Jimma University

School of Graduate Studies

Jimma Institute of Technology

School of Civil and Environmental Engineering

Highway Engineering Stream

EVALUATION OF ROADSIDE DRAINAGE PROBLEM AND ITS REMEDIES: A CASE STUDY ON JIMMA TO AGARO

A Thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering)

By: Yusuf Negesso

.

February, 2017
Jimma, Ethiopia

Jimma University

School of Graduate Studies

Jimma Institute of Technology

School of Civil and Environmental Engineering

Highway Engineering Stream

EVALUATION OF ROADSIDE DRAINAGE PROBLEM AND ITS REMEDIES: A CASE STUDY ON JIMMA TO AGARO

A Thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering)

By: Yusuf Negesso

Advisor: Prof. Emer T. Quezon

Co-Advisor: Engr. Getachew Kebede

February, 2017

Jimma, Ethiopia

DECLARATION

I, the undersigned, declare that this Thesis entitled: "**Evaluation of Roadside Drainage Problem and Its Remedies: A Case Study on Jimma to Agaro**." is my original work, and has not been presented by any other person for an award of a degree in this university or any other universities, and all sources of materials used for thesis have been duly acknowledged. Therefore, whatever the result of my thesis final defense based on the criteria as evaluated by the examiners, will be ACCEPTED in good faith.

Signed:

Mr./Ms**. Yusuf Negesso** ______________ ______________

Signature Date

As Master Thesis Advisors, we hereby certify that we have reviewed carefully the document and prepared under our guidance by Mr **YUSUF NEGESSO,** his thesis entitled: **Evaluation of Roadside Drainage Problem and Its Remedies: A Case Study on Jimma to Agaro**."

Therefore, we recommend that this document would be submitted to fulfill the MSc Thesis requirements in this university.

Prof. Emer T. Quezon ______________ ______________

Main Advisor Signature Date

Engr. Getachew Kebede Warati ______________ ______________

Co-Advisor Signature Date

ABSTRACT

Roadside drainage channels perform the vital function of diverting or removing surface water from the highway right-of-way. Effective side drains will reduce the need for maintenance by preventing deterioration of the surface and will provide a drier and hence safer road. They should provide the most efficient disposal system consistent with cost, importance of the road, economy of maintenance, and legal requirements. This study was needed, for the reason of study area road user's and residents are suffering by the problem of runoff that damage both pavements and resident's properties, because of inadequate roadside drainage.

The objective of the study was to evaluate roadside water drainage problems and come up with remedial measures along the study area .The research study was focused on Jimma to Agaro road section from April, 2016 to February2017. The data collected was then be analyzed quantitatively and qualitatively. The purposive sampling techniques were used to distribute questionnaires and in order to achieve the desired objective, a systematic methodology was adopted which includes, analysis of hydraulic capacity for existing side drains, field observation and questionnaires was carried out. The major flood prone areas for the road side drainage problem are Yebu town, Bosa Addis keteme kebele in Jimma Town, Mane worede Mantine kebele, Gembe town,and Agaro town entrance by ascending order which were evidenced from the field observation. A number of effects of poor roadside drainage were include flooding which destroys residents property, dirtying the vehicle of the road users and pavement distress. Factors that have contributed to problem of roadside drainage along the study area to a large extent are increased presence of Garbage and polythene bags along the road, Construction of unplanned houses, topography of the study area and insufficient discharge capacity of existing roadside drains. Clean up all the existing roadside drainage, constructing planned house and re construction roadside drainage with good hydraulic capacity can mitigate this problem.

Key words: roadside drainage, property owners, catchment areas, road surface damage

ACKNOWLEDGEMENTS

Above all, I would like to say thank you to creator and governor of the world, the almighty Allah and Saints for his invaluable gifts to me.

I am very grateful to the Dire Dawa University and Jimma University, Department of Highway Engineering for allowing me to take part in the Master Program in Highway Engineering. Thank you JIT, you made my dream come true.

I would like to express my sincere gratitude to my Advisor, Prof, Emer T.Quezon for giving me encouragement, critical comment and helpful guidance is since early age of this thesis work and for his friendly approach throughout this thesis work. I am also indebted to my co-Advisoir Eng. Getachew Kebede for his support and encouragement. Without them, this work would not have been realized.

I am very grateful to all my teachers who taught me from grass root to this level.

Thanks to Allah, I have lots of exciting friends whom I met in my walk of life. Letters and words limit me to list your names. You all were great.

At last but not least, I would like to provide deepest gratitude to my family, without your encouragement and care this would not have happened.

Table of contents

Contents Pages

LIST OF TABLES

Contents page

LIST OF FIGURES

LIST OFAPPENDIX TABLES

LIST OFAPPENDIX FIGURES

LIST OF ACRONYMS

AACRA	Addis Ababa City Roads Authority
AASHTO	American Association of State Highway Transportation Officials
AMC	Antecedent moisture conditions
CN	Curve Number
DDM	Drainage Design Manual
DDU	Dire Dawa University
DEM	Digital Elevation Model
EMA	Ethiopia Mapping Agency
ERA	Ethiopian Roads Authority
FDRE	Federal Democratic Republic of Ethiopia
SCS	Soil conservation service
GDM	Geometric Design Manual
GIS	Geographic Information system
GPS	Global positioning system
IDF	Intensity-Duration-Frequency
IPMS	Improving productivity and marketing success
JIT	Jimma Institute of Technology
MOWR	Ministry of Water Resources
NO	Number
SCS	Soil Conservation Service
ORG	Oromia Regional Government
US SCS	United States Soil Conservation Service

CHAPTER ONE

INTRODUCTION

1.1 Background

Proper roadside drainage is essential for a highway to function properly. As discussed in (Jones et al., 2004) the primary purposes of roadside drainage systems are to minimize water depths occurring on road surfaces during heavy storms and to prevent seepage causing damage to the pavement construction.

When the provided roadside ditch fails to accommodate the discharge the road is said to have the drainage problem. The problem on highway drainage structures is world-wide (Saara and Saarenketo, 2006).

In Ethiopia, the effort to alleviate the failures on the roadside drainage structures is very little, even though the problem is so much large. Many times side ditches are found to be clogged, collapsed and washed away by the flood. Consequently, the quality of roads is much deteriorated and their life time is shortened. To address these problems investigations are necessary. Special attention shall be given to the failures in roadside ditches since any malfunction on these structures creates a wide-ranging problem (Mehari et al., 2015).

It is essential that adequate provision is made for road drainage to ensure that a road pavement performs satisfactorily. The main functions of a roadside drainage are: To prevent flooding of the road and ponding on the road surface, To protect the bearing capacity of the pavement and the subgrade material, and to avoid the erosion of side slopes (Rono,2014).

Water is the main contributor to the failure and damage to roads. Water can be in the form of ground water, surface water (streams and rivers) or rain, as runoff from the surrounding areas. Also, water may flow laterally from the pavement edges, or it may seep upward from a high ground water table. The water flow can damage the road in several ways. Water-related damage to pavement can cause one or more of the following forms of deteriorations: reduction of base, sub base, and sub grade strength, differential swelling in expansive sub-grade soils, stripping of asphalt in flexible pavements, and movement of fine particles into base or sub base materials resulting in a reduction of the hydraulic conductivity considerably. The damage to the road can be reduced if the flow of water is controlled. Minor damages can easily be repaired as part of the regular maintenance provided to the road and its structures. If the flow of water is not properly managed, the deterioration of the road will be more serious and occur more rapidly. This will lead to higher maintenance demands and in the worst cases result in serious damage (Belete, 2011).

Adequate drainage is essential during the design of roadways since it affects the serviceability and usable life of the roadway, including the structural strength of the pavement. Satisfactory cross-drainage facilities will limit the buildup of pond against the upstream side of roadway embankments and avoid overtopping of the roadway. If the formation of a pond on the carriageway occurs, hydroplaning (sliding of vehicles) becomes an important safety concern. Rapid removal of storm water from the pavement minimizes the phenomenon, which can result in the hazardous of hydroplaning. Adequate cross-slope and longitudinal grade enhance such rapid removal of storm water (Kassa, 2013).

In the study area, side drainage structures are not correctly functioning. The main causes are the inadequacy of roadside ditch for the duration of the rainy season to pass the flood, and improper alignment of a few side drainage structures on the road alignment. These problems cause damage to road pavement and side properties.

Starting from Jimma Agricultural and veterinary medicine collage to Agaro town, there is no proper roadside drainage, because in some place rain water is ponding on the side of the road. The rain water runoff is mainly contributed from very steep and elevated points along this road. For example, the run off that come from Bosa addis ketema kebele gravel roads cross and pond on the carriageway of this road. This problem may stop the traffic flow during heavy rain season.

1.2 Statement of the Problem

Roadside drainage channels perform the vital function of diverting or removing surface water from the highway right-of-way. They should provide the most efficient disposal system consistent with cost, an importance of the road, an economy of maintenance, and legal requirements (Zumrawi, 2014).

In our country, there is a good endeavor of expansion of roads, but many of them are not functioning well to the desired life time and quality. Out of the reasons, failure on roadside drainage structures comes first (Mehari et al., 2015).

In the study area, side drainage structures are not correctly functioning. The main causes are the insufficiency of existing roadside ditch for the duration of the rainy season to pass the flood and absence of side ditches in the place where it required. These problems cause damage to road pavement and side properties. Along with this road, the flow that comes from another ditch cross the pavement leads asphalt to distress, by washing the surfacing layer of the road at the entrance of Yebu town and another part of this road.

The rain water runoff is mainly contributed from very steep and elevated points along this road. For example, the run off that come from Bosa addis ketema kebele gravel roads cross and pond on the carriageway of this road.

The roadway between Jimma to Agaro town has variable topography which is subjected to flooding during rainy season. This is for the reason of inadequate road side drainage along the road. Starting from Jimma Agricultural and veterinary medicine collage to Agaro town, there is no proper roadside drainage; this problem may stop the traffic flow during heavy rain season. Also, the study area road users and residents are suffering by the problem of runoff that damage both pavements and residents properties, because of inadequate roadside drainage.

Currently, the problem of roadside drainage at some part of Jimma to Agaro road affects pavement, residents and road users. To improve this problem, the effect of inadequate roadside drainage should be estimated, and mitigation measures should be planned for sustainable and proper functioning based on ERA drainage design manuals 2002 and 2013 for low volume roads.

1.3 Research Questions

The research questions that the study wanted to answer are as follows:

1. Which sections of the road are prone to flooding that affect the traffic flows?
2. What are the factors or parameters that cause road side drainage problem along the study area?
3. What are the effects of water overflowing on the pavement and adjacent property?
4. What appropriate mitigation measures be recommended to address the problem?

1.4 Objectives

1.4.1 General objective

The general objective of the study was to evaluate roadside water drainage problems and come up with remedial measures along Jimma town to Agaro town road.

1.4.2 Specific Objectives

- To identify areas that are prone to flooding due to roadside drainage problems which affect the traffic flows.
- To determine factors that cause roadside drainage problem along the study area.
- To analyze the effect resulting from water overflowing due to roadside drainage problem on road pavement and adjacent property.
- To recommend appropriate mitigation measures.

1.5 Scope of the study

This study covers the provision of adequate roadside drainage facilities on Jimma to Agaro road. Maintenance is keeping all the components to the acceptable state for an efficiently working roadside drainage system. The study therefore mainly dwells on the state of road side drainage system within the study area on provision.

This research also gives attention to the effects water has on the road due to poor side drainage. It was looking at the various steps that should be taken so as to ensure sufficient roadside drainage system and how water causes road deterioration.

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

1.6 Significance of the research study

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

This research was aimed at coming up with findings on the effects of poor roadside drainage and maintenance systems in Jimma to Agaro road. It has also come up with the recommendation on the ways forward. It was supposed to find out reasons for inadequate provision of roadside drainage and the reasons for poor maintenance of the available side drains.

According to Kassa,(2013) The study, design, and construction of road drainage structures require skilled work force and intensive financial resources. If the drainage structures fail, high investment is required to maintain them to avoid traffic interruption. To minimize maintenance expenses proper protection and management of these road assets are important. Consequently, this study is beneficial to ERA Jimma Zone branch, Oromia road authority and others like zones in the Country for future roadside drainage structures construction to avoid problems by evaluating the performances of the existing drainage structures and proposing mitigation measures to avoid improper functioning.

The study will be beneficial for academicians and researchers who conduct similar researches on other roadside drainage structures. It may also support policy makers in their effort to address similar problems. Any organization working roadside drainage can use it as a further reference to construct roadside drainage.

1.7 Limitations of the project study

Limitations of the project study were few numbers of literatures available on the concerned study issues in our countries, work load given to researcher from DDU during the thesis work and financial problem.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

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. Water remaining on the surface combine with traffic action to cause potholes, cracks and other pavement failures (Zumrawi, 2014).

The roadside ditch is an important aspect of roadway structure and safety. Their design may be influenced by many factors, including motorists' safety, aesthetics, an economy of construction and maintenance. A stable ditch should provide adequate capacity for the intended design storm and be resistant to erosion failures. Ideally, the ditch design should also provide recoverable slopes to enhance driver safety in errant vehicles. Inadequate design of ditch capacity can result in compromised driver safety conditions, including water overtopping the ditch line and flooding the intended path of travel. Also, erosion failures can result in steeper ditch side slopes, and possibly failure of the roadway shoulder and structure. Adequate right-of-way should be acquired to accommodate the required ditch side slopes and capacity.

2.2 Highway drainage problem & water logging

Hazards associated with roads and roadsides were particularly predominant. Adverse roadway elements contributing to highway accidents were substandard road way alignment or geometry, lack of shoulders and shoulder defects, absent or inappropriate pedestrian facilities, narrow and defective lanes and bridges/bridge approaches, roadside hazards, undefined pavement center and edge lines, poor sight distances and visibility, unmarked and inappropriate design of intersections, serious allocation deficiencies along the route, haphazard bus shelters/stops, and others. The problems that identified are as follows: A) Drainage problems. B) Shoulder problems. C) Horizontal clearance problem. D) Environmental pollution problem (Mukherjee,2014).

Water logging: When water from any source finds no path to escape or drain out and create a hazardous situation is known as water logging. Excessive rainfall, inadequate side drainage sections, conventional drainage system with low capacity and gravity, natural siltation, absence of inlets and outlets, indefinite drainage outlets, lack of proper maintenance of existing drainage system, and over and above disposal of solid waste into the drains and drainage paths are accounted for the prime causes of water logging. During rainy season many roads are affected by water logging. This is cause due to an absence of any drainage system, improper maintenance of drainage facilities, etc.

The problem given above should be solved immediately; otherwise, the road network is unsuitable for use in its lifetime. Some remedial measures should be suggested to eliminate all the problems. Maintenance work should be done regularly by the authority. The people should be aware of the traffic rules and use the road properly (Mukherjee,2014).

2.3 Cross Drainage

Aspects of cross drainage that require special consideration in drainage design include: Hydraulic efficiency and capacity of the culvert in its initial (short) and Ultimate (long / extended) forms; Possible change in culvert operation (inlet control/outlet control) and subsequent outlet velocity changes; Potential variation in afflux and/or allowable headwater changes; Positioning of culvert inlets and outlets (within the stream); Changes to the inlet/outlet of adjacent culverts (in the same stream) where these are located within the median of a dual carriageway and where future widening will be within the median (e.g. culverts may become connected); Environmental considerations (e.g. scour prevention measures, fish or animal passage); resumptions (e.g. land required to accommodate future culvert inlets and outlets, allowance for maintenance access); and Cover over future culvert extensions due to carriageway widening (on the outside of the formation and/or in the median) (ERA, 2013).

2.4 Longitudinal Drainage

Aspects of longitudinal drainage that require special consideration for drainage design include: Drainage of the ultimate median which must be provided; Height of pipes and inlets designed to fit the initial and ultimate shapes of the median and carriageway; Designed capacity and hydraulic operation suitable for the initial and ultimate configurations; Conversion of an open channel within the median to an underground piped system and the requirements for outlets; Road safety impacts with drainage inlets structures within the median; Drainage connections to bridges (including any pollutant control devices) may need to be designed for the ultimate configuration (e.g. need to cope with additional surface run-off from a widened structure); Resumptions (e.g. land required to accommodate catch drains, diversion drains or channels, maintenance access, sedimentation basins); Environmental considerations (e.g. size and location of sedimentation basins) (ERA, 2013).

2.5 Surface Drainage

Surface drainage is a removal of water collects on the land and surface. Provision must be made for removal of water, from the rain that falls directly on the road or comes from the adjacent terrain. The road should be adequately sloped to drain the water away from the travel lanes and shoulders and then directed to drainage channels in the system, such as natural earth swales, concrete gutters, and ditches, for discharge to an adjacent body of water. The channels should be located and shaped to minimize the potential for traffic hazards and accommodate the anticipated storm-water flows. Drainage inlets should be provided as needed to prevent ponding and limit the spread of water into traffic lanes (Mukherjee,2014).

2.5.1 Removal of rainwater from the carriageway

Water has some unhelpful characteristics which impact on highway performance. It is a lubricant reducing the effectiveness of tyre grip on the carriageway wearing surface which can increase stopping distances. Spray from rainwater being thrown up by car tyres can reduce visibility which can lead to delays in reacting to events on the carriageway. Drag on car tyres from local rainwater ponding can alter the balance of vehicles traveling at the speed which can be alarming or cause skidding. It is incompressible therefore standing water effectively acts like a jackhammer on the wearing course right through to the sub-base when vehicles pass over a head. In extreme storms, rainwater can simply wash away roads on embankment should the culvert become blocked or lack capacity (Zumrawi, 2014).

2.5.2 Surface Drainage Methods

For rural highways on embankments, runoff from the roadway should be allowed to flow evenly over the side slopes and then spread over the adjacent terrain. This method, however, can sometimes adversely impact surrounding land, such as farms. In such instances, the drainage should be collected, for example, in longitudinal ditches and then conveyed to a nearby watercourse. When a highway is located in a cut, runoff may be collected in shallow side ditches. These typically have a trapezoidal, triangular, or rounded cross section and should be deep enough to drain the pavement subbase and convey the design-storm flow to a discharge point. Care should be taken to design the ditches so that the toe of adjoining sloping fill does not suffer excessive erosion.

2.6 Road Side Drains

Side drains Keep water off the surface of the road and keep the foundations of the road dry. Effective side drains will reduce the need for maintenance by preventing deterioration of the surface and will provide a drier and hence safer road.

