

**APPLICATION OF URBAN DRAINAGE SYSTEMS IN FLOOD REDUCTION  
IN CENTRAL ROAD OREDO LOCAL GOVERNMENT AREA, EDO STATE.**

**BY**

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**BENIN CITY, NIGERIA**

**P.M.B 1154**

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE  
AWARD OF A BACHELOR OF SCIENCES {BSCGEM - B.SC. GEOMATICS}  
DEGREE, IN THE FACULTY OF ENVIRONMENTAL SCIENCES, UNIVERSITY  
OF BENIN, BENIN CITY, EDO STATE, NIGERIA.

NOVEMBER 2025

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## CERTIFICATION

This is to certify that this project was carried out by **IBEKEH PRECIOUS EDAFE** with Matriculation Number: **ENV2006562** of the Department of Geomatics, Faculty of Environmental Sciences, University of Benin, Edo State, Nigeria.

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Date

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EXTERNAL EXAMINER

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Date

## **DEDICATION**

This project is dedicated to the Almighty God, the source of all creation, the architect of the universe, and the guide to all knowledge. Additionally, this research work is dedicated to the cherished memory of my beloved parents, Mr. & Mrs. IBEKEH . Their unwavering support and encouragement profoundly influenced my academic journey.

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## ABSTRACT

Flooding remains one of the most persistent environmental challenges confronting urban centers, particularly in developing countries such as Nigeria. This study investigates the application of urban drainage systems in flood reduction along Central Road, Oredo Local Government Area, Edo State, with emphasis on assessing existing drainage efficiency and developing sustainable solutions for stormwater management. The research integrates field observations, hydrological analysis, and Geographic Information System (GIS)-based spatial modeling to identify flood-prone zones, evaluate drainage capacities, and analyze runoff behavior within the study area. Findings reveal that the recurrence of flooding is largely attributed to inadequate drainage capacity, poor maintenance practices, and rapid urbanization, which increase surface runoff and hinder effective flow conveyance.

Based on the hydrological and spatial analysis, the study proposes practical interventions including drainage channel redesign, desilting programs, installation of retention structures, and the integration of nature-based solutions to improve stormwater conveyance and enhance urban resilience. Community involvement and public awareness were also identified as critical components for long-term flood management. This research contributes to sustainable urban planning and flood mitigation efforts by demonstrating how GIS-supported hydrological analysis can inform the design and optimization of urban drainage systems. The findings provide valuable insights and actionable recommendations for policymakers, engineers, and urban planners seeking to reduce flood vulnerability in similar urban environments.

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## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background of the Study

Urban flooding has become one of the most pressing environmental and infrastructural challenges facing many Nigerian cities, particularly fast-growing urban centers such as Oredo Local Government Area in Edo State. The rising frequency and intensity of flood events in this region are largely driven by rapid urbanization, poor land-use planning, inadequate drainage infrastructure, and increased rainfall variability associated with climate change (Woods, 2010). Situated within the core of Benin City, Oredo LGA experiences high population density, extensive impervious surfaces, and deficient stormwater management systems all of which heighten its vulnerability to seasonal flooding. These flood occurrences regularly disrupt socio-economic activities, damage infrastructure, degrade the environment, and pose serious health risks to residents.

The alteration of natural landscapes through urban expansion and the conversion of permeable surfaces into paved areas have further intensified flood hazards. Studies using Remote Sensing and GIS techniques have consistently identified parts of Benin City, including Central Road in Oredo LGA, as flood-prone due to low elevations, poor drainage connectivity, and the concentration of built-up areas (Merz, 2018–2020). In hydrological terms, a flood is defined as the overflow of water beyond its normal confines, submerging land and interfering with socio-economic and ecological systems (Abam, 2006). Globally, flooding is recognized as one of the most destructive natural disasters, resulting in annual economic losses exceeding \$60 billion and causing widespread displacement (Concertino et al., 2019; Nguyen-Huy et al., 2022). The main contributing factors include unregulated

urban growth, increased imperviousness, altered natural drainage, and climate-induced precipitation extremes (Balaban, 2009).

In Nigeria, the magnitude and impacts of flooding have grown significantly over the past decades. Between 1969 and 2020, the country recorded over 21,000 deaths and more than \$17 billion in economic losses due to flood events (Guha-Sapir et al., 2015). For example, the September 2020 flood affected 22 states, displaced over 24,000 people, and claimed 155 lives (Floodlist, 2020). Flood types commonly observed across Nigeria include: Urban Flooding – primarily caused by blocked or undersized drainage channels in built-up areas; River Flooding – resulting from riverbank overflows in floodplains; and Coastal Flooding – driven by tidal surges and rising sea levels (NIOMR; Folorunsho, 2001).

Recent GIS-based assessments have highlighted Central Road in Oredo LGA as a critical flood hotspot. Drainage density mapping, land-use analysis, and soil moisture data reveal high runoff potential in this corridor, attributed to its flat topography, limited infiltration capacity, and increasing urban density. Similar findings in neighboring LGAs—Egor, Ujunmwonde, and Ikpoba-Okha—further confirm that anthropogenic pressures and climatic changes are exacerbating flood risks throughout Benin City.

To effectively mitigate these challenges, modern approaches integrating Geographic Information Systems (GIS) and hydrological modeling have become indispensable. GIS enables spatial visualization, hydrological analysis, and flood prediction by combining topographic, climatic, and infrastructural datasets. When coupled with hydraulic modeling tools such as HEC-RAS, SWMM, or ArcGIS Hydrology, it provides the ability to simulate flood behavior, delineate hazard zones, and design efficient urban drainage systems. Therefore, applying GIS-based flood modeling and spatial analysis offers a scientifically

grounded framework for developing resilient and sustainable drainage infrastructure in flood

## **1.2 Statement of the Problem**

Urban flooding has become an increasingly persistent and disruptive challenge along Central Road in Oredo Local Government Area, Edo State, particularly during the rainy season. The recurrent nature of these flood events is primarily driven by rapid, unregulated urban expansion, insufficient and poorly maintained drainage infrastructure, ineffective land-use planning, and a lack of detailed, spatially-informed flood risk data. These factors collectively contribute to frequent waterlogging of roads and neighborhoods, destruction of residential and commercial properties, vehicular congestion, and heightened exposure to public health hazards, including outbreaks of waterborne diseases.

Although local authorities have made attempts to address these issues, most interventions have been reactive, implemented only after severe flood events occur, and often without the support of technical and geospatial analyses. Critically, the current flood mitigation strategies lack the integration of detailed hydrographic datasets, such as channel cross-sections, stream flow dynamics, drainage density, and digital elevation models elements that are crucial for understanding and managing urban flood risks effectively.

Moreover, existing flood risk assessments seldom leverage GIS-based hydrological modeling tools capable of simulating complex rainfall-runoff interactions, identifying flood-prone hotspots, or evaluating the performance of current drainage systems under varying climatic scenarios. This absence of predictive and spatially explicit modeling limits

the ability of planners and policymakers to design resilient and sustainable drainage infrastructure.

Consequently, there is an urgent need for a comprehensive, GIS-integrated flood modeling approach that combines hydrographic surveying with advanced spatial analysis. This would enable the generation of accurate flood risk maps, improve prediction of flood behavior, and support the formulation of targeted urban drainage strategies. Such an approach is vital for minimizing flood impacts, safeguarding infrastructure and human lives, and fostering sustainable urban development in Central Road and the broader Oredo LGA of Edo State.

### **1.3 Aim and Objective**

The aim of this project is to design and implement an efficient urban drainage system for Central Road, Oredo Local Government Area, Edo State, to mitigate recurrent flooding and enhance sustainable stormwater management.

The objective are to:

1. Identify and map flood-prone zones contributing to surface runoff and inundation within Central Road and its surrounding areas.
2. determine the design parameter across each catchment area.
3. Design a functional and sustainable drainage system

### **1.4 Scope and Limitation of the Study**

This study focuses on addressing the challenge of recurrent urban flooding along Central Road and its adjoining areas in Oredo Local Government Area, Edo State. It seeks to identify flood-prone zones, evaluate the current state and efficiency of existing drainage systems, and analyze the topographic, hydrological, and environmental factors contributing to poor stormwater flow and surface water accumulation within the study area.

A field reconnaissance survey was conducted to observe stormwater flow patterns, identify blocked or deteriorated drainage channels, and document areas frequently affected by waterlogging, erosion, and infrastructural damage. Topographic and spatial data were acquired and processed using Geographic Information System (GIS) tools to map elevation, slope, and flow direction. This spatial analysis provided essential insights into the runoff characteristics and the performance of the existing drainage network.

The research further proposes appropriate urban drainage interventions, including the design of open channels, culverts, and retention basins, tailored to manage stormwater effectively in the study area. Additionally, the study assesses the impact of rapid urban development, land-use changes, and inadequate drainage maintenance on flooding patterns, aiming to recommend sustainable, cost-effective, and practical flood mitigation strategies.

The scope of the study is limited by factors such as time constraints, limited access to high-resolution hydrological datasets, and restricted accessibility to certain locations during fieldwork. Nonetheless, efforts were made to ensure data accuracy and reliability through comprehensive mapping, field verification, and geospatial analysis.

### **1.5 Justification of the Study**

Addressing the persistent issue of flooding in Central Road, Oredo Local Government Area, is essential for safeguarding public health, protecting infrastructure, and enhancing the overall quality of life of residents. Frequent flood events in the area disrupt transportation networks, damage residential and commercial properties, spread waterborne diseases, and significantly reduce the functional lifespan of roads and other critical urban infrastructure. Consequently, there is an urgent need to evaluate and improve the performance of the

existing drainage systems to ensure effective stormwater management and sustainable urban development.

This study is justified by its potential to provide scientific and practical insights into the current state and efficiency of drainage infrastructure within the study area. By examining the relationship between urban growth, rainfall intensity, topography, and drainage performance, the research will identify the key deficiencies contributing to flood vulnerability. The findings will form a foundation for proposing cost-effective, sustainable, and technically sound drainage improvement measures tailored to the environmental and socio-economic conditions of Oredo LGA.

Beyond diagnosing existing challenges, the study adopts an integrated approach that combines field surveys, hydrological analysis, and GIS-based spatial modeling to propose targeted interventions. These include drainage redesigns aligned with natural flow paths, the use of retention and infiltration structures, and the integration of both engineering and nature-based solutions. By incorporating hydrological data, community needs, and environmental sustainability principles, the research advances from theoretical assessment to the development of actionable strategies for flood mitigation.

Ultimately, the outcomes of this study will serve as a vital resource for urban planners, engineers, and policymakers, guiding the design of more resilient, efficient, and adaptive urban drainage systems. Implementing the recommendations will not only reduce flood risks but also promote a healthier, safer, and more resilient urban environment for residents and businesses within Central Road, Oredo Local Government Area, Edo State.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Overview of Flood Occurrence and Impact

Urban flooding has become a persistent and escalating environmental hazard across many Nigerian cities, including Central Road in Oredo Local Government Area, Edo State. This phenomenon is primarily driven by a combination of natural and human-induced factors such as intense and prolonged rainfall, rising urban densities, unregulated land use, poor drainage infrastructure, and climate variability. As cities expand rapidly without adequate planning or drainage systems, the risk and frequency of urban flooding continue to grow (Adelekan, 2010; Nkwunonwo et al., 2020). Metropolitan areas like Lagos, Port Harcourt, Abuja, and Benin City (which includes Oredo LGA) are particularly vulnerable, experiencing repeated flood events that damage infrastructure, displace residents, compromise public health, and hinder economic activities. Despite various mitigation efforts, most flood control strategies in Nigeria remain reactive and poorly informed by spatial data.

