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A COMPARATIVE ANALYSIS OF DISCHARGE MEASUREMENT TECHNIQUES IN THE NORTHERNMOST TRIBUTARY OF RIVER KUBANNI, ZARIA, NIGERIA

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ABSTRACT

River or stream discharge is of great importance ranging from flood control, power generation, irrigation, water supply and dam construction. Hence, the need for stream discharge measurement becomes a paramount importance in water resources evaluation. A comparison has been made between stream discharge values using the Weir, Current metre and Float methods in Malmo tributary which is found in the northernmost part of River Kubanni in Zaria. This was made in order to establish the most effective method for measuring stream discharge for small rivers. The result observed from this study shows that there is no significant difference between the river discharges from the three techniques. This means that the techniques were suitable for the stream discharge measurements on the stream channel. However, the field observation shows that the weir technique is of greater applicability and more advantageous for continuous discharge measurements than the current metre and float methods. The weir technique can be used throughout the year and when the river becomes too shallow for current metre to be used. Also, the weir is of greater advantage compared to the float method, because the float is sometimes affected by vegetal growth, eddy current and wind. It is therefore recommended that for small river channels, the weir method is the most effective technique for stream discharge measurement.

Keyword: stream discharge, weir, current metre, float method.

INTRODUCTION

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 increasingly real in the face of increasing demand, relative static supply and deteriorating quality due to pollution (Ayoade and Oyebande, 1978).

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. Perhaps more embarrassing is that lack of running water has killed more people in Nigeria in 2015 alone than the murderous Boko Haram did in its six years insurgency. While the terror has claimed about 17,000 lives, the shortage of potable water and poor sanitation led to about 73,000 deaths (Wateraid, 2016).

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).

The scarcity of water and threats of flash floods in Nigeria require further understanding of the natural processes of water resources in order to manage and sustain current and future water resources. To make matters worse, rainfall fluctuation and climate change are expected to increase water scarcity in Nigeria. These combined factors will drive Nigeria to severe water stress. Hence, hydrological measurement become more essential in order to interpret water quality data and for water resource management (Ibrahim, 2011).

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).

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. Methods such as 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. The measurement is made by sub-dividing a stream cross section into segments, and by measuring the depth and velocity in a vertical within each segment. The total discharge is the summation of the stream cross section and their respective average velocities (Herschy, 1995).

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. Float is use only when it is impossible to use a current meter. The method measures the surface velocity, mean velocity is obtain 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).

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 use 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 (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 the Kubanni River in Zaria, Kaduna State.

MATERIALS AND METHODS

The study area is in Zaria, Kaduna state Nigeria located on latitude $11^{0}03^{|}$ N and longitude $7^{0}\ 42^{|}$ E while the study site is located in the northernmost part of Kubanni drainage basin with latitude $11^{0}\ 09^{'}22^{''}$N and longitude $7^{0}\ 37^{'}38^{''}$ E which is the Malmo tributary. The Kubanni has its source from Kampagi Hill in shika near zaria. It flows in the southeast direction through the premises of Ahmadu Bello University. It has four major tributaries namely; Malmo and Tukurwa which are found in the northernmost part and the Maigamo and Goruba which form the southernmost tributaries of Kubanni reservoir.

Zaria experiences the typical seasonal climate of northern Nigeria. It belongs to the AW climate of the Koppen's classification that has two distinct seasons; the dry or the harmattan season lasting between October to May, while the other season is the rainy season and lasts from May to October. The temperature of Zaria varies throughout the year. The minimum daily temperature rises gradually from its lowest 15˚C December and January to its highest 26˚C in April and May. The maximum daily temperature rises from its lowest 30.1˚C in December/January to its highest 39.5˚C in April/May. Mean monthly minimum temperature rises gradually from its lowest 9.4˚C in December to its highest 26.0˚C in April. Mean monthly maximum temperature rises gradually from its lowest 29.7˚C in January to highest 40.60˚C in April (Oladipo, 1985).

The soil of Zaria is termed "the Zaria soil group" and usually has material covering up to 14 feet (4.27m) in depth and consists of deposited silt and overlying sedimentary decomposed rocks. Alluvial soils are expensive in Zaria and in low land areas they are easily drained to produce what is known as the Hydromorphic soil/fadama. These are found around the Kubanni and Galma river basins and are mainly for sugarcane cultivation. It also supports vegetables like onions, spinach, pepper, tomatoes; hence contributing to market gardening (Ologe, 1973).

