CHAPTER ONE

1. INTRODUCTION

1.1 Background.

Drainage system is a process of removing & controlling excess surface water with in right of way. Drainage is an important feature in determining the ability of given pavement to withstand the effects of traffic and environment. (Adequate drainage is very essential in the design of highways since it affects the highway's serviceability and usable life. If bonding 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 (O'Flaherty, C.A. (2002).

The objective of drainage system is to prevent onsite water standing on the surface and convey the offsite storm runoff from one side of the roadway to the other. To carry out the offsite drainage. Culverts are closed conduits in which the top of the structure is covered by embankment. United States National Bridge Inspection Standards (USNBIS (United States National Bridge Inspection Standard), 1990) and ERA (Ethiopian Road Authority) drainage design manuals (ERA DDM, 2002 and 2011).

As the water can cause a serious impact on both the road access and its strength, an efficient drainage system is the most important part of road construction and maintenance works.

Good drainage needs to be taken into consideration at the early design stages in order to secure a long life for the road. With a well-designed drainage system, future rehabilitation and maintenance works can be considerably reduced and thus limit the costs of keeping the road in a good condition.

Ensuring good drainage begins when selecting the road alignment. A Centre line that avoids poorly drained areas, large runoffs and unnecessary stream crossings will greatly reduce the drainage problems. Provision of sufficient drainage is an important factor in the location and geometric design of highways. Drainage facilities on any highway or street should adequately provide for the flow of water away from the surface of the pavement to properly designed channels. In addition, traffic may be slowed by accumulated water on the pavement, and accidents may occur as a result of hydroplaning and loss of visibility from squish and sprig. The importance of enough drainage is recognized in the amount of highway construction dollars allocated to drainage facilities. About 25 percent of highway construction dollars are spent for erosion control and drainage structures, such as culverts, bridges, channels, and ditches (Wyatt et al, (2000).

Surface drainage encompasses all means by which surface water is removed from the pavement and right of way of the highway or street. A properly designed highway surface drainage system should effectively intercept all surface and watershed runoff and direct this water into adequately designed channels and gutters for eventual discharge into the natural waterways. Water seeping through cracks in the highway riding surface and shoulder areas into underlying layers of the pavement may result in serious damage to the highway pavement. The major source of water for this type of intrusion is surface runoff. An adequately designed surface drainage system will therefore minimize this type of damage. The surface drainage system for rural highways should include sufficient transverse and longitudinal slopes on both the pavement and shoulder to ensure positive runoff and longitudinal channels (ditches), culverts to provide for the discharge of the surface water to the natural waterways. Storm drains and inlets are also provided on the median of divided highways in rural areas. In urban areas, the surface drainage system also includes enough longitudinal and transverse slopes, but the longitudinal drains are usually underground pipe drains designed to carry both surface runoff and ground water. Curbs and gutters also may be used in urban and rural areas to control street runoff, although they are more frequently used in urban areas (Wyatt et al, (2000).

Roads will affect the natural surface and subsurface drainage pattern of a watershed or individual hill slope. Road drainage design has as its basic objective the reduction and/or elimination of energy generated by flowing water. Therefore, water must not be allowed to develop sufficient volume or velocity so as to cause excessive wear along ditches, below culverts, or along exposed running surfaces, cuts, or fills. Provision for adequate drainage is of paramount importance in road design and cannot be overemphasized. The presence of excess water or moisture within the roadway will adversely affect the engineering properties of the materials with which it was constructed. Cut or fill failures, road surface erosion, and weakened sub grades followed by a mass failure are all products of inadequate or poorly designed drainage. As has been stated previously, many drainage problems can be avoided in the location and design of the road: Drainage design is most appropriately included in alignment and gradient planning (Larson, C. L. June 1949).

1.2 Statement of problems

1. The design peak discharge calculated and the review peak discharge calculated of the return period is not equal. From this the road around this is damaged by over flooding of the water on the road because the calculated peak discharge for the design were less than the calculated peak discharge for the review at station, 0+30, 0+400 and 0+85 .Therefore before the culverts are constructing the design and the review data must be checked always when its design the road it must be the design peak discharge is greater than the review peak discharge to control the floods that over follow on the road.

2. Some problems influenced on drainage include: puddles on the surface area, poor surface flow, slope erosion, clogged ditches, pavement edge raveling, preliminary cracking, pavement pumping, and surface settlement.

3. Major failures caused by poor drainage conditions include washouts, slides, slip outs, road and pavement breakup and flood damage.

4. The inadequacy of drainage system during the rainy season to pass the flood, poor quality construction and improper maintenance of some drainage systems with respect to the road alignment.

This is the main reason why this study wants to analyze the factors contributing to the drainage and come up with corresponding recommended remedial measure.

1.3 Significance of the Study

The study construction of road drainage system is requiring skilled work force and intensive financial resources. If the drainage system fails, high investment is required to maintain them in order to avoid traffic interruption. To minimize maintenance expenses proper protection and management of these road assets is important. This research is aimed at coming up with findings on the effects of poor drainage and maintenance systems in *Upper Atbara and Setit Dam Complex Township paved road*. It would also come up with recommendation on the ways forward. It is supposed to find out reasons for inadequate provision of drainage system and the reasons for poor maintenance of the available drainage systems. Therefore; this study is beneficial to the region for future road drainage system construction to avoid problems by assessing the performances of the current drainage systems and proposing mitigation measures to avoid improper functioning.

