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MODELING OF STORM WATER DRAINAGE SYSTEM FOR OBUBRA LOCAL GOVERNMENT AREA, CROSS RIVER STATE OF NIGERIA

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ABSTRACT

A model was developed for the Obubra catchment and subsequently applied in the study of the catchment basin. The model developed gave a multiple regression correlation of 0.994 at a significance level of 0.05. The model was calibrated using the first ten (10) set of values and a correction of 0.995 was obtained and was further verified using the second set of ten (10) values which gave a correlation of 0.995. the model was also validated using velocity- area method for water flow measurement having a relationship as Q= AV with a correlation of 1.0. Although, studies conducted in different areas have shown that a hundred percent (100%) success may not always be achieved in the urban environment yet, their damaging effects can be mitigated through management measures that can carefully designed by government or affected communities. Adequate constitution and routine maintenance of drainage channels be made, ensuring that the velocity satisfies the minimum requirement.

Keywords: discharge, drainage, modeling, storm water, urbanization

INTRODUCTION

Storm water drainage has become a central issue in urban planning and management particularly in developed countries with substantial urban infrastructure in place. The magnitude of investment required to construct, operate and maintain urban storm drainage facilities and the potential for significant adverse social and environment impacts mandate to the use of the best possible methods of planning analysis and design .Land properly drained encourages effective tillage operations, Drainage systems are required in urban areas due to the relationship which occurs between human activity and the water cycles to provide water supply for human life, and the covering of land with impermeable surfaces that divert rain water away from the local natural system of drainage (Butler and Davies, 2004).Hydrological model is a simplified representation of a natural system. It can be said that "a model is a collection of symbols. If storm water were not properly drained, it will cause in conveniences, flooding and further health risks. It contains some further health risks. It contains some pollutants, originating from rain, the air or the catchment surface.

Urban drainage systems handle these types of water with the aim of minimizing the problems caused to human life and the environment. The increase in population density and buildings exert the most obvious influence on hydrological process in an urban area. Modification of the land surface during urbanization alters the storm water runoff characteristics.

The major modification which alters the runoff processes is the impervious surface of the catchment such as roofs, side waves, road ways, and parking lots, which were previously mentioned. Natural channels which were in existence before urbanization is yet another factor and storm drainage pipes are laid in the urbanized area to convey runoff rapidly to stream channels. Urban drainage systems should be designed to handle storm water and waste water with the aim of minimizing the problem encountered.

Traditionally, wet- weather collection systems have been designed to move storm water from the urban areas as quickly as possible providing safe drainage and thus avoiding problems of local flooding. This traditional conveyance approach leads to problems with decreasing ground water levels high downstream discharges and releases of pollutants to receiving water bodies. A comprehensive review of urban storm water models was made by Zoppu (2010). The reviewed models vary both terms of complexity and input data requirement and have been categorized in terms of their functionality, accessibility, water quantity and quality components and their temporal and spatial scale. Zoppu (2001) conclude that all models can be used as planning models, some as design tools but very few as operational tools.

MATERIALS AND METHODS

Description of area of study Obubra is located at the Central Senatorial District of Cross River State, Nigeria. The state is bounded in the North by Benue State in the West of Ebonyi and Abia State, South West by Akwa Ibom State and the Cameron Republic in the East. It lies between Latitude 6^0 5^1 N Of the equator and Longitude 8^0 18^1 E within the rainforest Zone of South Nigeria (Figure 1). It has an area of 1115km with a population of 172,549 based on the 2006 census. The mean annual rainfall of the area is 2250- 3000mm per annum and a mean annual temperature of between 21^0C -29^0C CRADP (1992). They main crops cultivated are yam, maize, melon, cassava, sweet potatoes, cocoyam and vegetables. It is expected that there will be an increasing need for industrial use of the river base on the development programs that are being put in place by state government and others.

