SUSTAINABLE STORM WATER MANAGEMENT IN NYALENDA INFORMAL SETTLEMENT IN KISUMU CITY, KENYA

ONTWEKA ZABLON ZACHARIAH
ADM. NO. PG/MA/196/2011

A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF ARTS IN PROJECT PLANNING AND MANAGEMENT

MASENO UNIVERSITY
SCHOOL OF PLANNING AND ARCHITECTURE
DEPARTMENT OF URBAN AND REGIONAL PLANNING

SEPTEMBER 2015

DECLARATION

Declaration by the student

I declare that the work on which this research project is based, hereby submitted to Maseno University for the award of degree of Master of Arts in Project Planning and Management has not been previously submitted for any award, that it is my work in design and execution, and that all material contained herein has been duly acknowledged.

Ontweka Zablon Zachariah Signature_________________ Date__________________

[PG/MA/0196/2011]

Department of Urban and Regional Planning

School of Planning and Architecture

Maseno University

Declaration by the supervisor

This research project has been submitted for examination with my approval as the University supervisor.

____________________________________ Date__________________________

Dr. G.G Wagah

Department of Urban and Regional Planning

School of Planning and Architecture

Maseno University

ACKNOWLEDGEMENT

First and foremost, I would like to thank my supervisor Dr. G. G. Wagah for his invaluable guidance throughout my research project. I would like to express special thanks to Mr James Kinyanjui, the Director Kenya National Bureau of Statistics and Mr. Maritim the Kisumu County Statistics Officer, for availing to me statistical data that I required for my project. I would also like to thank Dr. Leah Onyango, Mrs Jennifer Otieno, Eng Francis Ngige, Eng Margaret Malaba and Eng Mukui, Eng Maina Kamau and Eng George Oduor for their comments, criticism and assistance.

DEDICATION

This research project is dedicated to my father Richard Ontweka Okemwa. His inspiration and encouragement has kept me going in the intellectual journey. Thank you for your support.

ABSTRACT

Rural urban migration in developing countries has contributed to increase in population of urban centres with majority of the migrants settling in poorly drained informal settlements because they cannot afford to rent or buy decent housing. Over 60% of the urban population in Africa is estimated to live in informal settlements. In Kenya, many of these settlements are located on marginal land with little or no consideration for storm water management. This research sought to establish sustainable storm water management in Nyalenda informal settlement, a slum suburb in Kisumu, Kenya. The objectives of the research were to assess flooding levels in the slums, identify the causes of floods, assess the effects of flooding and assess the storm water infrastructure components that exist within Nyalenda informal settlement. Simple random sampling technique was used to select 330 respondents from the 16,631 households in the 14 villages in Nyalenda Informal settlement. Primary data was collected through observations, questionnaires, 10 key informant interviews and 4 focus group discussions while secondary data was sourced from books and journal publications. Data analysis was done through quantitative and qualitative statistical analysis techniques. Descriptive statistical analysis method was used to describe the rainfall intensity. The frequency, mean, variation and percentage distribution of rainfall and floods were examined. Regression analysis was used to predict the relationship between flood levels and rainfall intensity. Possible solutions were identified and considered in a multi criteria analysis to make a selection of the best solutions. Findings from the research indicated that floods in Nyalenda informal settlement develop when fast moving storm water flows into the low-lying flat areas in Nyalenda informal settlement at high speed but the inadequate storm water infrastructure cannot clear all the storm water. Other causes include lack of maintenance on the existing drainage infrastructure including rivers Nyamasaria and Auji, Ouru stream, culverts, bridges and open channels. Floods result in spread of water borne diseases, injuries, destruction of transport and communication, buildings and property, loss of human life, displacements and emotional stress. The best solutions consist of non-structural solutions such as increasing awareness, early warning systems, cleaning of existing infrastructure and mapping of flood hot spots. Structural solutions include planting vegetation cover, maintenance and de-siltation of drainage system. Development of evidence-based policy in flooding should be a priority for people who are responsible for planning for and responding to emergencies, healthcare, social care, and mental healthcare services. The key stakeholders and the residents should be involved in the implementation process especially during the making of the master plan.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS AND ACRONYMS

DMS	Degrees Minutes Seconds
GoK	Government of Kenya
ICPAC	Intergovernmental Climate Prediction and Applications Centre
IGAD	Intergovernmental Authority on Development
IPCC	Intergovernmental Panel on Climate Change
KFSSG	Kenya Food Security Steering Group
KIWASCO	Kisumu Water and Sewerage Company
LBDA	Lake Basin Development Authority
LVSWA	Lake Victoria South Water Services
NVSWCD	Northern Virginia Soil and Water Conservation District
UNCHS	United Nations Commission on Human Settlements
UNDP	United Nations Development Program
UN–HABITAT	United Nations Centre for Human Settlements
WHO:	World Health Organization
WRM:	Water Resources Management

DEFINITION OF TERMS

Sustainable means capable of being maintained at a steady level with minimal long-term effect on the environment and involves the simultaneous pursuit of economic prosperity, environmental quality and social equity.

Storm water management refers to the planned set of public policies and activities undertaken to regulate runoff and flood water under various specified conditions.

Flood is the rise of the water level, as in a stream or river resulting in its spilling over and out of its natural or artificial confines into land not usually submerged.

Informal Settlement is a residential area where there is an unplanned settlement of people and an area where housing is not in compliance with the current planning and building regulations. An informal settlement is also referred to as a slum or shanty town.

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE: INTRODUCTION

1.0. Background to the study

Rural urban migration in developing countries has contributed to increase in population of urban Centres. Many of the migrants settle in informal settlements because they cannot afford to rent or buy decent housing. Over 60% of the urban population in Africa is estimated to live in slums and informal settlements, UN-HABITAT (2010). These settlements develop with little consideration for drainage, which has meant poor storm water management and drainage systems in such areas, Parkinson (2003). Many of these settlements are however located on marginal and often poorly drained land. Consequently, most of these settlements are prone to storm water related flooding after prolonged rainfall, Barry (1997). Rising temperatures and increasingly variable rainfall patterns have resulted in increased frequency of extreme weather events such as floods and droughts. The increased risk of floods due to climate change and increased climate variability such as El nino in developing countries has been recognized, IPCC (2007); IGAD and ICPAC (2007). Studies have demonstrated that about 90% of all natural disasters that afflict the world are related to severe weather and extreme climate events GoK (2010). The effects associated with global warming such as sea level rise, more intensive precipitation levels and higher river discharges may increase the frequency and extent of the flooding on a worldwide scale, Jonkman (2004). Global population growth, more intensive urbanization in flood prone areas and limited development of sustainable flood-control strategies increases impacts of floods. Statistics show that flooding from storm water has a large impact on human well being on a global scale.

In the last decade of the 20th century floods killed about 100,000 people and affected over 1.4 billion people, Jonkman (2004). Floods have had devastating effects on the continents of Africa, Asia and the Americas in the period 1996 to 2005, Satterthwaite *et al*. (2007). It is reported that, during that period, 472 flood-disasters occurred in Asia killing 42,570 people, affected 1.3 billion people, and were responsible for economic losses estimated at $129 billion, Satterthwaite *et al.* (2007). In their study, Magrin *et al* (2007) recounted that the incidence of disasters related to floods increased 2.4 times between 1970 and 2005 and more increases are expected in the future. In the period 1996 to 2005, there were 290 flood-disasters in Africa which left 8,183 people dead, 23 million people affected, and which caused economic losses of $1.9 billion, Satterthwaite *et al,* (2007). St. Magdalene's flood occurred on and around the feast day of St.

Magdalene, 22 July 1342. In Danube area, 6,000 people were killed. In 1910, the great flood of Tokyo swept 3700 houses, 2200 partially destroyed and nearly 400,000 damaged. In USA, the Great Flood of 1927 overtopped much of the levee system along the lower Mississippi. The official death toll was 246 and more than 700,000 people were homeless. 137,000 buildings and homes were damaged or destroyed. Property damage topped $236 million, Barry (1997). The Los Angeles flood of 1938 occurred from late February to early March 1938, causing the Los Angeles river and the Santa river to overflow causing $40,000,000 worth of damage and causing 115 lives to be lost. January 1992 saw severe floods in South America, most notably Brazil. Magrin *et al* (2007).

Torrential rains and flooding affected 600,000 people in 16 West African nations in September 2009. The worst affected countries were Burkina Faso, Senegal, Ghana and Niger. The floods followed the 2007 floods that displaced more than a million people in Uganda, Ethiopia, Sudan, Burkina Faso, Togo, Mali and Niger, and claimed over 500 lives, United Nations (2009). These events and the continually increasing number of people affected by flooding during the 2009 to 2010 rainy season which numbered about 225,000 are the most recent examples of the growing flood risk in Africa, Jonkman (2005). The number of fatalities caused by floods in Africa during the period 1950 – 2009 shows that deaths have increased over the last 50 years, CRED (2004). The numbers indicate a need for urgent actions, for the planning of which, we first need to understand the reasons why flood risk has strongly increased in Africa. The last two decades have recorded six years with the warmest temperatures and rainfall variability in sub-Saharan Africa (SSA). Decreases in rainfall have been recorded in the Sahel region and increases in the East and Central African region. Consequently climate-related disasters such as floods and droughts have doubled in these regions within the last quarter century and Mozambique, Malawi, Kenya, Madagascar and Ethiopia are examples of SSA countries likely to experience unexpected extreme climatic events, World Bank (2009).

In Kenya, floods hazards are a recurrent phenomena. However, these flood hazards turn into disasters only in few places in the country. The most commonly affected places are the floodplains of the major rivers such as the lower Tana River, the lower Nzoia River at Budalang'i plains and the lower Nyando River at Kano Plains, The Republic of Kenya, LBDA &

JICA (1992). The Lake Victoria Basin in western Kenya is one of the most flood-prone regions in the country, GoK (2007). The basin covers an area of about 194,000Km² and is shared by the East African countries of Burundi, Kenya, Rwanda, Tanzania, and Uganda. The Kenyan side of the catchment has an area of 46,229 Km² and receives inflows from five major rivers: Nyando, Nzoia, Sio, Sondu and Yala, all of which rise from the Rift Valley and western highlands. Rivers Nzoia and Yala experience yearly floods in their lower reaches which affect the Budalangi plains, Otiende (2009). The Nyando River traverses the Kano Plains and covers a large area of the lower plains and is the most notorious for frequent flooding. The total area annually vulnerable to flooding from Nyando River is 15,000–20,000 ha. This area comprises the Kakola, Onjiko and Kochogo locations of Nyando District. The flow regime of the Nzoia is varied and is occasionally as low as 20m3/s and with extreme floods that may surpass 1100 m3/s, The Republic of Kenya, LBDA & JICA (1992).

According to GoK (2009), Kenya has experienced severe flood and drought disasters in different parts of the country that caused major disturbances, destroying property and resulting in food insecurity and even loss of life. In 1997/1998, the El Nino-associated floods affected many parts of Kenya, causing destruction to property, destruction of infrastructure, disruption of the communication networks, severe loss of life (human and livestock), famine and waterborne disease epidemics. With inadequate preparation for the El Nino floods, national resources were overstretched in the response phase, Oyugi *et al.* (2003). The floods caused some US $151.4 million in public and private property damage. Further, the floods were also associated with land degradation, increased soil erosion with the consequent silting of hydropower dams and erosion of riverbanks, which affected water intake facilities and river gauging facilities, which are the basis for the operation of the National Hydrological Services in the country DMCN (2004). The 2003 floods in Budalangi saw nearly 24,000 out of a population of 56,000 people displaced and 10,000 people were accommodated in the DO's camp, IFRC (2003).

In April/May 2013, Kenya experienced massive flooding in the Western Province at Budalang'i and the lower reaches of the Nzoia River and in Nyanza Province at Ahero within the lower Nyando River basin. The heavy rains that caused the flooding led to water supply disruption in urban and rural centres and washing away of river gauging facilities constructed along the rivers, Mutua (2001). The floods caused complete inundation of the Budalangi area and Nyando river floodplain, washing away of data loggers, water-level recorders, river gauging structures and bridges, affecting communication and flow monitoring activities in the field, DMCN (2004). Flooding is a major problem in all informal settlements in Nairobi. The Vulnerable population in the informal settlements suffers disproportionately from the adverse impacts of floods. The poor have fewer resources available for rebuilding and they generally receive little external support to recover from flooding, Napier *et al*. (2002). In the Maili Saba slum, next to the river, flooding is a normal occurrence. Houses are built of weak, inadequate building materials. Migration has led to more houses being built close to rivers, meaning greater disruption when floods occur, Agevi *et al* (2006). Kisumu County has continued to experience seasonal flooding along the banks of the main rivers that traverse the area. This has been mainly due to the flat terrain surrounded by hills in Kericho and Nandi counties receiving high rainfall. Winam Division that is Kolwa East, Kolwa Central and Lolwa West locations and Bwanda and Kawino locations are prone to flooding during the rainy season, Kisumu County (2013).

Nyalenda informal settlement is one of the largest informal settlements in Kisumu. As a residential area it dates back to the 1880s. Initially it had been a sparsely populated rural area next to the city. But with the arrival of the Kenya Uganda railway line to Kisumu and since the British were evicting local population from the city boundaries, more and more people moved to Nyalenda. As offering affordable housing close to the city centre, the settlement has become a popular destination for low- income residents of Kisumu City. Majority of houses in nyalenda informal settlement are of semi permanent nature, Cordaid (2012). About 60% of the County population lives in the informal settlements of Manyatta, Nyalenda and Obunga where most housing facilities lack basic amenities, Kisumu County (2013). Before 1925, Nyalenda, Nyamware, Kawino, and Middle Jimo areas were a stable lakeshore land with fishing and small-scale farming activities. In March of the same year, the lake regions experienced exceptionally heavy rains and many homes were abandoned and people settled in the upper lands. The situation did not last long and after a few years, life returned to normal along the lakeshore. In their Integrated County development plan, 2013- 2017, the Kisumu County (2013) identifies perennial flooding in Nyalenda informal settlement as one of the key challenges that should be addressed by the Kisumu County Government. Future rainfall projections for Kenya up to the year 2030 broadly indicate that there will be increases in annual rainfall, with the highest amounts expected in Western parts of Kenya around Mount Elgon, Elgeyo Escarpment and Cherangani Hills, the catchment of River Nzoia that drains through Budalangi, GoK (2012). If these projections are accurate, then there are likely to be far-reaching effects on the intensity and frequency of floods in the region, Mango *et al*. (2007); GoK (2009). The new constitutional dispensation in Kenya introduced a two tier government, the national and county level governments. Under this new system, it is expected that national and local county government structures will operationalize climate change policies and interventions GoK (2013). However, a government report GoK (2009) identified institutional weaknesses including the fact that the current management of floods in Kenya is not structured nor anchored in responsible agencies, current interventions are more reactive than preventive with the vulnerability of the community at risk that determines the extent of the flood disasters, lack of long-term mitigation and finally and inadequate funding for flood management.

1.1. Problem Statement

The Nyalenda informal settlement is characterized by lack of proper infrastructure, unsteady and unsafe housing, poor sanitation, a few job and educational facilities, perennial storm- water related flooding and accumulation of stagnant water. The conditions are exacerbated by the low-lying topography, the closeness of shacks along dirt roads, the lack of proper infrastructure and poorly developed storm water management systems. Storm water ponds and stagnates in the low lying areas of Nyalenda informal settlement. After heavy rains storm water seeps into shack houses causing property and infrastructure damages such as degradation of floors, walls and personal belongings including mattresses and clothes. The disruption, damage to properties, loss of possessions, as well as financial worries and other stresses from living in damp houses mean that flood from storm water can place a considerable strain. The poor communities living in the low-lying areas of Nyalenda informal settlement lack storm water harvesting systems and often worry about the risks to their liveli-hoods and health from flooding. There is therefore need for sustainable storm water management in Nyalenda informal settlement.

1.2. Objectives

1.2.1. Main Objective

The main objective of this research was to examine storm water management in Nyalenda informal settlement in Kisumu City.

1.2.2. Specific Objectives

The research was guided by the following objectives:

a. To identify the causes of floods in Nyalenda informal settlement
b. To assess the effects of flooding on Nyalenda informal settlement.
c. To assess flood risk levels in Nyalenda informal settlement.
d. To assess the storm water infrastructure components that exist in Nyalenda informal settlement.

1.3. Research questions

The research was guided by the following research questions:

a. What are the causes of floods in Nyalenda informal settlement?
b. What are the positive and negative effects of floods in Nyalenda informal settlement?
c. What are the flood risk levels in Nyalenda informal settlement?
d. What are the storm water infrastructure components that exist in Nyalenda informal settlement?

1.4. Justification

The research sought to determine the most feasible storm water management tools to control flooding from storm water in Nyalenda informal settlement. This research will help the county government create a master plan that will give a description of the actions to be taken to reduce the risk of flooding in Nyalenda informal settlement. The general public may use the information on the risk of flooding in purchasing a house, or in selecting a site to start a business. Knowledge of flood risk could aid decision-makers in: developing land development plans and land use zoning; planning emergency response strategies; waste disposal site selections; preparing infrastructure budgetary decisions; developing guidelines for operation of existing infrastructure; and general policy development. Water management professionals can utilize the flood risk information in planning, design, construction, operation & maintenance of drainage pipes, reservoirs and dikes.

1.5. Scope and Limitations of the study

The research focused on Nyalenda informal settlement in Kisumu City only. The relevance of the solutions to other parts or other informal settlements in Kisumu City was not investigated in detail. The data availability (rainfall data and maps) was not very good. There was limited data on water levels in rivers within Nyalenda informal settlement. Limited data was available on the water levels in Nyamasaria River (only data for period between March 2012 and July 2012 was available). There was no data on the water levels for the Auji River. Many values needed to be estimated and many assumptions made. Flood emergency measures were left out of this research because they were not considered useful in Nyalenda informal settlements. Flood emergency measures are only useful when there is a big flood once in a while instead of floods that recur several times a month. Measures that are only effective with one big flood once in a while, for example inflatable temporary dams Ven *et al*. (2009) were left out.

CHAPTER TWO: LITERATURE REVIEW

2.0. Introduction

This chapter entails a cross-examination of the existing literary materials from various sources on area related to storm water management. It draws from both the national and international experience of flooding. The review and presentation of the literature findings are given according to the set objectives.

2.1. Causes of Flooding

Flood occurs when the overflowing water submerges land and causes deluge. It is a cruel and violent expression of water. Flooding occurs when there is prolonged rainfall over several days, intense rainfall over a short period of time, or a debris jam causes a river or stream to overflow and flood the surrounding area. Severe thunderstorms can bring heavy rain in the spring and summer; or tropical cyclones can bring intense rainfall to the coastal and inland states in the summer and fall. Flash floods occur within six hours of a rain event, or after a dam or levee failure, and flash floods can catch people unprepared. The Kelly Barnes dam failure in 1977 is an example of this type of flood, Federal Investigative Board (1977). As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall.

Urbanization increases the amount of impervious areas, causing runoff to be two to six times over what would occur on natural terrain. During periods of urban flooding, streets can become swift moving rivers. Because of the buoyancy effects and power of moving water, even a foot of moving water can be enough to carry away some cars, Rantz *et al.* (1982). Several factors contribute to flooding. Two key elements are rainfall intensity and duration. Intensity is the rate of rainfall, and duration is how long the rain lasts. Topography, soil conditions, and ground cover also play important roles. Most flash flooding is caused by slow-moving thunderstorms, thunderstorms repeatedly moving over the same area, or heavy rains from hurricanes and tropical storms. Natural floods are the floods that are caused naturally by the overflow of the huge volume of water, from rivers, lakes, oceans, or by heavy rains or downpours, hurricanes, cyclones, or tsunamis, etc. Natural floods could be riverine floods – caused by rivers; estuarine floods – caused by a combination of sea tidal surges and storm-force winds; or Coastal floods – caused by cyclones, hurricanes and tsunamis. These are one of the most common natural disasters. Catastrophic floods are the floods that are caused by some significant and unexpected events, for instance dam breakages.

Heavy rainfall is one of the major causes of floods. The level of water in rivers or lakes rises due to heavy rainfall. When the level of water rises above the river banks or dams, the water starts overflowing, causing floods. The water overflows to the areas adjoining to the rivers, lakes or dams, causing floods or deluge. Flooding is more likely to occur if solid waste accumulates in drains, and blocked drains create insect breeding sites, thus encouraging disease transmission, Kolsky *et al.* (1995). In the research on Nyalenda informal settlement, the researcher found out that solid waste is damped haphazardly and accumulates in the river Auji leading to blockage and reduced discharge. The flood water causes havoc and great destruction in the areas where it flows. Floods are also caused due to heavy snow melting. Global temperature is rising due to global warming. Generally, floods occur more in the low-lying areas or the areas below the sea level. One of the main reasons is that rivers flow slowly in these areas. The volume of water increases in the low-lying areas. When the level of water rises in these regions, it causes floods. Floods also occur more in the coastal regions. Floods, in the coastal regions, are caused due to high tides, storms, cyclones, hurricanes, or tsunamis. Structural elements such as the incorporation of solid waste traps are an important design aspect of drainage systems, Armitage and Rooseboom (2000). Urban conditions exacerbate flooding problems; runoff is increased by impermeable urban surfaces and, due to inadequate development control mechanisms and their incompetent enforcement, settlements are constructed with little consideration for storm water drainage. The poor are disproportionately affected; they often reside in informal settlements located on marginal land – low-lying land, riverbanks, floodplains and steep hillsides – that the formal housing market does not want or need, Main (1994).

There are also several human causes of floods. Deforestation is one of the major causes of floods. As result, soil is easily eroded, and the eroded soil gets settled at the bottom of rivers and seas, thus raising the level of water in rivers and seas, which consequently causes floods. Sometimes floods are caused due to poor dams that cannot hold great volume of water and they give up causing floods in adjoining areas. Human causes of floods can be avoided, Parkinson (2002). There have been catastrophic floods and 'flood rich' periods in the historical past, generated by a wide range of climatic conditions that include extreme rainfall, warm rainfall on snow, ice break and storm surges. During the Little Ice Age (ca.1450-1850/1900) cold period, extreme floods were generated by a range of conditions (British Hydrological Society's British Chronology of Extreme Hydrological Events). Examples of such floods are: the extreme floods of November, 1770 on the River Severn, the 'Muckle Spate' of August, 1829 in Scotland, a catastrophic summer flood, caused by a summer frontal storm in north-east Scotland Lauder (1830), and the storm surge/ tsunami of January, 1607 that is held in the common memory and lore of local Somerset and lower Severn communities McEwen and Werritty (2007). In Britain, there are extreme 20th century floods that are within living memory of local communities and nationally and whose causes were determined. These include: March 1947 floods, generated by warm rain on snow and frozen ground, with spatial persistence and antecedent conditions of extreme cold and snow McEwen (2010) and August 1952 Lynmouth floods caused by a localised summer convective storm and intensified by the steep confined character of the Lyn catchment Delderfield (1953).

