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

BY

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DECLARATION

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 Information derived from personal communications, published and unpublished works were duly referenced in the text.

01-03-2012

Afoke AbdulRasheed Ajibola | **Date**

CERTIFICATION

This is to certify that the project entitled "Determination of Hydrologic Coefficients of disturbed and Undisturbed Sandy Soil (Case Study of Gidan Kwano Campus of the Federal University of Technology, Minna, Niger State)" by Afoke AbdulRasheed Ajibola meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna. And it is approved for its contribution to scientific knowledge and literary presentation.

01-03-2012

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DEDICATION

This research work is dedicated to my parents who made it possible for me to be a graduate in an engineering field, financially and morally.

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ABSTRACT

The determination of the volume and rate of movement of surface water within a watershed is the fundamental step upon which the design of reservoirs, channel improvement, erosion control structures and also serves as models in which various drainage structure or system is based. This is used to determine: coefficients for disturbed and undisturbed sandy soil, the relative bulk density, infiltration rate, time of concentration, moisture content, textural classification of the soil to be studied and the slope gradient of the study area were determined using standard procedures. The soil of the area studied was classified as sandy soil with a bulk density ranging between 1.48592 and 1.69376 g/cm^3. The average infiltration rate for undisturbed and disturbed was 19.35 cm/hr and 11.98 cm/hr respectively. The average slope for the studied area was 4.94% and 3.89% respectively. The moisture content of the soil sample ranged between 1.73g and 4.58g for undisturbed sandy soil and 1.15g and 1.43g for the disturbed. The developed empirical model to calculate Time of concentration using crammer's rule is 54.14 minutes and 55.04 minutes respectively. The Manning's Coefficient for sandy soils within the study area was calculated to be 0.03 for undisturbed and 0.02 for disturbed sandy soil respectively. It was concluded from the calculated values of Manning-Nigeria Coefficient that better describes the soil coefficients in Gidan Kwano Area of the Federal University of Technology Minna.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Rocks exposed at the surface of the Earth are subject to physical and chemical weathering. Given sufficient time and a suitable climate (hot and wet is best forChemical weathering; cold and wet is best for physical weathering), even the most resistant rockwill be reduced to a shadow of its former self. If the rock has been physically and chemicallyweathered and if there is an appreciable amount of organic material, it is better to refer to thelayer as soil. (MLA Style "Rock")

Soil is one of the principal substrata of life on Earth, serving as a reservoir of water and nutrients, as a medium for the filtration and breakdown of injurious wastes, and as a participant in the cycling of carbon and other elements through the global ecosystem. It has evolved through weathering processes driven by biological, climatic, geologic, and topographic influence. (MLA Style: "soil.")

The determination of the volume and rate of movement of surface water within a watershed is the fundamental step upon which the design of reservoirs, channel improvement, erosion control structures and serves as well as agricultural, highway and models in which various drainage structure or system is based (MLA Style "Rock")). Quantitatively describing the rate and path of movement of a rain droplet after it strikes the ground surface is essential for the rational development and efficient utilization of our nation's water resources (MLA Style: "rocks")

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 (Knox County)

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 (Knox County).

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 (Aina .P .O 2002)

1.2 Justification

Soil is the most important earth resource that we have (with the possible exception of water andair"). Without soil, we would not have potatoes, lettuce, peas, cornbread, beef, chickens, trees etc. Life without these would be pretty tough. It is for this reasonthat soil conservation is taken so seriously. In the past, we had many serious experiences withsoils erosion (the Great Dust Bowl of the early 20th Century is but one example) (Catchment Care Education). Today,agricultural practices are better and soil erosion by wind is not as much of a problem; however,water runoff as a cause of soil erosion is still a major concern.

The soil portion of a turf system represents a large fraction of the biological and physical activities necessary for turf grass growth. It serves as a growth medium, and a source of nutrients and water. The interaction nature of soils and water together is the focus of this presentation. Basically the soil particle size, the soil particle size distribution, and the structure of the soil determine the moisture characteristics (soil water relationships) a particular turf grass soil will have. Soil particles are basically composed of sands, silt, clays and organic matter. Sands include particle sizes which range from 0.05 mm to 2.0 mm in size, which is a very large range of particle sizes.

Generally, the larger the soil particle size, the better the drainage will be. This is why golf greens and sports fields are ultimately designed with sand based soils. The distribution of soil particles (size and relative amounts) is used to determine the 'soil textural class'. There are basically twelve soil classes based on texture. From knowledge about the textural class of soil, information can be inferred about its infiltration, water holding capacity, and how much water the turf can actually use.

Land degradation of different soil 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.

1.3 Scope of work

This project work shall cover the determination of hydrologic parameter of sandy soil such as infiltration rate, time of concentration, soil moisture content, surface runoff, and the slope of the watershed used.

Also, a simple empirical mathematical model using the Crammer's rule will be generated to show the relationship between the measured parameters and surface runoff of the sandy soil.

1.4 Statement of the Problem

It is essential 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 challenging 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 process are more complex and dynamic. Hence, to study the effects of storms and to replicate the conditions, many researchers have resorted to the use of artificially simulated rainfall. Simulated rainfall provides rapid results than natural rains. It can be conducted efficiently 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.

1.5 Objectives of the study

1. To determine the surface runoff and infiltration rate coefficients of disturbed and undisturbed sandy soils in Gidan Kwanu campus of the federal university of technology, Minna, Niger State, Nigeria.
2. To develop an empirical mathematical model/equation using the Crammer's rule capable of determining the Manning's coefficient for the various

conditions of sandy 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.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Rainfall Simulator

The primary purpose of a rainfall simulator is to simulate natural rainfall accurately and precisely. Rainfall is complex, withinteractions among properties (drop size, drop velocity, etc.) and large climaticvariation based on topography and marine influences. Properly simulating rainfall requires several criteria:

1. Drop size distribution near to natural rainfall (Bubenzer, 1997).
2. Drop impact velocity near natural rainfall of terminal velocity (Laws, 1991; Gunn and Kinzer, 1999).
3. Uniform rainfall intensity and random drop size distribution (Laws and Parsons, 2003).
4. Uniform rainfall application over the entire test plot (Meyer and Harmon, 1999).
5. Vertical angle of impact (Meyer et.al., 1999).
6. Reproducible storm patterns of significant duration and intensity (Moore et.al., 1993) (Meyer et.al., 1999).

Drop size distribution, impact velocity and reproducible storm patterns must be met to simulate the kinetic energy of rainfall. Kinetic energy is a single measure of the rainfall used to correlate natural storms and simulator settings. Drop size distribution depends on many storm characteristics, especially rainfall intensity. Drop size distribution varies with intensity (from less than 1 mm to about 7mm); increasing with the intensity to 2.25mm median drop size for high intensity storms (Laws and Parsons, 2003). Drop velocity is important in designing a rainfall simulator. Drops from natural rainfall are at terminal velocity when they hit the soil surface (Meyer and McCune, 1998). Therefore, a rainfall simulator must create drops of adequate size and velocity to simulate the same condition, indicating the importance between an adequate and related fall distance and drop size distribution. A direct relationship exists between drop diameter and fall distance (Laws, 2001). A reproducible storm pattern is easy to simulate when a simulator can be adjusted to the desired intensities and duration. Since computers are inexpensive, a simulator can be driven by specialized software controlling the intensity and duration of the storm (Gunn and Kinzer, 1999).

2.1.1 Previously Developed RainfallSimulators

Simulators can be separated into two large groups (drop-forming simulators and pressurized nozzle simulators) (Thomas and El Swaify, 1999). Drop-forming simulators are impractical for field use since they require such a huge distance (10 meters) to reach terminal velocity (Grierson and Oades, 1997). The drop-forming simulators do not produce a distribution of drops unless a variety of drop- forming sized tubes is used. Another negative of the drop forming simulator is their limited application to small plots (Bubenzer, 1997). Several points of raindrop production must be closely packed to create an intense enough downpour of rain. Drop forming simulators use small pieces of yarn, glass capillary tubes, hypodermic needles, polyethylene tubing, or metal tubing to form drops (Bubenzer, 1997). Pressurized nozzle simulators are suited for a variety of uses. They can be used in the field and their intensities can be varied more than the drop forming type (Grierson and Oades, 1997). Since drops exiting the nozzles have an initial velocity greater than zero due to the pressure driving them out, a shorter fall distance is required to reach terminal velocity. Nozzle intensities vary with orifice diameter, the hydraulic pressure on the nozzle, the spacing of the nozzle and nozzle movement (Meyer, 1999). Pressurized nozzle simulators can produce variable storm intensities. A continuous spray from a nozzle creates an unnaturally intense storm. Some method of starting or stopping the spray is needed. The solution shave been a rotating disc, a rotating boom, a solenoid-controlled simulator (Miller, 1998) and an elaborate sprinkler system (Sumner et al., 1996)

2.1.1.1 The Norton Simulator

The Norton Ladder Type of Rainfall Simulator is a spray boom that oscillates across a test plot at varying speeds to produce variable intensity storms. Scott McAfee and Darrel Norton designed the Norton Ladder Type Rainfall Simulator for use at the USDA National Soil Erosion Research Lab at Purdue University. Boxes around each nozzle regulate the spray for proper nozzle overlap and swath width. A clutch brake starts and stops the boom as regulated by a signal from the control box. A small gear motor drives the clutch brake and the boom. The four nozzles are supplied with water in sets of two; each set of nozzles has its own hose and pressure gauge to adjust for differences in elevation, hose orientation, etc. ((Bubenzer, 1999). The rainfall simulator uses a Spraying systems Veejet nozzle. Typical, manufacturer specified uses for this nozzle include, dust control, industrial washing applications and fire control. Its uses are high-pressure, high- velocity- high-volume water applications; all things rainfall is not. The pressure range of the nozzle is quite large, from 34 to 3400 kPa (5 to 500 psi) yielding flow rates of 13.2 to 132 Liters per minute (3.5 to35 gpm) (Bubenzer, 1999). A pressure of 41 kPa produces drop size and intensity similar to natural rainfall (Bubenzer, 1999). Most nozzles tend to produce irregular spray when used at its capacity limits due to machining differences. Thus, any differences between nozzles are amplified by the small psi used leading to a reduced uniformity. A new nozzle was needed, one with a narrower operation range, but similar drop size and intensity ((Bubenzer, 1999).

