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Computation Of Outflow Discharge of Lower River Ogun, South-Western Nigeria Using Muskingum Model

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Abstract
Flood in Nigeria have become a recurring disaster , causing devastating and loss of life. Nigeria flood problem is complex, with both natural and man-made causes especially in the south-western states, precisely Ogun State. The study adopt Muskingum model to estimate the outflow discharge in order to determine the inflow and outflow of Lower River Ogun, South-Western of Nigeria. The model was used to established relationship between the inflow and outflow of the River. The average monthly inflow discharge for Twenty Three (23) year was used to compute corresponding outflow discharge using using muskingum flood routine method. It was observed that the peak inflow occur in the month of September while the outflow is low in the month of August. This implies that the month of June is a critical month that needs special attention and there is need for channelization of this River before month of May every year, in order to prevent occurrence of flooding whenever there is heavy rainfall.

Keywords: Flooding, Outflow Discharge, Inflow Discharge, Muskingum Model, and Lower River Ogun.

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I. Introduction

Flooding in River Ogun as the perennial annual problems occurring in Ogun state during the rainy season due to largely release of water from the multi-purpose Oyan Dam reservoir built across Oyan River, a tributary of River Ogun, located in Abeokuta North Local Government of Ogun State.

Oyegoke and Sojobi (2012) submitted that this scenario have reiterated the urgent need for a paradigm shift in the design, construction, operation, modelling and management of River and Dams. The flow of the River Ogun network is influenced by rainfall in upstream region. Over the years, there had been cases of downstream flooding attributed to release of water from the Oyan Dam (Ufoegbune *et al.*, 2011).

The morphological study of river needs to be properly documented and analysed to understand the unique characteristics of each river. This is imperative so that the responses of the river due to any encroachment in the flood plain and for future man-made structures may be anticipated and preventive measures, as considered necessary, may be planned beforehand (Odunaya, 2008). Most rivers, particularly River Ogun, River Ofiki and River Opeki are not fully gauged with the resultant evidence of little or no hydrological record. Since independence, a larger number of development and protective works have been taken up on different river basins all over the country (Olatunji, 2012). The developmental works include construction of irrigation hydro-power, multipurpose water resources projects and navigation works. The protective works include flood embankment, marginal embankments, channels improvement and erosion control works. Most of the protective works have been taken up on major rivers where the problem of river instability and consequent bank erosion are particularly severe (Olusola, 2012).

Bahadori *et al*. (2006) opined that for a scientific approach to different river problems, proper planning and design of water resources project, an understanding of the morphology and behaviour of the river is a prerequisite. The morphology of river is a field of science which deals with the change of river plan, form and cross sections due to flooding and erosion. The morphological studies therefore play an important role in planning, designing and maintaining river engineering structures. In recent years there has been a growing awareness about the need for taking up morphological study of rivers in the country, especially with particular reference to their unique problems (Adegbola and Olaniyan, 2012).

Hughes (2009) affirmed that rainfall agencies in Nigeria were not dedicated to keeping accurate records. There were reported cases of missing and misleading data even in the major cities of the country. Nigeria's rivers were neglected and have tonnes of garbage deposited into them annually. Ragunath (2006) submitted that more than 80% of the rivers have no flow records, some of the rivers have flow records of duration less than 10 years with large missing data. Rainfall data can be used to infer rate of flooding in any catchment area of a river (Adegbola, 2006). Adegbola and Jolayemi (2012) simulated the flow condition of river Ogunpa using rainfall data obtained from Ogun Oshun River Basin Development Authority (OORBDA) in order to mitigate flooding of River Omi, South-Western, Nigeria.

II. Materials and Methods

2.1 Brief Description of Study Area

This research is intended for lower River Ogun, south-western, Nigeria, located within Ogun state. It is a waterway in Nigeria that discharges into Lagos lagoon. The river rises in Oyo state near Shaki, and flows through Ogun state into Lagos state (Nihinlola, 2004). It lies between longitude 2°28′ 33" and 3° 48′ 08" Easthing and Latitude 6° 37′ 10" and 9°26′ 39" Northing with catchment area of about 23,000 Km^2. Ogun River takes its source from Igaran hills at an elevation of about 530 M above mean sea level and flows directly southwards over a distance of about 480Km before it discharges into Lagos lagoon (Olusola, 2012). Lower River Ogun is a big river cutting cross three states with more than twenty (20) tributaries, one of which is Oyan River. Its major tributaries is south of Abeokuta area (Sojobi and Oyegoke, 2012). River Onigbongbo and Ewekoro, lies within North of Abeokuta that flows southward into Oyan River which supplies water to Abeokuta and its environments (Ikenweirwe *et al.*, 2007).

