AN INVESTIGATION INTO THE ADEQUACY OF THE DRAINAGE SYSTEM ON NAROK MAI MAHIU ROAD

BY: VICTOR K. RONO
B66/36769/2010

THE PROJECT PAPER PRESENTED IN PART FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF QUANTITY SURVEYING.

May 2014
DECLARATION

I, Victor K. Rono hereby declare that this project is my original work and has not been presented in any other university for the award of any degree.

Signed:

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Date:

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Victor Kipkorir Rono

B66/36769/2010

This project has been submitted for examination with my approval as a supervisor.

Signed:

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Date:

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Dr. Isabella Njeri Wachira- Towey

(UNIVERSITY SUPERVISOR)
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Most sincerely, I wish to thank the Almighty God for being my guide, hope and strength and for enabling me to come this far. I wish to say a big thank you for the gift of life and health.
DEDICATION
This work is dedicated to My Dad, Charles Cheruiyot and Mum, Priscilla Charuiyot for their commitment towards my education. They gave willingly and exceedingly beyond their ability that I should come this far. Thank you Mama, thank you Papa, I love you.
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## ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>IDP</td>
<td>Internally Displaced Persons</td>
</tr>
<tr>
<td>DDMI</td>
<td>Drainage Design Manual, Illinois</td>
</tr>
<tr>
<td>DMRB</td>
<td>Design Manual for Roads and Bridges</td>
</tr>
<tr>
<td>HDM</td>
<td>Highway Design Manual</td>
</tr>
<tr>
<td>KENHA</td>
<td>Kenya National Highways Authority</td>
</tr>
<tr>
<td>MoPW</td>
<td>Ministry of Public Works</td>
</tr>
<tr>
<td>SDDM</td>
<td>South Dakota Drainage Manual</td>
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ABSTRACT
Drainage is a must component in the road construction. In lay world language we know that tarmac and water are never “best friends.” For this reason in most designs of the road, the first thing to be put in place is drainage system. The presence of water in the pavement layer will tend to reduce the bearing capacity of the road and thereby its lifetime. It is required that the surface water from carriage ways and the shoulders should be efficiently drained off without allowing it to the sub grade of the road. The construction of Narok Maai Mahiu road was completed in 2011 however, it did not last even a year before it sections were washed away in May 2012 thereby disabling traffic and flooding the surrounding environment causing injuries and loss of property.

The research employed a research survey in order to obtain the information that would describe the state of drainage infrastructure in Narok Maai Mahiu road and how poor drainage affected the surrounding environment and the road users. The survey involved; Kenya National Highways Authority, Gauff Hp Consultants who designed the road and the drainage system, residents of the area adjacent to the road and the road users. Various data collection techniques that were used include questionnaires, photographs, observation and interviews.

The results indicated that Narok Maai Mahiu road drainage system was not adequate to satisfactorily drain the runoffs. As a result, the surrounding environment was greatly affected as exemplified by runoffs washing away some sections of the road and bridges, creation of gullies on peoples’ land, blockage of the road, loss of life and property and washing away of the fertility of the land. Poor design, workmanship and maintenance were the main challenges.

The study recommended that drainage facilities be improved through maintenance, gabions be built for remedying of gullies and construction of water conservation structures e.g. water pans to hold and reduce the speed of water. Furthermore, redesign of the whole drainage system in Narok Maai Mahiu road should be considered.
CHAPTER ONE: INTRODUCTION

“The basic underlying purpose of any drainage system is to keep people from water, to keep water from the people and to protect and enhance the environment while doing so.” (Thomas and Dedo, 2002). During the rains, part of the rain water flows on surface and part of it percolates through the soil mass as gravitational water until it reaches to the ground water. Some water is retained in the pores of the soil mass and on the surface of the soil particles which cannot be drained by normal gravitational methods and this water is termed as held water. It is required that the surface water from the carriageway and shoulder should effectively be drained off without allowing it percolate to subgrade. The surface water from adjoining land should be prevented from entering the roadway. The side drains should have sufficient capacity and longitudinal slopes to carry away all the surface water collected. Also in waterlogged areas special precaution should be taken. There are many such roads which are not having the proper drainage system. This causes the failure of the roads due to many reasons like increase in moisture content, decrease in strength, mud pumping, formation of waves and corrugations, stripping of bitumen, cutting of edges of pavement, frost action etc (Patil, 2011).

Drainage is a must component in the road construction. In lay world language we know that tarmac and water are never “best friends.” For this reason in most designs of the road, the first thing to be put in place is drainage system. The presence of water in the pavement layer will tend to reduce the bearing capacity of the road and thereby its lifetime. It is required that the surface water from carriage ways and the shoulders should be efficiently drained off without allowing it to the subgrade of the road (Mwangi, 2013).

Mwangi notes further that, it is essential that adequate provision is made for road drainage to ensure that a road pavement performs satisfactorily. The main function of a road drainage system is to prevent flooding of the road and ponding on the road surface, to protect the bearing capacity of the pavement and the sub-grade materials to avoid the erosion of side slopes.
Water and road construction do not make for a harmonious couple (Dawson, 2008). From this statement, Mwangi (2013) states, “for this reason it can be seen that there is a very serious effect of poor drainage on maintenance on the conditions of the road. Therefore surface water from adjoining land should be prevented from entering the roadway. The road drain should be built in such a way that it will have a sufficient capacity and longitudinal slope to carry away all surface water collected.

A road structure has to be provided with an adequate drainage to remove precipitation from its surface as expeditiously as possible, failure to which early pavement distortions and deterioration eventually occurs (Gichaga, 1989). Furthermore, flood waters are a deterrent to free traffic movement and create unnecessary perils for the users of the facility. For this reason, road designers provide pavement crown and shoulder slopes to expedite the removal of surface water (Paul and Norman, 1989).

As the water cause a serious impact on both the road access and its strength, an efficient drainage system is the most important part of urban road construction and maintenance works. Good drainage needs to be taken into consideration at the early design stages in order to secure a long life for the road. With a well-designed drainage system, future rehabilitation and maintenance works can be considerably reduced and thus limit the cost of keeping the road in a good condition (Mwangi, 2013).

1.1 Problem statement
Mai Mahiu- Narok road is about 60km west of Nairobi. The road is about 90km in length. The topography of the area is generally flat and is surrounded by Mt. Margaret, Mt. Longonot and the Aberdares Escarpment. Land use is mainly subsistence crop production and livestock rearing. The soils are of volcanic origin comprising pyroclastic materials mixed with volcanic ashes. The area experiences two rainfall seasons during the months of October to December (short rains) and March to May (long rains) annually. The peak rainfall during the long rains is observed during the month of April.
During the rainy seasons run-off from the surrounding mountains collects in the basin resulting in water logging of the soils and severe erosions. Cracks develop in the affected areas and hence resulting in land subsidence causing huge linear opening on the land surface. Resultant openings open sideways and extend longitudinally with time. According to the report of The Task Force on Mai Mahiu Disaster Risk Appraisal (2012), at the time the task force visited the area, the crack measured approximately 50M in length, between 2 and 10M in width and 4 to 6M in depth. The line of subsidence extended northwards towards the Jikaze IDP camp. A similar ground subsidence developed on the opposite side of the highway where it is threatening not only the road but also households settled in the area.

During these rains, parts of the road are washed away thereby interrupting traffic and thus necessitating the need for diversion and subsequently transport through the road is impaired. The water from the rains cut across the road due to inadequate drainage system. Having been completed and opened by President Kibaki in 2011 and barely a year later, in May 2012; some parts of the new road were washed away by the rains, raises questions as to the adequacy of the drainage system that original designs of the road provided. According to the Daily Nation of Thursday, May 17, 2012, “The Kenya Highways Authority on Thursday closed the Mai Mahiu-Narok road indefinitely because of dangerous cracks. Cracks believed to be caused by weak underlying volcanic soil, appeared on sections of the road a fortnight ago following heavy rains.” In another paragraph the Daily Nation continues to state, “On May 10, a section of the Mai Mahiu-Narok road was washed away by floods near Suswa market.” It is probable therefore that the drainage system provided for was not adequate.

However, there might be other causes of the problems experienced in Narok Mai Mahiu road during the rainy seasons as speculated by the media. These causes may include; weak underlying volcanic soils, volcanic activity amongst others. In the interest of this study, drainage system will be looked at in depth and studies on other probable causes will be left for further research. It is the state of the drainage in this road that informed a research on the adequacy of the drainage system in Narok Mai Mahiu road.
The economic recovery strategy 2003-2007 identifies transport as the third pillar of the economy expected to play a catalytic role in the development of other sectors of the economy. From this economic strategy, there is a clear indication that our economy is going to be impaired if a good road network with a good drainage system and in good state is not provided. It is therefore necessary that the concerned authorities ensure that proper designs with enough drainage provisions are made in order to facilitate the economic growth through easy movement of people and goods. More importantly, proper roads will reduce recurrent expenditure on roads through repairs and maintenance.

1.2 Objectives of the study
The objectives of this study include the following;

1. To examine the adequacy of the drainage system in Narok- Maai Mahiu road.
2. To study the effects of inadequate drainage systems on roads and the surrounding environment.
3. To investigate the reasons for inadequate drainage systems in Narok- Maai Mahiu road and the challenges faced by the institutions mandated with the responsibility of maintaining them.

1.3 Research hypothesis
Lack of adequate drainage systems is the cause of drainage problems experienced in Narok- Maai Mahiu road.

