MANAGING FLOODING IN RESIDENTIAL AREAS OF NAIROBI: A CASE STUDY OF SOUTH C

BY:

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DECLARATION

This Urban management project is my original work and has not been presented for a degree in any other university.

Signature…… Date……

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(Candidate)

This Urban management project has been submitted for examination with my approval as the University supervisor

Signature…… Date……

DR. Laban Shihembesta

(Supervisor)

DEDICATION

This work is dedicated to those who have helped shape my life to who I am today. They include my mother Mrs. Kolil, my brothers Alfred and Geoffrey, my Aunt Anne and cousin Mercy to whom I have drawn my inspiration from.

ACKNOWLEDGEMENTS

Completion of this project successfully has taken input of many. First I am grateful to my almighty God for the health and peaceful environment that He gave me during my urban management project.

To the project coordinator Dr. k'akumu Owiti, I am grateful for his guidance throughout the time I was undertaking my project. To my supervisor Dr. Shihembesta Laban I am so much grateful for his will, patience and guidance which were fundamental in the accomplishment of this project. I am also grateful to the residents of South C and professionals from County government of Nairobi who gave me the information I needed to aid in completion of my project.

I do also thank Ms. Mildred Ambani who aided in availing Geographical Information Systems data, Master of Urban Management class of 2014, my entire family, relatives and friends for their continued support during this period of my project. I always shall be grateful for your assistance.

ABSTRACT

Despite of the fact that flooding is witnessed both in urban and rural areas, its occurrence in urban areas has a unique nature, as the built environment plays a major role in its occurrence in addition to the natural phenomenon of heavy rains over time.

This study is premised on the view that urbanization leads to an increase in percentage of land covered by the built up environment to accommodate the rising population in urban areas, hence reducing ground water absorption rates consequently increasing storm water flow on pavements and tarmacked areas. On the same premise, natural channels are obstructed by the built up areas hence hampering natural flow of storm water leading to flooding.

The research identified South C neighbourhood in Nairobi as one of the most affected residential areas by floods during rainy seasons. The study focused on the causes of flooding witnessed over time, discussing the identifiable impact on human life, daily activities as well as economy of the country and how various management tools can be applied to aid in controlling the flooding problem that is becoming a major concern to the urban residents as a whole.

The study was conducted through multi-dimensional approach of data collection. Quantitative and qualitative data collection methods were used and those areas most affected by flooding phenomenon mapped out.

The study proposes interventions to curb flooding categorized into: Management of storm water drainage systems, establishment of specific building by laws in flood areas and enforcement of development control measures, putting in place disaster management structures, Multi-dimensional and intergovernmental approach in flood management as well as stakeholders' involvement to flood management.

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LIST OF ABBREVIATIONS

CDMP	:	Comprehensive Disaster Management Plan
ETHICAL	:	Accepted code of conduct
GIS	:	Geographical Information Systems
IFRC	:	International Federation of Red Cross and Red Crescent Societies
KASNEB	:	Kenya Accountants and Secretaries National Examination Board
KeNHA	:	Kenya National Highways Authority
KURA	:	Kenya Urban Roads Authority
KEWI	:	Kenya water institute
KURA	:	Kenya Urban roads authority
LAG TIME	:	The time difference between when heavy precipitation occurs and when peak discharge occurs in the streams draining an area
MASL	:	Metres Above Sea Level
NGO	:	Nongovernmental organization
NEMA	:	National Environmental and Management Authority
KMD	:	Kenya Meteorological Department
GFFS	:	Galway Flood Forecasting System Model

CHAPTER ONE

INTRODUCTION

1.1 Overview

Over decades urban flooding has been experienced in Kenya. However adequate attention has not been given on precise efforts to deal with it. In the past, any stratagem on flood disaster management fundamentally focused on riverine floods affecting large extents of rural areas. Urban flooding is significantly differs from rural flooding as urbanization ends up in coverage of large parts of the ground which were open: with roofs, roads and pavements and in the event of high intensity rainfall there is higher runoff which consequently increases the flood peaks as the water absorption rate into the ground is low or nonexistent.

Urban areas are usually densely populated and persons residing in vulnerable areas suffer due to flooding, sometimes occasioning in life losses. In a report done by World Bank, (2006) on Urban Flood Prevention and Drainage, they noted that in addition to the event of flooding the secondary effect of exposure to infection, also has its role in terms of human suffering, loss of livelihood as well as life.

Increased flooding in urban areas is widespread and brings up a great challenge to urban planners/managers, engineers and even architects over the world. Problems associated with urban floods array from localized incidents to major incidents, resulting in cities being flooded from hours to several days. The impact therefore, can be widespread, including temporary relocation of persons, damage to civic facilities, worsening of water quality and risk of spates (Hellmuth et al, 2007).

Rukmana, (2010) identified that the impact of floods in urban areas is also unique given its higher attentiveness of population and belongings. He summed up his paper on Annual Flooding noting that urban settlements in addition contains the major economic and social features and asset bases of any national population, so that urban flooding, by causing destruction and distraction beyond the constraint of the definite floodwaters, often transmits more serious consequences for societies.

Poorly premeditated and uncontrolled urbanization process has also contributed to the rising flood hazard due to inappropriate land use change (Abhas et al, 2012). As cities and towns grow outwards to sustain the rising population, large-scale urban growth occurs oftenly in the form of unplanned development in floodplains, coastal and inland areas as well as in other flood-prone areas

1.2 Background information

South C is located at the core of Nairobi, the capital city of Kenya. The city is geographically positioned between latitudes 1.163^0S and 1.283^0S and longitudes 36.817^0E and 37.104^0E. It is characterized by lowland terrain with the highest point being 1795 meters above mean sea level, while the lowest point is as low as 800 meters above mean sea level. The city has an area of 689 sq. km (266 sq. miles).

The study area has an area of 15.10km^2 with a population of 47,202 persons according to 2009 population census. It is situated next to Wilson Airport, bordered by South B to the East, Langata Estate to the West and the Nairobi National Park to the South. It is inhabited my middle class earners (according to answers corporation classifying high population density at 5,001 people/ km^2 and above with medium population density between 401 and 5,000 people/km^2 and Low population density at 400 people/km^2 or less, hence making the study area fall at medium population density having 3125 people/km^2).The study area is characterized by Bungalows and maisonettes with a few Multi dwelling Units coming up. It is largely zoned as a residential area under Zone number 10 classified under Nairobi City Development Ordinances and Zones with a few commercial units and Organizations.

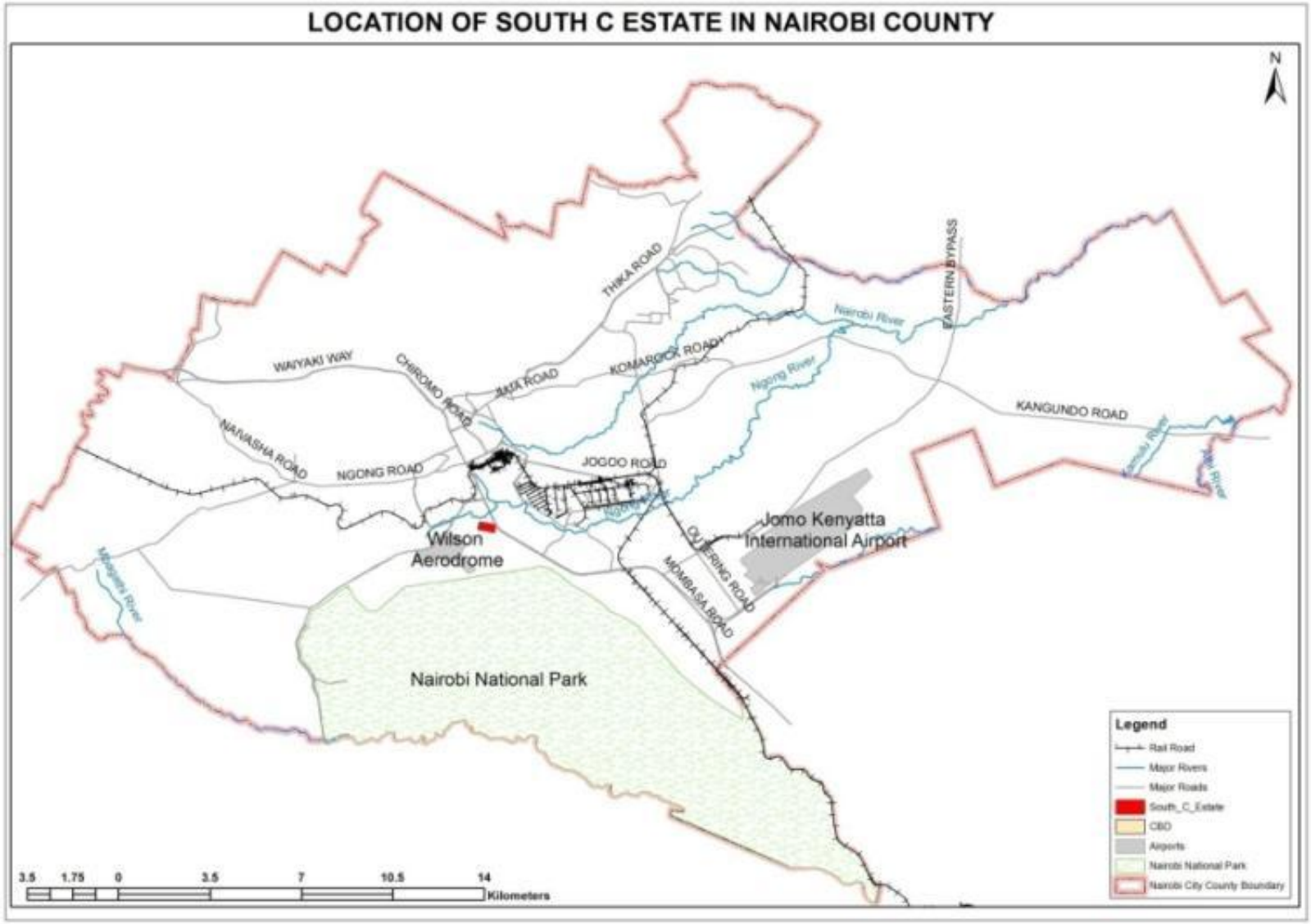
The study area has notable organizations like: the head office of the Kenya Red Cross Society, the Criminal Investigation Department (C.I.D) Kenya Police Training School, National Environmental Management Authority Head office (NEMA), Kenya National Bureau of Standards Head office (KEBS) and the extensive Toyota Training Academy.

Maps 1-1, 1-2 and 1-3 shows the location of study area in national, county and local context.

Map 1-1: Location of area of study in Kenyan Context.

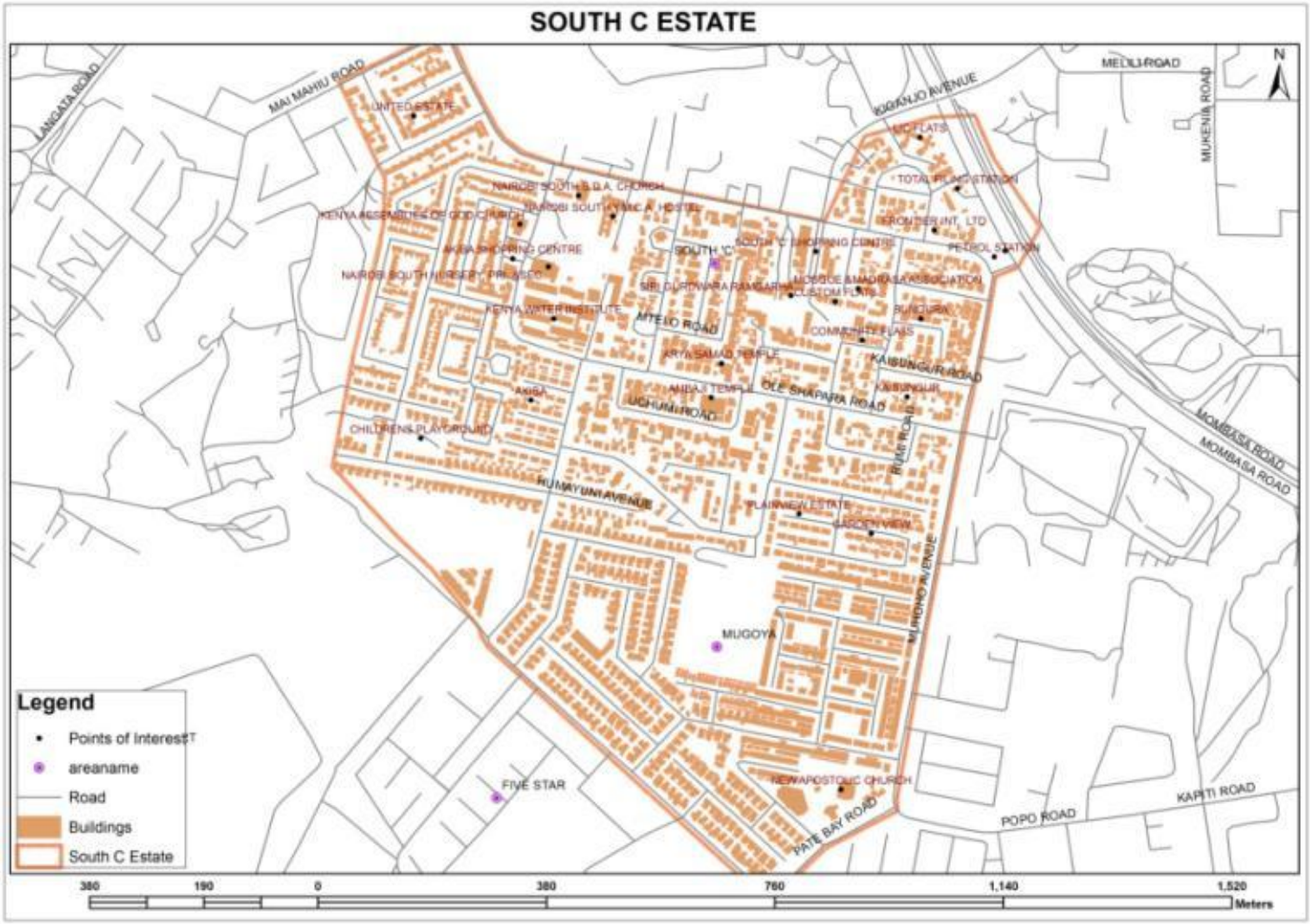
Source: *Adapted from Kenya GIs data*

Map 1-2: Location of study area in relation to Nairobi City County



Source: *Adapted from Kenya GIs data*

Map 1-3: Extend of the study area



Source: *Adapted from Kenya GIS data*

1.3 Problem statement

Flooding has been a common phenomenon in the world this century, witnessed both in urban and rural areas. Those in rural areas have been associated with the nature of terrain as well as bursting river banks caused by excessive flow of water due to heavy rains witnessed over time leading to displacement of individuals as well as property destructions. In urban areas however, apart from terrain; it is associated with poorly maintained drainage systems, littering and improper solid waste management which in the process leads to blocking of drainage systems preventing free flow of water and lack of drainage systems as well as water exit points. Apart from blockage of drainage systems, subsequent increase in developments with less concentration in upgrading of drainage systems limiting their capacity to handle storm water causes its overflow hence flooding.

In addition, paved roads, densification of buildings and generally increase in the ground area covered by buildings minimize the rate of water infiltration into the ground thus significantly contributing to flooding. The natural ability of the catchment to withstand natural hydrologic variability is normally eradicated when an area develops and due to the increase in impervious surface and disrupted native soils, infiltration capacity is consequently decreased. According to Vijay et.al (2006) Natural withholding capabilities of a catchment is removed by setting up of formal drainage systems such as pipes and gutters as well as channelization of natural waterways. Due to this nature of reduction in infiltration capacity, Banglore city is one of the urban areas that witnessed major flooding in 1997 and 2002 leading to destruction of infrastructure and property damages.

Unintended urbanization is the major ground of urban flooding. Various varities of low lying areas around the cities which were to be hassocks as well as flood absorbers are progressively built upon due to urbanization pressure. It has overtime resulted into inadequate channel capacity causing urban flooding. Delhi City, the capital of India has had its channel capacity collapse as a result of overwhelming it with urbanization pressure resulting in flooding during rainy seasons (Pareva, 2016).

Floods are considered the most disparaging of all natural disasters as they are the most common, result in to the greatest number of deaths, as well as damages (Miller, 1997). The study area has been experiencing one of the worst flooding menaces in Nairobi over time with damages being reported within the estate each time there are rains within the city and its environs.

Floods within the study area have led to property destructions, discouraged investors within the estate, interfered with the transport system due to diversions during flooding as well as difficulty in accessing the estate during flooding periods. In spite of all these issues, not much has been done to the major causes of flooding within the city and their impacts to its residents.

1.4 Objectives of the study

- To identifying causes and impacts of flooding in South C, Nairobi
- To review the current management set up of storm water/flooding in the study area.
- To propose ways of mitigating flooding in South C Nairobi

1.5 Research Questions

- What causes and impacts of flooding in South C Nairobi?
- How is the current authority on management of storm water/flooding effective?
- What mitigation measures should be considered to curb flooding in South C Nairobi?

1.6 Assumptions

- Flooding in south C is caused by poor drainage systems leading to destruction of properties.
- The current structure of Nairobi City County Government is not effective in management of floods.
- Nairobi City County has not put in place stringent measures to monitor and control floods within South C.

1.7 Significance of the study

Flooding is one of the most widespread and disparaging challenges facing cities all over the world. Steven (2013) suggests that of all natural disasters floods are the most frequent and that

the number of flood occasions is rapidly rising. In the year 2010 alone, Steven highlighted that 178 million individuals were affected by floods, with losses exceeding properties worth 40 billion dollars. With the increasing flooding levels in urban areas and the world as well, there is need to put in place a management plan to help mitigate the effects of the massive flooding being witnessed. In respect to this, the study identifies causes of flooding: its consequential effects hence coming up with a strategy to mitigate the impacts. The observed impacts of this phenomenon so far in Kenyan urban areas for instance Nairobi, Mombasa and Narok include: loss of lives, destruction of buildings and many other properties, destruction of urban vegetation cover, health conditions deterioration due to waterborne diseases and loss of valuable working time due to heavy traffic jams.

The study is aimed at identifying the contributory causes and effects of floods in south C. This will aid in coming up with recommendations to solve the big problem of flooding in the area, consequently enabling South C residents to enjoy residing in a flood free estate during rainy seasons.

The research will come up with recommendations to contain and harvest storm water which is the major cause of flooding when it breaks off the drains, for better use within the city of Nairobi which experiences water shortages over time. This will even reduce the cost of purchasing water within the estate during water rationing period. The research will also establish the reasons behind ineffective management of floods by the existing authorities within the city of Nairobi.

The site has been chosen as it has been the most affected residential area in Nairobi to the extent of being named “South Sea”. Secondly, flooding has been seen over time as either affecting only the poor due to the nature of environment they live in characterized by swamps, or those living along the riverine: however, South C is neither on a riverine nor a low class area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

Urban flooding has been a common phenomenon recently occurring frequently over a short period of time when there are heavy rains. This has raised concern among the various stakeholders in urban areas due to the observed impacts to the urban life and its' after math. Loss of lives, property destruction, vegetation cover carried away, overflow of drainage systems leading to diseases such as cholera are some of the observed impacts in our urban areas.

Smith (2002) notes that flood occurrence can be at any time, but weather/climate patterns have a strong influence on when and where they will occur. He also identifies land use practices in the upper catchment areas as contributory factors to the heightening of surface water run-off as well as flooding. Unplanned settlements in the lowlands can also contribute to more flooding due to possible blockages of water ways by the human activities in place.

In Kenya, the impact of flooding was demonstrated by the 1997/1998 El Nino which led to severe loss of lives, property and infrastructure destruction as well as disruption of the communication networks. Pardon et.al (2013), identifies that The El Nino-induced floods of 1997–1998 led to public and private property damage of worth 151.4 million US dollars. The number of individuals who lost family members, investments, property and monetary prospects were not taken into account in these figures.

In 2003, and 2014, a heavy down pour was also witnessed in Kenya with most of Kenyan urban areas being most affected. Nairobi and Narok Counties were most affected. In Nairobi, South C was the epic of flooding resulting to loss of properties as well as delays in waiting for the floods to subside. This greatly affected the residents' daily lives and caused routine disruption as well.

