FLOOD MITIGATION USING URBAN DRAINAGE SYSTEM AT EDAIKEN PRIMARY SCHOOL ROAD AND ITS ENVIRONS, BENIN CITY

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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 **JOSHUA ESTHER CHARLIE** with Matriculation Number: **ENV2009684** of the Department of Geomatics, Faculty of Environmental Sciences, University of Benin, Edo State, Nigeria.

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EXTERNAL EXAMINER 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 my beloved mother, Mrs. Udoh Theresa. Her unwavering support and encouragement profoundly influenced my academic journey.

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ABSTRACT

Flooding is a recurring environmental hazard that continues to pose significant challenges to urban development, particularly in rapidly growing cities of developing countries like Nigeria. This study investigates the causes, extent, and possible mitigation measures for flooding along Edaiken Primary School Road and its environs in Benin City**,** with the aim of improving stormwater management and promoting sustainable urban resilience. The research evaluates the efficiency of existing drainage infrastructure, identifies flood-prone zones, and designs an appropriate drainage system to mitigate runoff accumulation.

A combination of field observations, hydrological data collection, and GIS-based spatial analysis was employed to assess catchment characteristics and flow patterns. The drainage catchment was delineated into five sub-catchments (SC1–SC5), each with distinct topographic and hydrological properties. Results from the analysis revealed that sub-catchments SC3 and SC4 contribute the largest volumes of runoff due to their lower elevation and higher flow accumulation potential. The hydrological parameters indicated short times of concentration (0.284–0.583 hours) and high rainfall intensities (137.034–175.972 mm), which are typical of urbanized areas with low infiltration capacity.

The hydraulic design showed a progressive increase in discharge from 0.73 m^3/s upstream to about 7.00 m^3/s downstream, requiring drainage sizes ranging from 0.9 × 0.9 m to 1.0 × 1.0 m to efficiently convey peak runoff. The flow regime across the catchments was found to be subcritical to near-critical, signifying stable flow conditions suitable for lined drains. These results confirm that flooding within the area is primarily caused by undersized and poorly maintained drainage channels, coupled with rapid urban expansion that restricts natural flow paths.

The study concludes that effective flood control can be achieved through a combination of engineering, environmental, and community-based measures. It recommends the implementation of the proposed drainage design, the construction of a retention pond at critical locations (notably near SC3 and SC4), regular maintenance of drainage systems, strict enforcement of land-use regulations, and the integration of green infrastructure to enhance infiltration and reduce surface runoff.

This research contributes to the broader understanding of urban flood management and provides a practical, data-driven framework for sustainable drainage design. The findings serve as a valuable reference for engineers, urban planners, and policymakers seeking to mitigate flood hazards and improve the environmental resilience of urban settlements in Nigeria and beyond.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Flooding remains one of the most destructive natural disasters, posing serious risks to human lives and livelihoods worldwide. Recent studies estimate that global economic losses due to floods amount to roughly $60 billion annually (Nguyen-Huy *et al*., 2022; Convertino *et al*., 2019). Essentially, a flood occurs when a large volume of water overwhelms natural or artificial drainage systems, spilling over riverbanks or stormwater channels and causing widespread damage to homes, infrastructure, and economic activities (Abam, 2006).

Several factors contribute to the increasing frequency and intensity of floods. Rapid urban expansion, the spread of impermeable surfaces like concrete and asphalt, deforestation, and shifts in land use all reduce natural water absorption and increase runoff. Moreover, climate change has intensified rainfall patterns and sea level rise, further exacerbating flood risks in many parts of the world (Yin *et al.*, 2021).

Floods continue to rank among the most common and costly disasters globally, prompting governments and international bodies to invest in more effective mitigation strategies (World Bank, 2023). Recent data suggests that flooding causes between $20 billion and $40 billion in damages every year, with long-term consequences that go beyond immediate destruction. These events strain public finances, reduce investor confidence, and disrupt development in vulnerable regions, particularly in low- and middle-income countries (UNDRR, 2022).

Urban environments are particularly at risk because of their dense infrastructure and poor drainage. In Nigeria, cities like Benin City face recurring floods due to unregulated development, inadequate waste management, and blocked drainage systems. Specifically, the area along Edaiken Primary School Road has suffered repeated seasonal flooding, especially during heavy rains. These floods damage homes and roads, interrupt daily life, and pose health and safety risks for residents.

Urban drainage systems, when well-designed and maintained, play a crucial role in managing stormwater and mitigating flood impacts. This study explores how urban drainage can be effectively utilized to reduce flooding in the study area.

1.2 Statement of the Problem

The Edaiken Primary School Road and its surrounding areas have been facing persistent and increasingly severe flooding, particularly during the annual rainy season. These flood events have become a recurrent challenge, significantly disrupting the lives and livelihoods of residents in the area. The root causes of this problem can be traced to a combination of poor and insufficient drainage infrastructure, frequent blockage of stormwater channels due to improper waste disposal, and the rapid, unregulated urban development that has taken place without proper planning or environmental consideration.

Over the years, these issues have culminated in extensive damage to both public and private property, accelerated deterioration of road surfaces, and the emergence of serious public health risks, including waterborne diseases and mosquito infestations. The stagnant floodwaters often create breeding grounds for disease vectors, compounding the already vulnerable health conditions of the community.

Although government agencies and local authorities have attempted to address the problem through measures such as clearing drains, constructing culverts, and carrying out occasional road maintenance, these interventions have largely been reactive and short-term. The recurrence of flooding suggests that the solutions currently in place are inadequate and not rooted in a comprehensive understanding of the area's hydrology, land use patterns, and urban development pressures.

Therefore, there is an urgent need for a more strategic, sustainable, and data-driven flood mitigation approach. Such an approach should involve the integration of topographic data, spatial analysis, and hydrological modeling to properly assess the causes and extent of flooding. Without this shift towards informed and long-term planning, the area will remain at risk, and the socio-economic toll of recurring floods will likely worsen over time.

1.3 Aim and Objectives

The aim of this project is to design a drainage systems for Edaiken primary school road and its environs for flood mitigation.

The objectives are to:.

1. identify flood-prone areas contributing to the affected areas within the study location.

2.determine the design parameter across each catchment area.

3. design the drainage system that can accommodate the discharge volume.

1.4 Scope and Limitations of the Study

This study focuses on addressing the problem of urban flooding along Edaiken Primary School Road and its surrounding areas in Ugbowo, Benin City, Edo State. It aims to identify flood-prone locations, assess the state of existing drainage infrastructure, and analyze the physical and environmental factors contributing to poor stormwater flow and surface water accumulation within the study area.

Field reconnaissance was conducted to observe stormwater movement, identify blocked or damaged drains, and locate areas frequently affected by waterlogging and erosion. Topographic data were collected and analyzed using Geographic Information System (GIS) tools to map terrain features, slope gradients, and flow directions. This provided insights into runoff behavior and existing drainage challenges.

The study also proposes appropriate urban drainage solutions, such as open channels, culverts, and retention structures, that are suitable for managing stormwater in the area. It further evaluates the effects of rapid urban development and inadequate drainage maintenance on flooding, with the goal of recommending sustainable and practical mitigation measures.

The study may be limited by time constraints, availability of up-to-date hydrological data, and accessibility to some locations during field assessment. Despite these, efforts will be made to collect reliable data through mapping tools and field observations.

1.5 Justification of the Study

Addressing flood issues in the study area is crucial to improving public health, infrastructure, and the overall quality of life for residents. Frequent flooding disrupts transportation, damages property, spreads waterborne diseases, and reduces the lifespan of roads and other infrastructure. As such, there is an urgent need to investigate and improve the drainage systems serving Edaiken Primary School Road and its surrounding areas.

This study provides valuable insight into the effectiveness of the existing drainage infrastructure and evaluates its capacity to manage stormwater under increasing urbanization and changing rainfall patterns. By identifying where current systems fall short, the research creates a foundation for proposing practical, cost-effective, and sustainable drainage improvements.

In addition to diagnosing the current challenges, the study adopts a combination of field surveys, hydrological modeling, and spatial analysis to propose targeted solutions. These include drainage redesigns based on catchment characteristics, the integration of natural flow paths, and recommendations for both conventional and nature-based solutions. By considering engineering standards, terrain, community needs, and long-term sustainability, the study goes beyond analysis to offer implementable strategies for flood mitigation.

Ultimately, the findings and recommendations of this study are intended to guide policymakers, urban planners, and engineers in designing more resilient and efficient drainage systems. This will contribute not only to reducing flood risks but also to fostering a healthier, safer, and more functional urban environment for the people living and working within the study area.

CHAPTER TWO

LITERATURE REVIEW

2.1 CONCEPT OF FLOODING

Flooding is one of the most impactful and frequent natural disasters globally, typically resulting from the overflow of water beyond its normal boundaries, leading to the submergence of land and widespread destruction. According to Hirabayashi *et al*. (2022), such events occur when the volume of water surpasses the capacity of natural or artificial drainage systems, posing serious threats to communities and ecosystems. The term "flood" has deep historical roots, originating from the Old English word *flōd*, and is shared across many languages within the Teutonic family, reflecting its long-standing significance in various cultures (Kundzewicz *et al.,* 2017).

Technically, flooding often involves river overflows caused by intense or prolonged rainfall. It is broadly defined as a significant outpouring of water that spreads over land that is normally dry (Daniel and Udo, 2019). In recent years, the frequency and intensity of such floods have increased, largely due to climate change. Rising global temperatures have led to heavier rainfall, ocean thermal expansion, and accelerated melting of glaciers, all contributing to higher sea levels and greater risks of coastal and inland flooding.

The consequences of flooding are far-reaching and multifaceted. It affects residential communities, displaces people and animals, destroys crops, and severely damages infrastructure (Ujene *et al*., 2020). The environmental impact is equally troubling, as recurrent flooding contributes to soil degradation, pollution, and loss of biodiversity. Adeleke *et al.* (2023) emphasize that repeated flood events threaten the livability of many communities and undermine their long-term resilience.

In addition to floods, other environmental challenges such as droughts, desertification, erosion, and tsunamis compound the threat to ecological stability and human development (UNEP, 2023). Recognizing this, global organizations have intensified their efforts to understand and manage flood risks. The World Bank (2022) describes flooding as one of the most persistent and damaging natural hazards, noting its disproportionate impact on developing nations where infrastructure is weak and disaster preparedness is often inadequate.

In Nigeria, the problem is particularly acute. Unplanned urban development, insufficient regulatory enforcement, and a lack of integrated land-use planning have left many communities vulnerable. Developers frequently ignore zoning laws, building in areas prone to flooding, while limited funding and institutional capacity prevent the proper implementation of flood control systems like drainage channels and retention basins (Nextier, 2024; ICIR Nigeria, 2024).

