DETERMINATION OF HYDROLOGIC COEFFICIENT FOR DISTURED SANDY-LOAM SOIL (A CASE STUDY OF GIDAN KWANO CAMPUS OF FUT), MINNA, NIGER STATE.

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

DECEMBER, 2010

DEDICATION

This project work is dedicated to God almighty the author and finisher of our faith.

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I give thanks to Almighty God whom by his grace, favour and faithfulness has kept me through this project. I sincerely appreciate my supervisor Mr. John Jiya Musa who has patiently guided me through this project and his immeasurable contribution towards the success of this project which was beyond my expectations. Thank you sir.

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ABSTRACT

There was need to be able to estimate the amount of runoff that would occur after a storm event using a simple mathematical model, to save researchers and designers the cost and rigors of continuous field experiment, as well as failure such as collapsment of houses, bridges, canals, dams etc, because most of our engineers design and construct their structures based on the hydrologic coefficient gotten from other country. That is why a mathematical model was developed to suit different types of soil in Nigeria especially a disturbed sandy-loam soil in order to prevent life and properties. This was achieved by the determination of factors that directly affect runoff, such as infiltration rate, moisture content, slope, storm intensity, time of storm event, soil surface condition, and also the type of soil. A rainfall simulator was used to be able to have a replicate event. A catchment area of $18m^2$ (6m by 3m) was used and ten (10) replicate of the catchment area was investigated to have an accurate result. The type of soil used was found to be sandy-loam soil after a sieve analysis of the soil sample were conducted. The average infiltration rate of the ten plots was found to be 15.68cm/hr using a double ring infiltrometer. The average slope was found to be 2.592^0 using the change in height method. The average moisture content before and after the simulation was found to be 45.93% and 58.00 % respectively using the gravimetric method. A multiple linear regression was used to find the relationship between all the investigated parameters, and a simple linear mathematical model for a disturbed sandy-loam soil was developed to be

$Y = 0.062581x_1 - 1.64212x_2 + 0.099371x_3 + 0.399138$

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The sediment leaving disturbed areas, besides being a pollutant itself can carry nitrogen and phosphorus into water ecosystems, thereby accelerating eutrophication of lakes. In many cases, conservation management practices and structures can reduces off-site impact. One of such accepted management practice is vegetative filter strips (VFS) which are bands of planted of indigenous vegetation that may control transport of sediment and reduce non-point source pollution off-site (Subramanya,2006).

Vegetation reduces surface runoff by increasing infiltration, augmenting roughness of the soil surface, boosting evapotranspiration, and contributing to rainwater interception. Both the retardation of flow and reduction in runoff discharge reduce the kinetic energy of runoff, thus lower the sediment capacity

It is widely recognized that surface runoff is a serious problem with significant environmental and financial consequence. Surface runoff effects occurs both onsite and off-site, problems occurs from sediment on river beds and drainage network which reduces their capacity, increases flooding risk, block irrigation and shortens the design life of water reservoirs.

The final consequence is a loss of productivity which results into the increases of fertilizer consumption in order to maintain yield but later threatens the food production. Several hydro electric and irrigation projects have been destroyed as a result of surface runoff.

1.1.1 RUNOFF

Rainfall, it is not intercepted by vegetation or artificial surface such as roofs or pavements falls directly on the earth and either evaporates, infiltrates, or lies in depression storage. When the losses arising in these 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 sea or ocean. Hence, the water traveling over the land from one point to another is referred to as surface runoff (Michael and Ojha, 2006).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 surfaces become saturated, the interception-loss rate declines and infiltration capacity is reduced.

When the rate of rain fall 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 depressions prior to the beginning of surface runoff is called the initial detention or depression storage (Michael and Ojha, 2006).Runoff thus represent 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.

Sediments are also primary source of pollution and though phosphorous in water bodies can results in eutrophication. In order to reduce or eliminate these eroding effects on the soil on our Agricultural land and environment, there is a need to study this rainfall effect on our soil with a view to addressing them.

To achieve these, a sound hydrology research program is required in the area of direct measurement of erodibility, dispersion crusting and runoff at several field or sites. It however becomes difficult because of the amount of time and labour involve in obtaining such observation from natural rainfall condition. Hence, the natural rainfall or storms varies greatly in their intensity drop size distribution which makes it very difficult to observe replicate condition of such events.

To study the effect effectively and to replicate the condition, many researchers have resorted to the use of artificially simulated rainfall which can also be conducted efficiently from the standpoint of time and labour. The rainfall or storms characteristics can carefully be controlled and approach when using a simulator which is more adoptable for certain type of studies.

1.2 STATEMENT OF PROBLEM

Surface runoff is a serious problem globally, particularly in our local environment which causes reduction in cultivation depth of agricultural land, depletion of the soil fertility rate, threatening of food production and eventually abandonment of agricultural land when the useful past of soil known as sediment is being washed or erode away. It also causes the pollution of river channel and blockage of lands with contaminated sediments.

To overcome these problems a soil erosion research study is required which will allow for the collection of data from rain storms. Natural rainfall which could be use for data collection is not reliable since the certainty of the occurrence is not guaranteed. Hence, the use of artificially simulated rainfall is introduced

1.3 OBJECTIVES

1) To determine the surface runoff coefficient for a disturb sandy loam soil in g gidankwano area of Minna. Niger state

2) To develop a mathematical model or equation capable of simulating the surface hydrograph from small unguarded watershed.

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

1.4 JUSTIFICATION OF THE PROJECT

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 network,

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

(c) Determination of the rate pollution transport.

In Nigeria as a whole, it has been observed that we adopt other coefficient of hydrologic properties from other countries of the world to carry out design calculations for the various types of structures to construct on our various soils. Thus, such construction works end up giving way within the shortest period of time which leads to loss of lives and properties. Achieving the objectives stated above will enhance the quality of infrastructure available within the various communities, hence saving lives and properties.