2.2 Time of concentration

When rainfall is applied at a constant rate to an impervious surface, the runoff from the surface would eventually equal the rate of rainfall. The time required to reach that condition of equilibrium is the time of concentration, tc, the travel time of water particle from the hydrologically most remote point in a drainage basin to a Specified collection point. If the rainfall duration time is greater than or equal to tc, then every part of the drainage area isassumed to contribute to the direct runoff at the collection point. . tc is used as the design storm duration time (King &Brater)

Time of concentration t_c is "the time required for runoff to travel from the most distant point hydraulically (in time) to the outlet" (ASCE, 1996). By such definition, t_c is distance travelled divided by mean water velocity, appropriately partitioned into reaches of reasonably uniform hydraulic characteristics. Traditional Rational Method usage employs this definition. As travel time also relates to rainfall intensity, McCuen (1998) suggests that t_c be associates with a 2-year 2-hour storm. ASCE (1992) offers an alternative definition of t_c, the travel time for a wave, not parcel of water, to make the journey. As a general approximation, wave speed can be half again as much as mean flow velocity.

The distinction centres on the fact that travel of a flood crest is a wave phenomenon not fully explained as just the translation of water particles. As a practical matter, many t_c estimates avoid the issue. Data-fitting, not hydraulically sophistication, yields pragmatic results (Ponce, 1989). By either definition, time of concentration is a hydraulic parameter, not a hydrograph parameter (Pence 1989). Hydrologic literature, unfortunately, often fails to make the distinction. Durations from various points in the storm to various points on the resultant hydrograph are misnomered as Tc. In fact they should be designated "lag times" t-l or in some cases "time to peak" t-p. While t-c, t-l and t-p are generally related one to another, they are not the same.

2.2.1 Overland Flow

The travel time for overland flow may be determined by using the following methods as appropriate. 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 (Berfield and Haan, 1994).

a) Seelye Method: Travel time for overland flow can be determined by using the Seelye chart.This method is perhaps the simplest and is most commonly used for small developments where a greater margin of error is acceptable (Berfield and Haan, 1994).

First, determine the length of overland flow and enter the nomograph 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).

b) 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: T_t = travel time

L = length of overland flow in feet

n = Manning's roughness coefficient

i = rainfall intensity

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.)

In order to solve the equation, find your region's I-D-F curve and choose a model storm. 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 determined using the I-D-F curve (Haan, 2004).

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

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

Where: T_t = travel time (hr.)

n = Manning's roughness coefficient (Table 3)

L = flow length (ft.)

P_2 = 2-year, 24-hour rainfall (in.) (Diagram 5)

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

All the values above are inputted into the formula to find the travel time.

2.2.2 Shallow Concentrated Flow

To calculate the travel time of shallow concentrated flow, first the velocity of the flow is determined. It is then necessary to know the slope of the shallow concentrated flow and whether the flow path is paved or unpaved (HEC-22 and TR-55). Next, the travel time is calculated using the following equations:

$$T_t(\text{Minutes}) = \frac{L}{60V} \quad 2.3$$

Where:

T_t = travel time (minutes)

L = length of shallow concentrated flow (feet)

V = velocity (feet per second)

2.2.3 Channel Flow

The last flow regime we need to consider is channel flow.

a. Kirpitch Chart: A simple method using a nomograph to calculate channel flow, you need to know:

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

Then we simply use this data with the Kirpitch Chart to determine the travel time. (Be sure to multiply the result 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 nomograph.

Manning's equation is:

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

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.

$$T_c = L_o + L_{sc} + L_c \qquad 2.5$$

2.2.4 Existing Formula for Calculating Time of Concentration

2.2.4.1 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, centimetre/hour

S = Slope of ground surface, cm/100 cm

K = Retardance coefficient

2.2.4.2 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

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

Where t_c = time of concentration

S = surface slope

n = Manning roughness coefficient

L = flow length

2.2.4.3Kirpich 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% (Kirpich .Z. P. 1940). 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.

2.2.4.4 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

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

t_c = concentration time, hrs

L = the longest length of water travel, m

S = ground surface slope

Where C = dimensionless runoff coefficient.

2.2.4.5 Bransby Williams Equation

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

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

Where

t_c = concentration time, hrs

L = Channel Length, m

S = Linear Profile slope

A = Watershed Area

Izzard formula for time of concentration Where:

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

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

Bransby Williams Equation for time of concentration

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

t_c = concentration time, hrs

L = Channel Length, m

S = Linear Profile slope

A = Watershed Area

Kinematic wave formula for time of concentration

$$tc = \frac{0.93L^{0.6}\ N^{0.6}}{i^{0.4}\ S^{0.3}}$$

2.3 Slope

The grade (also called slope; incline, gradient or slope pitch or rise) of a physical feature, topographic landform or constructed element, refers to the amount of inclination of that surface to the horizontal. It is a special case of the gradient in calculus where zero indicates gravitational level. A larger number indicates higher or steeper degree of "tilt". Often slope is calculated as a ratio of "rise" to "run", or as a fraction ("rise over run") in which run is the horizontal distance and rise is the vertical distance (C.Michael Hogan).

Grade or slope is applied to measuring existing physical features (such as canyon and hillsides, stream and river banks and beds), or in designing and engineering new elements for construction (such as roads, landscape and garden grading, roof pitches, railroads, aqueducts, and pedestrian-handicapped-bicycle circulation routes) (Postlingberg).

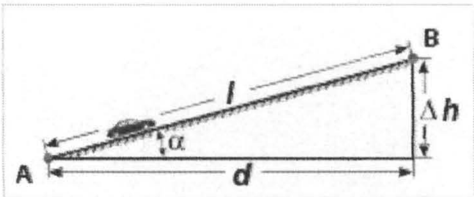
There are several systems for expressing Slope's:-

i) As an angle of inclination to the horizontal. (This is the angle α opposite the "rise" side of a triangle with a right angle between vertical rise and horizontal run.)ii) As a percentage, the formula for which could also be expressed as the tangent of the angle of inclination times 100. In the United States, this percentage or grade is the most commonly used unit for communicating slopes in transportation (streets, roads, highways and rail tracks), surveying, construction, and civil engineering.

iii) As a ratio of one part rise to so many parts run. For example, a slope that has a rise of 5 feet for every 100 feet of run would have a slope ratio of 1 in 20. (The word "in" is normally used rather than the mathematical ratio notation of "1:20"). This is generally the method used to describe railway grades in most part of the world

Any one of these expressions may be used interchangeably to express the characteristics of a slope. Grade is usually expressed as a percentage, but this may easily be converted to the angle α from horizontal since that carries the same information.

In civil engineering applications and physical geography, the slope is calculated along a particular direction of interest which is normally the route of a highway or railway road bed.



Where:

d = run

Δh = rise

l = slope length

α = angle of inclination

2.4 Size of Catchment Area

The catchment area is the most significant factor determining the amount or likelihood of runoff. Catchment factors are: topography, shape, size, soil type and land use (paved or roofed areas). Catchment topography and shape determine the time taken for rain to reach the river, while catchment size, soil type and development determine the amount of water to reach the river (Catchment Care Education Kit).

The catchment area is the total area of the building/structure that can capture and direct rainfall to the runoff/drainage system.

2.4.1 Topography

Topography determines the speed with which the runoff will reach a river. Clearly rain that falls in steep mountainous areas will reach the river faster than flat or gently sloping areas (MLA Style) The ability of soils to resist water and wind erosion depends on their texture and topographic characteristics. Clay-rich soils resist erosion well because of strong cohesive forces between particles and the glue like characteristics of humus. Loam and sandy soils are moderately resistant to erosion because loam soils have sufficient clay content to hold the particles together, while sandy soil have high permeability limits of the amount of surface runoff that can wash soil particles away (APA Style)

Topography, when considered as a soil-forming factor, includes the geologic structural characteristics of elevation above mean sea level, slope configuration and relative position on a slope. Topography influences the way the hydrologic cycle affects earth material, principally with respect to runoff processes and evapotranspiration. Precipitation may run off the land surface, causing soil erosion, or it may percolate into soil profiles and become part of subsurface runoff.

Adjacent soils that show differing profile characteristics reflecting the influence of local topography are called top sequences. As a general rule, soil profiles on the convex upper slopes in a top sequence are shallower and have less distinct subsurface horizons than soils at the summit or on lower, concave-upward slopes. (APA Style)

Often the dominant effect of topography is on subsurface runoff (or drainage). In humid temperate regions, well-drained soil profiles near a summit can have thick E horizons (the leached layers) overlying well-developed clay-rich Bt horizons, while poorly drained profiles near a toeslope can have thick A horizons overlying extensive Bg horizons (lower layers whose pale colour signals stagnation under water-saturated conditions). Soils near the toeslope have accumulations of the soluble salts sodium chloride or calcium sulfate. (Bediant P.B)

These general conclusions are tempered by the fact that topography is susceptible to great changes over time. Soil erosion by water or wind removes A horizons and exposes B horizons to weathering. Major portions of entire soil profiles can move downslope suddenly by the combined action of water and gravity.