Null hypothesis
Lack of adequate drainage systems is not the cause of the drainage problems experienced in Narok Maai Mahiu road
1.4 Scope and justification
This study covers the provision of adequate drainage facilities in our public highways, in particular Maai Mahiu- Narok road. For the purposes of this study, provision means putting in place all the necessary components for a functional road drainage system. Maintenance is keeping all the components to acceptable state for an efficiently working road drainage system. The study therefore mainly dwells on the state of road drainage system within the study area with respect to provision.

This research will also concentrate on the effects water has on the road due to poor drainage. It will look at the various steps that should be taken so as to ensure sufficient drainage system and how water causes increase in moisture content which eventually decreases the strength of the road and subsequently, road deterioration.

It is however, not within the scope of this study to include qualitative problems of drainage hydraulics, computation of flow in conduits or pertinent hydraulic elevation and aspects of mathematical modeling or design aspects of drainage on roads.

1.5 Significance of the study
Kenya is at the eve of developing into a middle income economy with its development being shown by the level of road network under construction. Roads are being either constructed or being improved throughout the country. It is therefore important to have good drainage systems in such roads if they are to be sustainable and economically viable as far as maintenance is concerned.

Inadequate drainage has far reaching consequences on the roads because poor drainage cause clogging of water on road surfaces and hence deterioration.
This research is aimed at coming up with findings on the effects of poor drainage and maintenance systems in Kenyan roads. It will also come up with recommendation on the ways forward.

It is supposed to find out reasons for inadequate provision of drainage system and the reasons for poor maintenance of the available drainage systems. It is also supposed to establish the reasons why the authorities mandated have failed in carrying out their mandate, the importance of good drainage systems on both roads and surrounding environment.

1.6 Organization of the study
The study is divided into five chapters; The first chapter basically introduces the study and contains the introduction, the background of the study, the problem statement, and objective of the study, research hypothesis, and significance of the study, scope and justification of the study, organization and definition of terms.

The second chapter contains the literature review. The literature review will help the researcher to get information on what has been done in the field of study and an overview of the achievements that have been made together with challenges that are faced.

The third chapter contains the research methodology. These includes research design, description of the area and population, sampling techniques, sample size, data collection instruments, data collection procedures, presentation and analysis.

The fourth chapter contains the results and data analyzed.

The fifth chapter contains conclusion, summary and discussion of the main findings, implementation, recommendation and areas of further research.
CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction
The essence of this chapter is to understand the drainage concept and to study critically and evaluate the various studies that have been carried out regarding drainage. To start off thereof; is to define the terms drainage and drainage system. Drainage according to Oxford English Dictionary (2007) refers to emptying accomplished by draining. Drainage system on the other hand according to the English Dictionary, refers to a system of watercourses or drains for carrying off excess water.

Currently, drainage is a concern on the Kenyan roads for it contributes immensely to the high rate of deterioration in the country. From research done in the past it shows that 80 percent of existing roadway problems can be traced to the presence of water from poor road drainage either in or on the road surface (Mwangi, 2013).

Adequate drainage is essential in the design of roads since it affects the highways serviceability and usable life, including the roads and pavement’s structural strength. If pounding on the travelled way occurs, hydroplaning becomes an important safety concern (Lewis and Andrew, 2007).

Drainage design involves providing facilities that collect, transport and remove water from the road. The design must also consider the water reaching the roadway embankment through natural stream flow or manmade ditches (Shahin et al., 1984)

Proper road drainage is absolutely critical if we expect roads to stand up to the damaging effects of weather and traffic. For long term non deteriorating roads cannot be built without providing good drainage. However not all water can be termed to be bad for the road (UNH, 2009).
2.1 Design considerations of roads

2.1.0 Basic concept
Road pavement consists of any construction above the original sub grade (bottom of excavation). The goal of road design is to limit deteriorations which reduce; riding quality, cracking, rutting, potholes, corrugations and other distresses (LASDTM, 2004).

The analogy is often made between a roadway and a building. The sub grade represents the basement, the sub-base is the first floor and the road surface or pavement represents the roof. It easily follows that the entire system, roadway or house should be built with the best materials, workmanship and design techniques available. This is to ensure that the road will last for the period that it is designed for (king, 1984).

A typical road construction is multilayered in form, comprising of unbound materials. Essentially, the lower indigenous sub grade layer is covered by a bound or unbound sub base, providing drainage and frost protection for the sub grade, and the road base layer upon which the asphalt layers are laid as a final surface coating. The structural design of a road relates to the ability of the road to carry the imposed loads without the need for excessive maintenance (Serfass and Courteille, 1980).

2.1.1 Structural layers
The road layers consist of three tiers; a surface course, a binder course and a base course together these constitute the top layer of the road structure (Serfass and Courteille, 1980).

There is a wide range of surface course products available, and these wearing mixtures must be designed to have sufficient stability and durability to withstand the appropriate traffic loads and the detrimental effects of environmentally induced stresses such as air, water and temperature changes, while in other cases the wearing course should be impermeable, to keep water out of the road structure (Moulton, 1980).
Moulton notes further that, the binder course is an intermediate layer. It is designed to reduce rutting and withstand the highest stresses that occur at about 50-70mm below the surface course layer. Binder mixtures typically use a large aggregate size (19-38 mm) with a corresponding lower asphalt binder content to produce a combination of stability and durability.

He goes ahead to state that the road base course is perhaps the most important structural layer, and is specifically designed to effectively distribute traffic and environmental loading to ensure that underlying unbound layers are not exposed to excessive stress and strains. The road base course should also exhibit long-life characteristics, ensuring that fatigue of the structure are resisted for as long as possible and no damage develops.

The sub base and sub grade layers constitute the foundations of the road structure, and since the formation and subsoil often comprise of relatively weak materials, it is of utmost importance that the damaging loadings are effectively eliminated by the layers above. These sub base layers consist of unbound materials, such as indigenous soils, crushed or uncrushed aggregate, or reused secondary material.

2.1.2 Performance and Serviceability of a Road

Road performance is defined as the ability of a pavement to satisfactorily serve traffic over time (AASHTO, 2003). Serviceability on the other hand, refers to the ability of a road to serve the traffic for which it was designed. Integrating both definitions will give a new understanding of the performance which can be interpreted as the integration of the serviceability over time (Youder and Witczack, 1975).

Performance is a broad, general term describing how road condition changes or how pavement structures serve their intended functions with accumulating use (George, et al, 1989). To measure and predict the performance of any road, a repeatable, well established and field calibrated condition rating system must be adopted (Shahin, et al 1984). Several methods and approaches have been developed to measure the pavement performance.
A road is a very sophisticated physical structure that responds in a complex manner to the external traffic and environmental loading. This is mainly due to the non-homogenous composition of the asphalt mixture, aggregate and sub grade soil, and the vast variation in traffic and environmental characteristics from a region to another. In the study area, asphalt roads and pavements demonstrated different types of both structural and functional distresses as a result of the combined effect of traffic and climate. In Kenya most roads deteriorate due to high axle loading and lack of proper drainage and road maintenance (Mwangi, 2013).

Therefore it’s important that roads and drainage systems monitored, scheduling the maintenance and rehabilitation works. Road performance depends on several factors but this project concentrates on the effects that inadequate drainage systems has on roads and the surrounding environment.

2.1.3 Other factors that affect road performance

2.1.3.1 Traffic loading associated factors
These include traffic volumes, axle load, number of equivalent single axle loads (esal’s), tire pressure, truck type axles, configuration, load application time and mechanism.

2.1.3.2 Material properties and composition
These include the main engineering properties of the materials used in pavement construction such as strength or bearing capacity, gradation, mix properties, elastic and resilience modulus and poison ratio in addition to the type of the construction material used.

2.1.3.3 Workmanship and construction practices
The best of materials is of little use unless good construction practices are used along with high standards of workmanship.

2.1.3.4 Environmental associated factors
Such factors include temperature, freeze and thaw, humidity and precipitation, and ground water.
Performance and serviceability of a road may also be affected by other factors such as Geometric features (longitudinal and cross slopes, provision of drainage facilities), design and construction factors such as pavement structure thickness, maintenance level, surface characteristics (micro and macro texture) and the quality of construction works including initial roughness level, and construction joints.

2.3 Drainage on the road structure
The principle types of drainage systems are: open drain, piped (positive) Drain, French Drain. The type of road drainage which is selected for a particular road will depend on such factors as to whether it is a rural or an urban road, or if it is in cut or fill and also on groundwater conditions (ForasFrbattha Report RC. 50, 1971).

Open drains are used to carry away surface water and can also pick up some subsoil water (depending on depth). Open drains facilitate the early visual detection of blockages but their use may be restricted by the lack of roadside space, safety considerations and the risk that they may be closed in by agricultural machinery.

Plate 2.0: Open drain

Source: Courtesy of Annie-Claude Pial, 2009
A piped positive drain is normally associated with an urban situation and is used in conjunction with gullies and kerbs. It may also be used in some rural embankment situations where it is deemed important that water from the road and hard shoulder should not be allowed to drain onto the embankment. A piped drainage system with gullies requires regular maintenance.

Plate 2.1: Piped positive drain
Source: Sevenhuijsen, 1994

A French drain is the most commonly used system on newly constructed roads in rural areas. Open jointed pipes are laid in a trench which is backfilled with a porous material. French drains are useful methods of providing both surface water and sub grade drainage where space is limited.

Plate 2.2: French drain
Source: Courtesy of Drycrete (2010)
The Highway Design Manual (2001) states that the design of road drainage systems, often involves the collection, conveyance, removal, and disposal of surface water runoff from the travelled way, shoulders and adjoining roadside areas. It goes further and explains that roadway drainage is also concerned with the handling of water from the following additional sources: surface water from outside the right of way and not confined to channels that would reach the travelled way if not intercepted at crossroads or streets.