1.5 SCOPE OF THE STUDY

The scope of this research covers the design, construction and testing of the rainfall simulator, with a particular interest on measurement of soil, erodibility, time of concentration, infiltration rate, slope and surface runoff at field site. This study is however limited to small plot size(6m by 3m) of a disturb sandy loam soil in fut. Minna, gidan kwano campus. This implies that the simulator did not operate on a large scale.

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 it is intercepted by the vegetation's, 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 Overland Flow

Overland flow is another example of shallow water flow that can be analyzed with vertically-averaged equations. It is considered to be an important sub-process of watershed hydrology. Regardless of its source (i.e., infiltration excess or saturation excess), it is considered to be the major contributor of channel flow. However, unlike channel flow, it is characterized by even small water depths that are in the order of a less than a couple of centimeters which makes its analysis more difficult when compared to channel flow. Although small depths and velocities proposes a laminar treatment of the process, other parameter such as the rainfall impact, highly variable roughness patterns and channelization favor a turbulent analysis for the process. It is because of these complications that the overland flow is generally assumed to experience all possible aspects of low hydraulics n a time and space dependent fashion. In the context of a general watershed model, however, such complication are generally lumped into one roughness parameter and the entire overland flow phenomenon is modeled as a turbulent flow similar to its channel flow counterpart. While this assumption may not be true at all times, it is the only feasible way to tackle the associated difficulties.

Overland flow is generally modeled as a one or two-dimensional process. Numerous one-dimensional models are used in simulating flows on idealized watersheds, laboratory flumes, or natural watersheds with well-defined slopes in a particular direction. Such models include the works of Judah *et al.* (1975), Ross *et al.* (1979), Heatwoleet *et al.* (1982) and Shakill and Johnson (2000), similarly an extensive database exists in two-dimensional treatment of overland flows. Some selected examples of two-dimensional overland flow models are the studies of Chow and Ben-Zvi (1973) Katopodes and Strelkoff (1988), Hromadka and Lai (1985), Hromadka and Yen (1986), Akanbi and Katapodes (1988), Zhang and Cundy (1989), James and Kim (1990), marcus and Julien (1990), Playanet *et al.* (1994), Tayfuret et al. (1993), Gottardi and Venutelli (1993b), Zhao et al. (1994), Di Giammarco *et al.* (1996), Gottardi and Venutelli (1997),Fiedler and Molz (1997), Hong and Mostaghimi (1997), Lal (1998), Esteveset *et al.* (2000), Fiedler and Ramirez (2000), Chang *et al.* (2000) and Dutta *et al.* (2000).

2.3.1 Types of Runoff

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

a. Surface Runoff

b. Sub-surface Runoff

C. Base flow

2.3.1.1 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).

2.3.1.2 Sub-surface Runoff

According (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 streams, rivers, or oceans is thus known as sub-surface runoff.

2.3.1.3 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 totals Runoff = surface Runoff + Base Flow (Including sub-surface runoff)

2.3.2 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).

2.3.2.1 Climate Factors

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

(a) Type of 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.

(b) 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 $I = \frac{KTx}{tn}$ 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.

(c) 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.

(d) Rainfall Distribution: Runoffs 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.

(e) Direction of Prevailing Wind: The direction of wind affects greatly the runoff flow the direction of prevailing wind is same as 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.

(f) 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).

(g) 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).

2.4 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.

Significant theoretical description of water flow through a porous medium began in 1856 with Henry Darcy's observations of saturated flow through a filter bed of sand in Dijon, France (Philip, 1995). Darcy found that the rate of flow of water, J(ms^{-1}), through his saturated column of sand of length L(m), was proportional to the difference in the hydrostatic head, H(m), between the upper water surface and the outlet:

$$J = K\left(\frac{\Delta H}{L}\right)$$

In which Darcy called K "un coefficient de pendent du degre` de perme abilite du sable" which is now referred to as saturated hydraulic conductivity Ks (ms^{-1}). In 1907, Edgar Buckingham of the USDA Bureau of Soils established the theoretical basis of unsaturated soil water flow. He noted that the capillary conductance of water through soil, now known as the unsaturated hydraulic conductivity, was a function of the sol's water content, u ($m^3 \cdot m^{-3}$), or the capillary pressure head of water in the soil, h(m).

The characteristics relationship between h and u was also noted by Buckingham (1907), so that he could write K = K(h), or if so desired, K = K(θ). Total head of water at any point in the soil, H, is the sum of the gravitational head due to its depth z below some datum, conveniently here taken as the s oil surface, and the capillary pressure head of water in the soil, h: H= h-z. Here, h is a negative quantity in unsaturated soil, due to the capillary attractiveness of water for the may looks and crannies of the soil pore system. Thus locally in the soil, Buckingham found that the flow of water could be described by

$$J = -K(h)\left(\frac{\partial H}{\partial z}\right) = -K(h)\frac{\partial H}{\partial z} + K(h) \qquad 2.6$$

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. In deference to the discoverers of the saturated form, equation 2.5, and the unsaturated form, equation 2.6, the equation describing water flow at any point in the soil is generally referred to as the Darcy-Buckingham equation.