2.2 Flooding types

Floods occur in different places and forms depending on the nature of terrain as and rainfall intensity. Most of the floods occur due to intense rainfall over a short period of time.

a) Upstream flooding

They occur in regions which experience within a small area, over a short period of time large amounts of rainfall. Here, with little or no consequence on areas downstream, the local area may flood with water rising and quickly flowing after the storm has passed (Stephen, 2015). Measurement of its lag times are usually done in days. Narok and its environs in Kenya is a good example of upstream flooding.

b) Downstream flooding

These are long duration floods that normally occur over an expansive region in a segment of a stream. This nature of floods affects tributary streams as well as larger streams as a whole. Have a longer lag time as tributary flows constantly leading to intensification of the discharge into larger streams (Stephen, 2015). A number of them have occurred, with the famous one being the great Mississippi river basin flood of 1993. In Kenya, the 2008 Nyando River sub basin flood in Nyanza affecting 2,541 people according to a report done by Ministry of Water and Irrigation on flood mitigation strategy in 2009 would be a good example of a downstream flood.

c) Flash floods

These types of floods occur when heavy rains are experienced over a short period of time with a low infiltration rate. The difference with upstream floods is that, they have very little lag time that may be only a few hours unlike upstream floods which are usually over a few days. Therefore in essence, upstream takes more time than flash floods (Stephen, 2015). Flash floods are usually more intense and considered more destructive to properties than human lives due to its nature of occurrence with little or no warning.

An example of flash floods in Kenyan urban areas occurred at the night of 12th May 2015 in South C due to the heavy rainfall which was triggered upstream of Ngong river (which passes through South C) resulting to flooding menace in the area and its environs. This resulted to damages with most roads becoming impassable forcing motorists to be on roads for long hours (Standard Paper, 2015).

2.3 Flooding types in urban areas

Action AID (2006), identified in its book on Climate change, urban flooding and the rights of the urban poor in Africa four major types of flooding within urban areas. The types are stated as:

a) **Localized flooding**

Localized flooding was identified to occur several times yearly in slum areas due to the nature and few number of drains and compacted pathways in between dwellings that tend to be converted to streams after intense rains. These path ways due to poor solid waste management in those slums tend to be frequently blocked by waste and debris.

b) **Flooding as a result of minor streams in urban areas rising promptly after heavy rains**

Another form of urban flooding identified takes place when minor streams in urban areas rise promptly after heavy rains, but usually pass through small culverts across the roads. Despite the fact that most of them are found to have been adequate during the design time, higher flows that exceed capacity tend to be observed due to the inevitable structure developments in urban areas as well as storm intensity due to factors such as climate change. On top of the storm, intensity channels over time may have accumulated a lot of debris in them that they are literally smaller than they were during their design time.

c) **Flooding as a result of changes in land use upstream leading to rechanneling of main rivers**

Apart from the rising of minor streams in urban areas, urban flooding is witnessed when main rivers channeling across urban areas are diverted by changes in land use and engineering developments upstream. High flows may occur due to dam operations like the hasty release of stored water leading to sudden flooding of urban areas. Sometimes, urban growth may expand over a section of floodplain, hence making some of the urban areas regions below flood level. This in turn reduces the area into which floods could naturally overflow hence causing devastating urban flooding.

d) Flooding in lowland areas as well as coastal cities

The final nature of urban flooding occurs in lowland areas as well as coastal cities. This is seen during the wet season when both river and rain water conglomerate to elevate the height of water in marshy areas that could have been swamped naturally at some times of the year. Storm waves can also convey flooding to such areas in addition to the wet season.

2.4 Causes of urban flooding

The work carried out by the Government of India through its National Disaster Management Authority informs management of flooding menace and provides a vivid understanding of urban flooding clearly differentiating it with rural flooding. The team categorizes flooding in urban areas being expressively diverse from rural flooding in that, urbanization leads to established catchments which upsurges the flood peaks from 1.8 to 8 times and flood volumes by up to 6 times. In their management paper on National Disaster Management Guidelines, they point out that flooding ensues very rapidly due to faster flow times, at times in a matter of very few minutes.

Abhas J. et.al (2011) on the other hand noted that flooding encompasses flow of water over localities which have been normally dry. He identified springs of floodwater to be, from glacial melt, from the sea in the form of storm surge, snowmelt or rainfall which can develop into riverine or flash flooding as the volume of water surpasses the capability of watercourses, and from ground infiltration as well. In addition according to his paper, failure of man-made water containment structures for instance dams and reservoirs or watercourses leads to occurrence of floods.

2.5 Causes of rising cases of urban flooding

2.5.1 Climate change

World Meteorological Organization (2007) in its report on flood management tools summarized a number of climatological changes observed over a period of time. It notes that the warmest years have been recorded since 1998 hence the global average sea level has been increasing at a

quicker rate than at any other period in the past 3,000 years, at approximately 3.4 mm per year from 1993 to 2008. World Meteorological Organization (WMO) associates these changes with Global warming.

Alterations of meteorological patterns associated with increased temperatures during the last 50 years are possible causes of increased impact of meteorological adversities like flooding which has been witnessed over time. World Bank (2010) did a report on climate risks and identified that patterns of climate change projected could have a cumulative effect on prevailing flood risks by: enhancing the speed at which the sea level rises, and altering local patterns of rainfall as well, that could lead to higher levels of riverine floods and in addition frequent and intense flash flooding. This has actually been seen in our towns.

- **Global warming**

Sunlight is the source of global warming. When this light from the Sun reaches the Earth, 30 % of it is redirected back into space by clouds, reflective ground surfaces, atmospheric specks, and ocean waves. The remaining 70 % of the light is absorbed by the air, land, and oceans, heating the planet's surface and atmosphere. However, some of the outgoing radiation, is reabsorbed by carbon dioxide, water vapor, and other atmospheric gases which are commonly known as greenhouse gases due to their heat-trapping capacity. This causes re-radiation back toward the Earth's surface, (Riebeek, 2007)

Humans have been artificially increasing the concentration of greenhouse gases in the atmosphere at a higher rate over the past 250 years, according to Riebeek (2007). Humans were pumping out over 8 billion tons of carbon dioxide per year by 2004 in which some of it was absorbed by natural sinks like forests and the ocean, and the rest amassed in the atmosphere. As soon as these greenhouse gases are released into the atmosphere, they stay there for decades.

According to the Intergovernmental Panel on Climate Change (IPCC), ever since the industrialization began in about 1750, carbon dioxide intensities have increased by 35 % and methane levels by a hooping 148 %. This has led to a bigger concentrations of greenhouse gases making it more difficult for thermal radiation to leave the earth, leading tomore warmimg of the earth. The high temperatures have led to high levels of evaporation consequently leading to the high rainfalls witnessed.

2.5.2 Changes in land uses

Changes in land use contributes to the intensification of flooding as it reduces the ease of the ground in seeping, absorbing and storing excessive flowing water. When a water catchment area is altered by changing its use into a built environment, it may consequently contribute to increase in urban flooding downstream as the said absorption rate of water by the ground will have been greatly minimized. New infrastructure developments such as transportation networks may lead to introduction of elevated structures hence obstruction of previous natural flow paths consequently contributing to flooding phenomenon.

2.5.3 Upsurge of urbanization rates

Wheater and Evans (2009) were critical that changing land use, with most open grounds being covered with buildings increases the area of land surface covered by impermeable materials leading to higher ground flow consequently leading to reduction in the rate of infiltration. Changing land uses has a direct effect on the natural water storage, altering natural watercourses restricting their capacity. Possible flood hazards could occur due to the constant narrowing and impediment such as bridges and culverts which are put up in urban areas for facilitation of water flow on designated areas. Narrowing of water channels consequently leads to movement of water at a higher speed causing downstream flow alteration as the excess run-off water is transported to the drainage system creating high absolution in a short period of time. This could lead to the destruction of existing drainage systems hence leading to overland flooding. The water which could be transported through this land is averted by developments causing more hazards in other places or alternatively could continue flowing through settlements leading to more flood hazards within the developments as they cannot be infiltrated due to the covered surfaces by pavements.

2.5.4 Dilapidated infrastructure

There is quite a bigger probability of increased flood risk where the infrastructure is old, dilapidated, lack of operations and maintenance in urban areas (Abhas J. et.al, 2011). This

phenomenon is frequently observed in most countries, as appropriate upkeep of such infrastructure facilities goes with a sizeable percentage of urban management bodies which most of the times may not be the main concern. For instance, devastating floods in New Orleans in 2005 was blamed on the lack of adequate maintenance of levees that were in place. Another case in point of a disastrous scenario that occurred due to poor planning as well as negligence of operation and maintenance of infrastructure was the famous 1972 Buffalo creek floods, in which 125 persons were swept away, injuring 1,121 individuals, destroying 507 houses and leaving more than 4,000 persons homeless.

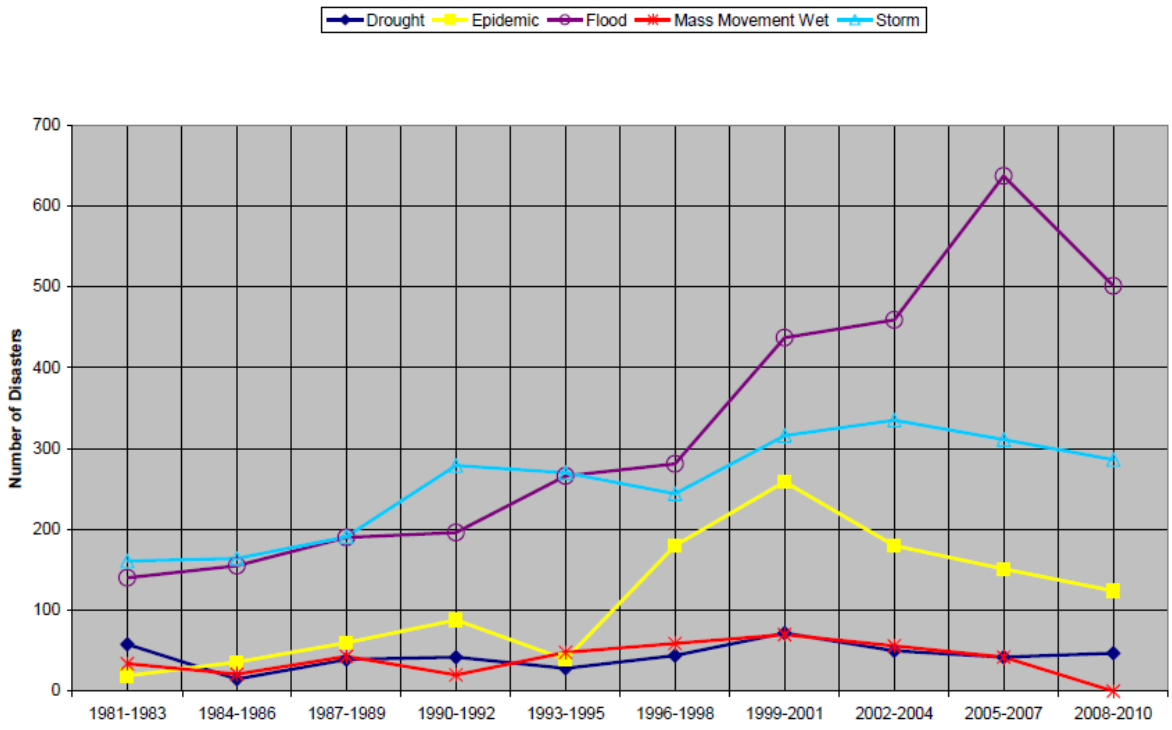
2.6 Impact of flooding

Flooding in urban areas is a worldwide spectacle which has led to destruction and monetary losses over time and proper and well thought level of management needs to be put in place to stop the far wide destruction. Centre for Research on the Epidemiology of Disasters (CRED) notes that, 178 million people in 2010 alone, were affected by flooding being the most recurrent amid all recorded natural disasters that particular year.

Statistics on Disasters recorded between 1980 and 2010 showed that flood events were becoming more frequent with time. Research conducted overtime based on disasters that frequently transpired implied substantial change in the intensity and pattern of flooding consequently leading to increased vulnerability for the rising world urban population (Abhas J. et.al, 2011).

Chart 2-1 below shows the statistical analysis for water related hazards between 1980 and 2010.

Chart 2-1: Trends of the recorded water-related adversities After Adikari and Yokhitani 2009



Source: *Abhas J. et.al, (2011)*

From the above chart, flooding is noted to be increasing fastest, in relation to the other identified impacts. The projected rise in disasters due to change in climate are predicted to influence contrarily in different regions, with an increase in flood hazard becoming a common future anticipation. The subsequent increase in hazards recorded and observed is related to the global trend in population of urban areas. IFRC (2010) indicates that about 50% of the world's population resides in urban areas, with low- to middle-income nations taking about two-thirds of this. They also note that world urban population has been growing at a higher rate than the rural population especially in the developing world at 2.1%, with 3.3% in the Middle East and Africa, and 2.7% in Asia-Pacific. United Nations (2015) noted that more persons reside in urban areas

than in rural areas globally, with 54 % of the world's population living in urban areas as at the year 2015.

The report makes a comparison between 1950 and 2050 in that, in 1950, 30 % of the world's population was living in urban areas and by 2050: it is projected to be at 66 % of the world's population. This shows that there is a very high rate of urbanization, increasing areas covered by the built environment to accommodate the urban population, subsequently increasing surface run off of storm water due to minimal water infiltration hence possible flooding occurrence.

The impacts of flooding can be categorized in the following:

Clare (2005), on her research book on the impacts of flooding on urban and rural communities, categorizes flooding into the following categories:

a) **Economic impact**

Floods cause damages that have financial costs to restore the damaged properties back to normal. This costs include: clean-up costs, repair costs, relocation charges, the costs of living in transitory housing and even the costs of having value of a house reduced or made harder to re-sell because it has been flooded or is in a amorphous water meadow.

b) **Non-economic losses**

Here it is in terms of loss of items of sentimental value, for instance memory items like photographs as well as the feeling of loss of homes that have been sentimentally attached to certain activities. This may also include emotional torture as well as psychological mistreatment by the change of homes and relocation as whole.

c) Impact on physical and psychological health

The health repercussions instigated by flood occurrence could result from: the phenomenon itself, disturbance and complications arising from trying to recover and from the anxiety about the risk of flood re-occurring.

Clare (2005) clarifies that probable health effects could be looked into at three time periods as indicated below:

i. **Instant effects:** death by drowning, injuries due to being struck by falling trees, electrocution, exposure to pollutants and even the stress of the scenario itself.

ii. **Medium term effects:** gastrointestinal illnesses, cardiovascular disease from over-exertion during recovery and clean-up processes, cuts, strains and even respiratory illnesses.

iii. **Longer term effects:** These are majorly categorized as psychological effects.

In addition, in terms of population density in urban areas due to proximity of people to one another within an urban environment, there is a higher likelihood of their being an epidemic of illness, especially if sewer flooding is involved.

d) Impact associated with evacuation and temporary accommodation

These impacts include the effects of having to live away from home as well as having to leave home (Clare, 2005). If there are large numbers of persons to be displaced, it will put pressure on existing services, and may mean that residents have to live in restricted and congested conditions, or have to move a distance from their homes to get safer places to live while floods are being witnessed.

2.7 Integrated urban Water management

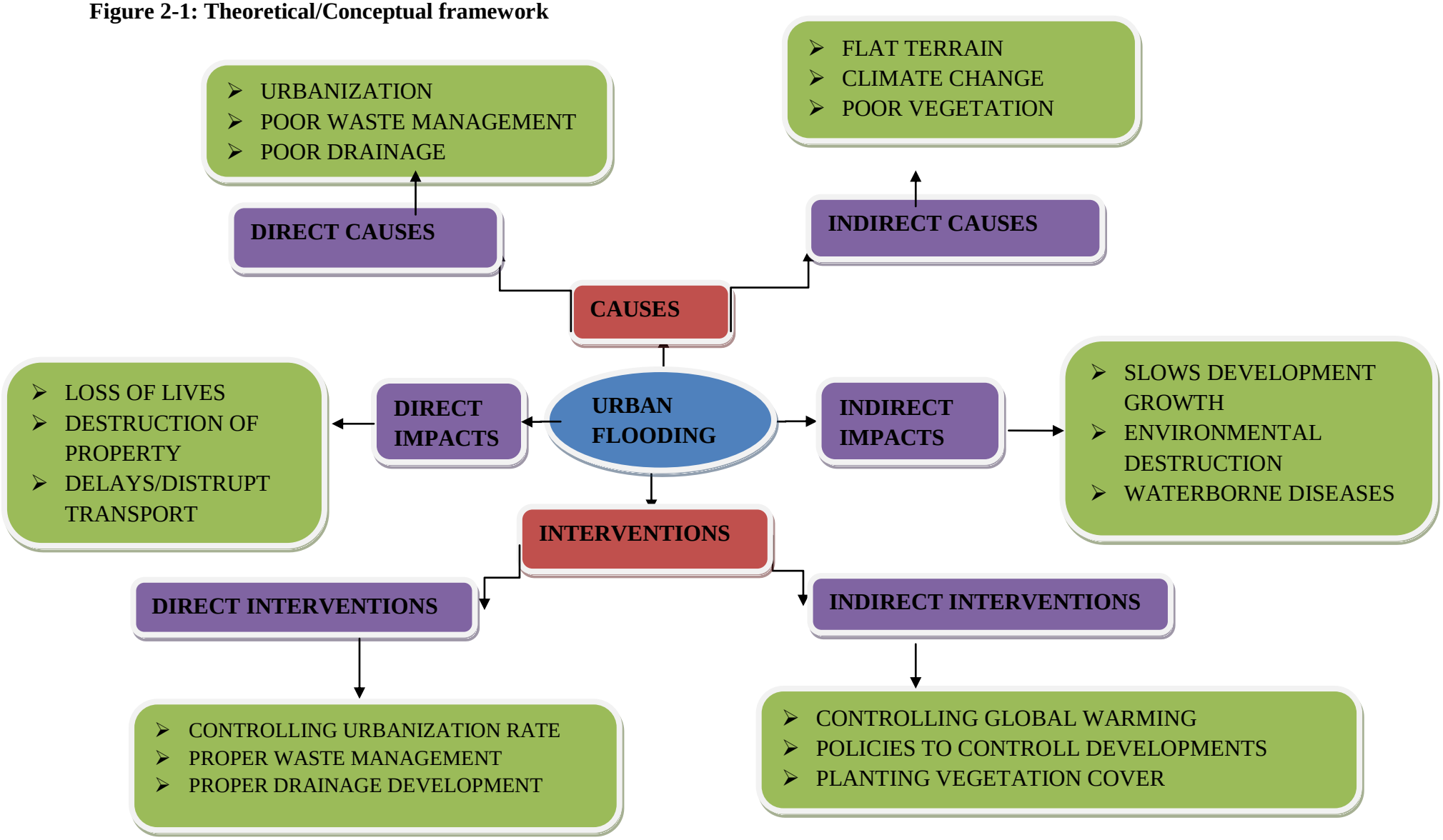
Developments in urban areas have transformed many of the concepts used in water infrastructure/ storm water management over the recent decades in cities. According to Carlos (2007), urban problems are depicted in terms of recurrent flooding, public health, and the loss of a varied atmosphere in many regions. He identifies that this problem has been getting worse with the transformation of a rural to urban environment. The longer the condition lasts, the bigger the legacy of ineffectiveness and burden for the generations to come. In his document on Urban flood Management he identifies a number of issues that need to be done to ensure that the situation including flooding menace coming up in our cities is contained.

Carlos (2007) notes that urban growth must occur with consideration of the sustainability of where individuals are expected to settle. To accomplish these rules he states that land use and settlement must be done in a way that conserves the natural settings and that enables the system to handle water supplies, sanitation methods, transport, effluent management, urban drainage, and garbage collection, dispensation and salvaging. So as to preserve natural infiltration urban

drainage is an important parameter that must be considered while an urban area grows, consequently evading transferring downstream the increased flow, volume and pollutant load from storm water runoff and soil erosion. Finally Carlos (2007) clarifies that Compacted waste must be salvaged to encourage sustainability, financial utilization of this resource, and its disposal. With this, Phenomena of flooding in urban areas can be contained or minimized over time hence consequently minimizing its effects both physically and economically.

