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ESTIMATION OF OUTFLOW DISCHARGE FROM AN UNGAUGED RIVER: CASE STUDY OF AWARA IN ONDO STATE SOUTHWESTERN, NIGERIA.

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ABSTRACT

Flooding has become the annual experience of Nigerian cities especially in the southwestern states of country, precisely Ondo state. This study uses Muskingum Cunge method river routing techniques to compute outflow discharge and to determine hydrographs of inflow and outflow pattern of Awara river Ikare Akoko, North east LGA in Ondo State, Southwestern of Nigeria. The Muskingum Cunge method of flood routine reflects the inter-relationship existing between the inflow and outflow of river. The average monthly inflow discharge for twenty years was worked on using Muskingum Cunge method of flood routine. Observation from the hydrograph shows that inflow peak occurs in the month of April, while the outflow in the same month is very low. This implies that the month of April is a critical month that needs a special attention and there is a need for channelization of this river before the month of April every year, in order to prevent occurrence of flooding whenever there is heavy rainfall.

Keywords: Flooding, Muskingum Cunge Method, Discharge, Hydrograph, Inflow peak

INTRODUCTION

Flooding is one of the major environmental crises one has to contend with globally. This is especially the case in most wetlands of the world. The reason for this is the general rise in sea level globally, due to global warming as well as the saturated nature of the wetlands in the Niger Delta. Cities in developing countries are particularly vulnerable to climate change impacts, especially changes in rainfall because of the exposure to extreme weather events. Excessive rainfall leads to flooding especially in areas with poor natural drainage systems, areas where water inundates the capacity of the soil to contain water and in areas where poor land use practices prevents drainages from channeling excess water away. (Tapsell and Tunstall, 2008; Eychaner, 2015; Borga *et al.*, 2010; Strydrom, 2002; Jonkman and Kelman, 2005).

Floods are defined as extremely high flows of river, whereby water inundates flood plains or terrains outside the water-confined major river channels. Flood hazard is measured by possibility of occurrence of their damaging consequences,

conceived generally as flood risk, or by their impact on society, conceived usually as the loss of lives and material damage to society. Floods cause enormous economic damage and human suffering needing control measures to reduce the impacts of flood in vulnerable areas. Flooding is the most frequent and costly of all natural disaster (Jones, 2000; Chanson et al., 2014; Burningham et al., 2008; Dyhouse, 2003; Apel et al. 2004).
Incidents of flood in Nigeria have attained emergency level. For example, the flood incidents of the year 2012 affected many geopolitical zones of the country, taking not less than 400 lives and damaged property worth trillions of naira., The purpose of this work is to predict flooding peak. This will serve as Flood Forecasting and Early Working System (FFEWS) for the people living in these areas. It was observed that in the recent and past times, the several incidents of flood were experienced at different parts of the country, as a result of a lack of coordinated prevention plan and non-availability of current or improved FFEWS in the country. For example, in late July 2012, at least 39 people were killed due to flooding in the central Nigerian Plateau state. Heavy rainfall caused the Lamingo dam to overflow near Jos, sweeping across a number of neighborhoods in Jos and approximately 200 homes were submerged or destroyed. In addition, at least 35 people were missing.

Accurate prediction of flood propagation is essential to take necessary measures for protection and warning system. Attempts have been made in the past to monitor river that causes flooding in the country, but with limited success. This present work will provide recent and reliable flooding risk map and dynamic model for FFEWS for the rivers and streams that are prone to flooding in the Southwestern part of Nigeria using Muskingum method.

Flood problems in Nigeria have taken a new dimension in recent time. There is increasing vulnerability of populations and infrastructure to flooding and flood related hazards. More communities are now been affected in the country. Flooding is among the most devastating natural hazards in the world claiming more lives and causing damage to property and infrastructure than any other natural phenomena (Casas et al. 2006; Alabi et al., 2017).

The great floods have also reduced Nigeria's crude oil production drastically by 500,000 barrels per day (bpd) in the Niger Delta (citation). The rate of spread, number of internally displaced persons and magnitude of losses counted in the affected States have attracted the attention of the federal government of Nigeria.

Flood Management is currently a key focus of many national and international research programmes with flooding from rivers, estuaries and the sea posing a serious threat to millions of people around the world during a period of extreme climate variability.