The study is expected to propose appropriate solutions to the drainage systems whose implementation would contribute to the sustainability of the case study road.

The study is beneficial for academicians and researchers who conduct similar researches on other road drainage system, soil conservation strategies, erosion and scouring prevention mechanisms and degradations of the stream channel.

1.4 Research questions

The fundamental questions that are addressed and investigate are:

❖ What are the major causes of drainage system that affect the road segment?

❖ What is the hydrological condition of the existing road drainage system of the study area?

1.5 Objectives

The main Objectives of the research study are as follows:

✓ To identify the major cause of the road damages which was affected by drainage problem.

✓ To evaluate the hydrological condition of the existing road drainage system in the study area.

1.6 Scope and Limitation of the Study

The thesis is limited to the Causes and effects of poor drainage system on the asphalt pavement of road layer and proposing mitigation measures of the problem that are finding only on drainage system. This research also concentrate on the effects water has on the road due to poor drainage. It would look at the various steps that should be taken so as to ensure sufficient drainage system and how water causes increase in moisture content which eventually decreases the strength of the road and subsequently, road deterioration. The research does not include structural design of all types of drainage system except proposing the type and size of the required drainage system.

1.7 Structure of the Research

The structure of research is as follow:

CHAPTER ONE content to: **INTRODUCTION** (Background ، Statement of the problems ، Significance of the study ، Research questions ، Objectives and Scope and Limitation of the Study.

CHAPTER TWO: content LITERATURE REVIEW (Introduction ، Road Surface Drainage، Shoulders ،Cross slope ، longitudinal drainage ،Subsurface drainage systems (culverts،Alignment of Drainage System، Description and Function of Road Drainage System ، Description of Road Drainage Systems ، Functions of Road Drainage Systems ، Failures of Road Drainage System ، Effects of Drainage on Roads، Culverts ، Components of a road and pavement drainage system ،Necessities to Construct Drainage System ،The Criteria for Roadside Channels ، Design Flood for Road Drainage System ، Flow Velocity in Road Drainage System ، Hydrological Analysis and Hydrological Equations for Determining Peak Flood.

CHAPTER THREE: content to METHODOLOGY (Research Methodologies ، Study Area ، Study period،Research design ، Study population ، Sample size and sampling procedures ،Study variables،Data collection process ، Data processing and analysis ، Ethical considerations ، Data quality assurance ، Limitations of the study and Rational Method

CHAPTER FOUR: content to RESULT AND DISCUSSION (Results from analysis، Causes and effects of drainage system on asphalt road that response from the Engineers ،Results from observation and photography
، Investigations of Design and Construction Performs on the study area، Results from Hydrological Analysis and Peak Discharge Computation

CHAPTER FIVE: content to CONCLUSION AND RECOMMENDATION (Conclusion and Recommendation)

CHAPTER TWO

2. LITERATURE REVIEW

2.1 General Description of Road Drainage Systems

This aspect of the study review the various literatures related to the topic under considerations in order to uncover critical facts and findings which have already been identified by previous researchers and numerous studying in and around the cause of drainage system and their problems. Road drainage systems that cross the rivers and valleys are vital components of the road network that contributes greatly to the national development and public daily life.

Any damage or failure of this highway drainage system can cause the risk of the lives of road users as well as create serious influence to the entire country economic development.

The reconstruction of this road drainage system needs considerable amount of skilled work force, money and time. Road drainage systems are essential components during the design development of road infrastructures. Drainage structures intended to allow the runoff of any flow of water with limited damages and disturbances to the road and to the surrounding areas. (ERA, manual 2002).

The two main types of water flows that can be considered are the flows that usually crossing the area that could be diverted by the presence of the road, and the flows generated by the runoff of the rainwater falling on the carriageway and its surroundings. The basic design techniques in roadway drainage system should be developed for economic design of surface drainage system including ditches, culverts and bridges (ERA manual, 2002). A hydraulic investigation and analysis of both the upstream and downstream reaches of the watercourse is necessary to determine the best location, size, and elevation of the proposed crossroad structure, whether a culvert. The investigation should ensure that any roadway system or roadway embankment that encroaches on or crosses the flood plain of a watercourse would not cause significant adverse effect to the flood plain and would be capable of withstanding the flood flow with minimal damage. It is significant to provide attention during design of the magnitude, frequency and appropriate water surface elevations for the design flood, the 100-year flood, and the overtopping or 500-year flood for all structures (ADOT, 2007).

A drainage system includes the pavement and the water handling system. They must be properly designed, built, and maintained. The water handling system includes: road surface, shoulders, drains and culverts; curb, gutter and storm sewer. When a road fails, whether it's concrete, asphalt or gravel, inadequate drainage often is a major factor. Design can direct water back into the road or keep it from draining away.

2.2 Road Surface Drainage

Removal and diversion of surface water from the roadway and adjoining land is termed as surface drainage. The surface water is to be collected and the disposed of. The water is first collected in longitudinal drains, generally in side drains and then the water is disposed of at the nearest stream, valley or water course. Cross drainage structures like culverts may be necessary for the disposal of surface water from the road side drains.
If surface water infiltrates into the road body, it reduces the load bearing capacity of the pavement, which may cause further damage of the road. To minimize these problems, it is important to secure adequate drainage of the road surface. According to ERA geometric design manual (ERA GDM, 2011) the normal cross-slope is not less than 3% in order to dispose water from the roadway quickly that minimize infiltration of water into the roadway. If the cross-slope is less, water will get time to infiltrate into the roadway and the elements of road surface drainage.