Flooding leads to widespread environmental and socioeconomic consequences—including destruction of ecosystems, disruption of infrastructure, contamination of water supplies, and increased prevalence of waterborne diseases (Ujene et al., 2020). Globally, flooding is the most common and destructive natural disaster, accounting for about 43% of all recorded disasters between 1998 and 2017 (UNDRR, 2018). It is especially devastating in developing countries, where limited funding, weak institutional frameworks, and inadequate environmental management practices hamper effective flood mitigation. The World Bank (2016, 2022) notes that the severity of flood impacts is exacerbated by uncontrolled development in flood-prone areas, poor enforcement of building codes, and

insufficient investment in sustainable drainage infrastructure. In urban environments, impervious surfaces such as roads, pavements, and rooftops hinder infiltration, increasing surface runoff and overwhelming existing drainage networks. Urbanization thus accelerates runoff accumulation, particularly during high-intensity rainfall, elevating flood risks.

Flooding takes several forms flash floods, riverine floods, and coastal floods each with unique triggers and impacts. Flash floods, often the most hazardous, occur rapidly with minimal warning, especially in hilly or urbanized regions where water quickly channels over saturated or impervious surfaces. River floods, on the other hand, occur when rivers overflow their banks due to cumulative rainfall or upstream discharges, affecting surrounding lowland communities. In the Nigerian context, the Nigerian Institute for Oceanography and Marine Research (NIOMR, 2021) emphasizes that while urban development alone does not cause flooding, it significantly elevates risk when not properly managed.

The inadequate mapping of flood-prone zones and the failure to incorporate predictive modeling in urban planning have left many areas like Central Road in Oredo LGA highly vulnerable. Globally, studies such as Luo et al. (2015) have identified countries in Africa, Asia, and South America as bearing the greatest burden of flood impacts. In countries like Bangladesh and India, annual monsoon floods affect vast populations, with millions displaced or affected each year (Bhuiyan and Al Baky, 2014; Coca, 2020). In Africa, floods contribute to significant food insecurity, infrastructure losses, and disease outbreaks. Understanding the mechanisms behind flood occurrence—both natural and anthropogenic is essential for designing effective mitigation strategies. Integrating tools such as hydrographic surveys, GIS-based modeling, and digital elevation analysis allows for a more accurate simulation of flood behavior and identification of vulnerable zones. These

spatially informed approaches are especially crucial for urban drainage planning and disaster preparedness in flood-prone urban corridors like Central Road, Oredo LGA, where traditional methods have proven insufficient.

Table 2.1: Annual expected population affected by river floods in year 2015.

<b>Countries</b>	<b>Population (in millions)</b>	<b>Continent</b>
India	4.84	Asia
Bangladesh	3.48	Asia
China	3.28	Asia
Vietnam	0.93	Asia
Pakistan	0.71	Asia
Indonesia	0.64	Asia
Egypt	0.46	Asia
Myanmar	0.39	Asia
Afghanistan	0.33	Asia
Nigeria	0.29	Africa
Brazil	0.27	South America
Thailand	0.25	Asia
Congo	0.24	Africa
Iraq	0.19	Asia
Cambodia	0.19	Asia

Source: Adapted from World Resources Institute (WRI, 2015)

## **2.2 Types of Urban Flooding**

Urban flooding occurs when the volume of water from rainfall or other sources exceeds the capacity of urban drainage systems, leading to water accumulation in streets, buildings, and public spaces. In rapidly urbanizing areas like Central Road in Oredo Local Government Area, Edo State, understanding the different types of urban flooding is essential for designing effective and targeted drainage and flood mitigation strategies. Flooding can be categorized based on its causes, behavior, and geographical context. Below are the main types of urban flooding relevant to urban environments:

**i. Pluvial Flooding (Surface Water Flooding)**

Pluvial flooding arises from intense rainfall that generates surface runoff faster than it can be absorbed or drained. This type is common in urban areas where impervious surfaces (e.g., concrete, asphalt) prevent infiltration. Poorly maintained or outdated drainage systems further exacerbate this form of flooding. It often occurs outside traditional floodplains, making it harder to predict and manage. Its impacts are typically localized but severe, especially during short-duration, high-intensity storms.

**ii. Fluvial Flooding (Riverine Flooding):** Fluvial flooding occurs when rivers or streams exceed their channel capacity, leading to the inundation of adjacent land. It is typically caused by prolonged rainfall, upstream snowmelt, or overflow from blocked or undersized channels. In Oredo and other parts of Benin City, this type of flooding can be worsened by encroachments on floodplains and riverbanks, reducing natural water storage areas and increasing flood severity.

**iii. Flash Flooding:** Flash floods are sudden, intense flood events typically triggered by short-duration, high-intensity rainfall in steep or highly urbanized catchments. They can occur within minutes to a few hours of heavy rainfall, leaving little time for warning or response. In urban settings, especially in topographically uneven zones of Oredo, flash floods pose a significant risk due to their rapid onset and high velocity, often overwhelming both natural and artificial drainage systems.

**iv. Sewer Flooding:** This type of flooding results from the overloading or blockage of combined sewer systems during heavy rainfall events. Inadequate maintenance, sediment buildup, or solid waste accumulation can obstruct flow and cause water to back up into streets, homes, and businesses. Sewer flooding is particularly hazardous due to its health and sanitation risks, as it often involves both stormwater and untreated wastewater.

- v. **Groundwater Flooding:** Groundwater flooding occurs when the water table rises above the surface, typically following extended periods of rainfall or in areas with naturally high water tables. Although less common in fast-draining urban environments, low-lying sections of Oredo with poor drainage and shallow aquifers may occasionally experience this type of flood. Its onset is gradual, but the duration and damage can be extension.
- vi. **Infrastructure-Induced Flooding (Man-Made Flooding):** Failures or malfunctions in man-made water infrastructure such as canals, levees, dams, reservoirs, water mains, or pumping stations can lead to localized or downstream flooding. These failures may result from poor design, lack of maintenance, or operational errors. While rare, when they occur, such events can be catastrophic, particularly in densely built-up environments.

Understanding these flood types and their specific implications for urban planning in Central Road, Oredo LGA is critical for implementing effective flood modeling, risk assessment, and infrastructure design using GIS and hydrographic data.

### **2.3 Flood Occurrences and Drainage Issue in Nigeria**

Urban flooding has emerged as one of the most persistent and escalating environmental challenges in Nigeria, affecting major cities, smaller towns, and peri-urban areas alike. Its increasing frequency, intensity, and impact are largely driven by rapid urbanization, unplanned development, inadequate drainage infrastructure, and evolving climate dynamics. Among these factors, deficient drainage systems stand out as a central contributor to flood vulnerability, particularly in flood-prone urban centers like Central Road, Oredo Local Government Area of Edo State. Nigeria's flood problem is multifaceted. Natural causes such as intense rainfall, river overflows, and unfavorable terrain are compounded by human-induced actions illegal settlements in floodplains, blocked drainage channels, and insufficient environmental planning. Oredo LGA, being a key administrative

and commercial area within Benin City, is particularly vulnerable due to a high density of impervious surfaces, outdated drainage infrastructure, and minimal integration of hydrological planning in development policies.



Figure 2.1: Flood incident in Oredo community

Flooding is a major environmental hazard in Nigeria, with both natural and human-induced causes. Natural factors include excessive rainfall, unfavorable terrain, and soil characteristics. Several studies have been made in Nigeria to ascertain the causes and the effects of flooding in the country.

A notable study by Komolafe et al. (2015) offers an in-depth evaluation of flood risks across Nigeria, highlighting the widespread nature and increasing frequency of flood incidents nationwide. The research underscores the high vulnerability of affected communities and their limited capacity to adapt, particularly in the face of more frequent and intense weather events linked to climate change. The authors emphasize that poor urban planning and

ineffective management practices significantly amplify flood hazards. They advocate for the adoption of advanced flood modeling techniques to improve the accuracy of flood prediction and spatial risk mapping.

Nkwunonwo et al. (2015) conducted a comprehensive analysis of flooding and flood risk reduction strategies in Nigeria, identifying rapid population growth, accelerated urbanization, inadequate urban planning, and climate change as key drivers of frequent flood events. The study highlighted disturbing trends and statistics from 1985 to 2014, emphasizing the urgent need for scientifically grounded approaches such as flood modeling and vulnerability assessments to enhance flood risk management and preparedness.

Similarly, Magami et al. (2014) explored the root causes and impacts of flooding in Nigeria. Their study pointed to a mix of natural and anthropogenic factors, including dam failures, river overflows, coastal storms, and unplanned human settlements in high-risk areas. The authors also stressed that climate change, intense rainfall, and poor maintenance of drainage systems are major contributors to the worsening flood situation across the country.

Nwigwe et al. (2014) investigated the underlying causes and consequences of flooding in Nigeria, attributing the issue to a combination of illegal construction, land reclamation, inadequate urban planning, insufficient drainage infrastructure, blocked canals, dam failures, and challenging terrain conditions. Their study highlighted the widespread effects of these factors, particularly in major urban centers and densely populated towns.

In a related study, Olajuyigbe et al. (2012) examined flood hazards in Lagos, Nigeria, identifying critical contributors such as elevated river levels, intense rainfall, limited drainage capacity, and construction within flood-prone zones. They proposed several mitigation measures including the establishment of setback zones from streams, well-

planned road networks with functional drainage, proper channelization, and the construction of additional dams to reduce pressure on existing ones.

Evans et al. (2017) analyzed the environmental and infrastructural drivers of flood disasters in Uyo, Akwa Ibom State. Their assessment revealed that refuse dumping in drainage channels, roads without drainage systems, blocked floodways, and excessive urban paving were major contributors to flood events. Utilizing rainfall and temperature data from 2005 to 2016, they conducted a multiple regression analysis, which confirmed the significant impact of rainfall intensity and lack of drainage infrastructure on flood severity. The study emphasized the adverse implications of flooding on environmental sustainability and called for systematic construction of roads with proper drainage as a key mitigation strategy.

Rufa'i (2020) investigated the level of household preparedness for flood risks in Nigeria, attributing increased flood vulnerability to climate change-induced excessive rainfall. The study emphasized the importance of domestic-level readiness, highlighting the growing threat of floods to lives and property as documented in existing literature. It called for improved awareness and proactive measures at the household level to mitigate the impact of recurring flood events.

In a related study, Okeleye et al. (2016) examined flood vulnerability among farmers in Oyo State, identifying key risk factors such as proximity of farms to rivers, poor drainage infrastructure, frequent heavy rainfall, and lack of institutional support. The findings showed that while farmlands were significantly affected, residential structures experienced minimal impact. The study also pointed out that farmers had limited coping strategies and recommended interventions including well-designed drainage systems, weather forecasting services, agricultural insurance, and early warning systems for flood events.

