STUDY AND DESIGN OF STORMWATER MANAGEMENT AND CONTROL MEASURES FOR ASABA, WARRI, EFFURUN AND ENVIRONS IN DELTA STATE, NIGERIA

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ABSTRACT

Climate change which is a direct effect of global warming has brought extreme weather changes to our environment, such as sea-level rise, more frequent rainfall with its associated flooding. The effects of these extreme changes have brought more flooding in our Cities, especially Asaba, Warri, Effurun, and Environs since they lie within the Niger Delta region of Southern Nigeria. Despite these extreme weather changes from global warming, less attention is being given to the management, and control of stormwater by government. The excess stormwater leads to loss of agricultural farmlands, contamination of groundwater and rivers and loss of lives and property of immeasurable values. Today, due to the global climate change, Asaba, Warri, Effurun, and its environs are experiencing more months and frequent rainfall rather than the old known pattern of six months dry and six months rainy seasons. The effect on these cities and environs has defied the efficacy of existing drainage systems put in place by government and corporate bodies over the years. Hence, there was an urgent need by the government of Delta State to study and construct sustainable drainage systems for the management and control of Stormwater in Asaba, Warri, Effurun, and Environs. This desire led to the Engineering Study and Design conducted in Asaba, Warri, Effurun, and Environs. Using interviews of locals, participatory meetings, and engineering survey, more in-depth knowledge of the flooding and causes was gathered. The study looked at how overland drainages can be incorporated into the nature-based gifts, such as Valleys, Waterways and Rivers for the safe evacuation of the excess runoff generated from the environment. Results obtained showed that improving the efficiency of these Natural Watercourses and Rivers would bring a better management and control of the outfalls of both existing and new drainages into these Natural Watercourses. For this to be successful, the inhabitants must be aware of the environmental hazards associated with blocking of Valleys and Waterways with structures and dumping of waste materials into Storm Sewers and Drains, which would create blockages for the efficient evacuation of the Stormwater generated from the Environment.

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Symbols and Definitions

To provide consistency within this section, as well as throughout this paper presentation, the following symbols will be used. These symbols were selected because of their wide use in many culvert design publications.

Table 1: Symbols and Definition

	Symbol	Definition	Units
	A	Area of cross section of flow	sq. m
	B	Channel width	m
	D	Culvert diameter or Channel depth	m
	d	Depth of flow	m
	dc	Critical depth of flow	m
	du	Uniform depth of flow	m
	g	Acceleration of gravity	m/s
	H	Total energy loss	m
	H_e	Entrance head loss	m
	H_f	Friction head loss	m
	h_o	Height of hydraulic grade line above outlet invert	M
	K_e	Inlet loss coefficient	-
	L	Length of culvert/channel	M
	P	Empirical approximation of equivalent hydraulic grade line	M
	Q	Rate of discharge	Cum/s
	S	Slope of culvert/channel	m/m
	R	Hydraulic radius	M
	V	Flow velocity of flow	m/s
	V_c	Critical velocity	m/s

1. Introduction

Climate change which is a direct effect of global warming has brought extreme changes to our environment, such as sea level rise, more frequent rainfall with its associated flooding. Flooding is the most common natural environmental hazard. It comes third as most damaging after Storm and Earthquakes. Yet, less attention is being given to the management and control of flooding.

The effects of these extreme changes have brought more flooding in our cities, especially Asaba, Warri, Effurun and environs. These cities are within the Niger Delta region of Southern Nigeria. Stormwater from extreme weather changes result in loss of agricultural farmlands, contamination of groundwater and rivers, and loss of lives and property of immeasurable values. As we witness the climate change that has engulfed the World lately, Asaba, Warri, Effurun and environs, are experiencing more months of rainfall rather than the old known pattern of six months dry and six months rainy seasons.

Beside these weather effects, the activities of inhabitants in Asaba, Warri, Effurun and environs have further diminished the efficiency of these natural watercourses with permanent structures and dumped-waste materials. These obstructions on the flow path create blockages for the efficient evacuation of the Stormwater generated from the Environment, which have led to the increased flooding and hazards experienced in the environment whenever it rains.

The effects of these weather changes and environmental hazards on these cities have defied the efficacy of the subsisting drainage systems put in place by government and some corporate bodies over the years. Hence, there was an urgent need by the government of Delta State to study and construct sustainable drainage systems for the management and control of this ever increasing stormwater in Asaba, Warri, Effurun and environs and bring relief and hope to the citizenry.

The desire led to the Engineering Study and Design carried out by ***Jefcon & Associates Ltd (Civil Engineering Consulting Firm)***, in Asaba, Warri, Effurun and environs. Using interviews of locals, participatory meetings and engineering survey, more in-depth knowledge of the flooding and causes was gathered. This study, therefore, looked at how overland drainages can be incorporated into the nature-based channels, such as the Valleys, Waterways and Rivers for the safe evacuation of the excess runoff generated from the environment.

Results obtained showed that improving the efficiency of these natural Valleys, Waterways and Rivers would bring a better management and control of the product from the outfalls on both existing and newly constructed drainages into these Natural Watercourses.

The study also recommended the types of overland drainage channels to be used, how the management and control of these natural watercourses (main receivers) and these drainage infrastructures could efficiently and safely evacuate the flood water generated to the receiving rivers.

For these projects to be successful after implementation, the inhabitants must be aware of the environmental hazards associated with blocking of drainage infrastructures and natural Valleys, and Watercourses with structures and waste materials.

2. Project Locations:

The projects are in Asaba, Warri and Effurun which are within the Niger Delta region of Southern Nigeria. **Asaba**, doubles as the State Capital and Headquarters of Oshimili South Local Government Area after the creation of Delta State in August 27, 1991. **Warri and Effurun** are metropolis belonging to the old Warri Province located in the lower Niger Delta of Nigeria.

2.1 Geographical Location of Asaba

Asaba is situated at the western bank of River Niger, overlooking the point where the Anambra River flows into it. It is sandwiched between Anwai in the North, Issele-Azagba in the West, Ibusa in the South, and River Niger in the East. The eastern axis of the territory is marked with low relief that falls to about 22 metres above mean sea level, while the western axis shows the features of high relief that rises to about 175 metres above mean sea level. The 2006 census shows that Asaba had a population of 149,603. Asaba has a large population of Igbo speaking people, but her position as Delta State Capital has made her to have a cosmopolitan population drawn from other ethnic nationalities such as Urhobo, Isoko, Ijaw, Itsekiri, Hausa and Yoruba people etc. Its geographical location lies between latitude 06^0 15’ 17.84” N and 06^0 09’ 38.49” N and longitude 06^0 36’ 23.48” and 06^0 45’ 13.35” E as shown in *Figure 1*. Asaba lies in a plain between 88m to 41m, and about sixty-five percent (65%) within this plain is sitting in a flat terrain, which is between 44m - 41m. There are some nature-based drainage routes that are tributaries to River Niger within Asaba, such as Iyi-Abi that is in the South and Anwai River in the North-East. The project section covers only an area of about 8,521.24 hectares (85.212-sqkm).