When designing for good road drainage system some considerations are; motorist safety, convenience to vehicular and pedestrian traffic, Aesthetics, flooding of the travelled way and adjacent property, sub grade infiltration, potential erosion, pollution and other environmental concerns, cost of construction and cost of maintenance (HDM, 2013).

The combination of stagnant water on the road surface and traffic tend to cause deterioration of roads. If this water is not drained in a short time it will tend to penetrate the roads body. Water can enter the road structure in one of two ways; either by water directly penetrating the surface or indirectly by ground water infiltration. This in the long run will reduce the load bearing capacity of the pavement, which cause further damage to the roads (Mwangi, 2013).

Mwangi states further that, in most cases common drainage problems can be avoided if due consideration is given during the design stage of the road. The time and cost spent trying to address problems during the construction stage or later on when the road is finished will normally be less than the costs of mitigating efforts.

The drainage systems that are required to remove the above mentioned sources of water on roads are called surface drainage and sub-surface drainage and are discussed below respectively.
2.4 Drainage features

2.4.0 Surface drainage
Surface drainage encompasses all means by which surface water is removed from the road. The gradation of aggregates and bituminous mixed should be adjusted in a way that water is not allowed to percolate into the compacted road surface. This is done by suitably choosing the wearing course which is adequately impermeable and providing requisite cross-slope to the top surface of the road so as to drain water quickly. Investigation shows that bituminous mixes recommended for road construction for various wearing courses are adequately impermeable to water when constructed. The entry of water in this course of the road occurs when cracks begin to appear on the road surface. For a good surface drainage system, shoulders, cross slope, longitudinal slope and longitudinal channels should be provided during road construction (Dawson, 1998).

Plate 2.3 Surface drainage

Source: Land and Water, 2001

2.4.1 Elements of a good surface drainage

2.4.1.0 Shoulders
Shoulders help provide lateral support for the pavement, carry water from the pavement to ditches, and give vehicles a place to go if they lose control or need to stop in an emergency. For drainage they need to be slightly steeper than the pavement and should be able to withstand occasional traffic. Erosion and washing of shoulders is a major problem and should be addressed by using less erosive material on the surface (Moulton, 1980).
2.4.1.1 Cross slope
Cross slope is provided to provide a drainage gradient so that water will run off the surface to a drainage system such as a street gutter or ditch. Water will flow faster on a paved surface. Therefore the slope of a road surface does not need to be steep. The cross slope should not be too steep. If it is, the water running off the side will start eroding the shoulder and sides of the road (Moulton, 1980).

Figure: 2.5: Cross slope
2.4.1.1.0 Types of cross slopes on road surface

Centerline: a surface configuration that removes water to both sides of the road from its longitudinal highpoint.

In sloping: this is surface configuration drains water from the entire width of the road

2.4.2 Longitudinal drainage

Main objective of longitudinal drainage is collection and removal of water that is on the road and immediate surrounding or water from adjacent areas (Mwangi, 2013). It’s fundamental for maintaining safety of traffic by eliminating water from the road surface at the same point reducing the possibility of water infiltrating into the road and pavement layers or foundation which may lead to deterioration (Van, 1989). Longitudinal surface drainage systems include gutters, channels, ditches, permeable land surface and swales complemented by their respective manholes, retain facilities and catch basins.

2.5 Subsurface drainage system

The need for subsurface drains as alternatives to open drains depends on site conditions; however, they require careful consideration owing to their high cost. These types of drains are required in urban areas, places with subsoil wells and in some types of cuttings. Subsurface drains include under drains and trench drains. They serve the following purposes; intercept water before it gets to the road, lower the water table and remove excess free moisture from the road (Van, 1989).

Subsurface drainage consists of three basic elements. A permeable base which is required to provide for rapid removal of water which enters the road structure, a method of conveying the removed water away from the road structure and this may consist of a base sloped towards a drainage ditch. At the most, this may consist of a pipe collector system and a filter layer to prevent the migration of fines into the permeable base from the sub grade, sub base or
shoulder base material (Wyatt and Macari, 2000). Wyat and Macari further states that excess fines in the permeable base will clog its drainage routes and render it ineffective.

All sub drains should be able to maintain the flow lines and the design slopes. The outlet water flow should be clear and uniform, indicating that erosion is not occurring and the system is not clogged. Side slopes on the road, drainage beds in the pavement and transverse drains are some of the measures of effecting subsurface drainage (Otumba, 2000).

Plate 2.6: Subsurface drainage

Source: Land and Water, 2001

2.5.1 Elements of a good subsurface drainage

2.5.1.0 Granular drainage layer
A well maintained granular drainage layer is uniform in thickness, the width detailed in the plans and specifications, and of the proper material gradation (Ireri, 2009).

2.5.1.1 under drains
A well maintained system of transverse and longitudinal drainage pipes effectively intercepts and carries water out of the granular layer. Under drains carry water from the granular drainage layer to edge drains. Edge drains are installed under shoulders, longitudinally adjacent to the pavement (Ireri, 2009).

Edge drains are constructed during roadways construction. Perforated pipes installed in a trench parallel to the roadway, which is then backfilled with an open graded aggregate. Caps of impervious soils are placed on top of edge drains to prevent surface water from draining into
them. Filters may be used to prevent fine grained soils from clogging the open graded aggregate or the pipe itself. Water from the under drains is collected in a non-perforated edge drain pipe that discharges into a roadside ditch or a storm water system (Ng’ang’a, 2001).

2.6 Components of a road and pavement drainage system
Drainage system on a given road and pavement is made up of various components, which are supposed to conduct the water to appropriate discharge points. It is important that components of a drainage system work well together. If one component of the drainage system breaks down, it will not only compromise drainage in that specific location, but may lead to overloading other drainage components which in turn may lead to more damage of roads due to flooding. Less effective components will show signs of its shortcomings through excessive scoring, accumulation of silt or entire washouts (Smart and Hebertson, 1992).

2.6.1 Ditches
Ditches carry water away from the roadway and into streams or other natural waterways. To do this, ditches must be properly shaped for safety, maintenance, water flow, and erosion control. The ditch should be at least one foot below the bottom of the gravel base in order to drain the pavement. Ditches should extend to shoulders with smooth transition to fore slope. A well maintained, smooth flowing ditch will be free of heavy vegetation (tall grass) and standing water, with enough grades to ensure self-cleaning and continuous flow (Barbagallo and Tricia 2005).

Roadway ditches are not supposed to cut across watershed divides or interrupt flow to critical water zones such as wetlands. The design flow should be determined, ditches should be grass lined unless hydraulic or other conditions require alternative channel lining materials (DDMI, 2013).
2.6.1.1 Erosion Control in Ditches

A ditch should be built to channel water away from the road system without creating erosion. The need for erosion protection should be evaluated for all channel and ditch designs. A channel lining is required when the design discharge velocity exceeds the scour velocity for a grassed ditch (See Table 2.0), or standing water resulting from flat ditch slopes. Paved ditches are discouraged from use as a channel lining; it is recommended that the designer use articulated concrete block revetment systems (HDM, 2013).

Ditches are constructed in four basic shapes: “V” shape, rectangular, trapezoidal and parabolic (Barbagallo and Tricia 2005).

“V” shaped ditches are constructed by a grader, front end loader, or by the use of a special ditching bucket attached to a backhoe or excavator. They are easily made with a grader and if the slopes are moderate, vegetation can be established and erosion kept at minimum.

Table 2.0: Permissible Flow Velocities for Grass-Lined Channels

<table>
<thead>
<tr>
<th>Channel slope</th>
<th>Lining</th>
<th>Permissible Velocity (ft/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5%</td>
<td>Reed canary grass</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Tall fescue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kentucky bluegrass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grass-legume mixture</td>
<td>4</td>
</tr>
<tr>
<td>5-10%</td>
<td>Reed canary grass</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Tall fescue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kentucky bluegrass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grass-legume mixture</td>
<td>3</td>
</tr>
<tr>
<td>Greater than</td>
<td>Reed canarygrass</td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>Tall fescue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kentucky bluegrass</td>
<td></td>
</tr>
</tbody>
</table>

Rectangular ditches are usually constructed by placing a backhoe directly in the ditch and travelling lengthways along it. This is a fast and cheap way to establish and clean a ditch. The flat bottom has the advantage of spreading the water out and slowing it down, but the square sides are difficult to establish vegetation on and cave-ins are common.

Trapezoidal ditches are an efficient way of channeling the water away. Sloping sides allow vegetation to be established and the flat bottoms spread the water out and slow it down, reducing erosion. Because of its shape, it has the capacity to carry more water than the “V” or rectangular ditch. It requires more expertise on the part of the operator to construct and it requires more right of way width. This shape is more expensive to construct but it does require less maintenance.

Parabolic ditch is constructed using the front end loader, backhoe, or excavator. It requires the removal of more fill than either the V or rectangular ditch. Sloping sides and a rounded bottom are easily vegetated and reduce erosion. Capacity is roughly equal to trapezoidal ditch. In terms of efficiency and long term cost effectiveness, this ditch may be the best.

Plate 2.7 Ditches

Source: Arable Ditches and Dykes, 2004

2.6.2 Culverts

Culverts are shallow passages that are fitted under roads that allow water to pass beneath them. They can be made of either steel, plastic or concrete. A culvert helps move water under a
road or driveway to a stream, lake or detention basin. The purpose of culverts is to safely convey water from one side of the roadway to the other. The water may be from natural streams or run off surface water from the road structure or areas close to the road. A culvert must be durable and have sufficient hydraulic capacity to carry a predetermined quantity of water for a given time (NAS, 1978).

