4	85.6	26.4	4.5
SEPT	205.5	84.2	25.6	5.7
OCT	85.8	79.2	25.2	7.4
NOV	1.5	73.3	25.7	8.4
DEC	0.5	64.0	22.2	7.7

Table 4.1b: Average summary of 30 years(1965-96) meteorological data of the study location (Emuligi Badeegi)

months	Average Rainfall (mm)	Average temperature (°c)	Average crop consumptive use (k)	Evapotranspiration(ET) (mm)	Average sunshine hour (p)
JAN	0.03	25.0	0.80	4.27	7.0
FEB	0.07	26.7	0.80	4.70	7.3
MAR	0.68	30.9	0.85	5.01	6.7
APR	1.90	30.2	0.85	5.38	7.3
MAY	4.20	27.8	1.00	6.09	7.4
JUN	5.78	27.4	1.15	4.60	4.9
JUL	6.93	27.4	1.30	5.62	5.2
AUG	7.37	20.4	1.25	4.49	4.5
SEPT	6.55	25.6	1.10	4.91	5.7
OCT	2.76	25.2	0.90	5.17	7.4
NOV	0.05	25.7	0.55	5.61	8.4
DEC	0.02	25.2	0.80	4.76	7.7

Source: N.C.R.I Badeggi meteorological dept

Note, this table is calculated from table 4.1a using Blaney-criddle model.

Months	Rainfall (mm)	Relative humidity (mm)	Temperature (°c)	Sunshine hour (%)(P)
JAN	1.24	59.2	25.34	6.68
FEB	2.2	49.1	28.1	6.90
MARCH	31.29	61.3	30.35	6.37
APRIL	64.74	71.2	30.65	7.04
MAY	147.89	78.5	28.65	7.22
JUNE	186.61	82.9	27.55	6.58
JULY	222.75	85.6	27.00	5.23
AUG	245.79	86.7	26.95	5.09
SEPT	186.81	85.5	26.7	5.92
OCT	111.57	82.3	27.6	7.02
NOV	1.48	73.1	27.35	7.95
DEC	0.0	63.5	25.00	7.12

Source: N.C.R.I Badeggi meteorological dept.

Table 4.2b: Average summary of 15 years (1985-99) meteorological data of the study location (Emuligi Baddegi)

Months	Average Rainfall (mm)	Average temperature (°c)	Average crop consumptive use (k)	Evapotranspiration(ET) (mm)	Average sunshine hour (p)
JAN	0.04	25.24	0.80	4.16	6.68
FEB	0.08	28.1	0.80	4.58	6.90
MARCH	1.01	30.35	0.85	4.71	6.37
APRIL	2.16	30.65	0.85	5.24	7.04
MAY	4.77	28.65	1.00	6.06	7.22
JUNE	6.22	27.55	1.15	6.20	6.58
JULY	7.19	27.00	1.30	5.50	5.23
AUG	7.93	26.95	1.25	5.14	5.09
SEPT	6.23	26.7	1.10	5.28	5.92
OCT	3.60	26.6	0.90	5.18	7.02
NOV	0.05	27.35	0.85	5.57	7.95
DEC	0.00	25.00	0.80	4.40	7.12

Source: N.C.R.I Badeggi meteorological dept.

Note: This table is calculated from table 4.2a using Blaney-criddle model.

Table 4.3 a: Summary of 1 year (1999) meteorological data of the study location (Emuligi Baddegi)

Months	Rainfall (mm)	Relative humidity (%)	Temperature (°c)	sunshine hour (%) (P)
JAN	0.0	54.0	18.0	7.56
FEB	2.8	57.0	17.0	6.85
MARCH	0.8	68.0	13.0	7.23
APRIL	112.1	70.0	12.0	6.85
MAY	135.4	79.0	10.0	7.35
JUNE	196.8	85.0	9.0	7.35
JULY	256.1	87.0	8.0	4.78
AUG	194.5	86.0	7.0	4.79
SEPT	153.7	86.0	8.0	6.05
OCT	98.0	85.0	13.0	6.64
NOV	0.0	72.0	14.0	8.48
DEC	0.0	63.0	18.0	7.15

Source: N.C.R.I Badeggi, meteorological dept.

