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FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
HIGHWAY ENGINEERING STREAM

PERFORMANCE EVALUATION OF EXISTING ROAD DRAINAGE STRUCTURE PROBLEMS: A CASE OF SEBETA CITY, OROMIA,ETHIOPIA

BY:TAYE FUFA GUTEMA

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Performance Evaluation of Existing Road drainage structure Problems

Case Study: Sebeta City, Oromia, Ethiopia

By

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A final thesis Submitted to Faculty of Graduate Studies of Jimma University, in partial fulfillment of the requirements for Degree of Master of Science in Highway Engineering

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As members of the examining board of the final M.Sc. open defense, we certify that we have read and evaluated the thesis prepared by TayeFufaGutema Entitled: Performance Evaluation of Existing Road drainage structure problems

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DECLARATION

I, declare that the work which will be presented in this study entitles **"**Performance Evaluation of Existing Road Drainage Structure problems: A case study of Sebeta city, Oromia, Ethiopia**"** is original work of my own, and it has not been presented for a degree in any other university.

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ABSTRACT

Drainage is one of the most important factors to be considered in the road design, construction and maintenance in different country. Poor drainage is often the main cause of road damages and problems with long term road serviceabilitythoughprovision of proper road surface drainage systems has such a great importance for the urban road to give the intended use and there by contribute to the overall development of a nation.Insufficient urban storm water drainage facility represent one of the most common sources of compliant from the citizens in many towns of Ethiopia and this problem is getting worse and worse with the ongoing high rate of urbanization in different parts of the country, especially in Sebeta city. The study was to evaluate the hydraulic capacity of the existing road drainage structures, to assess the effects of inadequate drainage structure on the road, to recommend the concerned body based on the findings in the study. An exploratory and descriptive type of methods was used to describe and evaluate the existing condition of drainage structure. Data collection methods were carried out using both primary and secondary data sources. The collected data were analyzed and presented using Arc-GIS, Glober mapper software, Digital camera, GPS device, measuring tape,surveying instruments of leveling.

Hydrological analysis was carried out by using Rational Method. Hydraulic parameters are determined by using Manning’s equation.

From the field evaluation, the drainage system in each road was rated as excellent, fair, good, or poor. The study reveals that more than 75% of the roadways in the selected sites were in poor drainage conditions, which lead to tremendous environmental problems. With the aid of a camera, pictures of the various degrees of drainage deterioration and its consequent effects on road pavement conditions were taken. Based on the result of this thesis the drainage system is insufficient at different area and most of the stations of the catchments were investigated that required construction of additional drainage system and its existing coverage and its proposed based on assessing hydrologic and hydraulic calculation. In Sebeta roads having inadequate drainage systems, deterioration often begins with the origin of cracks or potholes on the road pavements either at the edges or center of roadway due to different movement of traffic rate. As a result of this evaluation, it was discovered that road needs to be designed and constructed the additional size for cross fall to passes proper drainage. Such a way that they effectively drain off rain water from their surfaces into designated drainages. Finally, I recommend the concerned body to appropriate mitigation measures were proposed for required new drainage system in order to serve the area from different negative effect and drainage structures for the future purposes sustainably.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
CN	Curve Number
DC	Design Class
DDM	Drainage Design Manual
DEM	Digital Elevation Model
EMA	Ethiopian Mapping Agency
ERA	Ethiopian Road Authority
FHWA	Federal Highway Administration
GDM	Geometric Design Manual
GIS	Geographic Information System
HSG	Hydrological Soil Group
IDF	Intensity-Duration-Frequency
SCA	Sebeta City Administration
SCS	Soil Conservation Service

CHAPTER ONE

1 INTRODUCTION

1.1 Background of the Study

Drainage is one of the most important factors to be considered in the road design, construction and maintenance. When a road fails, whether it is concrete, asphalt or gravel, inadequate drainage is often a major factor to be considered. Poor drainage is often the main cause of road damages and problems with long term road serviceability. Though provision of proper road surface drainage systems have such a great importance for the urban road to give the intended use and there by contribute to the overall development of a nation, in particular in road sector, the practice of the construction of proper integrated drainage structures did not get due attention in our country[1].

Therefore the problems and achievements on the design, construction and maintenance of surface road drainage systems need to be assessed to provide remedial measures for the better performance of the road infrastructure. Insufficient urban storm water drainage facility represent one of the most common sources of compliant from the citizens in many towns of Ethiopia and this problem is getting worse and worse with the ongoing high rate of urbanization in different parts of the country, especially in Sebeta city [1]. Storm water collection systems must be designed to provide adequate surface drainage. Traffic safety is intimately related to surface drainage. Surface drainage is a function of transverse and longitudinal pavement slope, pavement roughness, inlet spacing, and inlet capacity

Drainage structures problems in urban areas introduce flooding, deterioration of roads, land degradation, sedimentation, water logging and etc. With urbanization, impermeability of land increases with the increase in impervious surfaces (i.e. residential houses, commercial buildings, paved roads, parking lots, etc.) with this drainage pattern changes, overland flow gets faster, flooding and environmental problems such as land degradation increases. And it becomes a crucial problem facing the existing and future road infrastructure [3].

During the last few decades an increase in frequency of extreme weather events such as heavy storms and floods has been reported in various parts of the world, for instance North Europe [4].

A surface drainage system collects and diverts storm water from the road surface and adjoining areas to avoid flooding. It decreases the possibility of water infiltration into the road and retains the road bearing capacity. Appropriate design of the surface drainage system is an essential part of road design [5]. Drainage is often described as the central and most important aspect of design, construction and maintenance of any road, including unsealed roads. Drainage of unsealed roads can be of even greater importance because lower quality design and construction standards and marginal materials are generally used, which are more permeable to water. Poor drainage will reduce the life of the pavement and have serious environmental impacts if left unchecked. There are many approaches to reducing erosion of exposed surfaces associated with unsealed roads, such as side drains, cut-off contour banks and batter slopes. Any road will readily concentrate runoff, so there is a need to design and construct roads to allow for frequent and safe discharge.

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 [6].

A drainage system includes the pavement and the water handling system. They must be properly designed, built, and maintained. The water handling system includes: road surface, shoulders, drains and culverts; curb, gutter and storm sewer. When a road fails, whether it's concrete, asphalt or gravel, inadequate drainage often is a major factor. Poor design can direct water back onto the road or keep it from draining away. Too much water remaining on the surface combine with traffic action to cause potholes, cracks and pavement failure

Roadside ditch networks, ubiquitous across much of the US, are designed to minimize local flooding risk by collecting and efficiently conveying road runoff to downstream surface water bodies. Unfortunately, runoff associated with road systems may be laden with contaminants from vehicles, road maintenance activities, and atmospheric deposition that may adversely affect sensitive receiving water bodies [7]. In addition to transporting road runoff, road ditches alter hill slope and watershed hydrology by re-routing and concentrating landscape-derived runoff and by lowering water table depths downslope of roads [8].

The hydrologic effects of road ditches have been corroborated through both modeling and empirical observation at multiple spatial scales. However, previous studies have primarily been limited to unpaved logging road networks in the US Pacific Northwest.

Culverts, Ditch and Bridges are the major drainage structures that convey storm water under roads. Their purpose is to prevent water from the more frequent storm events from overtopping and crossing the road as such conditions inhibit safe passage of vehicles. Particularly Bridges serve a variety of highway purposes including the elimination of conflicts with traffic and other modes of transportation. Moreover, Bridges enables watercourses to maintain the natural function of flow conveyance and sustaining aquatic life.

The use of hydraulic structures can also increase the capital cost of drainage facilities while lowering Operation &Maintenance costs. On the other hand, use of hydraulic structures can reduce initial and future maintenance costs by changing the In the characteristics of the flow to fit the project needs, and by reducing the size and cost of related facilities [9].

According to [3], drainage problems in urban areas introduce flooding, deterioration of roads, land degradation, sedimentation, water logging and etc. With urbanization, permeability of land increases with the increase in impervious surfaces (i.e. residential houses, commercial buildings, paved roads, parking lots, etc.) with this drainage pattern changes, overland flow gets faster, flooding and environmental problems such as land degradation increases and it becomes a crucial problem facing the existing and future road infrastructure.

Generally, drainage structures designed to prevent road damage during the most usual floods such as annual, 10-year, 50-year or 100-year flood, depending on the importance of the road and the type of structures [2]. If surface water penetrates into the road body, it reduces the load bearing capacity of the pavement, which may cause further damage of the road. To avoid these problems, it is important to secure adequate drainage of the road surface. According to [10] the normal cross-slope is not less than 3% in order to dispose water from the roadway quickly that avoids infiltration of water into the roadway. If the cross-slope is less, water will get time to infiltrate into the roadway and weakens the pavement that cannot withstand traffic load. 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 surface of the road [6] .To achieve proper drainage, drains (or ditches) a long side of road are essential to collect water from road surface and surrounding areas and lead it to an exit point where it can be safely discharged.

A typical urban storm water system consists of streets constructed with curbs, gutters, inlets, and roadside ditches; underground storm sewers; and open outfall channels such as stream and rivers receiving runoff [11]. Poor design can direct water back onto the road or keep it from draining away. Too much water remaining in the surface, base, and subgrade combined with traffic action will cause potholes, cracks and pavement failure [12]. Even on roads built with all the proper drainage elements, neglecting periodic maintenance is likely to result in flooding, washouts, and potholes. Regular annual evaluation of drainage systems is an important part of maintaining and managing roadways [12].

1.2 Statement of the problem

Lack of urban drainage structure is one of the most common sources of compliant from the residents in many urban centers of developing countries. The same is true for the locality of Sebeta area. In the densely populated town and cities are facing water logging and flooding during heavy rainfall. Many streets in Sebeta road are lack appropriate drainage structures that can drain the increasing storm water volumes due to the rapid urbanization of the town causing flooding of the streets, paralyzing traffic mobility, and damaging private and public property. Sebeta city area road located at a lower elevation at some place which is directly affected by surface runoff water contributed from surrounding mountain across the road sub-catchment watershed area. Most parts of Sebeta area are affected by flooding during the rainy season due to inadequate of existing drainage structure.

Some of the problems that have been observed in the Sebeta city are such as, deterioration of road, shoving, edge crack, shoulder erosion, silted drainage ditches, flooding. Particular areas affected by flood are Kenteri Alemgena Butajira Road (kebeles 02) and flat areas around the Furi stadium (kebele 04). The presence of ditches and culverts is relatively dense in the central commercial areas of town. However these structures did not control the flood problems. To avoid this problem, culverts and ditches drainage structures performance should be evaluated and mitigation measures should be proposed for sustainable and proper functioning.

1.3 Research Questions

This study aims to answer:-

1. How to evaluate the hydraulic capacity of the existing structures?
2. What are the effects of poor drainage structure on Sebeta city road performance?
3. How to recommend the concerned body based on the study area?

1.4 Objective of the study

1.4.1 General Objective

The general objective of the study is to evaluate the performances of the existing road drainage structures

1.4.2 Specific Objectives

- To evaluate the hydraulic the capacity of the existing road drainage structures
- To assess the effects of inadequate drainage structure on the road
- To recommend the concerned body based on the findings in the study.

1.5 Significance of the study

The benefit that will be draw from this study may contribute to current efforts by governments and other concerning body to solve the problem on drainage schemes that contribute for better service coverage .To understand problems of damage and preserve the structures by avoiding further deterioration for taking correct measures as well as to reduce any inconvenience and disruption to travel due to over flow of water in the main road due to flooding. The result of this study also may help in filling the gaps by identifying problems to Sustainability, taking proper designing of Storm water drainage system and proper functioning of drainage schemes in the town. In general, Sebeta area is the part of which facing the drainage problems, so further evaluation were contribute the solution for sustainable drainage structure in the area.

1.6 Scope of the study

The study addresses issues related to road surface drainage and the integration between drainage and road infrastructures in the study area. The specific focus of it includes: condition of existing road drainage structures, their network condition, maintenance of road drainage structure, drainage infrastructures integration on road performance in the study area affected.

CHAPTER TWO

2 LITRATURE REVIEW

2.1 General Description of Road Drainage Structures

Road drainage structures that cross the rivers and valleys are vital components of the road network that contributes greatly to the national development and public daily life. Any damage or collapse of these structures can cause the risk of the lives of road users as well as create serious influence to the entire country economic development. Furthermore, the reconstruction of these road drainage structures needs considerable amount of skilled work force, money and time. Road drainage structures are essential components during the design development of road infrastructures. Drainage structures intended to allow the runoff of any flow of water with limited damages and disturbances to the road and to the surrounding areas. The basic design techniques in roadway drainage system should be developed for economic design of surface drainage structures including ditches, culverts and bridges [2].

A hydraulic investigation and analysis of both the upstream and downstream reaches of the water course is necessary to determine the best location, size, and elevation of the proposed crossroad structure, whether a culvert or a bridge. The investigation should ensure that any roadway structure or roadway embankment that encroaches on or crosses the flood plain of a watercourse will not cause significant adverse effect to the flood plain and will be capable of withstanding the flood flow with minimal damage. It is significant to provide attention during design of the magnitude, frequency and appropriate water surface elevations for the design flood, the 100-year flood, and the overtopping or 500-year flood for all structures [13]. Culverts are usually, designed to operate with the inlet submerged if conditions permit. This allows for a hydraulic advantage by increasing discharge capacity.

Bridges are usually, designed for non-submergence during the design flood event, and often incorporate some freeboard. Providing significant amount of freeboard is important for bridges to allow passage of drift, debris, and ice at high water levels, as well as to accommodate uncertainty in the design of high water elevation or the possibility of an event more than the design event. The impact of sediment and other floating materials can attribute the damage of bridge deck [14]. A freeboard of 1.5m should be provided for bridges, for smaller streams of expected less size of debris, a freeboard of less than 1.5m is provided, however, according to ERA draft drainage design manual, the minimum freeboard must not be less than 1.0m [2].

According to [9], a hydraulic investigation and analysis of both the upstream and downstream reaches of the watercourse is necessary to determine the best location, size, and elevation of the proposed crossroad structure, whether a culvert or a bridge. The investigation should ensure that any roadway structure or roadway embankment that encroaches on or crosses the flood plain of a watercourse will not cause significant adverse effect to the flood plain and will be capable of withstanding the flood flow with minimal damage. It is significant to provide attention during design of the magnitude, frequency and appropriate water surface elevations for the design flood, the 100-year flood, and the overtopping or 500-year flood for all structures [2].

2.2 Road Surface Drainage structures

The surface drainage elements include road surface, side drains, and culverts; and the curbs, gutters and storm sewer systems. These elements work together as a system to prevent water from penetrating the pavement, remove it from the travel lanes to the side drains or gutter, and carry it away from the road. If surface water penetrates into the road body, it reduces the load bearing capacity of the pavement, which may cause further damage of the road. To avoid these problems, it is important to secure adequate drainage of the road surface. According to [10], normal cross-slope is not less than 3% in order to dispose water from the roadway quickly that avoids infiltration of water into the roadway. If the cross-slope is less, water is remain on the roadway and causes for the strength of pavement that cannot be resist traffic load.

2.3 Storm Drainage Facilities and Guidelines

Storm drainage facilities consist of curbs, gutters, storm drains, channels and culverts. The placement and hydraulic capacities of storm drainage structures and conveyances shall be designed to take into consideration damage to adjacent property and to secure as low a degree of risk of traffic interruption by flooding as is consistent with the importance of the road.

Surface Channels: Surface channels are used to intercept runoff and conduct it to an adequate outfall. They should have adequate capacity for the design runoff. Channel linings shall be used where vegetation will not control erosion.

Drainage Inlets: Drainage inlets are sized and located to limit the spread on traffic lanes to tolerable widths for the design storm.

Inlets shall be placed upstream of locations where the pavement cross slope reverses, such as on the high side of super elevated horizontal curves, to avoid concentrated flows crossing the carriageway.

Storm Drains: A storm drain is that portion of the storm drainage system that receives runoff from inlets and conveys the runoff to some point where it is then discharged into a channel

2.3.1 Elements of Good Surface Drainage structures

Crown: A road's crown should have sufficient slope from the pavement centerline to the edge to make sure water will effectively drain off the roadway surface. When the slope is too flat, water can pond on the surface and migrate through joints and cracks into the pavement or under the surface. This can lead to pavement cracking and potholes. Water that doesn't drain off the roadway can also present a safety hazard to motorists by introducing the possibility of hydroplaning.

Shoulders: To aid in drainage, shoulders should be flush with the adjacent roadway, slope slightly away from the roadway, and have no erosion problems or secondary ditches. earth shoulders should be mowed in accordance with local agency policies and procedures.