If the side drains are missing or not working then, water running along or across the road may lead to gully erosion. The foundations may get wet and soft leading to rutting. A common reason that side drains stop working is that people were crossing the drain block them: either vehicle driving across the drain damage them (ERA, 2013).

Side drains serve two main functions namely to collect and remove surface water from the immediate vicinity of the road and, where needed, to prevent any sub-surface water from adversely affecting the road pavement structure.

Seepage may occur where the road is in cut and may result in groundwater entering the sub-base or subgrade layers. Inadequate surface or subsurface drainage can therefore adversely affect the pavement by weakening the soil support and initiating creep or failure of the downhill fill or slope. Localized seepage can be corrected in various ways but seepage along more impervious layers, such as shale or clay, combined with changes in road elevation grades, may require subsurface drains as well as ditches.

Channel shapes are determined for a location by considering the terrain, flow regime and the quantity of flow to be conveyed (AASHTO 1992). Typically, ditch geometry is either V-shaped or trapezoidal. Roadway channels should provide recoverable slopes, thereby minimizing the impact of errant vehicles. This can be accomplished by designing ditch cross sections with mild side slopes. Depending on side slopes used, both V-shaped and trapezoidal ditches can provide driver safety and be economical to construct. When mild side slopes are used, the shape tends to approach a parabolic shape, which is recognized as being the most hydraulically efficient shape (AASHTO 1992). V-shaped ditches are more susceptible to erosion (AASHTO 1992), trapezoidal ditches may be preferred on certain soil conditions, such as fill sections and highly erodible soils.

The side slopes of the ditch/channel should not exceed the angle of repose of the soil comprising the ditch line and should be 3:1 or flatter. Where local conditions dictate the use of some rigid lining, the use of steeper slopes (>2:1) may be more economical (AASHTO 1992).

The successful design of roadside ditches must satisfy two requirements: ditch capacity and stability. In general, the 10-year storm is used to determine ditch capacity, while the 2-year storm is used to check ditch stability. The logic implied in the selection of storm return period is that the initial period after ditch construction before vegetation is developed constitutes the most critical period regarding ditch stability. After vegetation is fully developed, the channel is considered stable, and channel capacity becomes more critical. Highly traveled roads, such as interstates, may require an increase of the design storm to reduce the probability of capacity failure.

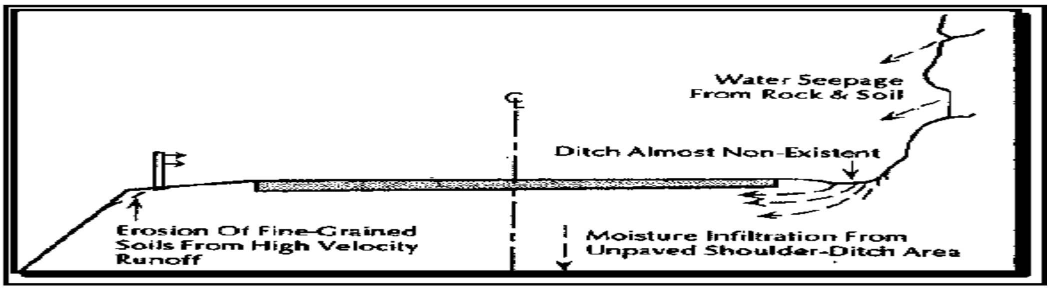

Figure 2.1: Inadequate side drains
Source: (ERA, 2013).

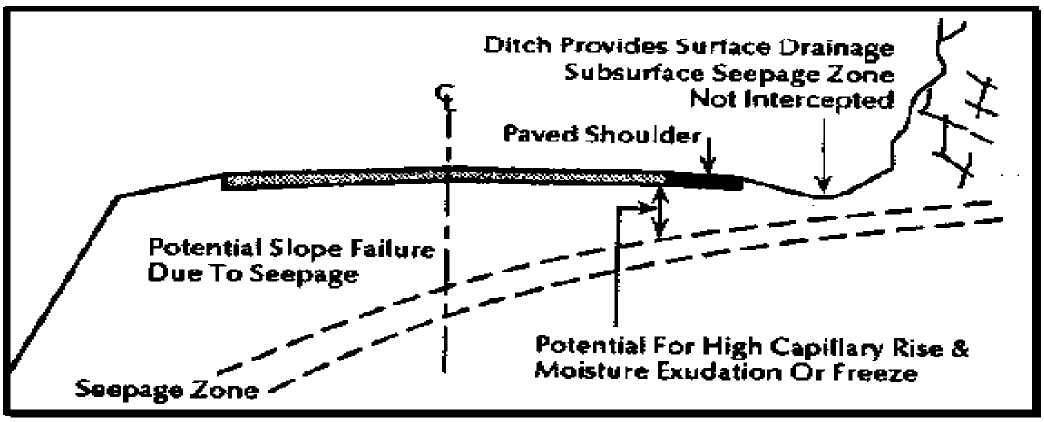

Figure 2.2: Inadequate side drains and subsurface drainage

Source: (ERA, 2013)

If the road has effective side drains and adequate crown height, then the in-situ subgrade strength will stay above the design value. If the drainage is poor, the in situ strengths will fall to below the design value.

The choice of side drain cross-section depends on the required hydraulic capacity, arrangements for maintenance, space restrictions, traffic safety and any requirements relating to the height between the crown of the pavement and the drain invert.

Under normal circumstances, the adoption of a trapezoidal cross-section will facilitate maintenance and will be acceptable from the point of view of traffic safety. It is much easier and appropriate to dig and clean a trapezoidal drain with hand tools, and the risk of erosion is lower. The minimum recommended the width of the side drain is 500mm. This shape carries a high flow capacity and, by carefully selecting the gradients of its side slopes, it will resist erosion (ERA,2002).

The V-shape is the standard shape for a drainage ditch constructed by a motor-grader or towed grader. It can be easily maintained by heavy or intermediate equipment, but it has relatively low capacity necessitating more frequent structures for emptying it. Furthermore, the shape concentrates flow at the invert and encourages erosion (Zumrawi,2014).

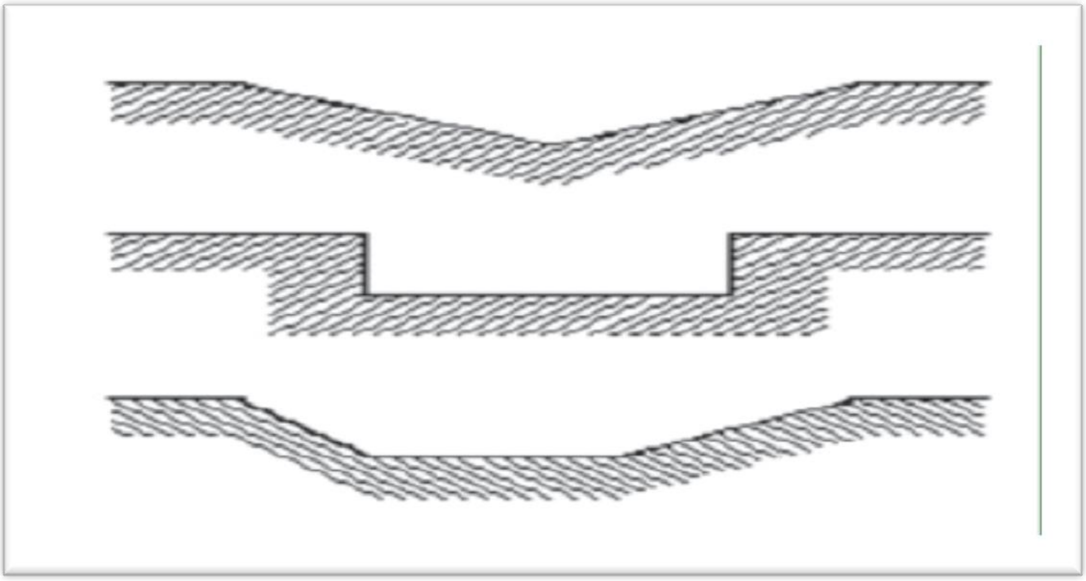

Figure 2.3: Types side drains

Source: (Zumrawi,2014)

The rectangular shaped drain requires little space but needs to be lined with rock, brick or stone masonry, or concrete to maintain its shape. In very flat terrain and reasonable soils, it is often best to use wide unlined "meadow drains." These are formed shallow and continuous depressions in the surface that avoid abrupt changes in surface profile. When properly designed, their capacity is high, and the flow velocity is low so that erosion should be controlled. When the subgrade is an expansive soil, changes in moisture content near to the road itself must be minimized.

As far as traffic safety is concerned, a wide and shallow drain for a given flow capacity is preferable to a deeper one but, particularly on the steep sidelong ground, the extra width required to achieve this may be impracticable or too expensive. Side drain covers can be used to provide extra road width in places where space is severely limited but their widespread use is not recommended. They are expensive, and the drains that they cover are then difficult to maintain.

Side drains (as well as the road itself) should have a minimum longitudinal gradient of 0.5%, except on crest and sag curves. The slackening of the side drain gradient in the lower reaches of significant lengths of the drain should be avoided to prevent siltation.

Access across side drains for pedestrians, animals and vehicles needs to be considered. Community representatives should be consulted about locations, especially for established routes. The methods that could be used are: Widening the drain and taking its alignment slightly away from the road; Hardening the invert and sides of the drain; Beam/slab covers or small culverts. The arrangement must be maintainable and not risk blockage of the side drain. Failure to accommodate these needs will usually result in later arrangements that compromise the function of the side drain. Groundwater in the subgrade can be released either by using a drainage layer at sub-base level or by incorporating gravel cross drains in the shoulder that exit via a weep hole in the side drain backed with a piece of filter fabric. The weep holes must be set at the correct level to take the water from the appropriate pavement layer and also the drain must be sufficiently deep so that there is little possibility of the water in the drain being of sufficient depth for it to flow back into the road. Deeper drains, comprising a filter-wrapped perforated pipe within a graded gravel backfill, can be constructed under very wet slope conditions to a depth of 1-1.5m below the level of the side drain invert and led to the nearest culvert inlet (ERA, 2011).

The roadside table should follow natural drainage lines where possible, to reduce water velocity and therefore erosion. They can be sown with grass and maintained by mowing, so they trap silt efficiently. Cut-off drains can be used to divert runoff water before it reaches critical areas, and diverting drains avoid excessive concentration of flow.

Concrete or wood dissipation structures will slow fast running storm water in drains and hence reduce downstream erosive potential (Griffiths et al.,2000).

2.7 Backwater Effect on Road Drainage Structures

When a roadway crosses a natural drainage way, the resistance to a 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 becoming 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 (Johnson et al., 2002). Bridges seem to more readily allow sediment transport than culverts and therefore have less accumulation up stream of the crossing (Wellman et al., 2000).

2.8 Erosion control in the side drain

When the water flows too fast, it will erode the bottom of the drain. The faster water flows, the more soil it can erode and carry away. There are various methods of reducing erosion, the two most common being to build simple scour checks or to line the drains.

Scour checks (sometimes called check dams) reduce the speed of water and help prevent it from eroding the road structure. The scour check acts as a small dam and, when naturally silted up on the upstream side, effectively reduces the gradient of the drain on that side, and therefore the velocity of the water. The energy of the water flowing over the dam is dissipated by allowing it to fall onto an apron of stones. Scour checks are usually constructed with natural stone, masonry, concrete or with wooden or bamboo stakes. By using natural building materials available along the road side, they can be constructed at low cost and be easily maintained after the road has been completed.

There must be sufficient cross-sectional area above the scour check (i.e. where the water has been slowed down) to accommodate the maximum design flow. Wide drains are also preferred to reduce the velocity of the water and minimize erosion but space is at a premium in the type of terrain where scour checks are required so wide drains may not always be practicable(ERA, 2011).

2.8.1 Water Disposal

Side drains collect runoff water. That water then has to be discharged from the drain. This can be either, To the adjoining ground using a turnout; or Across the road to the side drain on the downstream side of the road via a side drain relief culvert.

The position and number of turnouts should be indicated on the design drawings. The final location should be determined by site inspection, so they are provided where they will work.

2.8.2 Channel Location and Type

Assuming adequate functional design, the next most important design consideration is channel location. Locations that avoid poorly drained areas, unstable soil conditions, and frequently flooded areas can greatly reduce drainage related problems.

Often drainage and open channel considerations are not considered the primary decision factors in the roadway location; however, they are factors, which will often directly or indirectly affect many other considerations. Often minor alignment adjustments can avoid serious drainage problems (ERA,2013).

If a channel can be located far enough away from the highway, the concerns of traffic safety and aesthetics can be somewhat mitigated. The cost of additional right of way may be offset somewhat by the reduced cost of erosion control, and traffic protection. Ditches should be located where they can fully intercept the flow from the natural catchments adjacent to the road. The location of ditches is mainly dependent on the space available. Possible locations are: Along the edge of the road; along the top of cuttings; or at the toe of embankments.

In cuttings, ditches should preferably be positioned at the top of the cuttings to avoid potential erosion of the slope by surface water. Large sized ditches may create stability problems in the cutting slope and, therefore, appropriate measures should be taken.

Where ditches are located alongside the road, they may be designed to convey the runoff from the carriageway as well as that of the natural catchment. Ditches should preferably consist of earth channels lined with a native grass species (or the combination of species), to provide adequate resistance to flow erosion. However, this depends on the availability of water throughout the year for the native grass to grow.

The design criteria apply to roadside channels are: Channel side slopes shall not exceed the angle of repose of the soil and lining and shall be 2:1 or flatter in the case of the rock-riprap lining. Stone pitching or grouted riprap must be used for channel side slopes steeper than 2:1; Flexible linings shall be calculated using the method of allowable tractive force, and Channel freeboard shall be 0.3 meters.

2.9 Effect of Road Geometry on Drainage

Road surfacing materials are traditionally designed to be effectively impermeable, and only a small amount of rainwater should percolate into the pavement layers. It is important that any such water can drain through underlying pavement layers and away from the formation. Rainfall which does not permeate the pavement surface must be shed towards the edges of the pavement.

Drainage is a basic consideration in the establishment of road geometry and vertical alignments should ensure that: a) outfall levels are achievable, and b) subgrade drainage can discharge above the design flood level of any outfall watercourses. These considerations may influence the minimum height of embankments above watercourses. They could also influence the depth of cuttings as it is essential that sag curves located in cuttings do not result in low spots which cannot be drained. Drainage can then be affected over the edge of the carriageway to channels, combined surface water, and ground water drains or some other form of linear drainage collector. Gullies may be required at very close spacings on flat gradients (Mukherjee,2014).

Safety aspects of edge details are functions of the location, form, and size of edge restraint detail, and any associated safety barrier or safety fence provision. Roadside drainage features are primarily designed to remove surface water. Since they are placed along the side of the carriageway, they should not normally pose any physical hazard to road users. It is only in the rare event of a vehicle becoming errant that the consequential effects of a roadside drainage feature upon a vehicle become important.

Surface water channels are normally of a triangular concrete section, usually slip-formed, set at the edge of the hard strip or hard shoulder and flush with the road surface.

Significant benefits can include ease of maintenance and the fact that long lengths, devoid of interruptions, can be constructed quickly and fairly inexpensively. It may be possible to locate channel outlets at appreciable spacing’s and possibly coincident with watercourses.

It is reasonable to assume that the relative risk to vehicles and occupants from impingement on surface water channels is lower than would be expected from impingement on other drainage features such as kerbs, embankments and ditches, as the channels present a much lower risk of vehicles losing contact with the ground or overturning (Mukherjee,2014).

2.10 Rating and evaluating roadway drainage

Periodic inspection, rating, and evaluation of roadway drainage are required as a part of pavement management. It is considered good practice even without a formal pavement management program. A regular inspection program allows managers to identify and schedule necessary improvements on a timely and cost-effective basis.

Routine maintenance can often avert more serious drainage-related problems. While casual observation is frequently used, a scheduled and organized evaluation system produces more consistent results. These more formal evaluations also promote good recordkeeping which is very helpful in planning projects and reducing time and information loss due to staff turnover. Four rating categories can be described: excellent, good, fair, and poor. The ratings are described by the general condition, typical defects, and the recommended improvements. It is unlikely that all defects will be present. There may be only one or two in a specific section of road.

The extent of work required should help determine if the rating is poor, fair, or good. Annual costs associated with the necessary maintenance and improvements for each rating can be developed and used with a pavement management system for programming both short-range and long-range improvements (Walker D, 2000).

2.11 Hydrology

The hydraulic capacity of a drainage channel is dependent on the size, shape, slope and roughness of the channel section. For a given channel, the hydraulic capacity becomes greater as the grade or depth of flow increases. The channel capacity decreases as the channel surface becomes rougher (ERA,2013).

A rough channel can sometimes be an advantage on steep slopes where it is desirable to keep flow velocities from becoming excessively high. A good open channel design minimizes the effect on existing water surface profiles.

In the design of highway drainage structures, floods are usually considered regarding peak runoff or discharge in cubic meters per second (m^3/s). The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to the design of highway drainage structures. 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 is important to realize that any hydrologic analysis is the only estimation. Although some hydraulics analysis is necessary for all highway drainage structure design, the extent of such studies should be commensurate with the hazards associated with the hydraulics structures and with other concerns, including economic, engineering, social, and environmental factors. Because hydrology is not an exact science, different hydrologic flow estimation methods developed for determining flood runoff may produce different results for a particular situation. Therefore, the engineer should exercise sound engineering judgment to select the proper flow estimation method or methods in estimation design flows. While performing the hydrological and hydraulics analysis for the design of highway drainage systems, the hydraulic engineer should recognize and evaluate potential environmental problems that would impact the specific design of a drainage structure early in the design process (ERA, 2013).

2.11.1 Safety Consideration

An important aspect of highway drainage design is that of traffic safety. The shape of a roadside channel section should minimize vehicular impact and provide a traversable section for vehicles leaving the traveled way. The ideal channel section, from a safety standpoint, will have flattened side slopes and a curved transition to the channel bottom (ERA,2002).

2.11.2Maintenance Consideration

The design of open channels and roadside ditches should recognize that periodic maintenance inspection and repair is required. Provisions should be incorporated into the design for access to a channel by maintenance personnel and equipment.

When assessing the need for permanent or temporary access easements, entrance ramps and gates through the right of way fences, consideration should be given to the size and type of maintenance equipment required. Damaged channels can be expensive to repair and interfere with the safe and orderly movement of traffic. Minor erosion damage within the right of way should be repaired immediately after it occurs and action is taken to prevent the recurrence.