2.8 Theoretical/Conceptual framework

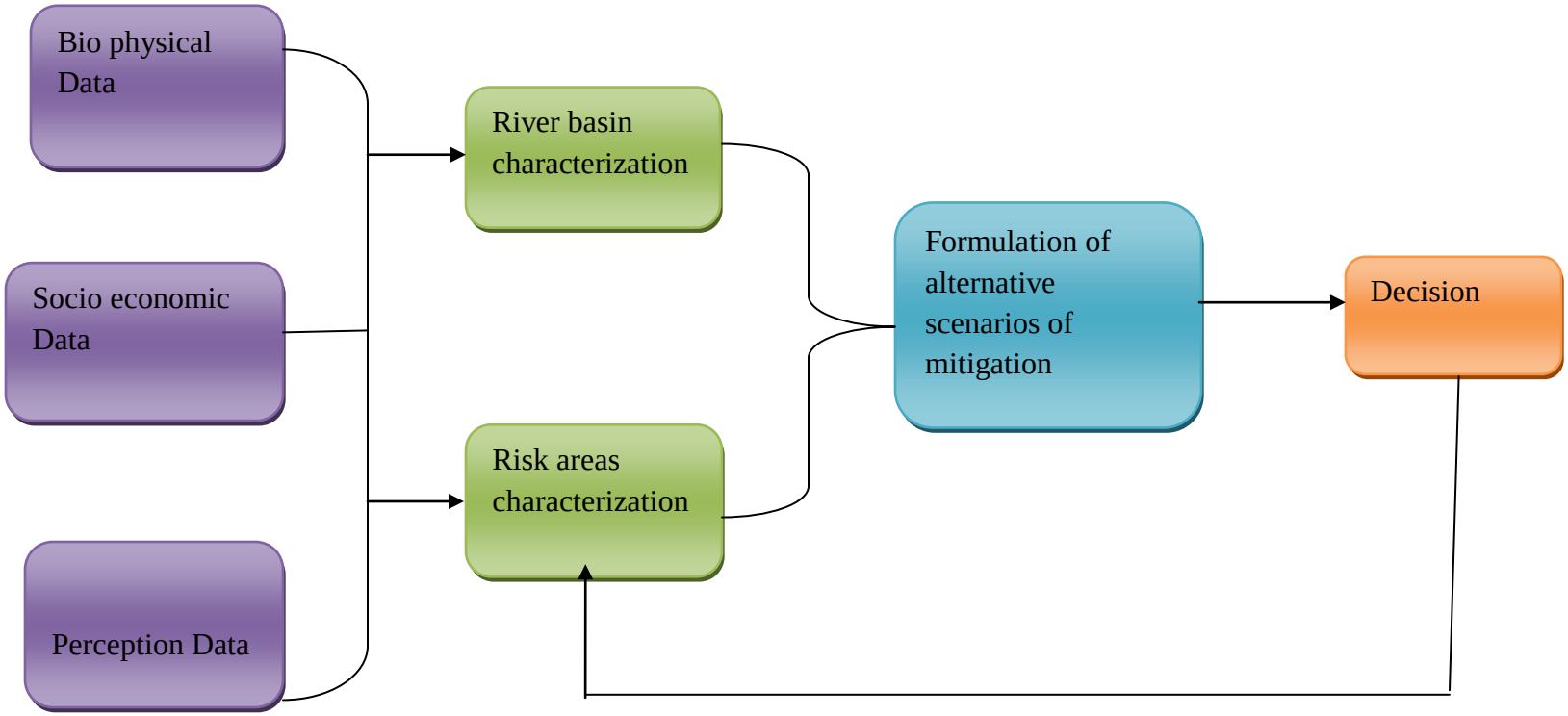
Figure 2-1: Theoretical/Conceptual framework



Source: Author, 2016

2.9 Conceptual model for flood analysis and management.

Figure 2-2: Conceptual model for flood analysis and management



Source: Bernardo .F, et al, (1998)

2.10 Model for Stakeholders and Actors in flood risk management

Figure 2-3: Model for Stakeholders and Actors in flood risk management

Source: Abhas K.Robin B. Lamond J, (2011)

2.11 Flood events over time

Abhas J. et.al, (2011) in their analysis observed that over the last decade most of the flooding events and in previous decades had occurred in highly concentrated urban areas in the stated regions of different parts of the w

orld. The table below shows countries which have experienced flooding phenomenon over time.

Table 2-1: Flood events over time in different parts of the world

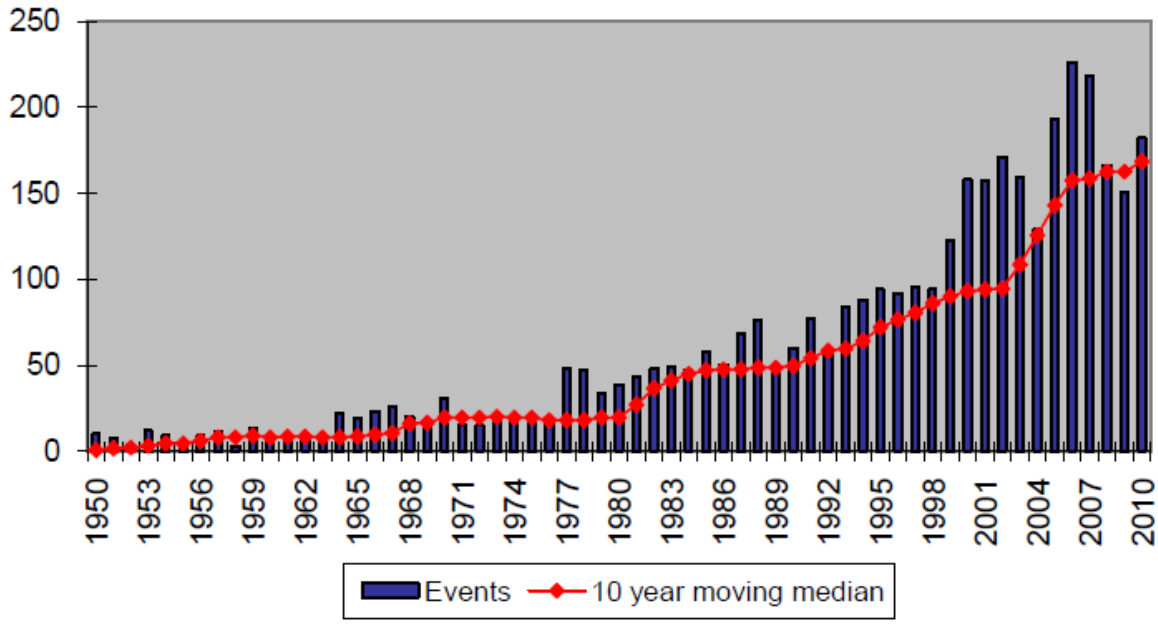
ASIA	AFRICA	SOUTH AMERICA	EURPOE	REST OF AMERICA
India (2002, 2004, 2005, 2007)	**Senega**l (2002, 2005, 2009	**Ecuador** (2002, 2008)	**Hungary** (2001, 2006)	**USA** (2001, 2002, 2005, 2006, 2008)
Indonesia (2002, 2004, 2007)	**Burkina Faso** (2003, 2006, 2007)	**Venezuela** (2000,2002)	**Poland** (2001,2010)	**Canada** (2003, 2005, 2006, 2008)
Philippines (2008, 2009)	**Mali** (2002, 2003, 2007)	**Peru** (2003, 2008, 2010)	**Romania** (2005, 2007)	**Costarica** (2002, 2007, 2008
Vietnam flood (2000)	**Nigeria** (2001, 2003, 2007)	**Colombia** (2005, 2007, 2009)	**Ukraine** (2001,2008)	**ElSalvador** (2005,2008) **Guatemala** (2002,2008,2009, 2010) **Honduras** (2007,2008,2010)
Srilanka (2003)	**Niger** (2003, 2007, 2008)	**Chile** (2000, 2001, 2002)	**Austria** (2002)	**Mexico** (2003, 2005, 2007, 2008, 2009, 2010
Pakistan (2003, 2010).	**Chad** (2001, 2007,	Brazil (2006, 2007,	France (2002, 2003)	**Nicaragua** (2000, 2007, 2008,

	2008)	2008, 2009)		2010)
	Sudan (2003, 2006, 2007)	**Bolivia** (2001, 2006, 2007, 2008)	**Germany** (2002)	**Panam** (2002, 2004, 2005, 2008, 2010)
	Ethiopia (2005,2006,2007)	Argentina (2001, 2007, 2008, 2009).	Switzerland (2005)	
	Kenya (2003,2006,2008)		**Bosnia-Herzegovina** (2001)	
	Uganda (2004,2007)		**Greece**(2000)	
			Italy (2000)	
			United Kingdom (2000,2004, 2005,2007).	

Source: Abhas J. et.al, (2011)

Also noted in their paper, are the trends of flooding over the last 6 decades raising concern of the disaster in waiting if not well managed and prioritized.

Chart 2-2: Number of reported flood events



Source: Abhas J. et.al, (2011)

Despite the trends observed above, it's not clear on whether it is the change in climate or human activities, for instance high population leading to increase in built up areas to accommodate the population hence covering the grounds with pavements on which water could flow over or be infiltrated through to reduce surface run off which eventually contribute to flood occurrence.

2.12 Case studies

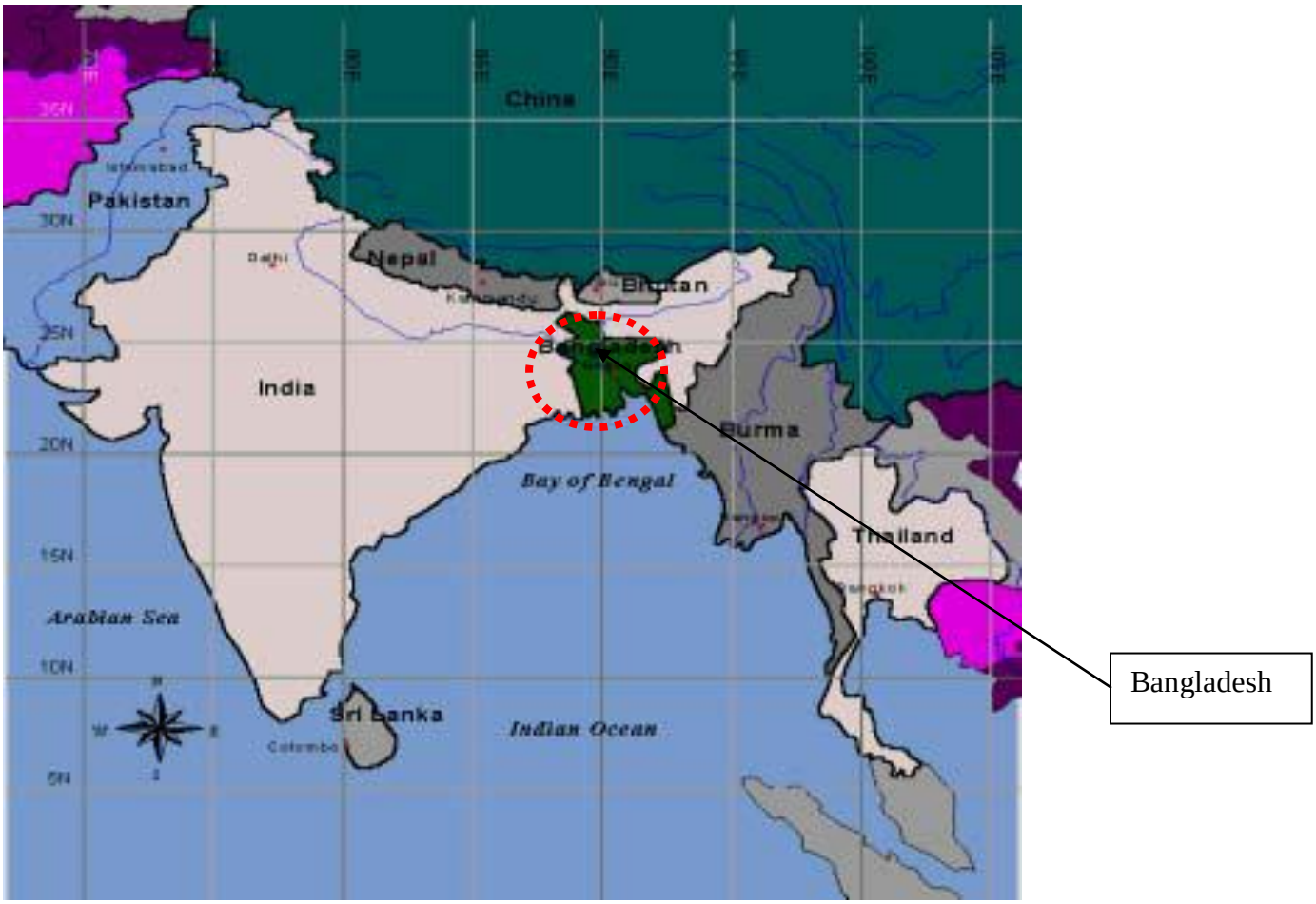
Case studies are done in point to aid in better understanding of flooding phenomenon giving a better view of how other countries and towns have handled it over time. This hence can give a guide on identifying the various causes of flooding, its effects and the management strategy that the affected individuals, towns and countries have applied to curb the situation, hence coming up with better solutions to deal with the phenomenon that is becoming common in Kenyan urban areas especially Nairobi during rainy seasons. Below are two identified case studies:

a) Bangladesh

❖ Location

Bangladesh, situated in South Asian sub-continent (See map 2-1) is one of the major flood encountering country in the world because of its distinctive topography as well as physical location. The country witnesses floods of varied magnitudes and kinds every single year. Since early sixties of the last century, the country has adopted different kinds of measures for flood management. According to Hossain A (2003) for the period of the last half century at least eight different types of worst flood events had been witnessed in the country affecting about half of the land area.

Map 2-1: Location map of Bangladesh



Source: Hossain A (2003)

❖ Physical Causes of flooding in Bangladesh

The country is covered by delta and a huge flood plain with 70% of the entire area being less than one metre above the sea level. Approximately 10% of the land is covered by Rivers and Lakes with the country experiencing intense monsoon rains, specifically over the higher grounds. The major cause of floods in 1998 was the above regular and extensive period of heavy rain which initiated all three major rivers to have their ultimate flow at once.

❖ Human Causes of the Floods in Bangladesh

Deforestation in the Himalayas and Nepal has overtime increased run off hence adding to flooding downstream. In addition, urbanization of the delta has overtime increased enormousness and regularity of flood occurrence. Moreover, construction of more dams in India has amplified the problem of sedimentation in Bangladesh. Sea level rise, increased rainfall and increased snow melt is blamed on global warming in the region.

❖ Consequences of the 1998 Floods

With 57% of the land area getting flooded over 1300 persons were killed, with 7 million homes destroyed making 25 million people homeless. The effects of the floods were a severe acute of drinking water as well as dry food with the spread of diseases such as cholera/diarrhea and bronchitis. Wrecked roads and bridges, fields of rotting crops and 2 million tons of rice was destroyed as the water receded. In addition ½ a million cattle and poultry were lost with overall costing the country almost 1 billion US dollars.

❖ Flood Management in Bangladesh

The Government of Bangladesh began to work with several international agencies to produce a Flood Action Plan in 1989 as the last resolution. This huge scheme contained twenty six action points which was expected to provide a long term solution to the country's flooding problems.

a. Short Term Management

Rescue vessels were put in place; stocking emergency supplies for food, medicines, water, fodder for livestock and as well as tents. Repairing as well as rebuilding of houses and services such as sewerage were redone and assistance from other nation states was requested.

b. Long Term Management

Deforestation reduction in Himalayas and Nepal was ordered with seven huge dams in Bangladesh built to store surplus water with five thousand flood housings put up to accommodate all the population. In addition, a 350km of ridge was built of seven metres high at a cost of 6 billion dollars to lessen flooding along the major river channels. Finally, creation of flood water storing areas was done with an operational and reliable Flood Warning System established.

❖ **Flood Mitigation Strategies in Bangladesh**

a. Structural Measures

In consideration to the concerns of safeguarding people's life and possessions, livelihood and food; the Government then emphasized on protecting High and Low Lands from floods through erection of embankments. As per the World Meteorological Organization of 2003, since early 1960s, the country had implemented about 628 large, medium and small-scale flood control schemes.

Table 2-2: Structural measures to control flooding

ITEM	QUANTITY	UNITS
Embankments	1000	Kilometers
Drainage channels	3500	Kilometers
Drainage structures	5000	Number
Dams	1	Number
Barrages	4	Number
Pump houses	100	Number
River closures	1250	Closure points

Source: Hossain. A, (2003)

b. Non-Structural Measures

The persons living in the High and Low Lands were not resistant to flooding during modest to extreme flood seasons in spite of all the structural activities. The Government of Bangladesh according to the World Meteorological Organization (2003) noted that, abating flood loss through non-structural ways was also very significant. They considered that early cautionary on flood could save life and property and with this view in 1972 Flood Forecasting and Warning System (FFWS) was established with ten Flood Monitoring Stations. This was after the disastrous floods of 1987 and 1988. Later in January 2000, the project was undertaken to improve the FFWS further. As a result, FFWS was expanded to cover the whole country with 85 Flood Observing Stations providing real time flood statistics with early warning for 24 and 48 hours lead-time.

The project on Flood Forecasting and Warning System to date helps the Government of Bangladesh, the disaster managers and the populations residing in the flood prone areas in; flood readiness as well as preparation of emergency mitigation strategies.

c. Policy measures

National Water Policy (NWPo), mandated to guide all the undertakings in the water sector, was introduced by the Government of Bangladesh. Furthermore, it wrote a National Water Management Plan (NWMP) that considered long term requirements, water resource utilization cutting across all sectors as well as its management. NWMP embraces the concern of water management induced adversities, for instance flood, erosion and drought cases. It in addition prepared a Comprehensive Disaster Management Plan (CDMP).

Circulating Disaster Management Strategies where the responsibilities of different agencies responsible for disaster mitigation were delineated during pre-disaster preparedness, rescue and evacuation operation at disaster and post-disaster relief as well as recuperation. The Government emphasized more on Flood Management issues particularly on the early warning readiness and rejoinder activities after the devastating floods of 1998.

d. Institutions that were responsible for Flood Management

Approximately 13 ministries and 53 Government Organizations were singled out to be incorporated in flood as well as water management. The Main national establishment mandated in the flood Controll was the Bangladesh Water Development Board (BWDB). Apart from BWDB, other several organizations were also involved at different stages of flood management. Below is a brief summary of selected Establishments and their mandates in regards flood management:

- Water Resources Planning Organization: Was tasked with planning of water resources management
- Bangladesh Water Development Board: Undertook Viability Studies, Operation, Execution, and Upkeep of Flood Management Projects, and Data Collection for Flood.
- Joint River Commission: Conducted arbitration for data and information exchange on Trans-boundary Rivers.
- Bangladesh Meteorological Department (BMD): Was tasked with long, medium and short array weather forecasting and propagation.
- Disaster Management Bureau (DMB): Was involved with dissemination of all information on natural disaster comprising flood information at all levels.
- Directorate of Relief: Was tasked with undertaking Relief and Recuperation operation in flood hit areas.
- Local Government Institutions (LGI): Did Implementation of small scale flood management schemes, Information Dissemination, Relief and Recuperation of flood victims.
- Non-Government Organizations (NGO): Did Promotion for flood management, Relief and Rehabilitation of flood victims.

e. Lessons derived from the case study

Human factors including deforestation, lack of maintenance of drainage systems are the major causes of flooding.

Policies are key in guiding flood control measures as they give clear directions on steps and guidelines to be undertaken, as well as spelling out institutions which should be involved and responsible for flood controls.

Structural measures including putting up of embankments as well as ensuring there is a clear storm water exit points in all areas are important measures in flood control.

Institutions should work harmoniously in curbing flooding menace to avoid duplication or evading of flood control measure

In places with excess storm water in which drainage systems cannot handle, dams should be constructed at intervals to store excess water along the water course lines, hence reducing water volumes on drainage systems, consequently controlling floods.

Education on causes and effects of floods is important to the society, so that they can be enlightened on the human causes which can be managed.

b) Budalangi

❖ **Location**

The lower reaches of Nzoia River is the home for Budalangi floodplain. The Nzoia River derives its Water from the Nzoia River catchment. It is approximately 334 km long with a catchment area of about 12, 900 km^2. The flood plains are located in Budalangi sub-county, Busia County in the western region of Kenya. Rivers Nzoia and Yala traverse the sub county causing floods periodically in the lower areas as they enter Lake Victoria.