Richards (1931) combined the mass-balance expression that the change in the water content of the soil at any point is due to the local flux divergence,

$$\left(\frac{\partial \phi}{\partial t}\right)_z = -\left(\frac{\partial j}{\partial z}\right)_t \qquad 2.7$$

With the Darcy – Buckingham description of the water flux J, to arrive at the general equation of soil water flow,

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(K(h)\ \frac{\delta h}{\delta z}\right) - \frac{\delta K(h)}{\delta h} \cdot \frac{\partial h}{\partial z} \qquad 2.8$$

Where t(s) is time. Unfortunately, this formula, known as Richards' equation, does not have a common dependent variable, for θ appears on the left and h on the right. The British physicist E.C Childs "decided to try some other hypothesis" ... that water movement is decided by the moisture concentration gradient ... [and] that water moves according to diffusion equations" (Childs, 1936). Childs and Collis-Georg (1948) noted that the diffusion coefficient for water in soil could be written as $K(\theta)dh / d\theta$. From this, in 1952 the American soil physicist Arnold Klute wrote Richards' equation in the diffusion form of

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(D\ (\theta)\ \left(\frac{\partial \theta}{\partial z}\right)\right) - \frac{\delta k}{\delta \theta} \cdot \frac{\partial \theta}{\partial z} \qquad 2.9$$

This description shows soil water flow to be dependent on both the soil water diffusivity function D (θ), and the hydraulic conductivity function K (θ), but this nonlinear partial differential equation is of the Fokker-Planck form, which is notoriously difficult to solve. Klute (1952) developed a similarity solution to the gravity-free form of Equation 2.9, subject to poundingof free water at one end of a soil column. Five years later, the Australian John Philip developed a power series solution to the full form of Equation 2.9, subject to the pounding of water at the surface of a vertical column of soil, initially at some low water content Θ_n(Philip, 1957).

This general solution predicts the rate of water entry through the soil surface, i(t) (ms^{-1}), following pounding on the surface. The surface water content is maintained at its saturated value, Θ_s. The cumulative amount of water infiltrated is I(m), being the integral of the rate of infiltration since pounding was established. As well, I can be found from the changing water content profile in the soil,

$$I = \int_0^t i(t)\partial t = \int_0^{\infty}[\theta(Z) - \Theta n]\,\partial Z = \int_{\theta n}^{\theta s} Z(\Theta)\partial\Theta \quad 2.10$$

Philip's (1957a) series solution for I(t) can be written

$$I\,(t) = St^{1/2} + At + A_3t^{3/2} + A_4t^{4/2} + \dots \quad 2.11$$

Where the sorptivityS ($ms^{-1/2}$) and the coefficients A, A_3, A_4,... can be iteratively calculated from the diffusivity and conductivity functions, D(Θ) and K(Θ). The form of equation 2.11 indicates that I increase with time, but at an ever-decreasing rate. In other words, the rate of infiltration $I = \frac{dI}{dt}$ is high initially, due to the capillary pull of the dry soil. But with time the rate declines to an asymptote. Special analytical solutions can be found for cases where certain assumptions are made about the soil's hydraulic properties.

When the soil water diffusivity can be considered to be a constant, and k varies linearly with u, an analytical solution is possible. This is because equation 2.9 becomes liberalized (Philip, 1969) and so there is an analytical solution for infiltration into a soil whose hydraulic properties can be considered only weakly dependent on u. At the other end of the scale of possible behavior, hi presented an analytical solution for a soil whose diffusivity could be considered a Dirac d-function, in which D is zero, except at us where it goes to infinity. For the analytical solution, this so-called delta-soil, or Green and Amptsoil, also needs to have $K = K_s$ at us, and K =0 for all other Θ.

2.5 Field Capacity (FC)

Field capacity is defined as the water content to soil that has been allowed to drain freely for two days from saturation with negligible loss due to evaporation. Initially, the hydraulic conductivity is close to the saturated values, so drainage is relatively fast. As water is lost from the soil, the metric potential decreases and the hydraulic conductivity begins to drop rapidly as the soil dries. By the time the metric potential has reached -5kPa, drainage is extremely slow from most soils.

This point is typically reached after 2 days, and the water content of the sol is then termed the field capacity for that soil. Since the water that has drained from the soil has done so too quickly to be useful to plants, the field capacity is often considered to be the upper limit of the amount of water that can be stored in any particular sol after rainfall or irrigation. The redistribution of draining water in a soil profile is a continuous process, which may be influence by many factors including antecedent moisture conditions, depth of wetting, soil texture, type of clay present, organic matter, presence of slowly permeable horizons, and the rate of evapotranpiration. Consequently, the metric potential can be different in deep horizons of less permeable soils than in overlying topsoil.

The field capacity concept is most acceptable for coarser and loamy textured soils, where a static state is more easily defined because of the sharp decrease in unsaturated hydraulic conductivity with a comparatively small drop in metric potential. Values ranging from -3 to -8 kPa have been reported for the metric potential at field capacity of rang freely draining soils (Webster Becklett, 1972; Dent and Scamell, 1981; U.S department of Agriculture, 1983; Cassel and Nielsen,1986). Ideally, field capacity should be determined in the field by monitoring soil water content. However, this is time-consuming, so in most applications a value for field capacity is estimated by equilibrating soil cores at published values of metric potentials that are thought to approximate to field capacity. Such values vary from -5 to -50 kPa (Cassel and Nielsen, 1986), but the water content at -5 kPa or -10 kPa is widely used to represent the field capacity for any soil. The amount of water lost readily by the soil after heavy rain (i.e. the difference between saturation and FC) is also significant in designing drainage (Scullion et al. 1986) and irrigation systems (Reeve, 1986).

2.6 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 decreases 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.

2.6.1 MEHTODS OF SURFACE RUNOFF ESTIMATIOIN

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:

1 Runoff Coefficients

The volume of runoff can be directly computed approximately by using the equation 2.37

$Q = KP$

Where Q = runoff

P =Precipitation

K = a constant having a value less than 1 or at eh most equal to 1. The value of K depends upon the imperviousness of the drainage area. Its value increases with the increase in imperviousness of the catchments area, and may approach unity (1.0), as the area becomes fully imperious.

