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

BY

ULOKO, ENEOJO SAMUEL

MATRIC No. 2006/24025EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

DECEMBER, 2010

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BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

DECEMBER, 2010

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

Uloko, Eneojo Samuel

06/12/10
Date

CERTIFICATION

This is to certify that the project entitled "Determination of Hydrologic Coefficients of Undisturbed Sandy-loam Soil (A Case Study of Gidan Kwano Campus of the Federal University of Technology, Minna, Niger State)" by Ulok, Eneojo Samuel 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.

Mr. John Jiya Musa
Supervisor

13/12/2010
Date

Engr. Dr. A. A. Balami
Head of Department

13/12/2010
Date

External Examiner

8/12/2010
Date

DEDICATION

I dedicate this project to my parents, Mr. and Mrs. Francis M. Uloko.

ACKNOWLEDGEMENT

I give thanks to God almighty, who gave me the insight, the source of my inspiration and author of my ability. Blessed be His name of the forever, amen.

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ABSTRACT

Estimating the amount of surface runoff in a watershed after a storm is of paramount importance as a mathematical equation will be developed from the various parameters such as infiltration rate, slope, moisture content, rainfall intensity and surface runoff to be able to develop a coefficient for the undisturbed loamy-sand soil in Gidan kwano campus of the Federal University of Technology Minna, Niger State. A rainfall simulator was used to simulate the type of rainfall condition in this area on an area of 6m by 3m, and ten (10) replicate of the catchment area was investigated in order to have a high degree of accuracy. The type of soil considered here is the Sandy-loam soil using the hydrometer methodafter conducting a hydrometer method of soil analysis. The average infiltration rate of the ten plots was found to be 21.2cm/hr using a double ring infiltrometer. The average slope was found to 3.0^0 (5.4%) using the change in height method. The average moisture content before and after the simulation was found to be 38.56% and 58.35% respectively using the gravimetric method. A multiple linear regression analysis was used using the Microsoft office excel 2007for which the relationship in the form of $y = mx + c$ was gotten as: $Y = -0.00228x_1 - 0.089751x_2 - 0.0138x_3 + 2.530299$; Where x_1 is the initial moisture content, x_2 is the infiltration rate and x_3 is the surface runoff.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

As a watershed begins to accept precipitation, surface vegetation and depression intercept and retain a portion of that precipitation. Interception, depression storage and soil moisture each contributes to groundwater accretion, which constitute the basin recharge. Precipitation that does not contribute to basin recharge is direct runoff (interflow), which flows into surface streams. The basin recharge rate is at its maximum at the beginning of a storm, and decreases as the storm progresses (Wilson, 1984).

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 servers as well as agricultural highway and various drainage systems is based. Quantitatively describing the rate and path of movement of a rain droplet after it strikes the ground surface is essential for the development and efficient utilization of our nation 's water resources (Wilson, 1984).

Basically, a method is needed whereby, for known or assumed condition within a watershed, the runoff hydrograph resulting from any real or hypothetical storm can be predicted with a degree of reliability. Such a method must be sufficiently general to allow the determination of the change in system response that would result from propose water management project within the watershed. Only with this type of analysis can such project be designed on rational basis to produce optimum conditions for a minimum cost (Wilson, 1984).

Some of the most common method of describing the hydrologic performance of a watershed has been based upon years of rainfall records and the resulting runoff from each storm. Though, a great number of water control project was designed and installed on smaller watersheds where little or no past hydrologic records and available (Wilson, 1984). Most of these designs were based on the already existing hydrologic coefficients developed for other areas of the world.

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 (Subramanya, 2006).

Rainfall, if it is not intercepted by vegetation or artificial surfaces such as roofs or pavements falls directly on the earth and either evaporate, infiltrates, or lies in depression storage. When the losses arises in this ways are all provided for, there may remain a surplus that, obeying the gravitational laws, flows over or below the surface to the nearest stream channel or river and finally into the stream or ocean. Hence, the water travelling over the land from one point to the other is referred to as the surface runoff (Wilson, 1984). This process is made possible when the rainfall reaching the soil surface is less than the infiltration capacity, all the water is absorbed into the soil and as the rain continues, plant surface becomes saturated, the interception-loss rate declines and infiltration capacity is reduced.

When the rate of rainfall exceeds the rate of infiltration, shallow depression begins to fill with water. When these depressions are filled to overflow level, water begins to move by overland flow towards streams. The water required to fill depression prior to the beginning of surface runoff is call detention or depression storage (Micheal and Ojha, 2006). Runoff thus represents the output from a catchment area in a given unit of time. Based on time delay, surface runoff is divided into two categories which are the direct runoff and the base flow (Subramanya, 2006).

The proportion of the total rainfall that becomes runoff during a storm represents the runoff coefficient. In the classical rational method, it is considered to be a constant depending on the characteristics of the drainage basins such as surface cover. Though, several authors have proposed a dependence of runoff ratio on the percentage of impermeable catchments area (Schaake *et al.*, 1967 and Boughton, 1987). Hebson and Wood (1982), in their studies assumed a constant runoff coefficient, interpretation as the percentage of contributing area of runoff generation.

The necessity of estimating the hydrologic performance of a watershed and the numerous complexities of this problem has resulted in many proposed methods of analysis.

1.2 Statement of the Problem

Surface runoff as it concerns soil erosion is considered a global problem particularly in our local environment, causes reduction in cultivable depth of agricultural level, depletion of soil fertility rate, threatening of food production and eventual abandonment of agricultural lands. It also causes the pollution of river channels and blocking of canals with contamination sediments. It is important for engineers and hydrologists to accurately predict the response of a watershed to a given rain event for a given watershed. This can be important for infrastructural development such as design of bridges, culverts, etc and management, as well as to asses flood risk.

To overcome this problem, a runoff research study is required which will allow for the collection of data from rain storms. Natural rainfall which could be used for data collection is not reliable since the certainty of its occurrence is not guaranteed, hence the use of artificially simulated rainfall.

1.3 Objectives of the Study

The broad objective of this project research work is to develop a model that best describes the condition of sandy-loam soils in Minna, Niger state that would improve the standard of construction activities.

The specific objectives therefore are:

i. To determine the surface runoff coefficient for sandy-loam soil in Minna, Niger state.

ii. To develop an empirical mathematical watershed equation capable of simulating the surface hydrograph from small unguarded watersheds.

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

1.4 Justification of the Study

Understanding the dynamics of the rainfall-runoff process constitutes one of the most important problems in hydrology, with obvious relevance for the management of water resources. Adequate knowledge of the rainfall-runoff process is needed for, among other things;

(a) Optimal design of water storage and drainage networks,

(b) Management of extreme events, such as floods and droughts and

(c) Determination of the rate of pollution transport.

In Nigeria as a whole, it has been observed that we adopt other coefficients of hydrologic properties from other countries of the world to carry out design calculations for the various types of structures we construct on our various soils. Thus, such construction works end up giving way within the short period of time which leads to loss of lives and properties.

Achieving the objectives stated will enhance the quality of infrastructures available within the various communities hence saving lives and properties.

1.5 Scope of the Study

The study is restricted to the modeling and determination of hydrologic coefficients for sandy-loamy soil in a small watershed, case study of the permanent site of the Federal University of Technology, Minna. This will look at standardizing the various coefficients for some basic soils used in Minna for construction works.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Rainfall is the primary source of water for runoff generation over the land surface. In common course of rainfall occurrence, over the land surface, a part is intercepted by vegetations, buildings and other objects, lying over the land surface and pavement to reach them on ground surface, this process is called interception. When all these losses are satisfied, then excess rainfall moves over the land surface and reaches to the smaller rills, known as overland flow. It again involves building of greater storage over the land surface and draining the same into channels/streams which is termed as runoff (Saresh, 2006).

2.2 Runoff

The term runoff is a descriptive term which is used to denote that part of hydrologic cycle which falls between the phase of precipitation and its subsequent discharge in the stream channels or direct return to the atmosphere through the process of evaporation and evapotranspiration.

Before runoff in a watershed can actually take place there must be a dry period and at the end of the dry period, there begins an intense and isolated storm. During this stage, all surface and channel storages get depleted, except in reservoir, lakes and ponds, from the previous storms. Under this condition, the source of stream flow is only the ground water flow which deceases with time. After the beginning of rainfall and before saturation of interception is the depression storage. Here every precipitation falls directly on the land surface or on stream surface which provides an immediate increment of stream flow (Saresh, 2006).

