DETERMINATION OF HYDROLOGIC COEFFICIENTS OF SANDY LOAM SOIL (CASE STUDY OF GIDAN KWANO CAMPUS OF THE FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE)

BY

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DECLARATION

hereby declare that this project work is a record of a research work that was undertaken and vritten by me. It has not been presented before for any degree or diploma or certificate at any niversity or institution. Information derived from personal communications, published and npublished works were duly referenced in the text.

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02-03-2012

Date

CERTIFICATION

ˌs is to certify that the project entitled "Determination of Hydrologic Coefficients of sandy m Soil (Case Study of Gidan Kwano Campus of the Federal University of Technology, nna, Niger State)" by Umar Justice Lukman meets the regulations governing the award of the ree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna. d is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my sweet mother, Rosemary Imoagene .

ACKNOWLEDGEMENT

My most sincere gratitude goes to God almighty who granted me the grace of healthy ving and wisdom to undergo and complete this research work. I cannot thank Him enough for is grace that was also made sufficient over my life throughout my stay in FUT, Minna. I say may His name alone be praised.

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ABSTRACT

There was need to estimate the amount of runoff that would occur after a storm event sing a simple mathematical model, to save researchers and designers the cost and rigors of ontinuous field experiment, especially in Nigeria. This was achieved by the determination of actors that directly affect runoff, such as infiltration rate, moisture content, slope, storm ntensity, time of storm event, soil surface condition, and also the type of soil. A rainfall imulator was used to be able to have a replicate event if the need arises. A catchment area of 8m^2 (6X3m) was used and ten (10) replicate of the catchment area was investigated to have an ccurate result. The type of soil used was found to be sandy loam soil after a sieve analysis of the soil sample. The average basic infiltration rate of the ten plots was found to be 1.3cm/hr using a double ring infiltrometer. The average slope was found to 2.00^0 (3.65%) using the change in height method. The moisture content before and after the simulation was found to be 23.76% and 26.99% respectively using the gravimetric method. The intensity of the simulated rainfall was and the time of simulation was 30mins. Having gotten sufficient data, multiple linear regression was used to find the relationship between all the investigated parameters, and a simple linear mathematical model was developed to be $Y = 28.979X_1 + 5.706X_2 + 6.863X_3 - 1.565C$. Where; X_1 = Initial moisture content (%), X_2 = Infiltration rates (cm/hr), X_3 = Surface Runoff (m^3) and C = Slope (Deg)

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Continued land development and land-use changes within cities and at the urban fringe present considerable challenges for environmental management. Hydrologic changes including increased impervious area, soil compaction, and increased drainage efficiency generally lead to increased direct runoff, decreased groundwater recharge, and increased flooding, among other problems (Booth, 1991). Hydrologic models, especially simple rainfall-runoff models, are widely used in understanding and quantifying the impacts on land-use changes, and to provide information that can be use in land-use decision making Basically, a method is needed whereby, for known or assumed conditions within a watershed, the runoff hydrograph resulting from any real or hypothetical storm can be predicted with a high degree of reliability. Such a method must be sufficiently general to allow the determination of the change in system response that would result from proposed water management projects within the watershed. Only with this type of analysis can such projects be designed on a rational basis to produce optimum conditions for a minimum cost (perman, 2011).

Some of the more common methods of describing the hydrologic performance of a watershed have been based upon years of rainfall records and the resulting runoff from each storm. Though, a great number of water control projects must be designed and installed on smaller watersheds where little or no past hydrologic records are available (Howard Perman 2011).

The concept of integrated watershed runoff coefficient has emerged as a new understanding for the interactions between the surface and subsurface pathways of water. This defines the bidirectional linkage that implies the main rationale for the unity of the two systems. In this regard, surface flow processes such as channel and overland flow are integrated to subsurface flow process in the unsaturated and saturated ground water flow zones via the dynamic interactions at the ground surface and channel beds. Only with this kind of approach can one determine a standard coefficient for some major soils in a watershed.

1.2 Statement of problem

It is important to study the relationship of rainfall, runoff and drainage basin characteristics. The establishment of a clear rainfall–runoff–drainage basin characteristics relationship is difficult due to the large number of variables which affect the process. It is more difficult to quantify the impact of vegetation change on rainfall-runoff relations for large basins where the interactions between land use, climatic characteristics and underlying hydrological are more complex and tend to change. therefore, to study the effects of storms and to replicate the conditions, many researchers have resorted to the use of artificially simulated rainfall system. Simulated rainfall provides easy results than natural rains. Which is carried out effectively from the stand point of time and labour. The storm characteristics can carefully

be controlled and the approach is more adaptable for certain type of studies.

1.3 Objectives of the Study

1. To determine the surface runoff and infiltration rate coefficients of disturbed and undisturbed sandy loamy soils in Gidan Kwano campus of the federal university of technology, Minna, Niger State, Nigeria.

2. To develop an empirical mathematical model/equation using the Crammer rule capable of determining the Mannining's coefficient for the various conditions of loamy soil in Gidan Kwanu area of Niger State for a small watershed.

3. To determine the relative contribution of the various components such as infiltration, surface slope and roughness and watershed shape in the generation of runoff hydrograph predicted by the model or equation.

1.4 Justification of the Study

Erosion, flooding and land degradation has increased noticeably in Nigeria during the last few decades through a breakdown in the equilibrium between population densities and traditional farming systems. Yet information concerning the extent causes, and control of water erosion in Nigeria still remains fragmentary and limited. This can be partly ascribed to the dependence upon field runoff plots under natural rainfall as the main data source (Lai, 2006; Roose, 2008). These are costly and demand long periods of observation. Because of financial limitations, measurements can be conducted only on a restricted number of sites. This failure can also be attributed to the dependent on results obtained from experiments conducted in foreign countries.

1.5 Scope of the Study

This project work shall cover the determination of hydrologic parameter such as infiltration rate, time of concentration, size , bulk density, type of soil, soil moisture content, sediment runoff and surface runoff. The slope of the watershed used shall also be determined.

Also, a simple mathematical model will be generated to show the relationship between the measured parameters and surface runoff.

CHAPTER TWO

2.0 LITERATUR REVIEW

By definition, hydrology is the scientific study of water and its properties, distribution, and effects on the earth's surface, soil, and atmosphere. Hydrologic analyses include estimation of peak runoff rates, volumes, and time distribution of storm waters runoff flows are fundamental in the design of storm water management facilities. This chapter addresses the movement of water over land resulting directly from precipitation in the form of storm water runoff (Perman, 2011.).

Land development changes how a watershed responds to precipitation. The most common effects are reduced infiltration and decreased travel time. Increased impervious surfaces and runoff velocities increase peak flow discharge volumes and rates. Total runoff volume is determined by the total drainage area of the receiving watershed, its infiltration characteristics, and the amount of precipitation. (Lai, 2006; Roose, 2008).

2.1 Time of Concentration

Time of concentration is a method used in hydrology to determinsse the response of a watershed to a rain event. It is defined as the time needed for water to flow from the most remote point in a watershed to the watershed outlet. It is a function of the topography, geology, and land use within the watershed (Hagan, 1994).

Time of concentration is useful in predicting flow rates that would result from hypothetical storms, which are based on statistically-derived return periods.URMP manual,2002. For many (often economic) reasons, it is important for engineers and hydrologists to be able to accurately predict the response of a watershed to a given rain event. This can be important for these things such as infrastructure development (design of bridges, culverts, etc.) and management, as well as to assess flood risk (Hagan, 1994).

2.1.1 Overland Flow

1. If the ground cover conditions are not homogeneous for the entire overland flow path, determine the travel time for each ground cover condition separately and add the travel times to get overland flow travel time. The average ground cover condition is not to be used. Travel time for overland flow is the simplest to measure and determine, and is most commonly used for small developments where a greater margin of error is acceptable (Berfield and Haan, 1994).

The procedures used to determine the overland flow are: 1.determine the length of overland flow and enter the monograph on the left axis, "Length in Feet". Intersect the "Coefficient of Imperviousness" to determine the turn point on the "Pivot" line. Intersect the "Percentage Slope" and read the travel time for overland flow (Hayes, 1994).

2. Kinematic Wave Method: This method allows for the input of rainfall intensity values, thus allowing you to adjust the model to a selected design storm, such as the region's 2-year, 10-year, or 100-year storms (Hayes, 1994).

The equation is

$$T_t = \frac{(0.93)L^{0.6}n^{0.6}}{i^{0.4}S^{0.3}} \qquad 2.1$$

Where:

Tt = travel time

L = length of overland flow in feet

n = Manning's roughness c

i = rainfall intensity Coefficient

S = slope in feet/foot

The first step is to decide on values for "L", "n", and "S". This leaves two unknown values (travel time and rainfall intensity.)

A trial and error process is then used to determine the overland flow time. First, assume a rainfall intensity value and solve the equation for travel time. Then compare the assumed rainfall intensity value with the rainfall intensity value that corresponds with the travel time on the I-D-F curve. The correct travel time will come from an assumed intensity which is equal to the intensity determine using the I-D-F curve (Haans, 2004).

c. Manning's Kinematic Equation: This is the method used in TR-55.

The equation is:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}s^{0.4}} \qquad 2.2$$

Where:

T_t = travel time (hr)

n = Manning's roughness coefficient (L = flow length (ft.)