Conditions, which require extensive repair or frequently recurring maintenance, may require a complete redesign rather than repetitive or extensive reconstruction. The advice of an Expert Drainage Engineer should be sought when evaluating the need for major restoration.

The growth of weeds, brush, and trees in a drainage channel can effectively reduce its hydraulic efficiency. The result being that a portion of the design flow may overflow the channel banks causing flooding and possible erosion.

Channel work on some projects may be completed several months before total project completion. During this interim period, the contractor must provide interim protection measures and possibly advance the planned erosion control program to assure that minor erosion will not develop into major damage.

2.12 Channel Design

Hydraulic design associated with roadway ditches is a process that selects and evaluates alternatives according to established criteria. These criteria are the standards established to insure that a highway drainage system meets its intended purpose without endangering the structural integrity of the facility itself and without undue adverse effects on the environment or the public welfare.

Side drains are essential for the performance of the road and they should be properly designed. Any savings in design cost will be far outweighed by increased maintenance costs over the life of the road.

The design of side drains should consider: Whether the drain serves the whole width of the road or just half the width; Does the drain serve just the road or does it also provide drainage to the adjoining areas; The gradient of the road; and the nature of the materials the road is crossing: are they easily eroded like silts and sands or erosion resistant likes stiff clays or rock. The designer controls a range of variables to fit the side drains to their environment: The channel shape and size; Whether or not the channel is lined; whether scour checks are provided and if so their spacing; and The spacing of turnouts or side drain relief culverts.

2.12.1Hydraulic Analysis

A hydrological analysis performed to determine the expected peak flow to the ditch for a selected storm. Stability of a ditch is most critical during the initial period immediately after construction when vegetation has not been fully established. A hydrological analysis is performed using the 2-year storm for use in stability analysis. When the 2-year storm velocity is obtained, it is compared against the maximum allowable velocity of the soil type comprising the ditch line. If the design does not meet stability requirements (the predicted 2-year storm velocity exceeds the maximum allowable velocity for the soil lining), the designer must revise the design. Revisions commonly include changes in selected geometry, selected lining, and adjustments in ditch grade. Upon revision, the designer must re-evaluate stability the ditch lining (natural or synthetic). When vegetation is fully established, or lined with a rigid lining (such as concrete or pavement), the ditch is considered stable.

When stability requirements are satisfied, the ditch must then be evaluated to ensure adequate capacity. Capacity is typically checked using the 10-year storm depth. If the 10-year storm depth is economically contained in the selected cross-section, capacity is achieved. If the selected ditch geometry is not adequate or economical, the designer should revise the geometry and repeat stability and capacity analyses.

Hydrological data for a roadway ditch is necessary for use in determining peak flow to the ditch. Rational Method can be used to approximate peak flow for the usually small drainage area associated with roadway ditches. When the conversion factor for metric units is kc=0.00278 to convert ha-mm/hr to m^3/s. Due to assumptions regarding the homogeneity of rainfall and equilibrium condition at the time of peak flow, the rational method should not be used on areas larger than about 0.5 km^2without subdividing the overall catchment into sub-catchments and including the effect of routing through drainage channels." Because rainfall intensity is not homogeneous (varies over time and space), the Rational Method will become more conservative (tendency to over-predict) peak flow for larger drainage areas, due to this underlying assumption.

The runoff coefficient accounts for any runoff losses that occur within a given drainage area, typically given as a function of land use. The runoff coefficient for drainage areas is an indication of the percent of rainfall volume that becomes runoff and a characteristic of the drainage area. Tables have been compiled providing runoff coefficients for various land uses. When more than one land use occurs within the same drainage area, common practice is to develop an area-weighted runoff coefficient accounting for each land use within the total drainage area. One of the “principle fallacies” of the Rational Method is the assumption that a single value for the runoff coefficient can be associated with a drainage area, despite total rainfall volume or antecedent conditions (Bedient and Huber, 1992). This assumption holds more accurate for predominately impervious land uses.

Rainfall intensity, I, is obtained from IDF (Intensity-Duration-Frequency) Curves for a given area, specified return period, and duration time. In Ethiopia, IDF curves are available in ERA manual, 2013. Time of concentration, Tc, is commonly assumed to equal the duration time. “This assumption is physically realistic because the time of concentration also is the time to equilibrium at which time the whole catchment contributes to flow at the outfall" (Bedient and Huber, 1992).

Drainage area should be determined based on available geographical information, such as topographic maps. Because drainage areas are often unsymmetrical in shape and difficult to quantify, a simplification to aid in the determination of area is to use rectangular strips to approximate drainage area.

In roadway design, the drainage area associated with roadside ditches is commonly divided into three subareas to account for land uses pavement, shoulder and ditch line, and area outside the right-of-way. Due to geometric nature of the roadway structure, land use area approximations within the roadway right-of-way (pavement, shoulder and ditch line) are typically easily attained. Area approximations outside the roadway right-of-way rely on the engineering judgment of the designer due to a variability of the landscape.

Runoff coefficients for the areas within the right-of-way (roadway pavement, shoulder and drainage ditch) can be easily applied. The area outside the right-of-way can consist of various land uses and, therefore, be further subdivided to best develop a weighted a runoff coefficient.

Inadequately accounting for runoff coefficients can lead to inaccuracies in the prediction of peak flow. Consequently, capacity and stability checks may be inaccurate. The time of concentration is used to enter the IDF curve to obtain rainfall intensity for a specific storm. Because the time of concentration is inversely proportional to rainfall intensity, accurate determination of the time of concentration is critical.

2. 13 Watershed Area

Most runoff estimation techniques use the size of the contributing watershed as a principal factor. Runoff rates and volumes increase with increasing drainage area. The size of a watershed will not usually change over the service life of the road drainage facility. However, agricultural activity and land development may cause the watershed area to change over time. Flow diversions and catchment area changes due to urbanization and other development inevitably will also occur at some point in the future. The drainage designer should try to identify or otherwise anticipate such changes. The watershed shape will also affect rainfall runoff rates. For example, a long, narrow watershed is likely to experience lower runoff rates than a short, wide watershed of the same size and other characteristics. Some hydrologic methods accommodate watershed shape explicitly or implicitly; others may not. If a drainage area is unusually irregular extremely narrow, the designer should consider using a hydrologic method that explicitly accommodates this watershed shape (ERA, 2013).

2.14 Rational Method

The Rational Method is most accurate for estimating the design storm peak runoff for areas up to 50 hectares (0.5 km^2). This method, while first introduced in 1889, is still widely used. Even though it has come under frequent criticism for its simplistic approach, no other drainage design method has achieved such widespread use (ERA, 2002).

Some precautions shall be considered when applying the Rational Method: The first step in applying the Rational Method is to obtain a good topographic map and define the boundaries of the catchment area in question. A field inspection of the area should also be made to determine if the natural drainage divides have been altered.

In determining the runoff coefficient C value for the catchment area, thought shall be given to future changes in land use that might occur during the service life of the proposed facility that could result in an inadequate drainage system. Also, the effects of upstream detention structures must be taken into account.

Restrictions to the natural flow such as highway crossings and dams that exist in the catchment area shall be investigated to see how they affect the design flows. The charts, graphs, and tables included in this section are not intended to replace reasonable and prudent engineering judgment that should permeate each step in the design process.

Characteristics of the Rational Method that limit its use to 50 hectares include: The rate of runoff resulting from any rainfall intensity is a maximum when the rainfall intensity lasts as long as or longer than the time of concentration. That is, the entire catchment area does not contribute to the peak discharge until the time of concentration has elapsed.

This assumption limits the size of the drainage basin that can be evaluated by the Rational Method. For large catchment areas, the time of concentration can be so large that constant rainfall intensities for such long periods do not occur and shorter more intense rainfalls can produce larger peak flows. Further, in semi-arid and arid regions, storm cells are relatively small with extreme intensity variations thus making the Rational Method inappropriate for catchment areas greater than 50 hectares.

Frequencies of peak discharges depend on rainfall frequencies, antecedent moisture conditions in the catchment area, and the response characteristics of the drainage system.

For small and largely impervious areas, rainfall frequency is the dominant factor. For larger drainage basins, the response characteristics control. For catchment areas with few impervious surfaces (little urban development), antecedent moisture conditions usually govern, especially for rainfall events with a return period of 10 years or less.

The fraction of rainfall that becomes runoff (C) is independent of rainfall intensity or volume. This assumption is only reasonable for impervious areas, such as streets, rooftops, and parking lots. For pervious areas, the fraction of runoff does vary with rainfall intensity and the accumulated volume of rainfall. Thus, the application of the Rational Method requires the selection of a coefficient that is appropriate for the storm, soil, and land use conditions. Many guidelines and tables have been established, but seldom, if ever, have they been supported with empirical evidence.

The peak rate of runoff is sufficient information for the design. Modern drainage practice includes detention of urban storm runoff to reduce the peak rate of runoff downstream. Using only the peak rate of runoff, the Rational Method severely limits the evaluation of design alternatives available in urban and in some instances, rural drainage design.

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 mean rainfall intensity for a 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)(ERA, 2002). The rational formula is expressed as:

$$Q = 0.00278\ CIA \qquad (2.1)$$

Where: Q = maximum rate of runoff, m^3/s

C = runoff coefficient representing a ratio of runoff to rainfall

I = average rainfall intensity for a duration equal to the time of Concentration, for a selected return period, mm/hr

A = catchment area tributary to the design location, ha

The coefficients given in are applicable for storms of 5-year to 10-year frequencies. Less frequent, higher intensity storms will require modification of the coefficient because infiltration and other losses have a proportionally smaller effect on 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. The product of C_f times C shall not exceed 1.0.

$$Q = 0.00278\, CC_f IA \qquad 2.2$$

2.15 Manning's Equation

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 (ERA.2002).

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 (ERA,2002).

$$Q = (AR^{2/3} S^{1/2})/n \qquad 2.3$$

Where, Q is the volumetric flow rate passing through the channel reach in m^3/sec.

A is the cross-sectional area of flow normal to the flow direction in m^2.

S is the bottom slope of the channel in m/m (dimensionless).

n is a dimensionless empirical constant called the Manning roughness coefficient.

R is the hydraulic radius = A/P.

P is the wetted perimeter of the cross-sectional area of flow in m.

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on Ethiopian Mapping Authority (EMA) topographic maps (1:50,000). Average flow velocity is usually determined for bank-full elevation. Manning's equation or water surface profile information can be used to estimate average flow velocity. When the channel section and roughness coefficient (Manning's n) are available, then the velocity can be computed using the Manning Equation (ERA,2002)

$$V = (r^{2/3} s^{1/2})/n \qquad 2.4$$

Where: V = average velocity, m/s

r = hydraulic radius, m (equal to A/P_w)

A = cross sectional flow area, m^2

P_w= wetted perimeter, m

s = slope of the hydraulic grade line, m/m

n = Manning's roughness coefficient

2.16 Overland Flow Path Selection

In drainage system design, the overland flow path is not necessarily perpendicular to the contours shown on available mapping. Often, the land will be graded and swales and streets will intercept the flow that reduces the time of concentration. Care should be exercised in selecting overland flow paths in excess of 60 m in urban areas and 120m in rural areas (ERA,2013).

(i) Calculation of the Time of Concentration for Overland Flow

Overland flow is the type of flow that occurs in small, flat or in upper reaches of catchments, where there is no clearly defined watercourse. Run-off, then, is in the form of thin layers of water flowing slowly over the fairly uneven ground surface. The kerby formula is recommended for the calculation of Tc in this case. It is only applicable to parts where the slope is fairly even.

$$Tc = 0.604\left(\frac{CvL}{S^{0.5}}\right)^{0.467} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2.5$$

Cv = roughness coefficient of land use

L = hydraulic length of catchment, measured along flow path from the catchment boundary to the point where the flood needs to be determined

H = height of most remote point above outlet of catchment (m)

S = Slope of the catchment

Tc=time of concentration (hours)

S=Slope of the catchment

H =height of most remote point above outlet of catchment (m)

$$S = \frac{H}{1000L} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2.6$$

(ii) Calculation of Time of Concentration for Defined Watercourses

In a defined watercourse, channel flow occurs. The recommended empirical formula for calculating the time of concentration in natural channels was developed by the US Soil Conservation Service.

$$Tc = \left(\frac{0.87L^2}{1000Sav}\right)^{0.385} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 2.7$$

Where:

Tc = time of concentration (hours).

L = hydraulic length of catchments measured along flow path from the catchment boundary to the point where the flood needs to be determined (km).

Sav= average slope (m/m).

$$Sav = \frac{H_{0.85} - H_{0.10}}{1000 * 0.75L} \quad \ldots\ldots 2.8$$

Where: S_{av} =average slope (m/m)

H 0.10L =elevation height at 10% of the length of the watercourse (m)

H 0.85L = elevation height at 85% of the length of the watercourse (m)

L = length of watercourse (km)

H = H 0.805L - H 0.10L (m)

The height of waterfalls and high rapids are subtracted from the gross H value.

2.17 Causes of Poor Drainage

Raj (1991) identified water logging as one of the causes of poor drainage. The causes of water logging are both natural and artificial. The natural causes include poor drainage of the sub-soil under favorable geological existence of hard pan below the surface, sub-emergence of land under floods and deep percolation from rainfall well as the artificial causes are excessive seepage from unlined ditches and distributaries, hydraulic pressure from upper saturated areas located at higher elevations, and poor maintenance of natural drainage or blocking of natural drainage by roads and railways. As further stated it that land drainage problems occur in flat areas of an even land surface with depressions or ridges preventing natural runoff and in areas without any provision of an outlet.

According to Hollis (1988), the most obvious change that urbanization brings to a drainage basin is that it replaces vegetated landscapes with less permeable surfaces like tarmac roads and buildings. There is less surface, storage and less water enter the soil and groundwater stores. The reduced water storage and vegetation cover mean lower evapotranspiration outputs. Consequently, the percentage of rain water that run off increases. Ajayi (1993) stated that in most developing countries, solid waste disposal is closely linked with wastewater drainage in that open sewers and drainage channels often end up also being receptacles for solid wastes generated in the community. This leads to blockages, reductions in capacity and an exacerbation of flooding problems. In such situations, Ajayi suggested that the Institutional arrangements be along the lines of an "Integrated Environmental Service" provider (incorporating water supply, wastewater, and solid waste functions) and a corresponding "Integrated Environmental Control Agency" Ajayi is of the view that the proposed Institutional arrangements will provide an appropriate framework for the equitable allocation of resources to the various environmental service needs and should result in a climate conducive to the implementation of the alternative approach being advocated.

A World Bank report (1996) indicated that poor drainage conditions in developing countries are a result of weak institutional capacity, inadequate regulatory policies, inadequate governance, and lack of public Education / awareness /participation. The resolution of problems associated with an infrastructural provision in most developing countries currently follows along the traditions of the developed countries. Often, this is not appropriate for the locality. A review of urban drainage practice shows that, in the past, the philosophy has been based on conveying peak flows of municipal waste water and storm runoff away from the urban areas as quickly as possible. This has resulted in downstream flooding and heavy pollution of receiving waters (Sonuga, 1993**)**. But it should not be forgotten that in some developing countries especially where the above-mentioned qualities exist, still drainage problems especially those related to weather conditions do still occur. World Health Organisation report (1992) considered poor operation and maintenance as the major cause of poor drainage conditions.

2.18 Problems related to poor drainage

Clarence (1984) reported that in many African countries sewage systems and disposal habits especially in urban areas rely upon storm water drainage and this is the major cause of health problems. Gordon (1971) indicated that waste water works remove about 70% of the water supplied together with sock ground water and surface runoff. This may enter or be admitted to the collecting system like Street gutters, open channels and covered structures for the removal of runoff accumulating from rain storms and melting snow since these are among the earliest public works of urban communities. They kept the low-lying and often highly developed positions of the community from being flooded by converting and increasing over land flows. The New Vision (2003) reported an indication that the slime (fecal matter) comes from septic tanks that are intentionally emptied into the drainage system during rainy seasons. This is what most landlords resort to because payment for sewerage emptying is expensive and sometimes they do not have the money to pay; also access to the area by cesspool emptier is difficult.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study area Location

The research study was carried out at Jimma town to Agaro town roadway, and it is under Jimma zone Oromia Region, in southwestern of Ethiopia. It is the special zone of the Oromia region, and Agaro is a Town and separate Woreda in Jimma zone. The area of this study was along Jimma to Agaro roadway, which is 45kilometer long.

The study was conducted on a road that crosses Jimma town, Manna and Gomma, woredas of Jimma zone. These zones are located in the Southwestern part of Ethiopia between Latitude 6^o and 9^o north and Longitude 34^o and 38^o east and between altitude ranges of 880 to 3340 meters above sea level (ORG, 2003).

Gomma is located 397 km Southwest of Addis Ababa and about 50 km west of Jimma town (ORG,2003). Its area is 1,230.2 km2 (ARDO, 2008). The annual rainfall varies between 800-2000 mm, while the mean minimum and maximum annual temperatures of the woreda vary between 7^{o}C-12^{o}C and 25^{o}C-30^{o}C, respectively (ARDO, 2008). The average annual rainfall is 1524 mm. Altitudinal range of the woreda is between 1387-2870 m. (IPMS,2007). Agro-ecologically, this woreda is divided into 8% high land (Dega), 88 %, intermediate high land (Weyina Dega) and 4% low land (Kolla) (IPMS, 2007).

Manna is located at 368 km southwest of Addis Ababa and 20 km west of Jimma town. The total area of the woreda is 478.98 km^2 (47,898 ha) of which 12% is Highland, 65% intermediate Highland and 23% lowland with altitudinal ranges between 1470–2610 m (ARDO, 2008). The mean minimum and maximum temperatures are 13.0^{0}C and 24.8^{0}C, respectively (ARDO,2008).

The study area started at Jimma town four loin’s roundabout with an elevation of 1750m above mean sea level and ends in the entrance of Agaro town at elevation of 1657m. Then route of the Road passing through two Woreda of various elevation. Therefore, the route of the road slopes and rises afterwards from the starting to end points.