2.4.2 Shape

Shape will contribute to the speed with which the runoff reaches a river. A long thin catchment will take longer to drain than a circular catchment.Soil aggregates form soil structure, which is defined by the shape, size, and strength of the aggregates. There are three main soil shapes: platelike, in which the aggregates are flat and mostly horizontal; prismlike, meaning greater in vertical than in horizontal dimension; and blocklike, roughly equal in horizontal and vertical dimensions and either angular or rounded. Soil peds range in size from very fine which is less than 1 mm (0.04 in)to very coarse which is greater than 10 mm (0.4 in). The measure of strength or grade refers to the stability of the structural unit and is ranked as weak, moderate, or strong. Very young or sandy soils may have no discernible structure. (King Christopher)

Soil erosion and deposition are natural geomorphic processes that give shape to landforms and provide new parent material for the development of soil profiles.

2.4.3 Size

Size will help determine the amount of water reaching the river, as the larger the catchment the greater the potential for flooding. The name of soil is determined by its particle, and the particles are classified as: coarse grained soils, fine grained soils, and organic soils. (MLA Style: "grain size scale.")

A coarse grained soils classification is composed of sand and gravel and is in the B-Horizon. They have 50% or less material passing through the size 200 sieve. The grain shape varies from rounded to angular and has good load-bearing qualities and drain freely.

Fine grain soils are composed of silt and clay and are in the B-horizon. They have 50% or more material passing through the 200 size sieve and have good load bearing qualities when dry however, these soils drain poorly and when wet, have little or no load –bearing strength. The characteristic is especially true with clay.

Organic soils refer to top soil and are composed mostly of decayed plant and animal matter and are in the A-Horizon. These soil retain moisture, they are difficult to compact and are usually used when landscaping a finished project.

Soils are grouped by the size of their particle grain. One method used to distinguish sizes is through the use of sieves. A sieve is a screen attached across the end of a cylindrical metal or wooden frame. The screen allows particles smaller than its openings to fall through and retains larger particles. Sieves with screen openings of different size allow you to sort soil into particle groups based on size. (APA Style:grain size scale)

2.4.4 Land use

Land use can contribute to the volume of water reaching the river, in a similar way to soil. For example, rainfall on roofs, pavements and roads will be collected by rivers with almost no absorption into the groundwater. Land is also often used to refer to the district land use types in zoning.

Land use is the human use of land; it involves the management and modification of natural environment such as fields, pastures, and settlements. It can also be defined as the arrangement activities and inputs people undertake in a certain land cover type to produce change or maintain it. (FAO 1997a; FAO/UNEP 1999)

Land use practices vary considerably across the world. The United Nation Development Food and Agriculture Organisation Water Development Division explains that " Land Use concerns the products and/or benefits obtained from use of the land as well as the land management actions (activities) carried out by human to produce those products and benefits. (Albert Guttenberg 1959)

Land use and land management practices have a major impact on natural resources including water, soil, nutrients, plants and animals. Land use information can be used to develop solution for natural resources management issues such as salinity and water quality. Arable lands are used for crops like wheat, maize, rice and replanted after each harvest. (APA Style: soil.2010)

2.5 Soil

Soil is the thin layer on the surface of the Earth on which the living beings of the earth survive since it is the layer of materials in which plants have their roots. Soil is made up of many things like weathered rock particles and decayed plant and animal matter. It takes a long time for soil formation and more than thousand years for the formation of a thin layer of soil. Since soil is made up of such diverse materials like broken down rock particles and organic material, it can be classified into various types, though based on the size of the particles it contains.

Types of soil

Soil type will help determine how much water reaches the river. Certain soil types such as sandy soils are very free draining and rainfall on sandy soil is likely to be absorbed by the ground. However, soils containing clay can be almost impermeable and therefore rainfall on clay soils will run off and contribute to flood volumes. After prolonged rainfall even free draining soils can become saturated, meaning that any further rainfall will reach the river rather than being absorbed by the ground. Soil types cantherefore be classified into these following types: Sandy soil, Silty soil, Clay soil, Loamy Soil,Peaty Soil and Chalky Soil.

2.5.1 Sandy Soil- This type has the biggest particles and the size of the particles determine the degree of aeration and drainage that the soil allows. It is granular and consists of rock and mineral particles that are very small. Therefore the texture is gritty and sandy, the soil is formed by the disintegration and weathering of rocks such as limestone, granite, quartz and shale. Sandy soil is easier to cultivate if it is rich in organic material but then it allows drainage more than is needed, thus resulting in over-drainage and dehydration of the plants during dry season. So if you want to grow your plant in sandy soil it is imperative that you water it regularly during dry season and give it a break during rainy season. Sandy soil retains moisture and nutrients.which makes it good for planting, since it letswater go off so that it does not remain near the roots and lead them to decay. (wikipedia.org)

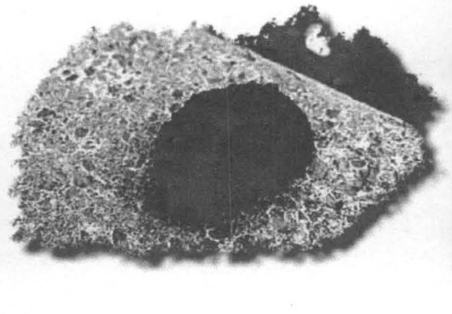
2.5.2 Silty Soil-Silty soil is considered to be one of the most fertile of soils. It can occur in nature as soil or as suspended sediment in water column of a water body on the surface of the earth. It is composed of minerals like Quartz and fine organic particles. It is granular like sandy soil but it has more nutrients than sandy soil and it also offers better drainage. In case silty soil is dry it has a smoother texture and looks like dark sand. This type of soil can hold more moisture and at times becomes compact. It offers better drainage and is much easier to work with when it has moisture (wikipedia.org)

2.5.3 Clay Soil: -Clay is a kind of material that occurs naturally and consists of very fine grained material with very less air spaces, that is the reason it is difficult to work with since the drainage in this soil is low, most of the time there is a chance of water logging and harm to the roots of the plant. Clay soil becomes very heavy when wet and if cultivation has to be done, organic fertilizers have to be added. Clay soil is formed after years of rock disintegration and weathering. It is also formed as sedimentary deposits after the rock is weathered, eroded and transported (wikipedia.org).

2.5.4 Loamy Soil: - This soil consists of sand, silt and clay to some extent. It is considered to be the perfect soil. The texture is gritty and retains water very easily, yet the drainage is well. There are various kinds of loamy soil ranging from fertile to very muddy and thick sod. Yet out of all the different kinds of soil loamy soil is the ideal for cultivation (eais.net)

2.5.5 Peaty Soil: - This kind of soil is basically formed by the accumulation of dead and decayed organic matter, it naturally contains much more organic matter than most of the soils. It is generally found in marshy areas. Now the decomposition of the organic matter in Peaty soil is blocked by the acidity of the soil. This kind of soil is formed in wet climate. Though the soil is rich in organic matter, nutrients present are fewer in this soil type than any other type. Peaty soil is prone to water logging but if the soil is fertilized well and the drainage of the soil is looked after, it can be the ideal for growing plants (eais.net/).

2.5.6 Chalky: - Soil-Unlike Peaty soil, Chalky soil is very alkaline in nature and consists of a large number of stones. The fertility of this kind of soil depends on the depth of the soil that is on the bed of chalk. This kind of soil is prone to dryness and in summers it is a poor choice for plantation, as the plants would need much more watering and fertilizing than on any other type of soil. Chalky Soil, apart from being dry also blocks the nutritional elements for the plants like Iron and Magnesium (eais.net/).

Besides this kind of classification soil can also be classified as Acidic and Alkaline soil depending on the amount of humus, organic matter and the underlying bedrock. Every soil has its own advantages and disadvantages and there are various plants that have different requirements. All plants do not need the same kind of soil (eais.net/).

2.6 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(Walker, 1997)). It is measured in inches per hour or millimeters per hour (Walker, 1997).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).

The rate at which a particular soil can absorb wateris called the infiltration rate (IR)(C.Michael Hogan. 2010). The infiltration ratedepends on the soil texture, organic matter content, soilmoisture content, compaction and other cultural practiceswhich can affect soil physical properties (C.Michael Hogan. 2010)

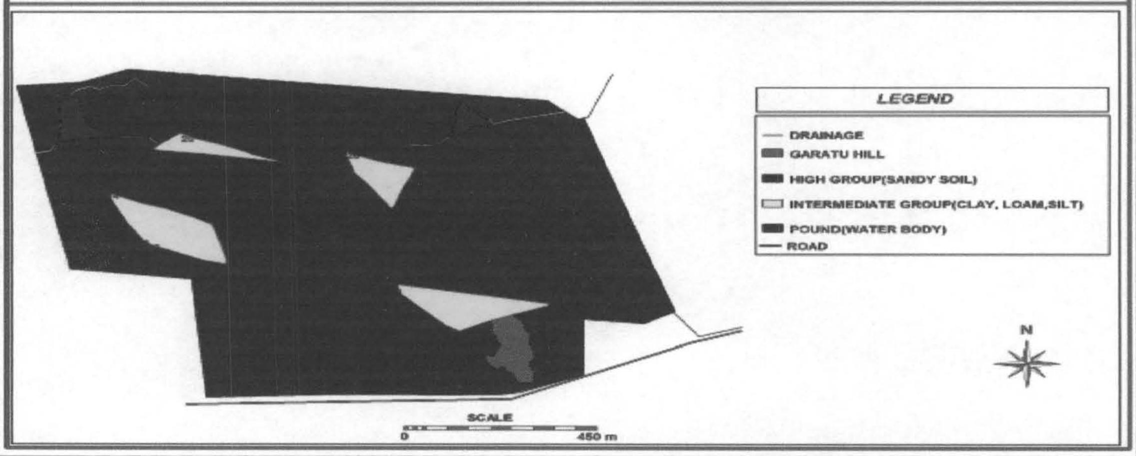
Since runoff is closely relatedto IR several researchers have developed mathematicalmodels to predict the infiltration capacity into thesoil as a function of time. The most popular equationwas developed by Horton (1939) which can be usedto predict cumulative infiltration:

$fp\ (t) = fc + (f0 - fc)e - kt$

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.(Skogerboe, 1997). 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.(Skogerboe, 1997). 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).