Though equation 2.37 cannot be rational because the runoff not only depends upon the precipitation but also upon the recharge of the basin. But this equation in gives more and more reliable results as the imperiousness of the drainage basin area increases and the value of K tends to approach infinity (Garg, 2005).

This formula is commonly used in the design of storm water drains and small water control projects, especially for urban area, where the percentage of the impervious area id quite high. This method of computing runoff should be avoided for rural areas and for analysis of major storms. Over time runoff coefficients have been developed by many researchers. The following are some of the basic coefficients which over time had been developed upon;

a. 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:

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

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.

b.Hydraulic radius

The hydraulic radius is a measure of channel flow efficiency. Flow speed along the channel depends on its cress-sectional shape (among other factors), and the hydraulic radius is a characterization of the channel that intends to capture such efficiency. Bases on the constant shear stress at the boundary' assumption, hydraulic radius is defined as the ratio of the channel's cross-sectional area of the flow to its wetted perimeter (the portion of the cross-section's perimeter that is "wet"):

$R_h = A/p$

Where:

R_h = hydraulic radius (m),

A = Cross sectional area of flow (m^2) and

P = Wetted perimeter (m)

The greater the hydraulic radius, the greater the efficiency of the channel and the less likely the river is to flood. For channels of a given width, the hydraulic radius is greater for the deeper channels.

The hydraulic radius is not half the hydraulic diameter as the name may suggest. It is a function of the shape of the pipe, channel, or river in which the water is flowing. In wide rectangular channels, the hydraulic radius is approximately by the flow depth. The measure of a channel's efficiency (its ability to move water and sediment) is used by water engineers to assess the channel's capacity.

c. Gauckler-Manning coefficient

The Gauckler-Manning coefficient, often denoted as n, is an empirically derived coefficient, which is dependent on many factors, including surface roughness and sinuosity. When field inspection is not possible, the best method determined n is to use photographs of river channels where n has been determined using Gauckler-Manning's formula.

In natural streams, n values greatly along its reach, and will even vary in a given reach of channel with different stages of flow. Most research shows that n will decrease with stage, at least up to bank-full. Overbank n values for a given reach will vary greatly depending on the time of year and the velocity of flow. Summer vegetation will typically have a significantly higher n values due to leaves and seasonal vegetation. Research has shown, however, that n values are lower for individual shrubs with leaves than for the shrubs without leaves. This is due to the ability of the plant's leaves to streamline and flex as the flow passes them thus lowering the resistance to flow. High velocity flows will cause some vegetation (such as grasses and forbs) to lay flat, where a lower velocity of flow through the same vegetation will not.

d. 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).

Darcy assembled his conclusion in the following equation:

$$Q = k\left(\frac{s}{e}\right)(h + e + \text{or} - h^{*})$$

Where:

q = rate of water flow (volume per time)

k = a coefficient dependent on tho "permeability" of the sand

s = cross sectional area of the sand filter

e = length of sand filter

h = reading of the upper manometer arm.

At this point, Darcy made use of the implications of his datum plane convention. Only under this convention, Darcy's law reduces to:

$$Q = k\left(\frac{s}{e}\right)(h + e)$$

In modern format, using a particular sign convention, Darcy's law is usually written as:

$$Q = -KA\frac{dh}{dl}$$

Where:

Q = rate of water flow (volume per time)

K = hydraulic conductivity

A = column cross sectional area

dh/dl = hydraulic gradient, that I, the change in head over the length of interest.

The law is often transformed by dividing through by the cross-sectional area and is then restated as:

$$q = \frac{Q}{A} = -K\frac{dh}{dl}$$

Where q now has the dimensions of a velocity, and is referred to as the Darcy, or superficial, velocity.

2. WATERSHED AREA, A

The basin (watershed) area for a drainage basin is that surface area contributing runoff to a specified collection point. Topographic information is used to determine the boundaries of the contributing surface area. For urbanized areas topographic information may come from residential subdivision or commercial and industrial development improvement plans. For underdeveloped areas topographic surveys of the watershed may be available or can be developed by various surveying and mapping techniques. For large areas it is common to use the Geological survey quadrangle sheets as a reliable source of topographic information. It is often necessary to develop sub watersheds within the primary watersheds being considered. Each sub-watershed will have its own shed area, time of concentration and rainfall intensity.

3. INTENSITY, I

The rainfall intensity, I, is dependent upon the duration of rainfall and the frequency of the storm event or the return period. Short duration storms and storms of longer return periods are often more intense than longer, frequent storms. Rainfall intensity/duration/ frequency (RDF) curves are developed from historically collected rainfall data from rain gauge recordings. Information gathered at a rain gauge site can be considered represent of 16 kilometers of that is expected to experience uniform meteorological conditions

4. Frequency Factor, C

For storms with a frequency or return period of 10 years or less, C_r is unity. However, for storms of higher periods, rainfall intensity increases, infiltration and other losses are reduced, and C_r increases.

5. Runoff Coefficient, C

Many factors or variables affect the magnitude of runoff coefficient, C. these include slope of the ground, type of ground cover, soil moisture, travel length and velocity of overland flow, travel length and velocity of stream flow, rainfall intensity and other phenomena. However, effects on the runoff coefficient are dominated by the type of ground surface and it is that variable that establishes the value of C. the engineer responsible for the design of highway and other drainage facilities must anticipate and assess the most likely effects of future development of all the land in the watershed of interest. Increasing volumes of storm runoff due to reduced infiltration and greater peak discharges due to decreased travel time attend increasing urbanization.

2.7 Time of Concentration, t_c

If rainfall were 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, t_c .