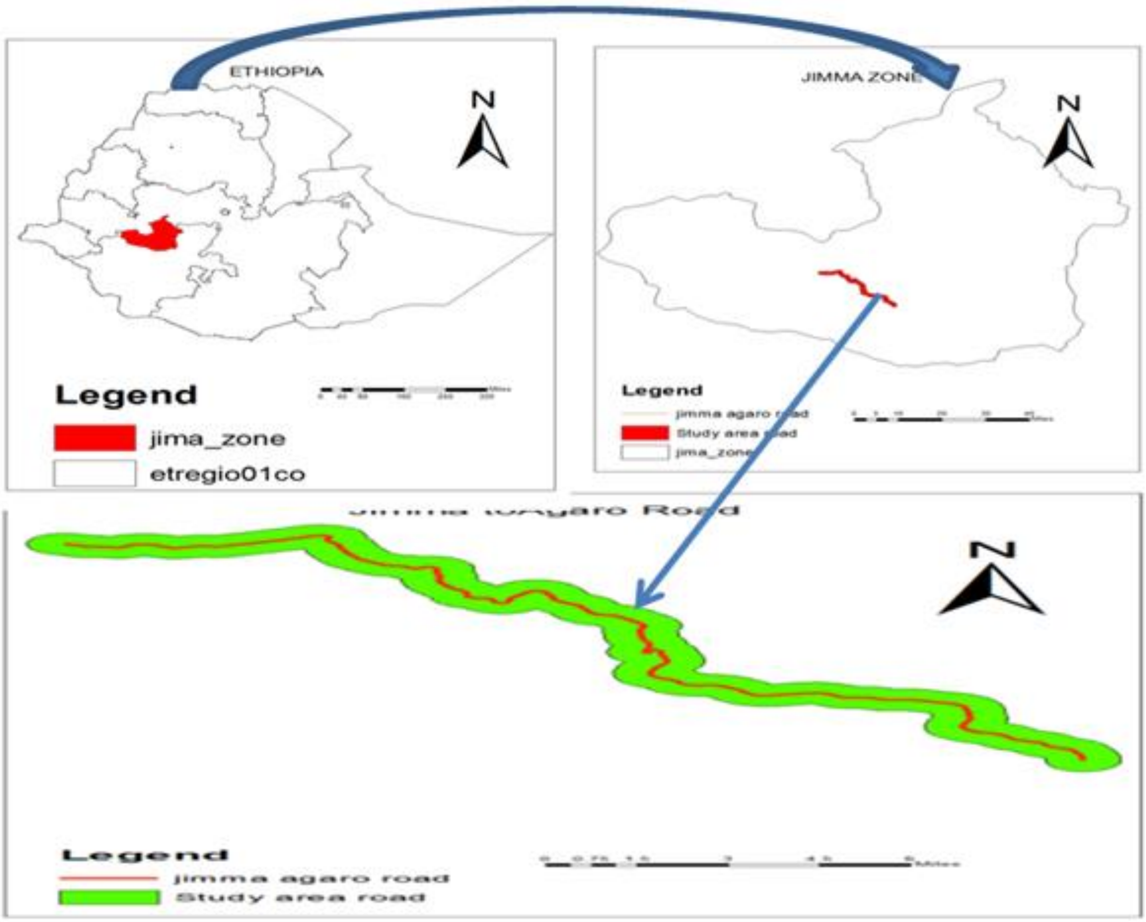

Figure 3.1 Map of Study Area

Source: MOWR, GIS database office

3.2 Study period

The study was conducted from April, 2016 to February, 2017 along Jimma to Agaro road, which is located in Jimma zone Oromia Regional state, in southwestern of Ethiopia.

3.3 Data Collection Procedure

In order to achieve the purpose of this research work ethical considerations were considered and official letter were collected from JIT to collect existing data from Ethiopia Road Authority Jimma district to collect the actual data about study area road, National Metrology Jimma District to collect Metrological data and Ethiopia Mapping Agency (EMA) to collect topographic map and digital elevation model map. Continuous reviewed related literature on relevant areas of roadside drainage such as reference books, research papers, standards specifications like ERA. Necessary data collection, organization, comparison, and analysis were obtained, and then subsequently compared the results with literature and standard specifications. A conclusion and recommendation are drawn based on the results.

3.4 Research Design

The study was both quantitative and qualitative because, among other things, it involved the observation of the nature of roadside drainage as well as the collection of the views from the community, particularly those who live along roadside whether there was any problem related to poor roadside drainage. During this design some variables were investigated, that included, causes of present floods and measures are so far taken to decrease poor roadside drainage along Jimma to Agaro road. The research survey was employed to obtain information that would describe the current state of roadside drainage infrastructure along Jimma to Agaro road and how poor roadside drainage system has affected road users during the rainy seasons and the residents living in the surrounding. The survey involved; ERA Jimma branch, engineers who took part in the design of any road, Road users and Residents living in the affected areas of Jimma to Agaro road. To achieving the objectives of the study, therefore, a case study design was adopted where survey research was used.

Various techniques of data collection such as questionnaires, photographs, observation, were employed in the study to obtain the information required to meet the objectives. A questionnaire is a research instrument consisting of a sequence of questions for the purpose of gathering information from respondents. Whereas, Photography is the art, science, and practice of creating durable images by recording light or other electromagnetic radiation, either chemically using a light-sensitive material such as photographic film, or electronically using an image sensor (Schewe, 2012)

3.5 Study Population and Sample

The specific population of this study is Topography field visiting, field observation, and questionnaire number of peoples. This all populations were sampled by purposive sampling method.

3.6 Study variables

The dependent variable in this study is road side drainage problems.

3.6.1 Independent variables

- Poor waste disposal,
- Lack of frequent cleaning
- Small side drains and
- Topography

3.7 Study material and methods

DEM data were obtained from MOWR, GIS database and was used as input data in ArcGIS to delineate watersheds. By using spatial analyst tools, digital elevation model of the study area Extracted from our country digital elevation model.

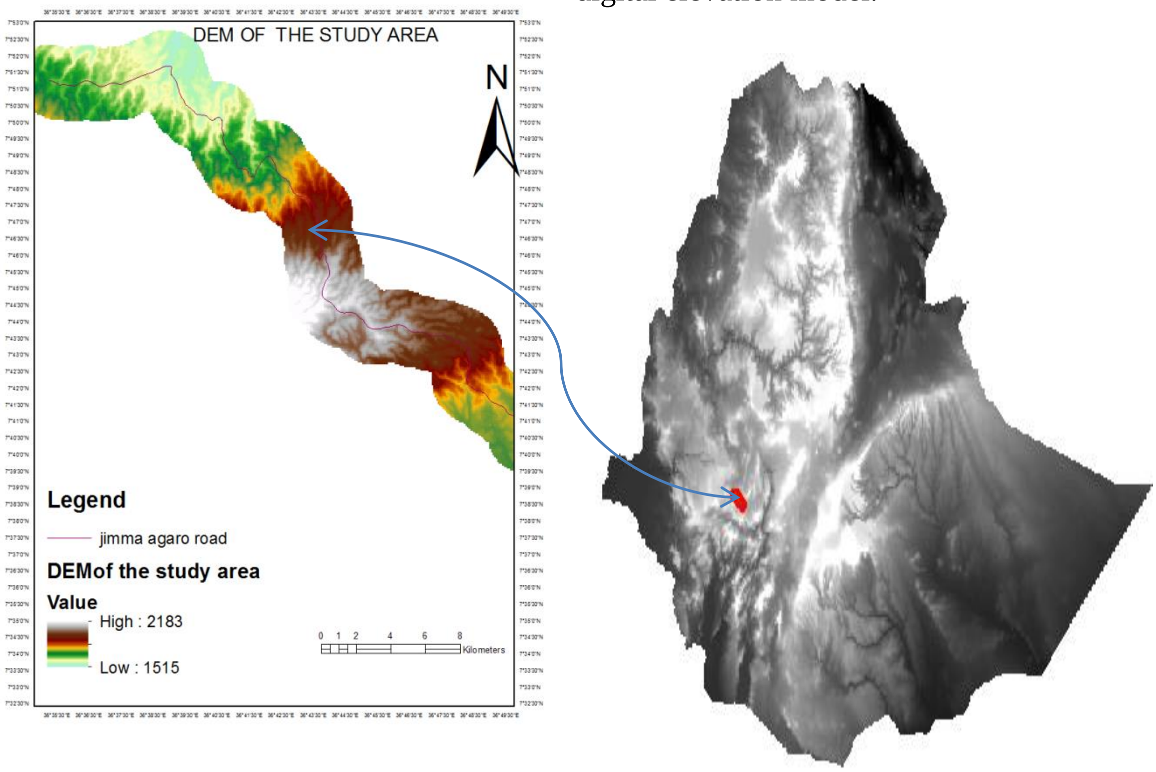

Figure3.2 Digital Elevation Model (DEM) of study area

Digital Elevation Model has analyzed by GIS Software and the common Microsoft office software such as word and excel were used to show research data in document form.

Land slope is the most important topographical factor influencing drainage for catchment areas. The Slope of the study area was classified based on the classification of ERA Geometric design manual of 2002. The slope map of Jimma to Agaro was derived from the available DEM with 90 meter resolution using the Spatial Analysis tool in raster form. It includes flat and rolling type of slope.

Land cover/use of the study area is also the other factor, which was used to estimate peak runoff. The existing land cover map of Ethiopia was used to know study area land covers. The land use class that includes Lowland perennial and Lowland annual types.

The mathematical equations that are used to determine peak discharges are Rational method equations. Recommendations in ERA 2002 and 2013 drainage design manuals are used to determine peak discharges.

Questionnaires were used to collect primary data. It was designed in two forms; one involving response by ERA Jimma branch office engineers and the other involving response from people who live in the surrounding area of the road and road users.

Questionnaire type was structured to be filled by road users and the people who live adjacent to affected Jimma to Agaro road areas. The road users referred here includes people who travel through that road frequently, the public service transport providers. It was intended to know how poor drainage has affected the lives of the people residing in the surroundings and how activities have changed because of roadside drainage. This will help in understanding how the poor roadside drainage has affected the road users and to obtain their views on the way forward.

Observation was carried out to determine repeated conditions on the roadside drainage along the study area in comparison with the accepted standards. A digital camera was used to take photographs of the current state of the road and the roadside drainage.

The Field survey measurement was done using digital camera, GPS device, to fix coordinate of road distressed along the study area. All these materials were used during field visit of the study area.

Table 3.1 Field Survey Measurement of Roadside Drainage Condition

Part of the road by coordinate		Place	Roadside Drainage condition	Suggested problem
1	X=0855802 Y=02519006 Z=2071	At Manna worede,Mantina kebele	Slope failure because of surface drainage problem	Road side slope failure
2	X=0860607 Y=0249386 Z=1902	Yebu town	Rain water ponded on the edge of the road	Silt soil accumulated on the side of the road along curve

3	X=0860771 Y=0249381 Z=1905	Yebu town	Mistake of poor workmanship, runoff come from ditch of one gravel road across the asphalt directly	Stripping of asphalt material from the road pavement,
4	X=0861116 Y=0249346 Z=1900	Yebu town	Absence of roadside drainage in Yebu town	Stripping of asphalt material from the road pavement
5	X=0861702 Y=0249387 Z=1899	Yebu town	Good roadside drainage at the exit of yebu town	A drainage outlet problem that damage the farmland and form gullies on the gate of two householders'
6	X=0864945 Y=0234502 Z=1641	Agaro entrance	Absence of roadside drainage at Agaro town entrance	Rain water ponded on the side of the road for the reason of absence of side drainage
7	Y=0234720 Z=1657 X=0868855	Bulbula village	Absence of roadside drainage	Road pavement edge failure because of roadside drainage problem and runoff crosses the road pavement
8	Y=0238221 Z=1611 X=0886687	Gembe	Pothole formed on the pavement	Because of surface drainage problem potholes, and different type of crack is formed at this place

10	Z=1576 X=0866758 Y=0243645	Haro town entrance	Stripping of asphalt	Because of roadside drainage problems bitumen material is stripped from the pavement
12	Z=1574 X=0863938 Y=0344867	Bosa Addis keteme kebele at Jimma town	Accumulation of silt soil on the side of the road	During rainy day the run off comes from elevated points of the place across the road
13	Z=1684 X=0850315 Y=0260220	Jimma town, in front of four loins roundabout	Road edge failure because of poor roadside drainage	The runoff flow on the side of the road without any side drainage form road edge failures
14	Z=1718 X=0849650 Y=0261078	At Jimma town near the back of Agricultural and Veterinary medicine college	Because of roadside drainage problem ponding of water on the pavement and roadside	The runoff that comes from highly elevated point ponded on the edge of the pavement

Photography was majorly used to capture the existing status of the roadside drainage and its effects along Jimma to Agaro road. It was meant to give a visual understanding of the research issues to the readers of this research project, the extent of deterioration, maintenance and the state of the drainage system.

Secondary data are the data that have been already collected by other researchers and are readily available from other sources, for example, the internet. Secondary data are economical and time saving. It helps to make primary data collection more specific, this is because the researcher was able to identify the gaps and deficiencies and what additional information need be collected (Kosso, 2011). It also assists in understanding the problem as it provides a basis for comparison of the data that is obtained from the field.

In the course of this research, secondary data were widely used. This data was obtained from analysis of the relevant literature concerned with road construction, road drainage construction and the design of the roadside drainage systems. The literature used in this research therefore was extracted from Drainage books, journals, research projects and the internet.

Study reports, 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 of 1:2,000,000 to determine geological formation that influence flood and channel characteristics are secondary data. The previous and the existing land cover are considered significantly. This is because during the construction period and at the existing condition the runoff entering in to the drainage structures is quite different.

3.8 Data Processing and Analysis

Data analysis was for the purpose of obtaining usable and useful information, irrespective of whether the data was qualitative or quantitative.

Data analysis began with editing data collected from the field and, which data was tabulated and presented in chapter four. Data was analyzed on the information about the respondents, existing side drainage system in the study area, factors responsible for poor road side drainage and the effects of poor side drainage in Jimma to Agaro road. This is important, for it guaranteed accuracy and consistence which was vital for reasonable analysis. Delineation of water, shade was by using GIS.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Delineation of watershed in the study area

Digital Elevation Model (DEM) of 90m resolution Obtained from MOWR has been used to delineate study area catchments by using hydro-processing tools in GIS software. Digital Elevation Model of the study area was extracted from Ethiopia DEM, by using spatial analyst tools.

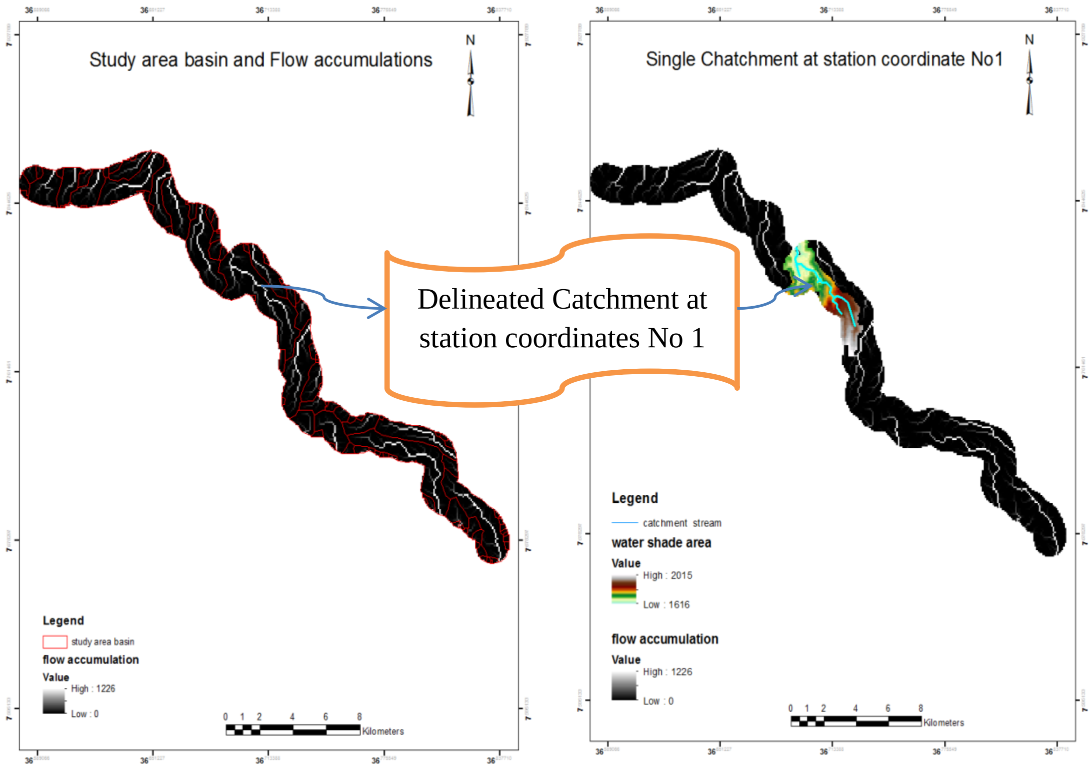

Figure 4.1 Flow accumulations at study area

For large catchment areas, it might be necessary to divide the area into sub-catchment areas to account for major land use changes. Obtain analysis results at different point within the catchment area to locate storm water joined to road side drainage structures. By using raster calculator in spatial analyst tool of Arc GIS, area for sampled watersheds was calculated and tabulated in table 4.1, for each purposely sampled catchment area. The example of extracted catchment areas is shown on map below.

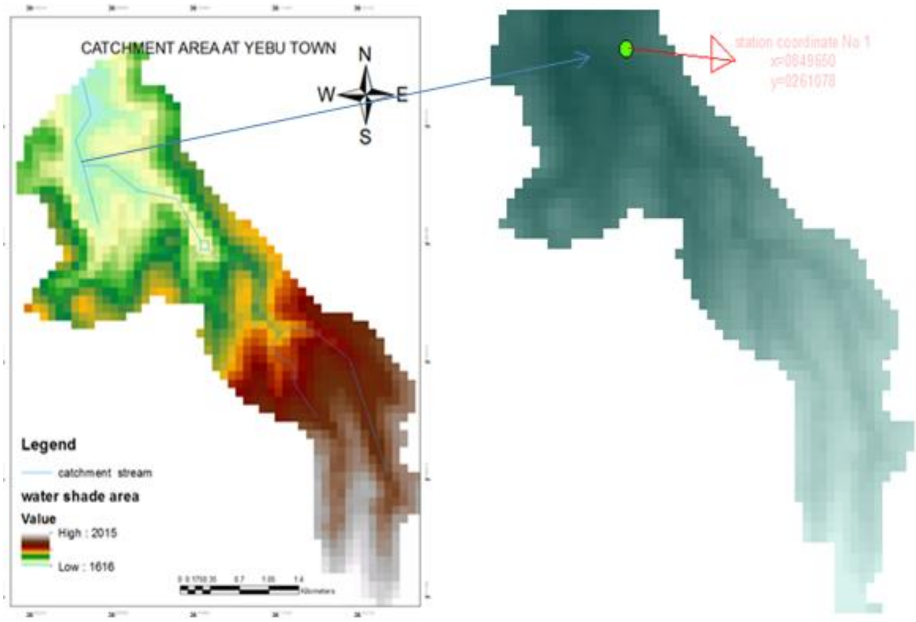

Figure4.2 Sample catchment area of study area (station coordinate No 1)

Table4.1 Sampled catchment areas and their station coordinates

No	Station coordinate	Catchment Area Km^2
1	X=0861702 Y=0249387	0.28
2	X=0861116 Y=0249346	0.33
3	X=0849650 y=0261078	0.27
4	X=0855802 Y=0251906	0.42
5	X=0868855 Y=0234720	0.49
6	X=0886687 Y=0238221	0.22
7	X=0866758 Y=0243645	0.25

For delineated drainage Catchment areas, runoff flow length was determined by field survey. Since catchment area was delineated, by using digital elevation model for the places those have bad roadside drainage problem, which affect pavement and adjacent properties by using digital elevation model.