P_2 = 2-year, 24-hour rainfall (in.)

s = slope of hydraulic grade line (feet/foot)

2.1.1.1 Shallow Concentrated Flow

To calculate the travel time of shallow concentrated flow, the velocity and slope of flow for the area is are determined, and whether the flow path is paved or unpaved. Next, the travel time is calculated using the following equations:

$$T_t(\text{Minute}) = L/60V \qquad 2.3$$

Where:

T_t = travel time (minutes)

L = length of shallow concentrated flow (feet)

V = velocity (feet per second)

2.1.1.2 Channel Flow

Simple methods using a monograph to calculate channel flow which are known are:

1. Length of channel flow in feet
2. Height above the outlet of the most remote point in the channel
3. Whether the channel is paved

simply use this data with the Kirpitch Chart to determine the travel time. (The resultant result must be multiplied by 0.2 if the channel is paved.)

b. Manning's equation: Manning's equation is used to determine the velocity of channel flow. Manning's equation can either be solved mathematically or by the use monograph.

Manning's equation is:

$$V = \frac{1.49r^{2/3}s^{1/2}}{n} \qquad 2.4$$

Where:

V = average velocity (ft./sec.)

r = hydraulic radius (ft.) and is equal to a/P_w

a = cross sectional flow area (ft.^{2})

P_w = wetted perimeter (ft.)

s = slope of the hydraulic grade line (ft./ft.)

n = Manning's roughness coefficient for open channel flow.

Once the velocity is found, the travel time is determined using the same method used for shallow concentrated flow. The time of concentration along the hydraulic path is simply the sum of the travel times for the overland flow, shallow concentrated flow, and channel flow.

$T_c = L_o + L_{sc} + L_c$

2.1.1.3 Calculating Time of Concentration

2.1.2 Izzard Formula

Based on a series of laboratory experiments by the Bureau for Public Roads, Izzard (1946) proposed a time concentration for roadways and turf surfaces. For small drainage areas without a defined channel and from which runoff behaves as a thin sheet of overland flow, the Izzard formula can be used for estimating the concentration time, t_c,

$$t_c = \frac{41L^{1/3}}{i^{2/3}}\left(\frac{0.007i+c_r}{s^{1/3}}\right) \qquad 2.6$$

Where:

t_c = concentration time, min

L = length of overland flow travel, cm

I = rainfall intensity, centimeter/hour

S = slope of ground surface, cm/100 cm

K = retardance coefficient

2.1.3 Kerby Formula

Kerby (1959) defined flow length as the straight-line distance from the most distant point of a basin to its outlet, measured parallel to the surface slope. Based on this definition, time of concentration can be evaluated as

$$t_c = 0.83(Lns^{-0.5})^{0.467} \quad 2.7$$

Where t_c = time of concentration

S = surface slope

n = Manning roughness coefficient

L = flow length

2.1.4. Kirpich Formula

The Kirpich empirical equation is normally used for natural drainage basins with well-defined overland flow routes along bare soil. For overland flow on impervious surfaces, the t_c obtained should be reduced by 60%. For overland flow on grass surfaces, the computed t_c should be increased by 100%. The Upland Method is a graphical solution for finding the average overland flow velocity and can be used for overland flow in basins with a variety of land covers. This method relates t_c to the basin slope and to the length and type of ground cover. The time of concentration, t_c, is commonly taken as the longest length of flow travel divided by the average velocity of flow.

$$t_c = 0.0078\left(\frac{L^{0.77}}{S^{0.385}}\right) \quad 2.8$$

Where:

t_c = concentration time, hrs

L = the longest length of water travel, m

S = ground surface slope = $\frac{H}{L}$

H = Difference in elevation between the most remote point on the basin and the collection point, m.

2.2.6.2 FAA Method

The Federal Aviation Administration (FAA, 1970) used airfield drainage data assembled by the U.S. Army Corps of Engineers to develop an estimate for time of concentration. The method has been widely used for overland flow in urban areas and is expressed as

$$t_c = \frac{0.39(1.1-C)L^{1/2}}{S^{1/3}} \qquad 2.9$$

Where;

t_c = concentration time, hrs

L = the longest length of water travel, m

L = ground surface slope, ms

C = dimensionless runoff coefficient.

2.1.6. Bransby Williams Equation

Bransbys Williams (1983) proposed the following expression for evaluation of time of concentration

$$t_c = 21.3L\frac{1}{A^{0.1}S^{0.2}} \qquad 2.10$$

Where;

t_c = concentration time, hrs

L = Channel Length, m

S = Linear Profile slope

A = Watershed Area

2.2.1 Types of soil

2.2.2 Loamy Soil

Loam is the soil material that is medium-textured. It feels as though it contains a relatively even mixture of sand, silt and clay because clay particles with their small size, high surface areas and high physical and chemical activities, exert a greater influence on soil properties than those of sand and silt. Loam soils are rather soft and friable. It has a slightly gritty feel, yet it is fairly smooth and slightly sticky and plastic when moist. Casts formed from this type of soils can be handled freely 'without breaking (www.rain.org/global.2009).

2.2.3 Clay Loam Soil

Soil is that thin outer layer of the made up of a mixture of mineral and organic materials, air and water formed from the underlying rocks, plant and animal material by different physical, chemical and biological processes. (Areola and Mamman, 1999).

This consists of soil material having the most even distribution of sand, silt and clay of any of the soil textural grade. When felt, it feels as if it posses more clay than sand or silt. Sticky and plastic when wet, it forms casts that are firm when moist and hard when dry. The moist soil forms a thin ribbon that will barely sustain its own weight when squeezed carefully between the thumb and fingers (WRB, 2006.).

2.2.3 Sandy Loam Soil

Sandy loams consist of soil materials containing somewhat less sand and more silt and clay than loamy sands. As such, they possess characteristics, which fall between the finer-textured sandy clay loam and the coarser-textured loamy sands. Many of the individual sand grains can still be seen and felt, but there is sufficient silt and/or clay to give coherence to the soil so that casts can be formed that will bear careful handling without breaking(WRB, 2006.).

2.3.1 Surface Runoff

This is the water flow that occurs when soil is infiltrated to full capacity and excess water from rain or other sources flows over the land. This is a major component of the hydrologic cycle (Keith, 2004). Runoff that occurs on surfaces before reaching a channel is also called a nonpoint source (Baven, 2004). If a nonpoint source contains man-made contaminants, the runoff is called nonpoint source pollution. A land area which produces runoff that drains to a common point is called a watershed (Nelson, 2004). When runoff flows along the ground, it can pick up soil contaminants such as petroleum, pesticides (in particular herbicides and insecticides), or fertilizers that become discharge or nonpoint source pollution (Baven, 2004).

2.3.2 Generation of surface Runoff

Surface runoff can be generated either by rain fall or by the melting of snow, ice, or glaciers. Snow and glacier melt occur only in areas cold enough for these to form permanently. Typically snowmelt will peak in the spring and glacier melt in the summer, leading to pronounced flow maxima in rivers affected by them. The determining factor of the rate of melting of snow or glaciers is both air temperature and the duration of sunlight. In high mountain regions, streams frequently rise on sunny days and fall on cloudy ones for this reason (Keith and Baven, 2004).

In areas where there is no snow, runoff will come from rainfall. However, not all rainfall will produce runoff because storage from soils can absorb light showers. On the extremely ancient soils of Australia and Southern Africa, proteoid roots with their extremely dense networks of root hairs can absorb so much rainwater as to prevent runoff even when substantial amounts of rain fall (South African Environmental Agency, 2001). In these regions, even on less infertile cracking clay soils, high amounts of rainfall and low potential evaporation are needed to generate any surface runoff, leading to specialized adaptations to extremely variable (usually ephemeral) streams (South African Environmental Agency, 2001).

2.3.3. Overland Flow

This occurs when the rate of rainfall on a surface exceeds the rate at which water is infiltrated into the soil, and any depression storage has already been filled. This is most common in the arid regions, where rainfall intensities are high and the infiltration capacity is reduced because of surface sealing, or in paved areas. This occurs largely in city areas where pavements prevent water infiltration (Susan, 2008).When the soil is saturated and the depression storage filled, and rain continues to fall, the rainfall will immediately produce surface runoff. The level of antecedent soil moisture is one factor affecting the time until soil becomes saturated. This runoff is saturation excess overland flow or saturated overland flow (Masten and Susan 2008).

2.3.4 Subsurface Return Flow

After water infiltrates the soil on an up-slope portion of a hill, the water may flow laterally through the soil, and exhilarate (flow out of the soil) closer to a channel. This is called subsurface return flow or through flow (South African Environmental Agency, 2001).

As it flows, the amount of runoff may be reduced in a number of possible ways: a small portion of it may evapotranspire; water may become temporarily stored in micro topographic depressions; and a portion of it may become run-on, which is the infiltration of runoff as it flows overland. Any remaining surface water eventually flows into a receiving water body such as a river, lake, estuary or ocean (Davis, 2008).

2.4.1 Infiltration

Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer (Walker, 1997).

Infiltration is governed by two forces, gravity and capillary action. While smaller pores offer greater resistance to gravity, very small pores pull water through capillary action in addition to and even against the force of gravity (Keith and Chris, 2002).

The rate of infiltration is affected by soil characteristics including ease of entry, storage capacity, and transmission rate through the soil. The soil texture and structure, vegetation types and cover, water content of the soil, soil temperature, and rainfall intensity all play a role in controlling infiltration rate and capacity. For example, coarse-grained sandy soils have large spaces between each grain and allow water to infiltrate quickly (Skogerboe, 1997). Vegetation creates more porous soils by both protecting the soil from pounding rainfall, which can close natural gaps between soil particles, and loosening soil through root action. This is why forested areas have the highest infiltration rates of any vegetative types (Walker and Skogerboe, 1997).

The top layer of leaf litter that is not decomposed protects the soil from the pounding action of rain, without this the soil can become far less permeable. In chaparral vegetated areas, the hydrophobic oils in the succulent leaves can be spread over the soil surface with fire, creating large areas of hydrophobic soil. Other conditions that can lower infiltration rates or block them include dry plant litter that resists re-wetting, or frost. If soil is saturated at the time of an intense freezing period, the soil can become a concrete frost on which almost no infiltration would occur. Over an entire watershed, there are likely to be gaps in the concrete frost or hydrophobic soil where water can infiltrate. Once water has infiltrated the soil it remains in the soil, percolates down to the ground water table, or becomes part of the subsurface runoff process (Walker, et.al., 1997).

