JIMMA UNIVERSITY

POST GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

Assessment on Cause of Poor Drainage Condition and Its Effect on Pavement Performance, Jimma City Bocho Bore Kebele

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

By:-Bethlehem Bita

November, 2017

Jimma, Ethiopia

JIMMA UNIVERSITY

POST GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HIGHWAY ENGINEERING STREAM

Assessment on Cause of Poor Drainage Condition and Its Effect on Pavement Performance, Jimma City Bocho Bore Kebele

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

By:-Bethlehem Bita

Main Advisor: Dr. Ing-Tameneh Adugna

Co- Advisor: Engineer Abel Tesfaye

November, 2017
Jimma, Ethiopia

DECLARATION

As members of the examining board of the final MSc open defense, we certify that we have read and evaluated the thesis prepared by By:-Bethlehem Bita entitled on "**Assessment on Cause of Poor Drainage Condition and Its Effect on Pavement Performance**," Jimma City Bocho Bore Kebele Roads and recommended that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Highway Engineering.

Submitted by:	__________	________
Bethlehem Bita	Signature	Date
Advisor**:**	________	_______
Dr. Ing- Tameneh Adugna	Signature	Date
Co-advisor Mr. Abel Tesfaye (MSC)	_________	______
	Signature	Date

Acknowledgement

My first thanks goes to almightily God who has given me the courage and strength to finish with my thesis.

Secondly, I would like to thanks Jimma University and my advisors Dr. Ing-Tameneh Adugna and Engineer Abel Tesfaye for their progress on this research. I am also greatly indebted to Ethiopian Road Authority for providing me full sponsorship to undertake my Masters' study.

Finally, I would like to express my humble gratitude to friends and who are always there by providing me morale support and encouragement.

Abstract

Poor drainage condition problem is one of the major challenges facing developing country. Poor drainage causes early pavement distresses leading to structural failures of road as pointed out by several researchers. In Jimma, new constructed roads were informed to fail rapidly after opened to traffic. Bocho Bore Kebele is found in jimma town which are affected by poor drainage condition.

The Objectives of this study are to assess the existing condition of drainage, cause of poor drainage and to evaluate its effects on pavement. An exploratory and descriptive type of methods was used to describe and explore the existing condition of drainage and pavement. Data collection methods were carried out using both primary and secondary data sources, the secondary data source was only relevant to support the primary data, which was accomplished with the help of topographic map and design data. The collected data were analyzed and presented using Microsoft-excel, tables, graphs, picture and percentages.

The result of this study, it was found that most roads in the kebele suffered from people awareness, construction problem, absent of routine maintenance and poor management system are causes for poor drainage condition. Based on respondent survey data, 80% had responded for poor condition, about 16% of the respondents for fair and only 4% thinks the drainage system is good. Result from cause of poor drainage condition occurred 69% due to people awareness and absent of routine maintenance, 19% due to construction problem of drainage structure, and 12% are due to cross slope difficult. This all problem lead to have low drainage inlet efficacy, at station 1+400 1+900 (Tilahun Shell to Noc) the evaluation shows that the efficiency of inlets is 40.36%. Due to surface water, debris and silt back to roadway, pavement distresses occurred.

Based on the result I conclude that, poor drainage condition and its contributing to the early deterioration of pavements, the existing drainage conditions inadequate to carry the flow. Absent of routine maintenance, people awareness and poor management systems are also the main cause for inlet not to work properly and failure of pavement.

This study recommends that to minimize early pavement failures, it is better to provide adequate drainage system alert people to use efficient drainage, improve routine maintenance ability and it helpful to increasing the service life of pavement.

Key Word: Drainage condition, pavement failure, maintenance, construction, over flow, manhole, inlet

Table of Contents

Acknowledgement i
Abstract ii
List of table vii
List of figure viii
Acronyms iv
CHAPTER ONE 1
INTRODUCTION 1
1.1 General Background of the Study 1
1.2 Statement of the Problem 2
1.3 Research Questions study: 4
1.4 Objective of the research study 4
    1.4.1 General objective of the study 4
    1.4.2 Specific Objectives of the study. 4
1.5 Significance of the Study 4
1.6 Scope and Limit of the Stud 4
CHAPTER TWO 5
LITERATURE REVIEW 5
2.1 General Description of the study: 5
2.2 Cause of Poor Drainage Condition 6
2.3 Highway drainage classification 6
    2.3.1 Road Surface Drainage 7
    2.3.2 Sub-surface drainage 7
    2.3.4 Cross drainage 7
    2.3.3 Longitudinal drainage 7
2.4 Hydrological Analysis 8
    2.4.1 Catchment Area 8
    2.4.2 Rational Method 9
    2.4.3 Runoff Coefficient 9
    2.4.4 Rainfall Intensity: 10
    2.4.5 Time of Concentration 10

2.5 Storm Drainage Systems 10
2.5.1 Longitudinal slope: 11
2.5.2 Cross Slope 11
2.5.3 Roadside and Median Channels 11
2.6. Effects of Pavement Failure: 12
2.6.1 Waste of Passenger Time 13
2.6.2 Impact on Economic Development 13
2.6.3 Poor drainage conditions 13
2.6.4 Traffic Load 13
2.6.5 Road Maintenance 14
2.6.6 Appropriate Construction Material 14
2.7 Rating of drainage condition 14
2.8 Pavement drainage 15
2.8.1 Design Frequency and Spread: 15
2.8.2 Gutter Flow 16
2.8.3 Flow Time in Gutter: 17
2.8.4 Inlet Locations 18
2.8.5 Inlet Types 18
2.8.6 Curb-Opening Inlets 19
2.8.7 Combination inlets 20
2.8.8 Grate inlets 21
2.8.9 Slotted Drain Inlets 21
2.8.10 Inlet Capacity: 22
2.8.11 Inlet Interception Capacity and Efficiency on Continuous Grades 22
2.8.12 Factors Affecting Inlet Interception Capacity in Sag Locations 23
2.9 Hydraulic Capacity 23
CHAPTER THREE 24
RESEARCHES AND METHDOLOGY 24
3.1 Study area 24
3.2 Study population 25
3.3 Sample Size 25

3.4 Study Variables 25
3.4.1 Dependent variable: 25
3.4.2 Independent variable: 25
3.5 Material 25
3.6 Reaserch Desighn 25
3.7 Data collection Process 26
3.7.1 Primary data: 26
3.7.2 Site visit / observations: 27
3.7.3 Photography: 27
3.7.4 Secondary data 27
3.8 Data processing and analysis 28
3.9 Ethical Consideration 28
3.10 Data Quality Assurance 29
3.11 Hydrology and Hydraulics Evaluation 29
3.11.1 Determination of Catchment Area .... `29
3.11.2 Rational Method 30
3.11.3 Rainfall Intensity 30
CHAPTER FOUR 31
RESULTS AND DISCUSSION 31
4.1 Existing Condition of Drainage System and Pavement: 31
4.1.1 Result from Questionnaires 33
4.1.2 Result from Field Assessment and Taking pictures 33
4.2 Cause of poor drainage condition 42
4.2.1 People awareness 42
4.2.2 Absent of routine maintenance..42
4.2.3 Construction of drainage structure...43
4.2.1 Cross Sectional Slope 47
4.3 Effect of Poor Drainage on Pavement.. 50
4.3.1 Evaluation of Drainage Efficiency 56
CHAPTER FIVE 61
CONCLUSION AND RECOMMENDATION 61

5.1 Conclusion....61
5.2 Recommendation....62
References:....63
Appendix A....65
Appendex B....83
Appendix C....83
Appendix D....85

List of table

Table 2-1 Runoff Coefficient -- -9

Table 2.2 Rating and evaluating roadway drainage -------------------------------- 14

Table 2.3 Suggested minimum design frequency and spread ---------------------- 15

Table 2.4 Manning’s for Street and Pavement Gutters ----------------------------- 17

Table 4.1 Existing condition of drainage manhole ---------------------------------- 31

Table 4.2 Existing condition of drainage inlets--------------------------------------31

Table 4.3 Response rate---33

Table 4.4 Existing Condition of Drainage Construction ---------------------------43

Table 4.5 Inlet Efficiency Computation --- 59

List of figure

Figure 2.1.Uniform Cross Section of gutter --- 16

Figure 2.2 Depressed curb opening --- 19

Figure 2.3 Curb opening inlet and combination inlet -------------------------------- 20

Figure 2.4 Slotted drain inlet at an intersection --------------------------------------- 21

Figure 3.1 Location of the study area-- 24

Figure 4.1a Existing condition of manhole and their Percentage Distribution------ 32

Figure 4.1b Existing Condition of Inlets and their Percentage Distribution -------- 32

Figure 4.2 Responses of engineers and their Percentage Distribution. -------------- 34

Figure 4.3 Responses of road user and resident --------------------------------------- 34

Figure 4.4 Manhole inlet in good condition --- 35

Figure 4.5 Waste disposal on the drainage structure----------------------------------- 36

Figure 4.6 Shows inlets closed by debris -- 37

Figure 4.7 Inlets closed by silt and mud in front of central source ------------------ 38

Figure 4.8 Manual cover damage and removed in front of total--------------------- 39

Figure 4.9 Drainage fills by debris around bus station ------------------------------- 40

Figure 4.10 Waste water and trash from resident home to outside the ditch-------- 41

Figure 4.11 Inlets contract over design -- 44

Figure 4.12 Assessment of drainage construction------------------------------------- 45

Figure 4.13 Drainage Inlet Structure Construction Problems------------------------ 46

Figure 4.14 Condition of drainage Construction and their percentage--------------- 47

Figure 4.15 during survey data collection at field (around Galimole) --------------- 48

Figure 4.16 Cross slope for right side and their Percentage Distribution ------------49

Figure 4.17 Cross slope for left side and their Percentage Distribution --------------49

Figure 4.18 Summery of Cause for poor Condition drainage --------------------------50

Figure 4.19 Formation of potholes due to Poor Drainage around genu hotel--------52

Figure 4.20 Pavement failure and inlets doesn’t work) --------------------------------53

Figure 4.21 Pavement failure and inlets doesn’t work ---------------------------------54

Figure 4.22 Waste water inter to manhole across on pavement structure-------------55

Figure 4.23 Typical cross section 14m width --56

ACRONYMS

AACRA	Addis Ababa City Roads Authority
AASHTO	American Association State Highway and Transportation Officials
AC	Asphalt Concrete
ADOT	Arizona Department of Transportation
ASTM	American Standard for Test Method
DC	Design Class
DDM	Drainage Design Manual
DEM	Digital Elevation Model
DOTS	State departments of transportation
DS	Design standard
EMA	Ethiopian Mapping Agency
ERA	Ethiopian Road Authority
FHWA	Federal Highway Administration
GDM	Geometric Design Manual
GIS	Geographic Information System
HEC	Hydraulic Engineering Circular
HSG	Hydrological Soil Group
HWDG	Highway Drainage Guidelines
IDF	Intensity-Duration-Frequency
JIT	Jimma Institute of Technology
SUDS	Sustainable Urban Drainage System

CHAPTER ONE

INTRODUCTION

1.1 General Background of the Study

Jimma city is located in southern west of Ethiopian which is a fast growing city in terms of infrastructural development that involves construction of roads. This development is leading to increased produced storm water volumes. The removal of storm water from street and highway pavement and median areas requires a well-designed drainage system**.**

A typical city, storm water system consists of roads constructed with curbs, gutters, inlets, and roadside ditches; underground storm sewers; and open outfall channels such as stream and rivers receiving runoff [1].These systems must be properly designed, built and maintained to properly collect water, avoid disruption of the roads transportation function, maintain safe travel conditions, and sustain infrastructure[2]. Inadequate urban storm water drainage problems represent one of the most common sources of compliant from the citizens in many towns of Ethiopia and this problem is getting worse and worse with the ongoing high rate of urbanization in different parts of the country [3].Adequate drainage is very essential in the design of highways since it affects the highway's serviceability and usable life. If pounding on the traveled way occurs, hydroplaning becomes an important safety concern. Drainage design involves providing facilities that collect, transport and remove storm water from the highway. Displacement of the material to the outer slope will lead to the accumulation of pollutants in the road area and eventually to the leaching of, e.g., heavy metals to the ground water or surface water bodies [4].These distresses affect the safety and quality on the pavement as they may lead to premature failure and traffic hazards. The Presence of excess water in pavement structures causes a progressive weakening of the structure as well as the sub-grade of the pavement layers. Drainage design involves providing facilities that collect, transport and remove storm water from the roadway. Water cause a serious impact on both the road access and its strength, an efficient drainage system is the most important part of urban road construction and maintenance works. Good drainage needs to be taken into consideration at the early design stages in order to secure a long life for the road. Drainage system includes the pavement and the water handling system. They must be properly designed, built, and maintained

In Jimma, new constructed roads were informed to fail rapidly after opened to traffic. These failures were contributed to many reasons such as, people awareness, poor management system, and poor quality of pavement materials, Excessive Traffic loads and other factors are cause for pavement failure. The most common road distresses are potholes, cracks, rutting, raveling depressions and damaged edges. Boch Bore road is a concrete asphalt road that is found in Jimama city center of the town. The kebele is the biggest kebele in the town by highly urbanized and which have high traffic flow because of its business area, had money hotels, government organizations, money residential place and also bus station are found in this kebele. Environmental factors which affect drainage and road performance are serious issues in the kebele road. The road has a functional classification of a main access, with a design standard of DS5. All surface runoff at the super elevation section had discharged with an opening of median 50 cm at an interval of 15 meter. The centers of side walk have 60 x 60 square areas at an interval of 10 meter maximum for plants. According to Jimma town asphalt roads project, feasibility study report, the road is very important for economic development of the city in general and region in particular. The road a width of 14 meters and on average 3.5 meters wide earthen side ditches on both sides of the road. Throughout the road length, there are many ditches even if most of them were not functioning properly during the rainy season.

Poor design can direct water back onto the road or keep it from draining away. Too much water remaining in the surface, base, and subgrade combined with traffic action will cause potholes, cracks and pavement failure. Even on roads built with all the proper drainage elements, neglecting periodic maintenance is likely to result in flooding, washouts, and potholes. Regular annual evaluation of drainage systems is an important part of maintaining and managing roadways [1].

1.2 Statement of the Problem

drainage is critical to pavement performance. It also known that maintenance and overlays do not greatly improve the life of pavements that do not have good drainage system. Because there is no way of stopping water from infiltrating the pavement surface, removal of that water is essential to extending the life of the pavement. The main purpose of subsurface drainage is to remove water as quickly as possible. When smooth layers under a flexible pavement surface become saturated with water and are not allowed to drain, they become weak. [5]

Pavement damage is the major problem of developing countries. The over flow of storm water on the road by runoff results buildup silt in the drainage leading to overturning of the water to the road and difficult to pavement performance and the vehicles. This major problem is spread all over the country. Jimma city is one of the built-up cities that are affected by poor drainage condition regarding to people awareness, construction problem, poor management system and absent of routine maintenance throughout the year. Re-construction of Bocho Bore kebele Road was carried out in 2003 after Ethiopian millennium years of transformation. After re-construction the road is failed rapidly after open to traffic. This road is selected due to the serious problems and failures caused by the poor drainage condition and the accumulation of subsurface water in the pavement structure.

Inadequate drainage is the major problem which is comes from the people awareness, poor construction and absent of routine maintenance throughout year in the town. The problem which is shown in most areas is inadequate drainage system and poor management system making a pavement surface to failure. It is most economical and effective to plan and upgrade drainage as part of road surface improvements and creating good management in order to teach people about the use of drainage properly. Routine maintenance is also one of effective and economical. Therefore, the objective of this research is to assess the cause and effect of poor drainage condition on pavement and to recommend best practice that could control pavement deterioration (failure) before the design life.

1.3 Research Questions study:

The researcher has formulated the following statement of problems try to be clarifying:-

- What is the existing condition of drainage and pavement?
- What is the cause of poor drainage condition?
- What is the effect of poor drainage condition on pavement?

1.4 Objective of the research study

1.4.1 General objective of the study

- To assess the poor drainage condition and its effect on pavement in, Jimma town Bocho bore Keble roads.

1.4.2 Specific Objectives of the study

- To assess the existing condition of drainage and pavement.
- To identify cause of poor drainage condition.
- To evaluate the effects of inadequate drainage system on pavement.

1.5 Significance of the Study:

This study is beneficial to kebele and town for better drainage condition and future of road construction to avoid problems by assessing the existing drainage system and proposing mitigation measures to avoid the problem. The study is expected to propose appropriate solutions to the drainage systems whose implementation will contribute to the sustainability of the case study on road performance. The study is beneficial for academicians and researchers who conduct similar researches on other road drainage condition and pavement evaluation. It may also support policy makers in their effort to address similar problems.

1.6 Scope and Limit of the Study:

The Scope of the research is to assess poor drainage condition and its effect on pavement. The qualification measures are found from road feature and drainage structures. The research does not include structural design of all types of drainage and pavement except proposing the type and size of the required drainage system and its efficiency. However hydrologic analysis and poor drainage condition that are subject to pavement failure are included.

CHAPTER TWO

LITERATURE REVIEW

2.1 General Description of the study:

The study of drainage condition of a road is very essential while studying of any road performance. A lot of factors contribute to pavement failure were investigated by many researchers. Some of the factors that cause highway failure have been identified. Poor drainage condition, poor design, construction and maintenance, use of low quality construction materials, poor workmanship and poor supervision of construction work and the applying of heavy traffic that were not meant for the road and the following will lead to highway failure. In additional situation, Poor highway facilities, no knowledge base, in adequate sanction for highway failure, no local standard of practice, Poor laboratory and in-situ tests on soil and weak local professional bodies in highway design, Poor construction and management also causes the premature failure of the pavement [6].

This researcher found that the loss of strength and durability due to the effects of poor drainage condition. Water is cause by loss of cohesion (strength) of the asphalt film, failure of the adhesion (bond) between the aggregate and asphalt, and degradation of the aggregate particles subjected to freezing [7]. The techniques of workable drainage systems are widely recommended and applied in many parts of the world, whereas the terminology varies in different regions, but with similar design philosophies. The basic design techniques in roadway drainage system should be developed for economic design of surface drainage structures including ditches, culverts and bridges.

