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# RESEARCH ARTICLE

## THE FEATURES OF URBAN STORM DRAINAGE IN ABA, NIGERIA

***Ogbonna Chukwuemeka Godswill, Eleazu Eberechi Ijeoma, Obinka Azubuike Nnaemeka and Ukpabi Jane Ijeoma**

Department of Urban and Regional Planning, Abia State Polytechnic P.M.B 7166 Aba, Nigeria

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**ABSTRACT**

Urban storm drainage is a network of closed or open conduits that receive runoff from inlets or surfaces, and conveys it to an outfall or downstream outlet. Drainage plays a very important role in evacuating stormwater from cities thereby reducing the possibilities of flood. This study examined the features of urban storm drainage in Aba, Nigeria. The study adopted geometric survey technique, and relied mainly on primary data which were collected through direct observation and measurements. Data collected were analyzed with appropriate parametric tests using SPSS for Windows, Version 17. Specifically, Analysis of Variance (ANOVA) was used to test the hypothesis of the study. Findings show that the geometries of the drains are characterised by structural deficiencies in terms of low hydraulic capacities, low invert grades, narrow wall thicknesses, incompletion, no systemization and lack of downstream outlets, which significantly contribute to urban flooding in Aba. The study recommends among other things, that the government of Abia State should plan for, and produce urban drainage master plan for the city of Aba, which will ensure the provision of standardized arteries and network of infrastructure for stormwater conveyance and treatment.



## INTRODUCTION

Urban drainage is composed of artificial system of sewers: pipes and structures that collect and dispose of storm and household/industrial wastewater (Butler and Davies, 2004). Urban drainage systems handle two types of flow: wastewater and stormwater. Piped systems consist of drains carrying flow from individual properties, and sewers carrying flow from groups of properties or larger areas. Sewerage refers to the whole infrastructure system: pipes, manholes, structures, pumping stations and so on (Tucci, 2001). There are basically two types of conventional sewerage system: a combined system in which wastewater and stormwater flow together in the same pipe, and a separate system in which wastewater and stormwater are kept in separate pipes (Tucci, 2001). The basic function of urban drainage is to collect and convey wastewater and stormwater to a treatment plant, or to be discharged into a river or some large water bodies downstream (FEPA, 1991). In contrast, isolated or low-income communities normally have no main drainage. Wastewater is treated locally (or not at all) and stormwater is drained naturally into the ground. These sorts of arrangements have generally existed when the extent of urbanisation is low (Musa, 2012). Urban storm drainage is a network of closed or open conduits that receive runoff from inlets or surfaces, and conveys it to an outfall or downstream outlet (American Association of State Highway and Transportation Officials [AASHTO], 1992). Stormwater is generated by rainfall, and consists of that proportion of rainfall that runs off from urban surfaces. Hence, the properties of stormwater, in terms of quantity and quality, are intrinsically linked to the nature and characteristics of both the rainfall and the catchment. When rainwater falls on a natural surface, some water returns to the atmosphere through evaporation, or transpiration by plants; some infiltrate the surface and become groundwater; and some run off the surface. The transformation of a rainfall hyetograph into a surface runoff hydrograph involves two principal parts. Firstly, losses due to interception, depression storage, infiltration and evapo-transpiration are deducted from the rainfall. Secondly, the resulting effective rainfall is transformed by surface routing into an overland flow hydrograph (Butler and Davies, 2004). The need for storm drainage arises from human interaction with the natural water cycle. Sewers usually drain in the same direction that nature does: by gravity. Gravity systems tend to be seen as requiring little maintenance when compared with systems involving a significant amount of mechanical equipment, or the need to maintain fixed pressures. But in some cases gravity is not enough, usually when the ground surface is relatively flat over extended area, and when it is not cost effective to provide treatment facilities for each natural sub-catchment. In these circumstances, it is appropriate to use pumping system (Butler and Davies, 2004). An effective storm drainage system has the capacity to remove overland flow soon after rainfall.

****Corresponding author: Ogbonna Chukwuemeka Godswill***
*Department of Urban and Regional Planning, Abia State Polytechnic P.M.B 7166 Aba, Nigeria*

Conventional systems on roads employ either open concrete drains and/or pipe drains (Owuama, Uja, and Kingsley, 2014). The drains mainly rely on gravity, and are therefore not sustainable in areas with insufficient slope, particularly in developing economies where socio-economic and cultural practices affect their maintenance (Owuama, 2012). Urban roads are often designed with camber towards open concrete drains on both sides of the road. Culverts are provided at crossings over open concrete drains (Owuama *et al*., 2014). Construction of road network in an urban or semi – urban settlement requires a good drainage system that can convey stormwater runoff from impermeable surfaces. The rate of urbanization affects the extent of impervious area – the roads, roof tops and large expanses of paved surfaces, where there is very little or no earth surface into which rainfall could infiltrate (Olukanmi, Adebayo, and Tenebe, 2014). Tucci (2001) observed that urban development alters the vegetation cover, affecting the elements of the natural water cycle in a number of ways. Roofs, streets, paved areas and patios make the ground impervious; the water that previously soaked into the soil now runs through the drains, so increasing surface runoff. The degree of imperviousness also affects the volume of runoff obtained in cities. Urbanization therefore has enormous effects on elements of hydrological cycle, like precipitation, infiltration, percolation, transpiration, evaporation, and surface runoff (Musa, 2012).