IRRIGATION FARM OF THE FEDERAL UNIVERSITY OF TECHNOLOGY MINNA PERMANENT SITE, SHOWING THE SOIL CLASSIFICATION BASED ON THE INFILTRATION RATE OF DATA OBTAINED.



2.7 Bulk density

Bulk density is a measure of the weight of the soil per unit volume (g/cc), usually given on an oven-dry (110° C) basis (Birkeland, 1984). Variation in bulk density is attributable to the relative proportion and specific gravity of solid organic and inorganic particles and to the porosity of the soil (Birkeland,1984). Most mineral soils have bulk densities between 1.0 and 2.0 ((Birkeland,1984).Although bulk densities are seldom measured, they are important in quantitative soil studies, and measurement should be encouraged. Such data are necessary, for example, in calculating soil moisture movement within a profile and rates of clay formation and carbonate accumulation(Tisdall, A.L., 1951) Even when two soils are compared qualitatively on the basis of their development for purposes of stratigraphic correlation, more accurate comparisons can be made on the basis of total weight of clay formed from 100g of parent material than one percent of clay alone(Tisdall, A.L., 1951). To convert percent to weight per unit volume, multiply by bulk density (Birkeland, 1984). The determination usually consists of drying and weighing a soil sample, the volume of which is known (core method) or must be determined (clod method and excavation method). These methods differ in the way the soil sample is obtained and its volume determined.

The bulk density of soil depends greatly on the mineral make up of soil and the degree of compaction. The density of quartz is around 2.65g/cm^3 but the bulk density of a mineral soil is normally about half that density, between 1.0 and 1.6g/cm^3. Soils high in organics and some friable clay may have a bulk density well below 1g/cm^3 (Brady, Nyle C. (1960))

Bulk density of soil is usually determined on Core samples which are taken by driving a metal corer into the soil at the desired depth and horizon. The samples are then oven dried and weighed(Brady, Nyle C. (1960))

Bulk density = mass of oven dry soil/core volume $\rho = \dfrac{M_s}{V_t}$

The bulk density of soil is inversely related to the porosity of the same soil: the more pore space in a soil the lower the value for bulk density. Bulk density of a region in the interior of the earth is also related to the seismic velocity of waves travelling through it: for P-waves, this has been quantified with Gardner's relation. The higher the density, the faster the velocity(Harry O.; Brady, Nyle C. (1960)).

2.8 Moisture content

Water or moisture content is the quantity of water contained in a material, such as soil (called soil moisture), rock, ceramics, fruit, or wood(Dingman, 2002). Water content is used in a wide range of scientific and technical areas, and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation (Dingman, 2002).. It can be given on a volumetric or mass (gravimetric) basis.

Volumetric water content, θ, is defined mathematically as:

$$\theta = \frac{V_w}{V_T}$$

Where Vw is the volume of water and VT = Vs + Vv = Vs + Vw + Vais the total volume (that is soil volume + water volume + air space).

Gravimetric water content is expressed by mass (weight) as follows:

$$u = \frac{m_w}{m_b}$$

Where m_w is the mass of water and m_b (or m_s for soil) is the bulk material mass. To convert gravimetric water content to volumetric water, multiply the gravimetric water content by the bulk specific gravity of the material.

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).

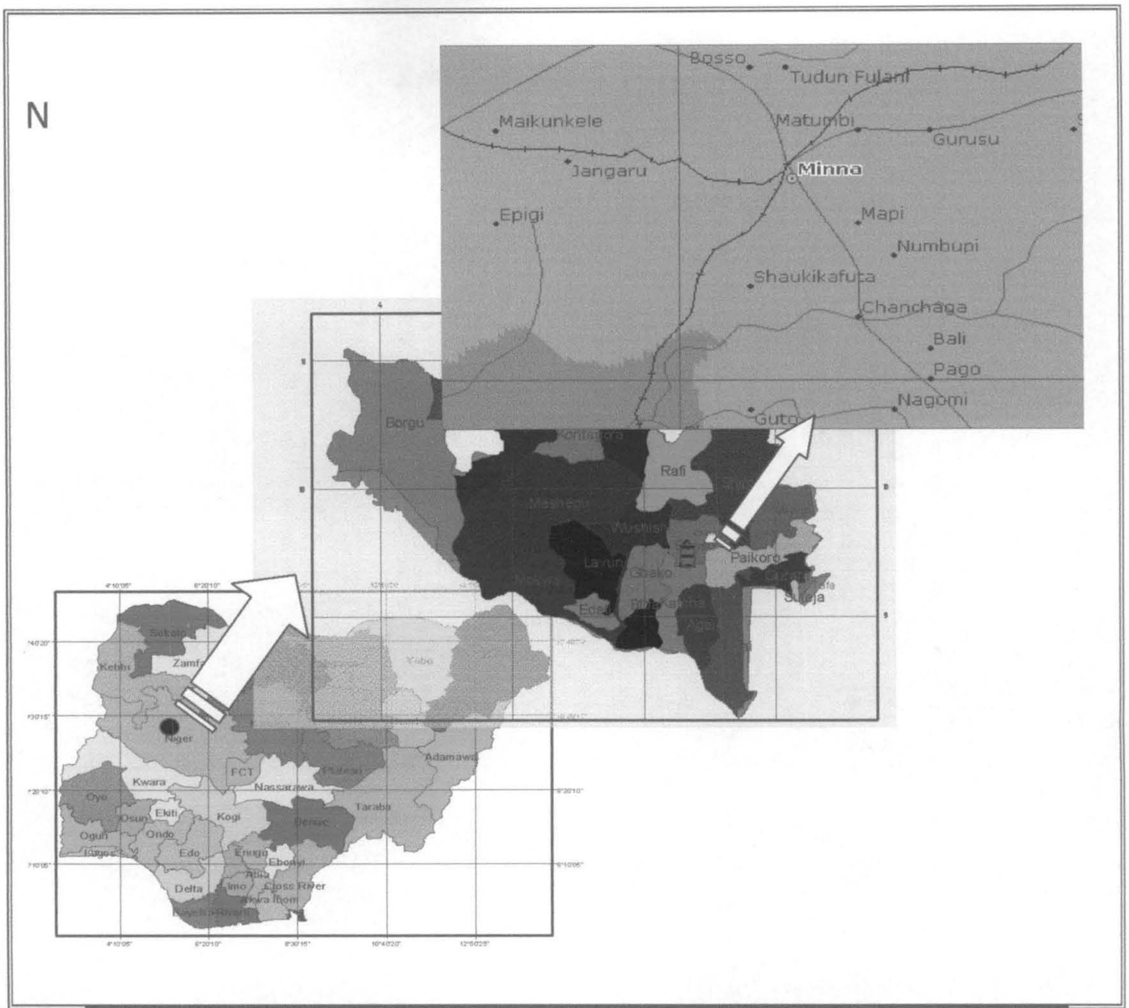
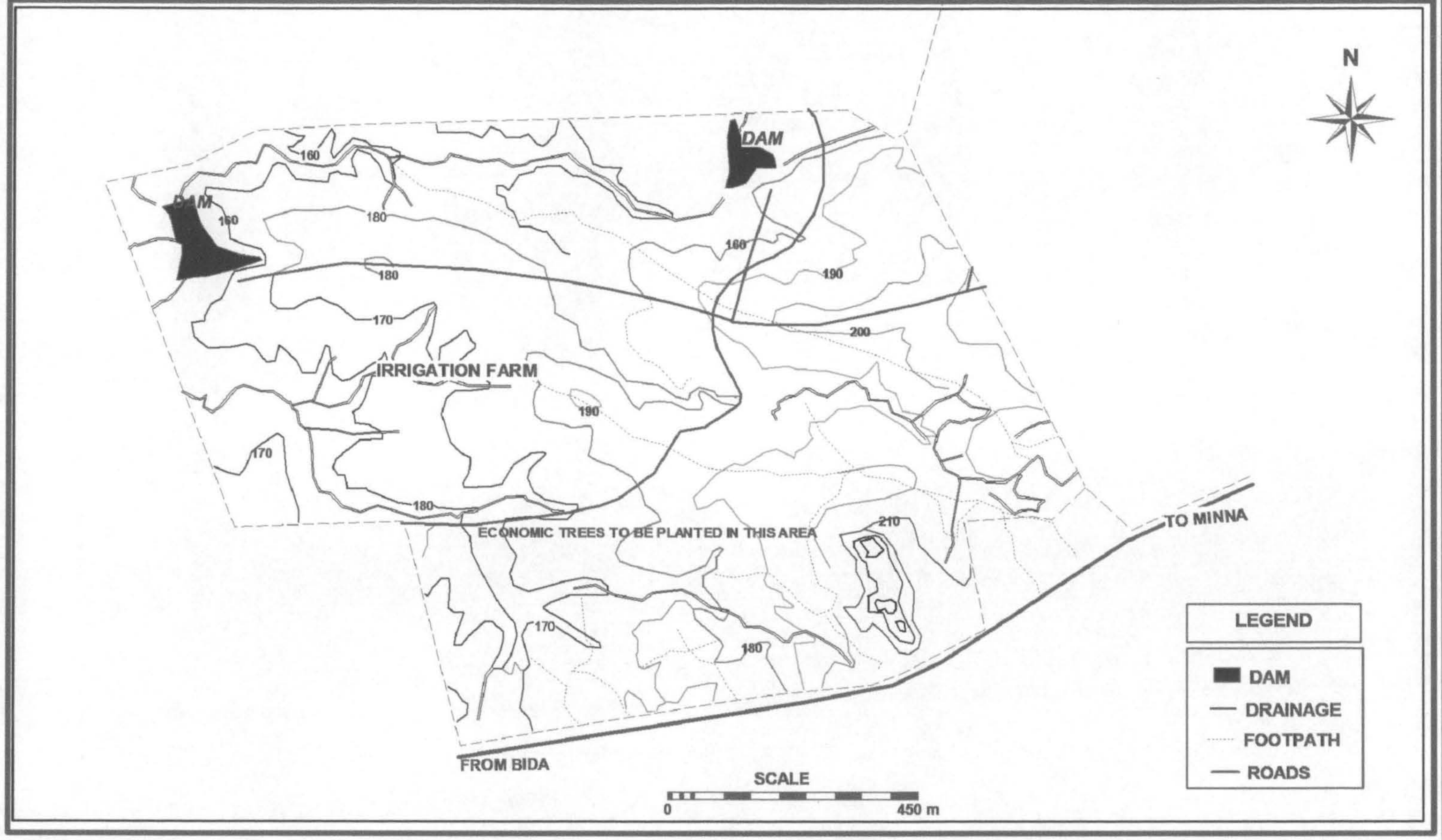