4.1.1. Computation of peak runoff by using rational method

In this study, the runoff water generated from the drainage catchments was determined based on drainage design manual of our country prepared by ERA in 2002.The peak runoff rate of the catchments in the study area was determined using the Rational Method. After watershed area delineation, watershed properties like soil type, land use (coverage), and curve number are computed. About 90% of the catchment is cultivated and the remaining is covered by small trees, shrubs, and scarcely distributed trees.

4.1.2. Catchment Parameters at Station coordinate No 1

From Table 4.1, the area of the drainage basin upstream from the point in question is found to be 28 hectares. The Rational Method is selected as the area in question is less than 50 hectares. As per Appendix B Table 6, design storm frequency of 10 years. The maximum rate of runoff for a 10-year and check a 25-year return period was determined as flows.

The following data were measured from Appendix A figure1, the study area was found in rainfall region B1 and Hydrologic Soil Group B. By using the IDF curve of rainfall region B1 the rainfall intensity was determined for selected return periods. The runoff coefficient were depends on the catchment slope, the permeability of the soil and vegetation cover. From land use map of Ethiopia, the land use of study area is lowland perennial and low land annual. Since soil type is district nitosoils and eutricfluvisols.

Table4.2.Property of study Area's catchment

Land use	Soil Type	Hydrologist Soil Group	Rainfall Region	AMC
Lowland perennial and lowland annual (cultivated)	District nitosoils(Nd) and eutricfluvisols(Je)	B	B1	wet

From field survey of study area, length of over land flow is 58m, and Length of main basin channel is 200 m. Slope of channel is 1.8 %, and Average overland slope is 2.0%. From Appendix B table 7, Open Channels surface, Manning's Roughness coefficient (n) of channel is 0.02. Hydraulic radius approximated by average depth is 0.6m.

From appendix B Table 2, runoff coefficient (C) for the overland flow area residential multi units-detached is 0.40.

From Appendix A Figure 4, with an overland flow length of 58 m, slope of 1.8 %, and a C of 0.40, the inlet time is 19 min.

From equation 2.4, Channel flow velocity (v) is 4.5m/s, then flow time is 3.03min, and total time of concentration (Tc) is the sum of inlet time and flow time which is 22min. The catchment area was found in rainfall region B1, and the IDF curve of rainfall region B1is used to determine rainfall intensity. Appendix A Figure3, was used to determine the rainfall intensity for selected return Periods (10year, 25 year).

I_{10} = (10 year return period) = 79 mm/hr

I_{25} = (25 year return period) = 83 mm/hr

From appendix A Table 5, weighted runoff coefficient (C) for the total catchment area is the sum of average slope of catchment, permeability of soil, and vegetation cover which is 0.4.

By using equation 2.1 and 2.2, the estimation of peak runoff for a 10-year and 25-year design storm for the given catchment area is calculated as the following

Q_{10}= 0.00278CIA =0.00278*0.4*79mm/hr*28ha=2.46m^3/s

While the return period is 25 year frequency factor from Appendix B table 4, is 1.1.

Q_{25} = 0.00278 C_f CIA=0.00278*1.1*0.4*83mm/hr*28ha=2.84m^3/s

The peak discharges on other sampled stations are computed with the same procedure and their values are tabulated in Tables 4.3, 4.4, 4.5, 4.6, 4.7, and 4.8.

Table4.3: Catchment Parameters for different return period (Station coordinateNo2)

Catchment Parameters	10 year return period	25 year return period
Length of overland flow(m)	73	73
Length of main channel(m)	867	867
Slope of channel	1.3%	1.3%
Average overland slope	1.5%	1.5%
Average hydraulic radius(m)	0.7	0.7
Weighted runoff coefficient	0.4	0.4
Inlet time(min)	23	23
Manning's roughness coefficient	0.02	0.02
Channel flow velocity(m/s)	20.9	20.9
Flow time(min)	0.69	0.69
Total time of concentration(min)	24	24
Rainfall intensity(mm/hr)	80	86
Peak runoff(m^3/s)	2.93	3.47

Table4.4 Catchment Parameters for different return period (Station coordinateNo3)

Catchment Parameters	10 year return period	25 year return period
Length of overland flow(m)	82	82
Length of main channel(m)	1400	1400
Slope of channel	1.7%	1.7%
Average overland slope	0.5%	0.5%
Average hydraulic radius(m)	0.6	0.6
Weighted runoff coefficient	0.4	0.4
Inlet time(min)	27	27
Manning’s roughness coefficient	0.02	0.02
Channel flow velocity(m/s)	4.63	4.63
Flow time(min)	3.12	3.12
Total time of concentration(min)	30.12	30.12
Rainfall intensity(mm/hr)	69	78
Peak runoff(m3/s)	2.07	2.58

Table4.5 Catchment Parameters for different return period (Station coordinateNo4)

Catchment Parameters	10 year return period	25 year return period
Length of overland flow(m)	70	70
Length of main channel(m)	325	325
Slope of channel	1.2%	1.2%
Average overland slope	1.5%	1.5%
Average hydraulic radius(m)	0.7	0.7
Weighted runoff coefficient	0.4	0.4
Inlet time(min)	21	21
Manning’s roughness coefficient	0.02	0.02
Channel flow velocity(m/s)	4.31	4.31
Flow time(min)	1.26	1.26
Total time of concentration(min)	22.26	22.26
Rainfall intensity(mm/hr)	81	85
Peak runoff(m3/s)	3.78	4.36

Table4.6 Catchment Parameters for different return period (Station coordinateNo5)

Catchment Parameters	10 year return period	25 year return period
Length of overland flow(m)	80	80
Length of main channel(m)	585	585
Slope of channel	1.5%	1.5%
Average overland slope	2%	2%
Average hydraulic radius(m)	0.6	0.6
Weighted runoff coefficient	0.4	0.4
Inlet time(min)	19	19
Manning's roughness coefficient	0.02	0.02
Channel flow velocity(m/s)	5.9	5.9
Flow time(min)	1.65	1.65
Total time of concentration(min)	20.65	20.65
Rainfall intensity(mm/hr)	82	87
Peak runoff(m3/s)	4.47	5.21

Table4.7 Catchment Parameters for different return period (Station coordinateNo6)

Catchment Parameters	10 year return period	25 year return period
Length of overland flow(m)	90	90
Length of main channel(m)	665	665
Slope of channel	2.5%	2.5%
Average overland slope	2%	2%
Average hydraulic radius(m)	0.7	0.7
Weighted runoff coefficient	0.4	0.4
Inlet time(min)	16	16
Manning's roughness coefficient	0.02	0.02
Channel flow velocity(m/s)	26.04	26.04
Flow time(min)	0.43	0.43
Total time of concentration(min)	16.43	16.43
Rainfall intensity(mm/hr)	98	105
Peak runoff(m3/s)	2.39	2.83

Table4.8 Catchment Parameters for different return period (Station coordinateNo7)

Catchment Parameters	10 year return period	25 year return period
Length of overland flow(m)	78	78
Length of main channel(m)	338	338
Slope of channel	2%	2%
Average overland slope	3%	3%
Average hydraulic radius(m)	0.7	0.7
Weighted runoff coefficient	0.4	0.4
Inlet time(min)	17	17
Manning's roughness coefficient	0.02	0.02
Channel flow velocity(m/s)	26.1	26.1
Flow time(min)	0.22	0.22
Total time of concentration(min)	17.22	17.22
Rainfall intensity(mm/hr)	97	102
Peak runoff(m^3/s)	2.7	3.12

4.2 Hydraulic Capacity

The hydraulic capacities of the roadside open channels in the study area were determined using the Manning's equation. Therefore, the peak rate of runoff and hydraulic capacities of the existing roadside channel were computed by equation 2.4, and obtained results was tabulated in table 4.9

Table 4.9 Hydraulic capacities

No	Station coordinate	Design Peak runoff rate(m^3/s)	Roadside ditch condition	Roadside ditch size and longitudinal slope			Hydraulic capacity, (m^3/s)
				Width(m)	Depth(m)	Bottom slope	
1	X=0861702 Y=0249387	2.46	Existing	0.6	0.7	2%	1.93
2	X=0861116 Y=0249346	2.93	Existing	0.6	0.8	1.8%	2.26
3	X=0849650 y=0261078	2.07	proposed	0.8	0.6	2%	2.4
4	X=0855802 Y=0251906	3.78	proposed	0.8	0.9	2%	3.93
5	X=0868855	4.47	Existing	0.5	1	1.8%	4.18

	Y=0234720						
6	X=0886687 Y=0238221	2.39	proposed	0.8	0.6	2%	2.6
7	X=0866758 Y=0243645	2.7	proposed	0.8	0.7	1.8%	2.76

As it can be observed from table 4.9, all existing roadside ditch of sub catchments at station coordinate 1, 2, and 5 are not sufficient to carry the runoff water contributed to them from surrounding areas.

As it can be understood from the above tables, all sub catchments have high Peak runoff rate, so the designer of new roadside drainage along the study area road can use as a reference.

4.3 Results from questionnaires

Questionnaires were administered to the engineers from the ERA Jimma Branch Office and Ethiopian road Construction Corporation Office. Another questionnaire was given to the residents of the area adjacent to study area road and road users. The questionnaire comprised of open ended and structured questions on issues that are related to the study.

From ERA Jimma Branch Office Engineers and Ethiopian road Construction Corporation Office eight Engineers were willing to give information on the drainage problem and two of them are refusing to answer questionaries' because they are busy by workloads.

From thirty six road users whose questionaries' distributed for response, thirty two are willing to give answers and full information on roadside drainage problem. Refusals are road users; those cannot read any language letters.

Twenty four questioners' are distributed to residents along the places in which roadside drainage affects road pavement and residential properties. Since nineteen of them are willing to give information on roadside drainage problems. The refuses are those who cannot read any language letters.

4.3.1 Response from Engineers

It was important to know the critical factors considered when designing a roadside drainage. This is because they helped to understand the reasons behind the design of every road and in this case, Jimma to Agaro road. To answer the objective of this study rating the following factors those can considered when coming up with a roadside drainage design was included in the questioner type for engineers.

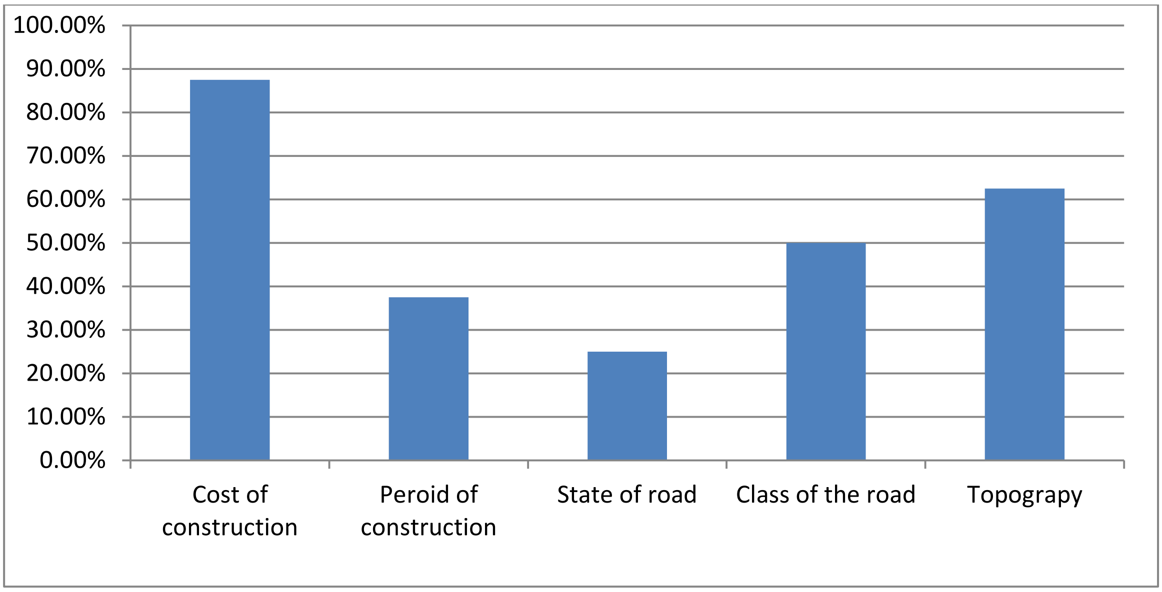

Figure 4.3 Considerations when coming up with a road and a roadside drainage design

The engineers' from ERA Jimma Branch Office and Ethiopian Road Construction Corporation Office indicated that the roadside drainage provided for Jimma to Agaro road has a problem and as there was no sufficient roadside ditches. 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 the design lacked capacity to adequately drain the runoffs during the rains. Also, they responded that, the major consideration when coming up with a road and road side drainage is cost of construction. Since topography of the site of design is the second factor considered. However, poor workmanship (seen through poorly worked drainage at Yebu town by the researcher during observation) and poor maintenance also contributed to the drainage problems along the study area road.

Figure 4.4 Taken august 25/2016 roadside ditches aligned directly to asphalt road at Yebu town.

To understand the background of the poor roadside drainage in the Country, this study sought to find out from the engineers the percentage of roads those having roadside drainage problem.

From the following figure the engineers' perception, that most of the rural roads in Ethiopia has roadside drainage problems. Some of the reasons cited were inadequate designs, lack of enough studies to establish the drainage requirements of the road and poor workmanship.

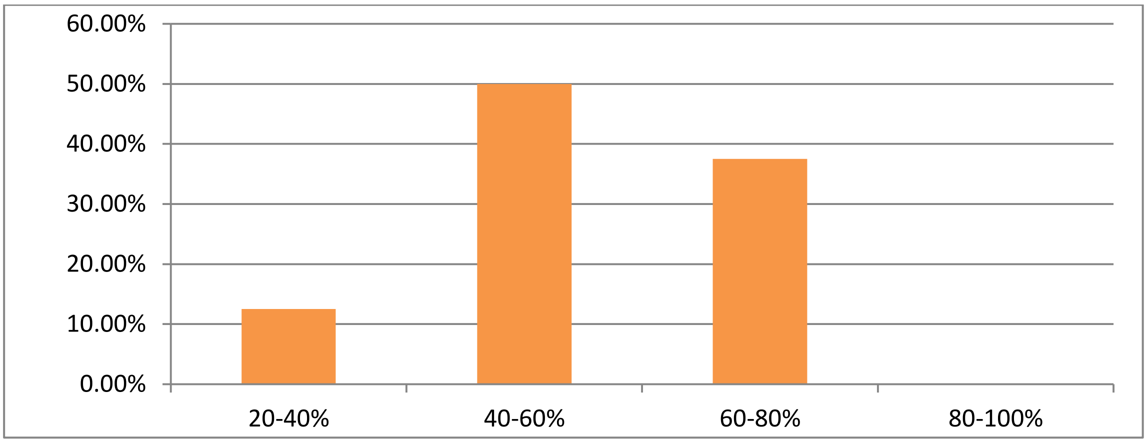

Figure 4.5 Percentage of roads with poor roadside drainage in Ethiopia

The engineers were in agreement that the drainage facilities were in a poor state and it needed remedial action with immediate effect in some place along the study area road. The ERA engineers in Jimma branch reported that the authority carried out an inspection of the road and its side drainage facilities yearly, but that emergency inspection was carried out when a problem occurred to ascertain its extent and to carry out required action.

Both ERA Jimma branch office and Ethiopian road construction corporation office engineers agreed that, there was a need for redesigning and reconstruction of the roadside drainage and road, there was also need to carry out maintenance until new construction carried out on the existing side ditch facilities to increase their efficiency and effectiveness. They reported that redesigns and reconstruction have been implemented, due to bad distress on this road. Farming practices in the area, according to the engineers cannot be blamed for the erosion of the road and drainage features, but instead the small capacity of the side drainage provided.

The damage on the road was severe mainly from June to august in Jimma zone, where some parts of the road washed away at this season. This showed the dangers that road users were exposed to and necessitated a move to correct the roadside drainage facilities. Regarding the roadside drainage in Jimma to Agaro road, the majority of the respondents revealed that roadside drainage was poor; some of them said that the roadside drainage was good and while small number of respondents was not sure about the idea as it is shown from figure 4.4.