Although urbanization itself isn't the root cause of flooding, it significantly worsens the situation. The Nigerian Institute for Oceanography and Marine Research (NIOMR, 2021) notes that the rapid expansion of built environments, with roads, rooftops, and pavements, reduces the land's ability to absorb water. During periods of heavy rainfall, this results in large volumes of surface runoff that collect in low-lying areas. Furthermore, poor construction practices, deforestation, and unchecked land-use changes interrupt natural water pathways, increasing the intensity and spread of floodwaters (NatureNews, 2024).

Floods can take on several forms, including flash floods, riverine floods, and coastal floods, depending on their origin and behavior. Typically, they are triggered by extreme weather events such as heavy rainfall, snowmelt, or storm surges (UNDRR, 2020). Among them, flash floods are especially dangerous due to their sudden onset and high velocity, often leaving little to no time for evacuation.

These types of floods are particularly deadly in densely populated areas, floodplains, and mountainous regions. In hilly areas, runoff quickly accelerates downslope, especially when the soil is impermeable or already saturated. This makes even moderate rainfall events capable of triggering destructive surface floods (Reuters, 2024).

In urban settings, the proliferation of impermeable surfaces like concrete roads and rooftops blocks natural infiltration pathways, increasing the volume of runoff and placing significant strain on already insufficient drainage systems. This not only leads to immediate flooding but also contributes to long-term degradation of city infrastructure (World Bank, 2022).

Understanding how both natural and human-induced factors shape flood risks is essential for developing sustainable and effective solutions. A comprehensive grasp of how urban growth, land-use change, and climatic conditions interact helps inform policy decisions, improve emergency preparedness, and reduce the vulnerability of at-risk populations.

Floods continue to account for a major share of global disasters. Between 1998 and 2017, they represented about 43% of all recorded natural disasters globally (UNDRR, 2018). This widespread occurrence highlights the shared vulnerability faced by both developed and developing nations. Luo *et al*. (2015) identified 15 countries with the largest populations exposed to river flooding, demonstrating that flood risk transcends borders and development levels.

In Africa, and particularly in Nigeria, the frequency and severity of flooding have escalated into a full-blown humanitarian crisis. These floods destroy homes, disrupt livelihoods, increase food insecurity, and displace thousands of families (Nature News, 2024). Beyond the immediate impacts, the long-term consequences, like damaged infrastructure and reduced agricultural output, make it difficult for communities to recover and thrive.

Despite the involvement of national governments and international aid organizations, significant gaps remain in managing and mitigating flood risks in the African region. The World Bank (2022) continues to highlight the overwhelming challenge of flood control in areas with fragile infrastructure and limited financial resources.

In addition to the destruction caused, floods also facilitate the spread of waterborne diseases, reduce access to clean water, and undermine food production, worsening poverty and slowing economic development (Sudha Rani *et al*., 2015; Rehman *et al*., 2019). The layered nature of these impacts means that affected communities often face long-term setbacks well after the floodwaters have receded.

Luo *et al*. (2015) also found that about 80% of the global population affected by river flooding resides in just a few countries, including several in Africa, Asia, and South America. Recent data continues to affirm that flood risks are rising, with new climate trends pointing to more frequent and intense rainfall events (Reuters, 2024).

Countries such as India and Bangladesh remain among the most vulnerable. In Bangladesh, nearly a third of the country is submerged during the monsoon season, creating large-scale humanitarian challenges and threatening millions of lives annually (Coca, 2020; UNDRR, 2022). Similarly, in West Africa, countries like Nigeria, Ghana, and Niger face seasonal floods that frequently damage roads, displace communities, and strain emergency services.

For instance, in 2022, Nigeria experienced one of its most severe flood disasters, affecting over three million people and displacing more than 1.4 million (Wikipedia, 2022 Nigeria floods). The scale of destruction revealed deep weaknesses in infrastructure, governance, and environmental planning. The lack of resilient stormwater systems, combined with unchecked urban sprawl, leaves millions at risk (Nextier, 2024).

These developments point to the urgent need for integrated flood management policies that address not only emergency responses but also long-term adaptation strategies. Climate-resilient infrastructure, improved early warning systems, community education, and robust land-use planning are all vital tools in the global effort to mitigate flood risks and build societal resilience (World Bank, 2022; NatureNews, 2024). The table 2.1 adapted from information based on the 2022 study by Rentschler, Salhab, and Jafino, published in *Nature Communications*, which provides comprehensive estimates of global flood exposure.

Table 2.1: Estimated Population Exposed to Significant Flood Risk (2022)

Country	**Estimated Exposed Population (in millions)**	**Continent**
China	395	Asia
India	390	Asia
Bangladesh	90	Asia
Vietnam	46	Asia
Indonesia	43	Asia
Pakistan	41	Asia
Egypt	39	Africa
Nigeria	35	Africa
Philippines	32	Asia
Myanmar	28	Asia
Thailand	26	Asia
Brazil	24	South America
United States	23	North America
Democratic Republic of the Congo	22	Africa
Cambodia	20	Asia

Source: Adapted from Rentschler and Salhab (2022)

2.2 URBAN DRAINAGE SYSTEMS TYPES AND FUNCTIONS

In today's rapidly growing cities, managing excess rainwater has become a critical part of urban planning. With the increase in built-up areas like roads, rooftops, and pavements, natural water absorption has greatly reduced, leading to faster and heavier runoff during rainfall. Urban drainage systems are specifically designed to tackle this problem. They help collect, direct, and dispose of rainwater and wastewater to reduce flooding, protect infrastructure, and ensure public health and safety (Bong *et al.*, 2021).

2.2.1 Types of Urban Drainage Systems

Urban drainage systems come in different forms, depending on the design, purpose, and challenges they aim to address. Broadly, they are categorized into conventional systems and sustainable or nature-based solutions**.**

A. Conventional Drainage Systems

i. Combined Sewer Systems: These systems use a single set of pipes to carry both stormwater and sewage. While this setup was once popular due to lower construction costs, it often leads to overflow problems during heavy rains. When this happens, untreated wastewater can end up in rivers or streets, posing serious environmental and health risks (USEPA, 2020).

ii. Separate Sewer Systems: In contrast, this system has two different pipes, one for stormwater and another for domestic sewage. This separation helps prevent the overflows seen in combined systems and improves the overall efficiency of waste treatment (Ahiablame & Shakya, 2021).

iii. Surface Drainage: This involves open gutters, roadside drains, and channels that guide runoff away from urban areas. It's a common system in many developing regions, including Nigeria, because it is easier and cheaper to install (Oloke *et al*., 2022).

iv. Subsurface Drainage (Underground Pipes): These are hidden pipelines installed below the surface to carry stormwater to nearby rivers or treatment facilities. While they keep streets looking clean, they can be expensive to build and require regular maintenance to avoid blockages (Alves *et a*l., 2020).

B. Sustainable Drainage Systems: To address the limitations of conventional systems, many cities are now adopting more environmentally friendly approaches, often called Sustainable Drainage Systems or green infrastructure**.** These aim to mimic how nature manages water, promoting infiltration, storage, and purification. These are:

i. Permeable Pavements: These are surfaces designed to let water seep through them, unlike regular concrete or asphalt. By doing so, they help reduce surface runoff and encourage groundwater recharge (Ossom *et al*., 2021).

ii. Green Roofs: These are rooftops covered with soil and plants. They absorb rainfall, reduce runoff, and offer extra insulation for buildings. They are particularly useful in cities where space is limited (Leung *et al*., 2022).

iii. Rain Gardens and Bioretention Areas: These small, planted areas collect and absorb rainwater from nearby surfaces. They not only reduce flooding but also help clean the water before it reaches the drainage system (Sood *et al.,* 2023).

iv. Infiltration Trenches and Basins: These are shallow ditches or pits filled with gravel that temporarily store runoff and allow it to soak into the ground. They help reduce pressure on conventional drainage networks (Kouame *et al*., 2021).

v. Detention and Retention Ponds: are specially designed basins that hold stormwater. Detention ponds temporarily store water and release it slowly, while retention ponds hold water permanently and help remove pollutants. They are commonly used in flood-prone areas (Adediji *et al*., 2023).

2.2.2 Functions of Urban Drainage Systems

Urban drainage systems serve many important functions that go beyond just moving water. Here's what they do:

i. Prevent Flooding: The most obvious function is to control floodwaters. By quickly channeling rainwater away from streets and buildings, these systems help prevent waterlogging and damage (World Bank, 2022).

ii. Protect Public Health: Proper drainage prevents stagnant water, which can breed mosquitoes and spread diseases. It also helps avoid sewage overflows that contaminate water sources (UNEP, 2023).

iii. Safeguard Infrastructure: Without drainage, water can weaken roads, foundations, and utility systems. Over time, this leads to potholes, building damage, and costly repairs (Ujene *et al*., 2020).

iv. Recharge Groundwater: By allowing water to soak into the ground, green infrastructure supports the natural replenishment of underground water sources (NIOMR, 2021).

v. Support Climate Adaptation: With climate change leading to more intense rainfall and rising flood risks, well-designed drainage systems is becoming essential for urban resilience (UNDRR, 2022).

2.2.3. Challenges in Urban Drainage Systems

Despite the vital role urban drainage systems play in reducing flood risks and maintaining environmental health, several challenges continue to limit their effectiveness, especially in rapidly urbanizing cities across developing countries like Nigeria. These challenges stem from a combination of technical, institutional, environmental, and social factors, which must be addressed holistically to improve urban flood resilience.

1. Poor Maintenance and Waste Management: One of the most common and pressing issues is the lack of regular maintenance. Drains, gutters, and culverts are frequently clogged with plastic waste, silt, and organic debris, reducing their capacity to channel stormwater effectively. This blockage often causes localized flooding even after short periods of rainfall. In many Nigerian cities, the habit of dumping refuse into open drains is widespread, largely due to inadequate public waste disposal systems and a lack of awareness about its consequences (Nextier, 2024). Without regular desilting and clearing, these systems become ineffective over time.

2. Rapid and Unplanned Urbanization: Urban areas are expanding at a fast pace, often without proper planning. In many cases, housing estates, shops, and markets are constructed on floodplains or in areas meant for drainage corridors. This unregulated urban growth puts pressure on existing infrastructure, which is either outdated or insufficient for current population levels. Additionally, the increase in impervious surfaces, such as concrete roads, rooftops, and pavements which leads to higher surface runoff and less natural infiltration, worsening flood risks (Oloke *et al*., 2022).

3. Inadequate Drainage Design and Capacity: Many urban drainage systems were built decades ago based on older rainfall data and smaller population sizes. Today, these systems

are overwhelmed during even moderate storms. Poor design standards, lack of hydraulic modeling, and absence of future climate considerations mean many systems are no longer fit for purpose. In some cases, roads are constructed without accompanying drainage or with insufficient slope for water to flow effectively, resulting in ponding and erosion.