2.2. Effects of floods in Informal Settlements

Major storm and flood disasters have occurred in the last two decades. In 2003, 130 million people were affected by floods in China EM-DAT (2006). In 1999, 30,000 died from storms followed by floods and landslides in Venezuela. In 2000/2001, 1,813 died in floods in Mozambique, IFRC (2002); Guha-Sapir *et al*. (2004). In terms of deaths and populations affected, floods and tropical cyclones have the greatest impact in South Asia and Latin America Guha-Sapir *et al*. (2004; Schultz *et al.* (2005). Deaths recorded in disaster databases are from drowning and severe injuries. Drowning by storm surge is the major killer in coastal storms where there are large numbers of deaths Nicholls (2003). Other effects of flooding include widespread damages and disruption to transportation, power and communication systems, as well as structural damage to buildings and infrastructure. The disruption, damage to properties, loss of possessions, as well as financial worries and other stresses from living in damp houses mean that flood events can place a considerable strain on households Lines (2002). These factors are recognized to be significant even in countries such as the United Kingdom, where flooding is typically small-scale, short-lived and shallow, Tapsell (1999). The nature of flooding events relates to the physical context and may affect communities in different ways.

Although floods are often associated with large-scale events with disastrous consequences, there is also more frequent flooding related to factors at a local level, which can cause many problems in the urban environment, although they are often a less immediate and obvious cause for concern Andjelkovic (2001). There is considerable empirical evidence to indicate that flooding and poor drainage have a significant impact on the prevalence of illness, and that large-scale flooding may disrupt water supply and sanitation systems and result in disease epidemics UN–HABITAT (2003). In poorly drained areas with inadequate sanitation, urban runoff mixes with excreta – spreading pathogens around communities and increasing risks to health from various waterborne diseases, Lines (2002). Infiltration of polluted water into low-pressure water supply systems can contaminate drinking water and is frequently a source of gastrointestinal disorders.

Populations with poor sanitation infrastructure and high burdens of infectious disease often experience increased rates of diarrhoeal diseases after flood events. Increases in cholera (Sur *et al.* (2000); Gabastou *et al.* (2002), cryptosporidiosis, Katsumata *et al.* (1998) and typhoid fever, Vollaard *et al*. (2004) have been reported in low- and middle-income countries. Flood-related increases in diarrhoeal disease have also been reported in India, Mondal *et al*. (2001), Brazil Heller *et al*. (2003) and Bangladesh, Kunii *et al.* (2002; Schwartz *et al*. (2006). The floods in Mozambique in 2001 were estimated to have caused over 8,000 additional cases and 447 deaths from diarrhoeal disease in the following months, Cairncross and Alvarinho (2006). The risk of infectious disease following flooding in high-income countries is generally low, although increases in respiratory and diarrhoeal diseases have been reported after floods, Miettinen *et al.* (2001); Reacher *et al.* (2004); Wade *et al.* (2004). An important exception was the impact of Hurricanes Katrina and Rita in the USA in 2005, where contamination of water supplies with faecal bacteria led to many cases of diarrhoeal illness and some deaths, CDC (2005); Manuel (2006).

Flooding may lead to contamination of waters with dangerous chemicals, heavy metals or other hazardous substances, from storage or from chemicals already in the environment (e.g., pesticides). Chemical contamination following Hurricane Katrina in the USA included oil spills from refineries and storage tanks, pesticides, metals and hazardous waste, Manuel (2006). Concentrations of most contaminants were within acceptable short-term levels, except for lead and volatile organic compounds (VOCs) in some areas, Pardue *et al.* (2005). There are also health risks associated with long-term contamination of soil and sediment, Manuel (2006); however, there is little published evidence demonstrating a causal effect of chemical contamination on the pattern of morbidity and mortality following flooding events, Euripidou and Murray (2004); Ahern *et al.* (2005). There are however, no chemical contaminations recorded by the researcher in Nyalenda informal settlement.

Increases in population density and accelerating industrial development in areas subject to natural disasters increase the probability of future disasters and the potential for mass human exposure to hazardous materials released during disasters, Young *et al.* (2004). There is increasing evidence of the importance of mental disorders as an impact of disasters, Mollica *et al. (*2004); Ahern *et al.* (2005). Prolonged impairment resulting from common mental disorders (anxiety and depression) may be considerable. Studies in both low- and high-income countries indicate that the mental-health aspect of flood-related impacts has been insufficiently investigated, Ohl and Tapsell (2000); Bokszczanin (2002); Tapsell *et al.* (2002); Assan *et al.* (2004); Norris *et al*. (2004); North *et al.* (2004); Ahern *et al.* (2005); Kohn *et al.* (2005); Maltais *et al*. (2005). A systematic review of post-traumatic stress disorder in high-income countries found a small but significant effect following disasters, Galea *et al.* (2005). There is also evidence of medium- to long-term impacts on behavioural disorders in young children, Durkin *et al*. (1993); Becht *et al.* (1998); Bokszczanin (2002).

Floods have always been an integral part of nature's renewal process, providing many long-term positive effects. Floods contribute to the health of ecologically important wetland areas. Healthy wetlands promote healthy water supplies and even affect air quality, Cordaid (2012). Floods also carry and deposit nutrient-rich sediments that support both plant and animal life in wetlands. Flooding also adds nutrients to lakes and streams that help support healthy fisheries. Floods distribute and deposit river sediments over large areas of land. The construction of the Aswan High Dam prevented the Nile from flooding major population centers downriver, but it also depleted once fertile agricultural lands along the banks of the river. Flooding also contributes to preventing erosion and maintaining land mass elevation. The land of the Mississippi River delta is disappearing because dikes and levees prevent floods from depositing new soil. Soil deposited by floodwaters prevents erosion and helps maintain the elevation of land masses above sea level, Lines (2002). The rapidly receding land of the Mississippi River delta is a direct result of man-made flood controls and levees that prevent topsoil-replenishing sediments from being deposited in the delta.

Many population centers depend upon ground water and underground aquifers for fresh water. Floodwaters absorb into the ground and percolate down through the rock to recharge these underground aquifers which supply natural springs, wells, rivers and lakes with fresh water. (http: // www.ehow.com/info_positive-effects- floods). The consequences of flood events can be devastating for poor communities. The poor have fewer resources available for rebuilding and they generally receive little external support to recover from flooding, Napier *et al*. (2002).

2.3. Assessment of Flood Risk Level

Floods are low-probability, high-impact events that can overwhelm physical infrastructure, human resilience and social organisation. Floods are the most frequent natural weather disaster (EM-DAT, 2006). Risk is exposure to an undesired event. It can be expressed in probability that the event will happen, often during a calendar year. A widely accepted description of risk was offered by Crichton as follows: “Risk is the probability of a loss, and this depends on three elements, hazard, vulnerability and exposure”, Crichton (1999). In their ‘Language of Risk’-Report, Samuels and Goudby (2009) refer to the term flood risk as “the probability multiplied by the consequence in which the multiplication is to be understood as including the combination across all floods. Environmental events are termed “hazards” from mainly a human perspective when humans cannot cope with them. They can become disasters, often defined as a situation where a community’s ability to cope with an event is surpassed, whether that event is environmental or non-environmental and whether that event is or is not extreme.

The definitions of ‘flood risk’ and ‘disaster’ indicate that, although related to each other, the two terms are not synonymous. Lumbroso (2007) differentiates risk from disaster in terms of impact. Whereas risk refers to any consequence that can be measured, a disaster denotes a large or even catastrophic event. Hence, both terms ask for a different way of management. According to the

UN International strategy for Disaster Reduction (UN-ISDR, s.d.), a disaster is defined as "a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources." Hewitt (1997) refers to "unnatural hazards" suggesting that "natural hazards" are not "natural" because they are generally hazardous to only humans. Vulnerability could be viewed as a state of conditions and processes resulting from physical, social, economic and environmental factors that increase the liability of a community with regard to the impact of hazards, Kumpulainen (2006). Kelman (2003) however observed that individuals, communities and societies maintain a constant level of risk, irrespective of external influences. Kumpulainen (2006) adopted the following notation for vulnerability: Regional Vulnerability = Damage potential **+** Coping capacity.

Risk assessment comprises three elements: hazard analysis (understanding what hazards exist, the likelihood of them occurring, their likely intensity, and their effect), vulnerability assessment (understanding who or what is vulnerable to the hazards) and capacity assessment (understanding what capacities exist within the community to reduce vulnerability), Kumpulainen (2006). Vulnerability to weather disasters depends on the attributes of the person at risk (including where they live, age, income, education and disability) and on broader social and environmental factors (level of disaster preparedness, health sector responses and environmental degradation) Blaikie *et al*. (1994); Menne (2000); Olmos (2001); Adger *et al*. (2005); Few and Matthies (2006). Poorer communities, particularly slum dwellers, are more likely to live in flood-prone areas. In the USA, lower-income groups were most affected by Hurricane Katrina and low-income schools had twice the risk of being flooded compared with the reference group Guidry and Margolis (2005).

There are several methods for the risk assessment in the case of flash flood. The risk of flash flood can be assessed through the accomplishment of processes: characterization of the area concerned, analysis of the hazard, assignment of probability to each reference scenario, assessment of the hazard, vulnerability analysis and assessment of the risk, Alessandro *et al* (2002). Flood risk mapping has been performed extensively for effective flood management, starting with the pioneering work of Garrett, Garrett (1989). Etkin (1999) describes how reliance on structural flood defenses increases vulnerability over the long-term in a process termed "risk transference". Structural defenses stop smaller floods and permit people to live in floodplains while remaining relatively dry. But Etkin (1999) accepts that vulnerability will increase as a result of this false sense of security. Most structural defenses must fail at some point, often by an event which exceeds the design flood. Then, the damage incurred by the flood is much greater than it would have been without the false sense of security imposed by the structural defenses. Short-term flood risk has decreased, but long-term flood risk has increased. Risk is transferred into the future and augmented, hence the term "risk transference". In inland areas, flood regimes vary substantially depending on catchment size, topography and climate. A detailed and uniform land-use map is an important prerequisite to perform flood risk calculations, since it determines what is damaged in case of flooding, De Maeyer *et al*. (2003). In the Flemish methodology, various land-use categories are distinguished (e.g., urban area, industrial area, infrastructure, crop land, pastures, etc.) and further subdivided according to their vulnerability level, which is related to the desired level of detail.

2.4. Storm water infrastructure in informal settlements

Storm water infrastructure includes items such as culverts under roadways, catch basins, and detention and retention ponds, smaller culverts under driveways. The drainage system is an essential part of living in a city or urban area, as it reduces flood damage by carrying water away, Parkinson (2003). When it rains, some water naturally seeps into the ground. The rest makes its way through drainage systems, into rivers and creeks and eventually into the bays, or directly to the bays through storm water outlets. In areas with houses, shops and roads there is need to create alternative ways for this water to drain away. Large amounts of water can build up quickly during heavy rain and storms, and without adequate drainage this flows towards low-lying land, causing flooding, damage and safety risks, Francis (2000). This is also true for Nyalenda informal settlement as found out by the research n Nyalenda informal settlement. The low lying areas of Nyalenda informal settlement are prone to perennial flooding as compared to high areas in Nyalenda informal settlement. Floodplains have a fundamental role in managing the flow of water by providing natural storage areas where floodwaters can be retained and slowly released as stream heights recede. Floodplains dissipate the power of floodwater and reduce associated damage. Floodwaters retain and replenish wetlands, and support the flora and fauna of floodplains and river systems. The majority of what is classed as problem flooding occurs when urban development and infrastructure (such as roads) have constricted the floodplain or blocked natural drainage lines and flow paths, Melbourne Water (2005).

Dwellings in informal settlements are built without conformity to prevailing planning regulations or building construction standards, Parkinson (2003). In his research, Armitage (2011) found out that the structures in informal settlements are self-constructed from cheap, readily available, scrap materials. Armitage (2011) further observed that it is common to have the buildings set into the ground with poor drainage. This is in agreement with the situation in Nyalenda informal settlement where areas such as Kapuothe are swampy and poorly drained. The usual reason for flooding in informal settlements is their precarious locations and inadequate storm water water infrastructure. Inhabitants of informal settlements are more vulnerable to the risks associated with flooding and are more susceptible to disruption because of the poor drainage infrastructure. Flooding in informal settlements is more likely to occur if solid waste accumulates in drains. Blocked drains also create insect breeding sites, thus encouraging disease transmission, Kolsky *et al.* (1995). Global climate change aggravates the risk of urban flooding in informal settlements, ActionAid (2006).

Studies on slum networking in New Delhi found out that slum networking links slums and the natural drainage paths that influence infrastructure and environment. The slum matrix concept integrates basic services like networks for house-to-house water supply and underground sewerage, storm water drainage, roads, landscaping and solid waste management, Tripathi and Jumani (2001). The majority of cities have strong natural drainage paths. The paths are nature's own means of disposal and, if properly exploited, are ideal routes for the infrastructure systems of sewerage, storm drainage, water supply and roads, Parikh (2001). Studies of several cities in India and in other parts of the world showed that slums are consistently located along these natural paths. Because of the close correlation between the slum locations and the natural drainage paths of a city, low cost service trunks, particularly for gravity based systems of sewerage and storm drainage can be built up. Underground storm drainage is minimized by using contoured roads as channels and to increase the ground recharge on road verges, to reduce the storm loads. Soft landscaping, such as grasses, is introduced as it absorbs more water and reduces its speed of flow, thus reducing the peak flows in the storm systems. Piped drains are only applied when storm water loads increase, Parkh *et al*. (2002).

In the Neshanic river watershed, the following types of storm water infrastructure were located and characterized: catch basins, also known as storm drain inlets, pipe inlets, culvert, basin discharges, ditches and swales, detention basin, basin outlet structure, basin Inflows, low flow channel and dams, Nick *et al* (2007). In its current form, the storm water system in Neshanic watershed is designed to gather rainwater from rooftops, roadways, parking lots, lawns and landscapes and convey it to the Neshanic River. The system as a whole lacks a universal design goal beyond moving water during storm events, Center for Neighborhood Technology (2009). There are three types of storm water infrastructure systems in the watershed, ditch and pipe system found primarily in the more rural areas of the watershed in the south, suburban subdivision systems spread throughout the watershed and urban system found along the highways and in commercial areas, Nick *et al* (2007).

Nkonldongo is one of the informal neighborhoods in city of Yaounde IV in Cameroon. In his research, Mabou (2003) noted that Nkonldongo settlement was bedeviled by the problem of inadequate services, especially drainage, water supply and sanitation. When it rains, the runoff level reaches buildings' floor level, leading to floods in the area. In this research on Nyalenda informal settlement, the researcher noted poor sanitation and solid waste management in Nanga and Katuoro. Mabou (2003) also observed that Valley 8 in Nkolndongo was a big swamp where the absence of good roads and storm water management infrastructure made access to the nearby neighborhood impossible or very difficult. In their research on Huruma informal settlements in Eldoret, the Ministry of housing (2007) found out that the top three priorities for infrastructure according to the residents of Huruma informal settlements are roads, stormwater drainage and street lighting. Conditions inside storm water infrastructure, for example, a drain can become very hazardous without warning. Water levels can rise even on a dry sunny day, rainwater can arrive suddenly, having fallen many Kilometers away, slow moving flows can quickly become raging torrents, areas with poisonous gases and low oxygen can be deadly, drains may contain steep, hidden slopes, making it easy to slip. Flooding due to stormwater infrastructure inadequacies is a challenge that many informal settlements face, Tripathi and Jumani (2001).

In Kenya the Lake Victoria Basin in western Kenya is one of the most flood-prone regions in the country, GoK (2007). The Kenyan side of the catchment receives inflows from rivers: Nyando, Nzoia, Sio, Sondu and Yala. The Nyando River traverses the Kano Plains and covers a large area of the lower plains and is the most notorious for frequent flooding. The Government of Kenya, GoK (2009) identified institutional weaknesses including the fact that the current management of floods in Kenya is not structured nor anchored in responsible agencies with current interventions being more reactive than preventive. According to the Kisumu County Government (2013), seasonal flooding is experienced along the banks of the main rivers mainly due to the flat terrain. The flood prone areas include Kolwa East, Kolwa Central and Lolwa West locations. About 60% of the Kisumu County population lives in the informal settlements of Manyatta, Nyalenda and Obunga where most housing facilities lack basic amenities. In their Integrated County development plan, 2013- 2017, the Kisumu County (2013) identifies perennial flooding in Nyalenda informal settlement as one of the key challenges to be addressed by the Kisumu County Government. Moreover, future rainfall projections for Kenya indicate that there will be increases in annual rainfall, with the highest amounts expected in Western parts of Kenya, GoK (2012). According to Mango *et al*. (2007), there are likely to be far-reaching effects on the intensity and frequency of floods in the region.

2.5. Study Gap

A research study gap is the missing element in the existing research literature and a researcher has to fill with a research approach to make the research work publishable. In other words, it indicates a finding from a research in which a key question has not been answered, Uyangoda (2011). Kisumu City, on the banks of Lake Victoria, suffers flooding every year. It is reported every year that the floods cause damage in the various areas that experience floods within Kisumu City. The informal settlements within Kisumu City mainly Nyalenda and Manyatta informal settlements are always affected by flood during heavy rains. Nyalenda informal settlement experiences perennial flooding leading to destructions. Just like Mabou (2003) found out in his study in Nkolndongo informal settlement, the lower Nyalenda informal settlement is flat and swampy. The inhabitants of the informal settlement are vulnerable to floods; a situation exacerbated by high the poverty level of the residents of Nyalenda informal settlement. The flood risk levels in Nyalenda informal settlement are unknown. The causes of the floods in Nyalenda informal settlement, the effects of floods and the storm water infrastructure components in Nyalenda informal settlement have not been established. The researcher sought to find out the causes of perennial flooding in Nyalenda informal settlement, the effects of perennial floods, the flood risk levels and the storm water infrastructure components in Nyalenda informal settlement and recommend for the storm water management solutions applicable to Nyalenda informal settlement.

2.6. Conceptual Framework

A conceptual framework is an alignment of key concepts of a study which helps to position it in the bigger research enterprise, Henning (2004). It is a form of ‘intermediate theory’ that helps to appropriately and logically connect all aspects of inquiry in the research**.** Within the conceptual framework of this research, fig. 2.1, the causes of storm water related floods were established. From the causes of floods, the mechanisms through which the residents would be exposed to floods were determined. Unlike in Few (2007), the researcher considered the effects from the causes and categorized the effects under health, physical and social effects. The study area was characterized and the rainfall trend over a 12 - year period determined. The monthly average rainfall was calculated to establish the long and short rains seasons. The flood hot spots were identified, the risk levels of flooding were then determined with use of the characteristics of the water system in Nyalenda informal settlement. In his framework, Few (2007) did not consider the flood risk levels and the contribution that storm water infrastructure had to flooding. In this research, the researcher determined the storm water infrastructure in Nyalenda informal settlement. The possible solutions were derived from the risk (the consequences and probability) and the causes. With the criteria and possible solutions a selection of sustainable solutions was made.

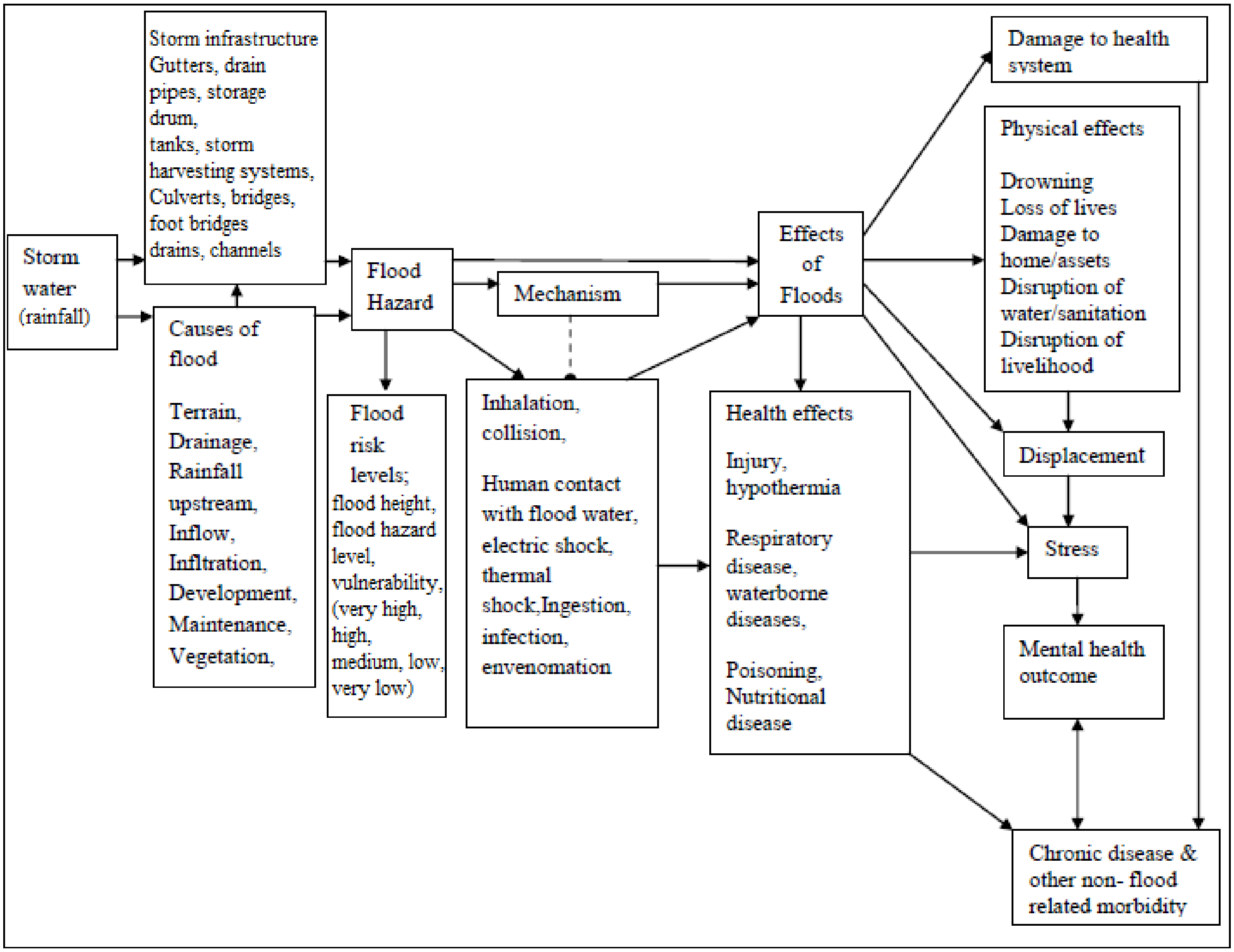


Figure 2.1 Conceptual Framework
Source: Modified from Few, 2007

CHAPTER THREE: METHODOLOGY

3.0. Introduction

This chapter presents a detailed description of the research design, population, target population, sampling techniques, data collection, data collection instruments, research procedure, data analysis and presentation techniques.