2.2.1 Shoulders

Shoulders help provide lateral support for the pavement, carry water from the pavement to ditches, and give vehicles a place to go if they lose control or need to stop in an emergency show figure 2.1. For drainage they need to be slightly steeper than the pavement and should be able to withstand occasional traffic. Erosion and washing of shoulders is a major problem and should be addressed by using less erosive material on the surface.

Figure: 2.1: Shoulders

2.2.2 Cross slope

Cross slope is provided to provide a drainage gradient so that water would run off the surface to a drainage system such as a street gutter or ditch. Water would flow faster on a paved surface. Therefore the slope of a road surface does not need to be steep. The cross slope should not be too steep. If it is, the water running off the side would start eroding the shoulder and sides of the road.

2.2.3 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. It's fundamental for maintaining safety of traffic by eliminating water from the road surface at the same point reducing the possibility of water infiltrating into the road and pavement layers or foundation which may lead to deterioration. Longitudinal surface drainage systems include gutters, channels, ditches, permeable land surface and swales complemented by their respective manholes, retain facilities and catch basins.

2.3 Subsurface drainage systems.

Subsurface drainage systems drain water that has infiltrated through the pavement and the inner slope but also groundwater. Subsurface drainage systems are directly linked to surface drainage systems. According to the SRA (15) handbook, culverts are road constructions with a theoretical span of ≤ 2.0 m. Culverts have an open inlet and outlet and conduct water underneath a road. The need for subsurface drains as alternatives to open drains depends on site conditions. Subsurface drainage consists of three basic elements. A permeable base which is required to provide for rapid removal of water which enters the road structure, a method of conveying the removed water away from the road structure and this may consist of a base sloped towards a drainage ditch. At the most, this may consist of a pipe collector system and a filter layer to prevent the migration of fines into the permeable base from the sub grade, sub base or shoulder base material.

2.4 Alignment of Drainage System

Alignment deals with the design of the directional transition of the highway in a horizontal plane and vertical plane. A horizontal alignment consists, in its most basic form, of a horizontal arc and two transition curves forming a curve which joins two straights. Culverts that have internal diameter less than or equal to 1.22m are minor drainage System. The vertical alignment of a culvert with respect to the stream channel is important to its hydraulic performance, to stream stability, to construction and maintenance costs, and to the safety & integrity of the roadway. Proper alignment is also particular importance to prevent outlet scour or excessive sediment build up in the road According to ERA geometric design manual (ERA, 2011).

2.5 Description and Function of Road Drainage System

Storm drainage facilities consist of curbs, gutters, inlets, storm drains, ditches, and culverts.

The placement and hydraulic capacities of storm drainage structures and conveyances should be designed to avoid/minimize damage to adjacent property and secure a low degree of risk of traffic interruption by flooding. Different types of structures are employed in the drainage systems (ERA, 2002).

2.5.1 Description of Road Drainage Systems

Two different types of drainage systems commonly used to direct water from the area surrounding the road and to evacuate extra water from the road structures. These are surface and sub-surface systems.

A surface drainage system collects and diverts storm water from the road surface and adjoining areas to avoid flooding. It decreases the possibility of water infiltration into the road and retains the road bearing capacity. Appropriate design of the surface drainage system is an essential part of road design (GDD 2011). Sub-surface drainage systems drain water that has infiltrated through the pavement and the inner slope but also ground water.

2.5.2 Functions of Road Drainage Systems

Drainage systems collect, transport, and dispose of surface/sub-surface water originating on or near the roadway right of way or flowing in streams crossing bordering the right of way. It prevents erosion of the back slope by runoff from the hill above. It intercepts water, not allowing it to enter side drain that may cause greater discharge in side drains.

2.6 Failures of Road Drainage System

The roadway shall not obstruct the general flow of surface water or stream water in any unreasonable manner to cause an unnecessary accumulation either of water flooding or water saturated uplands, or an unreasonable accumulation and discharge of surface water flooding or water saturated lowlands. The failure of road occurred on *Upper Atbara and Setit Dam Complex*

Township paved road. Due to inadequate capacity of the drainage. If the failure is sudden and catastrophic, it can result in injury or loss of life and property.

2.7 Effects of Drainage system on Roads

An appropriate understanding of the dynamics of water flow in roads is important for many reasons. It is well known that the rate of road deterioration increases if the water content of the granular material increases. Presents 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. In a recently performed accelerated load test, used a Heavy Vehicle Simulator (HVS) to show that the rate of rutting increased in all layers of a flexible construction when the ground water table was raised. On the positive side, ensuring proper (optimal) water content greatly improves packing of the road during construction, and may also increase its resilience when trafficked, even though this effect is often neglected. In conclusion, initially maintaining adequate water contents in asphalt road materials is beneficial but if the water content increases with time, negative effects will most likely emerge. It is generally desired to keep the road as close to or less than optimum water content as possible over time. „Water and road construction do not make for a harmonious couple! ‟ from this it can be seen that there is a very serious effect of poor drainage on the condition of roads. The different effects of water on roads which are supplemented with the case studies. *Upper Atbara and Setit Dam Complex Township paved road*. Having inadequate drainage systems, deterioration often begins with the origin of cracks or pot holes on the road pavements either at the edges along the drive way which differs by their shapes, configuration, amplitude of loading, movement of traffic and rate of deformation show figure 2.2.