2.2.1 Types of Runoff

Based on the time delay between rainfall and runoff, it may be classified into the following types:

i. Surface Runoff
ii. Sub-surface Runoff
iii. Base flow

2.2.1.1 Surface Runoff

Surface runoff is that portion of rainfall, which enters the stream immediately after the rainfall. It occurs, when all losses are satisfied and if rain is still continued, with the rate greater than infiltration rate, at this stage the excess water makes a head over the ground surface (surface detention), which tends to move from one place to another is known as overland flow. As soon as the overland flow joins to the streams, channels or oceans, it is therefore called surface runoff (Saresh, 2006).

2.2.1.2 Sub-surface Runoff

According to Saresh (2006), he described this as that part of rainfall which first leaches into the soil and moves laterally without joining the water-table, to the s streams, rivers, or oceans is thus known as sub-surface runoff.

2.2.1.3 Base Flow

This is the delayed flow, defined as that part of rainfall which after falling on the ground surface, infiltrated into the soil and meets the water-table and flow to the streams, oceans, etc. the movement of this type of runoff is usually slow and that is why it is referred to as the delayed runoff (Saresh, 2006).

Thus;

Total Runoff = Surface Runoff + Base Flow (Including sub-surface runoff)

2.3 Factors Affecting Runoff

The factors affecting runoff may be divided into those factors which are associated with the climate of the area and those associated with the watershed (physiographic factors).

2.3.1 Climate Factors

Climate factors of the watershed affecting the runoff are mainly associated with the characteristics of precipitation which includes:

2.3.3.1 Precipitation

The various types of precipitation within a given watershed have a great effect on the runoff. Precipitation which occurs in form of rainfall starts immediately in form of surface flow over the land surface depending upon its intensity as well as magnitude, while precipitation which takes the form of snow or hail, the flow of water on ground surface will not take place immediately, but after melting of the same. During the process of melting, the time interval of the melted water infiltrates into the soil and results in a very little surface runoff generation (Garg, 2005).

2.3.1.2 Rainfall Intensity

One of the most important rainfall characteristics is rainfall intensity which is usually expressed in millimeters per hour. Very intense storms are not necessarily more frequent in areas having high total annual rainfall. Storms of high intensity generally last for fairly short periods and cover small areas. Storms covering large areas are seldom of high intensity but may last several days. The infrequent combination of relatively high intensity and long duration, gives large total amount of rainfall (Sareh, 2006). A general expression for rainfall intensity is given by;

$$I = \frac{KTx}{tn} \qquad 2.1$$

Where;

I is the rainfall intensity,

k, x and n are constants for a given geographic location,

t is the duration of storm in minutes and

T is the return period in years.

2.3.1.3 Duration of Rainfall

Rainfall duration is directly related to the volume of runoff, due to the fact, that infiltration rate of the area goes on decreasing with the duration of rainfall, till it attains a constant rate.

2.3.1.4 Rainfall Distribution

Runoff from a watershed depends on the rainfall distribution. The rainfall distribution of this purpose can be expressed by the term distribution coefficient, which may be defined as the ratio of maximum rainfall at a point to the mean rainfall of the watershed. For a given total rainfall, if all other conditions are the same, the greater the value of distribution coefficient, greater will be the peak runoff and vice –versa. However, for the same distribution coefficient, the peak runoff would be resulted from the storm, falling on the lower part of the basin i.e. near the outlet (Garg, 2005).

2.3.1.5 Direction of Prevailing Wind

The direction of wind affects runoff greatly as it flows in the direction of prevailing wind. Since this is similar to the drainage system then it has a great influence on the resulting peak flow and also on the duration of surface flow to reach the outlet. A storm moving in the direction of the stream slope produces a higher peak in shorter period of time, than a storm moving in opposite direction (Garg, 2005).

2.3.1.6 Temperature

The process of evaporation depends mainly on temperature. If the temperature is more, the saturation vapour pressure increase, and the evaporation increases. Thus, evaporation is more during the dry seasons than when compared with the rainy season (Garg, 2005). In the case runoff temperature is considered negligible as it has no significant effect on it.

2.3.1.7 Wind Velocity

The process of evaporation depends upon the prevailing turbulence in the air which further affects the available water on the earth surface. If the turbulence is more or in other words if the velocity of the air in contact with water surface is more, the saturated film of air contacting the water vapour will move easily, and the diffusion and dispersion of vapour will become easier, causing more evaporation hence reducing the surface runoff (Garg, 2005).

Wind turbulence near the ground causes the transport of water vapour away from an evaporating surface and helps to maintain the gradient of water vapour between the surface and the air. In simple terms wind is a two-dimensional vector quantity expressed by its speed and directions.

Wind speed is expressed as an average in meter per second or as total wind run in kilometer per day. Wind direction is given in degrees and referrer to the direction from which the wind is blowing. For the purpose of computing evaporation of water from the soil and transpiration form plant surface wind speed is the variable used.

2.3.2 Physiographic Factors

The following are the different characteristics of watershed and channel, which affect runoff:

2.3.2.1 Size of Watershed

Assuming the depth and intensity and all other factor remaining constant, then two watersheds irrespective of their size will produce about the same amount of runoff. However, a large watershed takes longer time for draining the runoff to the outlet, as a result the peak flow expressed as depth, is being smaller and vice-versa

2.3.2.2 Shape of Watershed

The shape of the watershed has a great effect on runoff. The watershed shape is generally expressed by the terms 'form factor' and compactness coefficient.

Form factor is defined as the ratio of average width to the axial length of the watershed; expressed as:

$$\text{Form factor} = \frac{\text{Average width of thewatershed}}{\text{Axial length of watershed}} = \frac{B}{L} \qquad 2.2$$

Axial length (L) of the watershed is the distance between outlet and remotest point of the area, while the average width (B) is obtained by the area (A) with the axial length (L) of the watershed.

Thus, form factor $= \frac{B}{L} = \frac{\frac{A}{L}}{L} = \frac{A}{\text{LxL}}$ 2.3

The compactness coefficient of watershed is the ratio of perimeter of the watershed to the circumference of a circle, whose area is equal to the area of the watershed. This is expressed as:

$$= \frac{perimeter\ of watershed}{Circumference\ of\ a\ circle\ whose\ area\ is\ equal\ to\ the\ watershed} \quad 2.4$$

$$= \frac{\text{P}}{2\sqrt{\pi A}} \quad 2.5$$

Where P = perimeter of the watershed

A = Area of watershed $\pi = 3.142$

In respect of the watershed shape, there are two types of watersheds shape, which are commonly assumed, in which one is fan shaped and the other is fern shape. The fan shape watershed tends to produce higher peak rate very early than the fern shape, due to the fact that in the former all parts of the watershed contribute runoff to the outlet simultaneously, a short period of time, than the fern shaped watershed.

2.3.2.3 Slope of Watershed

The slope of the watershed has an import ant role over runoff, but its effect is complex. It controls the time of overland flow and time o concentration of rainfall in the drainage channel, which provide a cumulative effect on resulting peak runoff. An example of which is when you have a steep slope in a watershed, the time to reach the flow at outlet is less, because of greater runoff velocity, which results into formation of peak runoff very soon and vice-versa.

2.3.2.4 Orientation of Watershed

This factor affects the evaporation and transpiration losses of the area by making influence on the amount of heat to be received from the sun. The north or south orientation of watershed affects the time of melting of collected snow for snow producing areas. In the mountainous watershed, the part located on the windward side of the mountain receives high intensity of rainfall, resulting into more runoff yield while the part of watershed lying towards leeward side has a reverse trend of the same.

2.3.2.5 Soil Moisture

The magnitude of runoff yield depends upon the amount of moisture present in the soil at the time of rainfall. If rain occurs over the soil which has more moisture, the infiltration rate becomes very less, which result in more runoff yield. Similarly, if the rain occurs after a long dry spell of time, when the soil is dry, causing to absorb huge amount of rain water. In this condition even intense rain, may fail to produce appreciable runoff yield has reverse effect.

2.3.2.6 Land Use

The land use pattern and management practice used have great effect on the runoff yield. An example of this is found in the forest areas where the earth surface is covered with a thick layer of leaves and grasses, there a little surface runoff due to the fact that more than rain water is absorbed by the soil. While on barren fields, where not any type of cover is available, a reverse trend is obtained.

