Causes and Prevention of Flooding and Erosion in Urban Centres: A Study of Kube-Atenda Community, Ibadan North Local Government Area, Oyo State, Nigeria.

Joseph Sunday Onyemesim, M. K. C. Sridhar and A.O. Coker

Abstract-- Flooding and erosion are common features of many communities in Nigeria, resulting into loss of lives and properties. Incessant flooding and erosion of these communities have been issues of concern for years to the residents. This study focused on Ibadan metropolis with particular attention to the flood and erosion prone community of Kube-Atenda along Queen Elizabeth II road in Ibadan North Local Government Area of Oyo State with the aim of finding its causes and proffering a lasting Engineering solution to it. Focus Group Discussions (FGD) and Key Informant Interviews (KII) were conducted among selected residents in the community to know their perceptions on causes of flood and erosion and how they have been affecting them. In addition, the roads in the community were examined physically and the condition of the drainage channels were assessed. The 35-year rainfall data of the project area collected was analysed and compared using the California and Hazen method to predict the expected flood pattern. From the comparison, Hazen method gave a larger return period greater than 50 years while the California method gave a return period less than 50 years. The graph of Hazen plotted for 0.33 hour rainfall duration against 25 years return period produced a rainfall intensity (I) of 727mm/hr. Quantity of discharge (Q) of 70.5m^3/s was obtained using the Rational formula (Q = 0.00278CIA) and was finally incorporated into Manning's formula to design an economic rectangular drainage/culvert. The results of the study revealed that most of the roads which were untarred in the area have bared surfaces without drainage, and where drainage exists, they are badly maintained and poorly sized. Also, natural and man-made factors are the principal causes of flood and erosion in the community under study. Conclusively, the designed proposed drainage/culvert showed that it was adequate to accommodate more than its designed hydraulic capacity so as to contain and discharge the runoff being generated from the Community into Kube (Alagbafo) stream and prevent further flooding and eroding of the Community.

Key Words-- Community, Drainage, Erosion, Flooding, Rainfall Intensity, Rational formula, Return period.

1 INTRODUCTION

Developing countries have been faced with the problems of flooding due to poor planning of their cities and the location of buildings and properties on flood prone areas, and flood plains. Even the developed countries do record some sort of flooding as a natural disaster, as any natural disaster cannot be averted but can be controlled, by controlling the level of devastation which it would have on the city and people, and the only way this is done, is by the forecast of the weather and the evacuation of properties and people from the area. The vision of Nigeria to be among the first top Twenty nations with leading economy by the year 2020 may be a mirage, if lives and properties are not safe from the frequent occurrence of flood in the country. Flood is one of the major factors that prevent Africa's population from escaping poverty level (Action Aid, 2006).

Flood is defined as an overflow of mass or bodies of water that submerges or drowns land. Nwafor (2006) defined flood as a natural hazard like drought and desertification which occurs as an extreme hydrological (runoff) event. On the other hand, Abam (2006), defined flood as large volume of water which arrives at and occupy the stream channel and its flood plain in a time too short to prevent damage to economic activities including homes. A flood results when a stream runs out of its confines and submerges surrounding areas (Stephen, 2011). Flood not only affects the victims, but also has a great gross effect on the national economy of the country where poverty level rises due to the incidence. Halley (2001) identifies the major cause of flood in Africa to be inadequacy of drainage. On the contrary, the major cause of flood in Nigeria has been identified to be excessive rainfall (Wetch, 1977; Taiwo, 2008; Akanin and Bilesanmi, 2011; Aderogba, 2012a; 2012b). Meanwhile, flood usually occurs when there is a continuous downpour of rain for a long period, while resulted excess water has capacity beyond what available drainage can easily convey, due to its inadequacy or blockage of the drainage. These problems can lead to material losses to buildings and their contents, damage to urban infrastructure, people relocation, increased risk of diseases, and deterioration of water quality, among others.

Erosion on the other hand is the process by which soil and rock are removed from the earth's surface by exogenesis processes such as wind or water flow, and then transported and deposited in other locations (Wikipedia, 2017). There are four primary types of erosion that occur as a direct result of rainfall, they are *splash erosion, sheet erosion, rill erosion* and *gully erosion. Splash* *erosion* is generally seen as the first and least severe stage in the soil erosion process, which is followed by sheet erosion, then rill erosion and finally gully erosion (the most severe of the four). *Sheet Erosion* is the transport of loosened soil particles by overland flow. *Gully Erosion* occurs when the runoff water accumulates, and then rapidly flows in narrow channels during or immediately after heavy rains or melting of snow, removing soil to considerable depth. *Rill Erosion* refers to the development of small, ephemeral concentrated flow paths which function as both sediment source and sediment delivery systems for erosion on hill slopes. Generally, where water erosion rate on disturbed upland areas are greatest, rills are active. Flow depths in rills are typically in the order of few centimetres or less and slopes may be quite steep.

The causes of erosion are basically due to physical processes which are wind, water, glacial but the rate of erosion can be greatly affected by rainfall intensity, climatic condition, precipitation and human factors like deforestation, intensive farming, housing development, road construction and inappropriate maintenance of drainage system. Erosion causes problems such as desertification, decrease in agricultural productivity due to land degradation, sedimentation of waterways and ecological collapse due to loss of the nutrient rich upper soil layers. Water and wind erosion are now the two primary causes of land degradation; combined, they are responsible for 84% of degraded acreage, making excessive erosion one of the most significant global environmental problems. But in most part of the world, greater percentage of the world erosion are caused as a result of agents of flooding, so there is no way flooding would be tackled without it having large effect on the agents of erosion.

2 STUDY AREA

2.1 Brief History of Ibadan

Ibadan, surrounded by seven hills, is the largest indigenous city in West Africa and is located in the South Western part of Oyo State of Nigeria. It is the capital city of Oyo State and is centered about latitude 7^0 23' 47'' North and longitude 3^0 55' 0'' East and it is located approximately 119km North-East of Lagos. Ibadan metropolitan area covers a total land area of 3,123km^2 of which the main city covers 463.33km^2. These include the banks of streams as well as isolated wetland areas that dot the city, which is enclosed by valleys and swamps. Eleven Local Government Areas are grouped together to what is called the Ibadan metropolitan area, Ibadan region or Ibadan land. The overall population density of Ibadan metropolitan area is 586 persons per km^2.

It is situated close to the boundary between forest and grassland, which makes it a melting point for people and products of both the forests and grassland areas. Ibadan hosts the premier University in Nigeria, The University of Ibadan. As a result of these historical antecedents, Ibadan has continuously witnessed influx of people which has contributed to its rapid growth both in population and physical expansion to cover a very large land mass. Its population is estimated to be about 3,034,200 in the year 2011 according to the National Population Commission. The city of Ibadan is also naturally drained by four rivers with many tributaries: Ona River in the North and West; Ogbere River towards the East; Ogunpa River flowing through the city and Kudeti River in the Central part of the metropolis. Ogunpa River, a third-order stream with a channel length of 12.76 km and a catchment area of 54.92 km^2. Lake Eleyele is located at the northwestern part of the city, while the Osun River and the Asejire Lake bounds the city to the east.

Ibadan has a tropical rainy and dry climate with a lengthy rainy season and relatively constant temperatures throughout the course of the year. Ibadan's rainy season runs from March through October, though August sees somewhat of a lull in precipitation. This lull nearly divides the rainy season into two different rainy seasons. November to February forms the city's dry season, during which Ibadan experiences the typical West African harmattan. There are two peaks for rainfall, June and September. Floods usually result at these periods. These flooding are aggravated by the poor surface drainage systems of the lowlands. The mean total rainfall for Ibadan is 1420.06 mm, falling in approximately 109 days. The mean maximum temperature is 26.46^{0}C, minimum 21.42^{0}C and the relative humidity is 74.55%.