❖ **Topography**

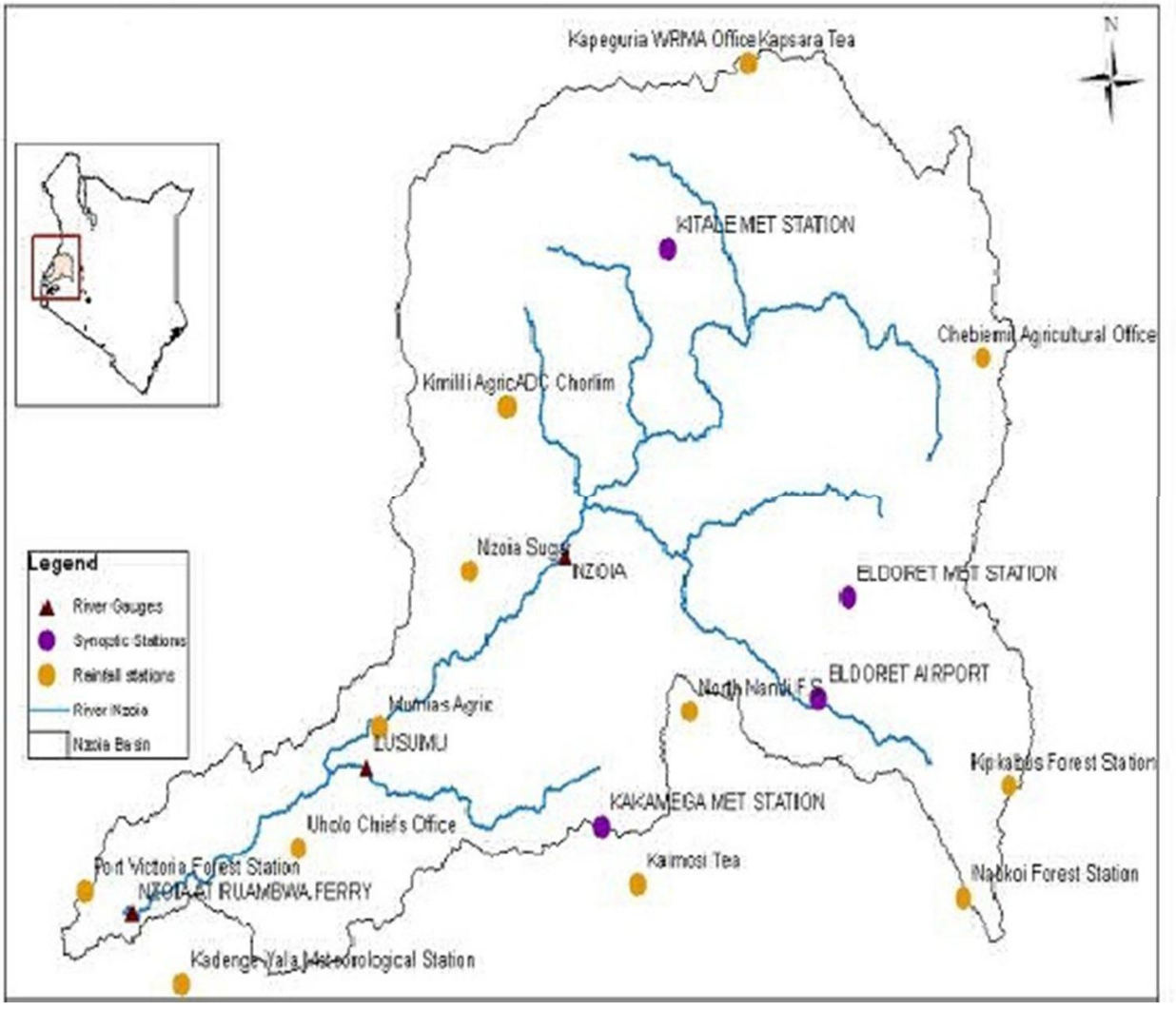
The floodplain has an altitude ranging from 1100 to 1350 m above mean sea level. Topography of the floodplain is fairly flat to very gently undulating with gradient of less than 2%. The catchment is divided into three sub-catchments:

i. Upper Nzoia sub-basin bounded by latitude 0° 04'N and 0° 55'S and longitudes 34° 55'E and 35° 10' E. This covers a total area of 1,500 km^2 with its altitude varying between 1,625 m and 1,825 m A.S.L.

ii. Middle Nzoia at Moi's bridge has a catchment area of 1,470 km^2 with its main streams being River Nzoia, River Kuywa and River Moiben. Both rivers Kuywa and Moiben drain into the river Nzoia.

iii. Lower Nzoia sub-basin is bounded by latitude 0° 04' N and 0° 11'S and longitudes 33° 57'E and 34° 14'E covering an area of 8,500km^2 . The basin has an altitude varying between 1,130 m and 1,225 m A.S.L. the area is generally flat and swampy. The permanent swamps cover a total area of 25km^2.

Map 2-2: Nzoia River Basin



Source: Adapted from Kenya GIS Data

- **Rainfall patterns**

The mean monthly rainfall pattern represents the maximum and minimum periods over the year with the maximum being from April to May and the minimum in the months of July to November. Minimum mean monthly precipitation is 20 mm and the maximum being 200mm respectively. The annual mean rainfall varies between 1,000 to 1,500 mm with the upper catchment characterized as a high rainfall zone with a mean annual rainfall varying between 1,500 to 1,700 mm.

- **Causes of flooding in Budalangi**

Truphena (2015), in her study identified a number of factors that had caused overtime flooding in Budalangi. These factors include:

- Geographical morphology of Budalangi in that it is found at the mouth of River Nzoia, which is a lowland.
- Silt loading in the lower catchment of the river.
- Population pressure, both upstream and downstream.
- Infrastructure development, particularly the dykes that were constructed between 1961 and 1982 from earth works. Their life span had elapsed and they could no longer withstand the strong currents from River Nzoia.
- Environmental degradation which included silting in the river bed and meanders.
- Communities in the flood plain not participating in interventions that were put in place for flood control.

- **Consequences of flooding in Budalangi**

Flooding overtime had been of the norm during rainy seasons in Budalangi. During this period, there had been impacts on the residents of Budalangi. These include:

- Roads and other infrastructure are destroyed and rendered unusable during flooding period.
- Displacement of families.
- Loss of Property and life.
- Destruction farm produce.

- Erosion top soils reach in production.
- Short and long term mental and emotional distress.
- Acute and chronic diseases from water borne pathogens.

❖ **Mitigation measures put in place to control and manage flooding in Budalangi**

a) Community based disaster management and floods early warning

This was done by procuring hydro-met stations and water level recorders that transmit data in real time to help in data collection and transmission of information on possible rains leading to flooding. Seven hydromets were procured and installed with a well spread network at Kipkabus, Nabkoi, Uhoro, Chorlim (Kitale), Kapenguria, Kiminini and Cheptongei. Three water level recorders were installed along the river at Segomre, Webuye and Rwambwa.

Kenya Meteorological Department (KMD) provided the Project office space in their compound that was used as a laboratory by the flood early warning team. This team received data, analyzed using Galway Flood Forecasting System Model (GFFS) to give flood forecast for two days. The forecast information was then compiled in to a daily bulletin which was sent to the Flood Management Coordinator who together with his team reviewed and disseminated information. The bulletins were produced on daily basis and disseminated almost immediately through a station that was put in place to aid in information dissemination called Bulala FM. The radio station sufficiently covered the floodplain as its transmission went to a radius of 100km.

b) Natural Resource Management

There was a clear view of meager natural resource administration increasing the rates of flooding at the Lower Nzoia Catchments Basin. It was as a result of a combination of pollution by non-degradable waste materials, poor land-use applications, and deforestation in the watershed catchment zones, as well as accretion of deposit in the lower segments such as Budalangi and Bunyala. This increased flooding rates created complications in water supply and sanitation, health, communication, agriculture, transport and education.

To solve this flooding problem through Natural Resources Management (NRM) the following areas were focused on (Truphena, 2015).

Improving management of terrestrial biodiversity-This was done through re-establishment of significant native plant types in the micro catchment parts through reforestation and afforestation schemes.

Introducing sustainable land use practices- This was done by introducing agricultural methods that safeguard the catchment area from soil corrosion and contamination load into the aquatic environs.

Management of inland water systems- This was achieved through proper water and sanitation programmes and putting in place pre-emptive measures for control of water pollution into the inland waters

Sustained linkage for natural resource management-This was achieved through adding efforts to alternative nature-based income activities so as to eradicate destructive undertakings like burning of charcoal and network development of participants from the non-governmental and governmental organizations with the determination to complement each other in natural resource management.

c) Lessons derived from the case study

Flood control measures should be assessed early and their effectiveness critically analyzed to enable appropriate actions be put in place to solve the flooding problem.

There is need to put in place a disaster management team composed of the communities affected and the expert orates from the relevant authorities.

There is need to do a study on changes in land-use, changes in climate and flood prone areas in affected areas hence proposing appropriate actions.

Afforestation is key in that it will reduce surface runoff hence normal water flow on their channels, consequently controlling flooding

There is need to control population pressure on catchment areas as well as near river banks, to reduce destruction of natural resources, like tree cover that aid in absorption of rain water, reducing surface runoff of excess water during rainy seasons.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

Logical methodical examination for new as well as useful facts on a specific topic is termed as research (Rajasekar. et.al, 2011). It entails inquiries of finding answers to scientific and social problems through systematic and objective analysis. The information required could be unruffled from diversified sources including past experiences, journals, books, nature, among others done with the aid of study, research, observation, exploration, comparison and reasoning.

Research can be basic as it entails examination on basic ideologies and grounds for manifestation of a specific spectacle or it can be applied research in which it tries to solve certain problems putting in to consideration well known and accepted theories and principles. Rajasekar. et.al (2011) explains that the rudimentary and applied researches can be quantitative, qualitative or even both which are one of the most essential research methods in this study. Quantitative research is concerned with the measurement of quantity whereas Qualitative research is based on qualitative sensation encompassing quality. This chapter establishes the methods of research as well as design that were employed in data collection and analysis for the study.

3.2 Overview

The study explores the problem of flooding in our urban spaces which has been a reality of life with the snowballing rates of floods all over the towns whenever rainy season knocks in. This has brought in numerous problems such as loss of properties, life, destruction of vegetation cover, delays in service delivery which need to be addressed.

The core of this research was based on an analysis of existing situation in Nairobi's South C with the goal of understanding management challenges that have contributed to occurrence of floods every time it rains and how management principles can be factored in to control the menace. The methodology was geared towards realizing the objectives of this study examining the causes and impact of flooding to urban residents, the possible mitigation measures as well as the existing

management structure of the city responsible for flood/storm water management. Intervention measures from the results have been proposed to enable control and management of flooding.

3.3 Research design

The study was a descriptive and mapping strategy that was done to ascertain the major causes of flooding being witnessed in South C part of Nairobi. In order to conceptualize the area and topic of study, Case studies with similar characteristics of the area of study were sampled to enable a better understanding of how the flooding phenomenon has been handled over time by the sampled countries and cities. The case studies highlighted causes and interventions that had been put in place both structural and non-structural to control flooding in those sampled countries and towns. The research study followed the process highlighted below.

a) Literature review

Literature from periodicals, books, Government documents, research thesis, internet sources as well as any other pertinent documents related to the topic of study. This was purposed to disseminate and synthesize arguments and concepts on flooding based issues. A number of case studies were undertaken to lay down a comparison in past flood events of different towns with Nairobi and establish the manner in which the issue was dealt with.

b) Field survey/visits

This involved carrying out of field study on site, and various visits to relevant offices and government departments especially those mandated with managing storm waters/floods and related activities. This included City Engineer, City planning and surveying offices, and National Environmental Management Authority.

c) Population and Sampling

Key informants were purposefully sampled for interviews in government offices so as to be able to access information from targeted officers. Simple random sampling was used in interviewing occupants/tenants of the study area. This was meant to avoid any form of bias in collecting data as well as diversifying information to aid in project research as well as increase percentage of data accuracy.

Information was obtained by using quantitative and qualitative methods in which there was adoption of a triangulation approach. Quantitative method involved majorly the usage of questionnaires.

d) Qualitative research

It was done to seek understanding of the research problem. It involved personal observation, obtaining specific information, opinions, behaviors and social context of the population in South C. This helped in exploring and describing flooding phenomena.

The main aim of this type of data collection that was used was to find out peoples' feelings, experiences from their own point of view.

3.4 Methods of Data collection

To achieve the study objectives both primary and secondary data sources were used. It involved both qualitative and quantitative techniques of data collection.

a) Primary Data

i. Observation

This involved observation and recording of what was considered as possible contributors of flooding incidences within South C and its environs. This included recording of information on nature of drains, built up area and the nature of developments within the area that was deemed to influence occurrence of flooding. In addition, existing land uses were identified and their possible contributions to experienced flooding in the study area, topography, and nature of culverts were looked into to identify if they contributed to flooding phenomenon over time. Soil types were identified and later analyzed if they have a contributory factor to flood occurrence.

ii. House hold questionnaires

This involved administering of questionnaires in a sampled out households. The study area as per 2009 census had a population of 47, 202 persons in an area of 15.10km^2.However the extent area of interest most affected by floods in South C as shown in map 3, has 100 courtyards with each courtyard having 24 households with an average of 4 individuals per house hold as per 2009 census. Therefore each courtyard houses 96 individuals. For the 100 courtyards in the study area,

50 household questionnaires were administered each representing 2 courtyards adjacent to each other, so that one chosen household represented two of the adjacent courtyards. Simple random sampling was used in interviewing households in the estates courtyards that were mapped out to be prone to flooding so as to get more reliably representatives and that all households had equal chances of representation with the same nature of information. This method helped to avoid any form of biasness in collecting of data as well aided in increasing percentage of data accuracy.

iii. Focused group discussions

This involved discussions with professionals from different organizations including two NEMA officials, three planners, two Engineers and two surveyors in city county government of Nairobi. Open and closed questions were prepared for the purposes of guiding the discussions undertaken which encompassed a combination of quantitative and qualitative questions. The aim of the discussions with professionals was to get their professional view point on causes, impact and possible solution of flood cases that had been experienced in study area over time.

Themes of the questionnaires

- Experience of flooding over time.
- Impact of flooding on family, health, work and investments.
- Information received prior flooding.
- Sources of sustenance as well as accountability before, for the period, and after the flood.
- Possible causes of flooding in the area.
- Management structure of floods in the city.
- Effects of flooding to the individuals and their respective families.
- Possible short and long term interventions to flooding.

iv. Mapping

Maps and data from GIS were used to gain clearer information on drainage systems and terrain of South C and its environs, mapping it out for analyzes purposes.

v. Photography

Photographing was used to show the existing situation of the area of study hence helped in data collection of the physical conditions of South C and its environs.

b) Secondary Data

Secondary data was obtained through reviewing various literatures on flooding. The other support sources included, Government documents, periodicals, research thesis, internet sources and any other applicable documents related to the study topic.

3.5 Characteristics of data

The data collected was descriptive in the form of pictures/images of the past experienced situations due to flooding phenomena. Mapping was also done broadly to show how the existing developments as well terrain contributes to flooding in the study area.

Table 3.1: Data types and possible sources in the field

DATA TYPE	INFORMATION	SOURCE OF DATA
Properties and residents affected by flood in South C	Residential Commercial Health Impact on the residents Buildings vacated	Local populace, media reports, county government of Nairobi
Other properties damaged	Cars or other vehicles damaged Out buildings or garden furniture damage	Local populace, media reports, county government of Nairobi
Roads	Types of roads affected (access main) length of road impacted Road closure time	County government of Nairobi, KURA and KENHA, local residents, media reports
Electricity and communication infrastructure	Area impacted properties and residents affected	County government of Nairobi, Kenya Power and Lighting, local populace

	Length of disruption	
Date/Year of previous floods	Inform from local residents Exact location of flooded points and their possible causes More or less severe than current flood Developments in the area impact on the flood events in the past Old flood marks	County government of Nairobi, media reports, local inhabitants
Extent of previous floods	Flood marks, Damaged areas	County government of Nairobi, media reports, local inhabitants

Source, *Author 2016*

3.6 Data Analysis

The whole process included coding of both qualitative and quantitative data in symbols to enable processing of data using Statistical Packages for Social Sciences SPSS. The next stage was processing of coded data which involved data entry, its validation and running the output. Data analysis was then done and its statistics presented. At this stage data was run inform of frequency distribution tables, simple and compound bar graphs and pie charts depending on the type of data collected for simple analysis purposes.

Quantitative data is presented in form of charts and graphs, qualitative data is presented inform of maps photographs and illustrations. For spatial representation, GIS has been used for analysis purposes. Integration of research modules through GIS for the efficient appraisal of management of flooding phenomenon has been employed according to a model developed by Francisco Nunes Correia et al, (1998). This has aided in guiding the stages of informed decision making: that is data collection stage, analysis and synthesis, formulation of alternatives and finally decision-making. Information and findings were finally interpreted and synthesized to facilitate writing of the research recommendations, as well as its conclusions giving possible interventions to the flooding phenomenon.

In the first step Bio-Physical, Socio-Economic and perception data were put to analysis based on the collected data. Then, the flood-prone areas were put in to context evaluating the flood risk, damage estimations as well as regulatory constraints on urban development or environmental protection. The circumstances under which formulation took place were based on urban growth development, and varied options of flood mitigation measures.

With the above in to consideration, four alternatives were advanced for consideration:

vi. 'Do-nothing' situation

This literally assumes that urban development will take place with minimal constraints, having zero structural or non-structural measures executed.

vii. Structural measures option

This option suggests that a dam can be built in the headwaters and retention basins in floodplain within the town to help in controlling and managing of flooding.

viii. Non-structural option

For this nature of scenario regulatory and zoning mechanisms will be put in to consideration both in flood plain areas and catchment regions. This will be basically through enforcement of environmental protection regulations.

ix. Combination of structural and non-structural mechanisms.

This option can be a more effective scenario in which dams are built in headwaters and retention basins in flood plains, then regulatory mechanisms put in place to enhance the effectiveness of the structures put in place to control flooding menace in urban areas.

3.7 Ethical considerations

In order to obtain informed consent on interviews, a brief explanation was done detailing out the aims and nature of the study. The brief explanation encompassed communication details of the researcher and directives on how to take part voluntarily.

Interviewees were be given assurance of withdrawal of their response at any time without giving a reason whatsoever.

3.8 Validity of research

Validity is the extent at which result obtained from data collected corresponds to the phenomena under study according to Mugenda and Mugenda (1999). Kumar (1999) further describe validity as the quality of measurement procedure that provides accuracy at all levels.

In this study the questionnaire, interview schedule and mapping analysis were done. Pilot interviews were done in South C to enhance validity of the study by making sure that all questions are put in to consideration to cover all the set research objectives.

3.9 Reliability of research

Mugenda (2008) noted that by pre testing an instrument, a reliability test as a method of making the test reliable is used. This identifies inaccuracies found in the study instrument which can be corrected later. In addition, pre-testing of instruments help to estimate time needed to administer the instrument.

The test-retest reliability of an instrument is assessed by administering it to the same people on two different instances or by varying the number of research instruments to avoid biasness and enhance reliability. For this study two number of researchers were employed as well as different collection methods of data was put in place to enhance data reliability.

CHAPTER FOUR

FINDINGS

4.1 Existing geographical description of South C and its environs

South C is located in the lower eastern part of Nairobi County having its close proximity to the rift valley region. This has direct link with the unique geographic phenomenon of the great rift valley which divides the City into two halves: eastern and western regions, with the eastern stretching from South -North from Rongai in the South, the Nairobi National Park to Industrial Area, Ruiru, across Eastlands, while the western stretching from Kiambu to Gigiri, Westlands, Langata, Ngong' road, Karen and Parklands. The eastern side has a higher altitude of 1700 MASL compared to the western side of the city with an altitude of 1600 MASL

Height difference exhibits itself noticeably along the low-high gulf that cuts across the city. This feature sees an impulsive vertical ascents as well as descents in numerous regions of Nairobi. The gradient that characters this split goes from the Nairobi National park, cutting across Magadi road and extends all the way to Rongai as shown in map 4-1 with the black streak roughly designating where the slope is located across the city.

