URBAN FLOOD RISK MANAGEMENT: A CASE STUDY OF ABOABO, KUMASI.

By

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DECLARATION

I hereby declare that this submission is my own work towards the MSc Geomatic Engineering and that, to the best of my knowledge, it contains no materials previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Floods are a serious global issue attracting attention and research from academia, the media and other international discourse. Consequently, they have become critical national issues especially with African countries who lack the financial resources and technical knowhow to mitigate its impacts. The Aboabo community (a suburb of Kumasi), located in the transitional forest zone of Ghana has become vulnerable to the devastating effects of flooding in recent times due to climate change, exponential population growth, and rapid urbanization. In order to reverse this trend and lessen the debilitating impacts of flooding on this community, there is a need for the development of a flood risk map which will form the basis of any future flood management and planning activities. This study presented a holistic approach in the development of a flood risk map and discusses its significance in Flood Risk Management.

In order to create a digital representation of the study area, a Digital Elevation Model (DEM) was created. Hydrological analysis necessary to determine flow direction and accumulated flow (resulting from e.g. rainfall, surrounding streams) was performed on the depressionless DEM of the study area. Reclassified slope angles (i.e. high slope areas, medium slope areas, and low slope areas) and stream buffer zones (within 50m of stream network) were added in ArcGIS environment to generate flood risk maps. The flood risk maps showed three risk zones -High risk, medium risk zone and low risk zone. To further demonstrate the potential of flooding in these three risk zones, a simulation-based approach was adopted. A simple vector-based method which only required the extents of flood levels in simulating flood extent based on the derived drainage lines, their depth and their capacity to hold rainfall run-off was used. With the aid of the elevation measure, flood water levels were selected. The flood contours showed the extent of flood at a given flood level. The flood model extents were further overlaid on a geo-referenced Google Earth image of the study area which visibly demonstrated areas at risk in the event of floods. Based on existing literature, questionnaires and interviews were administered to respondents in the Community and stakeholders to investigate the causes and effects of floods. With over 84% response rates, majority of the residents attributed the cause and effect of flooding to lack of drains/choked drains and gradual weakening of buildings respectively.

The research clearly demonstrated the application of GIS through hydrological analysis, carrying out flood simulations and the administering of questionnaires and interviews with stakeholders, is very essential in providing guidelines for Flood Risk Mapping.

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LIST OF ABBREVIATIONS

AMMA - Asokore Mampong Municipal Assembly DEM - Digital Elevation Model

FEMA - Federal Emergency Management Agency

GIS - Geographic Information Systems

GMA - Ghana Meteorological Agency

GPS – Global Positioning Systems

IPCC	-	Intergovernmental Panel on Climate Change
KMA	–	Kumasi Metropolitan Assembly
MRSC	-	Municipal Research and Services Center
NADMO	-	National Disaster Management Organization
NRDC	–	Natural Resources Defense Council
TCPD	-	Town and Country Planning Department
TIN	-	Triangular Irregular Network
VSES	-	Victoria State Emergency Services

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The effects of climate change are shown to have immensely affected the changing weather conditions in many parts of the world. There is a global concern about global warming. Global warming is leading to climate change as noted in the third assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2001). Global warming has caused incidences of tsunamis, melting of iceberg, washing away of shorelines, flooding and drowning of islands (IPCC, 2001).Consequently, flooding has become of great interest to humanity (Oppong, 2011). Floods claim approximately 20,000 lives annually, leaving people homeless in the process and have negative implications on at least 20 million people all over the world (Smith, 2011).

Floods have claimed over 10,000 lives in the United States of America since 1900 (Adeoye et al., 2009). Statistics also show in 1998, floods affected approximately 30 million people in 52 out of 64 districts in Bangladesh mainly as a result of climate change and economic growth in low-lying regions (Khan et al, 2011).

In July and August, 2010, Pakistan was hit by one of the worst floods in their history of disasters rendering 20 million people homeless (Straatsma et al, 2010).

Over 22,000 people in Nepal had to relocate temporarily due to floods. It further stated 46,000 houses were left totally damaged and more than 130,000 hectares of agricultural lands were submerged by floods (Asian Development Bank, 2007).

In 2011, Thailand also experienced heavy rains that lasted nearly 12 weeks claiming over 500 lives in the process. All these reports and studies, illustrates the devastating effects of floods (Orok, 2011).

Floods are crucial national issue as a great number of African countries lack the resources, both financially and technologically, to fight the effects and impacts of flooding (Satterthwaite et al., 2007).

Between 1996 and 2005, floods have posed several devastating and terrifying effects on the continent of Africa (Satterthwaite et al., 2007).. Within that period, there were approximately 290 flood-disasters reported. Over 8,183 people lost their lives, approximately 23 million people were consequently affected in diverse ways. The results of the huge economic losses were estimated at approximately $1.9 billion (Satterthwaite et al., 2007).

Flooding is one of the leading disasters in Ghana and has major impacts on people and their livelihoods. The period between 1968 and 2011, incidences of flooding have killed approximately three hundred people leaving over 3 million people affected (Okyere et al., 2012). Flooding also comes with an increase in epidemics especially through the spread of waste, flood water and the accumulation of water and consequent blockage tends to be conducive breeding grounds for mosquitoes (Feng et al., 2007; Messner et al., 2007).

Among the various types of land use/cover, urban areas have the greatest tendency of modifying the hydrological behaviour of a catchment. The construction industry (roads, buildings, etc) accompanying urbanisation creates impermeable surfaces impeding infiltration of water and lead to overland flow leaving urban areas highly susceptible to floods (flash floods) especially when there are bad drainage network systems (Okyere et al, 2012).

1.3 Problem Statement

The Aboabo community has been affected by flooding over the years which is caused by heavy down pours and streams overflowing its channels (AMMA, 2014).

The undulating nature of the terrain makes low lying areas susceptible to flooding. In addition to this, stream channels have been silted naturally by erosion and artificially by the dumping of both liquid and solid waste in them. The consistent and heavy torrential rains in 2010 and June 2013 and much recently in June, 2014 caused flooding in Aboabo (AMMA,2014). The floods caused damaging effects as shown in Figure 1.0 especially to residents in Aboabo Extension and Aboabo Number 1 where flooding has become an almost annual event. These floods destroy properties ranging from houses to personal belongings and in extreme cases, the loss of lives (NADMO, 2014).

Figure 1.0: Flooding in Aboabo- a shows a house flooded in Aboabo, b shows part of a road in Aboabo caved in by floods

(Source: Oppong, 2011)

Over the past years, Aboabo has increasingly become an urban area. It is particularly noted to be a slum and squatter settlement. Slums are urban areas that are overly congested. They are characterized by deteriorated and unauthorised buildings, poverty, social disorganisation and bad insanitary conditions which leave the community easily prone to flooding (Devadas et al, 1990).

Increase in population and hence urban development has contributed to the changes in land use and land cover as people are converting floodplains to industrial and residential use. The changes in land use associated with urban development affect flooding in many ways. Removing vegetation and soil, grading the land surface, and constructing of infrastructure and drainage networks increase runoff to streams from rainfall. As a result, the peak discharge, volume, and frequency of floods increase in nearby streams. Changes to stream channels during urban development limit the capacity of these channels to convey floodwaters (Frimpong, 2009).

Roads and buildings constructed in flood-prone areas are exposed to flood hazards. Information about stream flow direction and its subsequent accumulation can help communities reduce their current and future vulnerability to floods (Fosu et al, 2012)

City authorities in the Municipal Assembly claimed the annual occurrence of floods are as a result of residence building on water ways and resorted to the demolishing of buildings and illegal structure on water ways. They further associated the causes of these floods to the siltation of the water channels and other human activities (NADMO, 2014).

Some residents move temporarily out of their homes to various locations in the region during the rainy season in June and July. The damage and the cost of resettling victims and that of management which runs into several millions of cedis far outweighs the cost of taking a preventive measure by several hundreds of percentages hence the need for the project (AMMA, 2014).

The Government, Municipal Assembly and other agencies in years past have done little with regards to prevention of floods in the Aboabo Community. The main purpose of these agencies in the event of floods only provides help and relief items to the victims after the floods and also immediately undertakes temporary measures to prevent reoccurrence of floods (KMA, 2014). Much work has not been done with regards to the prevention or reduction of floods and its socio economic effects due to lack of enough resources and funds (Jeb et al, 2008).

Agencies identify likely flood prone areas using means such as identifying watermarks on structures, flood extent marks left after floods, reports from media and other related agencies and aerial photographic interpretation as in Kuma (1996). The aforementioned methods used by the agencies are awfully insufficient as there are several areas that experience floods from time to time.

There is lack of planning to mitigate flooding in Aboabo Community. There has therefore been the increasing need to research new methods to identify and additionally map flood risk zones. This will further help in planning and managing the annual flood menace (Nyarko, 2000).

This research presents the procedure through which the flood risk map of the Aboabo Community was generated as well as analyse the socio economic impacts of floods to the people of Aboabo.

1.4 Aim and Objectives

1.4.1 Aim

This project aims at building a flood risk map showing areas (suburbs and communities) prone to flood in the Aboabo Community. The map will enable stakeholders to be involved with disaster prevention and adaption methods to improve upon and make better policies in regards to managing flooding.

It further aims at showing areas that are at greater risk when flooding occurs and those areas vulnerable to flooding. The map makes it easier to prepare for flooding and to make emergency plans for evacuation should members of the community be caught in a flood.

1.4.2 Objectives

1. To identify the causes and socio-economic impact of flooding on residents in Aboabo Community;
2. To demonstrate the potential for flooding in urban areas through simulation of flood extents;
3. To suggest and develop flood management guidelines which can be implemented before, during, and after flooding.

1.5 Research Questions

- How will a flood risk map aid in managing floods?
- What are the causes of floods and its socio-economic impact on residents of the Aboabo Community?
- How will simulations be used to demonstrate the potential of flooding?
- What guidelines can be provided for implementation before, during and after the flooding events?

1.6 Significance of Study

The successful implementation of the project will:

- Enable the determination of hot spot areas of flooding in the Aboabo Community.
- Provide planners and disaster management institutions with a practical and cost-effective way to identify floodplains and other susceptible areas and to assess the extent of disaster impact.
- Provide basic information for land use planning. Allow development plans for new urban areas. Enable adequate evaluation of cost of flood and flood reduction benefits.

- Show areas that are more vulnerable/ prone to flood as it is easier to ensure that emergency plans for evacuation or preparedness are developed well and easily.
- Serve as the basis for insurance plans.
- Give a general guide for developer on where and how to build.
- It is intended to serve as a basic reference to stakeholders of flood management policies as well.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Floods can be mentioned as one of the most recurring and devastating disasters affecting human lives and causing severe economic damage worldwide. It can be dated as far back in history to the time of Noah. Floods occur naturally; nevertheless they pose a threat when they go beyond the capacities of affected communities, destroying lives and properties. Flood risks do not look likely to subside in the future, and with the recent incidence of climate change, flood intensity and frequency will pose as threats to many parts of the world (Ouma and Tateishi, 2014)

A flood is defined as the ―An overflowing or irruption of a great body of water over land in a built up area not usually submerged (Oxford English Dictionary, 2015).

―Flooding is a general temporary condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation or runoff‟‟ (Jeb and Aggarwal, 2008).

Approximately 15% to 20% of rainfall usually ends up as surface runoff in rivers. The rest of the rainfall water soaks into the ground or returns back to the atmosphere by means of evaporation and transpiration from plants (Plummer and McGeary, 1993).. The amount of rainfall runoff runs between 2% - 25% with variations in climate, elevation/slope, soil and rock type, infrastructure and vegetation. Steady and rather continuous rainfall can saturate the ground and the atmosphere which can further lead to floods as runoff nears 100% of rainfall‖ (Plummer and McGeary, 1993).

Flood risk mapping is a fundamental element of flood risk management. It further aids in the assessment and management of flood risks. Flood risk mapping and understanding requires knowledge of the various types and causes of flooding, their socio- economic impact and effects, the probability of it occurring, how they can be modeled and mapped, the relevant data for the production of flood risk maps and the likely sources of data and information for these disasters (Jha et al., 2012). A relatively detailed knowledge and understanding of flood risk relevant to different communities is also critical to the implementation of appropriate flood risk prevention/ reduction measures such as development planning, emergency systems, forecasting/prediction, and early warning measures.

The problems associated with environmental disasters which widely includes flooding poses major challenges yet to be totally eliminated. This Chapter of the study will focus on reviewing existing literature on the use of Remote Sensing and Geographic Information System in flood risk management worldwide; and particularly Ghana. It will further take a closer look at the types, causes and socio-economic impact and effects of flooding and techniques of mitigating flood hazards.

2.2 Floods

Floods occur due to the fast accumulation and release of runoff waters from upstream to downstream, which is caused by very heavy rainfall. Discharges quickly reach a maximum and diminish almost rapidly (Ouma and Tateishi, 2014). Floods also occur as a result of flow of a stream becoming so great that it exceeds the capacity of its channel and therefore overflows its banks (Cunningham and Cunningham, 2011).

A flood simply can be described as water overflowing onto usually dry land. Flooding mostly is as a result of heavy rainfall; nevertheless floods can occur in diverse ways that are indirectly related to current weather events. Therefore a total explanation of flooding should embrace practices that may not directly be related to meteorological events (Doswell, 2007).

Floods claim approximately 20,000 lives and in one way or the other have adverse effects on at least 20 million people worldwide, especially the homeless (Smith,2004). Flooding, after epidemics and transport accidents is considered one of the most common environmental disasters that occur all over the world. This is as a result of the geographical distribution of river floodplains and low-lying coasts and their longstanding attractions for human settlement (Smith, 2004).

2.2.1 Flooding in Global Perspective

According to the Belgium-based Centre for Research on Epidemiology of Disasters (CRED), the world's most disastrous floods to have occurred in terms of the number of people who lost their lives happened in the year 2004 in Haiti, a Caribbean island nation (CRED, 2011). The report also indicated that for fourteen (14) days, there were continuous and heavy rains which caused swelling of rivers and subsequently overflowing of river banks mostly in the southeastern parts along the areas that share borders with the Dominican Republic. The continuous rain generated floods that killed over 2,400 people, the Guardian Newspaper reported (CRED, 2011).

In Pakistan, the floods which destroyed at least 1,200 lives are already listed as the world's second worst flooding in the decade from 2001 to August 2010. "The number of people killed is very high for a natural event like a flood, which is among the easier disasters to predict and plan for," said CRED director Debarati Guha-Sapir.

The monsoon rains generated the floods that occurred in India in 2005 (CRED, 2011). These floods caused approximately 1,000 deaths, placing this disaster in second place after the floods that hit Pakistan. The monsoon rains in the region normally carries on into September and the help/aid workers feared the number of lives lost to flood occurrence could increase annually. Notably, one-third of Pakistan (an area close to the size of England) is under water (CRED, 2011).

Reports indicate that 7 out of the 11 worst floods on CRED's list for the decade between 2000 and 2009 occurred in India (CRED, 2011). Guha-Sapir asserts that countries like India, Pakistan and Bangladesh appeared top of the list of numbers of lives affected by floods due to the high concentration of relatively poor rural people living along and within some distance from the river banks.

During the years between 1996 and 2005, floods have had serious devastating effects on the continent of Africa (Satterthwaite et al., 2007). During that seven year period, approximately 290 flood-disasters have been recorded across the continent of Africa .Approximately 8,183 people were reported dead, 23 million people affected and there were reported economic losses worth approximately $1.9 billion (Satterthwaite et al., 2007).

Several media and aid organizations have widely reported a lot of flooding incidences in Sub-Saharan Africa. These floods are mostly flash floods which resulted from several and continuous days of rainfall (Paeth et al., 2010).

Mozambique for instance, is consistently affected by flooding almost annually and in 2000 recorded losses amounting to millions of dollars (ADB, 2007). Approximately 800 lives were lost and consequently there was the need for setting up a communitybased early warning system. These community-based early warning systems have dramatically reduced the number of casualties as well as fatalities in Mozambique‘s the yearly flood season (Wisner, 1979; ADB, 2007).

In 2013, the Ghana News Agency (GNA) reported the flooding incidence in Central Nigeria‘s Plateau State which resulted in the loss of at least 39 human lives. In similar reports,

it was indicated that torrential rain has caused flooding paralyzing most parts of the Philippine Capital, Manila. Nigeria has recorded some of the highest death tolls in the West African region. In the northern parts of the country, entire villages and agricultural land have been destroyed by flooding (ARB, 2010).

2.2.2 Flooding in Ghana

Flooding in Ghana has become a yearly menace. Experts are grappling with ways and means of containing the floods in order to save lives and property. Over the past decade, floods have claimed several lives, and destroyed public infrastructure and property (Sam Jr, 2009). Ghana has been highly ranked amongst the African countries that is most exposed to risks from multiple weather related hazards particularly natural hazards such as floods and droughts (UNDP/NADMO, 2009)

In urban areas, the flood-damage potential is high, due to the concentration of property and people in relatively small areas and also haphazard ways of building.

Urban flooding can simply be defined as a natural process in which drainage network systems overflow to their floodplains during rain storms. The causes of urban flooding in Ghana are generally diverse and to some great extent, highly interrelated (Sam Jr , 2009)

Water from the Bagre Dam in Burkina Faso aids in irrigation of farms during the dry season and replenishes water levels in the Akosombo Dam when it drops to minimal levels. However, in 2007 severe rainfall caused the dam to overflow. Consequently, water from the dam was then released into the White Volta River which flow into Ghana at a force of 900 m³ per second causing floods. This flood affected the whole nation and the northern regions in particular (Karley, 2009). The flood destroyed houses, water supply and drainage systems, collapsed bridges, schools, roads; and also crops and livestock. Many families were displaced. The displaced families sought shelter in school buildings and churches (Forkuo, 2010). Furthermore, the floods added health implications, more especially the threat of the outbreak of epidemics. The National Disaster Management Organisation (NADMO) found it rather difficult to provide adequate food and other forms of aids for the flood victims (NADMO, 2007).

It has been noted that heavy and continuous rainfalls are not solely the major cause of recent flooding in Ghana. This plight has been heightened by human activities such as damming and opening of dam gates as well as dumping of filth to hinder flow in water courses (Karley, 2009).

During the Accra flooding incidence in July 1995, floods caused damage to lives and property, disrupted utility services and public amenities such as water supply, telephone, electricity, roads and railways (Songsore, et al., 2006). Seventeen (17) lives were lost in this flood while commercial and industrial activity was disrupted.
The most affected areas were those located within the flood plain of the Odaw and the Onyasia rivers (Songsore, et al., 2006).

In the Kumasi Metropolis, it is observed that the terrain is generally undulating, characterised by steady, steep rising areas and valleys. In 2013, the Metropolis reported a lot of deaths due to the flooding in May- June (NADMO, 2014). Most commonly affected areas were Ahinsan Estate, Anwomaso, Oforikrom New Site, Aboabo and Asuoyeboah. These communities are fast growing urban areas and human activities such as dumping of refuse into drains and building in flood plains mostly obstructed the natural flood plains. The areas severely affected were realized to be relatively low lying areas and mostly have valley-like landscapes therefore causing runoff from upstream to downstream in the cause of either heavy or continuous rainfall (NADMO, 2014).

Some communities such as Aboabo, Atonsu S- Line, Susuanso and Suame also, have constructed structures and buildings very close to the course of rivers/ streams or obstructed the rivers/stream system. In the case of rainfall, rain from upstream collects into these streams and easily overflows its capacity causing floods. In 2013, two girls lost their lives as a result in Asuoyeboah (NADMO, 2014)

Over the past ten years, in the study area (Aboabo Community) the low-lying areas are mostly susceptible to severe annual flooding. This is generally as a result of insufficient and inadequate drains and culverts. Furthermore, there is the presence of silt which somewhat blocks and chokes major drains in the Community. The annual flooding is to a large extent caused by the streams not being able to cope with the increase in surface runoff arising from continual increase in paved surfaces, although lack of maintenance of drains and the disposal of solid waste into the stream also contribute to flooding (Duncan, 2000).

Flooding, is prevalent in low lying areas or lowlands since the flow of water accumulates in such areas. Aboabo has several areas affected by annual flooding within these low lying areas and much noticeably along streams and the Aboabo River. This happens if the water volume due to flow accumulation increases abruptly due to continuous and heavy rains which hit the communities during the rainy season (NADMO, 2014).

There has been a steady increase in the amount of surface water runoff in Aboabo over the past decade. This is as a result of the rapid increase in residential, commercial, infrastructure and urban development. Some years back, some amount of road works resulted in the increase of surface runoff. This caused an upsurge in the occurrence of flooding and erosion in some parts of the community which had not known such problems in the past (NADMO, 2014).

2.3 Types of Floods

Floods are one of the most frequent occurring natural disasters that directly and indirectly has sever effects on human and the environment (Hewitt 1997).A combination of both meteorological and hydrological extremes, such as extreme precipitation and flows brings about floods generally (Jha et al., 2012). However, floods also occur as a result of human activities. Flooding occurs as result of unplanned growth and development of urban areas interfering with floodplains, or from the opening of dam gates or the overtopping of an embankment that neglects the protection of planned developments (Balabanova and Vassilev, 2010).

Descriptions and types of floods differ vastly. These categorizations are basically based on a combination of sources, causes and socio-economic impacts on the environment and community as a whole. Considering these combinations, floods can be generally classified into riverine (or fluvial) floods, pluvial (or overland) floods, coastal floods, groundwater floods or the failure of artificial water systems. Also based on the speed of onset and force of flooding, floods can also be categorized and described as flash floods, urban floods, semi-permanent floods, and slow rise floods (Jha et al., 2012).

2.3.1 Riverine (fluvial) Flooding

Coastal rivers with short, steep headwaters often have floods that rise and recede fairly quickly. Riverine floods (River floods) are due to high water levels overflowing the natural or man-made banks of a stream or river. The different nature of riverine flooding can be accessed in terms of the causes of the flood, the timing and the depth between different locations. Continuous rainfall over the same area for a seemingly long period of time can cause a rise in the levels of rivers. According to the Federal Emergency Management Agency (FEMA), this brings about negative effects as it moves further downstream (FEMA, 2006). These effects can be worsened by rocks carried along the floodwaters from upstream thereby blocking the waters exit. Therefore the only option left for the direction of flow of the river is to overflow the embankment. Inland floods also occur. These are flows with relatively low gradients that move slowly down the river. This, according to Scottish Environment Protection Agency (SEPA), can sometimes last for several months (SEPA, 2008).

Road and building construction on a floodplain (where a river naturally overflows when its capacity is breached) may also increase the occurrence of a fluvial flood. This is as a result of the creation of impermeable ground on the flood plain which will definitely stand a greater risk of flooding due to the obstructions. A fast flowing water supply such as a river will gather speed if it is forced to squeeze through a tight gap creating a bottleneck effect (SEPA, 2008)

2.3.2 Pluvial (overland) Flooding

Pluvial flooding occurs when an extremely heavy downpour of rain saturates the urban drainage system and the excess water cannot be absorbed. Furthermore, pluvial flooding occurs when soil absorption, surface runoff or drainage cannot adequately disperse intense rainfall, and is usually caused by slow-moving thunderstorms. These floods occur after short, intense downpours which cannot be evacuated quickly enough by the drainage system or seeped into the ground (Donald Houston et. al, 2011).

Pluvial floods are generally classified as gradually occurring in a space of six hours or less. Pluvial flood occurs from continuous rainfall to the start of the flooding. This happens when rainfall overwhelms the urban (sub) surface drainage system and for some reasons unable to enter the system mostly due to human activities (Spekkers, 2010).

Natural events mostly bring about pluvial flooding but it may also come up from failure of flood defences and inadequacy of drainage network systems. Pluvial flooding has been predicted to become more frequent due to climate change and overdevelopment in flood plains. (SEPA, 2008)

2.3.4 Groundwater Floods or the Failure of Artificial Water Systems

When dam failure happens, it involves much significantly downstream flooding from probably swift flowing water and considerable presence of debris. Dam failures rarely do occur, but when it does happen, the effects thereafter, are severe. Dam safety could be monitored and early warning systems put in place to warn residents living downstream of potential risks that can occur due to dam failure as in the case of Victoria Dam in Sri Lanka, Western Australia (SEPA, 2008).

Levee failure typically occurs when floods go over their average capacity to handle, often with severe and tragic results. Poor and careless decisions made during dam design and construction or inadequate maintenance or operational mismanagement often causes dam failure. It may also result from natural hazards such as earthquakes, or from flow volumes that exceed capacity with or without some amount of pressure (FEMA, 2006).

2.3.5 Coastal Floods/Storm Surge

Storm surge occurs when the sea levels rises high above its normal tidal limit as a result of the action of intense low pressure systems over the open ocean. This therefore causes the sea level to rise as there is much less air pressing down on the sea. Combined with gale force onshore winds, this can lead to flooding of low-lying coastal land (SEPA, 2008).

In simple terms, a coastal flood is when the coast is flooded by the sea from a surge of a severe storm. The storm from a low pressure area where the sea level is higher pushes the water up and creates high waves. This contributes to the high sea level, but the wind can have a larger effect (Jimenez, 2009).

Coastal floods begin when waves move inland on an undefended coast or overtop or breach the coastal defence. The waves then attack the shore time and again. In the situation when it is a sandy coast, each wave in the storm surge takes away sand. Eventually a dune may collapse that way. The water may flow in at high tide and then recede at low tide. Once it breaches the defences, the sea enters fast, but slows down when it spreads over a larger area (Jimenez, 2009).

Actionaid (2006) based on a report on ‗Climate change, urban flooding and the Rights of the urban poor in Africa' grouped flooding into four types based on the causes. These are the type of floods that generally hits Ghanaian towns and cities.

2.3.6 Localised Flooding

This normally occurs due to inadequate drainage system coupled with highly compacted ground with pathways and roads between buildings/shelters turning into streams after a heavy downpour of rain. This situation is worsened by the damping of filth (waste and debris) into the few drains and therefore blocking them in the process.

2.3.7 Flooding caused by Small Streams in Urban Areas

Small streams found in urban areas easily overflow its extent due to increase in volume after heavy rainfall. In addition, relatively small and inadequate culverts are provided by city authorities for easy flow of water. These culverts may seem sizeable enough relative to the normal volume of water flow from such streams but gradual changes to development in the urban areas and duration and intensity of rainfall over a certain period of time usually lead to higher flows that exceed the capacity of the culverts. These drains are mostly filled with solid waste damped in by residents of the community thereby choking them. This makes the passage way even much smaller and inhibits the flow of water through them.

These two types of floods aforementioned are mainly the major types of flooding in Aboabo.

