UNIVERSITY OF NAIROBI

DEPARTMENT OF METEOROLOGY

PROJECT

ASSESSMENT OF FLASH FLOODS IN THE STREETS OF NAIROBI CITY, THEIR RELATIONSHIP WITH RAINFALL AND SURFACE RUNOFF DRAINAGE AND THEIR IMPACTS TO ITS RESIDENTS.

BY

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DECLARATION

This project is my original work and has not been presented for the award of a degree in the University of Nairobi or any other university.

Signature…………………………………………………………………………… date……………………………………

Wachira Silvia wanjiru

This proposal has been submitted with our approval as supervisors

Signature……………………………………………………………………………. date………………………………………..

PROF. MUTUA

Signature……………………………………………………………………………. date…………………………………………

DR. OPERE

DEPARTMENT OF METEOROLOGY

SCHOOL OF PHYSICAL SCIENCES

UNIVERSITY OF NAIROBI

Dedication

To my family;

my husband **Simon Ngugi** and son **Geremie Bruce Ngugi**,

my parents **David Wachira** and brothers **Collins and Denis**

Acknowledgement

I wish to recognize the hard work and mentoring of my supervisor prof. mutua. The ideas to bring up my project cannot go without recognition.

Also the Kenya meteorological service for the provision of data that was used in this study.

Abstract

Floods are a main issue in many parts of the world. Our country Kenya is no exception .Floods in the country have become a hazard and even to the extent of a disaster. This study has looked at the flash floods in Nairobi county which have happened over years even in recent years and has caused a lot of damage and loss of property even to the extent of life.

The rainfall data used was for the wettest year (2006) and month (April) since we are dealing with floods. This study has proven that the surface runoff drainage system is not adequate for the runoff in the streets of Nairobi. With the increasing rainfall intensities over the years due to climate change, the clogging of the drainage systems and they being of small diameters the flooding is due to happen since the result is more runoff on the surface than the one being drained.

The recommendation is that he systems to be maintained and unclogged regularly and the coming up roads to be accompanied by larger drainage systems.

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CHAPTER ONE

1.0 BACKGROUND

A disaster is an unexpected natural or man-made catastrophe of substantial extent causing significant physical damage or destruction, loss of life or sometimes permanent damage to the natural environment (English Dictionary 1.2.2). A hazard is a dangerous phenomenon substance or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental damage. When a disaster occurs the affected community or people may not be able to cope or manage the phenomenon at that time since most cases it exceeds the ability of the affected community or society using their own resources.

Disaster maybe grouped into **natural hazards** and **man-made hazards.** Natural hazards are those dangerous conditions that occur naturally due to events like:

- Geophysical: - earthquakes, landslides, tsunamis and volcanic activity.
- Hydrological: - avalanches and floods.
- Meteorological: -extreme hot temperatures, extreme cold temperatures, drought, wind gusts, cyclones and storms.
- Biological: - disease epidemics and insect/animal plagues.

Man-made hazards are conditions caused by humans. They mostly occur in or near human settlement. They may include transport accidents, industrial accidents or engineering failures. Others include wars, famine, riots, and terrorism.

Floods are an example of natural disaster. They are associated with climate as their main cause is rainfall which is a weather parameter. The likelihood of floods in an area is increased by many factors including: -

- Increasing human settlements.
- Increasing economic assets
- Reduction of natural water holding or retention.

The above factors especially in an urban setting reduces infiltration and percolation thus increasing runoff. This runoff increased may lead to a type of flood called flash floods.

Floods is as a result of snow melts and heavy and/or continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers and coastal areas. All in all prolonged heavy rains over an area is the major cause of floods.

Floods have the potential to cause damage to the environment causing fatalities and displacement of people and severely compromise economic activities of the society and of the government too.

Floods are of different types: -

- River floods; floods occurring when the river cannot hold the flowing water and it spills over the river banks. Occurs mostly in areas experiencing prolonged and/or increased heavy rainfalls.
- Coastal floods; floods occurring from ocean water that is driven to the low-lying coastal land by fierce storm winds. Can also be caused by tsunamis created by submarine earthquakes, landslides or volcanic eruptions.
- Flash floods; floods occurring when dried creek beds and gullies quickly become flooded by powerful fast-flowing torrents during a storm.
- Urban floods; here floods occur when rainfall downpour is quickly turning into runoff due to the concrete paved land. The runoff is increased due to lack of infiltration and percolation. Inadequate man-made drainage culverts may overflow and flood low-lying urban settlements.