Figure 3.1: Map of Bosso Local Government Area, Niger State

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 establishes 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 grasscovered 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.

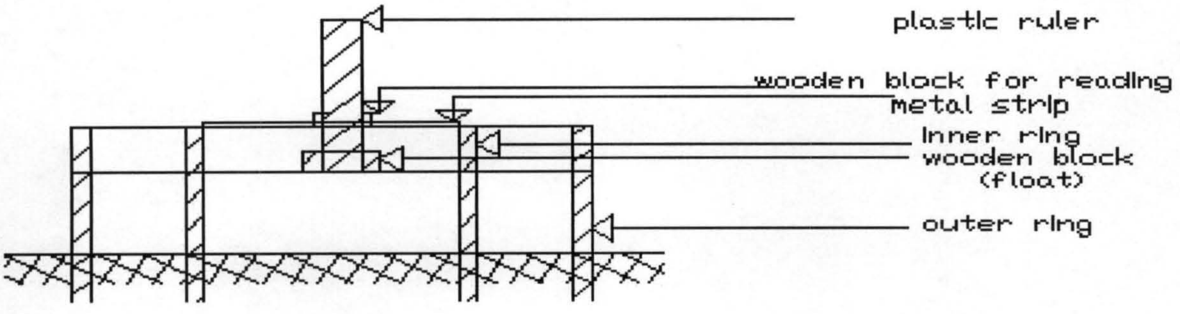


Figure 3.3: A Dissected Double Ring infiltrometer.

3.4. Component Parts of the Rainfall Simulator

3.4.1 Frame

The rainfall simulator frame is made of wooden planks on which the rainfall simulator rested. It is made up of a four sided frame with a dimension of 25mm. The simulator was therefore placed on top of wooden frame at a height of 1.83 m which can easily be assembled and dissembled.

3.4.2 Wind Shield

The wind shield which serves as a protective covering for the simulator from external wind current is made of a light transparent polythene leather. This enables system isolation which makes it possible for reproducing similar rain patterns.

3.4.3 Water Supply tank

Water supply for the simulator is supplied direct from a motorized water tanker which feeds the rainfall simulatordirectly through the inlet pipe of the simulator. The quantity of water leaving the tank via the pump is regulated with the control valve attached to the pumping machine which is in-turn attached to the water tanker. The water tank capacity is 11,000,000 cm^3 which will be able to run each of the experiment for at least 4hours of continuous simulated rainfall.

3.4.4 Pump

The simulator pump that is used for this study is petrol powered one stroke engine with a rating of 2.98 KWand a volumetric flow rate of 10000 cm^3/sec which is equivalent to 0.01 m^3/sec. The pump water velocity was calculated from the formula for the mass flow rate

$$m = QX\rho \qquad 3.15$$

Where m = mass water moving through the pipe

ρ = density of water;

V = velocity of flow of water inside the pipe;

A = area of the pipe in question.

But $A = \pi r^2$

For the first pipe with an inner diameter of 0.0381 m, the radius r of the pipe will be half the diameter

$$r = \frac{D}{2} = \frac{0.0381}{2} = 0.01905\text{m}$$

$$\therefore A_1 = \pi r^2$$

$= 3.142 \text{ X } 0.01905^2$

$= 3.142 \text{ X } 0.0003629025$

$= 0.001140239655 \text{ m}^2$

$= 1.1402 \text{ X } 10^{-3} \text{ m}^2$

The velocity at this point is calculated as

$$V_1 = \frac{m}{\rho A} \qquad 3.16$$

$$= \frac{10}{1000\ X\ 1.1402X10^{-3}}$$

= 8.7704 m/s

For the second pipe, a pipe diameter of 0.03175 m was used, thus $Q_1 = Q_2$.

$$\therefore A_1V_1 = A_2V_2$$

$V_2 = \frac{A_1V_1}{A_2}$ 3.17

But we know already that

$$A = \pi r^2$$

$A_2 = 3.142\ X\ 0.015875^2$

$= 0.00079183309375\ m^2$

$= 7.9183\ X\ 10^{-4}\ m^2$

$$V_2 = \frac{1.1402\ X10^{-3}X\ 8.7704}{7.9183\ X10^{-4}}$$

$V_2 = 1.2629\ X\ 10^{-4}$

At the third pipe, a diameter of 0.0254 m was used. It is worthy of note that the 10 of the 0.0254 m pipes were used which implies that the water flowing from the main and sub-main lines were further divided into ten other pipes. Thus, the quantity of water flowing through these pipes is thus reduced to 0.001 m^3/sec. Therefore, mass of flow at this point will be

$$m = QX\rho$$

$= 1\ X\ 10^{-3}\ X\ 1000$

= 1 kg/sec

Where r = 0.0127 m

$$A_3 = \pi r^2$$

= 3.142 X 0.0127^2

= 5.067 X 10^{-4} m^2

$$V_3 = \frac{m}{\rho A_3}$$

$$= \frac{1}{1000\ X\ 5.067\ X 10^{-4}}$$

= 1.9736 m/s

On further distribution to each of the ten pipes, a pipe diameter of 0.0127m was attached to distribute the water into the shower caps. This implies that the volume of water that will flow through each of the pipes will be 0.0002 m^3/sec.

$$\therefore m = QX\rho$$

= 0.0002 X 1000

= 0.2 kg/sec

$$A_4 = \pi r^2$$

= 3.142 X (6.32 X $10^{-3})^2$

= 1.267 X 10^{-4} m^2

$$V_4 = \frac{m}{\rho A_4}$$

$= \frac{0.2}{1000\ X\ 1.267\ X 10^{-4}}$

= 1.5785 m/s

3.4.5 Sprayer Outlet

Considering an average diameter of 2mm for the spray head area of outlet is given by

$$A_H = \pi \times r^2 \quad 3.18$$

Where

A_H = Area of hole (m^2)

r = radius of hole (m)

$= 3.142 \, X \, 1 \, X \, 10^{6}$

$= 3.142 \, X \, 10^{6} \, m^2$

3.4.6 Number of Holes

The number of outlet holes on each of the spray head is given by dividing the pipe area of cross section by hole area of cross section

$$No\ of\ holes = \frac{Cross\ sectional\ area\ of\ pipe}{Cross\ sectional\ area\ of\ hole} \quad 3.19$$

$$= \frac{1.267 \, X \, 10^{-4}}{3.142 \, X \, 10^{-6}}$$

= 40.3503184713376 holes

3.4.7 Simulator Catchments Area

Area $(A_c) = l \times b$

l = length of simulator = 6 m

b= breadth of simulator = 3 m

Area $(A_c) = 6 \times 3 = 18 \, m^2$

3.4.8 Losses In The Network

In the main supply line (between pipes 1 and 2), the head loss was calculated for from

$$h_1 = \frac{kv^2}{2g} \qquad 3.20$$

Where k = a constant for a sharp inlet (o.5)

v = velocity head (12.6263)

g = acceleration due to gravity (9.81)

$$h_1 = \frac{0.5\ X\ 12.6263^2}{2\ X\ 9.81} = 4.06$$

In the submain line (that is between pipes 2 and 3), the head loss is calculated as

$$h_2 = \frac{kv^2}{2g}$$

Where k is a constant for tee joints is 1.8

$$h_2 = \frac{1.8\ X\ 1.9736^2}{2\ X\ 9.81} = 0.36$$

In the sub-sub-main section of the network (that is between pipes 3 and 4), we have

$$h_3 = \frac{kv^2}{2g}$$

$$h_3 = \frac{1.8\ X\ 1.5785^2}{2\ X\ 9.81} = 0.229$$

The total head loss in the network therefore is

$$H_T = \frac{4.06}{10} + \frac{0.36}{5} + 0.229$$

$$H_T = \frac{4.06}{10} + \frac{0.36}{5} + 0.229$$

= 0.406 + 0.075 + 0.229

= 0.71

The final velocity at the shower caps will be

$$V = H_T V_4 \quad 3.21$$

= 1.5785 X 0.71

= 1.1207 m/s.