2.3.2.7 Soil Type

In any watershed, surface runoff is greatly influenced by the soil type, as loss of water from the soil is very much dependent on infiltration rate which varies with the type of soil.

2.3.2.8 Topographic Characteristics

This includes features of the watershed, which create their effect on runoff; it is mainly the undulating features of the watershed. Undulating watershed usually have greater runoff than the flat land, because of the reason that runoff water gets additional power to flow due to slope of the surface and little to infiltrate water into soil. Regarding channel characteristics, to describe their effect on runoff, the channel cross-section, roughness, storage and channel density are mainly considered.

2.3.3 Infiltration

A water droplet incident at the soil surface has just two options: it can infiltrate the soil or it can run off. This partitioning process is critical. Infiltration, and its complement runoff, is of interest to hydrologists who study runoff generation, river flow, and groundwater recharge. The entry of water through the surface concerns soil scientists, for infiltration replenishes the soil's store of water. The partitioning process is critically dependent of the physical state of the surface. Furthermore, infiltrating water acts as the vehicle for both nutrients and chemical contaminants.

This identifies the roles played by capillarity, the first term on the right hand side, and gravity, the second term. These two forces combine to move water through unsaturated soil.

2.3.4 Evapotranspiration (ET)

The water requirement of a given crop is represented by its evapotranspiration (ET), basically defined as the rate of transfer of water vapour from plant and soil surface to the atmosphere or is the sum of evaporation and plant transpiration. In evaporation, eater is evaporated from lake or pond surface and from rain droplets caught in the leaves of trees. Transpiration takes water out of the watershed by evaporation of water through the pores in leaves. The trees acquire water through the roots exclusively. This is the key element for the implementation of irrigation management strategies for crop production at both farm and irrigation scheme.

Factors affecting evapotranspiration include the plant's growth stage or level of maturity, percentage of soil cover, solar radiation, humidity, temperature and wind.

2.4 Methods of Surface Runoff Estimation

A storm event is generally characterized by its size and the frequency of its occurrence. The size of the storm is the total precipitation that occurs in a specified duration. How often this size storm is likely to repeat is called the frequency. The peak discharge resulting from a given rainfall is particularly influenced by the rainfall distribution, which describes the variation of the rainfall intensity during the storm duration. A rainfall may have been evenly distributed over the 4 hour period or the majority of it may have come in just a few hours, which is typical. These two scenarios present entirely different types of rainfall distributions and peak discharges. Several techniques have been available for the estimation of runoff volume and peak discharge. These vary from simplified procedures such as the rational formula for small, homogenous areas, to complicated computer programs that can handle more complex situations. Some of the common methods are:

2.4.1 Manning formula

The manning formula, known also as the Gauckler-Manning formula, or Gauckler-Manning-Stickler formula in Europe, is an empirical formula for open channel flow, or free-surface flow driven by gravity. It was first presented by French engineer Philippe Gauckler in1867, and later re-developed by the Irish engineer Robert Manning in 1890.

The Gauckler-Manning formula states:

$$V = \frac{K}{n} R_h^{2/3} . S^{1/2} \qquad 2.8$$

Where:

V is the cross-sectional average velocity (ft/s, m/s)

K is a conversional constant equal to 1.486 for U.S. customary units or 1.0 for SI units

n is the Gauckler-Manning coefficient (independent of units)

R_h is the hydraulic radius (ft, m)

S is the slope of the water surface or the linear hydraulic head loss (ft/ft, m/m) (S = h/L)

The discharge formula, Q = AV, can be used to manipulate Gauckler-Manning's equation by substitution for V. solving for Q then allows an estimate of the volumetric flow rate (discharge) without knowing the limiting or actual flow velocity.

The Gauckler-Manning formula is used to estimate flow in open channel situations where it is not practical to construct a weir or flume to measure flow with greater accuracy. The friction coefficients across weirs and orifices are less subjective than n along a natural (earthen, stone or vegetated) channel reach. Cross sectional area, as well as 'n', will likely vary along a natural channel. Accordingly, more error is expected in predicting flow by assuming a manning's n, than by measuring flow across a constructed weirs, flumes or orifices.

The formula can be obtained by use of dimensional analysis. Recently this formula was derived theoretically using the phenomenological theory of turbulence

2.4.2 Darcy's Law

In 1856 Henry-Philibert-Gaspard Darcy published a lengthy assessment of a proposed upgrading of the public water system for the French city of Dijon (Darcy 1856). His investigation of fountains called for information concerning the flow of water through sand filters; in an appendix to his report he included a description that has since come to be known as Darcy's law; the law is well known to hydrologists and Darcy's appendix has been partially translated into English (Hofmann and Hofmann, 1992).

In a number of experiments performed Darcy, he gradually increased the height of water in the upper manometer arm (the mean pressure) by adjusting his inflow and outflow faucets .in his first four sets of measurements, the lower end of the column was open to atmospheric pressure. Darcy observed that the outflow volume invariably increased proportionally with the pressure head (Hofmann and Hofmann, 1992).

He then averaged the ratios of hydraulic head (Darcy's charge) to flow rate for each set of measurements, obtaining four proportionality constants. Darcy attributed the variation among the constants to differences in grain size and purity between the sands in different columns. He also claimed without argument that the data showed that the flow rates varied in inverse proportion to length of sand column. This conclusion was not obvious since the data provide did not include multiple measurements at fixed heads for different column lengths; however, it is substantiated by comparison of his data for differing column lengths with roughly equal mean pressure values. Darcy then performed a similar set of experiments differing mainly in that the pressure at the bottom of the column could be varied widely above or below atmospheric. He was satisfied that his earlier conclusions held in these cases as well (Hofmann and Hofmann, 1992).

Assumptions: Darcy's law is only valid for slow, viscous flow; fortunately, most groundwater flow cases fall in this category. Typically any flow with a Reynolds number (based on a pore size length scales) less than one is clearly laminar, and it would be valid to apply Darcy's law. Experimental tests have shown that flow regimes with values of Reynolds number up to 10 may still be Darcian. Reynolds number (a dimensionless parameter) for porous media flow is typically expressed as

$$\mathrm{Re} = \frac{pvd30}{\mu} \qquad 2.9$$

Where;

P is the density of the fluid (units of mass per volume).

V is the specific discharge (not the pore velocity – with units of length per time),

D_{30} is the representative grain diameter for the porous medium (often taken as the 30% passing size from a grain size analysis using sieves), and

μ Is the dynamic viscosity of the fluid.

2.4.3 Darcy- Weisbach Equation

The Darcy- Weisbach equation has a long history of development, which started in the 18th century and continues to this day. It is named after two of the great hydraulic engineers of the

a and b are empirical friction factors of the velocity and velocity squared.

iv. Iterate steps 1 through 3 until the estimated value of t_c converges with the calculated value.

2.5.3 Kerby Equation

Kerby (1959) defined flow length as the straight-line distance from the 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;

$$t_c = 0.83(nL)^{0.47}/\sqrt{S} \qquad 2.21$$

Where;

t_c is the time of concentration

S is the surface slope

n is Manning roughness coefficient

L is the flow length

This relationship is not commonly used and has the most limitations. It was developed based on watersheds less than 10 acres (4 ha) in size and having slopes less than one percent. It is generally applicable for flow lengths less than 300m.

2.5.4 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;

$$t_c = \frac{0.39(1.1-C)L_1/2}{S_1/3} \qquad 2.22$$

Where, C is the dimensionless runoff coefficient.

2.5.5 Yen and Chow Method

Yen and Chow (1983) proposed the following expression for evaluation of time of concentration.

$$t_c = K_Y \left(\frac{NL}{S_{1/2}}\right)^{0.6} \qquad 2.23$$

Where K_y ranges from 1.5 for light rain to 1.1 for moderate rain and 0.7 for heavy rain and N is and overland factor.

2.6 Development of a Watershed Model.

Before going into the formulating mathematical expression that describes the mathematical process of runoff, a detailed qualitative description of the process would seem desirable. The process of such a description is to delineate the parts of the process for which quantitative relations are required and hopefully, to indicate a suitable form for these expressions. This qualitative description or conceptual model, may then serve as the basis upon which to develop the fundamental form of a mathematical watershed model.

All of the models currently used to predict watershed runoff, since they consist of quantitative relationships concerning hydrologic events, represents various types of mathematical watershed models. In contrast with the lumped parameter approached, individual components of the model for specific watersheds were carefully considered.