3.1. Research Design

According to Kothari (2004), selecting a research design is an important step in research for it facilitates the various research operations and it is the actual structure within which the research is conducted. This study is descriptive. The study is a cross sectional survey. Residents of Nyalenda informal settlement answered open-ended and closed ended questions administered through questionnaires. Key stakeholders answered questions administered through key informant interviews. Primary data was also obtained from observations and focus group discussions. Secondary data was identified from the Internet, books and journals. The study used both qualitative and quantitative data. Causes of floods and flood risk levels were addressed through questionnaires, focus group discussions and key informant interviews. Effects of floods and storm water management infrastructure in Nyalenda informal settlement were addressed through observations, questionnaires and key informant interviews. The study population comprised the households in Nyalenda informal settlement.

3.2. Study area

The study area covered the Nyalenda informal settlement, an established slum suburb of Kenya's third largest city Kisumu, Kenya. Figure 3.1 shows the location of Kisumu Cty in Kenya. The coordinates of Nyalenda informal settlement are 0° 7′ 36.03″ S, 34° 45′ 27.01″ E. Nyalenda informal settlement runs parallel to Ring road, South East of the Central Business District. The Nairobi road borders Nyalenda informal settlement to the North and a marshland forms the border in the South West. Nyalenda informal settlement consists of Nyalenda A Sub location (3.2 sq. Km) and Nyalenda B Sub location (4.7 sq. Km). Nyalenda A sub location and Nyalenda B Sub location are also electoral wards in Kisumu Town East Constituency and Kisumu Town Central Constituency respectively. Nyalenda A is subdivided into four units (Central, Dago, Kanyakwar and Western) while Nyalenda B is subdivided into five smaller units (Kilo, Got Owak, Dunga, Nanga and Western). There are seven Public primary and two public Secondary schools in Nyalenda informal settlement. Nyalenda informal settlement is accessible from two main roads, the Kisumu - Nairobi Highway and Ring Road. However, the internal road network is not well developed and many parts inside the settlement are only accessible by pedestrians and motorcycles. The settlement does not have any formal planning as a result of freehold tenure system. Nyalenda informal settlement is an area in rapid transition with original land owners selling land to newcomers who have been putting up quality residential houses, UN-HABITAT (2005). The majority of houses are of semi permanent nature and the informal settlement does not have a sewer line except a new one passing through the informal settlement but does not serve residents of Nyalenda informal settlement. Two rivers, Nyamasaria and Auji and Ouru stream, pass through Nyalenda informal settlement and drain into Lake Victoria.

Figure 3.1 Map of Kenya showing location of Kisumu City

Source: Google Earth, 2013

A map of Nyalenda informal settlement is shown in figure 3.2 below.

Figure 3.2 Map of Nyalenda informal settlement
Source: Google Earth, 2013

3.3. Study population

According to Mugenda & Mugenda (1999), population refers to the larger group of individuals, objects or items from which samples are taken for measurement. Oso and Onen (2008) define target population as a group of persons or objects about which the researcher wishes to draw conclusions. The Population data for Nyalenda informal settlement was sourced from the Kenya population and housing census, 2009. The sample frame of the study is shown in table 3.1 below.

Sub-location	Area (Km^2)	No. of Villages	Population	Households	% of total	No. of respondents	Respondents / Village
Nyalenda A	3.20	5	28,269	8,070	51.5%	160	32
Nyalenda B	4.70	9	32,430	8,561	48.5%	170	19
Total	7.90	14	60,699	16,631	100%	330	330

Table 3.1 Sample Frame for Nyalenda informal settlement.
Source: Kenya population and housing census, 2009.

3.4. Sample Size

A sample size is a small population selected for observation. For reliable conclusions to be drawn from the research, samples for research must be representative of the target group. In general, the larger the sample, the more representative it is likely to be and the more generalizable the results of the study are likely to be. According to the Kenya Population and Housing Census, 2009, Nyalenda A has 8,070 households, representing 48.5% of the total number of households in Nyalenda informal settlement while Nyalenda B has 8,561 households representing 51.5% of the total number of households in Nyalenda informal settlement. The sample size for inhabitants of Nyalenda informal settlement was based on the total number of households 16,631 households, Kenya population and housing census (2009). Using the scientific formula the sample size was calculated as shown below:

n= {(p [1-p])/ (A^2/z^2) + p [1-p] /N}/R. (Glen D. *et al.*, 1992).

Calculations

Using the total number of households 16,631,

Source: Kenya population and housing census (2009).

n = sample size

N = Population = 16,631 households

P = variance = 30%

A= precision required= 5%

Z= 1.96 for 95% confidence level

Assuming R, = Response Rate 95%, from formula:

$$n = \{(p\,[1-p])/\,(A^2/z^2) + p\,[1-p]\,/N\}/R.$$

$$n = \{(0.3[1-0.3])/\,(0.05^2/1.96^2) + 0.30[1-0.30]\,/16{,}631\}/0.95$$

$$n = \{(0.3[0.7])/\,(0.05^2/1.96^2) + 0.30[1-0.30]\,/16{,}631\}/0.95$$

$$n = \{(0.21)/\,(0.05^2/1.96^2) + 0.30[1-0.30]\,/16{,}631\}/0.95$$

$$n = \{(0.3[0.7]/\,(0.0025/3.8416) + (0.21)\,/16{,}631\}/0.95$$

$$n = \{0.21/\,(0.000651 + 0.0000126)\}/0.95$$

$$n = \{0.21/\,(0.000664)\}/0.95$$

$$n = \{316.45\}/0.95$$

n= 330, Sample size, n, = 330 households

The sample size used for residents of Nyalenda informal settlement was 330 respondents (households) drawn from amongst the 16,631 households. A total of 160 respondents were selected from Nyalenda A while 170 respondents were selected from Nyalenda B. This was proportional to the total number of households in Nyalenda A and Nyalenda B. Each village in Nyalenda A had 32 respondents while each of the 9 villages in Nyalenda B had 19 respondents. The sample included respondents from different genders, ages and professions so that results could be generalized.

3.5. Sampling Techniques

Sampling techniques refers to the process of selecting a number of individuals or objects from a population such that the selected group contains elements representative of the characteristics found in the entire group, Orodho and Kombo (2002). The simple random sampling technique was used to select respondents among the residents from the 5 villages in Nyalenda A sub location and from the 9 villages in Nyalenda B sub location within Nyalenda informal settlement**.**

3.6. Data collection

3.6.1. Observations

The preliminary data gathering was done by observation. It involved going out, learning and experiencing the lives of the people and establishing rapport with the residents and having a general view of the topography, the type of housing and storm water infrastructure in Nyalenda informal settlement. A transect walk was done in the community to get a general feel of the conditions by visiting water sources, noting street conditions before and after rain, visiting inside homes and public buildings. During these walks the researcher had the opportunity to ask questions. Many field visits were made to the informal settlement to gather as much information as possible. The researcher took images of the various activities that were relevant to the study during field survey. During the visits, the effects of the floods and characteristics of the storm water drainage system were determined. Observations were also used to locate the available storm water drainage infrastructure in Nyalenda A and Nyalenda B sub-locations. The researcher also noted the various methods of solid waste disposal that are used in Nyalenda informal settlement.

3.6.2. Key Informant Interviews

Informal interview was adopted at the beginning of observations fieldwork. In the unstructured interview there were no formal questionnaires; instead there was a series of topics from a checklist that were discussed randomly. This method helped reveal important background information on storm water and effects of flooding. For the latter part of this study semi structured interviews were adopted.

Key Informant interview was used to get information from: the Chief Nyalenda Location, the two Ward Representatives Nyalenda A and Nyalenda B, the Kisumu County Engineer, Chief Officer – Lands, housing and physical planning Kisumu County, the Director Meteorological department Kisumu, the Research Officer Water Resources Management (WRM), the Network Maintenance Engineer Kisumu Water and Sewerage Company (KIWASCO), the Nyanza Regional Manager Red Cross Society and the Manager NADUKATO, a local CBO dealing with storm water related flooding. The list of key informant interviews including the dates the interviews were carried out is attached in appendix E. Information about the risk of flooding, the causes of flooding and storm water management practices already implemented was gathered from the key informant interviews.

3.6.3. Questionnaires

A questionnaire is a form containing a set of questions, especially one addressed to a statistically significant number of subjects as a way of gathering information for a survey. 330 questionnaires were designed and submitted for filling by residents of Nyalenda informal settlement. The questionnaires had both fixed ended and open ended questions. 160 questionnaires were submitted to 160 households in Nyalenda A while 170 questionnaires were submitted to residents of Nyalenda B. 32 respondents in each of the 5 villages in Nyalenda A filled the questionnaires while 19 respondents from each of the 9 villages of Nyalenda B filled the questionnaires.

3.6.4. Focus group discussions

More detailed information about the risk of flooding and the available storm water management measures was sought through focus group discussions with responsible groups in Nyalenda informal settlement. 4 Focus Groups were formed, two groups from each of the two Sub Locations in Nyalenda informal settlement. Each of the four groups had six members and two of the six members in each group were female while the other four members were men. Each group also had a representative from NADUKATO, a local CBO dealing with floods, a representative of the youth age 18-35 years, one person with disability and a village elder. The Sub Chiefs and NADUKATO participated in the formation of the focus groups. This was to ensure that members of the same family were not in the same group. Through discussions, the focus groups were able to draft sketches of the storm water infrastructure and note areas most affected by flood events. Through the discussions the focus groups also determined the flood risk levels and explained the experiences of the community with regard to flooding.

3.7. Data analysis and Presentation

Quantitative and qualitative statistical analysis techniques were used in data analysis. In the quantitative analysis, descriptive statistical analysis method was used to analyze the data collected from the survey. The descriptive statistical analysis method was used to describe the characteristics and attributes of the sample. Using this, the researcher examined the frequency distribution, mean, variation and percentage distribution of attributes. With information on maximum monthly rainfall, statistical probability analysis was used to determine the probability or frequency of occurrence of floods. Using descriptive statistics the basic features of the data were described. Simple summaries about the sample and the measures were also identified. The three major types of estimates of central tendency, mean, median and mode were used. Descriptive statistical analysis was used to give descriptive statistics of means, frequencies and percentages which were then presented in tables, pie charts and graphs. Risk level was defined as a function of the hazard level and vulnerability level.

In the analysis, the hazard levels were defined as very low, low, medium, high and very high. Levels of vulnerability were identified as very low, low, medium, high and very high. The risk of flooding was categorized into high, moderate and low. Sources of Information for determining flood risk included: site-specific data such as stream gaging records, rainfall records, historic information – flood marks on buildings and other structures, newspaper accounts, marking of flood levels after an event, and geomorphic techniques, e.g., boulders along streams, water transported debris along stream and regional information.

With data collected on annual minimum, maximum and average annual rainfall, regression analysis method was used to determine the relationship between flooding and rainfall intensity. Causes of floods were identified from questionnaires and key informant interview of the Research Officer Water Resources Management. Qualitative data analysis was derived from answers to open-ended questions in the questionnaires and interviews. Codes were assigned to words and ideas in order to find patterns and trends. Coding method was used to organize the data. The data was then analyzed, sorted, coded, categorized and finally tabulated. The effects of flooding were considered under negative effects and positive effects. Information collected from interviews was used to group the effects into health effects, physical effects and social effects. The water infrastructure was sorted into bridges, culverts, storage sheds, open channels, closed channels, rivers and streams. With the maps, tables, information from interviews and literature, conclusions were drawn about the problems that have to be dealt with and possible solutions.

Muliti criteria analysis was used to select the sustainable solutions as shown in Appendix J. Values in the multi criteria analysis were assigned relative to each other. The criteria used to select the solutions to reduce the risk of flooding are costs, effectiveness, opinion of the residents and side effects. Cost of a solution plays the most important role because without sufficient funds, a solution cannot be implemented. Cost, therefore, had a weight of 5. The solutions with the highest costs got a value of -10 and the solution with the lowest cost a value of -1. The cheaper the solution the easier it will be to acquire funds for implementation of the solution. Effectiveness of a solution, the extent to which it will reduce the risk of flooding was split in two parts, the amount of cause - reduce and the amount of consequence - reduce. The effect of mitigating the causes of flooding is bigger than that of reducing the consequences. The effectiveness for the causes has a weight of 4 and the effectiveness for the effects has a weight of 2. The acceptance of a solution by the residents of Nyalenda informal settlement depends on the level of understanding of the solution. A weight of 3 is assigned to acceptance of the residents of Nyalenda informal settlement. The value for the acceptance of the residents is chosen between -5 and 5, because some solutions will affect the residents negatively and others positively. Some solutions have positive or negative effects on areas outside the study area and a weight of 1 has been assigned to this. Following focus group discussions, key informant interview of the chief, the Chief Officer – Lands, housing and physical planning Kisumu County, the Ward Representatives Nyalenda A and Nyalenda B and Manager NADUKATO, each solution was assigned different values of cost, effectiveness for causes, effectiveness for effects, acceptance by the residents and effects outside Nyalenda informal settlement. This is presented in appendix I. Each value was multiplied by the corresponding weight and the total score of each solution determined. The solutions with positive scores were selected and considered sustainable.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

This chapter gives a detailed account of the study findings which are presented according to the set objectives. The main objective of this study was to examine storm water management in Nyalenda informal settlement. The chapter focuses on the findings and discussions as per the set objectives. Some of the findings are presented in the form of tables, charts and graphs while others are given quantitatively in form of percentages.

4.1 Causes of floods in Nyalenda informal settlement

According to the residents of Nyalenda informal settlement and the Kisumu County Engineer, floods in Nyalenda informal settlement are caused by blocked storm water infrastructure, flat terrain, increased inflow from upstream, insufficient storm water infrastructure, low rate of infiltration and other causes. 35% of the residents felt that floods in Nyalenda informal settlement are caused by blocked storm water infrastructure 20% said that floods in Nyalenda informal settlement are caused by the flat terrain while 19% of the residents felt that floods in Nyalenda informal settlement are caused by increased inflow from upstream. 10% of the residents attributed floods in Nyalenda informal settlement to insufficient storm water infrastructure while 10% of the residents said that floods are caused by low rate of infiltration. 6% of the residents of Nyalenda informal settlement said that floods are caused by other causes. The Causes of floods in Nyalenda informal settlement are illustrated if Fig. 4.1 below.

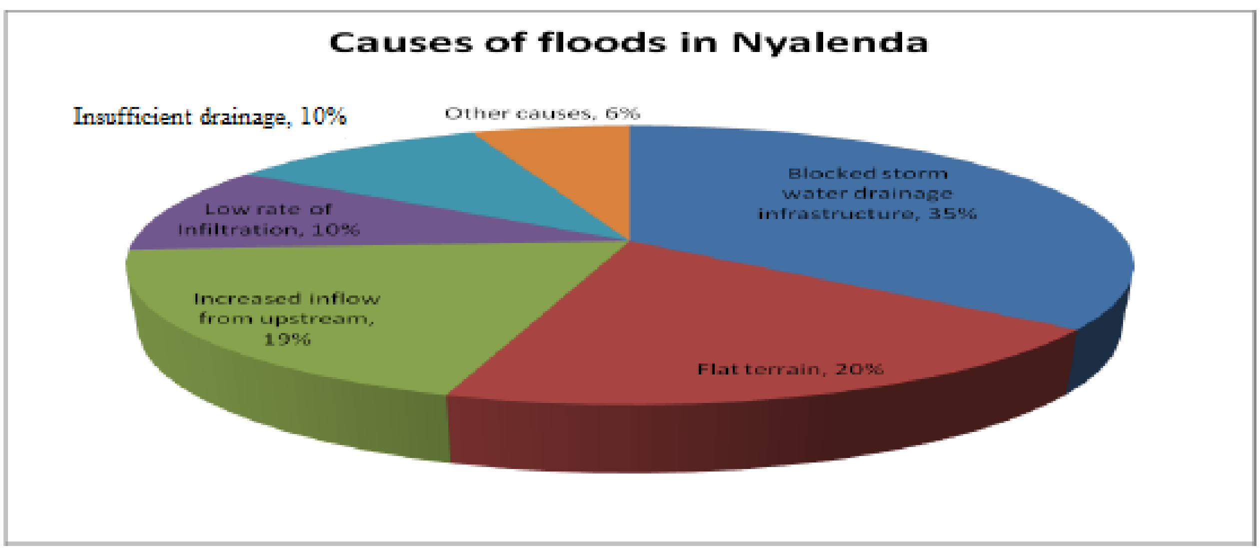


Figure 4.1: Causes of floods in Nyalenda informal settlement

4.1.1 Blocked storm water drainage infrastructure

Residents of Nyalenda informal settlement consider blocked drainage as one of the major causes of flooding. Land in Nyalenda is mainly privately owned. The buildings and estates are randomly constructed leading to blockage of the water path. This is exacerbated by the increasing density of structures due to increasing population. Storm water has to find its own path through the meandering footpaths and shallow channels. The culverts and bridges are blocked due to siltation and deposition of solid waste trappings swept from high areas in Nyalenda informal settlement and damped by storm water in the low lying areas. Plate 1 shows a blocked bridge at Nanga while plate 2 shows rising water levels in the same bridge after a day's rain.

Solid waste dumped directly into watercourses, drains, culverts, and other drainage structures blocks the drainage system. During storms the drainage structures are unable to carry the storm water due to constricted flow and reduced capacity, and therefore overflow thus causing floods. In an attempt to prevent flooding in most of the low-lying areas, refuse is piled near streams by residents, presumably to create levees with the result that storm water runoff carries refuse and other solid wastes into the streams reducing their capacity and posing serious health and environmental hazards to residents downstream. Sometimes the wind aids this process by blowing litter into drainage channels causing blockages. The impact of solid waste has assumed a new dimension because of the increasing use of plastics as packaging material, cans and bottles. These materials and other debris accumulate in drainage channels and cause flooding. Haphazard solid waste disposal in the high areas of Nyalenda such as Kilo leads to blocking of the available channels and culverts. Residents excavate their own terraces to drain water but these too do not last for long as they are blocked by the waste thrown haphazardly in the informal settlement. The river course for river Nyamasaria is blocked and clogged leading to flooding in Nanga and Dunga next to Lake Victoria. The different causes of blockage of storm water drainage infrastructure are shown in figure 4.2. In his research, Peter (2009) found out that flooding in Accra, Ghana, is caused by insufficient carrying capacities of the respective streams, brought about by the accumulation of silt brought into the streams by erosion and by blockages caused by solid waste deposited in the streams.

Plate 1: A blocked Bridge at Nanga
Source: Field survey, 2015

Plate 2: Rising water levels at blocked bridge
Source: Field survey, 2015

In Nyalenda informal settlement, the concrete lining of river Wigwa has caved in resulting in reduced carrying capacity. The river discharge is therefore reduced by the decrease in the volume of water that can be contained within the river. Peter (2009) in his research, notes that where drains are in deplorable conditions as a result of poor or lack of maintenance; dumping of refuse and human excreta in the drains; service and utility lines; undersized culverts crossing roads and unauthorized structures located within the flow paths of the drains, there is obstruction of flow hence flooding.

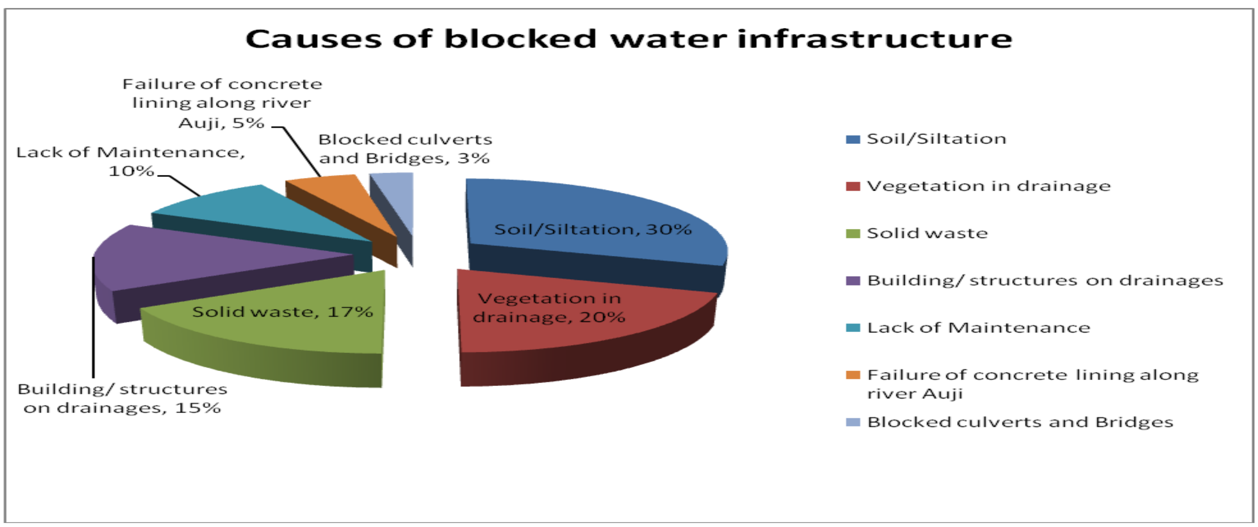


Figure 4.2: Causes of blocked water infrastructure

According to the Kisumu County Engineer and the Chief Officer-Lands, housing and physical planning Kisumu County, the major causes of blockage of storm water infrastructure in Nyalenda informal settlement are siltation 30%, vegetation growth in drainage 20%, solid waste

17% and building and structures on drainage 15%. Other causes of blockage of the storm water drainage system include lack of maintenance 10%, failure of concrete lining of the Auji River 5% and blocked culverts and bridges 3%.