Table 4.3b: Average summary of 1 year (1999) meteorological location (Emuligi Baddegi)

Months	Average Rainfall (mm)	Average temperature (°c)	Crop consumptive use (k)	Evapotranspiration(mm)	sunshine hour (p)
JAN	0.00	18.0	0.80	3.91	7.56
FEB	0.10	17.0	0.80	3.44	6.85
MARCH	0.03	13.0	0.85	3.41	7.23
APRIL	3.74	12.0	0.85	3.11	6.83
MAY	4.37	10.0	1.00	3.68	7.35
JUNE	6.56	9.0	1.15	4.08	7.35
JULY	8.26	8.0	1.30	2.89	4.78
AUG	6.27	7.0	1.25	2.68	4.79
SEPT	5.12	8.0	1.10	3.09	6.05
OCT	3.16	13.0	0.90	3.32	6.64
NOV	0.00	14.0	0.85	4.13	8.48
DEC	0.00	18.0	0.80	3.70	7.15

Source: N.C.R.I Badeggi meteorological dept.

This table is calculated from table 4.3a using Blaney-criddle model

Table 4.4a :Water budget for 30 years (1965-1985) at project site (Emuligi Badeegi) Blaney-criddle model.

Months	Rainfall (mm)	Evapotranspiration (ET)	Deficit (mm)	Surplus (mm)
JAN	0.04	5.08	5.04	
FEB	0.08	6.41	6.33	
MARCH	1.01	5.21	4.2	
APRIL	2.16	4.90	2.74	
MAY	4.77	4.12		0.65
JUNE	6.22	3.29		2.93
JULY	7.19	2.40		4.79
AUG	7.93	2.26		5.67
SEPT	6.23	2.72		3.51
OCT	3.60	3.57		0.03
NOV	0.05	4.97	4.92	
DEC	0.00	5.02	5.02	
TOTAL	39.28	49.95	28.25	17.58

Note: calculated from table 4B-2 using Blaney-morin Nigeria model.

Table 4.4b: Water budget for 15 years (1985-1999) at study location (Emuligi Baddegi)-Blaney-criddle model.

Months	Rainfall mm	Evapotranspiration (ET)	Deficit	surplus
JAN	0.03	4.27	4.24	
FEB	0.02	4.70	4.63	
MARCH	0.68	5.01	4.33	
APRIL	1.90	5.38	3.48	
MAY	4.20	6.09	1.89	
JUNE	5.78	4.60		1.18
JULY	6.93	5.62		1.31
AUG	7.37	4.49		2.88
SEPT	6.88	4.91		1.94
OCT	2.76	5.17	2.41	
NOV	0.05	5.61	5.56	
DEC	0.02	4.76	4.74	
[illegible]	[illegible]	60.61	31.28	7.31

Table 4.4c: Water budget for 1 year (1999) at [illegible]

Baddegi) Blaney-criddle model.

Months	Rainfall (mm)	Evapotranspiration (ET) (mm)	Deficit	Surplus
JAN	0.04	4.16	4.12	
FEB	0.08	4.58	4.5	
MARCH	1.01	4.71	3.7	
APRIL	2.16	5.24	3.08	
MAY	4.71	6.06	1.29	
JUNE	6.22	6.20		0.02
JULY	7.19	5.50		1.69
AUG	7.93	5.14		2.79
SEPT	6.23	5.28		0.95
OCT	3.60	5.18	1.38	
NOV	0.05	5.51	5.46	
DEC	0.00	4.40	4.4	
TOTAL	39.28	61.96	28.13	5.45

Note: This table is calculated from table 4.2b Blaney-criddle model.

Table 4D-1: Water budget for 30 years (1965-1985) at project site (Emuligi Baddegi)- Blaney-morin Nigeria.