The travel time of a water particle from the hydrological remote point in a drainage basin to a specified collection point. If the rainfall duration time is greater than or equal to t_c , then every part of the drainage area is assumed to contribute to the direct runoff at the collection point. Rainfall intensity for the rational method is assumed to be constant. If the duration of the storm is less than t_c, peak runoff will be less. For storms duration longer than t_c, the runoff rate will not increase further. Therefore, the peak runoff rate is computed with the storm duration equal to t_c. Actual rainfall is not constant and this simplifying assumption is a weakness of the rational method. Water moves through a watershed in some combination of sheet flow, shallow concentration flow, stream flow and flow within storm drainage structures (Pipes, canals, etc). There are many ways to estimate t_c, formulas exist for predictions of overland and channel flow. Time of concentration is the total time taken for water to move through each flow regime until it reaches the collection point. The time of concentration of overland flow may be estimated from the following empirical formulas:

2.8 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.

Considering the entire watershed to be composed of a composite group of essentially independent elements, it is apparent that the runoff water from one element is a source of supply or inflow to another element adjacent to it. On the basis of the above requirement of a uniform slope within an element, an assumption that all water flowing across an element moves parallel to the direction of the total outflow moving into each of the adjacent elements receiving this water simply the percentage of the total area of the element. Basically, the proposed mathematical watershed model requires the development of a runoff model for each element in the watershed.

The time distribution of runoff from each watershed element may be determined by combining the various component relationship outlined with the equation of continuity:

$$I - O = \frac{ds}{dt}$$

Where t = time

I = inflow

O = outflow

S = volume of water in storage

For an effective usage of the continuity equation (equation 2.52), the volume of water stored and rate of surface runoff are normally expressed in parametric form with the depth of water in the area as the parameter. Equation 2.52 can further be expressed as

$$I_1+I_2 - O_1 + \frac{2S1}{t} = O_2 + \frac{2S2}{t} \qquad 2.53$$

Where I_1, I_2, O_1, O2, S_1, and S_2 all stands for the initial and final rates of inflow, outflow and storage respectively. The composite runoff model for the whole area is obtained by starting at a known initial condition and applying equation 2.53 to determine conditions at all points in the system.

The conceptual model of surface runoff for a small watershed will result in a subdivision of the runoff cycle into several components. Each these components can independently be incorporated into the general mathematical model.

2.9 RAIN 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.

2.10.1 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.

2.10.2 RAINFALL SIMULATORS

Rainfall simulators or artificial rainfall applicators allow an investigator to create artificially conditions in which hydrological processes are set in motion. They have now become a standard item of research equipment for work on many other aspects of soil behaviors which could be classified under physical hydrology. The extension of their use to more general hydrological problems falling within the scope of system investigation has proceeded more slowly. The possibility of studying the hydrological cycle of a laboratory-size artificial catchment area has remained no more than an exciting future development. The theoretical and practical problems presented by such experiments are manifold, and yet sufficient progress has been made during the last ten years for Amorocho and Hart (1965) to propose a classification for this type of study.

For simulating rainfall, a wide variety of techniques and equipment ranging from up and down the slope with sprinkling cans to elaborate, push button-operated electronic and hydraulic machines have been developed. The most essential component of any simulator is the drop forming method. Researchers have used hanging yarn, tubing tip and nozzles as drop-formers.

Properly simulating rainfall requires several criteria:

1. Drop size distribution near to natural rainfall (Bubenzer, 1979a),
2. Drop impact velocity near natural rainfall of terminal velocity (Laws, 1941) (Gunn and Kinzer, 1949),
3. Uniform rainfall application over the entire test plot,
4. Uniform rainfall intensity and random drop size distribution(laws and parsons,1943)
5. Vertical angle of impact and
6. Reproducible storm patterns of significant duration and intensity (Moore *et al.*, 1983) (Meyer and Harmon, 1979).

Drop size distribution, impact velocity and reproducible storm patterns must be met to simulate the kinetic energy of rainfall. Kinetic energy ($KE = mv^2/2$) 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 than1mm to about 7mm), increasing with the intensity to 2.25mm median drop size fro high intensity storms (Laws and Parsons, 1943). Most design standards were based on Laws and Parsons (1943) studies.

2.10.2.1 TYPES OF RAINFALL SIMULATORS

Simulators Can be Separated into two Large Groups (drop-forming simulators and pressurized nozzle simulator) (Thomas and El Swaify, 1989). Drop-forming simulators are impractical for field use since they require such a huge distance (10 meters) to reach terminal velocity (Grierson and Oades, 1977). The drop-forming simulators do not produce a distribution of drops unless a variety of drop-forming sized tubes are used. Another negative of the drop-forming simulators is their limited application to small plots (Bubenzer, 1979). Several points of raindrop production must be packed to create and intense enough downpour of rain. Drop-forming simulators use small pieces of yarn, glass capillary tubes, hypodermic needles, polyethylene can be varied more than the drop forming type (Grierson and Oades, 1977). Since drops existing the nozzles haven 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, 1979).

The most popular nozzle is the Veejet 80100 nozzle run at 41kpa (6psi). it was chosen because it most closely resembles the drop size distribution of erosive storm patterns in the Midwest (Bubenzer,1979a). Accurate testing of nozzles must be ensure adequate spray coverage and uniformity in the plot.

a. Non-Pressure Droppers

Man simple simulators have used the principle of drops forming and dropping from the tip of tubes connected to a water supply. The size of the drop is related to the tube, metal, glass or plastic tubing has been or hypodermic needles which are manufactured to a high degree of accuracy.

3.5.1.3 Sandy Loam Soil

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

3.6 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.

3.7 Infiltration measurement

The infiltrometer rings will be placed randomly from each other and the measurement will be taken to the nearest centimetre. 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.

3.7.1 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

3.7.1 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.