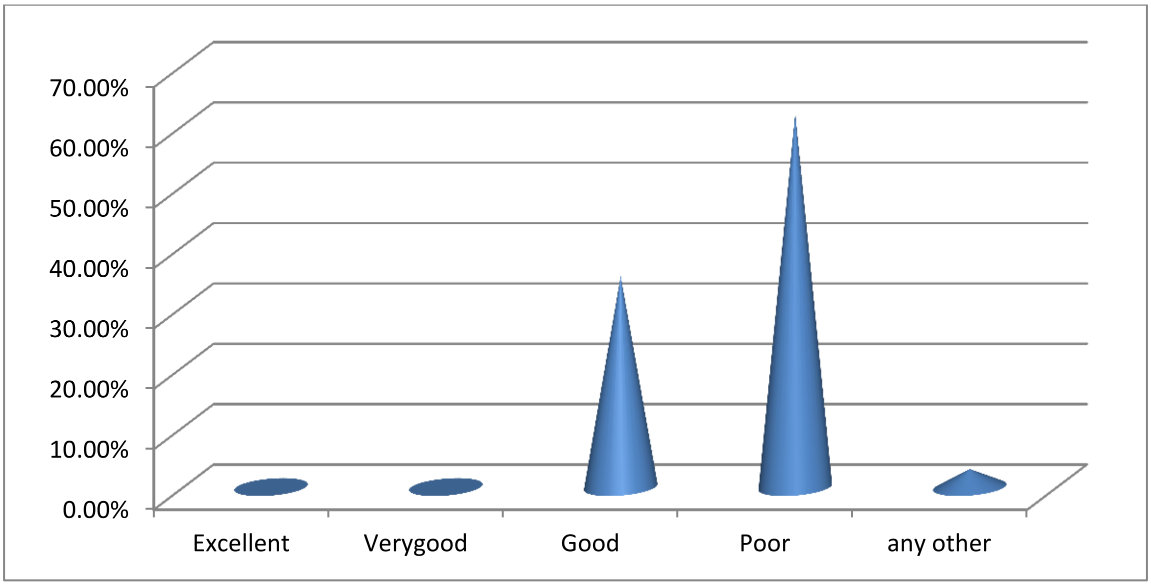

Figure 4.6 rating the roadside drainage in Jimma to Agaro road

As the respondents pointed out, one of the factors that cause roadside drainage problems in Jimma to Agaro road is lack of side drainage along the highway. There is the problem of road side drainage in Bosa Addis Keteme Kebele in Jimma Town. Also respondents pointed out that, excessive heavy rains are experienced in the area causing flooding along the study area road. This is mainly because of the rainfall is high between Jun to August. With this natural factor they have nothing much to do, but only to take the necessary precautions to control it by cleaning the existing drains and constructing side ditches thus have good discharge capacity along the road.

From the following table, some respondents responded that, Poor waste disposal in the town place leads to side drainage problems along the study area. According to their responses there is a lack of responsibility of the communities in the study area toward waste management, due to their poor attitude towards waste disposal and management.

This creates over flooding during rainy seasons and sometimes it can obstruct vehicles to move freely along the road.

Table 4.10 Factors that cause poor roadside drainage

Factors.	No. Of respondents.	Percentage
Heavy rains	2	20
Siltation	1	10
Poor waste disposal in the town places	2	20
Lack of side drainage along the highway	5	50
Human activities	-	-

4.3.2 Response from road users

It has been stated that 50.1% of the respondents (Figure 4.4) said that they were using the road repeatedly on a weekly basis. From the figure, it shows that the respondents could be relied on to give real information to achieve the study's objectives.

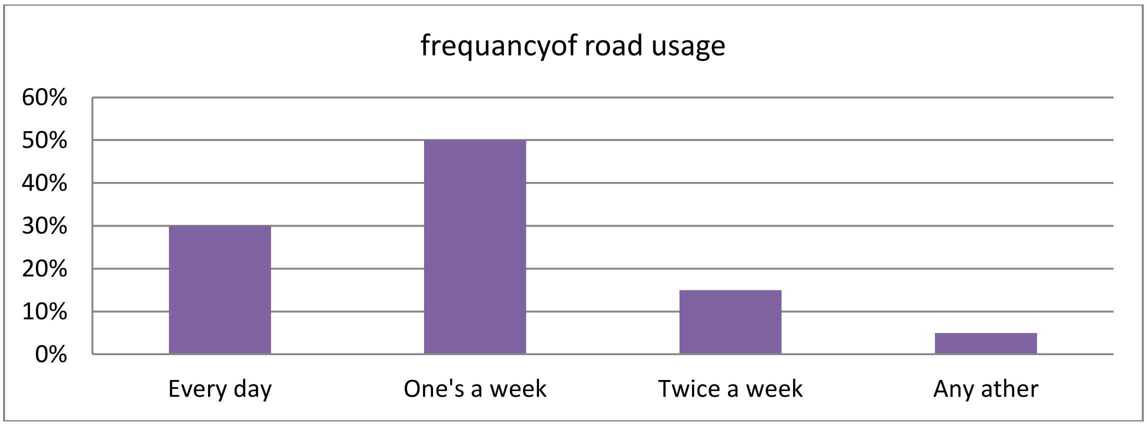

Figure 4.7 Frequency of road usage by road users

The road users were concerned about their safety and the convenience of going through Jimma to Agaro road during the rains. Only five percent think the roadside drainage provided for study area road is good, while, there was none of the respondents who thought the roadside drainage was very good. Also road user's respondents reported that, as the study area road constructed without roadside drainage in rural parts and some place of towns those this road crosses. Two of them responded that starting from Jimma Agricultural and Veterinary Medicine College with Gabriel Church as an example of this problem.

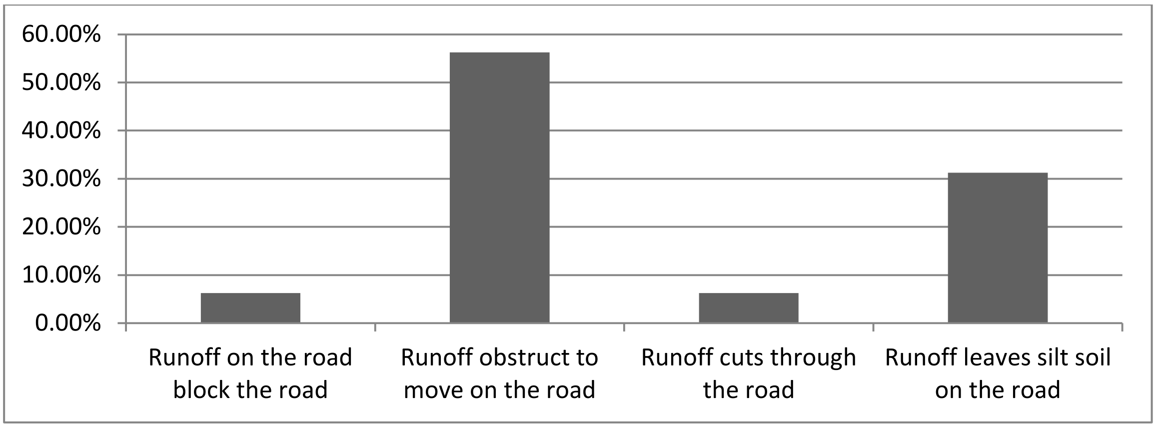

Figure 4.8 Effects of poor side drainage on the road user

The majority of respondents reported runoff obstructs to move on the road during the rains thereby hindering free movements of vehicles on the road. It also leaves silt soils on the pavement. So sometimes totally making impossible pedestrian to walk on the side of the road; Travelers would then become later in their businesses or other engagements. A significant proportion reported that runoffs famous rain water to overflow, leave debris and the pond on the carriageway. Such problem was seen at Jimma town, Addis keteme kebele, Yebu and Haro town by researcher during field observation.

Figure 4.9 Taken august 25/2016, A vehicle obstructed to move freely, at Jimma town bosa addis keteme kebele

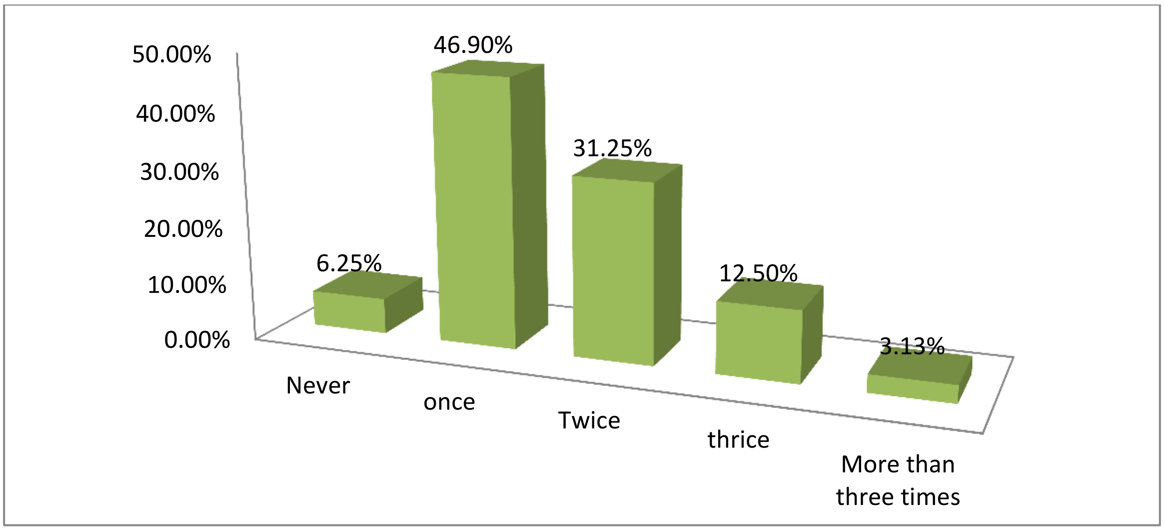

Figure 4.10 Responses of the road users on interruptions

The frequency of interruptions shows that most of the users had been interrupted once. However, among the respondents there were those who had never been interrupted only 6% of the road users respondents. This would mean that they were able to give satisfactory answers to the questions sought by this study.

This study continued to seek from the road users and residents whether they observed any improvements on the road since they were interrupted or affected in whichever way. The results are shown below;

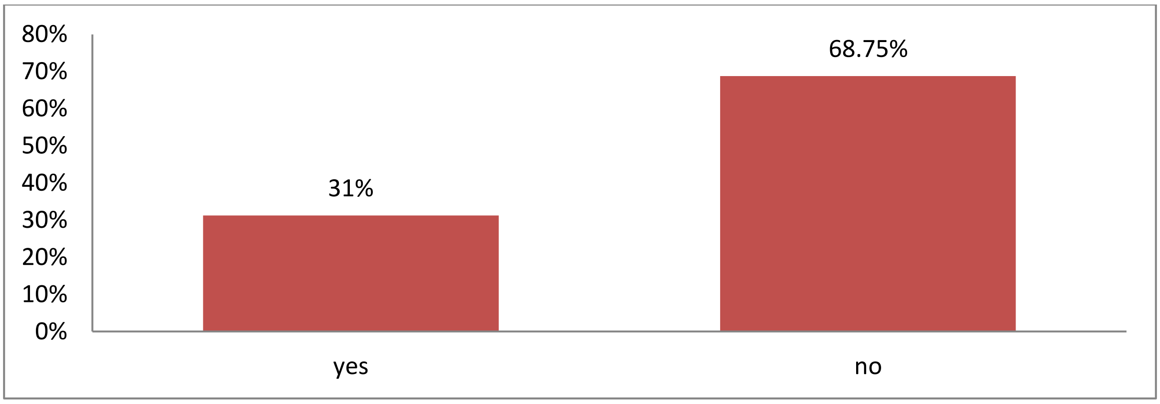

Figure 4.11 Improvement activities

From the figure 4.11, it shows that there have been ongoing activities geared towards the improvement of the side drainage system. A greater percentage of the respondents have observed improvement activities on the road, however, there is also a significant percentage that has never observed these activities being carried out. This shows that though there are efforts to improve the roadside drainage, enough has not yet been done yet. Most respondents pointed out that as the road authority needed to improve the facilities to an acceptable standard. From the questioners, there was a clear indication that the majority of the road users were not satisfied roadside drainage along study area road. The travelers report that they become late in their journals or other engagements for the case of the road pavement distress due to roadside drainage. It is therefore a concern that the road users are not satisfied with the side drainage along the road, there is a need to thus improve on the problem in order to obtain road users satisfaction.

4.3.3 Response from the residents

A good percentage of those who responded to the questionnaire come from within 50 meters from the road. This was important because it showed that they could respond to all the issues raised in this study so as to achieve the objectives.

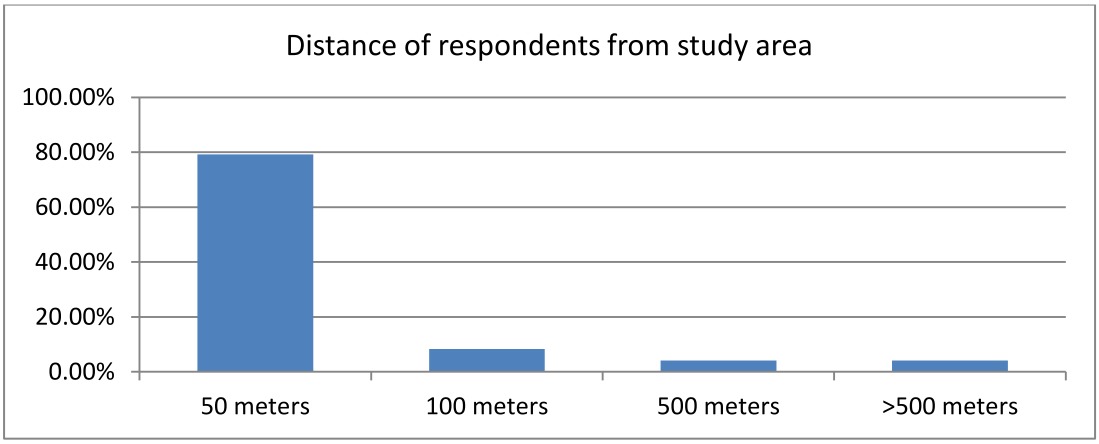

Figure 4.12 distance of resident respondent's house from the study area

As the response of the residents shows they were affected by the poor roadside drainage in the study area. The majority of the respondents along the road side reported that runoff had bad effects on their house, land and other properties. They stated that runoff due to roadside drainage problem eroded their land, thereby making the land less productive.

Respondents in the towns reported that the runoffs sometimes interred to their house and it became difficult to enter and leave their house, in addition to this they told as they affected to walk around their house because of ponded runoff water around their properties. There were those who said that runoffs had created gullies on their land, gullies would then reduce the arable land and also pose a serious risk to their animals.

4.4 Results from observation

The majority of this research work was drawn from the researcher's field survey and questionnaires were employed to reinforce the field survey data. In this research each and every roadside ditches of the study area have fully been surveyed and observed.

Poor roadside drainage can bring about flooding which in most cases submerges the buildings, roads and makes it hard for people to move about. Recently Jimma to Agaro road is facing extensive water logging during the rainy season (august 25/2016) as result of roadside problem. Inadequate side drainage problems become one of the most common sources of compliance from the residents in towns along the study area and this problem becoming worse in this year. Absence of side drains cause severe flooding which creates distresses to the road pavement and problems for road users. This condition was severely motivated because the natural drainage system, which conveys storm runoff from the areas of the river were not fully operated and the existing drains blocked with huge amount of silt sand accumulation and vegetation.

Walking in such dirty water of storm runoff has a lot of risks because flood runoff moves at a higher speed than what it seems like on top thus putting people’s lives at risk of dying. It is also good to note that, flood water contains a lot of debris and harmful species which have been swept away from their sand habitats which are dirty, and have a lot of hygienic consequences which people seem not to be aware of.

Figure 4.13 Taken august 25/2016, flooded road obstructed vehicle along the study area at Bosa addis keteme kebele at Jimma town.

4.4.1 The major flood prone sites in the study area

The major flood prone sites in the study area were identified through questionnaires from road users and residents along with field observations.

The purpose of identifying such flood prone areas was to analyze the effect resulting from water overflowing due to roadside drainage problems on the road pavements and adjacent property, and to determine factors that cause the perennial problem about roadside drainage along the study area.

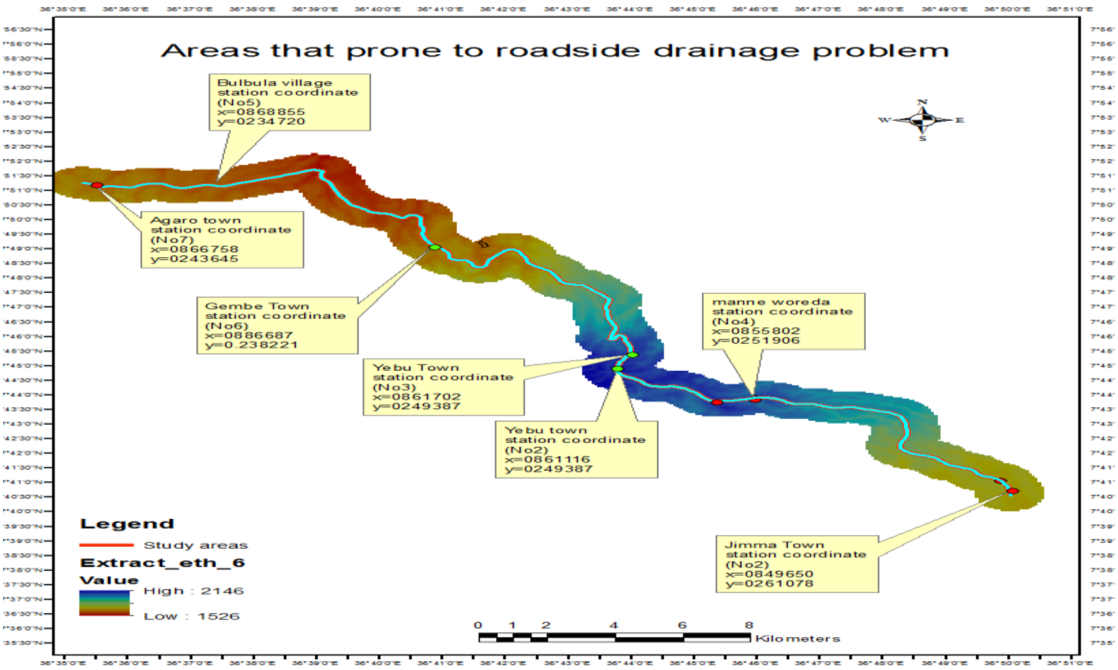

Figure4.14: Flooding prone areas

Table 4.11 Ranking of flood (prone areas high to low) from field observation

Specific site/Kebele	Ranking of flood prone areas (high to low) from field observation	❖ Roadside Drainage condition
Bosa Addis keteme kebele in Jimma Town (along Agaro get)	2nd	❖ Road edge failure because of poor roadside drainage ❖ Accumulation of silt soil on the side of the road ❖ Because of roadside drainage problem ponding of water on the pavement
Yebu town	1st	❖ A drainage outlet problem that damage the farmland and form

		gullies on the gate of two house holders' (at the exit of yebu town) ❖ Stripping of asphalt material from the road pavement, ❖ runoff come from ditch of one gravel road and affect residents of another side
At Mane worede, Mantine kebele	3rd	❖ Slope failure because of surface drainage problem
Gembe town	4th	❖ Because of surface drainage problem potholes, and different type of crack is formed at this place
Agaro town entrance	5th	❖ Rain water ponded on the side of the road for the reason of absence of side drainage and obstacle the pedestrians walk along the road

As described in Table 4.11, the major flood prone areas for the reason of road side drainage problem are Yebu town followed by Bosa Addis keteme kebele in Jimma Town (along Agaro get), At Mane worede Mantine kebele, Gembe town, Bulbula town, and Agaro town entrance by ascending order ,which were evidenced from the field observation. At the listed places, different road distress leads vehicles to move slowly.