Urbanization in developing countries is characterized by high population concentration in small areas, poor public transportation, inadequate basic infrastructure and social facilities, high level of pollution, and flooding (Ogbonna, 2014). As cities develop, its impact on drainage include: increase in peak flows (up to 7 times) and in frequency owing to the higher runoff capacity through conduits and canals, and impermeabilization of surfaces; increased sediment production from unprotected surfaces and production of solid waste (refuse); and deterioration in quality of surface and ground water owing to the transport of solid material and clandestine sewage and storm water connections (Tucci, 2001). In cities of the developing countries urban development is dynamic and random. Properly designed and managed urban drainage systems with its interactions with other urban water systems are often lacking (Tucci, 2001). Urbanization in Nigeria and particularly in major cities like Lagos, Kano, Kaduna, Abuja, Port-Harcourt, and Aba poses great challenge to policy makers in meeting up with the provision of urban infrastructure. The situation is worse with storm drainage and sewage systems as most cities of Nigeria do not have sewerage (National Emergency Management Agency [NEMA], 2012). Urbanization in Nigeria creates a major impact on drainage because there is no regulation for source control of the urban drainage peak flow. The resultant effects are excessive flow exceeding the hydraulic capacities of the drains, and subsequent flooding with disastrous consequences on urban transportation, settlements, goods, and properties (Agbonkhese, Yisa, and Daudu, 2013). The hydraulic conveyance of a drain is facilitated if the ground surface or its invert has sufficient slope. An area or drain invert is sufficiently sloped where the grade is greater than 2% (Owuama, 2012), and this has been exceedingly difficult to achieve in the coastal plains of southern Nigeria. Even where sufficient grade is achieved, due to human activities the drains may be blocked with refuse, grit, yard or construction materials resulting to urban flooding (Owuama *et al*., 2014). Urban drainage in Aba is essentially roadway drainage, with sealed or open concrete drains on both sides of the major roads. The city does not have urban drainage master plan, and there has never been a specific integrated urban drainage project. Aba has a relatively flat coastal terrain, with the average relief of about 54m above sea level (Njoku, Amangabara, and Duru, 2013). The city also has higher mean volumes of precipitation, and great number of rainy days leading to more complex management of storm drainage, since greater volumes of runoff must be routed somewhere. The mean transported load of solids is larger (because runoffs go on for a longer time); there is less time for urban cleaning (more sediment and refuse remain on the streets) and to maintain drainage structures; and more time to develop waterborne diseases like malaria and typhoid. Urban drainage in Aba is equally adversely impacted by uncontrolled urban spread and its clandestine concentration, increased rates of soil imperviousness, and encroachment on floodplains and natural water courses (Njoku *et al*., 2013). On the other hand, urban slums with very dense land occupancy practically eliminate empty spaces which could become part of a storm drainage system in the city.

There have been growing concerns over urban drainage in Aba. Flood as a nuisance in Aba metropolis and environs is acute and rising. These followed the rapid growth of the city in recent years, marked by expansion of impervious surfaces and the virtual absence of sewage systems. Akintoye, Digha, Uzochukwu, and Harrison (2015) used GIS mapping to conduct flood risk analysis of Aba and environs which revealed that about 60% of the entire landscape of the city is prone to flooding especially in densely populated areas with industries and markets. The hydrologic environment of the city has become more complex than in previous years resulting to the ubiquitous deluge of runoff on street surfaces. The consequences of flooding in Aba are devastating, including loss of lives, damage to property, road accidents, traffic congestion, breading of waterborne diseases, and various health challenges. Over the years, the Abia State government's reactions to flood disaster have been to give emergency palliatives to the victims, and thereafter increase channel conveyance with high cost and low efficiency (Owuama, 2012). The frequency of flood in Aba and its ravaging consequences have compelled stakeholders to seek post-construction solution to the problems of storm drainage in the city. Unfortunately there exists no empirical study of the urban storm drainage architecture in Aba. This study therefore examined storm drainage in Aba to ascertain its peculiar features with the view to providing baseline data for the preparation of urban drainage master plan for Aba and other cities in south-eastern Nigeria.

**The Study Area: Aba in Nigeria**

The study area is the city of Aba in Abia State, located in the south-eastern part of Nigeria (see figure 1 for map of Abia State and Aba). Aba is located approximately between latitudes $5^{o}$ 05'N to $5^{o}$ 08' north, and longitude $7^{o}$ 20'E to $7^{o}$ 28' east, and has sprawled to an approximate area of 26.7km$^2$. The study area is within the humid tropical rainforest zone of south-eastern Nigeria. The rainfall regime is bimodal and peaks in July and September with a small period of dryness which lasts for usually two weeks and locally known as 'August Break'. The rainy or wet season begins by late February and lasts till October or early November. Some years however experience rain in all the months including the months of the dry season, which is usually between November and February. The mean annual rainfall of Abia State is between 2550mm and 2890mm (FGN, 2003). The study area is bisected by the Aba River, a tributary of the Imo River. Aba is generally a low lying area with uniform topography. The highest elevation in the area is about 72m above sea level by the north-central part of the city, while the lowest height is about 36m above sea level by the Aba River valley. Greater part of the city lie in areas between 40m to 50m above sea level, and these areas are prone to flooding (Njoku *et al*., 2013). One hundred per cent of dwellings in Aba are not served by sewage system. The Metropolitan Area of Aba has complex urban drainage issues. Most of the problems currently observed in the area are related to the quantity and quality of storm runoff, and poor standard of stormwater conveyance infrastructure. The occurrence of flooding, and the ongoing problems of contaminated and stinking canals/drains are the results of unplanned urban growth, and lack of a government policy on urban drainage. Population pressure, demand for land and services, the state of urban infrastructure and lack of planning in Aba have led to an exponential increase in the risks of flooding.

the estimation of the width, depth and length of the drainage channels in the study area at different points, and then their mean values computed accordingly. The levelling instrument was used to measure the differences in slope of the drains at different points, and the measurements were subjected to Manning's formula for the estimation of the invert grades. The procedure also involved dipping calibrated metal rod into the drains to measure their depth, and level of ponding, or siltation by waste materials. All existing drains in Aba were constructed at the edge of the roads, hence the number of roads in Aba metropolis represent the study population. The census of roads in the city of Aba which was conducted by the research team showed a total number of 214. The sample size of approximately 90 was estimated from the population using the following model derived by Miller and Brewer (2003).

$$n = \left\{ \frac{N}{1+N(\alpha)^2} \right\} \quad \text{---- Equation 1}$$

Where: N = study population; n = required sample size; and α = margin of error (0.08). Cluster sampling technique was used to divide the city into four quadrants for purposes of fair representation, and equal numbers of roads were selected from each quadrant.