Fig. 1. Map of Oyo State showing Ibadan North Local Government Area.
Source: speakers office.gov.ng

2.2 Kube-Atenda Community

Kube community is located within Agodi vicinity, along Queen Elizabeth II road in Ibadan North Local Government Area of Oyo State. It is centered about Latitudes 7^0 23' 0''N and 7^0 24' 15''N and Longitudes 3^0 53'30''E and 3^0 53' 30''E as shown in Fig. 3. The community is a nucleated one and has both primary and secondary schools that serve as educational centre for the young ones in the area. The main occupation of Kube-Atenda people is trading and it has been the major source of their livelihood and has also boosted the economic activity in the community. Also, few artisans such as Welders, Carpenters, Cobblers etc. are present in the community. There are also pockets of fertile grassland in the community where the residents rear animals like Goat, Sheep, Fowl etc. and grew variety of crops such as maize, pepper, vegetables and others.

The topography of Kube-Atenda community can be described as generally flat due to the hilly nature of other areas surrounding it. The flatness of the area retards the flow of the surface runoff and prevents its rapid discharge to the main Kube (Alagbafo) stream. The roads from D' Castle Inn, Nigerian Television Authority (NTA) and Lasisi Apapa all slopes downward to Kube-Atenda community. This makes the area under consideration a valley-like site, thereby retaining surface runoff as flood.

Fig. 2. Kube-Atenda Imagery

Source: Google Earth, 2015.

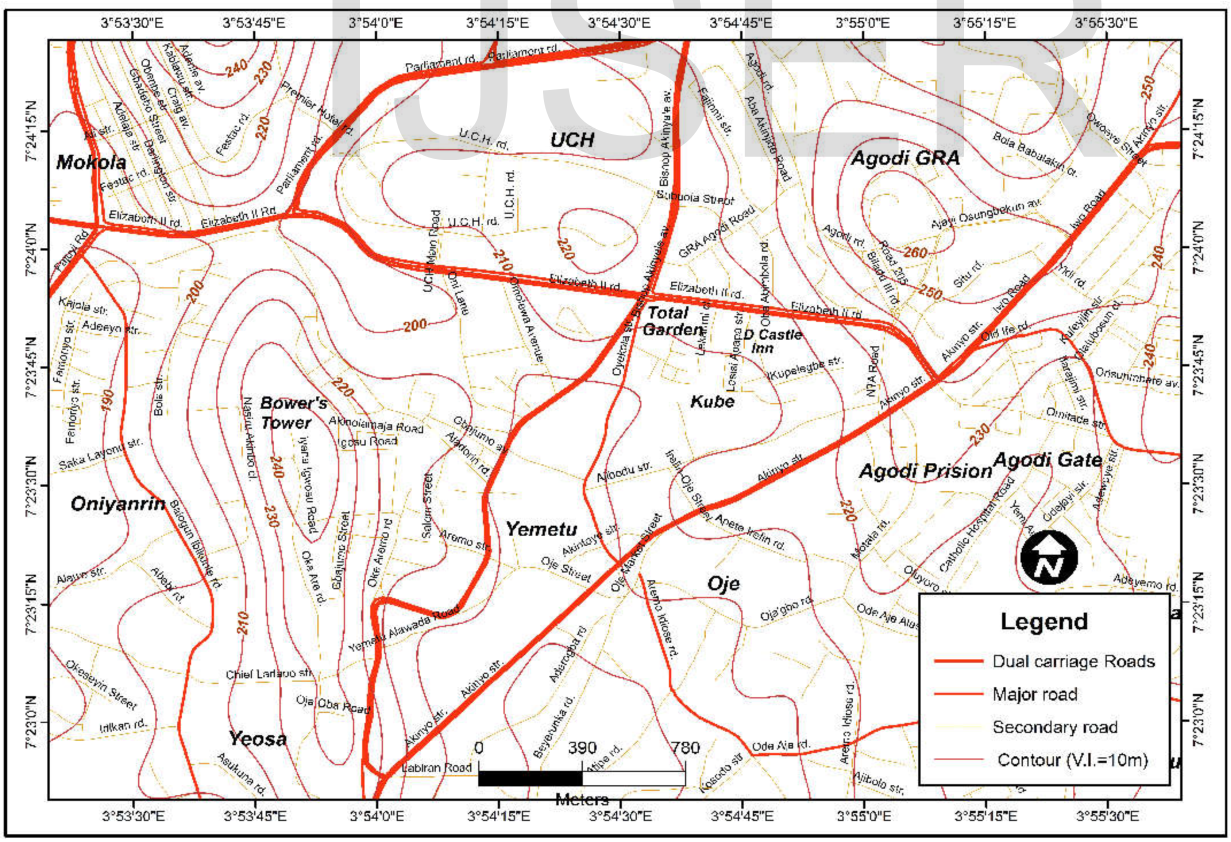

Fig. 3. Kube-Atenda Topographical Map

Source: Department of Geography, Faculty of the Social Sciences, University of Ibadan, Oyo State.

2.3 Flood and Erosion Problems of Kube-Atenda Community

One of the causes of flooding in Nigerian cities and communities is the lack of environmental control and poor environmental qualities. Agbola et al (2012) stated that the city of Ibadan has a history of flood disasters and the most recent occurred on 26th August, 2011. Floods are a common occurrence in the city and have been officially recorded since 1951.

Whenever it rains, catastrophic effect of flooding and erosion is experienced on the lands closer to the Kube (Alagbafo) stream channel and the environment due to the poor drainage system and poor environmental control in the vicinity. This causes devastating effect on life and property as people were sometimes rendered homeless due to the flooding, and the agent of erosion was also confirmed as the soil, crops and vegetation on some streets in Kube-Atenda Community were usually washed away by flood. Without a good drainage system and an improved environmental condition, there would always be flooding in Kube-Atenda Community due to the climatological changes in the environment. It was noted that the major problems being faced in the community was lack of drainage and indiscriminate waste disposal among the residents. This is always evident with the volume of wastes deposited inside some of the drainage channel which tends to interact with the direction of flow of the water thereby blocking it. Water sachets, waste nylons, empty water plastic bottles, papers, tyres, rags, leaves and host of others were observed in the drainage channel in the area with some of them even floating in the flood. Most of the drains in Kube-Atenda also need to be desilted and standard roads need to be constructed, because most roads in Kube are not tarred and this encourages the percolation and penetration of water into the soil thereby making the soil reach its saturation point which then makes the mass of water to build up and causing flooding and erosion.

Plate 1. Section of a Road in Kube-Atenda showing blocked Drainage/Culvert

Plate 2. Pot Hole - a devastating effect of flood on a tarred road in Kube-Atenda

Plate 3. Contaminated Spring Water - a devastating effect of flood in Kube-Atenda

Plate 4. One of the Buildings constructed on River bed in Kube-Atenda

Plate 5. Rill Erosion at Kube Football field after the rain on Tuesday morning (2-6-2015)

Plate 6. Gully erosion formed after Tuesday morning rain in Kube-Atenda (2-6-2015)

Plate 7. Some of the houses affected by erosion in Kube-Atenda

Plate 8. Refuse found inside an existing Drainage in Kube-Atenda

Plate 9. Dumped refuse and growing weed in a drainage channel in Kube-Atenda

Plate 10. Poorly sized and Undesilted Drainage in Kube-Atenda

3 METHODOLOGY

The data used for this research were gathered from the Ibadan rainfall data, Kube-Atenda topographical map, Kube-Atenda catchment area map and other available published and unpublished literatures. Focus Group Discussions and Key Informant Interviews were used to collect information on the causes and effects of flood and erosion in Kube-Atenda. The Focus Group Discussions (FGD) were conducted among Twenty-two (22) inhabitants of the community consisting 7 Males and 15 Females and the Key Informant Interviews (KII) were conducted among Three (3) prominent people consisting of 2 Males and 1 Female selected from the 22 inhabitants. The drainages and Roads in the Community were assessed and the flood movement in the Community was physically observed and its pictures taken as well. Also, the rainfall data got was interpreted and analysed using the *California* and *Hazen* method of expected flood prediction. After comparison of return period values of both California and Hazen, Hazen method which gave a larger return period greater than 50 years (>50 years) with its corresponding Rainfall Intensity (I) value was substituted together with Coefficient of runoff (C) and Catchment Area (A) into Rational Formula to obtain the excess runoff (Q) of water in the community that could lead to flooding and eroding of the community and finally, the runoff information got was substituted into Manning's Formula which was used in the Engineering design of drainage so as to contain and discharge the runoff being generated from the project area into Kube (Alagbafo) stream and prevent further flooding and eroding of the community.