Failures and severe distresses were observed on the road surface. 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 and this is the major cause of pavement deterioration because of the roadside drainage problem.

As one can see from figure 4.15 masonry roadside ditch at Yebu town is full of garbage and sediment, which can obstruct the normal flow of water in the channel. This can proof as there is no regular maintenance of roadside drainage along the study area road section and other flood prone areas shown on the figure below has no proper roadside ditch.

Figure 4.15 Taken June 12 to15/2016 the major flood prone areas along Jimma –Agaro road section

According to field observation the absence of ditches alongside of the road makes rainwater to collect on the pavement surface and the surrounding areas. The side's 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 on the road and side properties. But if there is no side drains the storm runoff can damage the pavement. In addition to this it affects the aesthetics of the whole place and it promotes stagnant water in the area as it can understand from the following figure.

Figure 4.16: Taken June 12/2016 Water ponded along the study area road at a Jimma town near the back of Agricultural and veterinary medicine college fence.

4.4.2 Observed Road Surface Damage

The different type of damages were observed in study area are; washing out of bitumen asphalt material, potholes and water detention, pavement distresses of cracking, failure of edges, the side drain full with dirty solid wastes and refuse dumps.

From the investigations conducted, figures 4.15 and 4.16 presents, proof of the reduction in service lifespan of this road 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 driveway of road pavements, stripping of bitumen off the surface of road pavements. Also, a poor maintenance culture result in gullies and gratings being blocked with silt, sand accumulate over time and in the growth of vegetation in and around the side drains which has resulted in total failure of the side drains structures. To check these very poor conditions of side drainages and road pavements, there is need to properly maintain them by regarding organization under which these roadside drainage channels are located. So that they would be able to perform routine cleaning of Silt sand accumulated over time that is visibly seen to have blocked these side drainages.

Figure4.17Taken June 12 to 14/2016, Road Surface Damage observed at study area

4.5 Factors that contribute to poor side drainage in Jimma to Agaro road

By depending on the methods studied above, the factors which contribute to roadside drainage problem in Jimma to Agaro road section are; presence of garbage and polyethylene bags along the road, the topography of the area, construction of unplanned and sub-standard houses, Heavy rains, Small drains, Poor waste disposal, Lack of frequent cleaning of the drainage systems and increased population along the side of this road.

 

Figure4.18 Taken June 12/2016, Solid waste and polyethylene bags disposed along the road of the study area, at Yebu and Jimma town.

A, Presence of Garbage and polythene bags along the road

According to field observation made, there is a lack of responsibility of the residents along the road toward waste management, due to their poor attitude towards waste disposal and management. As one resident of Bulbula town responded orally, traditional cultures and norms allow people to waste and practice open dumping along the road side of what their grandparents told them that the debris will decomposed and washed away by rain to a road ditch; not knowing that, such a practice will obstruct the drainage system and make it unable to perform its function. As it can be observed from figure4.18, Polythene bags left along the road, collected to each other by the action of runoff, can close the passage way of flood and creates a back–flow during rainy seasons.

Through direct observations at Agaro and Yebu towns, some side drains are blocked by solid waste and soil erosion, which is transported by the runoff from the surrounding hills. These wastes join the drainage channels and block the normal flow of water hence causing floods. This serious problem was also, seen in Jimma town between four loin roundabout and Jimma Gabriel church.

B, Construction of unplanned houses

The observation of study also shows that the buildings in the residential areas along the road were not planned. In conclusion the unsystematic layout of the buildings in towns tends to affect the layout of side drains.

Absence of master plan for the rural towns along the study area also results in the deterioration of Side drainages and its subsequent adverse effect on road pavement conditions. A lot of houses built today along the side of the study area road. Some houses are erected on the passages of side drains without having sufficient distance from drains.

To solve this problem, relevant government agencies in charge of town planning and development Such as the Ministries of housing and urban development should wake up to their responsibilities of ensuring that only government approved structures in line with the town planning master plan are erected on government approved lands and not on drainage channels. Also the immediate awareness must be given to the communities in which such problems are located. This problem has been seen in the towns such as Yebu, Alamayo and Gembe towns.

Figure 4.19 Taken June 12/2016, Blockage by silt soil, garbage and upland houses in yebu town along the study area

C, Increased population

As it was observed, as the number of population in the study area increases the problem of roadside drainage increases. The amount of solid and liquid waste disposed from every house would increase rather than the small number of population. This also covered the already existing side drains; and when it rains flooding is inevitable. It was discovered that the blocking of the side drains with solid wastes is the major factor causing flooding and water logging in the study area.

D, Topography

The geology of Jimma to Agaro also plays a significant role in influencing floods. The topography of study area is composed of Silt loam, or loam Soils those have a moderately low runoff potential due to moderate infiltration rate. But, according to oral response of engineers soil property is influenced by Jimma water table, which is, too near to the surface. Whenever it rains, the water does not therefore infiltrate easily, but instead remains on the surface causing floods. Based on the field investigation conducted during the period of this research the study area road section alignment is passing through steeply or hilly topography which is subjected to frequent flooding in rainy season.

4.6 Effects of poor roadside drainage in the study area

A number of effects of poor roadside drainage drawn from field observation and questioner's, were included flooding which destroys residents' property, dirtying the vehicle of the road users, which can make them extravagant to wash their car and affects the quality of housing because the houses on one less elevated side of the road are sometimes submerged in water for the duration of heavy rains.

It is easy to observe from this, the quality of life is generally affected through poor roadside drainage problem which becomes a public pain of the people in the surrounding areas, because the drainage system runs through the residential areas.

As it was observed during the field investigation of the study, Excessive rainfall, a conventional side drainage with low capacity, natural situation, indefinite drainage outlets, lack of proper maintenance of existing side drainage, and disposal of solid waste into the drains and drainage paths account for the prime causes of water logging are main factors those leads pavement to bad distresses along the study area road. From the observation of study area road it has been found that during the rainy season this road was affected by water over flooding. This is caused due to the absence of sufficient side drainage and improper maintenance of existing roadside drainage facilities.

Impacts of over flooding on adjacent properties are: soil erosion and gully formation in cultivated land, flooding of agricultural and inhabited areas.

Table4.12 Effects of poor roadside drainage on pavement layers and adjacent residential properties and road users

Effects of poor roadside drainage on pavement layers along the study area roads	Effects of poor roadside drainage on adjacent residents properties and road users
Lead pavement to damage or distress like; ➢ Pothole formation ➢ Depressions ➢ Lane or shoulder drop-off	➢ Erosion of farm land soil ➢ Formation of gullies around their properties ➢ Road congestion and disruption of other public services

➢ Edge cracking ➢ Washing out of bitumen and asphalt material ➢ Ponding of rain water on pavement surface and shoulder ➢ Road edge failure ➢ Gully along shoulder	➢ Travelers would later in their businesses or other engagements ➢ Affects the aesthetics of their environment

Figure 4.20 problem of roadside drainage outlet at the exit of yebu town

From field observations, the runoff that flows in the side drainage must have good outlets. The inadequate outlet in the surrounding area can results problem of soil erosion, that leads to environmental and property damages as it can be observed from figure 4.20. As one land owner responded, this soil erosion has around three hundred mater length, which crosses good farm land for crop production.

4.7 Measures to control the problem of roadside drainage along study road

A, Clean up existing ditches

As observed from field survey, clean up should be done in all existing roadside drainage mainly in the towns, to avoid sedimentation and siltation which are one of the main causes of roadside drainage. If this is put in place it will mitigate the problem of stagnant water, flooding, open space dumping and dumping garbage directly in the drainage system by providing garbage containers and collecting of solid waste around the place those have such problems.

B, Redesign and reconstruct of the study area road and ditches

As one of the ERA Engineer's team leaders responded they are re-designing this road side ditches and reconstruction will be started within one year. Through the upgrade of Jimma to Agaro road, there will be increased side drainage capacity, which is the most typical solution in the towns along the road for solving water quantity problems.

Table4.13 Effects of poor roadside drainage on pavement layers, its causes and Remedial measures in the study area.

Observed roadside drainage problem	Possible causes	Recommended remedial measures
 Pothole formation	Caused by poor side and surface drainage.	Filing potholes by appropriate and approved standard material
 Depressions	Caused by heavy traffic with ponding of water on the road.	Draining rain water by correcting surface and side drainage
 Shoulder drop-off	Caused by either shoulder erosion or settlement weakened base or sub-base because of pavement drainage problem causing water intrusion.	Draining rain water by correcting surface and side drainage

 Edge cracking	Caused by poor roadside drainage, which could aggravate a stripping problem	Filing by appropriate and approved standard material
Washing out of asphalt material 	Caused by runoff cross or flow along the pavement	Filing of appropriate and approved standard material with good roadside drainage
Ponding of rain water on pavement 	Caused by inadequate roadside drainage	Creating new side drainage
 Gully along shoulder	Caused by lack of defined ditch, channel along the road	Creating new ditch
Accumulation of silt soil in ditch 	Accumulation of silt soil and garbage in ditches	Remove debris that blocks ditches to allow water to flow through them freely

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1Conclusions

The major flood prone areas for the road side drainage problem are Yebu town followed by Bosa Addis keteme kebele in Jimma Town (along Agaro get), At Mane worede Mantine kebele, Gembe town,and Agaro town entrance by ascending order which were evidenced from the field observation.

The effects of poor roadside drainage were included flooding which destroys residents' property and affects the quality of housing since, the houses on the less elevated side of the road are sometimes immersed in runoff water during heavy rains. Runoff flooded on the pavement dirtying the vehicle of the road users, which can make them extravagant to wash their car. It is not suitable for driving even also affect the vehicle operating cost of the road users. Pavement distresses due to roadside drainage in the study area are washed out of bitumen asphalt material, potholes, water detention, pavement distresses of cracking, failure of edges, and the side drain full with dirty water.

The factors that have contributed to problem of roadside drainage along the study area are the increased presence of garbage and polyethylene bags along the road, the topography of the area, construction of unplanned houses, Heavy rains, inadequate roadside drains, and Poor waste disposal.

Clean up can mitigate those problems in existing roadside drainage, mainly in the town areas. The problem of stagnant water, flooding, open space dumping and dumping garbage directly in the roadside drainage system can alleviate by providing garbage containers and collecting of solid waste around the place those have such problems. The roadside drainage capacity along this road section can be increased to a good extent by redesigning and construction, which is the most typical solution in the towns along the road for solving water quantity problems.

5.2. Recommendation

- Proper roadside drainage need to be provided for flood prone areas such as, Yebu town, Bosa Addis keteme kebele in Jimma Town, Mane worede Mantine kebele, Gembe town, and Agaro town.
- Proper and frequent side drainage maintenance should be done mainly in the towns to avoid sedimentation and siltation along the study area.
- The road side ditches with good capacity, to discharge runoff from the surrounding area have to provide for study area.
- The houses constructed along roadside area, must have master plan, with sufficient distance from the road.
- Effect of runoff on the residents and the surrounding environment with in Jimma to Agaro road has to be considered during design and construction for rehabilitation the road section in the future.
- Garbage container must be provided for solid waste disposal, in the towns those prone to roadside drainage problems.

REFERENCE

Addis Ababa City Road Administration (2004). Drainage Design Manual, Addis Ababa.

Ajayi, J.O.K. (1993). Managing the lagos metropolitan storm water runoff problems under structural adjustment. Publishhed by African world press. Nigeria

AASHTO (American Association of State Highway and Transportation Officials). *Highway Drainage Guidelines*. 1992.

ARDO. 2008. Annual Report of Agriculture and Rural Development Office of Manna woreda, for year 2007/2008, Yebbu, Manna.

Belete D.A (2011).Road and urban storm drainage network integration in Addis Ababa. Jouranal of Engineering and technology research.Vol.3 (7).pp.217-225.

Dillman, D.A., Smyth, J.D., & Christian, L. M. (2009). Internet, mail, and mixed-mode surveys: The tailored design method. San Francisco: Jossey-Bass.

Drainage Design Manual Drainage manual, Addis Ababa, Ethiopia , ERA (2013). Ethiopian Roads Authority Drainage Design Manual (2002), Addis Ababa.

Griffiths.J.p, Hird,B.A and Tomlinson.P (2000)Rural Road Drainage Design For Environmental protection: Unpublished Project Report PR/INT/192/00

Herbert S. Lewis, *A Galla Monarchy: Jimma Abba Jifar, Ethiopia, 1830-1932* (Madison: University of Wisconsin Press, 1965), p. 56.

IPMS. 2007. Improving productivity and marketing success of Ethiopian farmers project Gomma Pilot Learning woreda Diagnosis and program Design.

Ireri, L.N (2009), An Investigation into Suitability of Storm Water Drainage Systems in Nairobi's CBD, B.A Building Economics, University of Nairobi.

Jones, A., Howison, J., Rees, J. R., & O'hagan, D. (2004). Part 1HA 106/04 Drainage of runoff from natural catchments (Vol. 4).

Kassa Y (2013) Performance Assessment of Road Drainage Structures and Proposed Mitigation Measures.

Lee, George M., "Study of highway drainage inlets, M.S. thesis, 1970" (1970). *Fritz LaboratoryReports.* Paper 427.

Mehari.T,G/Mariam.B,Ayele.T,Demissie.S,Jemberie.A.(2015).Investigating Highway Drainage Problems in the Sile River Bridge, South, Ethiopia.Journal of Multidisciplinary Engineering Science and TechnologyVol. 2 Issue 4, April-2015

Mukherjee D (2014) Highway Surface Drainage System & Problems of Water Logging In

Road Section in West Bengal, India. The International Journal Of Engineering And Science (IJES) || Volume || 3 || Issue || 11 || Pages || 44-51 || 2014 ||

ORG (Oromia Regional Government). 2003. Gomma district based development program: Project document. Oromia economic study project office. Addi Ababa, Ethiopia

Raj Vir Singh, (1991). Drainage and salinity control‟‟ First Edition, Humanshu Publications Lagos Nigeria.

Rono.B (2014) An Investigation into the Adequacy of the Drainage System on Narok Mai Mahiu Road.

Saara, A., & Saarenketo, T. (2006). Managing drainage on low volume roads. *Executive summary, ROADEX~ III The Northern Periphery Research, Oy, Finland*, 33-37.

Sandy, C. Richard , G and Fearchem, D. (1996).Environmental health Engineering in the tropics. African journal of environmental science and technology vol.2(8). Pp.208-216

Sonuga , F. (1993). „Challenges of the drainage in the developing countries‟‟ in proc. 6th int. Sounders college publishers San Diego New York.

The New Vision (2003). Article was published by New Vision printing press on 23rd August pg 1to 2.

The New Vision (1999).Article was Published by New Vision printing press on Wednesday the 13th October pg 3.

The United Nations Environment programme report.(1994).Thomas Nelson and sons‟‟s Ltd.U.K.

Walker.D,(2000) Local Road Assessment and Improvement Drainage Manual, University of Wisconsin–Madison

World Health Organisation Report (1992). Our planet, our health. World Health Organization.

Zumrawi E(2014) The Impacts of Poor Drainage on Road Performance in Khartoum. International Journal of Multidisciplinary and Scientific Emerging Research ©2014 IJMSER, All Rights Reserved Available at http://www.ijmser.com/

APPENDIX A: Mean Annual Rainfall, Rainfall Regions, Over land flow time and IDF Curves of Rainfall Region B1 of Ethiopia