Figure: 2.2: ***Effects of Drainage system on Roads***

2.8 By drainage effects of water on road

Softening and reducing the load carrying ability of sub grades and shoulders; increasing the disintegration of pavements and gravel surfaces;

Eroding roadside surfaces; Depositing sediment and debris in ditches, pipes , catch basins and waterways; and contributing to frost heaves and spring break-up. Creating driving hazards for passengers. Damaging adjacent property.

2.9 Culverts

Culverts are shallow passages that are fitted under roads that allow water to pass beneath them. They can be made of either steel, plastic or concrete. A culvert helps move water under a road or driveway to a stream, lake or detention basin. The purpose of culverts is to safely convey water from one side of the road way to the other show figure 2.3. The water may be from natural streams or runoff surface water from the road structure or areas close to the road. A culvert must be durable and have sufficient hydraulic capacity to carry a predetermined quantity of water for a given time (NAAS, 1986). Generally, drainage structures designed to prevent road damage during the most usual floods such as annual, 10-year, 25-year 50-year or 100-year flood, depending on the importance of the road and the type of structures (ERA, 2002) and to minimize the modifications in the hydrology of the area. Culverts conveying cross drainage flow from outside should be located on the natural drainage path of the flow. When the natural drainage path of the flow is a wide overland flow area, the designer should evaluate the need for multiple culverts in order to prevent concentrated flow at a single location. The proposed cross culvert must be aligned with upstream and downstream channels. Culverts are the most common cross drainage structures used on roads. They are built using a variety of materials, in different shapes and sizes, depending on the preferred design and construction practices. Culverts are required in order to (i) allow natural streams to cross the road, and (ii) discharge surface water from drains and the areas adjacent to the road. Culverts form an essential part of the drainage system on most roads. Culverts are constructed using different materials. The most common practice of culverts is based on the use of pre-cast concrete pipes, in-situ concrete boxes and corrugated steel pipes culverts. The box culvert is generally built with 1 to 3 cells of width 1m to 3m and the pipe culvert is built with 1 to 3 rows of pipes with diameters commonly ranging from 0.6m to 1m. Wing walls and aprons of concrete or stone pitching are used to protect the culverts from water flow erosion and scouring at upstream side. Culverts should slope enough so water will flow (NCHRP, (1997)).

Culvert drainage structures shall be adequate to avoid hazardous flooding and failures of road or embankment structures. Poorly designed culverts are also more appropriate to become blocked with sediment and debris during medium to large-scale rain events.

This can cause the road to fail, often introducing a large amount of fine sediment that can clog other structures downstream and also damage crops and property. Hard bank armoring and a proper sized structure can help to alleviate this pressure.

Providing scour protections are important at both inlet and outlet for all culverts to protect the structure from damage. Providing rock armor is significant protection measure of scour for inlets and outlets of culverts. Moreover, headwalls and end walls utilized to control erosion and scour, to anchor the culvert against lateral pressures, and to ensure bank stability. Constructing all headwalls from reinforced concrete material is significant and may be straight and parallel to the channel, however, flared or warped, with or without aprons is possible when the site and hydraulic conditions permit.

To prevent the possible piping failure, cement stabilized fill can be used to form the culvert invert bedding for a suitable length. These measures found to perform well in clayey/silt/sandy soils (ERA manual 2002).

Figure: 2.3: ***Culverts***

2.10 Components of a road and pavement drainage system.

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

2.10.1 Ditches

Ditches carry water away from the roadway and into streams or other natural waterways. To do this, ditches must be properly shaped for safety, maintenance, water flow, and erosion control. The ditch should be at least one foot below the bottom of the gravel base in order to drain the pavement. Ditches should extend to shoulders with smooth transition to fore slope show figure 2.4. A well maintained, smooth flowing ditch will be free of heavy vegetation (tall grass) and standing water, with enough grades to ensure self-cleaning and continuous flow.

Figure: 2.4: ***Ditches***

2.10.2 Erosion Control in Ditches

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

2.11 Necessities to Construct Drainage System

A complete drainage system design includes consideration of both major and minor drainage systems. The minor system, sometimes referred to as the "Convenience" system, consists of the components that historically considered as part of the "storm drainage system". These components include curbs, gutters, ditches, inlets, access holes, pipes and other conduits, open channels, detention basins, and water quality control facilities (Achleitner S. (2006). According to HEC (Hydrologic Engineering Centre) No. 22(10), the minor system normally designed to carry runoff from 10-year frequency storm events (FHWA (Federal Highway Administration), 2001).

Avoiding of improper alignment of drainage structures is significant in order to avoid hazardous problems of traffic and damage of foundations, abutments and piers of structures. Cross currents of stream and river flows are the causes of damage foundations, abutments and piers of drainage structures. Narrow sections and hard basement are important during construction of drainage structures in order to minimize the cost of construction with the exception of excavation cost. Constructing drainage configurations on hard basement avoids washing problem.