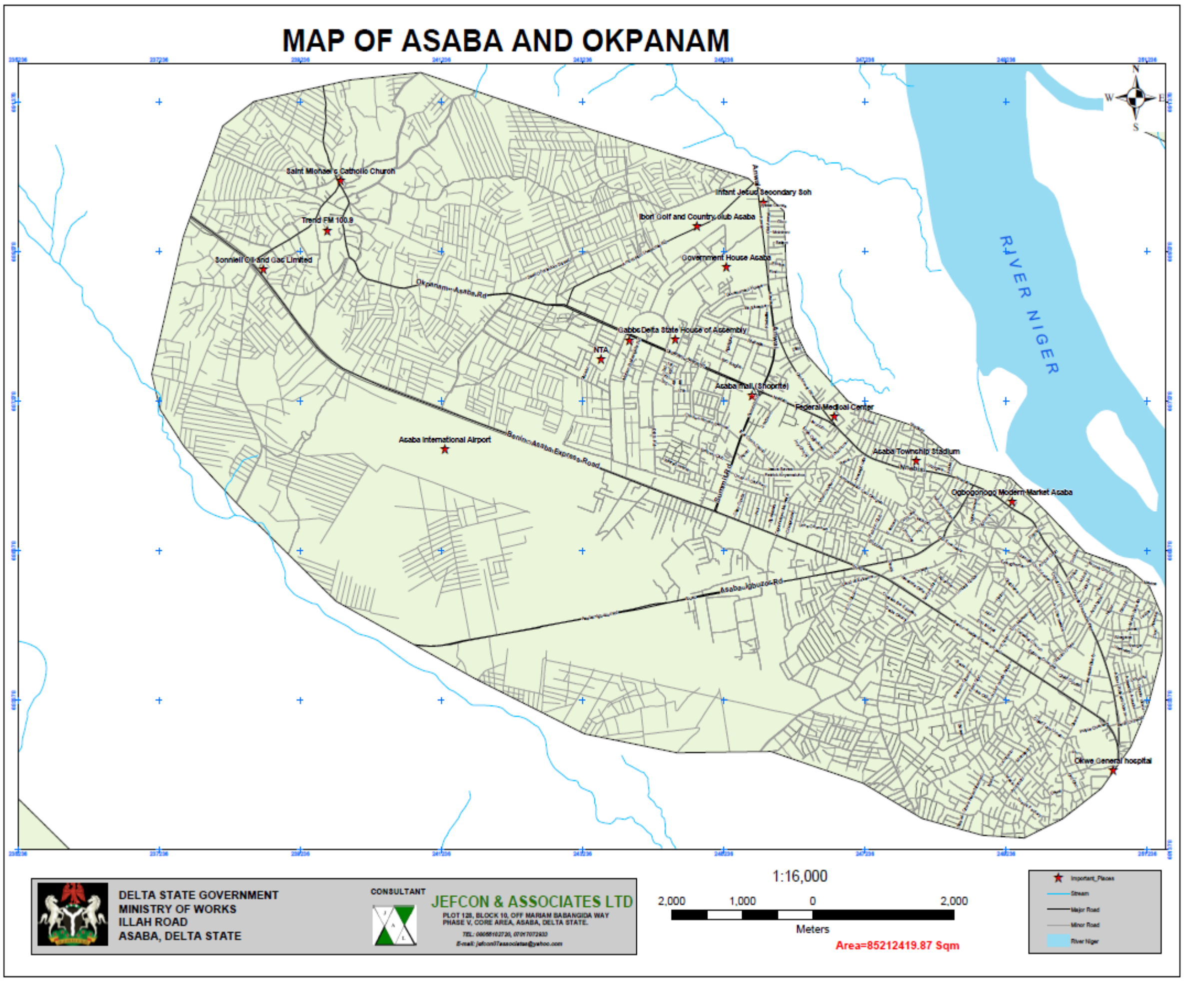


Figure 1: Map of Asaba and Okpanam

2.2 Geographical Location of Warri and Effurun

Warri and **Effurun** as shown in *Figure 2*, are located on Latitudes $5^{o}27'$ N and $5^{o}36'$ N and Longitudes $5^{o}40'$ E and $5^{o}48'$ E. They sit on the bank of Warri River which joined Forcados, and Escravos Rivers through Jones Creek in the lower Niger Delta Region to the Atlantic Ocean. Studies have shown this region to have moderate rainfall and humidity from May to October. Experience has shown it to have a short dry season from December to March, making construction activities to be at their peak during these months. The natural vegetation predominant in this region is rain forest with swamp forest in some areas. Warri is one of the oldest cities found within the lower Niger of Nigeria. The city is described as a low-lying plain which consists mainly of unconsolidated sediments of Quaternary age. The sediments are partly of marine, and of fluvial origin. It is one of the oil hubs in Delta State with Udu and

Uvwie kingdoms having been integrated to the larger cosmopolitan Warri. It originally, comprised three ethnic groups of Urhobo, Itsekiri and Ijaw people.

Figure 2: Google Map of the Project Area

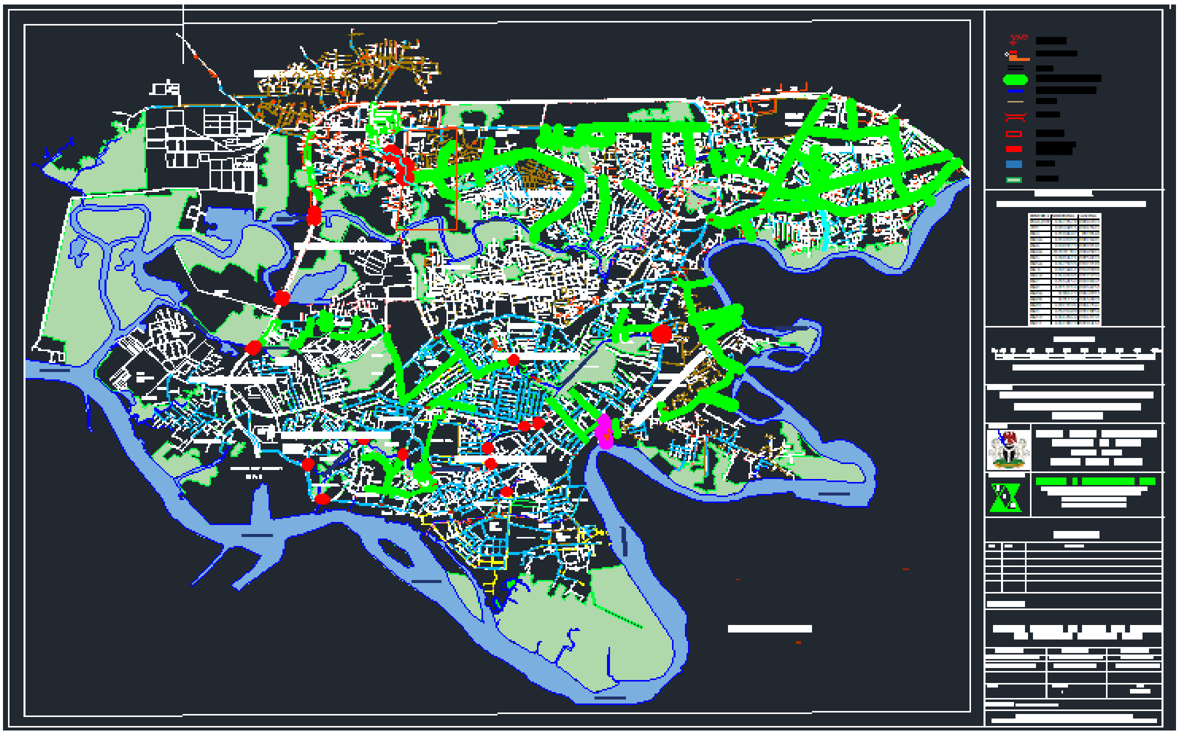


Figure 3: NEW WARRI AND EFFURUN MAP BY JEFCON IN 2019

3. Aim and Objectives of the Project

3.1 Aim

To identify all the flood prone areas in Asaba, Warri, Effurun and environs and develop an efficient and effective flood water control measures that would safely convey run-off from the streets to the natural watercourses and rivers without loss of lives and property.

3.2 Objectives

1. To identify the root cause(s) of flooding in Asaba, Warri, Effurun and environs.
2. To provide primary drainage channels that would incorporate the existing and new secondary and tertiary drains for efficient and effective evacuation of the floodwater from the environment to the natural watercourses.
3. To make the natural watercourses efficient by desilting and removal of obstructions on flow paths.

4. Methods of Approach

Asaba, Warri, Effurun and environs are viewed as hydrological basins that drain to the major Rivers (Niger and Warri) within their localities. These basins were broken into catchments using existing road networks for delineation as boundaries. In the case of Asaba, the absence of water bodies limited the design approach to nature-based type, such as valleys, streams and rivers that are tributaries to the River Niger. But in the case of Warri, and Effurun, the catchment areas contain lots of water bodies (swamps) and natural watercourses, which serve as the receiving basins for floodwater evacuation from the environment. The delineation with existing road networks into catchment areas made the application of the Rational Formula and the Hydrological Analysis convenient.