Although the Zaria environment belongs to the northern guinea savannah which is moist woodland undergrown with thick bushes and shrubs, the vegetation is gradually becoming artificial. Some of these vegetation include elephant grass, *Isoberlinadoka*, *Isoberlinatomentosa*, *Tamarindus*spp, locust beans, silk cotton trees, and baobab tree are commonly seen. Human activities such as cultivation, construction, bush burning and grazing have greatly modified the natural vegetal cover and composition (Jaiyeoba, 1995).

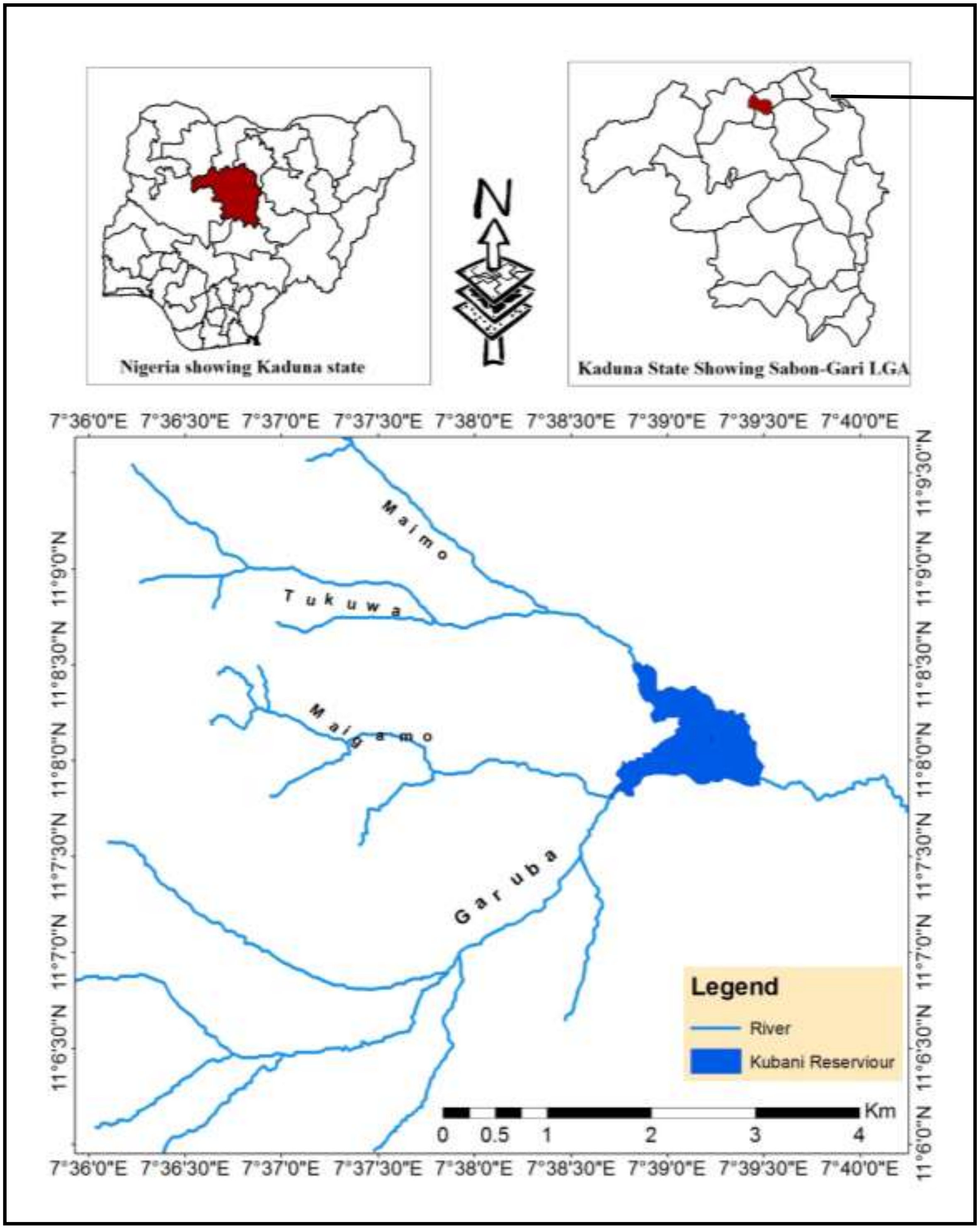

Fig 1: Kubanni Reservoir and its Tributaries
Source: Adapted from topographic map of Zaria sheet S.W 102, 2017

For this study, both Primary and Secondary data were used. The Primary data include stream discharge data that were obtained from the gauging station, using the weir, current metre and float method during the flow period of the tributary from May 2017 to January, 2018. Related materials obtained from maps form the secondary data.