2.7 Mathematical Model.

A functional limitation of almost all of mathematical relationships that have been proposed and sued to predict runoff from a known or assumed rainfall input is their dependence upon the concept of a lumped system. Thus, regardless of the number of components used in building the model, the parameters employed must represent an average or net effect of the particular component over the entire watershed. To obtain such a value requires knowledge of not only the particular component itself but of its complex interactions between all other components as well. In addition, unless all elements within the watershed are linear, a final or overall average coefficient will depend upon the magnitude and the time distribution of the system input; such an average may be determined only with previous knowledge of the system response to predict that response from which the average may be computed directly. Such method eliminates the need for the original lumped system model.

This hypothesis is fundamental though usually implicit, to all mathematical watershed models; this basic difference between implications for a lumped analysis and the one developed here-in-after is its use as a point relationship.

2.8 Rainfall Simulation

Rain plays a role in the hydrologic cycle in which moisture from the oceans evaporates, condenses into drops, precipitates (fall) from the sky, and eventually returns to the ocean via rivers and streams and to repeat the cycle again (Cerveny and Balling, 2002).

Rainfall is the source of the world's freshwater supplies. Rainfall is the driving force for the hydrologic cycle, that group of physical phenomena which control our water supplies. Rainfall characteristics affect the amount of runoff which occurs, the severity of erosion possible in various parts of Nigeria.

2.8.1 Precipitation

Precipitation is any form of moisture which falls to the earth. This includes rain, snow, hail and sheet. Precipitation occurs when water vapour cools. When the air reaches saturation point (also known as condensation point and dew point), the water vapour condenses and forms tiny droplets of water. Complex forces cause the water droplets to fall as rainfall.

2.8.2 Rainfall Simulators

Many researchers have used rainfall simulation for soil erosion studies. However, it is often difficult to find one source of reference regarding the potential and actual use or the miss-use of the technique (although see Hudson, 1984a and Hail 1970a). Some literature exists on specific experiments using rainfall simulator (Deplocy, 1983), but usually these do not give an over view of the research technique.

This discussion of rainfall simulator will address only field application, although it can be argued that it is in laboratory research that simulators are most useful. (FAO, 1993)

Field plot experiments depend upon rainfall, which is always unpredictable and frequently perverse. Use of rainfall simulator, can provide the following advantages.

i. The research work is greatly accelerated since the result are no longer dependent upon waiting for the right kind of rain intensity to come at the right time, thus the ability to take many measurements quickly without having to wait for natural rain.
ii. Efficiency of the research is increased by control of one of the most important variables (i.e. rainfall intensity, kinetic energy, etc)

iii. To be able to work with constant controlled rain, thereby eliminating the erratic and unpredictable variability of natural rain.

Therefore, it is no longer necessary to interpolate or extrapolate the results from the storm which most nearly matched the requirement, that is, the same storm can be created over and over until the result have been tested and confirmed (Hudson, 1984).

These advantages can only be achieved when an efficient simulator is used, such a simulator is one which can reproduce, accurately and repeatedly artificial rain which will have precisely the same effect on the soil as natural rain.

On the other hand there are some disadvantages:

i. It is cheap and simple to use a small simulator which rains on to a test plot of only a few square meters, but simulators to cover field plots of say $100m^2$ are large expensive and cumbersome.

ii. Measurements of runoff and erosion from simulation test cannot be extrapolated to field conditions, they are best restricted to comparisons

iii. Simulators are likely to be affected by wind and having to erect wind shield undermines the advantage of simplicity.

2.8.3 Classification of Rainfall Simulators

Rainfall simulators can be broadly classified into two main groups:

i. Non-pressurized droppers

ii. Pressurized simulators.

2.8.3.1 Non-pressurized Droppers

Many early simulators worked by water dripping off the ends of pieces of cotton thread. The numbers of threads determine the amount of rain and some control of the size was obtained by varying the size of the thread (Hudson, 1976). The original design on this principle was due to Ellison in the 1940's and was intended for laboratory use, although larger version were also built for the field studies (Hudson, 1976). When more variation in drop size was required, then this could not be achieved by thread droppers because many of the design produce drops of constant size. The droppers either make use of thread or nozzles to produce the constant sizes of simulated raindrops. The basic advantage of this method is that the size of the drop and heir fall velocity are constant, the distribution of rainfall across the test plot is uniform and can be achieved with low water pressure.

The advantages are that unless the device is raised up very high, the drops strike the test plot at a very much lower than the terminal velocity of the falling rain and therefore the values of the kinetic energy are also low. A large drop of 5mm needs a height of fall about 12meters to reach the terminal velocity and this is difficult to achieve in field conditions. To some extent, this can be compensated by using larger drops than in natural rainfall. Another disadvantage is that the size of the test plot is limited by practicalities of constructing a very large drop farming tank. A simulator using this approach and mounted on a small trailer has been successfully used for many years in Venezuela (FAO, 1993).

2.8.3.2 Pressurized Simulators.

The alternative to individual drop farmers is pressurized spraying nozzles. The first design which set out to reproduce both the drop size distribution and intensity of natural rain was the F-nozzle, and this was the basis of many simulators until around 1955 (Hudson, 1884). Many simulators are available, but none accurately recreates all the properties of natural rain (Hall, 1970) as cited by Hudson (1984). There is insufficient height in the laboratory for drops of water to achieve terminal velocity during falling, so their kinetic energy is low. To overcome this, water is released from low heights under distribution (Morgan, 1986). The intensity can be brought low by reducing the frequency of rain striking the target area, either by oscillating the spray over the target area or by intermittently shielding the target from the spray (Hudson, 1984). Rainfall is complex, with interaction among properties (drop size, drop velocity, etc) and large climatic variation. Therefore, rainfall simulator must create drops of adequate and related fall distance and drop size distribution. The pressurized simulator has been used both in the field and the laboratory.

Jacqueline (2003) reported the design of a pressurized rainfall simulator and as it was used for vegetative and erosion control of the overland flow. The land area covered by the simulator is 3.56m long and 1.0m wide. Though it is a very complex one, but it functioned reasonably well. It comprises of electric motor which provides the pressure and nozzles which provides the spray of water.

Pressurized rainfall simulator has also been used to study what happen to study top soil on cropland construction sites during rainstorm (Embarrass, 2005). The simulator shows the result o a 2-3 inch rainstorm in approximately 5-20 minutes.

Most commercial noses are drilled with all the holes of the same size, but it is easy to achieve a mixed up distribution of drilling hole of different size. A basic problem with sprinklers of this type is that like non-pressure drop farmers, they only achieve a low impact velocity unless falling from a considerable height. With pressure spray the impact velocity can be increased by pointing the spray downwards so that it eaves the nozzle with a velocity dependent on the pressure and then accelerates as it falls.

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).