2.4.2 Process of infiltration

The process of infiltration can continue only if there is room available for additional water at the soil surface. The available volume for additional water in the soil depends on the porosity of the soil and the rate at which previously infiltrated water can move away from the surface through the soil. The maximum rate that water can enter a soil in a given condition is the infiltration capacity. If the arrival of the water at the soil surface is less than the infiltration capacity, all of the water will infiltrate. If rainfall intensity at the soil surface occurs at a rate that exceeds the infiltration capacity, pounding begins and is followed by runoff over the ground surface, once depression storage is filled. This runoff is called Horton overland flow. The entire system of a watershed is sometimes analyzed using hydrology transport models, mathematical models that consider infiltration, runoff and channel flow to predict river flow rates and stream water quality (Lal, 1996).

2.4.3 Factors Influencing Infiltration

A number of factors impact soil infiltration. Some of these are:

- **Texture:** The type of soil (sandy, silty, clayey) can control the rate of infiltration. For example, a sandy surface soil normally has a higher infiltration rate than a clayey surface soil. A soil survey is a recorded map of soil types on the landscape.
- **Crust:** Soils that have many large surface connected pores have higher intake rates than soils that have few such pores. A crust on the soil surface can seal the pores and restrict the entry of water into the soil.
- **Compaction:** A compacted zone (plowpan) or an impervious layer close to the surface restricts the entry of water into the soil and tends to result in ponding on the surface.
- **Aggregation and Structure:** Soils that have stable strong aggregates as granular or blocky soil structure have a higher infiltration rate than soils that have weak, massive, or platelike structure. Soils that have a smaller structural size have higher infiltration rates than soils that have a larger structural size.
- **Water Content:** The content or amount of water in the soil affects the infiltration rate of the soil. The infiltration rate is generally higher when the soil is initially dry and decreases as the soil becomes wet. Pores and cracks are open in a dry soil, and many of them are filled in by water or swelled shut when the soil becomes wet. As they become wet, the infiltration rate slows to the rate of permeability of the most restrictive layer.
- **Organic Matter:** An increased amount of plant material, dead or alive, generally assists the process of infiltration. Organic matter increases the entry of water by protecting the soil aggregates from breaking down during the impact of raindrops. Particles broken from

aggregates can clog pores and seal the surface and decrease infiltration during a rainfall event.

Pores: Continuous pores that are connected to the surface are excellent conduits for the entry of water into the soil. Discontinuous pores may retard the flow of water because of the entrapment of air bubbles. Organisms such as earthworms increase the amount of pores and also assist the process of aggregation that enhances water infiltration.

2.5.1 Bulk density

soil was transferred into an empty can of known weight. The weight of the can and the soil content was taken before oven drying at a temperature of 110^0 for twenty-four hours. After drying, the can containing the soil was collected, allowed to cool before weighing again. Weight of the oven dry soil is calculated as weight of the oven dry clod with the container minus the weight of the container. The volume of the soil was determined from the volume of the can ($\pi r^2 h$). the bulk density was calculated using

$$Bulk\ density = \frac{weight\ of\ oven\ dry\ soil}{volume\ of\ oven\ dry\ soil}$$

$$D_b = \frac{wd}{vc}\ (g/cm^3)$$

Where;

w_d = weight of dry soil (g)

v_c= volume of the oven dry soil (cm^3)

Total porosity

The density method was used to determine the total porosity.

$$\text{Total porosity} = \frac{1-Db}{Db} \text{ X } 100$$

Where;

D_b = bulk density (g/cm^3)

D_b = particle density (g/cm^3)

Particle density is the weight per unit volume of solid space. Which can be determined using a pyrometer (specific gravity bottle). The gravity flask is weight and some. Some quantify of air-dry soil sample is added to the flask and the weight of the flask and soil are taken. The flask containing the sample is then flask is with water and at the same time the content is mixed gently to allow air trapped between the particles escape. The weight was taken and recorded. The temperature of then content is determined with a thermometer. The soil was transferred from the flask into a container, filled with boiled-cooled distilled water at constant temperature as before and the weight taken density of water was calculated as;

$$D_w \frac{\textit{weight of gravity bottle filled with water} - \textit{weight of specific gravity bottle}}{5c} \qquad 3.2$$

$$\frac{D_w (W_2 - W_1)}{(W_2 - W_3) - (W_3 - W_4)}$$

2.6.1 Soil

Soil is a thin outer layer made up of a mixture of mineral and organic materials, air and water formed from the underlying rocks, plant and animal material by different physical, chemical and biological processes. (Areola and Mamman, 1999).

2.6.1.1 Soil constituents

Soil consists of mineral matter, soil organic matter, and soil air and soil water.

2.6.1.2 Mineral matter

Mineral matters are solid inorganic materials in the soil. They include rock fragments which are undecomposed remnants of the original rock material from which the soil is formed, sand, silt and clay. In terms of mineralogy, these inorganic materials comprise the remnants of undecomposed primary rock minerals such as feldspars, micas, etc, clay minerals, oxide and mineral nutrients elements such as the bases, calcium, magnesium and potassium and trace elements like sodium, iron etc. (Areola and Mamman, 1999).

2.6.1.3 Soil organic matters

This include the litter of fallen leaves, twigs, fruits and animal droppings including carcasses on the soil surface, the humus formed from the decomposition of litter mixed with the mineral particles in the soil and the population of micro-organisms living in the soil which help in the breakdown of organic litter to release the nutrients stored in it to form humus. (Areola and Mamman, 1999).

2.6.1.4 Soil air

This acts as the 'atmosphere' for roots of plants micro-organism from where they obtain oxygen and into which they disposed unwanted gases. Soil air is replenished from time to time from the earth's atmosphere through the process known as gaseous exchange. However, the properties of soil air differ in some respects from those of the earth's atmosphere. (Areola and Mamman, 1999).

2.6.1.5 Soil water

This is the medium through which plants and many micro-organism obtain mineral elements from the soil. Soil water is important also as a weathering and leaching agent in soils. The water that occupies the macro pores during each rainfall and drain through the soil toward the water table is called 'free-draining or gravitational water'. It is of no use to plant, rather it washes away soil materials including plant nutrients. The water that is normally held within the micro pores is called 'Capillary water'. It is this type that is readily available to plant (Mamman, 1999).

2.6.1.6 Soil profile

Soil profile is the vertical section through the soil which underlying solid rock shows layers of earth of various, texture and consistency. Soil horizons are usually designated by the letters of the alphabets.

The A-horizon

This is the layer that is in direct contact with the atmosphere and the plant animal world. It is the zone of maximum chemical and biological activities in the soil. It is dark in colour because it column humus and also it also it loses fine humus and clay and silt particles to the horizons below through the processes of elevation and therefore referred to as an eluvia horizon.

The B-horizon

This is the second layer of a typical soil profile. It is an illuvial horizon because most of the find practical transferred from the A-horizon are usually deposited in it. It is generally more fine textured and compact than the A-horizon.

The C-horizon

It is made up of the soil parent material, that is the regolith or weathered material from which the soil is formed. It has little or no organic matters and its compactness is due to precipitation of accumulated materials and water over time (Onweluzo and Omotoso, 1999).

2.7.1 Soil Sampling

Soil sampling is the only direct method for measuring soil water content. When done carefully with enough samples it is one of the most accurate methods, and is often used for calibration of other techniques. This approach requires careful sample collection and handling to minimize water loss between the times a sample is collected and processed. Replicated samples should be taken to reduce the inherent sampling variability that results from small volumes of soil. Equipment required includes a soil auger or a core sampler (with removable sleeve of known volume to obtain volumetric water content), sample collection cans or other containers, a balance accurate to at least 1 gram and a drying oven.

Soil sampling involves taking soil samples from each of several desired depths in the root zone and temporarily storing them in water vapor-proof containers. The samples are then weighed and the opened containers oven-dried under specified time and temperature conditions (104Oc for 24 hours). The dry samples are then re-weighed. Percent soil water content on a dry mass or gravimetric basis, Pw, is determined with the following formula;

$$P = \left[\left(\frac{wet\ sample\ weight - dry\ sample\ weight}{dry\ weight\ sample}\right)\right] \text{x } 100$$

The difference in the wet and dry weights is the weight of water removed by drying. To convert to a gravimetric basis to water content on a volumetric basis, Pw, multiply the gravimetric soil water content by the soil bulk density (BD). Soil bulk density is the weight of a unit volume of even dry soil and usually is determined in a manner similar to gravimetric sampling by using sample collection devices which will collect a known volume of soil

$$BD = \frac{weight\ of\ oven\ dry\ soil}{unit\ volume\ of\ dry\ soil}$$

$$P_1 = P_w \text{ X } BD$$

Soil water content on a volumetric percentage basis is a preferable unit for irrigation management and this is easily converted to a depth of soil water per depth of soil. Comparison of the measured volumetric soil waster content with filed capacity and wilting point of the soil is used to determine the available soil water and the percent of total available soil water. Either of these figures can then be used to determine if irrigation is needed.

2.7.2 Soil moisture principles

Important soil characteristics in irrigated agriculture include:

1. The water-holding or storage capacity of the soil
2. The permeability of the soil to the flow of water and air.
3. The physical features of the soil like the organic matter content, depth, texture and structure; and

4. The soil's chemical properties such as the concentration of soluble salts, nutrients and trace elements.

The total available water, TAW, for plant use in the root zone is commonly defined as the range of soil moisture held at a negative apparent pressure of 0.1 to 0.33 bar (a soil moisture level called 'field capacity') and 15 bars (called the permanent wilting point). The total available water will vary from 25 cm/m for silty loams to as low as 6 cm/m for sandy soils. Other important soil parameters include its porosity, λ its volumetric moisture content, ω, its valuation, S, its dry weight moisture fraction, W, its bulk density, γ_b; and its specific weight vs. the relationships among these parameters are as follows.