4.1.2 Increased inflow from upstream

Nyalenda Informal settlement has two rivers flowing through the settlement. These are Nyamasaria and river Auji which are fed by small streams and small water channels. The overflow of river Wigwa causes flooding at Kachok, Katuoro, Kapuothe and Nanga while overflow of river Nyamasaria mainly causes flooding in Kachok, Dunga and Nanga. The Auji canal was built in 1981 by the World Bank. The canal starts at the north of Manyatta, flows through Nyalenda and drains into Lake Victoria at Dunga, (plate 3). A cross section of the river is given in Figure 4.3 below. Water from the higher areas in Nyalenda also drains through channels into river Auji commonly known as Wigwa in Nyalenda.

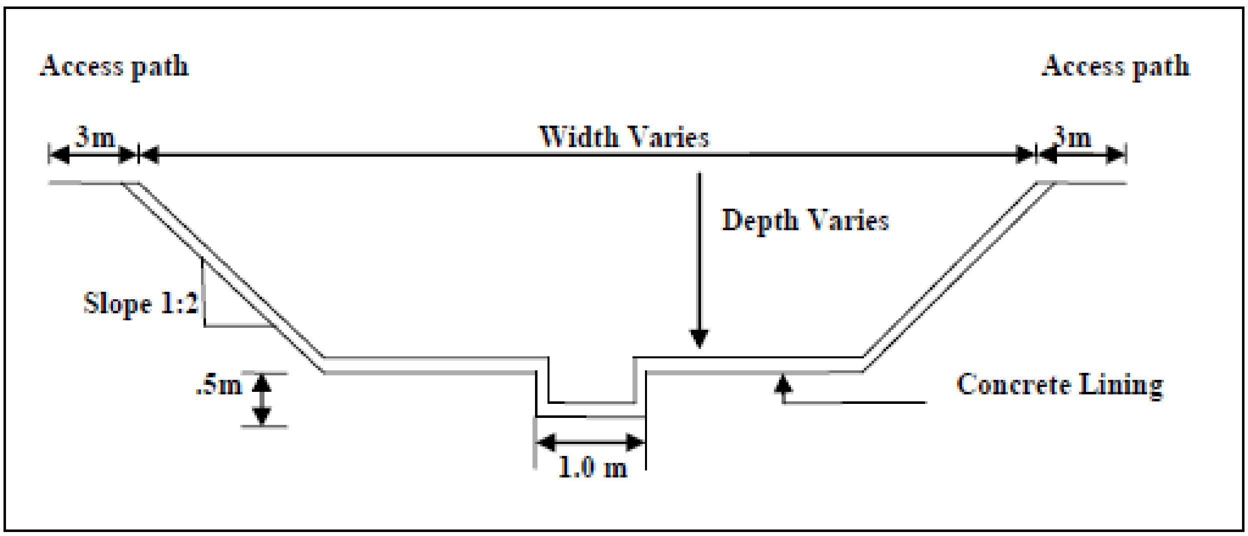


Figure 4.3: Cross section of river Auji
Source: Department of County Engineering, Kisumu County

This is the only available detailed information about the Auji and therefore the dimensions that are not given in the cross-section were estimated on site. The average width of the river is considered to be 5 metres and the average depth is considered 2 metres. The Nyamasaria River has a basin area of approximately 859Km^2 and is situated adjacent to the Nyando river basin, Ongor (2007). Both river Nyamasaria and river Nyando flow into the low lying Kano Plains. River Nyamasaria drains into Lake Victoria at Dunga, next to Dunga beach (plate 4).

Plate 3: River Auji flowing into Lake Victoria
Source: Field survey 2013

Plate 4: River Nyamasaria draining into the Lake
Source: Field survey, 2013

4.1.3 Low rate of Infiltration

According to Jagdale *et al*,(2012), Infiltration is the movement of water into the soil from the surface. The water is driven into the porous soil by force of gravity and capillary attraction. First the water wets soil grains and then the extra water moves down due to resulting gravitational force. Nyalenda informal settlement is characterized by low vegetation cover except in areas along rivers Auji and Nyamasaria. Katuoro area is rocky with black cotton and minimum vegetation cover consisting mainly of short grass. The little vegetation cover available is destroyed by livestock that graze along rivers Auji and Nyamasaria as shown in Plate 5**.** Destruction of the little vegetation that grows during the rainy season leaves the land exposed and vulnerable to erosion during floods.

Plate 5: Livestock grazing next to river at Nyalenda informal settlement
Source: Field survey, 2013

Nyalenda informal settlement consists mainly of black cotton soil. Black cotton soil consists of kaolinite and montmorillonite. High percentage of montmorillonite renders high degree of expansiveness. Vegetation does not do well on black cotton soil. This results in a reduction in infiltration rate. From the water balance equation, it follows therefore that lack of sufficient vegetation leads to a low rate of infiltration which in turn results in decrease in discharge hence flooding. According to Asdak (2010), infiltration is a part of hydrologic cycle that plays an important role in reducing the surface runoff that can cause the flood vulnerability in the downstream of watershed. The increase in population due to urbanization followed by the increase in the land cover development can increase the surface runoff. The more the rainwater infiltrates into the soil the less the surface runoff occurs, so that the magnitude of flooding can be reduced, Carlson and Toby (2004). The change in urban soil properties as the result of the population growth affects the infiltration; the infiltration is at the criteria of slow and very slow due to the soil compaction while the amount of surface runoff is greater (Yang and Zhang, 2011).

4.1.4 Flat terrain

Nyalenda is fairly flat area fed by natural springs that produce abundant water used for irrigation on small-scale gardens. Nyalenda was previously a swamp but due to an increase in population in urban Kisumu, buildings have come up to cater for the expanding population. Lower Nyalenda from Kachok to Kassagam, Kapuothe, Katuoro, Nanga and Dunga is generally flat with little vegetation cover. These low lying areas in lower Nyalenda areas are the worst affected by floods. Nicholls (1990) established that once a river overtops its banks, the maximum flood level reached depends greatly on the nature of the adjacent floodplain. Wide, flat floodplains can store a greater volume of floodwater than steep-sided valleys, and the resulting floods move more slowly. The flat terrain of the low lying places in Nyalenda informal settlement reduces the flow rate of flood water. A flat terrain with a minimal slope is a recipe for floods as compared to the steep slope upstream. In his research, Nicholls (1990) further found out that floods are also affected by the roughness of the terrain being passed over. Dense vegetation and artificial obstacles such as fences and houses slow down water flow, often leading to lower flood levels downstream.

4.1.5 Insufficient drainage

The researcher established from field observations that there exist two rivers in Nyalenda informal settlement namely river Nyamasaria and river Auji. An open water channel was recently developed and runs along Nyalenda ring road and stretches from Kachok to Labour College and down towards the boundary of Nyalenda B and Milimani estate. Several shallow trenches dug by inhabitants also help drain storm water in Nyalenda informal settlement. Generally, the bigger, straighter and smoother a river, creek or other channel, the greater its capacity to carry water and the less prone it is to flooding. The concrete lining in river Auji has caved in thus the river cannot carry water effectively during peak flows. River Nyamasaria has a lot of sediment build up which contributes to increased flooding. There are no dams in Nyalenda to store excess storm water. Very few individual households can afford water storage tanks to collect storm water. Excess storm water stagnates in ponds and only a little quantity is utilized for irrigation mainly at Kapuothe farms. Nyalenda in general lacks a storm water harvesting system and rain water is left to waste leading to stagnant water ponds and floods. According to Quist (2001), absence of drainage facilities and inadequate capacities of the existing drainage facilities also contribute to the problem of flooding. Quist (2001) further notes that from inspections and hydraulic calculations, some drains and culverts in the Mataheko and Kaneshie catchments are of inadequate capacity hence the perennial problem of floods**.**

4.1.6 Other causes

From key informant interview of the Chief Officer – Lands, housing and physical planning, the researcher found out that other causes of flooding include growth of vegetation in the drainage infrastructure, lack of maintenance on the existing infrastructure and uncontrolled development on privately owned land in Nyalenda. Growth of vegetation in river Auji has led to cracking of the concrete lining both at the top and bottom of the river. After heavy downpour the vegetation is washed away by fast flowing water leaving solid waste trappings which contribute to blockage of the drainage system. In their research, Wilgert *et al*. (2012) established that vegetation growth in drainage canals hampers the discharge and increases the probability of flooding during high rainfall events. The drainage infrastructure in Nyalenda informal settlement is not maintained or desilted and therefore the rivers are full of thick vegetation and silt throughout the year. In 2011, maintenance was carried out on river Auji all the way from Dunga, through Nanga, Katuoro, Kapuothe and Kassagam with the use of funds from the Constituency Development Fund, (CDF). However, all the excavated material was dumped at the river banks and this was swept back into the river after the subsequent heavy downpour. During the maintenance exercise, a culvert was also erected across Dunga road a few kilometers from Dunga beach. River Nyamasaria is blocked by thick vegetation at Dunga and the river flows into a swamp adjacent to Lake Victoria. In their study, Wilgert *et al* (2012) also found out that when maintenance of the drainage canals is omitted, extensive vegetation growth occurs in the drainage infrastructure.

4.2 Effects of flooding in Nyalenda informal settlement

4.2.1 Health Effects

In terms of occurrence, health effects can be categorized as: those happening during or immediately after the flooding. The effects of flood on health in Nyalenda informal settlement are shown in figure 4.4 below. According to the Chief Nyalenda location, the Manager NADUKATO CBO and the Research Officer, WRM, the effects of floods in Nyalenda informal settlement include: spread of water borne diseases, provision of breeding ground for parasites, injuries, expanded rodent habitats, disruption of health services, and contamination of water supply systems. According to the residents of Nyalenda informal settlement, the main health effect from floods is that the stagnant flood water provides breeding grounds for malaria causing female anopheles mosquitoes. The mosquitoes breed in the flood water and incease in number increasing the chances of malaria infection in Nyalenda informal settlement. 50% of the residents felt that flood water offers breeding ground to malaria transmitting female anopheles mosquitoes. According to the residents, spread of water borne diseases such as dysentery, diarrhea, cholera and typhoid make up 30% of the health effects of floods in Nyalenda informal settlement. According to residents of Nyalenda informal settlement, disruption of water supply, injuries and increased rodent habitat cater for 15%, 3% and 2% of the effects of flood on health in Nyalenda informal settlement.

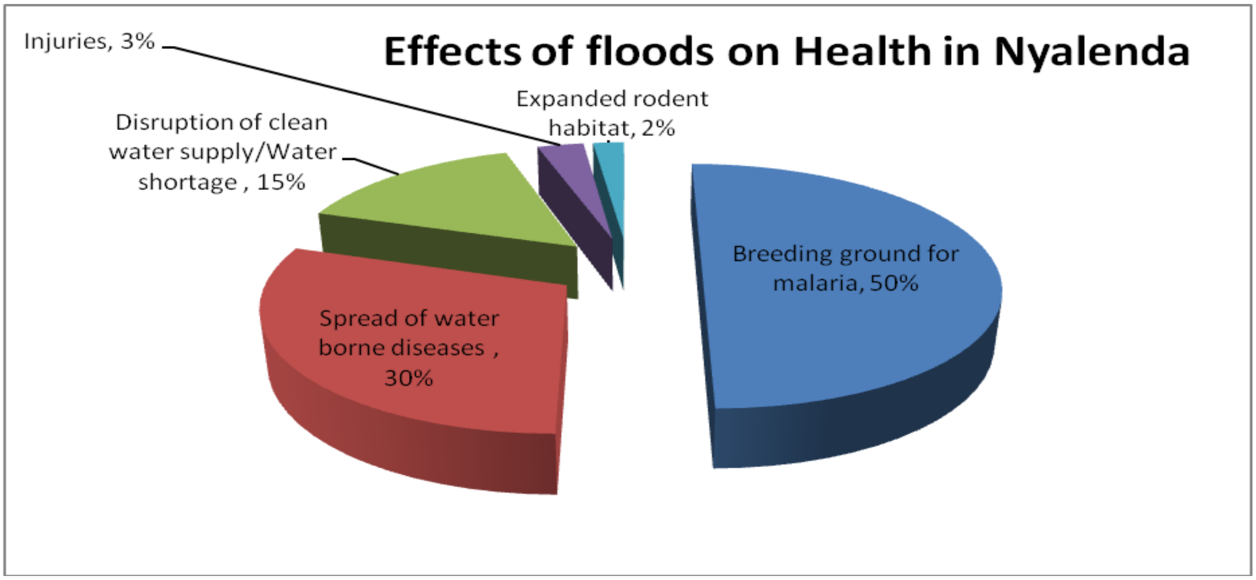
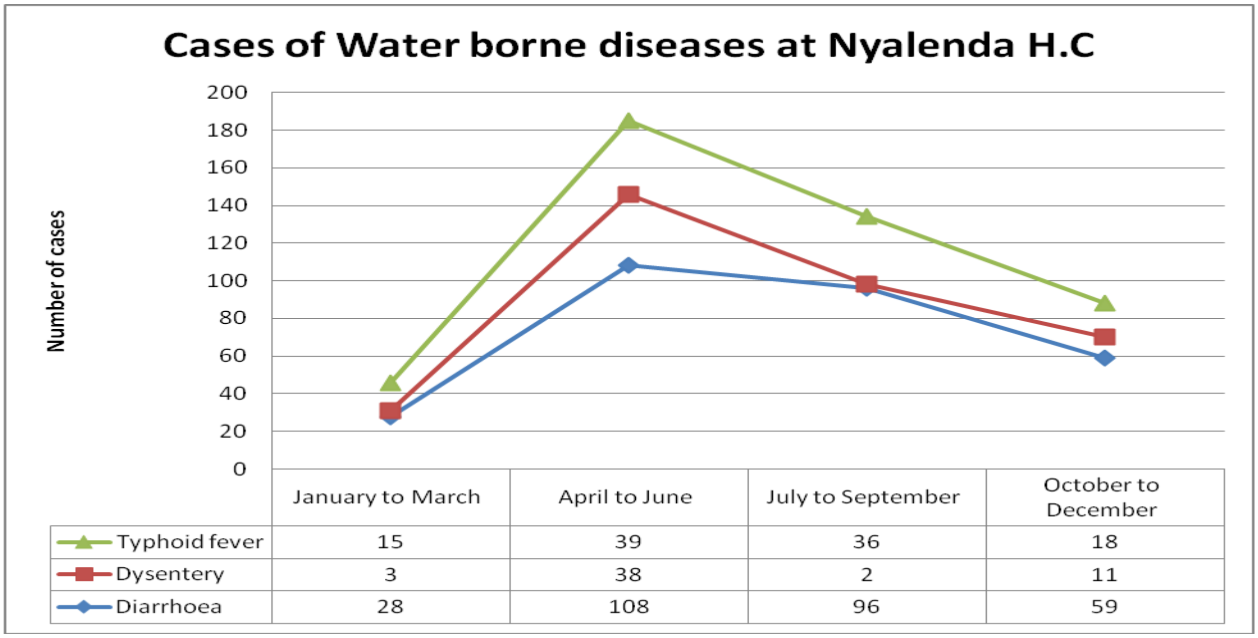


Figure 4.4: Effects of floods on Health
Source: Field survey, 2013

i. Spread of water borne diseases

Storm water carries with it solid waste and disease causing micro-organisms. The Network Engineer KIWASCO regretted that Nyalenda informal settlement lacks a sewage system and residents rely on pit latrines which overflow during the rainy season and mix with storm water. Plate 6 shows a failed manhole at Kassagam. During key informant interview, the Chief Officer, Lands, Housing and Physical Planning, Kisumu County observed that during floods, sewage overflow from manholes and mix with flood water leading to contamination and spread of water borne diseases. The contaminated water flows into river Auji and Nyamasaria as well as into Ouru stream. Plate 7 shows contaminated water flowing in river Auji. The contaminated water eventually flows into Lake Victoria resulting in contamination of the Lake. Microorganisms causing diseases such as dysentery, diarrhea, cholera and typhoid are spread by the contaminated storm water. In Nyalenda informal settlement, the patients are mostly treated at Nyalenda Health Centre, Kowino Dispensary and Pandpieri Health Centre. Data from the Kisumu District hospital indicates that there were more cases of water borne diseases reported in the three major health centres in Nyalenda after the floods resulting from heavy rains of March to April 2013. This is in agreement with Few *et al*. (2005), who noted that there was evidence of an increase in diarrheal disease after flooding in the former Czechoslovakia and Norway. During the July, 2004 floods in Bangladesh, outbreaks of diarrheal diseases occurred throughout Dhaka, with more than 17,000 patients seen at a single centre, Maryam *et al*. (2011). In Nyalenda informal settlement, data on the reported cases of diarrhoea, dysentery and typhoid in the three major health centres is presented in appendix F. The number of cases of water borne diseases reported in Nyalenda Health Centre in 2013 is shown in figure 4.5 below. 39 patients were treated of typhoid fever between April and June 2013 during heavy rain and flood season as compared to 15 cases of typhoid fever that were treated between January and March 2013, 36 between July and September 2013 and 18 cases of typhoid fever that were treated at Nyalenda health centre in Nyalenda informal settlement between October and December 2013. A total of 46 cases of diarhoea, dysentry and typhoid were treated at Nyalenda health centre in the months of January to March 2013 while a total of 185 cases were treated between April and June 2013. 134 cases of typhoid fever, dysentery and diarrhea were treated between July and September 2013 while 18 cases were reported and treated between October and December 2013.

The highest number of cases of typhoid fever treated at Nyalenda health centre was 39 between April and June 2013 when there were floods in Nyalenda informal settlement. 3 cases of dysentery were treated between January and March 2013, 38 between April and June 2013 (long rains season) and 2 cases were reported and treated between July and September 2013. 11 patients were treated between October and December 2013 during the short rains season. Between January and March 2013, 28 cases of diarrhoea were treated in Nyalenda health centre while 108 cases were reported between April to June 2013. 96 cases of diarrhoea were treated between July and September 2013 and another 59 cases of diarrhea were treated at the Nyalenda health centre.



	January to March	April to June	July to September	October to December
Typhoid fever	15	39	36	18
Dysentery	3	38	2	11
Diarrhoea	28	108	96	59

Figure 4.5: Cases of water borne diseases at Nyalenda health centre
Source: Field survey, 2013

According to the Nyanza Regional Manager Red Cross Society, toilets in flood- prone areas such as Nyaori and Kassagam collapse due to floods and the existing ones can no longer be used since they are flooded, in effect causing serious health risks.

Plate 6: Failed manhole at Kassagam
Source: Field survey, 2013

Plate 7: Contaminated river Wigwa
Source: Field survey, 2013

Residents in Nanga have raised their toilets to prevent the toilets from collapsing after floods. Leptospirosis, an emerging threat in most developing countries following flooding, is also of concern in Europe because it has been reported after recent outbreaks in Portugal (1969), the Russian federation (1997), and the Czech Republic (2003), Ahern *et al*. (2005). General infections resulting from direct contact with flood waters include skin irritation and infection (dermatitis), conjunctivitis, and ear, nose, and throat infections (Penning *et al*. 2005).

ii. Breeding ground for malaria causing mosquitoes

Storm water provides breeding ground for mosquitoes that cause malaria. This increases the incidences of malaria. Residents of Nyalenda informal settlement are affected by malaria more than other water borne diseases. Statistics on malaria from the Kisumu District hospital, (Figure 4.6) show that in the months of January to March 2013, a total of 714 cases of malaria were reported in Nyalenda health centre while 592 cases were reported at K'Owino and 310 cases of malaria were reported at Pandpieri health Centre. In the months of April to June 2013, a total of 1112, 1094 and 603 cases of malaria were reported in Nyalenda Health centre, K'Owino and Pandpieri Health Centre respectively. Therefore, more cases of malaria were reported after the floods of April 2013 as compared to the period between January and April 2013 when there were no floods (fig 4.6).

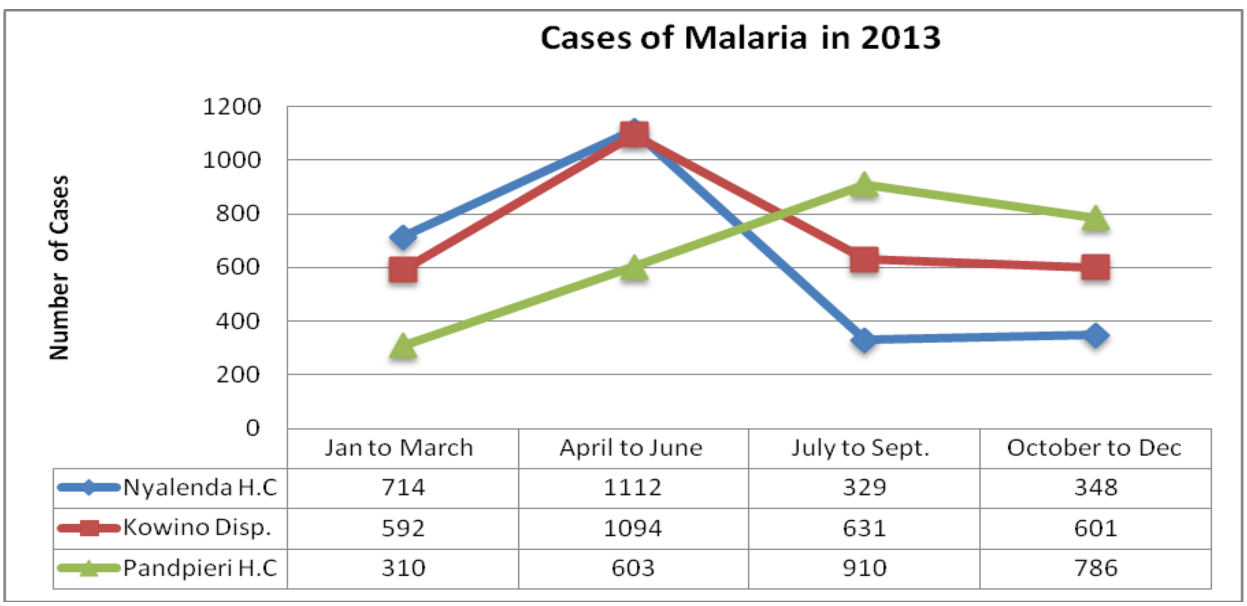


Figure 4.6: Cases of Malaria 2013
Source: Kisumu District Hospital

According to ICPAC, (2007), the 1997/98 El Nino floods in Kenya resulted in more deaths from malaria and rift valley fever epidemic as compared to the 2006 floods.

iii. Injuries

Floods cause injuries to residents of Nyalenda informal settlement who wade through the floods to higher grounds. The injuries also result from metallic items such as nails swept from upstream by the raging waters. In the period between April to June 2013, 33 injuries from nails and broken bottles were treated at Nyalenda helath centre, 13 at Kowino Dispensary and 27 at Pandpieri health centre while between January and March, only 2 were treated at Pandpieri health centre. In their research Ahern *et al.* (2005) found out that a total of 6% of the 108 households surveyed after the Nîmes, France, flooding reported contusions, cuts, and sprains. A few cases of burns, electrocutions, and sprains as well as wound infections and dermatitis were reported after floods, Vasconcelos (2006). Some of the other health impacts reported after floods include a few cases of snake bites as snakes tend to take refuge in households after flooding, Vasconcelos (2006).

iv. Expanded range of rodent habitats

According to the residents of Nyalenda informal settlement, stagnant rain water from flooding provides an expanded rodent habitat. Floods cause rodents to be displaced from their habitats and as a result, bring them into even closer contact with humans. According to Semenza *et al*. (2012), rodent populations respond rapidly to conducive weather conditions, such as heavy precipitation and flood events which can directly or indirectly propagate rodent-borne pathogens such as spirosis, a zoonotic bacterial disease. Outbreaks of rodent-borne Hantavirus have been associated with increases in mouse populations, driven by food supply as a result of prolonged floods, Epstein (2001).

v. Disruption of water supply/Water shortage

According to residents, floods lead to disruption of water supply systems through damage of water pipes. This leads to contamination of bore holes and piped water systems. The inhabitants then suffer from insufficient supply of clean drinking-water, water for washing and other domestic uses. In their research, Mogaka *et al*., (2006) established that the 1997/98 El Niño floods seriously damaged water supply infrastructure across Kenya including dams, water pans, and some pipelines in 22 districts which were either destroyed or severely damaged. Mogaka *et al.*, (2006) also noted that the 1997/98 floods also damaged irrigation infrastructure including intake structures, canals and drains, underground piping and dislodged storage tanks.