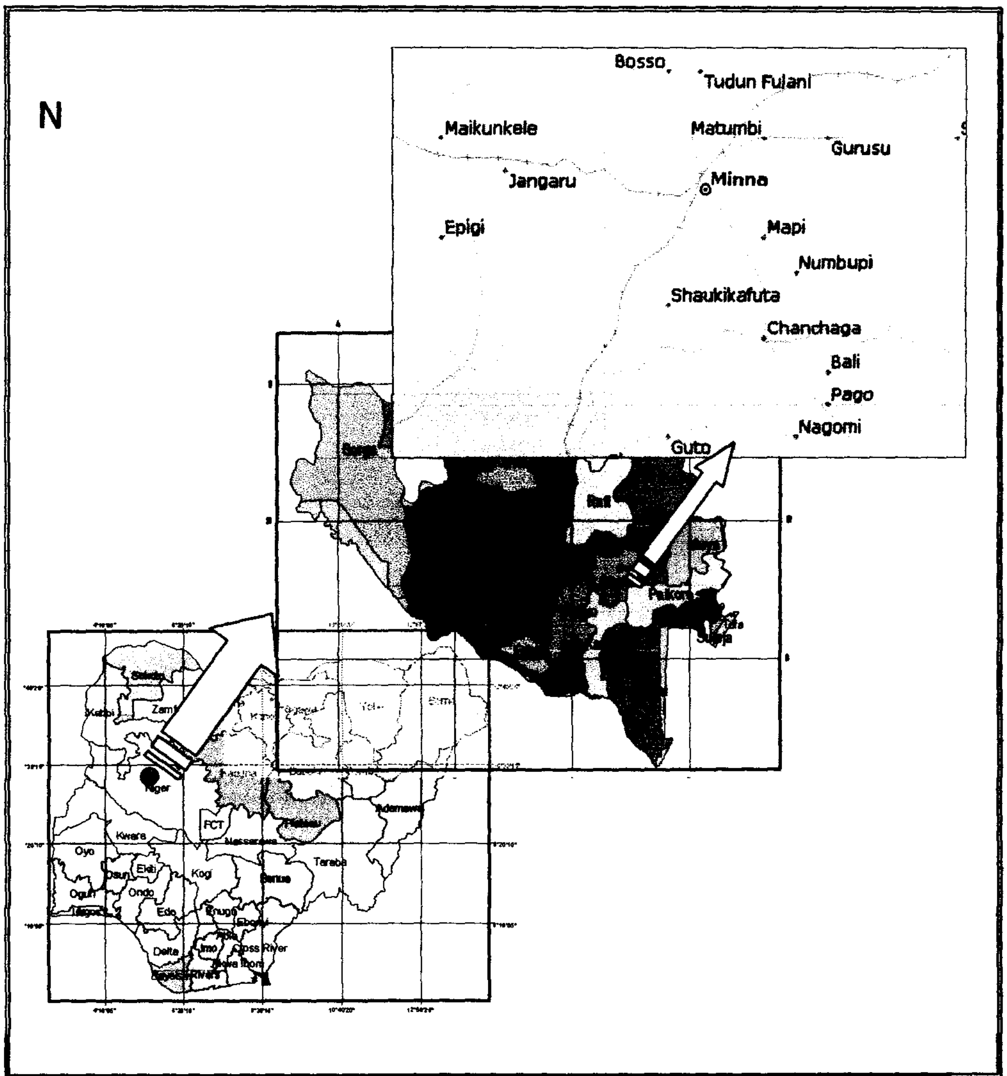

Figure 3.1: Map of Bosso Local Government Area, Niger State

3.2 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).

3.3 Climate

3.3.1 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).

3.3.2 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.

3.4 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.

The field topography and geometry should be measured. This 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. For example, a border or basin would require at most three stake lines, a furrow system as little as one, depending on the uniformity of the topography. The survey should establish 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). The important items of information that should be available from the survey are:

(1) the field slope and its uniformity in the direction of flow and normal to it;

(2) the slope and area of the field; and

(3) a reference system in the field establishing distance and elevation changes.

3.5 Soil Sampling

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

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

$$P_w = \left[\left(\frac{wet\,sample\,weight - dry\,sample\,weight}{dry\,weight\,sample}\right)\right] X100 \qquad 3.1$$

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

$$BD = \frac{weight\,of\,oven\,dry\,soil}{unit\,volume\,of\,dry\,soil} \qquad 3.2$$

$$P_y = P_w\ X\ BD \qquad 3.3$$

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

3.6 Infiltration measurement

The infiltrometer rings will be placed randomly from each other and the measurement will be taken to the nearest centimeter. The rings will be 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 will always be placed in the furrow. Having done that, a mat/jute sack will be spread at the bottom of the inner and outer compartments of each infiltrometer to minimize soil surface disturbance when water will be poured into the compartments. In grass – covered areas, they will be cut as low as possible with a cutlass so that the float could have free movement and care will be taken not to uproot grasses. Four sets (4) of infiltration measurements will be conducted at each location of which an average will be taken later.

According to Musa (2003), water will be collected from nearby canals using jeri-cans and buckets. The water will therefore be poured into the infiltrometer compartments simultaneously and as quickly as possible. As soon as the jeri –cans/buckets are emptied, the water level from the inner cylinder will be read from the float (rule) and the local time will be noted. Repeated readings will be taken at intervals of 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 120 minutes. The cylinder compartment will be refilled from time to time when the water level dropped half way. The water levels at both compartments (inner and outer) were constantly kept equal by adding water, as needed, into the outer compartment, which is faster. Some time will be allowed before starting another replicate measurement that no two infiltrometer will require reading the same time.

At each site, ten soil samples will be taken using the 50mm x 50mm core sampler from the surface layer (0-50cm) in the area outside the outer rings. These will be used for the determination of the initial moisture contents and bulk densities.

3.6.1 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 (1961). They both have a height of 250mm and the bottom ends of the ring were sharpened for easy penetration into the soil.

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 reading from the rule. Figure 3.2 shows a typical infiltrometer ring.

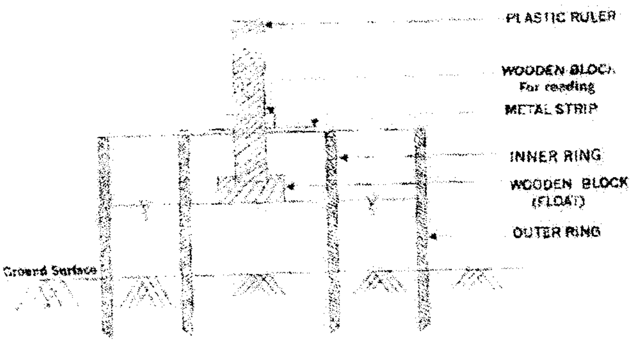

Figure 3.2: A Dissected Infiltrometer Ring.

3.7 Design of a Rainfall Simulator

3.7.1 Component Parts of the Rainfall Simulator

3.7.2 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.

3.7.3 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.

3.7.4 Water Supply tank

Water supply for the simulator is supplied direct from a motorized water tanker which will feed directly the rainfall simulator 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.

3.7.5 Pump

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

$$m = Q\,X\,\rho \qquad 3.14$$

Where, m is the mass water moving through the pump into the pipe channels which were made up of PVC within varying diameter to convey water to the simulator spray head, Q is the rate of discharge and ρ is the density of water.

Since Q = 0.01 m^3/sec

ρ = 1000kg/m^3

Therefore, m = 0.01 X 1000

= 10 kg/sec.

From the law of mass of conservation, the mass flow rate is

$$m = \rho V A \qquad 3.15$$

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.

$$r_1 = \frac{D}{2} = \frac{0.0381}{2}$$

$= 0.01905\text{m}$

$A_1 = \pi r_1^2$

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

$= 3.142 \text{ X } 0.0003629025$

$= 0.001140239655 \text{ m}^2$

$A_1 = 1.1402 \text{ X } 10^{-3} \text{ m}^2$

The velocity at this point was calculated as;

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

$$= \frac{10}{1000X1.1402X10^{-3}}$$

$= 8.7704$ m/s

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

Therefore, $A_1V_1 = A_2V_2$

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

But;

$A_2 = \pi r_2^2$

$= 3.142 \text{ X } 0.015875^2$

$= 0.00079183309375 \text{ m}^2$

$A_2 = 7.9183 \text{ X } 10^{-4} \text{ m}^2$

$$V_2 = \frac{1.1402X10^{-3}X8.7704}{7.9183X10^{-4}}$$

$V_2 = 12.62\text{m/s}$

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 0.001m^3/sec. Therefore, mass of flow at this point will be:

$$m = Q \; X \; \rho$$

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

= 1 kg/sec

Where $r_3 = 0.0127$ m

$$A_3 = \pi r_3^2$$

$= 3.142 \text{ X } 0.0127^2$

$= 5.067 \text{ X } 10^{-4} \text{ m}^2$

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

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

= 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 0.0002m^3/sec.

$$\therefore m = Q\,X\,\rho$$

= 0.0002 X 1000

= 0.2 kg/sec

$$A_4 = \pi r_4^2$$

= 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

3.7.6 Sprayer Outlet

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

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

Where

A_H = Area of hole (m^2)

r = radius of hole (m)

$r = \frac{d}{2} = \frac{2}{2}$

= 1mm

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

= 3.142 X 10^{-6} m^2

3.7.7 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

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

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

= 40.3503184713376 holes

3.7.8 Simulator Catchments Area

Area (A_c) = $l \times b$

l = length of simulator = 6m

b= breadth of simulator = 3m

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

3.7.9 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 is a constant for sharp inlet = 0.5

v = velocity

g = acceleration due to gravity = 9.81

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

In the sub main 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 = 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

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

$$= 0.406 + 0.075 + 0.229$$

$$= 0.71$$

The final velocity at the shower caps will be

$$V = H_T V_4 \qquad 3.21$$

$$= 1.5785 \text{ X } 0.71$$

$$= 1.1207\text{m/s.}$$

3.7.10 Kinetic Energy

$$KE = \frac{MV^2}{2} \qquad 3.22$$

In the main supply line (pipe 1),

$$KE = \frac{10X8.77^2}{2}$$

$$= 384.56J$$

In the sub-main supply line (pipe 2),

$$KE = \frac{10X12.62^2}{2}$$

$$= 796.32J$$

In the lateral supply line (pipe 3),

$$KE = \frac{1X1.97^2}{2}$$

$$= 1.94J$$

In the riser supply line (pipe 4),

$$KE = \frac{0.2X1.58^2}{2}$$

$$= 0.25J$$

3.8 RUNOFF PLOTS

Runoff plots are used to measure surface runoff under controlled conditions. The plots were established directly in the project area. Their physical characteristics, such as soil type, slope and vegetation were representative of the sites where water way structures schemes are planned.