The porosity, λ, of the soil is the ratio of the total volume of voids or space, V^p, to the total soil volume V:

$$\lambda = \frac{V_p}{V} \qquad 1.1$$

The volumetric water content, θ, is the ratio of water volume in the soil, V_w, to the total volume, V;

$$\theta = \frac{V_b}{V} \qquad 1.2$$

The saturation, S, is the portion of the pores space filled with water

$$S = \frac{V_w}{V_p} \qquad 1.3$$

These terms are further related as follows:

$$\theta = S \text{ x} \phi$$

When a sample of filed soil is collected and oven0dried, the soil moisture is reported as a dry weight fraction, W:

$$W = \frac{Wet\ Weight - Dry\ weight}{Dry\ Weight} \qquad 1.4$$

To convert a dry weight soil moisture fraction into volumetric moisture content, t he dry weight fraction is multiplied by the bulk density, γ_b; and divided by specific weight of water, γ_w that can be assumed to have a value of unity. Thus.

$$\theta = \frac{\gamma_b W}{\gamma_w} \qquad 1.5$$

The γ_b is defined as the specific weight of the soil particles, multiplied by the particle volume or one-minus the porosity.

$$\gamma_b = \gamma_b \text{ X } (1-\theta \qquad 1.6$$

The volumetric moisture contents at field capacity, θ_{fc}, and permanent wilting point, θ_{wp}, then are defined as follows

$$\theta_{fc} = \frac{\gamma_b W_{fc}}{\gamma_w} \qquad 1.7$$

$$\theta_{wp} = \frac{\gamma_b W_{fc}}{\gamma_w} \qquad 1.8$$

Where θ_{fc} and θ_{wp} are the dry weight moisture fractions at each point

Bulk density

Soil was transferred into an empty can of known weight. The weight of the can and the soil content was taken before oven drying at a temperature of 110^0 for twenty-four hours. After drying, the can containing the soil was collected, allowed to cool before weighing again.

Weight of the oven dry soil is calculated as weight of the oven dry clod with the container minus the weight of the container. The volume of the soil was determined from the volume of the can (πr^2h). the bulk density was calculated using

$$Bulk\ density = \frac{weight\ of\ oven\ dry\ soil}{volume\ of\ oven\ dry\ soil}$$

$$D_b = \frac{wd}{vc}\ (g/cm^3)$$

Where;

w_d = weight of dry soil (g)

v_c= volume of the oven dry soil (cm^3)

Total porosity

The density method was used to determine the total porosity.

$$\text{Total porosity} = \frac{1-Db}{Db} \text{ X } 100$$

Where;

D_b = bulk density (g/cm^3)

D_b = particle density (g/cm^3)

Particle density is the weight per unit volume of solid space. It was determined using a pyrometer (specific gravity bottle). An empty gravity bottle was weighed in air. Some quantify of air-dry soil sample is added to the flask and the weight taken. The flask containing the sample was filled with water and at the same time the content is mixed gently to allow air trapped between the particles escape. The weight was taken and recorded. The temperature of then content is determined with a thermometer. The soil was transferred from the flask into a container, filled with boiled-cooled distilled water at constant temperature as before and the weight taken density of water was calculated as;

$$D_w = \frac{weight\ of\ gravity\ bottle\ filled\ with\ water - weight\ of\ specific\ gravity\ bottle}{5c} \quad 3.28s$$

Particle density was calculated as

$$\text{Particle density } (D_p = \frac{D_w (W_2 - W_1)}{(W_2 - W_3) - (W_3 - W_4)} \quad 3.29$$

Where;

D_w = density of water

W_1= weight of specific gravity bottle

W_2 = weight of gravity bottle + soil

W_3 = weight of flask+ soil + water

W_4 = weight of gravity bottle filled with water

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The Federal University of Technology permanent site is known to have a total land mass of eighteen thousand nine hundred hectares (18,900 ha) which is located along kilometer 10 Minna – Bida Road, South – East of Minna under the Bosso Local Government Area of Niger State. It has a horse – shoe shaped stretch of land, lying approximately on longitude of 06^0 28' E and latitude of 09^0 35' N. The site is bounded at Northwards by the Western rail line from Lagos to the northern part of the country and the eastern side by the Minna – Bida Road and to the North – West by the Dagga hill and river Dagga. The entire site is drained by rivers Gwakodna, Weminate, Grambuku, Legbedna, Tofa and their tributaries. They are all seasonal rivers and the most prominent among them is the river Dagga. The most prominent of the features are river Dagga, Garatu Hill and Dan Zaria dam (Musa, 2003).

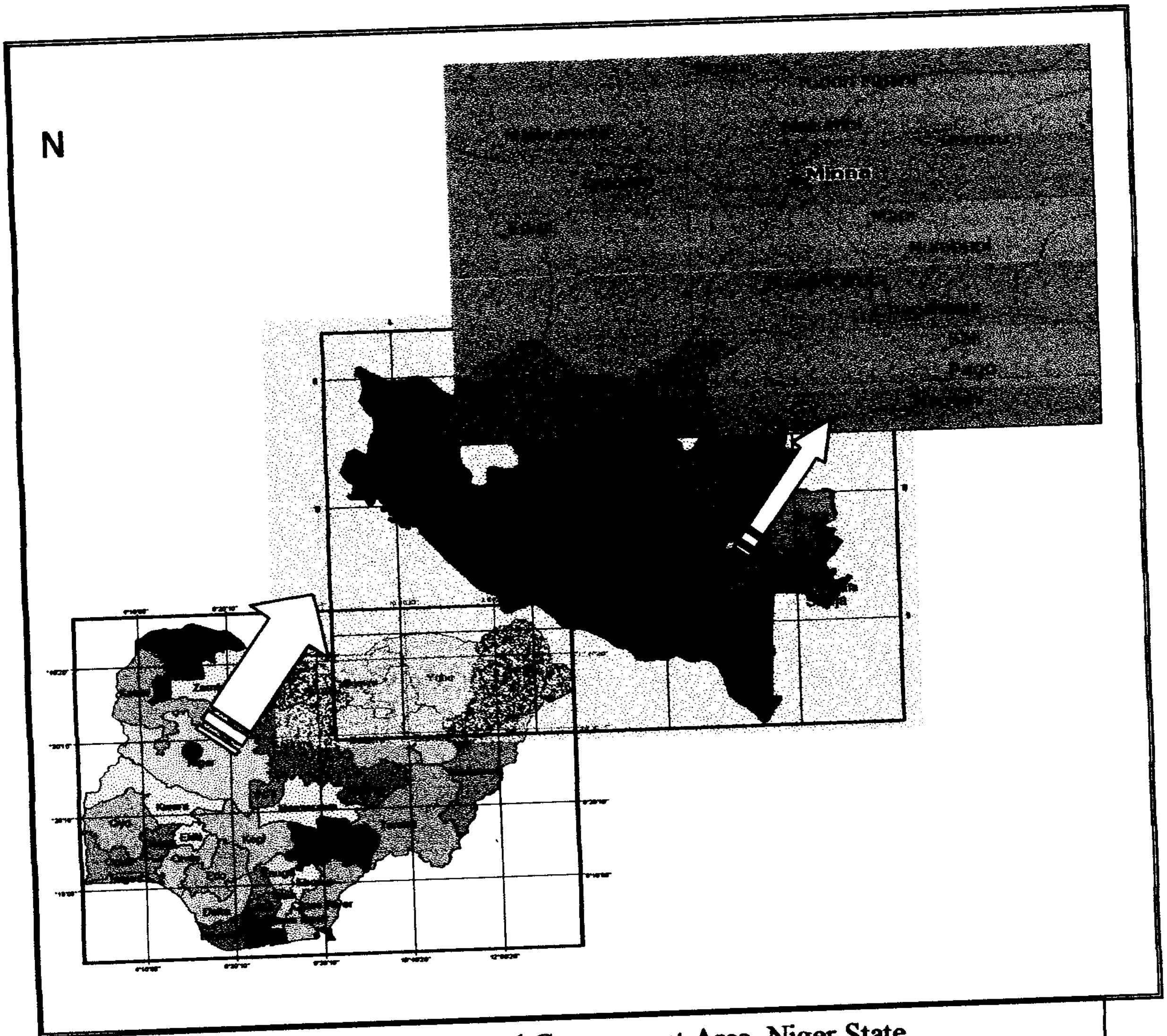
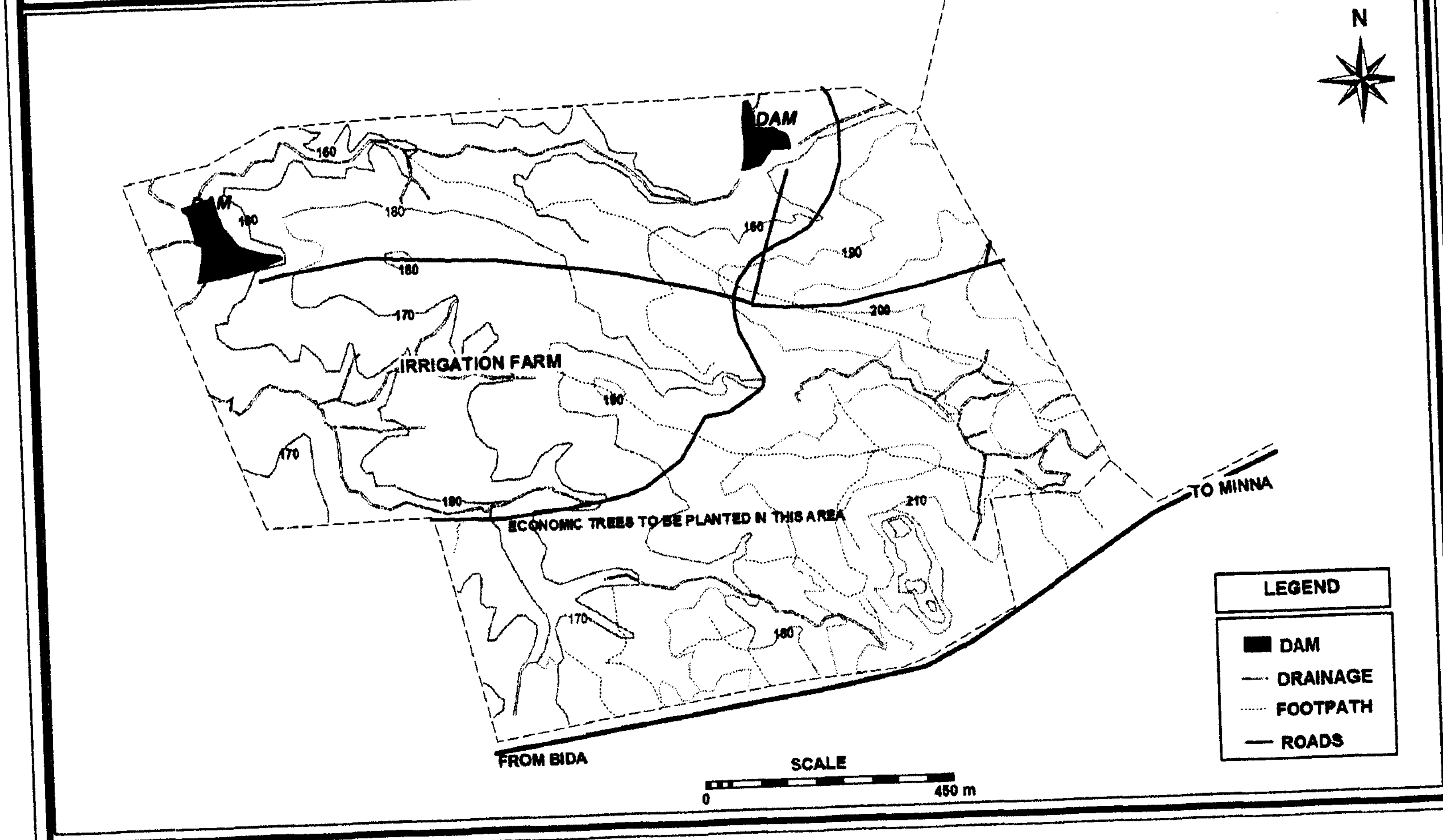