Ani et al. (2020) explored the economic, environmental, and social consequences of flooding, while Nnodim and Ezekiel (2020) focused on the perceptions of rural dwellers in Rivers State's Orashi Region. Their study linked recurrent flooding to prolonged rainfall, overflowing rivers, reservoir discharges, and climate change. Documented impacts included flooded farmlands, destruction of crops, damage to irrigation infrastructure, water pollution, and loss of aquatic ecosystems. Both studies emphasized the need for planning authorities to enforce flood control measures and adopt sustainable land-use strategies.

Ojikpong et al. (2016) further reinforced the widespread and devastating effects of flooding on livelihoods, noting that floods can destroy homes, disrupt economic activities, and endanger lives. Contributing factors to flood-induced damage includes the timing and season of occurrence, geographic location, river encroachment, embankment failures, substandard drainage infrastructure, and ineffective historical flood management practices. The study found that flooding negatively affects both rural and urban communities, often resulting in the collapse of buildings and bridges, inundation of markets and farms, and extensive crop loss.

Agbonkhase et al. (2014) examined the impacts of flooding across various asset categories, including human, natural, and physical resources, monthly income, and financial capital. The study revealed that flooding led to severe economic setbacks, causing negative returns on investment and widespread devastation across affected communities.

Oruonye et al. (2017) assessed the consequences of flood disasters on rural livelihoods and coping mechanisms in Lau Local Government Area of Taraba State. The research found that floods significantly undermined the socioeconomic well-being of rural residents,

especially by submerging farmlands and damaging crops, which also contributed to gully erosion and land degradation.

Ojikpong et al. (2016) conducted a flood risk assessment in residential areas within Calabar Metropolis, Cross River State, using flood coverage metrics to quantify the extent of vulnerability in urban neighborhoods. Drawing on data provided by the Calabar State Emergency Management Agency (SEMA), the study applied descriptive statistics and least squares regression analysis to identify key factors influencing flood exposure. The findings showed that low-lying residential zones were particularly prone to flooding. The authors recommended a multi-pronged strategy including floodplain zoning for urban agriculture and recreational purposes, drainage system upgrades, enforcement of flood control regulations, and development control measures to mitigate future flood risks.

These findings reflect a broader national pattern: urban flooding in Nigeria continues to escalate, driven by substandard drainage infrastructure, weak institutional governance, and poor environmental planning. Cities such as Benin City, Lagos, and Makurdi have become critical flashpoints for recurrent flood disasters. To address this, a comprehensive and integrated strategy is urgently required—one that combines hydrographic surveys, GIS-based flood modeling, sustainable urban drainage systems (SuDS), and multi-stakeholder collaboration to enhance resilience and long-term urban sustainability.

## **2.4 GIS Applications in Flood Modelling and Drainage Planning**

### **2.4.1 Overview of GIS Tools and Functions in Flood Management**

Geographic Information Systems (GIS) are powerful tools used for collecting, managing, analyzing, and visualizing spatial data. In flood modeling and drainage planning, GIS

facilitates the integration of hydrological, meteorological, topographic, and infrastructural data to assess and manage flood risk. In Oredo LGA, GIS can aid in delineating flood basins and evaluating flow accumulation using terrain models. Umar & Gray (2023) emphasize that GIS tools support real-time decision-making, particularly in dynamic urban environments Umar, N., & Gray, A. (2023). GIS technology plays a crucial role in flood prediction by enabling the collection, storage, analysis, and visualization of geospatial data. It allows for the integration of various types of data, such as topography, land use, rainfall, and hydrological data, to create detailed maps and models of flood-prone areas. Key advantages of using GIS include:

- a. **Data Integration and Visualization:** GIS can overlay multiple datasets, facilitating the visualization of flood patterns and the identification of high-risk areas. (Kourgialas et al., 2011).
- b. **Spatial Analysis:** GIS tools can perform spatial analysis to determine the extent and impact of flooding, helping to predict which areas are most vulnerable. (Sanyal et al., 2004).
- c. **Real-Time Monitoring:** With advancements in remote sensing and satellite technology, GIS can provide real-time data for monitoring flood conditions and updating predictions accordingly. (Degiorgis et al., 2012).

Table 2.2: Key GIS Tools & Functions:

<b>GIS Tool/Function</b>	<b>Application in Flood/Drainage Planning</b>
Digital Elevation Model (DEM)	Terrain analysis; watershed delineation
Hydrological Modeling Extensions (e.g., HEC-GeoHMS, ArcHydro)	Runoff estimation; stream network generation

<b>GIS Tool/Function</b>	<b>Application in Flood/Drainage Planning</b>
Overlay Analysis	Identifying flood-prone areas by layering land use, slope, soil
Buffer and Proximity Analysis	Assessing risk to infrastructure or settlements near rivers
Raster/Vector Analysis	Mapping flood extents and drainage paths
Remote Sensing Integration	Land use/land cover change detection for flood risk assessment
3D Visualization	Visual representation of flood depths and surface profiles

GIS software like ArcGIS, QGIS, GRASS GIS, ILWIS, and Global Mapper are commonly used for these applications. Adebayo, Y. R., & Mohammed, M. (2021).

#### **2.4.2 Use of GIS in Flood-Prone Zone Identification**

GIS allows for the integration of spatial datasets (topography, rainfall, land use, soil, drainage) to identify flood-vulnerable zones. This is done through:

- a.** DEM and Watershed Analysis; GIS uses DEMs to simulate water flow direction, accumulation, and watershed boundaries. This helps predict where runoff will concentrate and where flooding is likely to occur.
- b.** Land Use and Impervious Surface Mapping; GIS identifies high-risk urban zones with limited infiltration capacity (e.g., paved areas) and helps prioritize locations for green infrastructure or improved drainage.
- c.** Risk Zonation and Hazard Mapping; GIS is used to create flood hazard maps that classify areas by flood depth, frequency, and impact. It's useful for urban planning, insurance, and disaster preparedness.

### **2.4.3 GIS in Urban Flood Management in Nigeria**

#### **a. Lagos State**

Lagos State Ministry of the Environment partnered with World Bank to develop a flood vulnerability atlas using GIS and remote sensing. High-resolution DEMs and hydrological data were used to simulate flood scenarios. The GIS analysis helped prioritize drainage upgrades and establish flood early warning systems. World Bank (2014).

#### **b. Ibadan City (Oyo State).**

Researchers used ArcGIS to identify high flood risk zones by integrating rainfall, land use, slope, and soil data. Results guided the Ibadan Urban Flood Management Project (IUFM) funded by the World Bank.

#### **c. Benin City (Edo State)**

GIS has been used to support the Benin Stormwater Management Plan, where flood-prone areas like Uselu, Siluko Road, and Upper Mission were mapped using DEMs and land use data. GIS-based mapping informed where to construct culverts, channels, and retention basins.

#### **d. Port Harcourt (Rivers State)**

GIS and satellite imagery were used to analyze changes in drainage and land use. Highlighted how urban encroachment on wetlands increased flood severity. Findings informed urban renewal and slum upgrading programs. Nwachukwu, C. M. (2019).

GIS is a critical decision-support tool for modern urban flood modeling and drainage planning in Nigeria. Its ability to integrate spatial and temporal data makes it essential for: Predicting and mapping flood risk, designing effective drainage infrastructure, supporting emergency management and policy-making. Despite growing adoption, GIS use in flood management is still underutilized in many Nigerian states. Combining GIS with

hydrographic surveys, hydrologic modeling, and community engagement can dramatically improve urban flood resilience.

## **2.5 GIS in Flood Risk Mapping and Urban Planning**

Geographic Information Systems (GIS) have become essential tools in modern flood risk assessment and urban drainage planning. GIS provides a spatially oriented platform for collecting, storing, analyzing, and visualizing data related to topography, land use, hydrology, and infrastructure. In flood-prone urban areas like Central Road, Oredo Local Government Area of Edo State, the ability of GIS to integrate multiple data sources enables planners to better understand where, when, and how flooding occurs—and, most importantly, how to prevent or mitigate it.

GIS is a powerful, adaptable, and essential tool for flood risk assessment and urban drainage planning. Its ability to integrate spatial datasets, simulate dynamic flood scenarios, and support decision-making makes it indispensable for addressing urban flooding in high-risk areas like Central Road, Oredo LGA. However, unlocking its full potential requires investment in data infrastructure, technical training, and institutional collaboration to bridge the gap between science and urban policy.

### **2.5.1 Core Functions of GIS in Flood Risk Mapping**

GIS offers a wide range of analytical and visualization capabilities that enhance flood risk assessment, including:

- i. **Catchment Delineation and Flow Path Analysis:** Using Digital Elevation Models (DEMs) and hydrological tools within GIS (e.g., ArcHydro, QGIS Processing Toolbox), analysts can define drainage basins, identify upstream catchment areas, and trace flow direction and accumulation paths. This is essential for understanding how runoff travels across the

landscape and where water is likely to accumulate during heavy rainfall events. *Akinyemi et al. (2022)*.

- ii. **Integration of Multisource Data:** GIS allows the overlay of datasets such as: Rainfall intensity maps, Soil types and infiltration rates, Land Use and Land Cover (LULC) maps, Population density and vulnerable infrastructure. This layered approach helps identify flood exposure and vulnerability hotspots, which are critical for targeting flood mitigation strategies. *Odoh & Nwokeabia (2024)*.
- iii. **Development of Flood Hazard and Risk Maps:** Using historical flood data, terrain information, and modeled flood extents (from tools like HEC-RAS or SWMM), GIS can generate: Flood hazard maps (areas likely to flood under specific rainfall conditions), Flood depth and velocity maps, Flood risk maps (overlying hazard with exposure and vulnerability). These outputs are essential for evidence-based planning, zoning, and emergency response strategies. *Shuaibu et al. (2023)*.

### **2.5.2 GIS in Urban Planning and Land Use Management**

GIS plays a critical role beyond just flood modeling it supports holistic urban planning by identifying areas: Where development should be restricted (e.g., floodplains, wetlands), Where resilient infrastructure (e.g., retention ponds, green corridors) is most needed, where informal settlements are encroaching on natural drainage pathways. Planners can use these insights to: Update zoning regulations, Plan safe housing developments, Strategically locate stormwater infrastructure. *Nkwunonwo et al. (2020)*.

When paired with remote sensing technologies (e.g., satellite imagery, LiDAR), GIS enables: Continuous monitoring of land cover changes, Detection of impervious surface

expansion (e.g., roads, rooftops), Historical flood extent mapping using satellite-derived water indices (NDWI). Adelekan (2012).

### **2.5.3 Application to Central Road, Oredo LGA**

In Central Road, Oredo, GIS is particularly valuable because: The area is experiencing rapid, unregulated urbanization. The topography is relatively flat, requiring precise elevation data for flow path modeling. Drainage channels are often undocumented or blocked. There's a lack of centralized flood records. GIS can help identify: Low-lying flood-prone zones using DEMs, Blocked or undersized stormwater paths, Informal housing developments in high-risk areas. This information can directly feed into urban master plans, drainage redesign projects, and early warning systems.