Plate 2.8 Box culverts

Source: Courtesy of American Concrete, 2012

2.6.2.1 General Considerations in designing culverts
Culverts conveying cross drainage flow from outside should be located on the natural drainage path of the flow. When the natural drainage path of the flow is a wide overland flow area, the designer should evaluate the need for multiple culverts in order to prevent concentrated flow at a single location. The proposed cross culvert must be aligned with upstream and downstream channels. The designer must analyze the existing flow conditions of the areas located upstream and immediately downstream of proposed cross culverts. Land use conditions in upstream and downstream areas should be clearly documented in the Drainage Report, including photo documentation of the areas, if possible. This documentation of the existing conditions on the adjacent drainage areas, prior to construction, could provide useful information for subsequent adjacent property owner inquiries (DDMI, 2013).
2.6.3 Curbs and gutters

The primary reason for constructing curbs and gutters may be for delineation or pedestrian traffic rather than for drainage considerations. They will usually have an effect on surface water runoff and result in becoming a roadway drainage design consideration. Curbs serve several purposes, which include containing the surface runoff within the roadway, preventing erosion, and providing pavement delineation. Gutters are channels at the edges of pavement or shoulders formed by a cut or by a shallow depression or they may be part of the curb section. Gutter sections are provided on the travel side of a barrier or curb to form the drainage system for the roadway. A gutter section is often constructed of the same material as the wearing surface of the roadway. The curb confines all water runoff from the pavement surface to the gutter section with overflow onto the adjacent paved surface. Runoff will be carried along this section until it reaches either a curb opening for release to natural drainage path, or is guided into a drop inlet (Lepinski, 1985).

Plate 2.9: Curbs and gutters

Source: AAA Perfect Design Concrete, 2010

Advantages of curb and gutter system include;

- Conserve space in urban areas and other limited right of ways
- Eliminate the side ditch
- Control erosion by releasing runoff at designated protected areas
- Reduce pavement failure
2.6.4 Inlets

Storm water inlets are a vital component of the urban storm water collection and conveyance system. Inlets collects excess water from the street, transition the flow into sewers, and can provide maintenance access to the storm sewer system. They can be made of cast iron or concrete and are installed on the edge of the street gutter, or in the bottom of a swale. Roadway geometrical features often dictate the location of pavement drainage inlets (Chanson, 1999). Their primary function is transmitting runoff water from the road to the side drains. Inlets are three in types (Bruun, 1993):

**Curb opening inlets** have an opening parallel to the direction of flow in the gutter. The inlet group is adapted to curb and gutter installations. The curb opening is most effective with flows carrying floating trash.

**Grate inlets** provide a grate opening in the gutter or waterway. Grate inlets perform satisfactorily over a wide range of gutter grades. Their main disadvantage is that they are easily clogged by floating trash and should not be used without a curb opening where total interception of flow is required. This type of inlet is commonly used in Kenya.

**Combination inlet** provides both a curb opening and a grate. These are high capacity inlets which make use of the advantages offered by both kinds of openings.

The inlets are supposed to be free of debris and silting so as to function as required and avoid flooding of the roadway.

2.6.5 Roadside and median channels

Roadside channels and median channels are part of the storm drain system and are commonly used with uncurbed roadway sections to convey runoff from the road pavement and from areas which drain toward the road. Due to right of way limitations, roadside channels cannot be used
in most urban areas (SDDM, 1999). These channels also provide temporary storage of storm water to prevent serious inundation problems during major storms (Mutual, 2005).

### 2.6.6 Permeable land surface and impermeable surface

**Permeable land surface** include the land surface as well as associated vegetation cover that’s beside the road next to the shoulders. This permits the interception and infiltration of runoff water from the road. **Impermeable surface** on the other hand has a function of collecting and conveying runoff water through the inlets (USEPA, 2003).

### 2.6.7 Manhole

Manholes are generally made of precast or cast in place concrete. They are typically 4 feet in diameter. Manholes and junctions are used in sewer systems to provide a hydraulically efficient transition as alignment changes along the sewer line. Manholes and junctions are also used to provide access to storm sewers for maintenance purposes (Isles and Paul, 2010). To maintain hydraulic efficiency and adequate maintenance access, a manhole is located in one of the following points (Ascher and Kate, 2007).

- Where the pipe size changes
- Where the direction of the sewer line changes
- Where the invert grades along the sewers change
- Where drops are added to the vertical profile in conjunction with all laterals
- Where the lateral is not easily accessible for maintenance from the inlet
- Where the spacing between manholes exceed 400 feet.

Manholes are utilized to provide entry to underground storm sewers for inspection and clean out. Inlets can be used as manholes when entry to the system can be provided at the inlet so the benefit of extra storm water interception can be achieved with minimal additional cost.
Manholes should not be located in traffic lanes; however, when it is impossible to avoid locating a manhole in a traffic lane, care should be taken to ensure it is not in the normal vehicle wheel path. In the by-law 170, manholes shall comply with the following internal dimensions (DDMI, 2013).

<table>
<thead>
<tr>
<th>Depth</th>
<th>size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not exceeding 2ft.6 in.</td>
<td>2ft. 0 in x 1ft. 6 in</td>
</tr>
<tr>
<td>2ft. 6 in. – 4ft. 6 in</td>
<td>2ft. 6 in x 2ft. 0 in</td>
</tr>
<tr>
<td>Exceeding 4ft. 6 in</td>
<td>3ft. 9 in x 2ft. 6 in</td>
</tr>
</tbody>
</table>

2.6.8 Underground pipes
Pipe section can be made of either concrete or corrugated metal. Pipes that are used to construct sub drains can be of the following diameters; 300mm diameter pipes, 450mm diameter pipes and 600mm diameter pipes. Concrete pipes are commonly used and have been observed to have a long lifespan and less expensive. The minimum size used is 300mm and is at one meter deep below the ground level to provide cover to reduce loading from vehicles (USEPA, 2003).

2.6.9 Retention facilities
This is a reservoir that normally contains substantial volume of water at predetermined level of temporary storage of excess storm water runoff of subsequent slow release to down-stream channels or storm sewers (Ireri, 2009). This facilities can serve additional recreational or aesthetic function e.g. Uhuru Park in Nairobi.
2.7 Drainage problems
Successful drainage and maintenance depends on early detection of problems before conditions require major action. Signs of drainage problems requiring attention include: puddles on the surface area, poor surface flow, slope erosion, clogged ditches, pavement edge raveling, preliminary cracking, pavement pumping, and surface settlement (Charlotte, 2013).

These signs indicate the start of failures which occur as soil particles are gradually washed away and as excess water seeps into the roadway reducing the load carrying ability of the sub grade. Major failures caused by poor drainage conditions include washouts, slides, slip outs, road and pavement breakup and flood damage (Nyuyo, 1993). From a drainage point of view, Nyuyo observes that pavement maintenance consists largely of sealing cracks, patching, and repairing deteriorated surfaces. It is a cost effective treatment to extend the life of the pavement before more expensive maintenance will be required.

Stagnant water on or beside the roadway is a common sight of rainfall downpour yet it is a sign of future problems. Water soaks into the road structure unless the soil around and under it is relatively waterproof. The purpose of drainage design is to control the surface runoff and to control the free water in the sub base and sub grade (Mwai, 2001).

2.8 Water influences on road and pavement performance
Water is one of the five factors mentioned above. But, if it were not for presence of water in the roadway, all four of the other factors would either be eliminated or be much less of a problem. It is said that 80 percent of existing roadway problems can be traced to the presence of water from poor drainage either in or on the road pavement (Ireri, 2009).

Excessive water content in the pavement base, sub base, and sub grade soils can cause early distress and lead to a structural or functional failure of the road, if counter measures are undertaken. Water related damage can cause one or more of the following forms of deteriorations: reduction of sub grade and base strength, differential swelling in expansive sub grade soils, stripping of asphalt in flexible pavements, frost heave and reduction of strength
during frost melt, and movement of fine particles into base or sub base course materials resulting in a reduction of the hydraulic conductivity considerably (Lytton et al., 1992).

**TABLE 2.1: Effects of water on the road surface**

<table>
<thead>
<tr>
<th>Positive effects of water on the road</th>
<th>Negative effects of water on road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishing and maintaining vegetation for erosion control</td>
<td>Softening and reducing the load carrying ability of subgrades and shoulders;</td>
</tr>
<tr>
<td>Working gravel road surfaces</td>
<td>Increasing the disintegration of pavements and gravel surfaces;</td>
</tr>
<tr>
<td>Providing dust control; and</td>
<td>Eroding roadside surfaces;</td>
</tr>
<tr>
<td>Cleansing the road and pavement surface</td>
<td>Depositing sediment and debris in ditches, pipes, catch basins and waterways; and</td>
</tr>
<tr>
<td></td>
<td>Contributing to frost heaves and spring break-up.</td>
</tr>
<tr>
<td></td>
<td>Creating driving hazards for motorists.</td>
</tr>
<tr>
<td></td>
<td>Damaging adjacent property.</td>
</tr>
</tbody>
</table>

Source: UNH report (2009)

Control and elimination of water that contributes to these types of roadway damage is the primary reason for establishing an adequate drainage and its maintenance. To do this, it’s important that government institutions that are mandated with the construction and maintenance of roads, plan ahead (Mwangi, 2013).