4**.** Weak Institutional Coordination and Policy Enforcement: Urban drainage management often falls under the responsibility of multiple agencies, local governments, environmental bodies, urban planning authorities, and water boards. However, there is often a lack of coordination between these bodies, leading to duplication of efforts or complete neglect. Zoning laws and building regulations are poorly enforced, allowing developers to encroach on drainage channels. In some cases, even government-approved constructions obstruct natural watercourses, reflecting institutional lapses (ICIR Nigeria, 2024).

5. Limited Funding and Investment: Maintaining and upgrading urban drainage infrastructure requires significant investment, which is often lacking. Budget allocations for flood control and drainage are usually minimal and insufficient to cover growing infrastructure needs. In many developing countries, external funding from donor agencies or international bodies is relied upon, but this is not sustainable in the long run. The lack of financial resources also affects staffing, equipment availability, and the ability to implement innovative drainage solutions (World Bank, 2022).

6. Climate Change and Increasing Rainfall Intensity***:*** Climate change is significantly altering rainfall patterns, leading to more intense and unpredictable storms. Many cities are experiencing rainfall volumes that exceed the design capacity of existing drainage systems. Additionally, rising sea levels pose a threat to coastal cities by reducing the ability of low-lying drainage systems to discharge stormwater efficiently, particularly during high tides or storm surges (UNDRR, 2022; Reuters, 2024). These climate-related changes require drainage

systems to be adaptable and forward-looking, yet many current systems are still built using outdated assumptions.

2.3. Causes and Effects of Flooding in Nigeria

Flooding in Nigeria is a recurring and increasingly severe issue, driven by a combination of natural processes and human activities. These contributing factors are interconnected and have intensified in recent years due to urban growth, environmental mismanagement, and changing climate conditions.

2.3.1. Causes of Flooding in Nigeria

i. Heavy and Prolonged Rainfall

Nigeria’s rainy season often brings intense and sustained downpours, particularly in the southern and central regions. When rainfall exceeds the infiltration capacity of the soil or the design capacity of urban drainage systems, excess water rapidly accumulates on the surface, leading to flash floods. The situation is worsened when storms persist over several days, giving the land and infrastructure little time to recover (Adeleke *et al*., 2023).

ii. Poor Drainage Infrastructure

A major contributor to urban flooding is the widespread lack of effective drainage systems, especially in densely populated cities. Many areas either lack drains entirely or have systems that are poorly designed, outdated, or clogged due to neglect. Without proper channels to carry stormwater away, even moderate rainfall can lead to severe flooding (Oloke *et al*., 2022).

iii. Deforestation and Vegetation Loss

The large-scale clearing of forests and vegetation, often for agriculture, settlement, or infrastructure projects, reduces the ability of soil to absorb water. Trees and plant roots play a crucial role in stabilizing the soil and facilitating groundwater recharge. Once they are removed, runoff increases significantly, raising the likelihood of flooding during rainfall events (NIOMR, 2021).

v. Unregulated Urban Expansion

Rapid and often unplanned urban development has led to the encroachment on natural waterways and wetlands. Buildings are frequently constructed on floodplains or across drainage paths, blocking water flow and forcing it into streets and homes. Additionally, the increase in paved surfaces, such as concrete roads and rooftops, prevents water from soaking into the ground, further contributing to surface runoff (Nextier, 2024).

vi. Climate Change and Weather Variability

Global climate change has altered rainfall patterns, leading to more erratic and intense storms in Nigeria. Rising temperatures also contribute to sea level rise, especially in coastal states like Lagos, Bayelsa, and Delta. These changes not only increase flood frequency but also expand the geographic range of flood-prone areas (UNDRR, 2022; Reuters, 2024).

vii. Dam Mismanagement and Failures

Some floods in Nigeria have been traced to the sudden release of water from dams, either due to poor planning or structural issues. For example, emergency water discharge during heavy rains can inundate downstream communities, causing rapid and destructive flooding. Weak dam infrastructure and inadequate early warning systems make this a significant hazard (World Bank, 2022).

viii. Improper Solid Waste Disposal

A major challenge in many Nigerian cities is the indiscriminate dumping of refuse into drains, culverts, and waterways. This behavior blocks the flow of water, causing it to overflow onto streets and into homes during rainstorms. The lack of an efficient waste collection system contributes to this problem, especially in low-income neighborhoods (ICIR Nigeria, 2024).

2.3.2. Effects of Flooding in Nigeria

The consequences of flooding are far-reaching and affect every aspect of life, from human safety to national economic performance.

i. Human Casualties and Property Loss: Flood events often result in fatalities, particularly in cases of flash floods or dam failures. Thousands of people are displaced each year, and homes, vehicles, businesses, and public infrastructure such as roads, bridges, and power lines are frequently damaged or destroyed. In 2022 alone, flooding displaced over 1.4 million Nigerians (Wikipedia, 2022 Nigeria Floods).

ii. Displacement and Humanitarian Crises: Flooding forces families to leave their homes, sometimes permanently. Temporary shelters become overcrowded, and basic needs such as food, clean water, and sanitation are difficult to meet. This creates complex humanitarian emergencies, particularly when floods affect already vulnerable populations (UNEP, 2023).

iii. Health Risks and Disease Outbreaks: Flooded areas are fertile ground for waterborne diseases like cholera, typhoid fever, and dysentery. Stagnant water also provides breeding sites for mosquitoes, increasing the incidence of malaria and other vector-borne diseases. Poor sanitation and contaminated water supplies compound the health crisis after a flood (Ujene *et al*., 2020).

iv. Agricultural Damage and Food Insecurity: Nigeria's agricultural sector, especially in rural areas, is heavily affected by flooding. Farmlands are washed away, and crops are destroyed just before harvest. Livestock loss is also common. This not only affects farmers' livelihoods but also disrupts food supply chains, leading to inflation and food scarcity (Adediji *et al*., 2023).

v. Economic Disruptions: Floods damage critical infrastructure, delay transportation, and disrupt business activities. Local economies, especially small and informal businesses, suffer significant setbacks. Governments also incur high costs for emergency relief, rebuilding infrastructure, and compensating affected communities, diverting funds from other development priorities (World Bank, 2022).

2.4 FLOOD MITIGATION STRATEGIES

Flooding remains one of the most frequent and devastating environmental disasters in the world, and Nigeria is no exception. As both urban and rural communities face increasing risks from climate change, poor infrastructure, and unsustainable development, it has become vital to adopt comprehensive strategies that mitigate the impacts of flooding. Flood mitigation refers to the range of actions taken to prevent, reduce, or manage the adverse consequences of floods. These strategies can be categorized into structural, non-structural, and resilience-building approaches, each playing a critical role in flood risk management.

1. Structural Flood Mitigation Measures: Structural measures are physical and engineering-based interventions designed to control, divert, or store excess water during flood events. While they can be expensive and technically complex, these solutions are often indispensable in protecting highly vulnerable communities and infrastructure.

Dams and Reservoirs*:* These are large-scale hydraulic structures built across rivers to retain and control water flow. During periods of excessive rainfall, reservoirs created by dams store surplus water and release it gradually, reducing the risk of sudden downstream flooding. Functions: Besides flood control, dams support hydroelectric generation, irrigation, and drinking water supply. Example is the Kainji Dam in Nigeria serves both flood regulation and power generation functions. Dams can displace communities, alter ecosystems, and may fail catastrophically if not well-maintained (e.g., overtopping, structural breaches), as seen in some parts of sub-Saharan Africa (UNDRR, 2022).

Levees and Floodwalls: Levees (usually made of earth) and floodwalls (often concrete or steel) are constructed along rivers or coastlines to act as barriers against rising water. It is primarily used to protect cities and farmlands from riverine or coastal floods. If overtopped, breached, or poorly maintained, they can cause catastrophic flooding. Moreover, they may give communities a false sense of safety, encouraging risky development in floodplains (World Bank, 2023).

Flood Barriers and Gates*:* Permanent flood barriers and deployable gates (like the Thames Barrier in London) can block or redirect floodwaters.

i. Application in Nigeria: While such large-scale barriers are rare in Nigeria, local governments often use sandbags or makeshift blockades during heavy rains.

ii. Drawbacks: Temporary barriers need quick deployment and skilled labor. Permanent ones are expensive and may only protect localized areas.

Flood Diversion Channels and Bypass Systems: are man-made waterways that divert floodwaters away from critical infrastructure and urban zones. It acts as a relief outlet for overflowing rivers. The limitation is that it can result in displacement or flooding in the areas where diverted water is deposited, hence requiring sensitive planning.

2. Non-Structural Flood Mitigation Measures: These approaches focus on reducing flood risks through policies, planning, education, and nature based solutions rather than physical constructions. They are generally more cost effective and sustainable, particularly for long-term resilience (World Bank, 2021; Mahabir *et al*., 2020). These are:

Land Use Planning and Floodplain Management: proper urban planning and floodplain mapping helps planners decide where development should or shouldn't occur and prevent construction in high-risk flood zones. It reduces human exposure and maintains natural flood absorption areas like wetlands (Andoh *et al*., 2021; Mahmoud *et al*., 2022).

Early Warning Systems and Flood Monitoring: Technology such as rain gauges, river gauges, satellite imagery, and hydrological models can predict floods and enable authorities and communities to prepare or evacuate (World Meteorological Organization [WMO], 2023; NIMET, 2021). The challenges are that Nigeria's early warning systems are still developing. Issues include unreliable data, limited communication infrastructure, and poor public response (Ologunorisa *et al*., 2020).

Community Education and Risk Awareness: Raising public knowledge about floods, safety protocols, and environmental stewardship is crucial. Media campaigns, school programs, town hall meetings, and disaster drills all improve public readiness (Aboagye *et al*., 2021).

Nonetheless, low literacy levels and poor dissemination in remote areas limit the impact. In Nigeria, weak environmental awareness often leads to harmful behaviors like refuse dumping in drainage (Oladipo *et al*., 2023).

Flood-Resistant Construction***:*** Designing buildings to withstand flood conditions reduces long-term damage. Like raising buildings on stilts, using waterproof materials, installing elevated electrical systems. The applications are useful in coastal or riverine communities like those in Bayelsa and Cross River (Adekola *et al*., 2022; Nkwunonwo *et al*., 2020).

Flood Resilience and Adaptation Strategies**:** Rather than solely preventing floods, resilience strategies help communities prepare for, survive, and recover from flood events with minimal long-term disruption. These are:

Community-Based Flood Risk Management (CBFRM): emphasizes grassroots involvement in planning and decision-making. It enhances local knowledge, fosters ownership, and improves coordination between residents and agencies. In Practice, communities that participate in maintaining drains, monitoring water levels, and conducting drills respond more effectively during emergencies (Osei and Adeyemi, 2023; Chowdhury *et al*., 2021).

Integrated Water Resources Management (IWRM)*:* IWRM involves managing water for all uses; drinking, agriculture, sanitation, and flood control, in a coordinated way. The goal is to optimize water use without compromising sustainability (UNESCO, 2022). The challenges in Nigeria, overlapping mandates among water agencies often create confusion (Okoye *et al*., 2020). A coordinated IWRM framework is needed for long-term planning.