The 2015 MAM rainfall season flooding in Nairobi were as a result of urban flash floods. They resulted to loss of life and properties, damaged roads and bridges. This study investigated the flash floods that occurred and their social economic impact in the society.

1.1 PROBLEM STATEMENT.

Floods have been known to occur in many parts of the world. Kenya is one of the countries that experience river and most recently flash types of floods. Nairobi experienced flash floods in

2015 long rainfall season following unprecedented heavy downpour. The city's drainage systems were overwhelmed with the flood waters and runoff increased with increasing downpour. The flash floods resulted to mass displacements of city residents, damage to property including buildings, loss of lives of the residents, damage of roads and infrastructure.

In spite of all this, not much has been done to assess the relationship between rainfall and flash floods and their impacts in Nairobi and its residents.

This study is focused on the flash floods occurring over the last few years its relationship with rainfall and the surface runoff drainage of the city.


DAILY NATION | NEWS | BUSINESS | COUNTIES | SPORTS | BLOGS & OPINION

THURSDAY, JUNE 4, 2015

Four killed in raging city floods as overwhelmed drainage system fails to cope

A resident of Kayole in Nairobi tries to unblock a drainage system following Tuesday's rains that caused flooding in the area. At least four people were confirmed dead after heavy rains caused floods in the city. PHOTO | JEFF ANGOTE | NATION MEDIA GROUP

Figure 1; A resident of Kayole tries to unblock a drainage system

1.2 MAIN 0BJECTIVE

- ***To investigate the relationship between rainfall, drainage of surface runoff and flash floods in Nairobi***

1.2.1 SPECIFIC OBJECTIVES

1. ***To establish duration over Nairobi city***
2. ***To establish rainfall intensities over Nairobi city***
3. ***To establish the total discharge over the area***

1.3 JUSTIFICATION OF THE STUDY

Nairobi is the capital city of Kenya. It's a city that is important in commercial, industrial and administration purposes in the country. It's also a tourist destination county. It has a huge population of people living and/or working. This being so it is important that the city is reduced off any risk that may affect these important purposes of the county. This include the risk of floods in the county.

The effects of 2015 long rains in Nairobi were severe and left a lot of devastating effects. Understanding the impacts of the floods by assessing the social and economic effects would assist in the county's urban development supporting long term planning and decision making against any future extremes events.

1.4 STUDY AREA

Nairobi is the capital city of Kenya and is centrally located. Most of the county is urbanized and has a population of about 3 million people. It's a county that holds most government offices and investments. It's also an industrial county with many of the country's productive industries located here.

The county has two seasons of rains, that is, its bi modal. It has the MAM 'long rains' and the OND 'short rains'. Long rains occur in the months of March, April, and May while the short rains occur in the months of October, November, and December. The onset and cessation of these rains depends on a number of factors including the IOD (Indian Ocean Dipole), pressure systems, and local effects like topography. Their timings differ with seasons and years.