METHODOLOGY

Location of the study area

Awara river in Akoko North East Local Government Area of Ondo State, Nigeria is located; Longitude 70-30' and 80-00 'E and Latitude 50-30'and 60-00' N. The dam was built in the 1950s to supply water to Ikare township, Arigidi, Ugbe, and Imo-Arigidi.

Muskingum modeling method

The basic model used to carry out flood forecasting in this study is the Stream channel routing (Bates et al. 1996; Prachansri 2007). Stream channel routing uses mathematical relation to calculate outflow from a stream channel once inflow, lateral contribution and channel characteristics are known. Stream channel routing usually implies open channel flow conditions although there are exceptions, such as storm sewer flow, for which mixed open channel closed conduit flow condition may prevail. Two general approaches to stream channel routing are recognized, they are hydrologic and hydraulic approaches. An alternate approach to hydrologic and hydraulic routing as emerges in recent years. This approach is similar in nature to the hydrologic routing method yet contains sufficient physical information to compare favorably with the more complex hydraulic routing techniques. This hybrid approach is the basis of Muskingum Cunge method of flood routing (Papamichail and Georgiou, 1992; Yoon and Padmanabhan, 1993).

Muskingum method of flood routing was developed in the 1930's in connection with the design of flood protection schemes in the Muskingum River basin, Ohio, it is the most widely used method of hydraulic stream channel routing with numerous application in the United State and throughout the world.

The Muskingum method is based on the differential equation of Storage

$$I - O = \frac{ds}{dt} \quad (1)$$

In an ideal channel, storage is a function of inflow and outflow. This is the contrast with ideal reservoir in which storage is solely a function of outflow. In Muskingum method, storage is a linear function of inflow and outflow

$$S = K[XI + (1 - X)O] \quad (2)$$

Where S = Storage volume (m^3/s),

I = Inflow (m^3/s),

O = Outflow (m^3/s),

K = Time constant or Storage coefficient (hr.)

X = Dimensionless weighing factor

Alternatively, K could be expressed in seconds, in which case Storage volume is in m^3

Equation (2) above was develop in 1938 and has been widely used since then. To derive the Muskingum routing equation, equation (1) is discretized on the x-t plane to yield:

$$\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} = \frac{S_2 - S_1}{\Delta t} \quad (3)$$

Equation (2) is expressed at time level 1 and 2:

$$S_1 = K[XI_1 + (1 - X)O_1] \quad (4)$$

$$S_2 = K[XI_2 + (1 - X)O_2] \quad (5)$$

Then substituting equation (4) and (5) into equation (3) and-solving for O_2 yield

$$O_2 = C_0I_2 + C_1I_1 + C_2O_2$$

In which C_0, C_1 & C_2 are routing coefficients defined in terms of Δt, K and X as follows

$$C_0 = \frac{\Delta t/k - 2X}{2(1 - X) + \Delta t/k} \quad (6)$$

$$C_1 = \frac{\Delta t/k + 2X}{2(1 - X) + \Delta t/k} \quad (7)$$

$$C_2 = \frac{2(1 - X) - \Delta t/k}{2(1 - X) + \Delta t/k} \quad (8)$$

The routing parameters K and X are related to flow and channel characteristics, K being interpreted as the travel time of the flood waves from upstream end to downstream end of the channel reach.

The parameter X accounts for the storage portion of the routing. For a given flood event, there is a value of X for which the storage in the calculated outflow hydrograph matches that of the measured outflow hydrograph. The effect of the storage is to reduce the peak flow and spread the hydrograph in time. Therefore it is often used interchangeably with the term diffusion and peak attenuation.

The routing parameter K is a function of channel reach length characteristics that causes runoff diffusion. In the Muskingum method, X is interpreted as the weighing factor and restricted in the range (0.0 to 0.5) Values of X greater than 0.5 produces hydrographs amplification (negative diffusion) which does not correspond with reality.

Sources of data

Data was obtained from "Detailed Project Report for Awara Dam/Oyimo River Hydro Power Development, Ikare, Akoko North-East LGA, Ondo State by UNIDO Regional Centre for Small Hydro Power In Africa, Abuja, Nigeria (UNIDO-RC-SHP, 2010).