### **Limitations and Challenges in Nigeria**

While GIS has immense potential, its application in Nigerian flood management faces several challenges: Lack of high-resolution DEMs or rainfall data, Limited technical expertise in spatial modeling at the local government level, Data fragmentation across agencies, Weak policy frameworks for integrating GIS tools into statutory planning. Iro & Njoku (2024).

### **2.6 Integration of GIS and Hydraulic Modeling**

The integration of Geographic Information Systems (GIS) and hydraulic/hydrologic modeling is a transformative approach to urban flood risk assessment and drainage planning, especially in developing urban centers like Central Road, Oredo LGA in Edo State. This integration enables the visualization, simulation, and analysis of complex spatial and hydrologic relationships that drive urban flooding. It supports the creation of precise,

data-informed flood hazard maps and decision-support tools for urban planners, engineers, and emergency managers. Hydraulic models (e.g., HEC-RAS, SWMM, MIKE URBAN) simulate the behavior of water flow within urban catchments, including surface runoff, stream flow, and drainage channel dynamics. On the other hand, GIS manages spatially distributed datasets such as topography, land use, soil types, and infrastructure layouts. When combined, the two technologies provide a spatially explicit and physically realistic framework for modeling flood events under different scenarios. Musa et al. (2021).

### **2.6.1 Workflow of Integration**

A typical GIS-hydraulic modeling workflow includes:

- i. Data Preparation in GIS: Digital Elevation Models (DEMs), Land Use and Land Cover (LULC), Soil characteristics, Infrastructure layouts (roads, culverts, drainage pipes).
- ii. Model Input Extraction: Using GIS to define catchment boundaries, flow paths, and stream networks. Cross-sectional profiles and slope data are extracted from DEMs.
- iii. Simulation via Hydraulic Models: Input GIS-derived parameters into HEC-RAS or SWMM to simulate flow, water depth, and inundation extent. Run simulations for different rainfall return periods (e.g., 2-year, 10-year, 50-year storms).
- iv. Visualization of Results in GIS: Import flood extent, water depth, and velocity maps back into GIS. Produce flood hazard maps, risk zones, and impacted infrastructure layers. Tingsanchali (2012).

Table 2.3 Benefits of Integration

Benefit	Description
<b>Improved Spatial Accuracy</b>	GIS provides detailed terrain and land use data to refine hydraulic simulations.
<b>Scenario Simulation</b>	Integration enables "what-if" analysis to assess the impact of different rainfall intensities, land use changes, and drainage interventions.
<b>Realistic Urban Flood Modeling</b>	Combines both overland flow (pluvial) and channel flow (fluvial) to reflect complex urban flood behavior.
<b>Support for Decision-Making</b>	Outputs from GIS-hydraulic models can inform zoning, infrastructure upgrades, and emergency planning.
<b>Public Communication</b>	Visual maps and flood animations help convey flood risks clearly to stakeholders and residents.

### 2.6.2 Challenges of Integration

Despite its advantages, GIS-hydraulic integration faces some limitations:

- i. **Data Limitations:** High-resolution DEMs and accurate channel geometry are often unavailable or outdated in regions like Oredo LGA.
- ii. **Technical Expertise:** Requires interdisciplinary knowledge in hydrology, GIS, and modeling software.
- iii. **Model Assumptions:** Hydraulic models often simplify complex urban drainage behaviors, which can affect output reliability. Akinyemi et al. (2022)

### 2.6.3 Relevance to Central Road, Oredo LGA

In flood-prone areas like Central Road in Oredo, where rapid urban development, flat terrain, and poor drainage design intersect, GIS-hydraulic modeling offers a proactive tool

for: Locating drainage deficiencies, Designing targeted interventions, Predicting flood hotspots before rainy seasons, Informing long-term urban master plans with climate resilience. The integration of GIS and hydraulic modeling represents a robust, scalable, and scientific method for addressing urban flood challenges in developing contexts. For Central Road, Oredo LGA, such integration will enable a shift from reactive crisis response to predictive, sustainable drainage planning a crucial step toward urban resilience in the face of intensifying climate rise.

## CHAPTER THREE

### METHODOLOGY

#### 3.1 Description of the Study Area

Oredo Local Government Area (LGA) is located in the southern region of Edo State, Nigeria, and is one of the 18 LGAs that make up the state. Covering a total land area of approximately 249 km<sup>2</sup>, Oredo had an estimated population of 536,827 according to the 2006 National Population Census (NPC, 2006), though current figures are expected to be significantly higher due to rapid urbanization and migration. Geographically, Oredo LGA lies between latitude 6.30°N to 6.40°N and longitude 5.55°E to 5.70°E. It shares boundaries with: North: Egor and Ikpoba-Okha LGAs, South: Orhionmwon LGA, East: Ikpoba-Okha LGA, West: Uhumwonde and Ovia North-East LGAs.

The area falls within the tropical rainforest zone of southern Nigeria, characterized by a tropical wet and dry (Aw) climate. Annual rainfall ranges from 1,800 mm to 2,200 mm, with peak precipitation periods occurring between May–July and September–October. The mean annual temperature ranges between 20°C and 25°C, while relative humidity fluctuates between 60% and 95%, depending on the season. Oredo LGA comprises 12 political wards, including both urban and peri-urban communities. Some of the prominent wards include: Ogbe, GRA/Etete/iyekoba, Uzebu, Urubi, Oliha/Ukhegie, Iyaro/Eguadase, Unueru/Ugboka, Ogbelaka/Nekpenekpen, and Ibiwe/Iwegie/Ugbague. The Central Road area, which is the focus of this study, is part of the highly urbanized core of Benin City located within Oredo LGA. This corridor has experienced rapid population growth, increasing land use changes, and expansion of impermeable surfaces such as roads and buildings. These developments have led to a significant rise in surface runoff during rainfall events, often resulting in recurrent urban flooding. Topographically, Oredo is

predominantly flat to gently undulating, with elevations generally between 30 to 80 meters above sea level. This low-relief terrain, coupled with the absence or poor maintenance of stormwater infrastructure, hampers surface runoff, resulting in waterlogging and flash floods even during moderate rain events. The area is naturally drained by rivers such as the Ogba River and Ikpoba River, as well as by a network of open and covered artificial drainage channels.

However, many of these drainage pathways are often blocked by solid waste, siltation, and encroachment, which severely limits their effectiveness. This condition contributes significantly to urban flood vulnerability, particularly in the Central Road axis, where commercial and residential activities are densely concentrated. In essence, the combination of high rainfall intensity, poorly maintained drainage infrastructure, and flat terrain makes Oredo LGA especially Central Road a high-risk zone for flooding. This reinforces the need for integrated flood modeling and GIS-based drainage planning, which forms the core of this study.

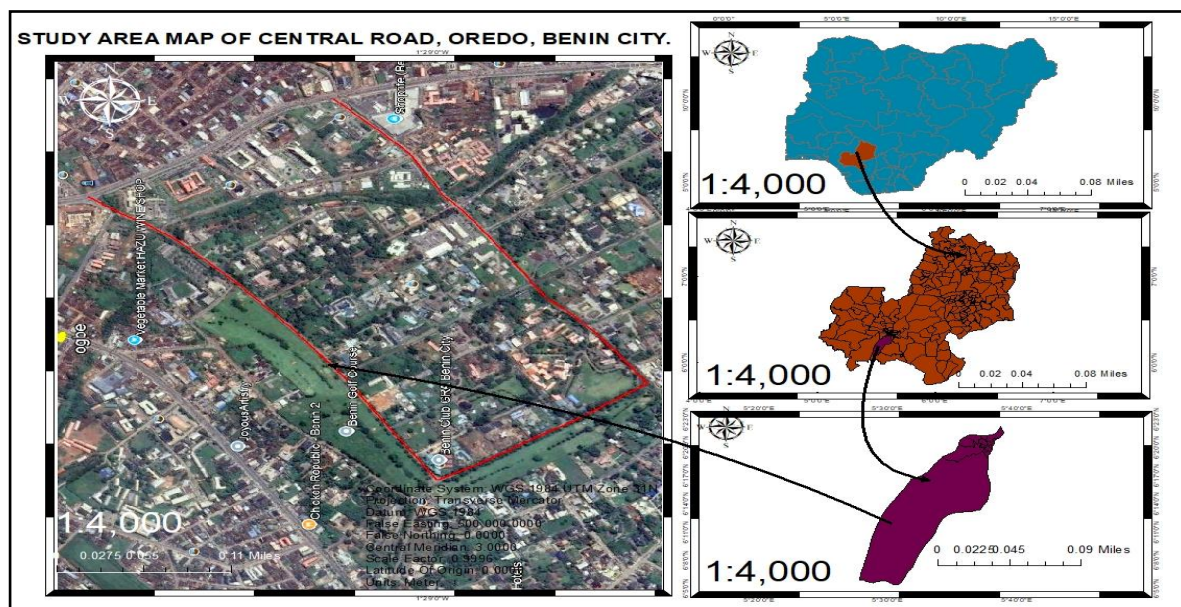


Figure 3.1: Study Area Map Of Central Road, Oredo Benin City.

### 3.2 Types and Sources of Data

The data utilized in this study were obtained from both primary and secondary sources, ensuring a comprehensive understanding of the flood dynamics within Central Road, Oredo Local Government Area. The combination of these datasets supports accurate analysis, mapping, and planning of effective urban drainage solutions.

Table 3.1: Description of Data Sources

Type	Description	Source
Primary Data	Direct data collected from the field to obtain real-time information on drainage structures, flood-prone zones, and runoff conditions.	Field surveys and on-site investigations.
Field Observations	On-site inspections to identify blocked drains, eroded surfaces, and areas susceptible to flooding during both dry and wet seasons.	Reconnaissance and physical site visits.
GPS Measurements	Geographic coordinates of culverts, gutters, flood hotspots, and drainage outlets captured with handheld GPS units.	GPS data acquired on-site
Secondary Data	Supplementary data such as maps, rainfall records, and satellite imagery used to enhance spatial and hydrological analysis.	Government agencies, open data repositories, and academic literature.

### 3.3 Data Collection Techniques

To effectively assess flood mitigation through improved urban drainage systems along Central Road and its surrounding neighborhoods, two major data collection approaches were employed: field reconnaissance and topographic/spatial data acquisition. These methods provided both physical and geospatial information required for a precise understanding of drainage functionality and flood vulnerability in the study area.

#### 3.3.1 Field Reconnaissance

Field reconnaissance involved direct observation of the study area to assess existing drainage infrastructure, flood-prone locations, and terrain conditions. During these

inspections, key features such as blocked channels, eroded sections, stagnant water zones, and areas of recurrent flooding were documented. A handheld GPS device was used to capture the exact coordinates of major drainage components, while a digital camera recorded photographic evidence of on-site conditions. Measuring tapes and rangefinders were employed to obtain dimensional data of culverts, gutters, and channels.

The primary purpose of this reconnaissance exercise was to gain firsthand insight into on-ground drainage challenges and to validate existing drainage maps or datasets. The information gathered guided the identification of priority areas for drainage improvement and served as reference data for subsequent GIS-based spatial analysis and design recommendations.