Figure 3.1: Map of Bosso Local Government Area. Niger State

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA PERMANENT SITE FARM



3.1.1 Vegetation and Land Use

Minna falls within the semi-wood land or tree forest vegetation belt with derived dry grass or shrub land known as the southern guinea savannah. This is also known as the transition belt, which lies between the savannah grass/shrub land of the north and the rain forest of the south. Due to intensive fallow type of agricultural practice and grazing of the land, the area is dominated by stunted shrubs; interspersed with moderate height tree and perennial foliage. Similarly, due to human activities and land use abuse which is characteristic of most expanding urban centre in Nigeria, the site is fast losing its remaining tree species to development. Along some river course and lowland areas, the vegetation is more wooded and resembles some forest affinities. The area is still being used as farm and grazing land by the residents of Minna and her environs (Musa 2003).

3.1.2 Climate

3.1.2.1 Rainfall

Minna generally is known to experience rainfall from the month of May to the month of October and on rear occasions, to November. It is known to reach its peak between the months of July and August. Towards the end of the rainfall season, around October, it is known to be accompanied by great thunder storms (Musa, 2003).

3.1.2.2 Temperature

The maximum temperature period in this area is usually between the months of February, March and April which gives an average minimum temperature record of 33^0C and maximum temperature of 35^0C (Minna Airport Metrological Centre, 2000). During the rainfall periods, the temperature within the area drops to about 29^0C.

3.1.3 Soils of the Area

The major soil found in this area is the sandy loam type with a sparse distinction of the sandy–clay soil and sandy soils. This has so far encouraged the residents of Minna metropolis and neighboring villagers to use the land for agricultural activities such as farming and grazing by the nomadic cattle rearers (Musa, 2003).

3.2 Field Topography and Configuration

This information requires that a surveying instrument be used to measure elevations of the principal field boundaries (including dykes if present), the elevation of the water supply inlet (an invert and likely maximum water surface elevation), and the elevations of the surface and subsurface drainage system if possible. These measurements need not be comprehensive or as formalized as one would expect for a land-leveling project (Oyebode, 2010).

The field topography and geometry measurement requires placing a simple reference grid on the field, usually by staking, and then taking the elevations of the field surface at the grid points to establish slope and slope variations. Usually one to three lines of stakes placed 20-30 meters apart or such that 5-10 points are measured along the expected flow line will be sufficient. The survey establishs the distance of each grid point from the field inlet as well as the field dimensions (length of the field in the primary direction of water movement as well as field width).

3.3 Infiltration measurement

The infiltrometer rings were placed randomly from each other and the measurements were taken in centimeters per minutes. The rings were driven into the ground by hammering a wooden bar placed diametrically on the rings to prevent any blowout effects around the bottoms of the rings. In areas where ridges and furrows existed, the inner rings were always placed in the furrow. Having done that, a mat/jute sack was spread at the bottom of the inner and outer compartments of each infiltrometer to minimize soil surface disturbance when water was poured into the compartments. In grass–covered areas, they were cut as low as possible with a cutlass so that the float could have free movement and care was taken not to uproot grasses. Four sets (4) of infiltration measurements were conducted at each location of which an average was taken later.

Water was collected from the nearby storage tank using buckets. The water was therefore poured into the infiltrometer compartments simultaneously and as quickly as possible. As soon as the buckets are emptied, the water level from the inner cylinder was read from the float (rule) and the local time was noted. Repeated readings were taken at intervals of 0 minute, 1 minute, 2 minutes, 5 minutes, 10 minutes, 15 minutes, 20 minutes 30 minutes, 45 minutes, 60 minutes, 75 minutes, 90 minutes, 100 minutes and finally at 180 minutes.

3.3.1 Description of the Infiltrometer Equipment

The infiltrometer rings were rolled iron sheet of 12-guage steel and the diameters of the inner and outer rings were 300 mm and 600mm, respectively as suggested by Bambe (1995) and also by Swartzendruber and Oslo (2001). They both have a height of 250mm and the bottom ends of the ring were sharpened for easy penetration into the soil (Oyebode, 2010).

Each infiltrometer was equipped with a float consisting of a plastic rule placed perpendicularly to one face of the wooden block. This wooden block was painted to prevent it from soaking water as it floats on the water. The plastic meter rule was clamped to the inner side of the inner rings; with another sharp – edge wood placed near the rule to facilitate taking readings from the rule.

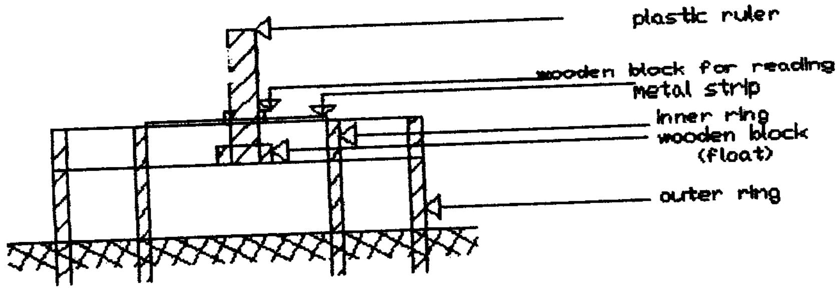


Figure 3.3: A Dissected Double Ring infiltrometer.

3. 4 Runoff Plots and Site Set-up

The exact size of each plot was the estimated size of the catchment planned for the study. Smaller dimensions were avoided, since the results obtained from very small plots are rather misleading.

Care was taken to avoid sites with special problems such as rills, cracks or gullies crossing the plot. These would drastically affect the results which would not be representative for the whole area. The gradient along the plot was regular and free of local depressions.

During construction of the plots, one out of the two plots was undisturbed and the other plot was thoroughly disturbed. A disturbed plot is one in which the structure of the soil has been changed sufficiently that test of structural properties of the soil will not be representative of in-situ conditions only properties of the grains (e.g grain size distribution, atterberg limits, and possibly the water content) can be accurately determined. An undisturbed plot is one where the condition of the soil in the plot is close enough to the condition of the soil in-situ to allow tests of structural properties of the soil to be approximate to the properties of the soil in-situ. Care was taken not to disturb or change the natural conditions of the plots such as destroying the vegetation or compacting the soil for the undisturbed soils while for the disturbed soils, every form of shrubs present on the plots were removed and the plot completely cleared of grasses.

The two project sites had a dimension of 6 X 3m each on vary slope measurements. The plots were prepared in March of 2011. Around the edge of each plot, long plywood which does not leak was placed, following the direction of the slope in a rectangular pattern to permit only runoff delivery and sediment within the experimental plot. The plywood extends 20cm above the ground surface and 10cm below the ground surface. A broad collector 1.2m long and 30cm wide was placed at the base of each of the plots to collect all the runoff and sediment produced during the simulated rain event. On the collector are spouts (15cm in diameter) through which runoff delivery empties into a collecting tank (250 liters) installed in pits just below ground level. Placed over the spout is a mesh to collect the sediment.

The plots were categorized into the disturbed and undisturbed soils for the various types of soils available within the Federal University of Technology, Minna Niger State. Records of rainfall depth for each storm were taken using a locally constructed rain-gauge.