Statistical analysis of data

The annual peak discharges were plotted against their corresponding periods. The daily stream flows of each month were added up to obtained the monthly total of all discharge. The estimated monthly discharges were converted into the volume of flow using the equation.

$$V_m = Q_a \times D \times 24 \times 3600 \quad (9)$$

Where: V_m - monthly total volume, Q_a - monthly volumetric flow rate

D - number of the days in which the observed discharges were recorded

To calculate the outflow of each month of the year, we apply the model equation having known our parameters such as the discharge (Q_a) as given and Inflow (V_m) as calculated, we thus calculate using:

$O= C_0I_2 + C_1I_1 +C_2O_2$

First, it is necessary to select the time interval Δt, in this case it is convenient to choose $\Delta t = 30$ d. In addition the chosen time interval should be such that the routing coefficient remains positive. With $\Delta t = 30$, $K = 60$, $X = 0.1$, $C_0 = 0.1304$, $C_1 = 0.3044$ and $C_2 = 0.5652$

Since $(C_0 + C_1 + C_2) = 1$, the routing coefficients can be interpreted as weighing coefficient.

RESULTS AND DISCUSSION

The result in table 1 was obtained by using Muskingum Cunge method of flood routine. Serial number 1 – 12 in the table indicate January – December. The table shows the inflow volumetric rate in third column and the corresponding outflow volumetric rate in the seventh column for thirty (30) days interval. The inflow in the second row is an input data from which the corresponding outflow and subsequent inflows and outflows were obtained by routine iteration.

Table 1: Data of inflow at a monthly interval and corresponding outflow

S/N	Time (day)	Inflow V_m (m^3/s)	C_0I_2	C_1I_1	C_2O_1	Outflow (m^3/s)
0	0	0	0	0	0	0
1	30	25401.6	710.358	7730.922	14357.426	22798.706
2	60	5446.08	22475.268	1657.503	12886.225	37018.996
3	90	172310.39	33095.707	52442.293	20923.78	106461.78
4	120	253733.75	36565.983	77223.315	60174.049	173963.347
5	150	280339.2	43455.442	85320.626	98327.109	227103.177
6	180	333158.39	52030.83	101396.032	128362.666	281789.527
7	210	398903.03	45695.833	121405.27	159272.342	326373.445
8	240	350334.72	54336.584	106623.61	184471.947	345432.142
9	270	416580.48	44740.925	126785.363	195244.254	366770.543
10	300	343013.76	11924.701	104395.492	207305.089	323625.283
11	330	91422.71	23360.306	27824.303	182918.638	234103.247
12	360	179095.68	23360.306	54507.381	132319.227	210186.914

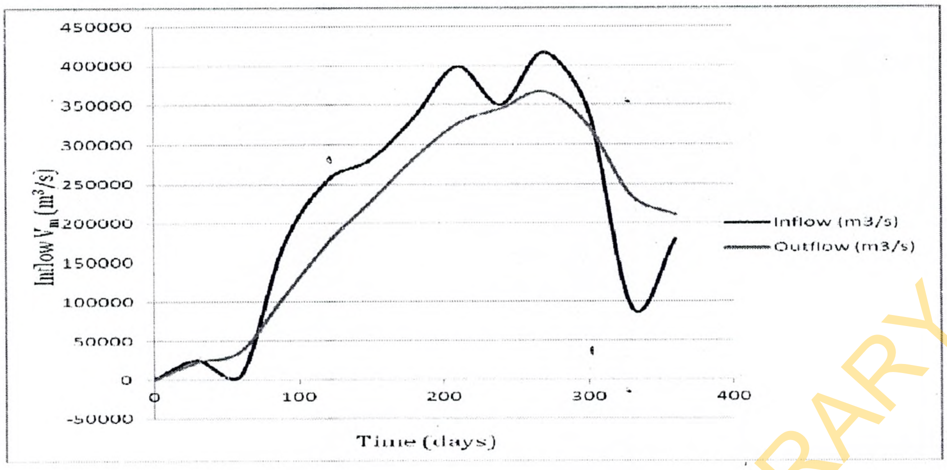

Figure 1: Hydrograph of inflow and outflow rate for a period of a year

Fig 1 shows the hydrograph of the inflow rate and outflow rate for river. It indicates that inflow has two (2) peaks, while outflow has only one peak. The peaks for inflow are 416580.48m^3/s in the month of September and 398903.03m^3/s in the month of July. The hydrograph shows that inflow rate is greater than outflow rate. It was observed that inflow rate. It was observed that inflow rate and outflow rate are more or less equal in month of January. This might be as a result of lower inflow rate or due to dry season during this period.