Slope: Slopes are normally referred to by the ratio of the run to the rise. For example a 3:2 slope is three feet horizontal distance to two foot vertical distance (run to the rise). The degree of fore slope and back slope is determined by design standards [2] design guide and local conditions (e.g., cohesive soils, or rights of way). Local conditions may require that slopes be designed and constructed steeper or flatter than the design guides suggest. Whatever slope has been designed and constructed should be maintained at the same ratio of run to the rise.

Ditches: Ditches collect runoff from the road surface. A well-maintained, smooth-flowing ditch will be free of heavy vegetation (tall grass, trees, cattails, etc.) and standing water, with enough grades to ensure self-cleaning and continuous flow. (Ditches with flat percent-of-grade allow residue or debris to settle and fill in the ditch. If sediment accumulates, water may erode a new path outside of the ditch area). The function of the drains (or ditches) a long side of road is to collect water from the road surface and the surrounding areas and lead it to an exit point where it can be safely discharged. The side drains need to have sufficient capacity to collect all rainwater from the road surface and dispose it quickly and in a controlled manner to minimize damage.

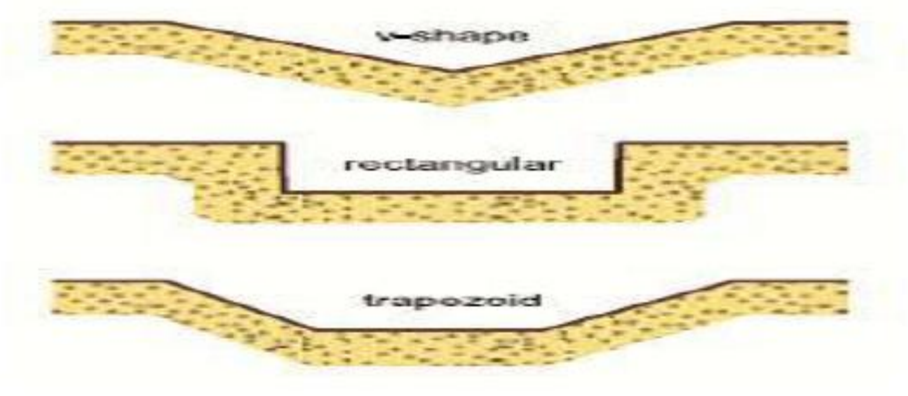

Figure 2.1The common shapes of side drains.

Sides drains can be constructed in three common forms: V-shaped, rectangular or as a trapezoid. The V-shape is the standard shape for ditches constructed by a motor grader. However, it carries a lower capacity than other cross-section shapes. The rectangular shape requires less space but needs to be lined with rock or concrete to maintain its shape. This shape is often used in urban areas where there is limited space for the drainage.

Trapezoid shaped side drain carries a high flow capacity and by carefully selecting the right gradients for its side slopes, will resist erosion. In urban areas especially commercial and residential areas the drains should be covered with concrete slab or small block for easy inspection and cleaning. The exact dimensions of the side drains are dependent on the expected amount of rainwater.

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 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.

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.

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 areeasily 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.

Culverts: Culverts are well maintained when the flow line and the design slope from inlet to outlet still exist. No sections have settled, and all joints are tight and not separated. The curtain walls are not exposed, and the downstream channel has not started to erode.

Inlets: In well-maintained inlets, the inlet structures are straight and true, marking devices are in place and visible, and the surrounding pavement and joints are sound and water tight. The inlets are free of debris and silting, and the adjacent vegetation is not impeding the ditch drainage flow. **Urban Drainage Systems:** Drainage issues unique to urban situations include water running from the pavement to a curb and gutter (shoulder) and then into a storm sewer system (ditch). Curb and gutter inlets and storm sewers are also used in rural areas where shoulders and fore slopes on roads are easily eroded or back slopes are too steep to cut in a ditch. Sometimes a curb and gutter system will be used on the low side of horizontal curves to control erosion of the shoulder material and to manage edge drop-offs.

Paved Curbs and Gutters: Curbs and gutters collect runoff water from the pavement and direct it to inlets. Maintenance activities include keeping curbs and gutters clear of debris and silt so that water can run freely to the inlets.

Inlets, Storm Drains, and Manholes: In enclosed drainage systems, water is collected from the curb and gutters by inlets and funneled through storm drains into an underground storm sewer. Storm sewer runs are connected by inlets (one storm drain) and manholes (where two or more storm drains meet) which, in addition to funneling water into the storm sewers, allow personnel to access the storm sewer.

Cross-section Slope: Drainage of the road pavement is provided by shaping the road carriageway with a camber or cross slope. The camber is the slope from either side of the center line towards the road shoulders. For roads with asphalt surface, the camber is normally 2 to 3%, because water will easily flow off a hard, waterproof surface. On earth and gravel roads, the camber needs to be steeper because the water will flow more slowly and the surface is often uneven. Gravel and earth surfaces also absorb some of the surface water unless it is quickly drained away from the road. Thus, it is recommended that the camber is 5 to 7%. On sharp curves, the camber is often substituted with a super elevation which leads the water to the inside of the curve. The super elevation is installed with gradual change of the road cross-section from a camber shape to a road surface shaped with a cross slope.

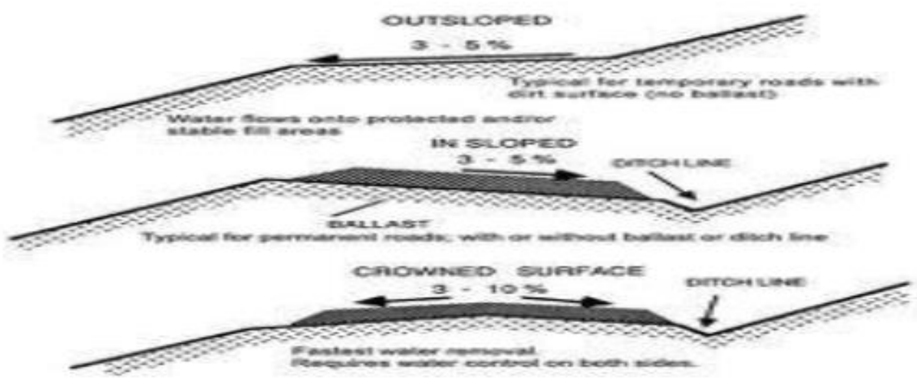

Figure: 2.2: Cross sectional slope, (Source: [3])

2.3.2 Types of Culverts

Culverts are constructed using different materials. The most common practice of culverts is based on the use of pre-cast concrete pipes, in-situ concrete boxes and corrugated steel pipes culverts. The box culvert is generally built with 1 to 3 cells of width 1m to 3m and the pipe culvert is built with 1 to 3 rows of pipes with diameters commonly ranging from 0.6m to 1m. Wing walls and aprons of concrete or stone pitching are used to protect the culverts from water flow erosion and scouring at upstream side. Culverts should slope enough so water will flow. A minimum drop of 15 cm across the road is desirable. This will keep sediment from accumulating in the culvert but will not cause extensive erosion at the discharge end.

Culverts can be classified into two based on their functional types, stream crossing and runoff management. Stream crossing culvert is a drainage structure installed on the stream with recommended skewed angle, 15 - 45 if conditions do not permit to install normal to the stream channel. Installing culverts normal to the stream channel decreases construction cost. Where large skew angles are required, consideration of the most appropriate road alignment is significant [15].Runoff management culvert strategically placed to manage and route roadway runoff along, under, and away from the roadway. Many times these culverts are used to transport upland runoff, accumulated in road ditches on the upland side of the roadway, to the lower side for disposal.

Strategically placed culverts, along with road ditch turnouts, will help to maintain a stable velocity and the proper flow capacity for the road ditches by timely out letting water. This will help to alleviate roadway flooding, reduce erosion, and thus reduce maintenance problems. Culverts preserve the road base by draining water from ditches along the road, and keeping the sub base dry. Generally, drainage structures designed to prevent road damage during the most usual floods such as annual, 10-year, 50-year or 100-year flood, depending on the importance of the road and the type of structures and to minimize the modifications in the hydrology of the area [2].

2.4 Backwater Effect on Road Drainage Structures

When a roadway crosses a natural drainage way, the resistance to flow of the structure may increase the water depth upstream of the drainage structure. This backwater effect may cause areas close to the drainage way to become flooded where previously they remained above the floodwaters. When dwellings or other manmade structures are close to the drainage way, a limitation placed on the maximum backwater effect tolerated for drainage structure design.

Aggradations increase the backwater effect; affect the pressure on the structure, and passes ability of the bridge [27]. Bridges seem to more readily allow sediment transport than culverts and therefore have less accumulation up stream of the crossing [28].

2.5 Flow Velocity in Road Drainage Structures

The introduction of a culvert to convey the stream flow beneath a roadway can cause an increase in flow velocity downstream of the structure. The increased flow velocity may be sufficient to cause erosion and degradation of the channel profile. This effect can be detrimental to downstream land users and to the culvert itself. If the natural stream velocity exceeds the erosive velocity, then the increased velocity at the culvert outfall will accelerate this naturally occurring process. Erosive velocity must be avoided to protect lower lands and the roadway embankment. The flow velocity at the outlet of the roadway drainage works shall not exceed the erosive velocity of the channel or the natural velocity of the channel, whichever is greater.

Table 2.1: Target outlet Velocities

Material Downstream of Culvert Outlet	Target Outlet Velocity (m/sec.)
Rock	4.5
Stones 150mm. diameter or larger	3.5
Gravel 100mm. or grass cover	2.5
Firm loam or stiff clay	1.2-2.0
Sandy or Silt clay	1.0-1.5

Source: [15].

2.6 Description and Function of Road Drainage Structures

Storm drainage facilities consist of curbs, gutters, inlets, storm drains, ditches, and culverts. The placement and hydraulic capacities of storm drainage structures and conveyances should be designed to avoid/minimize damage to adjacent property and secure a low degree of risk of traffic interruption by flooding. Different types of structures are employed in the drainage systems; Open channels whether artificial or natural convey the flows of water. Culverts, Ditch and Bridges convey flows under road cross-section. Energy dissipaters, used to control the velocities of flows, especially at culvert outlets. Storm drainage facilities, used to collect the runoff of the carriageway and surrounding areas and direct it to the channels [2].

2.6.1 Description of Road Drainage Structures

Two different types of drainage systems commonly used to direct water from the area surrounding the road and to evaluate extra water from the road structures. These are surface and sub-surface systems. A surface drainage system collects and diverts storm water from the road surface and adjoining areas to avoid flooding. It decreases the possibility of water infiltration into the road and retains the road bearing capacity. Appropriate design of the surface drainage system is an essential part of road design [10].

Sub-surface drainage systems drain water that has infiltrated through the pavement and the inner slope but also ground water. In ERA Low volume Roads drainage design manual the fall of 3-5% allowed on culverts to ensure that water flows without depositing silt and other debris. In flat terrain, where there is a high risk of silting, a factor of safety of two allowed in the design of the culvert. Moreover, all pipes should have a minimum diameter of 0.60m to ensure that they can be cleaned manually. It is important to install energy dissipating structures and/or armor at the outlet where scour and erosion are likely to occur. These structures are required where high exit velocity due to steep culvert installation, near proximity to channel banks, and drops at the end of the culvert. Culverts are drainage structures that have the span length of less than or equal to 6-meters otherwise it is major drainage structure [2].

Drainage structures that have span length of 6-meters and above is bridge. The sizing of minor drainage structures is of considerable economic importance, as these structures can comprise a significant cost of total road construction costs. The selection of the appropriate design flood and good practice in the design of these structures determines the initial costs, the provision of the desired level of serviceability to traffic, and the safety of the road users. With this respect, the most important parameters for the design of major and minor drainage structures are the design flood, hydraulics analysis and selection of construction materials.

2.6.2 Functions of Road Drainage Structures

Drainage structures collect, transport, and dispose of surface/sub-surface water originating on or near the roadway right of way or flowing in streams crossing bordering the right of way. It prevents erosion of the back slope by runoff from the hill above. It intercepts water, not allowing it to enter side drain that may cause greater discharge inside drains. In steep terrain, culvert capacity is usually governed by inlet control. The water depth at the entrance conditions governs the capacity of culverts subject to inlet control.

The entrance conditions include the geometry of the opening, the wing walls, head walls, the angle of wing walls & head walls and the protection of the culvert in to the headwater pond. Pipe roughness, outlet conditions including tail water level do not influence flow capacity of culverts operating under inlet control. When the culvert barrel is not capable of conveying as much flow as the inlet opening will accept the outlet control occurs [16].

2.7 Failures of Road Drainage Structures

The roadway shall not obstructs the general flow of surface water or stream water in any unreasonable manner to cause an unnecessary accumulation either of water flooding or water soaking uplands, or an unreasonable accumulation and discharge of surface water flooding or water soaking lowlands. The failure of culvert occurred on gravel road due to inadequate capacity of the culvert. If the failure is sudden and catastrophic, it can result in injury or loss of life and property. Water passing through undersized culverts will scour away the surrounding soil over time. This can cause a sudden failure during rain events. Degradation in streams can cause the loss of bridge piers in stream channels, as well as piers and abutments in caving banks.

2.7.1 Culvert Observation Activities

Culverts are major drainage structures. Culvert failure can be catastrophic, causing serious injury or death, and costly restoration or reconstruction. City and county road maintenance workers are generally not responsible for extensive culvert inspection and repair. However, as you drive over culverts in your jurisdiction or work in their vicinity, you can and should be aware of the signs of culvert stresses or other problems and report them immediately to your supervisor. Signs of potential problems could include the following: A dip in the pavement over a culvert (could indicate settlement or a structural problem).High water lines (may indicate a drainage problem). Accumulated debris and/or signs of bank erosion upstream of the channel (may indicate a drainage problem).

2.7.2 Maintenance Issues for Culverts

You may also need to perform some basic housekeeping/maintenance activities as directed by your supervisor. Culverts get clogged because debris accumulates at the culvert inlet. They become silted when the grade is too flat and the flow is restricted. To solve the debris/silt problem, conduct these maintenance activities: Stop debris upstream by using a barrier. Clean the culvert frequently, making sure debris can pass through the culvert. Steepen the culvert grade to promote self-cleaning. Scour is erosion from water in a roadway ditch or a stream channel. Scour may occur at culvert inlets if the inlet is choked with debris. Remove the debris to restore water movement. Another possibility is that the inlet capacity is simply inadequate. The makeup of the drainage area may have changed since the culverts construction. In this case, the culvert will have to be reconstructed to provide a larger opening/capacity. At outlets, scour occurs when a large volume of water is discharged at a high velocity. When scour occurs at outlets, curtain walls may be undermined. Repair the scour by backfilling the eroded area with suitable material, then placing riprap, concrete, or bituminous material to protect the outlet from further damage [17].

Fig: 2.3 scours of culvert at inlet discharge

Any drainage system is doomed to failure if it is not properly maintained. These failures can range from scoured stream banks or stream bottoms to such large failures as road washouts and damaged property adjacent to the stream. Large culverts should be inspected every two years. Maintenance should include periodic inspection to see that: The inside of the pipe is free from obstructions. Both the inlet and the outlet ends are free of debris and beaver dams has not washed away soil from below and around the culvert, creating a perched or elevated culvert end.

Fig 2.4 Road cracking due to failure of side ditch

Fig 2.5 Solid wastes filling pipe culvert and reduce the flow capacity

2.7.3 Causes of Culvert Scour

If a culvert is blocked with debris or the stream changes course, the culvert will be inadequate to handle design flows. Poor culvert location, Changes in upstream land use such as real estate development, deforestation, clearing due to settlement, inadequate design or poor construction activities of culvert, changes of slope, flow velocity, width and depth of channel and invert elevation. These entire scour causes may further result in excessive pond formation, washing out of roadway embankment and flooding of nearby properties.

2.7.4 Factors Affecting Scour at Culverts

The following factors must be considered for evaluating long-term scour at culverts:
Area of opening of the culvert, flood velocity, angle of flow, longitudinal slope, head water and tail water elevations and inverts elevation

2.7.5 Culvert Scour

Scour is the erosion or removal of streambed or bank material from bridge foundations due to flowing water .It is the most common cause of roadway bridge failures. Every bridge over water assessed as to its vulnerability to scour in order to determine the prudent measures for that bridge and the entire inventory Scour can have a long-term impact on bed degradation and affect entire channel reaches [16].

Hydraulic conditions and rates of erosion are vastly different at abutments and piers at any bridge site. Extent of erosion at abutments minimized, by placing them away from the riverbanks. Piers are located in the middle of peak flood zones, where flood velocity is the highest. The direction of flow is at right angles to the pier, which acts as an obstruction, with the water flowing on both of its sides. Hence, foundation all around a pier scoured. On the other hand, the foundation only on side exposed to the flow in case of an abutment may be scoured. Total scour at bridge footings is primarily sum of degradations and aggradations, local scour and contraction scour.