5. Findings and Observations

Studies were conducted over the entire flood prone areas, valleys, natural watercourses, swamps, and rivers, including existing drains in Asaba, Warri, Effurun and environs. The studies showed that:

i. there were no previous records of survey data and maps for the cities;

ii. while Warri had an old master plan, Asaba had none;

iii. a large part of the flooding noticed in Asaba, Warri, Effurun and environs could be attributed to blocked drainage channels with waste materials (decomposable and non-decomposable), silts, overgrown weeds etc. The result is that the flow discharge into the drainage channels is disturbed and hence could not be evacuate from the environment;

iv. most of the existing drains do not have discharge points as they were constructed without design specifications;

v. the rapid urban development in Asaba, Warri, Effurun and environs have caused the stripping of the vegetative covering, leaving the soil surface exposed to the damaging effect of erosion. This has created serious silt deposit inside the existing channels, thereby reducing the design flow volume;

vi. serious flooding noticed in many parts of Asaba, Warri, Effurun and environs is a result of non-functioning drains that have been filled with silt deposits over the years thereby reducing the original flow section as designed;

vii. most developers have encroached into the streets' right-of-way and in some cases completely blocked the natural waterways. These are more noticeable in Okpanam area of the Capital Territory, Effurun, Warri GRAs and Ugbogboro creek in *Ugborikoko, Sokoh Estate, Bendel Estate, Lower and Upper Erejuwa*;

viii. all the natural watercourses are overgrown with weeds and with large amount of silt deposits, and in some cases have become refuse dumps, especially in Tori Creek, Crawford Creek and Ugbogboro Creek/River;

ix. the geographical location of Asaba makes it possible to receive all the floodwater generated in Okpanam, since Okpanam town is situated at about 175m above Asaba. This difference in height created the heavy flooding that gathers at the centre of Asaba;

x. tidal waves from Warri River create temporary stoppage of discharge of floodwater from the environment, as its occurrence is independent of rainfall;

xi. most of the property developers make their foundations very low to the ground, which now makes the roads and drains created in these low-lying terrains, become elevated above the environment and make intercept of flow discharges difficult from the streets' drains. These drains provided, only address the removal of floodwater generated on the roads as they now act as embankments, leading to increased flooding in the environments;

xii. all the marshy swamps and lakes have been occupied with property developments having no regard for the natural watercourses. This is more noticeable in Effurun GRA, Warri GRA, Okumagba/Ugborikoko Marshy Lakes and Edjeba;

xiii. some of the drainage channels and culverts on the streets are under-sized, while some culverts across some of the waterways lie above the channel beds, making it difficult to speedily evacuate the floodwater. This is noticeable across Jakpa Road, Uti Road, Olumu Street/Okumagba Avenue;

xiv. some streets completely lack drainage system to evacuate the flood water generated in their environment. This is more noticeable in Baptist Mission Layout in Warri, and Enerhen and;

xv. most constructed drains along the major roads are with concrete slab over them, making it difficult for desilting and other maintenance works since their sections are small to allow human entrance.

Figure 4: BLOCK WATERWAY ON UGBOGBOROCREEK ACROSS DECO ROAD, WARRI

Figure 5: WATERWAY AROUND ESISI LAYOUT, WARRI

Figure 6: BLOCKED WATERWAY OFF CEMENTRY ROAD, WARRI

Figure 7: BLOCKED WATERWAY ON TORI CREEK, OFF JAKPA ROAD, EFFURUN

6. Engineering Survey

To develop an efficient and effective flood water control measures, a good knowledge of the topography of study area is important for the design. As much as practicable, the survey followed the existing street layouts. The delineation of the study areas into catchments and sub-catchment using road networks were made for ease of collation and analysis of ground data. Survey control points were established within the project areas for ease of referencing during the study and construction periods.

The spot heights (ground surface data) obtained during the Engineering Survey work were used to produce the terrain modelling showing the surface flow directions, generate contour map of the entire project area as well as perform the hydrological analysis. With the modelling of these rainfall-runoff flow patterns, an idea of the natural surface flow pattern was obtained for all the catchments (See *Figures 8 and 9).*