Emergency Preparedness and Contingency Planning***:*** Having structured response plans ensures quicker action during flood events. It includes evacuation routes, emergency shelters, communication plans, and pre-positioned supplies. In many Nigerian states, contingency plans exist on paper but lack regular drills, funding, or community involvement (Adelekan, 2021).

2.5 The Role of Urban Drainage in Flood Control

Urban drainage systems play a critical role in managing stormwater and reducing flood risks, especially in densely built-up areas. As cities grow and more natural surfaces are replaced with concrete, asphalt, and buildings, the ground loses its natural ability to soak up rainwater. This leads to increased surface runoff, which, if not properly controlled, can result in serious urban flooding. This includes:

1. Stormwater Regulation: Urban drainage systems are designed to collect and channel rainwater through an organized network of gutters, drains, culverts, and pipes. By guiding runoff away from roads, homes, and businesses, these systems help prevent the kind of water build-up that causes flash floods, particularly during intense downpours.

2. Infrastructure for Flood Prevention: Components such as retention ponds, detention basins, soakaways, and underground reservoirs serve as temporary storage areas for excess rainwater. These features help ease the burden on drainage networks during peak rainfall, releasing water gradually to prevent overwhelming the system.

3. Erosion and Sediment Management: By directing water along planned routes, urban drainage systems help prevent the erosion of soil and the build-up of sediment in rivers, culverts, and channels. If left unchecked, these issues can block water pathways and increase the likelihood of flooding.

4. Supporting Climate Resilience: As extreme weather becomes more common due to climate change, urban drainage systems must now be built to accommodate larger volumes of water.

To improve resilience, cities are increasingly turning to sustainable drainage solutions such as green roofs, rain gardens, and permeable pavements that allow water to filter back into the soil rather than running off rapidly into drains.

2.6. Previous Studies On Flood Mitigation Using Urban Drainage Sytem

Urban flooding has become a pressing challenge globally due to rapid urbanization, poor land-use planning, and inadequate drainage infrastructure. Numerous studies have been conducted to explore how urban drainage systems can be designed or optimized to mitigate flooding risks. This section reviews both international and Nigerian case studies that have successfully applied urban drainage systems for flood control, highlighting their methods, outcomes, and relevance to the current study.

In Guangzhou, China,Ma *et al*. (2024) carried out a study on Xiaoguwei Island in Guangzhou using a coupled hydrology/hydrodynamics model to evaluate the effectiveness of integrated gray-green infrastructure. The gray systems included upgrades to drainage pipes, while green systems consisted of permeable pavements, green roofs, and rain gardens. The results demonstrated that the combined system significantly reduced runoff during high-intensity rainfall events, managing up to 50-year return period storms effectively. This study reinforced the importance of hybrid systems in urban flood resilience.

In one of the most flood-prone megacities in South Asia, Dhaka,Bangladesh, Alam *et al*. (2023) used the Storm Water Management Model (SWMM) to redesign and optimize the stormwater drainage network in the Shantinagar and Motijheel areas. Field surveys and simulation modeling revealed significant drainage bottlenecks. The improved network design enhanced drainage efficiency, reduced peak runoff, and significantly lowered the occurrence of street-level flooding during monsoons.

In Newcastle, UK, Iliadis *et al*. (2023) adopted the CityCAT hydrodynamic model to simulate urban flooding under different blue-green infrastructure scenarios. The study combined economic cost and benefit analysis with hydrological modeling to identify optimal placement of retention ponds, bioswales, and rain gardens. This integrated approach not only reduced flood risks but also improved urban aesthetics and ecosystem services.
In West Africa, Conakry,Guinea(2020), a study conducted in a 26.7 km² urban catchment in Conakry tested the effectiveness of Low Impact Development (LID) strategies such as bioretention cells and permeable pavements. Using SWMM, researchers found that runoff peak flows could be reduced by as much as 67.8%, and flooding events at drainage junctions decreased by 85.3%. This result highlights the applicability of sustainable drainage systems in tropical urban areas.

Nnaji and Ude (2021) used CivilStorm and GIS to assess the adequacy of drainage networks in Nsukka, Enugu state. Over 70% of the drainage channels were found to be inadequate in conveying stormwater, particularly during the 5-year return period. The researchers recommended periodic dredging and reconstruction of undersized channels, highlighting poor maintenance and illegal constructions as key challenges.

A study involving over 400 residents and 18 environmental experts in Port Harcourt(2022), explored the link between urban drainage and flooding. Through focus groups and spatial surveys, the study revealed that poor waste management practices contributed significantly to blocked drains and recurring floods. It recommended integrated flood management combining education, enforcement, and improved infrastructure.

In Obubra LGA, Cross River State, Obio *et al*. (2024) developed a runoff estimation model using velocity–area flow calculations and a calibrated regression model (R = 0.995). The study highlighted how properly sized and well-maintained drainage channels effectively minimized flood occurrences. This case demonstrates the need for data-driven design and maintenance protocols in Nigerian urban settings.

In Abeokuta (Olorunsogo), Ogun state**,** Sobowale *et al.* (2024) conducted a capacity analysis of the existing drainage system using on-site measurements. Findings showed that while the drainage system could manage 32% of runoff within the first hour, overflow volumes surged to over 737,000 m^3 during high-intensity rainfall. The study emphasized the importance of comprehensive drainage design, strict enforcement of building codes, and land-use regulation.

In Onitsha, Anambra state (2024), an integrated approach involving hydro-geomorphic mapping and multi-criteria decision analysis was used to assess flood susceptibility in Onitsha. The study found that inadequate drainage, compounded by urban encroachment, exacerbated flood risks. Recommendations included redesigning drainage channels based on slope, catchment area, and urban growth patterns.

In Ilorin, Kwara state(2022), a GIS and Analytic Hierarchy Process (AHP)-based study modeled flood susceptibility in Ilorin. The study showed how high levels of impervious surfaces and undersized drains increased flood vulnerability. Researchers called for urban redesign that incorporates green spaces and surface permeability into future development plans.

2.7. Review of Relevant Literature

The reviewed literature reveals that urban flooding primarily results from inadequate management of heavy rainfall in densely built environments, especially where drainage infrastructure is insufficient and urbanization is rapid. This challenge is particularly pronounced in developing cities, including those in Nigeria, where poor planning and maintenance exacerbate flood risks.

Urban drainage systems are designed to collect and convey stormwater away from urban areas to prevent waterlogging and associated damages. Two main types of drainage systems are commonly discussed: conventional “gray” infrastructure, such as culverts, open channels, and underground pipes; and “green” or nature-based solutions, including retention ponds, green roofs, and permeable pavements. A hybrid approach, integrating both gray and green infrastructures, is widely recommended to improve resilience against increasingly frequent and intense rainfall eventsFlood mitigation strategies are broadly categorized into structural measures, such as enhancing drainage capacity, constructing reservoirs, and retention facilities, and non-structural solutions, including land-use regulation, public education, and emergency planning. Modern urban flood management increasingly relies on advanced modeling tools like SWMM, MIKE URBAN, and GIS to simulate flood scenarios and support effective planning and preparedness.

International case studies from China, the United Kingdom, Algeria, Bangladesh, and Guinea demonstrate successful flood reduction through improved drainage capacity, integration of green infrastructure, and data-driven planning approaches. These examples highlight the effectiveness of combining infrastructure improvements with systematic maintenance and monitoring.

Local Nigerian studies from Nsukka, Port Harcourt, Ilorin, and Abeokuta reveal challenges such as blocked and undersized drains, lack of routine maintenance, and inadequate design standards relative to current rainfall patterns. However, these studies also emphasize the potential of spatial analysis, hydrological modeling, and community engagement in enhancing urban flood management.

Overall, the literature underscores that mitigating urban flooding requires a multi-faceted approach involving improved infrastructure design, proactive urban planning, regular maintenance, and public involvement. These insights inform the current study's focus on assessing and improving the urban drainage system in the Edaiken Primary School Road area of Benin City.

CHAPTER THREE

METHODOLOGY

3.1 Description of the Study Area

The area under study is located along Edaiken Primary School Road and its immediate surroundings in the Ugbowo neighborhood of Benin City, Edo State, Nigeria. Geographically, it is situated roughly between latitudes 6.373°N; 6.376°N; 6.373°N;6.370°N and longitudes 5.617°E; 5.622°E; 5.624°E; 5.617°E. This area is a predominantly urban environment that serves multiple functions, blending residential homes, small businesses, and community institutions such as the Edaiken Primary School. The mix of land uses gives the area a lively and dynamic character that reflects the everyday life of its residents.

Topographically, the site is relatively flat, with elevations generally ranging between approximately 80 and 90 meters above sea level. This low-lying terrain, combined with dense urban development, contributes to significant surface drainage challenges. The area is highly prone to flooding and water logging, especially during the rainy season when heavy downpours occur frequently. The climate is tropical, with a distinct wet season from April to October and a dry season from November to March. Annual rainfall is substantial, averaging between 1,800 and 2,100 millimeters, and plays a pivotal role in shaping the local hydrology and environmental conditions.

The soil in this area is primarily comprised of a mix of sandy-clay and lateritic soils, characteristic of the tropical forest zones of southern Nigeria. These soils tend to have moderate to low infiltration rates due to their fine particle composition and a propensity for compaction over time. As a result, stormwater has difficulty percolating into the ground, causing surface runoff to accumulate quickly. This runoff often overwhelms the existing drainage infrastructure, intensifying flooding during periods of heavy rainfall.

Land use within the area is heavily influenced by its urban character. The built environment includes a mix of residential buildings, access roads, commercial spaces, open spaces, and small pockets of vegetation. However, rapid urbanization in recent years has significantly reduced the proportion of permeable surfaces available for natural infiltration, making surface runoff and flooding increasingly problematic. This loss of infiltration capacity has underscored the urgent need for improved flood management and mitigation strategies to protect both people and property.