The size of each plot should ideally be larger than the estimated size of the catchment planned for the study. Smaller dimensions should be avoided, since the results obtained from very small plots are rather misleading.

Care must be 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 should be regular and free of local depressions. During construction of the plot, care must be taken not to disturb or change the natural conditions of the plot 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 are removed and the plot completely cleared of grasses. Several plots were constructed in series in the project area which would permit comparison of the measured runoff volumes and to judge on the representative character of the selected plot sites.

Around the plots wooden planks were driven into the soil with at least 15 cm of height above ground to stop water flowing from outside into the plot and vice versa. A rain gauge was installed near to the plot in areas where there are no obstructions. At the lower end of the plot a gutter is required to collect the runoff. The gutter should have a gradient of 1% towards the collection tank. The soil around the gutter should be backfilled and compacted. The joint

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The process of agricultural development involves identifying existing constrain to agricultural production and subsequently providing a technical or management solution to these problems The physical observation of the area showed that the study area was discovered to be predominately farm land which is being used by the surrounding local inhabitants of the area who are farmers and some staffs of the university. The area is occupied also by the cattle rearers who move from one section of the land to another in search of green pastures for their cattle.

4.1 Soil Textural Class

Table 4.1 shows the various soil properties for ten different soils were surface runoff test was carried out. It was observed that the soil particles had varying percent of soil properties with plot 8 the highest sand percent of 74, clay percent of 8.0 and silt percent of 18 while plot 7 had the lowest percent of sand of 54 with a clay percent of 14 and percent silt was also 32. The mean percent value of the various areas for sand was calculated to be 64.2%, clay was 12.5% and silt was 23.3%. The soil water textural classification software was used to obtain the actual texture of the soil properties obtained from the field. It was also observed from the software that the soil characteristics showed that wilting point was 6.8%, a field capacity of 14.1% and soil saturation of 37%. When this result was compared with the other classification from for other results such as that of Adesoye and Partners (1984), it was discovered that there was a strong correlation between the two results which implies that the soil is sandy in nature.

Table 4.1: Percent distribution of the various properties of Loamy-sandy soil

Plot No	%Sand	%Clay	%Silt	Textural Class
1	66	11	23	Sandy-Loam
2	62	11	27	Sandy-Loam
3	59	12	29	Sandy-Loam
4	65	13	22	Sandy-Loam
5	62	16	22	Sandy-Loam
6	57	10	33	Sandy-Loam
7	54	14	32	Sandy-Loam
8	74	8.0	18	Sandy-Loam
9	72	13	15	Sandy-Loam
10	71	17	12	Sandy-Loam
Mean	**64.2**	**12.5**	**23.3**	**Sandy-Loam**

4.2 Soil Moisture Content

Table 4.2 shows the percent water content for the various plots of sandy-sand soil under consideration before the start of the experiment. It was observed that percent water retained in the soil was very minimal because of the nature of the soil with plot 5 having the lowest percent of 20.0 and plot 1 having the highest of 46.7 percent. From Table 4.1, it was observed that plot 5 had 62% sand content, 16% clay content while the silt content was 22%. Plot 8 is observed from Table 4.1 to have 66% sand, 11% clay and 23% silt content. The results that were obtained were compared with the works of Musa (2003), Eze (2000) and Sanni (1999). They were discovered that they were close and highly comparable.

Table 4.2 Percent moisture content before rainfall simulation

Plot no_	Weight of wet soil (kg)	Weight of dry soil (kg)	weight difference (kg)	Percentage moisture content (%)
1	0.23	0.184	0.046	20.0
2	0.26	0.152	0.108	41.5
3	0.21	0.142	0.068	32.4
4	0.28	0.191	0.089	31.8
5	0.24	0.128	0.112	46.7
6	0.24	0.139	0.101	42.1
7	0.25	0.147	0.103	43.2
8	0.31	0.172	0.138	44.5
9	0.29	0.160	0.130	44.8
10	0.28	0.172	0.108	38.6
Mean	**0.259**	**0.1587**	**0.1003**	**38.56**

Table 4.3 shows the percent moisture content of the various soils after the experiments had been carried out. Plot 4 showed the highest value of percent water retained to be 68.2 while plot 1 had the lowest of 45.1%. On comparing results of Table 4.3 with the soil analysis of Table 4.1, it was observed that plot 4 had 65% sand content, 13% clay content and 22% silt content. Though the area in question showed some element of water retention capability which means that water has

the tendency of flowing on the surface within the shortest time. The mean value of the percent moisture content was calculated to 55.35.

Table 4.3 Percent moisture content after rainfall simulation

Plot no	Weight of wet soil (kg)	Weight of dry soil (kg)	Weight difference (kg)	Percentage moisture content (%)
1	0.35	0.192	0.158	45.1
2	0.32	0.141	0.179	55.9
3	0.30	0.143	0.157	52.3
4	0.38	0.121	0.259	68.2
5	0.32	0.114	0.206	64.4
6	0.30	0.120	0.180	60.0
7	0.33	0.140	0.190	57.6
8	0.48	0.104	0.376	65.8
9	0.42	0.159	0.261	62.1
10	0.34	0.163	0.177	52.1
Mean	**0.35**	**0.14**	**0.21**	**58.35**

4.3 Infiltration Rates

Table 4.4 shows the average infiltration rate and the average cumulative infiltration for the various plots under consideration. It was observed that the infiltration for the various soils experienced a drop 15 minutes into its determination but picked up at 50 minutes into the process but became steady as from the 60th minute of the infiltration rate. An average cumulative infiltration of 21.19cm of water was used. This shows that movement of water through the soil was quite slow which has a possible implication of a different type of soil underlying the surface soil which was considered to be sandy-loam in textural classification. Theses was compared with the works of Musa and Egharevbe (2009), who in their work stated that there are possibility of some hard pan or rocks underlying some areas of the Gidan Kwano soils of the Federal University of Technology, Minna.

Table 4.4 Average infiltration rate and cumulative infiltration.

S/No	Time (min)	Average infiltration (cm/min)	Average cumulative infiltration
1	0	0	0
2	5	3.96	3.95
3	10	3.37	7.32
4	15	2.82	10.14
5	20	2.40	12.54
6	25	2.03	14.57
7	30	1.72	16.29
8	35	1.33	17.62
9	40	1.00	18.62
10	45	0.78	19.40
11	50	0.61	19.99
12	55	0.59	20.6
13	60	0.59	21.19

4.4 Slope

Various slopes were considered when carrying out the work which shows the rate of flow of water on the soil surface. Table 4.5 shows the various slopes that were considered in percentages and its conversion to degrees. It was observed that plot 8 had the highest degrees, these was closely followed by plots 2, the plot that had the lowest value slope was plot 10.

Table 4.5 Slope size for the various plots

Plot No_	Slope (%)	Slope (Deg)
1	5.7	3.26
2	6.7	3.83
3	5.7	3.26
4	5.7	2.98
5	5.0	2.86
6	4.8	2.75
7	3.7	2.12
8	7.2	4.12
9	6.0	3.43
10	3.0	1.72
Mean	**5.4**	**3.0**

4.5 Surface Runoff

Table 4.6 shows the total amount of water collected as surface runoff within a period 30 minutes of dispense of water from the rain simulator. It was observed that the highest values of surface runoff was recorded from plot 3 and while plots 7 and 10 were the closest to the previous value. The lowest values were recorded from plot 9 while the mean value of the surface runoff was calculated as 0.299m^3.