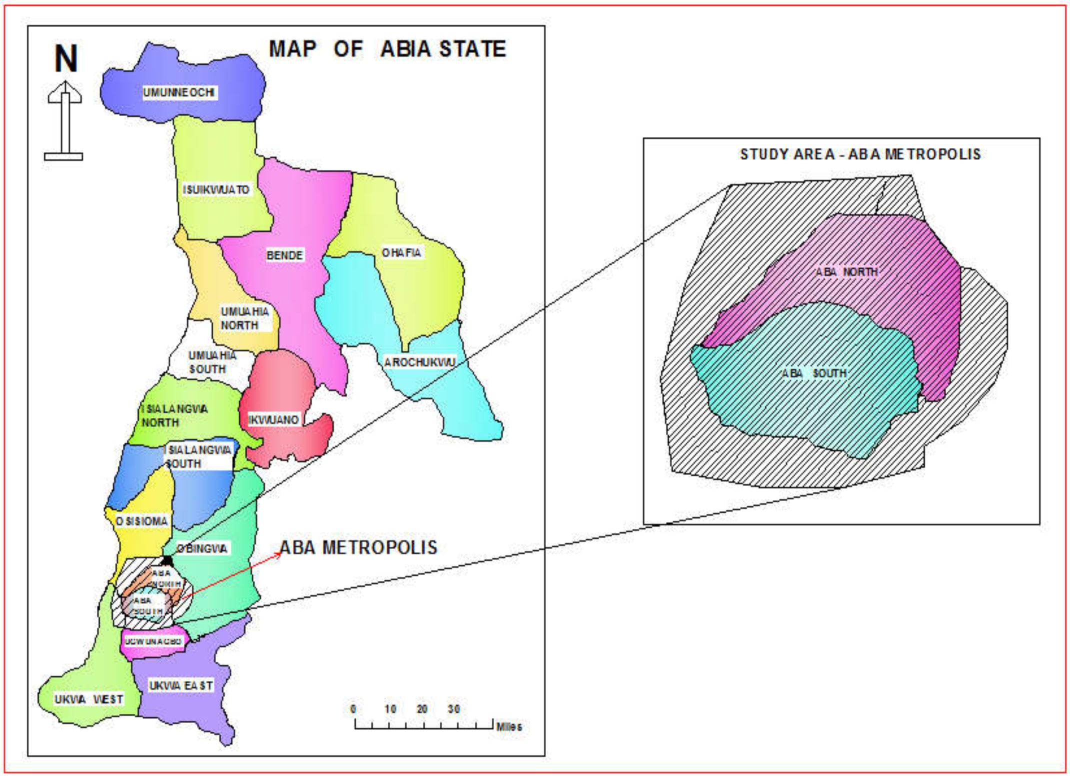



**Figure 1. Map of Abia State and Aba metropolis - the study area**

## MATERIALS AND METHODS

The researchers adopted the geometric survey design. This approach utilized direct measurement of geometric variables of the drainage channels, and canals using Measuring Wheels, Handheld Distance Laser (SPECTRA QM55), Leveling instrument (Di-Lev5), and Calibrated Metal Rods. The Measuring Wheels and Handheld Distance Laser were used in

Simple random sampling method was then used to select the roads or streets which the drains were measured. The study was based on both primary and secondary data. The primary data were collected through direct observation, and through direct measurement of the drains and canals. The secondary sources of data include government publications from Abia State Environmental Protection Agency (ASEPA) and ministry of works and housing Abia State, Nigeria. Data collected were analyzed with appropriate parametric tests using SPSS for Windows, Version 17. Specifically, Analysis of Variance (ANOVA) was used to test the hypotheses of the study. *P* value of ≤ 0.05 was considered statistically significant.

## RESULTS AND DISCUSSION

### *Characteristics of urban drainage in Aba*

The geometries of the drainage channels along the 90 sampled roads in the study area were measured. The measurements conducted on the drains were on the following variables: mean width; mean depth; mean wall thickness; mean invert grade; mean depth of silt or water/sludge of the drains; and flood condition of the roads. The results are shown in table 5 (see appendix A). Finding from these geometric measurements reveal the following:

- 33 out of the 90 roads surveyed (or 36.7%) do not have drainage channels
- Less than 5% of the drains have mean width of 1.5meters and above; about 22% have mean width up to 1meter, while over 78% of the drains have mean width of less than 1meter. Generally speaking, the existing drains can be said to be narrow especially when compared with volume of stormwater during peak flow.
- The mean depth of the drains range from 0.65m to 0.9m, with less than 4% having mean depth above 1meter. This also means that the drains are too shallow when their depths are compared with their invert grades.
- The mean wall thickness of the drains range from 0.13m to 0.16m, while only about 2.5% have up to 0.2m wall thickness. The drainage walls are narrow resulting to frequent collapse.
- Less than 20% of the surveyed drains have their mean invert grades up to 2%, while over 60% have mean invert grades of less than 1%. This means that more than 60% of the drains would generate flow velocity of less than 0.50m/s, which could result to ponding of the drains, and subsequent flooding of the streets during heavy rainfall.
- About 45% of the surveyed drains are more than 80% silted, while 73.5% are more than 50% silted. Only about 8.4% of the drains are silts free, and these are found around OgborHill district and areas close to Aba River where the invert slope of the drains are above 3%, and flow velocity high enough to allow for self cleansing of the drainage.
- 57% of the surveyed roads are flooded during the rainy season, with only 43% flood free. Figure 2 is a flood risk map of Aba, showing areas where the poor conditions of the drains contribute to flooding mostly along the streets. The roads that are flood free are generally roads in OgborHill district, roads within Park-roads – Ehi-road district, and some roads in remote residential districts. The roads in Ogborhill district are flood free because the area has a gentle slope that allows adequate flow velocity for runoff. The roads at the Park-road – Ehi-road district have shorter drains in length which effectively empty to the Aba River, some through the major canal along School road. Some roads in remotely located low density residential districts are not flooded because less runoff reaches the roads due to vast area of open country and vegetation, and increased permeability of the area.