3.5 Method of Measurement

3.5.1 Runoff Delivery and Sediment Load

After each simulated rainfall event, runoff and sediment load produced are channeled through the collector placed at the lower end of the plot. The sediment loads trapped on the collector by the mesh placed over it were scooped off into a soil bag. Sediments channeled into the tank were allowed to settle after which the runoff volume was determined. The clear water was collected with a bucket and measured with a graduated container. The sediment collected at the bottom of the tank plus the sediment collected on the collector were taken for oven drying to a constant weight. The sediment weights were determined after oven drying using a weigh balance. The sample weight divided by the area of the experimental plot gives the total soil loss from the plot. The total amounts of water collected in the container were measured and the volume was compared with the total simulated rainfall intensity within the plot area.

3.5.2.1 Soil Analysis

Soil samples were collected from each plot using a hand auger. The auger was position vertically upright on the soil surface. The handle was turned clockwise until the cylinder was full. It was lifted from the hole and the content emptied into a container. The samples were taken at a depth of 20cm. The samples were labelled before taking the next sample point.

3.5.2.2 Particle Size Analysis

The hydrometer method was used for the particle size determination. A sample (50 grams) of air dry soil was weigh into a 250ml beaker. 100ml of dispersing agent (sodium pyrophosphate solution) is added to the soil sample, mixed and allowed to soak for at least 30 minutes. The suspension is mixed for about 3 minute with a mechanical stirrer before transferring the content into a sedimentation cylinder and filled to mark with distilled water. A hand stirrer was inserted into the sedimentation cylinder to mix the content thoroughly and the time of completion of stirring was noted. A hydrometer is carefully lowered into the suspension and reading was taken after 40 seconds (R_{40}). The sands settles in about 40 seconds (silt and clay remains in suspension) and a hydrometer reading taken 40seconds determined the grams of silt and clay remaining in suspension. The hydrometer was removed and the temperature of the suspension was taken using a thermometer. The suspension was disturbed. Two hour after the final mixing of the suspension sand and silt would have settled (only clay remains in suspension). Another hydrometer and temperature reading was taken (R_{2hrs}). A blank sample containing 100ml of dispersing agent and 1 liters of distilled water was measured into a cylinder. The hydrometer was lowered into the solution carefully and readings were taken after 40 seconds (R_a) and readings after two hours (R_b). After the hydrometer readings have been obtained, the soil water mixture is poured over a screen to remove the entire sand fraction. The separated soil Percentage is calculated from

$$\% \text{ Sand} + \text{loamy} = \frac{(\text{Reading after forty seconds} - R_a) + R_c}{\text{Weight of soil}} \text{ X } 100 \qquad 3.22$$

$$\% \text{ loamy} = \frac{(R_{2hrs} - R_b) + R_d}{\text{weight of soil}} \times 100 \qquad 3.23$$

where

R_a= 40 sec, blank hydrometer reading

R_b= 2 hr, blank hydrometer reading

R_c = 40sec (Temperature × 0.360)

R_d = 2 hr correction factor (temperature × 0.36)

W = weight of soil sample used.

3.5.2.3 Soil Textural Class

The textural class was determined from the particle size analysis. After determining the distribution of sand, silt and clay from the particle size analysis, the soil was assigned a textural class based on the textural triangle. Within the textural triangle is various soil textures which depends on the relative proportion of soil particles.

3.5.3 Moisture Content

The weight of a clean and well labelled can was taken using a weigh balance. Soil clod was added into the can after which the weight was taken. The difference in weight between the weight of can plus clod and the weight of the can is the wet weight of the soil. The can containing the clod were taken to the laboratory for oven-drying to a constant weight at 104 ^{0}C. The can was removed from the oven, allowed to cool for several hours. After cooling the weight of the can containing the soil was taken. Weight of the dry soil is the difference in weight between the weight of the can plus soil after oven drying and the weight of the can. The moisture content was calculated as:

$$\% \text{ MC} = \frac{\text{loss in weight}}{\text{weight of soil after drying}} \times 100 \qquad 3.24$$

$$\text{MC} = \frac{W_w - W_d}{W_d} \times 100\,\%$$

3.25

where

W_w= weight of wet soil (g)

W_d=weight of dry soil (g)

3.5.4 Bulk density measurement

Core sampler is commonly used to take undisturbed soil samples. The cylinder of the core sampler, which has it cutting edge, is driven into the soil and uncompacted core obtained within the tube. The samplers were carefully trimmed at both ends. Empty labelled cans were weighed, they were then filled with soil core samples and weight again and were oven dried at 110°C for about 24hrs, and samples were again weighed.

Bulk density was determined as follows;

$\rho_b = Ms/Vs$

Where;

ρ_b= bulk density (g/cm^3).

Ms = mass of dry soil (g).

Vs = volume of soil (cm^3).

CHAPTER FOUR

4.0 DISCUSSION OF RESULT

4.1 Properties of sandy Loam Soil

Sandy loam soil consists of 80% sand and 35% loam soil. Sand (soil) can be graded based on its grain size (fine, medium, coarse) in the soil profile. Sandy loam is most suitable for Agriculture because of its stability when moist and also not too compacted which aids adequate aeration of the soil and also in the temperature control of the soil.

Properties like looseness of the soil, porosity, low water retention and etc, are very important for crop growth and development.

4.2 Determination of soil characteristics

The characteristics of the soil were analyzed in order to obtain the soil properties for the various land cover types. The analyzed soil was collected some centimeters below the test plot used. Each soil type has different properties and specific ranges in soil particle sizes.

Based on the USDA and FAO 2001 Classification, sand as a soil separately consist of mineral soil particles that are 0.05m to 2mm in diameter, silt as a soil consist of mineral soil particles that are 0.002mm to 0.05mm in diameter, clay as a soil separately consists of mineral soil particles that are less than 0.002mm in diameter.

The content of sand, silt and clay affects the physical behavior of soil. Particle size is important is important for engineering agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification.

The composition of the soil component considered for the study is presented in Table 4.1 which shows between the soil depth of 0-75cm, the soil was classified as sandy loam with varying percentages of sand, silt and clay. At the soil depth of 0-20cm,it was observed that the sample collected had 60% sand, 26% silt and 14% clay content; Thus giving it a higher bulk density of 1.50992g/cm^3. This implies that the rate of infiltration into the soil will be show because there are very few or little pore space existing within the soil profile.

4.3 Soil Bulk Density

Bulk density was determined by sampling soil 5cm depth with core sampler measuring between 90-95cm^3. The soil sample was oven-dried for 24 hours at 104$^0{}_c$ or 110$^0{}_c$. Determination of the bulk density is as calculated below (Gordon *et al.* 1993).

Bulk density can be expressed mathematically as

$$(Bulk\ Density) = \frac{mass\ of\ sample}{volume\ of\ sample}.$$

Table 4.3 Soil bulk density table.

	Depth (cm)	% sand	% silt	% clay	Soil type	Bulk Density (g/cm^3)
O	0-20	60	26	14	Sandy Loam	1.50992
A	20-50	68	12	20	Sandy Loam	1.47232
B	50-75	56	27	17	Sandy Loam	1.47312
C	75-110	48	39	13	Loam	1.4976

4.4 The Slope

The slope of any soil depends on both the length and gradient of the area. It has been observed that soil loss increases more rapidly with slope steepness than it does with slope length (Adediji, *et al.*, 2010). The presence of slope in predicting time of concentration has been seen to be important especially in some areas of extremely low slope. As the slope decreases to zero, the time of concentration increases to infinity.

Table 4.4: Average slope (degree) of the type of soil areas (Sandy loam soil)

Plot No	Undisturbed Sandy Loam	Disturbed Sandy Loam
1	5.70	3.50
2	6.70	4.80
3	5.70	3.50
4	5.70	3.80
5	5.00	5.00
6	4.80	4.30
7	3.70	7.20
8	7.20	2.20
9	6.00	3.10
10	3.00	5.50
Average slope (degree)	5.35	4.29

4.5 Time of concentration

The time of concentration is the time taken for water to travel from the most remote part of the drainage area to the point of interest for discharge calculations. DDM, 2006.

The time of concentration is computed as a summation of travel times within each flow path as follows:

$$t_c = t_{t1} + t_{t2} + t_m$$

Where:

st_c = time of concentration (hours)

t_t = travel time of segment (hours)

m = number of flow segments

While in some other cases, there are some available equations that can determine the time of Concentration provided the various parameters are available. Table 4.3 below shows some of the available time of concentration equations.

Table 4.5: Average time for a 0.25 m^3 container to be filled up for each plot observed under various soil conditions during the dry season

Plot No	Undisturbed Sandy Loam	Disturbed Sandy Loam
1	38.48	36.56
2	40.15	38.40
3	42.46	32.34
4	43.20	46.56
5	39.25	44.49
6	39.25	47.50
7	36.48	44.30
8	41.54	46.15
9	45.20	49.50
10	36.25	41.25
Average T_d (Mins)	40.23	42.71

4.6 Infiltration Rate

The movement of water into the soil is called infiltration. Soil type is the most important factor in determining the infiltration rate. (When the soil has a large percentage of well-graded fines, the infiltration rate is low). In some cases of extremely tight soil, there may be, from a practical standpoint, essentially no infiltration.