Table 2 shows the computed river discharge at a monthly interval and subsequent outflow. Serial number 1 – 12 in the table indicate January – December. The table shows the computed river discharge in third column and the corresponding outflow volumetric rate in the seventh column for thirty (30) days interval. The inflow in the second row is an input data from which the corresponding outflow and subsequent inflows and outflows were obtained by routine iteration.

Table 2: Computed River discharge and the corresponding outflow

S/N	Time (day)	Discharge Q_a (m^3/s)	C_0I_2	C_1I_1	C_2O_1	Outflow (m^3/s)
0	0	0.01	-	-	-	0.01
1	30	0.002	0	0.003	0.006	0.009
2	60	0.064	0.008	0.001	0.005	0.014
3	90	0.979	0.128	0.02	0.008	0.155
4	120	0.105	0.014	0.298	0.088	0.399
5	150	0.129	0.017	0.032	0.226	0.274
6	180	0.149	0.019	0.039	0.155	0.214
7	210	0.131	0.017	0.045	0.121	0.183
8	240	0.161	0.021	0.04	0.103	0.164
9	270	0.128	0.017	0.049	0.093	0.158
10	300	0.035	0.005	0.039	0.09	0.135
11	330	0.067	0.009	0.011	0.075	0.095
12	360	0	0	0.02	0.054	0.074

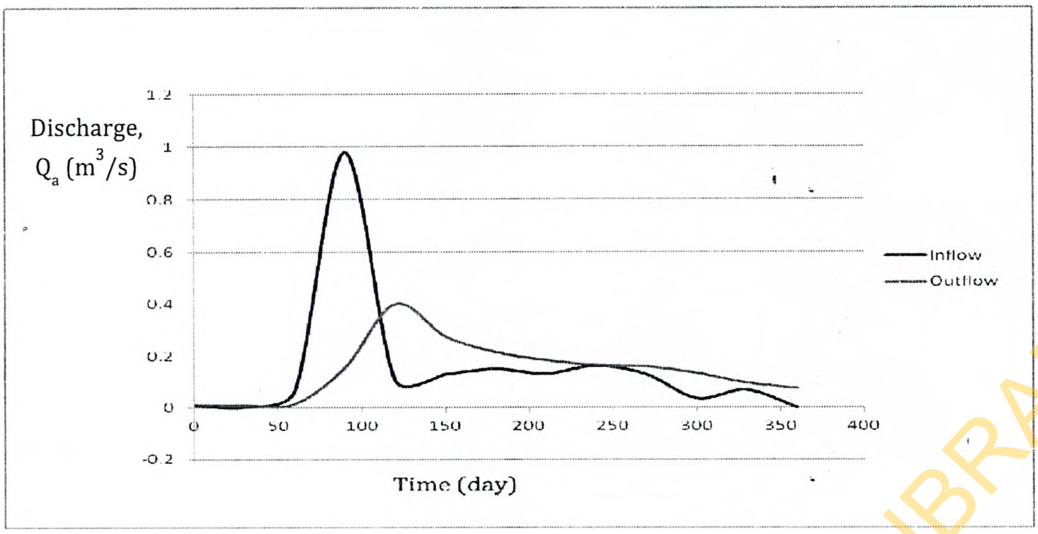

Figure 2: Hydrograph of the discharge (m^3/s) against time (day)

Fig. 2 shows that the inflow discharge has a peak of 0.97 in April while outflow has a peak of 0.398 in May of the same year. This shows an interval of a month (30 days) between the inflow and outflow peak. This implies that, it will take at least 30 days for any flooding shift to return back to normal in this location. The environmental risk implication of this is that, whenever there is a flooding, it will take at least a month before the place can be safe for habitation. Furthermore, there is a very wide gap between the inflow peak and outflow discharge in April. This shows that the rate of outflow is far lagging behind the inflow in this river for the month of April. This make the month of April to be critical. Thus, there is a need for channelization of this river before the month of April every year.

CONCLUSION

Whenever the inflow discharge is far higher than the outflow discharge, this may result into flooding. It was observed that there is a very wide gap between the inflow peak and outflow discharge in April. This shows that the rate of outflow is far lagging behind the inflow in this river for the month of April. Thus, there is a need for channelization of this river before the month of April every year, in order to prevent occurrence of flooding whenever there is heavy rainfall. This process could be used to estimate outflow discharge of any river with known parameters.

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