Results from laboratory and field tests conducted on a number of roads indicated that the moduli of base and sub grade materials were strongly affected by moisture content (Yuan et al., 2003). Furthermore, a relatively rapid decrease in the level of serviceability to transmit dynamic loads imposed by the traffic would be greatly weakened (Moulton, 1980 and Tangpithakkul, 1977). Movement of a wheel on road with a saturated sub grade can produce a moving pressure wave, which in turn can create large hydrostatic forces within the structural section.
This pulsating pore pressures significantly influence the load carrying capacity of all parts of the pavement structure (Cedergren, 1974).

Cedergen (1988) evaluated early field tests that included both drained and un-drained sections; he estimated that a flooded un-drained pavement experiences 10 to 70,000 times the damage from a load event compared to a drained pavement. As a conservative single value, he suggested that an un-drained road experiences 15 times the damage compared to a well-drained pavement.

2.8.1 Eliminating sources of water from the roads

2.8.1.1 Lowering the ground water table
Some roads are built at or very close to the natural ground water. In addition; seasonal changes in the water level after heavy rains are to be expected. In cases where the road grade can’t be kept above the ground water table, interceptor drains or lower ditches may be needed to draw down the water level under the roadway. The use of free-draining embankment gravel will be necessary to prevent drawing moisture up into the road structure (Lytton et al., 1992).

2.8.1.2 Reduce hydrostatic pressure
Another way in which water can enter into the road system is by hydrostatic pressure. Water builds up pressure as it travels downhill in the form of an underground spring. When the roadbed or ditches of a road come close to or intercept the underground water, the water is no longer confined and pressure causes it to push upward into the road and ditches (Lytton et al., 1992). Some type of interceptor drain is needed to cut off the downhill seepage or flow (Mwangi, 2013).
2.8.1.3 Minimize water vapor movement with goods soils
Water, in the form of moisture vapor, moves upward from warmer soil areas to cooler soil areas. Moisture also flows downward from the warm surface of a pavement to its cooler underside at night during the summer time (Cedergen, 1988). There is a natural tendency for moisture vapor to flow downward in the hot seasons and upward during the cold seasons. The result could be saturation of the roadway structure below the structural layer (USEPA, 2003).

2.8.1.4 Remove water from penetrating the surface
Surface runoff entering through cracks in the road or soaking through the shoulders is a common source of water problems. This source can usually be kept to a minimum by sealing surface joints and cracks and by keeping the shoulder shaped up to promote rapid runoff (Lytton et al., 1992).

2.8.1.5 Prevent frost heaves
Frost heaves can be a major problem in colder climates. The heaving results from the formation of ice lenses in wet soil when freezing temperatures drive the frost line below ground (Cedergen, 1988).

2.8.1.6 Use of geotextile in road design
“Geotextile” is any permeable, man-made textile material used as an integral part of a roadway, structure, or a project. It’s a new concept in road construction that involves using of permeable sheets of man-made textiles such as polypropylene, nylon, polyethylene, etc. The advents of these synthetic fabrics help in improving soil strength and building better roads. The geotextile acts as a filter through which water passes while it restricts fine-grained soil from entering into coarse-grained soil (sand or gravel). The fabric allows water to drain into the trench, while it permanently separates the soil materials. The gravel remains clean and cannot clog with fine material. Geotextiles can be used under parking lots, walls, athletic fields, lawns, tennis courts, and other areas (USEPA, 2003).
2.9 Chapter Summary
Chapter two of this research project centers on explaining what drainage is and describing in detail the essence of drainage and its relationship with the road construction. General consideration in road design and drainage are discussed. The chapter looks at structural layers, performance and serviceability of a road, drainage features and drainage problems on the road.
CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction
This chapter outlines research design; research techniques adopted in this research; data collection procedures and data analysis and presentation methods. The main aim of this chapter is to outline how this study found answers to the research questions that were derived from the research problem. It looked at the data collection instruments and how those instruments were employed so as to obtain information and therefore achieve the research objectives.

3.1 Research design
Research design is the visualization of data and problems associated with the embodiment of the data in the entire research project (Leedy, 1996). It is the arrangement of conditions for the collection and analysis of data in a manner that aims to combine relevance to the research process with economy in procedure and it constitutes the blueprint for the collection, measurement and analysis of data (Kothari, 2004).

This research undertook a research survey. Research survey refers to the collection of information from a sample of individuals through their responses to questions (Weiss et al., 2001). Research survey was employed in order to obtain information that would describe the current state of drainage infrastructure in Narok-Maai Mahiu road and how poor drainage system has affected road users during the rainy seasons and the residents living in the surrounding. The survey involved; government institutions responsible for construction and maintenance of highways, engineering consultants who took part in the design of that road, the contractor who built the road, road users and residents living in the affected areas of Narok Mai Mahiu road. For the purposes of achieving the objectives of the study therefore, a case study design was adopted where survey research was used.

Various techniques of data collection such as questionnaires, photographs, observation, interviews among others were employed in the study to obtain the information required to
meet the objectives. A **questionnaire** is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents (Gillham, 2008). Whereas, **photography** is the art, science and practice of creating durable images by recording light or other electromagnetic radiation, either chemically by means of a light-sensitive material such as photographic film, or electronically by means of an image sensor (Schewe, 2012). It provides a less biased recording than observations; in addition, they can then be analyzed by others in their original formats (Flick, 2002). **Observation** refers to the systematic examination of real-time processes or operations with the goal of identifying needs/challenges or improving processes and practices that is, what can be seen. Observations typically incorporate a prescribed protocol containing specific measures of observable behavior and the narrative recording of the program activities and their context (Lofland and Lofland, 1995). The qualitative research **interview** seeks to describe the meanings of central themes in the life world of the subjects. The main task in interviewing is to understand the meaning of what the interviewees say (Kvale, 1996). It seeks to cover both a factual and a meaning level, though it is usually more difficult to interview on a meaning level (Kvale). Interviews are particularly useful for getting the story behind a participant’s experiences. The interviewer can pursue in-depth information around the topic. Interviews may be useful as follow up to certain respondents to questionnaires, e.g., to further investigate their responses (McNamara, 1999).

### 3.1.1 Population

Population is the total collection of elements about which one would wish to make some inferences (Lapin, 1990). It is composed of the entire set of objects, events or people that can be studied (Rea and Parker, 2005). In research, however, the interest is in the working or study population. The working population is that part of the general population that possesses the characteristics that the research aims to study, that is, fulfills the requirements of the research (Scheaffer et al., 2001). In this study the working population is divided into three groups; the engineers, the road users and the residents along the Narok Maai Mahiu Highway.
The research focused on the engineers from both Kenya National Highways Authority (KENHA) and those from Gauf Hp Consultants. At the time of construction however, the client was the Ministry of Roads and Public Works (MOPW), therefore KENHA inherited an already completed road. The engineers from KENHA therefore, were chosen as the target population for this study because they have the background knowledge on the general design of the highway and its construction. Gauf Hp Consultant’s engineers also possess the understanding of the construction of the road from the feasibility stage to design and then finally construction and completion of the Narok Maai Mahiu road. Road users and residents of the area along Narok Maai Mahiu road were also the target population of this study because they were directly affected by the poor state of the drainage system.

3.4 Sampling design and Sampling frame

**Sampling** is concerned with the selection of a subset of individuals from within a statistical population to estimate characteristics of the whole population (Dilman, 2009). There are several compelling reasons for sampling, including; economy, greater accuracy of results and greater speed of data collection timelines and inaccessibility of some population elements (Nguru, 2008). Furthermore, the sampling procedure is determined by the purpose of the sampling and the parameters of the working population (Leedy and Ormrod, 2001).

Sampling frame refers to the source material or device from which a sample is drawn. It is a list of all those within a population who can be sampled, and may include individuals, households or institutions (David and George, 2005). In many practical situations the frame is a matter of choice to the survey planner, and sometimes a critical one. Some very worthwhile investigations are not undertaken at all because of the lack of an apparent frame, others, because of faulty frames, have ended in a disaster or in cloud of doubt (Smith, 2009).

The sample frame for this study include engineers from institutions that are concerned with construction and maintenance of roads and their facilities in accordance to the Kenya roads act 2007, residents of the area along the road and road users.
3.5 Sampling Technique and Sampling Size

Sampling techniques include random sampling, stratified sampling and systematic sampling. Random sampling includes choosing subjects from a population through unpredictable means. In its simplest form, subjects all have an equal chance of being selected out of the population being researched (Chambers, 2003). Stratification is the process of dividing members of the population into homogenous subgroups before sampling. The strata should be mutually exclusive: every element in the population must be assigned to only one stratum. The strata should also be collectively exhaustive (Sarndal, carl-Erik; et al., 2003). Systematic sampling is a statistical method involving the selection of elements from an ordered sampling frame (Black, 2004). The most common form of systematic sampling is an equal probability method where every \( K^{th} \) case in the population frame is selected for inclusion in the sample. Once the population frame is randomized, the next step is to decide on the sampling interval. The confidence level set in determining the sample size is 95% confidence level of the target population while the response is taken to be within positive or negative 5% (+ or -5%) of the population. The sample size for the population was calculated using the formula below;

\[
 n = \frac{Z^2 pqN}{e^2 (N - 1) + Z^2 pq}
\]

(Chava F and Nachmias D, 1986)

Where;

\( N \) – Size of the population

\( P \) – Sample proportion

\( n \) – Size of the sample

\( q \) – 1-\( P \)
e – Accepted error (e=0.5, this is because estimate should be within 5% of the true value)

Z – The value of the standard deviation at a given confidence level.

\[
\text{Total sample population } \quad n = \frac{1.96^2 \times 0.95 \times 0.05 \times 530}{0.05^2 \times (530 - 1) + (1.96^2 \times 0.95 \times 0.05)}
\]

=64

The proportion of the sample groups of road users, residents and engineers were then calculated as shown below:

\[
\text{Road users } \quad n = \frac{1.96^2 \times 0.95 \times 0.05 \times 300}{0.05^2 \times 530 + (1.96^2 \times 0.95 \times 0.05)}
\]

=36

\[
\text{Residents } \quad n = \frac{1.96^2 \times 0.95 \times 0.05 \times 200}{0.05^2 \times 530 + (1.96^2 \times 0.95 \times 0.05)}
\]

=24

\[
\text{Engineers } \quad n = \frac{1.96^2 \times 0.95 \times 0.05 \times 30}{0.05^2 \times 530 + (1.96^2 \times 0.95 \times 0.05)}
\]

=4

Systematic sampling technique was used to select the participants for the sample and to minimize cost while maximizing generalizability. There are a variety of different sampling methods available to the researcher to select from. Sampling method falls in two categories: Probability sampling is where individual in the population is known and each has a certain
probability of being selected. A random process decides the sample based on each individual’s probability (Smith, 2001). This will apply in the Kenya national highways authority.