Time (Mins)	Undisturbed Sandy Loam	Disturbed Sandy Loam
0	0.00	0.00
1	1.00	0.85
2	2.70	1.55
5	4.50	3.65
10	5.60	5.25
15	7.85	7.75
20	9.00	9.45
30	10.50	11.05
45	11.70	13.25
60	12.90	14.65
75	13.70	15.35
90	14.80	16.15
100	15.60	16.85
120	16.70	16.95
150	16.70	17.15
180	16.70	17.15
Average cumulative infiltration	10.00	10.44

Table 4.6b: Average Cumulative infiltration of the various types of soils under the disturbed and undisturbed condition during the dry season

Time (Mins)	Undisturbed Sandy Loam	Disturbed Sandy Loam
0	0.00	0.00
1	1.00	0.85
2	2.70	1.55
5	4.50	3.65
10	5.60	5.25
15	7.85	7.75
20	9.00	9.45
30	10.50	11.05
45	11.70	13.25
60	12.90	14.65
75	13.70	15.35
90	14.80	16.15
100	15.60	16.85
120	16.70	16.95
150	16.70	17.15
180	16.70	17.15
Average cumulative infiltration	10.00	10.44

Table 4.6c: Regression analysis of Infiltration rates for the various soils of Gidan Kwano

Type of Soil and condition of soil		**Seasonality equation of the form Y = Mx +C**	
Soil	Condition	`Dry	Dry
Sandy loam	**Undisturbed**	**0.782**	$Y = -0.088X + 14.08$
	Disturbed	**0.810**	$Y = -0.102X + 15.73$

Table 4.6d: Regression analysis of cumulative infiltration for the various soils of Gidan Kwano

Type of Soil and condition of soil		Seasonality values of R^2	Seasonality equation of the form Y = Mx +C
Soil	Condition	Dry	Dry
Sandy loam	Undisturbed	0.780	$Y = 0.089X + 4.957$
	Disturbed	0.738	$Y = 0.096X + 5.016$

4.7 MOISTURE CONTENT

The moisture content of the soils was determined by collecting the wet soil samples at the beginning of the surface runoff. The samples were initially weighed and placed inside electric oven at a between 104-105° Celsius. At each site where the various types of soil samples were collected and taken to the standardized plots, the moisture content that was observed are presented in Tables 4.6. At each of the site, the moisture content samples were collected between 0 and 60 mm depth. It was observed that during the dry season, the moisture content lower when compared with that of the wet season. Though, the difference observed was not that much but it shows the effect of the antecedent rain on the soil during the wet season.

The difference in the soil moisture content during the wet and dry season may be due to the moisture lost as evapotranspiration and that which percolates to the soil. Water bodies around the study area as there is no water to replace that which is lost, the soil becomes drier and in some cases caked to form a hard clod. The degree of slope of the study also aid the surrounding water bodies as steeper slopes usually experience a rapid movement of water provided where there final destination is not saturated; and does not experience any form of water logging or the soils are not tightly packed together which reduces the rate of movement of water to the barest minimum. Another possible effect may come from the surrounding farm lands which have been heavily compacted as a result of the various forms (vehicular and human) of movement which might have created a hard pan in some of these areas or the presence of an underlying rock in some of the study areas which do not allow the passage/infiltration of water to move down the soil profile but horizontally or even above the soil surface as surface runoff. This played a very important role in the determination of the model for the various soils considered.

Table 4.7a: Observed moisture content for dry season

Plot No	Undisturbed Sandy Loam	Disturbed Sandy Loam
1	2.18	3.43
2	5.59	6.55
3	5.23	6.89
4	6.82	5.47
5	6.44	6.37
6	6.00	6.22
7	5.76	6.19
8	6.58	5.12
9	6.21	5.58
10	5.21	6.18
Average Mc	5.60	5.80

4.8 DEVELOPING MANNING-NIGERIA COEFFICIENTS

From the pre-existing model developed by Papadakis and Kazan (1986) from the Navier-Stokes equations, the basis of that was adopted to allow the simulation of sheet flow over the land surface. The total land slope of the land was fixed at 6% with a standard length of 6m to mimic the situation explored in the problem statement.

This model had the following variables of

i. length of the watershed,

ii. surface roughness (usually Manning's n),

iii. slope of the watershed, and

iv. Rainfall intensity.

The model is expressed as:

$$T_c = kL^a n^b S^{-y} i^{-z} \qquad 4.1$$

Where T_c is the time of concentration, L is the watershed length, n is Manning's n, S is the watershed slope, and i is the rainfall intensity. k is a constant and a, b, y, z are exponents.

From the above model, Cahill and Li (2005) added the antecedent soil moisture variable to form a new model. It is expressed as:

$$T_c = kL^a n^b \theta^{-x} S^{-y} i^{-z} \qquad 4.2$$

Where the added variable Θ is the antecedent soil moisture and x is an exponent of Θ the empirical mathematical method and Crammer's rule were employed to determine the various exponents for the Manning-Nigeria coefficient. Details of the mathematical calculation are attached in the appendix.

Using the FAA Equation that

$$T_c = 1.8(1.1 - c)\left(\frac{L^{0.5}}{S^{0.33}}\right) \qquad Take\ C\ to\ be\ (0-1)$$

The model developed for this study is stated below

as:

$$T_c = 0.938L^{0.878}n^{0.324}\theta^{-0.222}S^{-0.049}i^{-0.075} \qquad 4.3$$

Where T_c is the time of concentration in minutes, L is the watershed length of the study area in meters, n is Manning-Nigeria's n, θ is the antecedent soil moisture in percent, S is the slope, and i is the rainfall intensity in mm/hr.

From equation 4.3, making n our subject of formula we have that

$$Logn^{0.324} = Log\left(\frac{T_C}{0.938L^{0.878}\theta^{-0.222}S^{-0.049}i^{-0.075}}\right) \qquad 4.4$$

$$0.324Logn = Log\ T_c - 0.938\text{Log}(L^{0.878}\theta^{-0.222}S^{-0.049}i^{-0.075}) \qquad 4.5$$

$$Logn = \frac{LogT_C - 0.938Log(L^{0.878}\theta^{-0.222}S^{-0.049}i^{-0.075})}{0.324} \qquad 4.6$$

Equation 4.6 above was used to determine the Manning-Nigeria coefficient for Sandy Loam soils considered in this study the values obtained using equation 4.6 was compared with the model developed by Cahill and Li (2005) and Kerby (1959). The model developed by Cahill and Li (2005) states that

$$T_c = 0.951\,.\,L^{0.5}\,.\,n^{0.326}\,.\,\theta^{-0.459}\,.\,S^{-0.053}\,.\,i^{-0.674} \qquad 4.7$$

From equation 4.7, making n the subject of formula to be able to determine the Manning coefficient using the Cahill and Li model, we have

$$Logn = \frac{LogT_c - 0.951Log(L^{0.5}\theta^{-0.459}S^{-0.053}i^{-0.674})}{0.326} \quad 4.8$$

While the model developed by Kerby in 1959 states that $T_c = \frac{0.83(nL)^{0.467}}{\sqrt{S}}$ thus

making n the subject of formula, we have

$$T_c * S^{0.5} = 0.83(nL)^{0.467} \quad 4.9$$

The final equation for n is now;

$$\frac{LogT_c + 0.5LogS + 0.081}{0.467} = Logn + LogL \quad 4.10$$

$$\left(\frac{LogT_c + 0.5LogS + 0.081}{0.467}\right) - Log\,L = Logn \quad 4.11$$

Substituting all the data's gotten from the field into the new manning's Nigeria Equation; the Coefficient for the sandy loam soil gotten was then tabulated below

		Manning-Nigeria Model	**Cahill and Li Model**	**Kerby's Model**
pe of soil	Condition of soil	Dry	Dry	Dry
ndy Loam	Undisturbed	0.10	61.38	40.27
	Disturbed	0.23	65.31	41.50

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion.

The factors of water cycle (precipitation, infiltration, surface runoff) which affect soil in general plays a major role in agricultural productivity, of which this is the major reason for research in the study of hydrology.

The sandy loam soil within the premises of the Federal University of Technology Minna (Gidan Kwano campus) was observed to have an average infiltration rate of 10.00 10.44 *cm/hr* for undisturbed and disturbed condition of movement of water into the soil is gradual and steady. This is in conformity with the works of Musa and Egherveba (2009) and that of Ahenaku (2010). It can therefore be concluded that the infiltration capacity for sandy loam soil within the academic premises where the research was carried out, is relatively stable over the dry season.

The model developed in this research; gave a good description of the hydrologic parameters for sandy loam soil within the Gidan Kwano campus of F.U.T Minna. It was concluded that this model can equally be applied to locations with similar loamy soil in Niger State, Nigeria. Since they possess similar properties and characteristics. The N.R.S.C best calculate the time of concentration for the entire area of study within a short time. The calculated time of concentration for time lag equation can be used as one of the parameters in determining the values of n (manning coefficient).

5.2 Recommendation

1. All readings and values obtained regarding the soil in question should also be field or laboratory measured instead of assumed.
2. This research should be carried out in raining period to determine the consistency and accuracy of this model.
3. Samples obtained should be tested or analyzed in different laboratories by different experts or several times, so as to make sure that the data obtained is more reliable.