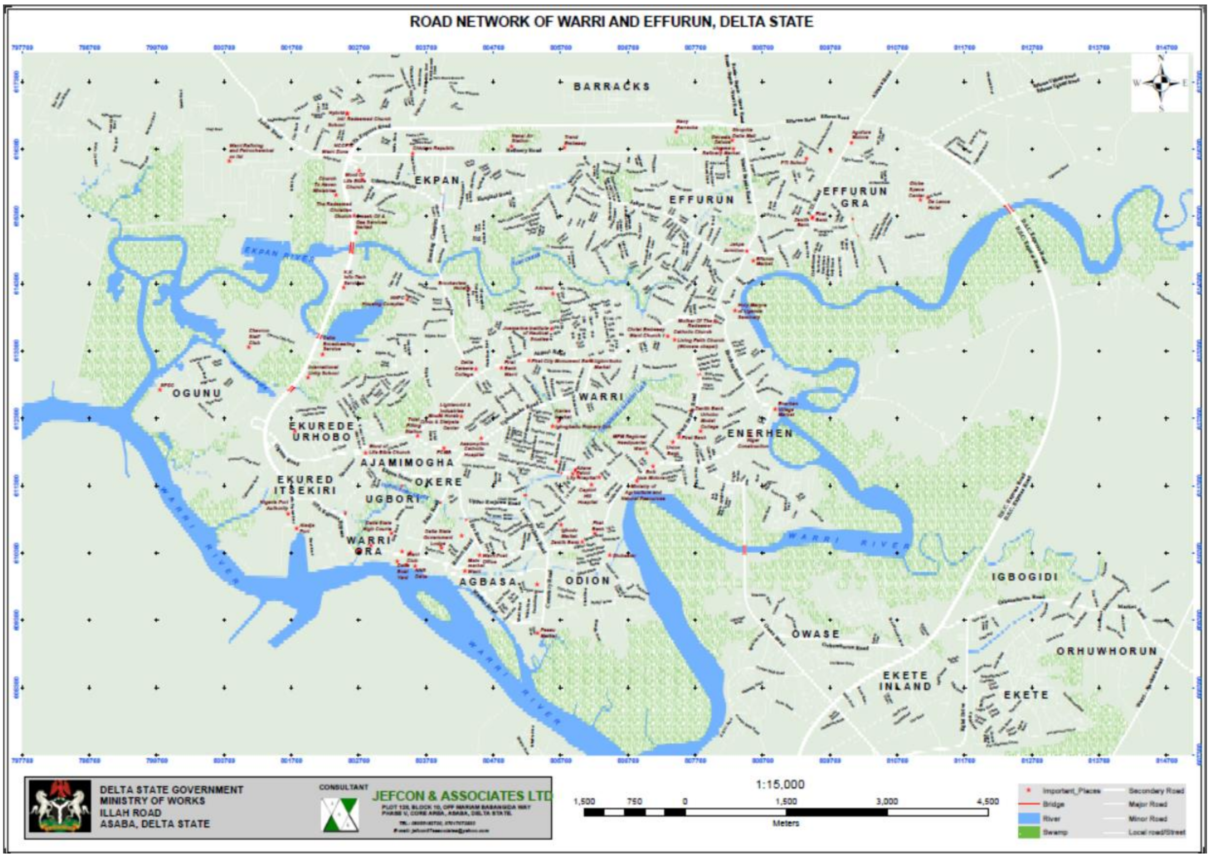


Figure 8: ROAD NETWORK OF WARRI AND EFFURUN

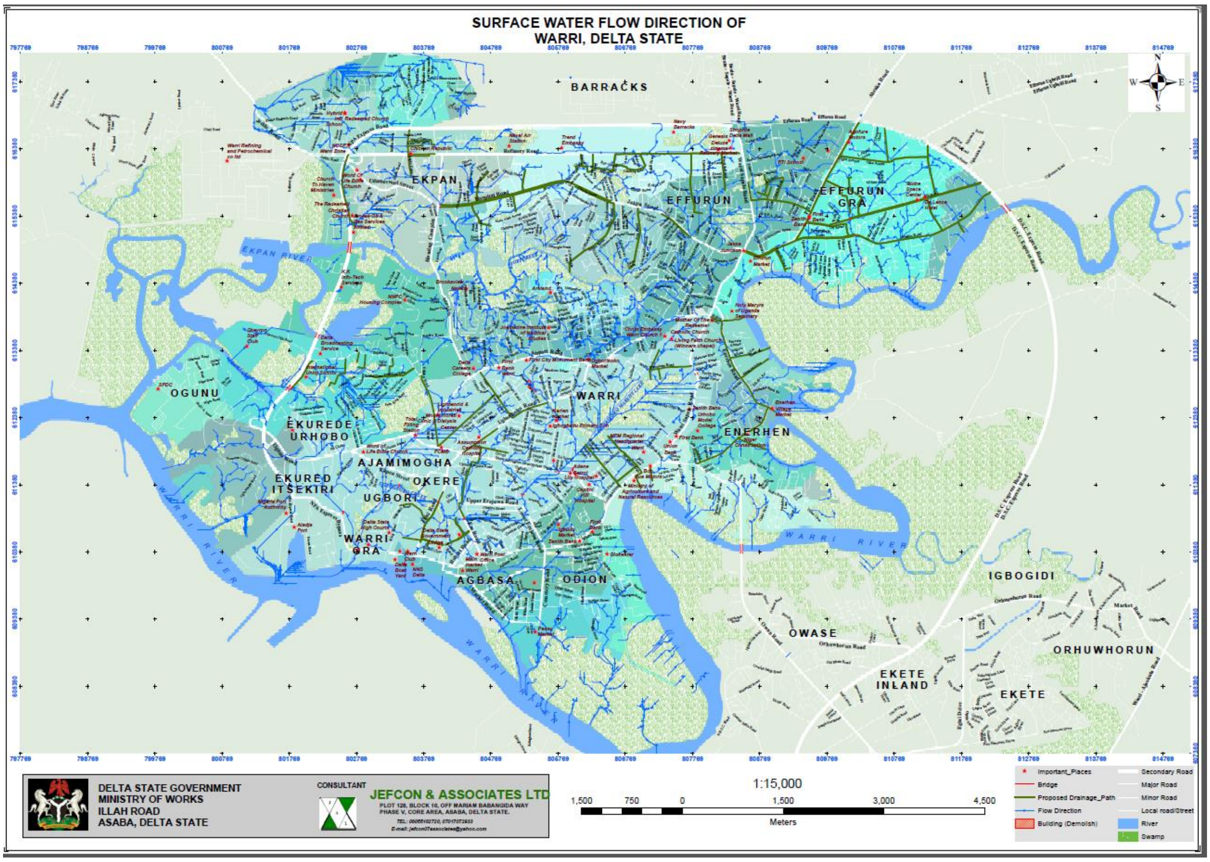


Figure 9: Surface Water Flow Direction of Warri

7. Engineering Design Analysis

The engineering design of a stormwater drainage system requires a large data collection effort. The data requirements in the stormwater management and control measures for Asaba, Warri, Effurun and environs include knowledge of topography, drainage boundaries, imperviousness, soil types, and locations of existing drainage channels, manholes, culverts inlets and outlets. In addition, identification of other types of utilities and their locations in the ground is critical. These data collated enabled the study and design works for the new drainage network systems to be achieved. The engineering analysis of the drainage system recommended for this project considered four major aspects:

i. Hydrological analysis
ii. Hydraulic analysis.
iii. Structural analysis of sections
iv. Bill of Engineering Measurement and Evaluation (BEME)

7.1. Hydrological Analysis (Stormwater Estimation)

The design works relied on information provided from rainfall data of over 30 years collated from three meteorological stations (Enugu, Benin and Onitsha) that are climatically similar and near to Asaba. The design works also obtained information from the Federal Ministry of Works, Highway Manual Part 1: Design, for the rainfall Intensity-Duration-Frequency (IDF) Curves for Warri (*See Figure 12*). The hydrological analysis of the rainfall data for a drainage basin is the most essential in hydraulic design of drainage facilities. Intensity-Duration-Frequency (IDF) design curves are used to estimate peak rainfall intensity (I) with different design frequencies (5, 10, 25, 50 and 100) years for the determination of peak **Discharge** (Q_p).

DURATION (HOURS)	RETURN PERIOD, T= 10YRS
0.2	159.34
0.4	127.76
0.7	99.98
1	90.82
2	50.13
3	35.39
6	20.01
12	11.27
24	6.35