### *Physical condition of the drains*

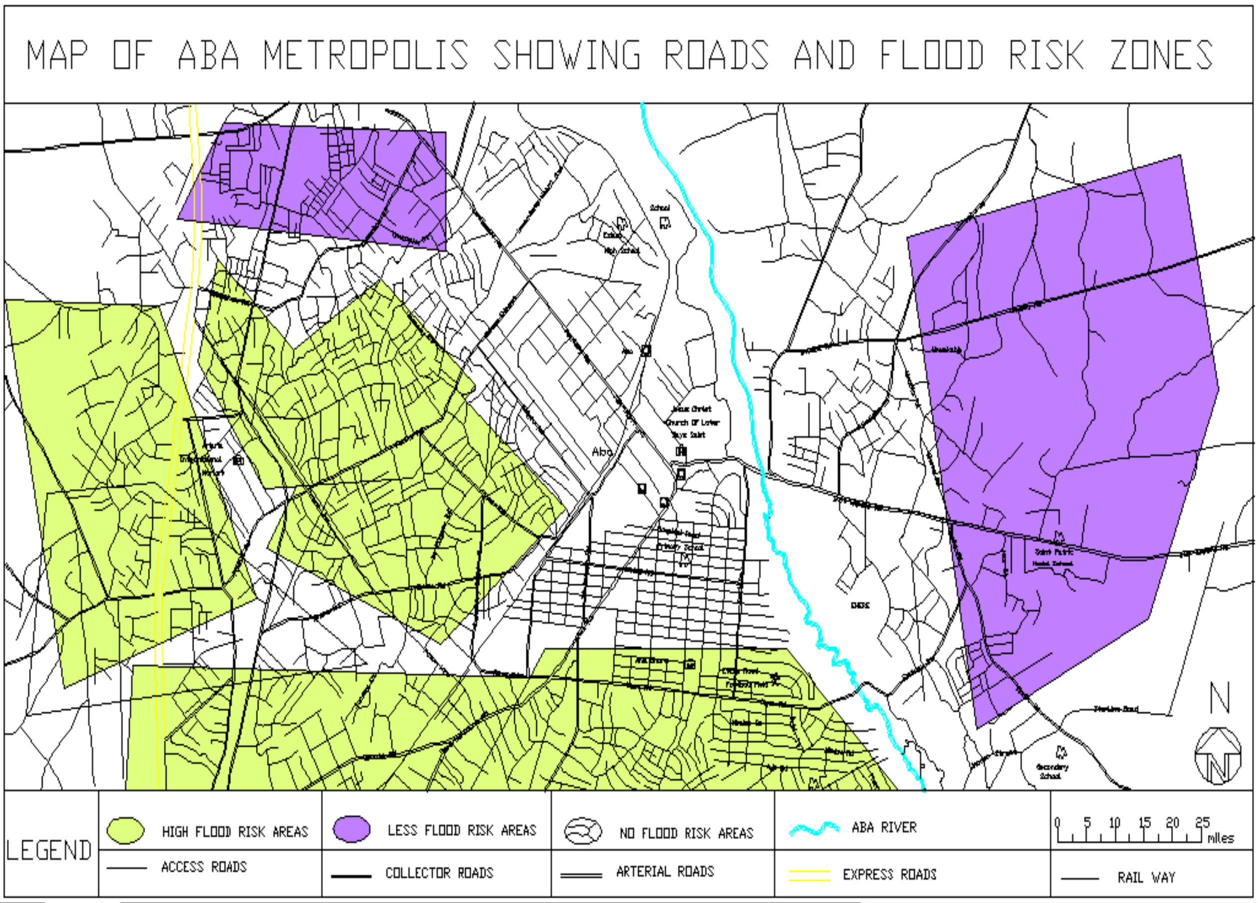
The survey examined the physical conditions and level of maintenance of the drains in the 90 sampled roads in Aba, and the results are shown on Table 1. Findings in table 1 show that majority of the existing drains have collapsed sections (see Figure 3). Generally they have narrow wall thicknesses, and sometime minimal pressure such as may be exerted by a truck forces the drainage walls to collapse. More than half of the existing drains are silted with a combination of mud, sand, and refuse (see Figure 3). Again about 85% of the drains are filled with pond water or sludge. Due to very low invert grade, runoff is trapped inside the drains especially where they have no downstream discharge points, or where the outlets are blocked. Sometimes excessive ponding is caused by household sewage which is clandestinely discharged directly into the storm drains. Only about 32% of the drains have downstream outlets, and these are the drains close to the Aba River. The rest of the sewers actually empty no where; they simply end where the road ends, or connect to other storm drains which also terminate with the roads. More than 82% of the drains emit stench. They equally breed mosquitoes and other disease carrying organism. It is common practice in the study area for households to secretly channel their domestic sewage to the gutters, and this practice worsens the health conditions of the neighbourhoods.

### *Classification of roads based on the state of their drainage channels*

The survey classified roads according to the nature and quality of their drainage channels as illustrated in Figure 4. It reveals that only 32% of the roads surveyed have drains at both sides, 13% have drains at only one side of the road, and 18% of the roads have drains constructed at certain parts but terminated midway. There is incomplete construction of some of the roads, so also their drainage channels. In such cases, the drains have constituted more problems to the roads, leading to erosion of the segments, and flooding. A good number of the roads in the study area (37%) do not have drains at all.