TABLE 1
ROAD AND DRAINAGE SYSTEM ASSESSMENT

Name of Street	Surface Condition	Present Situation	Drain Type	Drain Dimension (mm)	Quality of Drainage	General Remark
Lasisi Apapa Street	Tarred surface	Road tarred, pot holes filled with water but motorable	Block wall drain on both road sides	500 x 500 deep	Fair	Inadequately sized channel, and poorly maintained.
Kube Street	Earth surface	Marshy surface but motorable	Block wall drain at a particular spot in one side	450 x 250	Bad	Poorly sized drain and blocked at some points with refuse.
Alagbafo Street	Earth surface	Not motorable and in a very bad condition	No drain	No drain	No drain	Badly maintained street
Kube Football Field	Earth surface	Marshy surface but motorable to a length	No drain	No drain	No drain	Badly maintained field
Ogundare Close	Earth surface	Motorable	No drain	No drain	No drain	Badly maintained
Unnamed Street	Earth surface	Partially motorable to a length	No drain	No drain	No drain	Hilly, poorly undulating and marshy surface.

Source: Author's field data

TABLE 2
RUNOFF COEFFICIENT FOR KNOWN DEVELOPED AREAS

Land Use	Area (Ha)	Runoff Coefficient (C)
Roads	80	0.70
Lawns	17.0	0.10
Residential Area	50.0	***0.30***
Industrial Area	10.0	0.80

Source: Engineering Hydrology, Second Edition by K. Subramanya.

3.1 California Method

If n = total number of records (years)
P = frequency of occurrence
m = rank of flood

From above, $P = \frac{m}{n}$ ....*(1)*

To predict future flood, a graph between frequency and discharge can be drawn.
Modified California Method: The frequency (probability) is given by the following equation:

$$\mathrm{F} = m - \frac{1}{N} \quad (2)$$

Where: m = number of years during the period of record that a flood is equaled or exceeded
N = total number of years to be plotted

3.2 Hazen Method

This method is used in calculating the return period or recurrence period of a flood. By using this method, one can get the return period and also the probability of occurrence. The equation is given by:

$$\mathrm{T} = \frac{\mathrm{n}}{m} - 0.5 \quad (3)$$

Where all the parameters still maintain their usual meaning as above.

TABLE 3
IBADAN RAINFALL DATA

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
1980	0	16.7	15.7	92.7	131	199.3	238.9	605	**324.4**	292.7	50	0
1981	Trace	16.1	32.1	97.4	164.6	**253.4**	98.6	17.8	44.9	193.6	13.3	Trace
1982	6.2	56	15.4	120.6	96.9	97.8	70.1	32.6	104.9	**159**	0.7	0
1983	0	17.1	Trace	85.2	265.2	**199.6**	46.5	29.8	92.7	70	17.3	41.6
1984	0	9.6	119.6	153.8	**208.8**	208.8	87.6	193.2	144.3	195.8	53.6	2
1985	1.7	0	103	194.7	166.6	147.6	**321.5**	244.5	201.3	169.4	48.2	4.1
1986	Trace	87.8	80.1	86.7	111.9	**283.1**	230.5	50.7	186	176	35.1	0
1987	0	28.1	47.8	125.9	51.3	113.6	151.1	**413.3**	221.6	132.4	0	0
1988	0.7	7.2	92.2	172.2	86.3	**281.3**	260.7	97.5	151.8	220.5	27.1	0.2
1989	0	0	0	138.6	207.4	184.7	189.5	139.9	149.2	**214.4**	Trace	0
1990	20.1	46.9	37.5	179.3	160.4	113.7	**286.9**	76	168.4	168	8	18.7
1991	Trace	165.5	19	174.1	135.3	82.3	**219.9**	191.4	170.4	182.8	2.2	26.4
1992	0	0	28.5	92.9	103.6	**237.4**	202.3	107.8	127.4	152.5	36.2	0

1993	0	25.9	141.7	44	145.9	187.5	26.2	**384**	235.5	183.2	55.9	48.3
1994	2.1	30.2	20.9	75.4	**234.8**	62.9	177.4	36.8	135.1	112.7	17.6	0
1995	0	11.4	106.3	118.5	256.6	**267.8**	188.9	204.1	159.4	185.1	36.6	Trace
1996	0.1	125.1	133	167.7	146.7	187.4	**305.7**	242.9	184.9	160.2	0	Trace
1997	9.3	0	**200.4**	158.1	128.9	98.8	63.8	111.8	113.6	182.9	5.8	23.7
1998	0	23.4	37.6	70.1	133,7	95.8	115.4	149.3	**248.2**	122.2	17.1	5.2
1999	0.3	75	111	74.2	122.7	321.9	**385.8**	149.6	209.5	348	16.9	0
2000	30.1	0	95.7	126.1	80.6	116	220.7	**232.4**	127	215.9	0	0
2001	0	8.4	121.6	142.2	231.2	114.9	257.1	53.2	**285.6**	72.3	2.1	1.1
2002	0	6.9	57	122.8	184.3	**323.8**	171.7	247.2	114.5	207.4	79.7	0
2003	25.2	81.6	3.6	184.1	**191.3**	147.8	156.2	40.9	128.5	132.1	57.2	0
2004	78.7	32.5	92	**231.9**	183.9	181.2	161.2	156.2	196.3	0.3	0	Trace
2005	0	33.1	101.9	118.2	114.7	212.6	182.9	64	**225.7**	134.9	4	12.2
2006	19.1	1.5	109.1	79	197.3	164.5	65.2	128.1	**312.5**	166	17.8	0
2007	0	0.5	36.2	39.5	**303.8**	173.7	138.3	98.1	231.7	254	6.5	8.3
2008	0	24.1	71.6	111	164.6	**248.7**	92.7	150.4	183.9	199.4	55.9	69.1
2009	1.5	138.1	80.4	203.7	129.9	217.4	205.6	10	**328.5**	205.5	55.6	0.5
2010	0.8	18	64.4	88.8	195	76.9	109.5	**320.3**	311.3	214.7	24.6	0.3
2011	0	1.6	19.8	9.4	0	0	3.8	**187.2**	1	48.6	8.8	0
2012	0	9.2	1.8	10.2	**54.6**	7.4	9.6	12.4	0.2	21.8	1.8	2.6
2013	21.8	8.4	86.8	**175.6**	82.2	102.6	100	0	100	70	4.8	6
2014	0.4	0.6	12.4	31.4	110.8	101.4	53.0	67.2	74.6	**146**	16	0

Source: Department of Geography, Faculty of the Social Sciences, University of Ibadan, Oyo State.