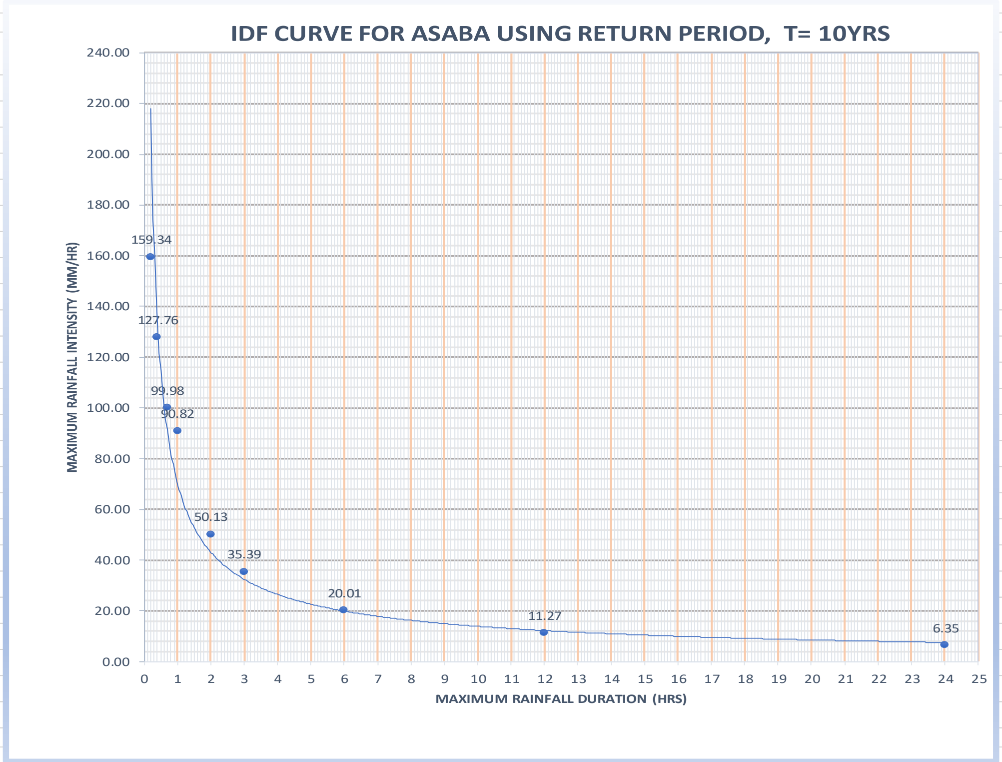


Figure 10: RETURN PERIOD, T=10 YRS IDF CURVE FOR ASABA

DURATION (HOURS)	PERIOD, T= 25YRS
0.2	178.59
0.4	144.02
0.7	113.46
1	102.17
2	57.43
3	40.48
6	23.09
12	13.33
24	7.60

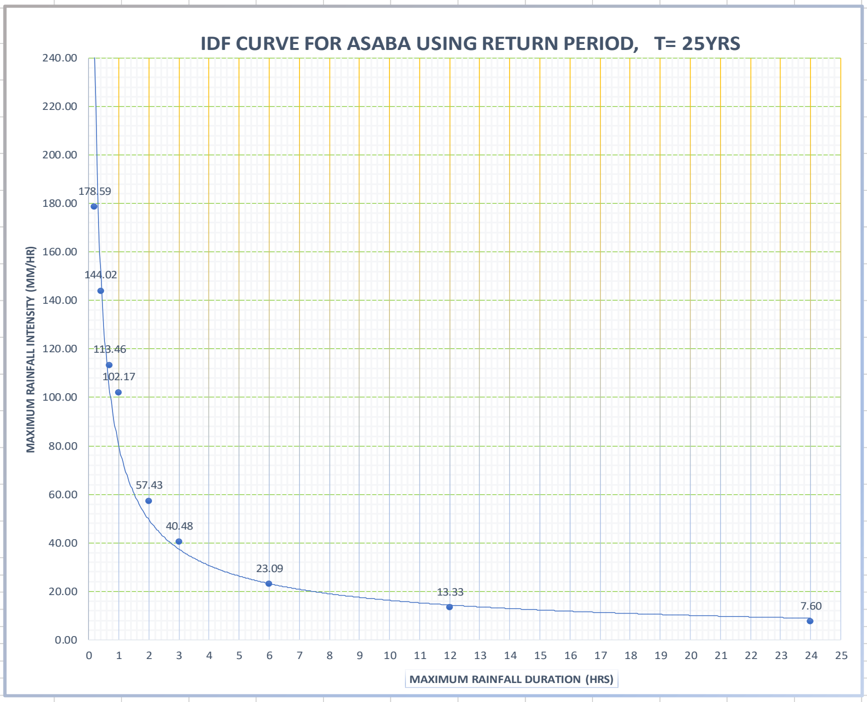


Figure 11: RETURN PERIOD, T=25 YRS IDF CURVE FOR ASABA

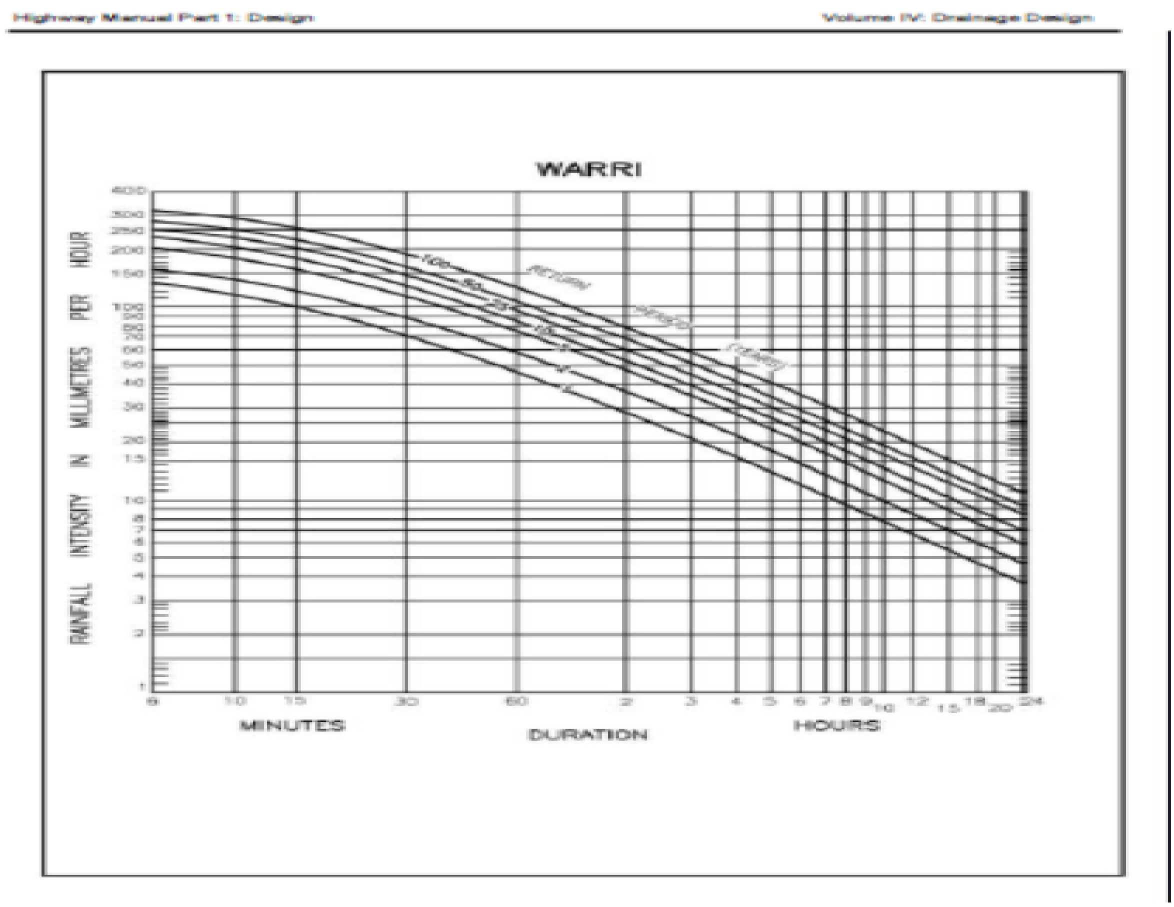


Figure 12: INTENSITY-DURATION-FREQUENCY (IDF) CURVES FOR WARRI

7.2 Description of Core Hydrologically Terminologies

i. Rainfall Intensity

This term is used to define the amount of rain falling during a specific time within the most intense period of the rain. This value is then converted into the amount of rain that will fall in one hour. The rainfall intensity is expressed as:

Rainfall Intensity, I = Maximum Rainfall Depth (mm)/Duration (hr) …………….. Eq. 1

Rainfall Intensity has an important effect on runoff proportion, as it determines the rate at which rainfall runoff arrives at the soil surface and, consequently, when infiltration rate of the soil is low to allow absorption, flooding of the environment does occur.

ii. Return Period

Since this study involves the design of hydraulic structures for the management and control of high flood levels without failing, a knowledge of design frequencies (Return Periods) of these maximum rainfall intensities must be obtained. This Return Period (T) is the average number of years during which a flood of a given magnitude will be expected to be equalled or exceeded once. It is computed using ***Weibull's*** method of ranking and expressed as: -

Return Period, T = (n+1)/m ………………………………………. Eq. 2

$$T = (n+1)/m$$

Where,

n = number of years

m = event ranking

T = recurrence interval

The derived data were used to generate the rainfall Intensity-Duration-Frequency (IDF) Curves for Asaba and Warri for the various rainfall intensities used in the computation of peak flow discharge (Q_p) at different durations or time of concentration (T_c).

7.3. Hydraulic Design of Drainage Channels

The hydraulic design of a drainage channel requires excellent knowledge of the topography and rainfall data of the project area. The design of a drainage channel is affected by factors such as topography of the project area, selection type, design frequency, expected volume of stormwater and economy. The design discharge is affected by channel section, channel roughness, channel slope, and runoff coefficient factors.

In hydraulic engineering, two types of flow are usually encountered, laminar and turbulent flow. Laminar flow is rarely encountered when dealing with flows in pipes and ducts. Most flows in nature are turbulent, and this is encountered when dealing with floodwater.

The primary consideration for the final selection of any drainage channel is that its design should be based on appropriate hydrological, hydraulic, and geotechnical analyses, which will lead to an economic and efficient hydraulic control systems. These control systems are the designed *Tertiary, Secondary and Primary* channels that would safely control and convey stormwater to the natural receivers without causing destruction to lives and property. In addition to sound structural design, good construction practices are necessary for a drainage channel to function efficiently.

7.4. Channel Selection

In channel selection for control of stormwater in Asaba, Warri, Effurun and environs, great care was taken in channel depth selection because of the high-water table, especially in Effurun and Warri Metropolis. The shapes and types of hydraulic channel sections recommended for use were dependent on the magnitude of the designed peak flow discharge of the floodwater, topography, and geology of the project areas. This contributed to the various shapes and types adopted such as *cast-in-place Concrete or Precast Concrete* Rectangular, Square and Circular shapes (*See Figures 9, 10 & 11*).

In the design of stormwater drainage system, **manholes** are the most common appurtenances because of its various uses. Their primary functions include:

i. Providing maintenance access.
ii. Serving as junctions when two or more channels merge.
iii. Providing flow transitions for changes in channel sizes, slope, and alignment.
iv. Providing ventilation.

Manholes are generally made of precast or cast-in-place reinforced concrete. They are typically 1.2m to 1.5m in internal dimension and are required at regular intervals, even in straight sections, for maintenance reasons. Manholes provide gradual transitions from circular pipe flow to box ducts flow (open or closed) alignment to minimize energy losses. Another primary function is to provide a transition that minimizes erosion in the receiving water body.

From the hydraulic design analyses carried out, which were based on the results of the hydrological analyses of the drainage basins, various types of drainage channels were recommended for use such as Rectangular, Square, and circular shapes. These recommended channel sections were for the Tertiary, Secondary and Primary channels that would safely and efficiently convey the Stormwater to River Niger and Warri River.

7.5. Time of Concentration (Tc)

The t**ime of concentration** (***T_c***), which is defined as the longest time it takes the rain falling at the most distant point within a watershed to reach the point under reference. It is one of the most important variables in the estimation of design discharges.

It should be noted while dealing in watersheds with flat terrain or low topographic slope, that the calculation of ***T_c***, using commonly accepted equations often results in unreasonably large values. That is, as the slope approaches zero, the travel time approaches infinity. Through research works, it is recommended that an adjustment of 0.005 be made to the slope in both the **Kerby** and **Kirpich** methods to allow for more realistic results.

The adjusted **slope** becomes S_{low} **Slope = S_o + 0.0005** ……………………………………… Eq. 3

Therefore, if **$S_o \leq 0.002$** m/m (0.2%), a low slope condition exists, and adjustment should be made.

There is also, another method of computing ***T_c***, using the application of **Kerby** formula, which is expressed as:

$$t_c = 1.44(Ln)^{0.467}S^{-0.235} \quad \text{……………………. Eq. 4}$$

Flow Length, $L = \{[t_c/1.44]^{1/0.467}\}/ns^{-0.467}$ ………………………………. Eq. 4.1

Retardance roughness coefficient, $n = \{(t_c/0.1.44)^{1/0.467}\}/Ls^{-0.5}$ ……………..Eq. 4.2

One of the common methods for estimating the ***Time of Concentration (T_c),*** is in the application of **Kirpich** formula.

This is expressed as:

$$t_c = 0.0195\{L^{0.770}/S^{0.385}\} \quad \text{……………………. Eq. 5}$$

Travel Length, $L = \{t_cS^{0.385}/0.0195\}^{1/0.770}$ ………………………………………. Eq. 5.1

Slope, $S_o = \{0.0195L^{0.770}/t_c\}^{1/0.385}$ …………………………………. Eq. 5.2

where,

t_c = is in minutes.

L = maximum length of travel in meters.

S = slope of the catchment in mm^{-1} over the total length, L.

Kirpich *method yields very conservative or short times of concentration that results in high peak runoff rates, especially from the Rational method.*

i. Kerby – Kirpich Method

The **Kerby – Kirpich** method of computing time of concentration (T_c), is one of the best approaches, which produces T_c estimates that are consistent with watershed time values independently derived from real world storms and runoff hydrographs. This is expressed as:

T_c = *Inlet time + Channel flow time*

$$T_c = t_{ov} + t_{ch} \quad \text{.......... Eq. 6}$$

$$T_c = t_{ov} + (0.0195L^{0.770}/(\sqrt{s_o})^{0.770}) \quad \text{.......... Eq. 6.1}$$

where,

t_{ov} = *overland flow time*

t_{ch} = *channel flow time*

The Kerby – Kirpich method for estimating T_c is applicable to watersheds ranging from 0.70Km^2 to 389 Km^2, main channel lengths between 1600m and 80000m, and main channel slopes of between 0.002 and 0.02 (m/m).

ii. Overland Flow

Inlet time (Overland flow)*:* is the time required for water to reach a defined channel such as a street gutter, plus the gutter flow time to the inlet. In the hydraulic design of stormwater sewer, the time of concentration (T_c), is the time required for all water contributing to the runoff within the watershed to reach a point, which is equal to the inlet time and the time of flow through the channel to the point under consideration.