2.3.8 River Floods

Urban growth leads to vast use of land. Residents start to build along flood plains of rivers leading to major socioeconomic losses as well as loss of human life anytime these rivers overflow their banks and inundate the flood plains. In some developed countries, levees have been raised artificially. There is always the risk of the possibility that these levees may be breached causing massive urban flooding (Oppong, 2011)

The main river found in the Aboabo basin is the Aboabo River. Flowing from the north to south, the valleys in which the river flows are very wide with floodplains found in the valley floor (KMA, 2011). Some areas here are liable to floods especially in the north-western part of Aboabo Number 1 along the Kumasi – Accra railway line. This is due to building of some houses and structures in the floodplain. It is noted that areas hit by this type of floods are those with structures built very close to the river bank and in the flood plain.

2.3.9 Wet Season Flooding in Low Land and Coastal Cities

This basically occurs in lowland and coastal cities. Wet season flooding could last for eight or more weeks in some areas. This is due to the combination of rain and river water. The levels of water increase in swamps which under normal circumstances, would have been naturally submerged during some periods of the year. Storm surges could also result in lowland and coastal flooding (Oppong, 2011)

2.4 Causes of Flooding in Urban Areas

Flooding is generally considered as an environmental hazard. It is quite a natural process and is simply the reaction of a natural or man –made system to the presence of too much water at a particular period of time.

Natural causes of flooding refer to those causes that are not caused by human influence directly. An example of the natural causes of floods includes the rising global temperatures which in turn speeds the melting of glaciers and ice caps and cause early ice thaw on rivers and lakes. This further increases the volume of water and causes the river or lakes to overflow its banks and hence, cause flooding (NRDC, 2015).

Human causes of flooding describe the flooding caused by the direct actions and inactions of humans. There is therefore a direct/indirect human influence of some sort (Oppong, 2011).

The Aboabo community is extremely overcrowded which constantly threatens the Asokore Mampong Municipal Assembly management system. Due to the population size, the sewage and waste water management system is overburdened, the drainage network system is inadequate, and the dumping of household and commercial garbage disposals is mostly in open landfills and direct discharges to the River, streams and drains (AMMA, 2014).

There are several known and some unidentified causes of floods. Some are briefly described below.

2.4.1 Urbanisation

The number of people migrating from the rural to urban areas tends to be increasing greatly on daily basis. As urbanization increases, the need for construction of buildings and structures for shelter and other activities increases.

There is an increase in risk of flooding specifically where there is an intertwining in inappropriate, or inadequately maintained infrastructure, low-quality shelters, and lower resilience of the urban poor (World Bank, 2008).

The construction of buildings and structures has in some cases come into close proximity to streams and other primary drainage facilities. These drainage channels have subsequently been rendered incapable of coping with the high volume of runoff water during rainfall, which invariably carries large amounts of silt (Sam Jr, 2009).

The drainage systems in Aboabo have been impacted negatively due to the fast growing settlement rate in this area.

Due to ignorance and sheer disregard of building regulations many people build haphazardly putting them at risk to the dangers of erosion and flooding. Paved roads and setting up of these buildings/shelters increases the imperviousness of the catchment areas. The catchment areas easily respond to rainfall and subsequently increase runoff (A MMA, 2014).

2.4.2 Building in Flood Plains

Several buildings and structures have been constructed in flood plains. Some structures are ignorantly and dangerously built some few metres from the stream channel or even across natural watercourses. With the onset of an inundation these places are at high risk of flooding. Some residents, particularly in Aboabo Number 2 have even constructed low walls across the entrance of their houses and ramps on pathways to avoid flooding.

2.4.3 High Rainfall Intensities

The incidence of heavy rainfall is generally the cause of flooding in the Aboabo Community. The river and drainage network system in Aboabo usually cannot carry all the water in its channels after a heavy downpour thereby causing flooding. It is worth mentioning that this situation is worsened by human induced activities. Also with the portions of land untarred, the ground becomes saturated after a heavy downpour and the soil is rendered incapable of storing water after saturation point has been attained leading to increased surface runoff. This is based on information retrieved through interactions with communities along the Aboabo River during field surveys.

2.4.4 Nature of Terrain

Flooding is rampant in low lying areas/lowlands. Since rivers flow more slowly in such areas, if the water volume increases abruptly or suddenly, floods occur (Oppong, 2011). There is a reduction in the amount of infiltration of water into the ground on steep slopes. This means water can easily flow down to rivers as overland flow. Steep slopes also make it easier for more through flow within the soil. These two situations can both raise river levels easily. Relatively gentle slopes or flat land also allows easy penetration of water into the soil and increase lag times (Jackson, 2012).

2.4.5 Absence and Inadequate Capacity of Drains and Culverts

A major contribution to the problem of flooding in Aboabo is the absence of drainage systems and the inadequate capacities of the already existing drainage facilities. Reconnaissance and field survey works carried out during this research showed that quite a number of drains and culverts in both Aboabo Number 1 and 2 are of inadequate capacity.

The few existing drains are mostly choked or have deposits of silt, and so are rivers and streams as is the case of the Aboabo River. This therefore causes drastic reduction in the capacity of the river and stream channels. Flooding is likely to occur as a result of these aforementioned instances. In addition some of the drains constructed as shown in Figure 2.0 are well above the ground/road level rendering it useless for flood water passage should there be a surface runoff after the rains.

Figure 2.0: Drain constructed well above surface level

2.4.6 Maintenance

There exists a schedule for maintenance of existing drains periodically in the Municipal Assembly but this schedule is rarely adhered to due to some limitations especially financial constraints. Most of the existing drains have not been maintained since construction and some are in bad state beyond repair. These drains therefore, barely serve its purpose of construction (AMMA, 2015).

2.4.7 Erosion, Sediment Delivery and Damping of Refuse in River, Streams and Drains

Untarred roads and paths easily allows for gullying and erosion on land surfaces and the soil between buildings. This leads to the undermining of portions of the roads and buildings, and obstructs flow of water entering drains.

There is sediment delivery that accompanies this erosion problem. The sediment is carried along with the flood waters therefore choking drains and further reducing the capacity. The Aboabo River and its banks as well as drains are mostly used for damping of refuse which includes faecal matter, and solid waste as shown in Figure

2.1a and Figure 2.1b. The accumulations of sediments, vegetation and refuse are in evidence both along drainage channels and adjacent to culverts (Sam Jr, 2009)

Growth of grass and weeds are a common sight in many sections along the River and streams. This impedes easy flow and risk of flooding of the banks during downpour of rain.

Figure 2.1: Some causes of floods in the Aboabo Community

2.4.8 Obstructions

Water, telephone and power services crossing the drains at some point through pipes act as obstruction to the free flow of water through these drains. The sediments and refuse carried by the flowing water is easily trapped which further reduces the flow capacity of the drains (Sam Jr, 2009). Some unauthorized buildings have also been sited right on watercourses which also further distort the drainage network system and obstruct free flow as well (NADMO, 2014).

2.5 Effects/Impact of Floods

Effects of flood generally refer to the several types of harm and dangers that come along as a result of flooding incidence. It deliberates on a vast range of harmful effects on humans, their physical and emotional well-being, their day to day activities, their health and properties, on public infrastructure and amenities, the environment, ecological systems, industrial production and the competitive strength of the affected economy (Parker et al, 1987).

The impact and damages caused by flooding is almost impossible to quantify as there could be other developing effects in later years after its occurrence and some effects may take some years to notice. Flooding is natural phenomenon that is almost impossible to totally eradicate but in most instances the damaging effects are mostly as a result of human activities directly and indirectly and changes to the environment. Occurrence of floods can be a catalyst for other unforeseen hazards both natural and human induced, or can be a major part of a long term chain of cascading events (Action Aid, 2006).

2.5.1 People and Health

Floods pose serious threats to the health, well-being and general human life. The impact of flooding on the residents of Aboabo varies and involves physical injuries, health related issues and disease and in extreme cases, death. Sprains and strains are amongst the most reported cases of flood related injuries. Residents in their bid to escape floods, either cling to objects being carried along the fast-flowing water. People get trapped when there are instances of buildings or structures collapsing (Du et al. 2010). Some of the injuries that occur are before the floods set in when residents seek to find shelter. Some injuries also occur during the floods and some after the floods. It is not easy and simple to quantify the cases of ill health in totality as a result of flood events (Few et al. 2004). This flood water can cause failure of electrical systems resulting in electrical shocks and other forms of secondary damage.

Cholera, diarrhea, typhoid fever and malaria are the common diseases that affect the residents of Aboabo during and after flood events. Flood waters sometimes mix with raw sewage and in effect increases the risk of outbreak of water-borne diseases. The God of Kings Clinic in the Community is not well equipped and also does not have the capacity to accommodate the patients. Some lose their lives as a result of these ailments and some in the process of the floods, die. In 2014, two deaths were recorded in the Community (AMMA, 2015).

Occurrence of deaths, witnessing injuries and destruction of homes and properties due to floods, can cause severe psychological problems in some individuals. The grief and loss of properties, as well as health issues, can lead to stress, depression and in some instances, anxiety (Ahern and Kovats, 2006). Children and the elderly according to studies and researches conducted are more vulnerable to death, particularly from drowning, than adults (Bartlett 2008).

2.5.2 Building and Infrastructure

Flooding has a great impact on the built environment considerably, as many buildings and structures are affected by the floods. In Aboabo, both completed and uncompleted buildings and structures are abandoned as a result of fear of what is now an annual occurrence. The main Bridge in Aboabo Number 2 is affected by the floods. This cause traffic and impedes movement of residents as the bridge is rendered inaccessible. Pathways are also flooded and generally commuting is almost impossible in the occurrence of floods. This indirectly affects daily activities of residents as well as major disruptions in the lives of people and businesses.

Some buildings and structures are constructed without adhering to any building laws and with no permits (AMMA, 2014). They are typically constructed with materials and techniques that cannot stand should there be extremes in weather conditions or the occurrence of natural disasters. These structures are totally or partially destroyed when hit by floods with ease (Parry et al. 2009).

2.5.3 Business/Trading and Education

Floods do not only directly affect people, buildings, infrastructure and the environment, but also have indirect impacts, such as losses from interruption in business activities. Damage to business premises and buildings, the increase in cost and travel time as well as the loss of income are indirect impacts of floods that are more often difficult to quantify. This represents a significant percentage of the overall cost of flood damage to communities (Ingirige et al, 2011).

Businesses sometimes close down temporarily during and after the floods and sometimes can take up to months to recover and return back to normal trading. This is sometimes due to inability to access roads and pathways, time to clean up and sometimes lack of access or failure of basic services, such as water supply and power cuts.

Children are unable to commute from their residence to the schools during the floods. This is as a result of flooded roads and pathways as well as the school premises. Pupils in Mighty Royal School in Aboabo Number 2 in particular boycott school totally when there is a likelihood of a heavy downpour. This is due to the flooding of the roads leading to the school as well as the school premises whenever rains set in.

The disruption to education, over a long term period can lead to children suffering academically.

2.5.4 Water and Sanitation

Cholera, diarrhea and typhoid fever ailment and sometimes, deaths are primarily caused by a lack of pure drinking water, improper storage and handling of drinking water, poor hygiene practices and the deterioration of sewage and sanitation facilities which lead to the contamination of drinking water in flood affected areas (Kunii et al 2002; Ahern et al. 2005). There is an interruption in water supply and contamination leading to health issues. Waste collection and sanitation facilities can become overwhelmed leading to pollution and contamination of drinking water supplies (Ayeva, 2011). The waste water mixing with the flood water is a major cause of environmental pollution.

The sources of water for most of the residents in Aboabo are individual taps and open wells. The open wells get contaminated by the flood water in the events of floods leaving the water unsuitable for human consumption. The provision of noncontaminated water during and post flood events is very essential.

For the past 10 years, flooding has remained a major hindrance to the development of Ghana as both governments and international bodies continue to pump huge money in the form of aids into helping flood victims in the recovery process by the provision of relief items like blankets, food items and other household stuff through NADMO (NADMO, 2014).

Residents bear extra clean-up costs also due to wastewater mixing with flood water and entering and destroying their properties. The cost of recovery after floods both to households and the Municipal Assembly runs into millions of Ghana Cedis.

The trend and the effects/impact of floods continue to escalate, hence the need to reduce the trend.

2.6 GIS and Flood Management

Geographic Information System (GIS) is defined as any system that integrates, captures, stores, analyzes shares, manages, and displays data that is linked to location or geographic data. GIS merges computer database technology with geo-referenced and cartographic information, resulting in digital maps and databases with fundamental applications in areas such as natural resource management, ecosystem conservation, environmental studies, utility management, infrastructures and transportation planning, town and regional planning, municipal government and also commercial applications. It is an ideal tool for integrating data from the land itself (e.g. data gathered from satellites) and socio-economic data (e.g. tax records).

The power of a GIS lies in its ability to analyze relationships between features and their associated data. This analytical ability results in the generation of new information, as patterns and spatial relationships are revealed (Milla, 2005).

Although there are several definitions of GIS, ranging from the technologically-based to those focusing on organizational aspects, GIS is about evaluating geographical relationships through spatial analysis, database management/analysis and graphical display (Dunn, 1997).

The main advantage of using GIS for flood management is that, not only does the system generate a visualization of flooding but also it also creates means to further analyse and estimate probable impacts of flooding incidence (Hausmann et al, 1998).

2.6.1 Flood Risk Management

Disaster Risk Management deals with the organization of resources and responsibilities for dealing with aspects of emergencies including prevention of hazards, disasters and their mitigation. Risk is the probability of a loss depending on three elements; hazard, vulnerability and exposure (Crichton, 1999).Flood Risk Management involves the preparedness before the disaster, response during the floods and means of recovery after the occurrence (Hobeika et al, 1985). Studies of risk includes issues pertaining to the identification and estimation of risk, risk assessment and evaluation include monitoring and management of the said risk (Gerrard, 1995).

Flood risk management is considered as one of the most effective means to address flood control issues. It comprises of floodplain management, flood control maintenance activities, protection of flood prone areas, other flood hazard mitigation activities, and preparation for flood disasters where mitigation activities cannot totally curb flooding from its occurrence.

Flood Risk management includes flood prevention/ mitigation, its control and floodplain management (MRSC, 2015)

Traditionally, flood control measures have basically aimed at controlling flood waters. This has been achieved partially through the setting up of some sort of levies by the streams to curb the floods. Traditional means of floodplain management has also been primarily aimed at controlling the construction of building and setting up of structures in the floodplain (FEMA, 2009).

Presently, the Town and Country Planning Department of the Asokore Municipal Assembly in collaboration with other flood stakeholders are putting plans in place to formulate a much more comprehensive and substantive flood hazard mitigation methods (AMMA, 2014)

Flood Risk Management guidelines when implemented reduces future flood damages drastically in the event of its occurrence.

2.7 GIS and Flood Risk Mapping

Great attention has been given to the use of GIS and Remote Sensing to manage and control floods and in the production of flood risk maps. A lot of research has been done using diverse methodologies in the production of flood risk maps.

2.7.1 Flood Risk Mapping

Flood risk mapping is very important for land use and planning in flood prone areas. It creates easily read, rapidly accessible charts and maps which aids with the easier identification of flood risk areas and prioritize their mitigation effects (Forkuo, 2011).

A flood risk map is a map that shows areas that would be flooded by stream discharges of a given magnitude for a given amount of rainfall. They are used to determine areas prone to flooding when discharge of streams exceeds the bank-full stage or runoffs or flows exceed the capacities of their channels (Bapalu and Sinha, 2005).

It is primarily necessary in planning to ensure that works undertaken to provide mitigation or warning systems produce a sound return on the investment. It is also useful to assist with post-disaster recovery planning and management.

A vital component for appropriate land use planning in flood-prone areas is Flood Risk Mapping. Flood Risk Mapping is a presentation of easily-read, rapidlyaccessible charts and maps which facilitates administrators and planners to identify areas of risk and prioritize their mitigation and response efforts. Owing to the continually changing nature of land use, flood-prone areas need to be examined because of how they affect development or might be affected by development (Bapalu and Sinha, 2005).

The application of GIS, performing analysis and carrying out simulations can be a very useful tool in Flood Risk Mapping because it provides vital information in the case of planning and in the events of emergency.

Flood Risk Mapping further aids in analysing the characteristics of the nature of the terrain of the study area and the drainage network system. These contribute immensely to accurate and timely intervention strategies and curbing the impacts thereafter (Fava et al, 2010).

Continuous updating and monitoring of risk maps is, therefore, most important for proper flood risk management: decision makers need up-to-date information in order to allocate resources appropriately (Jha et al., 2012).

Without a noticeable rise in cases of flood risk events, it is assumed the socio economic impacts of floods will continue to increase due to the upsurge in exposure of primary and secondary receptors (Sakyi, 2013).

Flood hazard modeling requires a great amount of field measurements and knowledge coupled with modeling experience. A lot of expertise is even required to decide on which floodplain features should be included in or excluded from the mapping process (Fokuo, 2010).

For example, some of the features that could pose a potential barrier to impede floodplain flow are roads and railway embankments. Culverts or pipes underneath the roads and railway embankments could also greatly influence flooding mechanisms. The locations and dimensions of these features could be obtained through a both terrain and mapping analysis, from asset surveys and various forms of field measurements (Sun et al, 2008).

Duan et al (2009) focused on using a hydraulic model HEC-RAS in a GIS and Remote Sensing environment for the area of Ping River basin, Northern Thailand. The inundation area and the flood depth for the year 2005 flood event in Chiang Mai province was generated using the 1D HEC-RAS flood model. The model was verified by comparing the model results with the remote sensing image, and hazard maps were prepared using the model output and other socio economic data.

Poulter and Halpin (2008) analyzed the effects of horizontal resolution and connectivity on the extent and timing of flooding from sea-level rise using digital elevation data. Conclusion was drawn from these studies to prove that elevation data indeed was essential in the mapping of possible coastal flooding. The research further proved the extent and timing of the flood inundation are sensitive to horizontal resolution and the modelling of hydrological connectivity.

Forkuo (2010) exhibits the integration of GIS and ASTER imagery in flood hazard mapping. The study further described classification of land use and Digital Elevation Modeling using elevations digitized from the topographic map of the study area. The highest point of elevation of each district in the study area, nearness of each district to the catchments area and portions of properties at risk were determined within the GIS environment. Flood hazard mapping was then addressed from perspective of different mapping scales in which administrative units were selected as the unit of investigation.

Sakyi (2013) used an SRTM DEM data of 90m resolution and further run hydrology analysis in the GIS Environment. A flood risk map was produced after determination of slope and creation of stream buffer areas. Classified land cover maps, Landsat 5 TM (1990) and 7 ETM+ Images (2006) were then overlaid and a land cover change detection map of the area was produced in addition.

Fosu et al (2012) modelled the Susan River and carried on with hazard mapping using a Geographic Information System, spatial technology and the HEC-RAS hydraulic model as tools .A DEM was created from Contour Data. The geometric data needed for the modelling process were extracted from the DEM, topographic map and field measurements. A remotely sensed image was then classified into various land cover types which was used for estimating the roughness coefficient of the various cover types during the modelling process. The model results were displayed and analysed in ESRI ArcGIS environment. The flooded area was geometrically overlaid on the topographic map to delineate the affected buildings. The hazard map produced clearly showed the spatial distribution of the flooded area which was mainly located at areas with relatively low relief.

2.7.2 Flood simulation/Modelling

Flood simulation aids in providing an interactive and stimulating solution to create awareness of the increasing risk of flooding. It also helps policy makers in deciding how much money to spend on some forms of flood defences, authorization of buildings to be constructed and how to create public awareness.

There are various popular one, two and three dimensional hydraulic models which includes HEC-RAS, SOBEK, MIKE 2, and FLO2D. Their methods and subsequent results showed the capabilities, strengths and shortfalls of these models (Fosu et al, 2012).

Fosu et al (2012) used a Geographic Information System, spatial technology and the HEC-RAS hydraulic model as tools to achieve the aim of river modeling and hazard mapping for the Susan River in Kumasi. The results from the model were displayed and analysed in ESRI ArcGIS environment. The flooded area was geometrically overlaid on the topographic map to delineate the affected buildings.

Wang et al (2008) used remote sensing and GIS tools in calculating the diverse water levels at each particular grid of the study area with common hydrological models which included Soil Conservation Service Technical Release 55 (SCS TR-55) model and Manning equation. The result of this study proved that the careful integration of GIS, RS and hydrologic model is an effective way to estimate likely maximum flood. Since the research area of Guiyang city is characterized by mountainous landform, the model was critically validated and further calibrated for flood inundation simulations. The result of this research helps in obtaining flood information for emergency response planning and also the evaluation of the amount of risk to the Community and its residents.

Yamaguchi et al (2010) developed a GIS-Based Flood-Simulation Software. The developed software enables risk managers to simulate flooding using these three functions; that is the automatic definition of the calculation area, automatic acquisition of topographic data, and the rapid output of the result. The information generated by the developed software enables risk consultants to precisely assess the hazard/risks and to suggest measures to curb its occurrence. The simulation software provides the depth of water, speed of the current and visual information such as 3-D computer graphics of the facility assessed.

CHAPTER THREE

3.0 STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter describes the characteristics of the study area. It further describes the techniques and methods used in production of a flood risk map of the study area. The Chapter also discusses procedures used in collection of information on the causes and effects of floods in the study area from residents of the Community.

3.2 Study Area

3.2.1 Location and Size

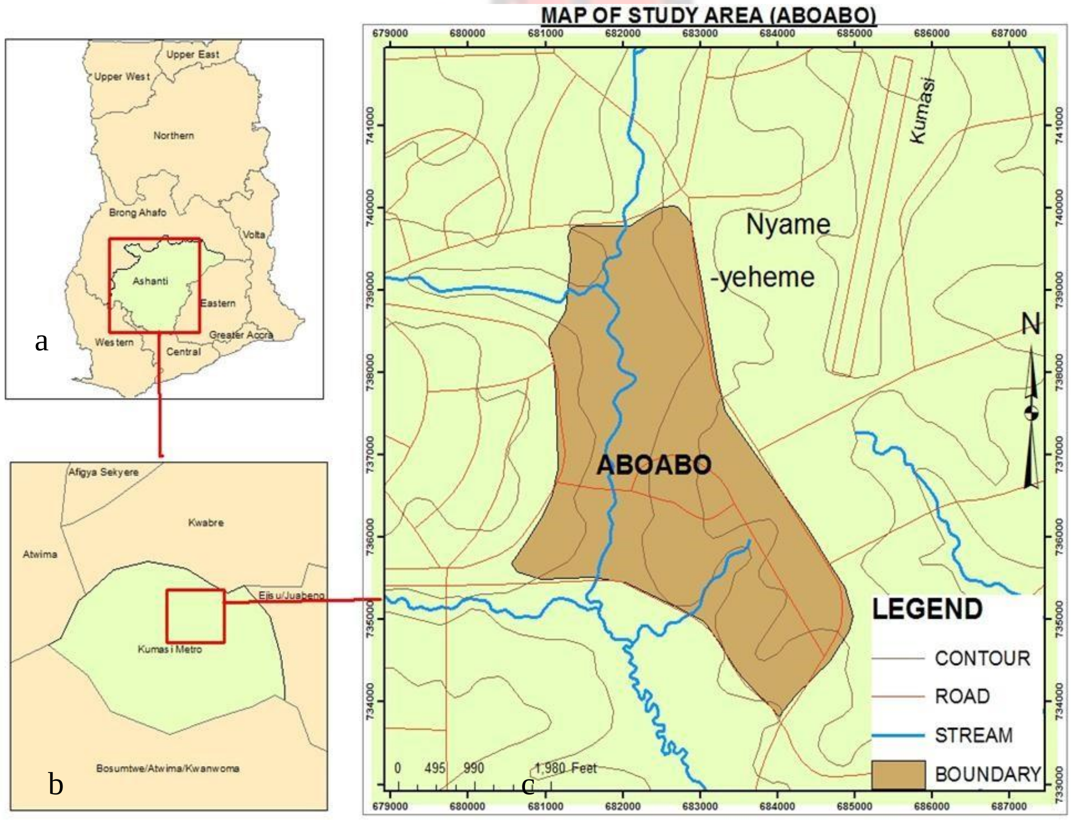

Figure 3.1: Map of Aboabo- a Showing the Study Area in National Context, b Showing the Study area in the Metropolis, c Showing the Map of the Study Area.

Aboabo is located within the city of Kumasi and falls under the Asokore Mampong Municipal Assembly (AMMA) which is fast growing municipality with an annual growth rate of 5.47 per cent (KMA, 2006).

It is located in the transitional forest zone of Ghana and lies about 270km north of Accra, the national capital of Ghana. Residents of the community are predominantly traders. It has a total area of approximately 1.21778375 square kilometres and lies between latitude 6º35‘N and 6º40‘N and longitude 1º30‘W and 1º35‘W and elevation within the range of 249 and 281 meters above sea level (KMA, 2014). It is bounded by Dichemso to the North, Asawase to the West, Amakom and Braponso to the South and Adukrom and Akrom to the East (Town and Country Planning Department, KMA). Figure 3.1 shows a map of the study area in regional and national context.

3.2.2 Climate

The Municipal Assembly falls within the wet sub-equatorial climate type. It experiences an average minimum temperature of 21.5ºC and a maximum average temperature of 30.7ºC. The average humidity of the Municipal Assembly is about 84.16% at 09:00 GMT and 60% at 15:00 GMT. There has been a significant increase in population growth and the environment due to the moderate temperature and humidity and the double maxima rainfall regime (214.3mm in June and 165.2mm in September). This is as a result of the absence of severe climate conditions (KMA, 2006).

3.2.3 Vegetation

The Community falls within the moist semi-deciduous South-East Ecological Zone. Some species of trees found within the Municipal include Ceiba, Triplochlon, Celtis and some exotic species. There exist some other patches of vegetation cover spread over the peri-urban areas of the Municipal Assembly. The fast growing rate of urbanization in the Aboabo Community has contributed to the depletion of most of these trees as well as vegetation cover (KMA, 2006).

3.2.4 Relief and Drainage

The Asokore Mampong Municipal Assembly falls within the plateau of the South–West physical region which ranges from an elevation of 250 to 300 metres above sea level characterised by an undulating topography. The Municipal Assembly is surrounded by some major rivers and streams, such as Subin, Wiwi, Sisai, Owabi and Nsuben.

The study area harbours part of the Aboabo River which flows from the North to the South on the far western part of the study area. The length of the Aboabo River is 6,050 meters (6.05 km), about 2.5 meters wide upstream and 30.5 meters wide downstream (KMA,2006).The drainage density is rather high around the central part of the Aboabo basin and the drainage network system in the study area forms a dendritic pattern. Biotic activities in the Aboabo Community which includes urban development, encroachment and haphazard disposal of waste have negatively impacted the drainage system (KMA, 2006).