### **3.3.2 Topographic and Spatial Data Collection**

Alongside field reconnaissance, topographic and spatial datasets were collected to analyze the terrain configuration of the study area. Elevation points obtained from the field were processed using Geographic Information System (GIS) software to produce a Digital Elevation Model (DEM) a three-dimensional representation of the land surface as shown in figure 3.2 below. This process was complemented by the use of satellite imagery and topographic maps to identify slope gradients, flow accumulation zones, and natural drainage pathways. These datasets enabled a clear understanding of runoff behavior, highlighting low-lying and flood-prone areas that require drainage redesign or intervention.

By integrating spatial analysis and terrain modeling, the study was able to pinpoint areas with poor drainage connectivity, thus providing the foundation for accurate flood risk mapping and system optimization.

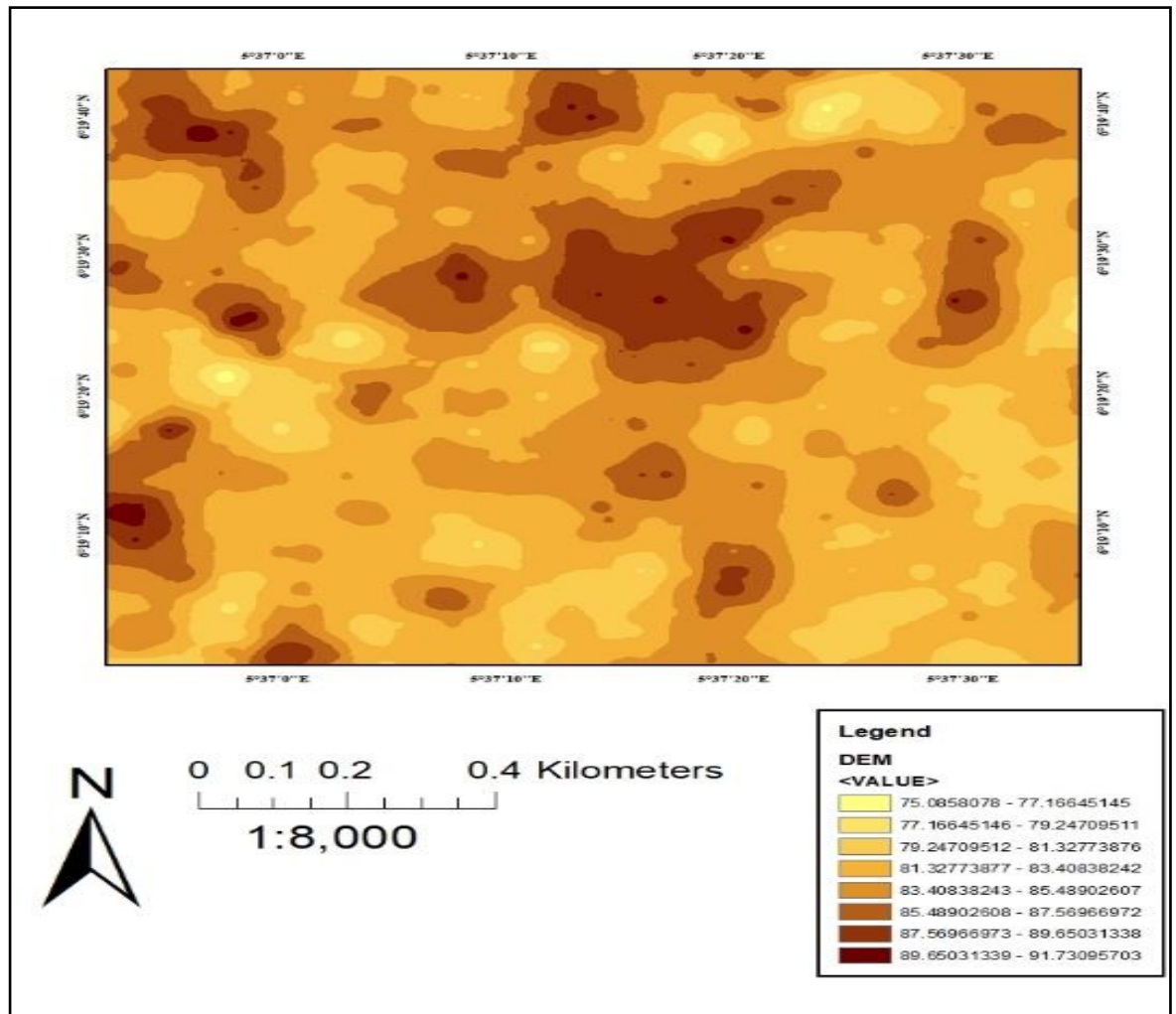


Figure 3.2: DEM Map of Sturdy Area

### 3.4 Tools and Equipment Used

To ensure precision and reliability in both field data collection and spatial analysis, a range of tools and equipment were utilized. These instruments supported the accurate measurement, mapping, and interpretation of drainage patterns and flood behavior within Central Road, Oredo LGA.

### **3.4.1 Global Positioning System (GPS) Device**

A handheld GPS unit was employed to capture precise geographic coordinates of drainage structures such as culverts, inlets, outlets, and low-lying flood zones. The coordinates were later imported into GIS software for mapping and spatial correlation with topographic data.

### **3.4.2 Digital Camera**

A digital camera was used to document field observations, including the physical state of drainage systems, evidence of erosion, blockages, and recurrently flooded locations. These photographs provided visual validation during spatial analysis and report documentation.

### **3.4.3 Measuring Tape**

Measuring tapes and rangefinders were utilized to record the linear dimensions of gutters, road segments, culverts, and open channels. The measurements were crucial for estimating hydraulic capacity and verifying the adequacy of existing drainage structures.

### **3.4.4 Topographic Maps**

Topographic maps obtained from relevant agencies served as reference materials for understanding natural elevations, contours, and drainage directions. These maps were used as base layers for creating a Digital Elevation Model (DEM) and for performing slope and watershed analysis within the GIS environment.

### **3.4.5 Satellite Imagery**

High-resolution satellite images were employed to analyze land use, urban growth, and surface water flow patterns. The imagery enabled identification of areas where rapid

urbanization and unplanned construction have obstructed natural drainage channels or increased runoff accumulation.

### **3.4.6 Mapping and Geospatial Software (Global Mapper and Google Earth Pro)**

Two main software tools were used for spatial data processing and visualization:

- i.** Global Mapper was applied to process elevation data, generate contour lines, perform terrain profiling, and simulate flow accumulation. It was also used for watershed delineation and floodplain mapping to determine natural drainage behavior.
- ii.** Google Earth Pro provided updated satellite imagery and 3D terrain visualization, which supported location verification, landmark identification, and digitization of visible drainage features. This software was especially useful for validating field-collected GPS data.

### **3.4.7 Microsoft Excel**

Microsoft Excel was utilized for organizing, tabulating, and analyzing field and survey data, including rainfall records, flow measurements, and dimension data. It also aided in performing basic statistical computations and creating graphical outputs to support result interpretation.

## **3.5 Procedures for the Analysis**

### **3.5.1 Evaluation of the Existing Drainage Infrastructure in the Study Area**

To effectively evaluate the drainage network along Central Road and its adjoining areas in Oredo Local Government Area, a combination of field observation, hydraulic analysis, and spatial data interpretation was employed. This integrated approach provided a detailed understanding of the condition, capacity, alignment, and performance of the existing drainage systems. The analysis aimed to determine whether the current infrastructure can

efficiently manage stormwater runoff, particularly during intense rainfall events that often trigger urban flooding.

- i. **Field Reconnaissance Survey:** The evaluation commenced with a reconnaissance survey of the project area. This involved a systematic on-site inspection of roadside gutters, open and covered concrete drains, culverts, and natural discharge channels. The survey focused on identifying visible indicators of drainage failure such as: Structural deterioration or collapse of drain walls, Blockages caused by silt or indiscriminate solid waste disposal, Evidence of erosion or scouring at discharge outlets, and Frequent waterlogging or ponding in specific sections. Attention was also given to the orientation, slope, and continuity of existing channels to assess their ability to convey runoff effectively. The findings from this exercise provided critical baseline data for diagnosing drainage deficiencies and prioritizing areas for rehabilitation or redesign.
- ii. **Measurement of Drainage Geometry:** Following field reconnaissance, geometric data were collected for all major drainage components. These measurements included channel width, depth, length, side slope, and longitudinal gradient. The shape of each drainage channel (rectangular, trapezoidal, or circular) was also recorded, as it directly affects flow dynamics and hydraulic efficiency. The geometric data were analyzed to evaluate whether the existing drains conform to standard hydraulic design parameters. This information was essential for estimating the discharge capacity of the channels and determining whether they are adequate for the prevailing stormwater volumes in the study area.
- iii. **Hydraulic Capacity Assessment Using Manning's Equation:** To quantitatively assess the hydraulic performance of the existing drainage network, Manning's Equation was applied. This equation is widely used in open-channel flow analysis to estimate the discharge capacity ( $Q$ ) of drainage systems based on their physical and hydraulic characteristics.

The general form of the equation is:

$$Q = \frac{1}{n} \times A \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} \quad (3.1)$$

Where:

**Q** = Flow capacity (m<sup>3</sup>/s)

**n** = Manning's roughness coefficient (depends on channel surface)

**A** = Cross-sectional area of flow (m<sup>2</sup>)

**R** = Hydraulic radius (m), defined as A/P, where P is the wetted perimeter

**S** = Channel slope (m/m)

This computation enabled the determination of whether the existing drainage dimensions and slopes are sufficient to convey stormwater generated from design rainfall events. Channels found to have inadequate discharge capacity were flagged for redesign or expansion as part of the flood mitigation recommendations.

- iv. Estimation of Peak Runoff Using the Rational Method: The volume of stormwater generated during rainfall events was estimated using the Rational Method, which is applicable for small urban catchments. The formula is:

$$Q = 0.278 \times C \times I \times A \quad (3.2)$$

Where:

**Q** = Peak runoff (m<sup>3</sup>/s)

**C** = Runoff coefficient (depends on land use)

**I** = Rainfall intensity (mm/hr)

**A** = Catchment area (km<sup>2</sup>)

The calculated runoff will be compared with the drain's flow capacity. If the runoff exceeds the channel's capacity, flooding is likely to occur.

- v. Time of Concentration Calculation: The time of concentration was estimated using the Kerby–Hathaway Formula:

$$T_c = 0.604 \times \left( r \times \frac{L}{\sqrt{S}} \right)^{0.467} \quad (3.3)$$

Where:

$T_c$  = Time of concentration (hours)

$r$  = Surface roughness coefficient

$L$  = Hydraulic length of the catchment (km)

$S$  = Average slope of the catchment (m/m)

This value guided the selection of rainfall intensity used in runoff calculations.

- vi. GIS-Based Catchment and Drainage Analysis:

Geospatial techniques were also employed using Global Mapper and Google Earth Pro. Digital Elevation Models (DEMs) of the study area was analyzed to delineate catchment boundaries, map elevation gradients, and detect low-lying flood-prone areas. The spatial analysis reveals whether existing drainage structures are appropriately located and where coverage is insufficient.

