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STUDY OF THE NATURE OF URBAN FLOOD IN BENIN CITY, EDO STATE; NIGERIA

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ABSTRACT

The Niger Delta region of Nigeria is mostly flat, low lying, swampy basin resulting in severe regular flooding which has led to a limited land area available for human habitat. Approximately 7000km^2 of land cannot be used owing to flooding. This study assessed the nature of urban flood in Benin City, Edo State; Nigeria. Thirty-five streets and roads were identified as areas prone to regular flooding and twelve of these streets including Uselu – Ugbowo Road, New Lagos- Uselu Road, Sakpoba – Oka Road, Plymouth – Oliha Road, Uwasota-Ogida road, Ogida-textile-Urubi Road, Television Road, Erhummunse Road, Upper Mission Road, Wire road, Forestry Road were identified as the most critical. The types of flood experienced are flash flood and flood pondages. 52% of the total area is inundated for more than two hours during flood episodes with an average water height of 1m. Laboratory analyses of soil samples collected from the twelve streets and roads show a greater clay fraction than any other soil fraction with clay as 52.23%, sand 28% and silt 19%. Permeability is low with a value of 1.17 x 10^{-3}cm/sec. Bulk density ranged from 1.9gcm^3 at Forestry road to 3.12gcm^3 at Sakpoba – Okah road. The degree of variability between and within locations of the factors of flooding in Benin City showed that there is no significant variation between the locations of the flooded area in Benin City at P>0.05 level of significance. However, there was significant difference in the variation among the parameters with Clay varying significantly at P>0.05 level of significance from all others, while silt and sand are not different from each other as similarities exist between the other parameters. By this implication, Clay is the dominant soil type of the study area. In consonance with dominance of the clay soil in the study area, bulk density is high. It is therefore concluded that the soil condition is a major determinant of flooding in Benin City. The flooding problems has resulted in traffic congestion and lost of man-hours giving rise to lopsided concentration of vehicular traffic.

KEY WORDS: flood, flashflood, flood pondages, Niger Delta, Bulk density

INTRODUCTION

Throughout the history of mankind, floods have brought untold wealth and prosperity to civilization (United Nations, 2003), and yet at the same time, they have caused tremendous losses and resulted in untold suffering for millions of people (United Nations, 2003; Abam, 2004; Akobo, 2005; Gobo and Abam, 2006; Houser *et al.,* 2006; Amangabara and Gobo, 2007). Even today, floods lead all natural disasters resulting in severe economic losses (United Nations, 2003; World Bank, 2003). In the Niger Delta region, floods results in loss of lives, destruction of social/economic infrastructure e.g. roads, bridges, houses; outbreak of diseases, surface water and groundwater contamination, and disruption of economic activities (Benka-Coker, 1998; Ekugo, 1998; Gobo *et al*., 2006 Ogbonna, *et al.,* 2004; 2006, 2008 a & b).

The Niger Delta region of Nigeria is mostly flat, low lying, swampy basin resulting in severe regular flooding aggravated by the topography, geology, soil patterns, hydrology, and heavy rainfall (Abam, 2004). Flooding in the Niger Delta region has resulted in a limited land area available for human habitat; approximately 7000km^2 of land cannot be used owing to flooding (PHDSMP, 2008). Research data available on flood around the Niger Delta region identified three types of flood in the Niger Delta region viz:

1. The regular diurnal flooding associated with tidal invasion of creeks and ocean surges on coastlines.
2. The annual floods related to the discharge pattern of the Niger – Benue River systems, and
3. Flash or Urban Floods, The type which is associated with intense and long duration rainfall events, aggregation of precipitation of runoffs and poor infiltration due to impervious cover that leads to inundation of streets, houses and or the overflowing of stream banks (Gobo *et al.,* 2004; Akobo, 2005; Teme and Gobo, 2005).

Flooding is not restricted to the least developed countries. It is however, the citizens of these least developed countries that suffer the highest toll from the occurrence of flooding. The most vulnerable being women and children in these countries (United Nations, 2003)

Studies have indicated that flooding in the Niger Delta are mostly caused or aggravated by Intense, long duration rainfall events (Gobo, 1988; Aziegbe, 2006; Houser *et al.,* 2006; Amangabara, 2006; Amangabara *et al.,* 2008). Dam breakage/river bank collapse or recession (Fox, 2002; United Nations, 2003; Abam, 2004). Urbanization – high percentage of total

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impervious cover compared to total non-impervious cover (Akintola, 1978; Odemerho, 1988, 1993; Amangabara and Gobo, 2007). Defective design/obstruction of drainage channels (Ayotamuno and Gobo, 2004; Abam, 2004; Akobo, 2005; Itulua, 2008). High soil moisture content (percentage of saturation) Soil consistency (high liquid limits and Plasticity) were identified by Teme and Gobo, (2005); Akobo, (2005); Amangabara and Gobo, (2007) as some of the causes of flooding in the Niger Delta region.