3.2.5 Geology and Minerals

The Municipal Assembly is dominated by the Middle Precambrian Rock. The Middle Precambrian is made up of both stratified and plutonic rocks. The stratified rocks lies unconformable on the Lower Precambrian rocks and on the Hillman Migmatite, a hybrid rock of uncertain age, and are divided into two groups (Morey, 1978). This geological structure has both positive and negative effects directly and indirectly on the economy locally. The existence of the Precambrian Rock has given rise to job developments especially in the construction sector. There exists a number of smallscale mining, stone quarrying and sand winning Industries in the Municipal Assembly. The uncontrolled extraction of the aforementioned natural resources poses as a severe threat to the environment although it has led to several job opportunities in the municipality (KMA, 2006).

3.2.6 Soils and Agricultural Land Use

The major soil type in the Municipal Assembly is the Forest Ochrosol. This is a rich type of soil suitable for the growth of various types of food crops such as maize, plantain and cassava. However, due to the increasing rate of urbanization, agriculture in the Municipal has for the past twenty years seen a very drastic change (KMA, 2006). The increasing need for residential, industrial and commercial land uses has surpassed the use of land for the purpose of agriculture. It has been estimated that approximately 80% of arable lands in Aboabo have been converted to residential and commercial areas. Both traditional and exotic vegetables are widely cultivated mostly for household use than food crops (KMA, 2006).

3.3 Materials and Tools

The following materials, software and tools were selected to aid in the collection and analysis of information and data for the purpose of the study.

- Digitized Topographic Map of Aboabo with contour Interval of 2m
- Scanned layout of Aboabo
- Garmin Hand Held GPS
- ESRI‘s ArcGIS 10.1 was used for the data processing and analysis.
- Statistical Package for the Social Sciences (SPSS) Version 16

3.4 Dataset and Acquisition

The ArcInfo interchange files were imported to ArcGIS shape files using the Import .e00 to Coverage tool. The resulting coverages were converted to shapefiles.

The digitized topographic map of Aboabo was georeferenced with the aid of four selected control points to first order polynomial using Accra Ghana Grid coordinate system. The boundary of the study area was digitised to ArcGIS polygon shapefile. An extraction analysis (clip) was used to crop all input shapefiles falling within the extents of the study area. The resulting boundary shapefile served as a clip feature to the Clip tool.

The following map properties were identified and tested: map scale, coordinate system, map units and grid interval. Figure 3.2 illustrates the detailed step by step approach carried out in the research.

3.5 Methodology

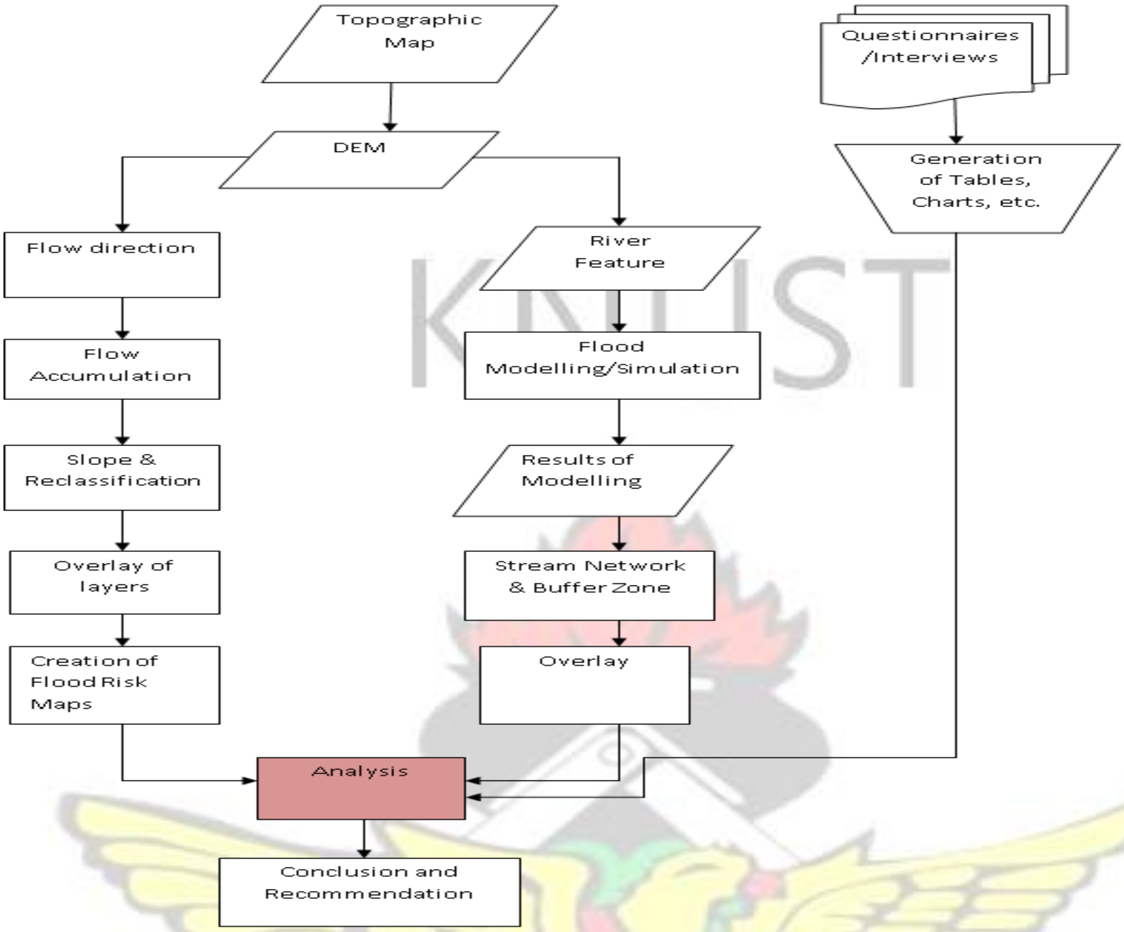

Figure 3.2: The flow diagram of the Methodology

3.6 Questionnaires and Interviews

Primary data in the form of questionnaires and interviews were deployed in the collection of non-spatial information on the occurrence of floods and its effects. Primary data were collected purposely to address the objectives as outlined by the researcher for the purpose of the study. Questionnaires and interviews were used for easy and scientific analysis of large amounts of information from a number of people in a relatively short period of time and in a cost effective way.

3.6.1 Questionnaires

A total of 238 questionnaires were given out to residents of the Community. Based on reconnaissance survey carried out, the closed format /closed –ended questionnaire style was used. This format uses multiple choice questions, where respondents were to choose among any of the given multiple choice answers. It aided in the easy administration and analyses of the questionnaires. It also helped to avoid answers which were irrelevant from respondents. However, other opinions from respondents outside the multiple choice answers were noted (Mensah, 2010). Sample of the questionnaire forms are shown in Appendix C1.

The questionnaires had questions on:

- The areas in the Communities that experienced flooding
- The causes of floods in the Community
- The Occurrence of floods in the Community
- The Impact of flood on infrastructure and transport
- The Impact of flood on health of affected victims
- The Impact of flood on education
- The impact of floods on trade and business activities
- The Impact of flood on water and sanitation
- Post floods

All the questionnaires were considered valid with thirty-eight cases of non-response leaving the total Questionnaires analysed at 200.

Univariate analysis was performed with the aid of the SPSS Software from the responses of the questionnaires and the findings analysed and presented in tables and charts.

3.6.2 Interviews

A semi-structured interview was carried out with another set of questionnaires used as an interview guide (Appendix C2). The interview guide helped to focus the interview on the topic without constraining the respondents in the process. Officials of the National Disaster Management Organization (NADMO), Town and Country Planning, Ghana Meteorological Agency and Metropolitan Waste Management Department were duly interviewed on their operational needs with regards to flooding.

The aim for collection of data through questionnaires and interviews as discussed in Section 3.6 was mainly to investigate the causes of flooding in the Aboabo Community as well as the effects and socio-economic impact as a hazard on life, property and daily activities of residents. It also aimed to access the role of stakeholders/flood management personnel in the prevention/ mitigation of the floods, what could be done during its occurrence and post flood management (Sakyi, 2013).

3.7 GPS Survey

A GPS survey was conducted in order to validate and test the accuracy of the input data. A hand held Garmin was obtained and used for the validation purpose (Appendix B). GPS Coordinates of some areas was selected and laid over the flood risk zones to produce a flood risk map of the area showing the locations within the study area that are in the different flood risk zones. The digitized topographic map of Aboabo was used as a reference material to aid in the location of areas.

3.8 Flood Risk Mapping

3.8 .1 Digital Elevation Model

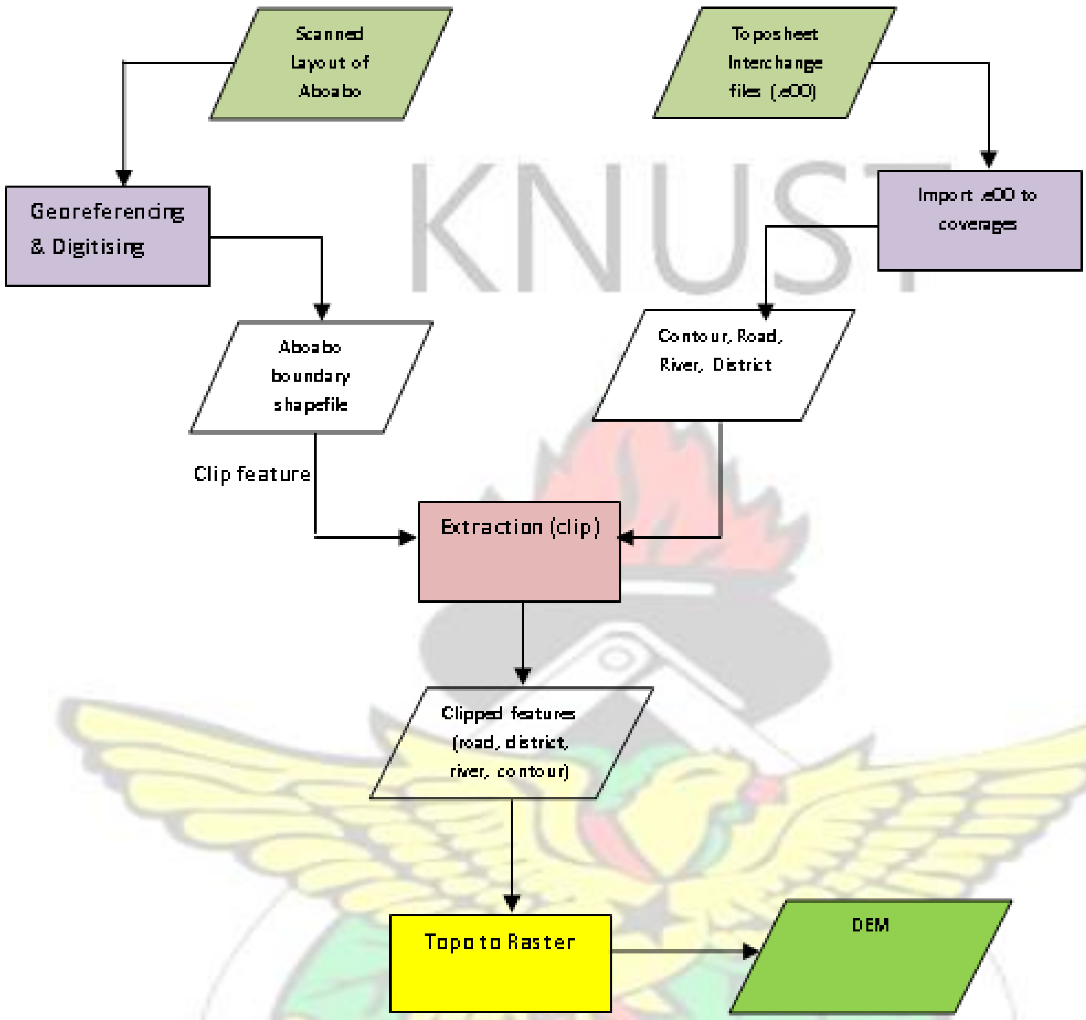

Figure 3.3: Flow Diagram Outlining Steps Undertaken to Generate DEM of Study Area

A Digital Elevation Model (DEM) was created using the contours of interval 2m from the digitized topo sheet. A DEM is a digital representation of ground surface topography or terrain (ESRI, 2014). The triangular irregular network (TIN) model was first generated and then the DEM subsequently generated (Forkuo, 2008). The Topo to Raster operation in ArcGIS was used to interpolate the elevation values for the study area using the contour data as input. The output of this operation was a DEM of the study area and is shown in Figure 4.1.

3.8.2 Filling of Sinks /Removal of Pits

The depressions (Sinks) were filled to further carry out hydrology analysis on the DEM (Orok, 2011). A part of the basin that is surrounded by neighbouring areas with much higher elevation is termed as a sink. Depressions (also known as pits or sinks) are that part of the DEM which impedes the flow of water to an outlet at the edge of the DEM. To best perform effective representation and hydrology analysis such as of flow direction and accumulated flow, it was necessary to use a dataset that was free of pits/sinks (ESRI, 2014). Results can be seen in Figure 4.3.

3.8.3 Flow Direction

A flow direction raster was created from the depressionless DEM. The approach used is commonly referred to as an eight-direction (D8) flow model as shown in Figure 4.4. In this model eight valid output directions relates to the eight adjacent cells into which the flow of water could travel into.A grid of D8 flow directions which are defined, for each cell, as the direction of one of its eight adjacent or diagonal neighbours with the steepest downward slope. The flow direction for each cell was determined according to the steepest descent to one of its 8 neighbouring cells. The direction values were coded as 1,2,4,8,16,32,64 and 128.

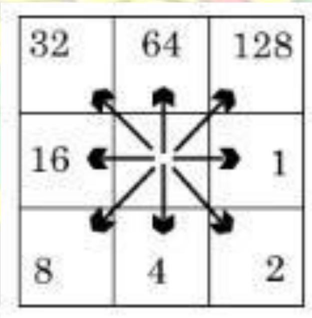

Figure 3.4: Flow Direction Model (D-8 method)

Source: Tarboton (1997)

Therefore, if the steepest descent of a cell is to the left, its Flow direction was coded as 1, if it was to upper right, it was coded as 32. The steepest descent was calculated by dividing the elevation difference by the distance between the cell centers (O'Callaghan and Mark, 1984).. Results are shown in Figure 4.5.

3.8.4 Flow Accumulation

Flow accumulation was used to generate the drainage network based on the direction of flow of each cell. A network of high-flow cells were created by selecting cells with the greatest accumulated flow (Orok, 2011). Results are shown in Figure 4.7.

3.8.5 Drainage Basin

The drainage basins of the study area were delineated to determine basins and watershed boundaries in the dataset (Orok, 2011). The drainage basins were created by locating the pour points at the edges of the analysis window, then further identifying the contributing area above each pour point. This results in a raster of drainage basins as shown in Figure 4.6. Analysis was performed to understand the flow and movement of water on the surface of these basins (ESRI, 2014).

3.8.6 Stream Network

A stream network was delineated by applying a threshold value to the results of the Flow Accumulation (Orok, 2011). On the basis of Flow Accumulation data, it was assumed areas where accumulated flow exceed 1000, are catchment areas. For the stream network, a set of raster linear features were represented as 1, on a background of No Data (0) (ESRI, 2014). Results can be seen in Figure 4.8.

Table 3.1 Old and New Flow Accumulation Values (Source: Orok, 2011)

Flow Accumulation(Old values)	New Values
≥ 1000	1
< 1000	0

3.8.7 Buffer Zone

A buffer zone around areas that are within 50m of the stream network was created from the result of the stream network analysis using the Euclidean Distance method. These zones or buffers were used in further analysis to determine which areas in the study area falls within or outside the defined zone. Areas within the 50m buffer zone were assigned a new value of ―1‖ while areas farther than 50m were assigned a value of ―0‖. The distance mapping functions computed an output raster dataset where the output value at each location is potentially a function of all the cells in the input raster datasets (ESRI, 2014). Results can be seen in Figure 4.9.

3.8.8 Slope Angles

The slope angles of the DEM as measured in degrees were calculated and results are shown in Figure 4.10. The slope angles were further reclassified to create three categories. Reclassification was done to simplify the interpretation of the slope angle data obtained.

- Areas with slope angles above 4.4 degrees (High slope areas)
- Areas with slope angles between 1.3 and 4.4 degrees (medium slope areas)
  Areas with slope angles below 1.3 degrees (low slope areas).

The total area and its corresponding percentage were also determined (Orok, 2011). Results are shown in Figure 4.11.

3.8.9 Overlaying of layers and Production of Flood Risk Maps

The reclassified slope angles and the created stream buffer areas were added using the raster calculator in ArcGIS. The two factors were considered and the slope angle was given more influence. The output dataset was then reclassified into 3 zones. The resultant layer resulted in the production of the flood risk maps showing three zones High risk, medium risk zone and low risk zone and can be seen in Figure 4.11.

3.9 Flood Simulation

The flood modelling method used for this research is a very simple and basic flood simulation model employed in Nyarko (2002), Fosu and Konadu (2007) and Forkuo and Tsawo (2013). It is a vector-based method which only requires the extents of flood levels in simulating flood extent based on the derived drainage lines, their depth and their capacity to hold rainfall run-off (Forkuo and Tsawo, 2013).

This flood modelling model uses contours to show particular flood levels from drainage lines. The DEM was further interpolated to smaller contour intervals of 0.2m. Flood level extents were selected based on this interval. For the purpose of simulation, a catchment was selected from the delineated drainage basin of the study area.

3.9.1 Cross-sections Across Drainage Line

Elevation values were extracted from the DEM along the banks of the drainage line. The mean of the bottom elevation represented the average elevation of the drainage line of two successive cross-sections determined (Fosu and Konadu, 2007; Fokuo and Tsawo, 2013).

In order to validate this concept of flood modelling, inundation levels observed during flood events vary based on the bottom elevation of drainage lines and that of the adjacent areas. It was therefore rational to section drainage lines with cross-sections and uses the average bottom elevation between consecutive cross-sections to represent the mean elevation along the drainage line between these cross-sections (Fosu and Konadu, 2007; Fokuo and Tsawo, 2013).

3.9.2 Flood Contour Derivation

The mean bottom elevation of consecutive cross-sections determined from the profiles represented the average minimum elevation between the cross-sections above which features in the catchment depending on their elevation, will be inundated in an event of flood.

Flood water levels of 0.4, 0.8, 1.2, 1.6, 2.0 and 2.4 m were selected as flood water levels with the elevation measure as a guiding factor. Flood level contours for each of the flood water levels were consequently computed for each of the consecutive crosssections and then selected from the contours derived at 0.4 m interval.

The flood level contours derived for the selected flood water levels indicated areas that are likely to face inundation in the event of any flood at the specified water levels. The flood contours further indicated the extent of flood at a given flood level. The flood level contours were converted into polygons. The flood model extents were further overlaid on a geo-referenced Google Earth image of the study area which visibly illustrated areas at risk in the event of floods (Forkuo and Tsawo, 2013).

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter presents the findings of the study. This information was gathered through various methods such as hydrologic analysis, flood modelling, field observations, administration of questionnaires and semi-structured interviews.

4.2 Flood Risk Mapping

4.2.1 Triangular Irregular Network (TIN) of the Study Area

The TIN was used to represent the terrain surface of the study area. It represented the surface form and structure and gave an overview of the terrain of the study area. It showed areas of the same elevation represented by a particular colour from the lowest, 249.739m to the highest elevation on the study area, 281.1m.

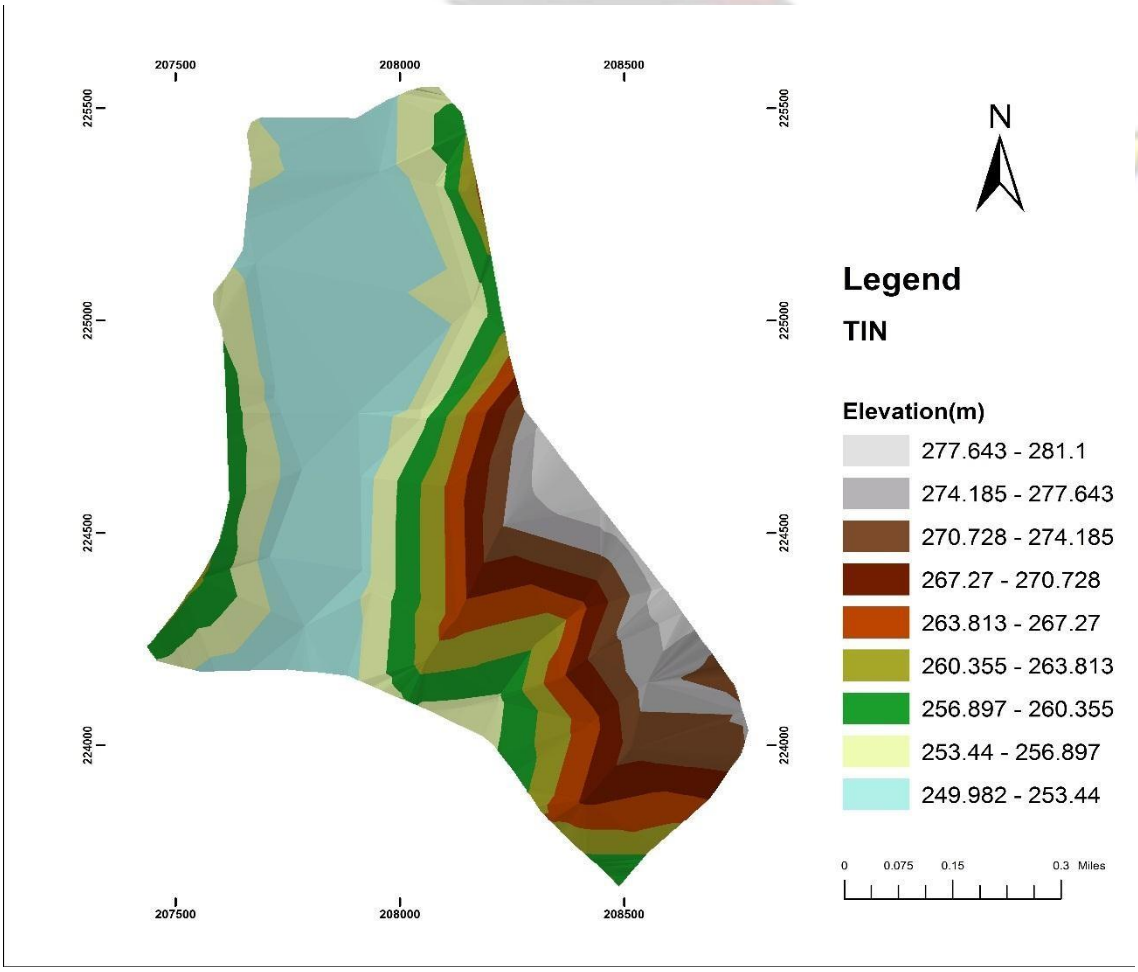

Figure 4.1: TIN of Study Area

4.2.2 Digital Elevation Model (DEM) of the Study Area

The flow of water on the surface is usually determined by the terrain of the study area. The DEM was created primarily for the analysis of hydrological processes. From the DEM as can be seen in Figure 4.2, the lowest elevation of the study area is 249.739m and the highest elevation was 281.1m.

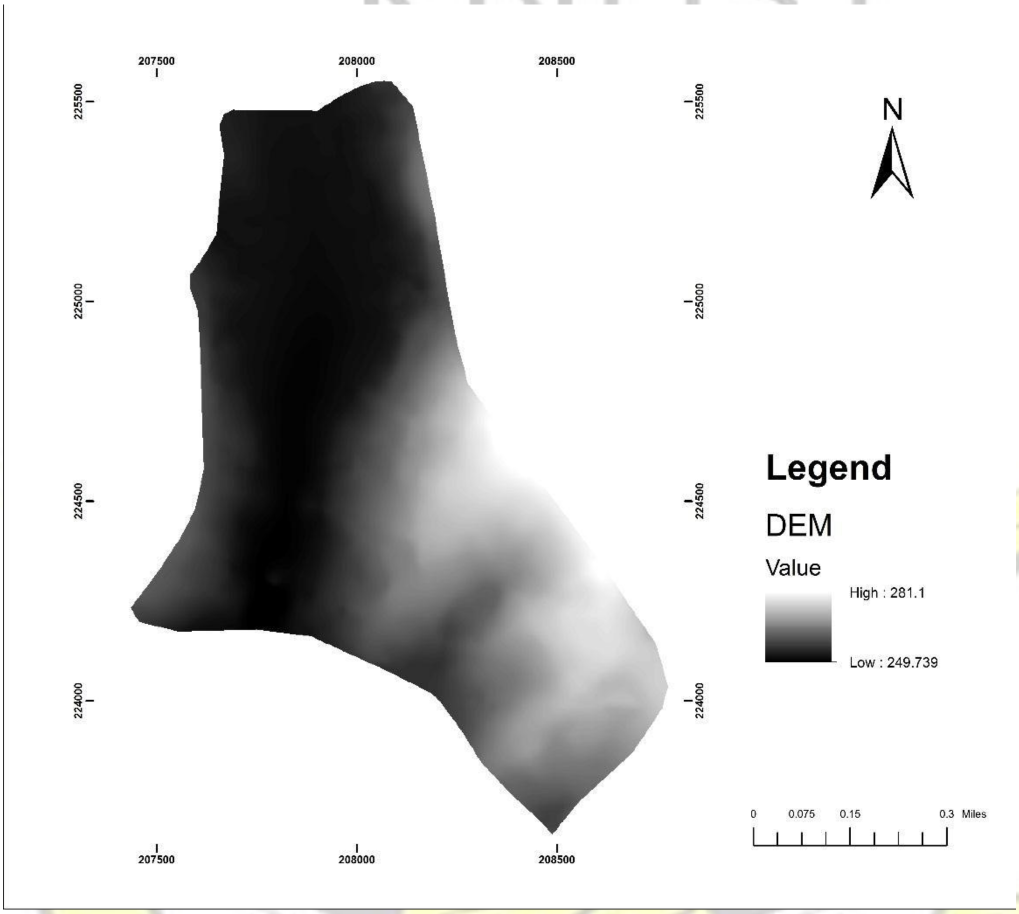

Figure 4.2: DEM of Study Area

4.2.3 Depressionless DEM/Filling of Sinks

Depressions (also known as pits or sinks) are areas in the DEM which do not allow the flow of water to an outlet at the edge of the DEM. In order to use the DEM for hydrological modeling, all depressions/sinks were filled as shown in Figure 4.3. The darkened portions marked areas of very low elevation.