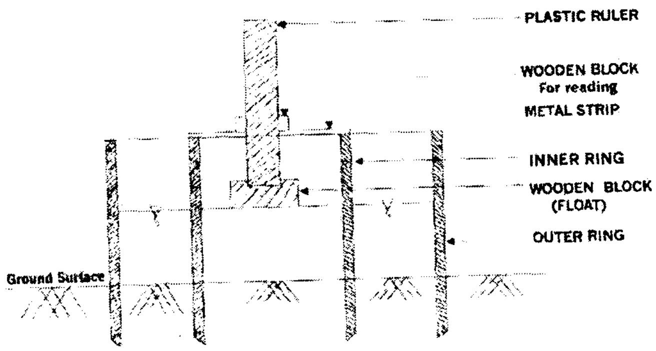

Figure 3.3: A Dissected infiltrometer Ring.

3.11.4 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.

3.11.5 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 110 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)

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

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

Where

W_w= weight of wet soil (g)

W_d=weight of dry soil (g)

3.11.6 Bulk density

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

$$Bulk\ Density = \frac{Weight\ of\ oven\ dry\ soil}{Volume\ of\ oven\ dry\ soil} \qquad 3.26$$

$$D_b = \frac{W_d}{V_c}\ (g/cm^3)$$

Where;

W_d = weight of dry soil (g)

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

An array of tubes of different sizes may be used to produce rain of different size drops. The advantages of this method are that the size of the drops and their fall velocity are constant, the distribution of rainfall across the test plot is uniform and can be achieved with low water pressures.

The disadvantages are that unless the device is raised up very high, the drops strike the test plot at velocity much lower than the terminal velocity of falling rain, and therefore the values of kinetic energy are also low. A large drop of 5mm diameter needs a height of fall of about 12m to reach 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 the practicalities of constructing a very larger drop forming tank.

(b) Pressure Sprays

The simplest possible form of spray, which may be perfectly suitable for some simple applications, is a spray from a watering can, or the rose connected to a pressurized hose pipe. Most commercial roses are drilled with all the holes of the same size, but it is easy to achieve a mixed drop distribution by drilling holes of different sizes. A basic problem with sprinklers of this type that, like non-pressures drop formers, they only achieve a low impact velocity unless falling from a considerable height. With pressure sprays the impact velocity can be increased by pointing the spray down wards so that it leaves the nozzle with a velocity dependent on the pressure and then accelerates as it falls.

(C)The Norton Simulator

The Norton Ladder Type Rainfall Simulator is a spray boom that oscillates across a test 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 roper 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 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 rainfall is quite large, from 34to 3400kpa (5 to 500psi) yielding flow rates of 13.2 to 132 liters per minute (3.5 to 35 gpm). A pressure of 41 kpa (6psi) produces drop size and intensity similar to natural rainfall (Bubenzer, 1979).

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.

2.11 Soil

Soil is that thin outer layer of the earth made up of a mixture of mineral and organic materials, air and water formed form the underplaying rocks and plant and animal material by various physical, chemical and biological process. (Areola and Mamman, 1999)

2.11.1 Soil Constituents

Soil consists of minerals matter, soil organic matter, soil airs and soil water.

2.11.1.1 Mineral Matter

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

2.11.1.2 Soil Organic Matter

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

2.11.1.3 Soil Air

This acts as the "atmosphere" fro roots of plant and soil micro-organisms from where they obtain oxygen and into which they disposed unwanted gases. Soil air is replenished form time to time form the earth's atmosphere through the process known as gaseous exchange. However, the properties of soil air differ in some respects from those of the earth's atmosphere.

2.11.1.4 Soil Water

This is the medium through which plants and many micro-organisms obtain mineral elements from the soil. Soil water is important also as a weathering and leaching agent in soils. There are different forms of soil water. The water that occupies the macro pores during each rainfall and drains through the oils toward the water table is called free-draining or gravitational water that is normally held within the micro pore is called capillary water. It is this type that is readily available to plants (Mamman, 1999).

2.12 Soil Profile

This is the vertical section through the soil to the underlying solid rock showing layers of earth of varying course, texture and consistency. Soil horizons are usually designated by the letters of the alphabet.

2.12.1 The A-Horizon

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

2.12.2 The B-Horizon

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

2.12.3 The C-horizon

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

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).