2.2 Muskingum Model

The water budget across River Ogun was analysed using water balancing approach. The daily stream flows of each month were added up to obtain the monthly total of all the discharge (Alabi *et al*., 2017). The estimated discharge were converted into the volume of flow using equation:

$$V_m = Qa \times D \times 24 \times 3600 \quad (1)$$

Where:
V_m = monthly total volume
Q_a = monthly volumetric flow rate.
D = number of the days in which observed discharges were recorded.
To calculate the outflow of each month of the year, the model equation was applied.

$$I - O = \frac{ds}{dt} \quad (2)$$

Where I = estimated volumetric flow rate
O = outflow rate
S = storage
K and x were determined based on river channel reach. The balance equation;

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

But can also be re-written as;

$$S_2 - S_1 = K(x(I_2 - I_1) + (I - x)(O_2 - O_1) \quad (4)$$

Combining the two equations and re-arranging terms,

$$O_2 = C_o I_2 + C_1 I_1 + C_2 O_1 \quad (5)$$

Where:
O = outflow rate

$$C_o = \frac{(Kx - 0.5\Delta t)}{K - Kx + 0.5\Delta t} \quad (6)$$

$$C_1 = \frac{(Kx + 0.5\Delta t)}{K - Kx + 0.5} \quad (7)$$

$$C_2 = \frac{(K - Kx - 0.5\Delta t)}{K - Kx + 0.5\Delta t} \quad (8)$$

$C_0 + C_1 + C_2 = 1$ as outlined by (Alabi *et al.,* 2017)

The model equation were applied after determining discharge (Qa) and inflow (Vm). It is necessary to select the time interval Δt, routing period (k), and weighing factor (x). In this case it is convenient to choose Δt = 30, K = 60, x = 0.17. These were adopted from literature of flood routing (Ogbonna, 2017; Hakim *et al*., 2016 and Alabi *et al*., 2017). The C_0 = 0.0740, C_1 = 0.3888 and C_2 = 0.5370. Since ($C_0 + C_1 + C_2$) = 1, the routing coefficient can be interpreted as weighing coefficient (Birdie and Birdie, 2005).

2.3 Collection of Hydrological Data

The data used in this paper was collected from Ogun Oshun RiverBasin Authority (OORBA), Ogun State, Nigeria. The Eighteen year available discharge dat was collected from 1995 t0 2018.

III. Results and Discussion

In 1999, the inflow rate was higher than the corresponding outflow, this implied that there would not be flooding, the peak inflow and outflow was observed in September. The inflow was at its peak in September with its corresponding peak outflow in December in the year 2000. In 2001, the inflow was at its peak in September, while the peak outflow was observed in November, of the same year. This shows two months interval (60 days) between the inflow and outflow peak. It implies that it will take at least two months before the place can be safe for habitation whenever there is flooding. The inflow and outflow was at its peak in the month of September and December respectively in the year 2002. The environmental risk implication of this is that, whenever there is flooding, it will take at least three (3) months before the place can be safe for habitation. In 2003, the peak inflow and outflow was observed in October of the same year with inflow value higher than outflow. From the year 2004 to 2006, the outflow value was higher than the inflow value most especially in the month of October for the inflow while the month of December for the outflow. This implied that there would be flooding in the month of October.

It was observed from the Table 1 that from the year 2007 to 2011, the inflow value was higher than the outflow value in the month of July and September, while the outflow was at its peak in the month of December, when there will be no flooding for those years. In 2012, the peak inflow and outflow was observed in the month of September and December respectively. The peak outflow was higher than peak inflow for that year, there would be flood in the same year. This shows an interval of three (3) months between the inflow and outflow. This implies that whenever there is a flooding, it will take at least three months before the place can be safe for habitation. In 2013, the inflow was high in September with corresponding high outflow observed in the same year. The inflow is higher than the outflow for such year, there will be no flood.

In 2014, the peak inflow was observed in July with corresponding peak outflow in the month of August. The peak inflow and the corresponding outflow were observed in the year 2015 in the month of November. In 2016, the inflow was high in October and the outflow was at its peak in the same month of October. In the year 2017, the peak inflow was observed in August while the peak outflow was observed in November. This might be as a result of the lower discharge rate. In 2018, the peak inflow was observed in September with the corresponding peak outflow in October the same year. From 2014-2018, the peak inflow rate is higher than peak outflow, which implied that there would be no flood in lower River Ogun for those years.