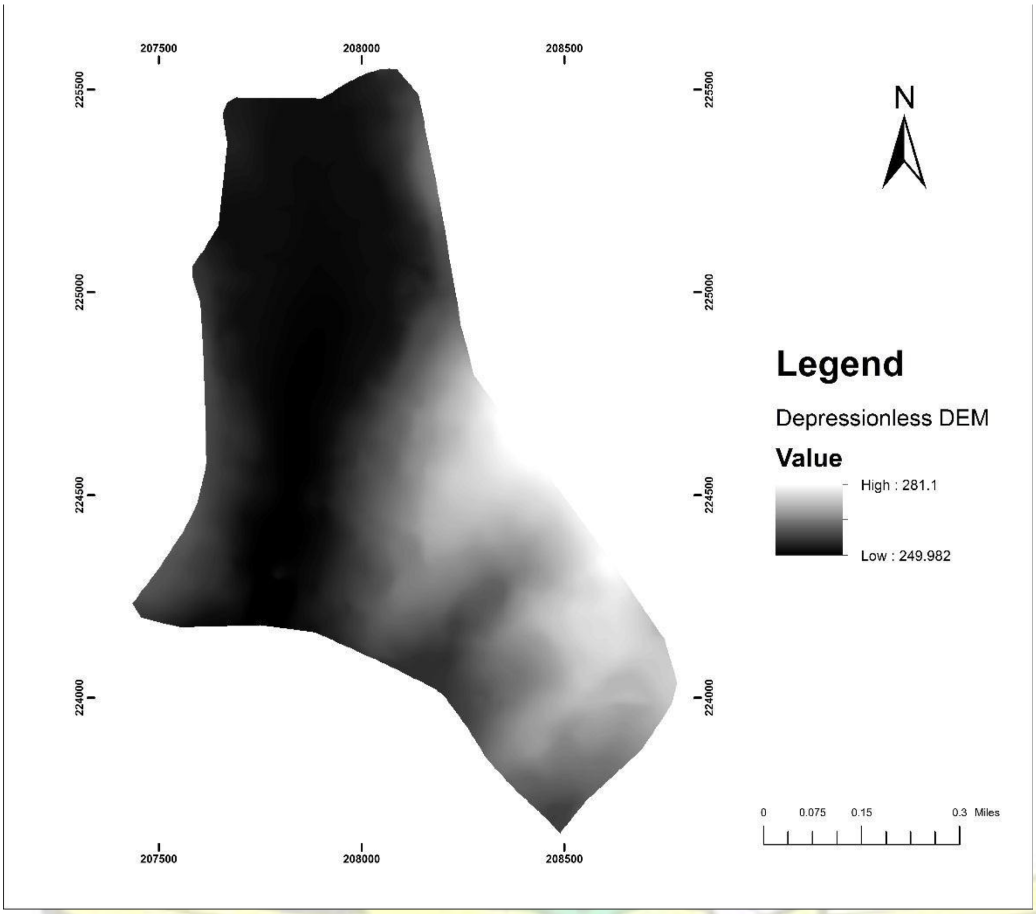

Figure 4.3: Depresionless DEM of Study Area

4.2.4 Flow Direction

The flow direction identified the downward-slope direction for each cell. The flow direction analysis enabled the determination of flow accumulation in different cells within the study area. Figure 4.4 shows the results of the Flow Direction on the DEM of the study area.

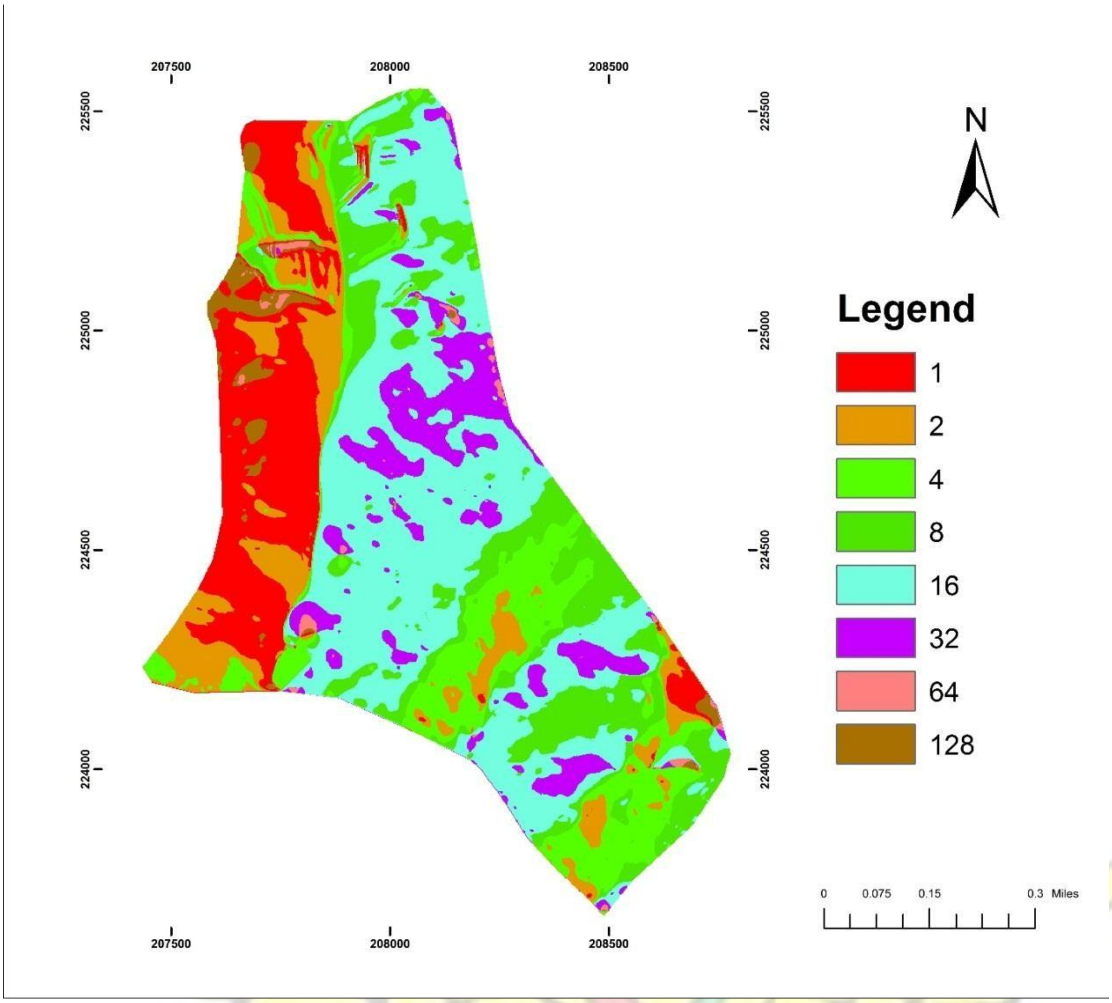

Figure 4.4: Flow Direction on DEM of Study Area

4.2.5 Drainage Basin

The Drainage basin used the results of the Flow Direction raster in Figure 4.4 to identify the drainage basins. Drainage basins were made up of the connected cells that drain to a common location. Results are shown in Figure 4.5.

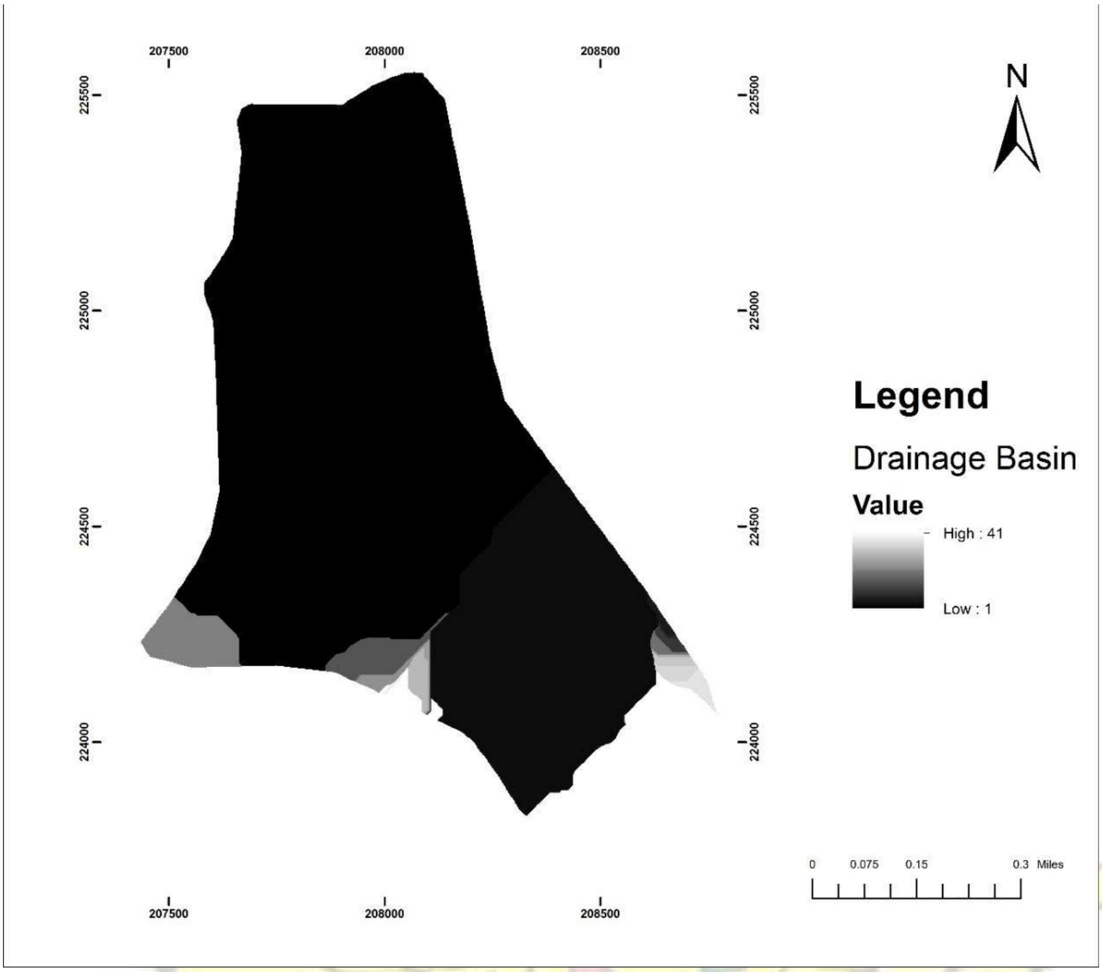

Figure 4.5: Drainage Basin of Study Area

4.2.6 Flow Accumulation

Figure 4.6 shows the results of the flow accumulation analysis carried out on the depressionless DEM. The flow accumulation identified how much surface water flow accumulated in each cell. The cells with high accumulation values were identified as stream or river channels. Figure 4.6 further shows the cells that have the greatest amount of water accumulation flowing on the surface of the depresionless elevation model.

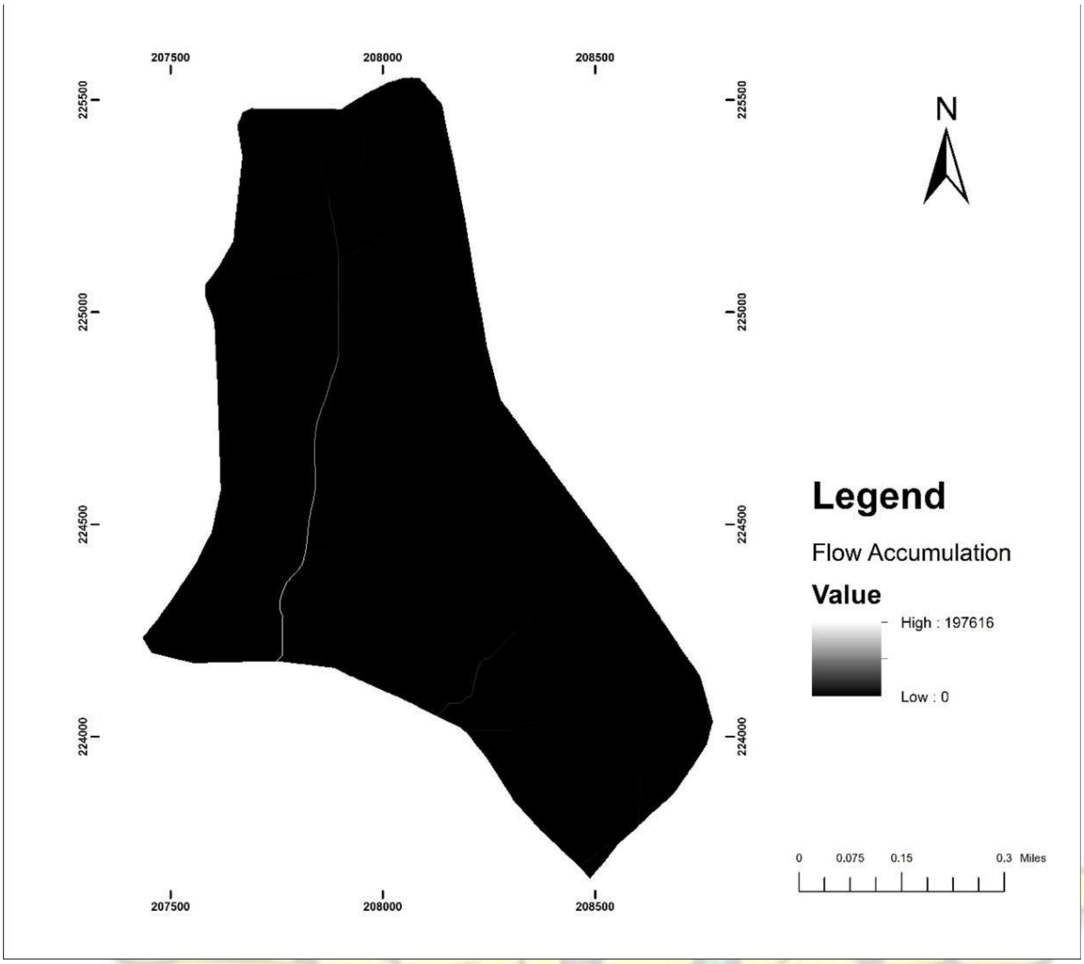

Figure 4.6: Flow Accumulation of the Study Area

4.2.7 Stream Network

Stream Network captured only those cells with high flow accumulation values (in this case, greater than 1000) into a stream raster. The stream network indicated the path of formation of large body of flowing surface water in the occurrence of rainfall or the sudden release of large quantity/amount of water in the study area. The stream network in Figure 4.7 displayed the path of streams for cells with threshold values >= 1000. It was further deduced that built-up/urban areas close to this stream network are likely to be inundated when an incidence of flood occurs.

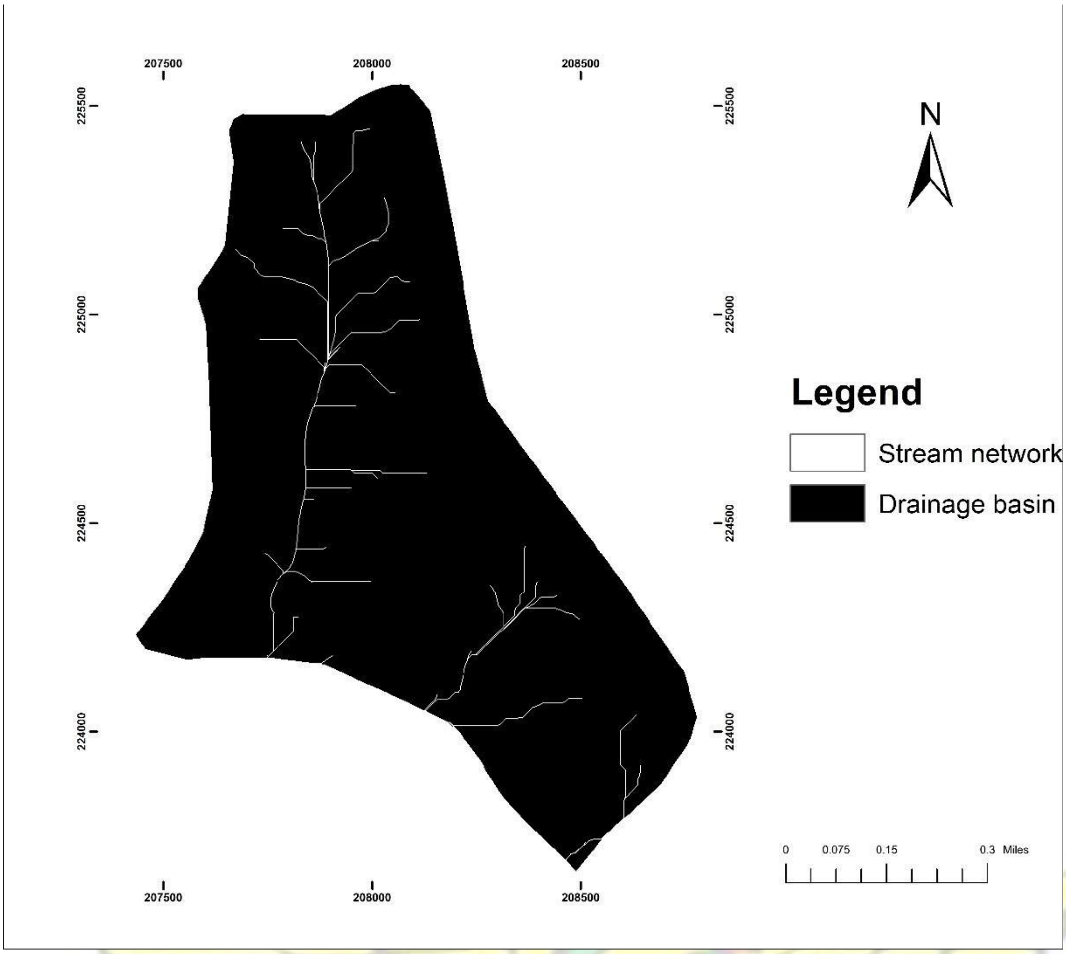

Figure 4.7: Stream Network of the Study Area

4.2.8 Buffer

The Euclidean Distance function measured the straight line distance from each cell to the closest source. In order to show the areas in the study area that are at greater risks in the event of an inundation, a buffer was created within 50m of the stream network. Figure 4.8 shows the results of the stream buffer zone created. The distance was measured from cell center to cell center. This distance ranged from the closest to the farthest within 50m range. Settlements within this area are most likely to be inundated when floods occur and will be at great risk in the event of floods.

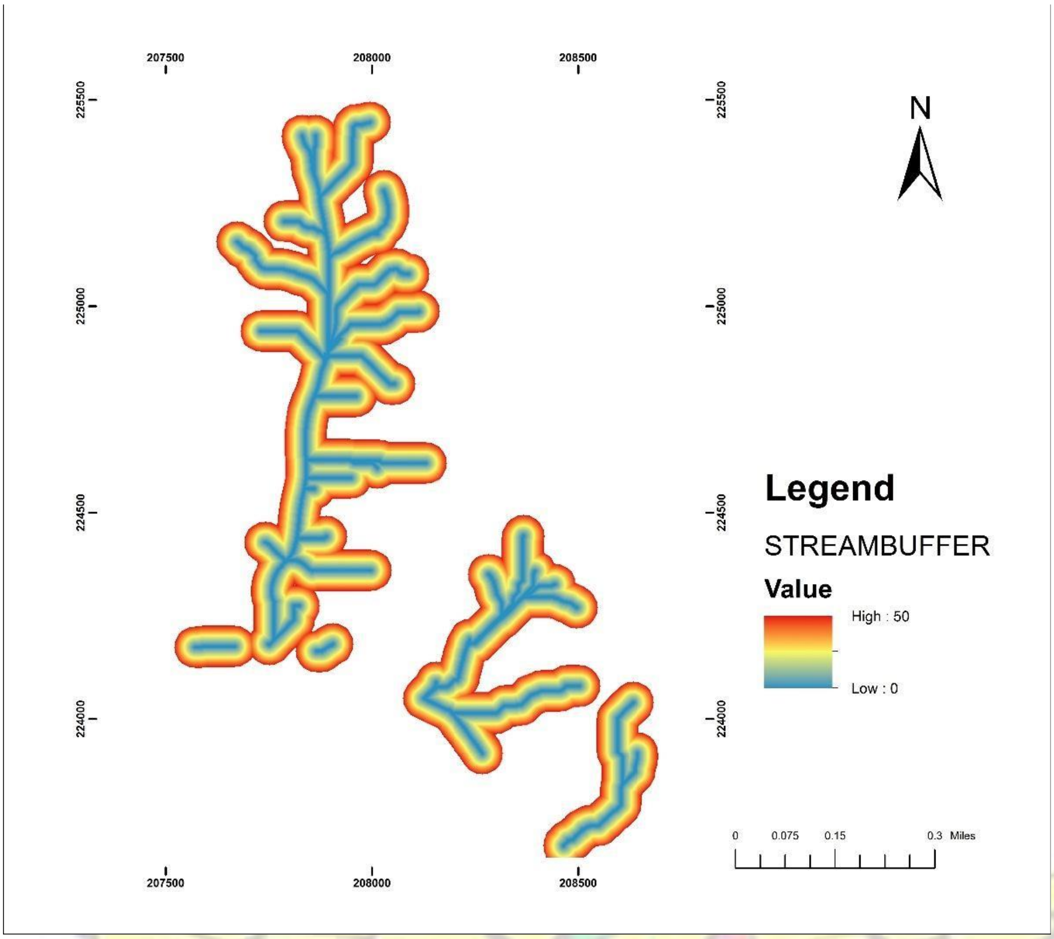

Figure 4.8: Buffer Zone around Stream Network

4.2.9 Slope

One of the most critical factors considered in flood modelling and determining flood prone areas is the slope steepness of the elevation. The slope tool as implemented in ArcGIS calculated the maximum rate of change from a cell to its neighbours, which is typically used to indicate the steepness of terrain. Figure 4.9 revealed the varying slope angles of the DEM. This further led to the discovery of areas falling within and out of the stream buffer zone which had varying slope angles.

The lower the slope angles of an area, the closer to water level. Figure 4.9 also shows some portions within the stream buffer zone which were well above water level. Such areas will likely be less vulnerable than other areas within the stream buffer zone.

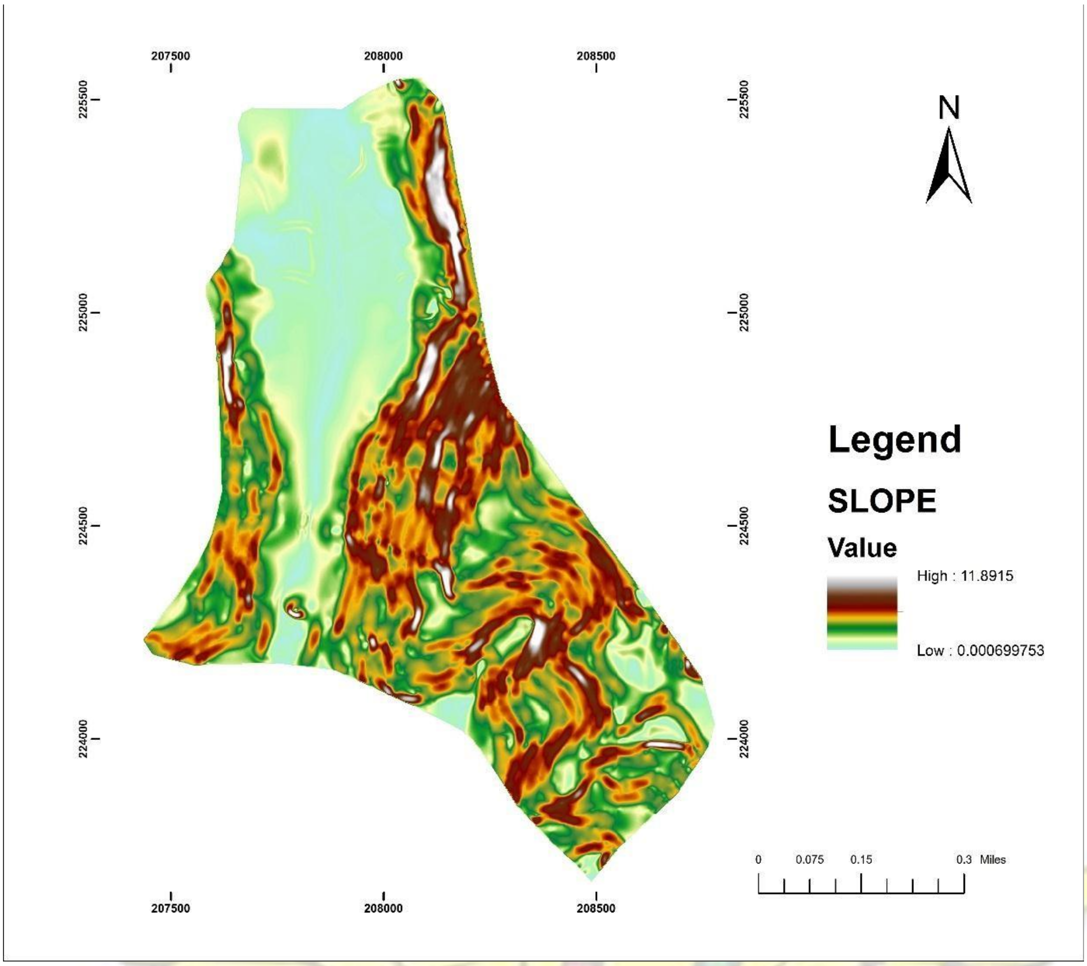

Figure 4.9: Slope of the Study Area

The slope angles were further reclassified as shown in Figure 4.10. One way to convert surface data into more usable information for an analysis was to reclassify the surface. Reclassifying the slope angle values created a range of values and equalled them to a single value. This reclassification divided up the study area into three classes (low, medium and high) as a means of aggregating and generalizing detailed data. Reclassifying reduced the number of output categories for an overlay analysis (ESRI, 2014).

The result of the total area and its corresponding percentage determined is shown in Table 4.1.

Table 4.1: Table showing Area and Percentage covered by Slope angles

Slope Angle	Slope Description	Percentage (%)	Area (sq. km)
Below 1.3	Low	29.12	0.355

1.3 – 4.4	Medium	56.33	0.686
Above 4.4	High	14.55	0.177

Table 4.1 further revealed that the city is mainly characterised by areas with medium slope and secondly, low lying areas.