One city in the Niger Delta that is known for severe flood occurrences is the ancient city of Benin, the capital of Edo State, Nigeria. The city experiences flash floods on street and flood pondages in low-lying areas. Although according to Odemerho (1993) a number of areas in the city were exposed to flooding as far back as 1965, the severity, frequency and widespread occurrence are said to be very recent. For example, the 1965 Master Plan for Drainage and Sewage identified only two areas prone to flooding. The number of flooded areas identified subsequently rose to thirty-eight in 1981 and forty-five in 1985 (Rashid, 1982, Odemerho, 1988). More areas are being exposed to flooding as the city extends beyond its traditional city walls (the moat). According to Odemerho (1993), this is despite the huge capital outlay, where over 80% of the yearly allocation for flood control for the entire State is spent on Benin City alone in other to curtail the flood menace. The aim of this study therefore, was to identify the areas prone to consistent flooding in parts of Benin City and to examine the environmental factors responsible for such floods. The objective is to find solution and evolve a mitigation measures to these floods that have constituted a serious menace to the people. This study is important in many ways. First, it adds to the body of literature on flood occurrence and mitigation in Benin City in particular and the Niger Delta region in general. Second, it identifies and highlights those critical environmental (geo-technical) factors that cause the floods and direct policy formulation in the mitigation of flood problems in Edo State.

AREA OF STUDY

This study was carried out in the Metropolitan area of Benin City (Lat. 6º 17' to 7º 12'N and Long. 5° 15' to 5° 41'E), the capital of Edo State, Nigeria. The city lies in the northwestern portion of the Niger Delta, west of the lower Niger valley and the southwestern plains and ranges. The city region is a tilted plain sloping in a southwest direction. Its highest elevation occurs around the Ishan Plateau and Asaba Plateau (Omiunu, 1988).

Figure 1. Location Map of Nigeria Showing Benin City.