### *Primary agents that cause siltation of the drains*

Certain factors were identified as primary agents causing siltation of the drains and these include: poor road quality; indiscriminate refuse dumping; soil erosion; poor road cleaning habit; and washed out compound wastes as presented in Table 2. The results in table 2 indicate that poor road quality is a significant factor causing siltation of drains in Aba. Some of the urban roads are poorly constructed, worn out, or simply without asphalt surfaces. During heavy rainfall, sand and mud are washed into the drains. Collection and disposal of solid wastes are phenomenal problems in the city of Aba. Some of the residents of the city have very poor habits of waste disposal, sometimes converting drainage channels and canals to dumpsites. Almost all the drains in the city have huge deposits of solid wastes, mostly composed of polythene materials, used plastic, sacs, cans, food remains, paper, and so on.




Source: produced by authors, 2016

**Figure 2. Flood risk map of Aba metropolis**

**Table 1. Physical condition of the drainages**

| S/N | Condition | No. of roads affected | Percentage |
|---|---|---|---|
| 1 | Collapsed sections | 73 | 81.1 |
| 2 | Silted | 66 | 73.3 |
| 3 | Filled with sludge/pond | 77 | 85.6 |
| 4 | Closed design | 6 | 6.7 |
| 5 | Downstream outlet | 29 | 32.2 |
| 6 | Emits stench | 74 | 82.2 |
| 7 | Breads mosquitoes/diseases | 74 | 82.2 |

Source: Authors' Field Survey, 2016

**Figure 3. Drain silted with sludge and refuse**

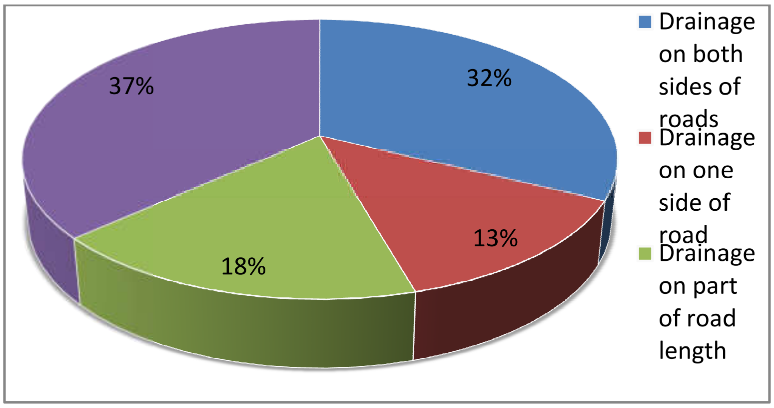



**Figure 4. Percentage of roads with drainage channels**

**Table 2. Causes of drainage siltation**

| S/n | Causes of siltation | No. of roads affected | percentage |
|---|---|---|---|
| 1 | Poor road quality | 68 | 75.6 |
| 2 | Indiscriminate refuse dumping | 90 | 100 |
| 3 | Poor road cleaning habit | 84 | 93.3 |
| 4 | Washed out compound waste | 59 | 65.6 |
| 5 | Erosion/ landslide | 7 | 7.8 |

Source: Authors' Field Survey, 2016

**Table 3. Structural problems with drains**

| S/N | Structural problem | No. of roads affected | percentage |
|---|---|---|---|
| 1 | No existing drain | 21 | 36.8 |
| 2 | Silted drains | 40 | 70.2 |
| 3 | Lack of downstream outlet | 41 | 72 |
| 4 | Insufficient invert grade | 39 | 68.4 |
| 5 | Insufficient capacity due to narrow width | 37 | 64.9 |
| 6 | Blocked culverts, grates, scuppers and manholes | 28 | 49.2 |
| 7 | Erecting buildings/structures on drains | 22 | 38.6 |

Source: Authors' Field Survey, 2016

Poor road cleaning habit is another major cause of silty drains. Urban road cleaning is not seriously carried out in Aba. Few roads are occasionally swept manually, mostly by women. Most of the roads have tick deposits of sand, dust, and litter, and these are blown into the open drains by moving vehicles. A significant number of the drains are silted by household sewage or compound wastes which are either channelled directly into the drains or washed in by storm water as the case may be. Some drains are also silted by erosion and landslide of adjoining areas.

**Structural problems with drainage channels on the flooded roads in Aba**

The researchers examined the structural deficiencies of the existing drains in the 57 flooded roads, to determine their contributions to the incidence of flooding on those roads. The results are shown in Table 3. Analyses of table 3 show that 21 roads out of 34 that do not have drains are flooded during rainy season. The other roads without drains that are not flooded happen to be some roads near the Aba River where the slope is fairly steep, and some suburban roads where vast open country aid storm water infiltration. Other structural conditions of the drains which exacerbate flooding are as follows:

Siltation: more than 70% of flooded roads in Aba have silted drainage channels

**Lack of Downstream outlets:** drainage channels found in 72% of the flooded roads have no downstream outlets. They simply terminate where the roads end

**Insufficient invert grade:** in about 68% of the flooded roads, the slopes of the drains are less than 0.5%, which is insufficient to allow for timely hydraulic conveyance of storm water downstream, considering the rainfall intensity in the region.

**Size of the drains:** The mean width and depth of the drains are comparatively too small. The capacities of drains cannot accommodate deluge of discharge from built – up environment with impermeable land covers such as interlocking stone, asphalt or concrete slab. Owuama, Uja, and Kingsley (2014) in an earlier study noted that a rainfall intensity of 100mm/hr on a plot of built up area (33m by 20m) can generate 660m$^3$ of water per hour. This is characteristics of Aba and the entire South-eastern region of Nigeria, and to handle flows of this nature, special design consideration must be applied in constructing storm drainage system.

**Blocked culverts, grates, scuppers and manholes:** most of the drains have their culverts and grates completely blocked by mud, solid wastes, and polythene materials. This condition exists in about 49% of the flooded roads. Most of the drains have poorly constructed scuppers and manholes.

There is also the problem of erecting structures (kiosks, shops, showrooms, sales platforms) on drainage channels. These help to block the drains thereby causing flood.