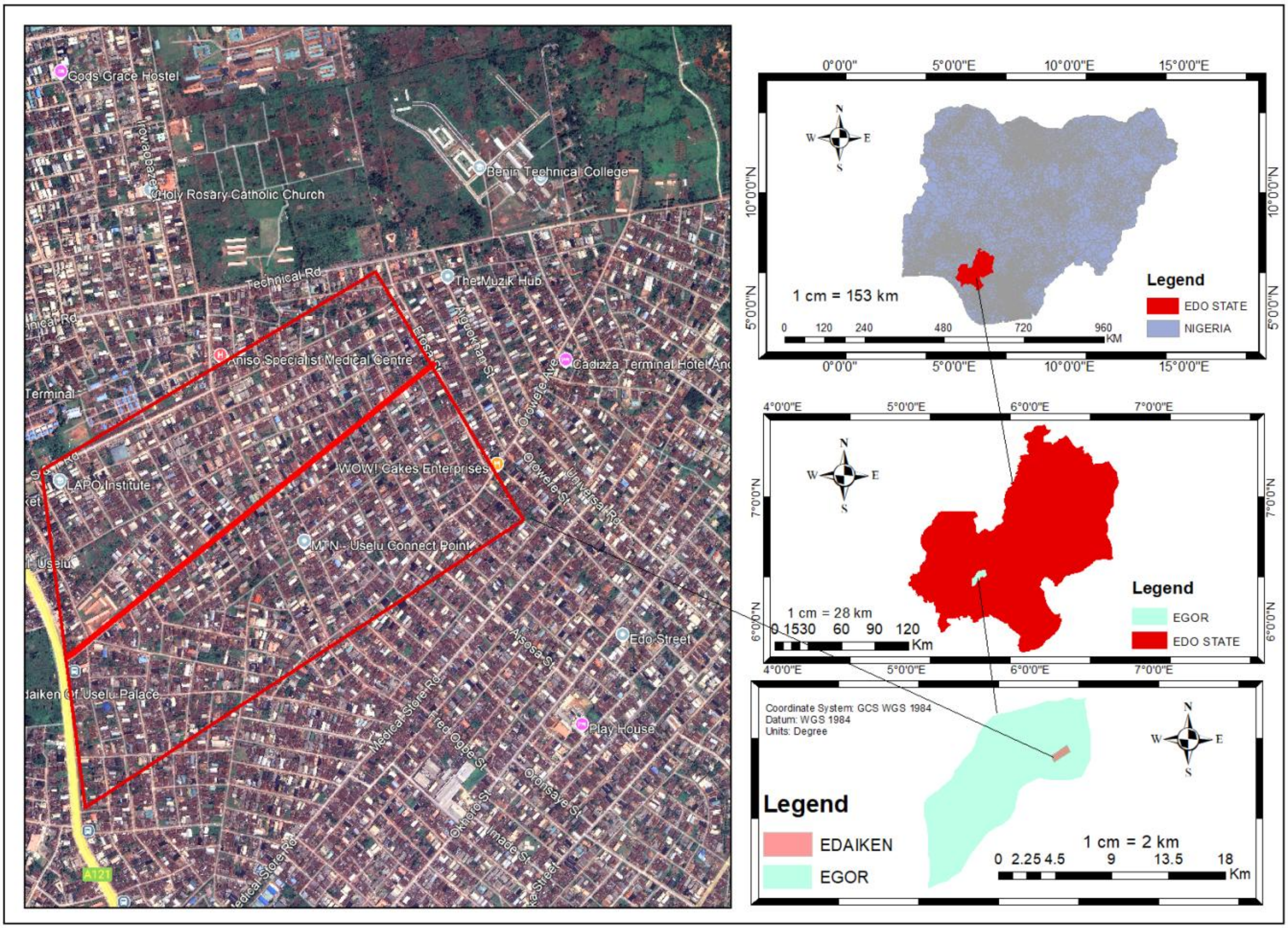

Figure 3.1 Study area map of Edaiken primary school road and its environs.

3.2 Types and Sources of Data

Table 3.1 shows the data used in this study were drawn from both primary and secondary sources to provide a comprehensive understanding of the flood situation and support effective analysis and planning.

Table 3.1: Description of Data Sources

Type	Description	Source
Primary Data	Direct data collected from the field to capture real-time information on drainage and flood conditions.	Field survey, on-site investigation.
Field Observations	On-site inspections to identify blocked drains, visible flood-prone areas, and general site conditions.	Field visits during dry and wet conditions.
GPS Measurements	Use of handheld GPS devices to capture the coordinates of culverts, gutters, flood hotspots, and other drainage features.	GPS data collected on-site
Topographic Surveys	Collection of elevation and slope data using tapes, leveling rods, and other instruments to analyze surface gradients and flow directions.	Digital leveling tools and manual measurement.

3.3 DATA COLLECTION TECHNIQUES

To effectively study flood mitigation using urban drainage systems around Edaiken Primary School Road and its surroundings, two key data collection methods were employed: field reconnaissance and topographic/spatial data collection. These techniques provided both the physical and geospatial information necessary to assess drainage conditions and flood risks in the area.

3.3.1 Field Reconnaissance

This involved physically inspecting the study area to observe existing drainage structures, identify problem spots, and gather first-hand information about the terrain. During these site visits, features like blocked drains, eroded areas, or waterlogged zones were documented. Tools such as handheld GPS devices were used to record exact locations of important features, while digital cameras helped capture visual evidence of drainage conditions. Measuring tapes and rangefinders were also used to get dimensions of culverts, channels, and other structures.

The purpose of this reconnaissance was to understand what is actually happening on the ground and compare it with available data or drainage maps. This helps identify where upgrades or changes are needed and ensures that any proposed solution is based on real conditions. The information gathered also served as a reference for updating drainage system maps and validating future design improvements.

3.3.2. Topographic and Spatial Data Collection

Alongside the field visits, spatial and topographic data will be collected to map the physical landscape of the area. This included using topographic maps and satellite images to create a Digital Elevation Model (DEM), a 3D representation of the land surface. Elevation points gathered during fieldwork will be used in GIS software to generate a detailed view of how water flows across the area.

This type of data is crucial for identifying low-lying or flood-prone zones and understanding how stormwater moves through the environment. With slope and flow direction maps derived from the DEM, it becomes easier to pinpoint where water naturally accumulates or where new drains might be needed.

3.4 TOOLS AND EQUIPMENTS USED

To ensure accurate data collection and analysis for the study, a variety of tools and equipment was used during both fieldwork and spatial analysis. These instruments are essential for gathering location-specific information, assessing drainage structures, and generating relevant maps and models.

3.4.1 Global Positioning System (GPS) Device

Handheld GPS units was used to obtain precise geographic coordinates of key drainage features such as culverts, inlets, gutters, and low-lying areas. These coordinates helped in mapping the drainage layout and integrating field data into GIS software for spatial analysis.

3.4.2. Digital Camera

Photographs were taken during field reconnaissance to document the physical condition of drainage structures, visible signs of erosion, blockages, and flood-prone zones.

3.4.3. Measuring Tape

was used to measure the dimensions of culverts, gutters, road sections, and drainage channels.

3.4.4. Topographic Maps

Topographic sheets provided by relevant government agencies will be used to understand terrain elevations and natural drainage flow paths. These maps served as the base for creating a digital elevation model (DEM) and performing slope and watershed analysis.

3.4.5. Satellite Imagery

High-resolution satellite images were used to analyze land cover, urban development patterns, and surface water pathways. This will aid in identifying areas where urbanization may have obstructed natural drainage systems.

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

Global Mapper and Google Earth Pro are the primary software tools used for spatial analysis and map generation.

i. Global Mapper was used to process elevation data, generate contour lines, and analyze surface runoff directions based on the digital terrain model (DTM) of the area. It allows for terrain profiling, watershed delineation, and floodplain mapping.
ii. Google Earth Pro provided satellite imagery and 3D visualizations that supports location verification, landmark identification, and the digitization of visible drainage features. It was especially useful for tracing drainage paths and validating field data.

3.4.7. Microsoft Excel

Excel was used for organizing and analyzing data collected from the field, including tabulating measurements, rainfall records (if available), and survey notes. It will also aid in simple calculations and graphical representations.

3.5 PROCEDURES FOR THE ANALYSIS

3.5.1. Evaluation of the Existing Drainage Infrastructure in the Study Area

To effectively assess the current drainage network at Edaiken Primary School Road and its environs in Benin City, a combination of physical inspection, hydraulic analysis, and spatial data evaluation will be adopted. These methods provide a comprehensive approach to understanding the condition, capacity, and coverage of existing drainage systems. The evaluation process integrates fieldwork with computational analysis to determine whether the infrastructure is capable of managing stormwater during rainfall events, especially under urban flood risks.

i. Field Reconnaissance Survey

The evaluation began with a reconnaissance survey of the project area. This involved a thorough physical inspection of roadside gutters, concrete drains, culverts, and natural discharge points. The survey focused on identifying signs of system failure such as structural damage, blockages by solid waste or sediment, evidence of frequent flooding, or erosion at outlets. The orientation, continuity, and visible slopes of the drainage channels were also examined. Observations from the field provided essential baseline data and revealed drainage structures that are either deteriorated, inadequate, or non-functional.

ii. Measurement of Drainage Geometry

Following the field reconnaissance, detailed measurements of the geometric features of existing drains were taken. These include the channel width, depth, length, and longitudinal slope. The dimensions are vital for computing the hydraulic capacity of each drainage element and for checking their conformity with standard drainage design criteria. Where applicable, the shape of the channel (rectangular, trapezoidal, or circular) was recorded, as this influences the flow behavior and cross-sectional area.

iii. Hydraulic Capacity Evaluation Using Manning’s Equation: To determine whether the existing drainage channels can adequately convey stormwater runoff, their flow capacity was calculated using Manning’s Equation, a widely accepted formula in open-channel hydraulics.

The equation is expressed as:

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

Where:

Q is the flow rate or discharge (m^3/s)

n is Manning's roughness coefficient (dimensionless)

A is the cross-sectional area of flow (m^2)

R is the hydraulic radius, calculated as A/P (P = wetted perimeter)

S is the slope of the channel or water surface (m/m)

The computed discharge values provide insight into how much stormwater the drains can handle under existing conditions.

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^3/s)

C = Runoff coefficient (depends on land use)

I = Rainfall intensity (mm/hr)

A = Catchment area (km^2)

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:

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

Where:

Tc = 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 reduce flooding along Edaiken Primary School Road and its environs, practical and technical strategies are essential for guiding drainage improvement proposals. These strategies must ensure infrastructure is capable of handling runoff while remaining cost-effective, sustainable, and appropriate for the local environment.

The process begins with a gap analysis, comparing stormwater runoff calculated using the equation (3.2) (Rational Method) to existing drain capacity (evaluated using equation (3.1) (Manning's Equation). This identifies undersized or failing infrastructure.

Next, drainage redesign should be catchment-based, ensuring each sub-area has appropriately sized structures to handle its runoff volume using Civil 3D(land desktop companion).

GIS tools and Digital Elevation Models (DEMs) assist in locating flow paths and low-lying areas, guiding the placement of new drains. All designs should follow national engineering standards, such as those outlined in the Federal Ministry of Works Highway Design Manual.

Beyond conventional solutions, nature-based options like permeable pavements, bioswales, and rain gardens can be integrated to enhance stormwater management and environmental sustainability.

Lastly, community engagement ensures that local insights into flood-prone areas and drainage issues are reflected in the proposals, making the solutions both practical and locally supported.