Weir Method

For the purpose of this study, the 120^0 V-notch sharp crest weirs with a calibrated stage measurement was installed at gauging station of Malmo tributary with a discharge formula;

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

Where Q = Discharge in m^3/s H = Head of water in meter (stage).

The stage observation was done twice a day, by 8:00 am in the morning and the other by 6:00 pm in the evening.

Velocity Area Method

The current metre and the float were used since discharge by definition is the product of velocity and cross sectional area. Therefore in order to get the discharge both the velocity and the cross sectional have to be computed. This will also be done twice a day.

Since Q = VA --2

Where V = velocity measured in m/s. A = cross sectional area (width X depth)

RESULTS AND DISCUSSIONS

Observation of the stream discharges for the northernmost tributary was carried out throughout their flow period starting from 3rd May 2017 to 11th January 2018 using the control structure (weir) method simultaneously with the Velocity- Area method. The summary of the stream discharges are presented on Tables below:

Table 1a shows the daily mean instantaneous discharge values obtained using the Weir in m^3/ s throughout the study period. The summary statistics shows that daily mean instantaneous discharge varied from as low as $0.00002m^3/s$ on 25thDecember2017 to the highest value of $0.2659m^3/s$ on 6th July 2017 with a mean of 0.5117and standard deviation of 0.5608.

Table 1b and 1c shows the daily mean instantaneous stream discharges values in m^3/s obtained using the current metreand the float method for Malmo tributary. Result of the river discharges shows that the daily mean instantaneous discharges varied from as low as 0.0109 m^3/s and 0.0263 m^3/s on 5th May to the highest values of 0.2865 m^3/s and 0.2588 m^3/s on 9th July m^3/s for current metre and float method respectively. The current metre has a mean of 0.6034, with standard deviation 0.6286. For the float method it has a mean of 0.5557 and a standard deviation of 0.5743.

Date	May	June	July	August	September	October	November	December	January
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**	

1a: Mean instantaneous Discharge Values in m^3/ s for 2017 – 2018 using the Weir method

Malmo River
Sum Total = 5.8895
Source: Fieldwork, 2017.

1b: Mean instantaneous discharge values in m^3/s for 2017 – 2018 using current metre.
MALMO RIVER
Sum total = 5.4302
Source: Fieldwork, 2017.

Date	May	June	July	August	September	October	November	December	January
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**			

1c: Mean instantaneous discharge values in m^3/s for 2017 – 2018 using Float method
MALMO RIVER
Sum total = 5.0012
Source: Fieldwork, 2017

Comparison between the Weir, Current metre and Float method in determining the stream discharge upstream of River Kubanni

A comparison between of discharge values obtained from the weir, current metre and float method were made. Comparison was made to see whether there is significant difference in the result obtained using the Velocity- Area method and the Weir technique. Comparison were only made between the days it rains for that of the weir since the current metre and the float method can be applicable only after a rainstorm or when the rainfall is well established. Analysis of Variance (ANOVA) was used to see if there is significant difference between the result obtained from the weir, current metre and float method in determining the stream discharge for the southernmost tributary of River Kubanni at 0.05 significance level.

MALMO RIVER

Factor		Sig	Remark
Weir	Current Meter	0.332	No Significant difference
	Float Method	0.892	No Significant difference
Current Meter	Float Method	0.589	No significant difference

Variables	Sum of Square	Df	Mean Square	F- cal	Sig	Remark
Between Groups	0.006	2	0.003	**1.067**	0.348	No Significant difference
Within Group	0.309	106	0.003			
Total	0.315	108				

Source: Authors Computation, 2017

The comparison of the discharge values obtained using the current metre, float and weir techniques from table 2a indicates that there is no significant difference in the results obtained between the weir, current metre and float methods. Thus implying that both methods are suitable for measuring stream discharges for small rivers. However, having a closer look at the three set of data, it shows that the weir has a lower mean of 0.5117 and standard deviation of 0.5608 values compared to the current metre and the float method with mean of 0.6034, 1.2337 and standard deviation of 0.6286, 0.5743 respectively. Thus, this implies that the weir technique is more superior to the current metre and the float method. Besides, it readily provides mean daily discharge data throughout the year. The current metre and the float method are only applicable during raining season and are not capable of providing stream discharges all year round data for small rivers.

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 in one of the northernmost tributaryof River Kubanni, Zaria, Nigeria. Although the weir technique is more superior to the current metre and float method because it readily provides stream discharge throughout the year while the current metre and float method are only applicable after rainstorm or when the raining season is well established. With this it is therefore recommended that the weir technique should be used to measure stream discharges of small rivers like Malmo, Zaria Nigeria.

RECOMMEDATION

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

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.

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

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.

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