Degradation is a general and progressive (long-term) lowering of the channel bed due to erosion over a relatively long channel length. Local scour is due to increase in local flow velocities and turbulence levels because of obstruction caused by bridge piers and abutments to the water flow. Contraction scour is because of increased water velocity in the bridge opening due to decrease in cross-sectional area of waterway at the bridge crossing. Scour at a bridge crossing a river classified as general scour, contraction scour, or local scour. General scour occurs irrespective of the existence of the bridge and can occur as either long-term or short-term scour. Short-term general scour develops during a single or several closely spaced floods. Long-term general scour has a considerably longer timescale, normally of the order of several years or longer and includes progressive degradation and (lateral) bank erosion.

Degradation is the general lowering of the riverbed. Bank erosion may result from channel widening, meander migration, a change in river controls, or a sudden change in the river course. General scour is a process of streambed erosion or degradation. It is associated with the natural variations in the flow and occurs irrespective of the presence of the bridge.

Contraction scour results from general increases of the velocities where the flow is constricted during the velocity approaches the bridge opening and is characterized by a general lowering in the bed elevation due to the contracted section. Contraction scour can be further split into two types of scour viz., live bed scour, occurs when sediment transported into the bridge area scours the streambed. The other is clear water scour occurs during clear water stages and the increased flow velocities create higher shear stresses and thus scour the streambed [18].

By contrast, local scour is due to changes in the local flow pattern at the bridge, which is usually associated with three-dimensional flows and vortex systems. It is also characterized by the formation of scour holes at the base of the bridge foundation. In general, local scour is a continuous process of streambed degradation that results from turbulence of water at the floodplains and underneath the bridge. Localized scour is the combination of local and contraction scour. The types of localized scour include clear-water scour and live-bed scour. When the bed resistance upstream of the scoured area is equal to or less than the critical or threshold shear stress for the commencement of the particle motion, clear water scour occurs. The maximum scour depth in clear-water scour attained when the flow is not able to get rid of the particles from the scour hole anymore.

Live-bed scour is also known as scour with sediment transport. It occurs when general bed load is transported by the stream. Similar scour depths are achieved when the materials removed from the scour hole is equal to materials supplied to the scour hole from upstream after some time.

2.7.6 Protection Measures of Failure on Drainage Structures

According to [2] a check dam, which is a low dam or weir constructed across a channel, is one of the most successful techniques for halting degradation on small to medium streams in Ethiopia. Providing erosion protection measures at structures is significant to protect against the erosive force of turbulent flow. Gabions are used to protect bridge piers, abutments, and culvert wing walls. Longitudinal stone dikes placed at the toe of channel banks can be effective countermeasures for bank caving in degradation streams. Precautions to prevent outflanking, such as tie backs to the banks, may be necessary where installations are limited to the vicinity of highway stream crossing. In general, channel lining alone is not a successful countermeasure against degradation problems [2].

Current measures in use to alleviate aggradations problems at roadways include channelization, bridge modification, continued maintenance, or any combination of these channelization may include excavating and cleaning channels, constructing cutoffs to increase the local slope, constructing flow control structures to reduce and control the local channel width, and constructing relief channels to improve the capacity at the crossing.

Except for relief channels, these measures are intended to increase the sediment transport capacity of the channel, thus reducing or eliminating problems with aggradations [2].
Culvert drainage structures shall be adequate to avoid hazardous flooding and failures of road or embankment structures. Poorly designed culverts are also more appropriate to become jammed with sediment and debris during medium to large-scale rain events. This can cause the road to fail, often introducing a large amount of fine sediment that can clog other structures downstream and also damage crops and property.

Hard bank armoring and a proper sized structure can help to alleviate this pressure. Providing scour protections are important at both inlet and outlet for all culverts to protect the structure from damage. Providing rock armor is significant protection measure of scour for inlets and outlets of culverts. Moreover, headwalls and end walls utilized to control erosion and scour, to anchor the culvert against lateral pressures, and to ensure bank stability.

Constructing all headwalls from reinforced concrete material is significant and may be straight and parallel to the channel, however, flared or warped, with or without aprons is possible when the site and hydraulic conditions permit. To prevent the possible piping failure, cement stabilized fill can be used to form the culvert invert bedding for a suitable length.

2.8 Erosion Hazards at Culvert Inlets and Outlets

2.8.1 Erosion Hazards at Culvert Inlets

Erosion hazard may exist if a defined approach channel aligned with the culvert axis. Aligning the culvert with the approach channel axis will minimize erosion at the culvert inlet. When aligning the culvert with the channel neglected and modification of channel carried out to bend into the culvert, erosion can occur at the bend in the channel. Riprap or other revetment needed to protect the hazard of erosion. At design discharge, water will normally pond at the culvert inlet and flow from this pool will accelerate over a relatively short distance. Significant increases in velocity only extend upstream from the culvert inlet at a distance equal to the height of the culvert.

Velocity near the inlet is approximated by dividing the flow rate by the area of the culvert opening. The risk of channel erosion should be judged based on this average approach velocity. The protection provided should be adequate for flow rates that are less than the maximum design rate. Since depth of poundage at the inlet is less for smaller discharges, greater velocities may occur. This is especially true in channels with steep slopes where high velocity flow prevails.

Culvert inverts are sometimes placed below existing channel grades to increase culvert capacity or to meet minimum cover requirements [19]. The advantages of providing a depression or fall at the culvert entrance are to increase culvert capacity. However, the depression may result in progressive degradation of the upstream channel unless resistant natural materials or channel protection is provided. Caution must be exercised in attempting to gain the advantages of a lowered inlet where placement of the outlet flow line below the channel would also be required. Locating the entire culvert flow line below channel grade may result in deposition problems. Recessing the culvert into the fill slope and retaining the fill by either a headwall parallel to the roadway or by a short headwall and wing walls does not produce significant erosion problems. This type of design decreases the culvert length and enhances the appearance of the roadway by providing culvert ends that conform to the embankment slopes.

A vertical headwall parallel to the embankment shoulder line and without wing walls should have sufficient length so that the embankment at the headwall ends remain clear of the culvert opening. Normally riprap protection of this location is not necessary if the slopes sufficiently flat to remain stable when wet. Wing walls flared with respect to the culvert axis are commonly used and are more efficient than parallel wing walls. The effects of various wing wall placements upon culvert capacity are discussed in [19]. Use of a minimum practical wing wall flare has the advantage of reducing the inlet area requiring protection against erosion. Most inlet failures reported have occurred on large, flexible-type pipe culverts with projected or mitered entrances without headwalls or other entrance protection.

When soils adjacent to the inlet are eroded or become saturated, pipe inlets can be subjected to buoyant forces. Lodged drift and constricted flow conditions at culvert entrances cause buoyant and hydrostatic pressures on the culvert inlet edges that, while difficult to predict, have significant effect on the stability of culvert entrance.

2.8.2 Erosion Hazards at Culvert Outlets

Erosion at culvert outlets is a common condition. Determination of the local scour potential and channel erosion should be standard procedure in the design of all highway culverts. Culvert outlet velocity is the primary indicator of erosion potential. Local scour is the result of high-velocity flow at the culvert outlet, but its effect extends only a limited distance downstream as the velocity transitions to outlet channel conditions.

Natural channel velocities are usually less than culvert outlet velocities because the channel cross-section, including its flood plain, is generally larger than the culvert flow area. Thus, the flow rapidly adjusts to a pattern controlled by the channel characteristics. Long, smooth-barrel culverts on steep slopes will produce the highest velocities. These cases will require protection of the outlet channel at most sites without any doubt. However, protection is also often required for culverts on mild slopes. For these culverts flowing full, the outlet velocity will be critical velocity with low tail-water and the full barrel velocity for high tail-water. Where the discharge leaves the barrel at critical depth, the velocity will usually be in the range of 3 to 6 m/s [29].

A common mitigation measure for small culverts is to provide at least minimum protection and then inspect the outlet channel after major storms to determine if the protection must be increased or extended. Under this procedure, the initial protection against channel erosion Natural channel velocities are usually less than culvert outlet velocities because the channel cross-section, including its flood plain, is generally larger than the culvert flow area. Thus, the flow rapidly adjusts to a pattern controlled by the channel characteristics. Long, smooth-barrel culverts on steep slopes will produce the highest velocities. These cases will require protection of the outlet channel at most sites without any doubt.

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A common mitigation measure for small culverts is to provide at least minimum protection and then inspect the outlet channel after major storms to determine if the protection must be increasedor extended. Under this procedure, the initial protection against channel erosion should be sufficient to provide some assurance that extensive damage could not result from one runoff event. Culverts are generally constructed at crossings of small streams, many of which are eroding to reduce their slopes. This channel erosion or degradation proceeds in a uniform manner over a long length of stream or it may occur abruptly with drops progressing upstream with every runoff event. Information regarding the degree of instability of the outlet channel is an essential part of the culvert site investigation. If substantial doubt exists as to the long-term stability of the channel, measures for protection should be included in the initial construction [29].

Standard practice is to use the same end treatment at the culvert entrance and exit. However, the inlet is designed to improve culvert capacity or reduce head loss while the outlet structure should provide a smooth flow transition back to the natural channel or into an energy dissipater [29]. Outlet transitions should provide uniform redistribution or spreading of the flow without excessive separation and turbulence. Therefore, it may not be possible to satisfy both inlet and outlet requirements with the same end treatment or design.

2.9 Land Use of Sebeta City

Land use planning is one of the most important planning tool for provision of municipal infrastructure and other facilities. It also helps for reducing urban problems and managing built up areas. Land in urban centers is an important element for urban drainage planning. From the total area of the town that covers 9827.14 ha, residence receives the lion share counting 43%, followed by green area and industry that covers 29% and 11% respectively. The remaining 17% of land has been allocated for five land use categories as presented in the Table 2.2.

Table 2.2: Sebeta land use categories

Land use of Sebeta town	**Land use category**	**Area (ha)**	**Percent**
1	Residence	4,219.59	42.94
2	Commerce	259.66	2.64
3	Administration	296.31	3.02
4	Industry	1,117.35	11.37
5	Infrastructure	202.06	2.06
6	Service	643.28	6.55
7	Urban agriculture	238.66	2.43
8	Green area	2,850.23	29.00
Total		9,827.14	100

Source: [25]

2.10 Hydrological Analysis

A hydrologic analysis is prerequisite to identifying flood hazard areas and determining those locations where construction and maintenance will be unusually expensive or hazardous. The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to the design of drainage system. Errors in the estimates will result in a structure that is either undersized and causes more drainage problems or oversized and costs more than necessary. On the other hand, it must be realized that any hydrologic analysis is only an approximation. The relationship between the amount of precipitation on a drainage basin and the amount of runoff from the basin is complex, and too little data are available on the factors influencing the rural and urban rainfall-runoff relationship to expect exact solutions.

According to [2], the rainfall regions is classified in to four major rainfall regions and eight sub-rainfall regions in the country and developed IDF curves. To compare the developed IDF curve with generated IDF curve of the study area local rainfall data are required. The already developed regionalized IDF curve by [2], is used to determine rainfall intensity. It developed four IDF curves for rainfall regions in the country. The developed curves are for A1&A4, A2&A3, B, C &D. The study area lies on sub-region A2 and the IDF curve was constructed for B, C and D rainfall regions together. Therefore, I will use the rainfall intensity from the IDF curve for the corresponding return period.

2.10.1 Hydrological Equations for Determining Peak Flood

In the design of drainage facilities, the basic computation is the determination of runoff. This can be done by either of two methods: the Rational Method or the SCS (Soil Conservation Service) method. In most cases rational and soil conservation service, (SCS) methods of flood estimation are applied for minor drainage structures due to unavailability of gauged data.

2.10.2 Rational Method

Rational formula method is recommended to determine the peak discharge, or runoff rate, from drainage areas up to 0.5km2. If a hydrograph is required to consider the effects of storage, use the Modified Soil Cover Complex method, or a similar method. Among a number of methods for estimating a design discharge, the rational formula is an empirical formula relating runoff to rainfall intensity. According to [2], the rational formula is most accurate for estimating the design peak runoff for small catchment areas of up to (0.5km2).

Actual runoff is far more complicated than the values that are calculated by rational formula. Rainfall intensity is seldom the same over an area of appreciable size or for any substantial length of time during the same storm. Even if a uniform intensity of rainfall of duration equal to the time of concentration that occurs on all parts of the drainage area, the rate of runoff would vary in different parts of the area because of differences in the characteristics of the land surface and the non-uniformity of antecedent conditions. However, for this thesis, the same characteristics of the land surface and uniform antecedent conditions are considered. Under some conditions, maximum rate of runoff occurs before all of the drainage areas are contributing.

Temporary storage of storm water routing toward defined channels and within the channels themselves accounts considerable reduction in the peak rate of flow except on very small areas. Due to these facts, for this thesis the rational method is not used to determine the rate of runoff for large drainage areas. For the design of highway drainage structures, the use of the rational method should be restricted to drainage areas up to 0.5km2 in Ethiopia. Hence, for this thesis the maximum value of the catchment area, 0.5km2, is considered.

Equations

The rational formula estimates the peak rate of runoff at any location in a catchment area as a function of the catchment area, runoff coefficient and means rainfall intensity for duration equal to the time of concentration (the time required for water to flow from the most remote point of the basin to the location being analyzed).

The basic assumptions in rational method to determine peak flood are:

1. The peak rate of runoff at any point is a direct function of the average rainfall intensity for the time of concentration to that point.
2. The recurrence interval of the peak discharge is the same as the recurrence interval of the average rainfall intensity.
3. The time of concentration is the time required for the runoff established and flow from the most distant point of the drainage area to the point of discharge.

The main reason that is required to limit the use of rational method for small watersheds pertains to the assumption that rainfall is constant throughout the entire watershed. Severe storms, say a 10-year return period, generally cover a very small area. Applying the high intensity corresponding to a 10-year storm to the entire watershed could produce greatly exaggerated flows, as only a fraction of the area may be experiencing such intensity at any given time.

The variability of the runoff coefficient also favors the application of the rational method to small and developed watersheds.

The procedures in rational method to determine peak flood are:

1. Obtain the necessary information for each sub area:
   - i) Drainage area
   - ii) Land use
   - iii) Soil types (highly permeable or impermeable)
   - iv) Distance from the farthest point of the drainage area to the point of discharge
   - v) Difference in elevation from the farthest point of the drainage area to the point of discharge

2. Determine the time of concentration for the selected recurrence interval with duration equal to the time of concentration
3. Determine the rainfall intensity for the selected recurrence intervals
4. Select the appropriate runoff coefficient
5. Compute the design flow (Q= 0.00278CIA)

The rational formula is expressed as: Q =0.00278CIA
Where,

Q= Peak flow in cubic meter per second (m3/sec)
C= Dimensionless weighted runoff coefficient
I= Rainfall intensity in millimeters per hour (mm/hr.)
A= Drainage area in hectares (ha)
Cw= (A1C1 + A2C2 +---+ AnCn) / (A1 + A2 +--- An) (3.2)
Cw=Weighted Runoff Coefficient
C1, C2, --------Cn= coefficient of runoff for parts of the drainage area.
A1, A2, ------, An= parts of drainage areas with different runoff coefficients.

2.10.3 Runoff Coefficient

The runoff coefficient (C) is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the designer. A typical coefficient represents the integrated effects of many drainage basin parameters

The most common definition of a runoff coefficient is the ratio of the peak rate of direct runoff to the average intensity of rainfall in a storm [2]. The runoff coefficient is a dimensionless ratio intended to indicate the amount of runoff generated by a watershed given an average intensity of precipitation for a storm. While it is implied by the rational method, intensity of runoff is proportional to intensity of rainfall; calibration of the runoff coefficient has usually depended on comparing the total depth of runoff with the total depth of precipitation. The runoff coefficient accounts for the effects of infiltration, detention storage, surface retention, evapotranspiration, surface retention, flow routing and interception. The product of runoff coefficient and rainfall intensity is the rainfall excess of runoff per hectare. The runoff coefficient should be weighted to reflect the different conditions that exist within a watershed.

2.10.4 Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate in mm/h r for duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the catchment area, the rainfall intensity can be determined from Rainfall-Intensity-Duration curves. Rainfall intensity is a function of geographic location, design exceedence frequency (or return interval), and storm duration. It is true that the greater the return interval (hence, the lower the expedience frequency), the greater the precipitation intensity for a given storm duration. Furthermore, as storm duration increases average precipitation intensity decreases.

The relation between storm duration, storm intensity, and storm return interval, is represented by a family of curves called the intensity-duration-frequency curves, or IDF curves. Quantification of rainfall is generally carried out using is pluvial (Return Period) maps and intensity-duration-frequency (IDF) curves [21]. The IDF relationship is a mathematical relationship between the rainfall intensity, the duration, and the return period (the annual frequency of exceedance).