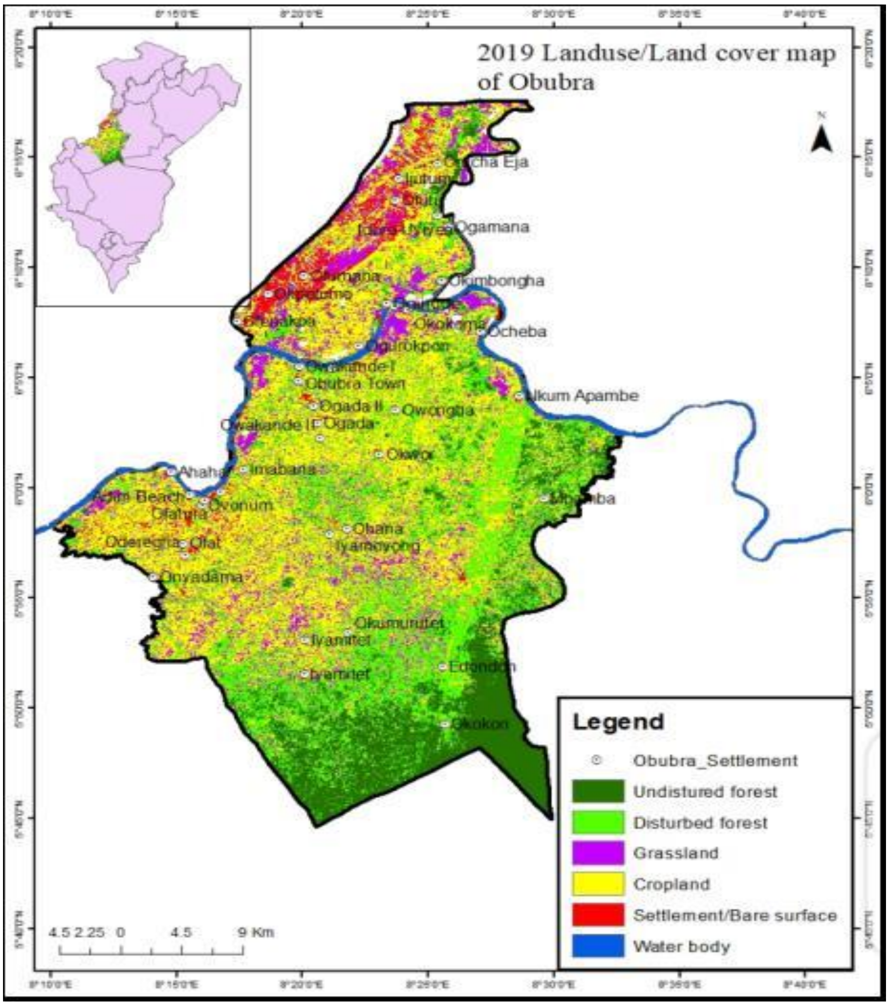

Figure 1: Map of Obubra Local Government Area.

Rainfall and Evaporation Data.

Rainfall and Evapo-transpiration measurements for the data were done in Nigeria Meteorological Centre (NIMET) of the Margaret Ekpo International Airport Calabar, Cross River State. Two sets of rainfall data obtained for the study. The first was a twenty -four (24) months daily rainfall data, while the second one was thirty-six (36) yearly/monthly rainfall data from 1979 to 2014.

Land use data

This was obtained from the most recent use topo map (2014) of the study area obtained from the State Ministry of Lands and Survey Calabar. The Land Development Software was engaged with the application of the poly-line approach in discretizing both the total basin area and the area that has become built- up (Okon, 2012).

Slope of the Catchment

The topographic map with the aid of Land Development Software was use to generate the sub- catchment of the area, the profiling approach was equally employed for confirmation.

The study area was divided into regular grids of 25m by 25m square. Stakes were dumpy level was used to determine the elevation of the corner points with equal elevation were joined to produce a contour map which assisted in the computation of the slope using the expression;

$$G = \frac{\Delta Y}{\Delta X}$$

Where Δy = Change in height between the first and the last contour

Δx = Corresponding horizontal distance

A global positioning system (GPS) instrument was used the entire length of the flow was covered within the sub- drainage basin. The plot of the inlet and outlet elevation was obtained to the overland flow length. The tangent of the angle formed gave the value of the slope (Uyanah 2006; Okon, 2012).

Mulligan and Wainwright (2004) identified three (3) purposes among others to which a general model is usually put. They include; An aid to research, as a tool for simulation and prediction and as a research product.

To effectively execute the objectives of this study, different approaches were employed to develop a model with the right result to serve as a tool for the analysis of storm water drainage in Obubra catchment.