2.12 The Criteria for Roadside Channels

Roadside channels and median channels are part of the storm drain system and are commonly used with uncurbed roadway sections to convey runoff from the road pavement and from areas which drain toward the road. These channels also provide temporary storage of storm water to prevent serious inundation problems during major storms (Manual, 2002).

In Ethiopia, the design discharge frequency for permanent roadside ditch linings should be according to the values that are presented in Appendix B of Table 8 and channel side slopes should not exceed the angle of repose of the soil and/or lining should be 2:1 or flatter in the case of rock riprap lining. Stone pitching or grouted riprap must be used for channel side slopes steeper than 2:1

2.13 Design Flood for Road Drainage System

Drainage works designed for storms having a recurrence interval of at least that are presented in Appendix B of Table 7. Moreover, all bridges and major culverts checked for performance under a storm event less frequent than the design storm events that are presented in Appendix B of Table 7.All other drainage structures checked for the storm having the next lower frequency than the design storm event. Minor culverts designed for a 10-year storm and checked for adequate performance with a 25-year interval storm event.

2.14 Flow Velocity in Road Drainage System

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

2.15 Hydrological Analysis

A hydrologic analysis is prerequisite to identifying flood hazard areas and determining those locations where construction and maintenance would be unusually expensive or hazardous. Since many levels of government plan, design, and construct highway and water resource projects that might affect each other, interagency coordination is desirable and often necessary. In addition, agencies can share data and experiences within project areas to assist in the completion of accurate hydrologic analysis. 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 would result in a structure that is either undersized and causes more drainage problems or oversized and costs more than necessary. On the other hand, it must be realized that any hydrologic analysis is only an approximation. The relationship between the amount of precipitation on a drainage basin and the amount of runoff from the basin is complex, and too little data are available on the factors influencing the rural and urban rainfall-runoff relationship to expect exact solutions. The hydrological information required for estimating the design floods are obtained from previous studies, ERA drainage design manual IDF (Intensity-Duration-Frequency) Curves, and topographic map of the study area. ERA classified rainfall regions in to four major rainfall regions and eight sub-rainfall regions in the country and developed IDF curves. The already developed regionalized IDF curve by ERA is used to determine rainfall intensity. ERA developed four IDF curves for rainfall regions in the country. The developed curves are for A1&A4, A2&A3, B, C & D Lake Tana rainfall regions. The study area lies on sub-region B1 and the IDF curve was constructed for B, C

Therefore, I used the rainfall intensity from the ID curve for the corresponding return period (from Ethiopian national methodology).

2.16 Hydrological Equations for Determining Peak Flood.

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

2.16.1 Rational Method

Rational formula method is recommended to determine the peak discharge, or runoff rate, from drainage areas up to 0.5km2. If a hydrograph is required to consider the effects of storage, use the Modified Soil Cover Complex method, or a similar method. Among a number of methods for estimating a design discharge, the rational formula is an empirical formula relating runoff to rainfall intensity. According to ERA drainage design manual 2002 and AASHTO 1990, the rational formula is most accurate for estimating the design peak runoff for small catchment areas of up to (0.5km2). Actual runoff is far more complicated than the values that are calculated by rational formula. Rainfall intensity is seldom the same over an area of appreciable size or for any substantial length of time during the same storm. Even if a uniform intensity of rainfall of duration equal to the time of concentration that occurs on all parts of the drainage area, the rate of runoff would vary in different parts of the area because of differences in the characteristics of the land surface and the non-uniformity of antecedent conditions. However, for this thesis, the same characteristics of the land surface and uniform antecedent conditions are considered. Under some conditions, maximum rate of runoff occurs before all of the drainage areas are contributing. Temporary storage of storm water routing toward defined channels and within the channels themselves accounts considerable reduction in the peak rate of flow except on very small areas. Due to these facts, for this thesis the rational method is not used to determine the rate of runoff for large drainage areas. For the design of highway drainage structures, the use of the rational method should be restricted to drainage areas up to 0.5km2 in upper Atbara dam. Hence, for this thesis the maximum value of the catchment area, 0.5km2, is considered (ERA DDM (Drainage Design Manual).

Characteristics of the Rational Method that generally limit its use to 0.5km2 include:

(1) The rate of runoff resulting from any rainfall intensity is a maximum when the rainfall intensity lasts as long as or longer than the time of concentration. That is, the entire catchment area does not contribute to the peak discharge until the time of concentration has elapsed.

(2) The frequency of peak discharges is the same as that of the rainfall intensity for the given time of concentration. Frequencies of peak discharges depend on rainfall frequencies, antecedent moisture conditions in the catchment area, and the response characteristics of the drainage system. For small and largely impervious areas, rainfall frequency is the dominant factor.

(3) The fraction of rainfall that becomes runoff (C) is independent of rainfall intensity or volume.

This assumption is only reasonable for impervious areas, such as streets, rooftops, and parking lots. For pervious areas, the fraction of runoff does vary with rainfall intensity and the accumulated volume of rainfall.

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

Equation: 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:

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

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)

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

1. The peak rate of runoff at any point is a direct function of the average rainfall intensity for the time of concentration to that point.

2. The recurrence interval of the peak discharge is the same as the recurrence interval of the average rainfall intensity.