2.10.5 Runoff and Curve Numbers

The physical catchment area characteristics affecting the relationship between rainfall and runoff (i.e. the CN values) are land use, land treatment, soil types, and land slope.

Land use is the catchment area cover and it includes agricultural characteristics, type of vegetation, water surfaces, roads and roofs. Land treatment applies mainly to agricultural land use, and it includes mechanical practices such as contouring or terracing and management practices such as rotation of crops. The SCS method uses a combination of soil conditions and land-use to assign a runoff factor (curve number) to an area. These runoff factors or curve numbers (CN), indicate the runoff potential of an area. The higher the CN, the higher is the runoff potential.

2.10.6 Hydrological Soil Groups

Soils are classified into hydrologic soil groups (HSGs) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSGs are A, B, C and D.

Group A the soils have high infiltration rates and have low runoff potential even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 7.62mm/hr). These soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam or silt loam textures can be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments [22].

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (3.81mm/hr-7.62mm/hr). Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures can be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments [22].

Group C These soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine-to-fine texture. These soils have a low rate of water transmission (1.27mm/hr to3.81mm/hr). These soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments [22].

Group D soils have high runoff potential and very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-1.27mm/hr). Water movement through the soil is restricted. Soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential [22].

2.10.7 Time of Concentration

The time of concentration is the time required for water to flow from the hydraulically most remote point of the catchment area to the point under investigation. Use of the Rational Method requires the time of concentration (t_c) for each design point within the catchment area. The duration of rainfall is then set equal to the time of concentration and is used to estimate the design average rainfall intensity (I). For a specific drainage basin, the time of concentration consists of an inlet time plus the time of flow in a closed conduit or open channel to the design point.

Inlet time is the time required for runoff to flow over the surface to the nearest inlet and is primarily a function of the length of overland flow, the slope of the drainage basin, and surface cover. Pipe or open channel flow time can be estimated from the hydraulic properties of the conduit or channel. An alternative way to estimate the overland flow time is to use Figure 5-2 to estimate overland flow velocity and divide the velocity into the overland travel distance. For design conditions that do not involve complex drainage conditions, Figure 5-3 can be used to estimate inlet time. For each catchment area, the distance is determined from the inlet to the most remote point in the tributary area [2].

To obtain the total time of concentration, the pipe or open channel flow time must be calculated and added to the inlet time. After first determining the average flow velocity in the pipe or channel, the travel time is obtained by dividing velocity into the pipe or channel length. Manning's Equation can be used to determine velocity [2].

The time of concentration is the sum of Tt values for the various consecutive flow segments:Tc = Tt1 + Tt2 + … Ttm

Where:

Tc = time of concentration, hr

m = number of flow segments

2.10.8 Travel Time

Travel time (T_t) is the time it takes water to travel from one location to another in a catchment area. T_t is a component of time of concentration (T_c), which is the time for runoff to travel from the hydraulically most distant point of the catchment area to a point of interest within the catchment area. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

Following is a discussion of procedures and equations for calculating travel time and time of concentration.

Travel time is the ratio of flow length to flow velocity:

Tt = L/(3600V)

Where:

Tt = travel time, hr

L = flow length, m

V = average velocity, m/s

3600 = conversion factor from seconds to hours.

2.11 Hydraulic Equations

Discharge is determined for a known opening size of the drainage structure and bottom slope and/or the size of the drainage structure is determined for a known discharge and bottom slope by trial and error method. The Manning's equation can be used for uniform flow in a pipe, and stream channel, but the Manning's roughness coefficient needs to be considered variable, dependent upon the depth of flow. The Manning's equation is used for calculating the cross-sectional area, wetted perimeter, and hydraulic radius for flow of a specified depth in a pipe of known diameter and/or stream channel cross-section.

Manning's equation is applicable for a constant flow rate of water through a channel with constant slope, size & shape, and roughness. Roughness coefficients represent the resistance to flood flows in channels and flood plains [2]. In addition as per [2] guide for selecting manning's roughness coefficients for natural channels and flood plains. Roughness values for flood plains can be quite different from values for channels; therefore, roughness values for flood plains should be determined independently from channel values. For this research, the Manning's roughness coefficients will be used for different materials.

For a given depth of flow in a channel with a steady, uniform flow, the mean velocity, V, can be computed with Manning's equation:

$V = (1/n)\, R^{2/3} S^{1/2}$
Where
V = velocity, m/s
n = Manning's roughness coefficient
R = hydraulic radius = A/P, m
P = wetted perimeter, m
S = slope of the energy grade line, m/m (note: for steady uniform flow,
S = channel slope, m/m)

The selection of Manning's 'n' is generally based on observation; however, considerable experience is essential in selecting appropriate 'n' values. The range of 'n' values for various types of channels and floodplains is given in. n from table

For a given channel geometry, slope, and roughness, and a specified value of discharge Q, a unique value of depth occurs in steady uniform flow. It is called the normal depth. The normal depth is used to design artificial channels in steady, uniform flow and is computed from Manning's Equation:

Formula of peak discharge (Q)

Q = (1/n) AR2/3S1/2

Where:

Q	=	discharge, m3/s
n	=	Manning's roughness coefficient
A	=	cross-sectional area of flow, m2
R	=	hydraulic radius = A/P, m
P	=	wetted perimeter, m

If the normal depth computed from Manning's Equation is greater than critical depth, the slope is classified as a mild slope. Conversely, if the normal depth is less than critical depth, the slope is a steep slope. Thus, uniform flow is subcritical on a mild slope and supercritical on a steep slope.

2.12 Rating of existing drainage structure

The existing drainage systems in the selected sites were rated based on the rating system developed by [12]. This rating system consists of four rating categories: excellent, good, fair, and poor. The ratings are based on the general condition, typical defects, and the recommended improvements as illustrated in Table 2.3.

Table 2.3: Rating System for Roadway Drainage

Rating	Condition	Improvement
Excellent	Wide adequate ditches or like-new curb, gutter and storm sewer system. All culverts clean and sound. Overall, pavement and shoulder have adequate crown, ditching or storm sewer on the majority of the section.	No improvement necessary
Good	May need localized cleaning of ditches, storm sewer and culverts, minor repairs to curbs, inlets and culverts. No drainage-related pavement damage.	Minor or localized repairs
Fair	Minimal crown on pavement. Some areas need shoulder slope improvement. Ditching improvement or cleaning needed on up to 50% of ditches. Pavement distress from localized flooding or ponding indicates improvements are needed in some storm sewer, inlets or ditching. Some culverts need cleaning or minor repairs	Several improvements necessary
Poor	No pavement crown, Shoulders create secondary ditch. Frequent ponding. Significant ditching improvements needed on more 50% of the roadway. Frequent localized flooding or erosion with pavement distress or failure. Significant improvement in storm sewer, curb or inlets and/or major culvert replacement or improvement	Major improvement in drainage required

2.13 Requirements to Construct Drainage Structures

A complete drainage system design includes consideration of both major and minor drainage systems. The minor system, sometimes referred to as the "Convenience" system, consists of the components that historically considered as part of the "storm drainage system". These components include curbs, gutters, ditches, inlets, access holes, pipes and other conduits, open channels, detention basins, and water quality control facilities [23].

The culvert skew shall not exceed 45 degree as measured from a line perpendicular to the roadway centerline. Culvert skews should be constructible with standard designs of 150, 300 and 450 skew .Culvert skews are not advisable unless conditions do not permit to install culverts normal to the natural streambed. Sharp changes in the direction of flows to force shorter culvert crossings are prone to scouring. The eroded material has potential to block the culvert opening. Sharp and small radius bends also reduce the hydraulic efficiency of a channel [24]. Installing culverts without wing walls and head walls will decrease the hydraulic efficiency of the culvert. As a result, scouring and potential of diversion of water will be created.

2.14 Design Consideration

Properly designed, installed, and maintained culvert pipe will provide satisfactory performance for many years. However, inattention to any one of these conditions can result in failure. The need to replace a culvert may result from a variety of factors: inadequate pipe capacity, structural failure due to excessive soil loading ,washout due to water overtopping the road, end scouring from poor end treatment, improper jointing resulting in water piping along the outside of the pipe, erosion due to excessive water transport of sand and gravel, corrosion from acid or salt laden soils and water, improper end walls resulting in embankment failures, poor installation and/or bedding condition resulting in settling, joint separation, or structural failure of the pipe. Faster release of runoff upstream can cause flooding at downstream culverts if they are too small. This situation is often encountered when residential, commercial, institutional, or industrial development makes it necessary to replace existing culverts.

CHAPTER THREE

3 METHODS AND MATERIALS

3.1 Description of the study area

Sebeta City is one of the urban centers in Oromia special zone surrounding Addis Ababa situated at about 24km on the south western direction of the capital city of Ethiopia along Addis-Jimma road. The area is dominated by different chains of mountains including Wochocha, Mogle, and Furi Mountains.

Geographically, Sebeta City is located within an approximate geographical coordinates of 8053’38.50’’N_8059’58.17’’N latitude and 38035’11.91’’E_38039’33.75’’E longitude on the globe and its average elevation is 2365 meters above sea level [30]. With regard to relative location, it shares common boundaries with Addis Ababa in the North, North east and east, Burayu City in the North and rural villages of Sebeta Awas (Figure-3.1).

According to the previous structure plan of the City, the total administrative area of the City was 9,900 hectares[30]. The City plan currently under revision has proposed the total administrative area of the City to be 17,500 hectares. Thus, the administrative area of the City has increased by 7,600 hectares or 76.77percent from the previous total administrative area of the City for the coming ten years of planning period. Climate of the area is classified under woinadega (sub-tropical) zone that has the same general characteristics of climatology as that of Addis Ababa. Globally it is a part of tropical humid climatic region, which is characterized by warm temperature and high district in the south and western directions.

Currently the City is administratively subdivided into nine local administrative kebeles as 01 kebele (Sebeta), 02 kebele(Alemgena), 03 kebele (Woletie), 04 kebele (Furi), 05 kebele (Dima), 06 kebele (Daleti),07 kebele (Sebeta 2), 08 kebele (Kerabu) and 09 kebele (Furi Gara Bollo). Among these kebeles the study Was conducted in 02 kebele(Alemgena), o4 kebele (Furi), and 08 kebele (Kerabu) .

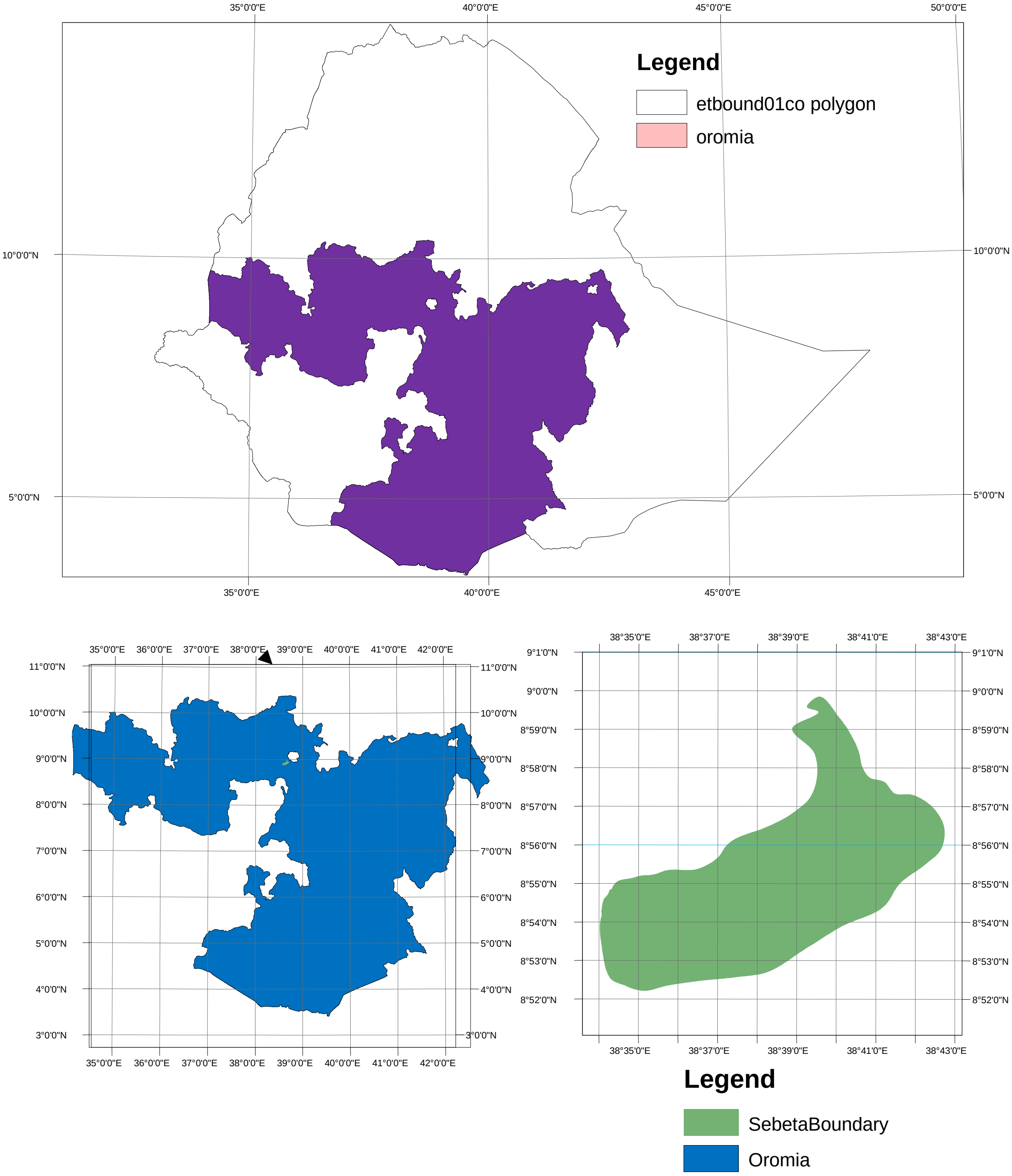

Fig. 3.1 Location Map of the Study Area

3.2 Study variables

3.2.1 Dependent and independent variables

Dependent variable refers to performance evaluation of existing road drainage structures where as independent variable refers to peak discharge, design parameters, topography features.

3.2.2 Materials

The materials and tools used for this research are:-

- Arc-GIS to obtain hydrological and physical parameters and spatial information of the catchments of the study area.
- DEM data data is used as an input data for Arc-GIS, Glober mappar software for catchment delineation and estimation of catchment characteristic.
- Digital camera,
- GPS device, and
- measuring tape
- Surveying instruments of leveling

3.3 Research Design

Research design is defined as a plan of a research specifying what is to be done and how to do it [26]**.** It involves the structuring and organizing of all procedures of data collection, analysis, reporting in qualitative and quantitative research. To answer the research questions a descriptive survey design utilizing both quantitative and qualitative methods was employed. A quantitative approach usually uses research instruments, such as questionnaires, to collect, interpret, and analyzes data statistically. It also involves the frequency of an event or number of respondents to a particular phenomenon. Fundamentally, in the qualitative methods, the interviews and document analysis techniques were used to collect data.

Research survey was employed in order to obtain information that would describe the current state of drainage structure in Sebeta town road and how poor drainage structure has affected road users during the rainy seasons and theresidents 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, road users and residents living in the affected areas of Sebeta town. For the purposes of achieving the objectives of the study therefore, a case study design was adopted where survey research was used.

3.4 Sample Size Determination and Sampling Technique

Purposive sampling was the sampling technique which was employed in this research study, this is to mean: Because of financial constraints of the 9kebeles in the city, this study was conducted onlyin 02 kebele(Alemgena), o4 kebele (Furi), and 08 kebele (Kerabu).