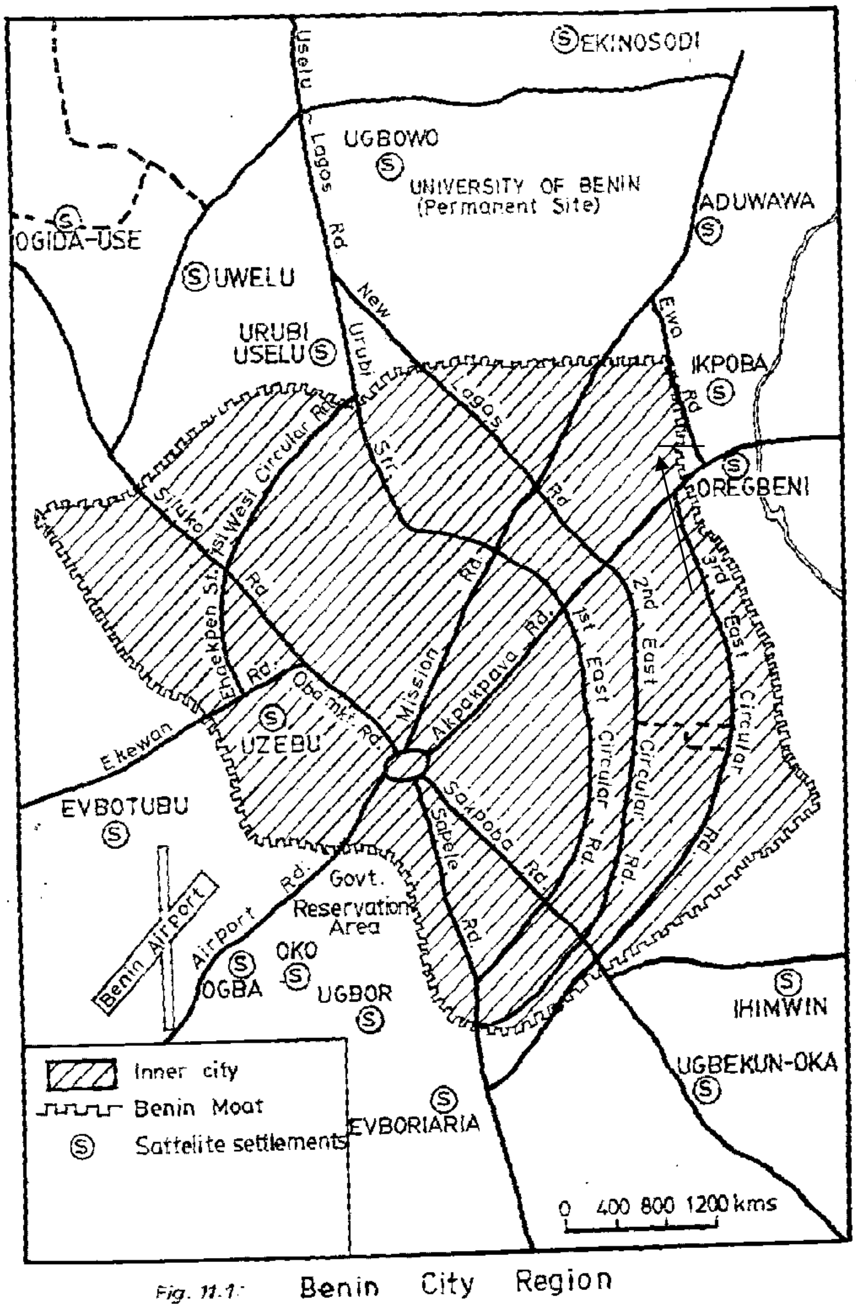


Figure 2: Map of Benin City

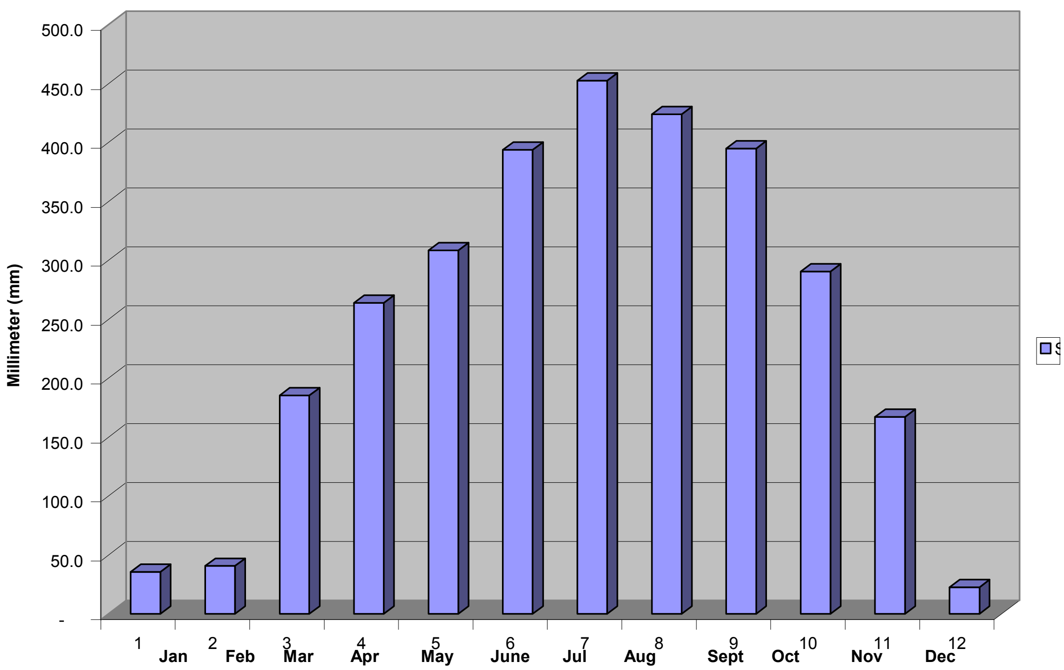
Other than the Ikpoba hill, which forms part of the plateau in the northwest corner of the city region in Etete and Aduwawa areas, the rest of the city region is relatively a flat terrain. The soil is lateritic (mostly red or reddish brown in colour containing clay particles). The city is drained by two principal river systems - The Ikpoba River draining the eastern portion and the Ogba River draining the western part of the city (Odemerho, 1988).

Table1: Mean Monthly/Annual Rainfall of Benin City Region (1997 - 2007) in Millimeters