Water Balance Process

The water balance process was used in the models between (a) Input from the catchment (rainfall), (b) Output from the catchment (runoff), (c) Losses from the catchment (evapotranspiration)

The model developed was guided by the use of the following existing equations to suit the required objectives of the research. The modified balance equation may be summarized as;

$Rr + Rc + Ri + Rt + Si + Lg = Ei + Tp = Se = Og + \Delta s$

Where Rr = recharge from rainfall, Rc = recharge from canal seepage, Ri = recharge from field irrigation, Rt = recharge from tanks, Si = influent seepage from rivers, Lg= inflow from other business, Et = evapotranspiration ground water, Tp = draft from ground water, Se = effluent seepage to rivers, Og = outflow to other business and Δs = Change in ground water.

The water balance is a method by which we account for the hydrological cycle of specific area with emphasis on plants and soil moisture. In its simplest form (see figure 2), the equation needs inflow = outflow + recharge in storage (O)

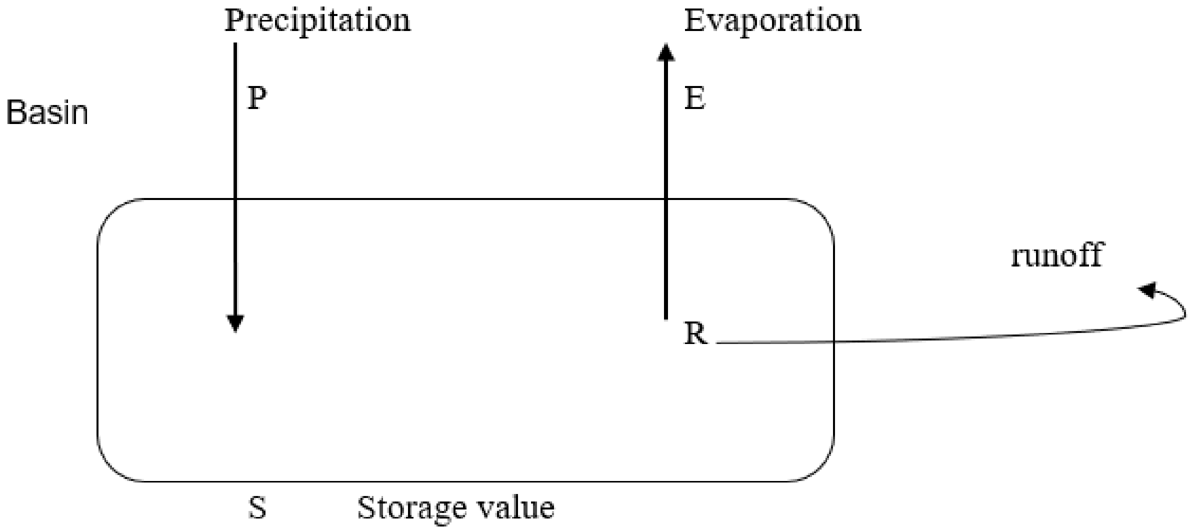

Figure 2: Illustration of water balance diagram

RESULT AND DISCUSSIONS

The model developed has the following variable: A= cross sectional area (m^2), W= width of channel (m), V= velocity of flow (m/s) and D = depth of channel (m)

Twenty (20) data set (table 1) were selected to carry out the modeling of storm water drainage of Obubra catchment. The first Ten (10) values was used for the calibration of the model and the last ten (10) data for verification of the said model as shown in table below. The parameters were measured using a current meter on the river close to the area affected by storm

Table 1: Relationship between depth, width, velocity, cross sectional area and discharge.

	Depth(m)	**Width**	**Velocity**	**Area**	**Measured Discharge (Q)**	***Predicted Discharge (Q)***
1	4.5	362.33	1.992	1630.485	3247.926	3306.303
2	3.7	501.12	1.676	1854.144	3107.545	3060.098
3	5.3	467.61	1.050	2478.333	2602.250	2732.356
4	4.1	352.06	1.652	1443.446	2384.573	2463.783
5	5.7	272.47	1.454	1553.079	2258.177	2241.265
6	5.7	356.50	1.023	2032.050	2078.787	2099.122
7	5.7	356.50	1.020	2032.050	2072.691	2093.806
8	5.7	356.50	1.008	2032.050	2048.306	2072.540
9	3.3	578.10	1.045	1907.730	1993.578	2029.049
10	3.7	501.12	1.050	1854.144	1946.851	1950.732
11	5.3	325.72	1.104	1726.316	1905.853	1848.727
12	2.9	523.23	1.231	1517.367	1867.879	1851.840
13	3.7	501.12	1.900	1854.144	3522.874	3457.059
14	2.9	362.33	1.565	1050.757	1644.435	1812.044
15	3.3	585.05	1.800	1930.665	3475.197	3397.755
16	4.5	347.24	1.020	1562.580	1593.832	1494.591
17	3.7	346.72	1.211	1282.864	1553.548	1476.709
18	4.1	494.24	1.600	2026.384	3242.214	3141.393
19	3.7	342.06	1.104	1265.622	1397.247	1264.171
20	1.7	578.10	1.331	982.770	1308.067	1370.245

Table 2 below shows the Pearson Correlation between measured and predicted discharge represented by X and Y respectively, and it as well indicates the product of X and Y square of X and Y.