Map 4-1: Map showing change in altitude across Nairobi city

Source: Adapted from Google 2016

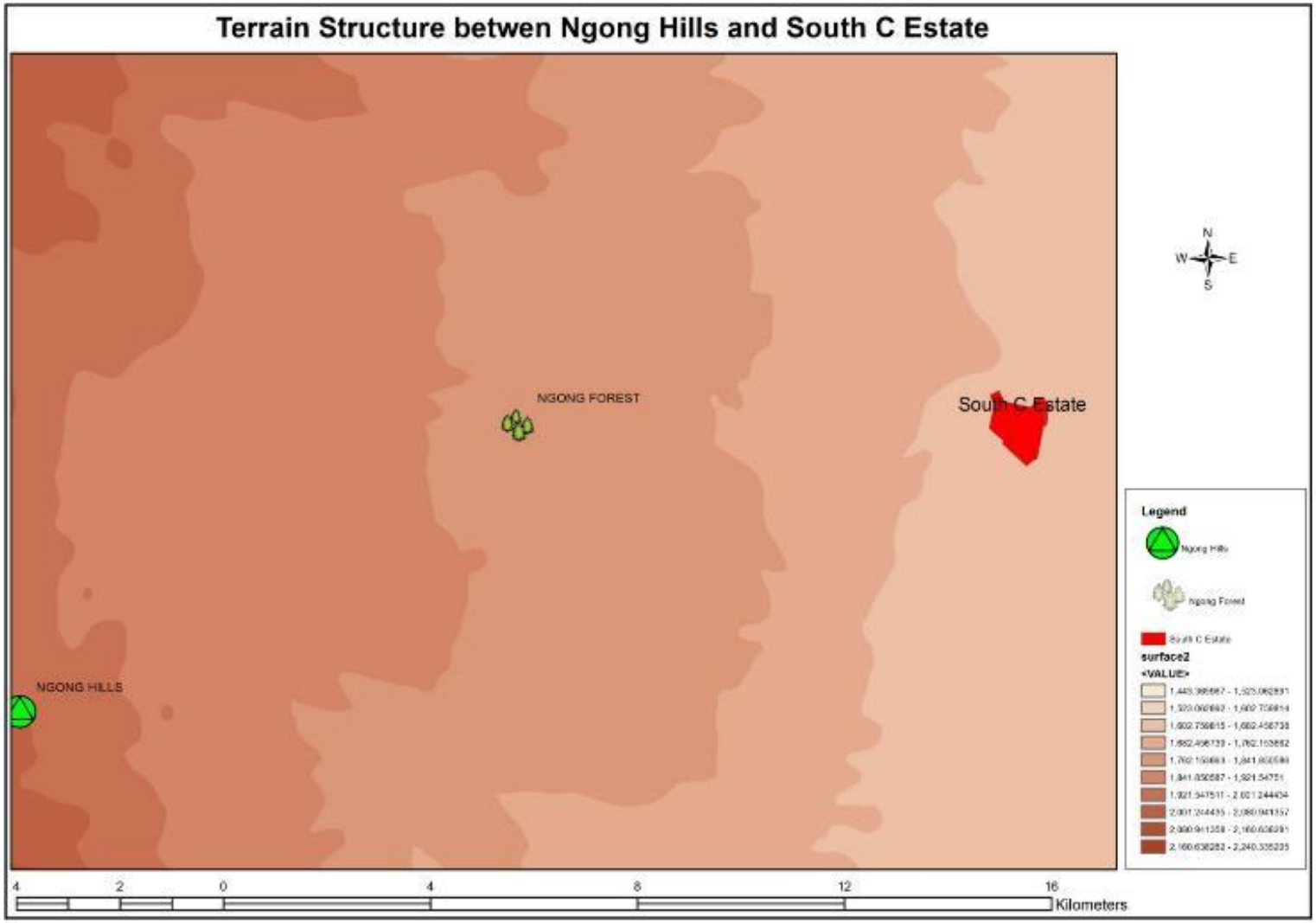
Height difference between the eastern and western sections of Nairobi has dictated the city zoning consequently demarcating the wealthy and working class areas.

The above mentioned slope greatly impinges on the drainage of Nairobi. Water flows swiftly towards the eastern parts every time it rains upon reaching the Eastern plains, the water spreads out creating a flood plain that is manifested in the National Park. This expounds why some areas of the city, South C included experiences flooding whenever rainy season sets in. These are the regions that are adjacent to the slope as detailed in blue on map 4-1 above.

According to the residents, flooding occurs even when it has not rained in or around South C. the interviewed residents noted that Excess water from Langata, Karen and Ngong finds its route to South C and the National Park causing floods in this flood plain. To this extent the study area has a name tag ‘South Sea’ due to the witnessed frequent floods.

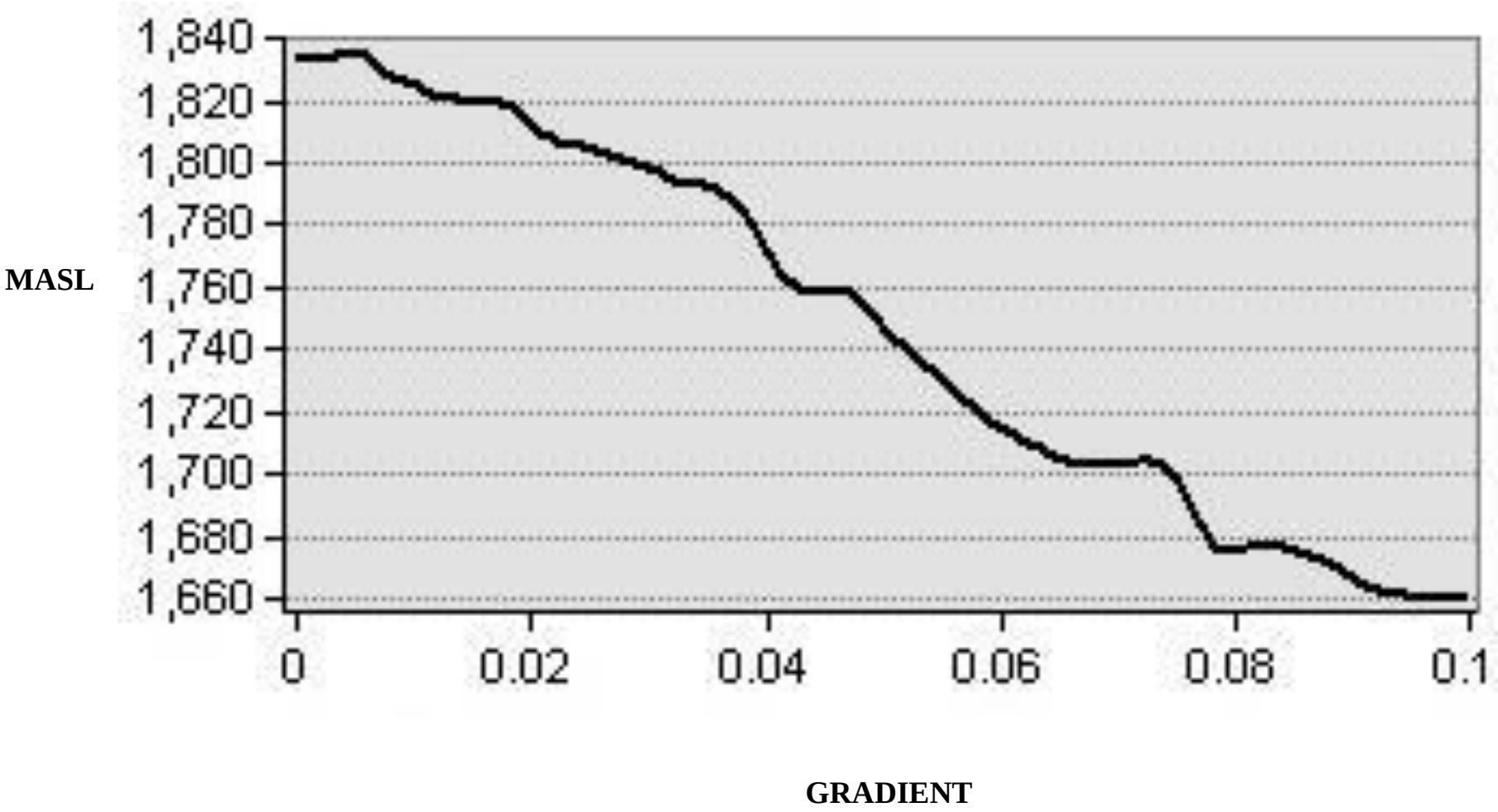
Below is Map 4-2 showing the terrain structure between Ngong Hills and South C Estate and chart 4-1 showing the profile graph-profiling the terrain.

Map 4-2: Terrain structure between Ngong Hills and South C Estate



Source: Adapted from Kenya GIs data

Chart 4-1 Profile graph between Ngong hills and South C



Source: Adapted from Kenya GIS data

4.2 Terrain and profile analysis

Terrain structure as indicated in map 4-2 above, from Ngong down to South C shows a continuous decline in Height above sea level from 2,240.335205 MASL to 1,443.365967 MASL. This shows clearly that South C is located at one of the lowest levels. This has been one of the contributory factors to flood occurrence as storm water from the high altitude level end up within South C and its environs.

The profile graph as shown in chart 4-1 above clearly indicates the slope inclination from Ngong forest area at **1840 MASL** to surrounding areas of South C at **1660 MASL** (Profile graph shows the lowest height from the picked highest level in Ngong area and the highest height from the lowest level picked around South C). The profile graph clearly indicates how the terrain is from the west of Ngong areas to the East of Nairobi area, South C being part. From the slope, due to nature of flow of water through gravity, the flow of storm water during rainy seasons can be determined ending up in South C due to its lowest altitude, hence the witnessed floods over time.

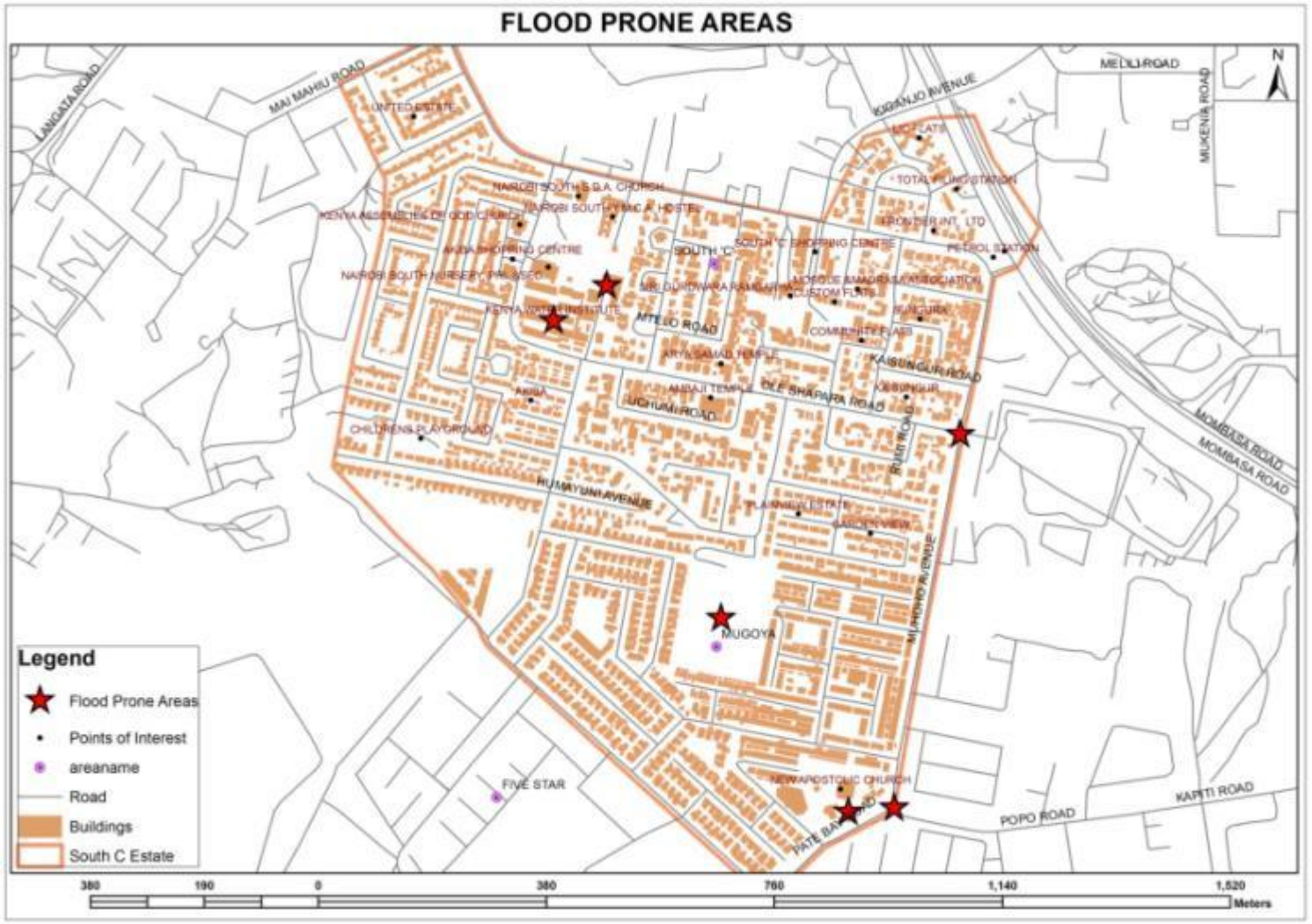
4.3 Population of South C

Population growth throughout Kenya is one of the highest recorded units in the world according to World Bank report of 2014 which was at 2.64% with an urbanization rate of 4.34%, world fact book (2016).The report attributed this to the blend of high fertility rate and relatively young population implying high growth persisting for some time. The study area lies within Nairobi city which has experienced over time one of the highest growth rates of 4.1% per year. World fact book notes that it is highest than any city in Africa and estimates that Nairobi's population will reach 5 million in 2025. South C has an area of 15.10km^2 with a population of 47,202 as per 2009 population census.

4.4 Flood prone areas of South C

Most parts of the study area experiences flooding, however there are a number of identified roads including: Muhoho Avenue, Oleshapara road, Popo road, Pate Bay road and other areas like Mugoya estate, areas surrounding new apostolic church and Kenya Water Institute as mapped below that are hit worse by this phenomenon.

Map 4-3: Flood prone areas in South C



Source: Adapted from Kenya GIs data

4.5 Causes of increased flooding in South C

4.5.1 Uncontrolled development

Flooding occurrence in South C starts from the upper regions of Rongai and Ngong hills area ending up in South C which is on the lowest level with the problem of lack of exit point of storm water especially at the point where Muhoho Avenue meets Pate Bay road. Flooding in the study area, has been immensely contributed to the nature of uncontrolled developments leading to more percentage of ground coverage as well as encroachments on road reserves blocking drainage systems, apart from the problem of lack of exit point of storm water. Maps detailed out by the professionals (planners and surveyors) haven't been put into good use to aid in controlling of upcoming developments, regardless of increase in knowledge of how and where floods have frequently occurred, resulting in predictive flood maps.

The uncontrolled developments have led to increase in density in areas that were previously low density including, Rongai, Ngong, Langata and even South C with the introduction of high-rise buildings as well as commercial nodes. This has resulted to increased plot ratios as laid down by the guide of Nairobi City Development ordinances and Zones from the maximum of 75% and ground coverage from the maximum of 35%, reducing ground absorption rates as well as depleting and overcoming the capacity of the original drainage systems. This has greatly contributed to occurrence of floods in study area as witnessed over time.

Plate 4-1: Original character of South C

Source: Fieldwork, 2016

Plate 4-2: Ongoing high rise developments in South C

Source: Fieldwork, 2016

4.5.2 Poor infrastructure maintenance

It is characterized by inadequate maintenance of the existing drainage systems leading to blockage of culverts hindering free flow of water. Waste materials, silt as well as extensions have led to blockage of these drainage systems, hence even little amount of down pour leads to instant flooding due to blockage of water ways down the drainage system.

In addition to blockages of drainage systems, there is little or no sign of their rehabilitation as well as replacement, renewal of the aging infrastructure with the increasing population in urban areas. Plate 4-3 illustrates this scenario.

Plate 4-3: clogged drainage systems

Source: Fieldwork, 2016

4.5.3 Changes in Land use and increased population density

Within the study area and its surrounding environs great changes in land uses to accommodate the rising population by providing residential as well as commercial services is evident. This has been done with less or minimum consideration of drainage as well as infrastructure needs which has consequently led to overwhelming of the capacity of the existing drainage systems visa vis

the population they serve. With the above changes, receptors have overtime been exposed to the flooding risk.

Rising land demand due to population increase, has resulted to increase in land prices, according to City county land valuer: Ksh.30, 000,000 per plot of 1/4 of an acre in the year 2015, which was Ksh.10, 000,000 between the years 2000 and 2005. This situation has consequently led to illegal developments of available open spaces for commercial as well as residential purposes consequently reducing ground coverage percentages.

4.5.4 Poor solid waste maintenance

Nairobi city has a poor solid waste collection problem and South C is no different. Solid waste is thrown along the road side by residents. These waste ends up in drainage systems blocking the drainage channels. Plate 4-4 shows the nature of solid waste materials dumped on drainage systems hindering free flow of storm water.

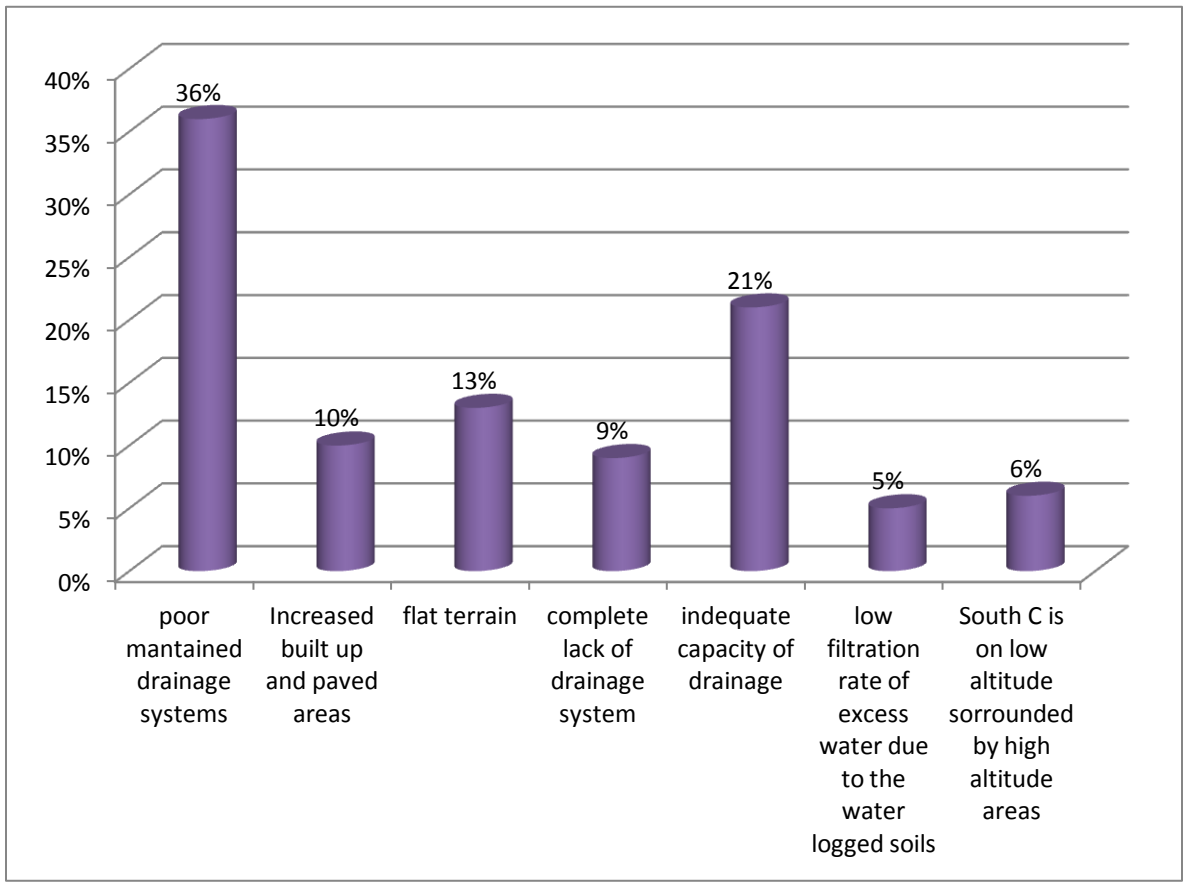
Plate 4-4: waste poorly disposed off on the drainage system

Source: Fieldwork, 2016

A summary of causes of floods as per the interviewed respondents

Field study was done between January and April 2016, below is a summary of the findings from the respondents interacted and interviewed.