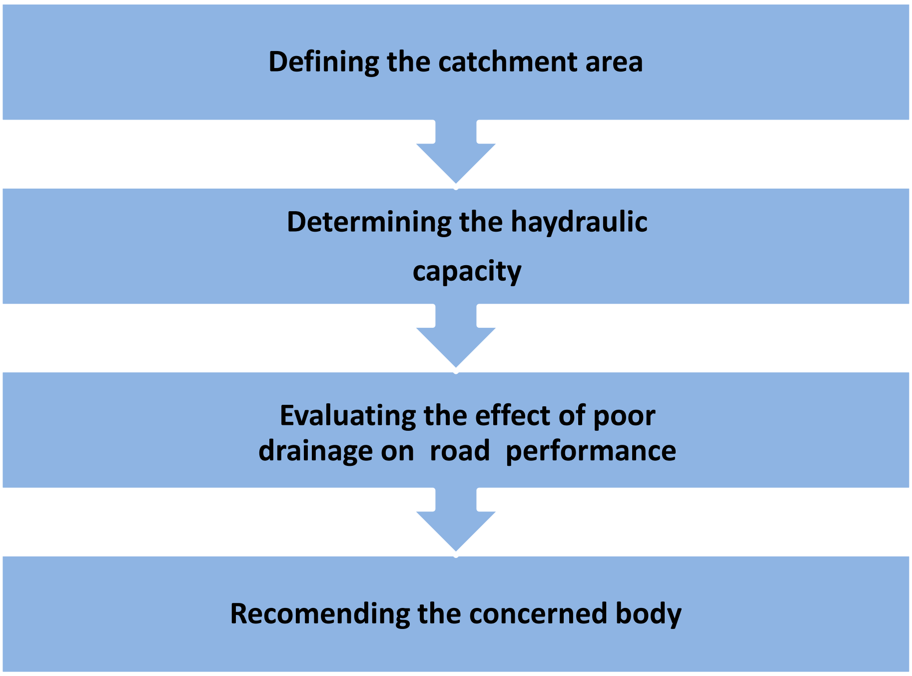

Fig: 3.2 procedures of determining hydraulic capacity and evaluating the performance of existing drainage structures

3.5 Data collection process

To conduct the research both quantitative and qualitative data types are used. In this study both primary and secondary data source was used.

3.5.1 Primary data source

In primary Data the Questionnaire is asking the Engineers and people living around the study area and interviews were asked to get more information and to clarify the ambiguous response. The study area information was gathered from the residents and road users.

Questionnaire type one

Type one questionnaire was structured to be filled by government bodies in charge of construction and maintenance of drainage systems in highways, in particular Sebeta city Engineers.

The main objective of this questionnaire is to know the responsibilities, and challenges experienced by the bodies mandated to construct and maintain the road. In addition, it sought to understand the role of the Government body and surrounding people in the drainage system provision in road.

Questionnaire type two

This type of questionnaire was structured to be filled by road users and the people who live adjacent to the Sebeta town 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 problem of drainage structures has affected the lives of the people residing in the environment and how activities have changed because of drainage. This will help in understanding how the problems drainage structure has affected the road users and to obtain their views on the way forward.

Site visit / observations: site visit was carried out to ascertain current conditions poor drainage system in Sebeta city road in comparison with the acceptable standards (ERA manual). The research employed use a physical observation, which was filled through observations and a digital camera was used to take photographs of the current state of the road and the drainage structures. The inspection process was accompanied by representative photographs to aid in the evaluation process. The field visits have been conducted during normal weather conditions as well as during the intense rain events, as Sebeta town is known for its heavy summer and intense rainfall events compared to other town in Ethiopia.

Photography

Photography is an indirect way of data collection. It was majorly used to capture the current status of the drainage system in Sebeta town 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 structures.

3.5.2 Secondary data source

The research were conducted first by identification of the causes of road drainage problems through literature review and desk study on selected road drainage problem on the study area The Secondary data were collected from different written documents, topographical maps, published and unpublished data and internets. Topographical maps of 1:50,000 for catchment characteristics (area, slope, etc.) determination, soil, and land use/land cover map of 1:2,000,000 for determination of soil and land cover of the catchment for flood estimation, geological maps of1:2,000,000 to determine geological formation that influence flood and channel characteristics are secondary data.

Sebeta meteorological station is third station which means only records daily rainfall, maximum and minimum temperature. Rainfall intensity which is important for analysis peak discharge is not recorded because no instrument called hyetograph .The main choice is using the IDF curve developed by [2].

The sources of the secondary data were the following institutions:

- Town administration/Sebeta municipality
- Kebele administration offices
- Community lives in Sebeta
- Road users and Engineers in city administration

3.6 Data Processing and Analysis

Collected data checked and analyzed using Software like Arc-GIS, Google earth, Global mapper, MS excel, Digital camera, GPS device, measuring tape and Surveying instruments of leveling. In addition to this Microsoft office software will be used. The drainage structure data were collected from Sebeta town roads and analyzed by tables and graphics. Analyses, the following factors shall be evaluated and included if they have a significant effect on the final results: Drainage basin characteristics including size, shape, slope, land use, geology, soil type, surface infiltration, and storage; Stream channel and flood plain characteristics including geometry and configuration, natural and artificial controls, channel modification, aggradations and debris.

Meteorological characteristics including precipitation amounts and type, storm cell size and distribution characteristics. It also includes storm direction, and time rate of precipitation (hyetograph).These parameters can be obtained from long-term climatic data, hydrological data, and geological data, soils, land use/land cover maps prepared at medium and large scales for general purposes and hydrographic and topographic survey and geotechnical investigations along the road route.

The hydrologic methods approved by [2] and limitations on their use follows. The rational method for drainage areas less than 50 hectares (0.5 $kilometer^2$); The main reason that I used these manuals as the lead documents is, in our country these manuals are guidelines and best of all materials regarding drainage system design and performance evaluation of drainage structures.

CHAPTER FOUR

4 RESULTS AND DISCUSSION

4.1 Existing Condition of drainage structures

The existing condition and coverage of Road infrastructure have been fully surveyed and studied in the three sample kebeles to study whether the Road infrastructure in the study area are in a good performance or not, because Roads adequately integrated with storm water drains have a good performance with longer service life than those without storm water drains. The bases as well as surface degradation of roads will get down when there is a proper integration between road and urban storm water drains. Existing drainage structures are generally classified ditches, culverts and bridges. Ditch drainage lines are found in some areas especially along main roads. Drainage channels, constructed by masonry are found along sub-mains and local roads. Regarding dimensions of existing drainage structures, concrete pipes culverts 100cmdia and that of masonry open channels vary depending on the need and design of each channel.

According to [3], the bed slope of drainage structure was determined above 2% to drain the water properly from the drainage structure types but it depends on the topography of the earth. The types of existing drainages in the town are trapezoidal and rectangular which was constructed from concrete and masonry. For the trapezoidal parts of drainage structure which had a problem to drain water properly, The major road in Sebeta town had showed the problem of asphalt cross fall slopes while considering cross section property of standard specification. According to [2], the minimum slope of normal cross fall is 3% in order to dispose water from the roadway properly and that avoids infiltration of water into the roadways.

Questionnaires were administered to the engineers from Sebetacity. Another questionnaire was given to the residents of the area adjacent to Sebeta city 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. Total 29 questionnaires were prepared and distributed to the respondents. out of questionnaires distributed 29(100%) were filled and returned appropriately. Based on the responses obtained from respondents the analysis and interpretation of data are presented. The population, sample size and sample technique for questionnaire data collection methods are shown in Table 4.1.

Table 4.1: Response rate

Respondent	Population	Sample	Percentage of inadequate structure			State of drainage structure			Level of satisfaction			Improvement activity		Sampling technique
			Total	Inade-quate	Adeq-uate	Good	Fair	Poor	Satis-fied	Dissati-sfied	Extre-melyDis sati-sfied	Yes	No	
Engineers	3	3	100	75	25	5	10	85	5	40	55	85	15	Whole pop.
Road user	20	16	80	80	20	2	8	90	6	41	53	90	10	Purposive
Residents	16	12	75	75	25	4	8	88	10	40	50	88	12	Purposive
Total	39	31	79											

4.1.1 Appropriateness of the drainage structure

The engineers‟ from Sebeta indicated that the drainage structure provided for Sebeta city road was inadequate and lack of serviceable. 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 construction and totally no clearance of ditches and culverts which is fully by grass,solid waste andgarbage. As part of understanding the background of the poor drainage structure provisions in the Sebetacity roads, this study sought to find out from the engineers the percentage of roads that lacked adequate drainage structure.All Engineers are responses as about 75%-100% are inadequate drainage structure(see Figure 4.1).

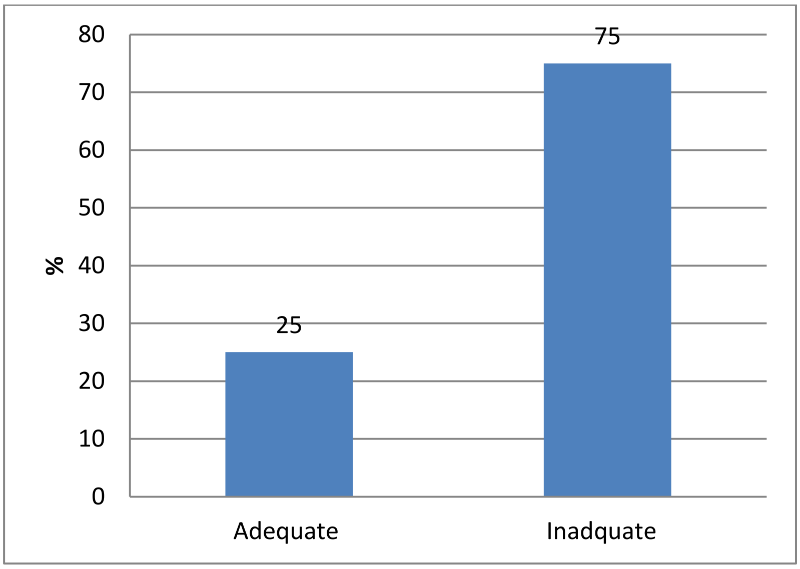

Figure 4.1Percentage of inadequate road drainage structure

Most of the respondents are responses drainage structures are poor. Based on respondent survey data, maximum of responses (approximately (90%) had responded for poor condition of drain and about 8% of the respondents for fair category in the areas of flood occurred during rainy season in the town. Only 2% thinks the drainage system provided good in Sebeta city roads (see Figure 4.2).

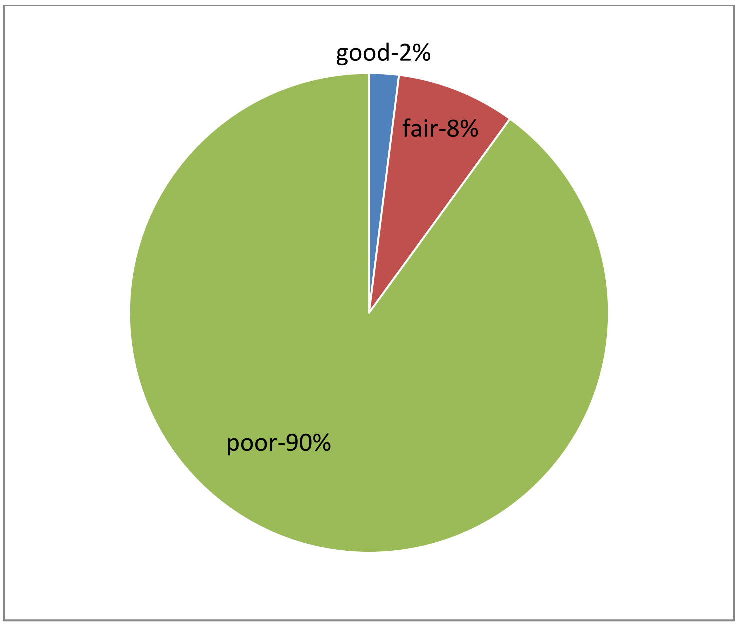

Figure 4.2: State of the drainage structure in Sebeta city road

The data shows that there have been ongoing activities geared towards the improvement of the drainage system. A greater percentage of the respondents haven't observed improvement activities on the road, however, there is also a significant percentage that have 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 (see Figure 4.3).

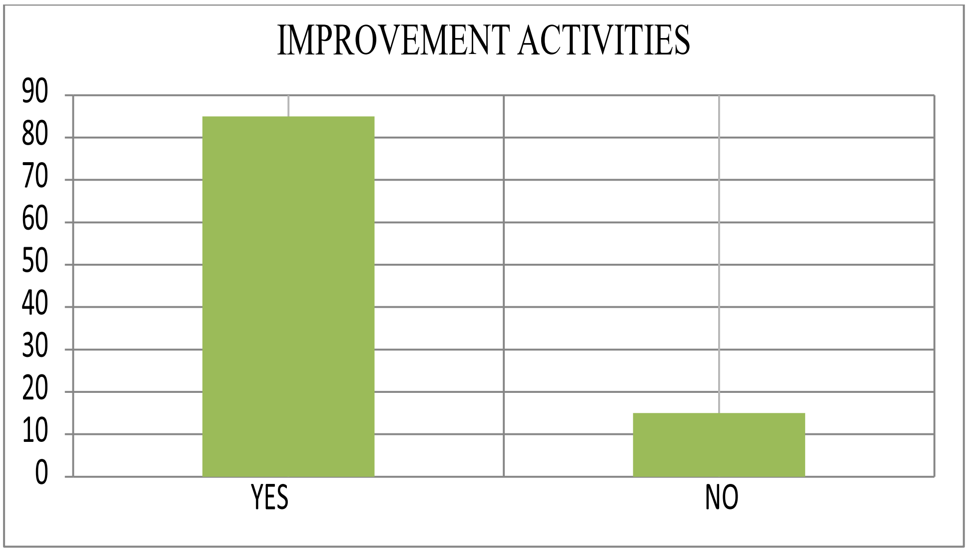

Figure4.3 Improvement activities

Road users and residents are extremely dissatisfied (see Figure 4.4).

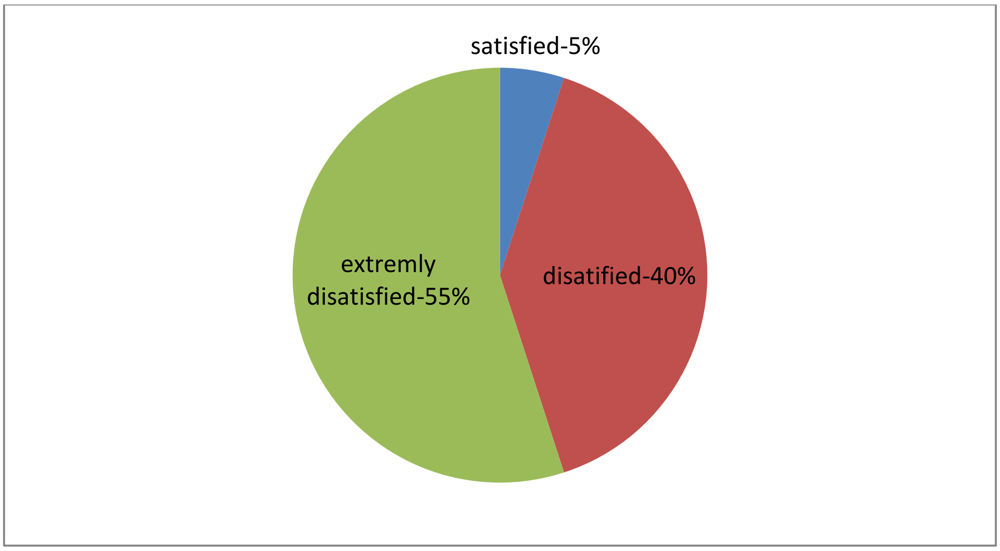

Figure 4.4Level of road user satisfaction

4.1.2 Rating and Evaluation of Road Drainage structure of existing Condition

Based on the field inspection conducted during the period of this research, inventories of the drainage systems in the streets of each site and their conditions are prepared.

The rating system for roadway drainage according to[12] is presented in Table 4.2.

Table 4.2: Drainage structure rating at different streets

Street Name	Type of road	Existing drainage Components	Rate
Railway to Alamu Borana Hotel	major	Culverts and ditches	Non function
Marga Bldng to Was	major	Culvert and ditch	Poor
Was to Nock	Major	Box culvert, no ditch	function
Nock to Dosha Clinic	major	ditch and culvert	Poor
Dosha Clinic to Jemo2	major	Culvert and ditch	Poor

From field inspection almost all drainage structure are poor. According to source [10]Poor indicates; no pavement crown, shoulders create secondary ditch, frequent ponding, significant ditching improvements needed on more 50% of the roadway. Frequent localized flooding or erosion with pavement distress or failure. Significant improvement in storm sewer, curb or inlets and/or major culvert replacement or improvement.

Fair indicates; Minimal crown on pavement. Some areas need shoulder slope improvement. Ditching improvement or cleaning needed on up to 50% of ditches. Pavement distress from localized flooding or ponding indicates improvements are needed in some storm sewer, inlets or ditching. Some culverts need cleaning or minor repairs.