3. The time of concentration is the time required for the runoff established and flow from the most distant point of the drainage area to the point of discharge.

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

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

The procedures in rational method to determine peak flood are:

1. Obtain the necessary information for each sub area:

i. Drainage area

ii. Land use

iii. Soil types

iv. Distance from the farthest point of the drainage area to the point of discharge

v. Difference in elevation from the farthest point of the drainage area to the point of discharge

2. Determine the time of concentration for the selected recurrence interval with duration equal to the time of concentration

3. Determine the rainfall intensity for the selected recurrence intervals

4. Select the appropriate runoff coefficient

5. Compute the design flow **(Q= 0.00278CIA)**

2.16.1.1 Runoff Coefficient

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

The most common definition of a runoff coefficient is the ratio of the peak rate of direct runoff to the average intensity of rainfall in a storm (Chow et al., 1988). The runoff coefficient is a dimensionless ratio intended to indicate the amount of runoff generated by a watershed given an average intensity of precipitation for a storm. While it is implied by the rational method, intensity of runoff is proportional to intensity of rainfall; calibration of the runoff coefficient has usually depended on comparing the total depth of runoff with the total depth of precipitation.

The runoff coefficient accounts for the effects of infiltration, detention storage, surface retention, surface retention, flow routing and interception. The product of runoff coefficient and rainfall intensity is the rainfall excess of runoff per hectare. The runoff coefficient should be weighted to reflect the different conditions that exist within a watershed.

$$Cw = (A1C1 + A2C2 +\text{---}+ AnCn) / (A1 + A2 +\text{---}+ An) \qquad (2.2)$$

Cw =Weighted Runoff Coefficient

C1, C2, --------Cn= coefficient of runoff for parts of the drainage area.

A1, A2, ------, An= parts of drainage areas with different runoff coefficients.

2.16.1.2 Rainfall Intensity

To determine the maximum discharge from a watershed, for a given storm frequency and duration, the designer should use the rain fall intensity for which the drainage area will yield the greatest peak discharge. 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. (ERA DDM 2002).

Rainfall intensity is a function of geographic location, design exceedence frequency (or return interval), and storm duration. It is true that the greater the return interval (hence, the lower the exceedence frequency), the greater the precipitation intensity for a given storm duration. Furthermore, as storm duration increases average precipitation intensity decreases.

The relation between storm duration, storm intensity, and storm return interval, is represented by a family of curves called the intensity-duration-frequency curves, or IDF) curves. Quantification of rainfall is generally carried out using is pluvial (Return Period) maps and intensity-duration-frequency (IDF) curves (Chow et al., 1988). Various rainfall contour maps developed to provide the design rain depths for various return periods and durations (Hersh field, 1961). The IDF 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.

2.16.1.3 Time of Concentration

The time of concentration is the time required for water to flow from the hydraulically most remote point of the catchment area to the point under investigation. Use of the Rational Method requires the time of concentration (Tc) for each design point within the catchment area. The duration of rainfall is then set equal to the time of concentration and is used to estimate the design average rainfall intensity (I). The time of concentration of a watershed is often defined to be the time required for a parcel of runoff to travel from the most hydraulically distant part of a watershed to the outlet. It is not possible to point to a particular point on a watershed and say, "the time of concentration is measured from this point". Neither it is possible to measure the time of concentration. Instead, the concept of time concentration is useful for describing the time response of a watershed to a driving impulse, namely that of watershed runoff.

The velocity of flow depends on the catchment characteristics and slope of the watercourse. It is estimated from appendix A on Figure 7, according to ERA drainage design manual 2011 for LVRs. The design return periods are taken from Appendix B in Table 7.

To determine time of concentration for over land flow there are many formula. Among these the Kerby and Kirpich formula are presented and for defined flow (Channel flow), U.S. SCS formula is presented.

Tc = 0.604[RL/S0.5] 0.467 **(2.3) Kerby Formula**

Where: Tc – Time of concentration in hours

L – Length of overland flow in kilometers

S – Slope in m/m

R – Roughness coefficient

Tc = 0.0013*M*(L^0.77/S^0.385) **(2.4) Kirpich Formula**

Where:

Tc – Time of concentration in hours

L – Length of overland flow in kilometers

S – Slope in m/m

m- Earth type coefficient

(m=1 for bare earth, m=2 for grass and m=0.4 for asphalt).

2.16.1.4 Catchment Area

Catchment area regression equations shall be used for all routine designs at sites where applicable; Catchment area can be determined from topographic maps and field surveys. For this thesis, the catchment area is determined from 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 investigate their effects on the flood flows.

2.16.2 The SCS method

The SCS runoff equation was developed to estimate total storm runoff from total storm rainfall (NRCS, 2004) that is, the relationship excludes time as a variable The SCS method for calculating rates of runoff requires much of the same basic data as the rational method namely catchment area, a runoff factor (curve number), time of concentration, and rainfall. However, the SCS method also considers the time distribution of the rainfall, the initial rainfall losses to interception and storage, and an infiltration rate that decreases during the course of a storm. It is therefore, potentially more accurate than the rational method and is applicable when the catchment area is larger than 0.5km2 (ERA, 2011).

