A COMPARATIVE ANALYSIS OF DISCHARGE MEASUREMENT TECHNIQUES UPSTREAM OF RIVER KUBANNI, ZARIA, KADUNA STATE, NIGERIA

BY

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DECLARATION

I declare that this Dissertation entitled: A COMPARATIVE ANALYSIS OF DISCHARGE MEASUREMENT TECHNIQUES UPSTREAM OF RIVER KUBANNI, ZARIA, NIGERIA; has been carried out by me in the Department of Geography and Environmental Management, Faculty of Physical Sciences, Ahmadu Bello University, Zaria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other Institution.

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(Name of Student) Signature Date

CERTIFICATION

The Dissertation entitled A COMPARATIVE ANALYSIS OF DISCHARGE MEASUREMENT TECHNIQUES UPSTREAM OF RIVER KUBANNI, ZARIA, NIGERIA; by Suleiman MUKHTAR meets the regulations governing the award of the degree of M.Sc. Geography and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is dedicated to my beloved parents Alhaji Mukhtar Abubakar and Hajiya Halima Usman, my wife Mrs Amina Ibrahim, my sisters Rahinatu. Surayya and Fatima.

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ABSTRACT

The study did a comparative analysis of discharge measurement techniques upstream of River Kubanni. Descriptive statistics and Analysis of Variance were used to analyze the stream discharge data collected for the study period using the three techniques. From the stream discharges obtained for 2017 and 2018 hydrological year using the weir method, it showed that there is an increment in the flow period from the tributaries with Malmo having the least flow period of 206 days.This study shows a significant difference in the stream discharge having Goruba tributary with the highest discharge value of 2,344,896 m^3/yr., followed by Maigamo and Tukurwa with a discharge values of 1,215,648 m^3/yr. and 1,127,520 m^3/yr. respectively, while Malmo tributary has the smallest discharge of 508,896 m^3/yr. using the weir technique because it gives the discharge throughout the flow period. The results shows a strong relationship between the stream discharge and the size of a river.In order to examine the most effective methods for measuring stream discharge the results observed from this study shows that the F- calculated for Malmo was 1.189 while F- critical was 3.09, Tukurwa has F-calculated of 0.510 while F-critical was 3.09, Maigamo has F-calculated of 0.911 while the F-critical was 3.09 and Goruba has F-calculated of 1.663 while the F-critical was 3.09 all at 0.05 significance level. The result show that there is no significant difference between the river discharges values obtained from the three techniques. Thus, both methods were suitable for the stream discharge measurements on the stream channels. The study therefore recommends that there should be continuous monitoring of stream discharge since it is the first requisite for planning of water resources development, measures to mitigate siltation should be employed because there is a relationship between stream discharge and sediment yield and lastly it is recommended that for small river channels, the weir method is the most effective technique for stream discharge measurement because of its consistency.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Almost every day, water makes the headlines somewhere in the world. Drought, Flood and Pollution are all big News, as water becomes the most precious and most contested essential resources. Man requires water for cooking, drinking, sanitation, agriculture and manufacturing processes. However, because water is freely available through rainfall, man has, until fairly recently, taken this unique resource for granted. Although more than 70 percent of the earth's surface is water, water has become a scarce commodity in many parts of the world. The threat of a world water crisis is becoming increasinglyreal in the face of increasing demand, relative static supply and deteriorating quality due to pollution (Ayoade and Oyebande, 1978, as cited in Yusuf 2013).

Research on water quantity and quality has become very vital, particularly in the developing countries like Nigeria where water availability continues to be a problem of great concern. The total amount of water on the earth surface, its partition and movement among major earth realms have been topics of speculation and investigation during more than a century (Chorley, 1964). While the hydrological cycle is well documented, the linkages between the various interdependent components are less well understood. This is true of those regions that suffer problem of water scarcity and there remain urgent requirement for regional water resources assessments especially in arid and semi-arid regions where optimal management of all water resources is essential (Berven, 2012).

Flow in open channels has been nature's way of conveying water on the surface of the earth since the beginning of the time. Rivers were the arteries for the development of early civilization,

and in modern societies, they remain central to local and global economies. Across the world, quality of life can be assessed in terms of the availability of freshwater and most of this comes from rivers. Hence, rivers are of importance to everyone dealing with water resources whether from the viewpoint of geomorphology or hydrology (Hart, 1992, as cited in Ibrahim 2011).

Rain falling onto hill slopes generates overland flow, or runoff, in two basic ways. If the amount of rain arriving at the surface of the soil exceeds the rate at which water can infiltrate the soil surface, water is stored in small depressions on the hill slope until the depressions are overtopped. Overtopping causes the water to flow down the hill slope. This is called overland flow and is common in semi-arid and arid regions (Baird, 1997; Cech, 2005).

Surface runoff, specifically open channel flow is a component of the hydrological cycle that can be measured for large geographic areas with reasonable accuracy. Flow information is necessary for water management in many diverse applications including water supply management, pollution control, irrigation, flood control, energy generation and industrial use (Herschy, 2002). Stream discharge is an important parameter of stream or channel flow and its measurement usually involves consideration of both stage and velocity. The discharge of a river relates to the volume of water flowing through a single point within a channel at a given time (Gregory and Walling, 1973).

Stream flow or discharge is defined as the volumetric rate of flow of water in an open channel including any sediment or other solids in a fixed unit of time. Stream flow cannot be measured directly but must be computed from variables that can be measured directly such as stream width, stream depth and stream flow velocity. Even though stream flow is computed from

measurement of other variables, the term “Discharge measurement” is generally applied to the final result of the calculations (Turnipseed and Sauer, 2010).

Understanding the discharge of a stream or river is essential for many important hydrological and geomorphological uses across a broad range of scales including global water balances, engineering design, flood forecasting, reservoir operation, water supply, recreation and environmental managements. Growing population and competing priorities for water including - preservation and restoration of aquatic habitat are spurring demand for more accurate, high frequency and accessible water data (Whiting, 2003; Hirsch and Costa, 2004).

Several methods are available for the measurement of river discharge and the choice will depend upon the magnitude and character of the channel and associated flow, cost and the accuracy required. These include velocity area techniques, dilution gauging, volumetric gauging, slope area technique, weirs and flumes methods. The most widely and commonly used method for spot measurement of discharge is the velocity-area techniques since discharge by definition is computed as the product of the cross sectional area and velocity (Herschy, 2002).

Current metres are often used in the velocity-area method for absolute discharge measurement. It consists of a rotor or series of cups that rotates at a speed proportional to the flow velocity. If the revolution can be counted over a fixed period, then the velocity can be computed from the calibration data. Current metres can be divided into two categories; mechanical and electromagnetic current metres. Typically, water depth and magnitude of velocity will determine the selection of the current metre for deployment while both current metres types vary in design; they are generally deployed in similar ways. Deployment of current metres can be carried out by

means of a wading rod, although at greater water depth and velocities, cableways, bridges or boats may also be used (Whiting, 2003).

Float method is another velocity-area method used in measuring river discharge. It is inexpensive and very simple means of measuring discharge. The method measures the surface velocity while the mean velocity is obtained using a correction factor. The basic idea is to measure the time that it takes the object to float a specific distance downstream (Whiting, 2003; Hirsch and Costa, 2004).

Another technique used in measuring discharge is by the use of control structures such as weirs and flumes. Weirs are overflow structures built across open channel to measure the volumetric rate of water flow. It usually consists of a crest, which is usually perpendicular to the direction of the flow. The weirs maybe classified into sharp-crested and broad-crested weirs. The sharp-crested weirs consist of a notch and crest which are formed by a sharpened metal plate, while the broad-crested weirs consist of a thicker construction usually concrete. Each type of weir maybe further classified according to the form of the crest and terms such as triangular notch or rectangular notch are used (Gregory and Walling, 1973).

However, it is crucial that the correct technique and instrumentation are used depending on the environmental and flow conditions encountered. This will ensure that discharge estimations are as reliable as possible. The most accurate technique for river discharge measurement is using stream gauge recorder (Ogunkoya, 2000). This equipment automatically records all stream flow event continuously. However, this equipment is very expensive to obtain for researchers in developing countries. Besides, they are vandalized and destroyed in the field. Consequently,

researchers have to resort to cheaper and yet a reliable technique of measuring river discharge as observed by (Yusuf, 2006).

To this end, this research will analyze the various techniques used in measuring river discharge and at the end adopt which methods best suits measuring discharge of small rivers like those of the tributaries ofKubanni River in Zaria, Kaduna State.

1.2 Statement of the Research Problem

The perception about water goes to the very height of the increasing worldwide concern about human health, the environment and the path towards sustainable development of all natural resources needed for economic development as water is one of the most essential resources particularly in arid and semi-arid regions (Ibrahim, 2011). Currently, almost half a billion people face shortage of water in 29 countries. By 2050, almost two-third of the people on our planet are forecast to experience some type of water stress and for over billions of them, the shortage will be severe and severally disruptive (Biswas, 1998, as cited in Ibrahim, 2011).

The demand for water doubles every 20 years, which is more than twice the rate of the world's population growth [US Agency for International Development USAID, 2003]. New water sources are becoming scarcer and to treat and remediate existing sources is becoming more expensive (Clothier, Green and Deurer, 2008). Just as world's population is unevenly distributed by region, so is annual supply of water. Rainfall is determined by uneven weather pattern as a result some areas of the world gets more precipitation than others. Because of extreme fluctuation in river discharge in some climatic regions, dams are constructed across rivers to

create water reservoir for power generation, flood control, irrigation and domestic supply (Spencer, 2003).

Several studies have been carried out on tributaries of the Kubanni drainage basin. For example, Yusuf, Iguisi and Bello (2007) made a comparison using the velocity area method with the weir technique, they pointed out clearly that the weir technique possess many advantages over the velocity area method, whereby it is easy to obtain the daily mean discharge of everyday while the velocity area method is only applicable after rain event and that will depend on the amount of rain fall because if the water level is too low current metre cannot be used while the float method is sometimes affected by vegetal covers and eddy current.

Zubairu (2009) made a comparison on a single tributary of River Kubanniusing a 2^{nd} order tributary which is RiverTukurwa using the Float method and the weir technique. The result showed that the Float has lower mean, standard error and standard deviation, variance and range than the weir techniques implying that the Float method is more superior to the weir technique.

Yusuf, Iguisi and Abdulsalam (2011), made a comparison between the current metre and float method in determining the discharge of Samaru stream, which is a first order tributary of River Kubanni. The results showed that there is no significant difference between the current metre and float method in determining the discharge.However, having a closer look at the result obtained showed that the float method has lower mean, standard error, and standard deviation and variation than the current metre. By this, it implies that the float method is better than current metre.

Yusuf (2013) assessed the sediment delivery into the Kubanni reservoir measured the stream discharge of Malmo and Tukurwa stream using the weir method while for Maigamo and Goruba

stream, the velocity area method was used. The results showed that the weir has lower mean, variance, standard deviation compare to the velocity area method, thus implying that the weir is superior to velocity area method.

None of the previous studies tried using both the current metre, float method and weir techniques for all the major tributaries of RiverKubanni thus creating a gap in knowledge which this research intended to fill. The study therefore tried to compare the current metre, float method and weir techniques on the four tributaries (Malmo, Tukurwa, Maigamo and Goruba) upstream of River Kubanni that is in order to ascertain the best technique to be used in assessing river discharge. It is against this backdrop that the study wished to answer the following research questions;

i. What is the stream discharge of the tributaries upstream of River Kubanni using the float, current metre and weir technique?
ii. . What is the difference in the stream discharges of the tributaries upstream of River Kubanni using the three methods?
iii. How effective are the methods used in assessing stream discharge upstream of River Kubanni?

1.3 Aim and Objectives

The aim of this study is to carry out a comparativeanalysis of discharge measurementtechniques upstream of River Kubanni. The aim was achieved through the following objectives, to:

(i) determine the stream discharges of the tributaries upstream of River Kubanni using the float, current metre and weir technique.

(ii) compare the stream discharges of the tributaries upstream of River Kubanni using the three methods.

(iii) examine the effectiveness of the methods for measuring stream discharge upstream of River Kubanni.

1.4 Hypotheses

In order to achieve the aim and objectives of the research, the following hypothesis was postulated at 0.05 level of significance:

$H_{0:}$ There is no significant difference in the results obtain using the Float, Current metre and the Weir technique in determining the stream discharges upstream of River Kubanni.

1.5 Scope of the Study

This work was mainly restricted to observation of the stream discharges on four of the tributaries upstream of River Kubanni namely; Malmo, Turkurwa, Maigamo and Goruba all in Zaria, Kaduna State using the float, current metre and the weir methods. Four gauging stations were established along the tributaries which served as the sampling point where the stream discharges were obtained using the three methods. This was in order to find out the most effective method in determining stream discharges for tributaries like those for River Kubanni, Zaria. The study was limited to 2017 and 2018 hydrological year.

1.6 Justification of the Study

The requisite for planning of water resources development is the availability of accurate data of stream flow for a considerable period of time to determine the extent and pattern of available

supply of water. Therefore the importance of stream flow measurement need not to be over emphasized. But in many countries no attention has been paid for stream flow measurement. Even in Nigeria, only in recent past some attention has been given to the stream flow measurement, but still we have a long way to go before the system of collection of stream flow data could be put on a systematic, sound and uniform basis over the entire country (Whiting, 2003).

When a dam is constructed across a river, the resultant reservoir receives water and sediments from the catchment areas of the river network. Sediment yield in any reservoir or river has a relationship with the river discharge (Yusuf, 2013). Hence, the need for stream discharge measurement becomes a paramount importance in water resources evaluation. Stream discharge is quite important on both concentration of substance dissolved in the stream and on the distribution of habitat and organism throughout the stream and it is a major factor influencing water chemistry (Zubairu, 2009).

River discharge is of great importance ranging from flood control, power generation, irrigation, water supply and dam construction; hence, accurate measurement of river discharge needs to be obtained for proper planning purposes (Gregory and Walling, 1973). Thus, the best method of assessing river dischargeis necessary.

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Concept of Stream Discharge

Stream discharge can be defined as the rate of flow of water in an open channel including any sediment or other solids in a fixed unit of time measured in cubic metre per second. Stream discharge cannot be measured directly but can be computed from variables that can be measured directly such as stream velocity, stream depth and stream width. Stream discharge is equal to the product of the mean velocity and the cross sectional area of flowing water (Gregory and Walling, 1973).

$Q = VA$ …… (1)

Where Q = Discharge (m^3/s).

V = velocity m/s

A = Cross sectional Area (stream width X stream depth) m/s.

The simplest way to measure discharge is to divide the channel cross section into vertical rectangular subsections. Once the area (width X depth) of each of these subsections is established and multiplied by velocity to determine subsection discharge, the results can be added together to calculate total discharge. Subsection width is best measured with a cable or steel measuring tape, while depth can be measured by a wading rod in shallower channels and suspended sounding weights in deeper waters. Velocity, on the other hand, should be measured with a current meter. Many current meters rely on a wheel formed of several cups revolving around an axis. Each revolution generates an electronic signal that is counted and timed by the meter, which translates to water velocity (Leopold, 1994).