Non-probability sampling is the case where the population is not entirely known, thus individual probabilities cannot be known. Common sense or ease is used to choose the sample, but efforts are made to avoid bias and keep the sample representative (Smith). This will apply to respondents who work in the area, here referred to as road users and the residents of the area along the highway.

3.6 Data collection procedures

3.6.1 Data collection instruments
Gall (1996) highly recommended questionnaires as the most convenient and suitable instruments for both survey and statistical research. Fowler (1993) explains that vast majority of survey samples involve very small fractions of populations and small increments in the fraction of the population included in the sample will have no effect on the ability of the researcher to generalize from a sample to a population. Therefore questionnaires and observations were used as data collection instruments in this research project.

3.6.2 Primary data
Questionnaires were used to collect primary data. They were designed in two forms; one involving response by statutory bodies and engineering consultants in charge of highway construction and maintenance of the drainage systems and the other involving response from people who live in the vicinity of the area in question and road users.
**Questionnaire type 1**

Type one questionnaire will be structured to be filled by government bodies in charge of construction and maintenance of drainage systems in highways, in particular Kenya National Highways Authority (KENHA) and the consultants.

The key objective of this questionnaire is to know the responsibilities, and challenges experienced by the bodies mandated to construct and maintain the national highways. In addition, it sought to understand the role of the consultant in the drainage system provision in Narok Mai Mahiu road and the challenges it experienced in design the road through questionnaire type 1.

**Questionnaire type 2**

This type of questionnaire was structured to be filled by road users and the people who live adjacent to Narok Mai Mahiu road. The road users referred here includes people who travel through that road frequently, both the public service transport providers and those using private vehicles and pedestrians. It was intended to know how poor drainage has affected the lives of the people residing in the environs and how activities have changed because of drainage. This will help in understanding how the poor drainage system has affected the road users and to obtain their views on the way forward.

**Observation**

Observation was carried out to ascertain recurrent conditions on the drainage system in Narok Maai Mahiu road in comparison with the acceptable standards. The research employed use a physical observation checklist, which was filled through observations. Oral questions were asked to get more information and to clarify the ambiguous response. A digital camera was used to take photographs of the current state of the road and the drainage system.
Table 3.1 Observation Checklist

<table>
<thead>
<tr>
<th>Part of the road</th>
<th>Drainage system condition</th>
<th>Suggested action</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>

Source: Field Survey, 2014

*Photography*

According to Kothari (2004), photography is an indirect way of data collection. It was majorly used to capture the current status of the drainage system in Narok- Maai Mahiu road. It was meant to give a visual understanding of the research topic to the readers of this research project, the extent of deterioration, maintenance and the state of the drainage system.

### 3.6.4 Secondary data

Secondary data is the data that have been already collected by other researchers and are readily available from other sources, for example, journals, and internet. Secondary data is economical and time saving. It helps to make primary data collection more specific, this is because the researcher is able to identify the gaps and deficiencies and what additional information need be collected (Kosso, 2011). It also assists in understanding the problem as it provides a basis for comparison of the data that is obtained from the field.
In the course of this research, secondary data was extensively used. This data was obtained from analysis of the relevant literature concerned with road construction, road drainage construction and the design of the road drainage systems. The literature used in this research therefore was extracted from Drainage books, journals, research projects and the internet.

3.7 Data analysis and presentation techniques
Data analysis is for the purpose of obtaining usable and useful information irrespective of whether the data is qualitative or quantitative. The research employed various statistical tools for the analyzing of the data collected from the field.

The data collected by the questionnaires and observational forms were converted into numerical codes representing measurement of variables using the statistical package for social sciences (SPSS) for windows version vista and Microsoft excel.

Descriptive statistics- frequency tables and charts were used in chapter four to present a summary of the data by describing the type of data collected and its frequency and occurrence. Plates were also used to clearly show some of the information captured through photography. Descriptive statistics was used because it enables meaningful description of scores or measurements using few statistics. Quantitative and qualitative statistics were then used to test the significance of the results on the adequacy of drainage system in Narok Maai Mahiu road.
CHAPTER FOUR: DATA PRESENTATION AND ANALYSIS

4.0 Introduction
This chapter focuses on the presentation and analysis of data obtained from the research observations and questionnaires. The data collected from the respondents and field study was presented in order to achieve the objectives of this research project.

4.1 Results from questionnaires
Questionnaires were administered to the engineers from KENHA and Gauff Hp consultants. Another questionnaire was given to the residents of the area adjacent to Narok Maai Mahiu road and people who use the road, herein referred to as road users. The questionnaire comprised of open ended and structured questions on issues that are related to the study.

Table 4.1 Response rate

<table>
<thead>
<tr>
<th>Respondent</th>
<th>No. of planned questionnaires</th>
<th>The response</th>
<th>The response rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineers</td>
<td>4</td>
<td>4</td>
<td>100%</td>
</tr>
<tr>
<td>Road users</td>
<td>36</td>
<td>20</td>
<td>55.5%</td>
</tr>
<tr>
<td>Residents</td>
<td>24</td>
<td>15</td>
<td>62.5%</td>
</tr>
<tr>
<td>Total</td>
<td>64</td>
<td>39</td>
<td>60.9%</td>
</tr>
</tbody>
</table>

Source: Field study, 2014

A response rate of 50% is adequate for data analysis and reporting, 60% is good and above 70% is very good (Mugenda and Mugenda, 1999). There was a response rate of 60.9% for this study and therefore good enough for the analysis of the data.
4.2.1 Results from questionnaire type one: Response from the Engineers

Figure 4.1 Considerations when coming up with a road design

Source: Field study, 2014

It was important to know the critical factors considered when designing a road drainage system. This is because they helped to understand the reasons behind the design of every road and in this case, Narok Maai Mahiu road.

Appropriateness of the drainage system

The engineers’ (both from KENHA and consultant) indicated that the drainage system provided for Narok Maai Mahiu road was inadequate and therefore inappropriate. The magnitude of the water from the hills surrounding the area in which the road is situated was overlooked during design. They also indicated that studies that were carried out before designing the road were not sufficient to satisfactorily ascertain the amount of water that would cross the road at a point in time and therefore the design lacked capacity to adequately drain the runoffs during the rains. However, poor workmanship (seen through poorly worked stone pitching and
gabions) by the contractor during construction and poor maintenance also contributed to the drainage problems in Narok Maai Mahiu road.

As part of understanding the background of the poor drainage system provisions in the Kenyan roads, this study sought to find out from the engineers the percentage of roads that lacked adequate drainage.

**Figure 4.2 Percentage of roads with inadequate drainage system**

![Figure 4.2 Percentage of roads with inadequate drainage system](source)

Source: Field survey, 2014

From Figure 4.2, it can be observed from the project engineers’ perception, that most of the roads in Kenya lack adequate drainage system. Some of the reasons cited were inadequate designs, lack of enough studies to establish the drainage requirements of the road and poor workmanship as a result of corruption.

The study also sought to understand whether the washing away of Narok Maai Mahiu road a year after construction was expected, the engineers responded that it was never expected because studies were done before the inception of the road to ascertain the drainage requirements. It was therefore expected that due diligence was observed during the study.
State of the drainage facilities

The engineers were in consensus that the drainage facilities were in a poor state and therefore needed action with immediate effect. The KENHA engineer in charge of Narok Maai Mahiu road reported that the authority carried out inspection of the road and its drainage facilities yearly but that emergency inspection was carried out when a problem occurred to ascertain its extent and to carry out required action.

Both KENHA and Gauff Hp consultants have carried out a study on the effects of poor drainage system on the surrounding environment. They both agreed that though there was need for redesigning and reconstruction of the drainage system, there was also need to carry out maintenance on the existing drainage facilities to increase their efficiency and effectiveness. They reported that redesigns and reconstruction have not been implemented, due to lack of resources and commitment by the government. Farming practices in the area according to the engineers cannot be blamed for the erosion of the road and drainage features but instead the small capacity of the drainage system provided.