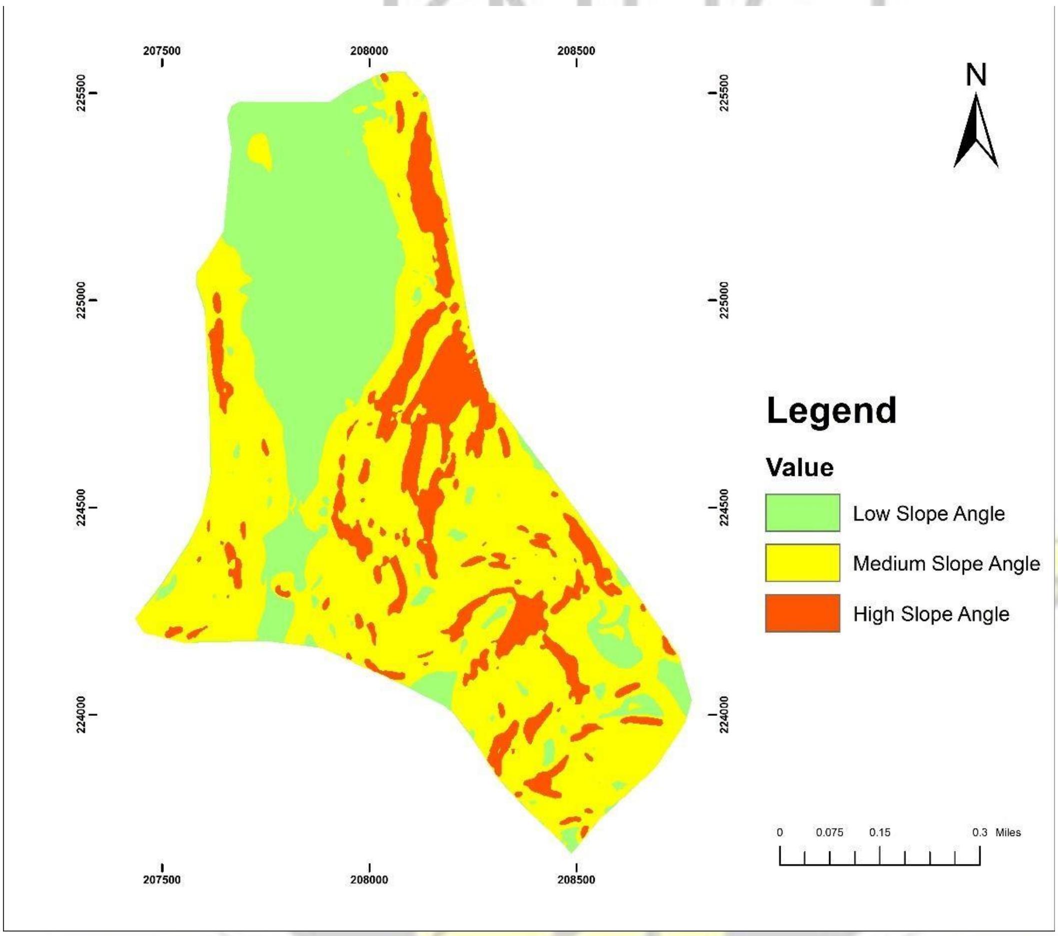

Figure 4.10: Slope Map of the Study Area

4.3 Overlay of Layers and Production of Flood Risk Map

The two factors, slope angles in Figure 4.10 and stream buffer zones in Figure 4.8 were considered for production. It was deduced that the slope angle was a much more important factor amongst the two. The slope angles were therefore given an influence of 0.90 while the stream buffer areas were given an influence of 0.10 (Orok, 2011).

The two datasets were further added and a new layer created in ArcGIS. The output as shown in Figure 4.11 resulted in a new layer showing three flood risk zones:

- Areas within the stream buffer zone and in the low slope areas (High risk zone)

- Areas within the stream buffer zone and in the medium slope areas (Medium risk zone)
- Areas out of the stream buffer zone and in the high slope areas (Low risk zone).

Results of the Flood Risk Map are shown in Figure 4.11. Figure 4.12 shows the Flood Risk Map with some towns in the study area indicated in the various flood risk zones. The total area and percentage for the zones were calculated as shown in Table 4.2.

Table 4.2: Table Showing Area and Percentage Covered by Flood Risk Zones

Zone	Percentage (%)	Area(sq.km)
Low Risk Zone	11.03	0.1343
Medium Risk Zone	67.71	0.8245
High Risk Zone	21.26	0.2589

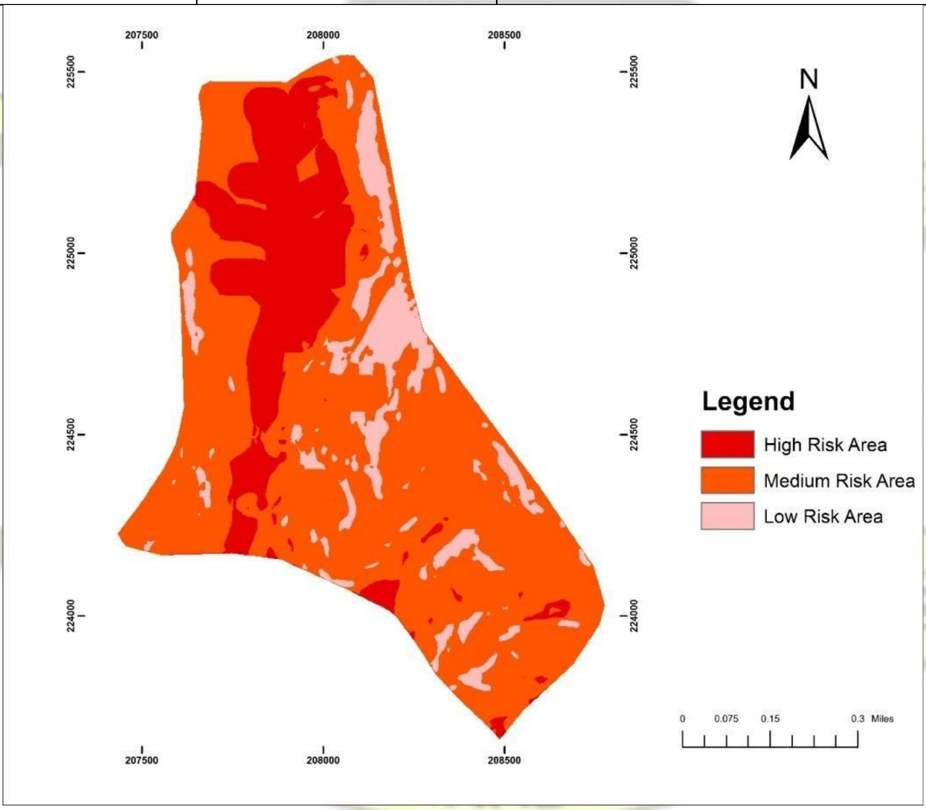

Figure 4.11: Flood Risk Map of Study Area

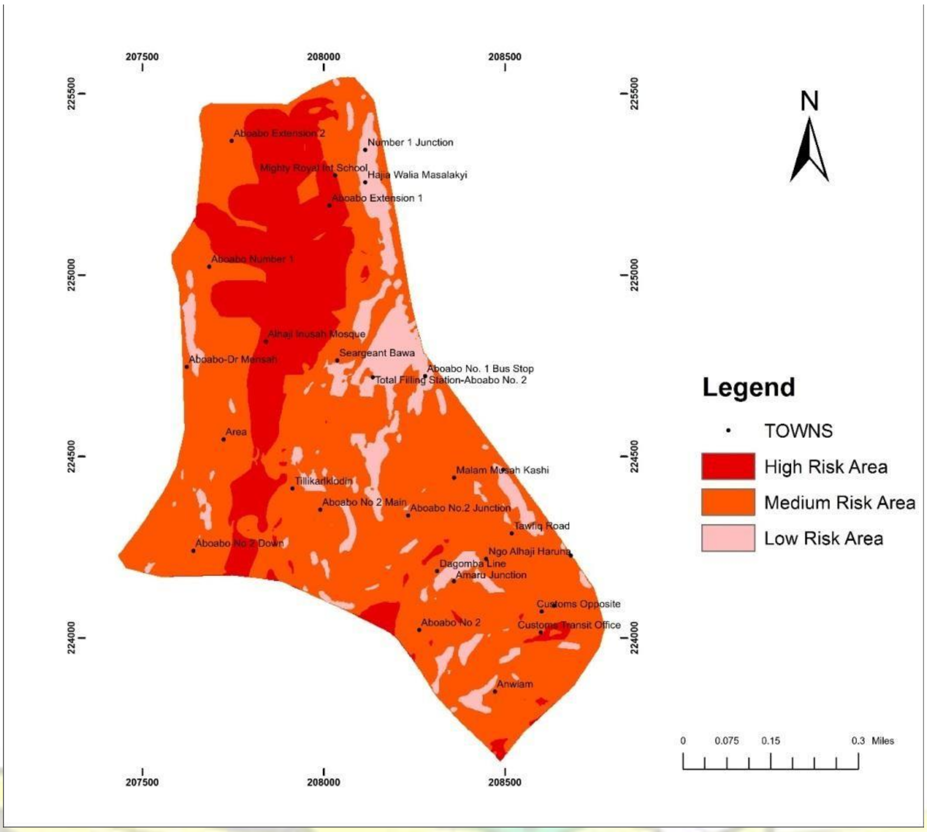

Figure 4.12: Flood Risk Map of Aboabo Showing Towns in the Community

4.4 Flood Simulation/Modelling

Table 4.2 shows the six cross-sections which were determined along the drainage line with the mean bottom elevation.

Table 4.3: Table showing the bottom elevation and Mean Bottom Elevation at Consecutive Cross-sections

Cross-sections	Bottom Elevation	Mean Bottom Elevation at Consecutive Cross-Sections
A-A'	251.32	251.07
B-B'	250.82	250.51
C-C'	250.20	249.84
D-D'	249.48	249.08
E-E'	248.67	248.24
F-F'	247.8	

Figure 4.13 shows the top and side view of cross-section positions along the drainage line of the basin/catchment under study.

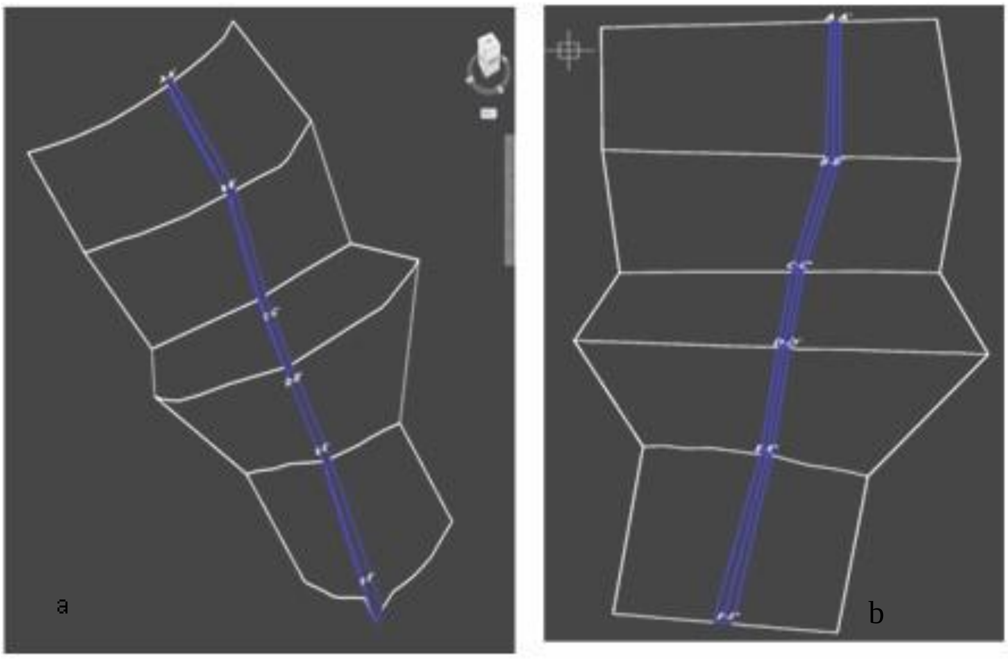

Figure 4.13: Top (a) and side (b) view of Cross-section Positions Along the Drainage Line (Vertical Exaggeration *10m)

Table 4.4 shows the flood level contours derived from flood water levels for each of the consecutive cross-sections.

Table 4.4: Flood Contour Levels and its Corresponding Water Levels in Metres

CROSS-SECTIONS	MEAN BOTTOM ELEVATION	Flood Contour level	Water level (m)	Flood Contour level	Water level (m)	Flood Contour level	Water level (m)	Flood Contour level	Water level (m)	Flood Contour level	Water level (m)
A-A'/B-B'	251.069	252	0.931								
B-B'/C-C'	250.513	251.6	1.087	252	1.487						
C-C'/D-D'	249.843	251.2	1.357	251.6	1.757	252	2.157				
D-D'/E-E'	249.078	250.8	1.722	251.2	2.122	251.6	2.522	252	2.922		
E-E'/F-F'	248.243	250.4	2.157	250.8	2.557	251.2	2.957	251.6	3.357	252	3.757

The flood level contours derived for the selected flood water levels indicated areas that will face likely inundation in the event of any flood at the specified water levels. The flood level contours were converted into polygons in ArcGIS. The flood contours indicated the flood extents at a given flood level. The flood model extents were further overlaid on a geo-referenced Google Earth image of the study area which visibly illustrated areas at risk in the event of floods. The image in Figure 4.14 shows areas of the study area that will be inundated at the specified flood water levels (Forkuo and Tsawo, 2013).

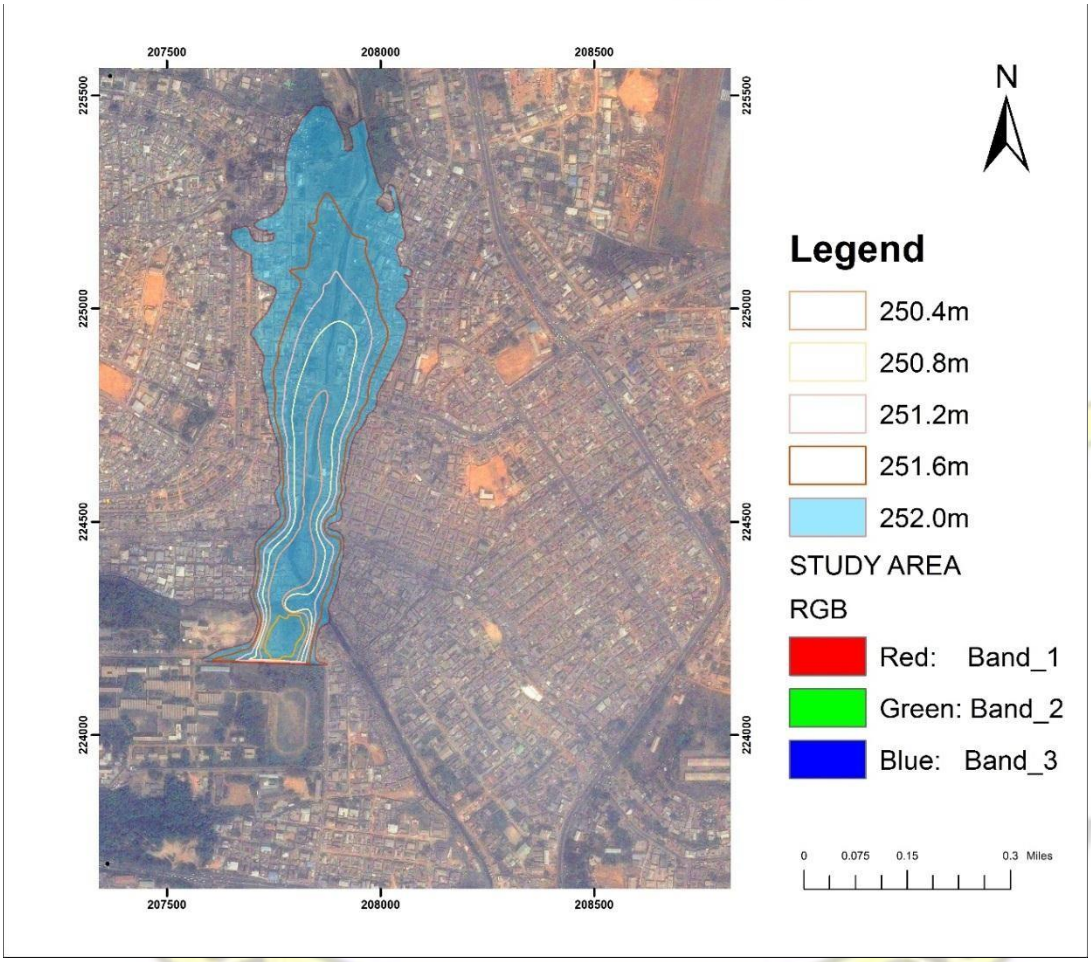

Figure 4.14: Flood Extent at Flood Water Levels

4.5 Results for Questionnaires and Interviews

4.5.1 Demographic Characteristics

A total number of 238 questionnaires were administered with 200 responding.

Majority of the respondents were selected from Aboabo Extension (69) and Aboabo Number 1(53) due to information gathered from reconnaissance survey indicating the frequent and severe effects of floods in their areas. Forty eight of the respondents were from Aboabo Post Office whiles

30 were from Aboabo Number 2 which recorded the least occurrence of flood amongst these suburbs. Out of the 200 administered, there were responses from 104 males and 96 females. The distribution as can be seen in Appendix C3 shows that majority of the respondents the questionnaires administered fell within the ages of 2039 years which represents 48.5% of the population sampled, 6% were under 20 years,
33.5% were between the ages of 40-59, 8.5% represented 60-79years, and 3.5% represented those above 80 years. 29% of the sampled population had only primary education, 33.5% had up to secondary education, and 10% had reached the tertiary level whiles 27.5% had no form of education. A greater number of the sampled 200, that is 91 respondents, were self-employed, 65 were public/civil servants, 17 were students and 27 of the respondents were unemployed as shown in Appendix C3.

Figure 4.15 indicated a majority of respondents, 191 out of the 200 had experienced flooding in the community at some point while just 9 respondents had not. This confirmed the fact flooding is of frequent occurrence in the community.

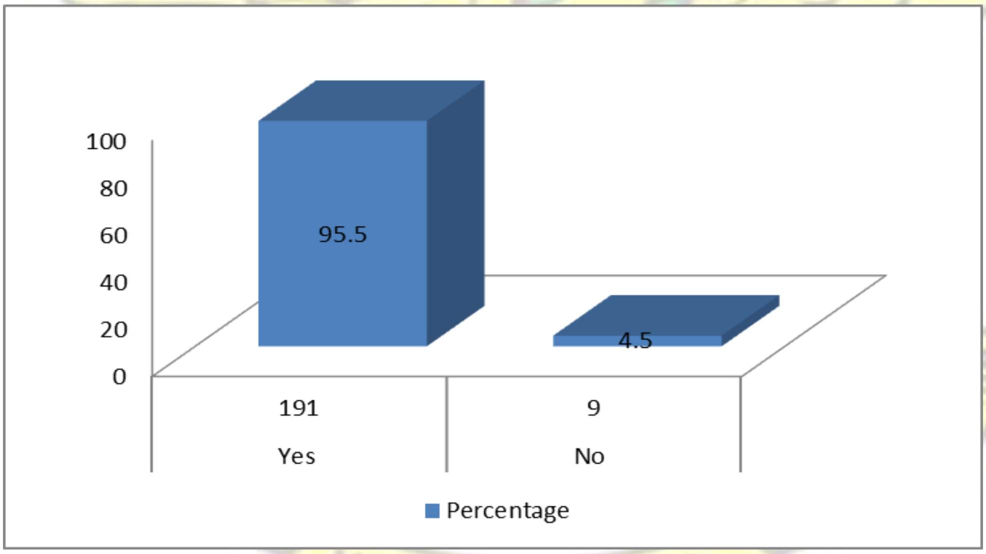

Figure 4.15: Number of respondents who have experienced floods in the Community

35% of the respondents stated the floods occurred annually, 24% responded it occurred biannually, 15% indicated it occurred biennially, 21.5% said it is a regular occurrence, more than three times a year whereas 4.5% responded it never happened.

4.5.2Causes of floods

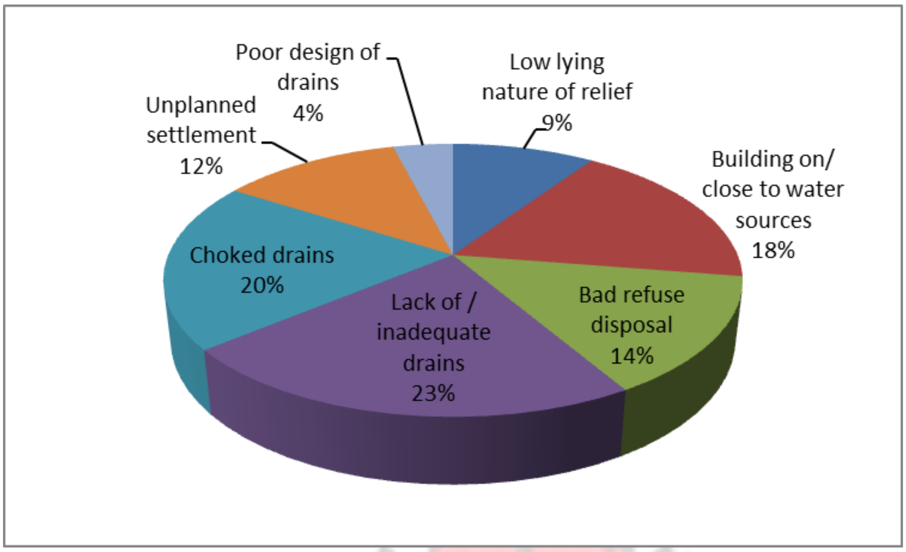

Figure 4.16: Causes of floods according to respondents in the Community

Figure 4.16 gives an overview of the main causes of floods according to the respondents. The major causes of floods were lack of inadequate drains according to 23% of the respondents and choked drains as can be seen in Figure 4.17a and b which formed 20% of the response.

Figure 4.17: Showing some Causes of Floods in the Community: a Shows Drains Choked with Solid and Liquid Waste, b Shows a Resident Clearing a Drain of Silt, c Shows Part of a Drain Destroyed

The next cause of floods according to the survey was 18% indicating building on or close to water sources, 14% stated bad refuse disposal, 12% indicated unplanned settlements, 9% stated low lying nature of relief and the remaining 4% attributed the cause of floods in the Community to the poor design and condition of drains as seen in Figure 4.17c.

Figure 4.18: Buildings Lined up less than 100metres from the Bank of the Aboabo River

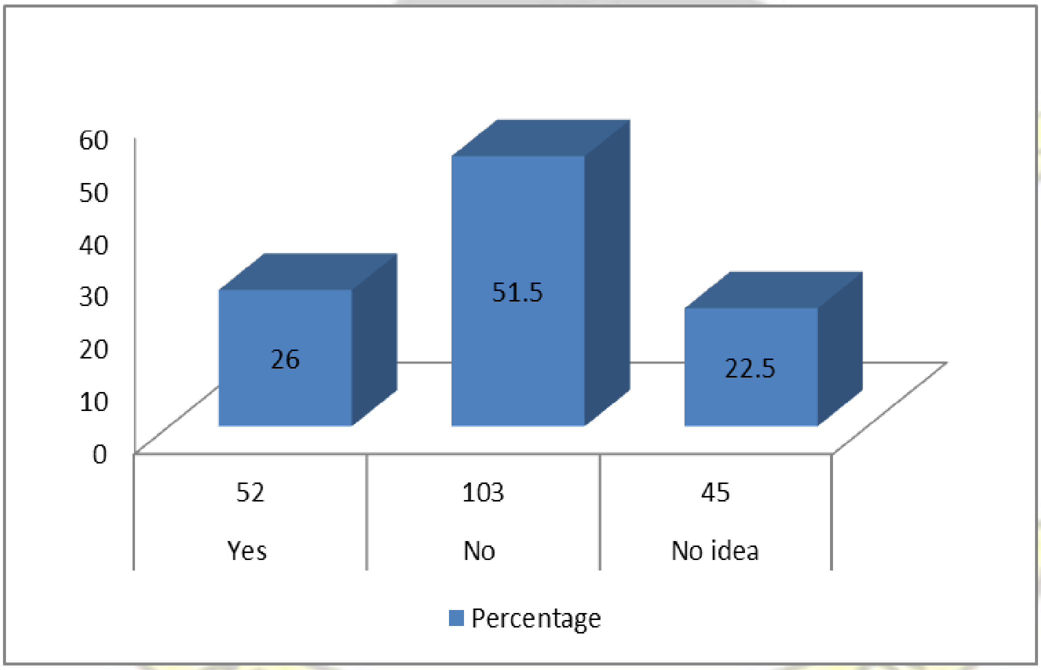

Figure 4.19: Respondents in the Community on Authorization to Build

There was a follow up question with regards to authorization to build as presented in Figure 4.19. Twenty six percent responded they acquired building permits before building, 51.5% responded they did not while 22.5% had no idea as to what building authorization was or what the need for building authorization was. This illustrates that quite a number of people build or set up structures without proper authorization and this has contributed to the causes of floods in the community.

Figure 4.18 shows buildings lined up less than 100 metres from the bank of the Aboabo River.

Figure 4.20 shows a portion of Map of the study area showing an overlay of the stream network on the topographic map of the study area in ArcGIS. This overlay revealed some parts of the urban areas built to obstruct the stream network channel.