Stream discharge has two components. The first is flow velocity, and the second is the volume of water in the stream. Flow velocity is influenced by the slope of the surrounding terrain, the depth of the stream, the width of the stream, and the roughness of the substrate or stream bottom. If the surrounding terrain is steep, then rain water will have less time to sink into the ground and runoff will be greater. In an area with level terrain, such as farm land, the rain water has time to sink into the ground and there is less runoff. The flow velocity will also vary as the width or depth of a stream changes. For instance, if you squeeze a water hose with your hand, the flow velocity of the water increases. This is because you have reduced the area that the water must flow through,

while the volume of water passing through the hose remained constant. The same thing happens in a stream when the stream channel changes in its width or depth. The substrate of the stream bottom also affects the flow velocity since water moves faster over a smooth surface than a rough surface. Flow velocity is greater when the stream bottom is comprised of sand and clay and lower when it is cobble, rock, and boulders (Leopold, 1994).

The volume of water in the stream is affected by the climate of the region. Areas with more rain will have more water draining into surrounding streams and rivers. Seasonal changes affect stream volume as well. In the summer there will be less water in the stream compared to the winter. The number of tributaries that merge with a stream or river contribute more water to the system, increasing the stream volume. Humans are also responsible for altering the volume of water in streams. Water is removed for consumption, industry, and irrigation. Roads and parking lots cover vast areas, preventing rain-water from soaking into the ground. Instead, the water is forced to run off into surrounding streams and rivers(Leopold, 1994).

2.1.2 Components of Stream Flow

When a storm occurs, a portion of rainfall infiltrates into the ground and some portion may evaporate. The rest flows as a thin sheet of water over the land surface which is termed as overland flow. If there is a relatively impermeable stratum in the subsoil, the infiltrating water moves laterally in the surface soil and joins the stream flow, which is termed as underflow (subsurface flow) or interflow. If there is no impeding layer in the subsoil the infiltrating water percolates into the ground as deep seepage and builds up the ground water table. The ground water may also contribute to the stream flow, if the ground water table is higher than the water surface level of the stream, creating a hydraulic gradient towards the stream. Low soil

permeability favors overland flow. While all the three types of flow contribute to the stream flow, it is the overland flow, which reaches first the stream channel, the interflow being slower reaches after a few hours and the ground water flow being the slowest reaches the stream channel after some days. When the overland flow starts (due to a storm) some flowing water is held in puddles, pits and small ponds; this water stored is called depression storage. The volume of water in transit in the overland flow which has not yet reached the stream channel is called surface detention or detention storage (Whiting, 2003).

2.1.3 Classification of Streams

Streams may be classified as Influent and Effluent streams or as Intermittent and perennial streams. If the groundwater table is below the bed of the stream, the seepage from the stream feeds the ground-water resulting in the buildup of water mound. Such streams are called influent streams. Irrigation channels function as influent streams and many rivers which cross desert areas do so. Such streams will dry up completely in rainless period and are called ephemeral streams. The ephemeral streams, generally seen in arid regions, which flow only for a few hours after the rainfall, are of no use for conventional hydropower. However, they can occasionally be used in pure pumped storage schemes, where the actual consumption of water is only marginal (Gravalle, 2014).

When the groundwater is above water surface elevation in the stream, the ground water feeds the stream, such streams are called effluent streams. The base flow of surface streams during the dry season is the effluent seepage from the drainage basin. Most of the perennial streams are mainly effluent streams. If the groundwater table lies above the bed of the stream during the wet season but drops below the bed during the dry season, the stream flows during wet season (due to

surface runoff and groundwater contribution) but becomes dry during dry seasons. Such streams are called intermittent streams. While in the case of perennial streams, even in the droughts, the ground water table never drops below the bed of the stream and therefore they flow throughout the year (Whiting, 2003).

2.2 Review of other Relevant Literatures

2.2.1 The Measurement of Stream Discharge

The channel discharge is the volume of water flowing through a given channel cross-section in a given time. A number of different methods have been developed to measure discharge. These can be grouped into instantaneous measurements, where discharge is measured at a particular point in time, and continuous measurementsfor a record of discharge variations through time (Turnipseed and Sauer, 2010).

2.2.1.1 The Velocity–Area Method (Instantaneous Measurement)

Discharge is measured in cubic metre per second (m^3/s). It increases with the area of the channel cross section and with the velocity of flow (Turnipseed and Sauer, 2010). Discharge can be calculated for a given channel cross-section by measuring its cross-sectional area and the mean flow velocity:

$Q = A \times V$

Where Q = discharge (m^3/s)

A = cross-sectional area (width X depth)

V = mean flow velocity (m/s)

The first stage is to stretch a tape measure across the width of the channel. The channel is then divided into a number of sub-sections. This varies according to the width of the river, but discharge is usually gauged at twenty or more subsections. Ideally, the discharge flowing through each sub-section should be similar, so these are more closely spaced where the flow is deeper and faster. Velocity measurements are then made using a flow metre (Turnipseed and Sauer, 2010). A commonly used design is a propeller mounted on a rod, which is lowered into the flow. The flow velocity is directly proportional to the rate at which the propeller is turned by the flow. A digital readout shows the velocity in m s−1 or, if you are not so lucky, the number of rotations per minute. (This can then be converted to the equivalent velocity using a simple formula.) One velocity measurement is made for each of the sub-sections. Since flow velocity increases from zero at the channel bed to a maximum near the water surface, a representative average flow needs to be measured. Velocity measurements should therefore be made at a distance below the water surface that is 0.6 of the total depth (i.e. 0.4 of the depth from the bed). Thus if the depth of flow was 1 m, you would measure the velocity at a depth of 0.6 m below the surface (or 0.4 m above the bed). The discharge flowing through each sub-section can be calculated by multiplying the sub-section width (w), depth (d) and velocity (v) (Turnipseed and Sauer, 2010).

In order to calculate the discharge for the whole cross-section, the discharges for each of the subsections are added together. The discharge flowing through the ‘left over’ triangles adjacent to each bank is usually assumed to be negligible and is not included in this calculation. This method is not very suitable for steep, turbulent, rocky streams where accurate current meter measurements are hard to obtain. A more appropriate technique in this case is to use dilution gauging. A chemical ‘tracer’ substance such as salt or dye is released into the flow, either as a

single large ‘gulp’ or ‘slug’, or by continuously injecting it into the flow. Changes in concentration are monitored further downstream. Since the amount of dilution increases with discharge, it is possible to relate the change in concentration to stream discharge (Turnipseed and Sauer, 2010).

Float is another method used for measuring discharge of a stream, it is inexpensive and simple. This method measures the surface velocity, therefore the mean velocity is obtained using a correction factor. The basic idea is to measure the time that it takes the object to float a specific distance downstream. It is therefore expressed as

V surface = Distance travel / time

A = stream width X stream depth

2.2.1.2 Continuous stream flow measurement

The velocity-area method only gives you one measurement of discharge at a particular point in time. In order to plot hydrographs, it is necessary to have a continuous record of flow. Discharge is difficult to measure directly. However, it is related to stage, the water level or height, which is much easier to record. Stage is converted to discharge using a rating curve. Using this, the discharge corresponding to a given stage can either be read off from the graph or calculated using the rating equation. This is of the form Q=ahb, where Q=discharge, h=stage, while a and b are coefficients, which describe the unique relationship between stage and discharge for the cross-sectionthis relationship is affected by the shape of the crosssection (Turnipseed and Sauer, 2010).

At lower flows, small increases in discharge result in relatively large increases in stage because the channel is narrow near its bed. As the flow increases, a greater increase in discharge is needed to produce the same increase in depth, because the channel widens above the bed. Therefore a wide, shallow channel will have a different relationship (relatively small increases in stage with rising discharge) to a narrow, deep channel (relatively large increases in stage with rising discharge). The rating curve is derived from discharge measurements made at different stages. Measurements are difficult to make at high flows, so most rating curves tend to be less reliable at high flows (Turnipseed and Sauer, 2010). Another problem is that if a large flood alters the shape of the cross-section, the rating curve has to be re-calibrated. This can be avoided using a gauging structure such as a flume or weir. These have a regular cross-sectional area and the flow velocity is controlled by the structure. The rating curve can be derived using a combination of measurements and hydraulic theory (Turnipseed and Sauer, 2010).

Another continuous stream discharge measurement techniques is the used of control structures especially weirs and flumes, these involves a similar theoretical basis to the velocity area method of discharge measurement. However the cross sectional area is accurately known from the water level and dimensions of the structure through or over which the water flow, and the flow velocity can be computed from the form of the control and the head of water above it. It is therefore possible to establish a theoretical and stable relationship between stage and discharge for a particular control structure, so that a simple stage measurement will be sufficient to provide a value of discharge. The type of structure used and details of its design will depend upon the purpose of measurement, the nature of the stream channel, the sizes of the channel and the resources available (Gregory and Walling 1973). Weirs may be classified into sharp-crested or thin plate weirs, and broad crested weirs. In the sharp-crested weirs the notch and crest is formed

by a sharpened metal plate, while in the broad crested weirs a thicker construction usually made of concrete is used.

Sharp-crested weirs are commonly used in small catchments and the triangular form is especially suited to the accurate measurement of flow as low as 0.1 m/s. The 90^0 V notch is the commonly triangular weir form, although 120^0 notch are also employed depending on the sizes of the channel. Broad crested weirs have the advantage over the sharp crested weirs that they are not easily damaged by debris, and they are therefore usually to be preferred for larger catchment.

Many discharge formula are available for different forms of sharp crested weir, and the final choice must depend upon the accuracy required. Some of the simple formula are given below

90^0 V- notch $Q = 1.38H^{2.5}$

120^0 V-notch $Q = 2.47H^{2.5}$

½ (90^0) V- notch $Q = 0.69H^{2.5}$

Where Q = Discharge in m^3/s H = Head of water in metres

2.2.2Factors Affecting Stream Discharge

The factors that affect stream flow of a basin from a storm are broadly classified into three major groups. These include climatic factor, basin characteristics and basin infiltration characteristics. The major climatic factor affecting stream flow are the precipitation characteristics which include intensity, duration, aerial distribution, forms of precipitation and evapotranspiration. When precipitation is in the form of snow, the runoff from the basin is less. Rise in temperature melts the snow and generates runoff from the basin at a later date. But if precipitation takes place

in form of rainfall, its water will start flowing on the surface when the soil deficiency is met after the start of the rain fall depending upon its intensity and magnitude (Zubairu, 2009).

Intensity of the storm is directly proportional to the magnitude of the flow appearing in the stream. Rainfall at higher intensity causes immediate rise in discharge of the stream and is found to be more pronounced in small catchments. Duration of a storm also has direct effect on the volume of runoff from a basin. Rainfall of a given intensity occurring for longer duration gives rise to more stream discharge. When the intensity is constant and the storm duration is longer, the peak discharge in the stream will rise gradually to a maximum and will continue at the maximum till the storm lasts (Gravalle, 2014).

Aerial distribution of the storm also affect the runoff of a stream both in magnitude and temporal distribution. Maximum runoff occurs when rainfall from the entire area of the basin contributes to the runoff. When a storm moves upstream to downstream of a catchment at a rate equal to the movement of water in the channel then the effect will be a maximum flood peak at the outlet. Discharge in a stream is lower and can continue for a long time when the storm moves from the basin outlet to the upstream (Yusuf, 2013).

Evapotranspiration rate is inversely proportional to the stream flow from a basin. That is to say when the rate of evapotranspiration increases, the amount of water loss in the basin also increase which in time decrease the stream flow. On the other hand if the rate of evapotranspiration is at its minimal, the amount of water that escapes to the atmosphere is less, thus increase the stream flow of a basin (Gravalle, 2014).

Of the basin characteristics, the most important determinants of stream discharge are the basin size, shape, relief, stream density and land use. Total runoff from a catchment expressed in depth

is independent of the area. Therefore, total volume of precipitation available at a river section is directly proportional to the catchment area and the peak flow can be approximated to the square root of a drainage area. The peak flow per unit area decreases as the area increases and the period of surface runoff increases with area (Zubairu, 2009).

The shape of the catchment affects the stream flow in the following way. An elongated catchment has lesser peak and longer runoff duration than a fan- shaped catchment of the same area. A catchment having extensive flat area gives rise to low peak and less runoff, whereas a catchment with steep slope produces high peak flood. Rate of infiltration from a flat catchment is more which affect the velocity of overland flow. Therefore, the time of arrival of the peak at the outlet is late and so is the total time period of runoff for such flat shaped catchment. The basin slope plays an important role in urban hydrology where catchment is usually small. For a high intensity and long duration storm, the effect may be less pronounced (Yusuf, Iguisi and Abdulsalam, 2011).

Stream density also affect the stream flow of a basin. This is defined as the number of streams of a given order per square kilometer computed by dividing the total number of streams of the same order of the basin with the catchment area.

Topography is an important feature in terms of stream flow or run off producing capacity. All things being equal;

(i) Evapotranspiration is less from a higher elevation area.

(ii) Rainfall pattern may change with elevation from the mean sea- level.

(iii) A higher elevation usually has steeper slope than lower elevation area.

(iv) Higher altitude areas are less pervious and therefore infiltration is less in mountainous regions than low lying alluvial zones and

(v) Groundwater storage capacity is less for plateaus.

The geology is responsible for the rate of infiltration during a storm. If good aquifer material forms the basin then surface runoff will be less due to increase in infiltration, but for a basin composed of impervious materials the runoff will be highly peaked. Presence of faults, fissures and cracks in the geological formation result in the diversion of storm water to a new location where they terminate. Such formations may also divert water from a basin to an adjoining one as watershed leakage (Yusuf, Iguisi and Abdulsalam, 2011).

The land use has great effect on the resulting surface runoff. For example, consider a virgin forest area in which thick layer of mulch leaves and grasses have accumulated, even the heaviest down pours would be unable to generate surface runoff that would reach the streams. What we will have as sources of stream flow will be subsurface flow and ground water flow. On the other hand if the forest is removed and the land is cultivated after removing the mulch, the ground will becomes compacted, as a result even a mild rainfall will result in appreciable surface runoff (Yusuf, 2013).

2.2.3 Importance of Stream Discharge

The requisite for planning of water resources development is the availability of accurate data of stream flow for a considerable period of time to determine the extent and pattern of available supply of water. Therefore the importance of stream flow measurement need not to be over emphasized. But in many countries no attention has been paid for stream flow measurement. Even in Nigeria, only in recent past some attention has been given to the stream flow

measurement, but still we have a long way to go before the system of collection of stream flow data could be put on a systematic, sound and uniform basis over the entire country (Turnipseed and Sauer, 2010).

When a dam is constructed across a river, the resultant reservoir receives water and sediments from the catchment areas of the river network (Yusuf, 2013). However, sediments yield in any reservoir or river has a relationship with the river discharge. Hence, the need for stream discharge measurement becomes a paramount importance in water resources evaluation. Stream discharge is quite important on both concentration of substance dissolved in the stream and on the distribution of habitat and organism throughout the stream, Discharge is also a major factor influencing water chemistry (Zubairu, 2009).

Water resources scientist, policy makers need accurate information about the properties of river they study and manage. Stream discharge is an important measure of river environment and influence sediment transport, erosional capacity and flood dynamics. Increasing population and competing priorities for water including preservation and restoration of aquatic habitat are spurring demand for more accurate and accessible data (Gravalle, 2014).