Months	Rainfall(mm)	Evapotranspiration (ET) (mm)	Deficit	Surplus
JAN	0.00	3.91	3.91	
FEB	0.10	3.44	3.34	
MARCH	0.03	3.41	3.18	
APRIL	3.74	3.11		0.63
MAY	4.37	3.68		0.69
JUNE	6.56	4.08		2.48
JULY	8.26	2.68		3.59
AUG	6.27	2.68		3.59
SEPT	5.12	3.09		2.03
OCT	3.16	3.32	0.16	
NOV	0.00	4.13	4.13	
DEC	0.00	3.70	3.70	

Table 4A-1 Summary of 30 years meteorological data (1965-1995) of the study location (Emuligi Baddegi)

Months	Rainfall (mm)	Relative humidity	Air temperature (°c)	sunshine hour % (P)
JAN	1.0	59.1	25.0	7.0
FEB	2.0	52.9	26.7	7.3
MARCH	21.0	61.6	30.9	6.7
APRIL	57.0	70.6	30.2	7.3
MAY	130.2	77.4	27.8	7.4
JUNE	173.5	81.7	27.4	4.9
JULY	214.7	84.5	27.4	5.2
AUG	228.4	85.6	26.4	4.5
SEPT	205.5	84.2	25.6	5.7
OCT	85.8	79.2	25.2	7.4
NOV	1.5	73.3	25.7	8.4
DEC	0.5	64.0	22.2	7.7

Source: N.C.R.I Baddegi, metrological dept

Table 4A-2 Average summary of 30 years meteorological data (1965-1995) of the study location (Emuligi Baddegi).

Months	Average rainfall(mm)	Average temperature(°c)	Average crop consumptive use (k)	Evapotranspiration (ET) mm	Average sunshine
JAN	0.03	25.0	0.80	5.27	7.0
FEB	0.07	26.7	0.80	6.23	7.3
MARCH	0.68	30.9	0.85	5.52	6.7
APRIL	1.90	30.2	0.85	5.07	7.3
MAY	4.20	27.8	1.00	4.24	7.4
JUNE	5.78	27.4	1.15	2.51	4.9
JULY	6.93	27.4	1.30	2.47	5.2
AUG	7.37	26.4	1.25	2.03	4.5
SEPT	6.85	25.6	1.10	2.62	5.7
OCT	2.76	25.2	0.90	3.83	7.4
NOV	0.05	25.7	0.85	5.02	8.4
DEC	0.02	25.2	0.80	5.01	7.7

Calculated from table 4A using Blaney-morin-Nigeria model.

Table 4B-1 Summary of 15 years (1985-1999) meteorological data of the study location. (Emuligi Baddegi)

Months	Rainfall (mm)	Relative humidity	Air temperature (°c)	sunshine hour % (P)
JAN	1.24	59.2	75.34	6.68
FEB	2.2	49.1	28.1	6.90
MARCH	31.29	61.3	30.35	6.37
APRIL	64.74	71.2	30.65	7.04
MAY	147.89	78.5	28.65	7.22
JUNE	186.67	82.9	27.55	6.58
JULY	222.75	85.6	27.00	5.23
AUG	245.79	86.7	26.95	5.09
SEPT	186.81	85.5	26.7	5.97
OCT	111.51	82.3	27.6	7.02
NOV	1.48	73.1	27.35	7.95
DEC	0.0	63.5	25.00	7.12

Source: N.C.R.I Baddegi metrological dept.

Table 4B-2 Average summary of 15 years (1985-1999) meteorological data of the study location (Emuligi Badeggi)

Months	Average rainfall(mm)	Average temperature(°c)	Average crop consumptive use (k)	Evapotranspiration (ET) mm	Average sunshine
JAN	0.04	25.24	0.80	5.08	6.68
FEB	0.08	28.1	0.80	6.41	6.90
MARCH	1.01	30.35	0.85	5.21	6.37
APRIL	2.16	30.65	0.85	4.90	7.04
MAY	4.77	28.65	1.00	4.12	7.22
JUNE	6.22	27.55	1.15	3.29	6.58
JULY	7.19	27.00	130	2.40	5.23
AUG	7.93	26.95	1.25	2.26	5.09
SEPT	6.23	26.7	1.10	2.27	5.97
OCT	3.60	26.6	0.90	3.57	7.02
NOV	0.05	27.35	0.85	4.97	7.95
DEC	0.00	25.00	0.80	5.02	7.12

Note: calculated from table 4B-1 using Blaney-morin-Nigeria model.