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Min	Max	Mean	SD
1997	61.0	-	139.4	228.1	328.2	633.1	796.6	492.6	211.2	319.1	214.3	68.2	3,491.80	-	796.6	291.0	241.6
1998	25.4	6.0	174.0	149.1	211.6	504.5	255.2	352.7	365.0	439.1	286.3	33.6	2,802.50	6.0	504.5	233.5	164.2
1999	86.0	149.8	223.0	311.4	180.0	270.3	349.9	233.8	368.3	463.7	207.2	0.3	2,843.70	0.3	463.7	237.0	127.5
2000	66.0	-	95.9	166.4	217.0	250.6	597.9	392.0	577.6	232.9	153.6	57.5	2,807.40	-	597.9	234.0	195.5
2001	-	11.6	151.7	371.8	491.4	390.5	268.5	457.0	455.7	381.0	217.1	5.7	3,202.00	-	491.4	266.8	186.3
2002	-	13.5	154.6	383.2	301.3	344.6	274.1	623.5	284.3	285.8	126.1	6.8	2,797.76	-	623.5	233.1	183.5
2003	26.7	103.2	226.6	283.0	315.3	202.2	327.4	398.6	399.2	224.1	148.5	2.9	2,657.70	2.9	399.2	221.5	132.2
2004	9.9	19.9	73.5	278.4	270.2	308.0	303.5	391.9	355.5	196.4	168.3	0.6	2,376.10	0.6	391.9	198.0	141.3
2005	33.8	35.3	295.7	299.9	263.9	615.6	828.2	634.4	230.4	279.8	182.3	71.5	3,770.80	33.8	828.2	314.2	252.5
2006	84.7	57.1	323.0	166.1	430.8	227.7	484.9	273.4	536.0	175.3	134.4	0.1	2,893.50	0.1	536.0	241.1	172.7
2007	-	51.1	181.0	265.9	384.2	583.5	492.7	414.7	561.7	197.9	-	-	3,132.70	-	583.5	261.1	222.7
10yrs monthly total	393.50	447.50	2,038.40	2,903.30	3,393.90	4,330.60	4,978.90	4,664.60	4,344.90	3,195.10	1,838.06	247.20	32,775.96	43.70	6,216.40	2,731.3	1,725.9
Min	-	-	73.5	149.1	180.0	202.2	255.2	233.8	211.2	175.3	-	-					
Max	86.0	149.8	323.0	383.2	491.4	633.1	828.2	634.4	577.6	463.7	286.3						
10yrs Monthly Avg	35.8	40.7	185.3	263.9	308.5	393.7	452.6	424.1	395.0	290.5	167.1	22.5	2,979.6			248.3	

Source: Nig Met Agency
Benin City.

Fig. 3 Mean Monthly Rainfall 1997 - 2007



The city experiences rainfall throughout the year with peaks in July. Between 1997 and 2007 July and August were the wettest months. Lower amounts of rainfall were recorded from December to February (Table 1, Fig.3). The mean annual rainfall is, above 2980 mm. The wet season spread from April to October while the dry season is from November to March. The pattern of relative humidity correlated with that of the rainfall described above. High values (over 95%) occurred in the node in the rainy season. In the dry season, the high daily relative humidity values ranged from 86.5 to 94.0% and occur around 0600hrs. As a result of the heavy rainfall and other flood inducing factor e.g. building on floodplains, defective gutters, destruction of natural flood retention attenuations and low infiltration rate etc. the City experiences severe flash flood since the early 1980s (Odemerho, 1993; Omiunu, 1988).

Flood studies for this city is very important, because the city has outgrown its traditional status to a modern city (Onokerhoraye, 1977; Ozo and Ikhuoria, 1983) and serves as a hub for transporters linking all part of the country by road.

STUDY METHODOLOGY/DESIGN / APPROACH

This study was conducted for 24months (July 2006 to September 2008).

1. Identification of Flooded Areas/Types of Flood experienced.

The city was demarcated into zones on a map acquired from the Edo City Transport Company. Based on this demarcation, a field recognizance survey was conducted after a rainfall event to identify areas that flood and the type of flood occurrence, percentage of flooded portion in relation to the length of the street, duration/residence time of the floodwaters were determined. Streets that were flooded were measured with metered tape and results compared with scale on the map to ascertain the length of the road. For roads that have gutters, the length of the gutters in relation the length of the road, the gutter widths (top and Base – wetted perimeter) were measured with metered tapes. For Flood height, a stake was prepared and calibrated. After a rainfall event, the stake is usually pinned in the floodwaters and the watermark read-off. The time it takes the floodwater to clear was also recorded.

2. Soil Characteristics in flooded areas:

Six (6) soil samples from each street of the twelve streets were collected from three horizons (0-15 cm, 15 – 30cm and 30 – 45cm) using hand auger at random and mixed to form one homogeneous sample per site. The samples were collected in clean polythene bags to avoid contamination, according to the method of Hodgson (1983). The dried samples were later disaggregated and sieved to obtain the clay fractions (< 63μm). Particle size analysis was done using the hydrometer method. Bulk density was determined by the core method as modified by Evans *et al* (1982).

The pyenometer method was used to determine particle density. Total porosity was calculated from particle density and bulk density. Moisture content was first determined *in situ* with Stevens Hydra Probe II soil sensor and in the lab by gravimetric method in which samples were oven dried at 110^{0}C three hours to a constant weight and results compared. The double ring infiltrometer method as described by the FAO Corporate Document Repository was used to determine infiltration rate. Stickiness, plasticity and consistency were determined by rubbing the samples between the thumbs and fingers.