Figure 1 shows the hydrograph of the inflow rate and outflow rate of Lower River Ogun from 1995-2018. The peak inflow and outflow for each year is presented in the Figure. It indicates that inflow has two (2) peaks, while outflow has only one peak. The peaks for inflow are 1085460480 m^3/s in the year 1997 and 4943380800 m^3/s in year 2018. While the peak outflow is 2298080347.00 m^3/s in the year 2018. The hydrograph shows that inflow rate is greater than the outflow rate. This might be as a result of lower discharge rate due to low rainfall intensity.

Table 1: Computed Inflow and Corresponding Outflow of Lower River Ogun for the year 1995

S/N	Time (day)	Inflow Vm (m^3/s)	C_0I_2	C_1I_1	C_2O_1	Outflow (m^3/s)
1.	30	40042080	2546159.62	15568360.70	21502596.96	39617117.28
2.	60	36167040	3024556.42	1175947.54	21274391.98	25474895.94
3.	90	40872384	2963433.60	15893070.29	13680019.12	32716183.17
4.	120	40046400	3143093.76	15570040.32	17568590.36	36281724.44
5.	150	42479424	3207029.76	16516000.05	19483286.03	39206315.84
6.	180	43338240	8768438.78	16849907.71	21053791.60	46672138.09
7.	210	118492416	9355115.52	46069851.34	25062938.16	80487905.02
8.	240	126420480	35342542.08	49152282.62	43222004.99	127716829.40
9.	270	477601920	15836307.84	185691626.50	68583937.40	270111871.70
10.	300	214004160	28560211.2	83204817.41	145050075.10	25681510.37
11.	330	38594880	28349222.40	150056893.40	137909710.70	316315826.50
12.	360	38309760	28349222.40	148948346.90	169861598.80	347159168.10

Table 2: Computed Inflow and Corresponding Outflow of Lower River Ogun for the year 2018

S/N	Time (day)	Inflow Vm (m^3/s)	C_0I_2	C_1I_1	C_2O_1	Outflow (m^3/s)
1.	30	39238560	2835689.47	15255952.13	21071106.72	39162748.29
2.	60	38320128	24246967.68	14898865.77	21030395.83	60176229.28
3.	90	45152640	2900136.96	17555346.43	32314635.12	52770118.51
4.	120	39191040	22543833.60	15237476.35	28337553.64	661118863.59
5.	150	304646400	18668289.02	118446520.30	35505829.75	172620639.10
6.	180	252274176	17602220.16	98084199.63	92697283.18	208383703.00
7.	210	237867840	29134100.74	92483016.19	111902048.50	233519165.40
8.	240	393704064	36584179.20	153072140.10	125399791.80	315056111.10
9.	270	4943380800	40020099.84	1921986455.00	169185131.70	331191686.50
10.	300	540812160	17552733.70	2102677678.00	177849935.70	2298080347.00
11.	330	237199104	3203960.83	922230116.40	1234069147.00	2159503224.00
12.	360	43296768	3203960.83	16833783.40	1159653231.06	1179690975.60