4 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Estimation of Rainfall Intensity and Runoff Depth

The estimation of the rainfall intensity and runoff intensity were considered for durations of *0.33 hour, 1 hour, 2 hours, 6 hours and 24 hours.* The Runoff constant (coefficient) used is that for a residential area according to *Table 2* above which is *0.30.*

$$I = \frac{P}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where: I = rainfall intensity
P = rainfall depth in millimetre (mm)
t = time of concentration in hours (hrs)

Rainfall Intensity = Rainfall depth (mm) / Duration (hrs)
Runoff Depth = Runoff constant (coefficient) x Rainfall depth
Runoff Intensity = Runoff depth (mm) / Duration (hrs)

TABLE 4
RAINFALL AND RUNOFF DEPTH

Year	Rainfall Depth (mm)	Runoff Depth (mm)
1980	324.4	97.32
1981	253.4	76.02
1982	159.0	47.70
1983	199.6	79.56
1984	208.8	62.64
1985	321.5	96.45
1986	283.1	84.93
1987	413.3	123.99
1988	281.3	84.39
1989	214.4	64.32
1990	286.9	86.07
1991	219.9	65.97
1992	237.4	71.22
1993	384.0	115.2
1994	234.8	70.44
1995	267.8	80.64
1996	305.7	91.71
1997	200.4	60.12
1998	248.2	74.46
1999	385.8	115.74
2000	232.4	69.72
2001	285.6	85.68
2002	323.8	97.14
2003	191.3	57.39
2004	231.9	69.57
2005	225.7	65.71
2006	312.5	93.75
2007	303.8	91.14
2008	248.7	74.61
2009	328.5	98.55
2010	320.3	96.09
2011	187.2	56.16
2012	54.6	16.38
2013	175.6	52.68
2014	146.0	43.80

4.1.2 Flood Exceedance and Return Period (T) Calculation

From the data in *Table 4* above, hydrologic rainfall data (Rainfall Depth) is selected using the Annual maximum series of rainfall from *Table 3*. For the selection of the time of concentration for drainage/culvert design and using the Federal Republic of Nigeria Highway Manual 1-307.03, it stated that a minimum concentration time of *20 minutes* should be used for the design purpose and *33 minutes (0.33 hour)* was adopted as the minimum concentration time for this work.

TABLE 5
RAINFALL INTENSITY FOR CALIFORNIA METHOD

Year	Rank	Rainfall Intensity (mm/hr)						
N	m	0.33hrs	1hr	2hrs	6hrs	24hrs	Probability for California method (P) = m/n	Return Period (T) = 1/P
1987	1	1252.40	413.3	206.60	68.80	17.22	0.029	34.48
1999	2	1169.00	385.8	192.90	64.30	16.08	0.057	17.54
1993	3	1163.60	384.0	192.00	64.00	16.00	0.086	11.63
2009	4	995.45	328.5	164.25	54.75	13.69	0.114	8.77
1980	5	983.03	324.4	162.20	54.07	13.52	0.143	6.99
2002	6	981.21	323.8	161.90	53.97	13.49	0.171	5.85
1985	7	974.24	321.5	160.75	53.58	13.40	0.200	5.00
2010	8	970.60	320.3	160.15	53.38	13.35	0.229	4.37
2006	9	946.97	312.5	156.25	52.08	13.02	0.257	3.89
1996	10	926.36	305.7	152.85	50.95	12.74	0.286	3.50
2007	11	920.61	303.8	151.9	50.63	12.66	0.314	3.18
1990	12	869.39	286.9	143.45	47.82	11.95	0.343	2.92
2001	13	865.45	285.6	142.8	47.6	11.90	0.371	2.70
1986	14	857.88	283.1	141.55	47.18	11.80	0.400	2.50
1988	15	852.42	281.3	140.65	46.88	11.72	0.429	2.33
1995	16	811.52	267.8	133.90	44.63	11.16	0.457	2.19
1983	17	803.64	265.2	132.6	44.2	11.05	0.486	2.06
1981	18	767.88	253.4	126.7	42.23	10.56	0.514	1.95
2008	19	753.64	248.7	124.35	41.45	10.36	0.543	1.84
1998	20	752.12	248.2	124.1	41.37	10.34	0.571	1.75
1992	21	719.4	237.4	118.7	39.57	9.89	0.600	1.67
1994	22	711.52	234.8	117.4	39.13	9.78	0.629	1.59
2000	23	704.24	232.4	116.2	38.73	9.68	0.657	1.52
2004	24	702.73	231.9	115.95	38.65	9.66	0.686	1.46
2005	25	683.94	225.7	112.85	37.62	9.40	0.714	1.40
1991	26	666.36	219.9	109.95	36.65	9.16	0.743	1.35
1989	27	649.70	214.4	107.2	35.73	8.93	0.771	1.30
1984	28	632.73	208.8	104.4	34.8	8.70	0.800	1.25
1997	29	607.27	200.4	100.2	33.4	8.35	0.829	1.21
2003	30	579.70	191.3	95.65	31.88	7.97	0.857	1.17
2011	31	567.27	187.2	93.6	31.20	7.80	0.886	1.13
2013	32	532.12	175.6	87.8	29.27	7.32	0.914	1.09
1982	33	481.82	159.0	79.5	26.50	6.63	0.943	1.06
2014	34	442.42	146.0	73.0	24.33	6.08	0.971	1.03
2012	35	165.45	54.6	27.3	9.10	2.28	1.000	1.00

4.1.3 Rainfall Intensity-Frequency Curves for California Method of Rainfall Analysis

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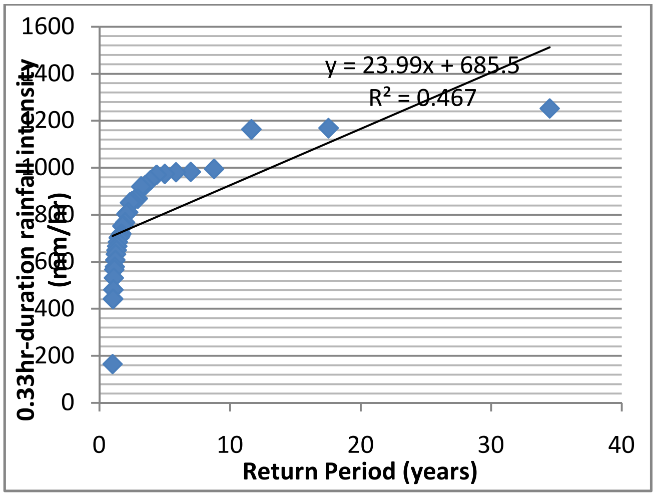

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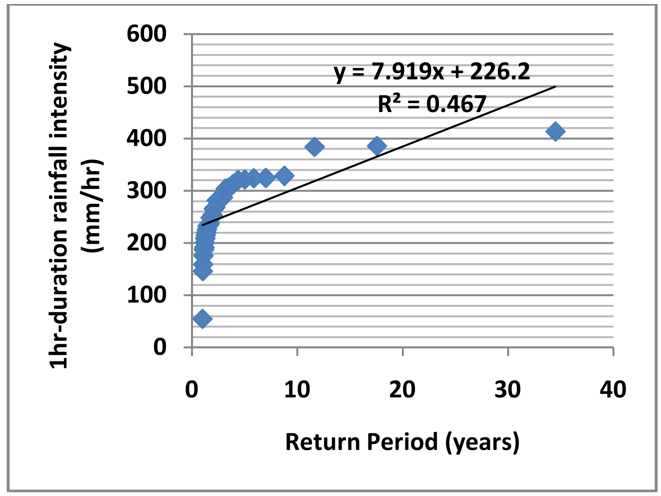

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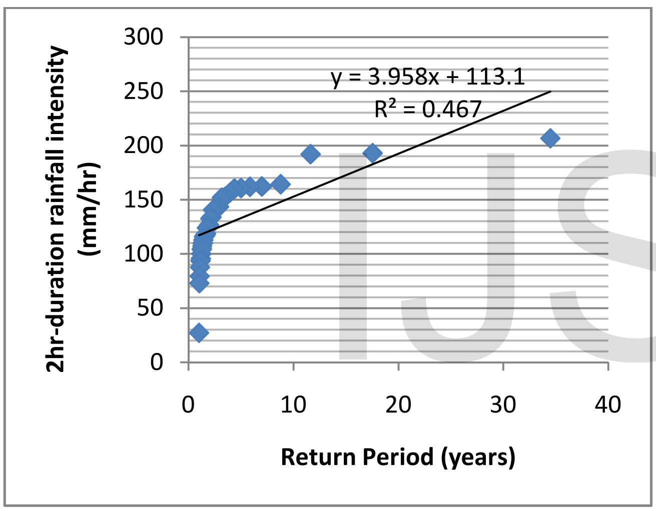