4.2.2 Physical Effects

Flooding in Nyalenda informal settlement has several physical effects as illustrated if fig 4.7. Data from the red cross showed that the physical effects consisted of destruction/ submerging of buildings, destruction of transport and communication infrastructure, destruction of agriculture, crops and vegetables, loss of human life and loss of livestock. 45% of the physical effect of floods was the destruction and submerging of buildings in the flood prone areas in Nyalenda informal settlement, 27% destruction of transport and communication infrastructure, 25% of the bphysical effect constituted destruction of crops and vegetables while 3 % is the loss of human life and death of livestock.

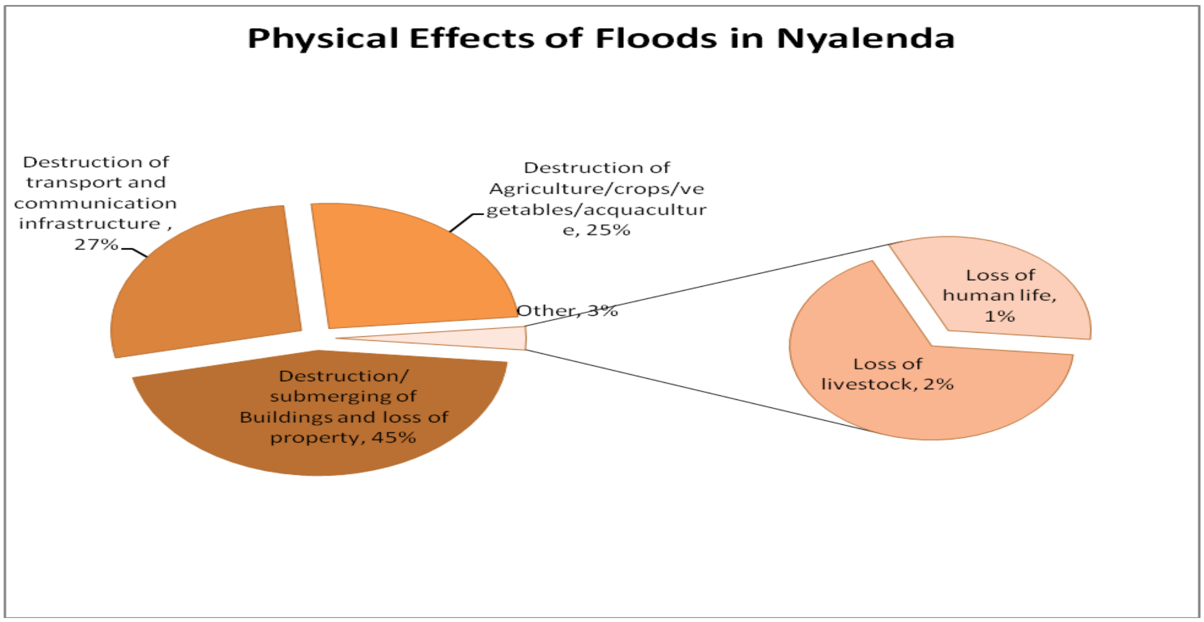


Figure 4.7: Physical Effects of floods in Nyalenda informal settlement

i. Destruction of transport and communication infrastructure

Flood water renders roads inaccessible and washes away bridges on feeder roads. During the key informant interview of the Kisumu County Engineer Kisumu, the Engineer observed that in April 2013, several businesses as well as transport flow along the main Nairobi- Kisumu Highway were affected after a section of the Nyamasaria Bridge was swept away by floods. Plate 8 shows a picture taken by the researcher during field survey and shows a section of Nyamasaria Bridge that was swept away by floods in April 2013. This resulted in a huge traffic snarl up along the Nairobi – Kisumu Highway.

Plate 8: A section of Nyamasaria Bridge swept away by floods in April 2013
Source: Field survey, 2013

As communication links and infrastructure such as power plants, roads and bridges are damaged and disrupted, economic activities come to a standstill, resulting in dislocation and the dysfunction of normal life for a period much beyond the duration of the flooding. According to Otiende (2009), the October 2006 floods in Kenya caused damages to major roads in the country including a 5km section of the main Bura and Garissa-Dadaab roads that was completely cut off resulting in the isolation of communities for extended periods and disruption of transport, communication and business activities. In their research, Hirji *et al*, (2006) noted that relief operations coordinated by the government and other relief and humanitarian agencies during flood disaster were also affected due to destruction of transport infrastructure by floods.

ii. Destruction of buildings and loss of property

Floods in Nyalenda has led to property destruction, the worst being during the el-nino rains in which the floods caused by overflow of river Nyamasaria destroyed dwelling houses and swept away those whose walls were made of mud. As a result the residents were left homeless and forced to move to higher ground. Roofs of schools are also blown off by heavy storm which then affects smooth learning. Floods also lead to destruction of property which is submerged by flood waters that access buildings. In some cases, property is swept away by the raging water. In examining the effects of flooding, Akinmade (2005) opined that natural homes and other structures built on flood plains are subjected to damage and loss when inundated by floodwaters. Flood assessment studies undertaken along the last 20 km reach of the Nzoia River in western

Kenya indicated that annual flood damages amount to about US$4.8 million in the Budalang'i floodplains. The average annual flood damage in the Kano Plains is about US$ 850,000, Eitel *et al.* (2006)

iii. Destruction of crops/vegetables

Fast flowing storm water in Nyalenda informal settlement leads to destruction of farm lands in areas adjacent to rivers Nyamasaria and Auji. Crops destroyed include maize, bananas and vegetables such as 'sukuma wiki' planted in fertile farmlands along the rivers and owned by small scale farmers. Plates 9 and 10 show pictures taken by the researcher during field survey. The plates show crops grown adjacent to river Auji at Kapuothe and Kassagam. Flood waters from the Auji River destroy the crops that are grown adjacent to the river.

Plate 9: Farmlands at Kapuothe
Source: Field survey, 2013

Plate 10: Farmlands at Kassagam
Source: Field survey, 2013

In Nyamthoyi farms where most farming in Nyalenda informal settlement is carried out, the farmlands flood each year leading to crop damage and poor harvests. Storm water also causes soil erosion and sweeps away fertile soils and dumps silt on farmlands which is unsuitable for plant growth. Floods that occurred in Phalombe and Zomba in Malawi in 2014 seriously affected the Agricultural sector with a total of 7,705 hectares having been completely washed away by flood water, Temwani *et al.* (2014).

iv. Loss of human life

Floods cause loss of life of human beings in Nyalenda informal settlement. From key informant interview of the Nyanza Regional Manager Red Cross Society, the Manager observed that in 1997, the Elnino associated floods claimed the lives of 4 people in Nyalenda informal settlement. The victims were washed away by fast flowing waters. The most affected are children who drown while crossing or swimming in the storm water. Plate 11 below shows a child swimming in the swelling River Auji, oblivious of the danger he is exposing himself to.

Plate 11: A child swimming in the swelling river Auji
Source: Field survey, 2013

The spillover effects of the loss of livelihoods are felt in business and commercial activities even in adjacent non-flooded areas in Kisumu. Waterborne diseases such as cholera that result from flooding lead to death if not treated in time. Jonkman *et al*. (2005) reviewed 13 flooding episodes with 247 reported deaths from Europe and the US for the causes and circumstances of flood-related deaths and found out that approximately two thirds of the deaths occurred as a result of drowning. A great burden is attributed to heart attacks, hypothermia, trauma, and vehicle-related accidents, Few *et al*, (2004). Whitlow (1996) described floods as the commonest of the natural hazards which has in recent decades accounted for no less than 64% of all deaths resulting from natural hazards. Bolten *et al*, (1998) in their study of floods in United States concurred with Whitlow (1996) when they observed that about 100 persons lose lives in floods every year.

Bolten *et al*. (1998) also found out that the 1993 flood of the Mississippi River took about 50 lives.

v. Loss of livestock

Fast flowing water from the rivers sweeps away poultry and livestock including cattle, goats and sheep kept by small scale farmers and who rely on grazing along the shores of rivers Nyamasaria and Auji. In his study of floods in Malawi, Rolle (2014), showed that Malawi is regularly hit by floods and approximately 26,000 people are affected by floods each year with agricultural families often being the hardest hit by floods, which wash away poultry and livestock.

4.2.3 Social Effects of Floods

Social effects of flooding in Nyalenda informal settlement are illustrated in fig 4.8 below. 35% of residents of Nyalenda informal settlement felt that floods affect education, 23% said that floods cause displacements, 23% of the residents associated floods with psychological effects. 12% of the residents interviewed said floods cause cause hunger and food shortage while 10% of the residents attributed floods to decreased purchasing and production power. Majority of the residents felt that among the social effects of floods, education is the most affected. This is because floods lead to closure of schools lying in lower Nyalenda both in Nyalenda A and Nyalenda B sub locations. Moreover, schools in the higher areas of Nyalenda informal settlement are used as displacement camps.

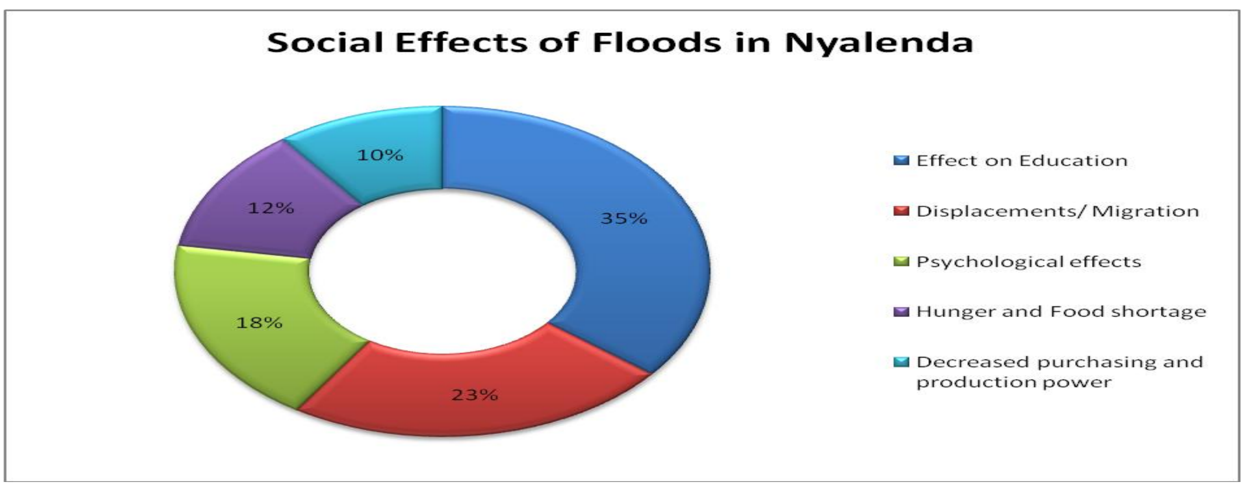


Figure 4.8: Social Effects of floods in Nyalenda informal settlement

i. Displacements/ Migration

Floods in Nyalenda informal settlement lead to submerging of buildings and make them inaccessible. Residents of the informal settlements are then forced to move from their homes in lower Nyalenda especially Kassagam in Nyalenda A and Nanga in Nyalenda B to higher ground in search of shelter. Data from the Red Cross shows that, in 2012, 139 households were displaced in Nyalenda A and 91 households were displaced in Nyalenda B after the floods. During the key informant interview, the Nyanza Regional Manager Red Cross Society disclosed that in 2013, 96 households were displaced in Nyalenda A and 73 in Nyalenda B Sub locations. According to the Regional Manager Red Cross Society, on 26th March 2014, 60 homesteads were displaced by floods. Residents affected by floods move to centres at higher grounds or to areas not affected by flood. The affected residents of Nyalenda informal settlement camp at Nyalenda shopping centre, Pandpieri shopping centre, Nyamasaria Church and Nyamasaria School.

IDMC (2011) found out that extreme, sudden-onset weather events - primarily floods and storms displaced more than 38 million people worldwide in 2010. The devastating floods in Pakistan, caused by unusually heavy monsoon rains in July and August 2010, mostly affected the southern province of Sindh with more than seven million people affected and 1.5 million made homeless, NDMA, (2010). According to NDMA the 2010 floods caused the largest mass displacements in Pakistan's history. According to the UNHCR (2011), Kambar Shahdadkot was one of the worst-hit districts in the province, with over a million people affected, around 75,000 homes destroyed and some 337,000 people left homeless

ii. Effect on Education

The Nyanza Regional Manager Red Cross Society observed that during floods in Nyalenda informal settlement, learning in both primary and secondary schools is affected. The schools that are affected by flooding in Nyalenda A are: Kassagam Primary and Kassagam Secondary Schools. During heavy downpour, learning is disrupted due to submerging of classrooms. The students are forced to go back home until the flood water level goes down. The researcher found out from key informant interview of the Ward Representative Nyalenda A, Mr Onunga, that learning was disrupted as a result of flooding in March 2013 to April 2013. The schools affected were Senior Chief Onunga School for the Deaf, St. Mark Nyabera Primary school and Kassagam Secondary school. According to the Ward Representative, Nyalenda B, the rains in March 2013 flooded classrooms and access roads forcing students to return home. The Ward Representative Nyalenda B further noted during key informant interview that the worst affected schools in Nyalenda B were Nanga primary and Nanga secondary schools. During floods, primary schools in upper Nyalenda are used as evacuation centers for those affected by floods in the lower side of Nyalenda. Heavy storms also blow off roofs of schools which then affect smooth learning. In their research, Saleem *et al.* (2013) report that in 2000 in Cambodia severe floods directly affected between 500,000 and 1 million students in 1,000 – 2,000 schools in 8 provinces. They also established that in 2004, the Indian Ocean tsunami destroyed 750 schools in Indonesia, 150,000 students were left without schools while 51 schools were destroyed in Srilanka, 44 in Maldives, and 30 in Thailand.

iii. Hunger and Food shortage

From the key informant interview, the researcher found out that during floods, crop and vegetation in Kapuothe and Kassagam are destroyed by the raging water. This results in low harvests which culminate in food shortage. Vegetable prices then go up and those who cannot afford suffer from hunger. In their research in Budalangi (a flood prone region in Kenya), Gichere *et al* (2010) found out that of all the crops planted, only maize and potatoes yielded more than half (> 50%) of the expected yield after floods. According to KFSSG (2008), floods affect the nature and distribution of pests and diseases, with resultant impacts on livestock and human health and in turn, on livelihoods, food security, and the economy. In their research, Hirji *et al*, (2006) noted that some effects of floods include shortages of food and other basic supplies across the country.

iv. Psychological Effects

Floods lead to loss of life, displacements and destruction of property which then leaves the residents shocked or traumatized after incidences of flood havoc. Floods result in increase in physical and emotional stress and increased susceptibility to psychosocial disturbances which lead to anxiety, depression and apathy. In their recent studies in five English communities, Tapsell *et al.* (1999) indicated that some flood victims attribute physical symptoms, ill health as well as considerable psychological trauma to the flood experience. In their 2005 review on the global health impacts of flooding, Ahern *et al*, (2005) report that flooding affects people of all ages and it can herald: bereavement; economic problems for families; behavioral problems in children; increased substance use and/or misuse; increased domestic violence; as well as exacerbating, precipitating or provoking people's existing problems with their mental health.

4.2.4 Positive Effects

i. Floods deposit nutrient-rich alluvial soil on farms

Flood distributes and deposits river sediments on land at Kapuothe. The fertile river sediments replenish nutrients in topsoil thus make agricultural lands in Kapuothe more fertile. Plate 12 below was taken by the researcher during field survey. It shows crops and vegetables growing along river Auji in Nyalenda informal settlement. Obatola (2005), describing the effects of floods on the people of the Niger Delta, concluded that floods have a tremendous influence on the pattern of human life and economic activities in the Delta region. Obatola (2005) observed that at present, crops like yams, cassava and maize are restricted to drier parts of this area and that yams and cassava are the main food crops grown by the natives; farming activities begin around mid – December when the floods are receding. All these point to the positive effects of flood on man and the environment as well as the effects of flood on socio-economic activities. The most intensive agriculture in Kisumu County is practiced along the Lake shore in the lower lying flood plains of Nyalenda and Dunga, Kisumu County Government (2013).

Plate 12: Crops along river Auji in Nyalenda informal settlement

Source: Field survey, 2013

ii. Recharge of ground Water

The research officer WRM informed the researcher during key informant interview that in Nyalenda informal settlement, flood waters absorb into the ground and percolate down to recharge underground aquifers which supply rivers with fresh water. One of the most significant phenomena observed in the Kuiseb River during the 2006 flood season was that small floods yield ground water recharge fluxes very similar to those generated by large floods, Dahan *et al*. (2007). Along its long route, the Kuiseb River usually transmits all of its flood water to the channel bed and it rarely flows all the way to the ocean since the water infiltrates into the ground, Ofer *et al.* (2008). Floods in Nyalenda informal settlement also bring fresh water for irrigation and domestic use. Flood water is usually characterized by low salinity since the streambed and its alluvium are more regularly flushed by such floods, Scanlon (2004). Residents interviewed noted that after floods, the residents get more stock of mud fish in areas adjacent to rivers.

4.3 Flood risk in Nyalenda informal settlement

Characterization of area concerned

Rainfall

Data from the Meteorological department gave the monthly rainfall for Nyalenda informal settlement for the period 1991 to 2013 as shown in figure 4.9. There are two heavy rain seasons during a year. These are the long rains season, March - May and the short rains season, October – December. The maximum amount of rainfall received over the long rains season, March to May is 400mm. The maximum monthly rainfall received over the short rain season, October to December in the period 1991 to 2013 was 505mm. The average amount of rainfall received in the months of March, April and May is 212.50mm, 240.0mm and 165mm respectively. During the short rains season, the months of October, November and December, Nyalenda informal settlement received 122.5mm, 195.0mm and 255.0mm of rainfall respectively. Nyalenda informal settlement received 465.5mm of rainfall in the period between the two rain seasons (June, July and August). The average amount of rainfall received in January and February was 160.0mm and 90.0mm respectively. The total amount of rainfall received annually during the long rain season between March and May is 617.50mm while the total amount of rainfall received over the short rain season October to December is 572.50mm. The exact dates of the seasons differ every year but, the rain in the long rainy season is much heavier than that in the short rain season Nyalenda informal settlement receives the highest amount of rainfall in the month of April, average 240.0mm.

According to SANA (2004), Nyalenda informal settlement receives an annual rainfall of between 1500mm - 1800mm. In the period 1991 to 2013, data from the metrological department shows that Nyalenda informal settlement received an average of 1905.5mm of rainfall annually.

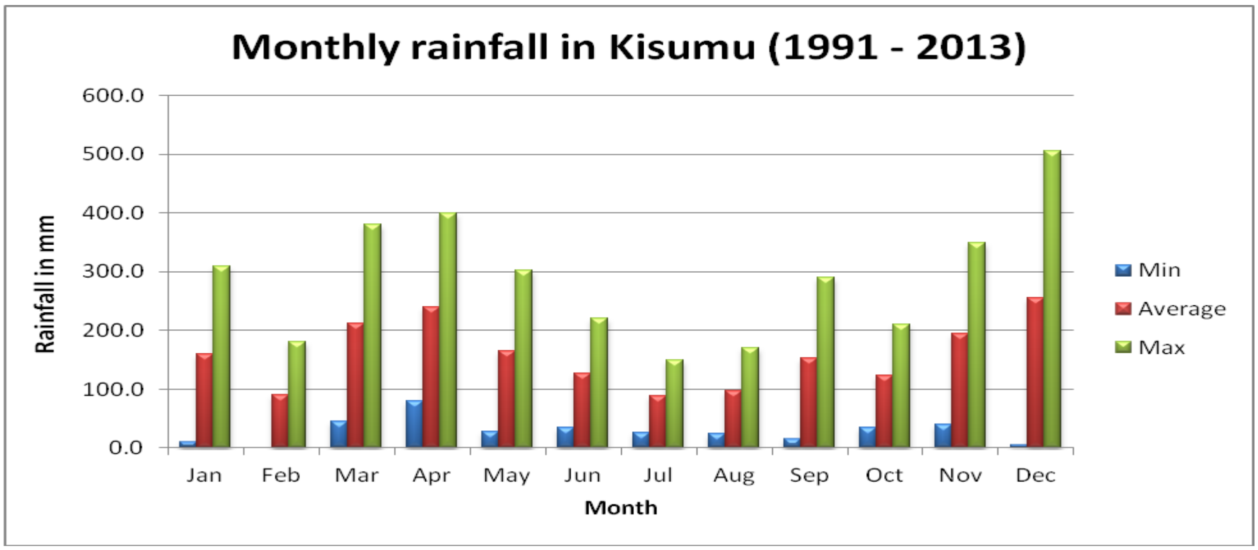


Figure 4.9: Monthly Rainfall in Kisumu (1991 – 2013)
Source: Meteorological Department, Kisumu.