A World Bank report indicated that poor drainage conditions in developing countries as a result of insufficient infrastructural, weak institutional capacity, inadequate regulatory policies, inadequate governance, and generally lack of public Education awareness participation [8]. These are problems associated with infrastructural provision in most developing countries currently follows along the traditions of the developed countries. In Europe, sustainable Urban Drainage System (SUDS) is used with its main focus maintaining drainage system and good health, protecting valuable water resources. From pollution and preserving biological diversity and natural resources for future needs

In Africa the drainage problem is very critical. Cause pavement distress and for several environmental problems like, malaria deceases. In Jimm a lot of roads across the country having inadequate drainage system which affects Pavement serviceability, safety and riding quality on the roadway as it may lead to water pounding which increasing the failures and is a traffic hazard.

2.2 Cause of Poor Drainage Condition

The over flow is direct related to the drainage area which is the most important watershed characteristic that affect runoff. Effects of water on the operational of the pavement system are Water in the asphalt surface can lead to moisture damage, modulus reduction, and loss of tensile strength [9]. The large contribution drainage area the larger will be the flood runoff and Well-known that water blocking as one of the causes of poor drainage [10]. The causes of water blocking 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 as 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 [11]. Poor drainage will reduce the life of the pavement and great environment impact if not giving attention to the problem. Too much water remaining in the surface, base, and sub grade combined with traffic action will cause potholes, cracks and pavement failure [12].

The artificial causes are during construction and improper use of drainage systems by the peoples. Poor design and construction can direct water back onto the road or keep it from draining away. Absent of routine maintenance also cause for both poor drainage and pavement failure. Routine maintenance required continuously on every road whatever its engineering characteristics or its traffic Volume. Inadequate drainage leads to major cause of pavement distresses due to large amount of costly repairs before reaching their design life and pavement service life can be increased by 50% if water can be drained without delay [13].

2.3 Highway drainage classification

2.3.1 Road Surface Drainage

Removal of surface water from the roadway and adjoining land is termed as surface drainage. If surface water penetrates into the road body, it reduces the load bearing capacity of the pavement, which may cause further damage of the road. To avoid these problems, it is important to secure suitable drainage of the road surface. According to ERA geometric design manual the normal cross-slope is not less than 2.5% in order to dispose water from the roadway quickly [14]. A freeboard of less than 1.5m is provided, however, according to ERA draft drainage design manual, the minimum freeboard must not be less than 1meter.

2.3.2 Sub-surface drainage

Removal of additional soil-water from the sub-grade is termed as sub-surface drainage. The primary goal of this type of drainage is to improve properties of the subsoil and base materials for improved performance of supported structures, such as highway or airfield pavements [15]. Sub-surface drainage systems drain water that has infiltrated through the pavement and the inner slope but also ground water.

2.3.3 Cross drainage

Structure used to convey surface runoff through embankment. Highway crosses a river or stream, cross drainage Works have to be provided. [14] Sometimes water from side drains also is diverted away from the road through cross Drains. The design shall be such that the backwater (the headwater) caused by the structure for the design storm does not:

- Increase the flood hazard significantly for property;
- Overtop the highway; or.
- Exceed a certain depth on the highway embankment

2.3.3 Longitudinal drainage

Main objective of longitudinal drainage is collection and removal of water that is on the road and immediate surrounding or water from adjacent areas [15]. Longitudinal surface drainage systems include gutters, channels, ditches, permeable land surface and swales complemented by their respective manholes, retain facilities and catch basins.

2.4 Hydrological Analysis

A hydrologic analysis is prerequisite to identifying flood hazard areas and determining those locations where construction and maintenance will be unusually expensive or hazardous since levels of government plan, design, and construct highway and water resource projects that might affect each other, interagency coordination is desirable and often necessary. The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to the design of drainage system. Errors in the estimates will result in a structure that is either undersized and causes more drainage problems or oversized and costs more than necessary [14].

The classification of rainfall regions in to four major rainfall regions and eight sub-rainfall regions in the country and developed IDF curves. To compare the developed IDF curve with generated IDF curve of the study area local rainfall data are required. However, local rainfall data are not available near the study area. The already developed regionalized IDF curve is used to determine rainfall intensity. Developed four IDF curves for rainfall regions in the country, the developed curves are for A1&A4, A2&A3, B, C & D and Bahir Dar & Lake Tana rainfall regions [14]. The study area lies on sub-region B1 and the IDF curve was constructed for B, C and D rainfall regions together.

2.4.1 Catchment Area

A catchment area is determined from topographic maps and field surveys. 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 points within the catchment area, or locate storm water drainage structures and assess their effects on the flood flows In determining the size of the contributing catchment area, any subterranean flow or areas outside the physical boundaries of the drainage study area that have runoff diverted into it shall be included in the total contributing catchment area. [14]

2.4.2 Rational Method

One of the most commonly used equations for the calculation of peak flow from small areas in urban is the rational formula, given as:

$Q = 0.00278 \text{ CIA}$ ……………………………………………… Equation 2.1

- Peak flow occurs when the entire watershed is contributing to the flow
- Rainfall intensity is the same over the entire drainage area.
- Rainfall intensity is uniform over time duration equal to the time of concentration, t_c. it is time required for water to travel from the hydraulically remote point of the basin to the point of interest

Frequency of the computed peak flow is the same as that of the rainfall intensity, 10-year rainfall intensity is assumed to produce the 10-year peak flow. Coefficient of runoff is the same for all storms of all recurrence Because of these inherent assumptions, the Rational formula should only be applied to drainage Areas smaller than 50 ha [14].

2.4.3 Runoff Coefficient

The runoff coefficient (C) is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the designer the runoff coefficient in equation above is a function of the ground cover and it relates the estimated peak discharge to a theoretical maximum of 100 percent runoff. [14].

Table 2.1 of the runoff coefficient

Land Use	Percentage	Runoff Coefficient(C)
Mixed Residence	66.7	0.68
Health center	4.1	0.60
Government Compound	7.2	0.50
Cobble Stone road	4.2	0.75
Gravel fill road	17.8	0.65
Total	100	
Representative C=		0.66

2.4.4 Rainfall Intensity:

The rainfall intensity (I) is the average rainfall rate in mm/hr. for duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the catchment area, the rainfall intensity can be determined from Rainfall-Intensity-Duration curves. Rainfall-Intensity-Duration curves for use in Ethiopia are given in appendix A at the end of the chapter.

2.4.5 Time of Concentration:

It is defined as the time required for surface runoff to flow from the remotest part of the catchment area to the point under consideration. Each point in the catchment has its own time of concentration [14]. I can use a number of methods that can be used to estimate time of concentration (t_c), some of which are intended to calculate the flow velocity within individual segments of the flow path (e.g., shallow concentrated flow, open channel flow, etc.). Time of concentration can easily be computed using federal aviation administration formula which is frequently used and recommended for over flow in urban basin [16].

$Tc = 1.8 * (1.1 - C) * L^{0.5} / S^{0.33}$ ……………………………………………...Equation 2.2

Where: C = Rational method runoff coefficient

L = Length of overland flow, ft.

S = Surface slope, %

2.5 Storm Drainage Systems

Highway storm drainage facilities collect storm water runoff and convey it through the roadway right-of-way in a manner which adequately drains the roadway and minimizes the potential for flooding and erosion to properties adjacent to the right-of-way.[14] Storm drainage facilities consist of curbs, gutters, storm drains, channels and culverts. The placement and hydraulic capacities of storm drainage facilities should be designed to take into consideration damage to adjacent property and to secure as low a degree of risk of traffic interruption by flooding as is consistent with the importance of the road, the design service requirements and available funds. Roadway features considered during gutter, inlet and pavement drainage calculations include:

- Longitudinal slope
- Cross slope
- Roadside and median ditches

2.5.1 Longitudinal slope:

A minimum longitudinal gradient is more important for a curbed pavement, since it is susceptible to storm water spread. Flat gradients on uncurbed pavements can also lead to a spread problem if vegetation is allowed to build up along the pavement edge. Gutter grades should not be less than 0.5 percent. Minimum grades can be maintained in very flat terrain by use of a saw tooth profile [14].

2.5.2 Cross Slope:

Drainage of the road pavement is provided by shaping the road carriageway with a camber or cross slope a careful check should be made of designs to minimize the number and length of flat pavement sections in cross Slope transition areas. In areas of intense rainfall, a somewhat steeper cross slope may be necessary to facilitate drainage and in such areas normal cross fall not less than 2.5 percent on paved roads. [14]

2.5.3 Roadside and Median Channels:

Roadside channels are commonly used with uncurbed roadway sections to convey runoff from the highway pavement and from areas which drain toward the highway. Due to right-of-way limitations, roadside channels cannot be used on most urban arterials. They can be used in cut sections, depressed sections, and other locations where sufficient right-of-way is available and driveways or intersections are irregular. Where practicable, the flow from major areas draining toward curbed highway pavements should be intercepted by channels as appropriate [14]. It is preferable to slope median areas and inside shoulders to a center swale, to prevent drainage from the median area running across the pavement. This is particularly important for high-speed facilities, and for facilities with more than two lanes of traffic in each direction. Pavement drainage requires consideration of surface drainage, gutter flow, and inlet capacity. The design of these elements is dependent on storm frequency and allowable spread of storm water on the pavement surface. This research presents guidance for inlets and Drainage of Highway Pavements efficiency.

2.6 Effects of Poor Drainage on Pavement

Pavement distress greatly affects serviceability, safety, and riding quality of the road. After construction, roads deteriorate with age as a result of use and therefore, they need to be maintained to ensure that the requirements for safety, efficiency and durability are satisfied. Normally, new paved roads deteriorate very slowly in the first ten to fifteen years of their life, and then go on to deteriorate much more rapidly unless timely maintenance is undertaken [17]. It is well known that the rate of road deterioration increases if the water content of the granular material increases. No less than six adverse effects related to excess water: reduction of shear strength of unbound materials, differential swelling on expansive sub grade soils, movement of unbound fines in flexible pavement base and sub base layers, pumping of fines and durability cracking in rigid pavements, frost-heave and thaw weakening, and stripping of asphalt in flexible pavements [18]. Water content of the granular material increases rate of road deterioration before the design life of the road. Pavement surface drainage takes long stayed recognize as an important factor in roadway design. Because of this reasons the pavement drainage condition of the city must be stay in good performance especially at the study area..

Water on the pavement can interrupt traffic, reduce skid resistance, increase potential for hydroplaning, and limit visibility due to splash and spray, and cause difficulty in steering a vehicle when the front wheels encounter puddles. It is said that 80 percent of existing road way problems can be traced to the presence of water from poor drainage either in or on the road pavement [19]. Cracking just like inadequate joint sealant allow water to penetrate into the sub base and the sub grade and tends to soften the sub base and the sub grade the water most of the time tends to weaken the soil [20]. Pavement maintenance consists largely of sealing cracks, patching, and repairing deteriorated surfaces. It is a cost effective treatment to extend the life of the pavement before more expensive maintenance will be required The different effects of water on roads which are supplemented with the case studies are given below. The detrimental effects of water on the Structural support of the pavement system are outlined by AASHTO as follows: Water in the asphalt surface can lead to moisture damage, modulus reduction, and loss of tensile strength [21].

- Saturation can reduce the dry modulus of the asphalt by as much as 30% or more.
- It reduces the strength of unbounded granular material and Sub-grade soils.
- Act with water causes stripping of bituminous mixture.

Pavement failures have great effect in the developing of once country and have environmental and economic impact.

2.6.1 Waste of Passenger Time:

Journey time is wasted in due to damaged roads. The times opposite coming vehicles will have to Share the same lane some of them do this to avoid pot holes, pavement gulley other defected parts of the Road way.

2.6.2 Impact on Economic Development

Compared to general world standards, Ethiopia is well endowed with natural resources, with close to 60 percent of its total land area estimated to be potentially arable .

2.6.3 Poor drainage conditions

During rainy seasons, the water to enter the pavement from the sides as well as from the top surface this occurrence becomes more dangerous and the top layer gets detached from the lower layers.

2.6.4 Traffic Load

Increase in traffic loading especially on new roads where the design is based on reduced traffic is a major cause of cracking. The increase of traffic loads both in terms stated that with the increase of traffic loads both in terms of numbers and axle loads due to increased economic and developmental activities in the country [22]

2.6.5 Road Maintenance

road sides, traffic structures and facilities are kept condition of road performances. Routine maintenance required continues on every road whatever its characteristics engineering properties or its traffic volume. Highway maintenance ensures that the road way the road sides, traffic structures and facilities are kept in a condition of performance same or nearly as operational as the road was newly built [21].

2.6.6 Appropriate Construction Material

The most problems in road damage are bad design, poor appropriate construction material and lack of drainages. Based on ERA and AASHTO manual all materials for road construction and maintenance must be tested and confirm adequate by competent examiners before being used for provision of adequate and appropriate design features affecting the performance.

2.7 Rating of drainage condition

The existing drainage systems in the selected sites were rated based on the rating system developed and consists of four rating categories: excellent, good, fair and poor [22]. The ratings are based on the general condition, typical defects, and the recommended improvements as illustrated in Table 2.2.

Table2.2 shows Rating and evaluating roadway drainage

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

2.8 Pavement drainage

Effective drainage of highway pavements is essential to the maintenance of highway service level and to traffic safety. Water on the pavement can interrupt traffic, reduce skid resistance, increase potential for hydroplaning, and limit visibility due to splash, spray, and cause difficulty in steering a vehicle when the front wheels encounter puddles. The desirable gutter profile grade for curbed pavements should not be less than 0.5 avoided [23]. The drainage inlets receive the surface water collected in ditch and gutter and serve to covey the surface water to storm drain and they also limit spread of surface water onto travel lane when located along shoulder of the road [10].

2.8.1 Design Frequency and Spread:

Spread and design frequency is not independent. The implications of the use of criteria for spread of one-half of a traffic lane are considerably different for one design frequency than for a lesser frequency. The interdependency of spread and design frequency also have different implications for a low-traffic, low-speed highway than for a higher classification highway. Recommended design frequency for depressed sections and underpasses where ponded water can be removed only through the storm drainage system is a 50-year frequency event Table 2.3 provides suggested minimum design frequencies and spread based on the type of highway and traffic speed [24].

Table 2.3 suggested minimum design frequency and spread

Road Classification		Design Frequency	Design Spread
High Volume or <70 km/hr (45mph)		10-year	Shoulder + 1 m (3ft)
Divided or Bi- > 70 km/hr (45 mph)		10-year	Shoulder
Directional Sag Point		50-year	Shoulder + 1 m (3 ft)
Collector	< 70 km/hr (45mph)	10-year	1/2 Driving Lane
	> 70 km/hr (45mph)	10-year	Shoulder
	Sag Point	10-year	1/2 Driving Lane
Local Streets	Low ADT	5-year	1/2 Driving Lane
	High ADT	10-year	1/2 Driving Lane
	Sag Point	10-year	1/2 Driving Lane

2. 8.2 Gutter Flow

Gutter flow calculations are necessary in order to relate the quantity of flow in the curbed channel to the spread of water on the shoulder, parking lane, or travel lane. Gutter flow calculations are necessary in order to relate the quantity of flow in the curbed channel to the spread of water on the shoulder, parking lane, or travel lane. Flow in a gutter operates under the principles of open channel flow. Gutter capacity is a function of the geometric shape of the gutter, the roughness of the pavement surface, the longitudinal slope, and the allowable spread [22]. The gutter capacity for a uniform cross slope (as shown in Figure) may be computed using Equation.

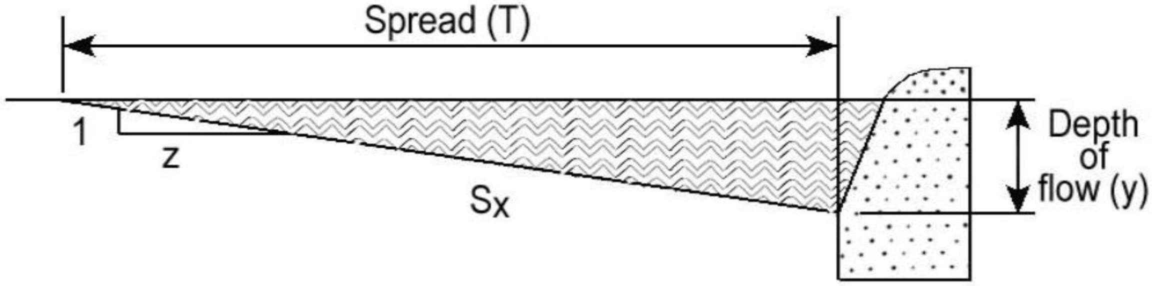


Figure 2.1.Uniform Cross Section of gutter Cross Slope, S_x, $= \frac{1}{z}$

$$Q = \frac{0.56}{n} S_x^{5/3} * S^{1/2} T^{8/3} \quad \text{....Equation2.4}$$

Where:

Q = Gutter flow rate, cfs

n = Manning's roughness coefficient

S = Longitudinal (gutter) slope, ft

S_x = Pavement cross slope, ft `

T = Spread width, ft

Spreads on the pavement and flow depth at the curb are often used as criteria for spacing Drainage inlets0

$$d = TS_x \quad \text{.... Equation 2.5}$$

Where:

d = depth of flow, m

A modification of the Manning's equation can be used for computing flow in triangular channels. The modification is necessary because the hydraulic radius in the equation does not adequately describe the gutter cross section, particularly where the top width of the water surface may be more than 40 times the depth at the curb. To compute gutter flow, the Manning's equation is integrated for an increment of width across the section. [21]

Table 2.4 Manning's for Street and Pavement Gutters

Type of Gutter or Pavement	Manning's n
Concrete gutter, troweled finish	0.012
Asphalt Pavement: Smooth texture Rough texture	0.013 0.016
Concrete gutter-asphalt pavement: Smooth Rough	0.013 0.015
Concrete pavement: Float finish Broom finish	 0.014 0.016
For gutters with small slope, where sediment may accumulate, increase above values of "n" by	0.002

2. 8.3 Flow Time in Gutter:

Component of the gutter flow is necessary in order to evaluate time of concentration for the contributing drainage area to an inlet. Method for estimating the average velocity in a reach of gutter is needed. The Velocity in a gutter varies with the flow rate and the flow rate varies with the distance along the gutter, i.e., both the velocity and flow rate in a gutter are spatially varied. The time of flow can be estimated by dividing the length of the gutter with an average velocity.