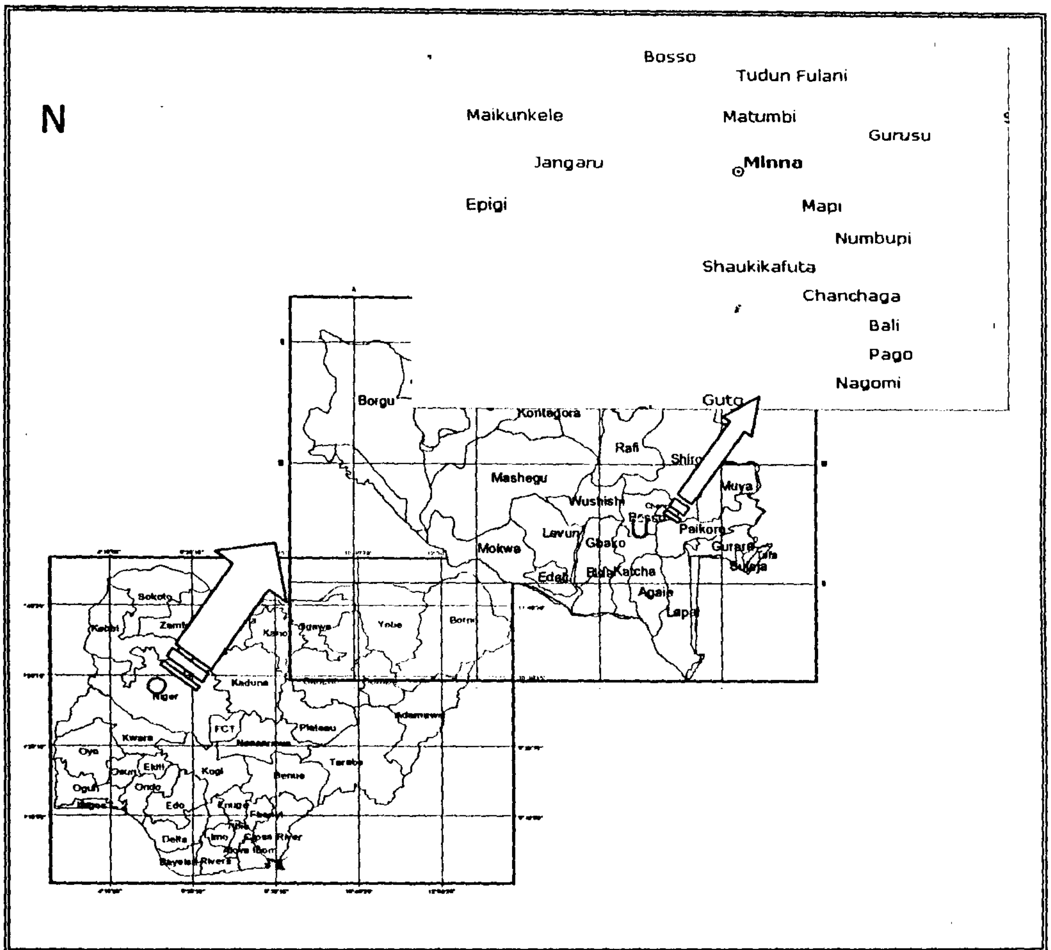

Figure 3.1: Map of Bosso Local Government Area, Niger State

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.

3.3 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.

3.4 Area of Study

The area of study is using rainfall simulator to determine some hydrological coefficients for some soils using a surface runoff after a rainfall intensity of 30 minutes within the permanent site farm of the Federal University of Technology, Minna, located along the Minna – Bida highway, Niger State Nigeria.

3.5 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 neighbouring villager to use the land for agricultural activities such as farming and grazing by the nomadic cattle rearers (Musa, 2003).

3.5.1 Types of soils

3.5.1.1 Loamy Soil

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

3.5.1.2 Clay Loam Soil

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

3.11.7 Total Porosity

The density method was used to determine the total porosity.

$$\text{Total porosity} = \frac{1 - D_b}{D_p} \times 100 \qquad 3.27$$

Where;

D_b = bulk density (g/cm³)

D_p = particle density (g/cm³)

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

$$D_w = \frac{\text{weight of gravity bottle filled with water} - \text{weight of specific gravity bottle}}{50} \qquad 3.28$$

Particle density was calculated as

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

Where;

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

4.1 Results

The results obtained from site survey; textural class analysis, infiltration rate, soil moisture content, slope and surface runoff are shown below.

4.1.1 Soil Textural Class

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 class contains.

The results of the textural class of the soil in the experimental plots as determined from the department of soil science laboratory are shown in table 4.1.

Table 4.1: Result of textural class analysis

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

4.1.2 Soil Moisture Content

The results of the moisture content before and after rainfall simulation of the soil in experimental plots as determined by oven drying method in the department Of Agricultural and Bioresources Engineering, soil and water conservation engineering laboratory are shown in table 4.2.

Table 4.2 Results for initial soil moisture content

PLOT NO_	WET kg	DRY kg	MC (%)
1	0.24	0.186	22.5
2	0.26	0.12	53.8
3	0.29	0.129	55.5
4	0.32	0.199	37.8
5	0.24	0.118	50.8
6	0.21	0.102	51.4
7	0.25	0.13	48
8	0.31	0.182	41.3
9	0.33	0.191	42.1
10	0.28	0.123	56.1
MEAN	0.273	0.148	45.93

Table 4.3 Results for final soil moisture content

PLOT NO	WET kg	DRY kg	MC (%)
1	0.28	0.184	34.3
2	0.29	0.1	65.5
3	0.36	0.112	68.9
4	0.41	0.185	54.7
5	0.3	0.112	63.7
6	0.27	0.098	62.2
7	0.32	0.121	61.9
8	0.43	0.21	51.2
9	0.45	0.199	55.8
10	0.34	0.13	61.8
MEAN	0.345	0.1451	58

4.1.4 Infiltration Rate

The cumulative amount of water that infiltrates into soil in five minutes interval for 60 minutes, are shown in table 4.4

Table 4.4 Infiltration Rates for the ten plots

s/no	TIME (min)	average infiltration (cm/min)	average cumulative infiltration (cm/min)
1	0	0.00	0.00
2	5	4.38	4.38
3	10	3.72	8.10
4	15	3.15	11.25
5	20	2.67	13.92
6	25	2.25	16.17
7	30	1.91	18.08
8	35	1.67	19.75
9	40	1.29	21.04
10	45	0.84	21.88
11	50	0.65	22.55
12	55	0.57	23.10
13	60	0.57	23.67

4.1.3 Surface Runoff

The surface runoff from the ten plots are shown in table 4.5

Table 4.5 Result for surface runoff

PLOT NO_	SURFACE RUNOFF (m3)
1	0.170
2	0.200
3	0.133
4	0.480
5	0.197
6	0.187
7	0.177
8	0.177
9	0.167
10	0.160
MEAN	0.205

4.1.3 Surface Runoff

The surface runoff from the ten plots are shown in table 4.5

Table 4.5 Result for surface runoff

PLOT NO_	SURFACE RUNOFF (m3)
1	0.170
2	0.200
3	0.133
4	0.480
5	0.197
6	0.187
7	0.177
8	0.177
9	0.167
10	0.160
MEAN	0.205

4.1.5 Hydrologic Coefficient, C

Hydrologic parameters; soil moisture content, infiltration rates, slope and surface runoff were determined and the results presented in table 4.7.