Table 4C-1 Summary of 1 year (1999) meteorological data of the study location (Emuligi Baddegi)

Months	Rainfall (mm)	Relative humidity	Air temperature (°c)	sunshine hour % (P)
JAN	0.0	54.0	18 0	7.56
FEB	2.8	57.0	17.0	6.85
MARCH	0.8	68.0	13.0	7.23
APRIL	112.1	70.0	12 0	6 85
MAY	135.4	79.0	10 0	7.35
JUNE	196.8	85.0	9.0	7.35
JULY	256.1	87.0	8.0	4.78
AUG	194.5	86.0	7.0	4.79
SEPT	153.7	86.0	8.0	6.05
OCT	98.0	85.0	13.0	6.64
NOV	0.0	72.0	14.0	8.48
DEC	0.0	630.	18.0	7.15

Table 4C-2 Average summary of 1 year (1999) meteorological data of the study location (Emuligi Baddegi)

Months	Average rainfall (mm)	Average temperature (°c)	Crop consumptive use (k)	Evapotranspiration mm	sunshine hour % (p)
JAN	0.00	18.0	0.80	5.01	7.56
FEB	0.01	17.0	0.80	4024	6.85
MARCH	0.03	13.0	0.85	3.32	7.23
APRIL	3.74	12.0	0.85	2.92	6.83
MAY	4.37	10.0	1.00	2.43	7.35
JUNE	6.56	9.0	1.15	2.00	7.35
JULY	8.26	8.0	1.30	1.18	4.78
AUG	6.27	7.0	1.25	1.17	4.79
SEPT	5.12	8.0	1.10	1.54	6.05
OCT	3.16	13.0	0.90	2.08	6.64
NOV	0.00	14.0	0.85	3.72	7.48
DEC	0.00	18.0	0.80		

Note; calcuated from table 4C-1 using Blaney-morin Nigeria model.

Table 4D-3: Water budget for 1 year (1999) at project site (Emuligi Baddegi) Blanney-morin Nigeria model.

Months	Rainfall (mm)	Evapotranspiration (ET) (mm)	Deficit (mm)	Surplus (mm)
JAN	0.00	5.01	5.01	
FEB	0.10	4.24	4.14	
MARCH	0.03	3.32	3.29	
APRIL	3.74	2.93		0.81
MAY	4.37	2.43		1.94
JUNE	6.56	2.00		4.56
JULY	8.26	1.18		7.08
AUG	6.27	1.17		5.1
SEPT	5.12	1.54		3.58
OCT	3.16	2.08		1.08
NOV	0.00	3.72	3.72	
DEC	0.00	4.15	4.15	
TOTAL	37.61	33.77	20.31	24.15

Note: calculated from table 4C-2 using Blaney-criddle Nigeria model.

Table 4.5a: Monthly mean temparature (°C) Maximum at Emilugi (1985-1999).