Table 4.6 Surface runoff for the various plots

Plot No_	Surface Runoff (m^3)
1	0.175
2	0.209
3	0.227
4	0.180
5	1.190
6	0.202
7	0.222
8	0.195
9	0.172
10	0.222
Mean	**0.299**

The transformation of rainfall into runoff over a catchment area is a complex hydrological phenomenon, as this process is highly nonlinear, time varying and spatially distributed. To simulate this process, a number of models have been developed across the world but not specifically for some soils in Nigeria thus making some of our water and other civil structures fail. Depending on the complexities involved, these models are categorized as empirical, black box, conceptual or physically based distributed models.

A model was derived using the excel Microsoft word of 2007 for sandy-loam soils in the Gidan Kwano area of Minna, Niger State. The parameters that were considered includes the initial moisture content of the soil of the various areas considered, infiltration rate, surface runoff, and the slope of the area. Table 4.7 below shows the various parameters which was used to obtain the equation of the form $\boldsymbol{Y = mx_n + c}$

Table 4.7 Parameters considered for the equation.

Initial moisture contents (%)	Infiltration rates (cm/hr)	Surface runoff (m^3)	slope of the plots (Deg)
20.0	20.5	0.175	3.26
41.5	22.2	0.209	3.38
32.4	19.7	0.227	3.26
31.8	21.9	0.182	2.98
46.7	23.4	0.19	2.86
42.1	20.2	0.202	2.75
43.2	18.7	0.222	2.12
44.5	24.2	0.295	4.12
44.8	20.4	0.172	3.43
38.6	20.7	0.222	1.72

On using the Microsoft excel 2007 version, the equation that best describe sandy-loam soils of the Federal University of Technology, Minna stated below was obtained as

$$Y = -0.00228x_1 - 0.089751x_2 - 0.0138x_3 + 2.530299$$

This implies that when values for x_1, x_2, and x_3 are fixed into the equation a coefficient will be obtained for sandy-loamy soils within the Federal University of Technology, Minna provided they have the same soil properties. It can be observed that the value of intercept of the equation obtained above was positive.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Over the years irrigation and drainage structures even roads, were been designed and constructed using hydrologic coefficients determined by researchers from other continents which has been found to be inefficient in some cases (e.g. in Nigeria) as failure of drainages, culverts, dams, roads, etc, are seen everywhere. This reasons amongst many actually called for the determination of our own indigenous hydrologic coefficient, as this would go a long way in helping soil and water conservation engineers in their designs and constructions. It is important to note from the statistical analysis obtained from the sites that there is a relative contribution of the various hydrologic parameters such as infiltration, surface slope, roughness and watershed shape in the generation of mathematical equation used to determine the coefficient for undisturbed sandy-loam soil.

The research work was able to develop a mathematical model capable of simulating the surface hydrograph from small ungauged watershed and the determination of the surface runoff coefficient suitable for undisturbed sandy-loam soil, although the efficacy of this mathematical model and runoff coefficient could not be determined since the scope of this research work does not involve validation using natural scenario of soil in question.

5.2 Recommendations

1) This experiment should be conducted using the natural rainfall and values compared with that of the simulated rainfall.
2) The equation determined in this project work should be validated.

3) Larger experimental plots should be investigated.

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APPENDICES

Mean Monthly Temperature (max) (°C) of Minna from 2007-2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	33.7	37.2	38.2	36.0	32.8	30.3	29.5	28.2	30.0	31.7	34.7	35.4
2008	32.7	35.6	38.6	36.4	33.2	31.9	29.5	28.6	30.3	32.2	36.0	35.6
2009	35.7	37.8	39.2	35.2	33.9	31.8	30.9	29.8	30.5	31.5	34.6	36.7
Mean	**34.0**	**36.9**	**38.7**	**35.9**	**33.3**	**31.3**	**30.0**	**28.9**	**30.3**	**31.8**	**35.1**	**35.9**

Source: Nigerian Meteorological Agency (NIMET), Minna Airport, Minna.

Mean Monthly Rainfall (mm) for Minna from 2007-2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	0.0	0.0	0.4	73.1	156.6	123.9	314.0	310.1	330.2	115.1	0.0	0.0
2008	0.0	0.0	0.0	40.2	146.8	132.7	305.1	244.3	258.9	141.2	0.0	0.0
2009	0.0	0.0	0.0	89.9	101.4	108.9	246.8	497.6	273.5	85.2	0.0	0.0
Mean	**0.0**	**0.0**	**0.1**	**67.7**	**134.9**	**121.8**	**288.6**	**350.7**	**287.5**	**113.8**	**0.0**	**0.0**

Source: Nigerian Meteorological Agency (NIMET), Minna Airport, Minna.

Mean Monthly Relative Humidity (%) for Minna from 2007-2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	22	30	41	64	76	80	85	88	83	77	56	33
2008	24	25	48	59	73	78	85	87	82	75	40	40
2009	40	43	37	70	73	77	81	85	80	76	44	26
Mean	**29**	**33**	**42**	**64**	**74**	**78**	**84**	**87**	**82**	**76**	**47**	**33**

Source: Nigerian Meteorological Agency (NIMET), Minna Airport, Minna.

Mean Monthly Wind Speed (m/s) for Minna from 2007-2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2007	214.5	127.9	113.2	107.8	72.3	68.9	58	45.3	39.7	25.4	26	98.9
2008	180.8	195.9	89.5	104.8	97.5	89.2	64.5	63.5	47.4	41.9	60.3	97.8
2009	75.5	76.8	99.4	110.8	81.7	82.8	73.8	47.5	45.9	35.4	75	90.8
Mean	**156.9**	**133.5**	**100.7**	**107.8**	**83.8**	**80.3**	**65.4**	**52.1**	**44.3**	**34.2**	**53.8**	**95.8**

Source: Nigerian Meteorological Agency (NIMET), Minna Airport, Minna.