Figure 2; Nairobi county area

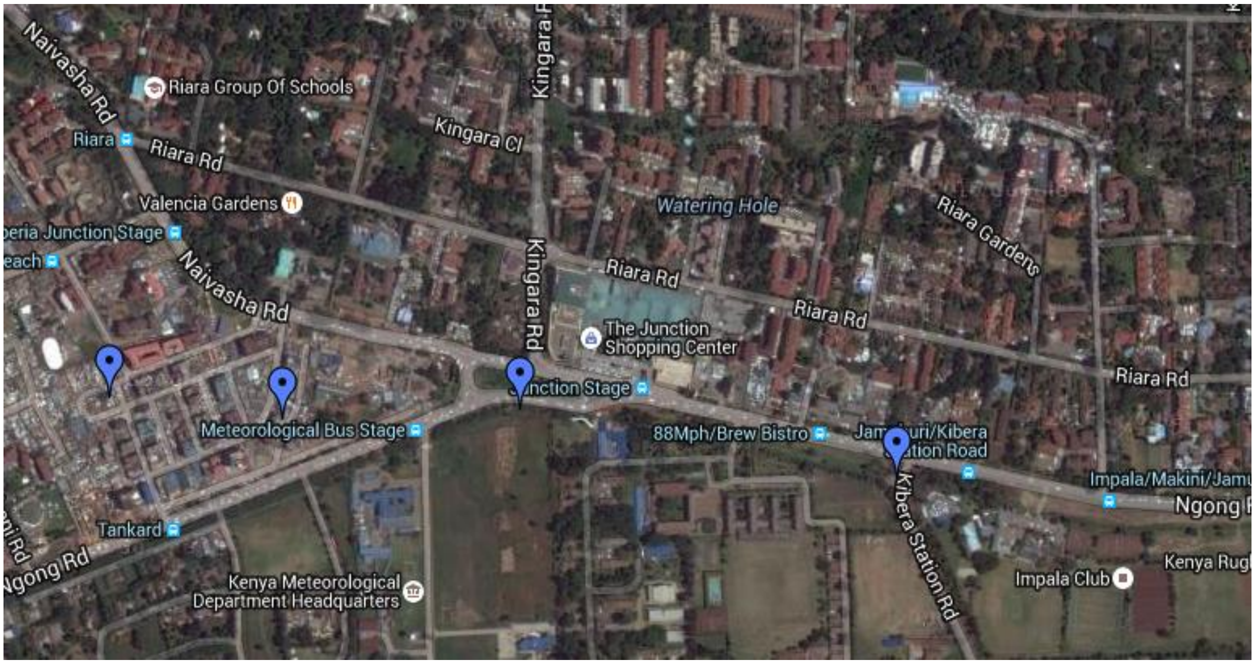

Figure 3; area showing Riara, Naivasha, Ngong and Makindu roads

Chapter two

2.0 LITERATURE REVIEW

Studies have been done by many researchers in the field of natural disasters.
Floods are one of the natural disasters that occur all over the word. There has been an attempt also to study flash floods being one of the type of floods experienced in urban area.
K.P. Georgakakos attempted a study of flash floods using analytical methods (analytical result for operational flash floods guidance 4th may 2005)

A model, the Sacramento is used to analyze the floods
John bosco, Makerere University noted that population pressure, urbanization and industrial development among others have resulted to severe degradation of environmental resources such as wetlands.

The long rains in 2015 started off later than the always expected dates from climatology and even extended to the month of June which is not always the case. Camberlin and okoola (2003) analyzed onset and cessation of rainfall in Kenya and linked their variations to atmospheric, oceanic and local conditions like winds and water bodies.

Other studies have shown that urban flash floods are particularly deadly because of the short time scales on which they occur, and because of the high concentration of population in cities (Mustafa, Christian flash flood monitoring system using passive infrared/ultrasonic sensors)
They continue to show that floods have caused fatalities in the world e.g. 2014 floods in Kashmir, India (between 300 and 400 casualties), the 2013 flash floods in Argentina (more than 5 casualties) or the 2012 flash floods in Kyushu, Japan (32 casualties) they also note that flash floods are short fuse weather events that usually peak in less than six hours.

Studies continue to show that flood duration is significantly shorter in urban than in non-urban watersheds (an empirical assessment of which inland floods can be managed, Emmanuel A. Frimpong)

CHAPTER THREE

3.0 DATA AND METHODS

3.0.1DATA

Data to be used in this study will include rainfall data for Nairobi County from Kenya Meteorological Services (KMS). This was daily rainfall data for Dagoretti corner as the representative of Nairobi for the years2004 to 2008 as representative year. Year 2006 was chosen since it was the wettest year and the month of April chosen too because it was the wettest month of that year. Wettest year and month because we are dealing with flooding.

3.1 METHODS

DATA QUALITY METHODS

3.1.1 Estimation of missing data

In case of any missing data the arithmetic mean method will be used to determine the missing records. The formula is given by:

$$\boldsymbol{D_m = \frac{1}{n}\sum D_a}$$

Where: D_m is the missing data being estimated

N is the number of available data entries

D_a is the total number of data

3.1.2 Test for homogeneity

This ensured that data collected was consistent. Data inconsistency may arise from change of observer to change of instrument among others.

Intensities

The intensities were obtained to achieve objective two. They were calculated as follows: Different durations of 1hr, 2hr, 6hr, 12hr and 24hr were taken to find the different intensities and their graphs obtained. The maximum intensity graph was obtained.

$$I = \frac{A}{D}$$

Where I is intensity in mm/hour

A is amount in mm

D is duration in hours

This is the basic method.