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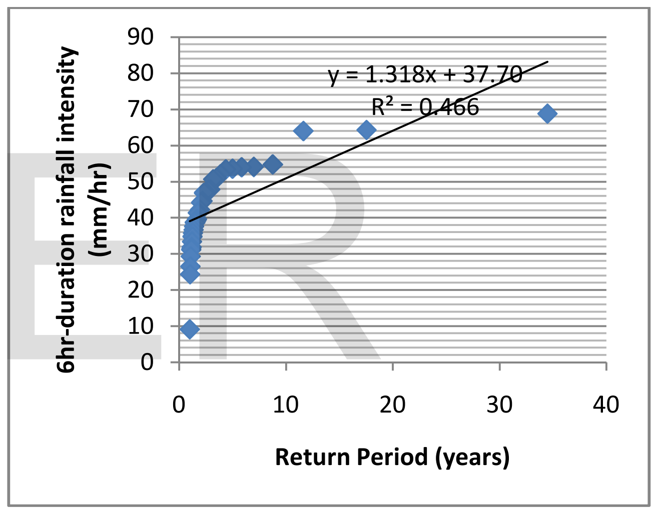

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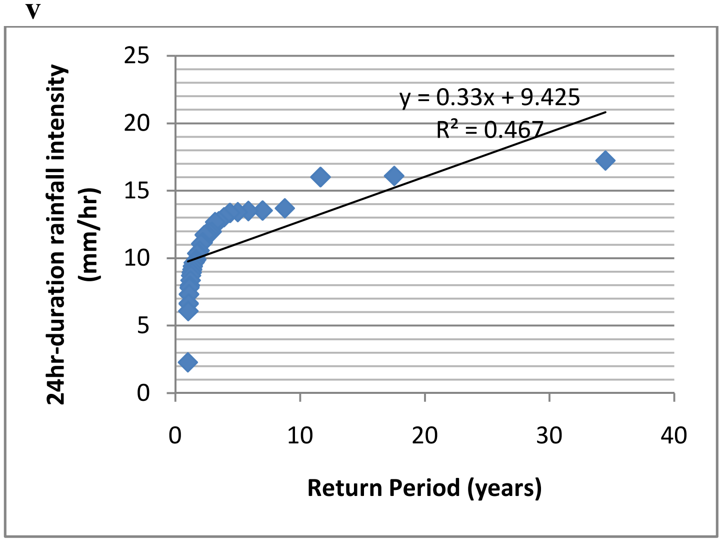
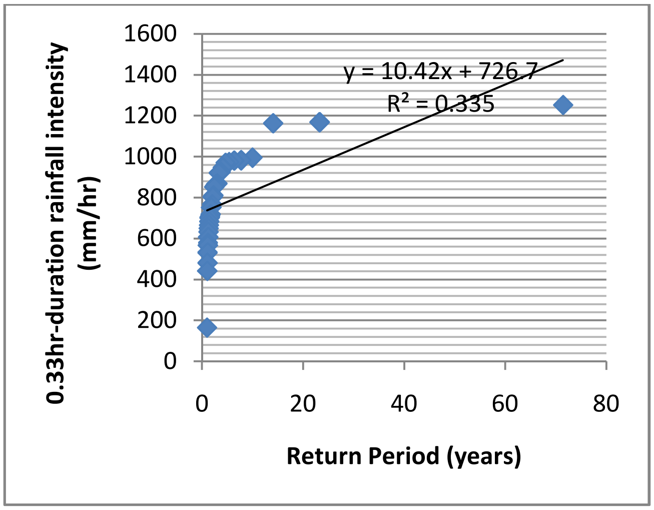


TABLE 6
RAINFALL INTENSITY FOR HAZEN METHOD

Year	Rank	Rainfall Intensity (mm/hr)						
n	m	0.33hrs	1hr	2hrs	6hrs	24hrs	Probability for Hazen method (P) = m-0.5/n	Return Period (T) = 1/P
1987	1	1252.40	413.3	206.60	68.80	17.22	0.014	71.43
1999	2	1169.00	385.8	192.90	64.30	16.08	0.043	23.26
1993	3	1163.60	384.0	192.00	64.00	16.00	0.071	14.08
2009	4	995.45	328.5	164.25	54.75	13.69	0.100	10.00
1980	5	983.03	324.4	162.20	54.07	13.52	0.129	7.75
2002	6	981.21	323.8	161.90	53.97	13.49	0.157	6.37
1985	7	974.24	321.5	160.75	53.58	13.40	0.186	5.38
2010	8	970.60	320.3	160.15	53.38	13.35	0.214	4.67
2006	9	946.97	312.5	156.25	52.08	13.02	0.242	4.13
1996	10	926.36	305.7	152.85	50.95	12.74	0.271	3.69
2007	11	920.61	303.8	151.9	50.63	12.66	0.300	3.33
1990	12	869.39	286.9	143.45	47.82	11.95	0.329	3.04
2001	13	865.45	285.6	142.8	47.6	11.90	0.357	2.80
1986	14	857.88	283.1	141.55	47.18	11.80	0.386	2.59
1988	15	852.42	281.3	140.65	46.88	11.72	0.414	2.42
1995	16	811.52	267.8	133.90	44.63	11.16	0.443	2.26
1983	17	803.64	265.2	132.6	44.2	11.05	0.471	2.12
1981	18	767.88	253.4	126.7	42.23	10.56	0.500	2.00
2008	19	753.64	248.7	124.35	41.45	10.36	0.529	1.89
1998	20	752.12	248.2	124.1	41.37	10.34	0.557	1.80
1992	21	719.4	237.4	118.7	39.57	9.89	0.586	1.71
1994	22	711.52	234.8	117.4	39.13	9.78	0.614	1.63
2000	23	704.24	232.4	116.2	38.73	9.68	0.643	1.56
2004	24	702.73	231.9	115.95	38.65	9.66	0.671	1.49
2005	25	683.94	225.7	112.85	37.62	9.40	0.700	1.43
1991	26	666.36	219.9	109.95	36.65	9.16	0.729	1.37
1989	27	649.70	214.4	107.2	35.73	8.93	0.757	1.32
1984	28	632.73	208.8	104.4	34.8	8.70	0.786	1.27
1997	29	607.27	200.4	100.2	33.4	8.35	0.814	1.23
2003	30	579.70	191.3	95.65	31.88	7.97	0.843	1.19
2011	31	567.27	187.2	93.6	31.20	7.80	0.871	1.15
2013	32	532.12	175.6	87.8	29.27	7.32	0.900	1.11
1982	33	481.82	159.0	79.5	26.50	6.63	0.929	1.08
2014	34	442.42	146.0	73.0	24.33	6.08	0.957	1.04
2012	35	165.45	54.6	27.3	9.10	2.28	0.986	1.01

4.1.4 Rainfall Intensity-Frequency Curves for Hazen Method of Rainfall Analysis

i



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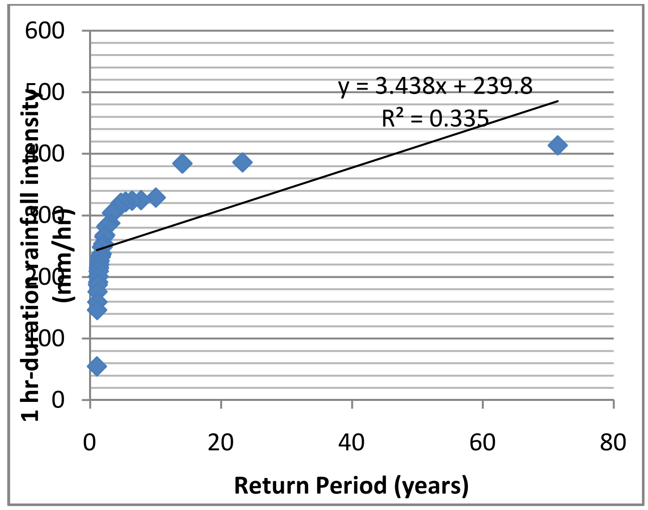