Statistical Analyses:
Descriptive statistics of mean, standard deviation was employed to analyze the flooded portions. To determine the degree of variability between and within locations of flooded areas we used the two-way analyses of variance (ANOVA). The Duncan Multiple Range test was employed to test for locations and parameters identified in the study. All statistical analyses were done with the aid of SPSS package.

PRESENTATION OF RESULTS

Flooded Areas and Flood Type:
The field recognizance survey identified thirty-five flood locations/portions on various streets and twelve of these flood locations can be described as very serious. The 35 portions/areas include:

- i. Odion and Eweka streets
- ii. Siloko and Textilemill roads
- iii. Powerline road off Dumez road
- iv. Dumez road by Sapele road
- v. Dumez road by St Maria Goreth Grammar School Junction
- vi. Sapele Road by Adesuwa College Roads
- vii. Sapele Road by NNPC Mega Patrol Station
- viii. Uwelu road by Uwelu Market
- ix. Esigie by First East Circular road
- x. Erhumunse Street by Owina Road
- xi. Saint Saviour road
- xii. Mosheshe Street and Ugbekun axis of Upper Sakpoba Road
- xiii. Isoloko road by UPSS Junction
- xiv. Isoloko by Teacher House
- xv. Iyoba road in Uselu
- xvi. New Lagos road by Eghosa Grammar School
- xvii. Lagos-Benin road by Uwelu road junction
- xviii. Lagos Road by Federal Government College Junction
- xix. New Benin Market by Mission road
- xx. New Lagos Road by Upper Forestry road junction
- xxi. Uselu-Lagos road by Ilorin/Ibadan Park
- xxii. Uselu – Lagos road by Tomline
- xxiii. Textile Mill road by Uwelu Junction
- xxiv. Five Junction (Uselu road/Wire road, TV road)
- xxv. Dennis Osadebe Avenue by Edo State Govt House
- xxvi. Osaghae by Omosefe street, Evbareke quarters
- xxvii. 2nd East Circulaar road by Aliha Market
- xxviii. Upper Mission road/extension by Aduwawa
- xxix. Sakpoba – Oka road
- xxx. Plymouth – Oliha road
- xxxi. Television/ Wire Road
- xxxii. Ewa road/Ikpoa Slope by slaughter market junction
- xxxiii. Airport road by Ihama Street
- xxxiv. Uwasota road by Ojo Street
- xxxv. Auchi Benin road by NITEL

The twelve streets/roads seriously affected, their length, percentage of flooded portion, duration of flood, type of flood and soil characteristics are presented in tables 2.

Table 2: Flooded Roads and Streets Selected for this Study

S/No	**Flooded Roads Identified for this Study**	**Length of Road (Metres)**	**Flooded Portion of Road (Metres)**	**Percentage of Flooded Portion (%)**	**Avg Height of Water Level (Metres)**	**Residence time of Flood waters (Hours)**	**Flood Type**
1	Uselu - Ugbowo Road	2,000	1,240	62	1.98	1:30 - 2 hrs	Flood Pondage
2	New Lagos – Uselu Road	1,200	1,050	88	1.52	2 - 4 hrs	Flash Flood
3	Sakpoba - Oka Road	2,570	1,570	61	0.91	> 24 hrs	Flood Pondage
4	Plymouth - Oliha Road	1,350	720	53	1.37	1 - 2 hrs	Flood Pondage
5	Uwasota - Ogida Road	2,740	1,030	38	0.76	2 - 3 hrs	Flash Flood
6	Ogida - Textile Mill - Urubi Road	2,740	800	29	1.04	2 - 3 hrs	Flash Flood
7	TV Road	1,090	190	17	0.91	1 - 2 hrs	Flash Flood
8	2nd Cementary Road	1,000	880	88	0.85	> 24 hrs	Flash Flood
9	Erhummunse Road	1,370	890	65	0.76	> 24 hrs	Flood Pondage
10	Upper Mission Road	820	340	41	0.91	> 24 hrs	Flash Flood
11	Wire Road (Five Junction)	1,210	760	63	1.85	4 - 6 hrs	Flash Flood
12	Forestry Road	1,040	550	53	1.04	2 hrs	Flash Flood
	Total length of road studied	**19,130**	**10,020**	**52**	**14**		
	Mean	**1,594**	**835**	**55**	**1**		

Soil Characteristics:

Soil characteristics in a watershed have a direct effect on the rainfall- process and they are included in most runoff estimating techniques. characteristics include soil layer thickness, permeability or infiltration rate, and the degree of moisture in the soil before the rain event. The greater the soil permeability, the ability to infiltrate rainfall to its lower strata, the less remains to become runoff (Horner *et. al*., 1994). The characteristics of the soil in the flooded portion as identified by this study are presented in table 3.