The damage on the road was severe especially in May 2012 when some parts of the road were washed away. This showed the dangers that motorist were exposed to and therefore necessitated a move to correct the drainage system. Combined system was specifically cited as the appropriate drainage system, however; separate system, open channel system and subsurface drainage system were also recommended by the engineers for the different parts of the road. As to whether the type of drainage facilities in Narok Maai Mahiu road are satisfactory, the engineers responded that it is not with enough capacity to satisfactorily drain away water during a heavy downpour.
4.2 Response from road users

Figure 4.3 Frequency of road usage by road users

Source: Field survey, 2014

A significant proportion of the respondents either use the road every day or twice a week. The data collected shows that 76% of the respondents use the road often on a weekly basis. This was important to this study as it showed that the respondents could be relied on to give authentic information to achieve the studies objectives.

The road users were concerned about their safety and the convenience of going through Narok Maai Mahiu road during the rains. The state of the drainage system compromised their safety as they travelled. Only 10% percent think the drainage system provided for in Narok Maai Mahiu road is good, whereas, there was none of the respondents who thought the drainage system was very good.
This research sought to find out how poor drainage affected both the road users and the residents through the questionnaire.

**Figure 4.5 Effects of poor drainage on the road user**

- Runoff on the road block the road: 90%
- Runoff wash away bridges: 60%
- Runoff cuts through the road: 70%
- Water leaves debris on the road surface: 50%

Source: Field Survey
Road users were in consensus when it came to the effects of the poor drainage system on the road. Majority reported runoff block the road during the rains thereby hindering free movements of vehicles on the road. It also washed away bridges during therefore totally making it impossible the passage of the road. A significant proportion reported that runoffs cut through the road and leave debris on the road after the rains; this debris would then hinder movement along the road and therefore inconvenience travelers. The travelers would then become late in their businesses or other engagements.

**Figure 4.6 Frequency of interruptions on road users**

As to the frequency of interruptions on users most had been interrupted once. However among the respondents there were those who had never been interrupted and constituted only 3% of the road users. This would mean that they were able to give satisfactory answers to the questions sought by this study.
This research sought to find out what the road users did when they were interrupted, the following were the results.

**Figure 4.7 Responses of the road users on interruptions**

Source: Field survey, 2014

It was found out that most of those who were interrupted waited for the water to subside then they proceeded with the journey and very few discontinued the journey. The effects of the water on the road according to this data have far reaching consequences. For example, if one was heading to Nairobi for a flight, they may easily miss the flight if they were to wait for the water to subside. Fresh farm produce from up country may perish on the way if an interruption was to occur on the road due to runoff and one had to wait or discontinue the journey completely, consequently, that will lead to heavy losses on the farmer and may generally affect the economy. There is therefore need for a better and improved drainage system adequate for the road.
This study continued to seek from the road users and residents whether they observed any improvements on the road since they were interrupted or affected in whichever way. The results are shown below;

**Figure 4.8 Improvement activities**

![Pie chart showing improvement activities]

Source: Field survey, 2014

The data shows that there have been ongoing activities geared towards the improvement of the drainage system. A greater percentage of the respondents have observed improvement activities on the road, however, there is also a significant percentage that have never observed these activities being carried out. This shows that though there are efforts to improve the drainage system, enough has not yet been done yet. There is therefore need to improve the facilities to an acceptable standard.
Level of road users’ satisfaction of the drainage system

From the data given below, there is a clear indication that majority of the road users are not satisfied with the state of drainage system in Narok Maai Mahiu road. It is therefore a concern that the road users are not satisfied with the state of the drainage on the road, there is need to thus improve on the system in order to obtain road users satisfaction.

Figure 4.9 Level of road user satisfaction

Source: Field survey, 2014

4.3 Response from the residents
A good percentage of those who responded to the questionnaire come from within 100 meters from the road. According to the data collected 50% come from within a hundred meters from the road and outside the 50 meters mark. This was important because it showed that they could respond to all the issues raised in this study so as to achieve the objectives.
Effects of poor drainage on residents

Figure 4.12 above shows how the residents feel they were affected by the poor drainage in the area. Majority of the respondents reported that runoff had had adverse effects on their land. They stated that runoff eroded their land thereby making the land less productive and therefore affecting food production in the area.

Some other section reported that the runoffs washed away their crops leading to no harvest or little if they were lucky enough. The same would hamper their economy at the same time putting them at risk of lack of food. There were those who said that runoffs had created gullies on their land, gullies would then reduce the arable land and also pose a serious risk to their animals.
Figure 4.11 Effects of poor drainage on the residents

Source: Field survey, 2014

A significant number of the residents had at one point in time been affected by the rains through washing away of their houses and property. This created a lot of losses on the side of the residents.

4.4 Results from observation and photography

This research project employed both observation and photography as tools for which data would be collected. This involved observation and taking of photographs to show the current state of the drainage system in Narok Maai Mahiu road. From observation also; a brief description of what was observed will be given with the help of photographs.

From observation, the state of the drainage system in Narok Maai Mahiu road is poor. However, some parts of the road have no problem with drainage, that is, from Nairagie Engare to Narok town the drainage system is fairly good although the system is poorly maintained.
Plate 4.1 Section of Narok- Maai Mahiu road

Source: Field study 2014

There is a serious drainage problem from Maai Mahiu to Duka Moja i.e. from 0km to approximately 40km that needs be addressed with immediate effect. This problem has prompted the Kenya National Highways Authority to put warning signs on the road especially now that the rainy season is approaching.

Plate 4.2 Caution on flash floods

Source: Field survey 2014

Ditches

Ditches in Narok Maai Mahiu road are in a poor state of maintenance. Ditches were filled by eroded sand, stones and other materials. They were also bushy. Some sections of the road lacked ditches, though it was not possible to determine whether they were originally provided.
Culverts

Most of the culverts provided in Narok Maai Mahiu road are piped culverts. From 0km to approximately 40km, pipe culverts were estimated at 436 in number. Pipe culverts however, are not adequate for a road with such magnitude of flash floods crossing. Box culverts provided were few but functioned very well. There were no blocked box culverts observed while carrying out the survey. Piped culverts were blocked by both sand and bushes which were observed at the entrance of those culverts.
During the field survey, parts of the road that were washed away during the rains were observed and photographs taken. These parts of the road were washed away as a result of inadequate drainage facilities to allow water to cross the road without interruptions.
Plate 4.7 Section of the road that was washed away by flash floods

During the field survey, particularly, observation and photography; a contractor (Kanasia Holdings LTD) was carrying out emergency maintenance on the road before the rains started. Some questions were put across briefly so as to understand the contractors view on the drainage problem in Narok Maai Mahiu road.

The contractors engineer explained that run off water resulting to the drainage problem experienced in Narok Maai Mahiu road was as a result of flash floods from Mt. Longonot. The water drained to Lake Magadi and therefore crossed the road. The speed with which the run off moved was high and thus threatened the stability of the road. The result was washing away of some parts of the road where drainage facilities were not adequate.
4.3 Testing of hypothesis

The hypothesis of the study was Lack of adequate drainage systems is the cause of drainage problems experienced in Narok-Maai Mahiu road.

From oxford dictionary, the word ‘adequate’ mean- enough in quantity, or good enough in quality, for a particular purpose or need. The study takes 25% as average. Assume confidence level of 90%.

\[ \mu = 25\% \]

\[ C = 0.9 \]

\[ =0.45 \text{ on both sides of } \mu = 25\% \]

This implies:

\[ Z=1.64 \text{ standard errors on both sides of } \mu = 25\% \]

The summation of squares of deviation is 2100 (calculated separate)

\[ n=4 \]

The total score of state of Narok Maai Mahiu road =30

The standard deviation \( S = 7 \) (calculated separately)

\[ Z=\frac{30-25}{6} \text{ where } =\frac{6}{\sqrt{n}} = \frac{7}{\sqrt{4}} \]

\[ = \frac{30-25}{3.5} =1.42 \]

Decision making:

Since actual Z (computed between \( \bar{x} =30 \text{ and } \mu = 25\% \)) is smaller than the Z value expected in the study, the hypothesis is accepted.
4.3 Chapter summary
From the data analysis and presentation above it is clear that there is a problem with the drainage system in the Narok Maai Mahiu road. This affects the traffic ability of the road and also the surrounding environment. The residents living along the road are affected by runoff through loss of property, loss of life and injury, loss of livestock, loss of crops and loss of fertility on their land through erosion. On the other hand, the taxpayer may lose a lot of resources towards funding the repairs and maintenance works on this road.
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.0 Introduction
The purpose of this chapter is to summarize the study that was conducted. It includes a review of the purpose of the study, a restatement and a summary of the study results, discussions and conclusions, recommendation and possible areas of study that coincide with this research topic.

5.1.1 Purpose of the study
The purpose of the study was to generally look into the adequacy of the drainage system provided in Narok Maai Mahiu road; it was supposed to look into the drainage facilities, their state and the effects of water on both the road and the surrounding. It further studied the challenges faced by the road users and those living along the road because of the poor state of the drainage system. It was also supposed to study the reasons for that state of the road and to establish the challenges faced by the institutions in charge of both construction and maintenance of the road.

5.1.2 Restatement of the objectives
The objectives of this study were as follows;

1. To examine the adequacy of the drainage system in Narok- Mai Mahiu road.
2. To study the effects of inadequate drainage systems on roads and the surrounding environment.
3. To investigate the reasons for inadequate drainage systems in Narok- Maai Mahiu road and the challenges faced by the institutions mandated with the responsibility of maintaining them.
5.2 Conclusion
This study was majorly concerned with the state of the drainage facilities in Narok Maai Mahiu road and whether the existing drainage system was adequate. It is general knowledge that good drainage is fundamental in the provision of a good road network system. The greatest concern that prompted this study was the manner in which water disrupted traffic and further washed away parts of the Narok Maai Mahiu road during a heavy downpour.