Discharge of the area

The coefficient of runoff of the area was taken to be 0.8 as the area is mainly concrete. The area was estimated using the scale that was given in the google map. With the coefficient, area and intensities for each chosen duration the discharge, Q, was calculated using the rational formula:

$$Q_1 = CIA$$

Where C is the runoff coefficient

I is the intensity

A is the area

Discharge of the runoff drainage culverts

The manning equation was used to calculate the discharge, Q, of the runoff drainage culverts in the streets around the representative area. The formula is written as:

$$Q=\frac{1}{n}AR^{2/3}S^{1/2}$$

Where A is the area of the culvert

R is the radius of the culvert

S is the slope of the culvert(taken as 0.001 i.e. change of slope every 1000ft)

n is the manning's roughness coefficient

The flow inside the culverts is assumed full as there would be no flooding unless they are. The computation therefore narrows down to:

$$R=\frac{A}{P}$$

Where A is the area of the culvert when full

P is the perimeter of the same culvert

$$A=\pi r^2$$

$$P=2\pi r$$

$$AR^{2/3}=\frac{A^{5/3}}{P^{2/3}}=\frac{(\pi r^2)^{5/3}}{(2\pi r)^{2/3}}$$

$$=\frac{\pi^{5/3}r^{10/3}}{(2\pi)^{2/3}r^{2/3}}$$

$$\mathbf{Q_2}=\frac{\boldsymbol{K r^{8/3} s^{1/2}}}{\boldsymbol{n}}$$

Where $\boldsymbol{K}=\dfrac{\boldsymbol{\pi^{5/3}}}{\boldsymbol{(2\pi)^{2/3}}}$

$\mathbf{Q_1}$ and $\mathbf{Q_2}$ were compared. (Henderson F.M. (1966). Open channel flow. *Macmillan series in civil engineering page 103 equation4-27).*

CHAPTER FOUR

RESULTS

4.0 METHODS OF QUALITY DATA CONTROL

4.0.1 Missing data

Data collected had no missing records

4.0.2 Consistency

The figure below shows the data for rainfall for the five years is consistent.

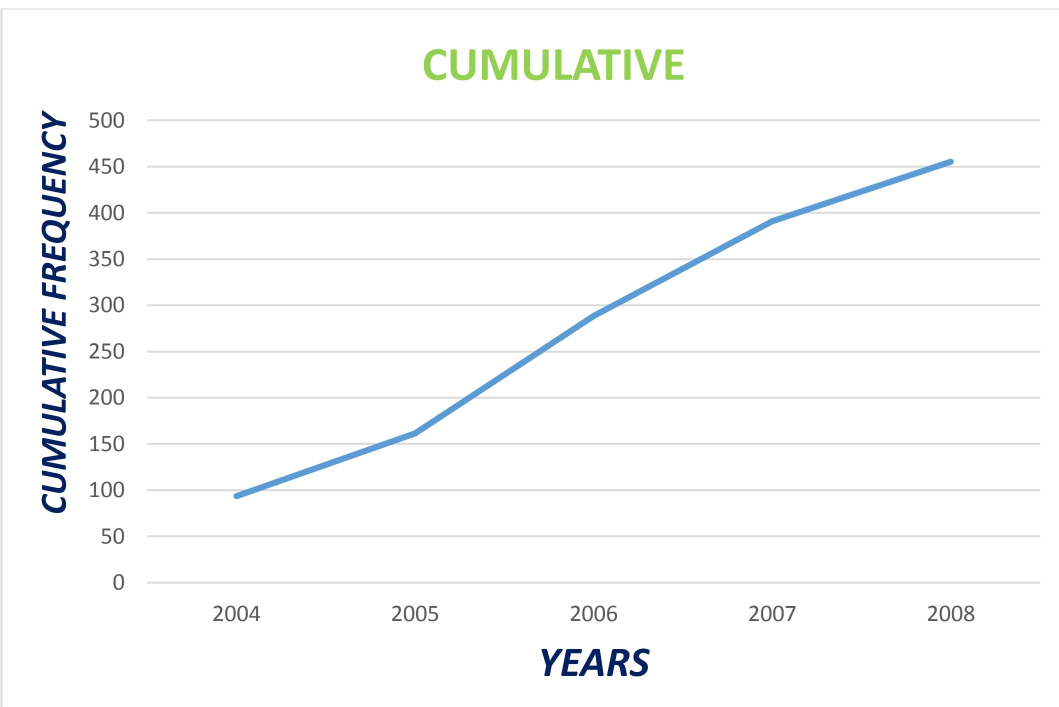

Figure 4; A graph showing rainfall consistency for the five years

4.0.3 Intensities of the month of April

The intensities were calculated using different durations that is, 1hr, 2hr, 6hr, 12hr and 24hr.