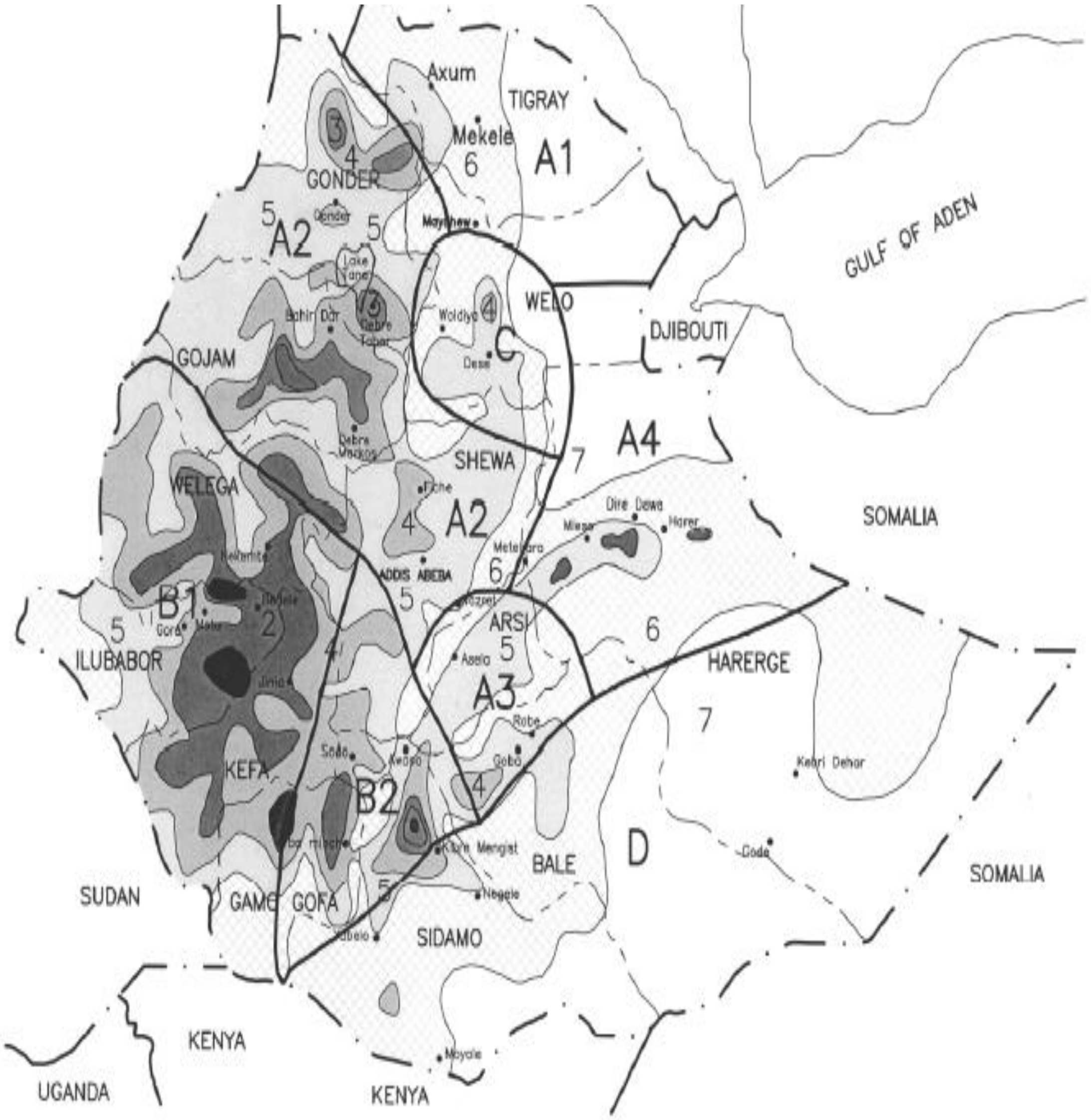

Figure1. **Mean Annual Rainfall for Ethiopia**

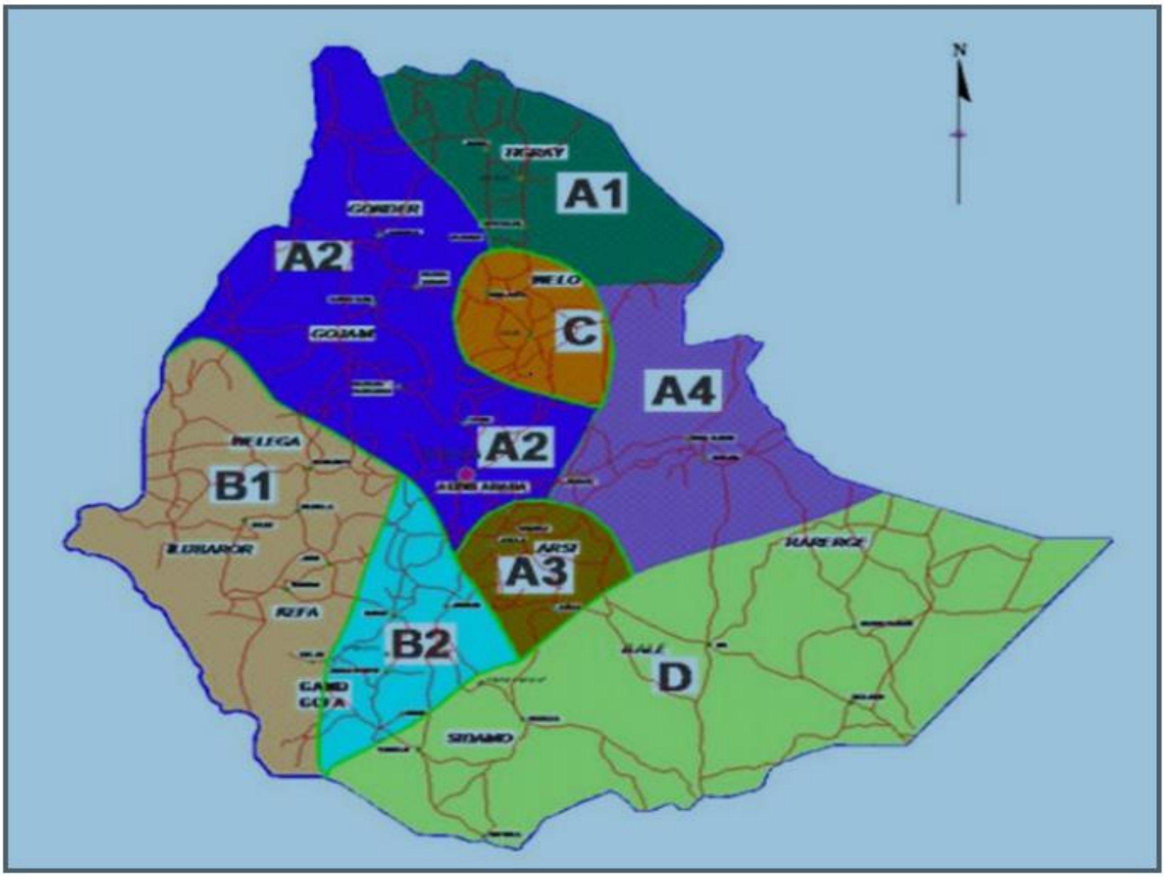

Figure2. Rainfall Regions

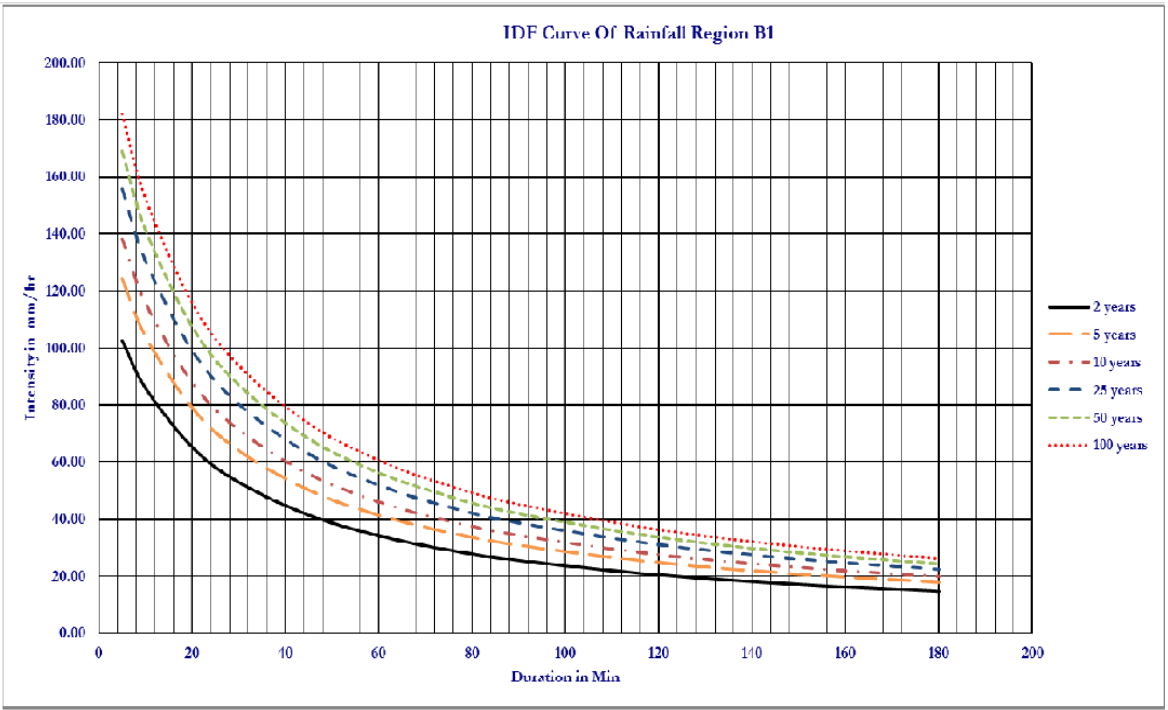

Figure3. IDF Curve of Rainfall Region B1

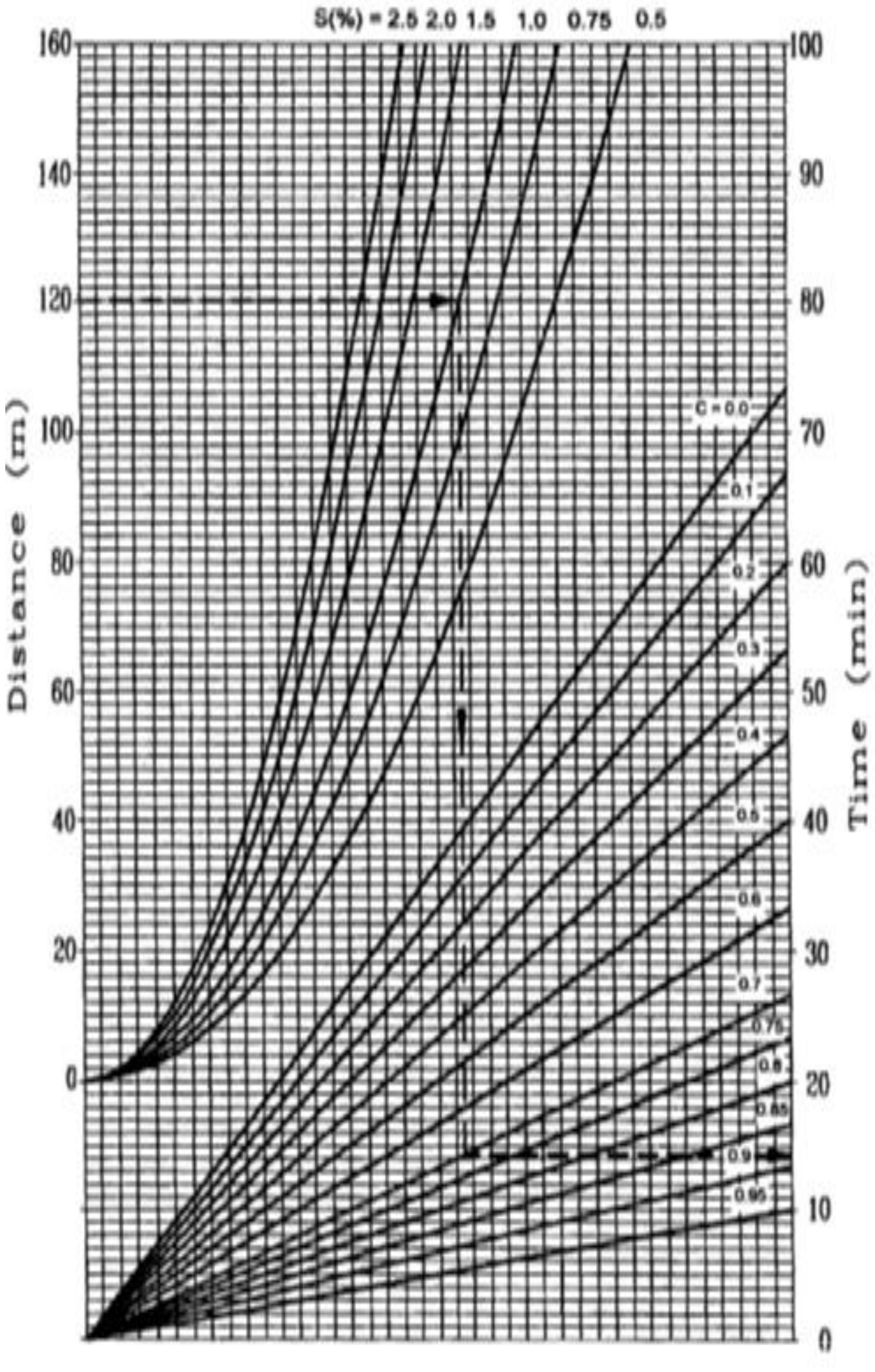

Figure4: Overland time of flow

Appendix B: Recommended run off coefficient C

Table 1: Recommended run off coefficient C for previous surface by selected hydrological soil grouping and soil range

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

Table2: Recommended run off coefficient C for previous 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

Table3: 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

Table4: frequency factors for rational method

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

Table5: Recommended Runoff Coefficient C for rural catchment

Factor		Description	Runoff Coefficient
Cs	Average slope of catchment	< 3.5% Flat	0.05
		3.5% - 10% Soft to moderate	0.1
		10% - 25% Rolling	0.15
		25% - 45% Hilly	0.2
		> 45% Mountainous	0.25
Cp	Permeability of soil	Well drained soil e.g. sand and gravel	0.05
		Fair drained soil e.g. sand and gravel with fines	0.1
		Poorly drained soil e.g. silt	0.15
		Impervious soil e.g. clay, organic silts and clay	0.25
		Water-logged black cotton soil	0.5
		Rock	0.4
Cv	Vegetation	Dense forest/thick bush	0.05
		Sparse forest/dense grass	0.1
		Grassland/scrub	0.15
		Cultivation	0.2
		Space grassland	0.25
		Barren	0.3
C = Cs + Cp + Cv			

Table 6: Design Storm Frequency (Yrs) by Geometric Design 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

Table7: Values of Roughness Coefficient n (Uniform Flow)

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

4 Various Open Channel Surfaces		
a. Concrete	0.012-	0.020
b. Gravel bottom with:		
Concrete	0.020	
Mortared stone	0.023	
Riprap	0.033	
c. Natural Stream Channels		
Clean, straight stream	0.030	
Clean, winding stream	0.040	
Winding with weeds and pools	0.050	
With heavy brush and timber	0.100	
d. Flood Plains		
Pasture	0.035	
Field Crops	0.040	
Light Brush and Weeds	0.050	

NATURAL STREAMS

1 Minor streams (top width at flood stage < 30 m)			
a. Streams on Plain			
1. Clean, straight, full stage, no rims or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8 Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravel, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
2 Flood Plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050

Table8: Roughness Coefficient Values (Manning's n) for Sheet Flow

Surface Description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤ 20%	0.06
Residue cover > 20%	0.17
Grasses:	
Short grass	0.15
Dense Grasses	0.24
Range (natural)	0.13
Woods:[2]	
Light underbrush	0.40
Dense underbrush	0.80

[1] The n values are a composite of information complied by Engman (1986)
[2] When selecting n, consider cover to a height of about 0.03 m. This is the only part of the plant cover that will obstruct sheet flow

Appendix C Questionnaires

Questionnaire Type One
Roadside Drainage Problems along Jimma to Agaro Road

This questionnaire is being administered for the collection of data to assist in the study of the Roadside Drainage Problems along Jimma to Agaro Road.The information collected is confidential and will strictly be used for academic purposes.

Sector: Technical Perspective.

Technical Aspect

A: basic information

1. Name...

2. Marital status…………………………………………………………………………

3. Occupation ………………………………………………………………………...

4. Education standard …………………………………………………………………..

5. Village of residence ……………………………………………………………….

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

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

1. From your design experience, was the design appropriate?

- Yes
- No

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

- Poor maintenance
- Poor workmanship
- Climate change
- Any other (specify)

2. Do you think the contractor observed due diligence in the construction of the Roadside drainage systems?

- Yes
- No

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

____

____

____

3. From your experience as an engineer, can you say other roads in Ethiopia were provided with Roadside drainage facilities?

- Yes
- No

If your answer is no, in your opinion what percentage of roads in Ethiopia are not provided with adequate drainage system?

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

4. Do you think that there was carelessness in the supervision of the contractor during the construction of the road?

- Yes
- No

Why do think that was the case?

____

____

____

____

7. From your engineering experience and practice, how can you rate the state of the Roadside drainage problem in Jimma to Agaro road?
   - ☐ Excellent
   - ☐ Very good
   - ☐ Good
   - ☐ Poor
   - ☐ Any other (specify)

____

____

__

8. How often do you carry out inspection to ascertain the state of the Roadside drainage problems in Jimma to Agaro road?
   - ☐ Monthly
   - ☐ Every three months
   - ☐ Every six months
   - ☐ Once a year
   - ☐ Any other (specify)

____

____

9. Have you carried out a research on the effects of the poor Roadside drainage system on the surrounding environment?
   - ☐ Yes
   - ☐ No

What did you find are the effects?

- ☐ ____
  ____

- ☐ ____
  ____
- ☐ ____
  ____
- ☐ ____
  ____
- ☐ ____
  ____
  ____

10. What do you think is the remedy to poor roadside drainage along Jimma to Agaro road?
    - ☐ Maintenance
    - ☐ Redesigning
    - ☐ Reconstruction
    - ☐ Any other (specify)

____
____
____

11. 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

12. Do you think poor farming practices are to blame for the erosion of the road and the surrounding?
    - ☐ Yes
    - ☐ No
13. If your answer in (12) is yes, what do you recommend as the best farming practice in the area?

- ☐ ____
  ____
- ☐ ____
  ____
- ☐ ____
  ____
- ☐ ____
  ____

14. What is the extent of the damage on the road?

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

____
____

15. In your own opinion based on the professional experience, is the type of drainage facility installed in Jimma to Agaro road with enough capacity to satisfactorily drain the water from the road?

- ☐ Yes
- ☐ No

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

____
____
____

Questionnaire Two

Adequacy of Roadside Drainage System in Jimma to Agaro Road

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

Sector: General Perspective.

General Aspect

A: basic information

1. Name..

2. Marital status? …………………………………………………………………

3. Occupation? ……………………………………………………………………

4. Education standard? ……………………………………………………………

5. Village of residence? …………………………………………………………

1. How often do you use Jimma to Agaro road?

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

____

____

2. How far is your home from the Jimma to Agaro road?

- ☐ 50 meters
- ☐ 100 meters
- ☐ 500 meters
- ☐ More than 500 meters
- ☐ Any other (please specify)

____

____

3. How often are heavy rains experienced in the area?

- ☐ Once a year
- ☐ Twice a year
- ☐ More than Twice a year
- ☐ No idea

4. In your opinion how do you find the condition of the roadside drainage problems along Jimma to Agaro road?

- Very good condition
- Good condition
- Fair condition
- Poor condition

5. How does poor drainage affect you as a road user?

- Runoff on the road block the road
- Runoff wash away the bridges
- Runoff cuts through the road
- Water leaves debris on the road surface
- Any other (specify)

____

____

6. How does poor drainage affect you as the resident?

- Runoff erodes the land
- Runoff create gullies on your land
- Runoff wash away crops
- Runoff washes away house and property
- Any other (specify)

____

____

__

7. How many times have you been interrupted by water on the road?

- Once
- Twice
- Thrice
- More than three times
- never

8. What did you do when you got interrupted?

- Discontinued the journey
- Found another route
- Waited for the water to subside then continued

- ☐ Any other (specify)

____

____

____

9. Since the last time you were interrupted, have you observed any improvements on the drainage system?

- ☐ Yes
- ☐ No

10. In your own view, how satisfied are you as a road user or resident with the state of drainage of the road?

- ☐ Extremely satisfied
- ☐ Satisfied
- ☐ Dissatisfied
- ☐ Extremely dissatisfied

11. Do you believe there is need of public awareness by the government institutions on road management?

- ☐ Yes
- ☐ No

Why do you think so?

____

____

____

12. What assistance does the government give to people affected by floods? ____

____

____

13. Is the assistance acceptable by the community if No/Yes give reasons why?

____

____

14. How do you think we can mitigate environmental problems which result from floods?

____

____