For small catchments, where overland flow is an important component of the overall travel time, the **Kerby** method can be used. Thus, Kerby's equation is:

$$t_{ov} = K(Ln)^{0.467}S^{-0.235} \quad \text{.......... Eq. 7}$$

Applying the SI unit: -

$$t_{ov} = 1.44(Ln)^{0.467}S^{-0.235} \quad \text{.......... Eq. 8}$$

where,

- t_{ov} = overland flow time of concentration, in minutes
- *K* = a unit's conversion coefficient, in which K = 0.828 for traditional units and K = 1.44 for SI units
- *L* = the overland-flow length, in feet or meters as dictated by K
- *N* = a dimensionless retardance coefficient
- *S* = the dimensionless slope of terrain conveying the overland flow

iii. Channel Flow

Channel flow time = length of flow / average channel velocity

Channel flow travel time is determined by dividing the channel distance by the flow rate obtained from Manning's equation. For channel flow component of runoff, the **Kirpich** equation is written as:

$$t_{ch} = L_{ch} / ((3600\ (^{1.49}/n)\ R^{2/3} S_{ch}^{1/2})) \quad \text{.. Eq. 8}$$

Applying the formula in SI units thus:

$$t_{ch} = \ 0.0195 L^{0.77} S^{-0.385} \quad \text{....................................... Eq. 9}$$

where:

- t_{ch} = channel flow time (hr.)
- L_{ch} = channel flow length (m)
- S_{ch} = channel flow slope (m/m)
- *n* = Manning's roughness coefficient
- *R* = channel hydraulic radius (m), and is equal to a/p_w,
- where: a = cross sectional area (m^2) and
- p_w = wetted perimeter (m), consider the uniform flow velocity based on bank-full flow conditions.

The channel flow time can be estimated with reasonable accuracy from the hydraulic characteristics of the channel. The inlet time recommended by the *Federal Highway Design*

Manual – Part 1 for design of culverts is **5 minutes** while a minimum of **20 minutes** is recommended for design of other hydraulic channel structures.

Table 2: Kerby Equation Retardance Coefficient Values

Generalized Terrain Description	Dimensionless Retardance Coefficient (n)
Pavement	0.02
Smooth, bare, packed soil	0.10
Poor grass, cultivated row crops, or moderately rough packed surfaces	0.20
Pasture, average grass	0.40
Deciduous forest	0.60
Dense grass, coniferous forest, or deciduous forest with deep litter	0.80

The hydraulic design analysis carried out recommended various types, shapes and sizes of stormwater drain channels ranging from 3.0m, 2.7m, 2.4m, 2.0m, 1.8m and 1.2m, of either precast or cast-in-place reinforced concrete circular channel, box channel, and trapezoidal channel for use in the various selected routes.

iv. Peak Discharge Computation

The basic consideration in the design of stormwater channels is that the system must be able to accommodate and transport maximum design load, without deposition of sediments, yet not attaining destructive velocities at the outlet. One of the earliest methods for computation of flow discharges is the use of ***Rational Formula***, also known as LIoyd – Davis method. This method has some limitations in its application, as it can only be applied to small drainage areas of up to 80 hectares (0.80Km^2). The latest methods now, use computer simulation to determine design discharges. However, due to its simplicity, the Rational formula is the most widely used method for quick estimation of flow discharges.

This **Rational** formula is written as: -

$$Q = CiA \qquad \text{Eq. 10}$$

where,

Q = peak Flow discharge (m^3/s)

C = a dimensionless runoff coefficient whose values depends on the catchment characteristics.

i = Rainfall intensity (mm/hr)

A = Catchment Area (Km^2)

When applying the Rational method to a basin, the basic assumption is that all portions of the area are contributing runoff. The ***time of concentration (T_c)***, is therefore assumed to be equal to the storm duration and in turn determines the appropriate precipitation intensity.

v. Hydraulic Channel Design

One of the most used equations governing Open Channel Flow is the ***Manning's Equation***. The Manning's equation is an empirical formula that applies to uniform flow in open channels and is a function of the *channel velocity, flow area and channel slope*. It was introduced by an Irish Engineer, Robert Manning, as an alternative to Chezy's equation for computing the value of discharge. This equation is also used for calculation of flow variables in partially full conduits, such as sewers as they also possess a free surface like that of open channel flow.

In hydraulic design of the stormwater channels, the peak flow rates (discharges) (Q_p) are obtained using this ***Manning formula*** and continuity equation in determining the dimensions of the channel sections.

The ***Manning formula*** is expressed as: -

$$Q = VA \qquad \text{Eq. 11}$$

$$Q = VA = (1.00/n)\, AR^{2/3}\sqrt{S} \qquad \text{Eq. 11.1}$$

where,

Q = Flow Rate, (m^3/s)

V = Velocity, (m/s)

A = Flow Area, (m^2)

n = Manning's Roughness Coefficient

R = Hydraulic Radius, (m)

S = Channel Slope, (m/m)

The values of Manning's roughness coefficient (n), are often given in Tables for different materials, as shown in Table 7 but this can be calculated from field measurements. In many flow conditions the selection of a Manning's roughness coefficient (n) can greatly affect computational results.

One of the earliest formulae in fluid dynamics that describes mean flow velocity of turbulent flow in open or sewer channels is from Antoine de **Che'zy**.

The **Che'zy** formula is written as:

$$\mathbf{V = C\sqrt{(Ri)}} \quad \text{.......... Eq. 11.2}$$

where,

V = Average flow velocity (m/s)

C = Chezy's coefficient ($m^{1/2}/s$)

R = Hydraulic Radius, (m) and

i = Hydraulic gradient, which for normal depth of flow equals the bottom slope (m/m)

hence,

$$\mathbf{V = C(RS)^{1/2}} \quad \text{.......... Eq. 11.3}$$

The Che'zy constant 'C' is a dimensionless quantity which can be calculated from Manning's formula:

thus,

$$C = K[R^{1/6}/n] = 1/n[R^{1/6}] \quad \text{.......... Eq. 11.4}$$

then,

$$V = 1/n\,[R^{2/3}S^{1/2}] \quad \text{.......... Eq. 11.5}$$

Manning's equation, which is based on Che'zy equation is a common method to calculate fluid flow within a channel.

In the hydraulic design of the sewer channels, the use of **Manning-Che'zy** equation is applied as a continuity equation for selection of the channels dimension. Thus, the peak design flow quantity can be obtained through the application of **Manning-Che'zy** equation written as:

$$Q_p = 1/n\,[AR^{2/3}S^{1/2}] \quad \text{.......... Eq. 12}$$

where,

$\mathbf{Q_p}$ = Peak flow discharge, (m^3/s)

V = Flow velocity, (m/s)

A = Cross-sectional area of the channel, (m^2)

n = Manning's Constant or Manning's Roughness Coefficient

R = Hydraulic Radius, (m)

S = Hydraulic gradient, (m/m)

From the geometric elements of hydraulic sections:

$A = \pi d^2/4$ ………………………………………………… Eq. 13

$R = d/4$ ……………………………………………… Eq. 14

Hydraulic radius (R) of a flow section is a shape factor, which depends upon the channel dimensions, and the flow depth. It is expressed as:

$R = A/P$ ……………………………………………… Eq. 15

where,

A = Cross-sectional area of the flowing water, (m^2) taken at right angle to the direction of flow.

P = Wetted perimeter or length in metres of the wetted contact between a stream of water and its containing channel measured in a plane at right angle to the flow direction.

It should be noted that **R** is not a radius at all. It is rather a geometric parameter indicating the efficiency of the cross section. In the storm channel design, attempt is made to select the best hydraulic radius since experiment has shown that the larger the flow area (A), as compared to the perimeter (P), the easier will the water move and vice versa.

In the hydraulic design of the channel sections, the use of manholes, grating and curb-inlets are recommended for placement at close intervals of 15.0m to 20.0m. The use of these appurtenances will improve the runoff intercept on the road, create access for maintenance, reduce the ingress of heavy objects into the sewer channel, and create ventilation.

For an optimum hydraulic section of a rectangular channel, channel depth is equal to half the width.