Understanding the discharge of a stream or river is essential for many important hydrological and geomorphological uses across a broad range of scales including global water balances, engineering design, flood forecasting, reservoir operation, water supply, recreation and environmental managements. Growing population and competing priorities for water including - preservation and restoration of aquatic habitat are spurring demand for more accurate, high frequency and accessible water data (Whiting, 2003). However it becomes very vital for hydrological measurement especially stream discharge which this study intend to look at because

in every river or reservoir there is a direct relationship between the sediment yield and the stream discharge. Therefore for proper planning and management of any water resource project, accurate measurement of discharge is the first and the most essential requirement.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 Study Area

3.1.1 Location

The study area is located in Zaria, Kaduna State, Nigeria between Latitudes$11^0$05'50" to $11^0$10'25"Northand Longitudes$7^0$35'40"to 7^o38'50" East.Zaria is one of the province that make up the Central high plains of Northern Nigeria and it is approximately 670mabove mean sea level. Zaria is the secondlargest city in Kaduna State, covering a total land mass of about 61km^2. It is a nodalpoint in terms of road and rail transport because of locational factors (Jatau, 1999;Arowolo, 2000). The Kubanni River takes its source from the Kampagi Hill in the Northwest near Shika, and Tsauni Hill in the southwest and itflows in a southeast direction through Ahmadu Bello University main campus, Samaru. Ithas four major tributaries upstream of the Kubanni Reservoir which include Malmo, Tukurwa, Maigamo and Gorubaused for this study as shown in figure 3.1

3.1.2 Climate

The study area belongs to the tropical continental type of climate corresponding to Koppen's tropical wet and dry climate zone (Aw), characterized by strong seasonality in rainfall and temperature distributions (Oladipo, 1985). It has two distinct seasons: the dry or harmattan season (October to March) and wet season (April to September). The seasons generally coincide with the southward and northward movement of the surface transition known as Inter-Tropical

Discontinuity (ITD) between the hot, moist tropical maritime air-mass (mTs) of Atlantic ocean origin to the south and the cold, drier tropical continental air-mass (cTs) blown by the northeast trades from the Sahara Desert.

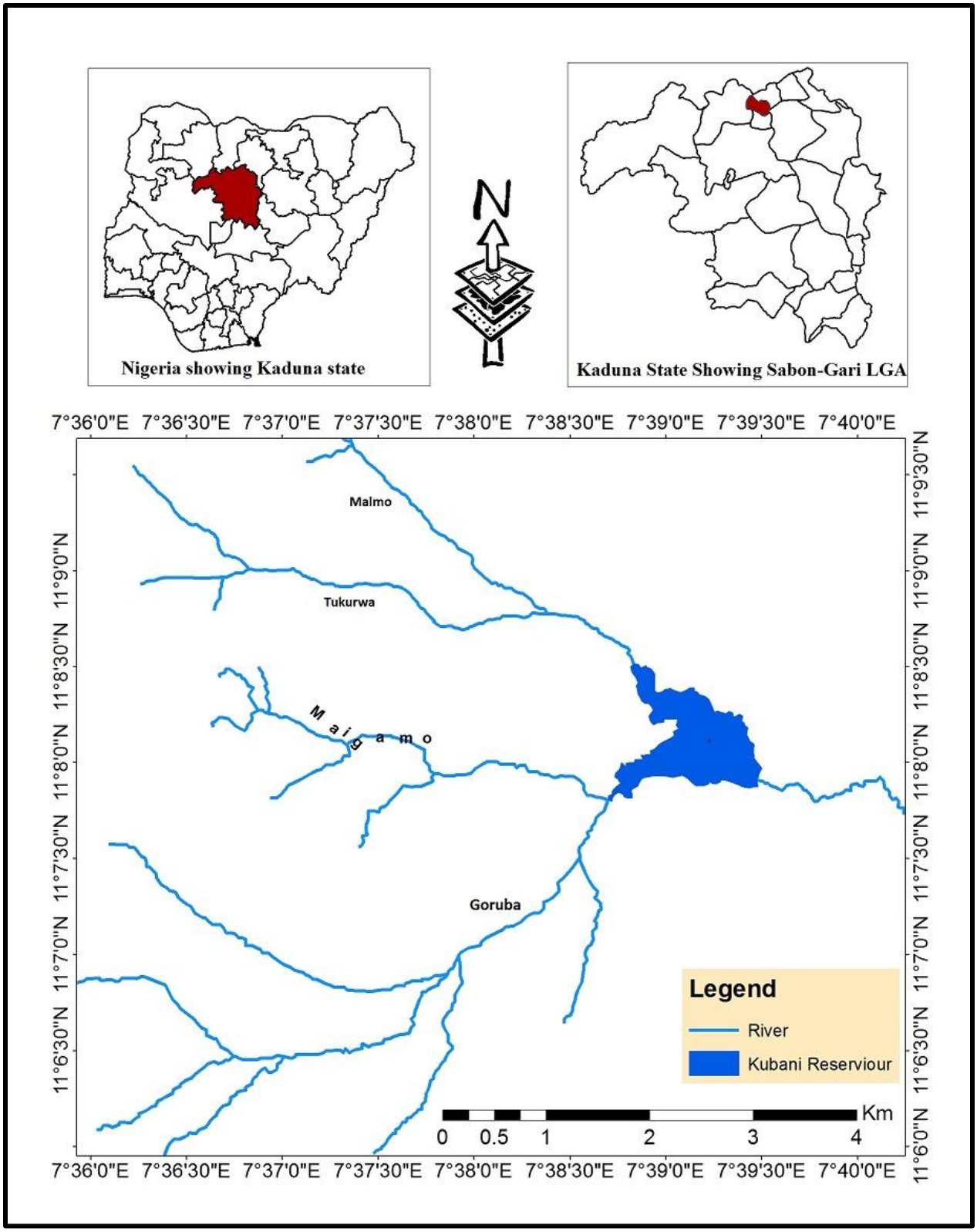


Fig 3.1: Kubanni Reservoir and its Tributaries
Source: Adapted from Topographic Map of Zaria sheet S.W 102.

3.1.3 Geology

The Zaria region is primarily underlain by the Basement Complex Rocks. The region is an area within the Zaria plain, a dissected part of the Zaria – Kano portions, an extensive peneplain, which had developed on crystalline metamorphic rock, and believed to be overlain by wind drift sediments. Wright and McCurry (1970), presented a fairly detailed description of the geology of Zaria region by classifying the basement complex rocks of Zaria into three principal groups:

(i) Younger metasediments found in a north-south trending belt. These younger metasediments include Quatzites (forming ridges), Schists and Phylites.

(ii) A re-mobilized older crystalline Basement Complex made up of Gneisses, Migmatites and oldermetasediments.

(iii) Granites and Granodiorites of late pre-cambrian to lower palaezoic age, which includes groups one and two above.

The geologic materials of the study area are composed mainly of fine-grained biotite gneiss and migmatites, with some coarse-grained granitic outcrops in a few places. The gneisses are moderately to weakly foliated, principally made up of quartz and oligoclase (Du preez and Barber, 1965 as cited in Yusuf 2013). Superficial deposits include young and old laterites, as well as young and old alluvium. Thorough and deep chemical weathering has developed thickregolith of varying degrees of induration. The laterites are different in morphological character and occur at different levels of the valley sideslope profiles. The massive and hardened laterites form older laterites (vermicular and vesicular types) and occur at high levels on the upland and close to the interfluves as mesas and buttes. As the older laterites are destroyed by erosion, the rubble is transferred to gentle sloping surface at lower levels where it undergoes re-

concretion to form what has been described as younger laterites (Wright and McCurry, 1970; Ologe, 1971; Bello, 1973).

The older alluvium is made up of brown to brownish red, fine to medium-grained, fairly indurated sands, clay and gravels. Thorp (1970) described sites of older alluvium located within the study area where gullies are incised into them. The younger alluvium which are mostly unconsolidated, are made up of grey-brown sands, silts and clay. Ololobou(1982), observed that within the Kubanni basin, the presence of younger laterite with recent alluvial deposits along the river are prominent, there exists a crust belt occurring across the Kubanni basin with recent alluvial deposits along the dam impoundment.

3.1.4 Relief

Zaria is situated on a plain which is part of the extensive gentle rolling peneplain which extends from Sokoto to Lake Chad, and northwards from south of Kaduna to TigueddiScarp near Agades (Niger Republic). This embraces most of the northern Nigeria and has been correlated with the mid-tertiary African planation surfaces, recognized in other parts of the continent (King, 1962). The plain, which is generally undulating, varies in altitude from about 550m to 740m above the sea level and is dotted with outcrops of rocky inselbergs, with the Kufena hill attaining a height of 820m and flat top lateritic ironstone capped residuals. The study area is between the Kufena Hill and one of such residuals, the Kampagi Hill, about 708m above sea level (Iguisi, 1996).

Valley side slopes exhibit a convex-concave form with few rectilinear elements (Ameh, 1966, as cited in Yusuf, 2013). Slope angles of the valley sides are generally low between 0.50 and 40; although relatively steeper slopes have been observed especially adjacent to isolated residuals and erosional scarps (Abubakar, 1966; Bello, 1973).

3.1.5 Soils

The soil type is highly leached ferruginous tropical soils, developed on weathered regolith overlain by a thin deposit of windblown silt from the Sahara desert during many decades of the propagation of the tropical continental air mass into the area (Wright and McCurry, 1970; Kowal and Omolokun, 1971; Tokarski, 1972). The soil pattern of Zaria have been described by Klinkenberg (1970) according to the geological units identified by Wright and McCurry (1970) as:

(i) Fadama Soils: These are soils that occur in the bottoms of extensive wide valley systems. They are generally classified as hydromorphic (Ipinmidun, 1972). Fadama soils are mostly dark grey clays with poor to very poor drainage, most of which have been formed in alluvial material. They occur widely in the Galma, Shika and Kubanni Basins.

(ii) Soils developed on Metasediments (Schists and Quartzites): As a result of the wide spread elongated quartzite ridges to the west of Zaria, soils are shallow and stony in the interfluve crests. However on the middle and lower slopes, soil profiles are deeper, become reddish-grey incolour, exhibit signs of clay accumulation, and hard iron concretions (Laterites) are found.

(iii) Soils developed on Granites: The soils close to the granitic outcrops appear deep and consist mainly of weathered material and do not show distinct profile development. They contain many unweathered fragments of quartz and feldspar. The clay and iron accumulation are not yet

apparent. Further away from the granite hills, very deep red clayey soils occur. On the lower slopes and in poorly drained areas, soils are mottled and generally of grey colour. They also contain fragment of quartz and feldspar. Most of the soils have a sandy loam texture (Kowal and Knabe, 1972; Kwabe, 1987).

Leaching of clay minerals and ions down the profile is the major soil development process. The soil exhibits a marked horizon differentiation with Iron oxides deposits in the clay-rich B-horizon, underlying the A-horizon, in form of mottles, concretions or as ferruginous hard pans called duricrusts. The topsoil is rather coarse due to elluviation of the fines of the A-horizon (Nyagba, 1986).

Kowal and Kassam (1978) and Jaiyeoba (1986) have observed that the organic matter and nitrogen contents of the soil are very low (1-2%) resulting from frequent bush burning, overgrazing, continuous cultivation and rapid oxidation decomposition of humified organic matter of the soil. The low activity of the clay particles has resulted in low cation exchange capacity (CEC) and exchangeable bases. The soils have an average pH of 7.1 and are generally neutral in reaction with profiles usually less than 150cm deep, below which occurs partially weathered rocks of the parent material. Man's activities which include grazing and cultivation, has exposed the soil of this area to erosion and the depletion of its nutrient status and as a result of the high clay content of the soil and the overlain drift, a shallow surface capping readily forms after high intensity rainfall and this tends to inhibit infiltration, favouroverland flow and consequently increases sediment yield.

3.1.6 Vegetation

The relatively deep tropical ferruginous soils and climate condition of Zaria are suitable for and sustain a good cover of savanna woodland (Northern Guinea Savanna) with a variety of grasses, woody shrubs and short trees. Even though the study area lies within the Guinea savanna zone, the fact remains that there is little natural or climatic vegetation and the area has become a derived savanna type which is characterized by shrubs, stems, and trees along with some tuft cover and some clusters of trees along river courses. The characteristic vegetation cover is hardly preserved due to urbanization and poor management practices, like fuelwood harvesting, annual bush burning, cultivation and intensive grazing (Rains, 1963; Ologe, 1971).

The land management practices have resulted in the evolution of thorny shrub interspersed with short annual grasses. Also, trees have developed some adaptive features such as thick cuticle and thick young twigs to enable them survive the high evapotranspiration and the annual bush burning.

The dominant shrub around the area is *Isoberlinadoka* with an average height of 50 cm. Other less frequent shrub species include*Pilliostigma spp*. and*Terminaleaavicenniodes.*The common grass communities in the study area are mostly Andropogon spp. (Kwabe, 1987), which are almost completely absent during the long dry season. However, the grasses sprout during the raining season, shrubs grow very rapidly, but no sooner than the raining season ceased than they become dry. Grazing also contribute to their absence. Trees here include *Magniferaindica* dotting everywhere, *Parkiaclappertoniana, Tamarindusindica*and severalothers, which are found to be useful to man. Yearly the trees are left standing while the area is being cultivated. During the raining season, the vegetation is thick and greenish, but are dry and brownish during the dry season with little of these plants retaining their leaves (Ologe, 1971).

3.1.7 Drainage

Zaria is drained by a numbers of rivers, the general pattern of flow of these rivers is dendritic reflecting the absence of structural control over the drainage channel. These rivers generally flow in southward direction.Zaria is characterized by two types of drainage basin based on stream frequency for drainage density (Yusuf, 2013).

The first type is characterized by large number of unbranched first order tributaries producing high stream frequency and drainage density, such rivers in Zaria are river Kubanni and river Saye. Zaria is drained by three major rivers. The largest of these river is river Galma which actually originate from Jos plateau and it is a tributary of river Kaduna. It carries water throughout the year.The second river in Zaria is river Kubanni which have many tributaries. The Kubanni River has its major source from Kampagi hill in Shika near Zaria. It flows in south east direction through Ahmadu Bello University (Yusuf, 2013).

The Kubanni River contain water even in the dry season because it obtains water from sub-surface flow even during the dry season. It is the river to which the ABU dam has been constructed.TheKubanni and Saye rivers are both tributaries of river Galma. Other rivers within Zaria includeBasawa River and Shika River which are also tributaries of river Galma and also river Yashi which drains the south western section of Zaria.These rivers are very important to the economic development and survival of Zaria as they provide most of the useful water for domestic, industrial and irrigational purposes (Mortimore; 1970).

3.1.8 Land Use

Except for the Malmo tributary which is dominated by urbanization in the northern margin, intensive farming activities, mining and grazing are prominent within the study area, especially

around the southern boundary. Two types of lands are found around the study area; Gonaor upland fields which support crops such as maize, millet, sorghum and groundnut, during the wet season and fadamaor lowland fields which supports crops such as sugarcane, onion, tomatoes, pepper, spinach and other garden vegetables throughout the year. There is a relative soil buffering by the addition of organic manure and fertilizer application (Norman, 1970; Jaiyeoba, 1995; Yusuf, 1999).

The farms are usually worked by manual labour, using crude and simple implement such as hoes and cutlasses. This method of farm preparation leaves the farm with some dried logs on the ground, and those that cannot be moved by manual labour are left standing. The dry logs are usually cut into smaller bits and are used for the purpose of firewood, which has been one of the most effective fuel type in the homes and also serves as the main source of energy, especially for farmers and restaurant operators (Yusuf, Iguisi and Abdulsalam, 2011).