The daily amount of rainfall received in the period 2012 to 2013 is shown in Appendix E. In the year 2013, the maximum amount of daily rainfall received was 80.10mm, on 19th March 2013 followed by 70.0mm on 31st March 2013. In 2012 the highest amount of daily rainfall recorded was 54.90mm on 27th April 2012 followed by 25th April when 50.8mm of rainfall was recorded as shown in figure 4.10. The amount of rainfall recorded between March 2012 and March 2013 was 1557.20mm.

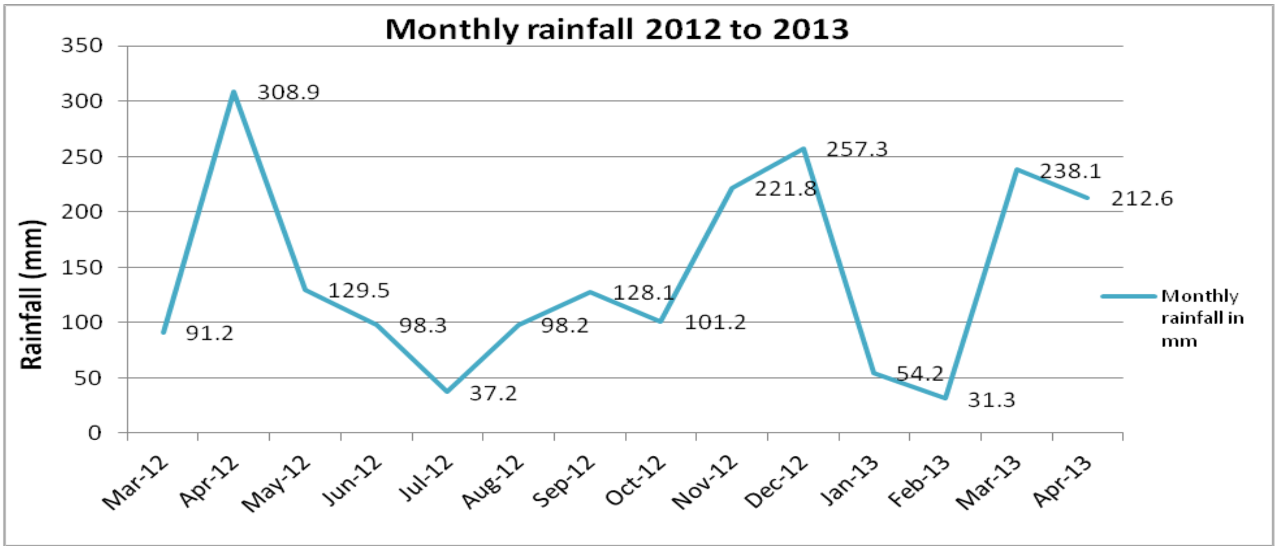


Figure 4.10: Monthly rainfall March 2012 to April 2013
Source: Meteorological department, Kisumu

According to the meteorological department, the highest amount of rainfall received in the years 2012 and 2013 was 308.9mm received in April 2012. The lowest amount of rainfall recorded was 31.3mm in February 2013. April is the second month on the long rains season.

Three rivers/ streams pass through Nyalenda informal settlement and each causes flooding in different areas when they overflow. These are as indicated in table 4.1. River Nyamasaria causes flooding in Dago, Oluti and Nyamthoi in Nyalenda A Sub location and Nanga primary school, Nanga Secondary school and Dunga in Nyalenda B Sub location. Auji River causes flooding in Kachok, Kanyakwar, Kassagam primary school, Kassagam secondary school, Kapuothe and Kowino market in Nyalenda A Sub location and Katuoro, Got Owak, Nanga primary school, Nanga secondary school and Dunga. Both Rivers Nyamasaria and Auji contribute to flooding at Nanga and Dunga. Nanga and Dunga are flat and lie in between the two rivers, Nyamasaria and Auji. Overflow of Ouru stream causes flooding in Kapuothe in Nyalenda A Sub location.

Table 4.1: Rivers and Streams that contribute to flooding in Nyalenda informal settlement

River/ Stream	**Areas where flooding occurs**	**Sub - Location**
Nyamasaria	Dago	Nyalenda A
	Oluti	
	Nyamthoi	
	Nanga Primary School	Nyalenda B
	Nanga Secondary School	
	Dunga	
Auji/Wigwa	Kachok	Nyalenda A
	Kanyakwar	
	Kassagam Primary School	
	Kassagam Secondary school	
	Kapuothe	
	K'Owino	
	Katuoro	Nyalenda B
	Got Owak	
	Nanga Primary School	
	Nanga Secondary School	
	Dunga	
Ouru	Kapuothe	Nyalenda A

The higher parts of Nyalenda informal settlement are the least affected by flooding while the low lying parts are the most affected. A map indicating the flood hot spots in Nyalenda informal settlement is shown in Figure 4.11 below.

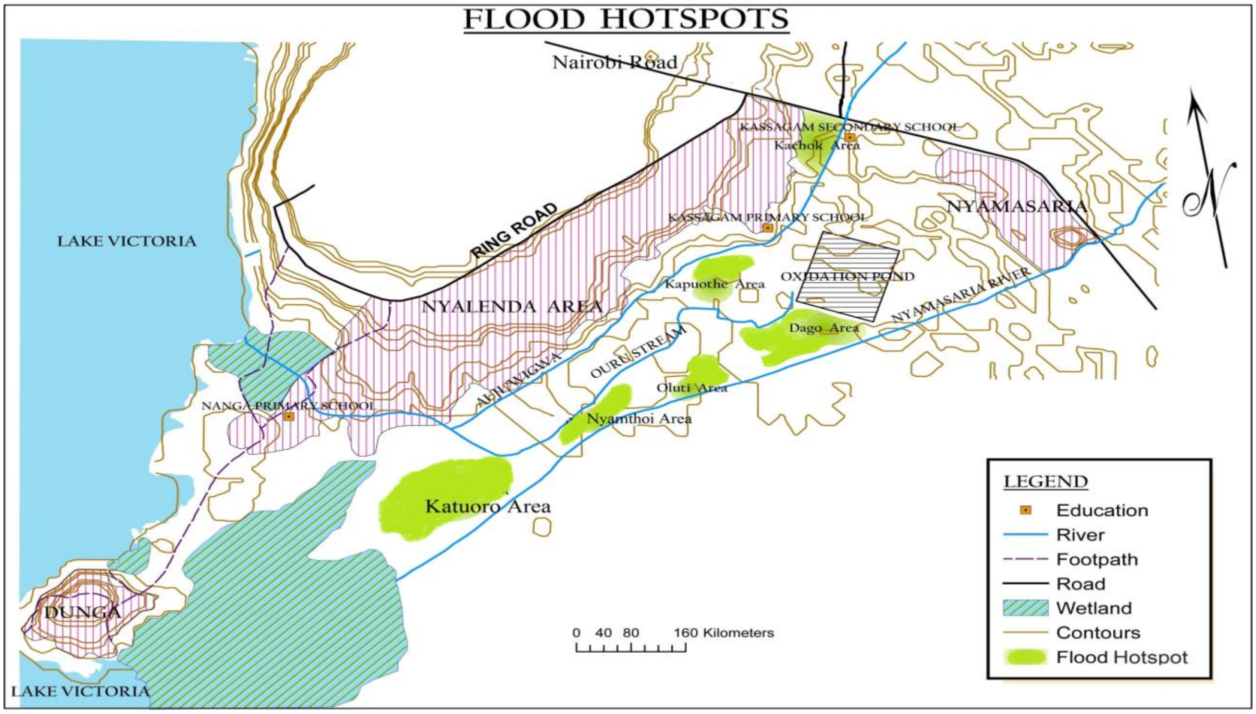


Figure 4.11: Flood hot spots in Nyalenda informal settlement
Source: Google Earth 2013

The hotspots and affected areas on the map were determined by having discussions with the residents and the local Community Based Organization (CBO) dealing with flooding. In Nyalenda A, flood hotspots are Kachok, Kassagam, Kapuothe, Nyamthoi, Dago and Kanyawar while in Nyalenda B Sub location, flood hotspots are Katuoro, Nanga and Dunga. The slope in Nyalenda A is generally steeper than that of Nyalenda B and therefore Nyalenda A is better drained compared to Nyalenda B.

The water level in Nyamasaria River between March 2012 and July 2012 is shown in appendix E. There was no data on the water levels for the Auji River. Moreover, there is no detailed information available about how often the Nyamasaria river floods. Only the water level at a point upstream from Nyamasaria Bridge is available. It is unclear at what level the Nyamasaria river floods. However, according to the residents of Nyalenda informal settlements and NADUKATO, the water level rises one day after heavy rain. For example, according to water level records from the CBO, on 28th April 2012, the water level in the Nyamasaria River was 2.4m. Data from the meteorological department show that Nyalenda informal settlements received 54.9mm of rainfall the previous day 27th April 2012.

NADUKATO measures the flood levels in Nyalenda informal settlement using markings on trees in the flood prone areas. Residents also determine the depth of flood water using good swimmers. The swimmers use their height to tell the flood levels over in Nyalenda informal settlement. The researcher used data on flood levels from NADUKATO and rainfall data from the Meteorological department to plot a graph of flood levels against rainfall intensity. A graph of flood levels in Nyalenda informal settlement is shown in Fig 4.12. The regression equation from the data collected on flood levels was $Y= 0.0174X + 0.3291$. The equation can be used to predict the flood levels in Nyalenda informal settlement based on the amount of rainfall expected. Regression equations can be used to predict the magnitude of flood flows for specified recurrence intervals for most streams in the state; however, they are not valid for streams with substantial regulation, diversion, or mining activity within the basin, Roland *et al* (2008). Stuckey and Reed, (2000) noted that regression equations can be used to compute flood flows for selected recurrence intervals for streams where no gaging-station data are available. From the equation, it was established that while flooding in Nyalenda informal settlements may result from heavy rain in the Nyalenda informal settlement, in most cases flooding from Nyamasaria River is caused by heavy down pour upstream in the Rift Valley. After heavy downpour in Nyalenda informal settlement, rain water drains through rivers Wigwa and Nyamasaria into Lake Victoria.

From the Focus group discussions it was established that flooding in Nyalenda also occurs when there is prolonged rainfall in Nyalenda informal settlement resulting in flooding from storm water, when there is intense rainfall over a short period of time, or when there is debris jam causing rivers Nyamasaria, Wigwa and Ouru stream to overflow after heavy downpour upstream. The data also indicated that a single one-day rain event can cause floods that persist for three days. If the rains persist from three days to one week, the water depth rises to one metre and it may take a month to disappear. This happens mainly during the long rain season when there is a lot of rainfall in the catchment areas and in Nyalenda informal settlement.

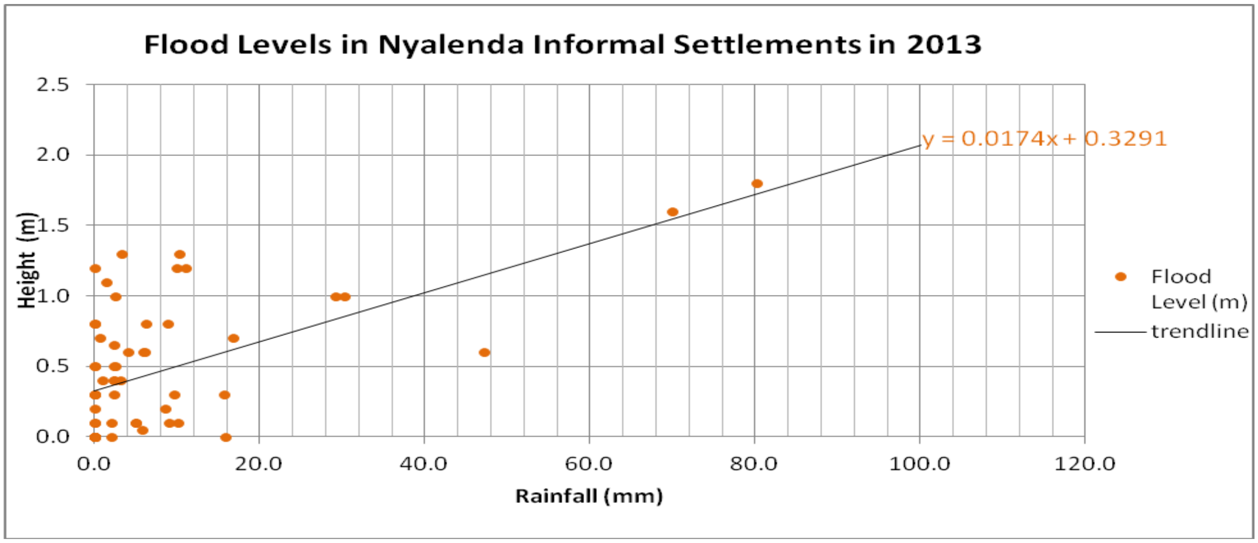


Figure 4.12: Flood levels in Nyalenda informal settlement
Source: NADUKATO CBO

Flood risk levels

From focus group discussions and key informant interview of the Red Cross Kisumu County Manager, four levels of hazard were considered, low, medium, high and very high. According to the residents of Nyalenda informal settlement and information from the Manager NADUKATO, heavy floods occur 1-2 times each year during the heavy rain seasons. The County Manager, Red Cross Society Kisumu pointed out that small floods occur many times a week during the two rainy seasons. Data from NADUKATO shows that during floods, the water reaches a depth of 1.8 metres at the worst affected areas of Nanga and Katuoro. Moreover, a flood from 10 cm in the lowest parts of Nyalenda informal settlement occurs around once a month in the rainy season. Rainfall data from the meteorological department shows that in the months of March and April 2013, the day with the highest amount of rainfall was the 19th March, at 80.10mm. Many times during these two months, the daily amount of rainfall was around 12mm. During these rains, residents experienced some small floods in Nyalenda informal settlement.

The vulnerability scale was established as very low, low, medium, high and very high. The risk level scale defined as a function of the flood hazard level and vulnerability level as indicated in figure 4.13 below. From focus group discussions and key informant interview of the Director, Meteorological department, Kisumu and the Red Cross Society County Director, it was established that the flood hazard level in the Months of March and April are very high due to the intense rainfall over the long rain season. As a result, the risk level is very high over the two months of March and April in the low lying areas of Nyalenda informal settlement. According to the Director, Meteorological department Kisumu County, the flood hazard level is high in the Months of May and October and medium between November and December. From Focus group discussions, the researcher found out that the risk level is lowest between January and February because of the small amount of rainfall received in the two months.

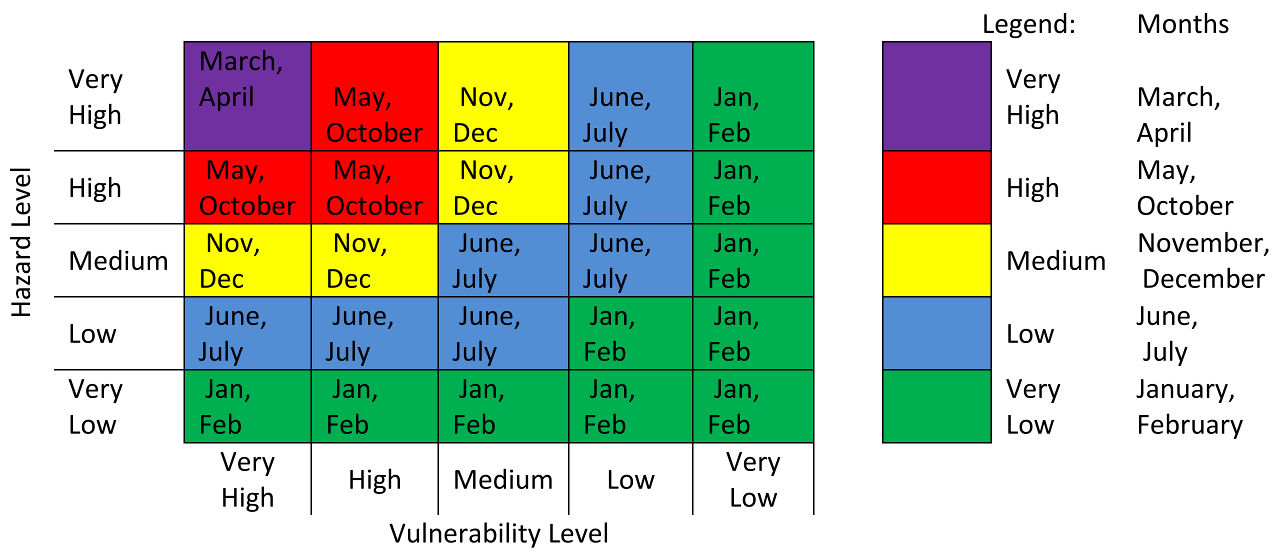


Figure 4.13: Flood risk assessment chart
Source: Field work, 2013

4.4 Storm water infrastructure components in Nyalenda informal settlement

From key informant interview of the Research Officer WRM, the researcher established that River Nyamasaria is also known as Kibos while river Auji is also known as Wigwa in Nyalenda informal settlement. The two rivers as well as a small stream, Ouru, pass through Nyalenda informal settlement. From key informant interview of the Kisumu County Engineer, the researcher established that River Auji is fed by several shallow trenches that are dug by residents of Nyalenda informal settlement to drain water from higher areas such as Western and Kilo. During Field observations, the researcher noted that the Auji River is also fed by an open channel that runs along Ring road and drains into river Auji. Ouru stream whose catchment is at Nyamthoi also drains into River Auji. River River Nyamasaria drains into Lake Victoria at a swamp in Dunga. Figure 4.14 illustrates the rivers, stream, wetlands, bridges and foot bridges in Nyalenda informal settlement.

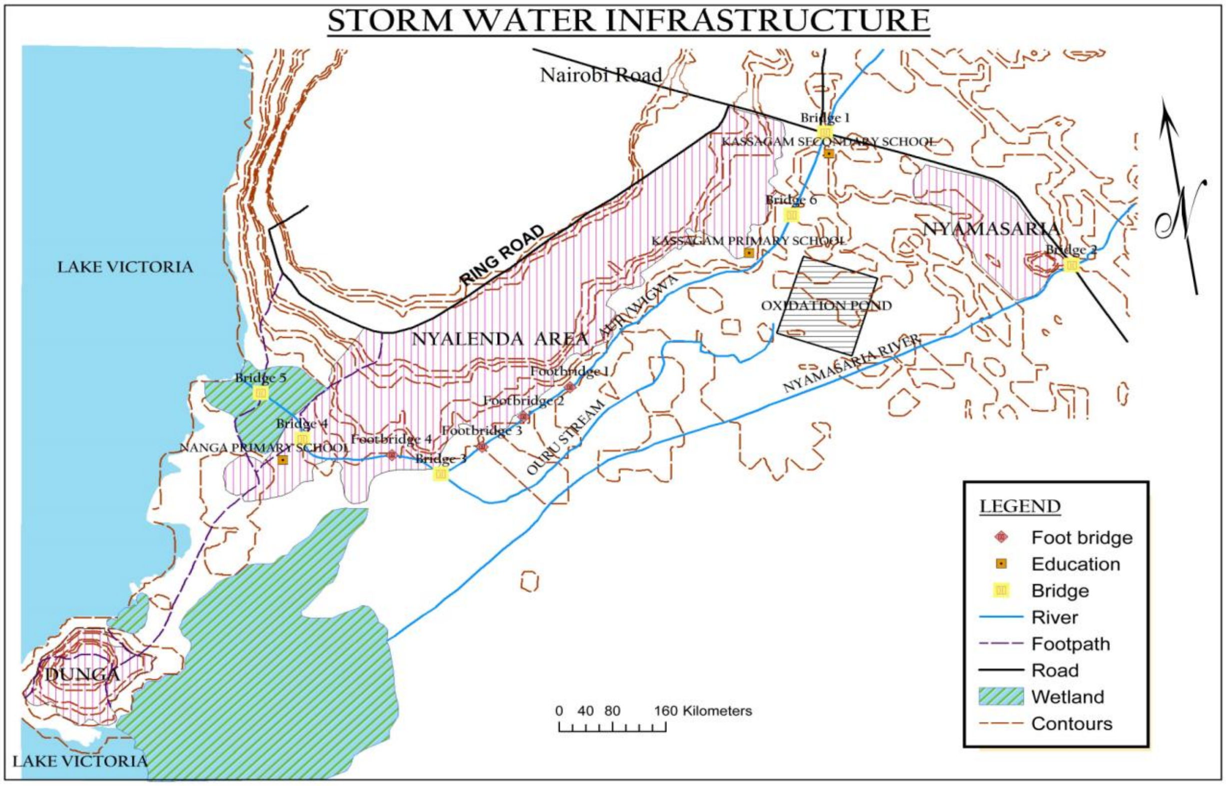


Figure 4.14: Storm water Infrastructure in Nyalenda informal settlement
Source: Google, 2013

According to the Chief Officer Lands, housing and physical planning, there are 3 bridges and 4 foot bridges across river Nyamasaria. During key informant interview, the Research Officer Water Resources Management pointed out to the researcher that a section of the bridge along Nairobi Kisumu highway was swept away by floods in April 2013 but was reconstructed as shown in plate 13 taken by the researcher during field survey. Data from the Kisumu County Engineer showed that new culverts have been constructed to drain water from Manyatta B across Nairobi Kisumu highway into drains in Nyalenda A Sub location. The newly constructed cross culverts now drain more water from the swampy areas in Manayata B adjacent to the Nairobi Kisumu highway. Plate 14 is a picture taken by the researcher during field survey and shows a culvert under construction at Kassagam in Nyalenda A.