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL	MEAN
YEAR														
1985	36.0	37.0	37.0	35.0	34.0	31.0	30.0	31.0	31.0	33.0	35.0	33.0	403.0	33.6
1986	32.0	37.0	36.0	36.0	34.0	32.0	30.0	31.0	30.0	32.0	33.0	32.0	395.0	32.9
1987	32.0	37.0	37.0	38.0	35.0	33.0	31.0	31.0	31.0	33.0	34.0	33.0	405.0	33.8
1988	33.0	36.0	37.0	36.0	34.0	32.0	32.0	33.0	31.0	33.0	35.0	33.0	405.0	33.8
1989	32.0	36.0	38.0	38.0	33.0	32.0	31.0	31.0	31.0	32.0	35.0	34.0	403.0	33.6
1990	35.0	36.0	39.0	36.0	33.0	33.0	30.0	31.0	31.0	33.0	35.0	35.0	407.0	33.9
1991	34.0	37.0	37.0	35.0	32.0	32.0	31.0	30.0	32.0	32.0	35.0	33.0	400.0	33.3
1992	34.0	37.0	38.0	35.0	34.0	32.0	32.0	30.0	31.0	33.0	34.0	35.0	405.0	33.8
1993	34.0	37.0	37.0	38.0	32.0	32.0	31.0	31.0	32.0	33.0	36.0	35.0	408.0	34.0
1994	34.0	37.0	40.0	37.0	34.0	32.0	32.0	31.0	31.0	33.0	33.0	34.0	408.0	34.0
1995	34.0	37.0	40.0	37.0	34.0	32.0	32.0	31.0	31.0	33.0	33.0	34.0	408.0	34.0
1996	32.0	36.0	38.0	38.0	35.0	32.0	30.0	32.0	31.0	32.0	34.0	35.0	405.0	33.8
1997	36.0	38.0	38.0	36.0	34.0	32.0	32.0	32.0	32.0	33.0	36.0	35.0	414.0	34.5
1998	35.0	39.0	40.0	39.0	34.0	33.0	32.0	30.0	31.0	33.0	36.0	35.0	417.0	34.8
1999	35.0	37.0	38.0	37.0	34.0	32.0	31.0	30.0	31.0	33.0	35.0	35.0	408.0	34.0
TOTAL	508.0	544.0	570.0	551.0	506.0	482.0	467.0	465.0	469.0	491.0	519.0	511.0		
MEAN	33.87	36.9	38.0	36.7	33.7	32.1	31.1	31.0	31.1	32.7	34.6	34.1		

Table 4.5b: Monthly mean temparature(°C) minimum at Emilugi (1985-1999)

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL	MEAN
YEAR														
1985	18.0	17.0	24.0	25.0	24.0	22.0	23.0	23.0	22.0	23.0	20.0	16.0	257	21.4
1986	16.0	21.0	24.0	25.0	24.0	23.0	23.0	22.0	24.0	23.0	22.0	16.0	263	21.9
1987	17.0	21.0	23.0	24.0	24.0	25.0	24.0	23.0	23.0	23.0	19.0	16.0	262	21.8
1988	18.0	20.0	24.0	25.0	24.0	23.0	23.0	23.0	21.0	23.0	23.0	18.0	265	22.0
1989	17.0	21.0	20.0	24.0	24.0	23.0	23.0	23.0	23.0	22.0	20.0	10.0	250	20.8
1990	18.0	19.0	19.0	24.0	23.0	23.0	23.0	23.0	23.0	23.0	21.0	20.0	259	21.6
1991	17.0	22.0	22.0	24.0	23.0	23.0	22.0	23.0	19.0	20.0	21.0	15.0	251	20.9
1992	13.0	14.0	21.0	23.0	22.0	23.0	21.0	21.0	21.0	21.0	18.0	12.0	209	17.4
1993	14.0	17.0	21.0	24.0	23.0	22.0	22.0	22.0	22.0	23.0	22.0	18.0	250	20.8
1994	18.0	18.0	24.0	24.0	24.0	23.0	23.0	23.0	23.0	23.0	19.0	15.0	257	21.4
1995	15.0	17.0	24.0	26.0	24.0	24.0	23.0	23.0	23.0	23.0	19.0	17.0	258	21.5
1996	15.0	21.0	24.0	25.0	23.0	22.0	23.0	22.0	21.0	21.0	16.0	16.0	249	20.75
1997	22.0	20.0	23.0	24.0	23.0	22.0	23.0	23.0	23.0	23.0	21.0	17.0	264	22
1998	17.0	21.0	23.0	27.0	25.0	24.0	24.0	24.0	23.0	24.0	20.0	16.0	268	22.3
1999	17.0	20.0	25.0	25.0	24.0	23.0	23.0	23.0	23.0	23.0	21.0	17.0	264	22
TOTAL	252.0	289.0	341.0	369.0	354.0	345.0	343.0	344.0	334.0	338.0	302.0	239		
MEAN	16.8	19.3	22.7	24.6	23.6	23.0	22.9	22.9	22.3	22.5	20.1	15.9		

Table 4.5c: Monthly mean relative humidity at Emilugi (1985-1999)