4.1.3 Results from observation and photography

This research 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 Sebeta 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 structure in city road is poor. The main challenges of the current drainage structures are: drainage structures are not well constructed, drainage systems are do not have the capacity to carry large amounts of water, hence resulting in overflowing, ponds or other spaces are not properly allocated to accommodate overflow of flooding; most ditches do not have proper slope to let water pass through them, in some areas there are no drainage structure provided at all, some of existing drainage ditches have been silted by sand and other rubbish materials

Fig 4.5 Existing Road Drainage Structures Problem at Furi Area

Figure 4.6 inadequate road drainage (over flow) around Kenteri/ Alemgane

Figure 4.7Solid waste dumped in to drainage ditches & culvert

Dumping of solid wastes in drainage facilities like demolished materials, soil, and house refuses plastic materials and others: This is to mean because of dumped solid waste in to the existing and urban drainage facilities the flood over flows and create a problem on residents and other urban infrastructure. The condition of the drain and its structures is very poor and getting deteriorated. The drain suffered from low capacity, natural siltation, absence of inlets, indefinite drainage outlets, lack of proper maintenance and over and above disposal of solid waste into the drain and the crossing culverts. The drain blocked with silt and sand accumulation, debris and vegetation as shown in above. It is clear that the drain and culverts being converted to dumpy place and subsequently obstructed the water flow.

Figure 4.8 Failure of ditch and pavement distress.

Severe distresses were observed on the road surface. It was found that the surface runoff water over flow on surface as a result road material was eroded. Therefore, the major cause of pavement deterioration is inadequate drainage.

Figure 4.9 Drainage ditches blocked with grasses, silt, debris & sand accumulation

It is clear that the drain and culverts being converted to dumpy place and subsequently obstructed the water flow. This bad condition of the side drain and its structures remains the same throughout the year causing the runoff water to flow on the surface of the road and unable to run off through the path far from the failed drain. The resultant effect of this critical situation causes serious distresses and damages on pavement. The road edges suffered from detachment of asphalt layer due to continuous contact of water leading to stripping of asphalt from aggregates resulting in severe pavement distresses of cracking, potholes and failure of edges

Maskeram Hotel

Figure 4.10 Severe failures of road due to water ponding on surface (Maskerem Hotel)

According to field observation made, some part of road have no drain ditches were constructed storm water collected at the edge of roads which reduce its capacity. It was found that the surface runoff water penetrated through the cracks and potholes cause a progressive inward penetration of the zone of soil movement leading to soil expansion and ultimately failure of the pavement. Therefore, the major cause of pavement deterioration is inadequate drainage. Significant cracking, potholes, heavy depression and edge failure

Figure 4.11No side drainage ditch from Was fuel station to Nock fuel station

Figure 4.12 Road edge failure and pond of water

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. The drain blocked with silt and sand accumulation, debris and vegetation as shown in Figure. It is clear that the drain and culverts being converted to dumpy place and subsequently obstructed the water flow.

This bad condition of the side drain and its structures remains the same throughout the year causing the runoff water to flow on the surface of the road and unable to run off through the path far from the failed drain. The resultant effect of this critical situation causes serious distresses and damages on pavement. The road edges suffered from detachment of asphalt layer due to continuous contact of water leading to stripping of asphalt from aggregates resulting in severe pavement distresses of cracking, potholes and failure of edges.

Figure 4.13Culvert and roadside ditch discharge points totally blocked with refuse dumps

Dumping of solid wastes in to drainage culverts (Including demolished materials, soil, house refuses, plastic materials and others): This has been aggravated the problem of flooding. This is to mean because of dumped solid waste in to the existing urban drainage facilities the flood over flows and create a problem on residents and other urban infrastructure and utilities. The drain suffered from low capacity, natural siltation, absence of inlets, indefinite drainage outlets, lack of proper maintenance and over and above disposal of solid waste into the drain and the crossing culverts. The drain blocked with silt and sand accumulation, debris and vegetation as shown in Figure. During the field observation the following condition of existing drainage structure problems are observed**,** major dominant problems that could be encountered in the study area are: sedimentation, drainage structures fully covered by grasses and brushes, traffic disturbance, flood overtopping, deterioration of roads, erosion of surface of the road, swamp formation at lower reaches of the catchment's, deposition of refuse material in the drainage structures, and stagnation of water.

Figure 4.14Survey Data for Analyses part

4.2 Hydrological Analysis

On Sebeta city road, drainage structures evaluation the maximum peak flood is computed taking into consideration the road standard and the design life span of the structure. The existing culverts that are found throughout the road length are short span culverts. Therefore, according to Annex -3, table 4.1 the design and check floods are determined. For example culvert at 0+423 near Meskarem Hotel is 1m diameterand Design & check storm frequency ofculvert is 10 and 25yrs

4.2.1 Delineation of Watershed Area

Watershed is the area of land where all of the water that falls in it and drains off of it goes to a common outlet, or watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, any point along a stream channel. The word watershed is sometimes used interchangeably with drainage basin or catchment. Delineation of the catchment area for existing drainage structures and proposed drainage structures are determined from digital elevation model by using Arch GIS and Global Mapper.

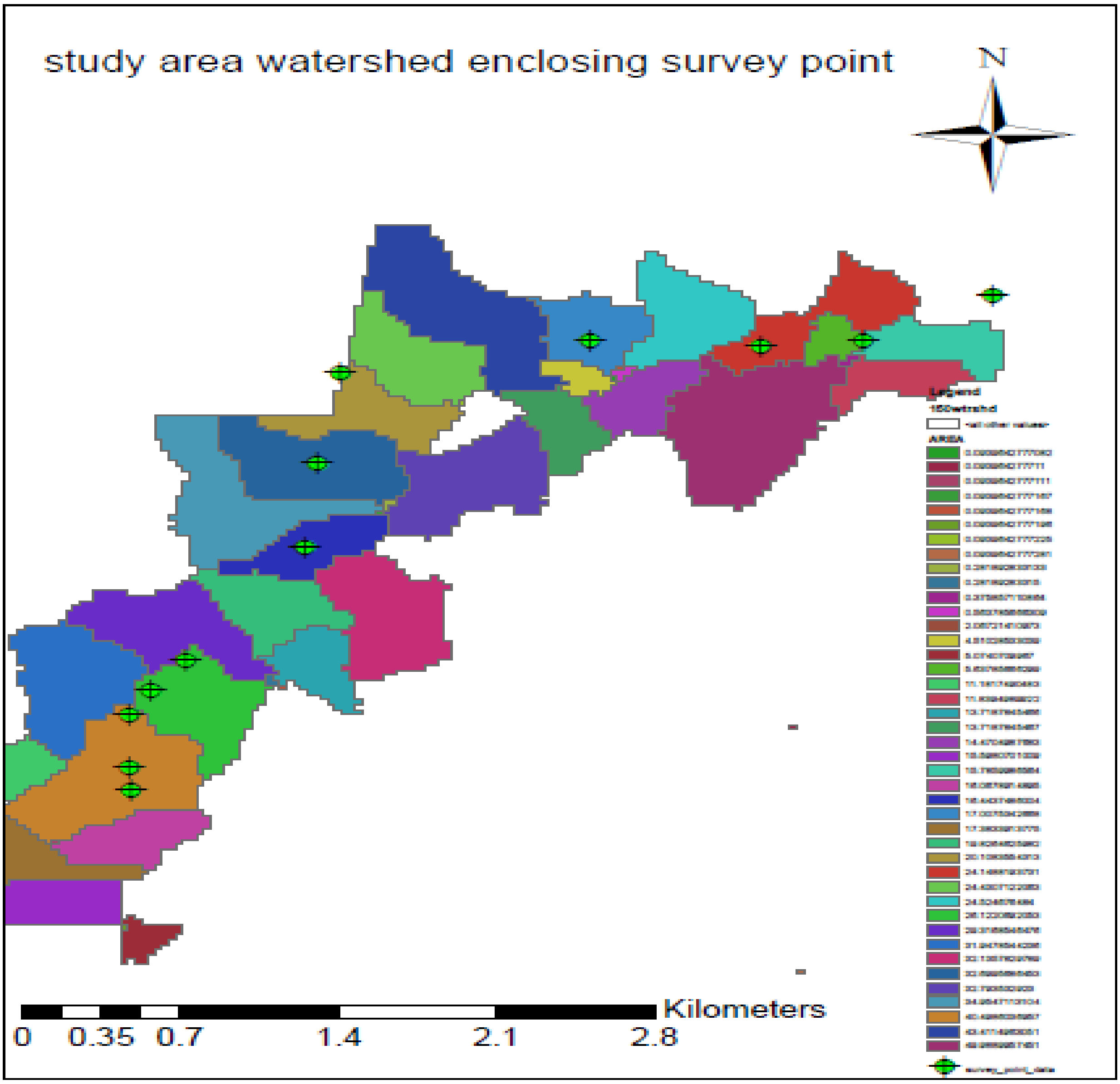

Figure4.15 Study area catchment (source:Arch GIS)

Table 4.3 Delineation of catchment areas for existing drainage structure

No	Station	Location	Existing drainage structureArea (hectares)
1	M.H(Maskeram Hotel)	Railway to Alamu Borana Hotel	40.50

2	M.B (Marga Bldng)	Marga Bldng to Was	31.95
3	A.S (Addis safer)	Marga Bldng to Was	29.32
4	P.K (Police Kebab)	WAS TO NOCK	34.96
5	F.S (Furi stadium)	NOCK TO DOSHA CLINIC	17.01

4.2.2 Computation of Catchment Parameters

Catchment Parameters at Station Maskeram Hotel (0+423) Drainage structure

Estimate the maximum rate of runoff at the inlet to a culvert on a road From a Digital elevation model, the area of the drainage basin upstream from the point in station Maskeram Hotel to be 40.499 hectares. The Rational Method is selected as the area less than 50 hectares. The road has a functional classification of a link road, with a design standard of DS4 [20]. From ANNEX-3 table 5-1 Design storm, the type of drainage structure is pipe and box culvert and design storm frequency of 10 yrs. and checked for 25yrs. Determine the maximum rate of runoff for 10-year and check a 25-year return period. The following data were measured

From a DEM and field survey, the following data were measured:

Length of overland flow = 78m Average overland slope = 2%

Length of main basin channel =985 m

Slope of channel = 0.054 m/m = 5.4%

Catchment area =40.499 hectare

By direct measuring the average bottom width of the natural stream channel is 0.6m, no side slopes b/c rectangular shape, 25-year storm depth is observed from flood mark and measured to be 0.9m. From ANNEX-6Table 5.2, Manning's roughness coefficient for concrete channels is 0.02.

Cross-sectional flow area (A) =b*d

Where b= width, d= depth, no slope

A= 0.6*0.9

= 0.54m2

Wetted perimeter (Pw) = b+2d

= 0.6+2*0.9

= 2.4m

Hydraulic radius (R) = A/P

=0.54 /2.4

= 0.225m

From Equation $V = (R^{2/3} S^{1/2})/n$

$V = (0.225m)^{2/3} * (0.02)^{1/2} / 0.02$

= 1.36m/sec.

Using n = 0.02, R (Hydraulic radius) = A/P = 0.225m and S = 0.02m/m, V = 1.36m/s.

Land Use and Soil Data

Overland Flow

The runoff coefficient (C) for the overland flow area from Table 5-3, ANNEX-8 of hydrology soil group D

0.15-0.2 and use average 0.175

Time of concentration

From ANNEX-8with an overland flow length of 78m, slope of 2% and C of 0.175, the inlet time is 23 min.

Channel flow velocity is determined from Manning's formula

$V = (R^{2/3} S^{1/2})/n$

Flow Time = L/V= 985 m) /(1.36 m/s)(60 s/min) = 12.05 min

And Tc = 23+ 12.05 = 35.054min - say 35.1 min

Rainfall Intensity

From ANNEX-1 meteorology stations on Figure 5-1Sebeta is in Region A2.

From ANNEX-4 (Intensity Frequency Duration) for Region A2 with duration equal to 35.1 minutes,

I10 (10-yr return period) = 70 mm/hr

I 25 (25-yr return period) = 86 mm/hr

Runoff Coefficient

A weighted runoff coefficient (C) for the total catchment area is determined in the following Table 4.4, by using the values from ANNEX-9

Table4.4, land use composition of the study area (urban)

Land Use	**staition**									
	M.H(0+423)		*M.B(1+225)*		*A.S(2+115)*		*P.C(4+330)*		*F.S(5+570)*	
	Percent	C	Percent	C	Percent	C	Percent	C	Percent	C
Mixed Residence	60	0.62	68	0.6	70	0.6	65	0.6	75	0.6
business area	22	0.7	5	0.7	10	0.7	5	0.7	2	0.7

health			6	0.6						
coble	15	0.7	18	0.7	20	0.7	3	0.7	15	0.7
asphaltic	3	0.7								
gravel road			3	0.65			2	0.65	5	0.65
parks							10	0.2		
light industrial									3	0.5
suburban							15	0.25		
total	100	0.65	100	0.62	100	0.63	100	0.52	100	0.62

Computation of Peak Runoff

The adjustment of the Rational Method for use with major storms can be made by multiplying the right side of the rational formula by a frequency factor Cf according to ANNEX-7, frequency factor for Rational formula.

The rational formula now becomes:

$Q = 0.00278CC_fIA$ from the rational equation

$Q_{10} = 0.00278CIA = 0.00278 \times 0.652 \times 70$ mm/h $\times$ 40.499 ha =5.14 m3/s

$Q_{25} = 0.00278\ C\ f\ CIA = 0.00278 \times 1.1 \times 0.652 \times 778$mm/h $\times$ 40.499 ha =6.9 m3/s

These are the estimates of peak runoff for a 10-year and 25-year design storm for the given basin.

The culvert and channel design would proceed with these values.

By similar procedure the other peak discharge are listed in Table 4.5.

Table: 4.5 Intensity and Peak runoff results

	Intensity peak run off result		Peak run off	
Catchment	I10	I25	$0.00278CIA=Q_{10}$	$Q_{25}=0.00278C_F$ CIA
M.H(0+420)	70	86	5.138480721	6.94428966
M.B(1+225)	68	98	3.771872586	5.97952742
A.S(2+115)	67	97	3.440168185	5.4785962
P.C(4+330)	72	88	3.638748672	4.89209544
F.S(5+570)	60	80	1.758899328	2.57971901

4.3 Hydraulic Analysis

The hydraulic capacities of the open channels in the study area were determined using the Manning's equation.

Table4.6Existing hydraulic structure

Location road culverts	Station	Types of culvert
M.H	0+423	Circular pipe
M.B	1+225	box culvert
A.S	2+115	Box culvert
P.C	4+330	Box culvert
F.S	5+570	Circular pipe

I. Hydraulic Calculation for Drainage Structure at Station M.H (0+423)

The existing hydraulic calculation are performed by measured the existing structure accordingly. The following are measured data based on the geometry of the culvert, its roughness and condition of occurrence.

Slope of culvert = 0.02 and Manning's roughness coefficient n listed in ANNEX-6 table 5-2

Table4.7, existing drainage structures hydraulic capacity parameters

station	**type of culvert**	**Dimesion**		V,by manning formula						**Discharge capacity**
		L	d	A	P	R	n	S	V	Q
M.H	circular pipe	1m dia		0.79	3.14	0.25	0.02	0.002	0.768497	0.60327
M.B	box culvert	1.7	2.3	3.91	6.30	0.62	0.02	0.003	1.789526	6.997046
A.S	box culvert	1.9	2.7	5.13	7.30	0.70	0.02	0.001	1.086764	5.575098
p.c	box culvert	2.0	3.0	6.00	8.00	0.75	0.04	0.011	2.164432	12.98659
F.S	circular pipe	1m dia		0.79	3.14	0.25	0.03	0.002	0.606199	0.475866

Based on the hydraulic calculation of the result drainage capacity of existing system were checked and presented in Table 4.7 to compare with proposed discharge this process also done first by determining the peak discharge for each existing catchment by used empirical equations (Rational method) as described in the methodology part of this study and then subtracted existing discharge this step is important know over flow peak (excess discharge) for each catchments and the result also presented in the following table 4.8

Table4.8. Existing, Proposed and Excess Discharge result

station	Existing discharge capacity	Proposed discharge capacity		Excess discharge	
	Q=V*A	for design Q10	for checkQ25	for design	for check
M.H	0.60327	5.13848072	6.94428966	4.53521	6.341019334

M.B	6.99705	3.77187259	5.97952742	-3.22517	-1.017518364
A.S	5.5751	3.44016818	5.4785962	-2.13493	-0.096502142
P.C	12.9866	3.63874867	4.89209544	-9.34784	-8.094493993
F.S	0.47587	1.75889933	2.57971901	1.283033	2.103852964

II. Drainage Size determination for existing and proposed

By used Manning equation determined the size of the culverts pipe based on the parameter a Size determination for existing at M.H (Maskrem Hotel (0+423)

For Design

Qc=(1/n) $AR^{2/3} S^{1/2}$ (Manning equation)

A(area of circular pipe)=$\prod D^2/4$

P (wetted perimeter of circular pipe) =$\prod D$

Hydraulic radius(R)

R=A/P=D/4

Qc= $\prod D^2/4(D/4)^{2/3} S^{1/2}/n$

4,5 = $\prod D^2/4(D/4)^{2/3} 0.002^{1/2}/0.02$

D=8.6 or 860mm (additional culvert pipe are required)

For check

Qc= (1/n) $AR^{2/3} S^{1/2}$ (Manning equation)

A (area of circular pipe)=$\prod D^2/4$

P (wetted perimeter of circular pipe)=$\prod D$

Hydraulic radius(R)

R=A/P=D/4

Qc= $\prod D^2/4 (D/4)^{2/3} S^{1/2}/n$

6.34=$\prod D^2/4 (D/4)^{2/3}$ =$0.002^{1/2}/0.02$

D=5.9m or 590mm (additional culvert pipe are required

Table 4.9 size determination for New Discharge

Station	Type of structure	for design	for check	D design	D check
M.H	circular pipe	4.5352104	6.34101933	8.601593	5.865694464

M.B	box culvert	-3.2251732	-1.0175184	safe	safe
A.S	box culvert	-2.1349302	-0.0965021	safe	safe
p.c	box culvert	-9.3478408	-8.094494	safe	safe
F.S	circular pipe	1.28303328	2.10385296	0.418177	1.293331831

4.4 Effects of poor drainage structures on the road

On a lot of Sebeta roads having inadequate drainage structures, deterioration often begins with the origin of cracks or potholes on the road pavements either at the edges Figure

(4.7, 4.9, 4.11,4.12) or along the driveway which differs by their shapes, configuration, amplitude of loading, movement of traffic and rate of deformation. These roads are poorly maintained, as physically noticed in the numerous failed side drains overtaken with vegetation (4.10, 4.11 , 4.12) and totally blocked drainage network. Entirely all the ratings on the existing culverts along the length of this road has been blocked by dirt,solid waste, weed and silt sand accumulation over time (4.7,4.11,4.12,4.) due to lack of maintenance thereby causing water to be retained on the surface of these culverts each time it rains. As a result of this surface retainment of water, the bituminous pavement layer becomes weak thereby resulting in a detachment of bituminous pavement layer (4.8,4.9, 4.11,).