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APPENDICES

> $k := 0.935$

$$k := 0.935$$

> $t := \ln(9.0)$

$$t := 2.19722457$$

> $b1 := k \cdot (a \cdot \ln(22.90) + b \cdot \ln(0.0086) - y \cdot t - x \cdot \ln(142.30) - c \cdot \ln(22.90)) = \ln(13.42)$

$$b1 := 2.927613012a - 4.446853526b - 2.054404979y - 4.635671567x - 2.927613012c = 2.596746132$$

> $b2 := k \cdot (a \cdot \ln(22.90) + b \cdot \ln(0.0086) - y \cdot t - x \cdot \ln(131.67) - c \cdot \ln(22.30)) = \ln(13.51)$

$$b2 := 2.927613012a - 4.446853526b - 2.054404979y - 4.563079371x - 2.902788544c = 2.603430152$$

> $b3 := k \cdot (a \cdot \ln(22.90) + b \cdot \ln(0.0086) - y \cdot t - x \cdot \ln(165.80) - c \cdot \ln(21.10)) = \ln(12.58)$

$$b3 := 2.927613012a - 4.446853526b - 2.054404979y - 4.778581397x - 2.851070292c = 2.532108251$$

> $b4 := k \cdot (a \cdot \ln(22.90) + b \cdot \ln(0.0086) - y \cdot t - x \cdot \ln(220.30) - c \cdot \ln(45.80)) = \ln(13.26)$

$$b4 := 2.927613012a - 4.446853526b - 2.054404979y - 5.044315887x - 3.575705625c = 2.584751985$$

> $b5 := k \cdot (a \cdot \ln(22.90) + b \cdot \ln(0.0086) - y \cdot t - x \cdot \ln(235.50) - c \cdot \ln(41.10)) = \ln(13.43)$

$$b5 := 2.927613012a - 4.446853526b - 2.054404979y - 5.106699704x - 3.474467594c = 2.597491011$$

> *with*(*LinearAlgebra*) :

>

$$A := [[2.927613012, -4.446853526, -2.054404979, -4.635671567, -2.927613012], [2.927613012, -4.446853526, -2.054404979, -4.563079371, -2.902788544], [2.927613012, -4.446853526, -2.054404979, -4.778581397, -2.851070292], [2.927613012, -4.446853526, -2.054404979, -5.044315887, -3.575705625], [2.927613012, -4.446853526, -2.054404979, -5.106699704, -3.474467594]]$$

$A := [[2.927613012 \; -4.446853526 \; -2.054404979 \; -4.635671567 \; -2.927613012],$
$[2.927613012 \; -4.446853526 \; -2.054404979 \; -4.563079371 \; -2.902788544],$
$[2.927613012 \; -4.446853526 \; -2.054404979 \; -4.778581397 \; -2.851070292],$
$[2.927613012 \; -4.446853526 \; -2.054404979 \; -5.044315887 \; -3.575705625],$
$[2.927613012 \; -4.446853526 \; -2.054404979 \; -5.106699704 \; -3.474467594]]$

> *c1* := *Determinant*(*A*);

$c1 := -1.171045205\,10^{-9}$

>

A1 := [[2.596746132 −4.446853526 −2.054404979 −4.635671567 −2.927613012],
[2.603430152 −4.446853526 −2.054404979 −4.563079371 −2.902788544],
[2.532108251 −4.446853526 −2.054404979 −4.778581397 −2.851070292],
[2.584751985 −4.446853526 , −2.054404979 −5.044315887 −3.575705625],
[2.597491011 −4.446853526 , −2.054404979 −5.106699704 −3.474467594]]

$A1 := [[2.596746132 \; -4.446853526 \; -2.054404979 \; -4.635671567 \; -2.927613012],$
$[2.603430152 \; -4.446853526 \; -2.054404979 \; -4.563079371 \; -2.902788544],$
$[2.532108251 \; -4.446853526 \; -2.054404979 \; -4.778581397 \; -2.851070292],$
$[2.584751985 \; -4.446853526 \; -2.054404979 \; -5.044315887 \; -3.575705625],$
$[2.597491011 \; -4.446853526 \; -2.054404979 \; -5.106699704 \; -3.474467594]]$

> *c2* := *Determinant*(*A1*);

$c2 := -1.028254250\,10^{-9}$

> $aii := \frac{c2}{c1}$

$aii := 0.878065377$

> $A2 := [[2.927613012, 2.596746132, -2.054404979, -4.635671567, -2.927613012],$
$[2.927613012, 2.603430152, -2.054404979, -4.563079371, -2.902788544],$
$[2.927613012, 2.532108251, -2.054404979, -4.778581397, -2.851070292],$
$[2.927613012, 2.584751985, -2.054404979, -5.044315887, -3.575705625],$
$[2.927613012, 2.597491011, -2.054404979, -5.106699704, -3.474467594]]$

$A2 := [[2.927613012, 2.596746132, -2.054404979, -4.635671567, -2.927613012],$
$[2.927613012, 2.603430152, -2.054404979, -4.563079371, -2.902788544],$
$[2.927613012, 2.532108251, -2.054404979, -4.778581397, -2.851070292],$
$[2.927613012, 2.584751985, -2.054404979, -5.044315887, -3.575705625],$
$[2.927613012, 2.597491011, -2.054404979, -5.106699704, -3.474467594]]$

> $c3 := Determinant(A2);$

$c3 := -3.8\ 10^{-10}$

> $aiii := \frac{c3}{c1}$

$aiii := 0.324496439$

> $A3 := [[2.927613012, -4.446853526, 2.596746132, -4.635671567, -2.927613012],$
$[2.927613012, -4.446853526, 2.603430152, -4.563079371, -2.902788544],$
$[2.927613012, -4.446853526, 2.532108251, -4.778581397, -2.851070292],$
$[2.927613012, -4.446853526, 2.584751985, -5.044315887, -3.575705625],$
$[2.927613012, -4.446853526, 2.597491011, -5.106699704, -3.474467594]]$

$A3 := [[2.927613012, -4.446853526, 2.596746132, -4.635671567, -2.927613012],$
$[2.927613012, -4.446853526, 2.603430152, -4.563079371, -2.902788544],$
$[2.927613012, -4.446853526, 2.532108251, -4.778581397, -2.851070292],$
$[2.927613012, -4.446853526, 2.584751985, -5.044315887, -3.575705625],$
$[2.927613012, -4.446853526, 2.597491011, -5.106699704, -3.474467594]]$

> $c4 := Determinant(A3);$

$$c4 := 2.6\ 10^{-10}$$

> $aiii := \frac{c4}{c1}$

$$aiii := -0.222023879$$

> A4 := [[2.927613012 −4.446853526 −2.0544049792.596746132
−2.927613012],
[2.927613012 −4.446853526, −2.0544049792.603430152
−2.902788544],
[2.927613012 −4.446853526, −2.0544049792.532108251
−2.851070292],
[2.927613012 −4.446853526 −2.0544049792.584751985
−3.575705625],
[2.927613012 −4.446853526 , −2.0544049792.597491011
−3.474467594]]

A4 := [[2.927613012 −4.446853526 −2.0544049792.596746132
−2.927613012],
[2.927613012 −4.446853526 −2.0544049792.603430152
−2.902788544],
[2.927613012 −4.446853526 −2.0544049792.532108251
−2.851070292],
[2.927613012 −4.446853526 −2.0544049792.584751985
−3.575705625],
[2.927613012 −4.446853526 −2.0544049792.597491011
−3.474467594]]

> c5 := Determinant(A4);

$$c5 := 5.85522602\ 10^{-11}$$

> $aiv := \frac{c5}{c1}$

$$aiv := -0.0499999999$$

> A5 := [[2.927613012 −4.446853526 −2.054404979 −4.635671567
2.596746132],
[2.927613012 −4.446853526, −2.054404979 −4.563079371
2.603430152],
[2.927613012 −4.446853526 , −2.054404979 −4.778581397
2.532108251],
[2.927613012 −4.446853526 −2.054404979 −5.044315887
2.584751985],
[2.927613012 −4.446853526 , −2.054404979 −5.106699704
2.597491011]]

$A5 := [[2.927613012, -4.446853526, -2.054404979, -4.635671567, 2.596746132],$
$[2.927613012, -4.446853526, -2.054404979, -4.563079371, 2.603430152],$
$[2.927613012, -4.446853526, -2.054404979, -4.778581397, 2.532108251],$
$[2.927613012, -4.446853526, -2.054404979, -5.044315887, 2.584751985],$
$[2.927613012, -4.446853526, -2.054404979, -5.106699704, 2.597491011]]$

> $c6 := Determinant(A5);$

$$c6 := 8.782839034 \, 10^{-11}$$

> $av := \frac{c6}{c1}$

$$av := -0.07499999999$$

>

PLATES

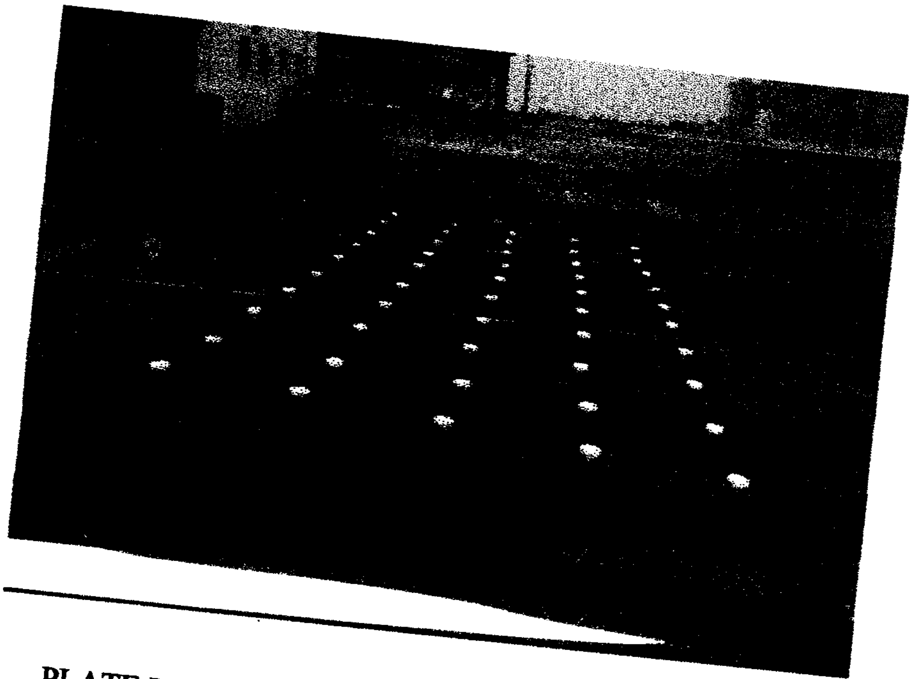

PLATE I: - THE RAINFALL SIMULATOR USED

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