The problem as was established through this study is the drainage system that is not adequate. Going by the responses from both the engineers, road users and residents, the problem lies in the drainage system. There was a general feeling that the type of drainage system is not adequate. There is therefore need for immediate remedies in order to achieve a good drainage system.

Maintenance of the existing drainage facilities was also found to be poor. There is therefore need to maintain the existing drainage facilities in order to mitigate to some extent the effects of water especially during the rains.

Poor drainage in Narok Maai Mahiu road has had a lot of far reaching consequences to the surrounding environment, residents and to the road users. It has contributed to loss of property, loss of life and traffic diversions and discontinuation of journeys. Furthermore, it has led to the erosion of the surrounding environment and hence the washing away of the fertility of the land hence reducing the productivity and thus lowering the economy of the community living thereof.

Reasons for inadequate drainage systems include; inadequate feasibility studies to ascertain the drainage requirements of the road, corruption which leads to poor workmanship by the contractors and government officials who are mandated to supervise construction and lack of adequate resources to carry out maintenance on the drainage systems.
5.3 Recommendations

5.3.1 Short term measures to KENHA
The following are the recommendations in the short term period;

- Improvement of drainage facilities through maintenance
- Public awareness campaign. This should be carried out so that people can be aware of the impacts of the rains.
- Carry out frequent inspections to check faults that may occur
- Encouraging better farming practices to check erosion
- Building of gabions/ healing of gullies using gabions
- Constructing soil and water conservation structures including water pans
- Continuous monitoring of rainfall in the area through establishment of rainfall observation stations
- Improve the drainage systems along the highways

5.3.2 Long term measures to KENHA

- Increase tree cover in Maai Mahiu area especially the neighboring hills, with appropriate tree species including planting of agro-forestry tree species to avoid erosion.
- Re-seeding of denuded land with grass cover
- Create possible alternative routes for use in the case the Maai Mahiu – Narok Highway is threatened
- Redesign the drainage system
- Complete overhaul and reconstruction of the whole system
- Proper and frequent maintenance of the drainage facilities in Narok Maai Mahiu road.
5.4 Areas of further study

In the course of this study, some other areas have been found to qualify for further research. The suggestions are based on observations made within the study area. Possible areas for further study are therefore;

- Importance of maintenance as a necessity for efficient water drainage from the road and pavement surface
- Effects of runoff on the residents and the surrounding environment within Narok Maai Mahiu road
- The role of poor workmanship in the construction of roads which result in the provision of inadequate drainage systems in our roads.
- The possibility of volcanic activity contributing to the state of drainage system in Narok Maai Mahiu road.
References


2. Design Manual for Roads and Bridges (DMRB)


APPENDICIES

Appendix A: Research permit

UNIVERSITY OF NAIROBI
Department of Real Estate and Construction Management
P.O. Box 30197, 00100 Nairobi, Kenya, Tel: No. +254-2-2724529
E-mail: dept-recm@uonbi.ac.ke

25 April, 2014

Ref: B66/36769/2010

TO WHOM IT MAY CONCERN
Dear Sir /Madam

VICTOR K. RONO

We confirm that the above named student is in the Department of Real Estate and
Construction Management pursuing Degree course in Bachelor of Quantity
Surveying.

He is carrying out his Fourth year project entitled; “An Investigation Of The
Adequate Of Drainage System In Narok Mahiu Mahiu Road” in partial
fulfillment of the requirements of the degree programme.

The purpose of this letter is to request you to allow him access to any kind of
material he may require to complete his research. The information will be used for
research purposes only.

Any assistance accorded to him will be appreciated.

[Signature]

Mary Kimani, PhD, MBS
Chair & Senior Lecturer
Dept. of Real Estate and Construction Management
Appendix B: Questionnaire Type One
Adequacy of Drainage System in Narok Maai Mahiu Road

This questionnaire is being administered for the collection of data to assist in the study of the adequacy of the drainage system in Narok Maai Mahiu road. The information collected is confidential and will strictly be used for academic purposes.

Sector: Technical Perspective.

Technical Aspect

• What is your academic background or field of training?
  o Engineer
  o Any other (specify)
    ..............................................................................................................................

• What are some of the considerations that are made when coming up with road design and appropriate drainage facility in Kenya? (More than one choice may be ticked).
  o State of road
  o Cost of construction
  o Class of the road
  o Period of construction
  o Topography

• From your design experience, was the design appropriate?
  o Yes
  o No

If the design was appropriate, what do you think is the problem?

  a) Poor maintenance
  b) Poor workmanship
  c) Climate change
  d) Any other (specify)
• Do you think the contractor observed due diligence in the construction of the drainage systems?
  o Yes
  o No

If your answer above is yes, why do you think so?
........................................................................................................................................

• From your experience as an engineer, can you say other roads in Kenya were provided with adequate drainage facilities?
  o Yes
  o No

If your answer is no, in your opinion what percentage of roads in Kenya are not provided with adequate drainage system?
  o 0 – 20%
  o 20 – 40%
  o 40 – 60%
  o 60 – 80%
  o 80 – 100%

• Narok Maai Mahiu road was washed away just a year after construction; do you think that was expected?
  o Yes
  o No

If your answer is yes, why do you think so?
........................................................................................................................................

• Do you think that there was laxity in the supervision of the contractor during the construction of the road?
  o Yes
  o No
Why do you think that was the case?

• From your engineering experience and practice, how can you rate the state of the drainage system in Narok Maai Mahiu road?
  o Excellent
  o Very good
  o Good
  o Poor
  o Any other (specify)

• How often do you carry out inspection to ascertain the state of the drainage system in Narok Maai Mahiu road?
  o Monthly
  o Every three months
  o Every six months
  o Once a year
  o Any other (specify)

• Have you carried out a research on the effects of the poor drainage system on the surrounding environment?
  o Yes
  o No

  What did you find are the effects?
  o .........................
  o .........................
  o .........................
  o .........................
  o .........................
• What do you think is the remedy to the sorry state of the drainage system in Narok Maai Mahiu road?
  o Maintenance
  o Redesigning
  o Reconstruction
  o Any other (specify)
  .................................................................

• Why do you think has hindered the above mentioned measures from being implemented?
  o Lack of resources
  o Lack of awareness
  o Poor planning
  o Lack of commitment by the government

• In your sincere opinion who has not responded to the poor state of the road?
  o KENHA
  o Gauf Hp consultants
  o Contractor
  o Any other (specify)

• What are the main challenges faced by your institution in the provision of maintenance services in Narok Maai Mahiu road?
  o ............................
  o ............................
  o ............................
  o ............................
  o ............................

• Do you think poor farming practices are to blame for the erosion of the road and the surrounding?
  o Yes
  o No
• If your answer in (15) is yes, what do you recommend as the best farming practice in the area?
  - ................................
  - ................................
  - ................................
  - ................................

• What is the extent of the damage on the road?
  - Very damaged
  - Fairly damaged
  - Good
  - Any other (specify)
    .................................................................................................................. 

• Which of the following descriptions is the best suitable type of drainage system existing in Narok MaaiMahiu road? More than one answer may be ticked.
  - Separate system
  - Combined system
  - Open channel drainage
  - Subsurface drainage
  - Any other (please specify)
    ..................................................................................................................

• In your own opinion based on the professional experience, is the type of drainage facility installed in Narok MaaiMahiu road with enough capacity to satisfactorily drain the water from the road?
  a) Yes
  b) No
  If your answer above is no, why do you think so?
Appendix C: Questionnaire Two
Adequacy of Drainage System in Narok Maai Mahiu Road

This questionnaire is being administered for the collection of data to assist in the study of the adequacy of the drainage system in Narok Maai Mahiu road. The information collected is confidential and will strictly be used for academic purposes.

Sector: General Perspective.

General Aspect

1) How often do you use Narok Maai Mahiu road?
   - Every day
   - Twice a week
   - One’s a week
   - Any other (please specify)
     ........................................................................................................

2) How far is your home from the Narok Maai Mahiu road?
   - 50 meters
   - 100 metres
   - 500 metres
   - More than 500 metres

3) How often are heavy rains experienced in the area?
   - Once a year
   - Twice a year
   - Thrice a year
   - No idea
4) In your opinion how do you find the condition of the drainage system in Narok MaaiMahiu road?
   - Very good condition
   - Good condition
   - Fair condition
   - Poor condition

5) How does poor drainage affect you as a road user?
   - Runoff on the road block the road
   - Runoff wash away the bridges
   - Runoff cuts through the road
   - Water leaves debris on the road surface
   - Any other (specify)

6) How does poor drainage affect you as the resident?
   - Runoff erodes the land
   - Runoff create gullies on your land
   - Runoff wash away crops
   - Runoff washes away house and property
   - Any other (specify)

7) How many times have you been interrupted by water on the road?
   - Once
   - Twice
   - Thrice
   - More than three times
   - never
8) What did you do when you got interrupted?
   - Discontinued the journey
   - Found another route
   - Waited for the water to subside then continued
   - Any other (specify)
   ………………………………………………………………………………..

9) Since the last time you were interrupted, have you observed any improvements on the drainage system?
   - Yes
   - No

10) In your own view, how satisfied are you as a road user or resident with the state of drainage of the road?
    - Extremely satisfied
    - Satisfied
    - Dissatisfied
    - Extremely dissatisfied

11) Do you believe there is need of public awareness by the government institutions on road management?
    - Yes
    - No

    Why do you think so?