2.16.2.1 Catchment Area

Catchment area regression equations shall be used for all routine designs at sites where applicable; In general, the catchment area can be determined from topographic maps and field surveys. However, for large catchment areas, it is necessary to divide the area into sub-catchment areas to account for major land use changes. Locate storm water drainage structures and assess their effects on the flood flows. A field inspection of existing or proposed drainage systems shall be made to determine if the natural drainage divides have been altered. These alterations could make significant changes in the size and slope of the sub catchment areas.

2.16.2.2 Rainfall-Runoff Equation

The SCS method is based on a 24-hour storm event. The characteristics of storms defined in terms of the relationship between the percentages of the total storm rainfall that has fallen as a function of time. Three basic types of storm are defined for three levels of maximum intensity, Type one being the least intense and Type three being the most intense. In Ethiopia, according to ERA drainage design manual a Type two distribution is used (ERA, 2002). It is applicable for interior rather than the coastal regions. Hence, type two distributions are appropriate for Ethiopia (ERA, 2002) and so for the study area. The SCS 24-hour storm distributions are based on the generalized rainfall depth-duration-frequency relationships collected for rainfall events lasting from 30 minutes up to 24 hours. Working in 30-minute increments, the rainfall depths are arranged with the maximum rainfall depth assumed to occur in the middle of the 24-hour period. The next largest 30-minute incremental depth occurs just after the maximum depth; the third largest rainfall depth occurs just prior to the maximum depth, etc. This continues with each decreasing 30-minute incremental depth until the smaller increments fall at the beginning and end of the 24-hour rainfall. A relationship between accumulated rainfall and accumulated runoff derived by SCS for numerous hydrologic and vegetative cover conditions are important for peak discharge determination. The storm data included total amount of rainfall in a calendar day but not its distribution with respect to time. The SCS runoff equation is therefore a method of estimating direct runoff from 24-hour storm rainfall (ERA DDM).

$$Q = (P - I_a)^2 / (P - I_a) + S \qquad \textbf{(2.5)}$$

For $P > 0.2S$

$Q = 0$ for $P \leq 0.2S$

Where:

Q = accumulated direct runoff, mm.

P = accumulated rainfall (i.e., the potential maximum runoff), mm.

Ia = initial abstraction (surface storage, interception, and infiltration prior to runoff), mm.

S = potential maximum retention, mm.

S is a site index defined as the maximum possible difference between P and Q as P⇒∞, P-Ia is called “effective rainfall”. It is related to the soil and cover conditions of the catchment area through the curve numbers. The curve number is a transformation of potential maximum retention (NRCS, 2004).

CN=1000/(S/25.4) +10 **(2.6a)**

S=25.4*((1000/CN)-10) **(2.6b)**

S is millimeter

CN=1000/ (10+S) **(2.6c)**

S is in inches

The relationship between Ia and S was found to be;

Ia= 0.2S **(2.7a)**

Substituting into (3.7a)

Ia = 50.8((100/CN)-1) **(2.7b)**

Q = [P – 50.8(100/CN - 1)] 2/ [P + 203.2(100/CN - 1)] **(2.8)**

2.16.2.3 Time of Concentration

Time of concentration is the time it takes water to flow from the edge of the catchment area to the point of interest. It is a combination of three values in SCS method of determining peak flow rate.

A. Sheet flow,

B. Shallow concentrated flow, and

C. Open channel flow

The type that occurs is a function of the conveyance system and is determined by field inspection. It is often a combination of these flows so that the total travel time is the sum of the time taken for the water to pass through all of the segments of the catchment. Travel time is the ratio of flow length to flow velocity:

T = L/ (3600V) (2.9)

Where:

T = travel time, hr

L = flow length, m

V = average velocity, m/s

The U.S. SCS formula to estimate time of concentration is:

Tc=((.87L^2)/1000Sav)^.385 (2.10)

Where:

Tc – Time of concentration in hours

Sav – Average slope in m/m

L – Hydraulic length of catchment along the flow path from the catchment boundary to the place where the flood needs to be determined (km).

Travel time is the time it takes water to travel from one location to another in a catchment area.

Tt is a component of time of concentration.

Tc=Tt1+Tt2+----+Ttm (2.11)

1. Sheet Flow

In sheet flow, travel time is determined by Manning's kinematic solution. The Manning's kinematic solution is expressed as:

Tt=[0.091(nL)^0.8/(P2)^0.5*S^0.4] (2.12)

Where:

Tt=travel time, hr

n= Manning's roughness coefficient

L=flow length, m

P2 = 2-year, 24-hour rainfall, mm

S = Slope of hydraulic grade line (land slope), m/m

According to ERA DDM 2002, the Manning's kinematic solution is based on the following criteria:

i. Shallow steady uniform flow

ii. Constant intensity of rainfall excess

iii. Rainfall duration of 24-hours

iv. Minor effect of infiltration on travel time

2. Shallow Concentrated Flow

After a maximum of 100 meters, sheet flow usually becomes shallow concentrated flow (ERA DDM, 2002). The average velocity for this can be determined by the following formulae according to the type of surface which water flows i.e. paved and unpaved. In these formulae, average velocity is a function of watercourse slope and type of channel.

Unpaved Surface: **V= 4.9178(S) ^ 0.5**

Paved Surface: **V= 6.1961(S) ^ 0.5** **(2.13)**

According to ERA DDM 2002 these two formulae are based on the solution of Manning's equation with different assumptions for n (Manning's roughness coefficient) and R (hydraulic radius, meter). According to the ERA DDM 2002 for unpaved areas, the value of n is 0.05 and R is 0.12; for paved areas, the value of n is 0.025 and R is 0.06.