$$V = \frac{K_U}{n}\left(S_L^{0.5} S_X T\right) \quad \text{(Equation 2.6)}$$

Where: Ku = 0.752

T = width of flow (spread), m

Sx = cross slope, m/m

SL = longitudinal slope, m/m

n = manning coefficient (table 2.3)

V = velocity in the triangular channel, m/s

Flow Time

$T_F = L/V$ ……………………………………….. (Equation 2.7)

Where**:** T_F = Flow Time

V = Velocity in a gutter

L = length of gutter

2.8.4 Inlet Locations

The location of inlets is determined by geometric controls which require inlets at specific locations, the use and location of flanking inlets in sag vertical curves, and the criterion of spread on the pavement. Inlets at these locations should be designed to capture 100% of the flow and also be located hydraulically to prevent excessive gutter flow and excessive ponding. In order to adequately design the location of the inlets for a given project. [23] The following information is needed:

- Layout or plan sheet suitable for outlining drainage areas
- Road profiles
- Grading cross sections
- Super elevation diagrams and
- Contour maps

2.8.5 Inlet Types

Inlets used for the drainage of highway can be divided into four major classes as follows:

- Curb-Opening inlets
- Combination inlets
- Slotted drain inlets
- Grate inlets

2.8.6 Curb-Opening Inlets

These inlets are vertical openings in the curb covered by a top slab. They can convey large quantities of water and debris. They are preferable to grates for pavement drainage especially at locations where grate inlets would be hazardous for pedestrians or bicyclists

- Collect water running along the bituminous curbing used under a guardrail system in high embankment areas.
- Discharge collected water through a 15" corrugated pipe exiting the back of the structure and traversing down the slope to the toe of the embankment.
- Economic structure to pre-cast because of its standardized dimensions

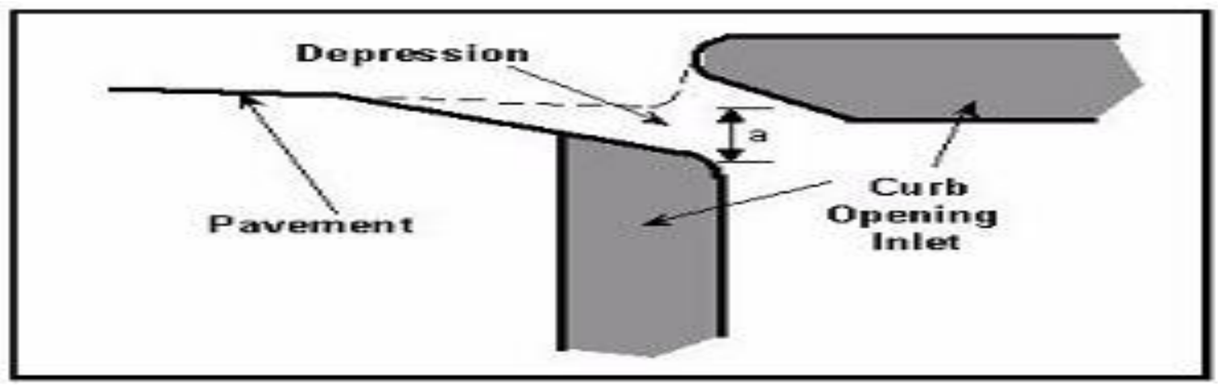


Figure 2.2 Depressed curb opening

The length of the curb opening inlet required for total interception of gutter flow on a pavement section with a uniform cross slope is expressed by equation. [21].

$L_T = Ku\ Q^{0.42}\ S_L^{0.3}\ S^{(-0.6)}$ ……. …………………………………………………………………… Equation 2.8

Where: Ku = 0.817

n = manning coefficient

LT = curb opening length required to intercept 100 percent of the gutter flow, m

SL = longitudinal slope

Q = gutter flow, m3/s

The efficiency of curb-opening inlets shorter than the length required for total interception is Expressed by equation

$E = 1 - (1 - L/LT)*1.8$ ……………………………………….... Equation 2.9

Where: L = curb-opening length, m

. LT Total interception by depressed

The length of inlet required for total interception by depressed curb-opening inlets or curb openings in depressed gutter sections can be found by the use of an equivalent cross slope, Se, in equation above in place of S_x. S_e can be computed using equation below.

Se = Se + Sw E_O ……………… ……………………………………. Equation 2.10

Where: Sw = cross slope of the gutter measured from the cross slope of the pavement S'w[100W] ,

For W in m; or = Sw – Sx

E_O = ratio of flow in the depressed section to total gutter flow determined by the gutter Configuration upstream of the inlet

2.8.7 Combination inlets

Inlet with curb opening and grate combinations are common. The designer should ignore the interception capacity of the grate when computing the capacity of a combination inlet. Combination inlets are sometimes used in order to place the inlet chamber and storm rain trunk line under the gutter pan and away from the sidewalk or utility space .

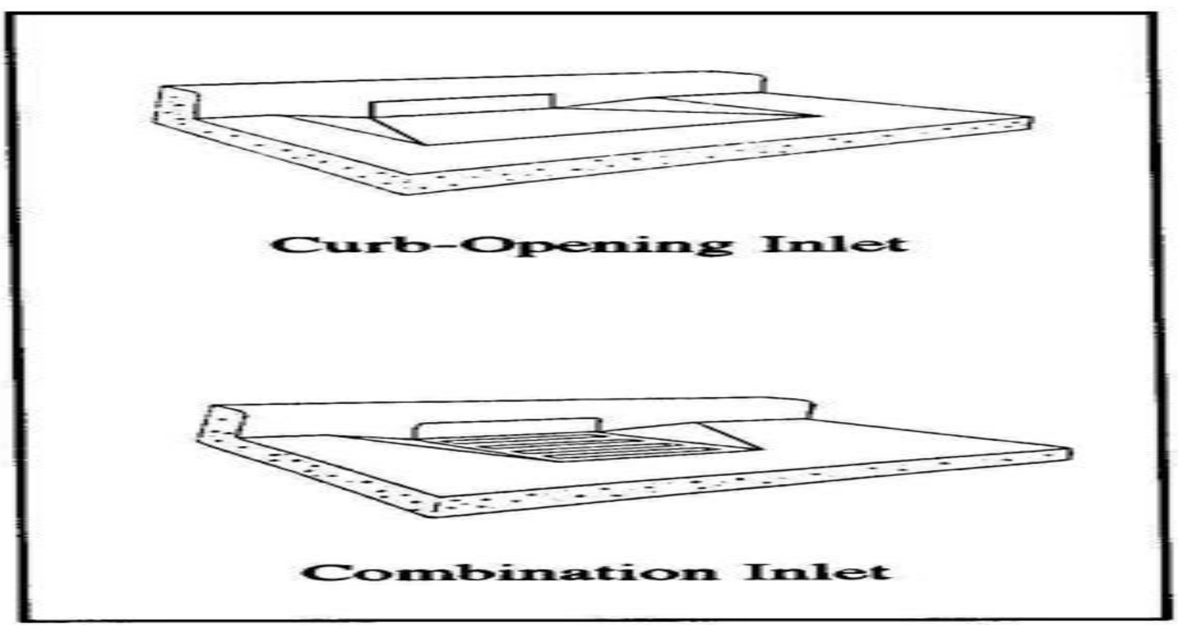


Figure 2.3 curb opening inlet and combination inlet

2.8.8 Grate inlets

Grate inlets and local depression at curb opening inlets should be located outside the through travel lanes to minimize the shifting of vehicles attempting to avoid these areas Typically, grate inlets are used in depressed medians, graded areas, ditches, at the toe of fill in urban areas and other areas not subject to traffic. Grates should be bicycle safe where bike traffic is anticipated and structurally designed to handle the appropriate loads when they do need to be located in areas subject to traffic.

2.8.9 Slotted Drain Inlets

Drainage inlets composed of a continuous slot built into the top of a pipe which serves to intercept, collect, and transport the flow. Slotted drain inlets consist of a slotted opening with bars perpendicular to the opening. Slotted inlets function as weirs with flow entering from the side. They can be used to intercept sheet flow, collect gutter flow with or without curbs, modify existing systems to accommodate roadway widening or increased runoff, and reduce ponding depth and spread at grate inlets. They can also be used to intercept flow in areas of limited space such as a retrofit in a problem area. The designer should ensure that maintenance access is provided with the design for this type of inlet. The two types of slotted inlets in general use are the vertical riser type and the vane type. VDOT does not have a standard for this type of inlet.

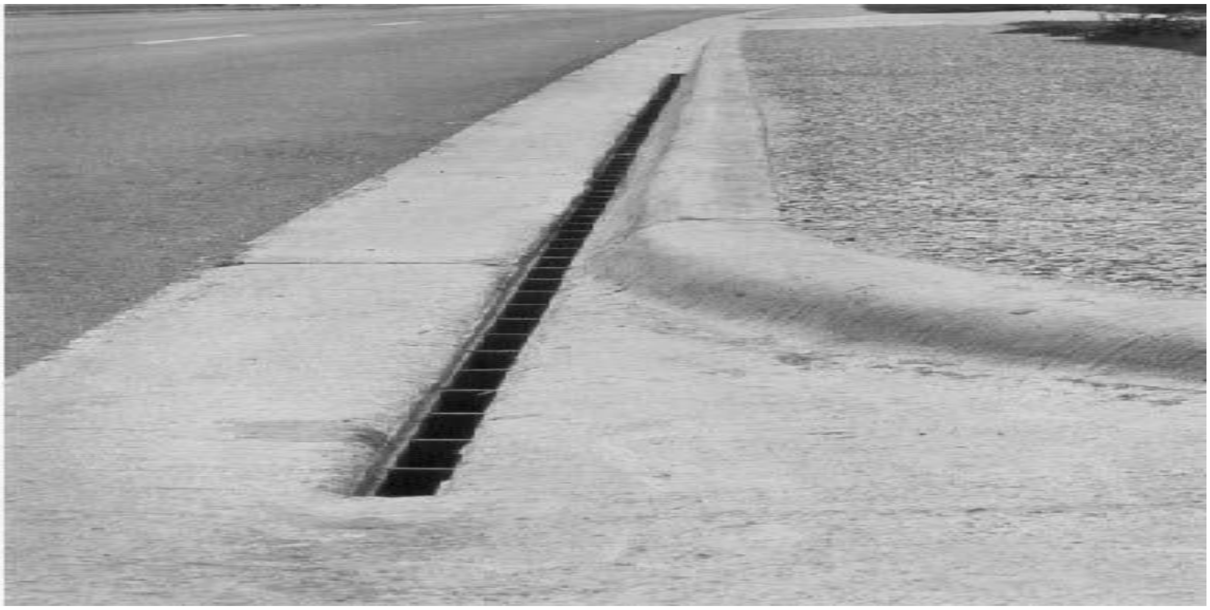


Figure 2.4 Slotted drain inlet at an intersection

2.8.10 Inlet Capacity:

The interception capacity of all inlet configurations increases with increasing flow rates, and inlet efficiency generally decreases with increasing flow rates. Factors affecting gutter flow also affect inlet interception capacity. The depth of water next to the curb is the major factor in the interception capacity of both grate inlets and curb-opening inlets. Interception capacity of a curb-opening inlet is largely dependent on flow depth at the curb and curbs opening length. Flow depth at the curb and consequently, curb-opening inlet interception capacity and efficiency, is increased by the use of a local gutter depression at the curb-opening or a continuously depressed gutter to increase the proportion of the total flow adjacent to the curb. Interception capacity is dependent on flow depth and inlet length. Efficiency is dependent on flow depth, inlet length and total gutter flow. [22]

2.8.11 Inlet Interception Capacity and Efficiency on Continuous Grades

Inlet interception capacity, Qi, is the flow intercepted by an inlet under a given set of conditions. The efficiency of an inlet, E, is the percent of total flow that the inlet will intercept for those conditions. The efficiency of an inlet changes with changes in cross slope, longitudinal slope, total gutter flow, and, to a lesser extent, pavement roughness [22]. In mathematical form, efficiency, E, is defined by the following equation:

$\mathbf{E} = Qi / Q$ ……………………………………..................................Equation2.11

Where: E = Inlet efficiency

Q = Total gutter flow, m^3/s (ft3/s)

Qi = Intercepted flow, m^3/s (ft3/s)

Flow that is not intercepted by an inlet is termed carryover or bypass and is defined as follows:

$\mathbf{Q_b} = Q – Qi$..……………………………………………………………….Equation 2.12

Where: Q_b = Bypass flow, m^3/s (ft3/s)

2.8.12 Factors Affecting Inlet Interception Capacity in Sag Locations

Grate inlets in sag vertical curves operate as weirs for shallow ponding depths and as orifices at greater depths. Between weir and orifice flow depths, a transition from weir to orifice flow occurs. The perimeter and clear opening area of the grate and the depth of water at the curb affect inlet capacity. The capacity at a given depth can be severely affected if debris collects on the grate and reduces the effective perimeter or clear opening area. Curb-opening inlets operate as barriers in sag vertical curve locations up to a ponding depth equal to the opening height. At depths above 1.4 times the opening height, the inlet operates as an orifice and between these depths, transition between weir and orifice flow occurs. The curb-opening height and length, and water depth at the curb affect inlet capacity. At a given flow rate, the effective water depth at the curb can be increased by the use of a continuously depressed gutter, by use of a locally depressed curb opening, or by use of an increased cross slope, thus decreasing the width of spread the inlet.[22]

2.9 Hydraulic Capacity

The hydraulic capacity of a storm drain is controlled by its size, shape, slope, and friction Resistance several flow friction formulas have been advanced which define the relationship Between flow capacity and these parameters. The most widely used formula for gravity and Pressure flow in storm drains is Manning's Equation [10]

$$V = Kv/n\ D^{0.6}\ So^{0.5} \quad \text{(Equation 2.13)}$$

$$Q = Kv/n\ D^{6.67}\ So^{0.5} \quad \text{(Equation 2.13)}$$

Where

V = mean velocity, m/s

Q = rate of flow, m3/s

KV = 0.397

KQ = 0.312

n = Manning's coefficient (table 7-1)

D = storm drain diameter, S_o = slope of the hydraulic grade line, m/m A monograph solution of Manning's Equation for full flow in circular conduits is presented in chart

CHAPTER THREE

Researches and Methodology

3.1 Study area

The study area is carried out at Jimma town, Bocho Bore kebele. Jimma is a located at (7.8°N latitude and 36.9°E longitude) in the south-west of Ethiopia Jimma special zone of the Oromia Region. This town has an elevation of 1780m above sea level.

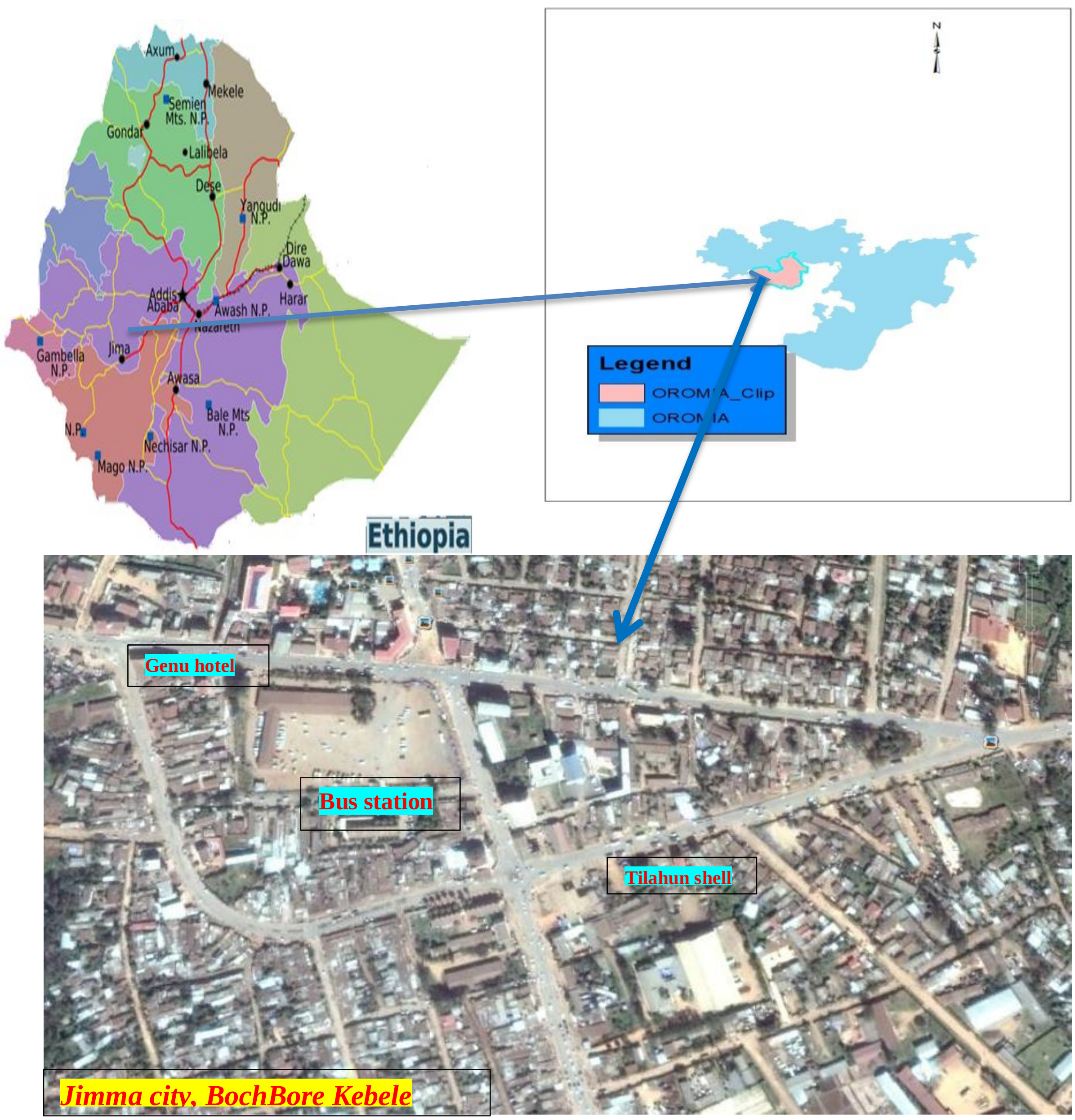


Figure 3.1 Location of the study area (source Google Earth)

3.2 Population

Population that takes faces the research purposes to study are poor drainage condition and its effect, on Bocho Bore kebele, Roads.