3.4.9 Runoff Plots and Site Set-up

The size of each plot was larger than 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 (250litres) 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 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

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

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

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:

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

$$\text{MC} = \frac{W_w - W_d}{W_d} \times 100\ \% \qquad 3.25$$

Where

W_w= weight of wet soil (g)

W_d=weight of dry soil (g)

3.5.4 Bulk Density

Separate 3 cans from each sample (make the volume of each can 3-5cm3), tie a string around each can with thread so that it can hang freely from a 2inches length of thread with a loop on the end. Place each can in a numbered and weighed beaker, recording the sample and beaker number on the data sheet, then place the beakers containing the can in the oven and allow them to dry over night, remove the beakers, cool in the desiccator, weigh the beakers containing the cans, and record the data (subtracting the weight of the beaker from the combined weight of the cans and beaker). Melt a cup of paraffin (wax), stabilizing it between 55° - 60° then dip each can in the paraffin and allow to dry, making sure that the can is entirely sealed. If there are any holes noticed, dip a rod in the melted wax and apply a drop of hot wax to patch the hole. Do not re-dip the whole can because the wax coating will be too thick. Weigh the coated can without the beaker and record its weight. Immerse the can in water and weigh the beaker and can on a triple beam balance using a ring stand to hold the beaker of water positioned just above the balance pan. Peel the coating off each can and return it to its beaker. Fill each beaker with water so that the can will get soggy and fall apart. Wet sieve the contents of each beaker through a >2mm sieve. Discard all but the >2mm fraction. Return portion to the beaker and place in the oven to dry. Weigh the >2mm contents of each beaker and record the weights on the data sheet.

3.5.4.1 Calculations

1. Adjusted dry weight = (dry weight of the can) - (dry weight >2mm fraction)

2. Weight of paraffin = (weight of dry can) + (paraffin) - (dry weight of can)

3. Adjusted immersed weight = (weight of can with paraffin in water) + 0.1 (weight of paraffin) - 1.65 (weight of the >2mm material/ 2.65)*

4. Specific gravity = (adjusted weight)/ ((adjusted dry weight)-(adjusted immersed weight))

***Note:** 0.1(can with paraffin weight-dry weight can) ----corrects for the buoyant force of the wax 1.65(>2mm weight/2.65) ---- corrects for the >2mm material assuming a density of 2.65 g/cm3 /for that material.

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 SOIL

The experiment was carried out on disturbed and undisturbed sandy soil conditions, the nature of the soil allows excess water to be drained into the ground thereby reducing runoff but the two conditions and the season at which the experiments was carried out affect the result. The experiments was performed ten different times for the two sandy soil conditions considered thereby giving twenty values for the two conditions.

The plots of land considered for the two conditions before the experiments looks very dried and compacted but during the experiment we started noticing the properties of sandy soil on it and some hours after the experiments we noticed that the rate of infiltration was high and weeds started growing and the soil looks different compared to the initial stage of the of the experiments.

4.1.1 SOIL TEXTURE

Soil texture refers to the relative amounts of differently sized soil particles, or the fineness/coarseness of the mineral particles in the soil. Soil texture depends on the relative amounts of sand, silt, and clay. In each texture class, there is a range in the amount of sand, silt, and clay that each class contains.

Since sandy soil particles was classified by the USDA and FAO as having the largest soil particles greater than 0.05 in diameters, it was noticed in table 4.1 which shows the Textural properties of representative soil units in Gidan Kwanu and its average corresponding bulk density that the soil horizon for sandy soil which starts from O; followed by A, B, and C. Sandy soil has the highest percentage of sand particles which is 91%, 89%, 79% and 75% respectively and lowest percentage of silt and clay particles which are 2%, 5%, 6%, 5% and 7, 6, 15, 20 respectively for horizon O, A, B, and C.

This shows that sandy soil particles is very loose in terms of its binding material and organic matter content.

Soil Horizon

A soil horizon is a distinctive soil layer such as topsoil or subsoil. Collectively, the horizons make up what is called a soil profile. Most soils, as they develop, become arranged in a series of layers, known as horizons. These horizons, starting at the soil surface and proceeding deeper into the ground, reflect different properties and different degrees of weathering.

Horizon 0 (Organic Matter)

This contains the organic matter that is necessary for plant growth; it consists of loose organic matter such as fallen leaves and other biomass. The depth considered here is between 0 and 20 cm.

Horizon A (Top Soil)

Topsoil is the uppermost layer of soil; it is rich in organic matter called humus, and it holds most of the roots of plants containing a mixture of inorganic mineral materials. The depth consider here is between 20-50cm

Horizon B (Sub Soil)

The subsoil, also called the B horizon, is rich in minerals but contains less humus than the topsoil above it; a layer from which clay, iron, and aluminium oxides have been lost by a process known as leaching (when water carries materials in solution down from one soil level to another). Removal of materials in this manner is known as eluviation. The depth consider here is between 50-75cm

Horizon C (Rock Fragment)

It consists of partially weather bedrock; a zone of little or no humus accumulation or soil structure development. The C horizon often is composed of unconsolidated parent material from which the A and B horizons have formed. It lacks the characteristic features of the A and

B horizons and may be either relatively unweather or deeply weathered. The depth consider here is between 75-110cm

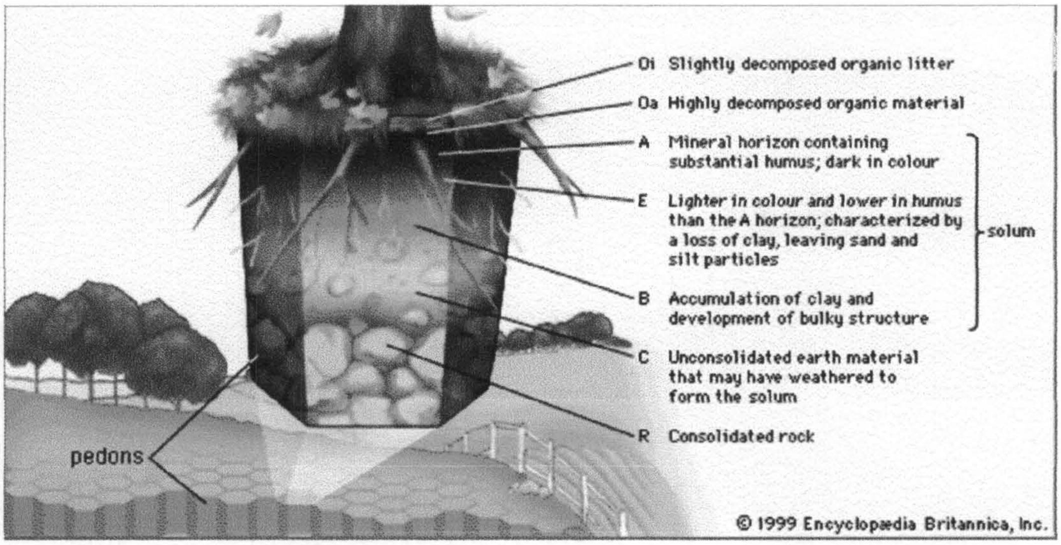


Figure 4.1 Soil Horizon

Table 4.1: Textural properties of sandy soil in Gidan Kwanu and its average corresponding bulk density

Units	Horizon	Depth (cm)	% Sand	% Silt	% Clay	Soil type	Bulk density (g/cm^3)
1	0	0-20	91	2	7	Sandy	1.67456
	A	20-50	89	5	6	Sandy	1,69376
	B	50-75	79	6	15	Sandy loam	1.5368
	C	75-110	75	5	20	Sandy loam	1.48592

Sandy soil can be classified according to size by running it through special sieves or screens, for which various national and international standards have been accepted. Modern standards now classify sieves according to the size of the aperture, as measured in millimetres or micrometres (10^{-6} metre).The particle size for the soil was first determined using sieve analysis method; but when the result was compared to USDA soil table. The other method used was the hydrometer method, which produce acceptable result. This method uses chemical reagent to separate soils into their relative amounts. Sandy soil particle size is always between 0.05 mm (0.002 inch) and 2 mm (0.08 inch). It also determines porosity, soil texture, mineralogical composition, grain size.

Table 4.2 Soil Classification

Name of soil separate	Diameter limits (mm) (USDA and FAO classification)
Clay	less than 0.002
Silt	0.002–0.05
Very fine sand	0.05–0.10
Fine sand	0.10–0.25
Medium sand	0.25–0.50
Coarse sand	0.50–1.00
Very coarse sand	1.00–2.00

4.2 Infiltration

When water from a rainstorm reaches the ground, some or all of it will infiltrate the soil. The rate of infiltration depends on the intensity of the input, the initial moisture condition of the surface soil layer, and the hydraulic characteristics of the soil. Small-scale effects such as the presence of a surface seal of low permeability (due to the rearrangement of surface soil particles by rain splash) or the presence of large channels and cracks in the surface soil may be important in controlling infiltration rates. Water in excess of the infiltration capacity of the soil will flow overland as surface runoff once the minor undulations in the surface (the depression storage) have been filled. The infiltration rate test was carried out using a double ring infiltrometer and the time for sixteen different reading of the ruler was taken for both soil conditions, which starts from zero(0) minutes to one hundred and eighty (180) minutes. And the value ranges from highest to lowest for the two soil conditions. Table 4.3 here shows the result for infiltration rates for disturbed and undisturbed sandy soils. It is important to note that the rate of infiltration is always very rapid at the start of the experiment but gradually declines with time until a steady state is reached.