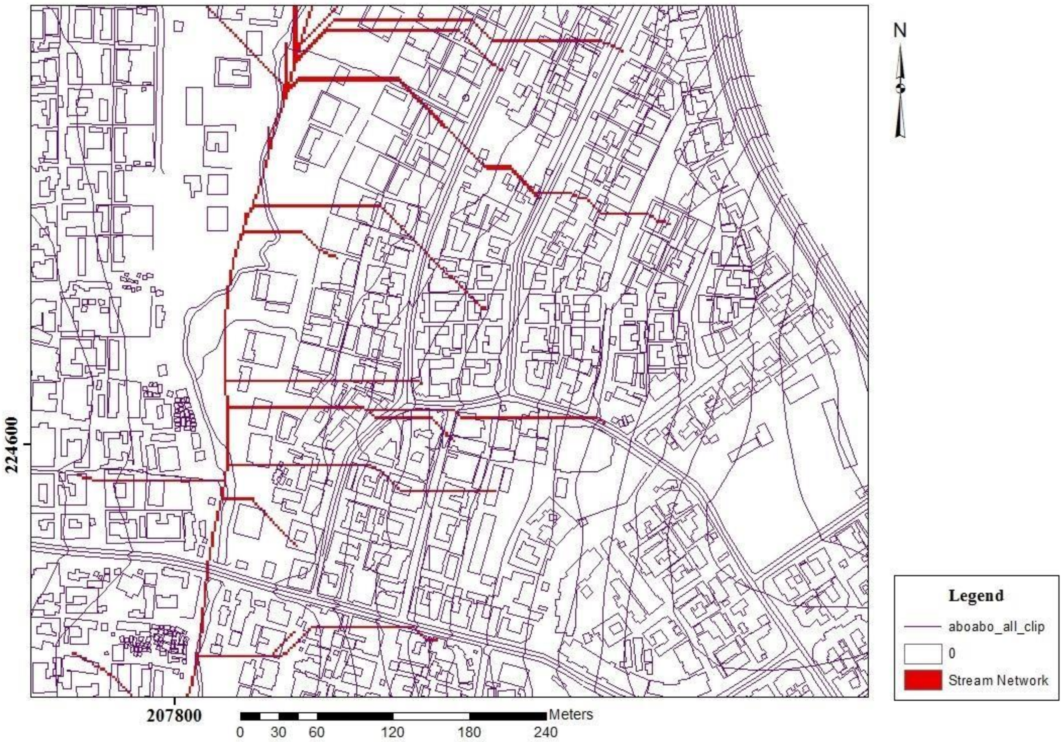

Figure 4.20: Figure showing a Portion of Map of the Study Area Overlaid on the Stream Network on the Topographic Map of the Study Area

4.5.3 Impact of flood on Buildings and Roads

The impact of floods on buildings and roads was very important in investigating the effects of floods in the Aboabo community. From the questionnaires administered, it was deduced that 129 out of the 200 respondents rented their accommodation while the remaining 71 owned the houses. 45.5% of the respondents lived in buildings built with cement blocks, 27% with bricks, 15.5 % with plywood whiles 12% lived in the traditional _atakpame' houses made with clay/mud. Forty eight of the respondents had a part of their houses caving in/collapsing as a results of the floods whiles 152 of the respondents had no significant damage to the housing itself but some recorded instances of losing windows or doors and damage to the roofing of their buildings. Thirteen percent of the respondents had to relocate either temporarily or permanently when the floods set in while 87% did not. Figure 4.21 shows a representation of the damaging effects of floods on buildings and structures in the study area.

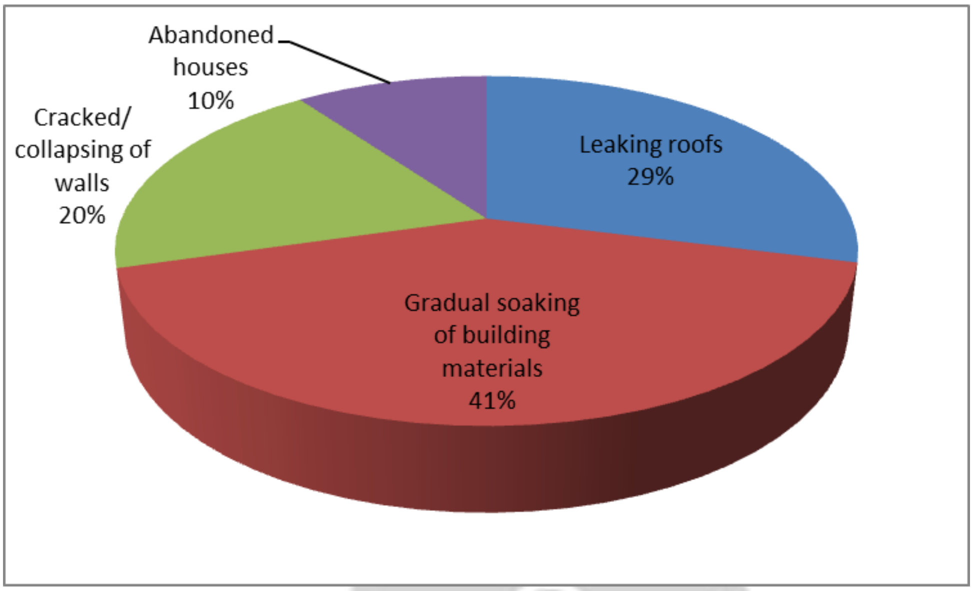

Figure 4.21: Damaging effects of floods on buildings and structures in the Community

Respondents were further probed on the damaging effects of the floods on physical structures. Forty one percent indicated there was the gradual soaking up of the building material especially building blocks which caused moulding and weakening of the structures over time. Twenty nine percent of respondents further indicated leaking roofs, 20% stated the floods caused the cracking/collapse of walls while 10% had to abandon houses totally and relocate. This proved how physical structures have been badly affected by the floods. Figure 4.22 shows the Alhaji Inusah Mosque which has been closed down due to the gushing in of flood waters in events of flood. Figure 4.23 shows some of the effects of floods on buildings and structures.

Figure 4.22: Alhaji Inusah Mosque

Figure 4.23: Effects of Floods on Buildings: a Showing Parts of the Walls of a Building Caved in by Floods, b showing a House some Few Metres from the River Bank Totally Abandoned due to the Constant Intrusion of Flood Water

62.5 percent of the respondents stated the loss of properties and valuables destroyed by the floods included mainly furniture, clothes, and electrical appliances including television sets, radios and sound systems.

Figure 4.24 shows that 49 percent of the respondents had the flood water staying at ground level, 26% had it gushing into the rooms through windows and doors and 25% went as far above the window level.

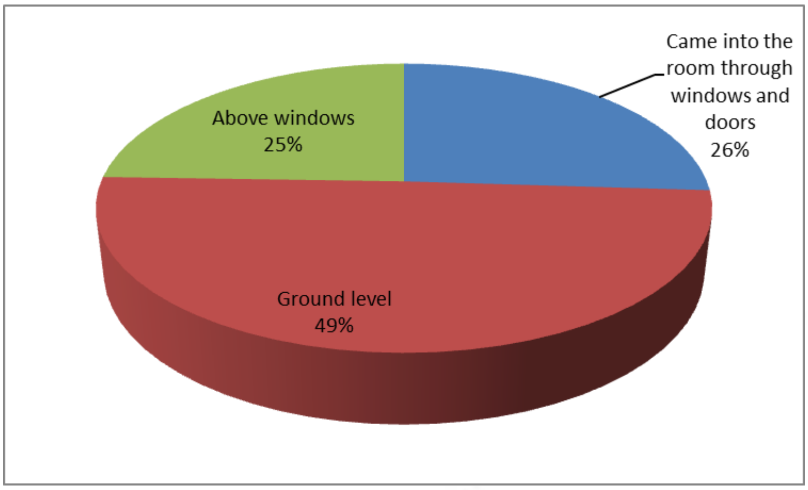

Figure 4.24: Level of Rise of Floods on Buildings as Indicated by Respondents

It was observed that members of the Community moved from one part to another mainly through foot/pathways. It was therefore of no surprise the survey as shown in Figure 4.25 indicated a majority of respondents, 54.5%, indicating the major means of transport that is affected by the floods is foot/pathways. 25.5% especially those who had to commute by road to and from their trade/business set ups indicated the effect of the floods on roads making it difficult for transportation services to run regularly.

20% further stated that the footbridges were seriously affected. Some respondents stated that, the water level sometimes rises up above the level of the bridges and in the process submerges them temporarily making them impossible to tread upon when flooding occurs.

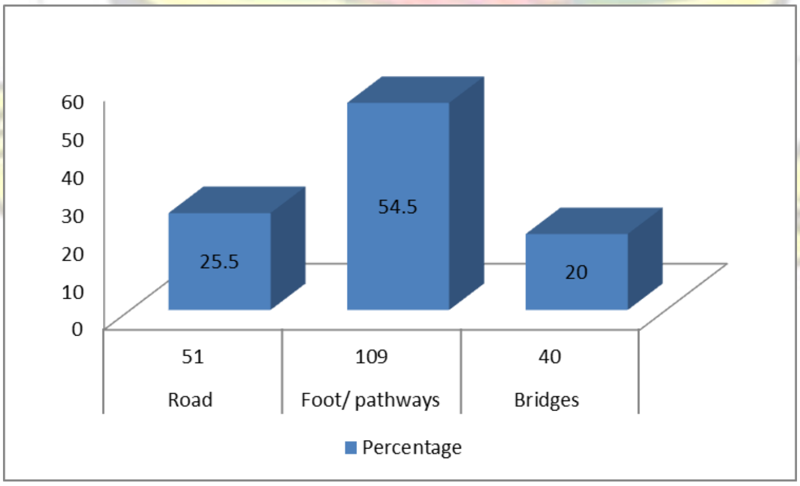

Figure 4.25: Showing means of transportation affected by floods as indicated by Respondents

Figure 4.26 illustrates some effects of floods on footbridges and foot/pathways.

Figure 4.26: Effects of Floods on Footbridges and Pathways: a showing a footbridge in Bad State, b showing Foot/Path way covered by Flood Water, c Showing Difficulty in Accessing Footpath

It was further observed that some portions of the roads were destroyed due to erosion as shown in Figure 4.27. This poses serious risk to motorists and can easily cause accidents.

Figure 4.27: a, b and c Showing Effects of Floods on Roads

4.5.4 Impact of Flood on Health

The health consequences due to flooding are complex and quite difficult to attribute to the flood event itself. Deaths, injuries such as sprains, water borne diseases and mental health illnesses are basically the main health effects during and after the flood event.

Majority of respondents, 97.5% ,% stated that health facilities were not affected by the floods. The premises and health facilities in the Community as shown in Figure 4.28 which include Paradise Maternity Home and Clinic, God of Kings Clinic (Bunsuo) and Asnod Traditional Medical Clinic are mostly not affected by flooding.

Figure 4.28: Health Centres in the Community

However, 47.5% stated it was impossible to access health facilities during flood events due to inability to move out of their compound and flooding of foot/pathways, bridges and roads. 52.5%, however, stated that the floods did not affect their access to health facilities.

52.5 percent of the respondents stated that at least a member of their household has been hit by some sort of ailment as a cause of the floods whiles the remaing 47.5 percent stated there has been no such incidence.Among the 105 respondents, Figure 4.29 indicates 46% reported there was an upsurge of malaria due to stagnant water which breeds mosquitoes as shown in Figure 4.30. Figure 4.29 further represents 19 percent indicated stated cases of typhoid fever, 11% stated diarrhoea whiles 14% stated fever and the remaining 10% stated cholera.

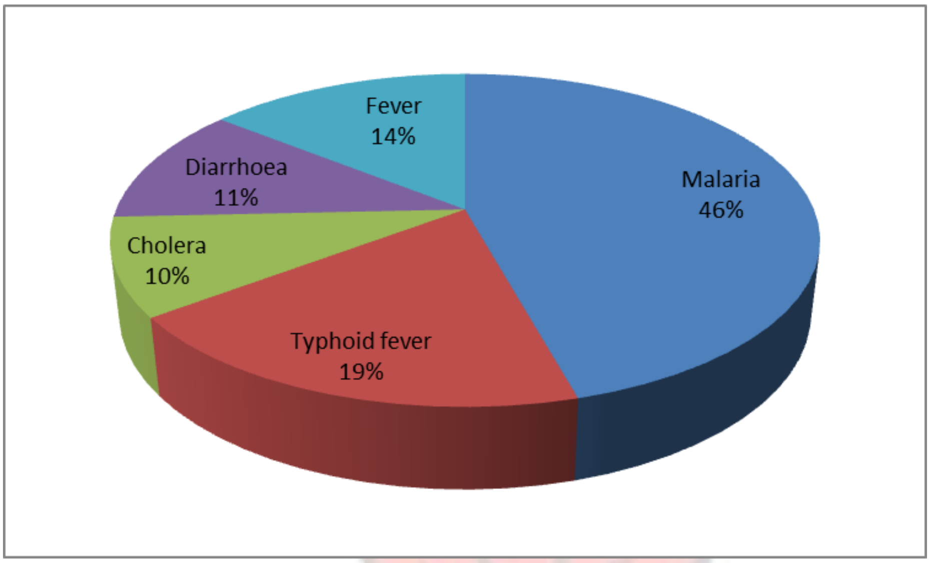

Figure 4.29 : Ailment faced by Residents during and after Floods as Indicated by Respondents

Figure 4.30- a,b,c showing Stagnant Flood Water after a Downpour

44 percent stated there were some cases of injuries due to sprains and strains basically in an attempt to move away from the flood waters and also due to the invisbility of bridges, footpaths and drains whiles 56% stated there has been no such incidence.

37.5% stated there has been reports of death due to floods in the community whiles 62.5% indicated they have not heard of any death cases due to floods.

4.5.5 Impact of Floods on Education

99 percent of the respondents stated some educational facilities were found in the Community with 1% responding in the negative. Figure 4.31 and Figure 4.33 shows the premises of Mighty Royal Primary and Junior High School which is greatly affected by floods anually. The school is situated less than 100m from the Aboabo River.

Figure 4.31: a,b,c Showing the Premises of Mighty Royal Primary and Junior High School

However , 78% respondents stated there was no physical damage to the school buildings due to floods while 22% noticed some change in the school buildings in the community as a result of floods such as the gradual soaking of the blocks which leave water marks. This causes moulds and blackens with time. There is also the occurrence of erosion of some portions of the school compound/premises and its immediate surroundings.

Figure 4.32: Inside the Premises of Mighty Royal Primary and Junior High School- a Showing Researcher Interacting with a Teacher, b Showing Students Returning to Classrooms after Sweeping Rain Water off Compound after a Downpour.

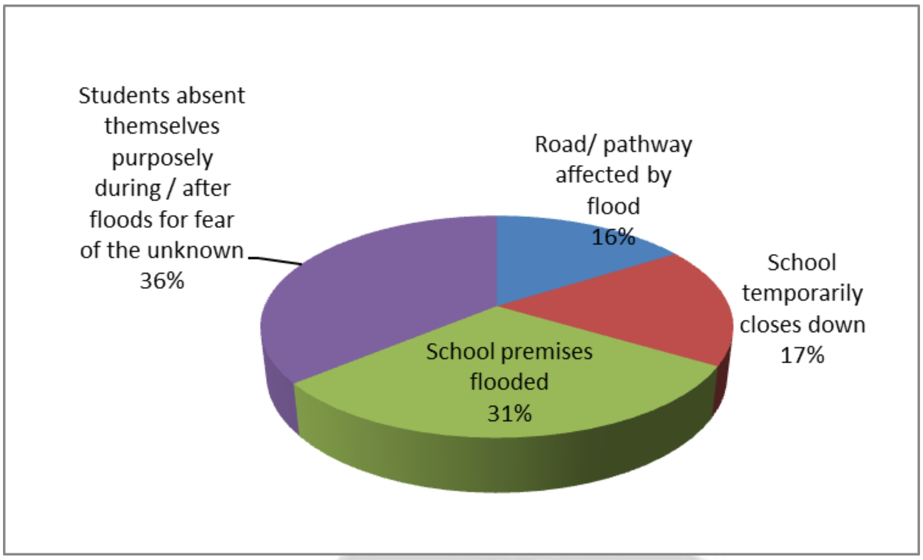

Figure 4.33: Effects of floods on Education as stated by Respondents

Figure 4.33 indicates flood occurrence indirectly affected the attendance of students and school activities. Thirty six percent of the students absent themselves purposely during/after floods for fear of the unknown, 31% due to the flooding of the school premises, 17% responded schools temporarily close down in the events of floods whiles 16% attributed their absence due to road/pathway being affected by floods.

4.5.6 Impact of floods on Water and Sanitation

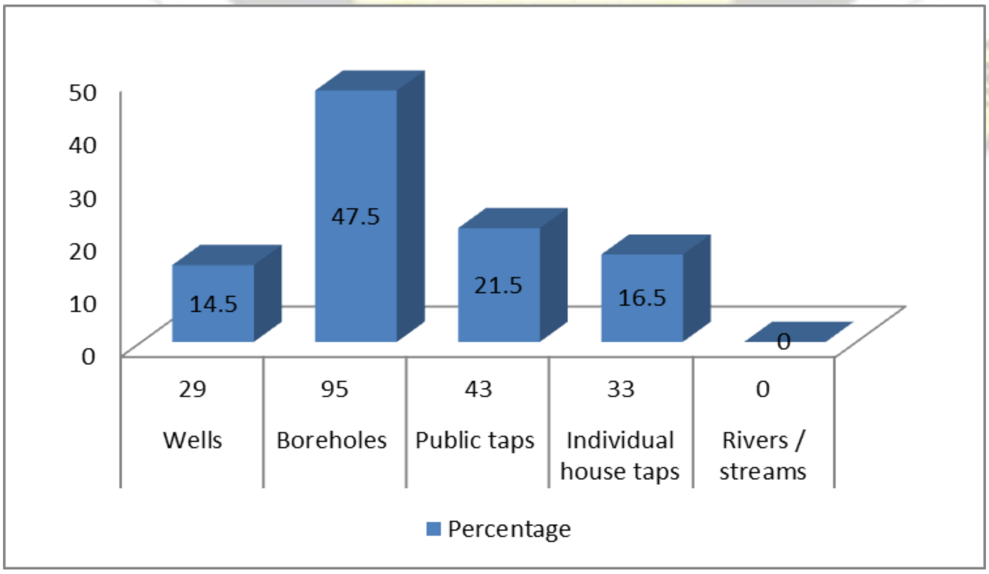

Figure 4.34: Sources of Water of Residents in the Aboabo Community as Stated by Respondents

The questionnaires administered asked respondents about sources of water in the community as indicated in Figure 4.35. Figure 4.34 shows respondents (47.5%) indicating that the biggest source of water is boreholes, 21.5% stated public taps, 16.5%, individual house taps, followed by both open and closed wells which formed 14.5%. Some residents stated rivers could have been a good source of water but the water from rivers is unsuitable for drinking or household activities.

Figure 4.35 : Showing some Sources of Water that are Affected by Floods in the Community- a showing Open well, b Showing Standing Public Taps, c Showing Individual House Taps

Respondents indicated all sources of water are affected by floods when they do occur.From Figure 4.36 , 41 % representing 82 of the respondents specified that open/closed wells are the sources of water most affected by floods, 23.5% representing 47 of the respondents stated boreholes, 15.5% signifying 31 of the respondents pointed out public taps gtes affcted by floods, 12.5% representing 25 of the respondents stating river/streams while the remaining 8% representing 15 of the respondents stating individual house taps.

Respondents indicated that one of the major causes of flooding in the area was bad sanitation and poor waste disposal practices in the community. The research further probed into the methods of waste disposal adapted by residents in the community.

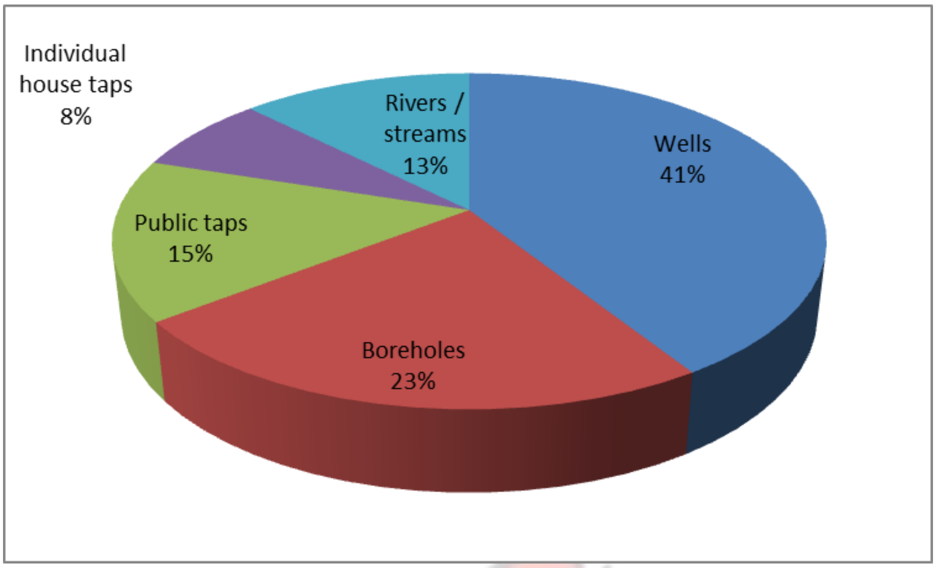

Figure 4.36 : Showing the Percentage of Respondents Indicating the Source of Water affected by Floods

From Figure 4.37, majority of the respondents, 28%, pointed out that they dumped their waste into the river, streams or drains, 20% indicated they burnt their rubbish, 16% stated they disposed of their waste using the public refuse damp, 14% specified the use of open places, 13% stated waste collectors and 9% responded land fill sites.

Figure 4.38 shows some forms of waste disposal in the study area.

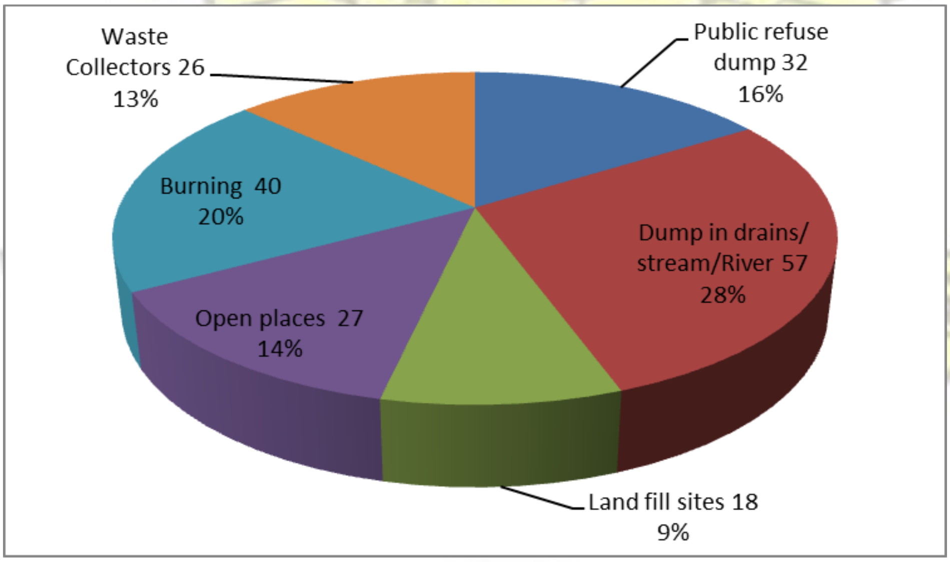

Figure 4.37 : Respondents' Response to Disposal of Waste

Figure 4.38: a,b,c Showing some Forms of Waste Disposal in the Community

From the survey , Figure 4.39 indicates that majority of the respondents,95, representing 47.5% use the public toilets, 25.5% used open defecation (free range), 23% have individual house toilet facilities whiles 4% used pit latrines.However, 51.5% stated free range was mostly affected by floods when they do occur, 27.5% stated pit latrine, whiles 15.5% indicated individual house toilet facilities with the remaining 5.5% mentioning public toilets as being affected by floods when they do occur.

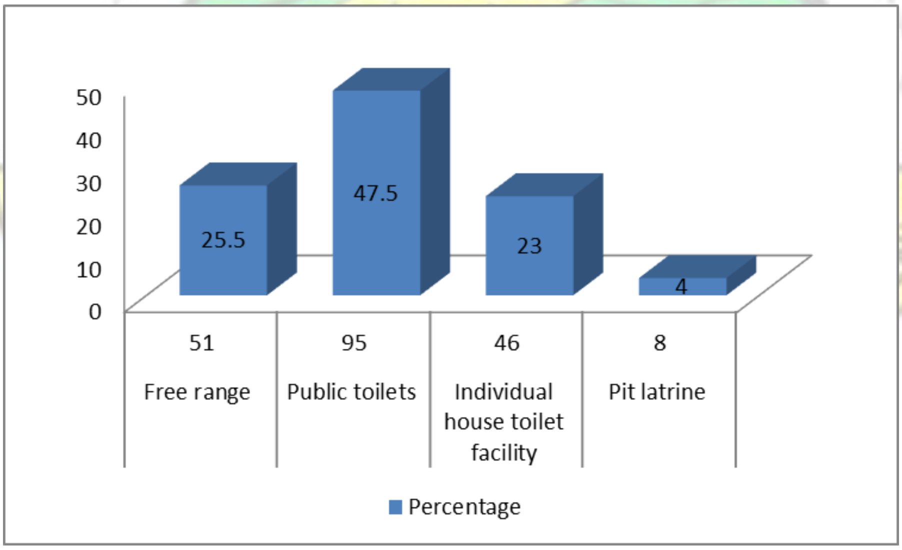

Figure 4.39: Sanitary Facilities used in the Community as Indicated by Respondents

4.5.7 Impact of Floods on Trading and Business activities

The research sought to investigate the impact of floods on trading and business activities in the community. From Figure 4.40, 81percent of the respondents stated the occurrence of

floods affected trading and business in the community whiles the remaining 19% pointed out it does not.

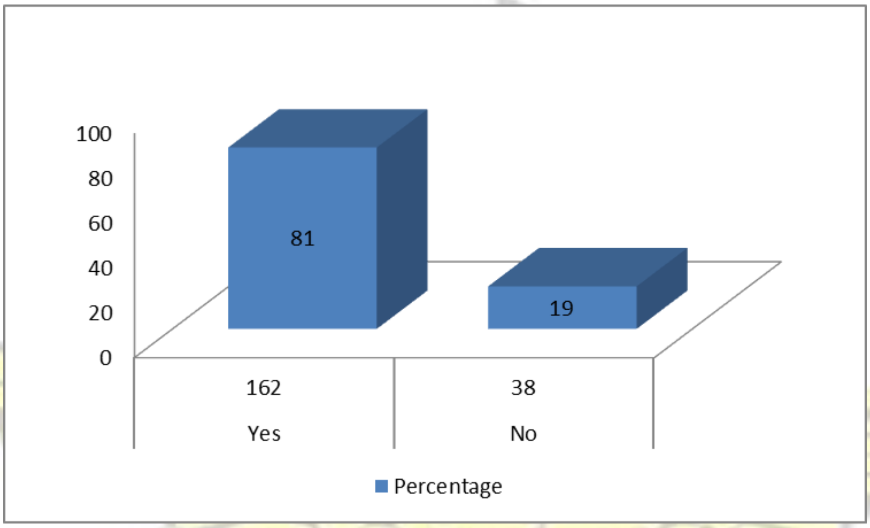

Figure 4.40: Respondents Response to the Effect of Floods on Trading and Business Activities

Respondents were further asked about the effects of floods on trade and business activities in the community as represented in Figure 4.41. Twenty five percent indicated there is loss/damage to buildings, money, stock, equipment, fittings, etc. as can be seen n Figure 4.43, whiles 22% pointed out there is low patronage from customers, 20% stated it tarnished the business‘s reputation and image and 20% stated the shops and trade sites are temporirily closed when floods set in and the remaining 13% stated there is reduction of time business/trade is conducted.