CHAPTER FOUR

RESULT AND DISCUSSIONS

4.1 Identification of Flood Prone Area Results

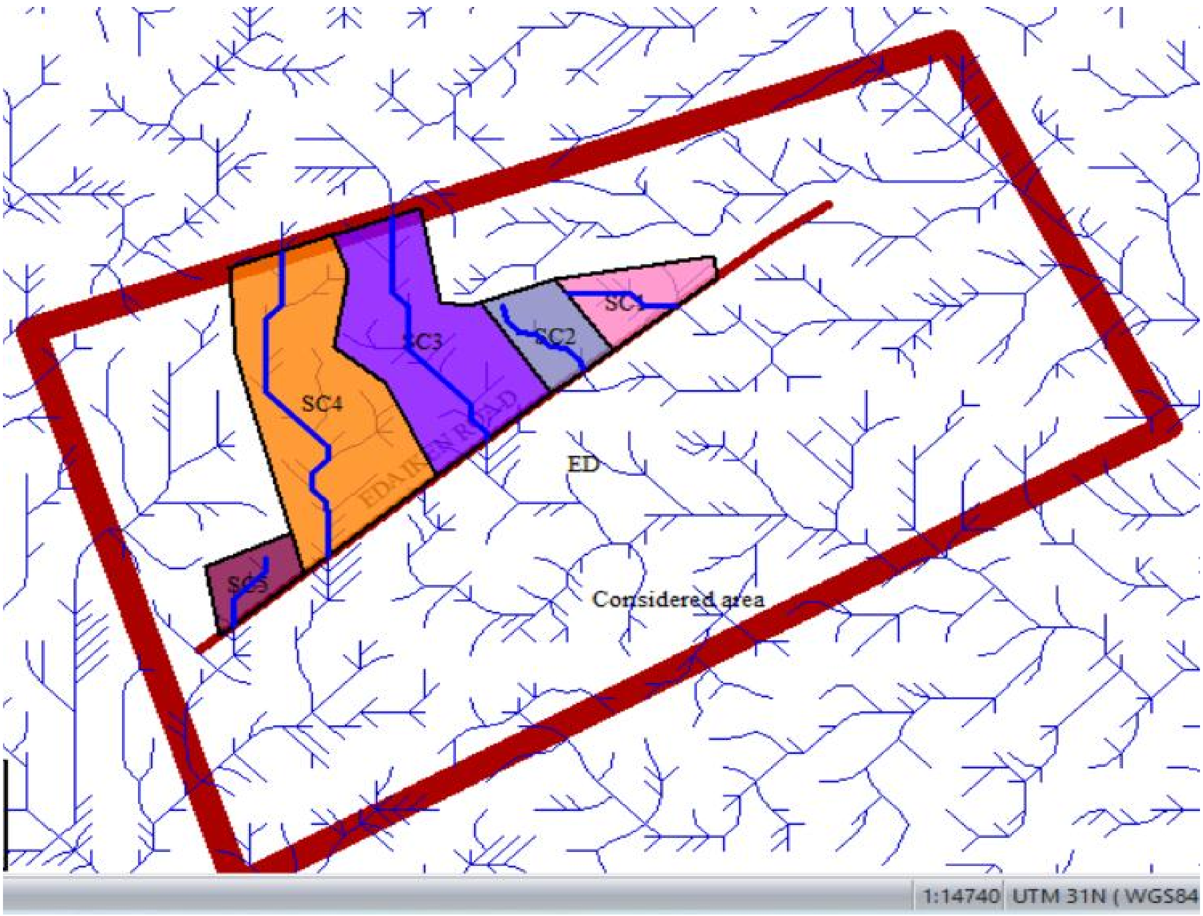

Figure 4.1: Flood-Prone Catchment Areas

Figure 4.1 presents the delineation of the various catchments contributing to flooding within the Edaiken Primary School Road area. The hydrological analysis revealed that the total flood-affected area covers a significant portion of the road corridor. The catchment was divided into five sub-catchments (SC1–SC5), each defined by its unique topographical and hydrological characteristics.

These divisions were based on the natural drainage pattern and the direction of surface runoff. The delineation process identified zones with higher runoff concentration, indicating that the lower-lying portions of the road, particularly downstream of SC3 and SC4, are more susceptible to flooding. The identification of these flood-prone sections provides the basis for appropriate drainage system design to mitigate surface water accumulation and flow congestion within the study area.

4.2. Presentation of the Design Parameter of each Catchment Area

S/N	**TC(hrs)**	**I(mm)**	**Q(m^3/s)**	**A(km)**	**R(m)**	**V(m/s)**	**DC(m/s)**	**Fr**
SC1	0.284	175.972	0.7279567	0.306	0.189	2.916	0.892	1.291
SC2	0.288	175.062	0.7293763	0.306	0.189	2.380	0.728	1.054
SC3	0.498	144.338	2.2983750	0.306	0.189	2.787	0.853	1.234
SC4	0.583	137.034	2.7823141	0.306	0.189	1.259	0.385	0.558
SC5	0.318	169.139	0.4876696	0.306	0.189	2.289	0.701	1.014

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 in Table 4.2 show the calculated design parameters for each sub-catchment within the study area. The time of concentration (TC) ranges from 0.284 to 0.583 hours, indicating relatively short response times typical of urban catchments with impervious surfaces. Rainfall intensities also vary slightly between 137.034 mm and 175.972 mm, reflecting the spatial variability of rainfall within the area.

The discharge (Q) values reveal that SC3 and SC4 contribute the highest runoff, with flow rates of 2.30 m^3/s and 2.78 m^3/s respectively. This implies that these sub-catchments are the major sources of flooding along Edaiken Primary School Road. Conversely, SC1, SC2, and SC5 produce smaller discharges, suggesting relatively lower runoff volumes due to smaller contributing areas or gentler slopes.

The Froude numbers (Fr), which range from 0.558 to 1.291, indicate that the flow regimes are mostly subcritical to near-critical. This means that the flows are stable and unlikely to cause severe erosion under normal conditions, provided the drains are well lined. The drain capacities (DC) across all catchments were found to be sufficient to convey the expected peak discharges when appropriately designed.

4.3. Design of the Drainage System

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

From	To	Catchment contributing flow	Catchment flow (qt)	Distance (m)	Drain Size	Proposed/adopted drainage sizes
1+570	1+190	-	-	373	0.6*0.6	0.9*0.9
1+190	00+969	SC1	0.7279567	224	0.6*0.6	0.9*0.9
00+969	00+725	SC1,2	1.457	245	0.7*0.8	0.9*0.9
00+725	00+325	SC1,2,3	3.7553	400	1.2*1.4	0.9*0.9
00+325	00+083	SC1,2,3,4	6.5376	242	1.5*1.6	1.0*1.0
00+083	00+000	SC1,2,3,4,5	7	83	1.5*1.7	1.0*1.0

Table 4.3 summarizes the hydraulic design results for the left-hand side of the drainage system. The table shows how the cumulative discharge increases progressively as more sub-

catchments contribute to the flow along the channel. Starting from point 1+570 to 00+000, the flow increases from 0.73 m³/s to approximately 7.00 m³/s**.**

To accommodate this increase in flow, corresponding adjustments were made to the drainage dimensions. The drain sizes were designed to range from 0.6 × 0.6 m at the upstream section to 1.5 × 1.7 m at the outlet, ensuring sufficient capacity to convey peak runoff without overtopping. The adopted drainage sizes (0.9 × 0.9 m to 1.0 × 1.0 m**)** were selected based on hydraulic capacity, construction feasibility, and maintenance considerations.

These results demonstrate that as runoff converges from multiple catchments, the hydraulic capacity of the drains must increase accordingly. The design ensures a self-cleansing velocity to prevent sedimentation while maintaining flow stability.

Table 4.3 shows that the left hand side is contributing to the quantity of discharge that flow in each catchment area. This also shows how the drainages are to be designed and the sizes befitting each catchment area.

Table 4.4: Result of right hand side contributing to the catchment flow

FROM	TO	CATCHMENT CONTRIBUTING FLOW	CATCHMENT FLOW (QT)	DISTANCE (m)	DRAIN SIZE	PROPOSED/ADOPTED DRAINAGE SIZES
1+570	00+000	-	-	1570	0.6*0.6	0.6*0.6

Although the right-hand side catchments were assessed, the analysis showed no significant discharge contribution. Consequently, nominal drainage sizes were proposed for this section. These drains are intended to manage minor surface runoff and prevent localized ponding rather than handle major flood discharges.

This finding aligns with the topographical gradient, which channels most runoff towards the left-hand side of the study area. As such, the right-hand drains serve primarily as auxiliary structures to support efficient overall stormwater conveyance.

The proposed drainage design from Figures 4.2- 4.6 are shown as follows:

.