Plate 13: Nyamasaria bridge under construction
Source: Field survey, 2013

Plate 14: Culvert under construction
Source: Field survey, 2013

There are also three bridges across river Auji in Nyalenda. River Auji was concrete lined but the section between Kachok and Lake Victoria has been damaged and swept away. From key informant interview of the Ward Representative Nyalenda B, the researcher found out that the last storm water infrastructure maintenance exercise was initiated in Nyalenda B by area Member of Parliament Shakir Shabir in 2011. According to residents of Nyalenda B, during the exercise, river Auji was de-silted using an excavator, cleaned up and the material dumped along the shores to protect overflow of water after heavy rains. Part of the material has since been swept back into the river.

The Kisumu County Engineer noted during key informant interview, that there 24 culverts across gravel roads in Nyalenda informal settlement. The researcher however found out that the culverts are blocked by soil and vegetation. The Kisumu County Engineer also observed during key informant interview that Nyalenda informal settlement does not have closed channels. The Chief Officer- Lands, housing and Physical Planning informed the researcher that 70% of buildings in Nyalenda informal settlement are semi permanent and do not have gutters to collect rain water. According to the Chief, Nyalenda Location, there are no water storage facilities in Nyalenda informal settlement except for individual storage tanks, drums and small buckets in households. During field survey, the researcher found out that the few semi permanent buildings that have gutters have worn out gutters which can only collect small amount of water for domestic use. According to the Research Officer Water Resources Management, Kassagam secondary school in Nyalenda A has rain water collection systems and use water storage tanks to store rain water. From field survey, the researcher found out that at Nanga and Dunga in Nyalenda B sub Location, new buildings are coming up and include residential buildings, schools and hotels which have rain water harvesting systems including water storage tanks, drums, gutters and drain pipes.

The Network Engineer, KIWASCO informed the researcher during key informant interview, that Nyalenda informal settlement does not have a sewage system that serves the inhabitants but there is a sewage line serving Milimani that passes through Nyalenda informal settlement and drains into the oxidation ponds at Kanyameda in Nyalenda A sub location. A new sewage is under construction by Victory Construction Company and is shown in plate 15 taken by the researcher during field survey.

Plate 15: Sewage line passing through Nyalenda informal settlement
Source: Field survey, 2013
According to the Network Engineer KIWASCO, the oxidation ponds for waste water treatment at Kanyameda are currently being upgraded to cater for the increasing population. The Manager, NADUKATO observed during key informant interview, that residents of Nyalenda informal settlement use toilets but the toilets in flood- prone areas such as Nyaori and Kassagam collapse during floods.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Floods occur in Nyalenda informal settlement when overflowing water submerges land and causes deluge. Flooding occurs when there is prolonged rainfall over several days, intense rainfall over a short period of time, or a debris jam causes rivers Nyamasaria, Auji or Ouru stream to overflow and flood the surrounding areas in Nyalenda informal settlement. Floods in Nyalenda informal settlement are caused by blocked storm water infrastructure, low lying flat terrain, increased inflow from upstream, insufficient storm water infrastructure, low rate of infiltration, growth of vegetation in the drainage infrastructure, lack of maintenance on the existing infrastructure and uncontrolled development on privately owned land in Nyalenda informal settlement. In Nyalenda informal settlement, solid waste is dumped into watercourses, drains, culverts, and other drainage structures. Nyalenda informal settlement is characterized by low vegetation cover except in areas along rivers Auji and Nyamasaria. Katuoro area is rocky with black cotton and minimum vegetation cover consisting mainly of short grass. The little vegetation cover available is destroyed by livestock that graze along rivers. Nyalenda informal settlement consists mainly of black cotton soil which has high degree of expansiveness. Nyalenda informal settlement is generally flat. Nyalenda lacks a storm water harvesting system and rain water is left to waste leading to stagnant water ponds and floods. The drainage infrastructure in Nyalenda informal settlement is not maintained or desilted and the rivers are full of thick vegetation and silt throughout the year. Growth of vegetation in river Auji has led to cracking of the concrete lining both at the top and bottom of the river. After heavy downpour the vegetation is washed away by fast flowing water leaving solid waste trappings which contribute to blockage of the drainage system. Land in Nyalenda is mainly privately owned. The buildings and estates are randomly constructed and block the water path. Storm water has to find its own path through the meandering footpaths

Floods in Nyalenda informal settlement result in spread of water borne diseases such as diarrhea, and typhoid. Stagnant water from floods provides breeding ground for malaria causing mosquitoes. Metallic items such as nails swept from upstream by the raging waters cause injuries to residents. Floods also renders roads inaccessible, washes away bridges on feeder roads and leads to destruction of property which is submerged by flood waters that access buildings. In some cases, property is swept away by the raging water. Submerging of buildings makes them inaccessible. Residents are then forced to move from their homes in Kassagam and Nanga to higher ground in search of shelter. Learning is also disrupted due to submerged classrooms. Flood water destroys crops and vegetation. Floods in Nyalenda informal settlement also cause loss of life of human beings. Fast flowing water from the rivers sweeps away poultry and livestock including cattle, goats and sheep who rely on grazing along the shores of the river.

Nyalenda informal settlement a slum suburb in Kisumu City, Kenya has two heavy rain seasons during a year. These are the long rains season, March - May and the short rains season, October to December. River Nyamasaria causes flooding in Dago, Oluti and Nyamthoi in Nyalenda A Sub location and Nanga primary school, Nanga Secondary school and Dunga in Nyalenda B Sub location. Auji River causes flooding in Kachok, Kanyakwar, Kassagam primary school, Kassagam secondary school, Kapuothe and Kowino market in Nyalenda A Sub location and Katuoro, Got Owak, Nanga primary school, Nanga secondary school and Dunga It was established that in Nyalenda informal settlement, the flood hazard level in the Months of March and April are very high due to the intense rainfall over the long rain season. The risk level is very high over the two months of March and April in the low lying areas of Nyalenda informal settlement. The flood hazard level is high in the Months of May and October and medium between November and December. The risk level is lowest between January and February. This is because of the small amount of rainfall received in the two months.

Most buildings in Nyalenda informal settlement are semi permanent and do not have gutters to collect rain water. There are no water storage facilities in Nyalenda informal settlement except for individual storage tanks, drums and small buckets in households. The few semi permanent buildings that have gutters have worn out gutters. Kassagam secondary school in Nyalenda A has rain water collection systems and use water storage tanks to store rain water. At Nanga and Dunga in Nyalenda B, new buildings have come up and include residential buildings, schools and hotels which have rain water harvesting systems including water storage tanks, drums, gutters and drain pipes. Two rivers and one stream flow through Nyalenda informal settlement. The rivers are Nyamasaria, also known as Kibos and Auji also known as Wigwa. Both river Nyamasaria and river Auji drain into Lake Victoria. A small stream, Ouru stream also flows through Nyalenda informal settlement and joins river Auji before draining into Lake Victoria. River Auji is fed by several shallow trenches. The shallow trenches are dug by residents of Nyalenda informal settlement to drain water from higher areas such as Western and Kilo. The Auji River is also fed by an open channel that runs along Ring road. There are three bridges across river Nyamasaria. Newly constructed culverts drain water from Manyatta B across Nairobi Kisumu highway into drains in Nyalenda A. There are also three bridges across river Auji in Nyalenda. River Auji was concrete lined but the section between Kachok and Lake Victoria has been damaged and swept away. In 2011, river Auji was de-silted, cleaned up and the material dumped along the shores to protect overflow of water after heavy rains. Part of the material has since been swept back into the river. There are few cross culverts across the gravel roads in Nyalenda informal settlement. Nyalenda informal settlement does not have closed channels. Nyalenda informal settlement does not have a sewage system that serves the inhabitants but there is a sewage line serving Milimani Estate that passes through Nyalenda informal settlement and drains into the oxidation ponds at Kanyameda in Nyalenda informal settlement.

5.2 CONCLUSION

Storm water related floods develop when fast moving storm water from high areas in Nyalenda informal settlement, Manyatta and adjacent hills flow into the low-lying flat areas in Nyalenda informal settlement at high speed but the inadequate and blocked storm water infrastructure cannot clear all the storm water. Floods in Nyalenda informal settlement are natural floods, they are caused naturally by the overflow of the huge volume of water, from rivers, or by heavy rains or downpours. Haphazard damping of solid waste in Nyalenda informal settlement leads to blockage of the storm water drainage system. The culverts and bridges are blocked by siltation and deposition of solid waste trappings. In an attempt to prevent flooding in most of the low-lying areas, Refuse piled near streams by residents, presumably to create levees in an attempt to prevent flooding, is carried by storm water runoff into drains and rivers. This, together with refuse and other solid wastes reduces their capacity. Sometimes the wind aids this process by blowing litter into drainage channels causing blockages. The impact of solid waste has assumed a new dimension because of the increasing use of plastics as packaging material, cans and bottles. The destruction of the little vegetation that can be supported by black cotton soil leaves the land bare and susceptible to floods. The growth of vegetation in the rivers reduces their discharge capacity leading to overflow of river Nyamasaria and Auji. Vegetation growth in Ouru stream hampers the discharge and increases the probability of flooding during high rainfall events. Moreover, cracking of the concrete lining of Auji river and the subsequent piling of the cracked concrete on the river bed blocks the water path hence the subsequent overflow of the river after heavy downpour. In 2011, maintenance was carried out on river Auji but during excavation, all the excavated material was dumped at the river banks and was swept back into the river after the heavy downpour.

Water borne diseases such as diarrhea, and typhoid caused by floods may lead to reduced productivity or even death of those affected. Incidences of malaria increase after floods in Nyalenda informal settlement. Money that would otherwise be used in development is then redirected to treatment of water borne diseases and malaria. Additional costs are incurred by the National and County Governments to repair road and transport infrastructure destroyed by flood. Families incur additional expenses to recover or acquire new property such as houses to replace those damaged by floods. Damage to infrastructure increases cost incurred to transport goods and services to the various markets within and outside Nyalenda informal settlement. Submerging of buildings by floods makes them inaccessible. Displacement of people due to floods could lead to breakage of families. Disruption of learning compromises the level of education because a lot of time is wasted. Destruction of crops and vegetation reduces the amount of food available to the residents on Nyalenda informal settlement. Food and vegetables become more expensive and beyond the reach of some poor families living in Nyalenda informal settlement. Loss of life, displacements and destruction of property by floods leaves the residents shocked or traumatized. Consequently, floods result in increased physical and emotional stress and increased susceptibility to psychosocial disturbances which lead to anxiety, depression and apathy. Fertile river sediments deposited by floodwater replenish nutrients in topsoil thus making agricultural lands more productive

Floods in Nyalenda informal settlement occur only during the two heavy rain seasons, the long rains season, March - May and the short rains season, October to December. The flood risk level in Nyalenda informal settlement is highest in the Months of March and April due to the intense rainfall. The flood risk level is lowest between January and February

Lack of gutters by most buildings in Nyalenda informal settlement means that very little water is harvested by the residents of Nyalenda informal settlement. The few individual storage tanks, drums and small buckets in households only store a small amount of storm water. Only Kassagam secondary school in Nyalenda A has rain water collection systems and use water storage tanks to store rain water. The new buildings coming up including residential buildings, schools and hotels which have rain water harvesting systems collect some storm water and reduce the amount of surface run off. The two rivers, Nyamasaria and Auji and one stream, Ouru, that flow through Nyalenda informal settlement overflow when they cannot contain the inflow from upstream and storm water from Nyalenda informal settlement. The shallow trenches dug by residents of Nyalenda informal settlement to drain storm water are poorly done and cause ponding of storm water. The open channel that runs along Ring road is blocked by vegetation growing in the channel. A section of the concrete lining for the channel that caved has resulted in reduced discharge by the channel. The newly constructed culverts that drain water from Manyatta B across Nairobi Kisumu highway into drains in Nyalenda A increase the amount of storm water during heavy rain events. There is no sewage system that serves the inhabitants. As a result, water borne diseases are easily spread by floods. There is need for sustainable storm water management techniques in Nyalenda informal settlement.

5.3 RECOMMENDATIONS

The Nyalenda community showed strong interest in both general community development and flood management. Integrated flood management requires skilled community members who are capable of using indigenous knowledge in flood water harvesting and modern governance systems in managing flood waters Control of storm water related flooding in Nyalenda informal settlement has focused on reactive measures and practices. Initial interventions have largely relied on the control of floods through structural measures, and later supported by certain non structural measures. These structural measures have only shifted or disturbed ecological balance rather than mitigating against flood risks.

Sustainable structural storm water management techniques include planting vegetation cover/cover crops/trees, joint community cleaning of drainage structures, maintenance and de-siltation of drainage system, enhancement of capacity of bridge at Nyamasaria, clean up of drainage system along Ring road, repair of Ouru stream, design and construction of bridges, box and pipe culverts, rain water harvesting and storage, repair Auji river, establishment of irrigation systems, construction of raised toilets, terraces, Gabions and sandbags, construction of dykes and construction of open water channels. The Ward Representative Nyalenda A informed the researcher of plans by the Kisumu County Government to de-silt the rivers Nyamasaria, Auji and Ouru stream that pass through Nyalenda informal settlement. If implemented, de-siltation will increase the discharge capacity of rivers, streams and other storm water infrastructure. The bridge at Nyamasaria is under construction and once complete it will help minimize the instances of flooding at Nyamasaria. There are a few raised toilets in Dunga area which is prone to flood water from Nyamasaria River.

Integrated storm water management skills should be provided through a village based community flood management organization. It is recommended that both structural and non structural measures of flood control and water use should be integrated. Strengthening of flood management organization at community level should be emphasized. This shall include providing technical skills in crop production, livestock husbandry and tree growing for improved food security during flood. Vegetation cover will trap solid waste which would lead to siltation and blockage of the rivers passing through Nyalenda informal settlement. Planting of vegetation cover will also increase the rate of infiltration and reduce the speed of storm water. The community should be engaged in joint cleaning exercises to unblock the culverts, channels and rivers. The concrete lining of river Auji should be repaired and the concrete damped in the river bed removed to ensure the river flows smoothly without blockages. The drain along Ring road should be cleaned to drain water from Milimani and avoid overflowing. New box and pipe culverts should be constructed along the gravel roads in Nyalenda informal settlement and drain off water from the settlement. The residents should be encouraged to construct this type of toilets to prevent contamination of storm water and the subsequent disease outbreak.

The non – structural techniques that should be adopted in Nyalenda informal settlement are: increasing awareness and early warning systems, maintenance of existing sewerage infrastructure, mapping of flood hot spots, creating awareness about effects of floods on health, solid waste management, better supervision of building design and construction, better supervision of bridge construction, creating awareness about rain water harvesting, provision of incentives for rain water storage, and land use planning. Awareness and early warning systems should be done to notify residents of Nyalenda informal settlement of any impending incidents of floods. This can be done through village elders, subchiefs and chief in public gatherings. This will prevent damage of property and loss of lives in case of floods. Early warning systems will enhance the preparedness of the locals. The flood prone areas of Katuoro, Kapuothe, Dunga, Nanga and Kachok should be mapped out and development in those areas regulated. Additional waste collectors should be introduced in Nyalenda informal settlement to help BAMATO solid waste collectors. This will enhance solid waste disposal and reduce the volume of solid waste that is swept by water into rivers and channels. There is need for creation of awareness on storm water harvesting. This can be done through giving incentives for rain water storage such as gutters and drums. Landuse planning and zoning will ensure land in Nyalenda informal settlement is properly used and the usage will be such that it helps mitigate against floods. Community members should be ready to cost share with government, NGO's and other stakeholders in establishment of flood hazard maps.

It is recommended that further research needs to be conducted before making a master plan for storm water Management. A more detailed research on the cost of the solutions is needed. Further research needs to be conducted to establish the effects of the solutions. It is also very important to keep the key stakeholders and the residents involved in the implementation process especially during the making of the master plan.

Reference

Affeltranger, B. (2001). *Public participation in the design of local strategies for flood mitigation and control. Technical Documents in Hydrology No 48*. Paris: UNESCO

Ahern, M., Kovats, R.S., Wilkinson P., Few, R. & Matthies, F. (2005). *Global health impacts of floods: Epidemiologic evidence.* London: Phoenix.

Akinmade, S.E. (2005). *Environmental science: the habitable earth. Jos*: Success Press

Alessandro, G., Colombo, C., Javier, H., Ana, L. & Vetere, A. (2002). *Guidelines on Flash Flood Prevention and Mitigation.* Italy: Institute for the Protection and Security of the Citizen.

Andjelkovic, I. (2001). *Guidelines on nonstructural measures in urban flood management, Technical Documents in Hydrology Series No 50*. Paris: UNESCO.

Armitage, N. & Rooseboom, A. (2000). *The removal of urban litter from storm water conduits and streams.* South Africa: University of Cape town, Department of Civil Engineering.

Barry, J. M. (1997). Rising Tide: *The great Mississippi flood of 1927 and how it changed America.* New York: Simon and Schuter.

Bolten, O.B. & Keller, E.A. (1998). *Environmental science: earth as a living planet.* New York; John Wiley & Sons Inc.

Cordaid (2012). *Storm water management: A situational analysis of informal settlements*. Nairobi: UN-HABITAT.

Crichton David (1999). *The risk triangle, CGU Insurance, Inchture.* United Kingdom: CGU Insurance Crescent.

DMCN, (2004). Coping with floods in Kenya: Vulnerability, impacts and adaptation options for the flood prone areas of Western Kenya. Nairobi: UNEP.

Eitel, B. & Ochola, S.O. (2006). *River Nyando basin project.* University of Heidelberg: Institute of Geography.

Epstein, P. R. (2001). *Climate change and emerging infectious diseases.* USA: Center for Health and the Global Environment, Harvard Medical School.

Federal Investigative Board (1977). *The 1977 Toccoa flood report of failure of Kelly Barnes dam.* USA: Department of Interior.

Francis, J. (2000). *Implications of gender in floods, Gender and Water Alliance, November*. http://www.genderand wateralliance.org/reports/discussion_paper_on_gender_and_floods_by_JF

Few, R., Ahern, M., Matthies, F. & Kovats, S. (2004*). Floods, Health and Climate Change: A Strategic Review.* United Kingdom: Tyndall Centre for Climate Change research.

Garrett, P. (1989). *Assessing flood risk, Water Bull, Vol. 355.*

Government of Kenya, (2009). *Flood mitigation strategy.* Nairobi: Ministry of Water and Irrigation.

Government of Kenya, (2010*). National climate change response strategy*. Nairobi: Ministry of Environment and Mineral resources.

Hasna, A.M. (2007). *Dimensions of sustainability", Journal of Engineering for Sustainable Development:* Energy, Environment, and Health: 47–57.

Henning, E. (2004). *Finding your way in qualitative research.* Pretoria: VanSchaick Publishers.

Howard, G., Bogh, C., Goldstein, G., Morgan, J., Shaw & Teuton, J. (2002). *Healthy Villages: a Guide for Communities and Community Health Workers*. Geneva: WHO.

IGAD & ICPAC (2007). *Climate change and human development in Africa: Assessing the risks and vulnerability of climate change in Kenya, Malawi and Ethiopia.* Nairobi: UNDP

Independent Electoral and Boundaries Commission, www.iebc.or.ke

IDMC, (2011). *Displacement due to natural hazard-induced disasters: Global estimates for 2009 and 2010*. New York.

IPCC (2007). *Impacts, adaptation and vulnerability. Contribution of working group II to the Fourth assessment report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

Jonkman, S. N. (2004). *Global perspective on loss of human life caused by floods*. Deft University of Technology Faculty of Civil Engineering: Road and Hydraulic Engineering Institute.

Jonkman, S. N. & Kelman, I. (2005). *An analysis of the causes and circumstances of flood disaster deaths.* Deft University of Technology: Road and Hydraulic Engineering Institute.

Kelman, I. (2003). *Beyond Disaster, Beyond Diplomacy. Natural Disasters and Development in a Globalizing World.* London: Routledge.

Kisumu County Government (2013). *First county integrated development plan 2013 -2017.* Kisumu: Kisumu County.

KFSSG (2008). *KFSSG's Long Rains Assessment Report. Kenya*: Kenya Food Security Steering Group.

Kolsky, P. J. & Blumenthal, U. J (1995). *Environmental health indicators and sanitation-related disease in developing countries: Limitations to the use of routine data.* World Health Statistics Quarterly, 48:132-139.

Kothari, C. R. (2004). *Research Methodology: Methods & Techniques:* New Age International

Kron, W. (2002). *Flood risk = hazard x exposure x vulnerability*. New York: Science Press.

Kumpulainen, S. (2006). *Vulnerability concepts in hazard and risk assessment, Natural and technological hazards and risks affecting the spatial development of European regions,* Special Paper 42. Finland: Geological Survey of Finland.

Mack, N., Woodsong, N., MacQueen, K., Guest, G. & Namey, E., (2005). *Qualitative research methods: A data collector's field guide. Research Triangle Park:* US Agency for International Development

Main, H. & William, S. W. (1994). *Marginal Urban Environments as Havens for Low- income Housing: Third World Regional Comparisons in Environment and Housing in Third World Cities.* Chichester: John Wiley and Sons.

Magrin, G., Gay, G., Cruz, C., & Moreno C. (2007*). Latin America. Climate change 2007. Impacts, adaptation and vulnerability.* Cambridge: Cambridge University Press

Maryam B, Zain A. & Amyn B. (2011). *Infectious diseases in the aftermath of monsoon flooding in Pakistan.* Pakistan: Aga Khan University

Melbourne water (2005*) Flood Management and Drainage Strategy, Port Phillip and Westernport Region.* Werribee: Creek

Mogaka, H., Gichere, S., Davi S. R. & Hirji, R. (2006). *Climate variability and water resources degradation in Kenya: improving water resources development and management.* World Bank.

Mugenda, O.M & Mugenda, A.G. (1999). *Research Methods, quantitative and qualitative approaches.* (pp. 46 – 48). Nairobi: ACTS Press.

Mutua, F.M. (2001). *Report on the Impacts of climate change on Water Resources in the Kenya*. Kenya: Nairobi.

Napier, M., Lade B., Santosa, H. & Rubin, M. (2002). *Understanding the interface between the environment and sustainable livelihoods in the integration of informal settlements in Asia, Latin America and Africa: a review of current thinking and practice*. Pretoria: CSIR Building and Construction Technology

NDMA, (2010). Situation Report; *Pakistan Floods – Preliminary damage and needs assessment.* Pakistan: Government of Pakistan.

Obatola, G.A. (2005). The *Niger delta and its environmental hazards.* Benin City; Ethiope Publishing House.