There are natural causes of flood in the study area such as: magnitude and frequency of rainfall; considerably flat topography; and soil structure (which are beyond the scope of this paper); but man does not have much control over them. However man has significant control over the anthropogenic causes of flood identified in table 4 by limiting construction and eliminating blockages from drains and the natural flood plains, and increasing the capacity of hydraulic conveyance structures to conveniently carry flood flow. The above analysis has revealed four fundamental problems which militate against effective functioning of the drainage systems in Aba: poor design; poor maintenance, poor physical planning, and poor environmental attitude of residents. Issues of size of drains, capacity, invert grade, downstream discharge, failed sections, incomplete construction, and road quality all border on design. Maintenance problem manifests in blocked culverts and grates, irregular de-silting, and lack of repairs on fallen sections. Urban drainage planning has not been carried out for the city of Aba. Everything that has been done on drainage so far is simply part of road construction.

There exists no specific drainage master plan or development scheme for the city. To compound the problem, the environmental attitude of majority of the residents is very bad. Aba is basically a commercial city. The traders are used to dumping garbage on the streets and gutters. In some neighborhoods residents see drainage channels as dumpsites. Household sewage is sometimes clandestinely channeled into storm drainage channels as there is no municipal sewage system in the town. These create environmental and health risks which the government grapple with very day.

**Comparison of drains on flooded roads with drains on flood free roads in Aba**

The study compared the geometric data of drainage channels on the flooded roads with those on the flood free roads, for the 90 roads sampled. For this purpose, the study formulated a hypothesis as follows:

**Ho:** there is no significant difference in the geometric characteristics of the drains between the roads that are flooded and the roads that are flood free in Aba. This hypothesis was tested using Analysis of Variance (ANOVA), and the result is shown in Table 4.

The ANOVA result in table 4 reveals the following:

- Comparison of mean width of drains for flooded roads with flood-free roads showed significant difference: ($F = 8.221$; $P = 0.004$) $P < \alpha$ (0.05) significant level; therefore *Ho* is rejected.
- Comparison of mean depth of drains showed no significant difference: ($F = 1.631$; $P = 0.205$) $P > \alpha$ (0.05) significant level; *Ho* not rejected.
- Comparison of mean wall thickness of drains showed significant difference: ($F = 8.026$; $P = 0.006$) $P < \alpha$ (0.05) significant level; *Ho* is rejected.
- Comparison of mean invert grade of drains showed significant difference: ($F = 99.235$; $P = 0.000$) $P < \alpha$ (0.05) significant level; *Ho* is rejected.
- Comparison of mean silt depth of drains for flooded roads with flood-free roads showed significant difference: ($F = 7.238$; $P = 0.009$) $P < \alpha$ (0.05) significant level; *Ho* rejected.

This results imply that whereas the differences in mean depth of drainage channels was not important to explain the flood condition of the roads, the differences in mean width, mean wall thickness, and mean invert slope, and mean silt depth were important. This means that the structural deficiencies of the drains in terms of their narrow width, narrow wall thickness, low invert slope, and high rate of siltation contribute significantly to flooding in Aba.

**Table 4. Anova**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Mean Drain Width | Between Groups | 1.847 | 1 | 1.847 | 8.221 | .004 |
| | Within Groups | 19.766 | 88 | .225 | | |
| | Total | 21.612 | 89 | | | |
| Mean Drain Depth | Between Groups | 100.148 | 1 | 100.148 | 1.631 | .205 |
| | Within Groups | 5403.765 | 88 | 61.406 | | |
| | Total | 5503.912 | 89 | | | |
| Mean Wall Thickness | Between Groups | .042 | 1 | .042 | 8.062 | .006 |
| | Within Groups | .460 | 88 | .005 | | |
| | Total | .502 | 89 | | | |
| Mean Invert Grade | Between Groups | 180.106 | 1 | 180.106 | 99.235 | .000 |
| | Within Groups | 159.715 | 88 | 1.815 | | |
| | Total | 339.821 | 89 | | | |
| Mean Silt Depth | Between Groups | 1.023 | 1 | 1.023 | 7.238 | .009 |
| | Within Groups | 18.493 | 87 | .098 | | |
| | Total | 19.516 | 88 | | | |

Source: Computer SPSS Data Analysis by Authors

**Conclusion and Recommendations**

The study analysed the features of stormwater drainage in Aba and observed that the geometries of the drainage channels are characterised by low capacity, low invert grade, poor structural standard, incomplete construction, and no systemization. This has been compounded by lack of drainage plan, poor maintenance of the drains, and poor environmental attitude of the residents. As a result, about 65% of all roads in the city of Aba are flooded in the rainy season, with the flood spreading inland to the residential neighbourhoods, and with serious health and environmental challenges. The study also discovered that whereas the differences in mean depth of the drains was not important to explain the flood condition of the roads, the differences in their mean width, mean wall thickness, mean invert grade, and their high rate of siltation were important.

In other words, these structural deficiencies of the drainage channels (narrow width, narrow wall thickness, low invert grade, high content of silt) significantly contribute to urban flooding in Aba, all other conditions being equal. The study therefore recommends that the government of Abia State should plan for, and produce urban drainage master plan for the city of Aba. The goal of the urban drainage master plan would be to create mechanisms for developing and managing standardized urban infrastructure for storm water runoff. This plan should be an integral part of the wider city's urban development and environmental master plan which is presently at the conception stage. The flood-control policy of the master plan will be able to provide structural and non-structural solutions for the whole watershed, in which the structural solutions will provide the arteries and network of infrastructure for stormwater conveyance and treatment, while the non-structural solutions will utilize municipal legislations to manage the entire system. The following other recommendations contained in this study would all form part of the specific targets which the urban drainage master plan would seek to achieve.

**Source Control:** Source control for storm drainage which is hitherto none existent in the city of Aba is hereby recommended. The system consists of several techniques which aim at controlling runoff quantity and quality as near to the source as possible. This has the advantage of creating increased recharge; less pollution discharged into rivers; reduced volume of downstream flow; smaller drainage channel and conduit sizes, and using storm water as a resource and as an element of urban amenity.