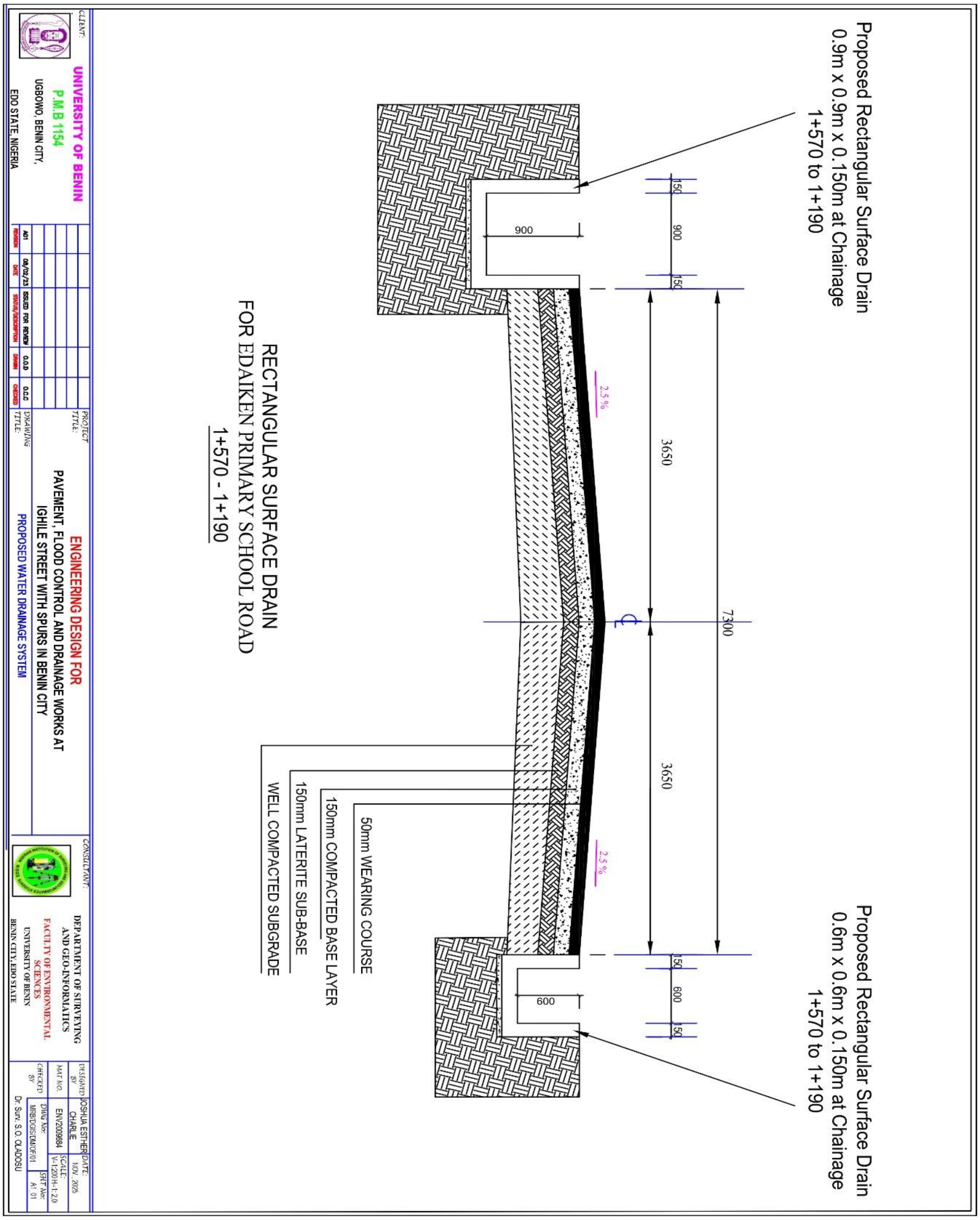

Figure 4.2: Drain size

1

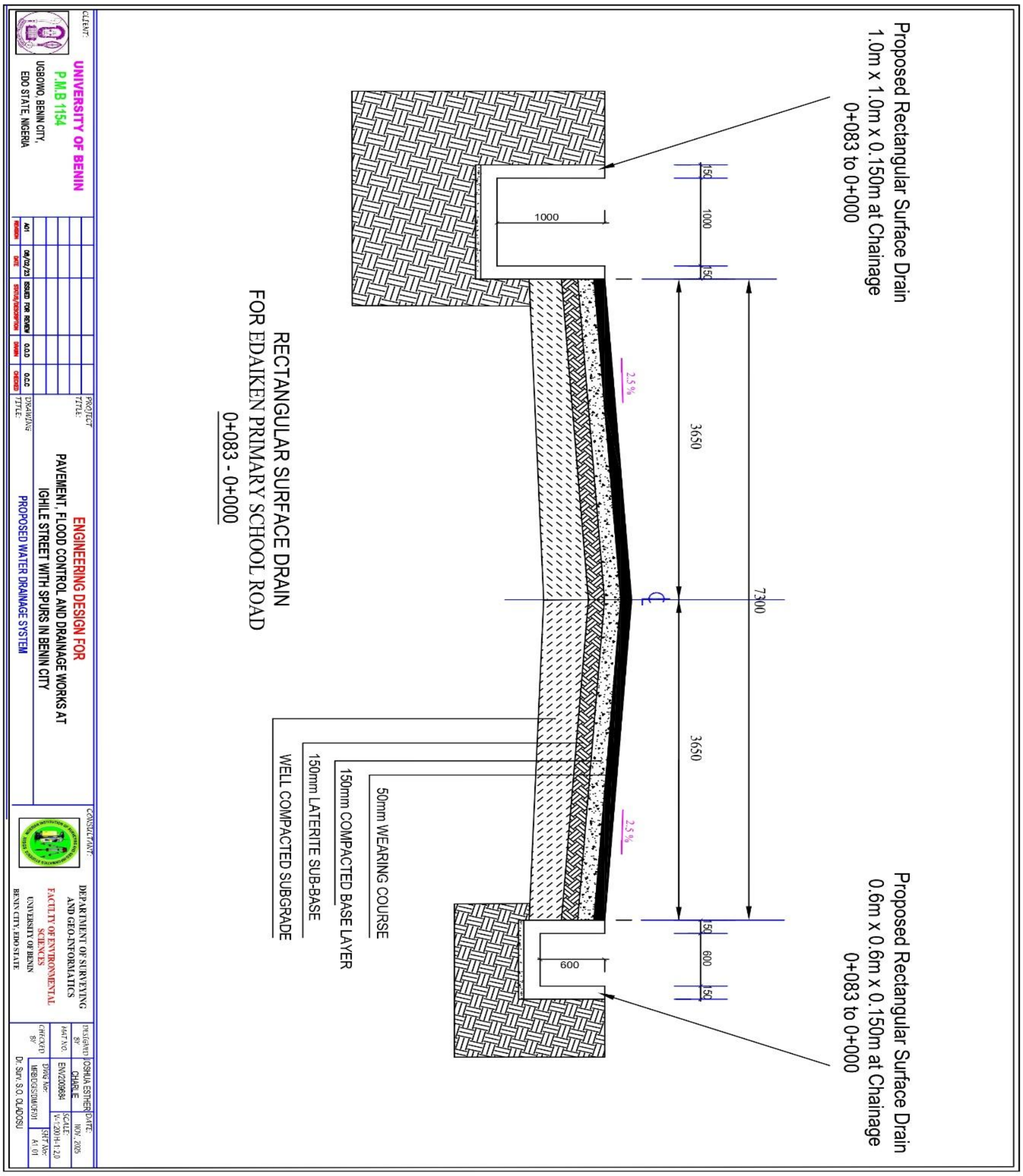

Figure 4.3:Drain size

2

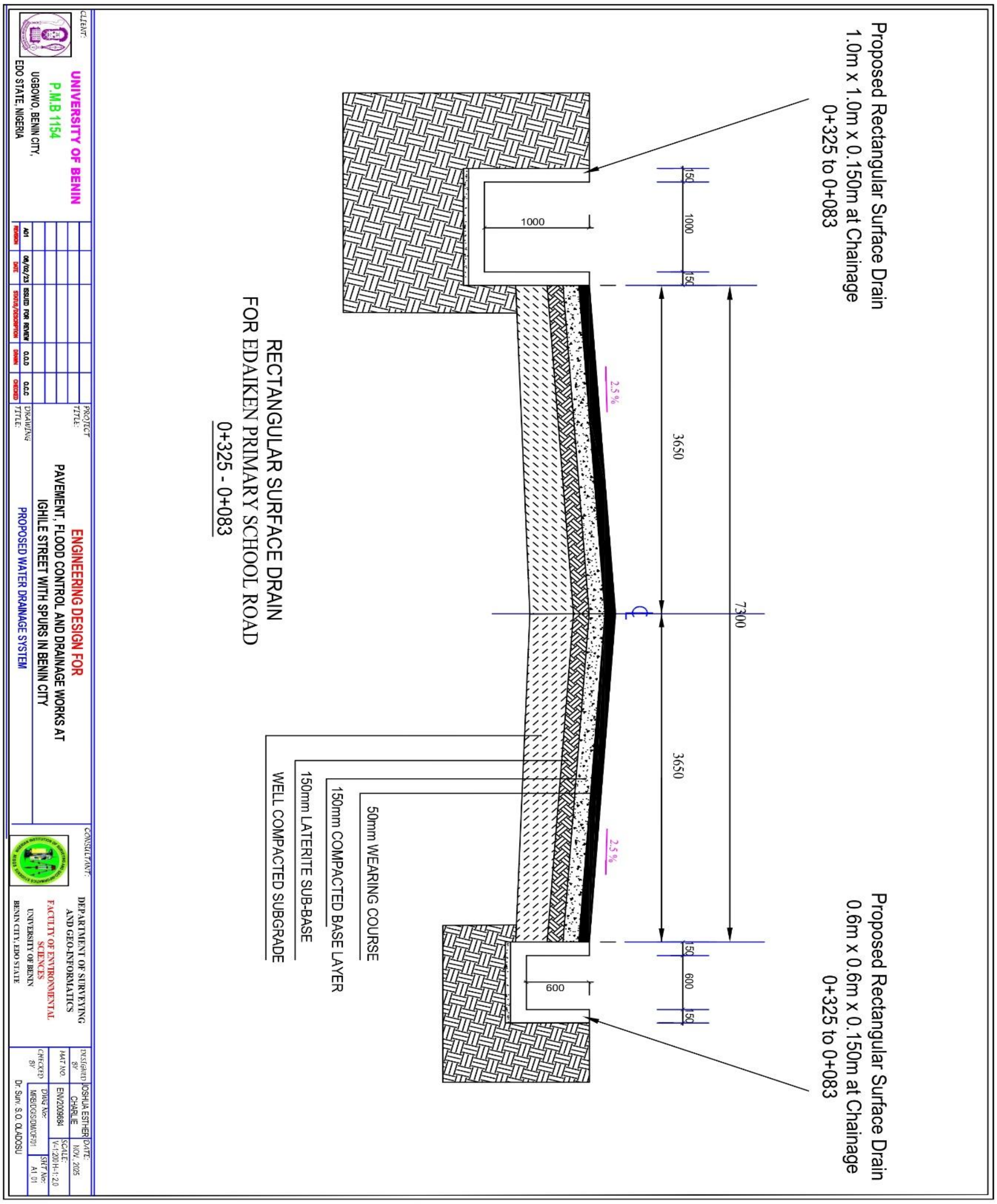

Figure 4.4: Drain size

3

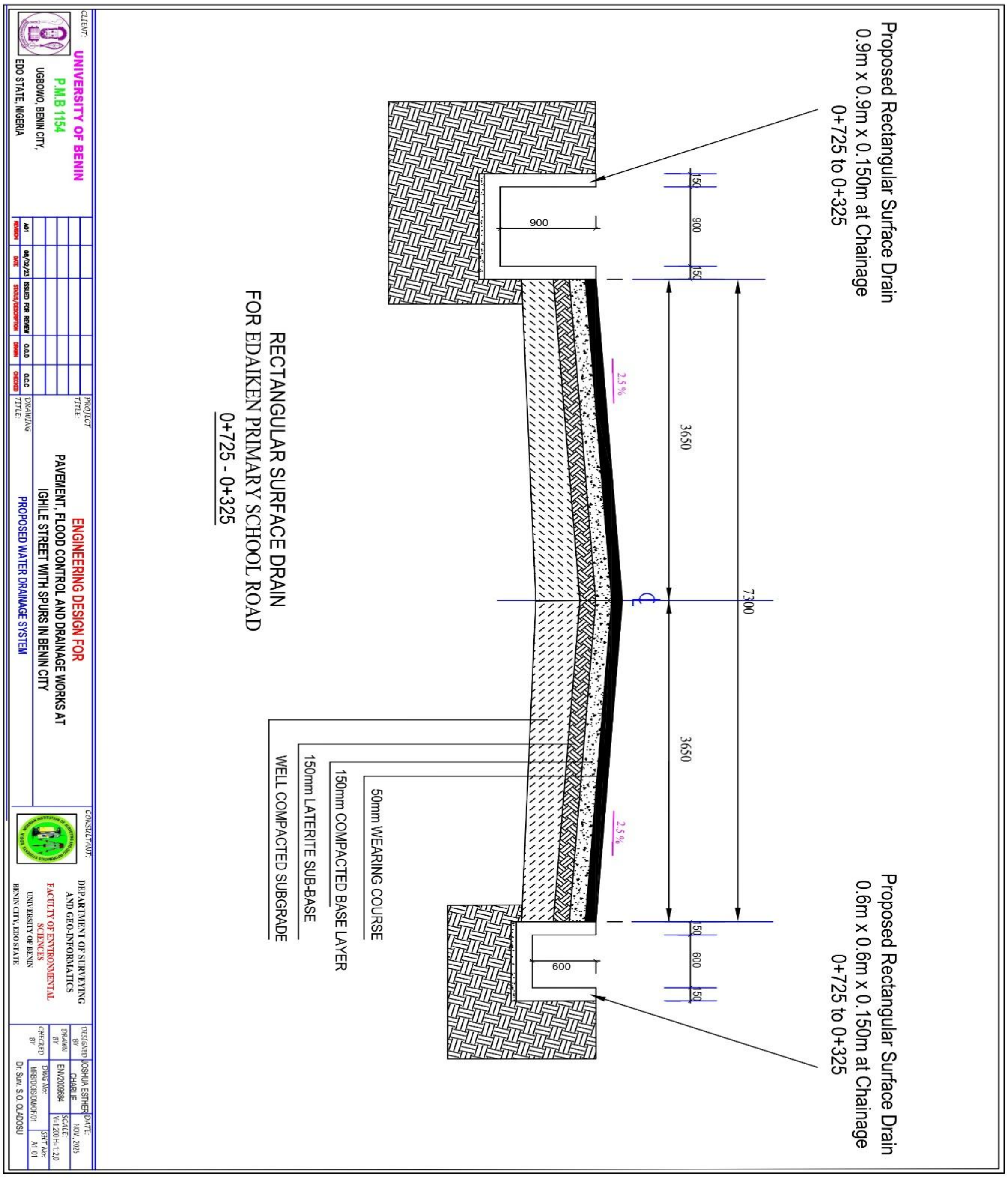

Fig4.4:Drain size

4

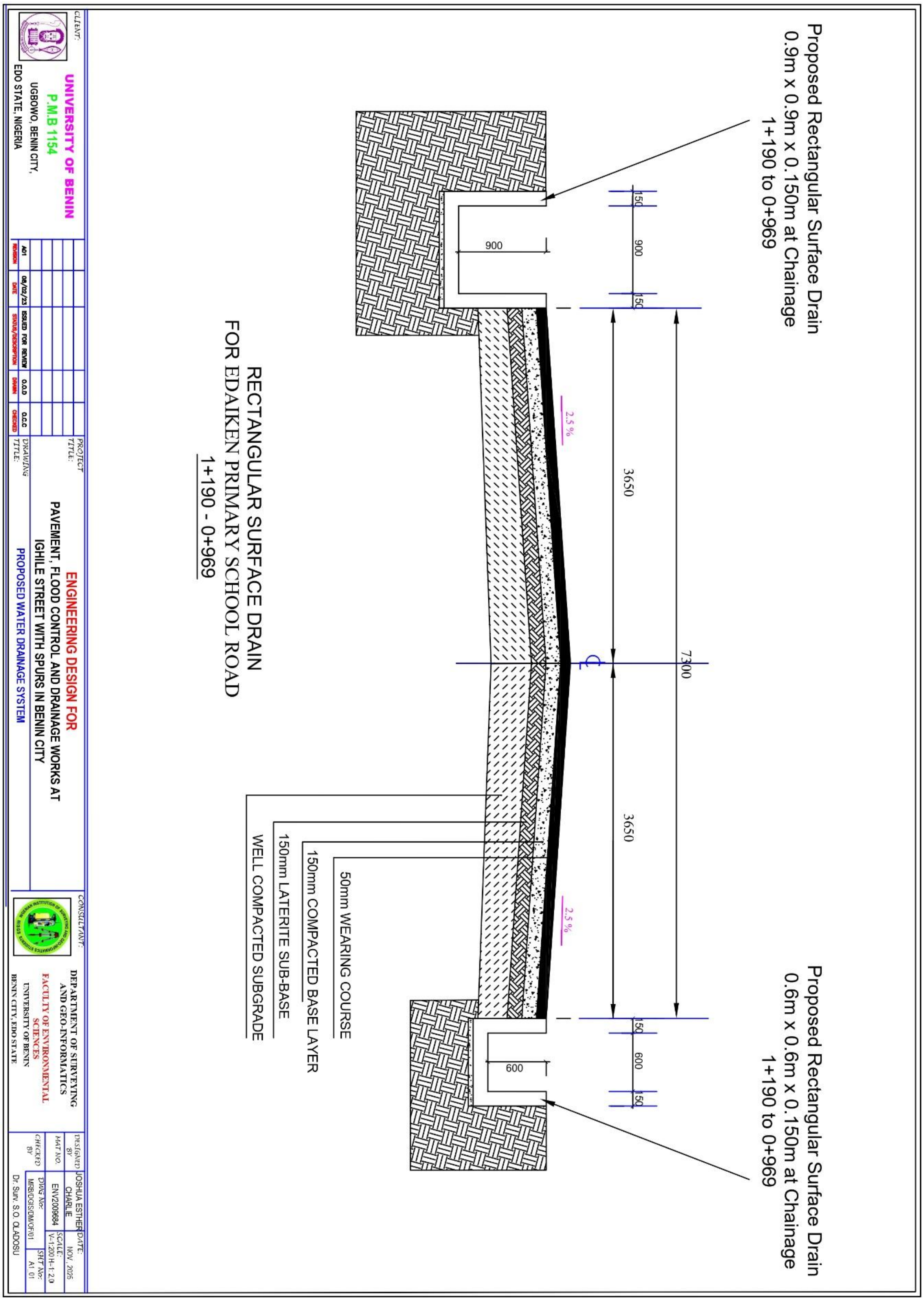
Proposed Rectangular Surface Drain 0.9m x 0.9m x 0.150m at Chainage 1+190 to 0+969
Proposed Rectangular Surface Drain 0.6m x 0.6m x 0.150m at Chainage 1+190 to 0+969
150
900
150
600
3650
7300
2.5 %
50mm WEARING COURSE
150mm COMPACTED BASE LAYER
150mm LATERITE SUB-BASE
WELL COMPACTED SUBGRADE
RECTANGULAR SURFACE DRAIN
FOR EDAIKEN PRIMARY SCHOOL ROAD
1+190 - 0+969
CLIENT:
UNIVERSITY OF BENIN
P.M.B 1154
UGBOWO, BENIN CITY,
EDO STATE, NIGERIA
A01 08/02/23 ISSUED FOR REVIEW O.O.D O.C.C
REVISION DATE STATUS/DESCRIPTION DRAWN CHECKED
PROJECT TITLE:
ENGINEERING DESIGN FOR
PAVEMENT, FLOOD CONTROL AND DRAINAGE WORKS AT
IGHILE STREET WITH SPURS IN BENIN CITY
DRAWING TITLE:
PROPOSED WATER DRAINAGE SYSTEM
CONSULTANT:
DEPARTMENT OF SURVEYING AND GEO-INFORMATICS
FACULTY OF ENVIRONMENTAL SCIENCES
UNIVERSITY OF BENIN
BENIN CITY, EDO STATE
DESIGNED BY: JOSHUA ESTHER CHARLIE
DATE: NOV, 2025
MAT NO. ENV2009684
SCALE: V-1:200 H-1:2.0
CHECKED BY
DWG No: MR/EDO/SGMOF/01
SHT No: A1 01
Dr. Surv. S.O. OLADOSU

Figure 4.6: Drain size 5

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study examined the causes and extent of flooding along Edaiken Primary School Road and its environs and developed a suitable drainage design to mitigate the problem. Using hydrological and GIS-based analyses, the research identified the flood-prone sub-catchments, evaluated runoff characteristics, and proposed drainage structures capable of efficiently conveying stormwater during peak rainfall events.

The findings revealed that the study area is highly susceptible to flooding due to poor drainage design, low-lying topography, and increased surface runoff from impervious urban surfaces. The delineation of five sub-catchments (SC1–SC5) showed that sub-catchments SC3 and SC4 are the most critical contributors to flooding. This is attributed to their topographic depressions and high runoff concentrations. The hydraulic analysis further indicated that runoff discharge increased progressively along the left-hand side of the drainage channel, reaching approximately 7.00 m^3/s at the outlet, while the right-hand side contributed only minor flows due to slope direction.