That is,

$D = B/2$ ………………………………………………………. Eq. 16

Table 3: Manning's Coefficients(n) for Streets and Gutters ((Onlinemanuals.txdot.gov, 2018))

Type of Gutter or Pavement	Manning's n
Concrete gutter, troweled finish	0.012
Asphalt pavement: smooth texture	0.013
Asphalt pavement: rough texture	0.016
Concrete gutter with asphalt pavement: smooth texture	0.013
Concrete gutter with asphalt pavement: rough texture	0.015
Concrete pavement: float finish	0.014
Concrete pavement: broom finish	0.016

Note: For gutters with small slope or where sediment may accumulate, increase n values by 0.02 (USDOT, FHWA 2001).

Table 4: RECURRENCE INTERVALS (Design Frequencies)- Federal Highway Design Manual – Part 1

TYPE OF STRUCTURE	RECURRENCE INTERVAL (YEARS)
Culverts	10
Channels Changes	25
Storm Sewers (Trunks and Laterals	10
Side Ditches	10
Storm water Inlets	10
Gutters	10
Depressed Roadways	25

i. Hydraulic Freeboard

Hydraulic freeboard is normally incorporated in the design of optimal channel sections as an additional safety measure, to prevent stormwater in the channel from exceeding the provided designed section. Stormwater flow is always accompanied with turbulence, which comes in the form of waves and fluctuation. In this study and design, a hydraulic freeboard of between 12% and 15 % of the section was provided.

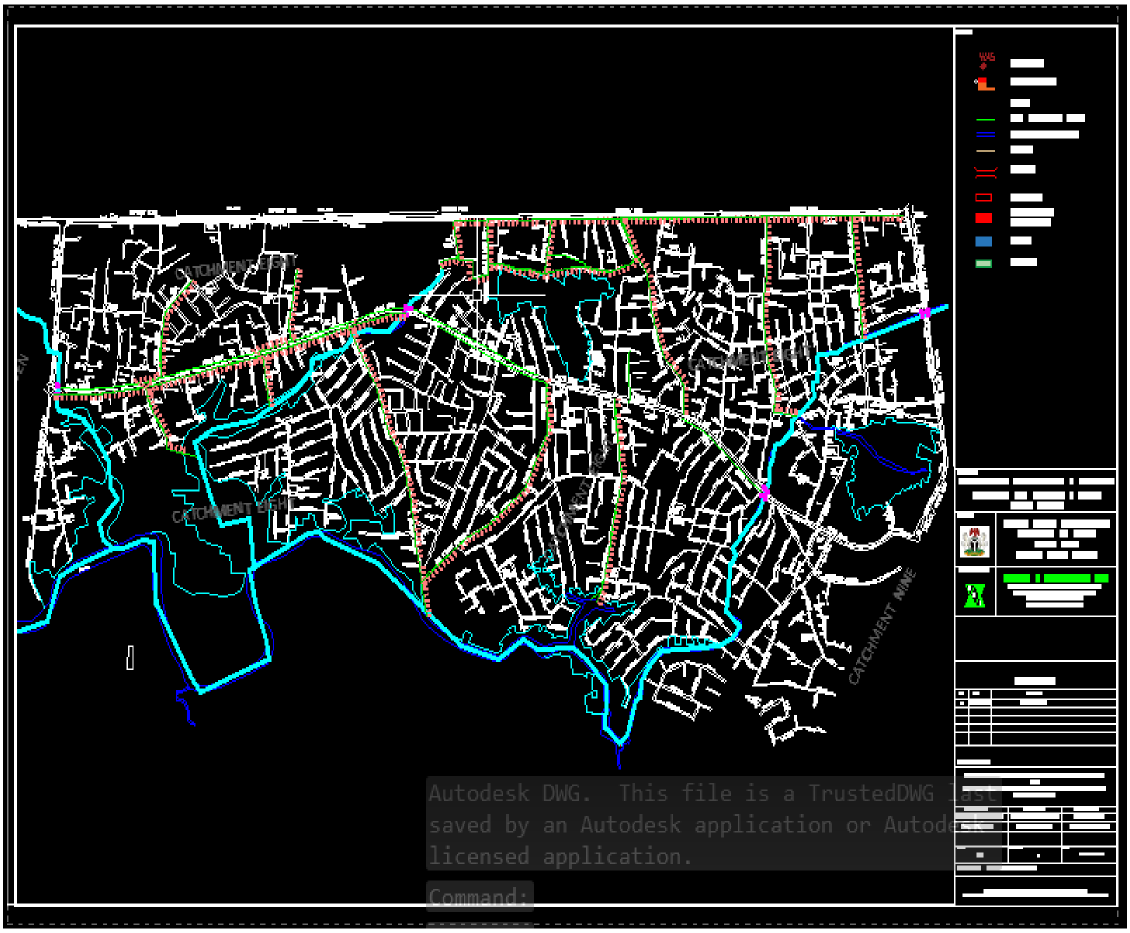


Figure 13: CATCHMENT 8 LAYOUT DRAWING

Table 5: HYDROLOGICAL ANALYSIS TABLE

CLIENT:	**DELTA STATE GOVERNMENT**				
CONSULTANT:	***JEFCON & ASSOCIATES LTD***	JOB REF. NO: DTSG/JAL/2018	DESIGNED BY:	ENGR. J.C. ONWUALU	
PROJECT:	**STORMWATER MANAGEMENT & CONTROL MEASURES FOR WARRI_EFFURUN AND ITS ENVIRONS**				

CATCHMENT 8 AREA CHARACTERISTICS

HYDROLOGICAL ANALYSIS SHEET

LOCATION OF SEWER	NODAL POINTS FROM - TO	GROUND ELEVATION (m) UPPER	LOWER	DIFF. (m)	DISTANCE (m)	SLOPE (S_o)	AREA (m²)	RUNOFF COEFICIENT C	TIME OF CONC. (Mins)	INTENSITY (I) (mm/Hr)	PEAK DISCHARGE Q_P (m3/s)	SUM OF PEAK DISCHARGE Q_P
SUB-CAT:8.1: REFINERY ROAD	REFINERY RD. R/ABOUT JUNCTN. TO SUNDAY UDI STREET JUNCTN.	6.262	5.608	0.65	262.0000	0.00250	15117.9000	0.55	15.0000	180.0000	0.41574	0.41574
SUB-CAT:8.2: REFINERY ROAD	SUNDAY UDI STREET JUNCTN. TO AKA AVENUE JUNCTN.	6.244	5.400	0.84	455.0000	0.00185	32865.0000	0.55	15.0000	180.0000	0.90379	0.90379
SUB-CAT:8.3: SUNDAY UDI STREET	REFINERY ROAD JUNCTN. TO WATERWAY	5.400	4.000	1.40	554.0000	0.00253	48594.6000	0.55	40.2656	110.0000	0.81666	2.13619
SUB-CAT:8.4: AKA AVENUE	REFINERY RD JUNCTN TO CHIEF UZOR STREET JUNCTN.	6.244	5.000	1.24	570.0000	0.00218	50389.5430	0.55	15.0000	180.0000	1.38571	1.38571
SUB-CAT:8.5: AKA AVENUE	CHIEF UZOR ST. TO ASORE CLOSE JUNCTN.	5.000	4.300	0.70	315.0000	0.00222	25350.9000	0.55	32.1878	138.0000	0.53448	1.92019
SUB-CAT:8.6: ASORE CLOSE	AKA AVENUE JUNCTN TO WATERWAY	4.300	3.550	0.75	124.0000	0.00605	3283.88500	0.55	37.8900	100.0000	0.05017	1.97036

Table 6: HYDRAULIC DESIGN ANALYSIS TABLE (Square channel)

SUB-CAT:8.5: OKOTOMI VALLEY	CATCHMENT 8 AREA CHARACTERISTICS		8
765	Sewer Location	EFURHIEVWE STREET JUNCTN JUNCTN. To IYI-UKWU STREAM	SUB-CAT:8.5: OKOTOMI VALLEY
	Design Frquency	10 yrs.	
FMWH 2013	Runoff Coefficient, C	0.5500	
	Slope, s =	0.0327	
	Manning's Roughness Coefficient (n)	0.0150	
	Catchment Area (m^2)	1433805.1000	
	Rainfall Intensity, I (mm/hr.)	94.0000	
	Computed Time of Concentration, t_c (mins.)	55.1397	
	Cummulative Peak Discharge, (CiA), $Q_{p,}$ (m^3/s)	**33.9612**	
	For SQUARE Channel section		
	Trial section (1800mm x 1800mm)		
	Try b (m) =	2.4000	
	And d (m) =	2.0000	
	Therefore, Wetted Area, A	4.8000	
	Wetted Perimeter, P =	6.4000	
	Hydraulic radius, R = A/P	0.7500	
	Provided Min. Design Slope	0.0025	
	Therefore, Designed Slope used	0.0327	
	From Manning - Che'zy's Equation,		
	Designed Discharge, Qp = 1/n $AR^{2/3}S^{1/2}$	47.7659	**Section Okay**
	Allowable Max. Channel Discharge, Qp	**40.6011**	**Section Okay**
	Therefore, Provide ONE-SIDED 2400mm x 2000mm PRY. Channel	***Single Sec. channel is 2400mm x 2000mm***	