The intensities for each duration is show in the table below:

Apr-06	1hr	2hr	6hr	12hr	24hr
0	0	0	0	0	0
6.4	6.4	3.2	1.066667	0.533333	0.266667
39.8	39.8	19.9	6.633333	3.316667	1.658333
11.3	11.3	5.65	1.883333	0.941667	0.470833
53.3	53.3	26.65	8.883333	4.441667	2.220833
70.1	70.1	35.05	11.68333	5.841667	2.920833
31.8	31.8	15.9	5.3	2.65	1.325
18.6	18.6	9.3	3.1	1.55	0.775
3.1	3.1	1.55	0.516667	0.258333	0.129167
2.4	2.4	1.2	0.4	0.2	0.1
1.8	1.8	0.9	0.3	0.15	0.075
0.5	0.5	0.25	0.083333	0.041667	0.020833
0.5	0.5	0.25	0.083333	0.041667	0.020833
0	0	0	0	0	0
1.1	1.1	0.55	0.183333	0.091667	0.045833
20	20	10	3.333333	1.666667	0.833333
17.4	17.4	8.7	2.9	1.45	0.725
9	9	4.5	1.5	0.75	0.375
2.2	2.2	1.1	0.366667	0.183333	0.091667
6.3	6.3	3.15	1.05	0.525	0.2625
3.8	3.8	1.9	0.633333	0.316667	0.158333
0	0	0	0	0	0
7.1	7.1	3.55	1.183333	0.591667	0.295833
1	1	0.5	0.166667	0.083333	0.041667

5.3	5.3	2.65	0.883333	0.441667	0.220833
8.4	8.4	4.2	1.4	0.7	0.35
1.8	1.8	0.9	0.3	0.15	0.075
4.6	4.6	2.3	0.766667	0.383333	0.191667
4.1	4.1	2.05	0.683333	0.341667	0.170833
0	0	0	0	0	0

Figure 5; A table showing the daily intensities for different durations

Each day intensity curve was obtained and shown below.