Sand mining is also conspicuous with their leftovers as holes, pit, gullies etc. used as material for molding bricks and building of mud houses, for both residential and animal shelter and in road construction. Minor fishing activities usually take place especially during the dry season both on commercial and consumption scales. Within the basin are mechanic workshops, whose refuse and wastes find their ways into the Kubanni River especially at the upper course.

Settlement pattern in the Kubanni basin is highly concentrated from the northeastern parts to the northwestern parts. The remaining settlements are scattered randomly within the basin. Urban areas, which include part of the university campus environment, the administrative and academicstaff residential areas are located within the catchment area of the Malmo tributary of the basin (Yusuf, 2013).

3.2 Methodology

3.2.1 Reconnaissance Survey

As part of preparation for the study, a reconnaissance survey was carried out in order to be acquainted with the study area. During the reconnaissance survey, observations were made on the nature of the terrain, type of streams, the sizes of the rivers, land use and where to install the weirs.

3.2.2 Types and Sources of Data

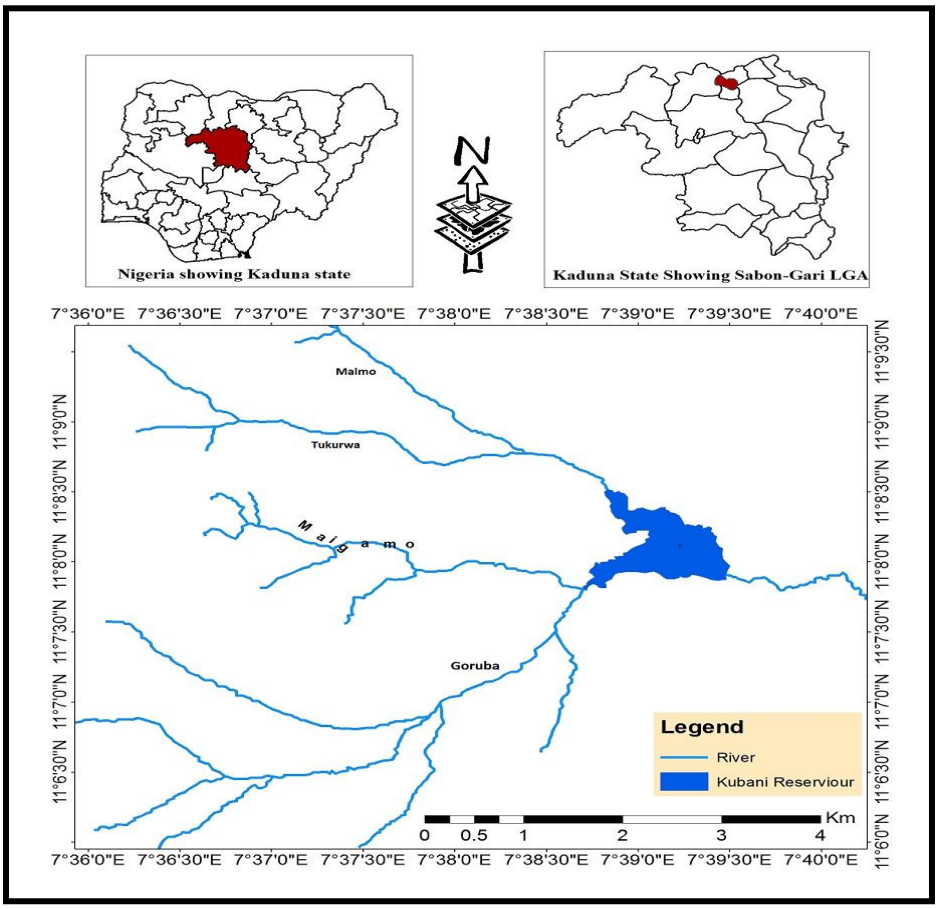
In order to achieve the aim and objectives of this study, both Primary and Secondary data were used. The source of primary data include stream discharge data that were obtained from the gauging stations, using the weirs, current metre and float method for the 2017 hydrological year. Related materials such as textbooks, past projects, theses and journals were used for conceptual framework and literature review.

3.2.3 Data collection

The velocity-area technique which consist of the current metre and the float were used simultaneously with the weir for this study in order to see the most effective method for determining stream discharge upstream of river Kubanni. Four gauging stations which serves as the sampling points were established along each of the tributaries where the stream discharges were obtained.

A calibrated 120^0 V-Notch sharp-crested weir was used for the Malmo tributary. The 120^0 V-Notch was already installed for the Malmo tributary by Yusuf (2006) with discharge formula of:

Q = $2.47H^{2.5}$ ---------- ---------- ------ (1)



While the 90^0 V-Notch sharp-crested weir wasused for Tukurwa which was also installed by Yusuf (2013). Two new 90^0 V-Notch sharp-crested weirs were constructed and installed at Maigamo and Goruba tributaries by the researcher. The 90^0 V- Notch has a discharge formula of:

$Q = 1.38H^{2.5}$ ---------- (2)

Where Q = Discharge in m^3/s

H = Head of water in metres (stage).



Fig 3.2: Map showing the Sampling Points along the Tributaries
Source: Adapted from Topographic Map of Zaria sheet S.W 102.

The difference in the discharge formulae for the streams is as a result of their shapes and sizes as the Malmo tributary is the smallest as shown (Plate 1 and 2). Measurements were observed after rainfall events and twice a day; in the morning (around 7.00am) and in the evening (around 6.00pm) everyday, which represent instantaneous and regular interval monitoring from May 2017 to January 2018. Subsequently, the daily average readings were inserted into the discharge formula in order to obtain the stream discharges. Also for the four tributaries, the current metre and the float methods were used in measuring the velocity component of the stream discharges immediately after rain event. This is based on the fact that discharge, Q (m^3/s), is a direct function of average stream velocity, V (m/s), and the cross-sectional area of the channel, A (m^2), at the point of measurement:



Plate 1: 120^0 V- Notch installed at a gauging station of Malmo tributary



Plate 2: 90^0 V-Notch installed at a gauging station of Goruba tributary

$$Q = AV \quad \text{---------- (3)}$$

The cross-sectional areas of the channels at the gauging stations were obtained by multiplying the channel width by depth. The relevant depth here is that measured from the water level to the bottom of the channel using installed weir while the width is measured using a measuring tape. The current metre consist of a rotor which rotates at a speed proportional to the flow velocity. The revolution was counted over a fixed period of 30 seconds so as to get the velocity from the calibration data.

For the float method, a float that will not be submerged in the river was used, the weir which serves as the staff gauge was used to determine the head or depth of the stream and a stop watch was also used to determine the length of travel by the float at a given time. Since velocity is a product of length over time, a distance of 15 metres was used divided by the time obtained from the stop watch (m/s). The cross- sectional area was also determined by the product of the width and the depth measurements.

However, the float can be obstructed by vegetation, eddy current and wind, a float coefficient of (0.85) was used to compute the velocity. The conversion factor is that the mean velocity in any given vertical profile is 0.85 times the surface velocity because the water on the surface flows faster than that beneath and this conversion ensures an accurate velocity reading for the whole cross-section (Lenon and Cleves, 1983).

3.2.4 Data Analysis

Objective i: To determine the stream discharge of the tributaries upstream of River Kubanni,

The current metre, float and the weir methods were used to determine the stream discharges of each of the tributaries and the results were presented in tabular form.

Objective ii: To Compare the stream discharges of the tributaries upstream of River Kubanni.

Analysis of Variance (ANOVA) was employed on the sum total of the mean instantaneous discharge data for all the tributaries using the three techniques. This was achieved with aid of SPSS 21 for the computation. This was in order to establish whether there is significant difference in the stream discharge values obtained from each tributaries using the three methods.

Objective iii: To Examine the effectiveness of the methods for measuring stream discharge upstream of river Kubanni

Descriptive statistics and Analysis of Variance (ANOVA) wereused to examine the effectiveness of the methods for measuring stream discharge upstream of river Kubanni. Descriptive statistics was used between the mean instantaneous stream discharge data obtained using the weir, current metre and the float methods to calculate the mean, standard deviation and coefficient of variation. Similarly Analysis of Variance was employed between the stream discharge data collected using the three methodsto see the most effective method for measuring stream discharge upstream of River Kubanni.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter present the results of the stream discharge obtained using the current metre, float method and the weir technique in order to ascertain the most effective method for determining stream discharge for River like Kubanni. Results were discussed and presented in tabular form.Observation of the stream discharges for the four tributaries were carried out throughout their flow period starting from 3rd May 2017 to 11th January 2018 using the three methods.

4.2 Discharge measurements for the Malmo stream

Table 4.1a shows the mean instantaneous discharge values for Malmo stream using the weir method.

Table 4.1a shows that Malmo stream has the shortest flow period of 206 days (from May to December 2017) compare to the remaining three tributaries which extend to January 2018, with a flow period of 239 days. This is actually earlier than the cases of Yusuf (2006) and Yusuf (2013) where it extended to April in 2006 and February in 2012. Yusuf (2006) and (2013) confirm the contribution to surface flow by subsurface flow during the dry season which makes it intermittent in nature. In this study, there is further reduction from the subsurface flow contributing to the surface flow. According to Yusuf (2006) the flow period was 359 days. Another study conducted by Yusuf 2013, the flow period has reduced to 246 days. However in this research, the flow period greatly reduced from 246 days in 2012 to 206 days. Climate change

Day	May	June	July	August	September	October	November	December	January

and human activities such as irrigation maybe some major factors that may have caused the reduction in the flow period. Other factors such as the infiltration capacity of the soil, the type of soil, rainfall intensity and duration and intervening factors like vegetation might have cause the reduction in flow period.

4.1a:Mean Instantaneous Discharge Values in m^3/s for Malmo Stream Using the Weir Method

1		.0442	.0060	**.0936**	.0078	.0014	.0008	.0008
2		.0151	.0032	.0022	.0078	.0014	.0008	.0008
3	**.0772**	.0045	.0013	.0014	**.2057**	.0014	.0008	.0008
4	.1025	**.2199**	.0013	**.0627**	**.1665**	.0014	.0008	.0008
5	.0151	.0627	.0007	.0022	.0442	**.0060**	.0008	.0008
6	.0014	.0151	**.2659**	.0014	.0078	.0014	.0008	.0008
7	-	.0014	.0561	**.1322**	.0045	.0014	.0008	.0008
8	-	.0004	.0151	.0099	**.1025**	.0014	.0008	.0008
9	-	.0004	**.2346**	.0060	.0215	.0014	.0008	.0008
10	-	.0001	.0151	.0032	.0014	.0014	.0008	.0008
11	-	.0001	.0032	.0022	**.1790**	.0014	.0008	.0008
12	-	-	.0021	**.1119**	.0442	.0014	.0008	.0008
13	-	-	.0013	.0060	**.1545**	.0014	.0008	.0008
14	-	-	.0013	**.1431**	.0253	.0014	.0008	.0008
15	-	-	**.1218**	.0078	.0078	.0014	.0008	.0008
16	-	-	.0215	.0014	**.0936**	.0014	.0008	.0008
17	-	-	**.1430**	**.1665**	.0060	.0014	.0008	.0008
18	-	-	.0215	.0151	**.1119**	.0014	.0008	.0004
19	**.0772**	-	**.1430**	.0022	.0078	.0014	.0008	.0004
20	.1321	-	.0123	.0022	**.0561**	.0014	.0008	.0004
21	.0151	-	.0078	.0014	**.0851**	.0014	.0008	.0004
22	.0014	-	.0013	**.1119**	.0389	.0014	.0008	.0004
23	-	-	.0013	.0099	.0078	.0014	.0008	.0002
24	-	**.0772**	.0013	.0078	**.0499**	.0014	.0008	.0002
25	-	**.1545**	.0013	.0060	.0215	.0014	.0008	.00002
26	-	**.2057**	.0013	**.1025**	.0014	.0014	.0008	
27	-	.0340	.0013	.0078	.0014	.0014	.0008	
28	-	**.1186**	.0013	.0078	.0014	.0014	.0008	
29	-	.0078	.0013	.0078	.0014	.0014	.0008	
30	**.0772**	**.1025**	.0013	**.1431**	**.1322**	.0014	.0008	
31	**.1218**		**.2346**	.0151		.0014	.0008	
Total	0.6210	1.0641	1.3244	1.1943	1.5969	0.0480	0.0248	0.0160

Sum = 5.89 m^3/s

Source: Fieldwork, (2017).

The measured daily mean instantaneous discharge values for the weir in m^3/s throughout the study period for the Malmo tributary recorded the lowest value of 0.00002 on 25th December 2017 while the highest value of 0.2659 m^3/s was recorded on 6th July 2017. A careful observation of the discharge using the weir shows that there are days of dry spell in the month of May and June. This means that rainfall is not well established unlike the other months whereby there is flow in the river channel throughout. Also,it can be observed that some figures are bold in table 4.1a, this shows the days it rained throughout the study period which gives a total of 37 days. This shows a great reduction in the number of rainy days compared to the study of Yusuf (2006) which was 62 days and Yusuf (2013) which was 45 days.

Table 4.1b shows the mean instantaneous discharge of Malmo stream using the current metre

Table 4.1b shows that the daily mean instantaneous discharges varied from as low as 0.0109 m^3/s on 5th October 2017 to the highest value of 0.2865 m^3/s on 9th July 2017.Table 4.1b further shows that the discharge data was available for 37 days of the study period. It is therefore clear that there is further reduction in the number of days it rained for the hydrological year in the study area as when compared to the work of Yusuf (2006) where it rained for 62 days and Yusuf (2013) where it rained for 45 days using the current metre. This can further be argued that factors such as geology, topography, rainfall intensity and duration, soil infiltration capacity, vegetation and human activities may have impacted the reduction in flow period.

Table 4.1c shows that the daily mean instantaneous discharges using the float method

Table 4.1c shows that the daily mean instantaneous discharges using the float method and the values varied from as low as 0.0263 m^3/s on 5th October 2017 to the highest value of 0.2588 m^3/s on 9th July 2017.

Day	May	June	July	August	September	October	November	December
1				.1118				
2								
3	.1260				.2041			
4		.1860		.1162	.1932			
5						.0109		
6			.2337					
7				.1604				
8					.1098			
9			.2865					
10								
11					.1329			
12				.1472				
13					.1218			
14				.1376				
15			.0842					
16					.1319			
17			.1962	.2024				
18					.0844			
19	.1356		.1386					
20					.0988			
21					.0866			
22				.1114				
23								
24		.1675			.0924			
25		.1925						
26		.2125		.1200				
27								
28		.1062						
29								
30	.0749	.1836		.1284	.2449			
31	.1463		.2128					
Total	.4828	1.0483	1.1520	1.2354	1.5008	.0109		

4.1b: MeanInstantaneous Discharge Value for the Malmo Stream using Current Metre in m^3/s

Sum = 5.43 m^3/s

Source: Fieldwork, (2017).

Day	May	June	July	August	September	October	November	December

Table 4.1c further shows that the discharge data was available for 37 days of the study period just like that of the current metre. Because the current metre and the float were used simultaneously after a rain storm. However in this study, it shows that there is further reduction in the number of days it rained for the hydrological year in the study area compared to the work of Yusuf (2006) where it rained for 62 days and Yusuf (2013) where it rained for 45 days using the float method. This can be attributed to climate change and human activities that may cause the reduction in flow period.. Other factors such as the infiltration capacity of the soil, the type of soil, rainfall intensity and duration and intervening factors like vegetation might have cause the reduction in flow period.