**Detention and flow retardation:** Due to high rainfall intensity and rapid urbanization creating impermeabilization, which characterise urban drainage in Aba, there is increase in the peak flow of surface runoff. To prevent this increase in flow from being transferred downstream, the study recommends some control measures which will involve the attenuation of volume generated using retention systems such as: tanks, lakes and small open-air or covered basins. The detention and flow retardation structures are basically divided into two types: storage type and infiltration type. Storage-type structures are detention ponds and retention ponds. This includes also the development and control of smaller reservoirs designed to retard runoff in parks, residential unit, parking lots, housing estates, and schoolyards. The infiltration-type structures include pervious pavements, infiltration trenches, ponds and inlets.

**Dykes and pumping stations:** Dyke should be constructed at the primary downstream end of the Aba River to prevent flooding the adjoining settlements, while pumping stations should be built to compensate for low invert grade for drains that extend long distances like those in Aba-Owerri road, Port-Harcourt road, Ngwa road, Faulks road, and Asa road. Through the means of pumping stations, low hydraulic velocity could be improved which would convey stormwater runoff to downstream discharge points.

**Downstream discharge:** Improvement of downstream discharge for all drainage channels in Aba is very expedient in other to reduce overflow of the drains, and subsequent flooding. Major conduits and canals should be constructed to run eastwards to the Aba River from the interior west of the city. Then remotely located drains can be connected to the conduits and canal for onward discharge to the river.

**Integrating solid waste collection with drainage maintenance:** Solid wastes passing into the drainage easily silt up the channels and reduce runoff capacity. It also creates environmental impacts downstream, thereby increasing the frequency of flooding. Collection of solid waste in Aba is highly inefficient. The less efficient a city's refuse collection system, the greater the load on the drainage system. It is therefore necessary to devise an efficient system that integrates drainage with refuse collection and urban cleaning. The compulsory monthly environmental sanitation in Abia State should be invigorated with greater emphasis on de-silting and cleaning of drainage channels.

**Public enlightenment and participation:** The environmental attitude of most residents of Aba especially regarding drainage channels and waste disposal is very poor. There is need for serious public enlightenment and civil education on the use and maintenance of drains, as well as healthy practices of waste disposal. Public participation in urban drainage management should also be encouraged. Residents should be made to be accountable for the general state of any drain across their individual properties.

**Funding for urban drainage:** The municipal authorities usually do not have sufficient funds to supply the basic infrastructure for sanitation and urban drainage. Therefore the cost of implementing structural measures and the operation and maintenance of urban drainage should be transferred to the owners of landed properties, and calculated on the basis of the impervious area, which is what generates the additional volume in relation to natural conditions. Through this means government will raise additional fund for the implementation of the urban drainage master plan.

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## Appendix A

**Table 5. Geometric data of urban drainage in Aba**

| S/N | Road | Drain | Mean drain width(m) | Mean drain depth(m) | Mean wall Thickness (m) | Mean invert grade(%) | Mean Silt Depth(m) | Flood condition |
|---|---|---|---|---|---|---|---|---|
| 1 | Aba- Owerri | Yes | 1.60 | 1.50 | 0.215 | 0.26 | 1.40 | Flooded |
| 2 | Umungasi | Yes | 1.50 | 0.80 | 0.15 | 0.26 | 0.60 | Flooded |
| 3 | Ayaba-Umueze | Yes | 0.85 | 0.70 | 0.15 | 0.85 | 0.40 | Flooded |
| 4 | MCC | Yes | 0.90 | 0.70 | 0.14 | 0.30 | 0.55 | Flooded |
| 5 | Okpu-Umuobo | Yes | 0.85 | 0.80 | 0.15 | 5.4 | 0.20 | Free |
| 6 | St.Pauls | Yes | 1.00 | 0.85 | 0.20 | 2.15 | 0.80 | Flooded |
| 7 | Margret Av. | Yes | 0.80 | 0.65 | 0.135 | 1.25 | 0.65 | Flooded |
| 8 | Nicolas | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 9 | Brass | Yes | 1.10 | 0.80 | 0.15 | 0.80 | 0.35 | Free |
| 10 | Faulks | Yes | 1.10 | 0.80 | 0.165 | 0.20 | 0.68 | Flooded |
| 11 | Ekenna | Yes | 0.80 | 0.70 | 0.15 | 1.23 | 0.23 | Free |
| 12 | Calabar | Yes | 0.85 | 0.65 | 0.135 | 0..92 | 0.12 | Free |
| 13 | Umuojima | Yes | 0.80 | 0.70 | 0.13 | 0.33 | 0.66 | Flooded |
| 14 | World Bank 1 | Yes | 0.85 | 0.70 | 0.13 | 0.41 | 0.64 | Flooded |
| 15 | World Bank 3 | Yes | 0.85 | 0.70 | 0.13 | 0.34 | 0.45 | Flooded |
| 16 | Adaelu | Yes | 0.80 | 0.65 | 0.145 | 1.25 | 0.15 | Free |
| 17 | Okigwe | Yes | 1.00 | 0.80 | 0.165 | 0.65 | 0.35 | Free |
| 18 | Eziukwu | Yes | 0.95 | 0.80 | 0.165 | 0.40 | 0.70 | Flooded |
| 19 | Urrata | Yes | 0.85 | 0.75 | 0.155 | 0.41 | 0.70 | Flooded |
| 20 | Umule | Yes | 0.90 | 0.77 | 0.15 | 0.21 | 0.72 | Flooded |
| 21 | Powerline | Yes | 0.85 | 0.75 | 0.16 | 0.32 | 0.74 | Flooded |
| 22 | Omenazu | Yes | 0.85 | 0.70 | 0.15 | 0.44 | 0.69 | Flooded |
| 23 | Immaculate | Yes | 0.90 | 0.80 | 0.145 | 2.15 | 0.24 | Free |
| 24 | GRA1 | Yes | 0.90 | 0.70 | 0.13 | 2.01 | 0.30 | Free |
| 25 | Asa | Yes | 0.90 | 0.85 | 0.17 | 1.51 | 0.35 | Free |
| 26 | Port-Harcourt | Yes | 1.10 | 0.90 | 0.195 | 0.52 | 0.90 | Flooded |
| 27 | Ngwa | Yes | 1.00 | 0.85 | 0.155 | 0.35 | 0.82 | Flooded |
| 28 | School | Yes | 1.10 | 0.85 | 0.16 | 1.50 | 0.65 | Free |
| 29 | Ehi | Yes | 1.10 | 0.90 | 0.16 | 0.91 | 0.45 | Flooded |
| 30 | Tenant | Yes | 1.10 | 0.80 | 0.155 | 1.50 | 0.45 | Free |
| 31 | Clifford | Yes | 1.20 | 0.80 | 0.16 | 1.50 | 0.53 | Free |
| 32 | Azikiwe | Yes | 1.20 | 0.80 | 0.165 | 1.64 | 0.46 | Free |
| 33 | East | Yes | 1.50 | 1.20 | 0.17 | 3.05 | 0.35 | Free |
| 34 | Pound | Yes | 1.10 | 0.75 | 0.155 | 1.66 | 0.55 | Free |
| 35 | St. Michaels | Yes | 0.95 | 0.80 | 0.155 | 1.10 | 0.45 | Free |
| 36 | Adazi | Yes | 0.95 | 0.75 | 0.15 | 1.50 | 0.46 | Free |
| 37 | York | Yes | 0.90 | 0.70 | 0.15 | 1.25 | 0.60 | Free |
| 38 | Market | Yes | 0.95 | 0.80 | 0.16 | 1.50 | 0.68 | Free |
| 39 | Park | Yes | 1.00 | 0.75 | 0.165 | 2.10 | 0.62 | Free |
| 40 | Millverton | Yes | 1.10 | 0.80 | 0.155 | 0.44 | 0.69 | Flooded |
| 41 | Georges | Yes | 0.90 | 0.75 | 0.145 | 2.20 | 0.61 | Free |
| 42 | Iheoji | Yes | 0.85 | 0.70 | 0.135 | 0.34 | 0.54 | Flooded |