Amongst the 200 respondents, 62 of them had some trade/business in the community and 138 did not. The 62 were further probed as the impact of floods to their trade/businesses. Fifty three out of the 62 stated it did whiles the remaining 9 stated the floods did not affect their business/trade.

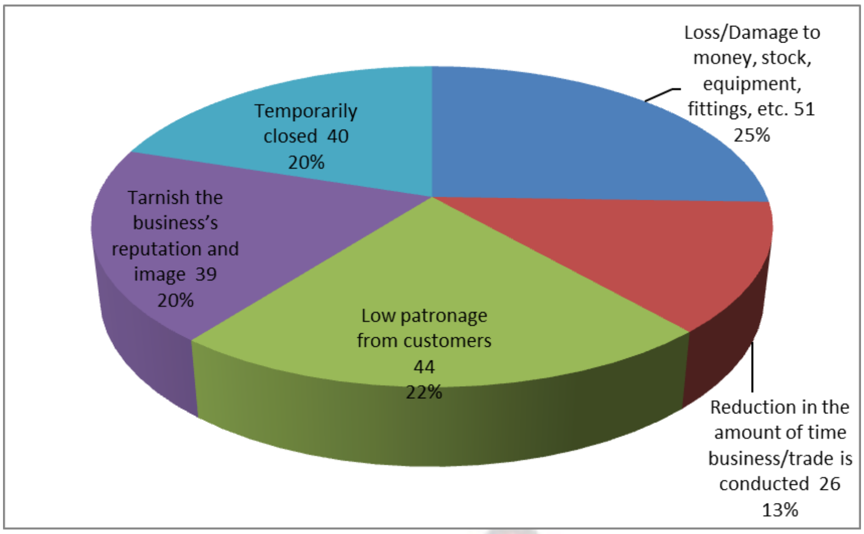

Figure 4.41: Effects of Floods on Trading and Business activities as Indicated by Respondents

From Figure 4.42, 53 respondents who had trade/ business in the community stated an estimate of the monies and income lost due to the occurrence of floods anually in the vicinity. 37.74 percent reported the estimate to be between 1000-5000ghc, 30.19% indicated between 500-1000Ghc, 18.87% stated below 500ghc , 3.77% stated above 5000Ghc whiles 5% could not clearly estimate the cost.

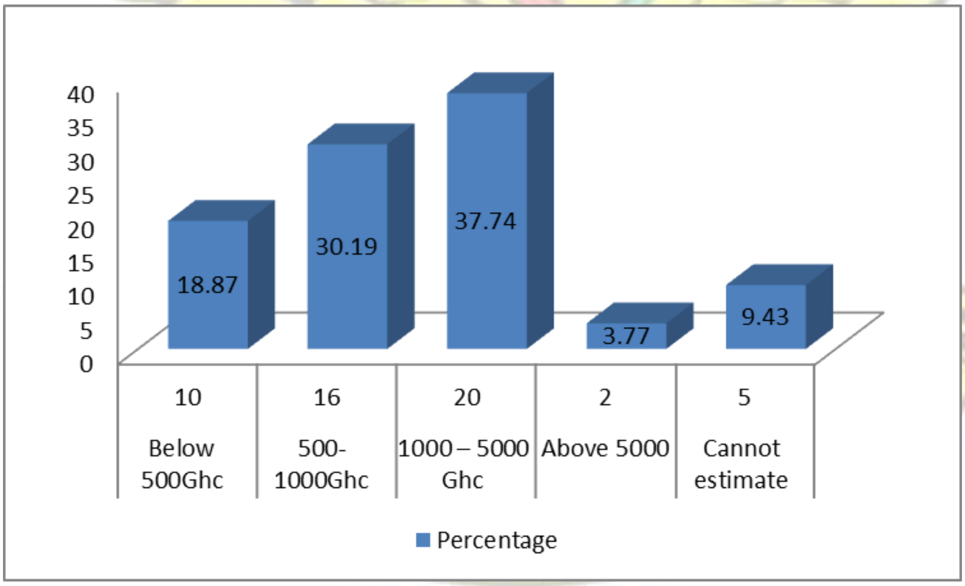

Figure 4.42: Estimation of Monies and Income Lost Annually by Owners of Trade and Businessses in the Community Due to Flood

Figure 4.43: Showing Effects of Floods on Trading and Business Activities – a Showing a Shop with Flood Extent Marks on its Wall, b Showing Researcher Interacting with an Owner of a Shop in the Community

4.5.8 Help/Relief

Respondents were further interrogated on help/aid received during and post floods as shown in Figure 4.44.

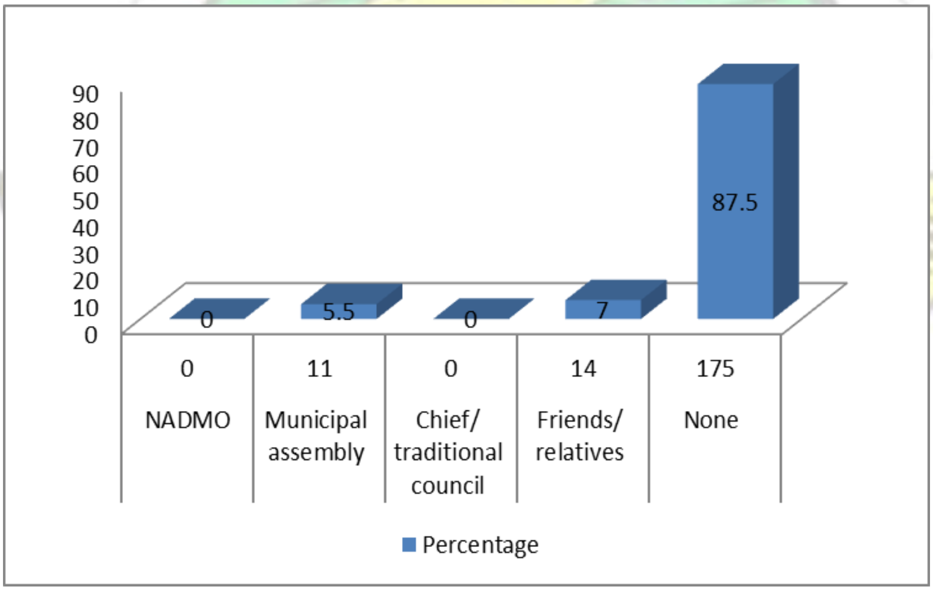

Figure 4.44: Respondents Response indicating any Form of Help/Relief during or Post Floods

Majority of the respondents,175 forming 87.5% stated that they receive no form of help/aid including relief items during and after floods. None of them have ever received any sort of help/aid from either NADMO or the Chief/Traditional Council, whiles 14% indicated they received help from Friends/Relatives and the remaining 5.5.% stating the Municipal Asembly offered some form of help/aid during the events of floods or post floods.

4.5.9 Flood Prevention

Figure 4.44 represented 57.5% of the respondents indicating floods can be prevented. On the contrary, 26.5% stated floods were inevitable and are bound to occur no matter what measures are put in place whiles the remaining 16% stated they had no idea if floods could be prevented or not.

The 115 respondents who stated floods can be prevented were further probed on suggested means of prevention.

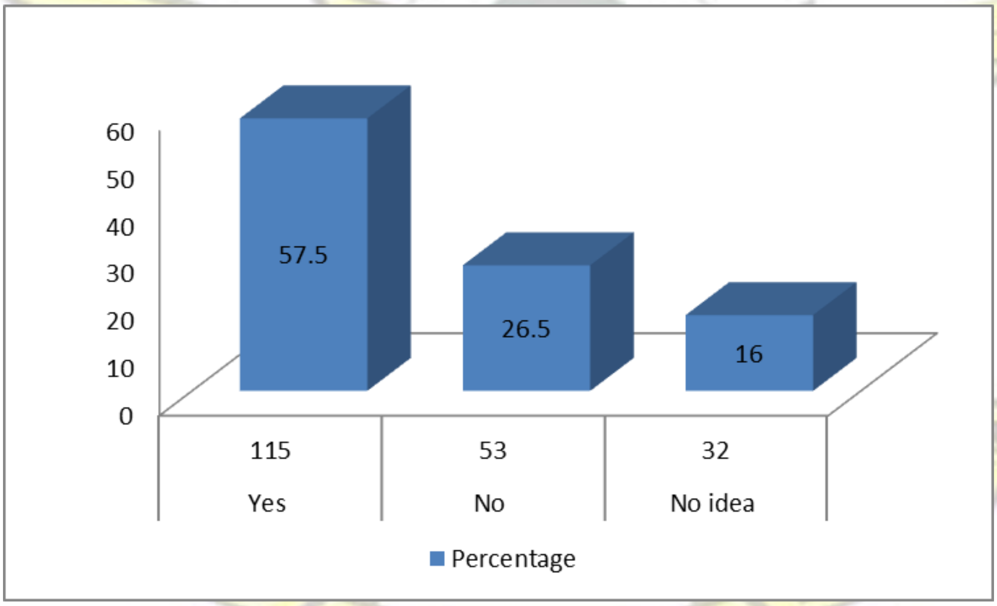

Figure 4.44: Respondents' Response on the Possibility of Prevention of Floods

From Figure 4.45, 30 out of the 115 which represents 26% of the respondents who stated floods could be prevented stated provision/proper maintenance of adequate number of drains could help prevent floods. Twenty two percent stated proper disposal of rubbish, additional 22% indicated education on prevention and dealing with floods could curb the incidence of floods.

However, 20% stated that building at authorized places and the remaining 19% indicated the raising of buildings/shelters/shops well above ground level could help ease the damaging effects of floods in the Aboabo Community. Some residents however suggested the raising of levees along the banks of rivers and streams to prevent flood waters from overflowing its banks.

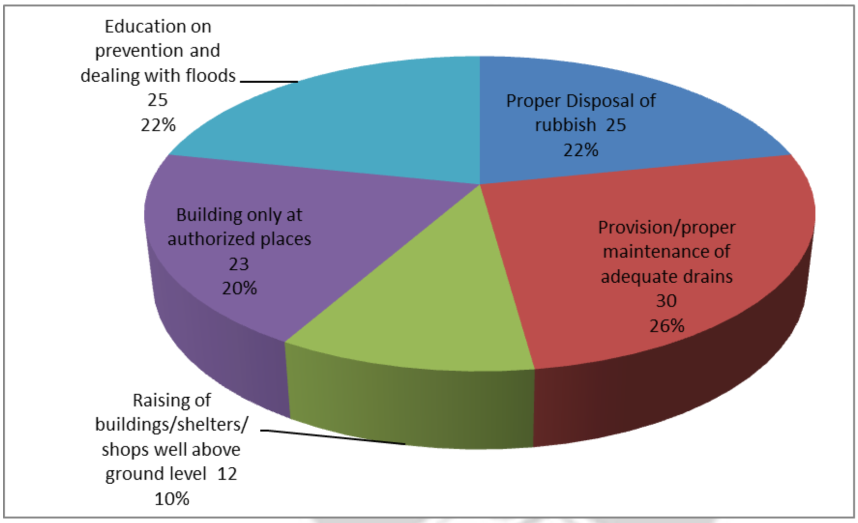

Figure 4.45 : Respondents' Suggestions on Flood Prevention

Figure 4.46: Some Strategies Adopted for Flood Prevention- a Showing some Form of Leeves Raised on Banks of River, b Showing Raised Structures off Ground Level

4.6 Results for Interviews

These results were deduced from the interviews conducted with stakeholders.

4.6.1 National Disaster Management Organization

The National Disaster Management Organisation (NADMO) is one of the government agencies that deal with management of disasters such as fire outbreaks, floods and other emergencies in Ghana. The tasks of NADMO are designed in to ensure that in periods of emergency, the government is prepared to fund relief efforts. The functions of NADMO include:

- Rehabilitation services for victims of disasters,
- Mobilization of people at various levels of society to support governmental programmes
- Ensuring the preparedness of the country in the management of disasters
- Coordinating the activities of various governmental and non-governmental agencies in the management of disasters
- Response to earthquakes, floods and rainstorms, and fires.

However, responses to flood disasters have been one of the main obligations of NADMO.

Flood prone areas are identified by past records and history on flooding in the municipality. The Organisation had no special policies or activities designed for flood prone areas and also were not equipped both materially and financially to carry out their duties. NADMO officials claimed the dumping of refuse into drains and rivers were the main cause of flooding in the Aboabo community. Some further added that, inadequate drains and haphazard ways of building by residents in the community contributed immensely to causing floods in the community. Officials stated that the Asokore Mampong Municipal Assembly had to wait on funding from the NADMO headquarters in Accra to offer relief to the flood victims but mostly the wait is futile (NADMO, 2014).

4.6.2 Town and Country Planning Department (Municipal Unit)

The Town & Country Panning unit of the Asokore Mampong Municipal of the mainly focuses on the provision of planning schemes (layouts) for both public and stool lands under the Municipal Assembly. It also deals with the formulation of policies to serve as a guide to the spatial growth and physical development of the Municipal Assembly. It therefore aims at promoting sustainable human settlements development based on principles of efficiency, orderliness, safety and healthy growth of communities. It further deals with the management of development plans in the Municipal to ensure organized and sustainable physical and socio-economic developments within the Asokore Mampong Municipal Assembly.

Officials at the Department stated that majority of land owners did not abide by the zoning plans when setting out their buildings. They further stated they worked directly with the Land Commission precisely the Survey Department when developing layout schemes and land use maps. Therefore zones close to the banks of Rivers are marked out as flood prone zones and not suitable for habitation. However, residents carry out their construction with little or no regards to the zoning plans.

Additionally, most of them did not obtain building permits before commencing construction works. They believed this was one of the major causes of floods since some of these buildings obstruct floodplains and the drainage system. The Assembly had an excavator for pulling down houses built without authorization. This excavator broke down two years ago and has since not been repaired. Officials further stated the lack of resources both financially and logistically restricted them from carrying out their set out duties.

Additionally, it should be ensured that rules and regulations regarding building in the flood plains and zoned out areas are seriously adhered to and offenders prosecuted severely according to the law (TCPD, 2015).

4.6.3 Metropolitan Waste Management Department

The Department is responsible for keeping the city tidy and healthy by the provision and delivery of effective and proficient waste collection services and programmes. It further ensures the provision of environmentally acceptable waste disposal services which in turn creates an environment suitable for healthy living.

Officials in an interview stated that the bad sanitary practices of residents contributed greatly to flooding in the community. They attributed the cause to the dumping of both solid and liquid waste into the river and drains, thereby choking them in the process and obstructing the flow of water.

Their function that aids in the prevention of floods includes:

- Cleansing and carrying out routine maintenance of drains
- Evacuating liquid and solid waste from homes and public toilets
- Managing sewage disposal
- Random education of the public on ways to keep their environment clean
- Developing and continuously updating environmental sanitation plans

However, officials stated that due to lack of human and financial resources, some of the functions have been neglected and the few that are carried out are not so effective. In addition, some officials suggested other alternatives such as building of incinerators and free waste collection should be implemented in managing waste disposal in the community. They further stated they had no means of identifying flood prone areas in the municipality (MWMD, 2015).

4.6.4 Ghana Meteorological Agency (GMA), Kumasi

The duties of the Ghana Meteorological Agency (GMA) include the provision of efficient and dependable meteorological information by collecting, processing, archiving, analysing and dissemination of meteorological findings/information to end users (GMA, 2013).

The agency plays no direct role in forming schemes or setting regulations for flood prevention, control and management. However, they coordinate directly with NADMO in giving out information on possible occurrence of floods based on meteorological findings.

They also stated the radio stations were the only means of disseminating information that had to do with rainfall and its intensity. They further indicated this was woefully inadequate (GMA, 2013).

CHAPTER FIVE

5.0 ANALYSIS AND DISCUSSION

5.1 Introduction

This section discusses and analyses the results of the methodology used in this research and its interpretations.

5.2 Analysis of Flood Risk Mapping and Simulation

The flood risk map as shown in Figure 4.11 shows areas within the Aboabo Community classified under three flood risk zones - high, medium and low. This informs the residents as well as stakeholders about the vulnerability of areas within the Community to flooding. Aboabo Community has a total area of approximately 1.2178 square kilometres. From the flood risk map, Figure 5.1 shows 0.8245 sq.km (67.71%) of the study area falling within the medium flood risk zone whiles 0.2589 sq.km (21.26%) fall within the high flood risk zone. The remaining 0.1343 sq.km (11.03%) of the land area falls within the low risk zone. High Risk Zones are most likely to be inundated in the occurrence of floods while low risk zones are at less likely to be inundated when floods occur.

Classified stream buffer zones and slope maps on the depressionless DEM of the study area as shown in Figure 4.8 and Figure 4.10 respectively were used in the production of the flood risk map. Research works by Orok (2011) and Sakyi (2013) showed the combination of stream buffer zone and reclassified slope angles aided in the delineating and classification of study areas into low, medium and high flood risk zones.

The TIN as shown in Figure 4.1 and DEM of the study area in Figure 4.2 illustrated the possible flow of water on the surface of the study area. Further hydrological analysis carried out on the DEM model created served as a guide in the identification of the extent of flood and the effect of the slope and nature of the terrain in flood occurrence (ESRI, 2014).

The filling of sinks in the DEM as represented in Figure 4.3 aided in the understanding of surface water runoff. Flow direction analysis showed the likely direction of surface water runoff on the depressionless model. This analysis further made it easy to identify the gentlest and steepest descending direction of every cell in the depressionless DEM (Sakyi, 2013).

Flow Accumulation analysis as deduced from Figure 4.6 indicated the cells on the elevation model where water collects as it flows downwards (Jenson et al, 1988). These revealed that settlements around the flow cells with high accumulation will most likely receive a much greater amount of water in the event of rainfall or any sudden release of water (ESRI, 2014). The Stream Network delineated showed the path of the stream network system in the study area.

The drainage basin delineated in Figure 4.5 showed areas on the DEM where surface water runoff converges to a particular point at a lower elevation. The lower points were noted to usually be the exit of the basin, where the water joins another water body and where water would pour out of the raster. The surface water on the area of the basin flows in stream channels and the characteristics of the basin such as its area and slope help in the prediction of flooding in any particular basin (UCAR, 2010).

From Table 4.1, it was deduced that the elevation model was mainly characterized by medium slope angles. Further analysis indicated the low slope areas were identified as areas that accumulate a great amount of water and do not allow water to drain downwards easily. High slope areas are areas that allow water to drain down the slope easily (Sakyi, 2013).

The slope of the drainage basin affects both the surface runoff speed and penetration of water. The lower the slope angles of a particular area, the closer to the water level of the area. From Figure 4.10, areas with low slope angles and within the stream buffer zone are at the most risks of being inundated by water in the event of sudden release of water or rainfall fall. Low slope angles indicate a higher rate of infiltration and consequently a decrease in surface runoff which increases the risk of flooding. Table 4.1 indicated that the study area is mainly constituted of medium to low lying areas with slope angles of less than 4.4 degrees, making it highly susceptible to flooding and its attendant implications. This information will greatly inform land use planners in development plans suitable for the community.

It was further deduced from Figure 4.12 that areas in the high flood risk zone such as Mighty Royal School and Aboabo Number 1-Extension fall within the stream buffer zones and also within a low slope angle area. Locations such as Aboabo Number 2 Junction and Tawfiq Road which fall within the stream buffer zone and also fall within the medium slope angle area have medium flood risk. Areas such as Spring

International School and Number 1 Junction fall outside the buffer zone and fall within high slope angle areas are low flood risk areas. Areas which fall outside the stream buffer zones and lie on high slope areas are at less at risk in the event of floods.

The flood risk map in Figure 4.11 indicates that areas with low slope angles that fall within the delineated buffer zone will get inundated at a faster rate as compared to areas with high slope angles that fall outside the buffer zone.

These conditions are however subject to change over the years due to the nature of settlements and human activities in the study area. These factors are likely to increase the vulnerability of the areas to flooding.

Table 4.2 and Appendix A showed the mean bottom elevation of consecutive crosssections determined from the profiles which were generated using field survey data. This represented the average minimum elevation between the cross-sections and depending on these elevations, above which features in the catchment area selected will be inundated during a flood event.

With the mean bottom elevation as a guiding factor as shown in Table 4.4, flood level contours were derived for each consecutive cross-section using water levels at which flood will occur. These flood level contours were saved as new layers and overlaid on a Google Earth image to show the extent of inundation. It also showed consecutive cross-sections, its mean bottom elevations, floods water levels with its corresponding flood contour level. Inundations during flood events varied based on the bottom elevation of river channels and that of adjacent areas. Water levels had to rise and overflow their banks to cause flooding.

However, it was rational to measure elevation of river banks and bottom elevations at consecutive cross-sections; then use the mean of the bottom elevations between consecutive cross-sections for flood simulation. The output contours represented the flood extents at different flood water levels as shown in Figure 4.14.

Field survey and investigations clearly indicated that the areas that were inundated within the predicted flood extents are well known to be at risk in the event of flooding.

It was identified that the affected elements included buildings, mainly residential and commercial establishments, as well as transportation networks. This can be ascribed to the fact that the Aboabo Community is a built up area and hence inevitably constitutes the mentioned features (Forkuo and Tsawo, 2013).

5.3 Analysis of the Causes of Floods

Based on the questionnaires administered and Interviews carried out with respondents in the Aboabo Community and stakeholders, the occurrence and causes of floods were analysed.

One of the objectives of this research was to find out the causes of floods in the study area. This was significant because discovering the causes of floods could aid policy makers and other stakeholders plan mitigation strategies to prevent or minimise the occurrence of floods. From the analysis of the questionnaires administered, the major causes of floods were inadequate drains or lack of drains, choked drains, building on/close to water sources , bad refuse disposal practices, unplanned settlements, low relief and poor design of drains as shown in Figure 4.16.

It was observed that there was an absence of a proper drainage network system in the Community and the few available were choked due to the disposal of rubbish into the drains as well as the presence of silt. Some parts of the drains have also been destroyed for various reasons rendering them incapable of serving the purpose of their construction.

The overlay of the stream network map on the topographic map revealed that some parts of the urban areas are built on the natural stream channels. These buildings and some road diversions obstructs the natural course of water during rainfall (Folorunsho and Awosika 2001; Ologunorisa, 2004; Adeoye et al., 2009). It was observed from field survey that buildings and shelters were set up haphazardly in the Community with a majority having no authorization to build. Houses and shelters built along the banks of the river within the floodplain were most vulnerable to floods. The aforementioned factors make flooding events inevitable.

5.4 Analysis of the Impact of flooding in Aboabo Community

Floods affect residents of the community in diverse ways. They have devastating consequences and affect the economy, environment and people. The effects of floods on health, education, water and sanitation, buildings and roads, trading and business activities of residents in the study area were analysed based on the questionnaires and interviews.

5.5 Analysis on the Effects of floods on Buildings and Roads

The impact of floods on buildings and roads as indicated in Figure 4.21 was very essential in investigating the effects of floods in the Aboabo community.

All respondents stated floods adversely affected buildings in the community. It was observed that some buildings deteriorate over time due to the frequent occurrence of floods.

Flooding in the community has led to the exposure of some parts of the buildings' foundations and has led to the gradual soaking up of base blocks. The weakening of the base blocks and building materials by the floods may result in the collapsing and caving in of buildings and structures. When building foundations are not well rammed i.e. well compacted or weak, frequent occurrence of floods leads to weakening of the foundation. This leads to settling of the building i.e. sinking of the building and consequently leads to cracking of the walls of the affected buildings. Accumulated flood water in parts of some buildings result in dampness which leads to the growth of moulds (Adedeji & Salami, 2011). One of the mosques in the community, Alhaji Inusah Mosque along the Aboabo-Dr Mensah Road has been closed down due to the frequent gushing in of flood water into the mosque which disrupts their praying sessions. The mosque is situated some few metres from the bank of the River.

Some buildings and structures in the community have been abandoned due to the regular intrusion of flood waters through the doors and windows. These flood waters sometimes cover the whole building structure.

Some respondents stated that, the water level sometimes rises up above the level of bridges and in the process submerges them temporarily making it impossible to tread upon when flooding occurs. This inhibits movement which affects the daily activities of residents.

Floods have significant effects on the economic growth of the community. It leads to a reduction in the family income by thousands of cedis due to the increase in costs by trying to fix the damage on houses and buildings and the loss of household gadgets.

5.6 Analysis of the Effects of Floods on Health

Floods create and cause health conditions through waterborne and vector borne diseases such as malaria and typhoid fever. Floods also lead to serious injuries and in some cases, lead to death.

From Figure 4.20, the stagnant water caused by floods serve as breeding sites for mosquitoes, and consequently exposes residents to diseases such as malaria. In some situations, the flood water submerges refuse damps and can lead to outbreak of infectious diseases The disruption of health services that comes up as a result of flood events is basically due to inability to access the few health centres easily as a result of the inundation of foot/pathways and other means of transport.

During the survey, some residents mentioned that they suffered from depression, restlessness and stress during and after floods. They further added they are thrown into a state of worry and despair as they watch on helplessly, the damaging effects of the floods. A section of residents also stated their perpetual fear anytime clouds gather and there is a sound of rain. This fear heightens during the annual rainy season in June/July.

Flooding is associated with the increased rates of anxiety and depression stemming from the flooding experience itself, troubles brought about by displacement from homes, damage to the home or loss of possessions and the stress in dealing with the replacement after its occurrence (WHO, 2002).

Sprains, cuts and strains are the most common injuries during flood events. Some residents in an attempt to move away from the flood waters and also due to the invisibility of bridges, footpaths and drains, suffer these injuries. Flooding events have led to the loss of some lives especially due to drowning or being trapped in the debris. The Assembly Man for Aboabo Number 2, in an interview stated two lives were lost due to floods in 2014.

5.7 Analysis of the Effects of Floods on Education

The occurrence of floods poses a threat to educational infrastructure and has effects on the total well-being of children with regards to school attendance, access to school premises, sanitation, physical and social security of the students.

Schools in the community adhered to early closing hours with the slightest change in the clouds as this signifies the likelihood of rains. Consequently, closing early enabled students to reach their homes in time and not get caught up in any flood. After flood events, most schools in the affected areas are in bad condition. This does not only dishearten the students but also the parents and teachers.