Table 4.1d shows the summary of the mean instantaneous stream discharges for Malmo tributary using the three methods. The comparison shows that the weir method has the lowest discharge total of 4.61, the current metre has the highest total of 5.43, while the weir method also has the highest coefficient of variation of 109.6% and the float method has the least coefficient of variation of 103.3%.The current metre and the float methods were only applicable only after a rainstorm and when the rainfall became established because both methods cannot be used for river channel that the depth is too low and the float can be affected by vegetal growth, eddy current or wind hence the use of a correction factor for the float method (0.85). This therefore, implies that the weir method is more superior to the current metre and the float method because of its consistency. This is in conformity with the work of Yusuf, Iguisi and Bello (2007) in their comparison using the velocity area method with the weir technique.

1				.1075		
2						
3	.1249				.1842	
4		.1674		.0762	.2085	
5						0.0263
6			.2337			
7				.1281		
8					.0956	
9			.2588			
10						
11					.1231	
12				.1407		
13					.1296	
14				.1342		
15			.0987			
16					.0961	
17			.1598	.1847		
18					.0891	
19	.1336		.1392			
20					.0851	
21					.0844	
22				.1061		
23						
24		.1658			.0957	
25		.1849				
26		.1732		.1200		
27						
28		.0891				
29						
30	.0696	.1626		.1363	.1738	
31	.1113		.2033			
Total	.4394	.9430	1.0935	1.1338	1.3652	0.0263

4.1c: Mean instantaneous discharge values in m^3/s for Malmo stream using Float method

Sum = 5.00 m^3/s

Source: Fieldwork, (2017).

Table 4.1d: Summary of Malmo Instantaneous Stream Discharges Using the Weir, Current Metre and Float Methods

Month	Weir Method	Current Metre	Float Method
May	0.2762	0.4828	0.4394
June	0.8784	1.0483	0.9430
July	1.1429	1.1520	1.0935
August	0.9650	1.2354	1.1338
September	1.3370	1.5008	1.3652
October	0.0060	0.0109	0.0263
Total	4.61	5.43	5.00
Mean	0.5117	0.6034	0.5557
SD	0.5608	0.6286	0.5743
CV%	109.6%	104.2%	103.3%

Source: Fieldwork, (2017).

Fig 4.1 reveals that September is the month with the highest discharge values of 1.3370 m^3/s, 1.5008 m^3/s, and 1.3652 m^3/s using the weir, current metre and float methods respectively. This is in conformity with the study of Yusuf (2013) where he found that September was also the month with the highest discharge values. The discharge regime is noticed clearly from May to October with single maxima which is also in conformity with the study of Yusuf (2006), Yusuf, Iguisi and Bello (2007), Yusuf, Igusi and Abdulsalam (2011) and Yusuf (2013).

The regime diagram for the Malmo stream discharges using the three methods is presented in Fig. 4.1.

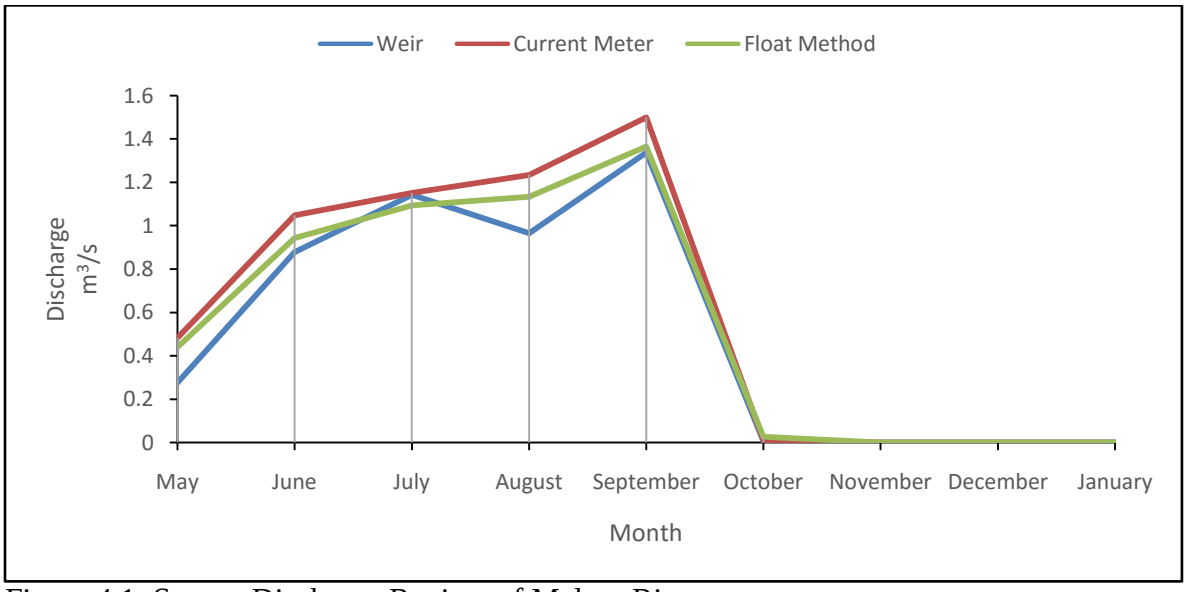


Figure 4.1: Stream Discharge Regime of Malmo River
Source: Authors Computation, (2017).

4.3 Discharge Measurements for the Tukurwa Stream

Table 4.2a shows that Tukurwa stream has a longer flow period of 239 days compared to Malmo stream which has a flow period of 206 days. It is therefore obvious that the flow period for this hydrological year has increased as compared to the work of Yusuf (2013) where it flows for 192 days. This further confirms the contribution to surface flow by subsurface flow during the dry season as observed by Yusuf (2013). Although Malmo and Tukurwa streams lie on the same drainage basin, the characteristics of each stream differ making one stream to have more flow period than the other. Thus, the Tukurwa stream has a larger sub-basin (Yusuf, 2013).

Day	May	June	July	August	September	October	November	December	January

The measured daily mean instantaneous discharge values using the weir method in m^3/s throughout the study period for the Tukurwa tributary recorded the lowest value of $0.00004 m^3/s$ on 11thJanuary2018 while the highest value of 0.3848 m^3/s was recorded on 18th September 2017. It was observed that the discharge measurement using the weir method shows that there are days of dry spell in the month of May when the rainfall was not well established. But from July to October there was a steady flow in the river channel throughout.

Day	May	June	July	August	September	October	November	December
1		.1396	.0930	**.1000**	.0476	.0431	.0247	.0055	.0008
2		.0431	.0572	.0350	.0389	.0350	.0247	.0055	.0008
3	**.1875**	.0247	.0278	.0279	**.3385**	.0350	.0247	.0055	.0008
4	.1000	**.0625**	.0189	**.1073**	**.2563**	.0279	.0247	.0055	.0008
5	.0389	.0247	.0164	.0523	.0799	**.0625**	.0190	.0055	.0004
6	.0120	.0120	**.1772**	.0389	.0431	.0389	.0190	.0055	.0004
7	.0044	.0084	.0431	**.2822**	.0431	.0389	.0190	.0055	.0004
8	.0001	.0055	.0278	.0431	**.1311**	.0350	.0190	.0055	.0004
9	-	.0044	**.2202**	.0431	.0476	.0247	.0190	.0055	.0004
10	-	.0025	.0313	.0389	.0431	.0247	.0190	.0044	.0004
11	-	.0007	.0246	.0389	**.1311**	.0247	.0190	.0044	.00004
12	-	.0002	.0246	**.1578**	.0389	.0247	.0190	.0044	
13	-	.0002	.0246	.0431	**.1980**	.0247	.0164	.0044	
14	-	.0002	.0246	**.2090**	.0431	.0247	.0164	.0044	
15	-	.0002	**.1149**	.0476	.0431	.0247	.0164	.0044	
16	-	.0002	.0799	.0389	**.2319**	.0247	.0164	.0044	
17	-	.0002	**.1772**	**.1874**	.0523	.0247	.0120	.0044	
18	-	.0002	.0738	.0625	**.3848**	.0247	.0120	.0044	
19	**.1875**	.0002	**.3239**	.0431	.0431	.0247	.0120	.0044	
20	.1311	.0002	.0680	.0431	**.2691**	.0247	.0101	.0044	
21	.0572	.0002	.0475	.0389	**.2202**	.0247	.0101	.0044	
22	.0247	.0002	.0475	**.3535**	.0476	.0247	.0101	.0044	
23	.0120	.0002	.0431	.0680	.0431	.0247	.0084	.0044	
24	.0025	**.2090**	.0350	.0431	**.1485**	.0247	.0084	.0044	
25	-	**.3096**	.0350	.0389	.0431	.0247	.0084	.0018	
26	-	.**3096**	.0313	**.3838**	.0431	.0247	.0055	.0018	
27	-	.1980	.0313	.0476	.0389	.0247	.0055	.0018	
28	-	**.2319**	.0313	.0431	.0350	.0247	.0055	.0018	
29	-	.0738	.0313	.0431	.0313	.0247	.0055	.0018	
30	**.0120**	**.3699**	.0278	**.1673**	**.1980**	.0247	.0055	.0018	
31	**.1875**		**.2957**	.0799		.0247		.0018	
Total	.9574	2.0323	2.3058	2.9473	3.3534	0.8844	0.4354	0.1281	0.0066

4.2a:Mean Instantaneous Discharge Values in m^3/s for TukurwaStream Using the Weir Method

Sum = 13.05 m^3/s

Source: Fieldwork, (2017).

1				.1325		
2						
3	.2057				.3711	
4		.0746		.1073	.3447	
5						.0259
6			.2111			
7				.1578		
8					.1471	
9			.2376			
10						
11					.1633	
12				.1584		
13					.1372	
14				.1898		
15			.1041			
16					.2328	
17			.1749	.2120		
18					.3258	
19	.2322		.3053			
20					.2315	
21					.2783	
22				.3745		
23						
24		.2835			.1407	
25		.3354				
26		.3212		.3865		
27						
28		.2217				
29						
30	.0315	.3690		.1736	.1761	
31	.1875		.3616			
Total	.6569	1.6054	1.3946	1.8924	2.5486	0.0259

4.2b: Mean Instantaneous Discharge Values in m^3/s for TukurwaStream Using Current Metre.

Sum = 8.12 m^3/s

Source: Fieldwork, (2017).

Table 4.2b shows the daily mean instantaneous stream discharge values in m^3/s obtained using the current metre for Tukurwa stream. Result of the river discharges shows that the daily mean instantaneous discharges varied from as low as 0.0259 m^3/s on 5th October 2017 to the highest value of 0.3711 m^3/s on 3rd September 2017. Based on the research, it can be observed that the onset of the rain was late and the number of rainy days has reduced compared to the work of Yusuf (2006) where it rained for 62 days and Yusuf (2013) where it rained for 45 days using the current metre.

Table 4.2c shows the daily mean instantaneous stream discharge values in m^3/s obtained using the float method forTukurwa stream. Result of the River discharges shows that the daily mean instantaneous discharges varied from as low as 0.0598 m^3/s on 5th October 2017 to the highest value of 0.3768 m^3/s on 30th June 2017. Table 4.2c further shows that the discharge data was available for 37 days of hydrological year just like that of the current metre because they were used simultaneously after a rain storm. It is therefore clearly observed that the onset of the rain was late and the number of rainy days has reduced compared to the work of Yusuf (2013) where it rained for 45 days. This can serve as a threat to farmers who rely on rainfall for their farming activities and also a threat to water resource expertise.

Table 4.2d shows the weir has the lowest total of 7.41, the current metre has the highest total of 8.12 while the weir method also has the highest coefficient of variation of 119.11% and the float method has the least coefficient of variation of 107.6%. The current metre and the float methods were only applicable only after a rainstorm and when the rainfall was already established because both methods cannot be used for river channel that the depth is too low and the float can be affected by vegetal growth, eddy current or wind hence the use of a correction factor for the float method (0.85).

Day	May	June	July	August	September	October	November	December
1				.1358				
2								
3	.1831				.2563			
4		.0698		.0728	.2808			
5						.0598		
6			.1889					
7				.1696				
8					.1160			
9			.2365					
10								
11					.1437			
12				.1273				
13					.1417			
14				.1786				
15			.1164					
16					.2007			
17			.1707	.1937				
18					.3213			
19	.2173		.2786					
20					.2182			
21					.2849			
22				.2927				
23								
24		.2658			.1864			
25		.3073						
26		.2839		.4201				
27								
28		.2203						
29								
30	.0337	.3768		.1813	.1656			
31	.1387		.3346					
Total	.5728	1.5239	1.3257	1.7719	2.3156	0.0598		

4.2c: Mean instantaneous discharge values in m^3/s for Tukurwa stream using Float method.

Sum = 7.57 m^3/s

Source: Fieldwork, (2017).

Table 4.2d presents the statistical summary of Tukurwa stream discharge measurements using the weir, current metre and float method.

Table 4.2d: Summary of Tukurwa Instantaneous Stream Discharges using the Weir, Current Metre and Float Methods

Month	Weir Method	Current Metre	Float Method
May	0.387	0.6569	0.5728
June	1.4925	1.6054	1.5239
July	1.0134	1.3946	1.3257
August	1.9483	1.8924	1.7719
September	2.5075	2.5486	2.3156
October	0.0625	0.0259	0.0598
Total	7.41	8.12	7.57
Mean	0.8235	0.9026	0.8411
SD	0.9809	0.9801	0.9046
CV%	119.11	108.6%	107.6%

Source: Field Survey, (2017).

By this, it implies that the weir method is more superior to the current metre and the float method because of its consistency.This is in conformity with the work of Yusuf, Iguisi and Bello (2007) in their comparison using the velocity area method with the weir technique. Yusuf (2013) in an examined the sediment delivery into the Kubanni reservoir measured the stream discharge of Malmo and Tukurwa stream using the weir method while for Maigamo and Goruba stream, the

velocity area method was used. The results showed that the weir has lower mean, variance, standard deviation compare to the velocity area method, thus implying that the weir is superior to velocity area method. Besides, the weir readily provides discharge value throughout the year while the velocity area method can only be used only after rain fall or when the rainfall is already established. Having a closer look at the results from this study, it shows that the weir has the lowest values followed by the float method and lastly the current metre. With this we can conclude that this study is in conformity with that of Yusuf (2013) where he stated that the weir is superior to the current metre and float methods.

Fig 4.2 reveals that September is the month with the highest discharge values of 2.5075 m^3/s, 2.5486 m^3/s, and 2.3156 m^3/s for the weir, current metre and float methods respectively. This is also in conformity with the study of Yusuf (2013) where the discharge regime is noticed clearly from May to October with single maxima. Although rainfall data for the year 2017 (Institute of Agricultural Research [IAR], 2018) reveals that July is the month with the highest rainfall value, the lag time serves as the factor that makes the discharge regime to be high in September. This means the soil carrying capacity must be attained before it can flow as runoff.