MONTH YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL	MEAN
1985	54.0	21.0	61.0	75.0	76.0	85.0	85.0	86.0	84.0	80.0	71.0	56.0	834	69.5
1986	62.0	68.0	73.0	75.0	76.0	82.0	86.0	85.0	84.0	82.0	75.0	59.0	907	75.58
1987	61.0	61.0	62.0	60.0	67.0	80.0	84.0	87.0	85.0	78.0	72.0	64.0	861	71.75
1988	61.0	52.0	64.0	73.0	78.0	82.0	84.0	86.0	84.0	83.0	71.0	69.0	887	73.92
1989	47.0	24.0	56.0	72.0	81.0	83.0	86.0	89.0	85.0	84.0	73.0	51.0	831	69.25
1990	72.0	52.0	47.0	72.0	84.0	86.0	89.0	87.0	87.0	86.0	86.0	81.0	929	77.42
1991	69.0	72.0	72.0	61.0	85.0	82.0	91.0	92.0	88.0	88.0	81.0	66.0	967	80.58
1992	65.0	53.0	66.0	82.0	84.0	86.0	88.0	87.0	87.0	82.0	68.0	69.0	917	76.42
1993	51.0	52.0	62.0	67.0	75.0	83.0	87.0	87.0	87.0	83.0	80.0	67.0	881	73.42
1994	66.0	46.0	68.0	69.0	80.0	81.0	84.0	85.0	85.0	81.0	69.0	55.0	869	72.42
1995	50.0	40.0	69.0	69.0	75.0	81.0	84.0	89.0	85.0	81.0	67.0	69.0	859	71.58
1996	67.0	65.0	65.0	65.0	78.0	83.0	80.0	88.0	87.0	77.0	65.0	68.0	888	74.00
1997	57.0	30.0	54.0	70.0	77.0	82.0	84.0	82.0	83.0	82.0	72.0	57.0	830	69.17
1998	52.0	43.0	33.0	68.0	82.0	82.0	85.0	84.0	85.0	82.0	74.0	59.0	829	69.08
1999	54.0	57.0	68.0	70.0	79.0	85.0	87.0	86.0	86.0	85.0	72.0	63.0	892	74.33
Total	888.0	736.0	920	1068.0	1177.0	1243.0	1284.0	1300.	1202.0	1234.0	1096.0	953.0	13101	1091.75
Mean	59.2	49.1	61.3	71.2	78.5	82.9	85.6	86.7	85.5	82.3	73.1	63.5	878.7	73.26

Table 4.5d: Total Monthly rainfall(mm) at Emilugi (1985-1999)

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL	MEAN
YEAR														
1985	0.0	0.0	175.7	6.9	99.8	322.1	195.7	234.5	305.8	25.0	0.0	0.0	1365.5	113.79
1986	0.0	0.0	19.9	59.7	72.9	245.0	140.7	145.8	182.3	88.9	0.0	0.0	955.2	79.6
1987	0.0	2.7	28.0	28.0	123.9	103.2	247.7	405.1	156.3	91.3	0.0	0.0	180.2	98.35
1988	18.6	3.8	23.2	160.4	92.8	184.5	203.1	111.9	285.2	56.6	0.0	0.0	1134.1	94.51
1989	0.0	0.0	4.1	104.5	102.4	129.9	287.2	280.9	136.7	74.8	0.0	0.0	1120.5	93.38
1990	0.0	4.3	0.0	81.8	287.3	117.9	266.0	180.6	160.0	110.1	2.7	0.0	1210.7	100.89
1991	0.0	0.5	68.3	50.8	205.9	331.5	237.0	244.7	149.6	75.7	0.0	0.0	1364	113.67
1992	0.0	0.0	0.0	141.7	136.6	133.9	128.6	148.4	216.0	31.5	0.0	0.0	936.7	78.06
1993	0.0	0.0	61.6	8.9	154.7	241.8	206.9	308.4	240.4	152.8	0.0	0.0	1375.5	114.63
1994	0.0	0.0	0.0	38.9	171.9	151.4	75.8	425.7	194.0	602.1	0.0	0.0	1659.8	138.32
1995	0.0	0.0	22.9	43.8	92.3	128.7	236.7	307.5	152.2	105.6	12.3	0.0	1102	91.83
1996	0.0	18.9	0.0	12.6	199.9	190.7	207.8	326.1	170.5	41.8	0.0	0.0	1281.7	106.81
1997	0.0	0.0	64.9	53.9	129.3	279.2	219.0	227.2	145.7	135.4	7.2	0.0	1130.8	94.23
1998	0.0	0.0	0.0	67.1	213.2	78.5	239.0	145.5	153.7	103.0	0.0	0.0	1000	83.33
1999	0.0	2.8	0.8	112.1	135.4	196.8	256.1	194.5	153.7	98.0	0.0	0.0	1150.2	95.85
TOTAL	18.6	33.0	469.4	971.1	2218.3	2799.1	3341.3	3686.8	2802.1	1672.6	222	0.0	18034.5	1502.88
MEAN	1.24	2.2	31.29	64.74	147.89	186.61	222.75	245.79	186.81	111.51	1.48	0.0	1202.31	100.19