Table 3: Characteristics of Soil in the Flooded Roads and Streets

PARAMETERS	Uselu - Ugbowo Road	New Lagos - Uselu Road	Sakpoba - Oka Road	Plymouth - Oliha Road	Uwasota - Ogida Road	Ogida - Textile Mill - Urubi Road	TV Road	2nd Cementary Road	Erhummunse Road	Upper Mission Road	WIRE RD (Five Junction)	FOR	MEAN
Moisture (%)	2	4.6	1.8	1.7	3.3	2	1.3	1.1	1.1	0.9	1.2	1.5	1.875
Clay (%)	72.1	78.5	64.8	65.8	16.7	30.2	58.2	46.5	23.1	65.8	56.5	48.6	52.23333
Silt (%)	15.5	10.4	13.8	13.7	72.5	5.1	9.3	16.7	20.5	13.4	13.1	28.4	19.36667
Sand (%)	12.4	11.1	21.4	20.5	10.8	64	32.5	36.8	52.4	20.8	30.4	23	28.00833
Textural Class (%)	C/S	C/S	C/S	C/S	C/S	C/S	C/SA	CL	C	C/S	C	C	#DIV/0!
Bulk Density(g/cm^3)	2.7	2.5	3.12	2.9	2.8	2.8	2.1	2	2.5	2.4	2	1.9	2.476667
Clay Density(g/cm^3)	1.96	1.96	2.02	1.91	0.29	0.14	1.22	0.93	0.56	1.58	1.13	0.92	1.218333
Silt Density(g/L)	0.33	0.26	0.43	0.36	2.03	0.85	0.19	0.33	0.51	0.32	0.26	0.54	0.534167
Sand Density (g/L)	0.42	0.28	0.67	0.59	0.3	1.81	0.68	0.74	7.41	0.49	0.61	0.44	1.203333

Variability Test:

Table 4.1: Variability Test Analysis between and within locations of flooded areas in Benin City

Between-Subjects Factors

		Value Label	N
LOCATIONS	1.00	U-U	8
	2.00	N-U	8
	3.00	S-O	8
	4.00	P-O	8
	5.00	U-O	8
	6.00	0-U	8
	7.00	TVR	8
	8.00	CEM	8
	9.00	ERH	8
	10.00	UM	8
	11.00	WIRE	8
	12.00	FOR	8
CHARA	BULK DENSITY		12
	CLAY		12
	CLAY DENSITY		12
	MOISTURE		12
	SAND		12
	SAND DENSITY		12
	SILT		12
	SILT DENSITY		12

Table 4.2:

ANALYSIS OF VARIANCE (ANOVA) OF VARIABILITY BETWEEN AND WITHIN LOCATIONS

Dependent Variable: PARAMETERS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	29665.431[a]	18	1648.080	11.731	.000
Intercept	17146.493	1	17146.493	122.049	.000
LOCATION	3.251	11	.296	.002	1.000
CHARA	29662.181	7	4237.454	30.162	.000
Error	10817.655	77	140.489		
Total	57629.579	96			
Corrected Total	40483.086	95			

a. R Squared = .733 (Adjusted R Squared = .670)

Table 5.1:

DESCRIPTIVE ANALYSIS OF LOCATION LOCATIONS

Dependent Variable: PARAMETERS

LOCATIONS	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
U-U	13.426	4.191	5.082	21.771
N-U	13.700	4.191	5.355	22.045
S-O	13.505	4.191	5.160	21.850
P-O	13.432	4.191	5.088	21.777
U-O	13.590	4.191	5.245	21.935
0-U	13.362	4.191	5.018	21.707
TVR	13.186	4.191	4.842	21.531
CEM	13.137	4.191	4.793	21.482
ERH	13.510	4.191	5.165	21.855
UM	13.211	4.191	4.867	21.556
WIRE	13.150	4.191	4.805	21.495
FOR	13.163	4.191	4.818	21.507

Table 5.2:

DESCRIPTIVE ANALYSIS OF THE PARAMETERS

Dependent Variable: PARAMETERS

CHARA	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
BULK DENSITY	2.477	3.422	-4.337	9.290
CLAY	52.233	3.422	45.420	59.047
CLAY DENSITY	1.218	3.422	-5.595	8.032
MOISTURE	1.875	3.422	-4.938	8.688
SAND	28.008	3.422	21.195	34.822
SAND DENSITY	1.203	3.422	-5.610	8.017
SILT	19.367	3.422	12.553	26.180
SILT DENSITY	.534	3.422	-6.279	7.347

Table 6.1:

DUNCAN MULTIPLE RANGE TEST FOR LOCATIONS

	LOCATIONS	N	Subset 1
Duncan a,b	CEM	8	13.1375
	WIRE	8	13.1500
	FOR	8	13.1625
	TVR	8	13.1863
	UM	8	13.2113
	0-U	8	13.3625
	U-U	8	13.4262
	P-O	8	13.4325
	S-O	8	13.5050
	ERH	8	13.5100
	U-O	8	13.5900
	N-U	8	13.7000
	Sig.		.939

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 140.489.

a. Uses Harmonic Mean Sample Size = 8.000.

b. Alpha = .05.