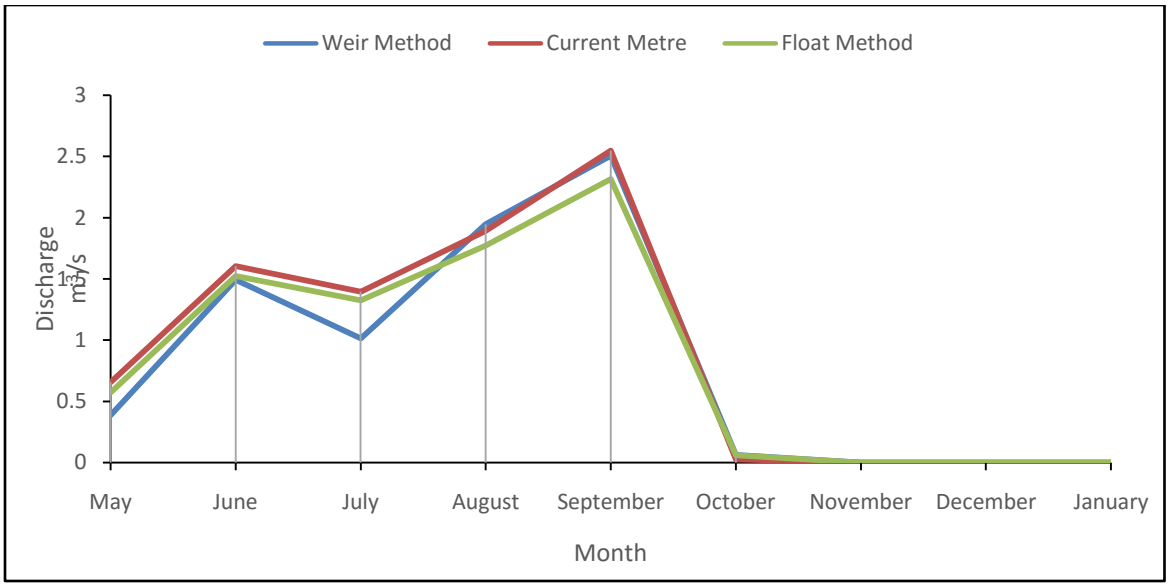


Figure 4.2: Stream Discharge Regime of Tukurwa River
Source: Authors Computation, (2017).

The mean instantaneous Discharge for Maigamo Stream using the Weir Method is presented in Table 4.3a

4.3a: Mean instantaneous Discharge Values in m^3/s for Maigamo Stream using the Weir Method

Sum = 14.07 m^3/s

Day	May	June	July	August	September	October	November	December	January
1		.0190	.0930	**.1578**	.0247	.0217	.0055	.0008	.00008
2		.0044	.0313	.1000	.0247	.0120	.0055	.0008	.00008
3	**.1875**	.0044	.0043	.0625	**.1485**	.0084	.0055	.0008	.00008
4	.1228	**.2822**	.0033	**.1578**	**.1396**	.0044	.0055	.0008	.00008
5	.0389	.0084	.0024	.0431	.0476	**.0217**	.0055	.0008	.00008
6	.0084	.0044	**.1149**	.0044	.0247	.0247	.0044	.0008	.00008
7	.0024	.0044	.0278	**.2700**	.0190	.0247	.0044	.0008	.00008
8	.0004	.0044	.0190	.1149	**.1000**	.0247	.0044	.0008	.00008
9	.00008	.0024	**.3385**	.0247	.0247	.0101	.0044	.0008	.00008
10	-	.0008	.0164	.0247	.0247	.0084	.0044	.0008	.00008
11	-	.0008	.0033	.0247	**.1228**	.0084	.0044	.0008	.00008
12	-	.0008	.0017	**.1311**	.0247	.0084	.0044	.0008	
13	-	.0002	.0007	.0247	**.1308**	.0084	.0025	.0008	
14	-	.00008	.0007	.0930	.0247	.0084	.0025	.0008	
15	-	.00008	**.1875**	.0247	.0247	.0084	.0025	.0004	
16	**.1875**	.00008	.1485	.0247	**.1396**	.0084	.0025	.0004	
17	.2203	-	**.2563**	**.2203**	.0247	.0084	.0008	.0004	
18	**.4701**	-	.1673	.0389	**.1673**	.0084	.0008	.0004	
19	.2439	-	**.1980**	.0247	.0680	.0084	.0008	.0004	
20	.0930	-	.1673	.0247	**.2563**	.0084	.0008	.0004	
21	.0572	-	**.3689**	.0247	**.3096**	.0084	.0008	.0004	
22	.0190	-	.0799	**.8149**	.2440	.0084	.0008	.0004	
23	.0084	-	.0572	.2440	.1073	.0084	.0008	.0004	
24	.0002	**.1875**	.0522	.0863	**.0799**	.0084	.0008	.0004	
25	-	**.8924**	.0799	.0431	.0431	.0084	.0008	.0002	
26	-	.0930	.0384	**.3848**	.0247	.0084	.0008	.0002	
27	-	.0738	.0384	.1396	.0247	.0084	.0008	.0002	
28	-	**.5862**	.0313	.0431	.0247	.0084	.0008	.0002	
29	-	.0431	.0278	.0247	.0247	.0084	.0008	.0002	
30	**.0044**	**.2822**	.0278	**.5862**	**.1073**	.0055	.0008	.0002	
31	**.2203**		**.1149**	.0279		.0055		.0002	
Total	1.8848	2.4950	2.6989	4.0107	2.5518	0.3314	0.0795	0.0166	0.0008

Source: Fieldwork, 2017.

4.4 Discharge Measurements for the Maigamo Stream

The result on Table 4.3a shows that Maigamo stream has a longer flow period of 236 days compared to Malmo tributary which has a flow period of 206 days (from May 2107 to January 2018). The flow period has increased compared to the work of Yusuf (2013) where it only flows for 172 days. This further confirms the contribution to surface flow by subsurface flow during the dry season as deducted by Yusuf (2013). Factors such rainfall duration and intensity, soil type, topography and intervening factors may have caused the increment to the flow.

The measured daily mean instantaneous discharge values using the weir method in m^3/ s throughout the study period for the Maigamo tributary recorded the lowest value of 0.00008m^3/s on 11thJanuary2018 while the highest value of 0.8149 m^3/s was recorded on 22nd August 2017. The discharge using the weir shows that there were days of dry spell in the month of May and June, Consequently rainfall was not well established. Although the rainy days differs with that of Malmo and Tukurwa tributaries, which are on the northernmost part of River Kubanni it still gives the same 37 days of rain storm.

Table 4.3b shows the daily mean instantaneous stream discharge values in m^3/s obtained using the current metre for Maigamo stream. Result of the river discharges shows that the daily mean instantaneous discharges varied from as low as 0.0255 m^3/s on 30th May 2017 to the highest value of 1.0756 m^3/s on 22nd August 2017. The result shows that the onset of the rain was late and the number of rainy days has reduced compared to the work of Yusuf (2013) where it rained for 45 days using the current metre.

4.3b: Mean Instantaneous Discharge Values in m^3/s for Maigamo Stream using Current Metre.

Day	May	June	July	August	September	October	November	December
1				.1462				
2								
3	.3267				.2419			
4		.2940		.1344	.3446			
5						.0261		
6			.1430					
7				.2957				
8					.1755			
9			.5324					
10								
11					.3397			
12				.1457				
13					.1237			
14				.1271				
15			.1963					
16	.3772				.1693			
17			.2329	.2665				
18	.4788				.1397			
19			.2117					
20					.1478			
21			.4484		.4010			
22				1.0756				
23								
24		.4851			.1344			
25		.8532						
26				.4170				
27								
28		.6055						
29								
30	.0255	.5428		.5070	.1073			
31	.3078		.1241					
Total	1.5160	2.7806	1.8888	3.1152	2.3249	0.0261		

Sum = 11.65 m^3/s

Source: Fieldwork, (2017).

Table 4.3c shows the daily mean instantaneous stream discharge values in m^3/s obtained using the float method for Maigamo stream. Result of the river discharges shows that the daily mean instantaneous discharges varied from as low as 0.0200 m^3/s on 30th May 2017 to the highest value of 1.1180 m^3/s on 22nd August 2017. Based on the research, it can be observed that the number of rainy days has reduced compared to the work of Yusuf (2013) where it rained for 45 days using the float method.

Table 4.3d shows that the weir method has the lowest total of 9.34 and the current metre has the highest total of 11.65, while the weir method also has the highest coefficient of variation of 104.1% and the float has the least coefficient of variation of 102.4%.

The current metre and the float methods were only applicable after a rainstorm and when the rainfall was already established because both methods cannot be used for River channel that the depth is too low and the float can be affected by vegetal growth, eddy current or wind, the meandering of the stream and the rock outcrops in the stream, hence the use of a correction factor for the float method (0.85). It therefore implies that the weir method is more superior to the current metre and the float method because of its consistency. This is in conformity with the work of Yusuf, Iguisi and Bello (2007) in their comparison using the velocity area method with the weir technique. Yusuf (2013) assessed the sediment delivery into the Kubanni Reservoir by measuring the stream discharge of Malmo and Tukurwa stream using the weir method while for Maigamo and Goruba streams, the velocity area method was used and discussed that the weir has lower mean, variance, standard deviation compare to the velocity area method, and concluded that the weir is superior to velocity area method. In addition the weir method readily provides discharge value throughout the year while the velocity area method can be used only after rain fall or when the rainfall is already established.

Day	May	June	July	August	September	October	November	December
1				.1301				
2								
3	.3259				.2342			
4		.2570		.1267	.3330			
5						0.0732		
6			.1048					
7				.2770				
8					.1411			
9			.4364					
10								
11					.2614			
12				.1834				
13					.1414			
14				.1383				
15			.1773					
16	.4393				.1475			
17			.2024	.2715				
18	.4774				.1205			
19			.1667					
20					.1560			
21			.3725		.2992			
22				1.1180				
23								
24		.4900			.1005			
25		.8813						
26				.3852				
27								
28		.6299						
29								
30	.0200	.5576		.4792	.1089			
31	.2364		.1022					
Total	1.4990	2.8158	1.5623	3.1094	2.0437	0.0732		

4.3c: Mean Instantaneous Discharge Values in m^3/s for Maigamo Stream using Float Method.

Sum total= 11.10 m^3/s

Source: Fieldwork, (2017).

Table 4.3d presents the statistical summary of Maigamo stream discharge measurements using the weir, current metre and float method

Table 4.3d: Summary of Maigamo Instantaneous Stream Discharges using the Weir, Current metre and Float Methods

Month	Weir Method	Current Metre	Float Method
May	1.0698	1.5160	1.4990
June	2.2305	2.7806	2.8158
July	1.5790	1.8888	1.5623
August	2.7229	3.1152	3.1094
September	1.7017	2.3249	2.0437
October	0.0217	0.0261	0.0732
Total	9.34	11.65	11.10
Mean	1.0362	1.2946	1.2337
SD	1.0789	1.3050	1.2634
CV%	104.1%	100.8%	102.4%

Source: Field Survey, (2017).

Having a closer look at the results from this study, it shows that the weir has the lowest values followed by the float method and lastly the current metre. This study is therefore in conformity with that of Yusuf (2013) where he observed that the weir is superior to the current metre and float methods.

The regime diagram for the Maigamo stream discharges using the three methods is presented on Figure 4.3.

The result figure 4.3 shows that August is the month with the highest discharge values of 2.7229, 3.1152 and 3.1094 m^3/s for the weir, current metre and float methods respectively. The stream discharge regime is noticed clearly from May to October with single maxima which is in conformity with the work of Yusuf (2013). This justifies Horton model of 1965 which explain that when rainfalls on a hill slope a little infiltrate and travel deep into the ground. The remaining water flows fast as overland flow into the stream channels. However, in a vegetated environment the precipitation is fully infiltrated into the soil. Infiltrated water subsequently travel laterally along the scope towards the stream and continue to flow even when precipitation is over. In this study, the soil had to attain it carrying capacity before it flows as runoff.

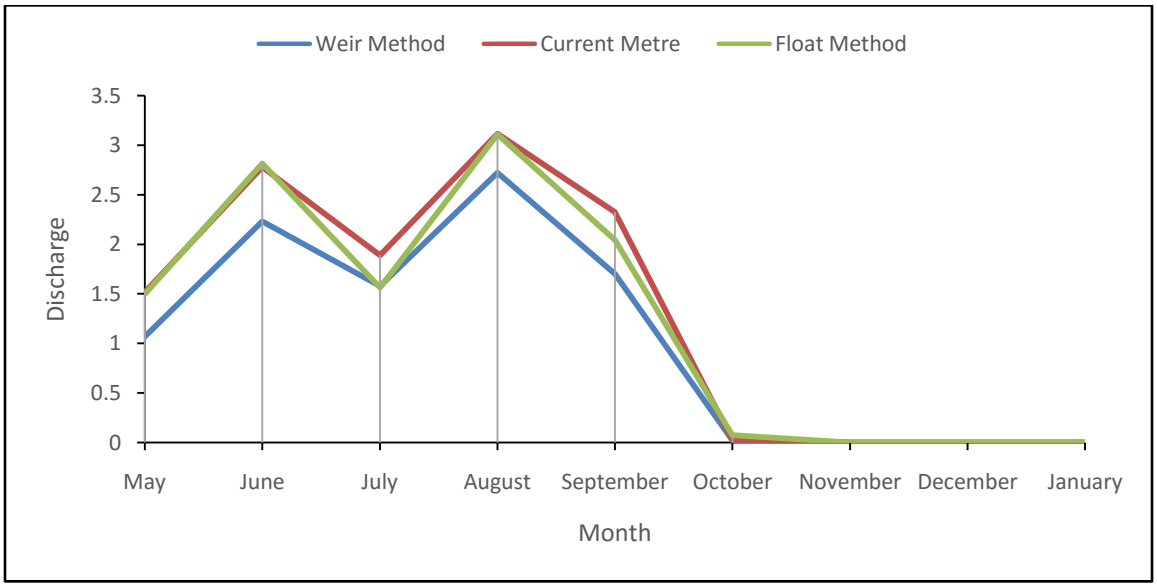


Figure 4.3: Stream Discharge Regime for Maigamo River
Source: Authors Computation, 2017

Table 4.4a present the mean instantaneous discharge for Goruba stream using the weir method

Day	May	June	July	August	September	October	November	December	January
1		.1000	.1951	**.6283**	.0680	.0625	.0120	.0044	.0004
2		.0313	.0930	.4177	.0680	.0523	.0120	.0044	.0004
3	**.1875**	.0247	.0431	.2563	**.1228**	.0523	.0120	.0044	.0004
4	.1673	**.1228**	.0350	**.3239**	**.2440**	.0523	.0101	.0025	.0004
5	.0680	.0247	.0278	.1673	.1396	**.0738**	.0101	.0025	.0004
6	.0350	.0247	**.0624**	.1149	.0680	.0476	.0084	.0025	.0004
7	.0084	.0247	.0930	**.8149**	.0625	.0431	.0084	.0025	.0004
8	.0008	.0247	.2439	.3848	**.3690**	.0431	.0084	.0025	.0004
9	.0004	.0247	**.4521**	.2957	.0680	.0431	.0055	.0025	.0004
10	.00008	.0247	.0624	.1772	.0625	.0431	.0055	.0025	.0004
11	-	.0247	.0572	.1073	**.2691**	.0431	.0055	.0025	.0004
12	-	.0247	.0572	**.6949**	.0523	.0431	.0044	.0025	
13	-	.0247	.0522	.4347	**.1396**	.0431	.0044	.0025	
14	-	.0120	.0522	**.7900**	.0680	.0431	.0044	.0025	
15	-	.0044	**.2439**	.4522	.0523	.0313	.0044	.0025	
16	**.1875**	.0044	.1396	.3848	**.4177**	.0313	.0044	.0018	
17	.1578	.0044	**.3535**	**.9465**	.0738	.0247	.0044	.0018	
18	**.4347**	.0008	.1396	.5071	**.1149**	.0247	.0044	.0018	
19	.2203	-	**.4883**	.2822	.0572	.0247	.0044	.0018	
20	.0799	-	.1149	.1772	**.3385**	.0247	.0044	.0018	
21	.0431	-	**.4347**	.1311	**.1578**	.0247	.0044	.0018	
22	.0247	-	.1396	**.9192**	.0738	.0217	.0044	.0018	
23	.0055	-	.1396	.4701	.0625	.0217	.0044	.0018	
24	.0002	**.1673**	.1396	.4177	**.3096**	.0217	.0044	.0018	
25	-	**.4347**	.1149	.3848	.0680	.0190	.0044	.0008	
26	-	.2439	.0930	**.6501**	.0572	.0190	.0044	.0008	
27	-	.1980	.0930	.4011	.0523	.0190	.0044	.0008	
28	-	**.3385**	.0799	.3848	.0523	.0141	.0044	.0008	
29	-	.0738	.0680	.2957	.0431	.0141	.0044	.0008	
30	**.0863**	**.3848**	.0624	**.5458**	**.1308**	.0120	.0044	.0008	
31	**.3096**		**.1673**	.0930		.0120		.0008	
Total	2.0171	2.3681	4.5384	13.0513	3.8632	1.0460	0.1815	0.065	0.0044

4.4a: Mean Instantaneous Discharge Values in m^3/ s for GorubaStream using the Weir Method

Sum = 27.14 m^3/s

Source: Fieldwork, (2017).