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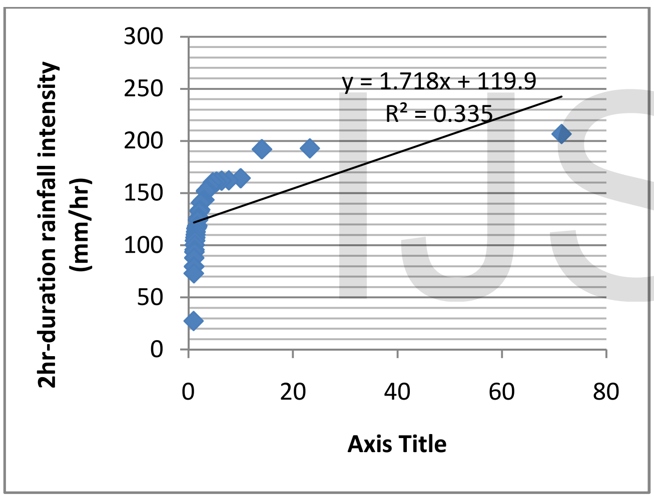

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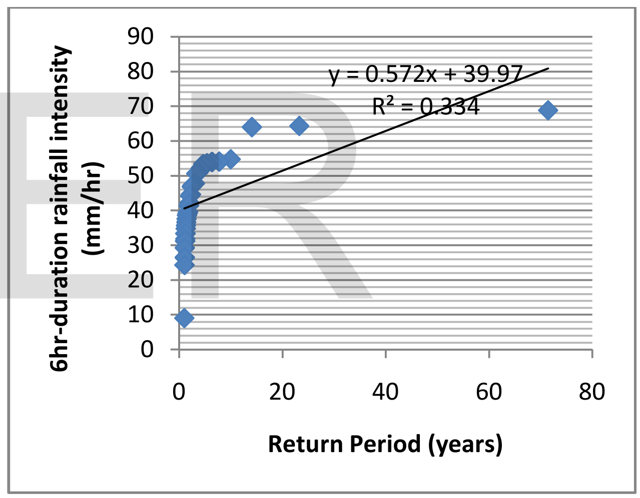

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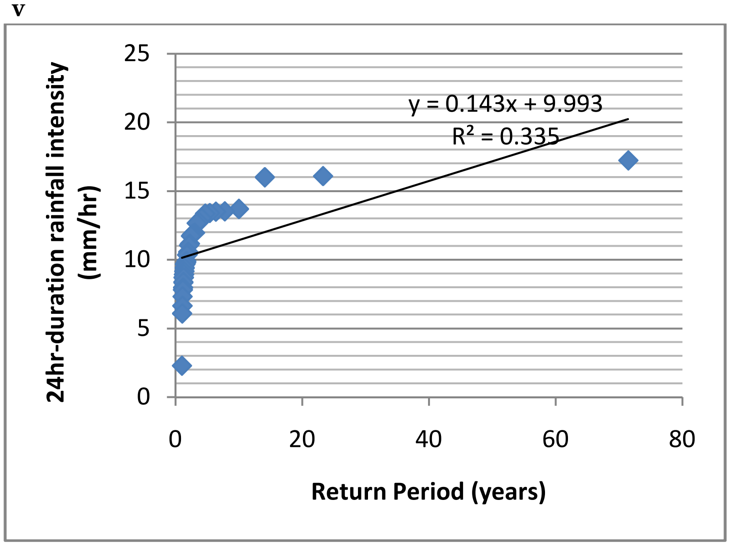

By comparing the 35-year rainfall data for the respective duration to the probability, the California method produced a 100% probability while that of the Hazen produced 98.6%. This implies that Hazen method gave a larger return period greater than 50 years (>50 years), while the California method gave a smaller return period less than 50 years (< 50 years). Hazen method was adopted to determine the rainfall intensity of Kube-Atenda Community since it gave a larger return period from the analysis and comparison. According to the Federal Republic of Nigeria Highway manual, 25 years return period is usually adopted during the design of a drainage/culvert. By plotting Rainfall Intensity-Frequency Curves of Hazen method for the individual values of 0.33hr, 1hr, 2hrs, 6hrs and 24hrs rainfall durations respectively against the return period of 25 years, the 0.33hr rainfall duration gave the highest rainfall intensity of *727mm/hr* as shown in Figure 4 below.

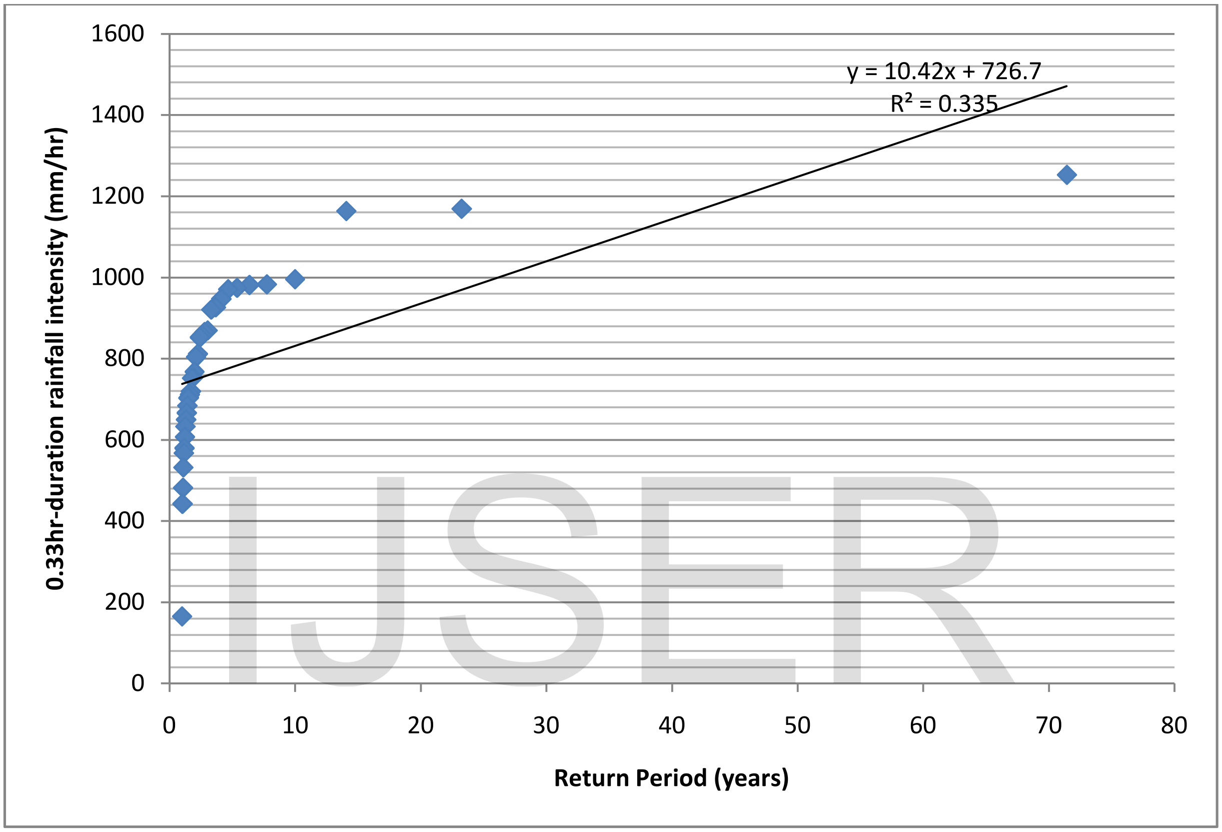

Fig. 4. Rainfall Intensity-Frequency Curve of Hazen method for 0.33hr (33 Minutes) rainfall duration

Source: Author's calculated data

4.2 Catchment Area Measurement

The Catchment Area Map and its corresponding values obtained using Geographic Information System (GIS) on Kube-Atenda topographical map in order to know the total land area that contributes runoff into Kube-Atenda community as flood and flows into the perennial Kube (Alagbafo) river are shown in *Figure 5* and *Table 7* below.