Continue……………..

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 43 | Ohabiam | No | 00 | 00 | 0 | 0 | 0 | Flooded |
| 44 | Omuma | Yes | 0.80 | 0.70 | 0.135 | 0.20 | 0.66 | Flooded |
| 45 | Izuogu | No | 0 | 00 | 0 | 0 | 0 | Flooded |
| 46 | Obohia | Yes | 0.80 | 0.65 | 0.13 | 0.31 | 0.65 | Flooded |
| 47 | Ohanku | Yes | 0.75 | 0.63 | 0.13 | 0.15 | 0.62 | Flooded |
| 48 | Ndiegoro | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 49 | Umuokpu | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 50 | Gravel | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 51 | Ikot-Ekpene | Yes | 1.60 | 1.2 | 0.182 | 3.45 | 0.48 | Free |
| 52 | Osusu | Yes | 0.90 | 0.70 | 0.155 | 0.33 | 0.63 | Flooded |
| 53 | Ebenma | Yes | 0.80 | 0.60 | 0.135 | 3.24 | 0.10 | Free |
| 54 | Egege | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 55 | Ukegbu | Yes | 0.90 | 075 | 0.15 | 2.65 | 0.45 | Free |
| 56 | Umuola | Yes | 0.90 | 0.75 | 0.155 | 2.60 | 0.22 | Free |
| 57 | Azuka | Yes | 0.85 | 0.70 | 0.145 | 2.00 | 0.63 | Free |
| 58 | Ovom | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 59 | Ehere | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 60 | Gera | No | 0 | 0 | 0 | 0 | 0 | Free |
| 61 | Medical Drive | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 62 | Ekenna | No | 0 | 0 | 0 | 0 | 0 | Free |
| 63 | Akpu | No | 0 | 0 | 0 | 0 | 0 | Free |
| 64 | FHA 1 | Yes | 0.75 | 0.64 | 0.135 | 2.01 | 0..24 | Free |
| 65 | FHA 4 | Yes | 0.75 | 0.60 | 0.13 | 2.01 | 0.40 | Free |
| 66 | Enyimba | No | 0 | 0 | 0 | 2.11 | 0 | Free |
| 67 | Ahukanna | No | 0 | 0 | 0 | 2.50 | 0 | Free |
| 68 | Eze-Anaba | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 69 | Peoples Rd. | No | 0 | 0 | 0 | 0 | 0 | Free |
| 70 | Igbere | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 71 | Umuoba | Yes | 0.90 | 0.75 | 0.155 | 3.55 | 0.05 | Free |
| 72 | New Umuahia | Yes | 0.90 | 0.80 | 0.15 | 2.10 | 0.58 | Flooded |
| 73 | Obikabia | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 74 | 7up | Yes | 0.90 | 0.94 | 0.16 | 4.05 | 0.12 | Free |
| 75 | Glass Ind. | Yes | 0.90 | 0.75 | 0.15 | 3.85 | 0.47 | Free |
| 76 | Ohuru-Ishimiri | No | 0 | 0 | 0 | 0 | 0 | Free |
| 77 | Umuelendu | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 78 | Ibe Av. | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 79 | St. Patrick's | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 80 | Umuoafor | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 81 | Umuodukwu | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 82 | Royal Palm | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 83 | Umuojima | Yes | 0.80 | 0.65 | 0.13 | 1.50 | 0.34 | Flooded |
| 84 | Zerock | No | 0 | 0 | 0 | 0 | 0 | Free |
| 85 | Chieme | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 86 | Umukalika | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 87 | Obeala | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 88 | Umuagu | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 89 | Nkwo-Elechi | No | 0 | 0 | 0 | 0 | 0 | Flooded |
| 90 | Kalunta | No | 0 | 0 | 0 | 0 | 0 | Flooded |

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