Table 2: The Pearson Correlation between measured and predicted discharges

X Measured	Y Predicted	xy	x^2	y^2
3247.93	3306.30	10738628.2	10549024.08	10931640.19
3107.55	3060.10	9509391.925	9656838.07	9364197.08
2602.25	2732.36	7110271.716	6771703.24	7465767.78
2384.57	2463.78	5875069.049	5686187.40	6070224.90
2258.18	2241.27	5061173.135	5099362.76	5023269.52
2078.79	2099.12	4363628.775	4321356.02	4406315.06
2072.69	2093.81	4339812.852	4296047.98	4384023.57
2048.31	2072.54	4245197.356	4195559.11	4295422.88
1993.58	2029.05	4045067.043	3974352.64	4117039.64
1946.85	1950.73	3797784.273	3790229.59	3805354.01
1905.85	1848.73	3523401.724	3632275.14	3417791.67
1867.88	1851.84	3459011.943	3488971.13	3429310.02
3522.87	3457.06	12178782.45	12410638.40	11951258.04
1644.43	1812.04	2979788.583	2704165.50	3283504.65
3475.20	3397.76	11807868.33	12076994.19	11544739.72
1593.83	1494.59	2382127.002	2540299.17	2233803.45
1553.55	1476.71	2294138.157	2413512.33	2180668.32
3242.21	3141.39	10185070.79	10511954.22	9868352.24
1397.25	1264.17	1766358.296	1952298.31	1598127.51
1308.07	1370.25	1792372.677	1711038.94	1877572.59
45251.83	**45163.59**	**111454944.3**	**111782808.20**	**111248382.83**

$$\boldsymbol{r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum x)^2}}}$$

$$r = \frac{20(111454944.3) - (45251.83)(45163.59)}{\sqrt{[20x111782808.20 - 2047728044)x(20x111248382.83 - 2039749699}}$$

$$\boldsymbol{r = \frac{2229098885 - 2043734978}{\sqrt{1879288120x185217957.4}}}$$

$$r = \frac{185363907.1}{186568117.64}$$

$$r = 0.993545464491829$$

$$r = 0.994$$

Table 3: Correlation matrix for the variables (Depth, Width, Velocity, Area and Discharge)

	Depth(m)	*Width*	*Velocity*	*Area*	*Discharge (Q)*
Depth(m)	1				
Width	-0.6552	1			
Velocity	-0.3112	0.187935	1		
Area	0.5959	0.180404	-0.166	1	
Discharge (Q)	0.12122	0.31068	0.731471	0.540934	1

The result from the correlation matrix (Table 3) for the variables shows that, there is a significant positive relationship between discharge and cross sectional area there is significant positive relationship between discharge and depth width and a strong positive relationship between discharge and velocity.

The develop mode for the study state

Thus;

$Q = -2417.75A + 11.68D + 0.33W + 1772.15V + 1.24A$

where; Q= discharge rate (m^2/sec), D= depth of channel flow (m), W= width of the channel flow (m), V= velocity of flow (m/s), A= cross sectional area (m^2)

CONCLUSION

The perennial flooding in most parts of Obubra cause by storm water has been a thing of grave concern to all residents and stake holders in recent times. In urban storm drainage systems studies, rainfall -runoff processes are normally analysed by the application of mathematical models sometimes in combination with others various water quantity and quality sampling techniques urbanization has been shown to increase surface runoff, by creating more impervious surface such as pavement and structures that impede percolation. When this happens, the water flow directly into streams of storm water runoff drains, where erosion and siltation can be major problems, even when flooding is not. A well-designed storm water system will improve this effectiveness of the natural system. More so, consideration should therefore be given to the importance of reducing erosion because of the potential for public and private property damage. A redesign of inadequate drainage channels of basin is recommended to ensure that the drains are adequate enough to safely discharge the runoff generated.

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