3.3 Sample Size

The sample size is to be taken according to the limited coverage area of the selected area of poor drainage and Pavement failure in the kebele. The Purposive sampling was used for sampling technique which was working in this research. The study was conducted on Bocho Bore kebele, generally the basic aims to select these kebeles were they have high traffic load from other kebele in the town and relatively hill area which over flow is more visible.

3.4 Study Variables

3.4.1 Dependent variable: condition of poor drainage.

3.4.2 Independent variable: overflow, construction quality, people awareness and routine maintenance, pavement failure, cross slope and inlets condition.

3.5 Materials

The materials I used for this research: - surveying instrument, leveling to check cross slope, design data is used as an input data for catchment area and estimation catchment characteristic. Topography map, Digital camera and measuring tape are used beside Microsoft word and excel which used to analysis data.

3.6 Research Design:

The data is analyzed and interpreted using both descriptive and exploratory methods approach. Descriptive and exploratory survey designs are used in this study.

Descriptive type: - Is used to describe the condition of the drainage, condition of pavement, surface water, failed road, and operation of drainage system. It involves the structuring and organizing of all procedures of data collection, analysis, reporting in qualitative and quantitative research. To answer the research questions a descriptive survey design utilizing both quantitative and qualitative methods was employed. A quantitative approach usually uses research instruments, such as questionnaires (with consultant and road engineers), to collect, interpret, and analyzes data statistically. It also involves the frequency of an event or number of respondents to a particular phenomenon. Fundamentally, in the qualitative methods, the interviews and document analysis techniques were used to collect data.

Exploratory type:- Was particularly used to explore the existing condition by making some required physical measurements such that, depth of the drainage and drainage width, thickness, cross slope and compare with standards. The data will be attempted to collect from the Organizations, site investigation and from different stakeholders on the issues of drainage condition and its effect on pavement performance and ranking of pavement damage.

3.7 Data Collection Process

To full fill the research, both quantitative and qualitative data types are used. The research will be conducted from primary and secondary data.

3.7.1 Primary data:

To achieve the objectives, various data were collected from design drawings and by direct field survey. Primary data which are collected during field survey includes questioner and the identification of the causes of poor drainage Condition and Pavement damage through field surveying including existing drainage and Condition of drainage, types, cross slope by using leveling instrument spacing and size by observations. Primary data are collected during field survey includes:

- Questioner of government stuff and road users
- Drainage Condition of the study area
- Pavement Condition of the study area
- Measuring size, spacing, and death existing condition drainage structure.

Two types of questioner are conducted in research area. The Interview was accompanied in the field on Jimma town local urban government staff; Consultant and road users are interviewed. Oral equation with different Engineer and consultant to yield the information required on poor drainage, effects and the proposed solutions to the problem.

- Evaluating Condition of drainage system
- Measuring the existing drainage inlet manual types and size

- Assessing the Condition of pavement distress due to poor drainage.

Oral questions were asked to get more information and to clarify the uncertain response. The study area information was gathered from the contractor and supervisors Survey was collected from government bodies about construction, maintenance and management system of road and drainage systems particular jimma town Engineers and with supervisors. The main objective of this questionnaire is to know the responsibilities, and challenges experienced by the bodies mandated to construct and maintain the road. In addition, it required to understand the role of the Government body and surrounding people in the drainage system provision in road.

3.7.2 Site visit:

Site visit (observations) was carried out to ascertain current conditions poor drainage system in jimma town bocho bore keble road in comparison with the acceptable standards. The research employed use a physical observation checklist, which was filled through observations and a digital camera was used to take photographs of the existing state of the road and the drainage system.

3.7.3 Photography:

Photography is an indirect way of data collection. It used to capture the existing condition and status of the drainage system in the kebele road. It was expected to give a visual understanding of the research topic to understand the level of deterioration, maintenance and the state of the pavement and drainage system.

3.7.4 Secondary data:

The secondary data are found from written document, literature review, topography map of the study area, different design data of the study area and previous research done in the area. Secondary data are collected during the research period to support the primary data. These data includes:

Design data from jimma municipal, Ethiopian Road Authority, Jimma District and from Mmetaferia consulting Engineering PLC land use map of the study area Rainfall intensity which is important for analysis peak discharge is not recorded because instrument called hyetograph .The main choice is using the IDF curve developed by ERA. So, I used the rainfall intensity from the IDF curve for the corresponding return period.

3.8 Data processing and analysis:

Based on the data collected on the site and design report, the methodology is assumed to assist conduct the research both quantitative and qualitative data types are used to assess the cause of the problem. The construction and storm drainage operation of the system is assessed by observing the existing construction and operation system of the drainage. Collected data checked and process analyzed using rational methods. The drainage condition data were collected from Jimma town, Bocho Bore kebele roads and analyzed by tables and graphics. For all drainage condition, the following factors shall be evaluated operation of drainage, constriction of drainage and condition of pavement and management system of road owner. slope, land use, geology, soil type, surface infiltration, and storage; Stream channel and flood plain characteristics including geometry and configuration, natural and artificial controls, channel modification, aggradations and debris. The hydrologic methods approved by FHWA, Federal Highway Administration manual and ERA manual and limitations on their use follows: Rational Method - only for drainage Areas less than 50 hectares (0.5 kilometer2 these manuals are the lead information documents and main reference tools for my thesis work. The main reason that I used these manuals as the lead documents is, in our country these manuals are guidelines and best of all materials regarding drainage system design and performance evaluation of drainage structures.

3.9 Ethical Consideration

The research and data collection will be conducted after approval is given from the highway Engineering stream and to proceed the work. Before the collection of the data the Purpose of the data collection will be clearly described to the organizations by the data collectors and the principal Investigator. The data will be collected based on the willingness of the Organizations to give information. The data will be kept confidential and will be used only for the research purpose.

3.10 Data Quality Assurance

To assess the major factors affecting pavement performance through poor drainage condition and problem related to engineering solutions. In order to increase the quality of the data I will prepare a field work manual to check every day Progress and also

Assistants are selected and trained to handle the data carefully. The collected Data will be also checked for reliability and accuracy.

3.11 Hydrology and Hydraulics Evaluation

According to data collection and the design report of the study area, we observe Rational Method is available to calculate peak runoff rates for small urban catchment areas. It shall be used with attention if the time of concentration exceeds 30 minutes. Rainfall is a necessary input. We need to assess the hydrology and hydraulics of the Study areas because of the following reasons:

- To check the efficiency of inlet used in the study area.
- To Estimate the maximum rate of runoff at the inlet to a drainage.

To recommend the system to get the parameters used in inlet efficiency calculation the area is calculated only by considering the road way and walk way but sheet flow to consider areas contributing to the inlet beyond the road surface.

3.11.1 Determination of Catchment Area:

Catchment area can be determined from topographic maps and field surveys. For this Thesis, the catchment area is found from Metaferia consulting Engineering PLC from the design data and topographic map of the study area. For Large catchment areas, it is necessary to divide the area into sub-catchment areas to Account for major land use changes, obtain analysis results at different points within the Catchment area, or locate drainage structures and assess their effects on the flood Flows For this thesis, a field inspection of existing drainage systems has been made to determine if the natural drainage divides have been different. These Variations could make significant changes of the size and slope of the sub-catchment Area However, it is obtained that the changes do not occur.

3.11.2 Rational Method

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

Q = 0.00278CIA ………………………………………………….. Equation 3.1

Where, Q = Peak flow in cubic meter per second (m3/sec)

C = Dimensionless weighted runoff coefficient

I = Rainfall intensity in millimeters per hour (mm/hr.)

A = Drainage area in hectares (ha)

C w = (A1C1 + A2C2 +- + An Cn) / (A1 + A2 +-- An) ……………… Equation 3.2

Where, C w = Weighted Runoff Coefficient

C n = coefficient of runoff for parts of the drainage area.

An = parts of drainage areas with different runoff coefficients.

3.11.3 Rainfall Intensity

The IDF curve relationship is a mathematical relationship between the rainfall intensity, the duration, and the return period. For this research, ERA regionalized IDF curves are used to quantify rainfall. The study area is found in the rainfall region of Ethiopia, Jimma is in rainfall sub-region B1 as shown in the Appendix A.

$Tc = 0.0013*M*\left[\frac{L^{0.77}}{S^{0.385}}\right]$ …………………………………….. …….Equation 3.4

Where: Tc = Time of concentration in hour

L = Length of overland flow in kilometers

S = Slope in m/m

M = Earth type coefficient

(m = one for bare earth, m=two for grass and m=0.4 for asphalt).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Result from Existing Condition of Drainage

Poor existing drains, improper operation and poor management system mainly cause severe overflow which creates damages and problems to the road pavement and road users. Drainage and Pavement condition of the study area is assessed by field surveying or by direct observation of inlets condition. The problem face in the study are, debris closed curb inlets, toilet connected to drainage, dumping of solid and liquid waste which affected the drainage system and pavement performance .The assessment done after the construction of road and drainage structure. The drainage operational conditions in the area are described as the following:

- Drainage structure working with problem.
- Drainage structure connects with toilet.
- Drainage manhole covers are removed.
- Drainage structure working without problem.
- Drainage structure out of function.

The existing conditions of drainage are try to describe quantitatively and categories these are inlet and manholes operate without problem, operate in good condition and which are totally out of function. The most prone area is selected to assess the problem. Tables below are identifying the condition of drainage in the study area.

Table 4.1 existing condition of drainage manhole

Station	No. of Manhole	Manhole in good condition	Manhole work with problem	Manhole out of function
0+700_1+100	40	14	23	10

Table 4.2existing condition of drainage inlets

Existing condition of inlets				
Station	No. of inlets	Inlets in good condition	Inlets work with problem	inlets out of function
1+300_2+000	70	16	33	21

The study area drainage is characterized under curb inlets and pipe drainage. It is known that curb inlets are not easily blocked by debris and silt. But in this site it is observed that most inlets and are closed and manhole fill by debris are major problem shown in area. From field observation and data analysis it is observed that, the existing condition of manhole is insufficient. Due to this, 43.3% of manhole work with problem and 33.3% work out of function and 23.3% work without problem figure below.

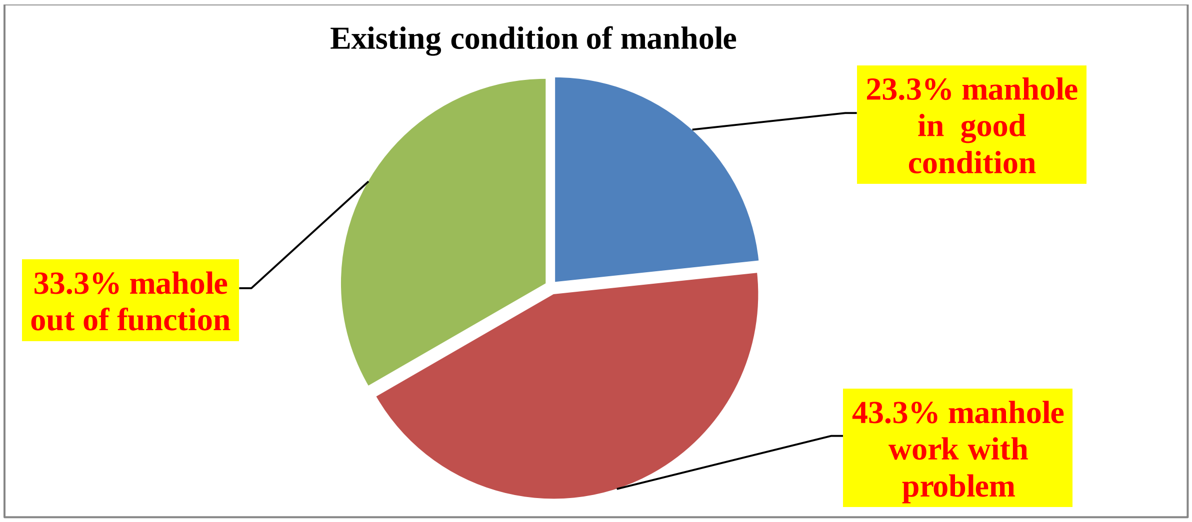


Figure 4.1a Existing condition of manhole and their Percentage Distribution

From field observation and data analysis it is observed that, the existing condition of inlet is insufficient. Due to this, 58% of drainage inlets work with problem and 20% work out of function and 23.3% work without problem figure below.

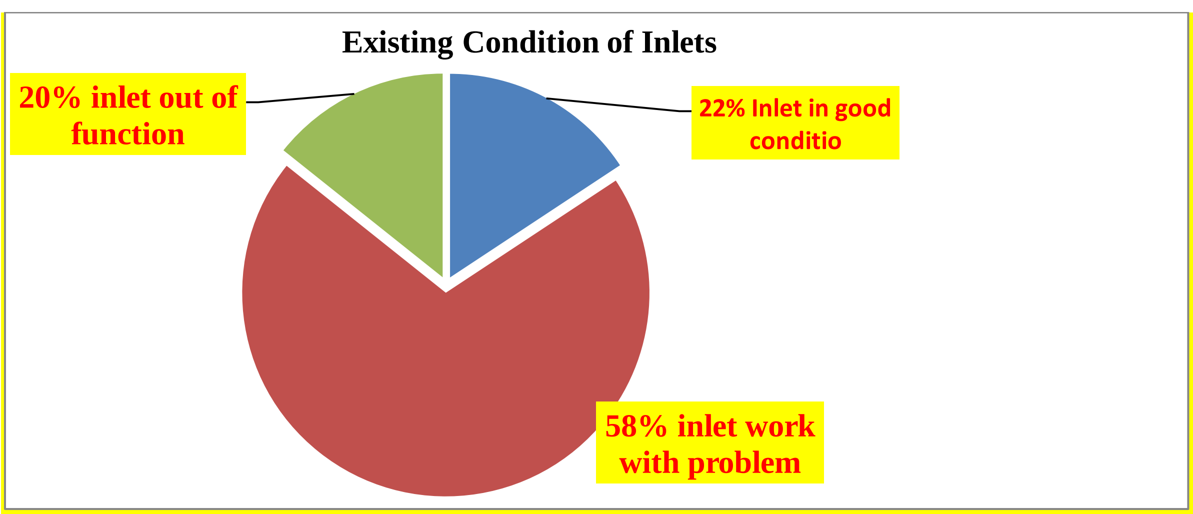


Figure 4.1b Existing Condition of Inlets and their Percentage Distribution

4.1.1 Result from Questionnaires

Questionnaires were controlled to engineers and consultant from Jimma city municipal another questionnaire was given to the residents and road user of the adjacent to Bocho Bore Kebele road and people who use the road, here referred to as road users. The questionnaire comprised of open ended and structured questions on issues that are related to the study. Totally 20 questionnaires were prepared and distributed to the proposed respondents. Out of questionnaires distributed 20 (100%) were filled and returned appropriately. Based on the responses obtained from respondents the analysis and interpretation of data are presented. A response rate of 50% is adequate for data analysis and reporting, 60% is good and above 70% is very good [26]. The population, sample size and sample technique for questionnaire data collection methods are as follows:

Table 4.3 Response rate:

Respondent	Number of proposed Population	Sample	%sample	Sample technique
Engineers and consultant	3	3	100	Whole population
Road users	25	21	73	Purposive
Residents	19	15	69.6	Purposive
Total	44	37	71.3	

The engineers and consultant from Jimma town indicated that most drainage problem of Bocho Bore Kebele is come from absent of routine maintenance and lack of people awareness. The magnitude of the water from the hills surrounding area in which the road is situated was overlooked during design. They also indicated that the amount of water that would cross the road at a point in time and inlets closed by solid disposal low capacity to intercept the runoffs during the rains. Poor construction, poor management system and absent of ditches clearance and manhole which is fully by grass and garbage are cause for poor drainage condition. As part of understanding the background of the poor drainage structure provisions in the kebele roads, this study wanted to find out from the engineers the percentage of roads that lacked adequate drainage condition. Depend on engineers answer and from data analysis 80% of poor drainage condition, 15% is good and 5% fair drainage condition. The following figure indicate that parentage of engineer response

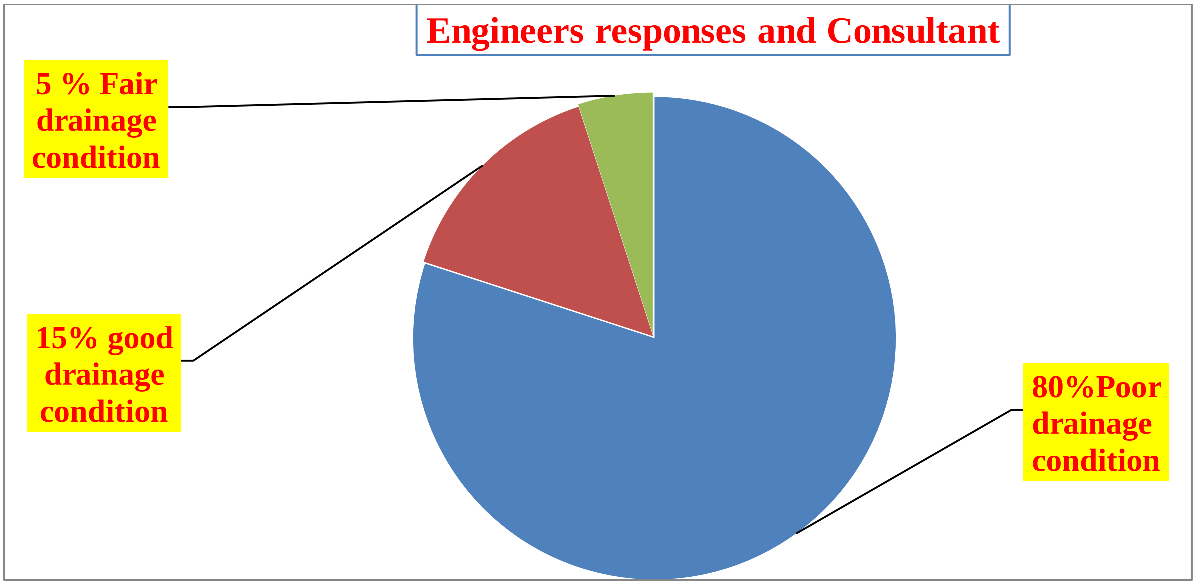


Figure 4.2 responses of engineers and their Percentage Distribution

The road user and resident in the study area indicated that drainage problem of Bocho Bore Kebele is comes from lack of good maintenance and poor management system. Most of the respondents are responses drainage system in the kebele is poor. Based on respondent survey data, maximum of responses approximately (80%) had responded for poor condition of drain and about 16% of the respondents for fair category in the areas of flood occurred during rainy season in the town. Only 4% thinks the drainage system is good.