Table 4.7 Parameters for the determination of hydrologic coefficient

Initial moisture content (%)	Infiltration rates (mm/hr)	Surface runoff (m3)	Time of surface runoff (min)	slope of the plot (θ)
27.5	23.4	0.17	2.00	2.58
53.8	22.1	0.20	2.77	2.33
55.5	24.2	0.133	2.00	2.66
37.8	26.6	0.480	2.20	2.25
50.8	22.2	0.197	2.86	2.00
51.4	25.2	0.187	2.50	2.17
48.0	24.9	0.172	4.10	2.75
41.3	21.8	0.177	1.24	2.08
42.1	23.6	0.167	3.10	2.22
56.1	22.7	0.160	3.15	2.40

4.2 Discussion of Results

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 a predominately farm land which is being used by the surrounding local inhabitants of the area who are farmers and some staffs of the university.

Soil texture depends on the relative amounts of sand, silt, and clay. Most surface soils fall into five general textural classes. Each class name indicates the size of the mineral particles that are dominant in the soil. Texture was determined in the field by rubbing moist-to-wet soil between the thumb and fingers. This observation was checked in the laboratory by mechanical analysis which separates particles into clay, silt, and various-sized sand groups. Taking the average percentage compositions of the ten soil plot as shown in table 4.1, the percentage of sand, clay and silt were found to be 64.2%, 12.5% and 23.3% respectively, giving a textural class of "sandy-loam".

Table 4.2 shows the percent water content for the various plots of sand-loam 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 1 having the lowest percent of 22.50 and plot 10 having the highest of 56.10 percent. it was also observed from the table that plot 1 had 90% sand content, 7% clay content while the silt content was 3%. Plot 10 is observed from Table 4.2 to have 89% sand, 7% clay and 4% 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.

The soil moisture content was determined in "wet basis" using equation 4.1

$$Moisture\ content = \frac{Weight\ of\ wet\ soil - Weight\ of\ Dry\ soil}{Weight\ of\ wet\ soil} X\ 100 \qquad 4.1$$

From Table 4.2 the average initial and final moisture contents were found to be 45.93% and 58.00%

respectively. It can also be seen that the soil has very good water holding capacity as it was able to retain water within the root zone of the soil. It also buttresses the water retention characteristics of sandy-loam.

Table 4.4 shows the average infiltration rate 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. A total cumulative infiltration of 55cm 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 Gidankwano soils of the Federal University of Technology, Minna.

From infiltration rates shown in table 4.4, the average infiltration rate of the soil was found to be 15.68cm/hr. This is of course important to know when determining the irrigation time. Water infiltrates more and faster into the soil at the early stage of the experiment and continues to drop as soil becomes saturated until it no longer take in more water. Once the values of the Infiltration rate are constant, the basic infiltration rate has been reached.

Table 4.5 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 were recorded from plots 4, 5 and 6. The lowest values were recorded from plot 3 which is $0.13m^3$ while the mean value of the surface runoff was calculated as $0.206m^3$.

Soil slope is one of the major factor that affects surface runoff, as it can be seen from the result in table 4.6, that the steeper the soil, the more the surface runoff.

Various slope sizes were considered when carrying out the work which shows the rate of flow of water on the soil surface. Table 4.6 shows the various slope sizes that were considered in percentages. It was observed that plots 7, 9 and 10 had the highest degrees while the lowest value slope was plot 8 which has a decree of 1.24.

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 developed for a disturbed sandy-loam soils in Gidankwano 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 4.5 above shows the various parameters which was used to obtain the equation of the form $Y = MX_n + C$

From table 4.5, equation for the determination of hydrologic coefficient of Sandy-Loamy soils (undisturbed) in Gidankwano and environs was determined through careful manipulation of the hydrologic parameters to be; $Y = 0.062581x_1 - 1.64212x_2 + 0.099371x_3 + 0.399138$

Where X_1 = Initial moisture content for the ten plots considered,

X_2 =Infiltration rates for the ten plots considered,

X_3 = Surface runoff for each of the plots under consideration and

C = Slope for the various plots.

This implies that when values for X_1, X_2, and X_3 are fixed into the equation a coefficient will be obtained for a sandy-loam 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 is positive.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

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. 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 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 the research work does not involve validation using natural scenario of soil in question.

5.2 RECOMMENDATION

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

Samples obtained should be tested or analyzed in different laboratories by different experts or Several times, so as to make sure that the data obtained is more reliable.

Since the study was carried out in the dry season, more research should be done during both seasons to ascertain whether there will be significant variations in the data obtained in both seasons.

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APPENDICES

Mean Monthly Temperature (°C) from 2007 – 2009 in Minna, Niger State

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
2007	33.7	37.2	38.2	36	32.8	30.3	29.5	28.2	30	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	35.6
2009	35.7	37.8	39.2	35.2	33.9	31.8	30.9	28.8	30.5	31.5	34.6	36.7

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

Mean Monthly Rainfall (mm) from 2007 – 2009 in Minna, Niger State

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
2007	0	0	0.4	73.1	156.6	123.9	314	310.1	330.2	115	0	0
2008	0	0	0	40.2	146.8	132.7	305.1	244.3	258.9	141	0	0
2009	0	0	0	89.9	101.4	108.9	246.8	497.6	273.5	85.2	0	0

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

Mean Monthly Relative Humidity (%) from 2007 – 2009 in Minna, Niger State

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	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

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

Mean Monthly Wind Speed (m/s) from 2007 – 2009 in Minna, Niger State

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	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	75.8	76.8	99.4	110.8	81.7	82.8	73.8	47.5	45.9	35.4	75	90.8

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