Chart 4-2: A Summary of causes of flooding in South C



Source: Fieldwork, 2016

From the above statistical analysis, poorly maintained drainage system was rated highest by 36% of the interviewed respondents to be the major contributory factor for flooding phenomenon witnessed in South C. This was attributed to blockage of drainage systems by non-degradable waste materials as well as silt which is not cleared regularly from the drains. As a result the drains have been rendered ineffective as storm water cannot flow through efficiently leading to overflows on roads as well as paved areas. This consequently led to flooding over time.

Another noted cause was the inadequate capacity of the drainage according to 21% of the respondents due to the changes in factors such as population increase consequently leading to increase in built up area to accommodate the rising population, which have increased surface run off. With the original design and size of drainage systems of 0.5 metres wide by 0.5 metres deep, the drainage systems capacities have been over whelmed by the increased storm water hence the witnessed flooding cases. This calls for the need to expand and re-design the drainage systems.

Other noted contributory factors to flooding by the interviewed respondents include flat terrain at 13%, built up and paved areas at 10%, complete lack drainage systems in some sections of the estate at 9%, low altitude of the estate and nature of soils being water logged hence low filtration at 6% and 5% respectively.

4.6 Effects of flooding in South C

South C over time has experienced flooding cases over time. These has caused havoc in the estate and the roads that serve and run across the estate. Plates 4-5 to 4-9 spells out the effects of flooding cases that was witnessed in the year 2015 between October and December

Plate 4-5: Submerged Vehicle by flash floods at South C Estate

Source: Standard Digital media, 2015

Plate 4-6: Motorists stuck in Nairobi's South C estate

Source: Standard Digital media, 2015

Plate 4-7: Floods in Nairobi's South C estate

Source: Standard Digital media, 2015

Plate 4-8: Flooded sections of South Cs Mugoya estate

Source: Field work, 2016

Plate 4-9: Sign board fell by the heavy flood rains at South C shopping Centre

Source: Fieldwork, 2016

4.7 Effects of floods in other areas of the city

Other areas of Nairobi city as well experiences the same problem of floods like South C. Plates 4-10 and 4-11, shows the damages and access inconveniences caused by floods on other parts of the City.

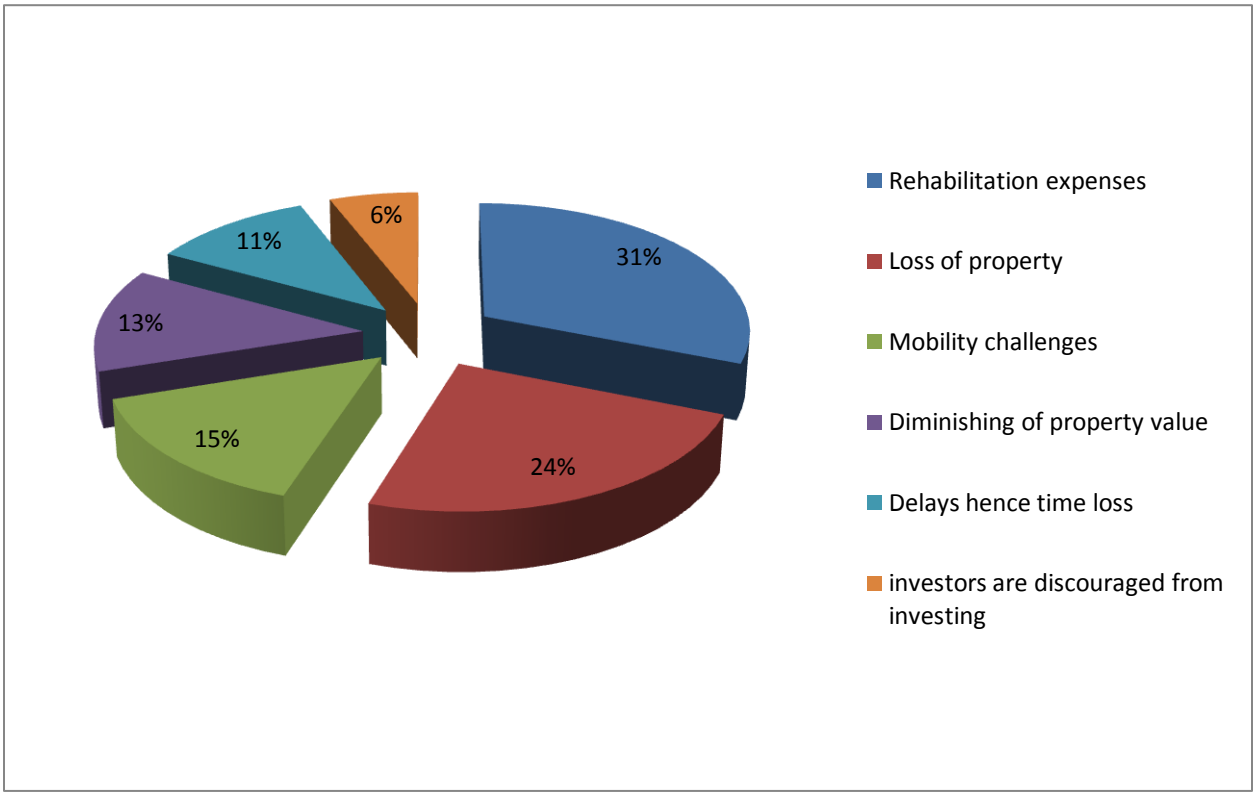
Plate 4-10: Demolished walls in Kileleshwa Estate by floods

Source: Fieldwork, 2015

Plate 4-11: Floods along a section of Mbagathi road

Source: Fieldwork, 2015

Chart 4-3: Summary of effects of floods



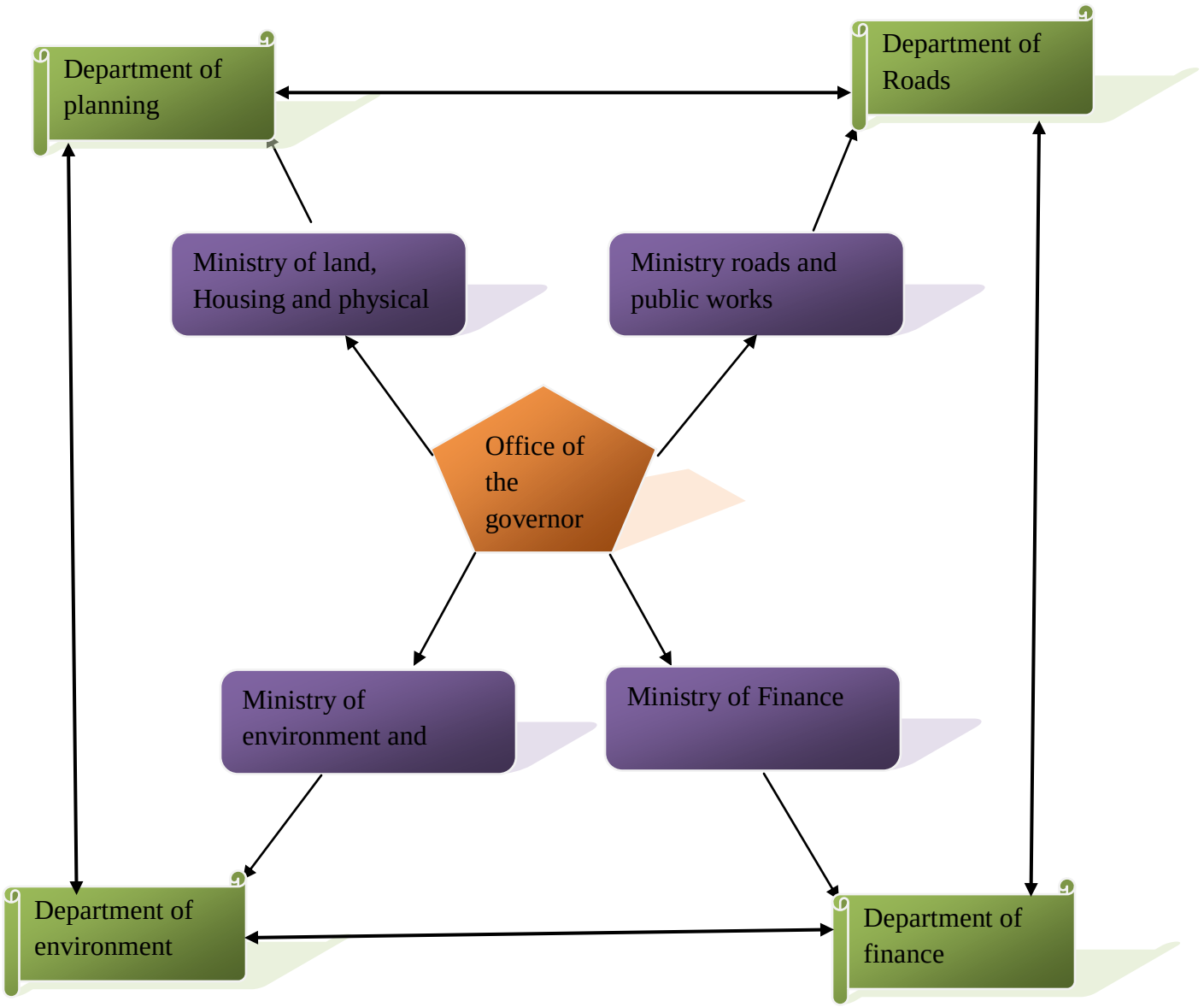
Source: Fieldwork, 2016

Effects of floods are numerous and devastating as witnessed in Kenya and other countries of the world. According to 31% of the respondents, the main effects of floods was the rehabilitation expenses with 24% indicating loss of property as the other major effect. However mobility challenges as an effect was noted by 15% of the respondents especially those who walk on foot with 13% citing diminishing of property values especially housing units as people tend to shy away from the estate due to the flooding problem. Delays hence time loss and discouragement of investors was noted by 11% and 6% of the respondents respectively.

4.8 Management set up of storm water/flooding in the study area

Nairobi city county has a management structure put in place to deal with storm water including other disaster in the process of running and managing the city. Figure 4-1 details out the existing Management structure of Nairobi City County.

Figure 4-1: Existing Management structure of storm water management in Nairobi City County government



Source: Field work 2016

4.9 Efforts by the County Government to control floods

The county government of Nairobi during November did set aside Kenyan shillings 300 million for the purposes of controlling floods and management of the phenomenon to avoid the menace that had been experienced over time. The County began by putting in place culverts and digging trenches to increase their capacity of handling storm water, which could cause more floods along the roads like what has been happening over the past years. Plates 4-12 and 4-13 show culverts and drainage systems being cleared and constructed in the month of November 2015 by county government of Nairobi.

Plate 4-12: Culvert and trench constructed by County government of Nairobi

Source: Fieldwork, 2016

Plate 4-13: Drainage systems being cleared by County government of Nairobi

Source: Fieldwork, 2016

4.10 Challenges faced by the county government in controlling floods

Withstanding the efforts the county government of Nairobi has done to control flooding, it has experienced a number of challenges according to the county government officials from departments of Planning, surveying, National environment management and roads. Unanimously, the professionals stated common challenges cutting across the departments tasked with controlling floods directly or indirectly as: inadequate funding hampering their effectiveness, long bureaucracies in accessing the little funds delaying flood controlling programmes hence being caught up with the phenomena, departments working in isolation hence replication of activities, political interference where Members of County Assemblies and Members of Parliament interfere with implementation of by-laws, by mobilizing stoppage of demolitions of illegal structures along road reserve encroachments which could have been used to expand storm water drains.

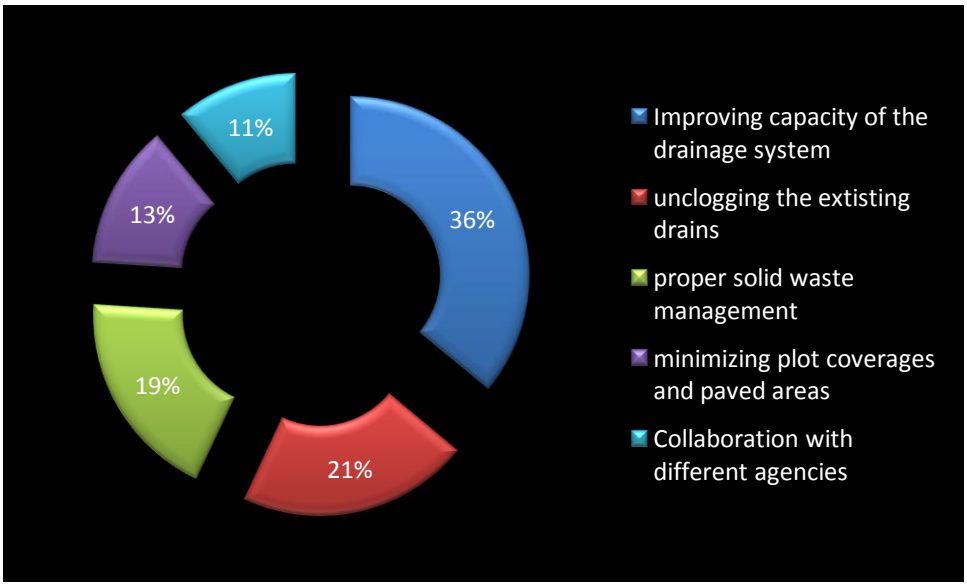
4.11 Suggested ways of flood control from the tasked institutions

The tasked institutions had their representatives interviewed two NEMA officials, three planners, two Engineers and two surveyors of City County government of Nairobi, giving the challenges they face in managing and controlling flooding. They however suggested a number of ways that will help boost flood control to ensure its effectiveness. The measures highlighted include: Provision of adequate funds and on time to help actualization of storm water channel expansions to meet the increased volume of storm water, Establishing clear structures within the institutions to avoid long bureaucracies and conflicts in discharging of duties, encouraging formation of registered resident organization to enable ease of access of residents, Educating residents on possible causes of floods to enable them avoid those caused by humans and implementing by-laws to the later without political interference.

4.12 Suggested ways of flood control from the resident respondents

Chart 4-4 below shows a summary of proposed ways of flood control from the resident respondents

Chart 4-4: Recommendations from Residents respondents



Source: Fieldwork, 2016

Of the interviewed respondents 36% proposed that improving capacity of drainage system will be able to accommodate the increased storm water caused by increased paved areas hence high rates of surface run off. 21% noted that unclogging the existing drains will help curb flooding as most drains are clogged by non-degradable materials mostly polythene paper as well as silt which hampers the flow of storm water hence flooding. Proper solid waste management was proposed by 19% of the respondents as this greatly contributed to clogging of drainage systems. Minimizing of plot coverage's as well as reducing paved areas within the built up plots and on road reserve by covering them with vegetation cover which allows infiltration of rain water therefore reducing surface was proposed by 13% with 11% respectively proposing Collaboration with different agencies proactively in putting in place measures to curb flooding including KENHA, KURA, County government of Nairobi, NGOs, among others.

CHAPTER FIVE

CONCLUSION AND RECCOMENDATIONS

5.1 Conclusion

5.1.1 Land use

Nairobi city has a moderately gently sloping land with the study area located at 1795 MASL compared to Ngongs' 2000 MASL. This means that in case of occurrence of rains the study area collects water form Ngong hills and its environs, with the problem of lack of an exit drainage system, water tends not to find its way out of South C hence flood occurrence.

Continuous increment of residential, commercial and road constructions on flood prone areas like South C have led to reduction of land area in which infiltration could take place hence enhancing water runoff both on the surface water systems and sewers. These scenarios have led to increase of urban flooding.

South C is a medium income residential area which is medially populated area (according to answers corporation classifying high population density at 5,001 people/ km^2 and above with medium population density between 401 and 5, 000 people/km^2 and Low population density at 400 people/km^2 or less, hence making the study area fall at medium population density having 3125 people/km^2) with much more economic activities performed to serve the community.

5.1.2 Drainage system, rocks and soil.

Drainage systems in South C like most of the parts in Nairobi and other major Kenyan towns like Nakuru, Eldoret, Nyeri, Mombasa and even Kisumu are dilapidated, old and incapacitated.

About 70% of the storm drains according to the city engineer are clogged by silt as well as solid wastes hence hindering their functionality and capacity. Some of them are encroached over by extensions hence unblocking them is made difficult to the authorities in place. In addition to encroachment, South C, has no clear water exit point in terms of drainage systems, hence flood occurrence, as most water received is not drained off the estate.

Drainage systems that are appropriately designed according to rainfall intensity and population projection, built and well maintained will ensure reduction in flooding in the flood prone areas. The design of drainage systems depends on the nature of the surface (rocks, soil and terrain) and the activities that are likely to be undertaken. With the study area having impervious rocks, with clay soils characterized by low infiltration and relatively flat terrain, gully drainage system is the ideal kind of drainage system that must be erected. It is able to comfortably drain runoff water that mounts up during the period of storms if built in appropriate sizes as per population as well as rainfall projections size. This gully type of drainage is the best for the study area, to enable ease of draining off of excess storm water since 90% of the study area is built up according to the city engineer in charge of infrastructure. In addition to the built up area, 41 % of the study area is composed of impervious surface while 59% is composed of pervious surfaces. This relatively high percentage of interconnected impervious surfaces contributes to the witnessed storm water runoff volumes. On top of the impervious rocks, the study area predominantly consists of clay soil, which translates consequently to poor drainage, hence levels low levels of water infiltration and high surface water runoff.

The County Government of Nairobi experiences challenges in ensuring the drainage systems are maintained and its efficiency maximized. This is due to lack of funds as well as long bureaucracies with conflicts in implementations of projects between National and county governments. The engineer in charge of infrastructure highlighted the need to have a clear framework in terms of responsibilities of each office and departments, precise and short bureaucracies as well as a clear coordination on resident involvement in design and execution of projects in regards to drainage systems. This will ensure there is an effective, implementable and workable drainage system to handle storm water during rainy seasons hence controlling floods.

In addition, The county engineer on behalf of the county government proposes that the drainage systems to be designed and constructed should be at a minimum of disruption of the natural drainage pattern and in addition it must drain surface and subsurface water out of the roadway in a manner that averts excessive water collection in unstable regions and successive downstream erosion. With this considerations, the issues of surface run off of storm water as well as blockages of existing drains will be solved hence flood control consequently.

5.1.3 Road network system

For the past decade floods in Nairobi and its environs has been a major concern. The phenomenon has led to increased damages leading to economic as well as financial losses and worst of all loss of human lives. For instance on 14th December 2015 classic 105 reported that more than 80 people had been killed by floods in Nairobi alone.

Physical structures like road gullies and culverts have been destroyed and blocked off over time. Actually in Nairobi County, floods in Road networks have greatly deteriorated and this was associated by respondents at 36% to poorly constructed drainage systems, lack of maintenances of those constructed drains and inadequate capacity of drains by 21% of the respondents. County government of Nairobi in the year 2015 set aside Ksh.300 million to renovate drainage systems and for the purposes of disaster management according Nairobi's CEC of environment and Natural resources Mr. Evans Ondieki as at the year 2015.

When constructing roads engineers should put in to consideration a number of factors to avoid damaging and wash off of pavement aggregates as well as drainage systems during heavy precipitation. These factors include: the nature and terrain of the place as well as existing soil structures, i.e. whether prone to erosion or its porousness.

These factors will help the engineers responsible of road construction to design and construct the road that will reduce the soil malleability by use of lime and cement. When the slope is gentle, the consideration of improving drainage pattern should be put in high consideration in terms of capacity and levelling to enable its handling of storm water due to its slow lag caused by the flat terrain. This will ensure reduction of the amount of runoff as the drainage systems can able to withstand the storm water. In addition to the design of drainage systems, the round and box culverts is highly recommended since they are good in transporting of flood water to the where it right destination.

The study area has its culverts destroyed and blocked by solid materials as well. Consideration should be put in place during their designs to ensure the blockage issue is dealt with. Culverts designed must be in a position to:

- Sustain increased runoff caused by projected land development and increased coverage of built up area.
- Deliver sufficient transport of water, sediments and debris, without drastic variations in patterns of flow.
- Circumvent extreme ponding at the entrance which might lead to damage of property, sediment accumulation and clogging of culvert
- Function properly after fill has settled.