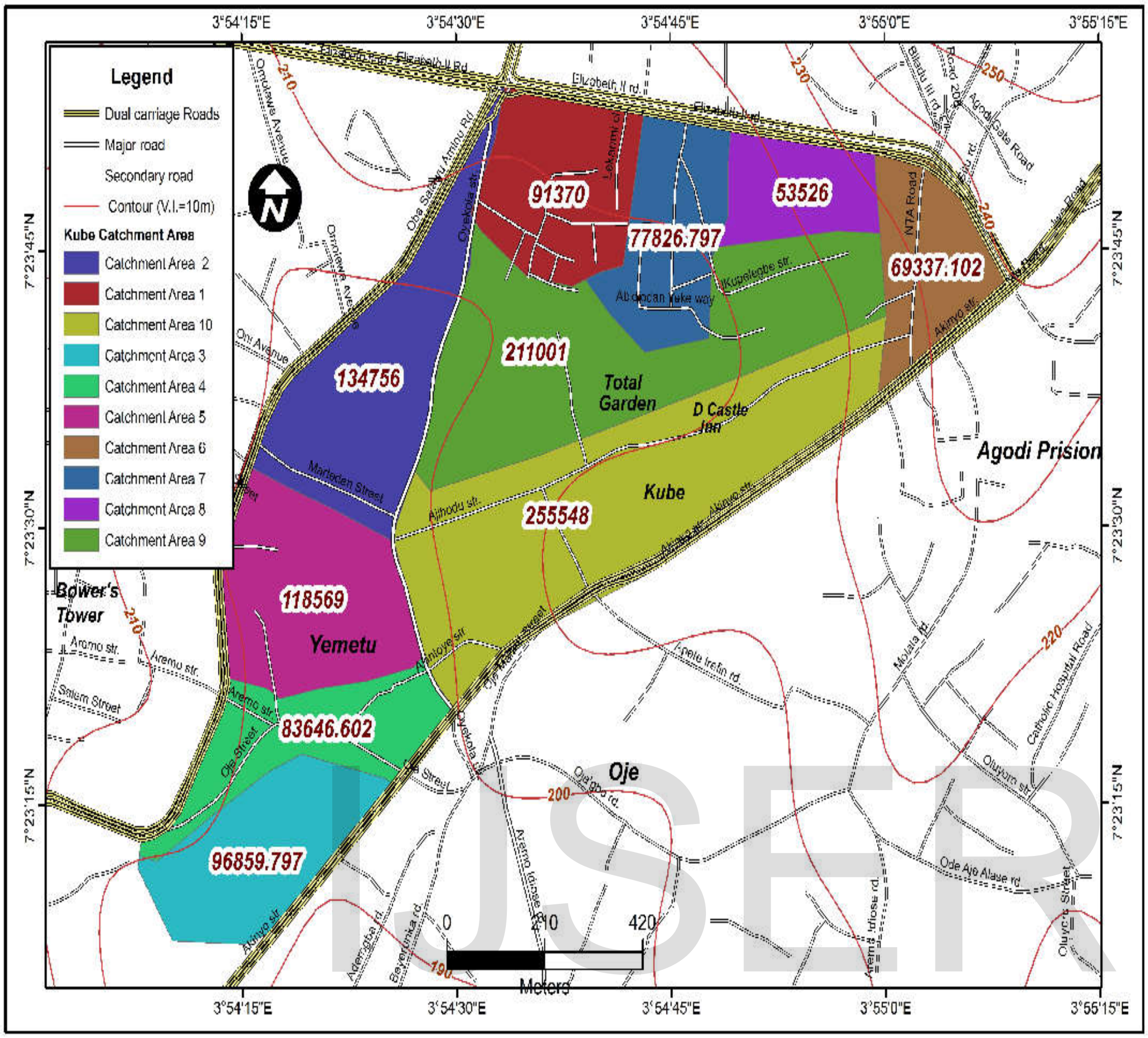

Fig. 5. Kube-Atenda Catchment Area Map

Source: Department of Geography, Faculty of the Social Sciences, University of Ibadan, Oyo State.

TABLE 7
CATCHMENT AREA CALCULATION

Catchment Area	Catchment Area (Square metre) (m^2)	Catchment Area (Hectare) (Ha)
Catchment Area 1	91,370	9.14
Catchment Area 2	134,756	13.48
Catchment Area 3	96,860	9.69
Catchment Area 4	83,647	8.36
Catchment Area 5	118,569	11.86
Catchment Area 6	69,337	6.93
Catchment Area 7	77,827	7.78
Catchment Area 8	53,526	5.35
Catchment Area 9	211,001	21.10
Catchment Area 10	255,548	22.55
Total Catchment Area		***116.24***

Source: Author's field data

4.3 Analysis and Design Of Drainage/Culvert

The drainage to be designed will convey runoff through the following routes:

- from Methodist Primary School (beside Nigerian Television Authority) through Kube Street and down to Lasisi Apapa Street.
- From D' Castle Inn junction, along Queen Elizabeth II road down to Lasisi Apapa Street.

In the design of a drainage/box culvert, the required parameters are mainly using the Manning's formula/equation and after which the Quantity of discharge which is in metric cubic (m^3) is calculated. The design duration used for this study is one (1) hour duration and a return period of 25 years so that the drainage/culvert can drain water from the study area without overflowing or collapse.

In the calculation of the quantity of discharge, the Rational Method is being applied.

The rational formula is:

$$Q = 0.00278\ C\ I\ A \qquad (5)$$

Where: Q = quantity of discharge / maximum rate of runoff (cfs or m^3/sec.)
C = runoff coefficient
I = average rainfall intensity (in./hr. or mm/hr.)
A = drainage or catchment area (ac or ha)

Recall that: C = 0.30 (Residential area)
I = 727 mm/hr
A = 116.24 Ha

$Q = 0.00278 \times 0.30 \times 727 \times 116.24$

$Q_{design} = 70.50\ m^3/s$

4.4 Economic Design Of A Rectangular Drainage/Box Culvert

The discharge in any channel depends on velocity of flow, cross sectional area, bedslope, etc., and could be expressed mathematically as;

$$Q = AV \qquad (6) \qquad \text{and} \qquad V = R^{2/3} S^{1/2}/n \qquad (7)$$

$$A = B \times Y \qquad (8) \qquad P = B + 2Y \qquad (9)$$

Where: Q = quantity of discharge, V = velocity of flow, A = area, Y = depth, B = breadth, P = wetted perimeter, S = channel slope, n = manning's roughness coefficient and R = hydraulic radius.

Substituting the value of B = A/Y into equation (9)

$P = B + 2Y$

$P = A/Y + 2Y$

$$dp/dy = -A/Y^2 + 2 = 0 \qquad (10)$$

Therefore, $A = 2Y^2$

Substituting $A = 2Y^2$ into equation (8) and making B subject of formula

$B = 2Y$

Therefore, $Y = B/2$ (most economic section)

$R = A/P$

$R = 2Y^2/4Y$

Therefore, $R = Y/2$

Since $Q = AV$, $A = 2Y^2$, $V = R^{2/3} S^{1/2}/n$ (Manning's formula)

$$Q = 2Y^2 \times R^{2/3} S^{1/2}/n \qquad (11)$$

TABLE 8
MANNING'S ROUGHNESS COEFFICIENTS (N) FOR OPEN CHANNELS

1. Asphalt	0.013 - 0.016
2. Brick (in cement mortar)	0.012 - 0.018
3. Concrete	
a. Trowel finish	0.011 - 0.015
b. Float finish	0.013 - 0.016

Source: Hydraulic Designers Manual, Texas department of transportation.