It was confirmed during field survey that the community has a number of schools including Battle Baptist School, New Aboabo M/A, Spring International School, Tigyaniya Islamic School, Nasru-deen Islamic Primary School and Mighty Royal School. Mighty Royal School (Primary and JSS section) which is located less than 100 metres from the River is noticeably affected by floods when there is heavy downpour especially during the rainy season. Some teachers stated cost of relocation deterred the authorities from relocating the school.

Residents living close to the Mighty Royal School in interactions with the researcher stated that the pupils are sometimes carried on the backs of some residents living nearby to escape the danger of the flood waters. The teachers further added that students have to come in early to sweep away flood waters from the premises when it rains. This greatly disrupts school activities as shown in Figure 4.31 and Figure 4.33b.

Schools cannot function effectively without students and its human resources. Floods increase factors such as the disruption of school hours. The difficulty in accessing the school premises can cause school children to miss out on school days or totally drop out of schools frequently affected by floods. With the frequency of occurrence of floods, the teachers may decline teaching offers in these affected areas. Consequently there is a shortage of qualified teaching staff in the schools. Ultimately, this shortage of qualified staff will also affect the enrolment of students, quality of education and hence the overall performance of the students and the schools (Chang et al, 2013).
These factors have negative socioeconomic implications on the Aboabo community.

5.8 Analysis of the Effects of Floods on Water and Sanitation

Water supply and sanitation conditions are greatly affected during floods.

The sources of water in the community which include public taps, open and closed wells, boreholes, the Aboabo River and individual house taps are affected to some degree.

Some open water sources are polluted by both liquid and solid waste which is washed along with the rushing of flood waters. As a result, some open and closed wells have hence been raised off the ground level. Where water sources are not properly protected, there is some amount of contamination.

Some water sources and latrines get flooded and therefore become unusable for some period of time. There is sometimes the disruption of entrance to public toilets by flood waters which causes inconvenience to residents that use these facilities. Improper waste disposal and bad sanitary practices as a result of flooding make it easy for diseases such as diarrhoea and cholera to spread. The general sanitation in the study area is quite appalling. A number of residents dump refuse into the Aboabo River and into drains as can be seen in Figure 4.38b. This was deduced to be one of the major causes of floods and the health effects thereafter in the community.

5.9 Analysis of the Effects of Floods on Trading and Business Activities

In spite of flooding being an annual occurrence in the Aboabo Community, it continues to disrupt the livelihood and business of the residents. Not only do floods affect the homes of residents but their income and occupations suffer greatly during and after the occurrence of floods (Shimi et al, 2010).

Some business owners indicated that they had their premises and buildings fully or partially inundated by flood water. Many also had their stock and equipment affected.

Floods interrupt regular business activities and disrupt working hours. Some businesses are affected through forced business closures with resultant lost sales. Some businesses had been impacted by the floods indirectly through their customers, suppliers and employees being affected by floods. There is also the negative portrayal of some areas in the community constantly affected by floods by the media and residents. Customers are driven away by the perception that once there have been records of floods in that area; all businesses are impacted when it occurs. This leads to low patronage of the businesses especially during the rainy season.

Flood water gushing into the buildings does not just leave the base of the buildings weak with time but also destroys items and equipment in the shops. Residents find it difficult to commute to and fro work due to the inundation of the pathways. Resources including time, money and work force are required to fix the damaging effects caused by floods. Losses caused by floods sometimes run into thousands of cedis and take owners some time to recoup. Majority of respondents' estimated their annual income lost from business due to the impact of floods to be between GH₵1000- GH₵5000 as indicated in Figure 4.42.

5.10 Analysis on Help/Relief

It was realised that 5.5% of respondents affected by floods stated there has been some form of help received from the Municipal Assembly during floods. This form of help mostly included desilting of drains and culverts and pulling down of some structures that obstructs drainage channels. The minority of respondents, who received any form of help, received them from relatives and friends in the form of temporary accommodation and other basic items.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This research sought to identify the causes and socio-economic impacts of flooding on residents in Aboabo Community and to develop flood risk maps that will help mitigate its catastrophic effects. In order to identify the causes and effects of flooding, survey questionnaires were administered to 238 residents of the Aboabo community leading to a response rate of about 84%. The research also utilized Geographic Information Systems and field survey data to generate flood risk maps. The development of flood risk map began with the use of DEM to perform hydrological analysis of the study area. This was followed by analysis on flow direction, flow accumulation, slope angle, buffer areas around stream network and drainage basins in the study area. The reclassified slope angles and the created stream buffer areas were combined in ArcGIS environment to produce the flood risk maps showing three zones -High risk, medium risk zone and low risk zone of the study area. A simple vectorbased simulation was further used to demonstrate the potential of flooding in the identified flood risk zones. Based on the response of the qualitative survey and simulation analysis, the following conclusions were reached.

1. The main causes of floods in study area based on survey responses are inadequate drains (23%), choked drains (20%), and bad refuse disposal (14%). While poor drainage design, unplanned settlement, and nature of terrain were mentioned as possible causes, they were not as dominant as the former causes.

2. The major adverse impacts of flooding in the study area based on survey responses include gradual soaking of building materials leading to weakened structure (41%), leaking of roofs (29%), cracking/collapsing of walls (20%), and forced evacuations/abandoning of houses (10%).

3. Flood risk maps enable accurate identification of high flood risk, medium flood risk, and low flood risk zones in a community based on which appropriate flood management and planning activities can be carried out. This will help flood management organizations such as NADMO to plan ahead of time in terms of their relief efforts as well as help engineering agencies to design appropriate drainage systems and ensure proper planning of communities.

4. Simulations such as the vector-based method offer an accurate means of demonstrating the potential for flooding in communities. As a result, City Engineers/Planners could use simulation tools to identify areas within their jurisdictions that are vulnerable to flooding. This insight will help them make informed decisions regarding where to spend scarce resources earmarked for flood mitigation.

6.2 Recommendations

Flood is an increasing problem in the Aboabo community. Although the occurrence of floods cannot be entirely prevented; hydrologic analysis of the study area and analysis from the questionnaires and interviews on the causes and effects of floods can provide some guidelines which can reduce the vulnerability of residents to floods. The Government, stakeholders and Residents of the Community all collectively play a role in the alleviation of floods.

The preceding findings in the chapters of this study have greatly explored how the use of questionnaires and interviews, GIS techniques coupled with computer simulations have been expedient in answering most of these questions.

It can accordingly be deduced that application of these aforementioned techniques are essential in all the several stages of flood management which includes flood prediction, prevention, mitigation and the identification of flood risk zones (Opolot et al, 2013).

It is recommended that the listed Management guidelines suggested below are established and undertaken to address the identified problems in the Community.

1. Early Warning Systems

They can be implemented with knowledge of flood risk management and support decision-making by involving the Municipal Assembly and the Community in participatory flood risk management analysis and in gathering all necessary information to inform planning and other courses of action.

2. Engineering Solutions

This will include the planning design and construction of adequate drains in the Community to improve the carrying capacity of the drainage network system.

Buildings and structures should be raised well above ground to prevent flood waters from gushing in and destroying properties in case of a flood event. Regulations concerning building should also be adhered to in new infrastructural developments

3. Land-Use Controls

Spatial planning and land use should establish and delineate areas in the community which are at risk to floods and should be avoided for residential development.

4. Improved Waste Disposal and Sanitary Conditions

The capacities of the drains and river channels that are frequently taken up by waste will be released for additional storage of surface runoff water.

Furthermore, sanctions should be put in place if residents engage in undesirable practices.

5. Public Attitude and Education

An important tool towards flood risk management is the education of residents in the community as well as the authorities involved on flood awareness, preparedness and safety.

6. Emergency help/relief

With the aid of the flood risk map, during an event of flood, the emergency response team can easily predict which areas in the Community will need aid the most.

The DEM of the study area should aid in showing the highest elevation points in the Community in case of evacuation.

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APPENDICES

Appendix A: Selected Crossections and their elevations

Crossection	Bank 1	Bank 2	Bottom Elevation at Crossection	Mean Bottom elevation at Consecutive Crossection
A-A'	252.32	252.45	251.32	
				251.07
B-B'	251.82	251.9	250.82	
				250.51
C-C'	251.2	251.28	250.2	
				249.84
D-D'	250.58	250.55	249.48	
				249.08

E-E'	249.87	249.88	248.67	
				248.24
F-F'	249.01	249.01	247.81	

Appendix B:GPS coordinates of Areas in Aboabo Community

		Latitude			Longitude		
ID	Name of Area	Deg	Min	Sec	Deg	Min	Sec
1	Anwiam	6	41	28	1	35	44.4
2	Customs Transit Office	6	41	33.3	1	35	40.3
3	Customs Opposite	6	41	35.2	1	35	40.2
4	Spring Int School	6	41	35.7	1	35	39.1
5	Unity Oil Filling Station-Aboabo No.2	6	41	40.2	1	35	37.6
6	Tawfiq Road	6	41	42.2	1	35	42.9
7	Ngo Alhaji Haruna	6	41	39.9	1	35	45.2
8	Amaru Junction	6	41	37.9	1	35	48.1
9	Dagomba Line	6	41	38.8	1	35	49.6
10	Aboabo No.2 Junction	6	41	43.8	1	35	52.2
11	Malam Musah Kashi	6	41	47.2	1	35	48.1
12	Alhaji Harun Tijanyi Mosque	6	41	47.9	1	35	43.7
13	Alhaji Inusah Mosque	6	41	59.4	1	36	5
	Seargeant Bawa	6	41	57.7	1	35	58.6
14	Total Filling StationAboabo No. 2	6	41	56.2	1	35	55.4
15	Aboabo-Dr Mensah	6	41	57.1	1	36	12.1
16	Aboabo No. 1 Bus Stop	6	41	56.3	1	35	50.7
17	Aboabo No 2 Down	6	41	40.6	1	36	11.5
18	Area	6	41	50.6	1	36	8.8
19	Aboabo No 2	6	41	33.5	1	35	51.2
20	Aboabo No 2 Main	6	41	44.3	1	36	0.1
21	Tillikarlklodin	6	41	46.2	1	36	2.6
22	Number 1 Junction	6	42	16.6	1	35	56.1
23	Aboabo Number 1	6	42	6.1	1	36	10.1
24	Mighty Royal Int.School	6	42	14.3	1	35	58.8
25	Hajia Walia Masalakyi	6	42	13.7	1	35	56.1
26	Aboabo Extension 1	6	42	11.6	1	35	59.3
27	Aboabo Extension 2	6	42	17.4	1	36	8.1
28	Masalakyi Nasriya	6	42	4.7	1	35	59.5

Appendix C1: Community Questionnaire

This project aims mainly at investigating the causes of flooding in the Aboabo Community as well as the effects and socio economic impact as a hazard on life, property and daily activities of residents. It also aims at suggesting recommendations to mitigate the problem.

NB: This is a purely academic research and the anonymity of respondents is assured.

Information provided by residents will be used purely for academic research purposes.

Kindly answer by ticking or filling in the blank where appropriate

A. BACKGROUND

1. (a) Name of Suburb (Area) ………………………………………………………………

(b) Sex: Male [ ] Female [ ]

(c) Age (i) 1-19 [ ] (ii) 20-39 [ ] (iii) 40-59 [ ] (iv) 60-79 [ ] (v) 80+ [ ]

(d) Education: (i) Primary [ ] (ii) Secondary [ ] (iii) Tertiary [ ] (iv) None [ ]

(e) Occupation: (i) Student [ ] (iii) Civil Servant [ ]

ii) Public Servant [ ] (iv) Unemployed [ ]

Other [ ] Specify ……………………………………………

(f) How long have you been living/working in this community?

(i) 1-10 [ ] (ii) 11-20 [ ] (iii) 21-30 [ ] (iv) 30+ [ ] 2. (a)

Has your community ever experienced flooding before? Yes [ ] No [ ]

(b) When was the last occurrence? ……………..

(c) How long did it last? ....

(d) How often do floods occur in your locality? (i) Biannually [ ]   (ii)
Annually [ ]   (iii) Biennial [ ]   (iv) Often, more than 3 times a year [ ]
(v) Never [ ]

3. What, in your opinion is/are the causes of these floods?

(i) Building on/close to water courses [ ]   (ii) Bad refuse Disposal [ ]

(iii) Unplanned Settlements   (iii) Lack of/Inadequate Drains [

(iv) Poor design of Drains [ ]   (v) Choked drains [ ]   (vi)

low lying nature of relief [ ]

B. IMPACT OF FLOOD ON INFRASTRUCTURE AND TRANSPORT

4. Housing Agreement   (i) Renting [ ]   (ii) Ownership [ ]

5. Did you obtain a building permit?   Yes [ ]   No [ ]   I don't know [ ]

6. What building material is your house/shelter made of?   (i) Clay Mud/Atakpame [ ]
(ii) Brick [ ]   (iii) Cement block [ ]   (iv) Plywood [ ]

7. Did part of your house cave in or collapse due to the floods?   Yes [ ]   No [ ]

8. Did the caving in /collapsing of the house force you to relocate either temporarily/permanently to a new area? Yes [ ] No [ ]

9. What was the extent of flood on your premises? (i) Ground level [ ]   (ii) Came into the rooms through windows/doors [ ]   (iii)Above windows [ ]
Specify…………………………………………………………………

10. Did the house lose any valuables/properties?   Yes [ ]   or   No [ ]

If Yes, specify………………………………………………………………………………

11. What are the effects of floods on physical structures?

(i) Cracking/collapsing of walls, floors, etc [ ] (ii) Leaking roofs [ ]

(iii) Abandon house temporarily/permanently [ ] (iv) Gradual soaking up of blocks [ ]

12. Which means of transportation got flooded and hence hindered movement? (i) Road [ ]

(ii) Foot/Pathways [ ] (iii) Bridges [ ]

13. How did transport problems due to floods affect daily activities?

………………………………………………………………………………………

………………………………………………………………………………………..

C. IMPACT OF FLOOD ON HEALTH

14. Did the floods affect health facilities in the community? Yes [ ] No [ ]

15. Did the floods interfere with access to health services? Yes [ ] No [ ]

16. Did any of the household members get sick due to the floods? Yes [ ] No [ ]

17. Which of the following ailment was/were experienced due to the floods? (i) Diarrhoea [ ] (ii) Cholera [ ] (iii) Fever [ ] (iv) Malaria [ ] (v) Typhoid Fever [ ]

18. Did anyone get injured due to the floods? Yes [ ] No [ ]

19. If yes, what were some of the reported injuries?

………………………………………………………………………………………

20. Were there any death cases due to flooding? Yes [ ] No [ ]

D. IMPACT OF FLOOD ON EDUCATION

21. Are there any education facilities in your community? Yes [ ] No [ ]

22. Was there any damage to school infrastructure (classroom blocks, etc.) due to the floods?

Yes [ ]   No [ ]

23. Did the floods affect daily school activities? Yes [ ]   No [ ]

24. If yes to Question 22 above, what is/are the reason (s)?

(i) Road/ pathway affected by flood [ ]   (ii) School premises flooded [ ]

(iii) Students absent themselves purposely during/after floods for fear of the unknown [ ] (iv) School temporarily closes down [ ]

E. IMPACT OF FLOOD ON WATER AND SANITATION

25. What is/are your main source(s) of water in your community?

(i) Wells [ ] (ii) Boreholes [ ]   (iii) Public Taps [ ]

(iv) Individual house taps [ ]   (v) Rivers/Streams [ ]   (vi) Other [ ]

Specify…………………………………………..

26. Which of the sources of water got affected by the floods? (i) Wells [ ] (ii) Boreholes [ ]

(iii) Public Taps [ ]   (iv) Individual house taps [ ]   (v) Rivers/Streams [ ]

(vi) Other [ ] Specify…………………………………………..

27. How do you dispose of waste? (i) Dustbins [ ]   (ii) Open places [ ]

(iii) Public refuse damp [ ]   (iv) Landfill site [ ]   (v) Damp in drains/stream [ ]

(vi)Burning [ ]   (vii) Waste collectors [ ]

28. What kind of sanitary facility do you use? (i) Individual house toilet facility [ ] (ii) Public toilets [ ] (iii) Pit latrine [ ] (iv) Free range [ ] (v) Other [ ]

Specify…………………………..

29. Which of the sanitary facilities got affected by the flood?

(i) Individual house toilet facility [ ] (ii) Public toilets [ ] (iii) Pit latrine [ ]

(iv) Free range [ ] (v) Other [ ]

Specify………………………..

F. IMPACT OF FLOOD ON TRADING AND BUSINESS ACTIVITIES

30. Do floods affect business and trading activities? Yes [ ] No [ ]

31. What are the effects of floods on trade/business? (i) Loss/Damage to money, stock, equipment, fittings, etc [ ]

(ii) Reduction in the amount of time business/trade is conducted [ ]

(iii) Low patronage from customers [ ]

(iv)Tarnish the business's reputation and image [ ]

(v) Temporarily closed [ ]

32. Do you trade/ have a business in the Community? Yes [ ] No [ ]

33. What is the estimate of your income annually lost from business due to the flood?
(i) Below 500Ghc [ ] (ii) 500-1000 Ghc [ ] (iii) 1000 – 5000 Ghc [ ]

(iv) Above 5000 [ ] (vi) Cannot estimate [ ]

F.POST-FLOODS

34. Did you receive any help/ aid during/after the floods from the following?
(i)National Disaster Management Organisation (NADMO) [ ] (ii) Municipal Assembly [ ] (iv) Chief/traditional council [ ] (v)

Friends/Relatives [ ] (vi) None [ ]

(vii) Other [ ] specify...

35. Do you think these floods can be prevented? Yes [ ] No [ ] I don‘t know [ ]

36. If yes, how?

(i) Proper Disposal of rubbish [ ] (ii) Provision/proper maintenance of adequate drains [ ] (iii) Raising of buildings/shelters/shops well above ground level [ ]

(iv) Building only at authorized places [ ]

(v) Education on prevention and dealing with floods [ ]

37.Any Other Comments?...

……………………………………………………………………………….

THANK YOU

Appendix C2: Questionnaire for Officials of Government sectors

1. Name of Institution ………………………………………………………..

....

2. What are the functions of your Department?

………………………………………………………………………………………………

………………………………………………………………………………………………

3. Which areas in the Municipal Assembly have been affected by floods in the past years?

....

....

4. What are the likely causes of floods in Aboabo community?

....

....

5. What role does your Institution/Organisation play in the prevention/during and post floods?...

....

....

6. What measures have been taken by your Institution/organisation to prevent floods?

....

....

....

7. What measures have been put in place to control or manage the floods when they set in? ………………..

....

....

8. Have you been able to identify flood prone areas in the Community? Yes [ ] No [ ]

9. If yes, how are you able to identify this/these flood prone area(s)?
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

10. Any Other Comments?
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

THANK YOU

Appendix C3: Results of SPSS Analysis Name of Suburb

	Frequency	Percent
Aboabo Number 1	53	26.5
Aboabo Extension	69	34.5
Aboabo Post office	48	24.0
Aboabo Number 2	30	15.0
Total	200	100.0

Sex

	Frequency	Percent
Male	104	52.0
Female	96	48.0
Total	200	100.0

Age

	Frequency	Percent
1-19 years	12	6.0
20-39 years	97	48.5
40-59 years	67	33.5
60-79 years	17	8.5
80 + years	7	3.5
	Frequency	Percent
1-19 years	12	6.0
20-39 years	97	48.5
40-59 years	67	33.5
60-79 years	17	8.5
80 + years	7	3.5
Total	200	100.0

Education

	Frequency	Percent

Primary	58	29.0
JHS/ Secondary	67	33.5
Tertiary	20	10.0
None	55	27.5
Total	200	100.0

Occupation

	Frequency	Percent
Student	17	8.5
Public/ Civil Servant	65	32.5
Self-employed	91	45.5
Unemployed	27	13.5
Total	200	100.0

How long have you been living/working in this community

	Frequency	Percent
1-10 years	39	19.5
11-20 years	94	47.0
21-30 years	50	25.0
30 + years	17	8.5
Total	200	100.0

Has your community ever experienced flooding before?

	Frequency	Percent
Yes	191	95.5
No	9	4.5
Total	200	100.0

How often does floods occur in your locality?

	Frequency	Percent
Annually	70	35.0
Biannually	48	24.0
Biennial	30	15.0

Often, more than 3 times a year	43	21.5
Never	9	4.5
Total	200	100.0

What, in your opinion is the causes of these floods

	Frequency	Percent
Low lying nature of relief	19	9.5
Building on/ close to water sources	36	18.0
Bad refuse disposal	28	14.0
Lack of / inadequate drains	45	22.5
Chocked drains	40	20.0
Unplanned settlement	24	12.0
Poor design of drains	8	4.0
Total	200	100.0

Housing Agreement

	Frequency	Percent
Renting	129	64.5
Ownership	71	35.5
Total	200	100.0

Did you obtain a building permit?

	Frequency	Percent
Yes	52	26.0
No	103	51.5
No idea	45	22.5
Total	200	100.0

What building material is your house built of?

	Frequency	Percent
Brick	54	27.0
Cement/Blocks	91	45.5

Clay/mud	24	12.0
Plywood	31	15.5
Total	200	100

Did part of your house cave in or collapse due to the floods

	Frequency	Percent
Yes	48	24.0
No	152	76.0
Total	200	100.0

Did the caving in /collapsing of the house force you to relocate either temporarily/permanently to a new area

	Frequency	Percent
Yes	26	13.0
No	174	87.0
Total	200	100.0

What was the extent of flood on your premises?

	Frequency	Percent
Came into the room through windows and doors	52	26.0
Ground level	99	49.5
Above windows	49	24.5
	Frequency	Percent
Came into the room through windows and doors	52	26.0
Ground level	99	49.5
Above windows	49	24.5
Total	200	100.0

Did the house lose any valuables/properties?

	Frequency	Percent
Yes	125	62.5

No	75	37.5
Total	200	100.0

Which means of transportation got flooded and hence hindered movement

	Frequency	Percent
Road	51	25.5
Foot/ pathways	109	54.5
Bridges	40	20.0
Total	200	100.0

What are some of the effects of flooding on physical structures?

	Frequency	Percent
Leaking roofs	58	29.0
Gradual soaking of blocks	83	41.5
Cracked/ collapsing of walls	39	19.5
Abandoned houses	20	10.0
Total	200	100.0

Did the floods affect health facilities in the community?

	Frequency	Percent
Yes	5	2.5
No	195	97.5
Total	200	100.0

Did the floods interfere with access to health services?

	Frequency	Percent
Yes	95	47.5
No	105	52.5
Total	200	100.0

Did any of the household members get sick due to the floods?

	Frequency	Percent
No	95	47.5
Yes	105	52.5
Total	200	100.0

Which of the following ailment was/were experienced due to the floods?

	Frequency	Percent
Malaria	48	45.7
Typhoid fever	20	19
Cholera	10	9.5
Diarrhoea	12	11.4
Fever	15	14.3
Total	105	100.0

Did anyone get injured due to the floods?

	Frequency	Percent
Yes	88	44.0
No	112	56.0
Total	200	100.0

Were there any death cases due to flooding?

	Frequency	Percent
Yes	75	37.5
No	125	62.5
Total	200	100.0

Are there any education facilities in your community?

	Frequency	Percent
Yes	198	99
No	2	1
Total	200	100.0

Was there any damage to school infrastructure (classroom blocks, etc.) due to the floods?

	Frequency	Percent
Yes	44	22.0
No	156	78.0
Total	200	100.0

Did the floods affect daily school activities?

	Frequency	Percent
Yes	124	62.0
No	76	38.0
Total	200	100.0

If yes to Question 22 above, what is/are the reason (s)?

	Frequency	Percent
Road/ pathway affected by flood	32	16.0
School temporarily closes down	35	17.5
School premises flooded	61	30.5
Students absent themselves purposely during / after floods for fear of the unknown	72	36.0
Total	200	100.0

What is/are your main source(s) of water in your community?

	Frequency	Percent
Wells	29	14.5
Boreholes	95	47.5
Public taps	43	21.5
Individual house taps	33	16.5
Rivers / streams	0	0.0
Total	200	100.0

Which of the sources of water got affected by the floods?

	Frequency	Percent
Wells	82	41
Boreholes	47	23.5
Public taps	31	15.5
Individual house taps	15	7.5
Rivers / streams	25	12.5
Total	200	100.0

How do you dispose of waste?

	Frequency	Percent
Public refuse dump	32	16.0
Dump in drains/ stream/River	57	28.5
Land fill sites	18	9
Open places	27	13.5
Burning	40	20.0
Waste Collectors	26	13
Total	200	100.0

What kind of sanitary facility do you use?

	Frequency	Percent
Free range	51	25.5
Public toilets	95	47.5
Individual house toilet facility	46	23.0
Pit latrine	8	4.0
Total	200	100.0

Which of the sanitary facilities got affected by the flood?

	Frequency	Percent
Individual house toilet facility	31	15.5
Free range	103	51.5
Pit latrine	55	27.5
Public toilet	11	5.5

Total	200	100.0

Do floods affect business and trading activities?

	Frequency	Percent
Yes	162	81
No	38	19
Total	200	100

What are the effects of floods on trade/business?

	Frequency	Percent
Loss/Damage to money, stock, equipment, fittings, etc.	51	25.5
Reduction in the amount of time business/trade is conducted	26	13
Low patronage from customers	44	22
Tarnish the business's reputation and image	39	19.5
Temporarily closed	40	20
Total	200	100

Do you have a trade/run a business in the Community?

	Frequency	Percent
Yes	62	31
No	138	69
Total	200	100

Do floods affect the trade/business?

	Frequency	Percent
Yes	53	85.49
No	9	14.51
Total	62	100

What is the estimate of your income lost from trade/business due to the flood?

	Frequency	Percent
Below 500Ghc	10	18.87
500-1000Ghc	16	30.19
1000 – 5000 Ghc	20	37.74
Above 5000	2	3.77
Cannot estimate	5	9.43
Total	53	100

Did you receive any help/ aid during/after the floods from the following?

	Frequency	Percent
NADMO	0	0.0
Municipal assembly	11	5.5
Chief/ traditional council	0	0.0
Friends/ relatives	14	7.0
None	175	87.5
Total	200	100.0

Do you think these floods can be prevented?

	Frequency	Percent
Yes	115	57.5
No	53	26.5
No idea	32	16.0
Total	200	100.0

If yes how?

	Frequency	Percent
Proper Disposal of rubbish	25	21.74
Provision/proper maintenance of adequate drains	30	26.09
Raising of buildings/shelters/shops well above ground level	12	10.43
Building only at authorized places	23	20
Education on prevention and dealing with floods	25	21.74
Total	115	100.0