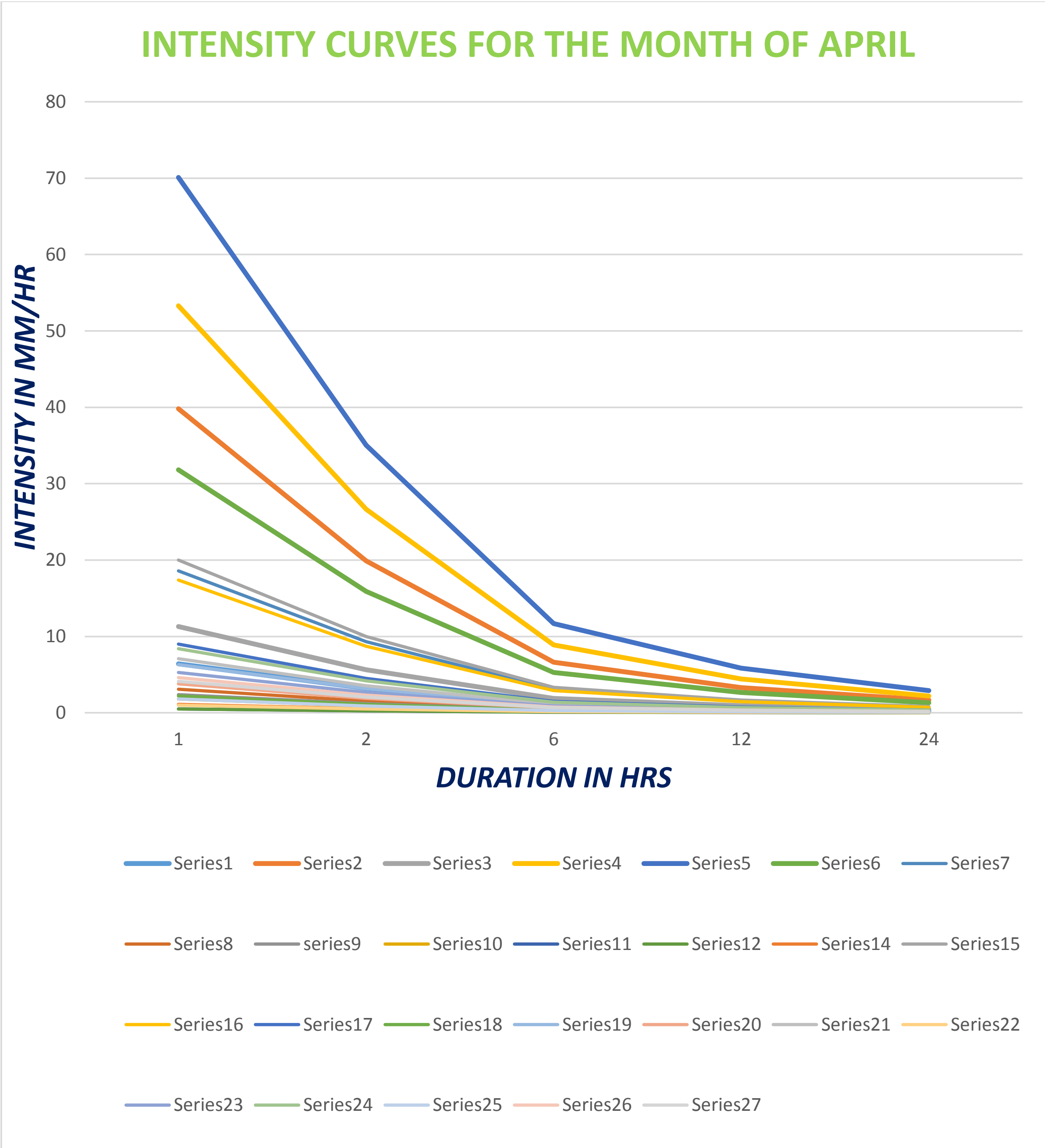

Figure 6; graphs showing the daily intensities

Each series represents each day.

The day with maximum intensity for this month was represented by series 5. The maximum intensity curve was obtained for the same durations and is as below:

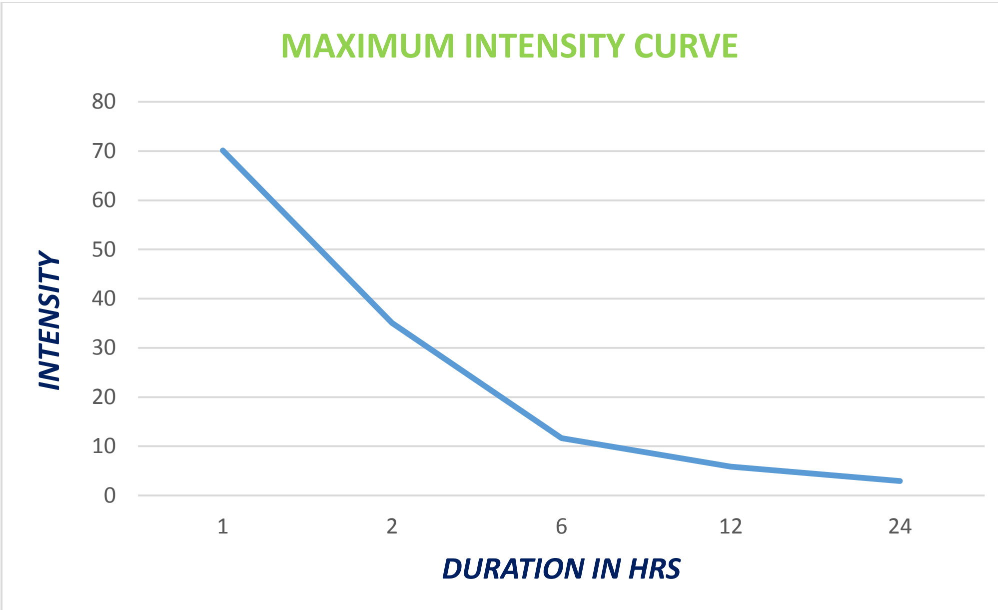

Figure 7; a graph showing the maximum intensity

4.0.4 Discharge of the area

Discharge was found for each intensity for the different durations. The results were as shown below:

Q for the area around naivasha road, gong road, makindi road and riara road

intensities	Column1	Column2	coefficient	area(m2)	discharge(m3)	Column3
I1	70.1		0.8	293400	Q1	16453872
I2	35.05		0.8	293400	Q2	8226936
I6	11.6833333		0.8	293400	Q6	2742312
I12	5.84166667		0.8	293400	Q12	1371156
I24	2.92083333		0.8	293400	Q24	685578

Figure 8; a table showing the discharge of different intensities

0.8 is the runoff coefficient of concrete ground

4.0.5 Discharge of the culverts

k was calculated to be **1.979079357**

r was taken as **300mm i.e.0.3m, 450mm (0.45m), 750mm (0.75m)**

s was taken as **0.001**

n was taken as **0.012** (the Manning's roughness coefficient for concrete, steel troweled)(Henderson F.M. (1966). Open channel flow. *Macmillan series in civil engineering page 99 table 4-2).*

Q_2 was then calculated for each diameter of the culverts

diameter	discharge	discharge Q
300mm	0.210348123	504.816m^3
450mm	0.620176538	1488.424m^3
750mm	2.421653477	5811.968m^3

Figure 9; a table showing the discharge of the culverts of different diameters

Q_2 was significantly smaller than **Q_2.** This shows that the discharge output from the area is much greater than the discharge that can be accommodated by the runoff drainage systems of the same area. The runoff left out on the surface causes the flash floods in the streets. This is worsened if the drainage systems are clogged with trash since their holding capacities are reduced greatly.

4.0.6 Impacts of the flash floods to the residents

Some of the impacts of floods in the county are reported in the daily newspapers.

Submerging of cars including both public matatus and private cars in the streets of Nairobi.

Collapsing of buildings and walls

Deaths of residents

Close up of businesses where the waters get inside the building

Relocation of the affected people to other places

A fence that collapsed following a heavy downpour in Nairobi, April 28, 2016. Photo/COURTESY

Figure 10; a picture showing collapse of a wall due to floods

Figure 11; a house invaded by the flooding waters

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

SUMMARY AND CONCLUSION

5.0.1 Summary

This study aimed at assessing the problem of floods in the streets of Nairobi including what causes them, their effects to the residents and how they can be prevented and controlled.

Rainfall for five years, that is 2004 to 2008, was considered and the wettest year and month taken as representatives since the study was about floods. 2006 and the month of April were taken as representatives. The intensities were calculated and the maximum intensity taken. The intensities taken were for different hour durations. The discharges of the area and the drainage systems were calculated and compared. The discharge of the systems was significantly smaller than the discharge of the area.

The floods have caused a lot of damage over the years and little has been done to control or prevent their occurrences in future.

5.0.2 Conclusion

The drainage systems being of smaller capacity than the runoff discharge from the designated area the floods are bound to occur every time there is rainfall downpour. With the systems further being clogged the situation gets only worse.

5.1 Recommendation

The diameters of most of the runoff drainage systems since independence have remained. With urbanization, population increase and rise in rainfall amounts there is need to increase the runoff drainage diameters and hence their capacities.

Maintenance of the systems is also important to reduce the clogging which plays a major role in reducing the capacities of draining away the runoff on the streets.

REFERENCES

Geogakakos K.P. (2005): analytical results for operational flash floods guidance.

Camberlin P. Okoola (2003): the onset and cessation of the long rains in eastern Africa and their inter annual variability

Mustafa, Christian: flash flood monitoring system using passive infrared / ultrasonic sensors

Emmanuel A. Frimpong: empirical assess of which inland floods can be managed

Daily nation Thursday June 4 2015

Fernando gazquez:Flash floods event recorded by air temperature changes in caves

John szpilman; Flood mitigation with and without planning, the roles of ideas interests and institutions.

k. gireesan,2015;Chennai floods; lessons for sustainable cities

Gwenael jovannie; how to "build back better" after a flooddisaster

Tulshi kumar das; fighting floods for survival experiences of suffering people in Bangladesh

Virginia garofaro;unravelling past flash flood act in a forested mountain catchment of the Spanish central system.