The designed drainage system, with adopted sizes ranging from 0.9 × 0.9 m to 1.0 × 1.0 m**,** was found to be hydraulically adequate to manage stormwater effectively. The flow conditions within the channels were mostly subcritical, ensuring stability and minimizing erosion risks. These results confirm that proper hydraulic design, combined with sustainable management practices, can significantly reduce flooding in the study area.

In conclusion, the research demonstrates that flooding along Edaiken Primary School Road is primarily a result of inadequate drainage capacity and poor maintenance. The application of GIS-based hydrological analysis provided a clearer understanding of the flow patterns and guided the development of a reliable drainage system to control surface runoff. Implementing the proposed design will help alleviate the recurring flooding challenges, enhance road durability, and improve the environmental and social conditions of the area.

5.2 RECOMMENDATIONS

Based on the findings, the following five key recommendations are proposed to ensure sustainable flood mitigation and long-term drainage performance:

i. Implementation of the Proposed Drainage Design: The designed drainage system should be constructed according to the proposed specifications, ensuring that the channel sizes are adequate to convey peak runoff. Proper construction and adherence to design standards will prevent overflow and structural failure.

ii. Development of a Retention Pond: A retention pond should be established at the downstream section, particularly near sub-catchments SC3 and SC4, to temporarily store excess runoff during heavy rainfall. This will regulate peak flows, reduce waterlogging, and enhance infiltration.

iii. Regular Maintenance of Drainage Infrastructure: Periodic desilting, cleaning, and inspection of the drainage network should be prioritized to maintain its hydraulic efficiency. Clogged or debris-filled drains significantly reduce capacity and lead to recurrent flooding.

iv. Enforcement of Land Use and Environmental Regulations: Urban development should be strictly monitored to prevent construction on natural drainage paths and floodplains. The enforcement of building setbacks and waste disposal regulations is essential to preserve drainage integrity.

v. Integration of Green Infrastructure and Public Awareness: Nature-based solutions such as vegetated swales, infiltration trenches, and permeable pavements should be incorporated to enhance stormwater absorption. Public enlightenment campaigns on proper waste disposal and community participation in maintaining drains will ensure long-term system sustainability.

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