Table 7: HYDRAULIC DESIGN ANALYSIS TABLE (Trapezoidal Channel)

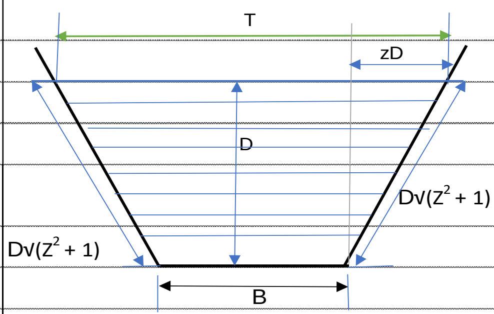
SUB-CAT:8.5: OKOTOMI VALLEY	CATCHMENT 8 AREA CHARACTERISTICS		9
765	Sewer Location	EFURHIEVWE STREET JUNCTN JUNCTN. To IYI-UKWU STREAM	SUB-CAT:8.5: OKOTOMI VALLEY
	Design Frquency	10 yrs.	
FMWH 2013	Runoff Coefficient, C	0.5500	
	Slope, s =	0.0327	
	Manning's Roughness Coefficient (n)	0.0150	
	Catchment Area (m^2)	1433805.1000	
	Rainfall Intensity, I (mm/hr.)	94.0000	
	Computed Time of Concentration, t_c (mins.)	55.1397	
	Cummulative Peak Discharge, (CiA), Q_p, (m^3/s)	**33.9612**	
		zD	
	For TRAPEZOIDAL Channel Section		
	Trial section (3200mm x 1200mm X 1800mm)		
	Try T (m) =	3.2000	
	Try B (m) =	1.2000	
	And D (m) =	1.8000	
	Therefore, Wetted Area, A =1/2(T+B)D	3.9600	
	Z = 1/√3	0.577350269	
	zD	1.039230485	
	Slope, D√(Z^2 + 1)	2.078460969	
	Wetted Perimeter, P = B+2D(√z^2+1)	5.3569	
	Hydraulic radius, R_h = A/P	0.7392	
	Provided Min. Design Slope	0.0025	
	Therefore, Designed Slope used	0.0327	
	From Manning - Che'zy's Equation,		
	Designed Discharge, Qp = 1/n $AR^{2/3}S^{1/2}$	52.7965	**Section Okay**
	Allowable Max. Channel Discharge, Qp	**44.8770**	**Section Okay**
	Therefore, Provide ONE-SIDED 3200mm x 1200mm x 1800mm PRY. TRAPEZOIDAL Chhannel	***Single Primary. channel is 3200mm x 1200mm x 1800mm***	

Figure 14: Types of Stormwater Sewer Channels

Figure 15: L-Shaped Precast Stormwater Sewer Channel under construction

Figure 16: Completed Rectangular Precast Stormwater Sewer Channel

8. Recommendations

The details from the findings and observations of this study and design by **Jefcon & Associates Ltd** (Consultant) for the Stormwater Management and Control Measures for Asaba, Warri, Effurun and environs, showed that the topography of Asaba & its environs and that of Warri, Effurun & environs have similarities in its flood management and control approaches. Due to the nature of the terrains, the study on these cities and their environs have recommended optimal and efficient Pre-cast Open and Closed (underground sewers) concrete systems. Therefore, the recommendations put forward for consideration and implementation for both project areas are that:

1. the natural watercourses and downstream primary drainage channels should be considered as Priority No.1. This involves clearing of the natural watercourses of weeds, waste, silt deposits and demolition of encroached properties along their paths; and construction of the downstream primary drainage channels that would receive flood water from the streets' drains to these natural watercourses. This will bring immediate improvement to the flood water discharge on the existing system that do not have discharge points.

Figure 17: CONCRETE MATTRESS

2. canalization of some of the watercourses with concrete mattresses, (See Fig. 17) is recommended as Priority No.2. This involves construction of 6m – 10m width of trapezoidal channels made with concrete mattresses. This will stop encroachment by property developers and create a definite demarcation of the natural watercourses. This will bring improvement on the existing systems while the construction of new infrastructures for more efficient and effective evacuation of flood water from the environment would be in progress.
3. the need for updated Survey Maps for Asaba, Warri, Effurun, and environs by Delta State Ministry of Lands and Survey is recommended as Priority No.3. The presence of these maps will aid future planning and construction of infrastructural developments, as lack of these maps caused delay and increased project cost.
4. with the implementation of items. 1 &2 above, the need to construct drainage channels in the flood prone areas is recommended as Priority No. 4. The construction of these street drainage channels (tertiary and secondary channels) on the identified flood prone areas will create greater improvement on flood management and control of the environment.
5. government Ministries and Agencies in-charge of urban development must stop approval of property developments on the natural watercourses and streets' rights-of-way, while identifying and demolishing those properties built on these mapped out routes for quick evacuation of the flood water generated within the environment.
6. government Ministries and Agencies in-charge of drainages must have a holistic maintenance and repair response plan with motivated team. This team should carry out quick repair to damages on drainage channels as well as carry out periodic manual de-silting of the drainage channels.
7. the State Orientation Agency and similar Agencies in charge of public enlightenment should do more at educating the populace on the hazards associated with discharge of waste materials and blocking of drains and natural watercourses, as studies have shown that some see it as a normal way of living.
8. the government should make it mandatory for property developers to create more areas for grassing and vegetations than stone or concrete interlocking pavements, as the use of the later increases runoff in the streets.

9. Merits of the Recommended Options

The merits to be derived from the use of these recommended pre-cast concrete structural elements of rectangular, square and circular channels are as mentioned below:

1) The use of precast primary receivers for the construction of the downstream channels to receive stormwater discharges from the streets' right-of-way will reduce the construction time required for evacuation of the current flooding menace that is being encountered in the environment, since non-functioning drains will now have discharge points.
2) There are savings in project delivery in terms of time, handling and cost optimization during fabrication and execution of the project. Since all these various types of channels with different operations will run simultaneously.
3) There is reduced construction risk to workers and passers-by during deep execution works since earth moving equipment will be deployed for the placement of the heavy precast concrete elements in the deep excavations. This will improve the overall safety rating of the project.
4) There will be reduced exposure time to the excavated sections with the use of precast structural elements over cast-in-place concrete types as the works are in built-up areas. This will improve the overall safety rating of the project.
5) There is no need for long exposed excavated trenches as is the case with cast-in-place concrete since smaller segments of work excavation are needed to place the precast elements.
6) The use of precast concrete structural elements will reduce in-situ construction errors, which would create greater quality control on the project.
7) Finally, with adequate funding, the State government would complete the project within a short time, which will save her citizens the agony of economic and human losses occasioned with the hazardous and devastating flood water.

10. Conclusion

- From the details of the findings, observations, photographs obtained from the report of the Committee set up by the State government, and on further study and design carried out by **Jefcon & Associates Ltd** (Consultant) for the stormwater management and control measures for Asaba, Warri, Effurun and environs it is evident that major causes of the flooding in the study areas come from :

i. rapid urbanization without the provision of the necessary infrastructure to cope with the growth rate. Warri has no dump site and no organized waste management system;

ii. blockage of the natural watercourses with property developments;

iii. lack of regular desilting and clearing of wastes and weeds from the drains and waterways;

iv. and finally, inadequate sizing and poor construction of the drainage channels;

v. The study revealed that though, Asaba, Warri, Effurun and environs are blessed with natural watercourses and rivers, the functions of these natural watercourses have been inhibited with uncontrolled property developments. The consequence of these actions from the citizenry is the resultant effect of increased flooding in the environment;

vi. Government must as a matter of urgency remove these inhibitors from the natural watercourses and create defined water routes for the evacuation of flood water from the environment. This will bring improved efficiency to the new and existing drainage systems which would lead to a permanent solution to the flooding in the environments;

vii. a health synergy between the Ministries handling the infrastructural developments and Ministry of lands and Survey, by allowing participation of key professionals in each Engineering project during conceptualization, design and implementation will bring a better service delivery and saving in cost for the government.

viii. the government should implement the recommended priorities and carry out mapping of the majors towns and cities in the State, to create defined paths for the watercourses and stop property developers from encroaching and;

ix. finally, it is our belief that if these prioritized recommendations are implemented, a permanent solution to the flooding of Asaba, Warri, Effurun and environs would have been provided.

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