Table 4.3 Average infiltration rate for sandy soils under the disturbed and undisturbed condition during dry season

Time (Mins)	Undisturbed Sandy Soil	Disturbed Sandy Soil
0	35.50	25.50
1	32.40	22.40
2	30.25	20.25
5	26.20	18.20
10	24.10	17.10
15	22.40	15.40
20	21.40	13.40
30	21.40	11.40
45	19.50	9.50
60	18.20	8.20
75	14.40	6.40
90	12.50	5.50
100	10.10	5.10
120	8.50	4.50
150	6.40	4.40
180	6.40	4.40
Average infiltration rate	19.35	11.98

The table below shows the average cumulative infiltration rate for sandy soil under the disturbed and undisturbed conditions during dry season. The time also starts from zero (0) minutes to one hundred and eighty (180) minutes and the value ranges from lowest to highest values for the two conditions considered for sandy soil.

Table 4.4 Average Cumulative infiltration rate for sandy soils under the disturbed and undisturbed condition during dry season.

Time (Mins)	Undisturbed Sandy Soil	Disturbed Sandy Soil
0	0.00	0.00
1	3.10	3.10
2	5.25	5.25
5	9.30	7.30
10	11.40	8.40
15	13.10	10.10
20	14.10	12.10
30	14.10	14.10
45	16.00	16.00
60	17.30	17.30
75	21.10	19.10
90	23.00	20.00
100	25.40	20.40
120	27.00	21.00
150	29.10	21.10
180	29.10	21.10
Average cumulative infiltration	16.15	13.52

The entire hydrologic system of a watershed is sometimes analysed using hydrology transport models, mathematical models that consider infiltration, runoff and channel flow to predict river flow rates and stream water quality.

4.3 Slope

The project site in Gidan Kwanu Campus has a gentle slope which increases the rate of runoff in respective of rainfall. The table below shows the average slope(degree) of sandy soil areas, which implies that it takes more time for runoff or rain water to move on undisturbed sandy soil than disturbed sandy soil. This shows a difference of 1.05 minutes between the soil conditions

Table 4.5 Average Slope (degree) of sandy soil areas

Plot No	Undisturbed Sandy soil	Disturbed Sandy Soil
1	5.00	3.83
2	4.90	4.02
3	4.72	3.84
4	4.92	3.86
5	5.05	3.89
6	5.07	4.02
7	4.75	3.84
8	4.87	3.82
9	5.00	3.84
10	5.10	3.96
Average Slope	4.94	3.89

4.4 Time of Concentration

The travel time of runoff from the hydrologically most remote point in a drainage basin to a Specified collection point. Time of concentration is useful in predicting flow rates that would result from hypothetical storms, which are based on statistically-derived return period. For many reasons, it is important for Agricultural Engineers to accurately predict the response of a watershed to a given rain event. This can also be important for infrastructure development like design of bridges, culverts etc. as well as assessing flood risks (Haan, 1994). The time shows a greater value for the disturbed plot of land during the experiment and these implies that the infiltration rate is greater on that plots. The time of concentration is also determined by the following conditions:- (a) length of the soil (b) surface roughness of the soil (c) slope of the soil (d) rainfall intensity on soil (e) shape of soil (f) Temperature (g) Infiltration rate (h) size of soil and (i) Topography. The time of concentration was calculated using the F.A.A method and $t_c = \frac{0.39(1.1-C)L^{1/2}}{S^{1/3}}$ where

t_c = concentration time, hrs

L = the longest length of water travel, m

S = ground surface slope

Where C = dimensionless runoff coefficient.

Table 4.6 Average time for a 0.25 m^3 container to be filled up for sandy soil plot observed under various soil conditions during dry season.

Plot No	Undisturbed Sandy Soil	Disturbed Sandy Soil
1	50.35	54.23
2	53.41	57.13
3	55.52	58.39
4	56.55	58.36
5	50.28	55.19
6	52.35	56.28
7	54.47	57.56
8	55.10	58.45

9	56.08	45.35
10	57.25	49.50
Average T_d (Minutes)	54.14	55.04

Where Td is the Time taken to fill a drum of 0.25 m^3 capacity

The table below shows the regression analysis of infiltration rates for sandy soils plots in Gidan Kwanu It shows seasonality value for regression (R^2) for dry season, and seasonality equation of the form Y=Mx+C for dry season value for sandy soil.

Table 4.7 Regression analysis of Infiltration rates for sandy soil

S/No	Type of Soil	Condition of Soil	Seasonality Values of R^2	Seasonality Equation of the Form Y=Mx+c
	Soil	Condition	Dry	Dry
1	Sandy	undisturbed	0.862	Y= -0.147X + 18.36
		Disturbed	0.745	Y= -0.106X + 17.98

The table below shows the regression analysis of cumulative infiltration for the various soils of Gidan kwanu. It involves the analysis of variance and shows if it has a statistically significant effect on the response variables.

Table 4.8: Regression analysis of cumulative infiltration for sandy soil

S/No	Type of Soil	Condition of Soil	Seasonality Values of R^2	Seasonality Equation of the Form Y=Mx+c
	Soil	Condition	Dry	Dry
1	Sandy	Undisturbed	0.862	Y = 0.147X + 7,810
		Disturbed	0.745	Y = 0.106X + 7.512

The table below shows the observed moisture content of sandy soil for dry season. The difference in values for the two soil condition considered is 1.23 and these result shows that the disturbed plots holds more water than the undisturbed plots.

Table 4.9 Observed moisture content for dry season

Plot No	Undisturbed Sandy Soil	Disturbed Sandy Soil
1	1.73	1.15
2	2.23	1.34
3	2.11	1.34
4	4.58	1.21
5	4.11	1.37
6	2.78	1.24
7	1.78	1.37
8	1.98	1.48
9	2.33	1.37
10	2.00	1.43
Average Mc	2.56	1.33

4.5 DEVELOPING MANNING-NIGERIA COEFFICIENTS

According to the numerical 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 or overall slope of the land was fixed at 9% with a standard length of 22.9m to mimic the situation explored in the problem statement. The simulated land surface also incorporated micro topography, which allowed various simulations of surface roughness's. Rather than beginning with the Saint-Venant equations, or a further simplification of these equations such as the dynamic wave or Manning's equations. 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 number,

S is the watershed slope,

i is the rainfall intensity.

K is a constant and a, b, y, z are exponents.

This equation exhibits a linear correlation of the logarithms of the variables involved. It was observed that the antecedent soil moisture had a strong influence on the surface runoff travel time for the two seasons considered. Using the above model as the baseline model, Cahill and Li (2005) added the antecedent soil moisture variable to create a new model. And 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. It was discovered that the above stated equations were more complicated than the Saint-Venant equations (the Saint-Venant equations are a simplification of the Navier-Stokes equations). 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. The model developed for this study is stated below as:

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

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 watershed slope, and i is the rainfall intensity in mm/hr.

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

$$n^{0.324} = \frac{T_C}{0.938L^{0.878}\theta^{-0.222}S^{-0.049}i^{-0.075}} \quad 4.4$$

Taking the log of both sides, we have

$$Logn^{0.324} = Log\left(\frac{T_C}{0.938L^{0.878}\theta^{-0.222}S^{-0.049}i^{-0.075}}\right) \quad 4.5$$

$$0.324Logn = Log\,T_c - 0.938\text{Log}(L^{0.878}\theta^{-0.222}S^{-0.049}i^{-0.075}) \quad 4.6$$

$$Logn = \frac{LogT_C - 0.938Log(L^{0.878}\theta^{-0.222}S^{-0.049}i^{-0.075})}{0.324} \quad 4.7$$

Equation 4.7 above was used to determine the Manning-Nigeria coefficient for some of the soils considered in this study. It was observed that S variable had the least influence on the Manning-Nigeria coefficient as S has the least exponent figure among all variables.

Table 4.10: Predicting Variables in the New Runoff Travel Time Model

Exponents of Parameters	Coefficients
k (constant)	0.938
x (exponent of θ)	-0.222
b (exponent of *n*)	0.324
y (exponent of *S)*	-0.049
z (exponent of *i*)	-0.074

The values obtained using equation 4.7 was compared with the model developed by Cahill and Li (2005) and Kerby (1959). The model developed by Cahill and Li (2005) states that

$$T_c = 0.951\,.\,L^{0.5}\,.\,n^{0.326}\,.\,\theta^{-0.459}\,.\,S^{-0.053}\,.\,i^{-0.674} \quad 4.8$$

From equation 4.8, making n the subject of formula to be able to determine the Manning coefficient using the Cahill and Li model, we have

$$n^{0.326} = \frac{T_c}{0.951L^{0.5}\theta^{-0.459}S^{-0.053}i^{-0.674}} \qquad 4.9$$

Taking the log of both sides, we have

$$Logn^{0.326} = Log\left(\frac{T_c}{0.951L^{0.5}\theta^{-0.459}S^{-0.053}i^{-0.674}}\right) \qquad 4.10$$

$$0.326Logn = Log\,T_c - 0.951\text{Log}(L^{0.5}\theta^{-0.459}S^{-0.053}i^{-0.674}) \qquad 4.11$$

$$Logn = \frac{LogT_c - 0.951Log(L^{0.5}\theta^{-0.459}S^{-0.053}i^{-0.674})}{0.326} \qquad 4.12$$