Table 4.6: Mean monthly ground water fluctuation measurements (cm) for July 1998-June 1999)

Months	peizometer (5) (cm)	peizometer (6) (cm)	peizometer (7) (cm)	peizometer (8) (cm)
JAN	50	58	68	60
FEB	50	52.5	66.5	55
MARCH	58	66.2	71.6	59.4
APRIL	61	69	78	64.75
MAY	65.5	71	82	68
JUNE	70	72.5	85	70.25
JULY	73.5	75.25	87	73.5
AUGUST	79	79.5	88.5	79.5
SEPTEMBER	86	89	95.5	89
OCTOBER	100	100	100	100
NOVEMBER	89.7	94	95.85	87.1
DECEMBER	63.5	74	81.63	74.5

Source: Umaru (1999)

Table 4.9: HYDRAULIC CONDUCTIVITY (K) OF SOIL (PROJECT SITE)

λ = 38.5cm square L = 7.5, λc = 15cm

Time (mins) 1	F1 Vol. (CK3) 1	B Vol. (CK3) 1	F2 Vol. (CK3) 3	Time (mins) 1	F1 Vol. (CK3) 1	F2 Vol. (CK3) 2	Time hr. 1	Vol. (CK3) 2	Discharge (m3/hr) 3	Hydraulic conducts CK/HR K=(3)+L A.HC
4.0	88.0	26.50	50.0	76.0	12.5					
8.0	75.0	23.5	46.0	80.0	15.8	Total				
12.0	59.0	22.0	46.5	84.0	16.5					
16.0	56.0	22.0	47.5	88.0	16.0					
20.0	50.0	23.0	46.0	92.0	15.0	F1	2	868.2	434.5	$7.52x10^{-4}$
24.0	45.0	22.5	46.0	96.0	13.5					
28.0	44.0	27.5	45.0	100.0	12.0	F2	2	409.5	204.75	$3.55x10^{-1}$
32.0	42.0	22.5	43.5	104.0	12.5					
36.0	33.0	22.0	44.0	108.0	12.3	F3	2	763.950	381.75	$6.61x10^{-1}$
40.0	25.5	22.0	44.0	112.0	12.0					
44.0	24.8	22.0	43.5	116.0	12.0					
48.0	26.0	22.0	43.0	118.0	12.0					
52.0	26.3	22.0	43.0							
56.0	23.0	22.0	43.0							
60.0	21.9	22.0	43.0							
63.0	23.8	22.0	43.0							
72.0	22.4	22.0	43.0							

Table 4.10 RESULT OF HYDRAULIC TESTING ON SOIL RAMPLES AT EMILUGI (PROJECT SITE).

Sample Description	Hydraulic reading (mm hg) 40 segs	Temperature (°)	Hydrometer Reading (mm hg) 2 hrs	Temperature (°)	% Band	% Silt	% Clay	Textural Triangle Classificati
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1st Fringe	1.00	27	0.00	27	92.96	0.00	7.04	Sandy
Bottom	24.00	27	10.00	27	44.96	28	27.04	Sandy
2nd Fringe	2.50	27	0.5	27	94.96	0.0	5.04	Sandy