4.5 Discharge measurements for the Goruba stream

Table 4.4a shows that Goruba stream has the longest flow period of 239 days (from May 2017 to January 2018) compared to the other three streams. When compared with the work of Yusuf (2013). It can be observed that the flow period of Goruba stream has increased from 175 days to 239 days in 2017. This confirm the contribution to surface flow by subsurface flow during the dry season. It can therefore be confirmed that there is a great increase from the subsurface flow contributing to the surface flow compared to the study conducted by Yusuf (2013) because of factors such as rainfall intensity and duration, soil type, geology, shape and size of the channel.

The measured daily mean instantaneous discharge values using the weir method in m^3/s throughout the study period recorded the lowest value of 0.00004m^3/s on 11thJanuary2018 while the highest value of 0.9465 m^3/s was recorded on 17th August 2017. The result on Table 4.4a shows that the discharge measured by the weir method shows some days of dry spell in the month of May and June, meaning that rainfall is not well established. Although the rainy days differs with that of Malmo and Tukurwa tributaries, which are on the northernmost part of River Kubanni, the Maigamo and Goruba which are on the southernmost part of River Kubannistill gives the equal days of rain storm (37 days).

Table 4.4b shows the daily mean instantaneous stream discharge values in m^3/s obtained using the current metre for Goruba stream. Result of the river discharges on Table 4.4b shows that the daily mean instantaneous discharges varied from as low as 0.0543 m^3/s on 5th October 2017 to the highest value of 1.1484 m^3/s on 7th August 2017. Based on the research, it can be observed

that the onset of the rain was late and the number of rainy days has reduced compared to the work of Yusuf (2013) where it rained for 45 days using the current metre.

Table 4.4c shows the daily mean instantaneous stream discharge values in m^3/s obtained using the float method for Goruba stream. Result of the river discharges on Table 4.4c shows that the daily mean instantaneous discharges varied from as low as 0.0647 m^3/s on 5th October 2017 to the highest value of 1.2056 m^3/s on 7th August 2017. Based on the research, it can be observed that the onset of the rain was late and the number of rainy days has reduced compared to the work of Yusuf (2013) where it rained for 45 days using the current metre.

Table 4.4d shows that the weir has the lowest total of 13.50 and the current metre has the highest total of 17.44 while the weir method has the highest coefficient of variation of 136.2% the float method has the least coefficient of variation of 128.6%.

The current metre and the float methods were only applicable only after a rainstorm or when the rainfall is already established because both methods cannot be used for river channel that the depth is too low and the float can be affected by vegetal growth, eddy current or wind hence the use of a correction factor for the float method (0.85). By this, it implies that the weir method is more superior to the current metre and the float method because of its consistency. This is in conformity with the work of Yusuf, Iguisi and Bello (2007) in their comparison using the velocity area method with the weir technique. The results showed that the weir has lower mean, variance, standard deviation compare to the velocity area method, thus implying that the weir is superior to velocity area method. Besides that the weir readily provides discharge value throughout the year while the velocity area method can only be used only after rain fall or when the rainfall is already established. Having a closer look at the results from this study, it shows that the weir has the lowest values followed by the float method and lastly the current metre.

Day	May	June	July	August	September	October	November	December
1				.7995				

With this we can conclude that this study is in conformity with that of Yusuf (2013) where he stated that the weir is superior to the currentmetre and float methods.

Day	May	June	July	August	September	October	November	December
1								
2								
3	.2781				.1844			
4		.1715		.3069	.4208			
5				.6279		.0543		
6			.1199					
7				1.1484				
8					.5346			
9			.5004					
10								
11					.3570			
12				.8199				
13					.2141			
14				.6986				
15			.2239					
16	.3283				.5811			
17			.3578	.9864				
18	.3969				.1729			
19			.6012					
20					.4576			
21			.5328		.3257			
22				.7992				
23								
24		.4093			.7446			
25		.5076						
26				.8224				
27								
28		.2778						
29								
30	.1296	.5292		.8213	.2066			
31	.4795		.1406					
Total	1.6124	1.8954	2.4766	7.2026	4.1994	0.0543		

4.4b: Mean Instantaneous Discharge Values in m^3/s for GorubaStream using Current Metre.

Sum total = 17.44 m^3/s

Source: Fieldwork, (2017).

3	.3190				.1649	
4		.1366		.2403	.3918	
5						.0647
6			.1027			
7				1.2056		
8					.5425	
9			.4682			
10						
11					.3374	
12				.7911		
13					.2214	
14				.7332		
15			.2185			
16	.2815				.4073	
17			.3168	.9547		
18	.3186				.1787	
19			.5508			
20					.3586	
21			.4774		.2256	
22				.7375		
23						
24		.3991			.7332	
25		.4682				
26				.6885		
27						
28		.2545				
29						
30	.4075	.4988		.8978	.1610	
31	.1153		.1524			
Total	1.4419	1.7572	2.2868	6.8766	3.7224	0.0647

4.4c: Mean Instantaneous Discharge Values in m^3/s for GorubaStream using Float Method**.**

Sum total = 16.15 m^3/s

Source: Fieldwork, (2017).

Table 4.4d presents the statistical summary of Goruba stream discharge measurements using the weir, current metre and float method

Table 4.4d: Summary of GorubaInstantaneous Stream Discharges using the Weir, Current Metre and Float Methods

Month	Weir Method	Current Metre	Float Method
May	1.2056	1.6124	1.4419
June	1.4481	1.8954	1.7572
July	1.8487	2.4766	2.2868
August	6.3136	7.2026	6.8766
September	2.6138	4.1994	3.7224
October	0.0738	0.0543	0.0647
Total	13.50	17.44	16.15
Mean	1.5004	1.9379	1.7944
SD	2.0435	2.4506	2.3067
CV%	136.2%	126.5%	128.6%

Source: Field Survey, (2017).

Fig 4.4 shows that August was the month with the highest discharge values of 6.3136 m^3/s, 7.2026 m^3/s and 6.8766 m^3/s using both the weir, current metre and float method respectively. An interesting observation in this study is that the discharge regime of Maigamo and Goruba streams which are on the southernmost part of Kubanni River had their highest values in August while Malmo and Tukurwa streams had their highest discharge values in the month of September. Therefore the discharge regime was noticed clearly from May to October with single maxima which was in conformity with the work of Yusuf (2013).

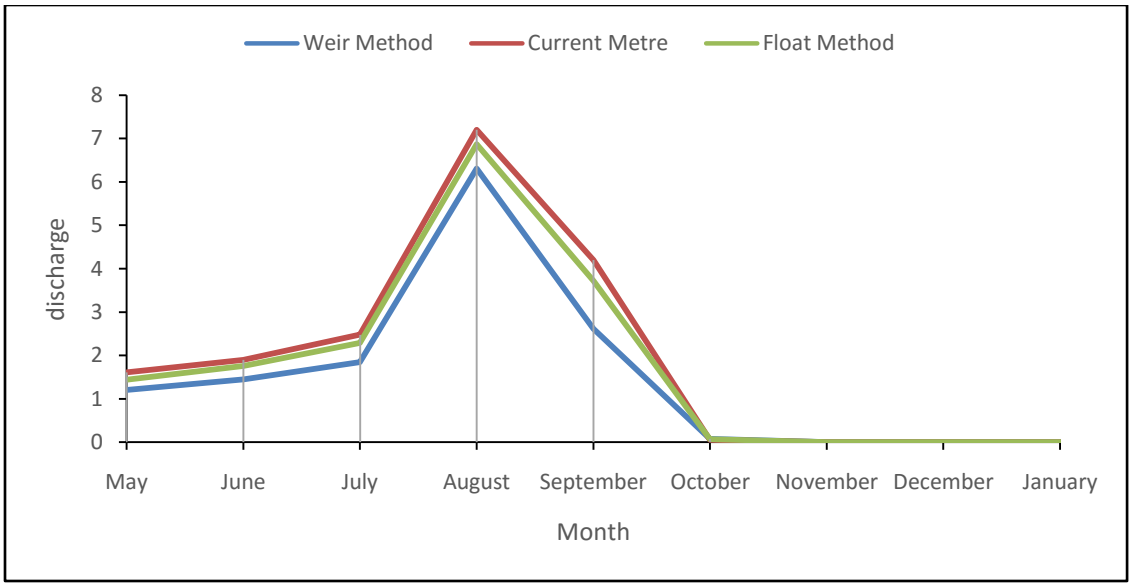


Figure 4.4: Stream Discharge Regime for Goruba River
Source: Authors Computation, (2017).

4.6Comparison of the Stream Discharges of the Tributaries Upstream of River Kubanni

The comparison of stream discharge using the weir method is presented in Table 4.5a

Table 4.5a: Comparison of Stream Discharges using the Weir Method

Streams		Sig	Remark
Malmo	Tukurwa	0.091	No Significant difference
	Maigamo	0.029	Significant difference
	Goruba	0.001	Significant difference
Tukurwa	Maigamo	0.967	No significant difference
	Goruba	0.001	Significant difference
Maigamo	Goruba	0.001	Significant difference

Variables	Sum of Square	Df	Mean Square	F- cal	F-critical	Remark
Between Groups	0.872	3	0.391	20.868	2.60	Significant difference
Within Group	12.774	917	0.014			
Total	13.646	920				

Source: Authors Computation, (2017).

Table 4.5a showsthat between Malmo and Tukurwa tributaries, there is no significant differencein discharge using the weir. However, between Malmo, Maigamo and Goruba it shows that there is a significant difference in discharge. It therefore implies that Malmo and Tukurwa tributaries maybe smaller in sizes and in basin characteristics compare to Maigamo and Goruba. Also comparing the stream discharges between Tukurwa with Maigamo, it shows that there is no significant difference in their stream discharges. But between Tukurwa and Goruba there is a highsignificant difference in the stream discharges. There is also a significant difference in the stream discharges between Maigamo and Goruba tributaries. This is because of the soil infiltration capacity, rainfall intensity and duration and other intervening factors.

The table 4.5s also shows the stream discharge values between and within groups with their total values for the four tributaries. The degree of freedom and the mean square of each of the dependent variable, the F- calculated as well as the F-critical were also shown. Table 4.5a shows that the F-calculated (20.86) is greater than the F- critical (2.60) which is the table value using the weir technique at 0.05 level of confidence. Therefore since the F-calculated is greater than the F-critical we conclude that there is a significant difference between the stream discharges upstream of River Kubanni using the weir technique. The Goruba stream has the highest discharge values of 2,344,896 m^3/yr., followed by Maigamo stream with discharge value of 1,215,648 m^3/yr., Tukurwastream has a discharge value of 1,127,520m^3/yr., and Malmo stream which is the smallest in size has the least discharge value of 508,896m^3/yr. respectively. Consequently it means thatGoruba, Maigamo and Tukurwa streams contribute immensely to Kubanni reservoir in terms of availability of water because of their sizes. Generally, the result shows that there is a significant difference in the stream discharges from the four tributaries of

River Kubanni because of the differences in sizes and basin characteristics, soil infiltration capacity, rainfall intensity and duration.

This study therefore in conformity with the work of Yusuf (2013) and it has also shown that Goruba stream has the highest discharge value, followed by Maigamo and Tukurwa streams while the Malmo stream has the least discharge value.

The comparison of stream discharge using the current metre is presented in Table 4.5b

Table 4.5b: Comparison of the Stream Discharges using the Current Metre

Stream		Sig	Remark
Malmo	Tukurwa	0.321	No Significant difference
	Maigamo	0.001	Significant difference
	Goruba	0.001	Significant difference
Tukurwa	Maigamo	0.171	No significant difference
	Goruba	0.001	Significant difference
Maigamo	Goruba	0.002	Significant difference

Variables	Sum of Square	Df	Mean Square	F- cal	F critical	Remark
Between Groups	2.033	3	0.678	20.53	2.60	Significant difference
Within Group	4.886	146	0.033			
Total	6.919	149				

Source: Authors Computation, (2017).

Table 4.5b shows that between Malmo and Tukurwa tributaries, there is no significant difference using the current metre. However, between Malmo, Maigamo and Goruba it shows that there is a significant difference. It therefore implies that Malmo and Tukurwa tributaries maybe smaller in sizes compare to Maigamo and Goruba. Also comparing the stream discharges between Tukurwa with Maigamo, it shows that there is no significant difference in their stream discharges. But

between Tukurwa and Goruba there is very significant difference in the stream discharges. There is also a significance difference in the stream discharges between Maigamo and Goruba tributaries.

The table also shows the stream discharge values between and within groups with their total values for the four tributaries. The degree of freedom and the mean square of each of the dependent variable, the F- calculated as well as the F- critical were also shown. As shown in the table 4.5b, the F-calculated (20.53) is greater than the F- critical (2.60) which is the table value using the current metre at 0.05 level of confidence. Therefore since the F-calculated is greater than the F-critical we conclude that there is a significant difference between the stream discharges upstream of River Kubanni

The Goruba stream has the highest discharge values of 1,506,816 m^3/yr., followed by Maigamo stream with discharge value of 1,006,560 m^3/yr., Tukurwa stream has a discharge value of 701,568m^3/yr., and Malmo stream which is the smallest in size has the least discharge value of 469,152m^3/yr. respectively. It therefore means that Goruba, Maigamo and Tukurwa streams contributes immensely to Kubanni reservoir in terms of availability of water because of their sizes. Over all, we conclude that there is a significant difference in the stream discharges from the four tributaries of River Kubanni.