5.1.4 Global warming

Global warming has been associated with climate change over time. Mendel (2006) notes in his report on Climate change, flooding in urban areas and the rights of the urban poor in Africa that: change in climate has been due to emission of carbon gases from various industries and other toxic materials which have led to depletion of ozone layer. This has led to increased heat intensity hence high evaporation rate. This situation has consequently resulted in increased rainfall intensity over coming drainage system capacities hence the witnessed flooding cases in most of the cities roads as well as roads and streets of other towns in Kenya, Narok and Nakuru being two major examples. With this there is an urgent need to tackle the issue of global warming caused by depletion of ozone layer, by reinforcing the existing rules and regulations, controlling emission of gases to the atmosphere by stiffening the existing penalties and putting in place stronger enforcement rules.

Generally there is a type of flooding associated with global warming in urban areas known as surface water flooding. This is kind of flooding is caused by heavy and lengthy rainfall leading to overpowering of the drainage systems capacity often leading to major economic losses and devastating social and environmental impact.

This type of flooding phenomenon often occurs with no warnings, making its management and prediction hard. Normally there is a likelihood of surface water flooding occurring in urban areas because of the high percentage of paved and tarmacked surfaces, that normally limits water permeation increasing the amount of water surface run off in addition to its rapidity.

This has built up by the fact that natural drainage courses are more often changed in towns and cities to accommodate human consumption, which results in reduced capacity for excess water.

5.2 Recommendations

5.2.1 Management of storm water drainage

South C does not have a clear exit drainage system for water, hence there is need to design an exit drainage system for storm water to join the one at Nairobi west out falling in to Ngong River, hence consequently controlling floods, as the issue of water stagnation leading to floods will have been dealt with.

In addition to the study, the county government should develop a storm water database that gives a full inventory of the existing infrastructure to enable monitoring of the conditions of the drainage systems, hence identify when there is need to be repaired or and upgraded.

The study identified that storm water over flow the channels due to blockage of existing drainage channels by soil and waste materials. Hence there is need to manage storm water drainage channels by designing waste material as well as eroded soil blockage grills at culvert inlets to enable collection and clearance of the waste materials that found its way through the water channels. Its collection will be made easy hence reduction in culvert blockages by waste materials or eroded soils ensuring free flow of water.

Existing drainage systems that originates from Langata area ending at the junction of Pate Bay road and Muhoho avenue within south C estate where flooding occurs most should be opened up to join the one at Nairobi west area draining in to Ngong river. This will ensure continuous flow of storm water minimizing occurrence of floods.

The county Engineer in charge of infrastructure detailed out that the existing drainage systems have been overwhelmed by the increasing capacity of storm water. No effort has been made to expand the existing drainage systems since they were planned for and constructed in 1948 when Nairobi's master plan was launched. With consideration that there was more open space in 1948, storm water would be absorbed in the open spaces. With the increase in ground coverage reducing the percentage of open spaces to 10% storm water has increased due to less ground

infiltration channeling the excess water to the 1948 designed and constructed drainage systems which were as shallow and wide as 0.5 x 0.5 metres. This has led to overflow of the excess water hence flooding. This necessitates the need to re-design and expand the drainage systems to handle storm water consequently controlling flooding.

The re-design of drainage systems should consider the following factors:

- **The capacity-** the systems should be capacitated to sustain the peak overflow projected from at least a frequency of 25-years, with a 24-hour storm duration. This will be calculated using Rational method equation as follows: Q = C x I x A in which:

Q = Storm Water Runoff (in cubic feet per second)

C = Coefficient of Runoff

I = Rainfall Intensity (in inches per hour)

A = Area of Drainage Zone (in acres)

- **Shape of the drainage system-** the system should be trapezoidal, rectangular or triangular with stable side slopes having a ridge height of at least 150mm and 15% allowance of settlement.
- **Slope of the drainage system-** Drainage systems must be designed in a manner that prevents storm water from stagnating for a longer period of time covering the channel vegetation. Designs should be at a velocity higher than 50cm/s so as to avoid sediment accumulation in the drainage channels

In essence, expansion should begin from the high altitude levels of Ngong and Langata areas all the way beyond South C to Ngong River where they will be drained down the river. The expansion should be done in relation to the urbanization rates of Nairobi at 4.1% increasing the built up area reducing infiltration rates hence with the existing drainage systems their sizes should be at a minimum of 3 by 2.5 metres to handle 7.5m^3 of storm water/second hence minimizing storm water overflow. In addition to them being expanded, the drains should be covered by concrete leads to reduce instances of being used as dump sites for waste materials by residents. The more the population, the more the developments hence with more residential and

commercial units: ground coverage by the built up structures increases consequently reducing ground absorption rates.

Most of the water will flow on pavements and roads increasing surface runoff volumes as well as speed. This will definitely lead to flooding if the drainage channels are not expanded to accommodate the changing urban environment.

5.2.2 Recommendations to KURA

The study is serviced by roads under the Jurisdiction of Kenya Urban Roads Authority (KURA) hence its management. KURA should undertake the following to contribute in flood control within the study area:

- Redesign the drainage systems as per the population, rainfall intensity as well as terrain of the ground as per the Roads engineers' recommendation.
- Continuous monitoring of rainfall within Nairobi and high altitude areas of Ngong hills, where storm water begins through establishment of rainfall observation stations to enable determination of the nature and size of drainage systems.
- Carrying out regular inspections to check blockage points that may lead to overflow of storm water due to hindrance of water movement through the drains.
- Re-seeding of denuded land/road reserves with grass cover to enhance infiltration rates.
- Conducting Public awareness campaigns ensure awareness of the impacts of the rains.

5.2.3 Diversion of water from High Altitude areas

Most floods witnessed in South C originate from the high altitude areas of Ngong which is at 2000 Metres above Sea Level to South C which is at 1795 Metres above Sea Level. South C being on the lower altitude, most of the storm water end up within the estate with the existing storm drains being overwhelmed by the amount of storm water from uphill areas. Apart from expanding the drainage systems, diversion of water should be done to areas of need and stored for future use. Two main areas would work best for this:

A Dam should be built in Nairobi National park and storm water diverted from Langata areas. The piece of land on which the proposed dam will be built shall be provided by Nairobi National

park in consultation with the National and Nairobi City County government. This will help reduce volume of water flowing to South C hence reducing amount of storm water which will be handled by the storm drains.

The dam will provide drinking water for wild animals and act as scenery to tourists, earning the country foreign exchange. This in one way will provide funds that will boost in flood control as more tourists means more revenue generated.

Storm water from Ngong hills areas should also be diverted to Kajiado and its environs. Another dam should be built at the slopes of Ngong hills in Kajiado County, identified and purchased by the county government of Kajiado in consultation with the residents.

Kajiado being a semi-arid area with an annual average rainfall of 650 mm, the region is always dry in most parts of the year with seasonal rivers. The dam will provide water for crop irrigation during dry seasons and for animals belonging to the communities living within Kajiado.

5.2.4 Development controls

The county government should control developments by adhering to existing zoning regulations. For the case of South C, ground coverage should be maintained at a maximum of 35% as stipulated by Nairobi City Development Ordinances and Zones guide. This will ensure there is a maximum open to sky ground unbuilt, that absorbs excess rain water hence reducing surface run off, which has over time contributed to flooding. However with reduction in plot coverage, plot ratios should be increased to accommodate the ever rising demand for housing in Nairobi due to population growth as seen from the population census over time.

In addition to zoning, Afforestation should be enhanced especially in Ngong hills area where most of the runoff comes from. This will increase water absorption rates reducing surface run off downhill consequently controlling flooding

Population pressure on Ngong hills being a catchment area should be controlled to avoid deforestation in order to maintain tree cover that aid in absorption of rain water, reducing surface runoff of excess water during rainy seasons.

5.2.5 Appropriate land use planning

Integrated land use and flood management programmes should be put in place to ensure a working system that gives a lasting solution to flooding menace. As seen from the findings, flooding has been contributed by the nature of land use being attributed to the built environment by 10% of the respondents. In addition, resource management in the water catchment area as well as a comprehensive land use planning should be put into consideration to avoid depletion of natural resources which are vital for controlling flooding by increasing ground water absorption rates reducing surface run off which is a contributory factor to flooding.

Close consideration and priority should also be given to the aspects of environmental impact of structural and non-structural measures as this in one way or the other controls activities that could be contributory factors to flooding. Structural measures are more of physical measures on ground to curb or reduce flooding whereas nonstructural measures are more of management technique measures. Below is a summary of the proposed measures:

i. Proposed structural measures

- **Sustainable drainage**: A well designed, capacity calculated and projected design as per the Engineers determination (3 metres wide by 2.5 metres deep) should be put in to consideration with the projected rising population as well as increasing rainfall intensity. In places with no drainage systems, new and sustainable well projected in terms of their capacities should be designed and put in place. The new drainage systems should be well linked with the other storm water drains existing to provide an exit point for water to join Ngong River.

- **Building designs:** Buildings should be designed to have higher ground levels to the flood levels to be determined by the county engineers and architects depending on the established flood levels in affected areas of South C, with workable drains of their respective compounds to drain storm waters. In addition, buildings should have gutters and water tanks to harvest water reducing the amount of surface run off as well as collecting water to enhance its supply consequently addressing the problem of water shortages.

- **Increasing infiltration rates:** this will only be achieved through increasing vegetation cover consequently reducing ground coverage's. With rising demand of housing, high rise buildings should be done to increase occupation capacity and reduce ground coverage.

- **Solid waste management:** This should be done by putting in place waste collection points at designated areas to allow ease in collection of the solid waste which could have easily been dumped on drainage systems causing their blockages reducing their efficiency as well as capacity.

Solid waste collection should be made economical and viable, in that degradable and non-degradable materials are separated. Non-degradable should be recycled for use while the degradable mostly vegetables and other food material be processed animal feeds and as manure.

ii. Proposed Non-structural measures

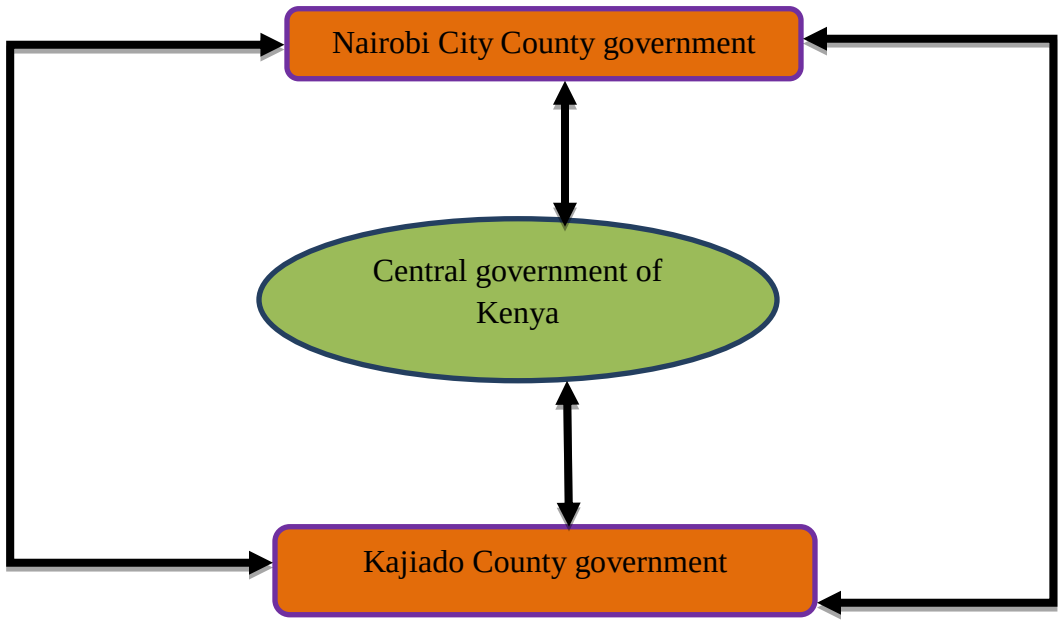
- **Putting in place accurate forecasting and warning systems:** This will greatly aid in preparedness as well as setting up of necessary preventive mechanisms that will reduce.
- **Solid waste management:** Apart from the structural perspective of solid waste management, non-structurally will be done through laws and regulations that prevent irresponsible waste dumping which could cause blockages of the available drainage systems.
- **Residents engagement/involvement:** Their engagements in coming up with preventive mechanisms at all stages will help in proposing better and relevant ideas, designs and even by-laws to aid in reducing flooding. In addition projects put in place to control flooding will be fully owned and supported by the community hence their sustenance over time.
- **Contingency plans:** Contingency plans should be clearly spelled out in case the measures put in place are not able to handle the level of flooding. This will aid in reducing damages and even loss of lives that could be experienced.

5.2.6 Multi-dimensional and intergovernmental approach in flood management

Multi-dimensional approach in management of flooding should be put into effect to enable proper handling of all issues that are related to causing flooding phenomena in our urban areas. Political, socio-economic, technological, and environmental dimensions as well multidisciplinary and multi-directional institutional framework should be put in to consideration in management of floods in urban areas. This is due to the complex nature of the urban areas that necessitates a wide range of knowledge and proficiency.

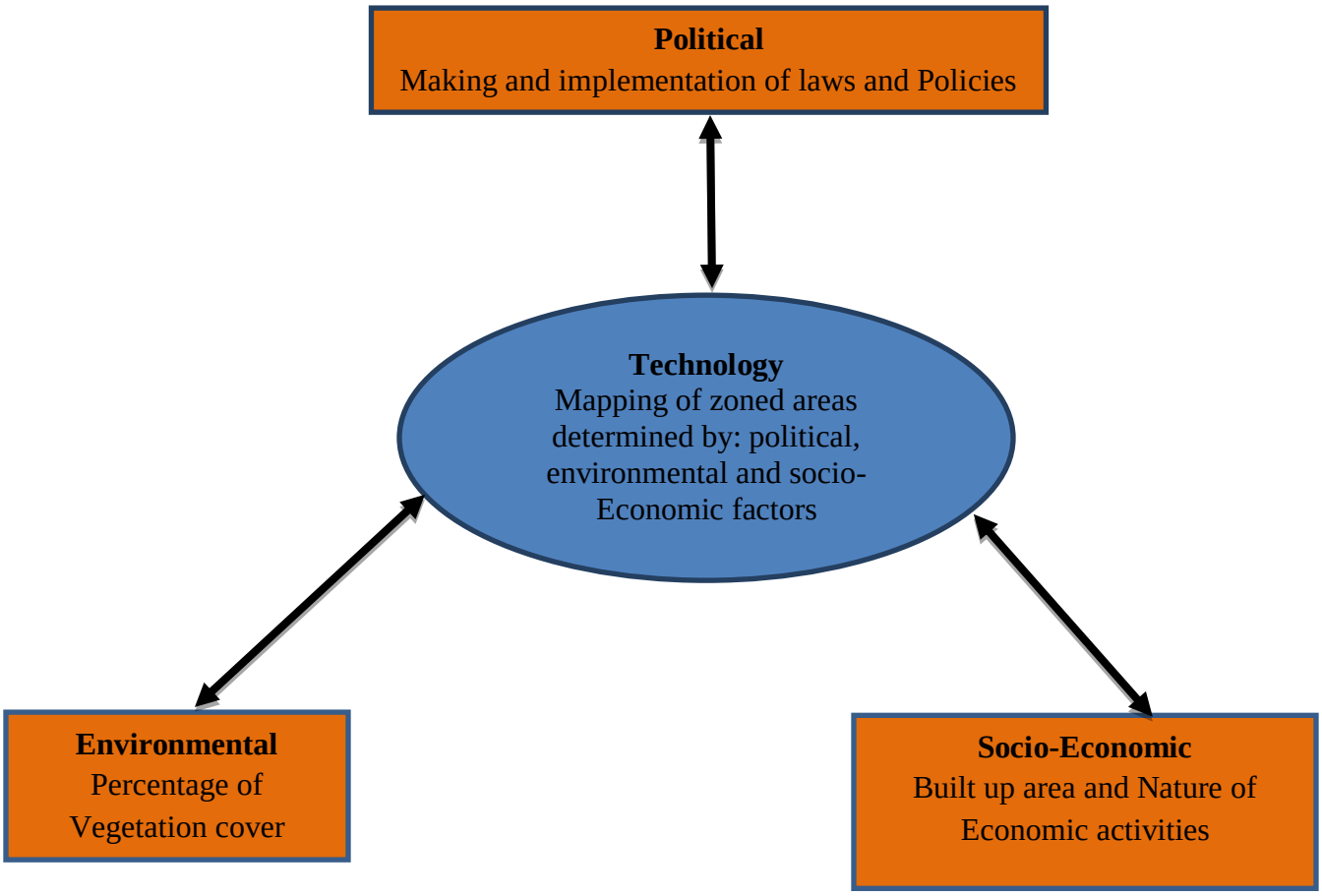
In addition to the multi-dimensional approach intergovernmental approach should be applied in flood management. The National government, Nairobi and Kajiado county governments should work together in the programme of flood control. National government should provide funds to ensure successful flood control measures and ensure coordination between Nairobi and Kajiado county government in flood management. The two county governments will manage floods by providing land water diversion channels and for building dams to hold diverted water from the high altitude areas of Ngong, Rongai and Langata areas. Figures 5-1 and 5-2 highlight the inter-governmental and multi-dimensional approaches to flood management respectively.

Figure 5:1 Intergovernmental approach flood management



Source: Author 2016

Figure 5:2 Multi-dimensional approach flood management



Source: Author 2016

5.2.7 Recommended Stakeholders contribution to flood management

a) Community/residents

The community/residents are the main stakeholders as they are the direct recipients/victims of flooding phenomenon. In the past, residents of South C have not been involved in flood management according to 81% of those interviewed. Respondents said that the government has been working by herself and the main activity being unclogging some drains when the long rains approach.

Management of floods is more than unclogging drains yearly hence there is need to involve the residents in order to up with substantial and lasting solutions. With the issue of clogged drains, residents should monitor the condition of local drains, culverts and other watercourses and report

any deficiencies or blockages to the appropriate agencies for action. With this drains effectiveness will be enhanced hence allowing free flow of storm water reducing flooding menace experienced during rainy seasons

Residents/plot owners should be involved in drafting proposed laws on ground coverage's as well as plot ratios to enable ease of implementation and adherence to the laws hence contributing to flood controls and management.