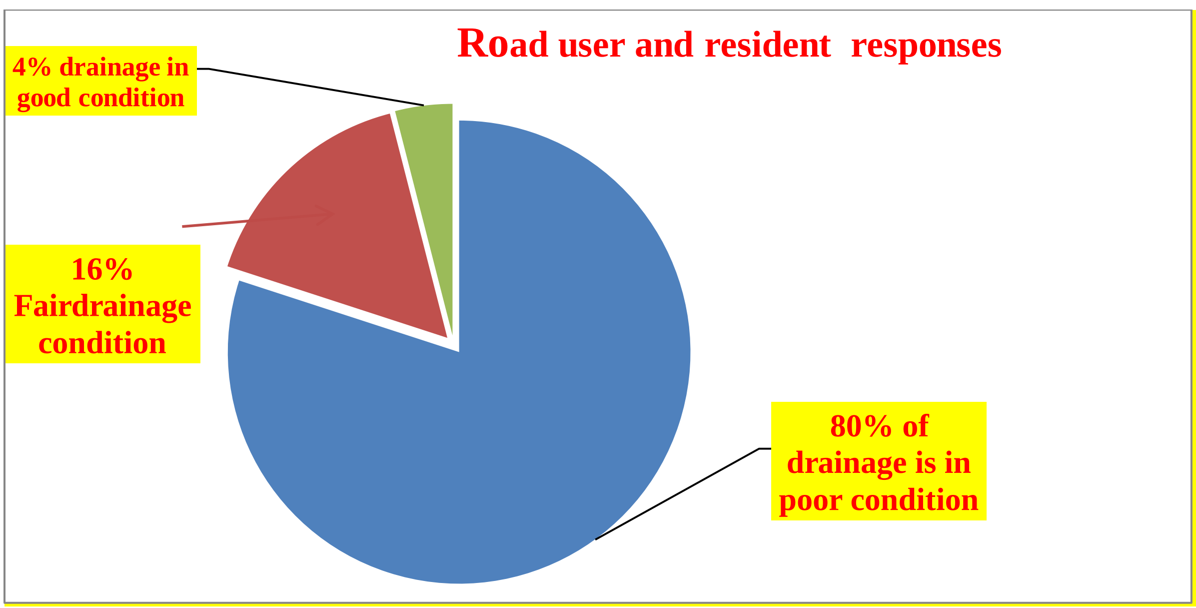


Figure 4.3 responses of road user and resident satisfaction and their Percentage Distribution

4.1.2 Result from Field Assessment and Taking pictures:

Field Assessment and taking photographs to show the current state of the drainage system in Bocho Bore kebele road, from observation also; a brief description of what was observed will be given with the help of photographs.

From observation, the state of the drainage system in the kebele road is poor. The main problems of the existing drainage condition are: people awareness, absent of routine maintenance of drainage, construction problem and poor management system. All this problem make drainage systems are lead to decrease the efficiency of drainage inlets and have low capacity to convey flood. The drainage capacity decrease and low efficiency of inlets lead to overflow water back to pavement structure and road are deteriorated before design life. The existing drainage facilities the surface water back to pavement, then it create pothole due to over flows and have greater problem on road and residents. If drainage structure does not have the capacity to carry surface water, overflowing, ponds other spaces are not properly allocated to accommodate discharge. Most ditches do not have proper slope to pass water. Dumping of solid wastes in to drainage Containing, debris, house refuses, plastic materials and others has been serious problem of drainage in the study area. Other problems are construction quality, absent of routine maintenance and proper follow up does give attention by government management system are major problems. However, some parts of the road have no problem with drainage.

figure 4.4 manhole inlet in good condtion

Figure 4.5 waste disposal on the drainage structure

Figure 4.6 shows inlets closed by debris and connected with toilets, around genu hotel

Inlet cover overlapped with pavement and no opening at all

- Silt from adjacent property causes flooding.

*Figure 4.7 inlets closed by silt and mud in front of central source: field survey).*café

Figure 4.8 shows that manual cover damage and removed in front of total (source: field survey).

- Ditch cleaning needed and routine cleaning improves drainage capacity.
- Drainage structure doesn't function because of fill debris and silt up.

Figure 4.9 that drainage fills by debris (taken around bus station & feid roundabout)

Figure 4.10 waste water and trash from resident home to outside the ditch.

4.2 Cause of poor drainage condition:

4.2.1 People awareness

The awareness of residents in communities under which drainage channels are constructed and located is so negative. From the assessment conducted and seen in the photographs which taken from the drains sites during the field survey clearly shows that residents have converted the drains into refuse dump places. This results in blockage of these drains and drainage inlet sits ensuing failures which in turn does negatively affect conditions of the road pavement. There is very urgent need for government agencies and concerned bodies to organize programs towards educational residents on the need to keep drains located in their communities clean and not use them as refuse dump places. In situations where these residents refuse to care environmental sensitizations and warnings, acting of laws to punish lawbreakers with very strong enforcement and good management system should be put in the study area.

There is great need for adequate monitoring and control in the local construction process. This can be done by the provision of a standard method of practice which will be strictly followed, monitored and maintained. The professional bodies in the country will play a very Important role at this stage and they should be able to provide a local standard of practice for the country, maintain it and monitor compliance to the use of the standard. This is because a local standard will take awareness of the local peculiarities that will affect the environment where drainage works are located.

4.2.2 Absent of routine maintenance:

One of the main problems of drainage in the kebele is maintenance. The drains and pavement are rarely maintained and whenever maintenance is attempted it is done irregularly. The financing of the maintenance, rehabilitation and conservation of the drainage condition in had always been left to the government at the state and local levels who because of their lack of maintenance culture do not release funds for drainage maintenance at the appropriate time. The drains and pavement was left to deteriorate. The drainage worldwide were considered critical infrastructure in any nation's life and were paid superior attention

4.2.3 Construction of drainage structure

Pavement and drainage construction of the study areas are evaluated by direct field data collection of Inlet spacing, inlet size, curbs heights and By using level instrument I was check the cross slope comparing with the design data. The data collected from the ground is compared with the design data in the drawing. The design data from the drawing is curb inlet having a dimension of 50*50 and a curb having a height of 0.10m is used and the distance between inlets are 10 meter construct to collect surface water and 2.5% of cross slope inorder to fall water from the road to drain.

Data collected on the site shows some of curbs in the road are not constructed in the right position, dimension and manhole are constructed with problem in dimension like overlap with pavement. Since the above evaluation it was observed that, some of the capacity of existing drainage is comparatively enough to carry the storm discharge. Some of the existing inlet spacing is not enough to get a spread of less than the design capacity. Table 4.4 describes construction drainage of the study area by visualizing and measuring compare with the design data.

Table 4.4 existing condition of drainage construction:

Station	Explanation	Measures	Comment
0+700_1+400.	Manhole cover overlap with pavement & manhole edge rise	4 piece	no open space b/n Manhole cover& pavement and construct over design
1+400_2+300.	Curbs inlet Constructed over design(height of inlet)	(12 curb inlets) 0.15m	Inlet rise above pavement, water can't flow to inlets
	Total	16	

In addition to this the existence of construction of pavement slope and Construction of manhole edge is rise the storm water unable to enter to the inlet properly due to some construction error, waste water from resident and storm water back to the pavement surface and this lead to failure roadway before the design life. In the following figures I try to show construction problem of the study area during field assessment.

- Drainage structure Construction problem
  - Over design inlet height and small inlet opening
  - Surface water back to pavement due to poor construction.

Figure 4.11 inlets contract over design and manhole cover (around feidi roundabout)

figure 4.12 assessment of drainage construction

Figure 13 Drainage inlet structure construction problems and manhole cover not fit

From data collection in the field and analysis done it is observed that 21% of drainage structure construction problem and 79% of drainage construction is in good. The drain suffered from low capacity, over and under design inlet height, small inlet opening manhole covers overlap with pavement are lead to poor construction. The figure below shows that percentage of structural construction.

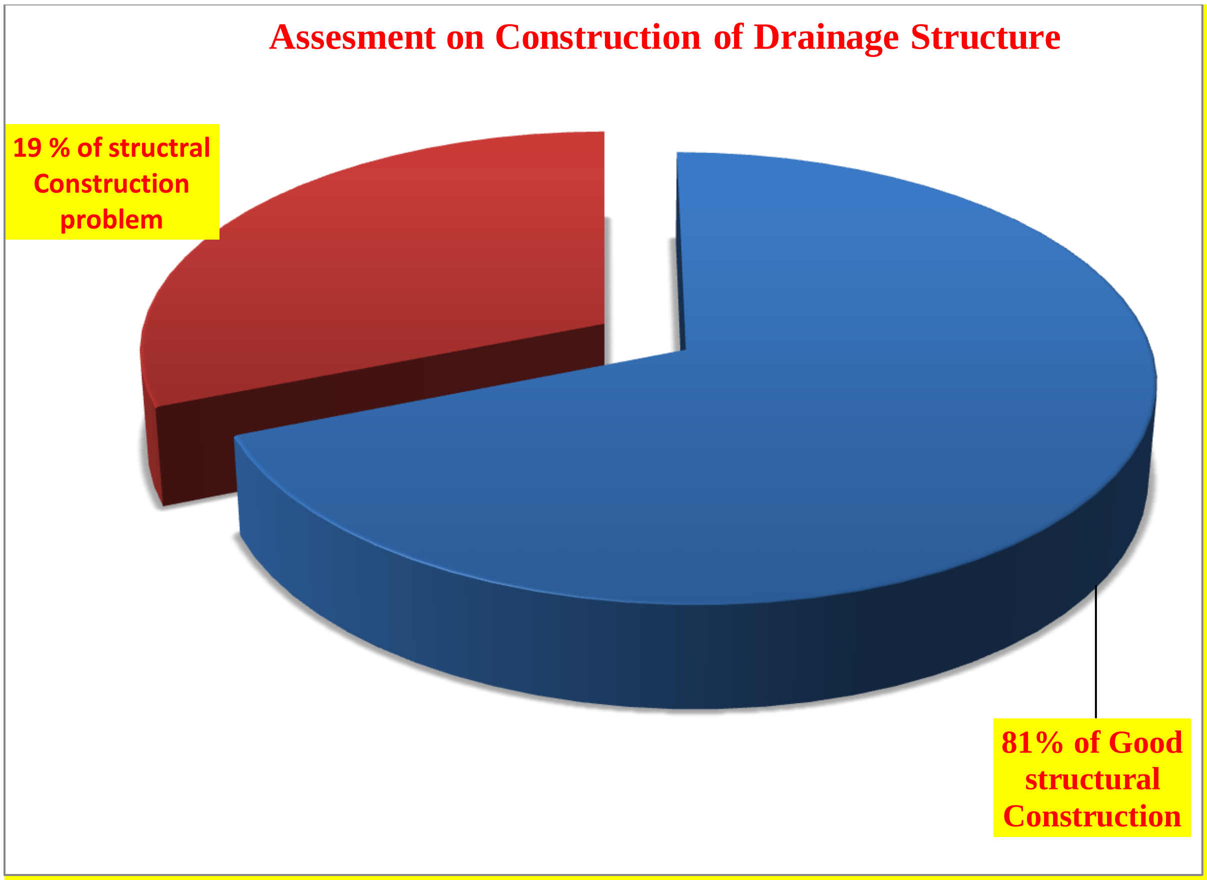


Figure *4.14 Condition of drainage construction and their percentage*

4.2.4 Cross-Section Slope

Drainage of the road pavement is provided by shaping the road carriageway with cross slope. The center of the road on paved surfaces should be higher than the shoulder. Cross fall slope is necessity for the performance of road to ensure proper drainage. The road surface should be crowned and water will run off to the drainage inlets. Avoids infiltration of water from the roadway, if the cross-slope is less, water will get time to penetrate into the roadway and weakens the pavement that cannot withstand traffic load. Some road in this kebele had showed the problem of asphalt cross fall slopes while considering with the design data. According to design data the slope of normal cross fall is 2.5% in order to dispose water from the roadway properly and that avoids infiltration of water from the roadways. During field surveying, the measurements had taken by using surveying instruments of leveling. The results from field survey shows that the right crosses slope had 87.5% greater than or equal to 2.5% and 12.5% of road had less than 2.5%. For left side crosses slope 88.5% slope had greater than or equal to 2.5% and 11.5% of road had less than 2.5%. Data is collected by 20 meter change for most prod area. In order to check cross slope the following equation is used.

$$Slope(\%) = \frac{(Center\ line - Elevation) * 100}{Distance}$$

Figure 4.15 during survey data collection at field (around Galimole)

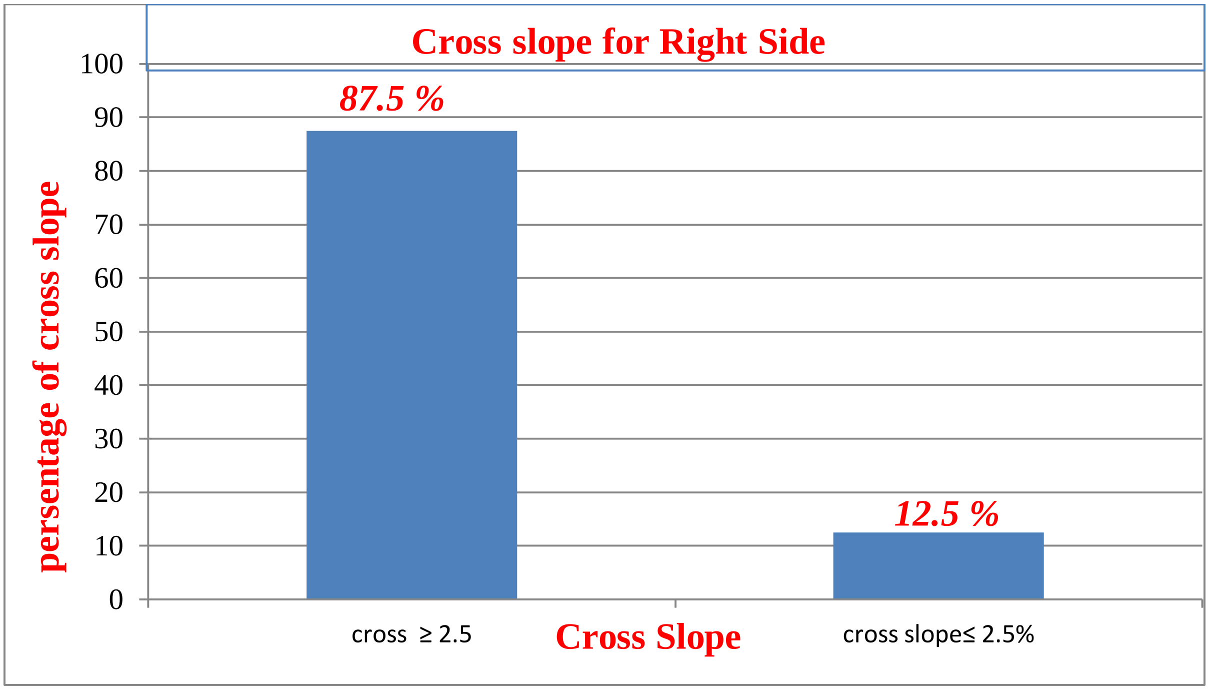


Figure 4.16: Cross slope for right side of the road and their Percentage Distribution