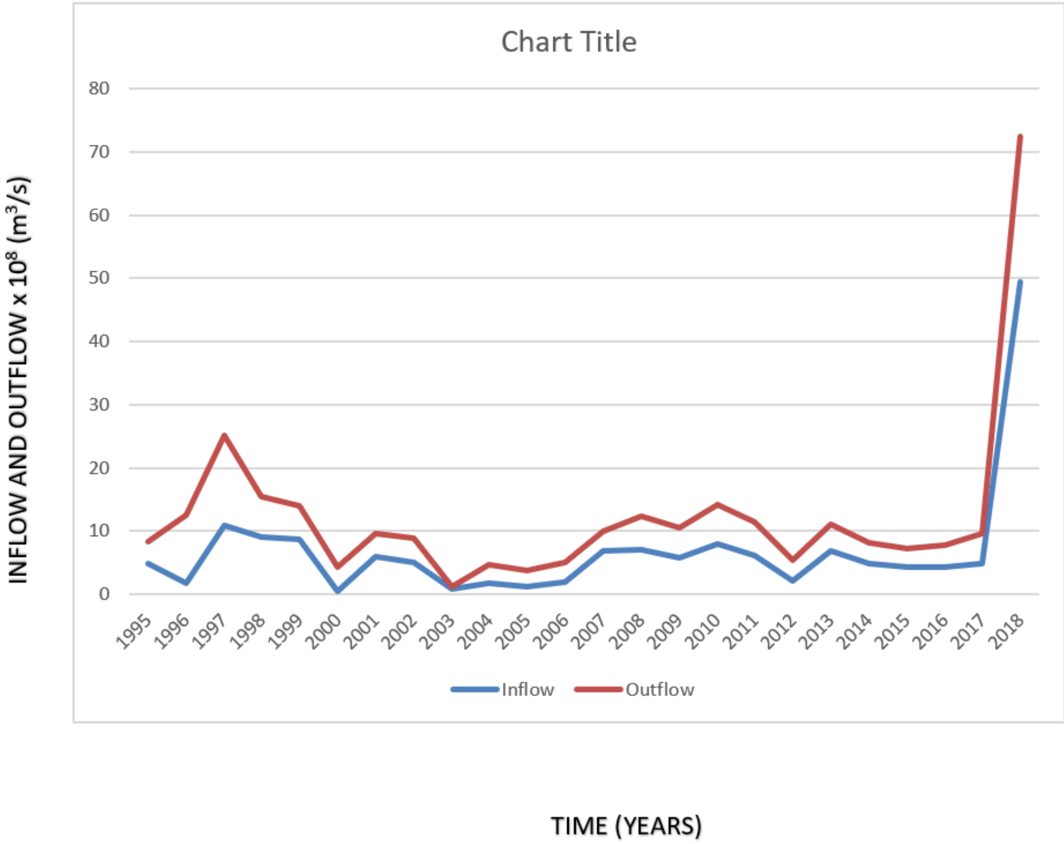
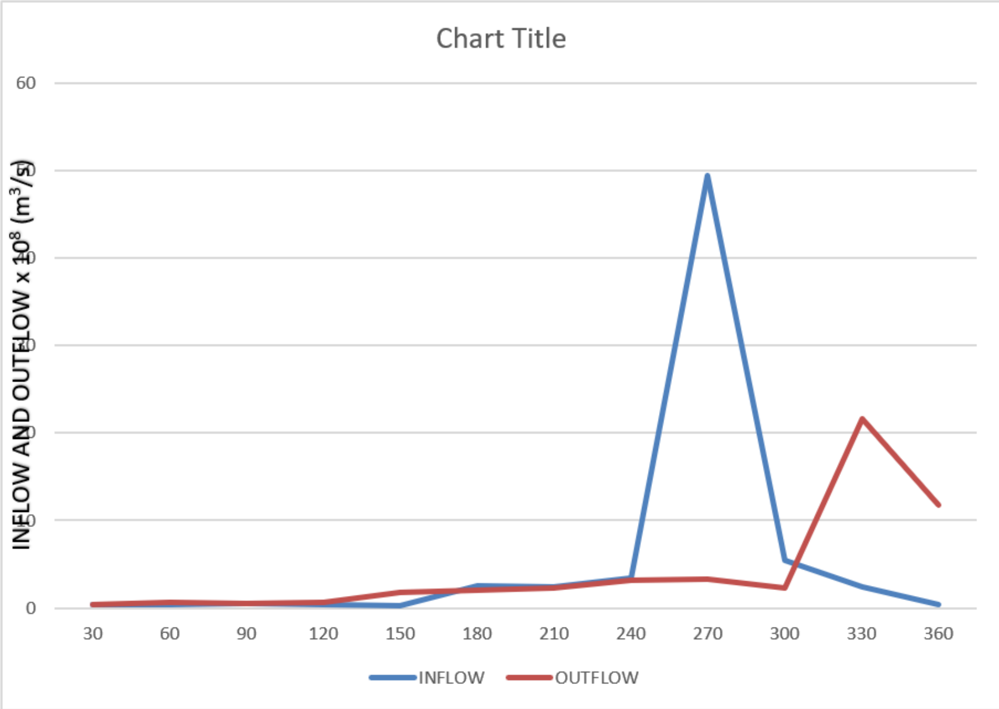


Figure 1: Hydrograph of Inflow and Outflow rate for the period of years.



TIME (DAY

Figure 2 : Hydrograph of Inflow and Outflow against time (days).

IV. Conclusion

I. Whenever the inflow discharge is far higher than the inflow discharge, this may resulted into flooding.
II. There is a wide gap between inflow and outflow discharge in September.
III. There is need for channelization before the month of June every year.

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