Table 6.2

DUNCAN MULTIPLE RANGE TEST FOR PARAMETERS

	CHARA	N	Subset 1	Subset 2	Subset 3
Duncan a,b	SILT DENSITY	12	.5342		
	SAND DENSITY	12	1.2033		
	CLAY DENSITY	12	1.2183		
	MOISTURE	12	1.8750		
	BULK DENSITY	12	2.4767		
	SILT	12		19.3667	
	SAND	12		28.0083	
	CLAY	12			52.2333
	Sig.		.727	.078	1.000

Means for groups in homogeneous subsets are displayed.
Based on Type III Sum of Squares
The error term is Mean Square(Error) = 140.489.

a. Uses Harmonic Mean Sample Size = 12.000.

b. Alpha = .05.

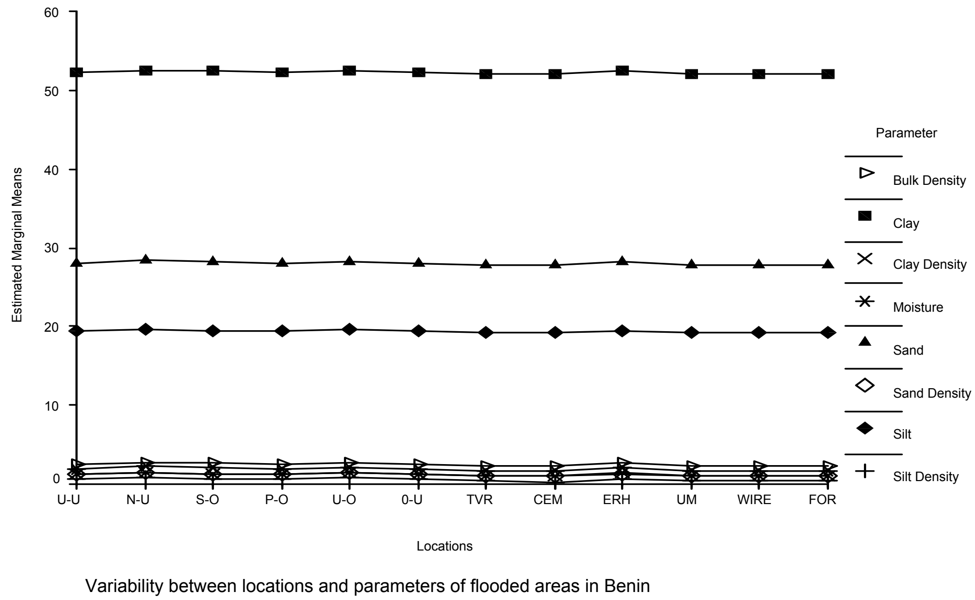


Fig 2 Variability between locations & parameters of flooded areas

From the analyses to determine the degree of variability between and within locations of the factors of flooding in Benin City; There is no significant variation between the locations of the flooded area in Benin City at P>0.05 level of significance. However, there was significant difference in the variation among the parameters with Clay varying significantly at P>0.05 level of significance from all others, while silt and sand are not different from each other as similarities exist between the other parameters

DISCUSSION OF RESULTS

The permeability

The permeability test results shows a low value of 1.17 x 10^{-3} cm/sec for the Silty/clay soil, while the sandy soils display a high range of 7.33 x 10^{-1} to 8.67 x 10^{-1} cm/sec across all the sampled locations. Infiltration capacity of soil depends on the permeability, degree of saturation, vegetation and amount and duration of rainfall (Todd, 1980). The streets that have more percentages of sand appear to have short flood resident time while those streets with high clay content e.g. New Lagos – Uselu Road and Sakpoba - Oka road have floodwater resident ranging from 4 hours and above.