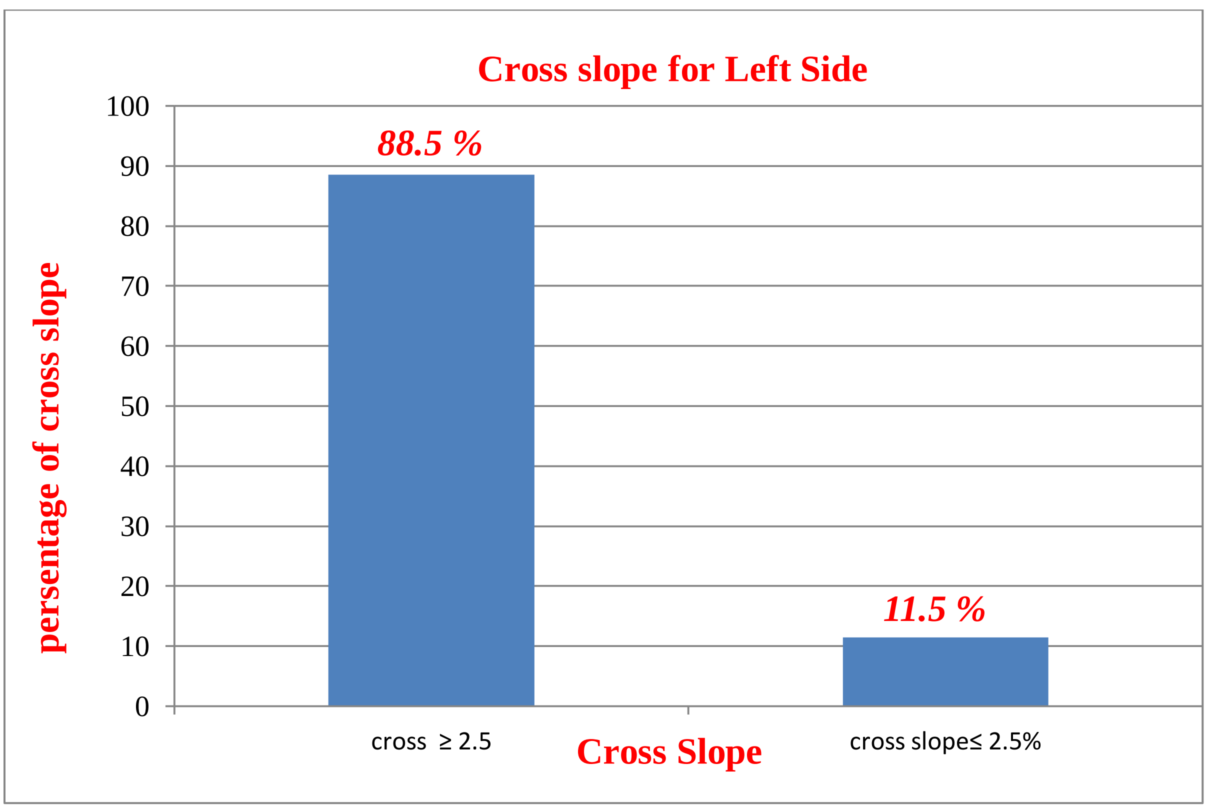
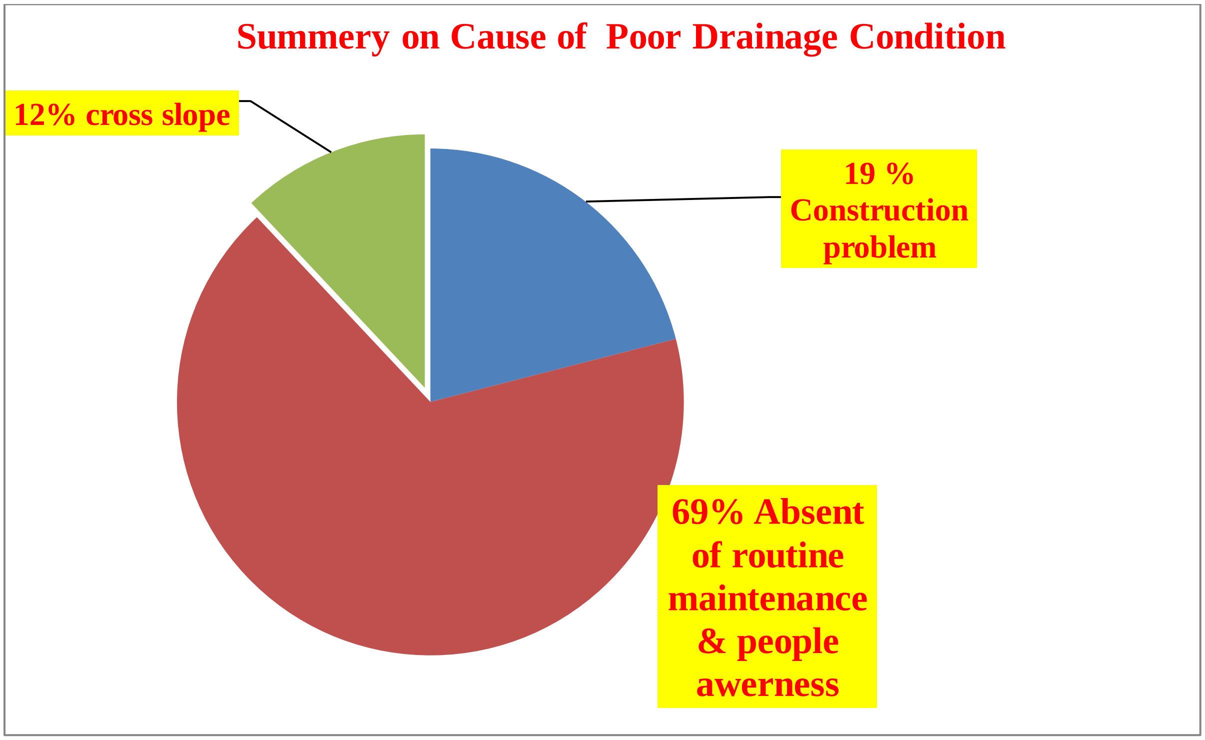


Figure 4.17: Cross slope for left side of the road and their Percentage Distribution



Figureb18 Summery of Cause for poor Condition drainage

4.3 Effect of Poor Drainage on Pavement

Properly designed and constructed subsurface drainage systems improve the life of pavement structures. Excessive water content in the pavement base, sub base, and sub grade soils can cause early distress and lead to a structural or functional failure of the road, if counter measures are undertaken. Ponding water on or beside the roadway is a common sight of rainfall downpour yet it is a sign of future problems. Water immerses into the road structure unless the soil around and under it is relatively waterproof. Water related damage can cause one or more of the following forms of deteriorations: reduction of sub grade and base strength, differential swelling in expansive sub grade soils, stripping of asphalt in flexible pavements.

The road suffered from severe distresses of potholes, cracking, rutting and heavy depressions. The absent of routine maintenance and lack of management system forms the drainage system block by waste disposal and lead to pavement deterioration before the service life. Due to lack of drainages facility in the kebele, flow of rainfall is staying on the roads for long time surface which causes pavement deterioration. Adequate water contents in granular road materials is beneficial to road construction but if the water content increases with time, negative effects will appear. The drainage conditions of this road are getting deformed by inadequate use of drainage system by the residents and poor management system. In area the drainage system is connected with the toilet. Since bad simile come from the drainage people close inlets to control it. This condition remains the same throughout the year causing the drain water to stay on the surface of the road before running off through the gully into the drain. The effect of poor drainage on the road is a detachment of bituminous pavement layer due to continuous contact of water. In other words, the pavement is seen to have failed due to stripping of bitumen from aggregates resulting to failure on the edges.

On a lot of roads across the kebele having inadequate drainage systems .Deterioration repeatedly begins with the origin of cracks or potholes on the road pavements either at the edges or along the driveway which differs by their shapes, configuration, and movement of traffic and rate of deformation. Curb inlets damaged, drainage manhole fill by debris & cover remove, causes for poor drainage condition and this lead to pavement failure and severe distresses were observed on the road surface.

Some effects of water on road are given below.

- Reducing the load carrying capacity of subgrades and shoulders.
- Dumping sediment and debris in ditches, pipes, catch basins and waterways.
- Creating driving hazards for drivers.
- Increasing the failure possibility of pavements and gravel surfaces.
- Eroding roadside surfaces.
- Damaging adjacent property.

Different effects of poor drainage conditions on pavement are presented in the study area.

According to field observation made, severe distresses were observed on the road surface. It was found that the runoff water over flow on surface and as a result road material was eroded. Significant cracking, potholes, edge failure as shown in figure below

Figure 4.19 Formation of potholes due to Poor Drainage around genu hotel

- Pavement settlement causes ponding.

Figure 4.20 shows that pavement failure and inlets doesn't work (in front of genu hotel)

Figure 4.21 shows that pavement failure and inlets doesn't work (in front of genu hotel)

Figure 4.22 Waste water inter to manhole inlets across on pavement structure

4.3.1 Evaluation of inlets

The length of the curb opening inlet required for total interception of gutter flow on a pavement section with a uniform cross slope is expressed by equation, which I try to show in the literature review. Based on the design data, i can observe that curb inlets are used for collecting surface water from the pavement and surrounding. To Evaluate efficiency of the inlet, i used Federal Highway Administration drainage design manual and ERA drainage design manual, rational method. The Rational Method is selected as the area less than 50 hectares. This evaluation is for different station which is the most affected area listed in the table 4.5. Computations at Station 1+400 to 1+900 (Tilahun shell_Hasen garage) are evaluation of minimum interception of gutter flow on a pavement of runoff at the inlet. From a design data the catchment area of the drainage is 0.014 Km^2 or 1.4 hectares.

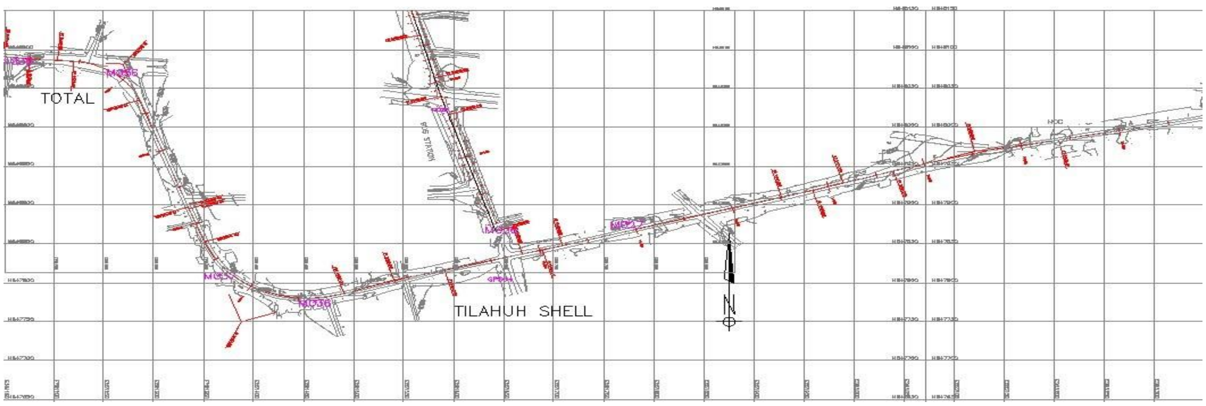


Figure 4.23 Typical cross section 14m width

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

Station = (1+400 to 1+900)

Initial station = (1+400 to1+410) =0+010

Cross slope, S_x = 2.5 %

Longitudinal slope, S = 0.5 %

Spread width, T = Shoulder +1= 4.5 m

Manning's coefficient, n = 0.015

Length of sheet flow, L = 20 ……………… (From contour map)

Run of coefficient, C = 0.68 ……………… (From equation 2.1)

Slope of sheet flow (S) = 3% ……………… (From design data)

Side slope (H: V) = 0.43…………………… (From design data)

Area:-

From data collection the catchment area of drainage are found from the design data which found from ERA, jimma district.

For Station = (1+400 to 1+900)

Catchment area: = **0**.014Km^2 or **1.4**ha .... (From design data)

Time of concentration (Tc):

$Tc = 1.8 * (1.1 - C) * L^{0.5} / S^{0.33}$ .... (By using equation 2.2)

$= 1.8 * (1.1 - 0.68) * (20^{0.5}) / 0.05^{0.33}$

I = 80mm / hr. .... (From Intensity –duration –frequency regions of B1)

= **9.08** min

- **Gutter Flow:**

Q = 0.00278 CIA .... (Using Equation 2.1)

Runoff Coefficient(C) = 0.68... (From Table 2.1)

the rainfall intensity (I) = 80mm/ hr .... (From Rainfall-Intensity-Duration curves) Catchment area (A) = 1.4ha

Q = 0.00278 *0.68*1.4ha*80mm/hr

Q = **0.21**m^3/s

- **Spread (T):**

$Q = \frac{0.56}{n} S_x^{5/3} * S^{1/2} T^{8/3}$ .... (usingEquation2.4)

$T = (Q n / (0.56 S_x^{5/3} * S^{1/2}))^{0.375}$

$= (0.0.21 * 0.015 / (0.56 * 0.025^{5/3} * 0.05^{1/2}))^{0.375}$

= **2.18** m < 4.6 (allowable Spread) (Using equation 2.4)

- **Gutter Depth:**

d = TSx (Using Equation 2.5)

=2.18 ∗ 0.025

= **0.05** m

- **Velocity (V):**

$= K_U \left(\frac{S_L^{0.5} S_X T}{n} \right)$ …………………….. (Using Equation 2.6)

$= 0.752 * (0.05^{0.05} * \frac{0.025}{0.015}^{0.5})$ 0.3m/sec………………… (Using equation 2.10)

= **0.4988** m/sec

- **Ratio of frontal flow to that of total gutter flow**

$$Eo = 1 - \left(1 - \frac{0.5}{2.18}\right)^{0.27} = 0.60$$

Rf (ratio of frontal intercepted to that of total frontal flow) = 1 (using chart 1)

- **Efficiency of curb-inlets**:

$L_T = Ku\, Q^{0.42}\, S_L^{0.3}\, S^{(0.6)}$ ………………………………………………………… (Using Equation 2.8)

$= 0.817 * 0.21^{0.42} * 0.03^{0.3} * 0.5^{(0.6)}$

= **1.2**m

$L = 1/L_T = (1/1.2) = 0.33$m

$E = 1 - (1 - L/L_T) * 1.8$ ……………………………………….. (Using Equation 2.9)

= 1 - (1 – 1.50 / 1.2m)*1.8

= 0.442

= **44.2**%

- **Intercepted flow**

Qi = E*Q ……………………………………………………. (Using Equation 2.11)

= 0.442*0.02104

= **0.0215** m^3/sec

.

Detail computation for different station in the study area is listed in table in the below.

Table 4-5 the inlet efficiency computation

Catchment area length and Station		Catchment Area (A)	Q_d	Ditch Capacity	Gutter Flow (Q)	Spread (T)	Gutter Depth (d)	Velocity (V)	Efficiency inlets (E)	Intercepted flow
From	To	ha	m^3/s	m^3	m^3/s	meter	meter	m/sec	%	m^3/s
0+700 Total	1+400 T.shell	3.6	1.18	1.04	0.36	2.4	0.06	0.542	56.9%	0.021
1+400 T.shell	1+900 Noc	2.7	0.31	0.78	0.18	2.05	0.048	0.4575	40.4%	0.0215
1+400 Tilahun Shell	2+300 S.Gibe hospital	1	0.43	2.56	0.2	2.12	0.05	0.485	42.4%	0.011
0+00 Bus Station	0+300 Feid.roundabout	2.8	0.35	0.36	0.5	2.3	0.07	0.612	64.2%	0.145

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study assessed the cause and effect of poor drainage condition on the failure of road performance. According to the result of this thesis, drainage systems are insufficient to carry surface water for the proposed design. Factors in contributing to the early deterioration of pavements and lead to great environmental problems, the following conclusion are listed.

- ✓ According to the result of this thesis existing drainage condition are inadequate to carry the flow for required design. After collecting questioners the responses from engineers, road users and residents indicated that above 80% problem of poor drainage condition.
- ✓ Absent of routine maintenance and poor management system are the main cause of inlet not work properly and failure of pavement which get worse the problem the study area.
- ✓ There is visibly very poor maintenance culture of the road as majority of the curb inlets are hardly visible due to blockage by debris and vegetation.
- ✓ During construction, Overlap of manhole cover, inlet space size and rise of frontal inlet are also cause for surface water back flow to pavement.
- ✓ Poor slope (crown) traps water against the road and this lead to failure of pavement and water related damage causes for stripping of asphalt is existed in the study area.
- ✓ The resultant effect of poor drainage on the road is a detachment of bituminous pavement layer due to continuous contact of water.
- ✓ At stations 1+400_ 2+300 (Tilahun shell_ S.Gibe hospital) drainage structure inlets and manhole filled by silt, blocked by waste material, as a result, runoff crosses the road, eroded road surface materials and lead to pavement failure.
- ✓ At stations 1+400 1+900 (Tilahun Shell _ Noc) the minimum inlet depression curb inlet opening due to construction problem and drainage system closed by trash is also a cause.
- ✓ From the literature I review and the result I get curb inlets less exposed to debris and silt than other inlets, because of problem of management system it have low efficiency to discharge surface water.
- ✓ Toilet, liquid waste and refuse waste which join the storm drainage system of Boch Bore road are the main problem of study area especially during rainy season.

5.2 Recommendation

From the assessment of this thesis I understand that drainage is the heart beat of the pavement. Proper drainage system provided to the road increases the life of roads. Therefore, it is recommend that:

- ✓ Improvement of routine maintenance important throughout the year to improve the life of pavement and creating good management system help to alert community.
- ✓ Programmed follow up and routine maintenance activity should be done by the concerned organization.
- ✓ A regular inspection program allows managers to identify and schedule necessary improvements on a timely and cost-effective center.
- ✓ Giving attention during construction particularly drainage structure in order to avoid the problems and reconstruction of the whole system.
- ✓ It is better to used skilled person and appropriate material during construction specially drainage structure.
- ✓ The efficiency of curb inlets can also be improved by providing inlet depressions in the road cross section.
- ✓ It is generally preferred to keep the road as close to or less than optimum water content as possible over time.
- ✓ As I recommend rectangular shape of ditch recommended for urban area. This is a fast and cheap way to establish and easy to clean ditch. The flat bottom has the advantage of spreading the water out and slowing it down.
- ✓ Cost effective treatment to extend the life of the pavement before more expensive maintenance cost will be required.
- ✓ New roads which are designed in the future should have suitable inlet depression for the designed road way.
- ✓ Toilet and refuses waste system should be separate from drainage to avoid the problem.

REFERENCES:

[1] P. W. Bedient, W. C. Huber,B. E. Vieux, (2008), "Hydrology and Flood plain Analysis" Prentice Hall, Inc. Upper Saddke River, NJ.

[2] L. W. Mays (2004), "Hydraulic Design Handbook" McGraw Hill,

[3] Getachew KebedeWarati, TameneAdugnaDemissie “Assessment of the Effect of Urban Road Surface” A Case Study at GinjoGuduru

[4]. Atilla Ansal, Kandilli Observatory and Earthquake Research Institute, Boˇgazic¸i University, Istanbul, Turkey

[5] W. Paterson, “Road Deterioration and Maintenance Effects: Models for planning and Management,” Baltimore: The John Hopkins University press, 1987.

[6] N. Okigbo, “Road maintenance in Nigeria, the way forward,” International journal of research in engineering science, Pan African journal series, Accra, Ghana, 2012

[7] N. D. Little, and R. D. Jones, “Chemical and Mechanical Processes of Moisture Damage in Hot-Mix Asphalt Pavements,” Moisture Sensitivity of Asphalt Pavements- A National Seminar, February 4–6, 2003 San Diego, California. Transportation Research Board of the National Academics, 2003

[8] World Bank Publications (1996).Sanitation in developing countries, urban management, World Bank-Washington DC

[9] N. Okigbo, “Road maintenance in Nigeria, the way forward,” International journal of research in engineering science, Pan African journal series, Accra, Ghana, 2012

[10] AACRA Drainage designee manual, November 2004

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

[12] D.Walker, L. Entine, and S. Kummer (2000),"Drainage Manual: Local Road Assessment and Improvement", Transportation Information system, University of Wisconsin, Madison, 16 pp.

[13] Rokade, S., Agarwal, P.K. and Shrivastava, R.(2012):"Study on drainage related performance of flexible highway pavements," International Journal of Advanced Engineering Technology (IJAET),Vol.3, Issue 1, pp 334-337.