### **3.5.2 Proposing Appropriate Drainage Improvements for Flood Mitigation**

To effectively mitigate flooding along Central Road and its adjoining neighborhoods in Oredo Local Government Area, it is essential to develop drainage improvement strategies that are technically sound, cost-effective, and environmentally sustainable. The proposed interventions aim to enhance the capacity and efficiency of the drainage network, ensuring it can adequately convey stormwater runoff during peak rainfall events while minimizing long-term maintenance and environmental impacts. The improvement process begins with a comprehensive gap analysis, comparing the design stormwater runoff (estimated using the Rational Method) with the existing drain capacities (evaluated through Manning’s

Equation). This comparison identifies inadequate or undersized drainage structures that fail to meet the required hydraulic capacity for efficient flow conveyance.

Subsequently, drainage redesign will adopt a catchment-based approach, where each sub-catchment is analyzed individually to determine appropriate drain dimensions and alignments corresponding to its specific runoff volume. Civil 3D (Land Desktop Companion) software will be utilized to support hydraulic profiling and channel sizing, ensuring technical precision in the proposed designs. To guide spatial decision-making, Geographic Information System (GIS) tools and Digital Elevation Models (DEMs) will be employed to delineate natural flow paths, detect low-lying flood-prone zones, and optimize the siting of new drainage channels. All redesigns will comply with national engineering standards, particularly those outlined in the Federal Ministry of Works Highway Design Manual, to ensure structural integrity, safety, and uniformity. In addition to conventional engineering solutions, the study advocates for the integration of nature-based and sustainable drainage systems (SuDS) such as: Permeable pavements to promote infiltration and reduce surface runoff, Bioswales and vegetated channels to enhance pollutant filtration, and Rain gardens or retention basins to temporarily store excess stormwater and regulate outflow.

Finally, community participation forms a vital component of the improvement strategy. Engaging residents and stakeholders during the planning and design stages ensures that local knowledge—particularly regarding frequently flooded zones and informal drainage practices—is incorporated into the final design. This participatory approach enhances the practicality, acceptance, and long-term success of the proposed drainage improvements.

# CHAPTER FOUR

## RESULTS AND DISCUSSION

### 4.1 Identification Of Flood Prone Area

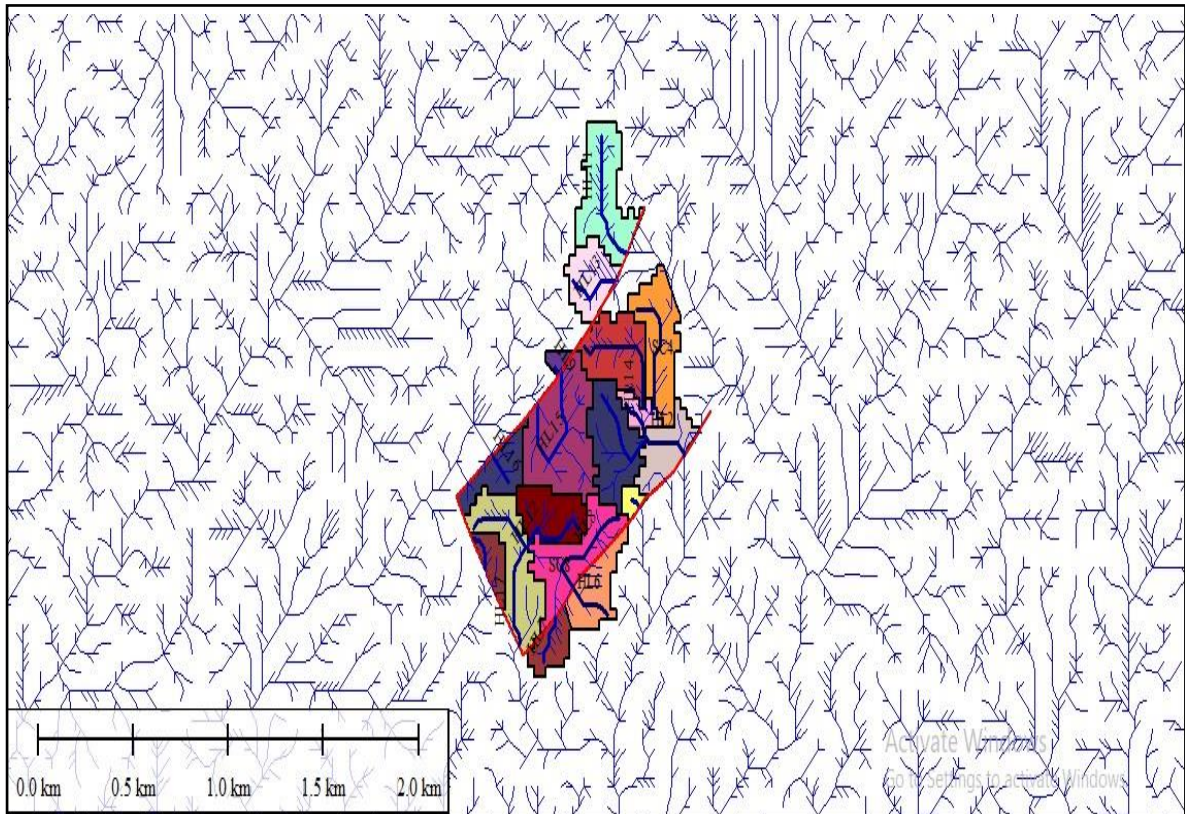


Figure 4.1: Flood-Prone Catchment Areas

Figure 4.1 illustrates the delineated catchment areas contributing to flooding along Central Road in Oredo Local Government Area, Edo State. The hydrological analysis indicates that a substantial portion of the road corridor is affected by surface runoff accumulation, highlighting the spatial extent of flood vulnerability across the study area. The watershed was subdivided into 13 distinct sub-catchments (SC1–SC13), each characterized by unique topographic gradients, flow accumulation patterns, and hydrological behavior. These subdivisions were defined based on natural drainage alignments and the direction of overland flow derived from the Digital Elevation Model (DEM).

The analysis further revealed that runoff concentration is highest in the downstream portions of sub-catchments SC7, which correspond to the lowest elevation zones along the corridor. These areas exhibit poor drainage response and are consequently more prone to flooding during high-intensity rainfall events. Identifying these flood-susceptible sections forms the foundation for the design and improvement of drainage systems aimed at minimizing surface water accumulation, enhancing flow conveyance, and promoting effective flood mitigation across the Central Road drainage net.

#### 4.2 Presentation of the Design Parameter of each Catchment Area

S/N	TC(hrs)	I (mm)	Q(m <sup>3</sup> /s)	A(km)	R(m)	V(m/s)	DC(m/s)	Fr
SC1	0.2948	174.2804	0.70195	0.02278	0.268	1.205	0.740	0.488
SC2	0.1930	185.8113	0.50495	0.01537	0.359	2.470	3.149	0.692
SC3	0.4267	150.2333	0.91933	0.03461	0.359	2.470	4.116	0.692
SC4	0.7300	138.6337	1.9609	1.4025	0.384	2.584	3.624	0.724
SC5	0.3530	148.1627	2.1062	1.4663	0.396	2.638	3.868	0.739
SC6	0.3010	153.5216	1.3816	1.02	0.304	2.211	2.255	0.619
SC7	0.6020	160.624	1.6575	1.6575	0.431	2.788	4.622	0.781
SC8	0.5180	121.268	1.691	1.581	0.417	2.730	4.316	0.765
SC9	0.6700	99.6912	0.1114	1.6193	0.424	2.760	4.468	0.773
SC10	0.2290	137.6854	0.5787	0.5787	1.428	0.389	2.606	0.730
SC11	0.3680	148.9545	2.3676	1.5555	0.413	2.710	4.216	0.759
SC12	0.3508	151.625	1.4906	1.4535	0.394	2.627	3.819	0.736
SC13	0.2010	152.7404	1.3087	1.4408	0.392	2.617	3.770	0.733

*TC* = Time of Concentration; *I* = Rainfall Intensity; *Q* = Discharge; *A* = Drain Cross-sectional Area; *R* = Hydraulic Radius; *V* = Stormwater Velocity; *DC* = Drain Capacity; *Fr* = Froude Number; *SC* = Sub-catchment.

The results presented in Table 4.1 summarize the computed design parameters for each sub-catchment within the Central Road study area. The time of concentration ( $T_c$ ) values, ranging between 0.193 hours and 0.730 hours, indicate relatively short runoff response times characteristic of urban catchments dominated by impervious surfaces such as asphalt and concrete. The rainfall intensities, which vary between 99.6912 mm and 185.8113 mm, reflect minor spatial variations in precipitation across the study area, possibly influenced by local topographic and microclimatic conditions.

Analysis of discharge ( $Q$ ) values reveals that Sub-catchments SC5 and SC11 generate the highest runoff volumes, with peak flow rates of 2.11 m<sup>3</sup>/s and 2.37 m<sup>3</sup>/s, respectively. This finding suggests that these two catchments are the primary contributors to flooding along Central Road due to their larger drainage areas, steeper slopes, or limited infiltration capacity. Conversely, SC2, SC9, and SC10 exhibit lower discharge values, implying smaller runoff volumes likely resulting from gentler gradients or reduced catchment extents. The computed Froude numbers ( $Fr$ ), ranging between 0.488 and 0.781, indicate that the flow regimes are predominantly subcritical to near-critical. This suggests that flow velocities are generally stable and not prone to excessive turbulence or erosion under normal hydraulic conditions, particularly where channels are properly lined.

Finally, the evaluated drainage capacities ( $DC$ ) demonstrate that, when adequately designed, the proposed systems are capable of accommodating expected peak discharges, thereby enhancing the efficiency of the urban drainage network and supporting flood reduction efforts within the study area.

### 4.3. Design of the Drainage System

Table 4.2: Result of left hand side contributing to the catchment flow

<b>From</b>	<b>To</b>	<b>Catchment contributing flow</b>	<b>Catchment flow (qt)</b>	<b>Distance (m)</b>	<b>Drain Size</b>	<b>Proposed/adopted drainage sizes</b>
00+000	00+142	-	-	142	0.7*0.7	0.9*0.9
00+142	00+450	SC13	0.022	308	0.6*0.3	0.9*0.9
00+450	00+850	SC10,11,12,13	3.285	400	1.2*1.8	1.0*1.0
00+850	00+930	SC10,11,12	2.513	80	0.9*1.2	1.0*1.0
00+930	1+090	SC10,11	1.711	160	0.9*0.9	1.0*1.0

Table 4.3 presents the hydraulic design outcomes for the left-hand side drainage system along Central Road. The results illustrate a progressive increase in cumulative discharge as additional sub-catchments contribute runoff along the drainage alignment. From chainage 00+000 to 1+090, the total flow rises from approximately 0.022 m<sup>3</sup>/s to about 3.285 m<sup>3</sup>/s, reflecting the downstream accumulation of stormwater from multiple contributing catchments.

To accommodate this increasing discharge, the drainage dimensions were systematically adjusted along the channel. The drain cross-sections were designed to vary from 0.7 × 0.7 m at the upstream section to 0.9 × 0.9 m near the outlet. This gradation ensures that each segment possesses adequate hydraulic capacity to safely convey peak runoff without overtopping or causing localized flooding. The adopted standard sizes ranging between 0.9 × 0.9 m and 1.3 × 1.3 m and 1.5 × 1.5 m were selected after considering hydraulic efficiency, construction feasibility, ease of maintenance, and long-term durability. These dimensions provide a balance between performance and practicality, ensuring the drain can handle variable flow conditions while remaining self-cleansing to prevent sediment deposition.