The bulk density

The bulk density of the soils ranged between 1.9gcm^3 at Forestry Road to 3.12gcm^3 at the Sakpoba – Oka road. At Uselu – Ugbowo road area bulk density is 2.7 gcm^3 and Uwasota – Ogida area is 2.8 gcm^3 Bulk density (>1.5gcm^3) reduces water infiltration and plant root penetration resulting in increased surface water pollution (Ekundayo and Fagbami, 1996; Ekundayo, 2003). There is a relationship between Soil infiltration capacity and bulk density. Both are very important factors in urban or flash flood generation. Soil infiltration is the process of water entering the soil. The rate of infiltration is the maximum velocity at which water enters the soil surface/profile. When soil is in good condition, it has stable structure and continuous pores to the surface. This allows water from rainfall to enter unimpeded throughout the rainfall event.

A low rate of infiltration is often produced by surface seals resulting from weakened structure and clogged or discontinues pores. If water infiltration is restricted or blocked, water does not enter the soil and it either ponds on the surface (This explains the flood pondages at Uselu – Ugbowo road especially along at Federal junction, Sakpoba – Oka road and Plymouth – Oliha roads).

Soil textural Class

The Soil characteristics of the twelve sampled streets indicate that clay fraction has an average of 52.23%. By implication, it is the dominant soil type of the study area. A product of deep chemical weathering with abundant free iron oxides. The parent sedimentary rocks, from which this soil group has weathered, are found to be dominated by oxidized sandstone, and with poorly sorted sand intermixed with clayey deposits. The abundant clayey content of the soil influences the infiltration rate of the soil greatly. Clay soils are easily saturated in water; when they are dry they develop cracks rapidly conducting water to the surface and seal shut once the soil is wet (USDA, 1998) this decreases the soil strength, increase detachment of particles. When the soil is saturated, water intake is very limited and as a result, surface runoff is initiated. Clay minerals also enhance bulk density of soil. In consonance with dominance of the clay soil in the study area, bulk density is high.

Drainage Network

There is good network of drainage network within the city, field measurements taken during the survey however showed defective designs. Some of the gutters are shallow compared to the length of the road, so when rain falls; they are quickly filled and spill over the road. The gutters other than being shallow also contained different types of waste ranging from broken woods, plastic bottles and water sachet blocked the drains.

Implication of Flood events

Some of the implications of flood occurrence in an urban centre like Benin City include the disruption of commercial and business activities, possible outbreak of diseases etc. For example, the volume of vehicular movements in Benin City has been significantly influenced by the nature and periodicity of flooding. Omiunu in 1984 shows that 42% of all vehicular traffic were found to have been stranded in the semi-permanent and permanently flooded areas during that year raining season.

In the case of the Uselu-Ugbowo road (an important interstate road), the frequent flooding of other adjoining roads such as, the Okhoro-Federal Government College Road aid, in no small measure, in the creation of heavy vehicular traffic along this road.

Many of the flood ponds gradually turn to stagnant pool of waters that produces foul odour, breed mosquitoes and sometimes obstruct the movement of people and goods, and could also lead to surface and ground water contamination. There is also the possibility of the prevalence of parasites, tetanus, malaria, hookworm, cholera and diarrhea as has been reported for other Niger Delta region having flood problems e.g (Stephens and Harpham, 1992; Ekugo, 1998; Ogbonna *et al.,* 2002; 2004; 2006). This could be due to the inability of the floodwater to filter through the soil and the large amount of run-off, which might have contributed to the presence of sufficient concentrations of the infections bacteria to cause the illness.

SUMMARY & CONCLUSION

In this study, we identified thirty-five flood prone areas and twelve of these locations are considered critical. The nature (type) of flood experience in the city are flash flood and flood pondages and takes between two hours to more than twenty-four hours for floodwater to subside causing tremendous hardship to residents in the area. Soil samples from the twelve areas considered critical indicate that clay fraction has an average of 52.23%. In our analyses of the degree of variability between and within locations of the factors of flooding in Benin City; There was no significant variation between the locations of the flooded area in Benin City at P>0.05 level of significance. However, there was significant difference in the variation among the parameters with Clay varying significantly at P>0.05 level of significance from all others, while silt and sand are not different from each other as similarities exist between the other parameters

By this implication, Clay is the dominant soil type of the study area. Clay soil by nature are easily saturated in rainfall events; in that condition, water intake is very limited which leads to flood pondages. Clay minerals also enhance bulk density of soil. In consonance with dominance of the clay soil in the study area, bulk density is high.

Apart from intensive rainfall and soil condition, poor drainage design and poor finishing of constructional structures, which involved little or no field survey and no information on the basic hydrology of the city also enhances the frequent flood episodes in the city. The flood control structures often lacked the proper flow gradient, drainage outlet and design capacity and poor integrations of landuse development control with drainage control efforts. Culverts built underneath major road junctions to interconnect the roadside drains are often blocked with solid waste materials like plastic bags and bottles, broken pieces of wood, saw dust etc.

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Appendix

Flash Flood

Urban Flash Flood

Flood Pondage