Furthermore, the existing ditches and culverts are seen to be so poorly maintained and blocked also by dirt and silt sand accumulation over time resulting in drain water to be retained on the pavement surface around the gullies each time it rains thereby causing failure on the edges of the road surface (4.8,4.9,4.12,4.).

In addition to above observation and photography the effects of the poor drainage system on the road also collected from interviews. Majority reported runoff wash away the ditches and culverts of the road during the rains thereby hindering free movements of vehicles on the road. It also runoff on the road block the road 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 results from the questionnaire and from above photographs show that existing drainage structures in Sebeta city are nearly out of services. Even the passage over the ditches made from wood by residents it is very difficult to pass especially for children. However, many respondents mentioned concerns about issues related to construction and maintenance. In addition to this poor planning and design also occurs. For example, they emphasized the lack of knowledge about the condition of drainage structures and the lack of effective tools to identify vulnerable places exposed to high flows and places where drainage measures are needed.

The causes of flooding are complex. A combination of factors can have an impact on causing flooding and consequences on road drainage structures. According to the questionnaire answers, clogging of drainage pipes, culverts and ditches by debris flow and fine-grade soil is one of the most important maintenance issues in current drainage systems. Some of the respondents stated that cleaning of drainage pipes, culverts and ditches is not specified at a certain time and is therefore only done when needed. This suggests that it is important to perform operations such as maintenance and cleaning regularly to prevent flooding. Finally they concluded that not only drainage structure but roads surface are eroded and even pavement surface change to gravel roads. Based on the survey results and the literature review, work and measures to prevent and mitigate damage to road constructions through maintenance and reconstruction.

4.5 Main reasons of drainage problems on Sebeta road

a) Poor maintenance

When erected structures and facilities such as drainages and road pavements are poorly maintained, their service lifespan is drastically reduced. From the investigations conducted, Figures (4.12, 4.9, 4.10, 4.11, 4.12) presents proof of this reduction in service lifespan and it is evident in the deterioration of drainages and subsequent road pavement conditions which are visibly noticed in the form of edge failures of road pavements, potholes along the drive way of road pavements, stripping of bitumen off the surface of road pavements and blockage of drainage channels such as culverts and underground drainage networks. Also these poor maintenance cultures results in culverts and ditches being blocked with dirt weed, silt and accumulation over time and in the growth of vegetation inside and around the side drains which has resulted into total failure of the drainage structures. To check these very poor conditions of drainages and road pavements, there is need to properly maintain them to perform routine cleaning of dirt, weed and silt sand accumulation over time that is visibly seen to have blocked these drainages structures.

b) Lack of awareness

The attitude of residents in communities under which these drainage channels are constructed and located goes a long way to determining the service lifespan of these drainage structures. From the investigation conducted in Figures (4.7, 4.8, 4.11,4.12) which clearly shows that residents have converted a culvert into refuse dump site. This results in blockage of these drains and its subsequent failures which in turn does negatively affect conditions of the road pavement found in this town. Towards enlightening residents on the need to keep drainages located in their communities clean and not use them as refuse dump sites.

c) Design Practices

Among many problem the main cause for the over topping, sedimentation, deterioration of roads, flood overtopping, was the lack of detail flood information during rainy season and inadequate hydraulic design. The construction of the drainage ditch design was carried out without some rational or statistical assessment of the expected flow which means that ignoring hydrological analysis and calculating hydraulic parameters during the design stage. The hydrological analysis is used to now peak flood of surrounding catchment. In general, drainage crossings must be designed to pass the appropriate storm flows and debris or to survive overtopping. Proper design and construction of drainage structures are vital components for road structure to function without traffic interruption.

Appropriate hydrological analysis of the catchment area where the drainage structure will be constructed and appropriate hydraulic parameters should be determined. If proper hydrological analysis and hydraulic calculation were not practiced, either overdesign or under design would occur that both involve excessive costs on a long-term basis. A drainage structure designed to carry allowable recurrence interval flood otherwise accidental flood may damage by under estimated (low peak runoff) construction or over topping storm runoff on the surface of drainage facility and road surface almost in every year. Design of the drainage structure for existing in study area is under estimated to carry out peak discharges.

d) Poorly executed construction jobs

Only proper design by itself does not make the drainage structure to serve properly up to its design life but also proper construction practice must be carried out by appropriate personnel according to the design. Poorly executed construction jobs are another factor which contributes to poor drainage and road pavement conditions in Sebetacity.From the investigation conducted, it is noticed and as shown in Figure(4.8, 4.12 ,) edge failure of ditch within short period of time. The resultant long term effect of this condition if not checked will be a total collapse or failure of the ditch facility. To prevent this condition from occurring, it is highly advised that engineers handling construction jobs should executed them with strict adherence to the blueprints of that exact job. The proper construction practice is important after proper design for drainage structures to function properly

CHAPTER FIVE

5 CONCLUSION& RECOMMENDATION

5.1 Conclusion

According to the result of this thesis the drainage structures are inadequate to convey the peak discharge for required design period and the drainage structures filled by solid waste and other rubbish materials, those problems are; by the responses from engineers, road users and residents, the problem lies in the drainage structures.

From the field evaluation, the drainage system in each road was rated as excellent, fair, good, or poor. The study reveals that more than 75% of the roadways in the selected sites were in poor drainage conditions, which lead to tremendous environmental problems. With the aid of a camera, pictures of the various degrees of drainage deterioration and its consequent effects on road pavement conditions as we see from the Figure. Many roads in Sebeta city are poor conditions due to different reasons. Poor drainage causes the premature failure of the pavement.Neglected urban drainage infrastructure lead to thedeterioration of the entire road structure. Simple clearing of the drains and culverts can prolong the life of urban drainage lines as well as roads as a proactive measure before the beginning of every rainy season.

The existing inadequate integration of road and urban storm water drainage structure an alternative and appropriate drainage infrastructure have been planned and designed with the help of ArcGIS with a full consideration of hydrology and hydraulics analysis. This will reduce and then avoid the existing roads deterioration problems if implemented as the original plan and design. Based on the result those problems are; due to the drainage design and construction practice adopted by ignoring of hydrology and hydraulic analysis, type of drainage structures provided and maintenance problems from concerned body and unawareness of the community. Therefore regular annual evaluation of drainage structures is an important part of maintaining and managing road.

5.2 Recommendations

Based on the engineering analysis of this thesis appropriate mitigation measures are recommended. On Sebeta city inadequacy of drainage structures have had serious negative on the road. In order to avoid these problems, the following appropriate mitigation measures are recommended;

Improvement of drainage facilities through periodic maintenance. Create 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.

At station at M.H (0+423), the existing pipe culvert was inadequate to pass flood through it during rainy season. In this station side ditch also must be clear daily, Therefore, to avoid this problem, increase the diameter of pipe according to its hydraulic capacity.

At station A.S (2+115),M.B(due to inadequacy of drainage structure and improper maintenance, over flowing and sedimentation occurred.

Therefore,to avoid this problem increase dimension of box culvert.

At stations F.S (5+570) drainage sewer pipe blocked by waste material, as a result, runoff crosses the road and eroded road surface materials. Therefore, to avoid this problem, construction of sewer pipe of 0.50-meter internal diameter is important at this station. For drainage filled and alignment problem, periodic cleaning and adjustment of the slope were recommended. Complete overhaul and reconstruction of the whole system.

Most of roads drainage ditches are open it is better to change closed ditches (channel). Sebeta city Administration is needs to plan out to solve the drainages problems and right time to facilitate adequate drainage structures. It is suggesting to upsetting the strong municipality in the Sebeta city Administration to improve quality of life. The Sebeta city Administration should encourage carrying out the feasibility in order to identified projects to improve drainage system as soon as possible. Before making any road surface improvements, make drainage improvements.

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Annexes

ANNEX-1 Meteorology Stations

Meteorological Region	Station	Years of Record	Meteorological Region	Station	Years of Record
A1	Axum	18	B	Bedele	19
	Mekele	35		Gore	45
	Maychew	24		Nekempte	27
A2	Gondar	40		Jima	45
	Debre Tabor	22		Arba Minch	11
	Bahir Dar	35		Sodo	28
	Debre Markos	44		Awasa	26
	Fitche	25	C	Kombolcha	46
	Addis Ababa	33		Woldiya	23
A3	Nazareth	40		Sirinka	17
	Kulumsa	31	D1	Gode	29*
	Robe/Bale	19		Kebri Dihar	38
A4	Metehara	28	D2	Kibre Mengist	24
	Dire Dawa	46		Negele	45
	Mieso	35		Moyale	18
* max 24 hour rainfall not given				Yabelo	34

Years of record through 1997

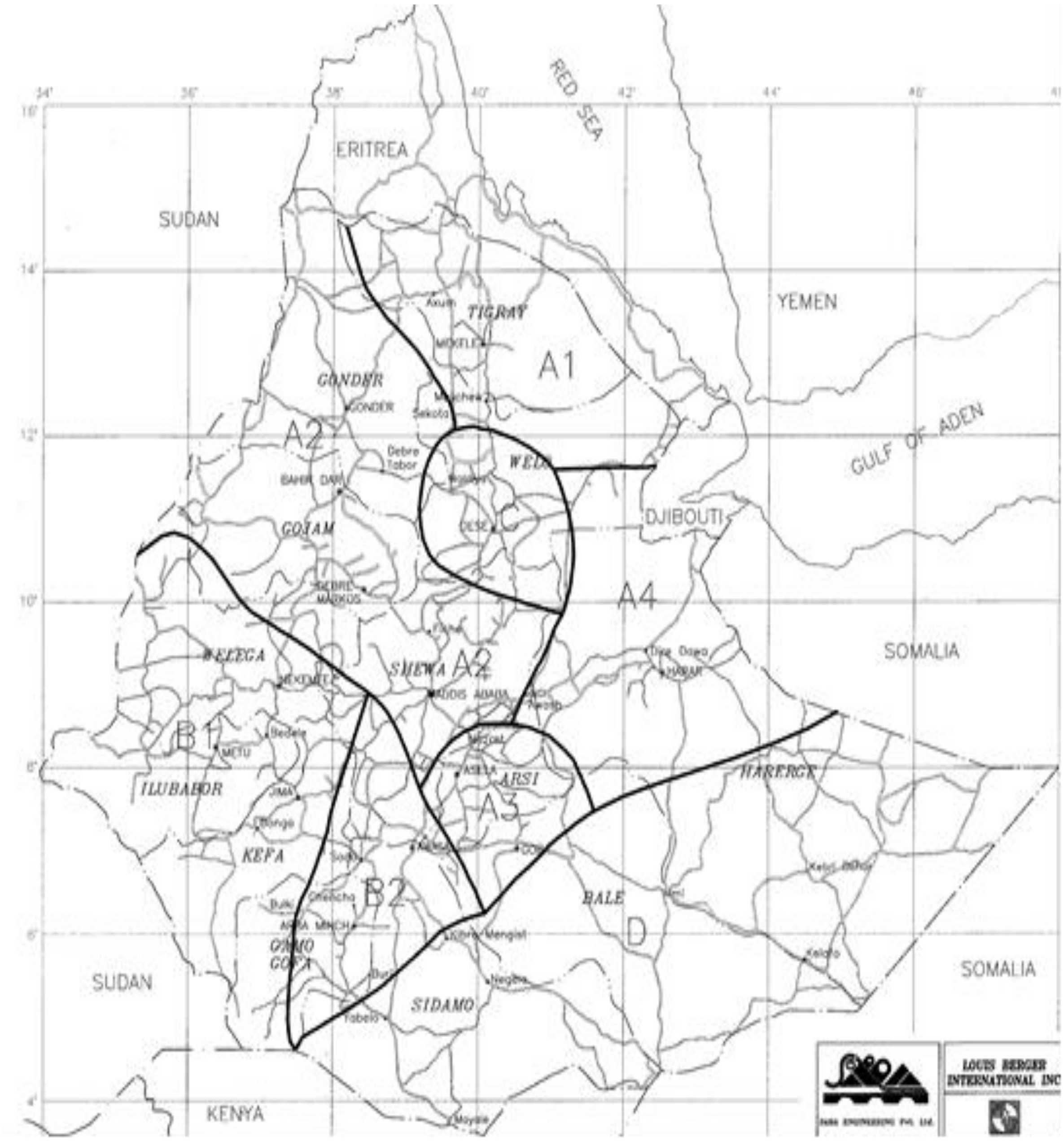


Figure 5.1: Rainfall Regions

Source: Ministry of Water Resources meteorology stations

ANNEX-2, Road Functional classification

Table 2-1: Road Classification, AADT, Carriageway Widths and Design Speeds

Road Functional Classification	Design Standard	Design Traffic Flow (AADT) (Mid-life)	Surface Type	Width (m)	Design Speed (km/hr.)				
				Carriageway	Flat	Rolling	Mountainous	Escarpment	Urban/Peri-Urban
	DC8	10,000 –15,000	Paved	Dual 2 x 7.3	120	100	85	70	50
TRUNK	DC7	3,000 – 10,000	Paved	7.3	120	100	85	70	50
	DC6	1,000 – 3,000	Paved	7.0	100	85	70	60	50
LINK, MAIN ACCESS	DC5	300 – 1,000	Paved	7.0	85	70	60	50	50
COLLECTOR	DC4 (2)	150 – 300	Paved	6.5 – 7.0 (1)	70	60	50	30	50
			Unpaved	7.0 – 7.5 (1)			45 (3)		
FEEDER	DC3 (2)	75 – 150	Paved	6.0	70	60	50	30	50
			Unpaved	7.0			45 (3)		
	DC2 (2)	25 – 75	Paved	3.3	60	50	40	25	50
			Unpaved	6.0			35 (3)		
	DC1	1 – 25	Unpaved	4.5	50	40	30	20	40
	Basic Access	<10	Unpaved	3.5					

Notes 1 Choice of *carriageway and shoulder widths* also depends on numbers of Large Heavy Vehicles defined as vehicles with 3 or more axles and with GVW > 10 tonnes (see Table 2.3)

2 The choice of *design standard* depends on the numbers of Large Heavy Vehicles as well as AADT.

3 Design speed is adjusted slightly to provide the same minimum radius of horizontal curvature as for the paved road option in mountainous terrain.