Table 4.5c shows that between Malmo and Tukurwa tributaries, there is no significant difference using the float method. However, between Malmo, Maigamo and Gorubathere is a significant difference. It therefore implies that Malmo and Tukurwa tributaries maybe smaller in sizes compare to Maigamo and Goruba. Also comparing the stream discharges between Tukurwa with Maigamo, it shows that there is no significant difference in their stream discharges. But between

Tukurwa and Goruba there is very significant difference in the stream discharges. There is also a significant difference in the stream discharges between Maigamo and Goruba tributaries.

The table 4.5c presents the comparison of stream discharges using the float method

Table 4.5c: Comparisonof Stream Discharges using Float Method

Stream		Sig	Remark
Malmo	Tukurwa	0.365	No Significant difference
	Maigamo	0.002	Significant difference
	Goruba	0.001	Significant difference
Tukurwa	Maigamo	0.168	No significant difference
	Goruba	0.001	Significant difference
Maigamo	Goruba	0.010	No significant difference

Variables	Sum of Square	Df	Mean Square	F- cal	F critical	Remark
Between Groups	1.759	3	0.586	17.481	2.60	Significant difference
Within Group	4.898	146	0.034			
Total	6.658	149				

Source: Authors Computation, (2017).

The table also shows the stream discharge values between and within groups with their total values for the four tributaries. The degree of freedom and the mean square of each of the dependent variable, the F- calculated as well as the F-critical were also shown. As shown in the Table 4.5c, the F-calculated (17.481) is greater than the F-critical (2.60) which is the table value using the float method at 0.05 level of confidence. Therefore since the F-calculated is greater

than the F-critical we conclude that there is a significant difference between the stream discharges upstream of River Kubanni.

The Goruba stream has the highest discharge values of 1,395,360 m^3/yr., followed by Maigamo stream with discharge value of 959,040 m^3/yr., Tukurwa stream has a discharge value of 654,048m^3/yr., and Malmo stream which is the smallest in size has the least discharge value of 432,000m^3/yr. respectively. The results obtained from the current metre and the float method were closely similar because the current metre and the float were used simultaneously after a rainstorm to obtain the stream discharges upstream of River Kubanni. The result shows that there is a significant difference in the stream discharges from the four tributaries of River Kubanni because of the difference in sizes, the basin characteristics, soil infiltration capacity and intervening factors.

The following streams; Goruba, Maigamostreams contributes immensely to Kubanni reservoir in terms of availability of water because of their sizes, the basin characteristics, soil infiltration capacity and intervening factors, while theTukurwa and Malmo streams contribute less in terms of availability of water to the Kubanni reservoir.

4.7 The effectiveness of the Methods for Measuring Stream Discharge Upstream of River Kubanni

In order to examine the effectiveness of the methods for measuring stream discharge a comparison was made between of discharge values obtained from the weir, current metre and float method. Comparison was made to see whether there is significant difference in the result obtained using the three techniques. The comparison was made between instantaneous stream discharges available for 37 days. Similarly Analysis of Variance (ANOVA) was used to test the

hypotheses stated earlier in chapter one which states that there is no statistically significant difference between the result obtained from the weir, current metre and float method in determining the stream discharges of the four tributaries upstream of River Kubanni at 0.05 significance level.

The effectiveness of the methods for Malmo stream is presented in Table 4.6a

Table 4.6a Effectiveness of the Methods for Malmo Stream

Techniques		Sig	Remark
Weir	Current Metre	0.284	No Significant difference
	Float Method	0.843	No Significant difference
Current Metre	Float Method	0.599	No significant difference

Variables	Sum of Square	Df	Mean Square	F- cal	F-Critical	Remark
Between Groups	0.007	2	0.004	1.189	3.09	No Significant difference
Within Group	0.320	108	0.003			
Total	0.327	110				

Source: Authors Computation, (2017).

Table 4.6a shows the different techniques used in measuring stream discharge for Malmo stream. It shows that between the weir, current metre and floatmethods there is no significant difference in the results obtained in determining stream discharge of Malmo stream. Also between the current metre and the float method, it shows that there is no significant difference in the results

obtained in determining stream discharge for small River channels like Malmo. Thus implying that both methods are suitable for measuring stream discharges.

The table 4.6a also shows the stream discharge values obtained between and within groups with their total values. The degree of freedom and the mean square of each of the dependent variable, the F- calculated as well as the F-critical were also shown. As shown in the Table 4.6a, the F-calculated (1.189) is less than the F-critical (3.09) which is the table value at 0.05 level of confidence. Therefore since the F-calculated is less than the F-critical we conclude that there is no significant difference between the results of the stream discharge obtained using the three methods for Malmo stream. Thus implying that both methods are suitable for measuring stream discharges for small Rivers which Kubanni is no exception. This study however, was in line with the studies of Yusuf, Iguisi and Bello (2007), Zubairu (2009), Yusuf, Iguisi and Abdulsalam (2011) and Yusuf (2013) where they pointed out clearly that the weir technique is superior to velocity area method.

The current metre and the float were only applicable only after a rainstorm or when the rainfall is already established. Because current metre cannot be used for river channel that the depth is too low and the float can be affected by vegetal growth, eddy current or wind hence the use of correction factor for the float method. Thus we conclude that the weir is superior to the current metre and the float methods in determining stream discharges because of its consistency.

The effectiveness of the methods for Tukurwa stream is presented in Table 4.6b

Table 4.6b Effectiveness of the Methods for Tukurwa Stream

Techniques		Sig	Remark
Weir	Current Metre	0.977	No significant difference
	Float Method	0.733	No significant difference
Current Metre	Float Method	0.604	No significant difference

Variables	Sum of Square	Df	Mean Square	F-cal	F-Critical	Remark
Between Groups	0.010	2	0.005	0.510	3.09	No significant difference
Within Group	1.031	108	0.010			
Total	1.041	110				

Source: Authors Computation,(2017).

Table 4.6b shows the different techniques used in measuring stream discharge for Tukurwa stream. It shows that between the weir, current metre and float methods there is no significant difference in the results obtained in determining stream discharge. Between the current metre and the float method, it shows that there is no significant difference in the results obtained in determining stream discharge for small River channels like Tukurwa. Thus implying that both methods are suitable for measuring stream discharges.

The table also shows the stream discharge values obtained between and within groups with their total values. The degree of freedom and the mean square of each of the dependent variable, the F- calculated as well as the F-critical were also shown. As shown in the Table 4.6b, the F-calculated (0.510) is less than the F-critical (3.09) which is the table value at 0.05 significant level. Therefore since the F-calculated is less than the F-critical we conclude that there is no significant difference between the results of the stream discharge obtained using the three methods for Tukurwa stream. Thus implying that both methods are suitable for measuring stream discharges for small channels like the Tukurwa stream. Although, the weir is more superior and have more advantage than the current metre and the float method because of its consistency.Unlike the current metre and float method which can only be used after rain storm or when the raining season is already established.

The float has greater applicability than the current metre since it can be used on either shallow or deep streams whereas the current metre cannot. However the float can also be obstructed by vegetal growth, eddy current or wind before reaching the gauging station where the stream velocity is noted.

This study is in conformity with the studies of Yusuf, Iguisi and Bello (2007), Zubairu (2009), Yusuf, Iguisi and Abdulsalam (2011) and Yusuf (2013) where they observed that the weir technique is more superior to the current metre and float method because of its consistency. Thus, it is certain that the weir is the most effective method for measuring stream discharges for Small River like Kubanni.

The effectiveness of the methods for Maigamo stream is presented in Table 4.6c

Table 4.6c Effectiveness of the Methods for Maigamo Stream

Techniques		Sig	Remark
Weir	Current Metre	0.387	No Significant difference
	Float Method	0.639	No Significant difference
Current Metre	Float Method	0.909	No significant difference

Variables	Sum of Square	Df	Mean Square	F- cal	F- Critical	Remark
Between Groups	0.083	2	0.042	0.911	3.09	No Significant difference
Within Group	4.942	108	0.046			
Total	5.025	110				

Source: Authors Computation, (2017).

Table 4.6c shows the different techniques used in measuring stream discharge for Maigamo stream. It shows that there is no significant difference in the results obtained using the weir, current metre and float methods in determining stream discharge.Also between the current metre and the float method, it shows that there is no significant difference in the results obtained in determining stream discharge. Thus implying that both methods are suitable for measuring stream discharges for small River channel.

The table 4.6c also shows the stream discharge values obtained between and within groups with their total values. The degree of freedom and the mean square of each of the dependent variable, the F- calculated as well as the F-critical were also shown. As shown in the Table 4.6c, the F-calculated (0.911) is less than the F-critical (3.09) which is the table value at 0.05 level of confidence. Therefore since the F-calculated is less than the F-critical we conclude that there is no significant difference between the results of the stream discharge obtained using the three methods. Thus, implying that both methods are suitable for measuring stream discharges for small channels like River Kubanni. Although, the weir is more superior and have more advantage than the current metre and the float method because of its consistency.

Unlike the current metre and float methods which can only be used after rain storm or when the raining season is already established. The float has greater applicability than the current metre since it can be used on either shallow or deep streams whereas the current metre cannot. However the float can also be obstructed by vegetal growth, eddy current or wind obstacles in the stream and meandering of the stream (shape) before reaching the gauging station where the stream velocity is noted. This study is however, in line with the studies of Yusuf, Iguisi and Abdulsalam (2011) and Yusuf (2013) where they observed that the weir technique is superior to

the velocity area method. Thus we conclude that the weir is the most effective method for measuring stream discharges for small streams.

The effectiveness of the methods for Goruba stream is presented in Table 4.6d

Table 4.6d Effectiveness of the Methods for Goruba Stream

Techniques		Sig	Remark
Weir	Current Metre	0.183	No Significant difference
	Float Method	0.428	No significant difference
Current Metre	Float Method	0858	No significant difference

Variables	Sum of Square	Df	Mean Square	F- cal	F-Critical	Remark
Between Groups	0.222	2	0.111	1.663	3.09	No Significant Difference
Within Group	7.218	108	0.067			
Total	7.440	110				

Source: Authors Computation, (2017).

Table 4.6d shows the different techniques used in measuring stream discharge for Goruba stream. It shows that between the weir, current metre and float methods there is no significant difference in the results obtained in determining stream discharge. Also between the current metre and the float method it shows that there is no significant difference in the results obtained in determining the stream discharge. By this it implies that both methods are suitable for measuring of stream discharge for small streams like Goruba.

The table 4.6d also shows the stream discharge values obtained between and within groups with their total values. The degree of freedom and the mean square of each of the dependent variable,

the F- calculated as well as the F-critical were also shown. As shown in the Table 4.6d, the F-calculated (1.663) is less than the F-critical (3.09) which is the table value at 0.05 significant level. Therefore since the F-calculated is less than the F-critical we conclude that there is no significant difference between the results of the stream discharge obtained using the three methods for Goruba stream. Thus implying that both methods are suitable for measuring stream discharges for small channels like the Goruba. Although, the weir is more better and has more advantage than the current metre and the float method because of its consistency.

The float has greater applicability than the current metre since it can be used on either shallow or deep streams whereas the current metre cannot. However the float can also be obstructed by vegetal growth, eddy current or wind before reaching the gauging station where the stream velocity is noted. This study is in agreement with the studies of Yusuf, Iguisi and Abdulsalam (2011) and Yusuf (2013) where they observed that the weir technique is more superior to the velocity area method. It is therefore certain that the weir is the most effective method for measuring stream discharge for small Rivers which like Kubanni.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This study attempted a comparative analysis of discharge measurement techniques upstream of River Kubanni. Zaria, Kaduna, Nigeria in order to ascertain the most effective method for measuring stream discharge. The four major tributaries namely; Malmo, Tukurwa, Maigamo and Goruba contributing water into the Kubanni reservoir were monitored for the 2017 to 2018

hydrological year. Data on stream discharges were obtained from the four gauging stations made up of a 120^0 and 90^0 V-notch control structures (weirs), simultaneously with current metre and float method.

Analysis of variance was used to determine the differences in the stream discharges using each of the three methods. Descriptive statistics was also employed to calculate the mean, standard deviation and coefficient of variation using the three methods. Similarly analysis of variance was also employed to test the null hypotheses which states that there is no significant difference between the discharge values obtained using the weir, current metre and the float methods. The results of the research shows an increment of flow period from the tributatries which contributes water to the Reservoir. This further confirms the contribution of surface flow by sub surface flow to the reservoir. Similarly, based on the study findings, it showed that there was a significant difference in the stream discharge with Goruba tributary having the highest discharge value of 2,344,896 m^3/yr., followed by Maigamo and Tukurwa with a discharge values of 1,215,648 m^3/yr. and 1,127,520 m^3/yr. respectively. While Malmo tributary which the smallest has a discharge value of 508,896 m^3/yr. using the weir technique because it gives the discharge throughout the flow period.This justifies the fact that there is a strong relationship between the stream discharge and the size of a river. Analysis of variance was employed to test the null hypotheses which states that there is no significant difference between the stream discharge results obtained using the weir, current metre and the float method in measuring stream discharge upstream of River Kubanni. The results revealed that there was no significant differencebetween the results obtained using the three methods, thus it implies that both methods were suitable for measuring stream discharge for Small River of which Kubanni is no exception. However, descriptive statistics shows that the weir has the least total, mean, and standard

deviation compare to the current metre and the float methods. By this it implies the weir is more superior to the velocity area method. Besides, field observation shows that the weir technique is of greater applicability and more advantageous for continuous discharge measurement than the current metre and the float methods because of its consistency, whereas the current metre cannot be applicable on shallow stream and the float is sometimes affected by vegetal growth, eddy current or wind.

5.2: Conclusion

The study has shown that there is no significant difference between the weir technique and the Velocity Area method in determining the stream discharge upstream of River Kubanni, Zaria, Nigeria. Although the weir technique is more superior to the current metre and float method because its consistency. It also shows that there is great significant difference in discharge between the four tributaries. While Goruba, Maigamo and Tukurwa streams have the highest discharge values, because of the following factors; precipitation intensity and duration, sizes and shapes of the channels, the soil infiltration capacity, the geology and topography. Malmo stream has the least discharge because of their difference in their sizes, the soil infiltration capacity, the geology and topography.Another interesting observation from the study shows that there was overall increment in the flow period from the tributaries which confirms the contribution of surface flow by sub surface flow to the Reservoir.Factors such as precipitation intensity and duration, sizes and shapes of the channels, the soil infiltration capacity, the geology and topography may have cause the contribution by subsurface flow.

5.3 Recommendations

Based on the results obtained from the research, some recommendations are hereby,

1. That there should be a continuous monitoring of stream discharge upstream of the Kubanni, since the first and foremost requisite for planning of water resource development is the availability of accurate data of stream flow for a considerable period of time to determine the extent and pattern of available water supply.
2. Measures to minimize siltation of the reservoir should be put in place since sediment yield in any reservoir has a relationship with the stream discharge
3. Measures to prevent or control flooding should be established since there was an increment in the flow period from each tributary, as water will be forced into the land destroying the farmland and properties since it's exceed its carrying capacity.
4. Lastly it is recommended that the weir method is the most effective technique for stream discharge measurement because of its consistency.

5.4 Critique of the Study

The study have analyzed the stream discharge measurement using the weir method, current metre and the float methods on the four major tributaries of River Kubanni which are upstream. However other methods other than the three methods can be used to obtained stream discharge for rivers like Kubanni which can form a scope for another study.

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