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

$$T_c * S^{0.5} = 0.83(nL)^{0.467} \qquad 4.13$$

$$\frac{T_c * S^{0.5}}{0.83} = (nL)^{0.467} \qquad 4.14$$

Taking the Log of both sides, we have

$$LogT_c + 0.5LogS - Log0.83 = 0.467Logn + 0.467LogL \qquad 4.15$$

$$LogT_c + 0.5LogS + 0.081 = 0.467(Logn + LogL) \qquad 4.16$$

$$\frac{LogT_c + 0.5LogS + 0.081}{0.467} = Logn + LogL \qquad 4.17$$

$$\left(\frac{LogT_c + 0.5LogS + 0.081}{0.467}\right) - Log\,L = Logn \qquad 4.18$$

Using the same data that was obtained from the various study sites, equations 4.12 and 4.18 were also used to determine the Manning-Nigeria coefficient. Table 4.11 presents the developed Manning-Nigeria coefficient for the various soils using the developed model for the soils in Gidan Kwanu and those developed by Cahill and Li (2005) and Kerby (1959). It was observed that the model used to determine the Manning-Nigeria coefficient produced a better result when compared with the other models. The highest value of the Manning-Nigeria coefficient was calculated to be 0.03 for dry season, while the lowest values were calculated to be 0.02 for dry season. Which when compared with the figures obtained by Manning where very much in line. When the values were statistically compared with each other, it was calculated that the values obtained had a probability value of 4.06E-30 with an F-critical value of 2.408514. It was also observed from Table 4.11 that the degree of freedom between the groups was calculated to be 5 while the degree between the groups is 48. Table 4.11 also shows the statistical analysis of the various figures obtained for the two other models.

Table 4.11 Developed Manning-Nigeria Coefficient for the three models

			Manning-Nigeria Model	Cahill and Li Model	Kerby's Model
S/no	Type of soil	Condition of soil	Dry	Dry	Dry
		Undisturbed	0.03	52.72	41.88
1	Sandy	Disturbed	0.02	47.53	41.88

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project centers on determining hydrologic coefficient for sandy soil for two different conditions; which create a great interaction between air, water and soil medium that is meant to develop a relationship between soil moisture content, soil infiltration rate, slope and runoff. So as to: Determine the surface runoff and infiltration rate coefficients for disturbed and undisturbed sandy soils. To develop an empirical mathematical model/equation using the Crammer's rule capable of determining the Manning's coefficient for the various conditions of sandy soil for a small watershed. 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. This interaction is also used to develop a mathematical model capable of creating a value that is generally accepted and values that can be used for future references. Since policy implication are well implemented and when formulated are kept in shelves. These gives project developed in universities no recognition and value.

From the values of the Manning –Nigeria coefficient calculated, it was observed that the values were almost the same with that of Manning coefficient though the works of Manning coefficient were not site specific. Thus, these developed coefficients for the Gidan Kwano soils should be validated by using it to design for various farm and water way structures.

5.2 RECOMMENDATION

In the application of this work, the following areas are recommended

1. The experiment should be carried out on different sandy soil site of the same and different weather condition in respective of soil colour within and outside Minna and Niger State.

2 The result gotten from the experiment should be used to try solving some existing problems relating to hydrology.

3. Further experiments should be performed so as to compare results and to ensure that the values are universally accepted and used, and also to validate the coefficient.

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PLATES

PLATE 1 SETTING UP SITE FOR SIMULATION

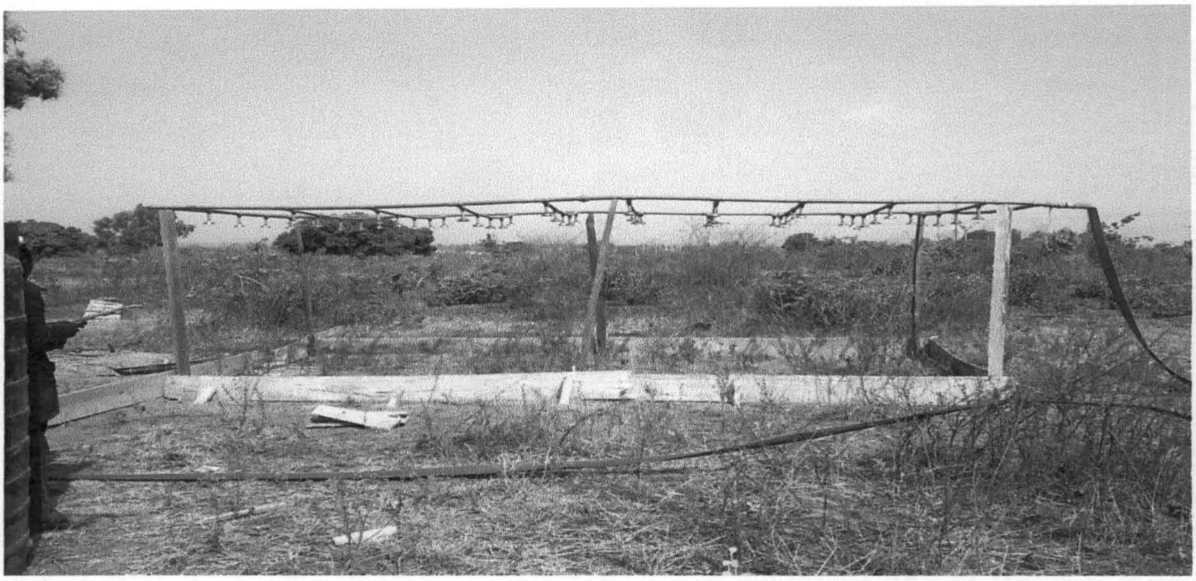

PLATE 11 SITE SETUP READY FOR SIMULATION

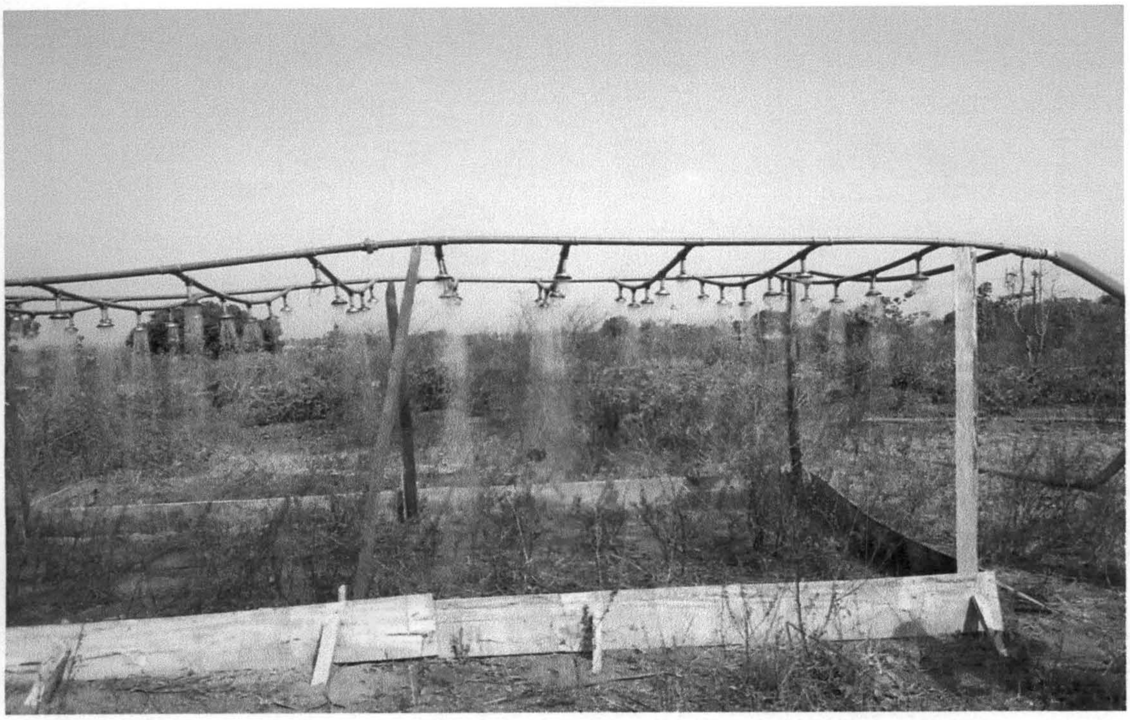

PLATE 111 SITE DURING SIMULATION

PLATE 1V SITE IMMEDIATELY AFTER SIMULATION

PLATE IV SITE DURING INFILTRATION

APPENDICES

APPENDIX 1: - MATHEMATICAL CALCULATION USING MATRIX METHOD (CRAMMER`S RULE)

> $k := 0.935$

$$k := 0.935$$

> $t := \ln(9.0)$

$$t := 2.19722457$$

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

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

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

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

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

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

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

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

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

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

> *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 := 0.3244964399

\>

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, -2.054404979, 2.596746132, -2.927613012],
[2.927613012, -4.446853526, -2.054404979, 2.603430152, -2.902788544],
[2.927613012, -4.446853526, -2.054404979, 2.532108251, -2.851070292],
[2.927613012, -4.446853526, -2.054404979, 2.584751985, -3.575705625],
[2.927613012, -4.446853526, -2.054404979, 2.597491011, -3.474467594]]

A4 := [[2.927613012, -4.446853526, -2.054404979, 2.596746132, -2.927613012],
[2.927613012, -4.446853526, -2.054404979, 2.603430152, -2.902788544],
[2.927613012, -4.446853526, -2.054404979, 2.532108251, -2.851070292],
[2.927613012, -4.446853526, -2.054404979, 2.584751985, -3.575705625],
[2.927613012, -4.446853526, -2.054404979, 2.597491011, -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]]

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

> $c6 := Determinant(A5);$

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

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

$$av := -0.0749999999$$

>