Overall, the results in Table 4.3 demonstrate that as runoff converges from multiple sub-catchments, the hydraulic capacity of the drainage network must be progressively increased. This design approach ensures stable flow conditions, minimizes the risk of sedimentation, and maintains effective flood mitigation throughout the drainage corridor on the left-hand side of Central Road.

Table 4.3: Result of right hand side contributing to the catchment flow

<b>From</b>	<b>To</b>	<b>Catchment contributing flow</b>	<b>Catchment flow (qt)</b>	<b>Distance (m)</b>	<b>Drain Size</b>	<b>Proposed/adopted drainage sizes</b>
0+000	0+142	-	-	142	0.7*0.7	0.9*0.9
0+142	00+490	SC1,8,9	7.186	348	2.0*2.0	1.3*1.3
00+490	00+646	SC2,3,5,4,6,7,9	14.401	156	2.0*2.0	1.5*1.5
00+646	1+000	SC3,5,4,6,7,9	13.896	444	2.25*2.5	1.5*1.5
1+000	1+090	SC7,9	8.049	90	1.8*1.8	1.5*1.5

Table 4.4 presents the hydraulic design outcomes for the right-hand side drainage system along Central Road. The results illustrate a progressive increase in cumulative discharge as additional sub-catchments contribute runoff along the drainage alignment. From chainage 00+000 to 1+090, the total flow rises from approximately 7.186 m<sup>3</sup>/s to about 14.401 m<sup>3</sup>/s, reflecting the downstream accumulation of stormwater from multiple contributing catchments.

To accommodate this increasing discharge, the drainage dimensions were systematically adjusted along the channel. The drain cross-sections were designed to vary from 0.7 × 0.7 m at the upstream section to 1.8 × 1.8 m near the outlet. This gradation ensures that each segment possesses adequate hydraulic capacity to safely convey peak runoff without overtopping or causing localized flooding. The adopted standard sizes ranging between 0.9

$\times 0.9$  m,  $1.3 \times 1.3$  m and  $1.5 \times 1.5$  m were selected after considering hydraulic efficiency, construction feasibility, ease of maintenance, and long-term durability. These dimensions provide a balance between performance and practicality, ensuring the drain can handle variable flow conditions while remaining self-cleansing to prevent sediment deposition.

Similarly, to Table 4.3, the results in Table 4.4 demonstrate that as runoff converges from multiple sub-catchments, the hydraulic capacity of the drainage network must be progressively increased. This design approach ensures stable flow conditions, minimizes the risk of sedimentation, and maintains effective flood mitigation throughout the drainage corridor on the right-hand side of Central Road.

The proposed drainage design from figure 4.1-5 are shown as follows:

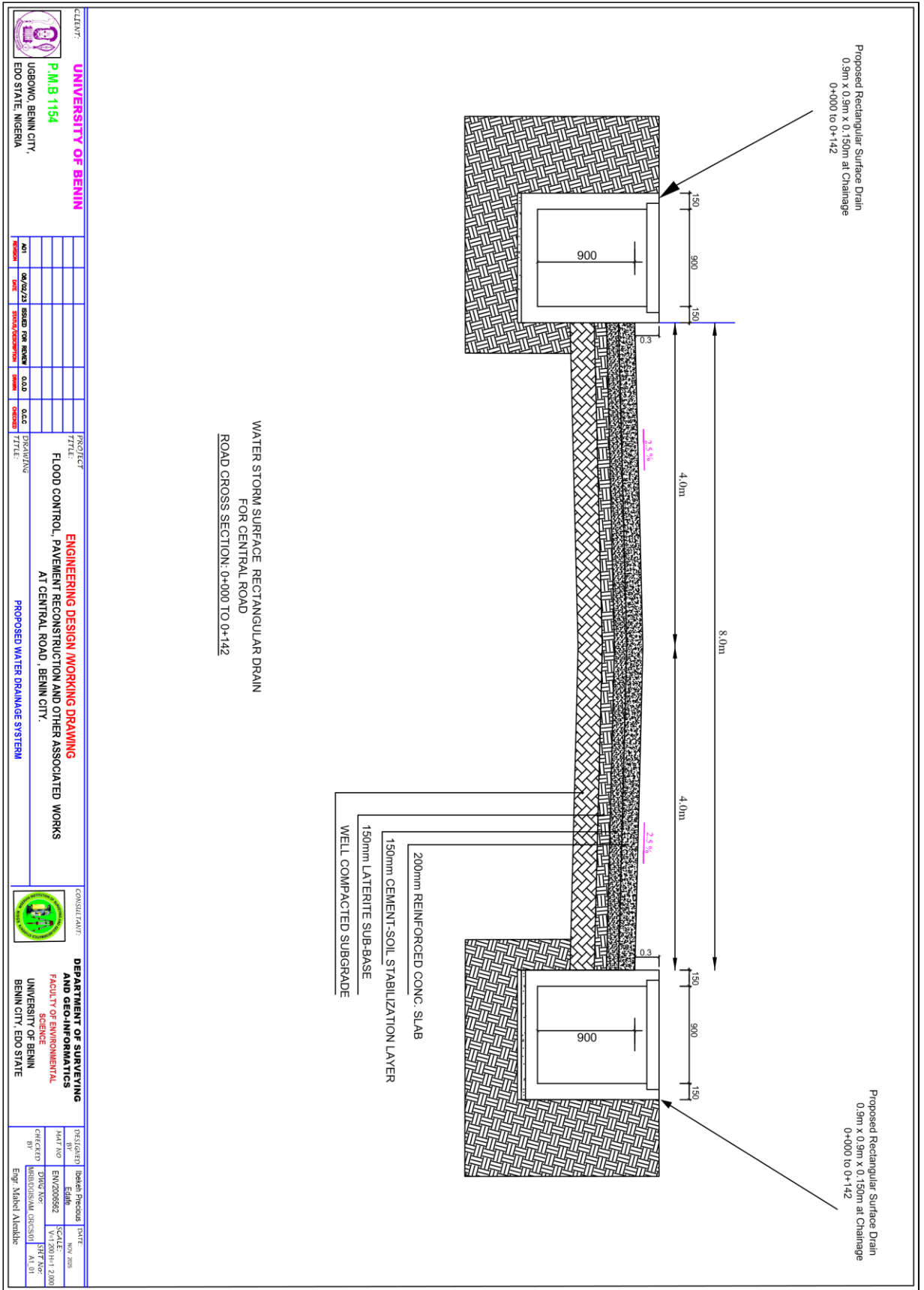


Figure 4.2

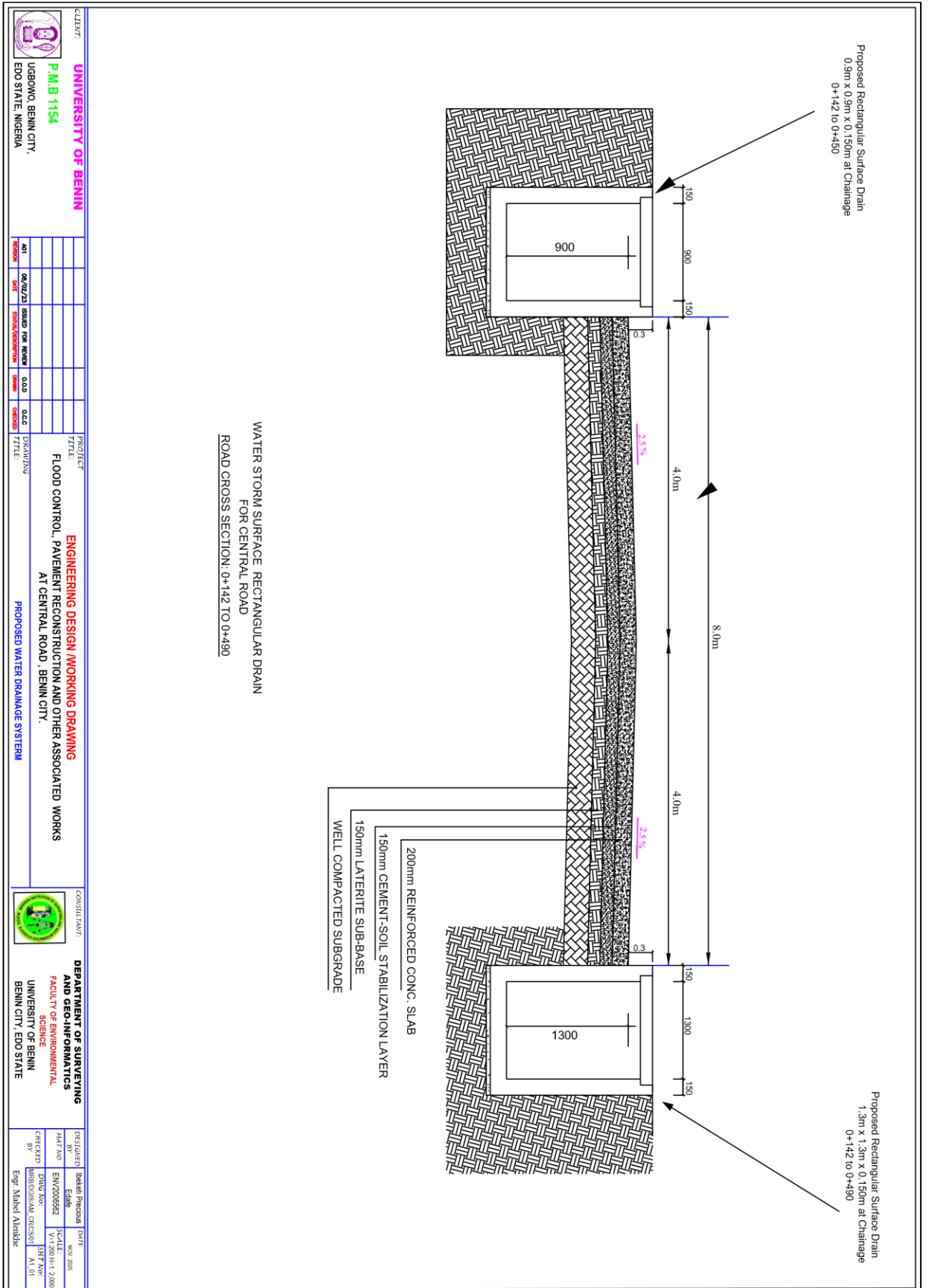


Figure 4.3



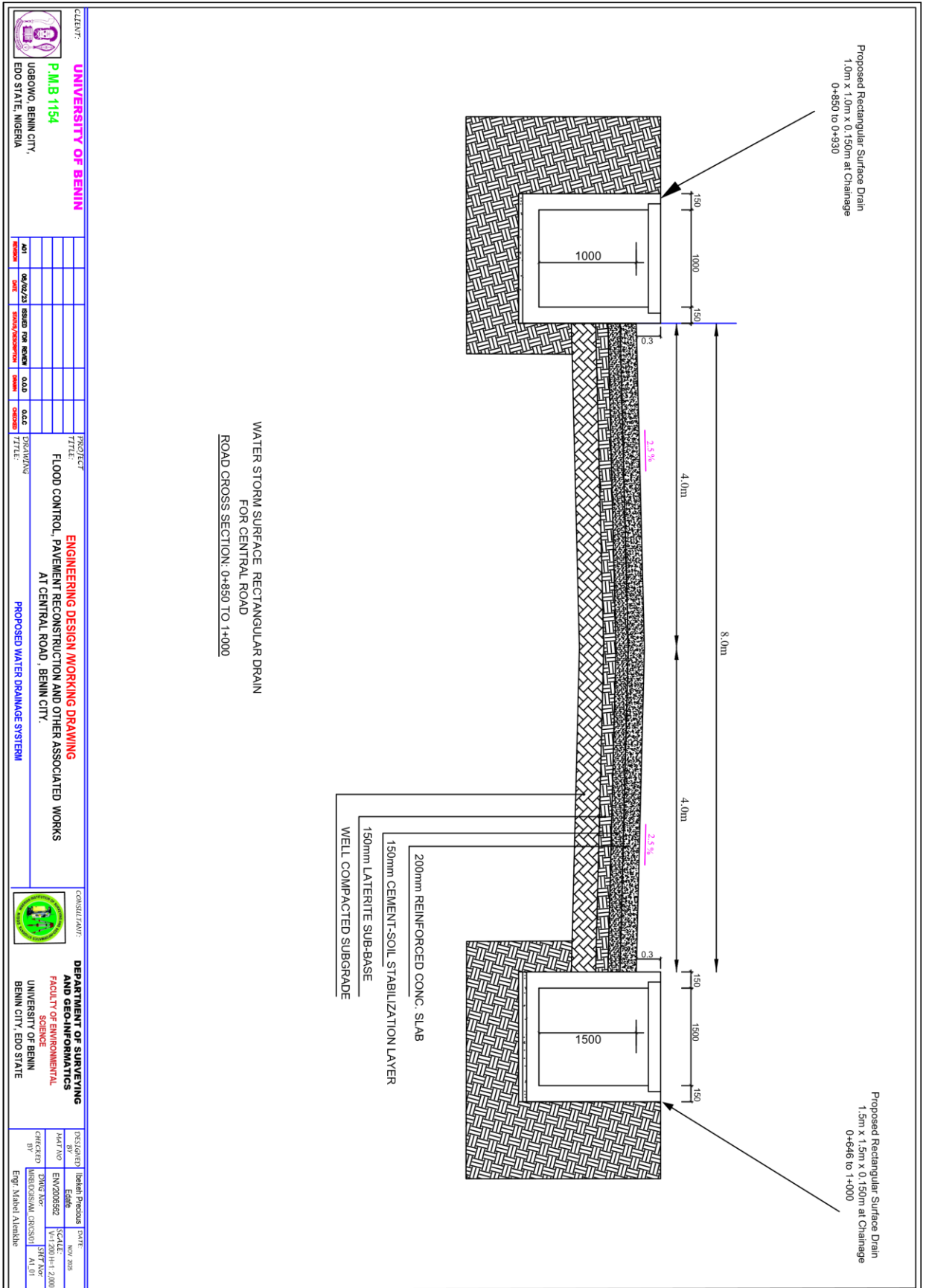


Figure 4.5

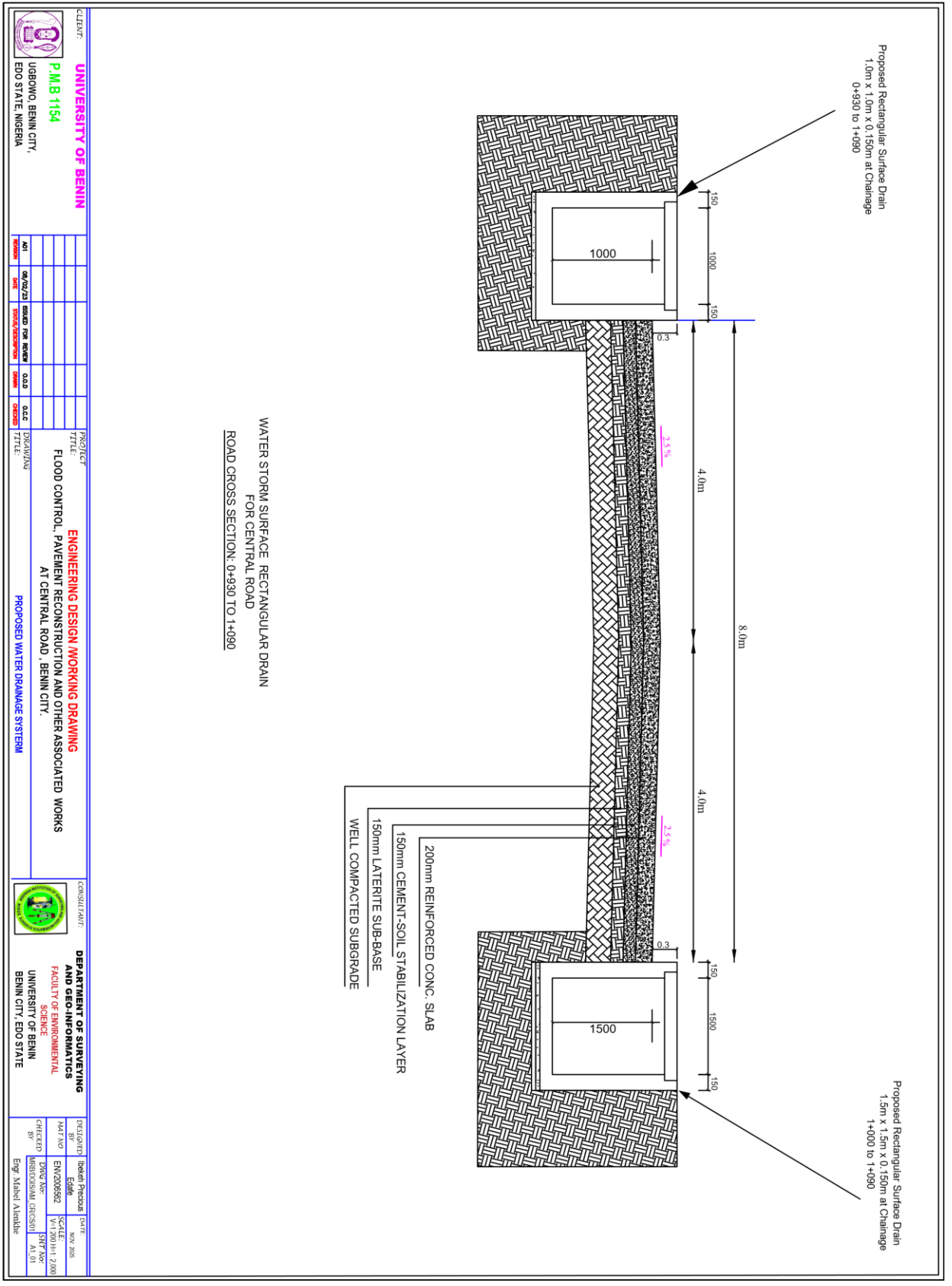


Figure 4.6

## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATIONS

#### 5.1 CONCLUSION

This study investigated the causes, spatial extent, and hydrological characteristics of flooding along Central Road and its adjoining areas in Oredo Local Government Area, Edo State, with the aim of developing a suitable urban drainage design to mitigate the problem. Through a combination of hydrological modeling and GIS-based spatial analysis, the research successfully identified flood-prone sub-catchments, evaluated runoff dynamics, and proposed drainage structures capable of efficiently conveying stormwater during high-intensity rainfall events.

The findings revealed that the area is highly vulnerable to flooding due to a combination of factors, including inadequate drainage design, low-lying topography, and the proliferation of impervious urban surfaces that limit infiltration. The delineation of thirteen sub-catchments (SC1–SC13) showed that SC7 and SC9 contribute the largest runoff volumes, primarily due to their depressed terrain and high flow accumulation zones. Hydraulic analysis further demonstrated that runoff discharge increases progressively downstream along the left-hand drainage channel, reaching approximately 7.00 m<sup>3</sup>/s at the outlet, whereas the right-hand side contributes relatively minor flows due to the area's slope orientation.

The proposed drainage system, designed with adopted dimensions ranging from 0.9 × 0.9 m to 1.3 × 1.3 m to 1.5 × 1.5, was found to be hydraulically adequate for managing stormwater under peak flow conditions. Flow regime analysis indicated that most sections operate under subcritical flow, which ensures channel stability and minimizes erosion risks. These results confirm that when proper hydraulic design is integrated with sustainable urban

drainage management practices, significant flood reduction can be achieved. In conclusion, the study demonstrates that the recurrent flooding challenges along Central Road are primarily the result of insufficient drainage capacity, poor maintenance, and unregulated urban development. The integration of GIS-based hydrological analysis proved instrumental in visualizing flow behavior and optimizing drainage design. The implementation of the proposed drainage network will substantially reduce flood risks, prolong road service life, and improve the environmental quality and overall living conditions of residents within the study area.

## **5.2 RECOMMENDATION**

Based on the findings of this research, the following recommendations are proposed to promote effective flood control, sustainable drainage management, and long-term environmental resilience within the study area:

- i.** Implementation of the Recommended Drainage Scheme: The proposed drainage system should be constructed strictly in accordance with the design specifications developed in this study. Adhering to the recommended dimensions and engineering standards will ensure that the channels possess adequate capacity to convey peak stormwater discharges. Proper supervision during construction is also essential to guarantee structural integrity, prevent flow obstructions, and minimize future system failures.
- ii.** Development of a Stormwater Retention and Detention System: A retention or detention basin should be developed in the downstream section of the drainage network, particularly around sub-catchments SC7 and SC9, where runoff accumulation is most significant. This facility will serve to temporarily retain excess stormwater, allowing gradual discharge and infiltration. The approach will help regulate peak flows, reduce the risk of downstream flooding, and enhance overall watershed management.

- iii. Regular Maintenance and Supervision of Drainage Systems:** Regular inspection, cleaning, and desilting of drains should be institutionalized to sustain their hydraulic efficiency. Blocked or debris-filled channels drastically reduce flow capacity and contribute to recurrent flooding. A scheduled maintenance program should therefore be established by relevant local authorities, incorporating community participation to ensure prompt reporting and clearing of blockages.
- iv. Enhancement of Land Use Management and Environmental Enforcement:** Strict enforcement of urban planning laws and environmental regulations is critical. Construction activities should be prohibited on natural drainage corridors and floodplains. Developers must comply with building setback standards and approved drainage layouts. Additionally, proper waste disposal systems should be promoted to prevent refuse from clogging drainage channels and impeding stormwater flow.
- v. Integration of Green Infrastructure and Public Participation:** Integrating green and sustainable urban drainage systems (SuDS) such as bioswales, rain gardens, infiltration trenches, and permeable pavements will improve infiltration, reduce runoff volumes, and enhance urban aesthetics. Community education and public awareness campaigns should also be implemented to encourage residents to adopt proper waste management practices and participate in local flood prevention initiatives. Such participatory efforts will foster environmental responsibility and ensure the long-term functionality of drainage infrastructure.

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