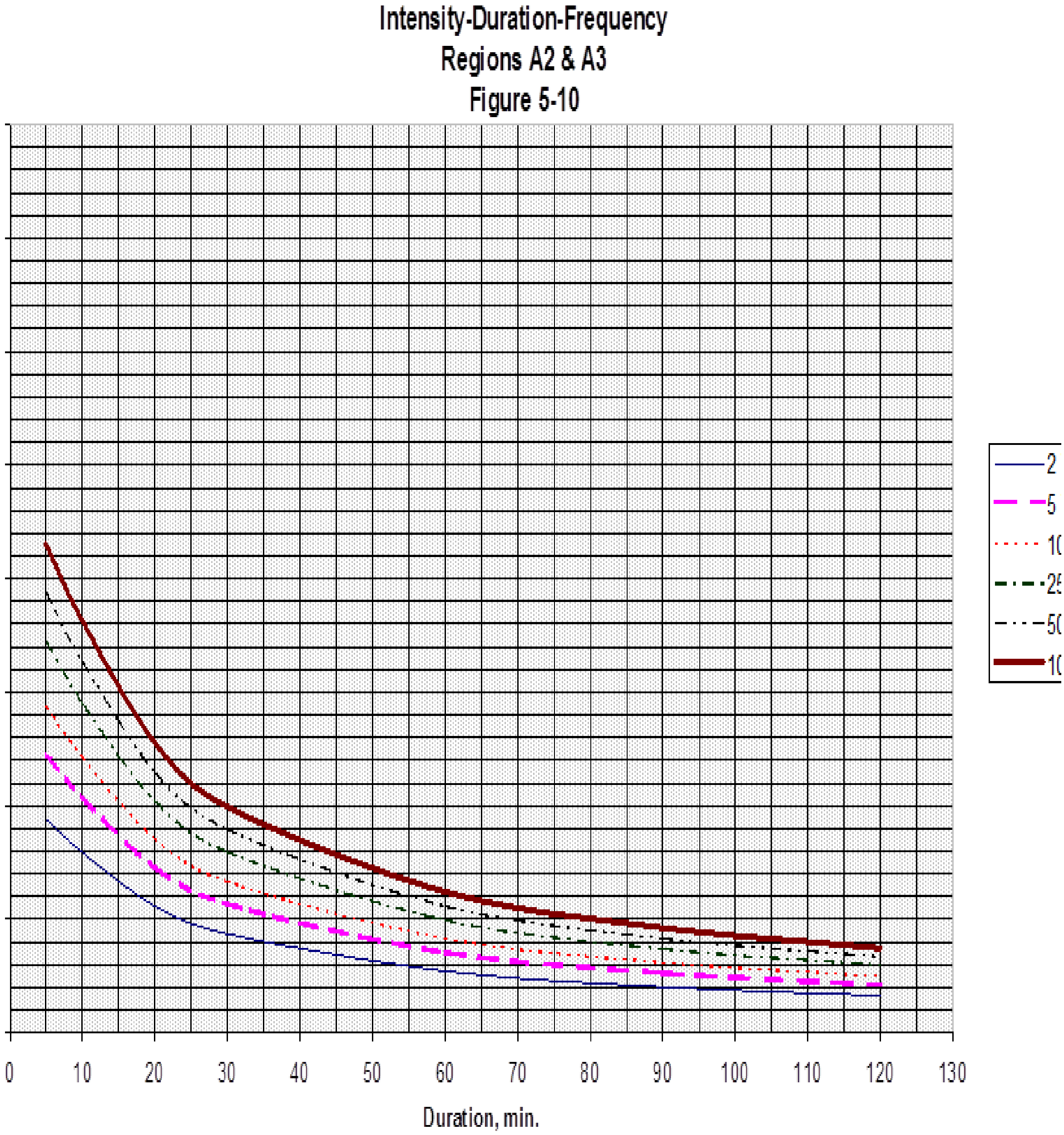
4 Transition curves are required for all road standards except roads traversing escarpments and road classes DC1 and Basic Access.

ANNEX -3

Table 5-1: Design Storm Frequency by Geometric Criteria Structure Type Geometric Design Standard

	DS1/DS2	DS3/DS4	DS5/6/7	DS8/9/10
Gutters and Inlets	10/5	2	2	-
Side Ditches	10	10	5	5
Ford/Low-Water Bridge	-	-	-	5
Culvert, pipe (see Note) Span<2m	25	10	5	5
Culvert, 2m<span <6m	50	25	10	10
Short span Bridges 6m<Span<15m	50	50	25	25
Medium Span Bridges 15m<Span<50m	100	50	50	50
Long Span Bridges Spans>50m	100	100	100	100
Check/Review Flood	200	200	100	100

ANNEX-4 Intensity frequency duration



ANNEX-5 Overland time of flow

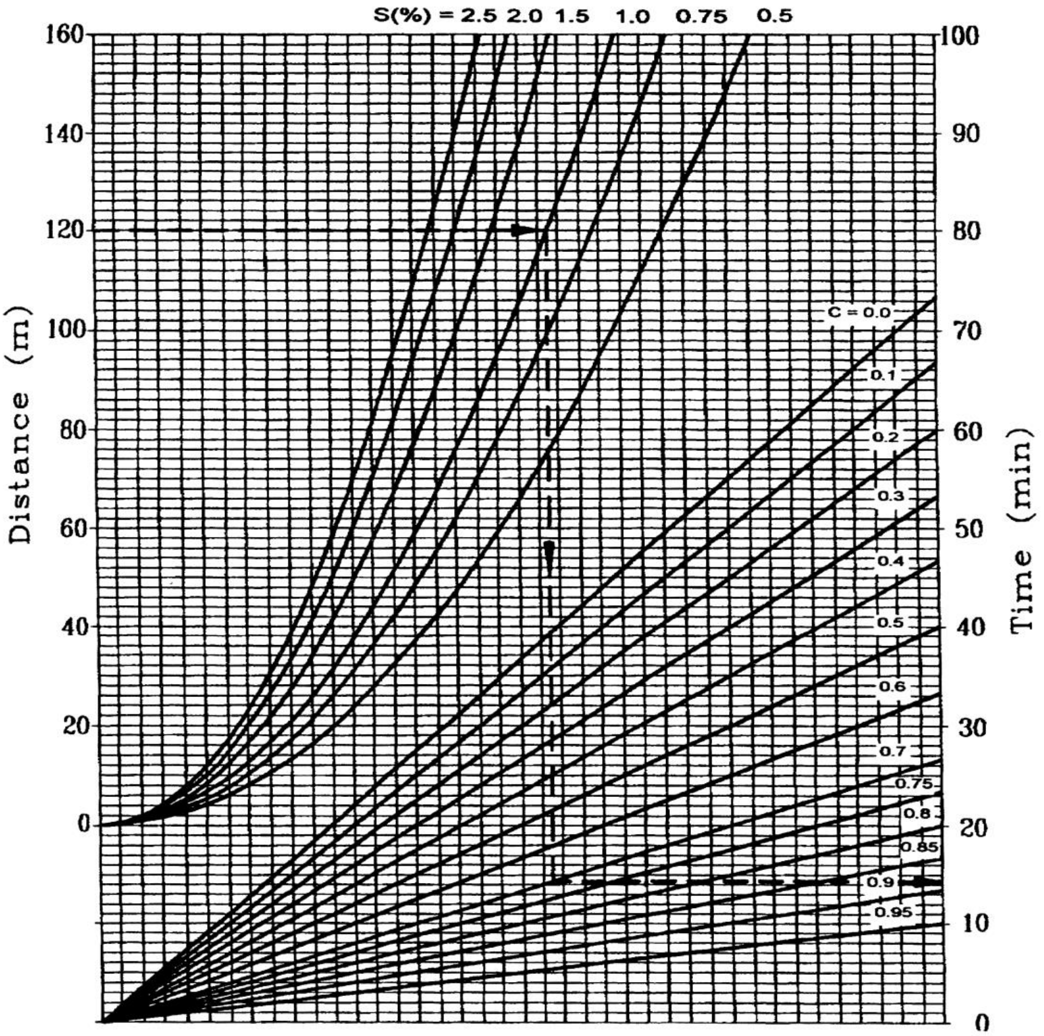


Figure 5-3 Overland Time Of Flow

Source: Airport Drainage, Federal Aviation Administration, 1965

ANNEX-6 ***Table 5-2 Values of Rouahness Coefficient n (Uniform Flow)***

Type of Channel and Description	***Minimum***	***Normal***	***Maximum***
a. Earth, straight and uniform	0.016	0.018	0.020
	0.018	0.022	0.025
1. Clean, recently completed	0.022	0.025	0.030
2. Clean, after weathering	0.022	0.027	0.033
3. Gravel, uniform section, clean			
4. With short grass, few weeds	0.023	0.025	0.030
	0.025	0.030	0.033
b. Earth, winding and sluggish	0.030	0.035	0.040
	0.025	0.030	0.035
1. No vegetation	0.025	0.035	0.045
2. Grass, some weeds	0.030	0.040	0.050
3. Dense Weeds or aquatic plants in deep channels			
4. Earth bottom and rubble sides	0.025	0.028	0.033
5. Stony bottom and weedy sides	0.035	0.050	0.060
6. Cobble bottom and clean sides			
	0.025	0.035	0.040
c. Backhoe-excavated or dredged	0.035	0.040	0.050
1. No vegetation	0.050	0.080	0.120
2. Light brush on banks	0.040	0.050	0.080
	0.045	0.070	0.110
d. Rock cuts	0.080	0.100	0.140
1. Smooth and uniform	0.012-	0.020	
2. Jagged and irregular			
	0.020		
e. Channels not maintained, weeds and brush uncut	0.023		
	0.033		
1. Dense weeds, high as flow depth			
	0.030		
2 Clean bottom, brush on sides	0.040		
	0.050		
3. Same, highest stage of flow	0.100		
4. Dense brush, high stage			
	0.035		
f. Various Open Channel Surfaces	0.040		
	0.050		
a. Concrete	0.070		
b. Gravel bottom with:	0.100		
Concrete			
Mortared stone			
Riprap			
c. Natural Stream Channels			
Clean, straight stream			
Clean, winding stream			
Winding with weeds and pools			
With heavy brush and timber			
d. Flood Plains			

ANNEX-7 Frequency Factors for Rational Formula

Recurrence Interval (years)	C_f
5	1.0
10	1.0
25	1.1
50	1.2
100	1.25

Table: Recommended Manning's n Values for Pipe

Type of Conduit	Wall Description	Manning's n
Concrete Pipe	Smooth Walls	0.010-0.013
Concrete Boxes	Smooth Walls	0.012-0.015
Corrugated Metal Pipes and Boxes,	68mm x 13mm corrugations	0.022-0.027
Annular or Helical Pipe	150mm x 25 mm corrugations	0.022-0.025
	125mm x 25mm corrugations	0.025-0.026
	75mm x 25mm corrugations	0.027-0.028
	150mm x 50 mm structural plate	0.033-0.035
	230mm x 64mm structural plate	0.033-0.037
Corrugated Metal Pipes, Helical Corrugations, Full Circular Flow	68mm x 13mm corrugations	0.012-0.024
Spiral Rib Metal	Smooth Walls	0.012-0.013

Table 5-3 Recommended Runoff Coefficient C for Pervious Surfaces by Selected Hydrologic Soil Groupings and Slope Ranges (see also Table 5-7)

Terrain Type	Soil Type			
	A	B	C	D
Flat, <2%	0.04-0.09	0.07-0.12	0.11-0.16	0.15-0.20
Rolling, 2-6%	0.09-0.14	0.12-0.17	0.16-0.21	0.20-0.25
Mountain, 6-15%	0.13-0.18	0.18-0.24	0.23-0.31	0.28-0.38
Escarpment, >15%	0.18-0.22	0.24-0.30	0.30-0.40	0.38-0.48

ANNEX-8: Typical Hydrologic Soils Groups for Ethiopia

	Soil Types	Hydrologic Soil Group
Ao	Orthic Acrisols	B
Bc	Chromic Cambisols	B
Bd	Dystric Cambisols	B
Be	Eutric Cambisols	B
Bh	Humic Cambisols	C
Bk	Calcic Cambisols	B
Bv	Vertic Cambisols	B
Ck	Calcic Chernozems	B
E	Rendzinas	D
Hh	Haplic Phaeozems	C
Hl	Luvic Phaeozems	C
I	Lithosols	D
Jc	Calcaric Fluvisols	B
Je	Eutric Fluvisols	B
Lc	Chromic Luvisols	B
Lo	Orthic Luvisols	B
Lv	Vertic Luvisols	C
Nd	Dystric Nitosols	B
Ne	Eutric Nitosols	B
Od	Dystric Histosols	D
Oe	Eutric Histosols	D
Qc	Cambric Arenosols	A
Rc	Calcaric Regosols	A
Re	Eutric Regosols	A
Th	Humic Andosols	B
Tm	Mollic Andosols	B
Tv	Vitric Andosols	B
Vc	Chromic Vertisols	D
Vp	Pellic Vertisols	D
Xh	Haplic Xerosols	B
Xk	Caloic Xerosols	B
Xl	Luvic Xerosols	C
Yy	Gypsic Yermosols	B
Zg	Gleyic Solonchaks	D
Zo	Orthic Solonchaks	B

Source: Ministry of Agriculture (MoA)

ANNEX-9 Recommended Runoff Coefficient C for Various Selected Land Uses

Description of Area		Runoff Coefficients
Business: Downtown areas		0.70-0.95
Neighborhood areas		0.50-0.70
Residential:	Single-family areas	0.30-0.50
	Multi units, detached	0.40-0.60
	Multi units, attached	0.60-0.75
	Suburban	0.25-0.40
Residential (0.5 hectare lots or more)		0.30-0.45
Apartment dwelling areas		0.50-0.70
Industrial:	Light areas	0.50-0.80
	Heavy areas	0.60-0.90
Parks, cemeteries		0.10-0.25
Playgrounds		0.20-0.40
Railroad yard areas		0.20-0.40
Unimproved areas		0.10-0.30

Source: Hydrology, Federal Highway Administration, HEC No. 19, 1984

Table 5-5 Coefficients for Composite Runoff Analysis

Surface		Runoff Coefficients
Street :	Asphalt	0.70-0.95
	Concrete	0.80-0.95
Drives and walks		0.75-0.85
Roofs		0.75-0.95

Source: Hydrology, Federal Highway Administration, HEC No. 19, 1984

Questionnaire

Evaluation of existing road drainage structure problems in Sebeta city

This questionnaire is being administered for the collection of data to assist in the study of the evaluation existing road drainage structure problems in Sebeta city.

The information collected is confidential and will strictly be used for academic purposes.

Sector: Technical Perspective.

Technical Aspect

1)What is your academic background or field of training?

- Engineer
- Any other (specify)

……………………………………………………………………………………

2) What are some of the considerations that are made when coming up with road design and appropriate drainage facility in Sebeta city? (More than one choice may be ticked).

- State of road
- Cost of construction
- Class of the road
- Period of construction
- Topography

3) From your design experience, was the design appropriate?

- Yes
- No

4) 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)

5)From your experience as an engineer, can you say other roads in Sebeta city were provided with adequate drainage facilities?

- Yes
- No

6)If your answer is no, in your opinion what percentage of roads in Sebeta city are not provided with adequate drainage structures?

- 0 – 20%
- 20 – 40%
- 40 – 60%
- 60 – 80%
- 80 – 100%

7)Sebeta city road was washed away just a year after construction; do you think that was expected?

- Yes
- No

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

…………………………………………………………………………………………………..

9) Do you think that there was laxity in the supervision of the contractor during the construction of the road?

- Yes
- No

10) 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 Sebeta city road?

- Excellent
- Very good
- Good
- Poor
- Any other (specify) ……………………………………………………………….

11)How often do you carry out inspection to ascertain the state of the drainage structure in Sebeta city road?

- Monthly
- Every three months
- Every six months

- Once a year
- Any other (specify) ………………………………………………………….

12) Have you carried out a research on the effects of the poor drainage system on the surrounding environment?

- Yes
- No

13) What did you find are the effects?

- …………………………
- …………………………
- …………………………
- …………………………

14) What do you think is the remedy to the sorry state of the drainage structure in Sebeta city road?

- Maintenance
- Redesigning
- Reconstruction
- Any other (specify) ……………………………………………………………………

15)Why do you think has hindered the above mentioned measures from being implemented?

- Lack of resources
- Lack of awareness
- Poor planning
- Lack of commitment by the government

What is the extent of the damage on the road?

- Very damaged
- Fairly damaged
- Good
- Any other (specify)

……………………………………………………………………………………………..
………………………………………………………………………………………………

16) In your own opinion based on the professional experience, is the type of drainage facility installed in Sebeta city road with enough capacity to satisfactorily drain the water from the road?

a) Yes

b) No

17) If your answer above is no, why do you think so?

Appendix : Questionnaire Two

Evaluation the existing road drainage structure problems in Sebeta city

This questionnaire is being administered for the collection of data to assist in the study of this thesis. The information collected is confidential and will strictly be used for academic purposes.

Sector: General Perspective.

General Aspect

1) How often do you Sebeta city road?

- Every day
- Twice a week
- One"s a week
- Any other (please specify)

…………………………………………………………………………………

2) How far is your home from the Sebeta city 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 structure in Sebeta city 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 structure?

- 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

12) Why do you think?