[14] ERA, 2011 Drainage design manual

[15] Mwangi, (2013), A Study on the Maintenance of Drainage Systems on Public Roads and Pavements, a Case Study of Nairobi's Industrial Area, Bachelor of Quantity Surveying, University of Nairobi.

[16] Design and construction of highway pavements and associated systems in Minnesota, including drainage, are guided by the Mn/DOT Standards Specifications for Construction

[17] Dr. Ndefo Okigbo Dept. Of Civil Engineering, The Federal Polytechnic Bida Nigeria.

[18] Ven Te Chow, etal, Applied Hydrology

[19] Oguara T. M. (2010), A management model for road infrastructure maintenance. Book of proceedings,19th engineering assembly.

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

[21] Okigbo N (2012), International journal of research in engineering science, Pan African journal series Accra Ghana.

[22]. Neenah foundry company, 1987, Neenah inlet great capacity. Neenah, WI 54956.

[23]. Department of Transportation Federal highway admission, 2001: Urban drainage design manual Larry W. Mays, 2004: Storm water collection system design hand book

[24] Thomas N. Debo. Andrew J. Reese, 2003: Municipal storm water management

[25] D. Walker, L. Entine, and S. Kummer (2000),"Drainage Manual: Local Road Assessment and Improvement", Transportation Information system, University of Wisconsin, Madison, 16 pp.

[26] W. Paterson, “Road Deterioration and Maintenance Effects: Models form planning and Management,” Baltimore: The John Hopkins University press, 1987.

[27] Smith, T. M. F.(2001). "Biometrika centenary: Sample surveys".Biometrika 88 (1): 167–243.

[28] Morth specifications (2001), published by Indian road Congress on behalf of Ministry of Transport and Civil and Environmental Research

Appendix A:

Chart 1. Time of Flow, Unit Peak Discharge, Velocity of flow

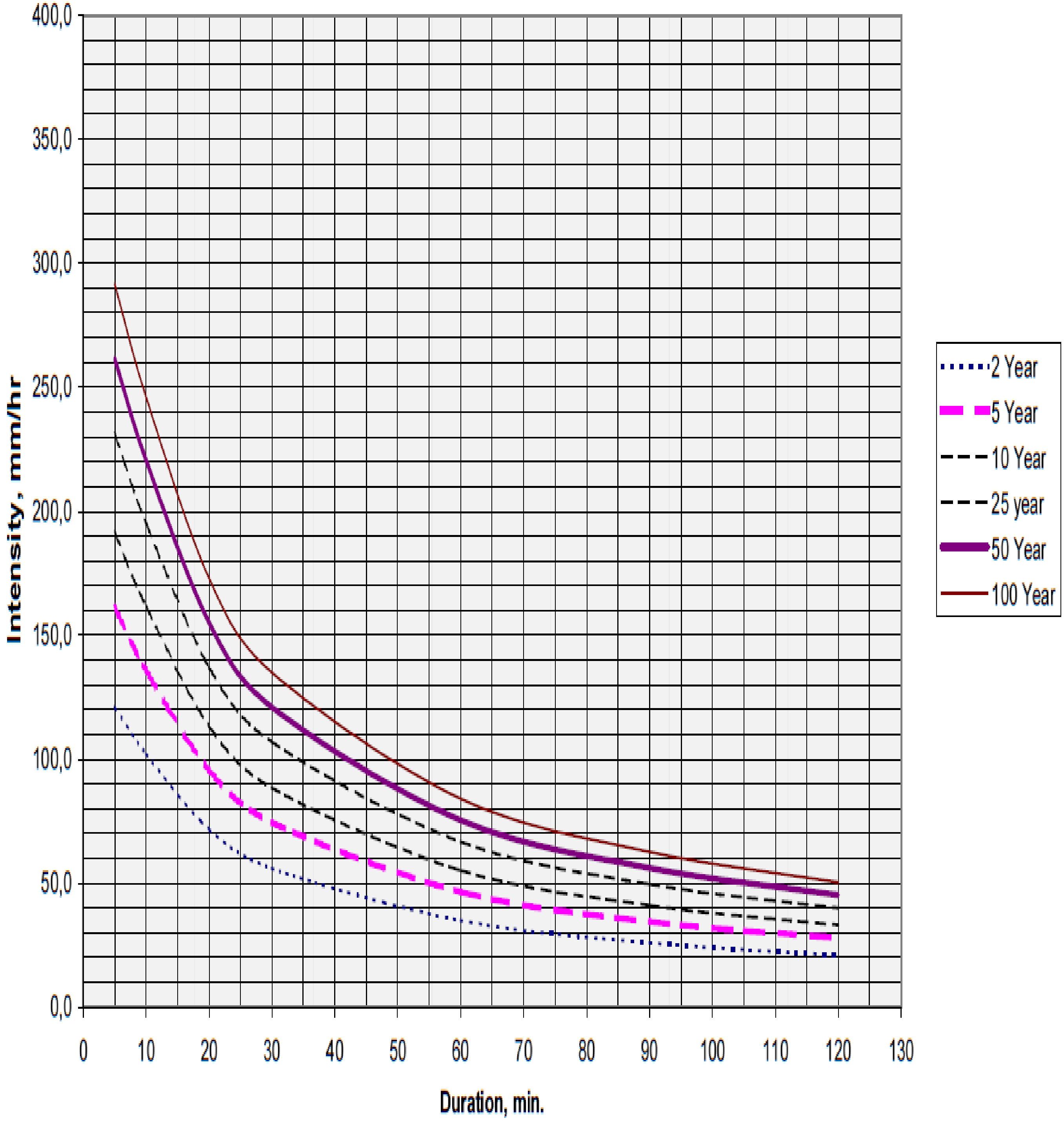


Figure1 Intensity –duration –frequency regions of B, C and D [1 and 13].

Chart 2

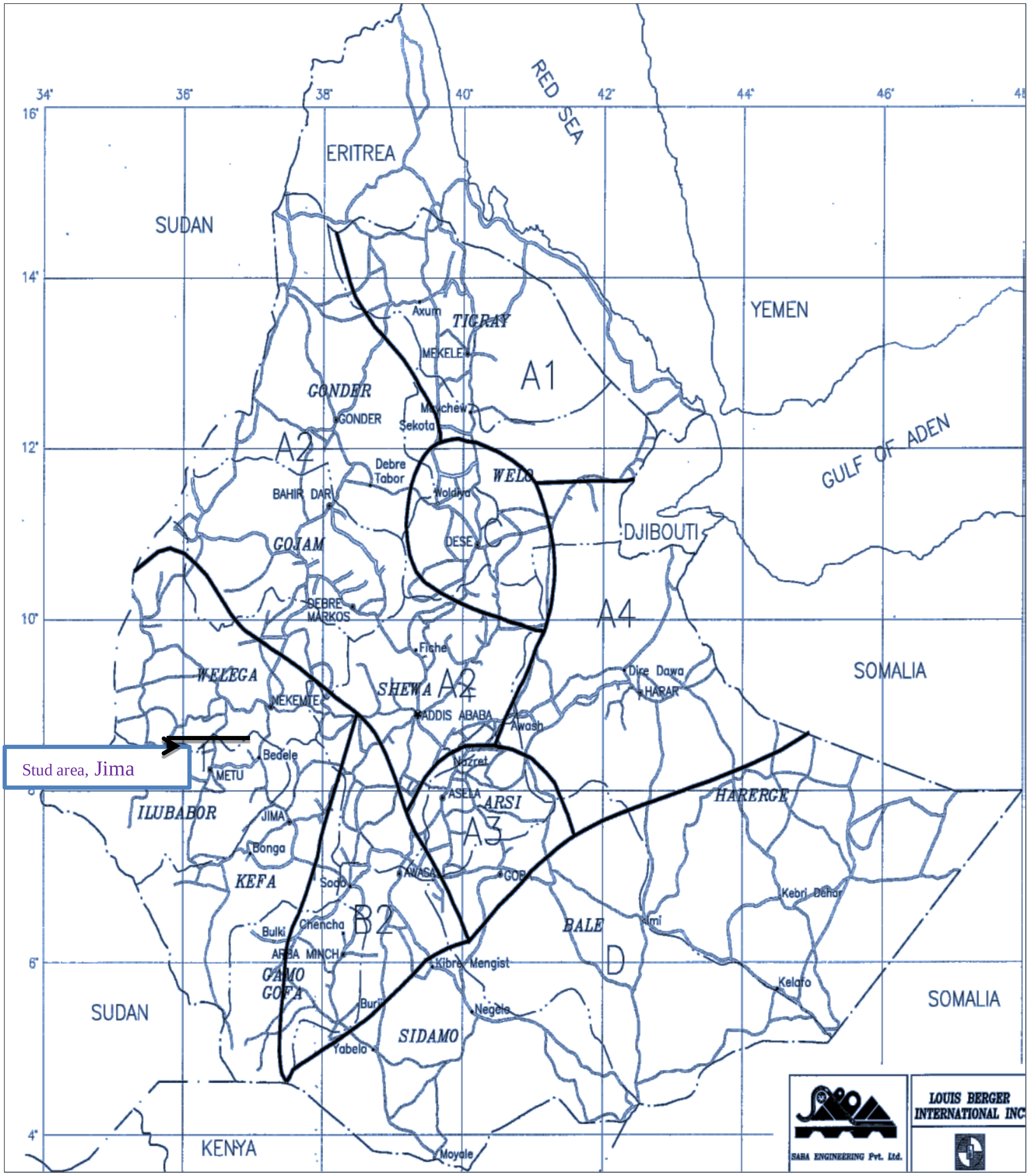
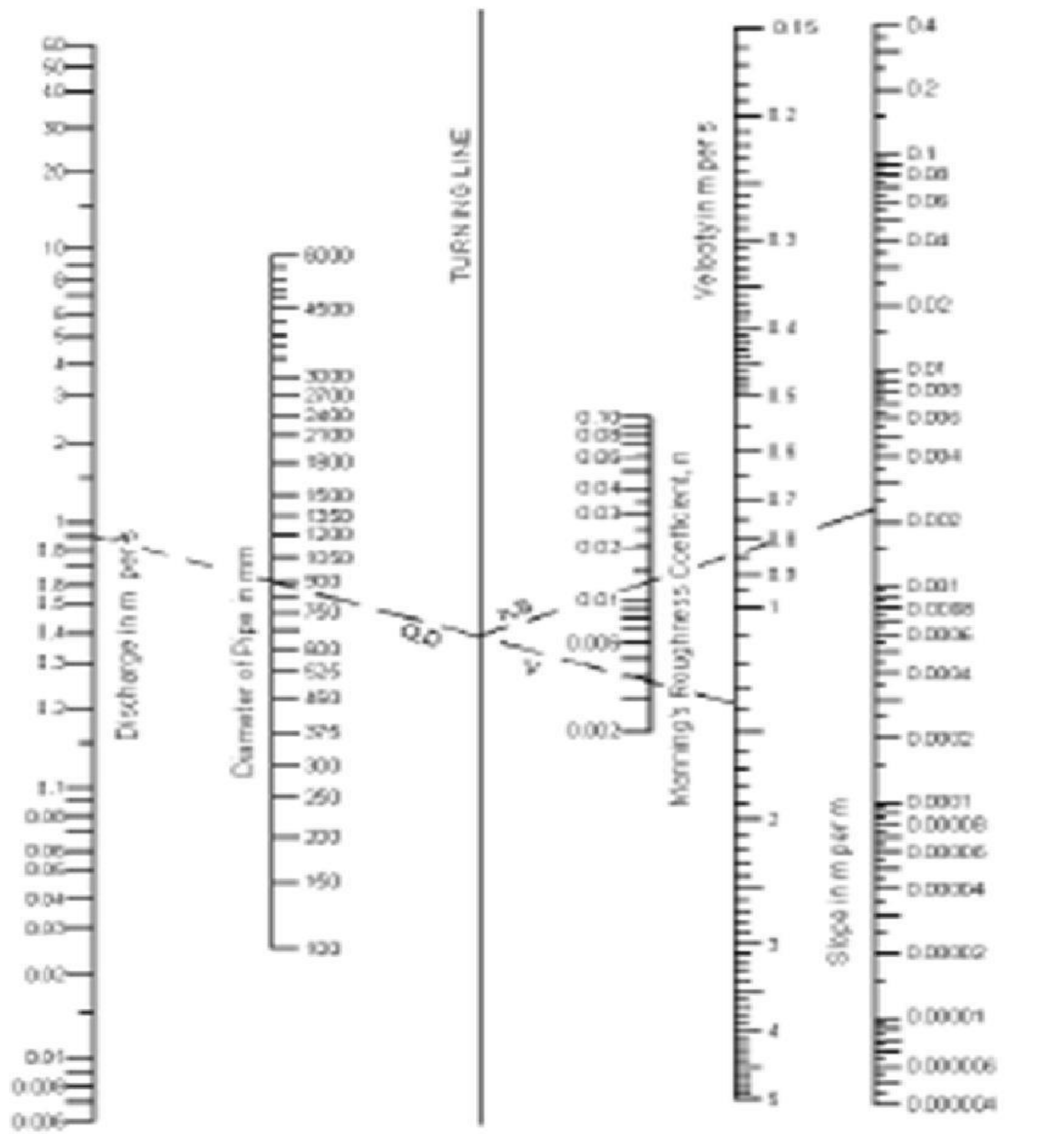


Figure 2 Rainfall Regions of Ethiopia

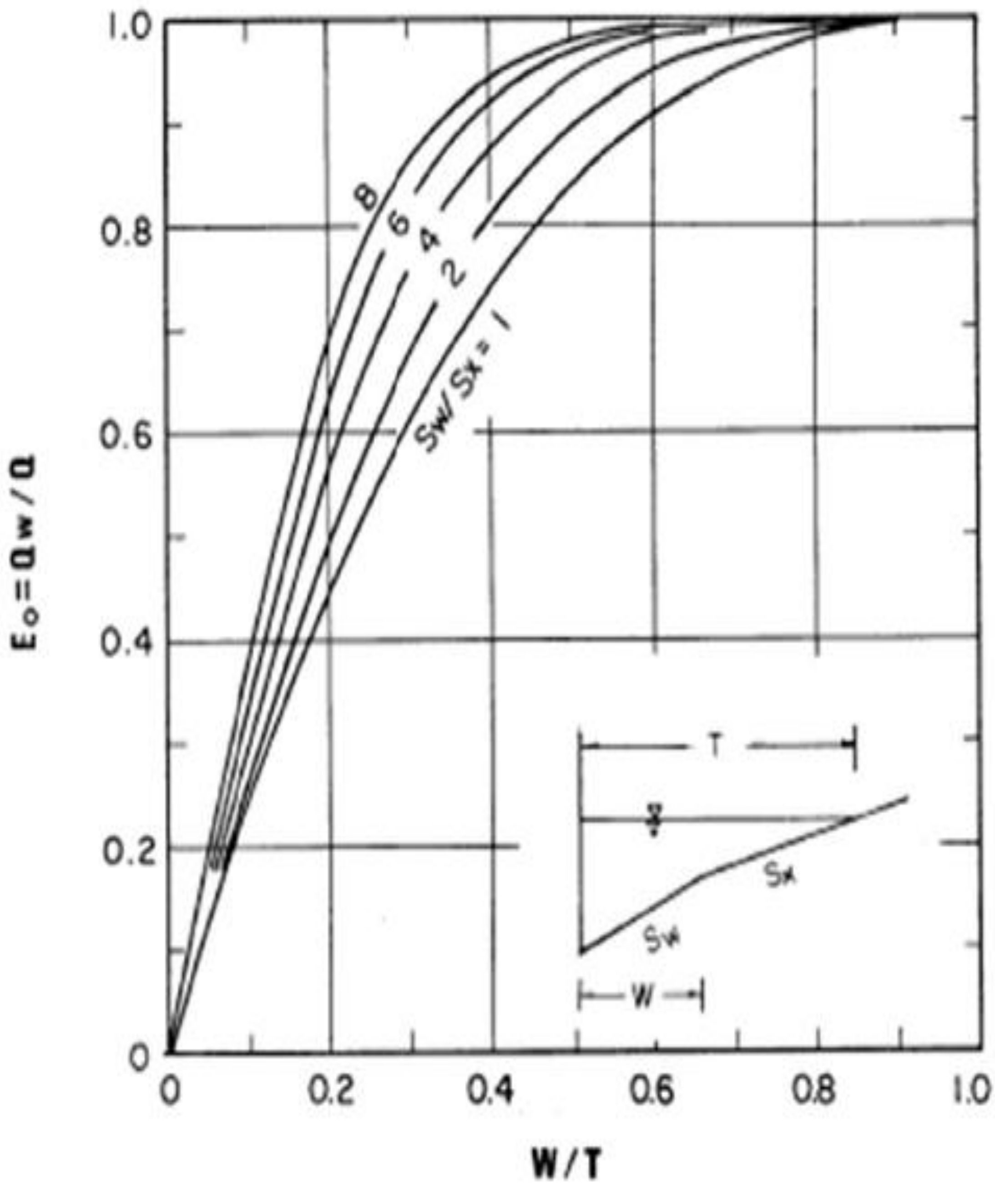
Chart 3 solution of manning equation for flow in storm drain



Solution of Manning's Equation for flow in Strom Drains.

Figure 3 solution of manning's equation for flow in storm drain

Chart 4



Ratio of frontal flow to total gutter flow.

Figure 4 ratio of frontal flow to total gutter flow.