Ofer D., Tatarsky, B., Yehouda, E. & Seely, M. (2008). *Dynamics of flood water infiltration and ground water recharge in hyperarid desert.* Namibia: Windhoek Press.

Ohl, C. A. & Tapsell, S. M. (2000). *Flooding and human health: the dangers posed are not always obvious*. British Medical Journal 321, 1167–1168

Ouano (1991). *Surface Water Drainage for Low-income Communities.* Switzerland: Geneva.

Orodho, A. J. (2003). *Essentials of education and social science research methods,* Nairobi: Paulime Publishers.

Otiende, B. (2009). *The economic impacts of climate change in Kenya: Riparian flood impacts and cost of adaptation.*Nairobi:

Oyugi, A., Ong'ang'a, O. & Awange, J.L. (2003). *Poverty reduction: A challenge for Lake Victoria basin.* Kisumu: Osienala.

Palmer, W.C. (1965). *Meteorological drought.* Italy: University of Bologna.

Parikh, H.H. (2001) *Slum Networking – Using slums to save cities. In Frontiers in urban water management*. Paris: UNESCO.

Parkinson, J. (2002). *Drainage and storm water management strategies for low-income urban communities, Environment and Urbanization*.

Penning- Rowsell, E. & Tapsell, S. (2005). *Key policy implications of the health effects of floods. Extreme weather and climate events: Risks to human health and public health responses.* Berlin: Heidelberg, Springer-Verlag.

Rantz, *T.*, (1982*). Measurement and computation of stream flow: Computation of discharge*: U.S. Geological Survey Water-Supply Paper 2175, p. 285.

Rauch, W. (2005). *Catchment management authority information Brochure*, www.cma.gov.au accessed 28th March 2013.

Roland, M. A. & Marla, H. S. (2008). *Regression equations for estimating flood flows at selected recurrence intervals for un-gaged streams in Pennsylvania*. Virginia: U.S. Geological Survey Department.

Rolle, F. (2014). *FAO's role in the preliminary response plan for Malawi*: Malawi.

Saleem, M. C., Shahneela, Zohra K. & Syed, G. A. (2013). *Flood disasters and its impacts on child Education in Sindh (A Case study of 2010 Flood)*. Pakistan: University of Sindh

Samuel, K., Gichere, K. & Olado, G. (2010). *Effects of drought and floods on crop and animal losses and socio-economic status of households in the Lake Victoria basin of Kenya*. Nairobi.

Santosa, H. (2003). *Housing for low- income in the urban fringe of Surabaya*. Indonesia: Institute of Technology.

Satterthwhaite, D., Saleemul, H., Reid, H. & Romero, P. L. (2007). *Adapting to climate change in urban areas.* London: International Institute for Environment and Development.

Scanlon, B.R. (2004). *Evaluation of methods of estimating recharge in semi arid and arid regions in the southwestern US.* United States: Washington, DC.

Semenza, J. C. & Menne, B. (2012). *Mapping climate change vulnerabilities to Infectious diseases in Europe. Environmental health perspective*.

Stuckey H. M. & Reed L. A. (2000). *Techniques for estimating magnitude and frequency of peak flows for Pennsylvania streams.* U.S. Department of Transportation: Branch of Information Services.

Surkar D., Parikh, H. & Zanders, M. O. (2002). *Sustainable infrastructure development for slums and villages.* India: Calcutta.

Tapsell, S. (1999). *The health effects of floods – the Easter 1998 floods in England*. Middlesex University: Flood Hazard Research Centre.

Tapsell, S. M., Tunstall, S. M., Penning-Rowsell, E. C. & Handmer, J. W. (1999). *The Health Effects of the 1998 Easter Flooding in Banbury and Kidlington. Report to the Environment Agency, Thames Region.* Flood Hazard Research Centre: Middlesex University.

Thesaurus online www.thesaurus.com/stormwater, 09/04/2013

The Republic of Kenya, LBDA & JICA, (1992). *Feasibility studies on Kano Plains Irrigation*

Project Vol. 1. Nairobi: JICA.

Temwani, J. N., Nzeru, T., Mlasaanthu, B., Tiyanjane K., Chirwa S. & Chanika, S. (2014). *GIS based assessment exercise in Phalombe and Zomba*. Malawi: Malawi

Tripathi, D. & Jumani, J. (2001) *Change after alliance – Sequel to alliance for change*. New Delhi: Tata McGraw-Hill Publishing Company.

UN–HABITAT (2003). *Water and Sanitation in the World's Cities – Local Action for Global Goals.* London: UN– HABITAT, Earth scan.

UNHCR, (2011). *Profile of the Internally Displaced Persons from the Floods of 2010 in Pakistan.* Pakistan: Enterprise for Business & Development Management (EBDM).

Uyangoda, J. (2011). *Writing research proposals in the social sciences and humanities: A theoretical and practical guide*. Colombo: Social Scientists' Association.

Vasconcelos, P. (2006). *Flooding in Europe: a brief review of the health risks.* Euro Surveill

Whitlow, J. (1996). *Environmental hazards in Douglas, (eds) Companion encyclopedia of geography: the environment and human kind*. London; Routledge**.**

Wilgert, V., Denie, A. & Huthoff, F. (2012). Effect *of vegetation growth in drainage canals on water management.* Netherlands: University of Twente.

Zripko, N. (2011). *Neshanic river watershed restoration plan. storm water infrastructure inventory, final report.* New Jersey: Department of Environmental Protection.

Appendix A: Questionnaires

Questionnaire for Inhabitants of Nyalenda Informal settlement:

Please answer all questions by putting a tick (   ) in the box that closely matches your views or write in the space provided.

1. Please indicate your gender

   Male ( )   Female ( )

2. Have you ever experienced floods in Nyalenda informal settlement?

   Yes (   )   No (   )

3. Which streams and/or rivers flow through Nyalenda informal settlement?

   ____

4. When did you last experience floods in Nyalenda informal settlement?

   ____

5. How often are you affected by floods?

   ____

   ____

6. Which areas are the most affected?

   ____

7. What are the main causes of flooding in Nyalenda informal settlement?

   ____

   ____

8. When did you witness the highest flood levels?

   ____

9. What was the maximum height of the water level then?

   ____

10. What are some of the effects of floods?

____

____

11. What has the community done to control the floods or reduce the impact of flooding?

____

____

____

12. What have other stakeholders done to control the floods?

____

____

____

13. Have the measures above been effective in the control of storm water?

Yes ( ) No ( )

14. What measures has the local administration enforced to mitigate against flooding?

____

15. What other sustainable flood control measures do you know of?

____

____

____

16. Briefly comment on the drainage system in Nyalenda informal settlement.

____

____

____

Appendix B: Interview Questions, Chief Nyalenda Location

1. What is your name?
2. What do you think are the causes of the floods?
3. When did Nyalenda last experience floods?
4. What were the flood levels?
5. What were the likely causes of floods?
6. What were the effects of floods?
7. What methods of flood forecasting are used in Nyalenda informal settlement?
8. When floods occur, what is your responsibility as a stakeholder?
9. What is the topography of Nyalenda informal settlement?
10. What factors influence the selection of a flood control method?
11. When floods occur, how is the water drained?
12. What regulations provide guidance on flooding?
13. Outline the different methods of flood control that are in place in Nyalenda informal settlement.
14. Discuss the importance of vegetation to flood control.
15. What flood control projects have been recently been carried out?
16. Outline common problems associated with flood prevention?
17. What do you think are the possible solutions to flooding?
18. Which of the solutions indicated above are sustainable in the Nyalenda informal settlement?

Appendix C: Interview Questions (Kisumu County Engineer and other stakeholders)

1. What is your name?
2. What is your job title and how is your job related to floods?
3. What do you think are the causes of the floods?
4. What are the effects of floods?
5. What factors influence the selection of a flood control method?
6. Do economic factors come into consideration?
7. Who carries out flood risk assessment?
8. When floods occur, how is the water drained?
9. What is the process for development approval in Nyalenda informal settlement?
10. What regulations provide guidance on flooding?
11. Which methods of flood control are most commonly used and why?
12. Outline the different methods of flood prevention that are suited to contrasting topographies.
13. Discuss the importance of vegetation to flood control.
14. What factors influence the flood channel design?
15. Once flood control method is in place, how can you guarantee that flooding will not occur?
16. How would environmental restrictions affect the construction of a flood control method?
17. What flood control projects have been recently been carried out?
18. Outline common problems associated with flood prevention?
19. What do you think are the possible solutions of the floods?
20. Which of the solutions indicated above are sustainable in the Nyalenda informal settlement?

Appendix D: Interview Director Meteorological department

1. What is your name?
2. What is your job title in the meteorological department?
3. What was the maximum, minimum and average annual rainfall for Kisumu last year?
4. What is the highest average annual rainfall Nyalenda has ever experienced?
5. In which months does Kisumu experience high rainfall and what is the intensity?
6. When did Nyalenda informal settlement last experience flooding?
7. What were the effects of the floods?
8. Which areas were most affected?
9. What are the causes of flooding?
10. What relationship exists between floods and rainfall intensity?
11. What storm water infrastructure exists in Nyalenda informal settlement?
12. Is the infrastructure sufficient?
13. What effect does poor or lack of infrastructure have on storm water management?
14. What methods are used by the department in flood forecasting?
15. How effective are the methods?
16. Is there any limitation to the forecasting techniques?
17. What measures are put in place to control of flooding?
18. In your opinion what storm water management techniques should be used in Nyalenda informal settlement?

Appendix E: List of Key informant interviews

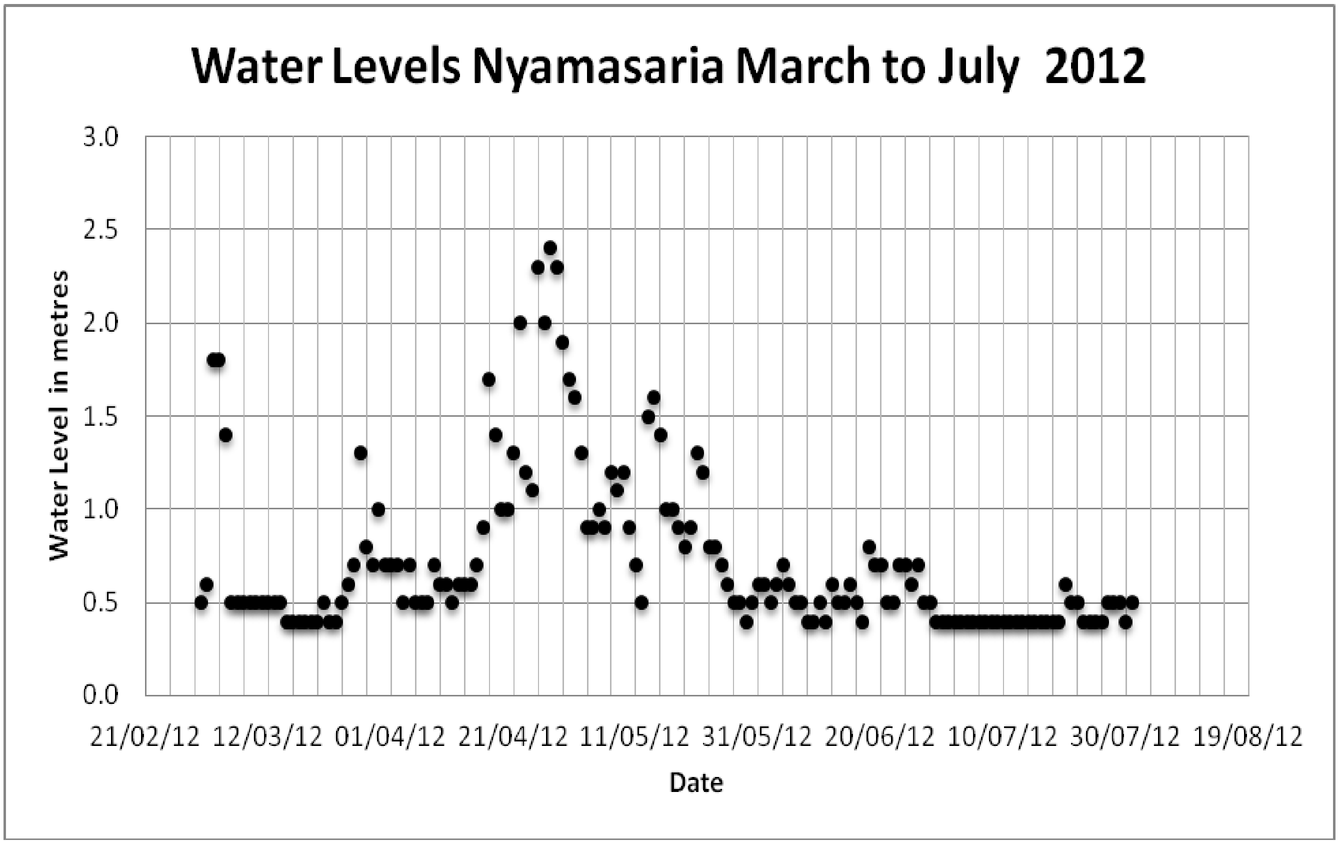
1. Interview with Gabriel Ochieng, the Chief Nyalenda Location in his office at Kassagam on 21st May 2013.
2. Interview with Mr. William Abong'o, Manager NADUKATO CBO on 23rd May 2013 at NADUKATO Offices along Ring Road in Nyalenda informal settlement.
3. Interview with James Oyugi Were, Ward Representative Nyalenda B Ward in his office at Katuoro in Nyalenda B on 18th June 2013.
4. Interview with Mr. Emmanuel Owako, Nyanza Regional Manager Red Cross Society on 25th June 2013.
5. Interview with Jackton Otieno Onunga, Ward Representative Nyalenda A Ward in his office at Kassagam in Nyalenda A on 27th June 2013.
6. Interview with Eng. Allan Ochieng, the Network Maintenance Engineer Kisumu Water and Sewerage Company (KIWASCO) in his office at KIWASCO on 10th July 2013.
7. Interview with Eng Kevin Ondola, the Kisumu County Engineer in his office on 23rd July 2015.
8. Interview with Mr. Derrick Obura the Chief Officer, Lands, Housing and Physical Planning, Kisumu County on 25th July 2013.
9. Interview with Mrs. Margaret Shamalla, Director Meteorological department Kisumu at her offices in Kisumu International Airport on 7th August 2013.
10. Interview with Ms. Lydia Akinyi, Research Officer Water Resources Management (WRM) in her office in Kisumu Town on 15th August 2013.

Appendix F: Daily Rainfall in Nyalenda

Daily Rainfall (mm) in Nyalenda informal settlement 2012 - 2013														
	2012										2013			
Date	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**
1	4.6	0	0.0	1.2	0.0	0.0	0.0	0.0	53.7	0.0	0.0	0.0	0.0	2.5
2	3.7	0	0.0	0.0	0.0	0.0	2.6	0.0	37.5	19.5	0.0	0.0	0.0	0.0
3	30.2	0	1.5	1.1	0.0	0.0	9.2	0.0	4.8	0.0	1.8	0.0	0.0	4.0
4	3.3	13.5	0.2	11.2	0.0	0.0	7.9	0.0	14.2	0.5	0.0	0.0	0.0	29.1
5	7.8	1.6	12.9	0.0	0.0	4.7	0.8	0.0	0.0	15.8	0.2	0.0	0.0	1.4
6	0	5.4	0.8	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	10.0
7	0	2.6	0.9	0.0	0.0	1.4	22.4	0.0	0.0	0.0	0.0	0.0	15.8	11.1
8	0	6.2	2.0	0.0	0.0	4.5	0.2	0.0	0.0	19.7	11.4	0.0	0.0	3.3
9	0	0	6.5	0.0	0.0	0.1	1.7	0.0	6.8	0.0	9.6	0.0	10.1	10.2
10	0	0	4.5	1.0	0.0	0.0	0.0	0.0	53.8	1.8	3.6	0.0	0.0	0.0
11	0	0.3	0.0	0.0	0.0	17.2	0.0	0.0	0.0	0.0	3.4	0.0	2.1	16.7
12	0	4	0.0	12.9	0.0	0.0	0.0	1.4	5.0	0.0	0.0	2.6	0.0	0.6
13	0	0.6	34.4	0.0	1.5	0.0	1.0	0.2	0.0	0.0	0.0	0.3	0.0	30.3
14	0	0.3	15.5	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0	4.6	5.7	0.0
15	0	7.2	0.0	7.8	0.0	0.0	0.0	0.8	10.8	0.0	0.1	0.0	0.0	2.5

16	0	4.9	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	5.0	0.0
17	0	25.5	10.5	0.0	0.0	15.4	0.0	3.7	0.0	3.0	0.8	0.0	0.0	2.4
18	0	0.5	0.0	17.2	0.2	2.8	37.2	0.2	11.2	2.2	0.0	0.0	0.0	2.3
19	0	16.5	1.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.1	47.1
20	0	0	2.9	1.6	17.3	0.0	1.0	0.0	0.0	0.0	0.0	5.8	2.3	0.0
21	0	1.5	25.7	0.0	0.0	0.0	0.0	0.0	0.1	1.2	0.0	0.0	9.7	8.9
22	0	33.3	1.0	3.4	12.4	0.8	0.2	22.3	0.0	46.5	0.0	0.0	0.0	0.0
23	0	15.4	3.7	16.2	0.0	0.0	9.6	8.4	0.0	41.1	0.0	0.0	15.7	2.3
24	0	0	1.9	8.8	0.7	0.0	11.7	0.0	0.0	17.2	0.0	0.0	0.0	3.2
25	0	50.8	0.0	1.0	0.0	17.6	8.2	4.9	0.0	0.0	0.0	0.0	6.3	0.0
26	0	0	0.0	13.2	0.0	6.5	1.4	0.0	1.6	0.0	0.0	0.0	0.0	8.6
27	20.5	54.9	0.0	0.0	0.2	0.0	8.7	35.3	0.0	21.8	0.0	0.0	6.0	9.0
28	0	5.9	0.0	0.0	0.0	0.0	3.1	21.3	0.0	41.0	0.0	0.0	6.1	0.0
29	0	31.7	0.0	0.0	0.0	0.5	0.8	0.0	22.3	24.3	0.0	0	0.9	2.1
30	8	26.3	0.9	0.0	0.0	26.7	0.0	0.0	0.0	0.0	0.6	_	2.3	5.0
31	13.1	_	2.7	-	4.5	0.0	_	0.0	_	1.7	22.7	_	70.0	__

Appendix G: Water levels Nyamasaria River



Appendix H: Letter of Introduction

I Ontweka Zablon Zachariah from Maseno University is conducting a research titled "Sustainable storm water management in Nyalenda informal settlement in Kisumu City, Kenya". I would like to take a little of your time to ask some questions relevant to my research.

Name……………………………………… Signature………………………

Appendix I: Statistics of Water borne diseases in Nyalenda informal settlement

Nyalenda Health Centre								
	January to March		April to June		July to September		October to December	
	<5 Years	> 5 years	< 5 years	> 5 Years	<5 Years	> 5 years	<5 Years	> 5 years
Diarrhoea	21	7	75	33	57	39	29	30
Dysentery	1	2	4	34	1	1	2	9
Typhoid fever		15	1	38		36	4	141
K'Owino Dispensary								
	January to March		**April to June**		**July to September**		**October to December**	
	<5 Years	> 5 years	< 5 years	> 5 Years	<5 Years	> 5 years	<5 Years	> 5 years
Diarrhoea	23	12	51	21	60	12	59	15
Dysentery		1		7	2	2		3
Typhoid fever	1	12		12		46		13
Pandpieri Health Centre								
	January to March		**April to June**		**July to September**		**October to December**	
	<5 Years	> 5 years	< 5 years	> 5 Years	<5 Years	> 5 years	<5 Years	> 5 years
Diarrhoea	20		43	71	47	28	62	74
Dysentery				4				
Typhoid fever		8		38	4	87	42	93

Appendix J: Multi criteria Analysis

	Cost (-10 to -1)	Effectiveness for causes(1 to 10)	Acceptance by the residents(-5 to 5)	Effectiveness for effects(1 to 10)	Effects outside Nyalenda (-5 to 5)	Total
Weight	5	4	3	2	1	
Structural techniques						
Construction of dam	-9	7	1	5	1	-3
Development of Irrigation systems	-6	6	4	1	1	9
Maintenance and desiltation of drainage system	-7	7	5	3	4	18
Design, construction of bridges, box and pipe culverts	-7	9	4	0	0	13
Construction of dykes	-10	8	4	5	0	4
Planting vegetation cover/cover crops/trees	-3	7	3	0	0	22
Construction of open water channels	-6	7	2	0	0	4
Rain water harvesting and storage upstream	-6	7	2	2	3	11
Terraces, Gabions and sandbags	-4	3	5	0	0	7
Enhancement of capacity of bridge at Nyamasaria	-5	5	5	1	4	16
Repair of Ouru stream	-4	4	5	2	0	15
Clean up of drainage system along Ring road	-4	5	5	0	1	16
Repair Auji river	-6	7	3	1	1	10
Construction of new sewerage network	-7	0	-1	5	3	-25
Construction of raised toilets	-2	0	4	3	0	8
Elevation of foundations of buildings	-4	0	-2	4	0	-18
Construction of roads on embankments	-6	2	-2	3	0	-22
Construction of flood barriers adjacent to buildings	-4	0	1	5	0	-7
Relocation of Kassagam Schools	-8	0	-4	6	0	-40
Relocation of Nanga schools	-8	0	-4	6	0	-40

Relocation of informal settlers from Lower Nyalenda	-8	0	-4	6	0	-40
Non- Structural techniques						
Increasing awareness and early warning systems	-2	0	4	6	0	14
Proper solid waste Management	-3	4	-1	3	0	4
Better supervision of building design and construction	-2	2	1	1	0	3
Better supervision of bridge construction	-2	2	2	0	0	4
Joint community cleaning of drainage structures	-2	4	2	4	0	20
Introduction of more outlets on road drainage	-4	2	-1	3	0	-9
Maintenance of existing sewerage infrastructure	-5	2	4	7	2	11
Creating awareness about effects of floods on health	-4	0	4	7	0	6
Mapping of flood hot spots	-2	0	4	2	1	7
Land use planning	-3	0	3	3	0	0
Provision of Incentives to encourage relocation	-4	0	3	5	-1	-2
Land use planning and management	-2	0	-1	0	0	-13
Creating awareness about rain water harvesting	-3	2	3	0	0	2
Provision of incentives for rain water storage	-3	0	5	1	0	2