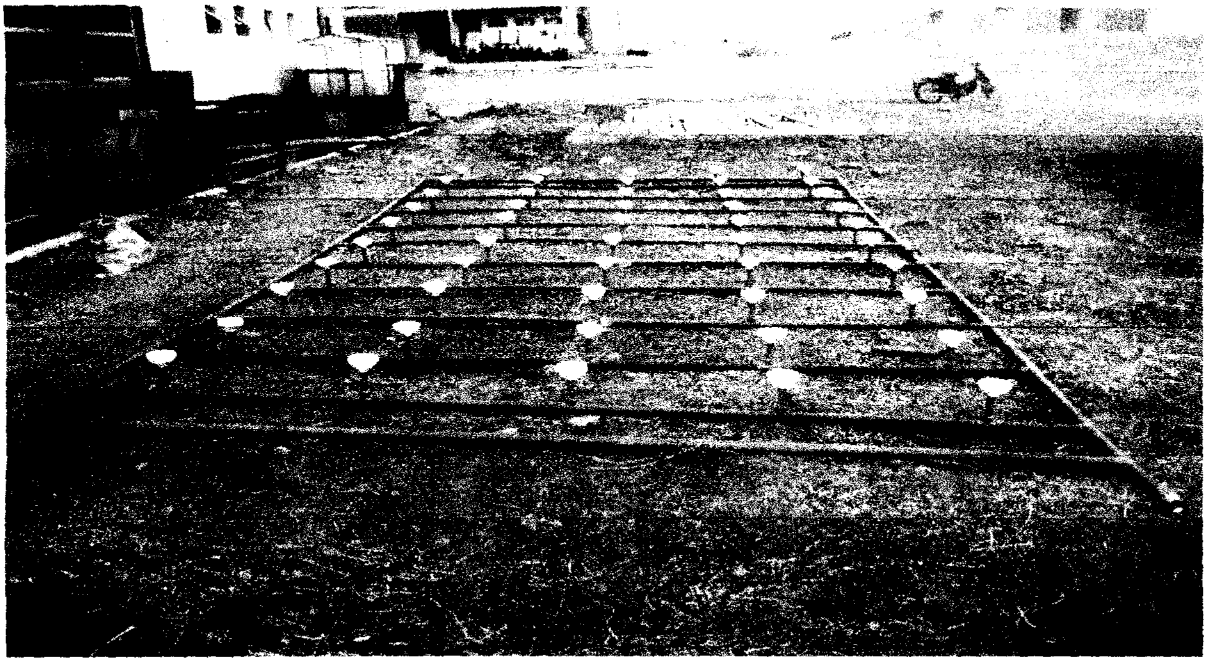

Plate A: shows the rainfall simulator used

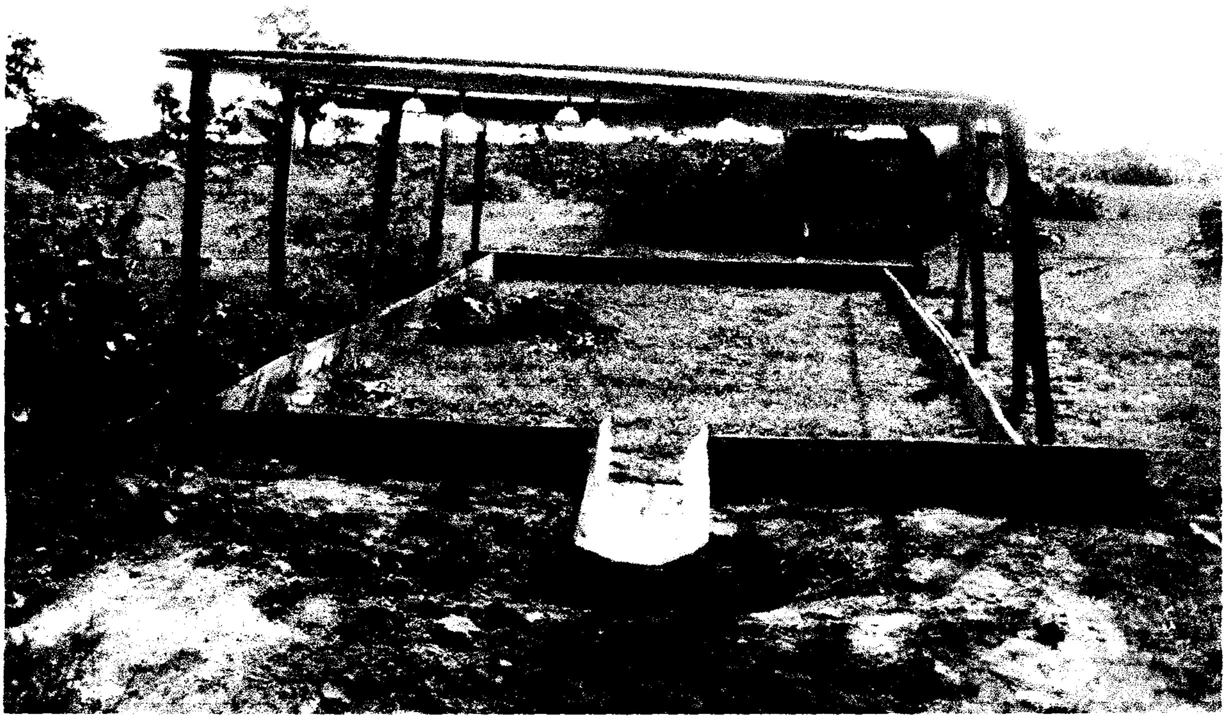

Plate B: shows a complete set-up of the rainfall simulator

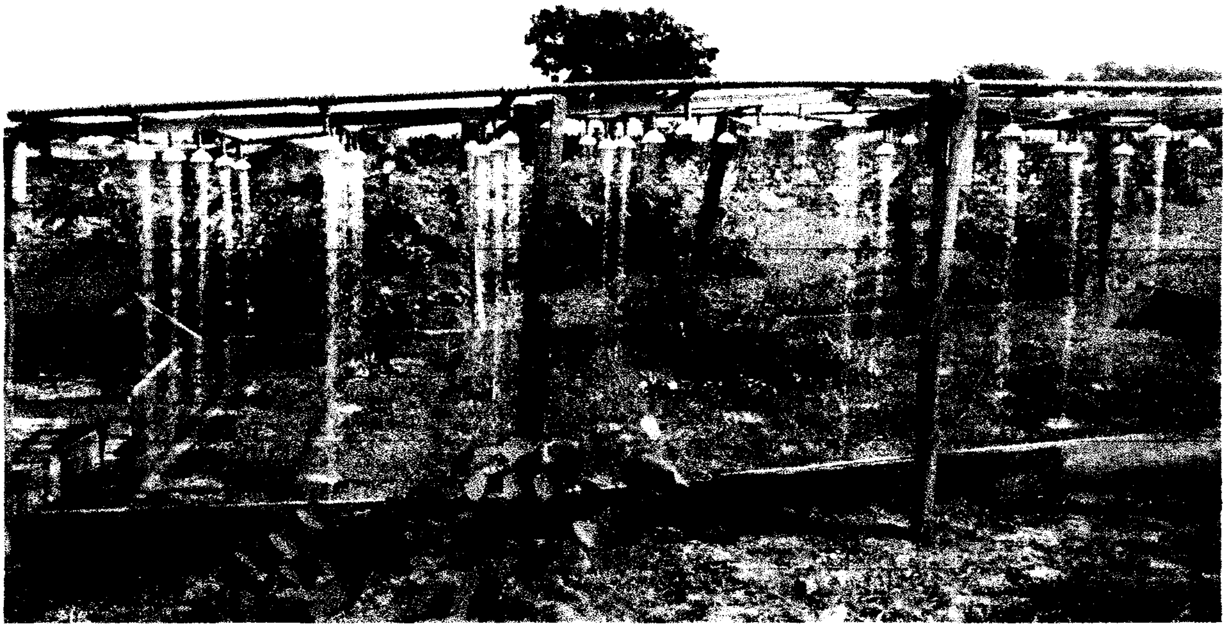

Plate C: shows the site during rainfall simulation

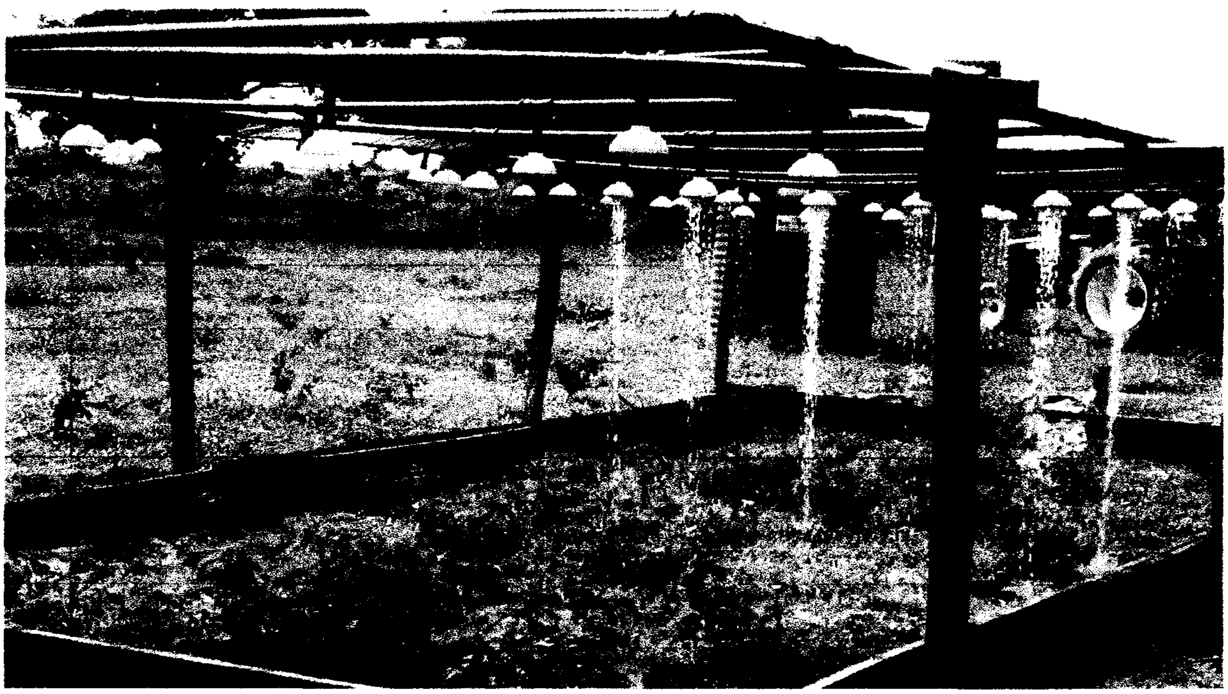

Plate D: shows the site just after rainfall simulation