Chart: 5

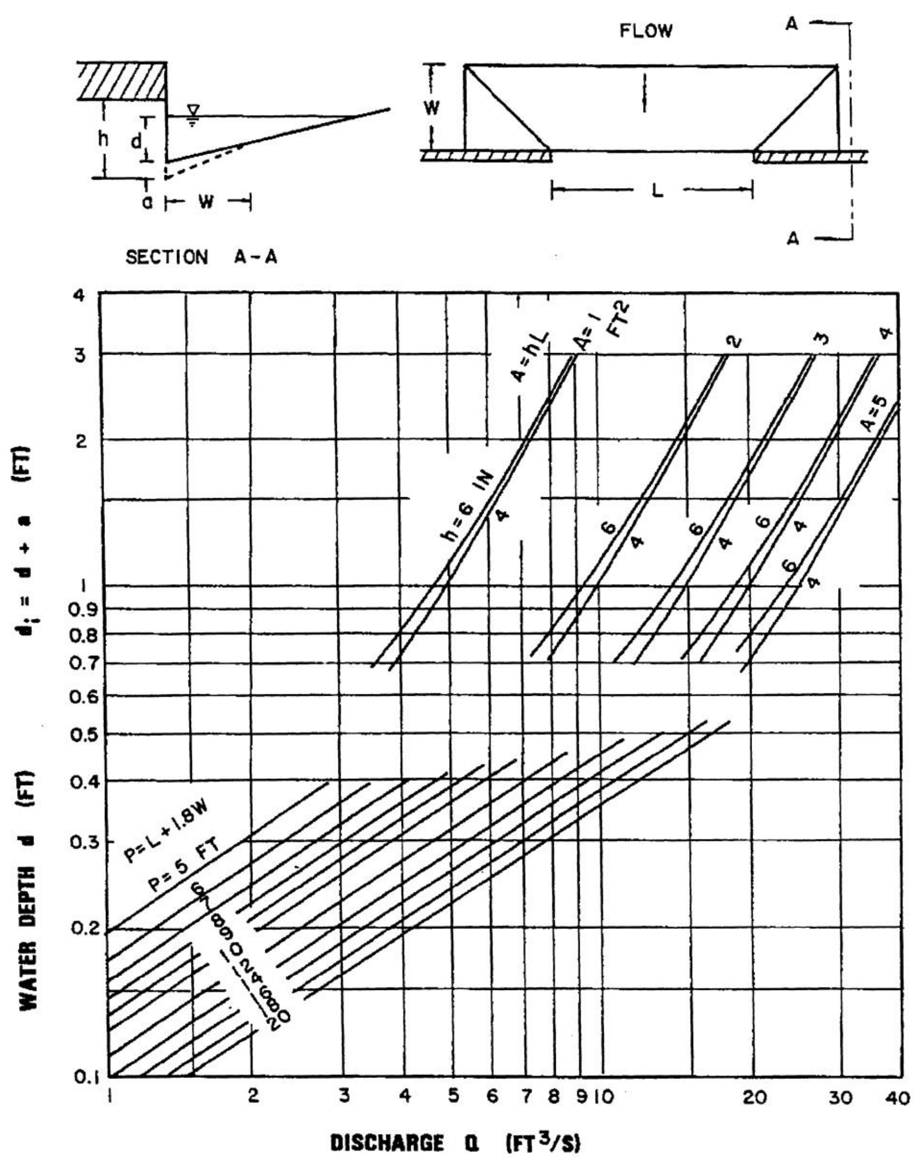


Figure 8.10 Depressed Curb-Opening Inlet Capacity In Sump Locations
Source: HEC-12 (FHWA, 1984)

Figure 5 Depreased curb opening inlet side flow intercept efficiency.

Chart: 6

August 30, 2000 DRAINAGE MANUAL 8.7.5(3)

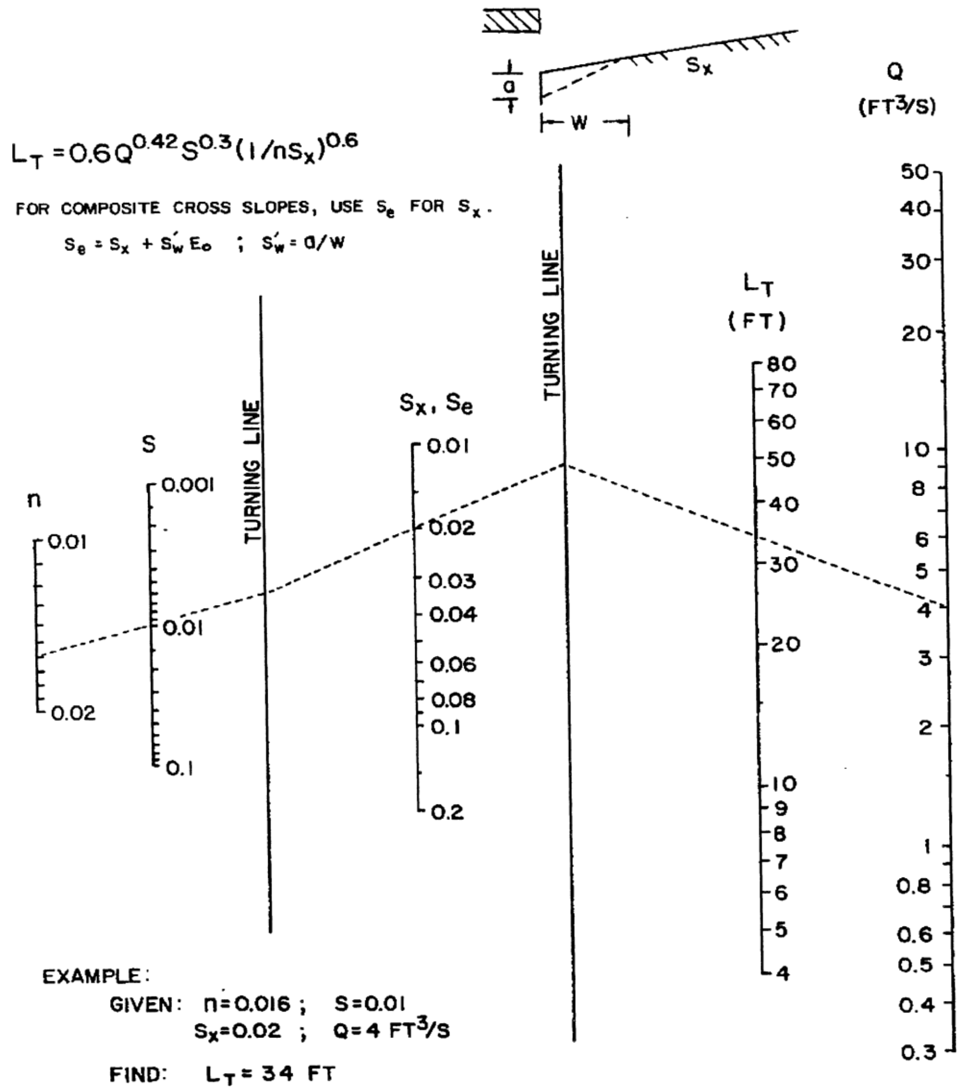


Figure 8.9 Curb Opening and Longitudinal Slotted Drain Inlet Length For Total Interception
Source: HEC-12 (FHWA, 1984)

Figure 5 curb opening and longitudinal slotted

Appendix B

Table 1

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

Table 1: Roughness Coefficients (Manning's n) For Sheet Flow

Table 2 hour depth (mm) versus frequency (yrs)

Region	24 HOUR DEPTH (mm) vs. FREQUENCY (yrs) TABLE					
	2	5	10	25	50	100
A1, A4	60	79	93	113	127	142
A2, A3	52	67	79	95	107	118
B and C	65	84	98	118	132	147
D	67	89	105	127	144	161
Bahir Dar	74	106	131	163	187	211

Table 3: Hydrological Characteristics of Soil Groups [14]

Average ground slope	Soil Permeability			
	Very low(Rock and hard clay)	Low(clay loam)	Medium (sandy loam)	High (sand and gravel
Flat (0-1%)	0.75	0.40	0.05	0.05
Gentle (1-4%)	0.85	0.55	0.20	0.05
Rolling (4-10%)	0.95	0.70	0.30	0.05
Steep (>10%)	1.00	0.80	0.50	0.10

Table 3: Ia Value for runoff curve numbers [1]

Table 4: values of roughness coefficient n (uniform flow)

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

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

Table 4: Storm Design Return Period –years

Table 5

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
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

Table 6

Type of Channel and Description	Minimum	Normal	Maximum
b. Cultivated area			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of spouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
3 Major Streams (top width at flood stage > 30 m). The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	--	0.060
b. Irregular and rough section	0.035	--	0.100
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		
Dense Brush	0.070		
Dense Trees	0.100		

Table 7: Geometric design standard

Structure Type	Geometric Design Standard			
	DC4	DC3	DC2	DC1
Gutters and Inlets	2	2	2	1
Side ditches	10	5	5	2
Ford	10	5	5	2
Drift	10	5	5	2
Culvert diameter <2meter	15	10	10	5
Large culvert diameter >2meter	25	15	10	5
Gabion abutment bridge	25	20	15	-
Short span bridge(<15meter)	25	25	15	-
Masonry arch bridge	50	25	25	-
Medium span bridge (15-50 meter)	50	50	25	-
Long span bridge(>50meter)	100	100	50	-

Table 7: Runoff Coefficient: Semi-arid Catchment

Average ground slope	Soil Permeability			
	Very low(Rock and hard clay)	Low(clay loam)	Medium (sandy loam)	High (sand and gravel)
Flat (0-1%)	0.55	0.40	0.20	0.05
Gentle (1-4%)	0.75	0.55	0.35	0.20
Rolling (4-10%)	0.85	0.65	0.45	0.30
Steep (>10%)	0.95	0.75	0.55	0.40

Table 11: Storm Design Return Period-years for Severe Risk Situations [13]

Soil Group	General Description	
A	Well drained, sandy	High infiltration, low runoff
B	Sandy loam, low plasticity	
C	Clayey loam, medium plasticity	
D	High plastic clay	Low infiltration, high runoff

Table 12: Antecedent Moisture Conditions [14]

Regions(*)	Antecedent Moisture Conditions
D	Dry
B	Wet
All other regions	Average
Bahir Dar area	Although in region A, use wet

Table 14 Runoff curve numbers [14]

Region	Frequency Interval (years)					
	2	5	10	25	50	100
A1, A4	60	79	93	113	127	142
A2, A3	52	67	79	95	107	118
B, C	65	84	98	118	132	147
D	67	89	105	127	144	161
Lake Tana	74	106	131	163	187	211

Table 15 recommended runoff coefficient C for pervious surfac

Land use			A	B	C	D
Cultivated land	without conservation treatment		72	81	88	91
	with conservation treatment		62	71	78	81
Pasture land	Poor condition		68	79	86	89
	Good conditions		39	61	74	80
	Fair conditions		49	69	79	84
Wood or Forest	Thin stands, poor cover no mulch		45	66	77	83
	Good cover		25	55	70	77
Open space, lawns ,park	Good condition, grass cover>75% area		39	61	74	80
	Fair condition ,grass on 50-75%		49	69	79	84
Urban districts	Commercial and business area 85% impervious		89	92	94	95
	Industrial districts 70% impervious		81	88	91	93
Residential	Average lost size	Average impervious				
	<0.05 hectares	65	77	85	90	92
	0.1 hectares	38	61	75	83	87
	0.2 hectares	25	54	70	80	85
	0.4 hectares	20	51	68	79	84
	0.8 hectares	12	46	65	77	82
Paved roads with curbs and stormdrains, paved parking area, roofs			98	98	98	98
Gravel roads			76	85	89	91
Earth roads			72	82	87	89
Open water			0	0	0	0

Table 16 selected hydrological soil groups and slopes ranges

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

Type of Drainage Area	Runoff Coefficient, C*
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
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
Lawns:	
Sandy soil, flat, 2%	0.05 - 0.10
Sandy soil, average, 2 - 7%	0.10 - 0.15
Sandy soil, steep, 7%	0.15 - 0.20
Heavy soil, flat, 2%	0.13 - 0.17
Heavy soil, average, 2 - 7%	0.18 - 0.22
Heavy soil, steep, 7%	0.25 - 0.35
Streets:	
Asphaltic	0.70 - 0.95
Concrete	0.80 - 0.95
Brick	0.70 - 0.85
Drives and walks	0.75 - 0.85
Roofs	0.75 - 0.95

*Higher values are usually appropriate for steeply sloped areas and longer return periods because infiltration and other losses have a proportionally smaller effect on runoff in these cases.

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

Appendix B:

Questionnaire Type One:

This questionnaire is ordered for the collection of data for the contribution of assessment of poor drainage condition and its effect on pavement, in jimma town Boch Bore kebele.

The information collected short; clear, simple and confidential.

1. What is your profession?
   A. Engineer C. Forman
   B. Surveyor D. if any other specify.
2. How does your organization give attention for routine maintenance throughout the year?
   ____
3. How does poor drainage condition shown in the keble can cause for pavement distress?
   ____
4. Does the design of Boch Bore kebele was correct design and well construct?
   ____
5. According to your profession what do you think the reason for poor condition of drainage system shown in the area?
   ____
6. Why do you think that was the cause for the problem of the kebele?
   A. People awareness C. Absent of routine maintenance
   B. Constriction problem D. Lack of good management
7. Do you think that there was lack of attention in the supervision of the contractor during the construction of the road?
   ____
8. Does your organization prepared place for debris and dispose of solid wastes water?
   ____
9. What does your organization preparation to proof the problem of poor drainage condition in the kebele?
   ____ .
10. Does drainage system for highway give rise to effective road development in Jimma?
    Yes [ ] No [ ]

Appendix C:

Questionnaire Type Two:

This questionnaire is ordered for the collection of data for the contribution of assessment of poor drainage condition and its effect on pavement, in jimma town Boch Bore kebele.

The information collected short; clear, simple and confidential.

1. Do you live in this kebele?

   A. Yes B. No

2. If your answer is yes for number one equation where do damp waste water and debris.

   A. Garbage. C. out of door

   B. Drainage manual D. other

3. What do you have a concept about use of drainage system

   ____

4. What do you think about condition of poor drainage system

   ____

5. How does poor drainage disturb your life style?

   ____

6. Do you have your own toilets?

   ____

7. Do you think over flow (flood), west water and debris are cause for pavement failure?

   ____

8. According to your opinion what is the main reasons for inadequate drainage?

   ____

9. Do you think construction problem cause for Poor drainage condition?
10. Do you think poor drainage condition effect on road?

   ____

Appendix D

Survey Data for Cross slope (Left side)				
Easting	**Northing**	**Center line**	**Elevation**	**Slope %**
263623.167	848335.299	1725.829	1725.679	2.14285714
263624.312	848338.754	1725.422	1725.299	1.75714286
263621.328	848332.392	1724.71	1724.558	2.17142857
263592.558	848353.617	1724.598	1724.597	1.01428571
263593.719	848356.596	1724.69	1724.488	2.88571429
263589.806	848352.795	1724.533	1724.42	2.61428571
263563.898	848369.919	1724.342	1724.138	2.91428571
263567.063	848373.478	1724.34	1724.215	1.78571429
263561.562	848360.964	1724.189	1724.085	1.48571429
263563.303	848377.978	1724.156	1724.001	2.21428571
263560.195	848379.374	1723.973	1723.723	3.57142857
263566.805	848377.51	1722.906	1722.81	2.37142857
263579.384	848424.287	1722.636	1722.498	1.97142857
263575.8	848425.166	1722.131	1722.002	2.84285714
263583.08	848422.065	1721.904	1721.712	2.74285714
263596.469	848470.368	1721.713	1721.658	1.78571429
263591.512	848471.656	1721.513	1721.427	2.22857143
263602.857	848467.185	1721.206	1721.195	2.15714286
263611.808	848511.121	1720.535	1720.519	2.22857143
263606.558	848514.597	1720.129	1720.079	2.71428571
263618.88	848509.895	1719.363	1719.297	2.94285714
263627.558	848553.666	1719.084	1719.076	3.11428571
263621.474	848556.066	1718.697	1718.621	1.08571429
263634.937	848552.462	1718.455	1718.452	0.04285714
263645.244	848596.65	1718.255	1718.121	2.91428571
263638.764	848598.706	1717.911	1717.759	2.17142857
263652.246	848594.777	1715.598	1715.426	2.45714286
263670.206	848644.796	1714.328	1714.214	1.62857143
263666.09	848646.604	1713.074	1712.911	2.32857143
263673.536	848644.358	1712.077	1712.068	2.12857143
263554.506	848376.77	1717.852	1717.772	1.14285714
263555.864	848380.168	1717.412	1717.305	2.52857143
263552.836	848373.753	1717.121	1717.029	1.31428571
263516.666	848394.196	1715.419	1715.312	2.52857143

Survey Data for Cross slope (Right side)				
Easting	**Northing**	**Center line**	**Elevation**	**Slope %**
263623.167	848335.299	1725.829	1725.683	2.08571429
263624.312	848338.754	1725.422	1725.221	2.87142857
263621.328	848332.392	1724.71	1724.517	2.75714286
263592.558	848353.617	1724.598	1724.397	2.87142857
263593.719	848356.596	1724.69	1724.488	2.88571429
263589.806	848352.795	1724.533	1724.32	3.04285714
263563.898	848369.919	1724.342	1724.138	2.91428571
263567.063	848373.478	1724.34	1724.215	1.78571429
263561.562	848360.964	1724.189	1724.085	1.48571429
263563.303	848377.978	1724.156	1724.001	2.21428571
263560.195	848379.374	1723.973	1723.723	3.57142857
263566.805	848377.51	1722.906	1722.721	2.64285714
263579.384	848424.287	1722.636	1722.498	1.97142857
263575.8	848425.166	1722.131	1722.009	1.74285714
263583.08	848422.065	1721.904	1721.712	2.74285714
263596.469	848470.368	1721.713	1721.558	2.21428571
263591.512	848471.656	1721.513	1721.427	1.22857143
263602.857	848467.185	1721.206	1721.195	2.15714286
263611.808	848511.121	1720.535	1720.519	2.22857143
263606.558	848514.597	1720.129	1720.079	1.71428571
263618.88	848509.895	1719.363	1719.197	2.37142857
263627.558	848553.666	1719.184	1719.056	1.82857143
263621.474	848556.066	1718.697	1718.621	1.08571429
263634.937	848552.462	1718.455	1718.242	3.04285714
263645.244	848596.65	1718.255	1718.121	1.91428571
263638.764	848598.706	1717.911	1717.759	2.17142857
263652.246	848594.777	1715.598	1715.426	2.45714286
263670.206	848644.796	1714.328	1714.114	3.05714286
263666.09	848646.604	1713.074	1712.911	2.32857143
263673.536	848644.358	1712.177	1712.068	1.55714286
263554.506	848376.77	1717.852	1717.772	1.14285714
263555.864	848380.168	1717.412	1717.305	1.52857143
263552.836	848373.753	1717.121	1717.029	1.31428571
263516.666	848394.196	1715.419	1715.312	1.52857143
263518.205	848396.038	1713.999	1713.799	2.85714286