Taking the value of S = 1.56% = 0.0156 and n = 0.012 (concrete trowel finish) and substituting the value of Quantity of discharge (Q) into $Q = 2Y^2 \times (Y/2)^{2/3} S^{1/2}/n$,

$70.50 = 10.41Y^{8/3}$

$Y^{8/3} = 6.77$

Y = 2.1m

Since $A = 2Y^2$

$A = 8.82m^2$

B = A/Y

B = 4.2m

Therefore, the Adequate Section chosen for the drainage area to effectively drain the study area of flood water should be;

B x Y = 4.2m x 2.1m

Check

$Q = AV = AR^{2/3} S^{1/2}/n$

$Q_{provided} = 2Y^2 \times (0.5Y)^{2/3} \times (0.0156)^{1/2} / 0.012$

$Q_{provided} = 2(2.1)^2 \times (0.5 \times 2.1)^{2/3} \times (0.0156)^{1/2} / 0.012$

$Q_{provided} = 94.9m^3/s$

Therefore, $Q_{provided}$ *(94.9m³/s)* > Q_{design} *(70.5m³/s)* ⟶ *(section satisfied).*

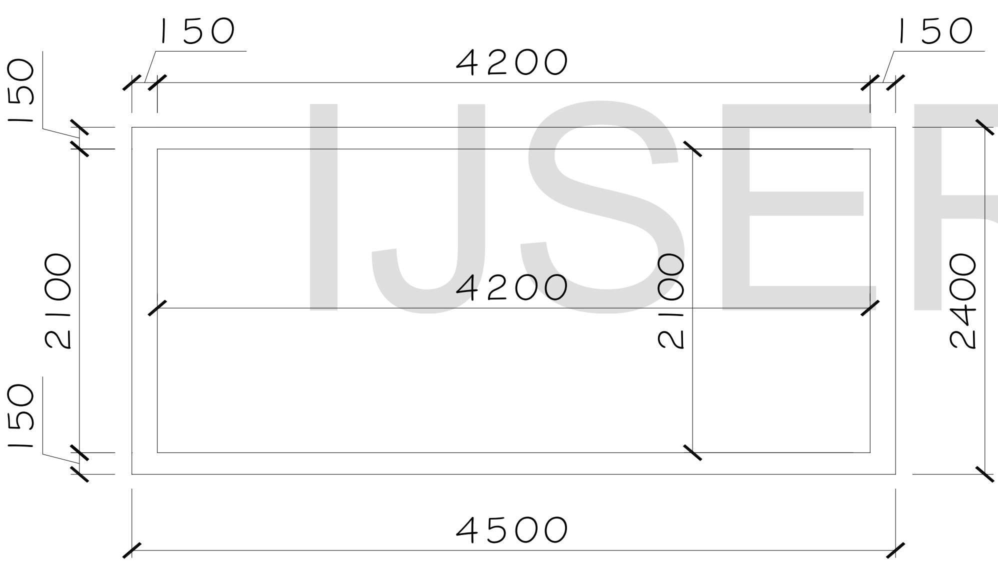

Fig. 6. Rectangular Concrete Channel Cross Section in Millimetre (mm).

4.5 Discussion

It can be deduced from the study that man induced factors such as: lack of provision of adequate drainage system, indiscriminate waste disposal, inadequate dredging of stream/river, location of the buildings on flood prone areas, lack of flood warning system and natural factors which include: rainfall, saturated soil, facilitate flooding.

Despite the fact that few of the residents have drainages at the front of their buildings, yet flood disaster is a prevalent environmental problem in the Community. This is because of the blockage of drainage channel with solid wastes as indicated by some of the residents. Flood in the study area also causes damage to properties, land degradation, loss of income to the residents as well as loss of lives. Lack of proper waste management may also contaminate the water sources (most especially the Kube spring water which is used by the community for drinking and other purposes) to transmit environment related communicable diseases such as typhoid, dysentery, while the stagnant water also breed mosquitoes which cause malaria fever through the anopheles mosquitoes.

During the interview, construction of new drainages, reconstruction of existing drainages and proper dredging of the Kube (Alagbafo) stream has been suggested by the residents as ways in which flood and erosion disaster can be mitigated in the study area.

Based on the data, the drainage/culvert has been designed to accommodate more than its design hydraulic capacity. If this can be compared with the present drainage capacity in the project area, it would be of great improvement if implemented, as it is obvious from findings that the existing drainage in the project area is undersized. To carry out the construction of the proposed drainage, the existing ones has to be demolished, the existing side ditch has to be thoroughly cleared. Despite the fact that the project could not be adequately quantified and priced, the item of work to be executed still includes demolition, excavation of trenches, dredging of the Kube (Alagbafo) stream, earthworks and expanding the drainage area to meet the proposed design.

5 CONCLUSIONS AND RECOMMENDATIONS

The exhaustive studies and investigations carried out in the research and documentation of this report should be an aid to proffer a lasting solution to the menace being faced in the community of the research study with regards to the flooding and erosion in the area whenever there is rainfall. It is believed by the author of this project that the menace of the Ibadan flood and erosion does not go beyond the Engineering solution if this report and several other experts can be considered.

The following are recommended;

i. *Acquisition Of Hydrological Data And Tools:* The Ministry of works, housing and Environment should always make it a priority to acquire data. Most of the data available at the planning authority were incorrect, incomplete, insufficient and non-existent. The acquisition of hydrological data will aid Engineers in finding solutions to most flood problems. This will require the acquisition of many hydrological tools and machines such as Flow metres, Sharp-edge wires, Computers etc.

ii. *Public Enlightenment Campaign:* Enlightenment of people of all categories in the study area on the need to stop disposing their waste through runoff is of paramount importance in this case. The government should intensify more effort through both print and other media to educate people on the danger associated with indiscriminate disposal of their waste.

iii. *Enforcement of Sanitation Law:* The existing sanitation law should be implemented to the last letter. Anybody caught in the act of dumping refuse into the drain or waterway should be prosecuted in line with the "polluter pays principle".

iv. *Afforestation Practice:* The residents of the study area should be encouraged to plant trees, cover crops and grasses in the form of terrace so as to enhance infiltration of water/runoff into the soil, retard overland flow of water and reduce erosion rate.

v. *Infrastructural Development:* The State Government should try as much as possible to let the dividend of democracy reach this Community. Drainages to all existing roads is paramount with the road surface well dressed and if possible, surface dress the roads with asphalt. The flooding site should be re-aligned vertically and the road surface should be made to camber for easy drainage of runoff into the side drains. Adequate and timely maintenance of all the drains is also proposed for a flood and erosion free environment.

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AUTHORS PROFILE

- Joseph Sunday Onyemesim holds a Bachelor degree in Civil Engineering from Federal University of Technology, Owerri (FUTO), Imo State, Nigeria and recently obtained his Masters degree in Civil Engineering with a specialisation in Public Health and Environmental Engineering in University of Ibadan, Oyo State, Nigeria, PHONE-- +2348035694071. E-mail-- sunnyjoe23b@yahoo.com
- Mynepalli kameswara Chandra Sridhar is a professor of Environmental Health in the Department of Environmental Health Sciences, Faculty of Public Health, College of Medicine, University of Ibadan, Oyo State, Nigeria, PHONE-- +2348037273836. E-mail-- mkcsridhar@gmail.com
- Akinwale Oladotun Coker is a professor of Civil and Environmental Engineering and the current Head of Civil Engineering Department in University of Ibadan, Oyo State, Nigeria, PHONE-- +2348033644074. E-mail-- cokerwale@yahoo.com