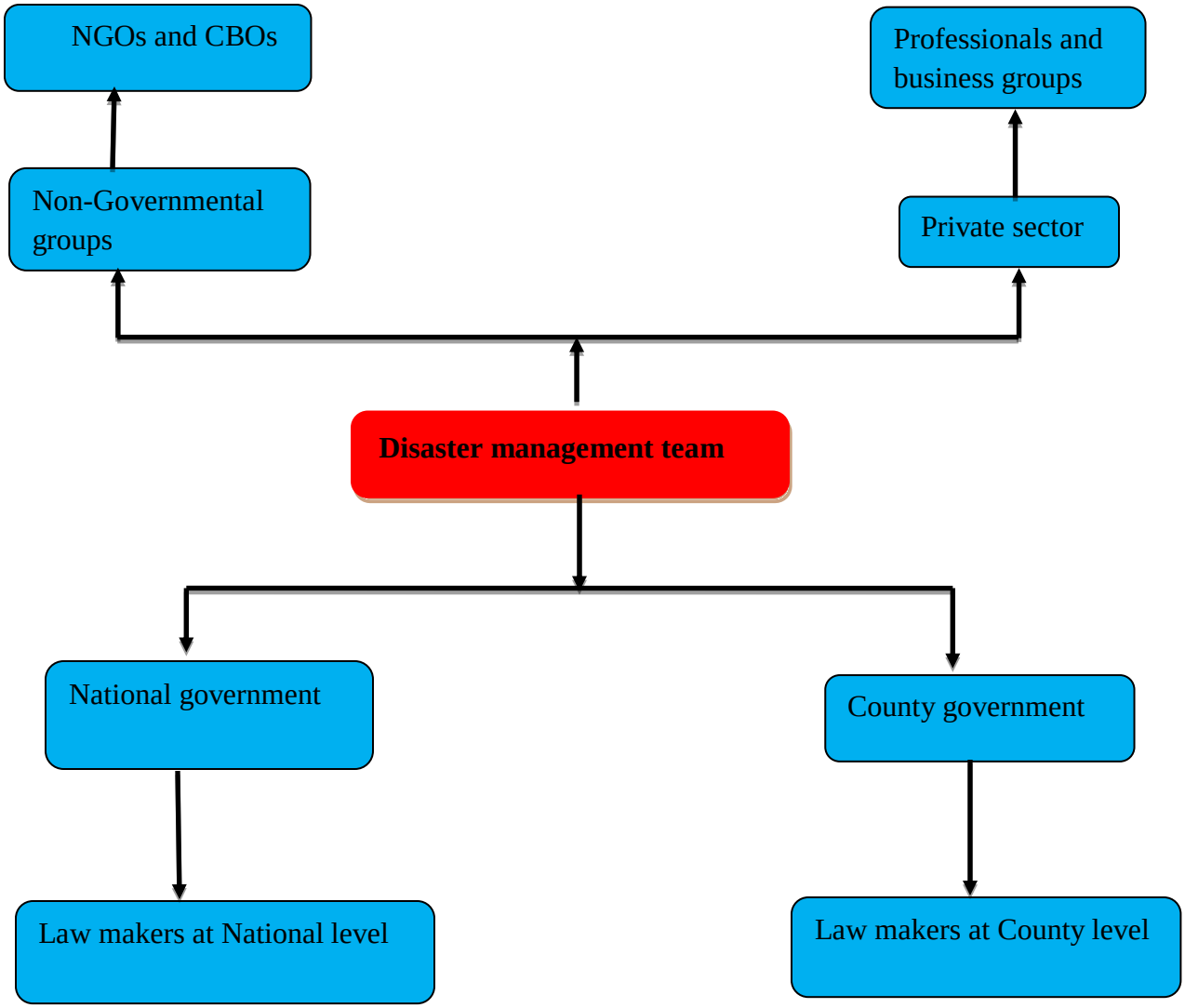
Residents should be educated on importance of proposer solid waste disposal to avoid clogging of drain as currently witnessed in the study area and noted by 36% of the respondents as a contributory factor to flooding. Proper solid waste disposal by the community will ensure free flow of storm water as a result of unclogged drains hence managing floods.

b) Disaster management team

They should monitor the water levels within the storing and transport structures to ascertain sufficient capability for extreme rainfall in addition to water availability during emergencies. An online GIS system grounded on manual measurement to improve accuracy or remote sensing should be installed for such a system management.

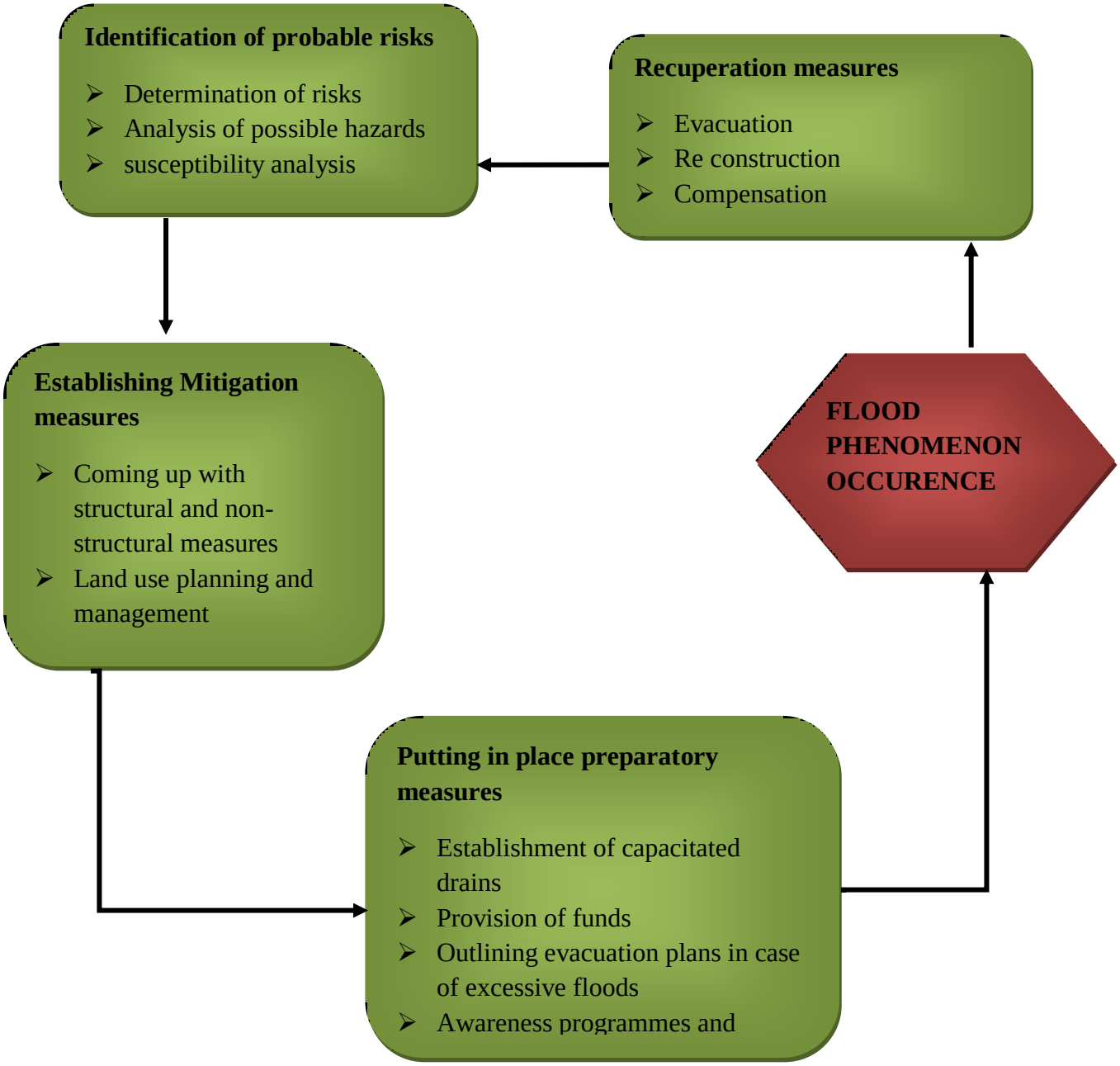
In addition to establishment of water levels, Disaster management team should also identify probable risks, establish mitigation measures as well as preparatory measures and in case of flood occurrence carry out recuperation to avoid unnecessary loss of lives and property. Figures 5-3 and 5-4 details out the proposed structure and roles of disaster management team respectively

Figure 5-3: Proposed Structure of the disaster Management team



Source: Author 2016

Figure 5-4: Proposed Roles of Disaster management team



Source: Author 2016

c) Nairobi City County Government

The County Government of Nairobi City should prepare resource maps to make available important information, data on the existing situation putting in place measures of Aid.

The County government of Nairobi should also ensure that roads are constructed to an appropriate heights, higher than storm drains of 2,000 mm to create safe areas for flood-affected communities.

In addition the County government should make sure they provide sanitary and health services as well as other basic necessities to the flood displaced victims on top of providing funds for their sustenance during that period

d) City managers and conjunction with urban planners

City managers in conjunction with urban planners should ensure that they check and ensure availability of mitigation infrastructures of floods (e.g., dykes, levees and floodwalls) in addition to other Key infrastructure like dams to harvest and store water and roads to enhance movement.

In addition the city managers should also disseminate public safety facts through putting in place early warning structures as well as stating the movements to be taken after reception of warnings.

The professionals should also employ best management practices in a bid to enhance storm water management. Through their management skills, regular unblocking of drains and repair of destroyed drains would go a long way in managing floods.

In addition, they should come up with policies that ensure the public prioritizes their surroundings though public awareness programs to educate them in regards to management of storm water to enhance flood control.

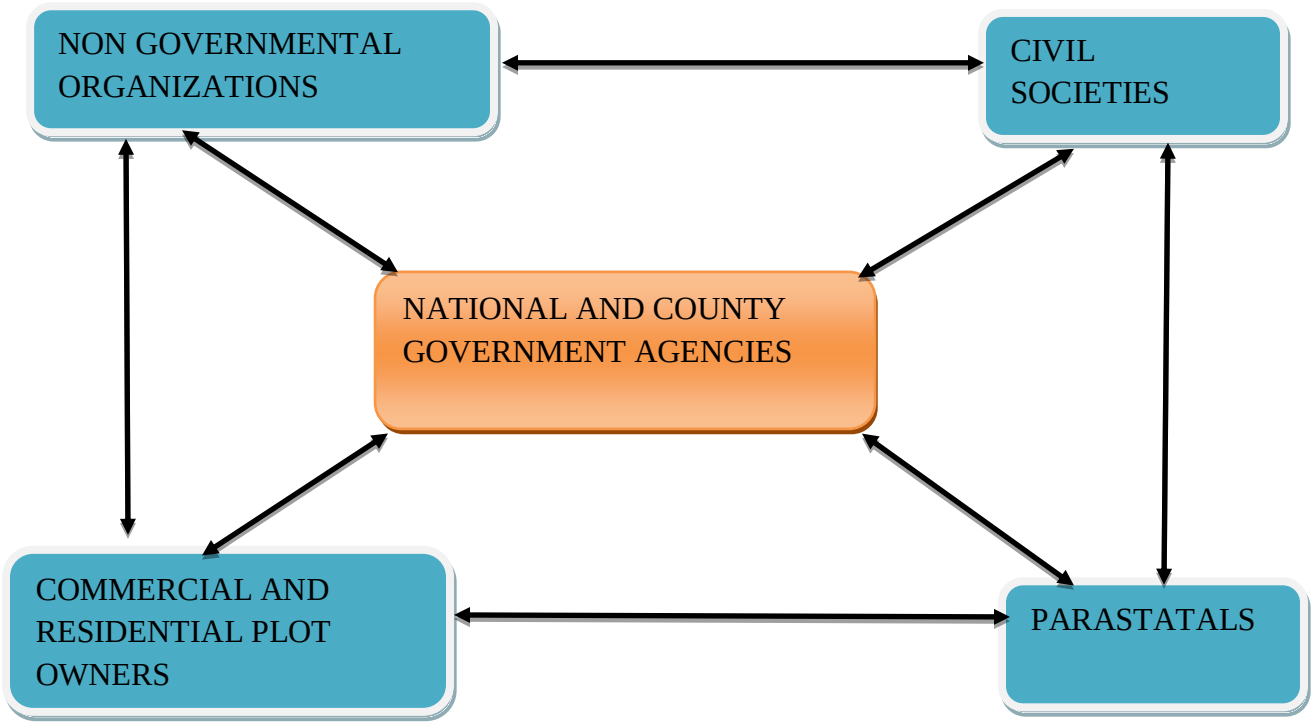
Finally these professionals should prepare master plans and identify implementation strategies to ensure flooding is controlled to the latter.

5.2.8 Proposed management structure of storm water/flooding in the study area

The County Government of Nairobi should establish an all-inclusive system in which the Government and Non-governmental organization are involved in flood control and management.

Figure 5-3 below shows the proposed structure which should be put in consideration for flood management purposes to evade disasters witnessed over time in South C and the entire Nairobi city county.

Figure 5-5: Proposed management structure of storm water/flooding



Source: Author 2016

The proposed Management structure is a synergy form in which different agencies work in consultation with each other.

Below is a summary role of each actor:

- **National Government Agencies-** These agencies work mutually and are: (The Senate, National Assembly, Ministry of land, Housing and physical planning, Ministry of

environment and natural resources, Ministry of Finance and National Treasury, Ministry of Transport and Infrastructure).Their roles jointly include:

i. Law and standards Establishment at national level, interpretation of laws for national regulatory targets and Provision of finances and incentives

ii. Preparations of policies that guide any kind of development, (land-use and planning policy).The national policies form the basis that lead local flood authorities' work.

iii. The national government apart from policies avails funds for management of floods as well as its mitigation

- **County Government Agencies**- These agencies work mutually like those in National government and are: (County Assembly, Ministry of land, Housing and physical planning, Ministry of environment and natural resources, Ministry of Finance and National Treasury, Ministry of Transport and Infrastructure).Their roles jointly include:

i. Law and standards Establishment at county level, provision of Professional Expertise, dissemination of ground information, providing coordination services between the different organizations and individuals involved in the project and funding of flood management projects.

ii. County government agencies should maintain a register of assets which are physical features that have a significant effect on flooding in the study area.

iii. County government should also coordinate with National government to ensure harmonized policies to avoid conflict in their implementation to curb floods.

National and county government basically plays same roles but at different levels and both provide coordination services to all other agencies and stakeholders involved to avoid conflicts ensuring a standard kind of implementation for successful flood control measures.

- **Civil Societies-**These societies provide research services on storm water management in addition to ensuring there is proper management of resources. These civil societies include: Agency for Cooperation and Research in Development, Green Belt Movement, and Pan African Climate Justice Alliance. Civil societies apart from research should coordinate with

other agencies including international donors and NGOs to avail funds for the purposes of flood mitigation**.**

- **Nongovernmental Organizations-**These organizations provide Professional Knowledge, disseminate information and implement new and best practices to curb floods. These include: Kenya Land Alliance and Land and Development Governance Institute.
  NGOs should work with civil societies to mobilize funds and ensure their transparency in use to implement proposed flood mitigation strategies

- **Commercial and Residential Plot Owners-**Tax payment as well as other charges to provide funds consequently supporting flood control measures and participating in voluntary incentive programs.

- **Parastatals-** Designing, planning and operating infrastructure, ensuring its effectiveness in handling storm water. Nairobi water and Sewerage Company is an example of such a Parastatal.

5.2.9 Enforcing the existing regulations.

County Government of Nairobi has existing rules and regulations that guide developments. However these regulations have not been implemented to letter due to: political interference where officers sent to enforce laws are blocked by politicians from performing their duties up to including death threats and ignorance by the county officers as well. This has led to increased plot coverage's from the stipulated maximum of 35% within the study area according to the current guide of Nairobi City development ordinances and Zones, encroachment of road reserves and even riparian reserves all over Nairobi, dumping of waste materials on existing storm drains and even building on top of storm drains contributing to the floods witnessed over time. When the laws in place are fully implemented flood control will be achieved.

In addition to implementation of existing by laws and regulations, there is need to ensure that the proposed flood management frameworks are in line with the existing laws and by laws to avoid unnecessary conflicts enhancing their effectiveness in flood control.

These frameworks and regulations should be based on the following guide lines:

- Bare minimum design principles: that is quality of materials, type of access points and minimum floor heights for approved developments within a zonal area.
- Consistent characteristics of a zoned area to avoid unnecessary impediments in terms of flow of storm water as well as circulation systems of traffic in case of emergencies due to possible excessive storm water which may lead to flooding. This will aid in ease of evacuation.
- Standard sizes of drainage systems guided by the serving population and number of subdivisions. Each piece of land subdivided should provide a minimum size of storm drain to be determined by the county roads engineer.
- Consistent building lines.
- Maximum plot coverage's as well building heights.

5.2.10 Areas of Further Study

The study was based on South C with its unique problems of lack of water exit points as well as being at the lowest contour level point in relation to its surrounding area, making the study area a storm water collection point after rains with lack of and poorly maintained drains in addition, leading to flooding. More studies should be done on other flood affected areas with different features contributing to flooding to come up with other possible solutions to flooding.

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APPENDICES

Appendix 1: Check list

UNIVERSITY OF NAIROBI

SCHOOL OF BUILT ENVIRONMENT

DEPARTMENT OF ARCHITECTURE AND BUILDING SCIENCE

Research Thesis by George Ketter

MANAGING FLOODING IN RESIDENTIAL AREAS OF NAIROBI, A CASE STUDY OF SOUTH C

CHECKLIST

1) Existing Land uses pattern
    - ❖ Their General layout
    - ❖ Other existing structures apart from residential
    - ❖ Distribution of the various land uses
2) General topography of the study area
3) Storm water Drainage pattern/Nature of the study area
4) Flood zones within the study area
5) Road network system and their orientation
6) Rainfall pattern over time
7) Solid waste collection and management
8) Nature of open spaces
9) Existing rivers by passing the study area
10) Any other observable characteristics and there on

Appendix 2: House Hold Questionnaire

UNIVERSITY OF NAIROBI

SCHOOL OF BUILT ENVIRONMENT

DEPARTMENT OF ARCHITECTURE AND BUILDING SCIENCE

Research thesis by George Ketter

MANAGING FLOODING IN RESIDENTIAL AREAS OF NAIROBI, A CASE STUDY OF SOUTH C

Declaration: information given here is CONFIDENTIAL, will be treated with ULTIMATE CONFIDENTIALITY and will be used for academic research purposes only.

Questionnaire No: …….. Date…/…..…/20……..

HOUSE HOLD QUESTIONNAIRE

Part A: Background information

1. Respondents Name (optional)

   ……..

2. Respondents Age

   ……..

3. Education level

(i) Primary (ii) Secondary

(iii)Polytechnic certificate (iv) College certificate

(v) College diploma (vi) Bachelors Degree

(vii)Masters degree (viii) Other (specify)

4. Age of the respondent (tick)

(i) 18 – 25 years ☐ (ii) 26 - 35 years ☐

(iii) 36 – 45 years ☐ (iv) 46 – 55 years ☐

(v) 56 – 65 years ☐ (vi) 65 years and above ☐

5. Marital status

a) {married} b){single} c) {widowed}

d) {divorced}

6. For how long have you stayed in South C estate (in years)

……

Flooding situation

7. a) Have you ever witnessed or experienced any cases of flooding in this neighborhood?

YES ☐ NO ☐

If yes

b). what were the effects of flooding

……

8. a) Why do you think this flooding occurs?

……

9a) Has flooding increased over time from when you moved in of the estate to now?

Yes ☐ No ☐

If yes, what can do you think has lead to this increase?

……

10a) where within the neighbourhood do most cases of flooding occur

……

b) Why do you think those particular places are affected most?

……

Measures to curb flooding

15a. Have there been any measures to address flooding in your neighborhood?

YES ☐

NO ☐

If yes:

a) What are the measures?

……

c) When were they done?

……

d) How effective have they been in addressing the problem of flooding?

……

b) Have you ever been involved in the previous initiatives aimed at solving flooding problems experienced in the past?

YES ☐

NO ☐

c) If yes How?

……

e) If no why?

……

d) How effective were they?

……

Alternative strategies

16a) what do you think can be done to reduce flooding in your neighborhood?

……

b) Why?

……

c) Who should take a leading role in reducing flooding in your neighborhood?

……

17) a) Is there any association formed to curb flooding menace in the estate

YES ☐ NO ☐

b) If yes which one and what is its role?

……

c) Are there any other groups involved in management of estate?

YES ☐ NO ☐

If yes which one and what are their roles and contribution towards management of flooding?

……..

18) a)Who does solid waste collection within the estate

……

b) Where are the collection points?

……

c) How effective is the collection?

……

THANK YOU

Appendix 3: Interview Schedule

UNIVERSITY OF NAIROBI

SCHOOL OF BUILT ENVIRONMENT

DEPARTMENT OF ARCHITECTURE AND BUILDING SCIENCE

Research thesis by George Ketter

MANAGING FLOODING IN RESIDENTIAL AREAS OF NAIROBI, A CASE STUDY OF SOUTH C

INTERVIEW SCHEDULE

Declaration: information given here is CONFIDENTIAL, will be treated with ULTIMATE CONFIDENTIALITY and will be used for academic research purposes only.

Questionnaire No: ……..

Date…/…..…/20……..

Name of the institution ……Designation……

1. Describe flooding situation in South C over the last three years?

   ……

2. a) Which parts/sections of South C are more prone to foods?

   ……

   b) Why are these parts/sections more prone to flooding?

   ……

3. What are the possible causes of flooding witnessed in the area?

   ……

4. What are the impacts of flooding?

……

5. a) Are there measures have you taken to curb flooding in South C?

   Yes ☐

   NO ☐

   b) If yes which ones

   ……

   c) Why those particular measures?

   .....

   d) If no why/ what are the challenges

   ……

6 a) Do you collaborate with any partner (individual, organization/agencies) to address flooding in South C and its environs? Yes ☐ No ☐

6b) who are the actors/partners in curbing flooding

……

7 What is the nature of collaboration?

……..

8 Describe the effectiveness of the collaboration

……

9. Which management structure is in place for managing flooding?

…… …….

10. What would you suggest as a way of dealing with flooding in South C?

……

THANK YOU