After determining average velocity, equation (3.9) is used to estimate travel time for the shallow concentrated flow segment.

3. Open Channel Flow

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (including streams) appear on Ethiopian Mapping Agency (EMA) topographic maps

(1:50,000). Average velocity is usually determined for bank-full elevation. Manning's equation or water profile information used to estimate average flow velocity. When the channel section and roughness coefficient are available, then the average velocity can be calculated by using Manning's equation. For this thesis, topographic map of the study area was used that was produced in 1:50,000 scale.

$$V = (R^{2/3}S^{1/2})/n \qquad (2.14)$$

$$R = A/P$$

After average velocity is calculated, Tt is calculated by using equation **(2.9)**

$$Tc = Tt1 + Tt2 + Tt3 \qquad (2.15)$$

Where,

Tt1=travel time for sheet flow

Tt2=travel time for shallow concentrated flow

Tt3 =travel time for open channel flow

Using the calculated time of concentration, unit peak discharge is obtained from **Appendix A** on **Figure 5**. After unit peak discharge is obtained, design peak discharge is determined using the formula:

Design Peak Discharge, $Qp = Qu*Q*A$ **(2.16)**

Where,

Qp = Design Peak Discharge, m3/sec

Qu =Unit Peak Discharge, m3/sec/100ha/mm

Q = Direct Runoff, mm

A = Area of the catchment, ha

2.16.2.4 Runoff and Curve Numbers

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

To describe these curves mathematically, SCS assumed that the ratio of actual retention to potential maximum retention is equal to the ratio of actual runoff to potential maximum runoff, the latter being rainfall minus initial abstraction. In mathematical form, this empirical relationship is:

$$F/S=Q/P-Ia \quad (2.17)$$

Where,

F = actual retention (mm)

S = potential maximum retention (mm)

Q = accumulated runoff depth (mm)

P = accumulated rainfall depth (mm)

Ia = initial abstraction (mm)

After runoff has started, all additional rainfall becomes either runoff or actual retention (i.e. the actual retention is the difference between rainfall minus initial abstraction and runoff).

$$F=P-Ia-Q \quad (2.18)$$

The potential maximum retention **S** has been converted to the Curve Number CN in order to make the operations of interpolating, averaging, and weighting more nearly linear. This relationship is

$$CN=25400/254+S \quad (2.19)$$

Zero potential maximum retention **(S=0 or CN=100)** represents an impermeable watershed**; CN = 0** represents a mathematical upper bound to the potential maximum retention ($S = \infty$), which is an infinitely abstracting watershed. As the potential maximum retention (**S**) can theoretically vary between zero and infinity **(2.18)** shows that the Curve Number, **CN**, can range from one hundred to zero. For highly permeable, flat-lying soils, S will go to infinity and **CN** will be zero; all rainfall will infiltrate and there will be no runoff. In drainage basins, the reality will be somewhere in between. Therefore, equation **(2.7b**) and **(2.8)** will be defined.

The curve number method was developed with daily rainfall data measured with non-recording gauges. The relationship therefore excludes time as an explicit variable (i.e. rainfall intensity is not included in the estimate of runoff depth) soils.

2.16.2.5 Hydrological Soil Groups

Group A Soils having low runoff potential and high infiltration rates even when thoroughly wetted (low runoff potential). These consist chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission in that water readily passes through them (> 0.30 in/hr.). (NRCS, 2007).

Group B Soils having moderate infiltration rates when thoroughly wetted. These consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 in/hr). (NRCS, 2007).

Group C Soils having low infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission (0.05 to 0.15 in/hr.). (NRCS, 2007).

Group D Soils having high runoff potential. They have very low infiltration rates when thoroughly wetted (high runoff potential). These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 in/hr.). (NRCS, 2007).

The type of soil on the study area is Nitisols (FAO, 1998) that covers almost 100% of the total soil coverage. In Nitisols about 70% of the soil is silt loam of hydrologic soil group B and the remaining 30% is clay (FAO, 1998) of hydrologic soil group C.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 Research methods

Both descriptive and exploratory types of research methods were employed. The descriptive type was used to describe the existing condition and coverage of roads and storm water drainage facilities. Whereas, the exploratory type was particularly used to explore the existing condition by making some required physical measurements, and compare with standards.

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

3.2 Study area

The Upper Atbara and setit township is located at the Upper Atbara&syteet Dam complex site which is in Al-Gadarif State, about 420 km South East of Khartoum.

As part of the Upper Atbara & Setit Dam Complex, a township is currently being constructed to provide residence for the dam operation team as well as the first class, fully serviced and local events.

The township consists of various types of Villas, a VIP Rest House, a Mosque, various Utility stations, etc. show map follow:

3.3 Study period

The time allocated for this study from April 2013 up to May 2017.

3.4 Research design

The data gathered from the study area are categorized and interpreted. These data are primary and secondary. Primary data source are gathered by using: Site visit, field survey and Secondary data source from review documents from written like topographic map, hydrographic map, Google earth and hydrological map finding the mitigation measurement. Then analyze and discuss the existing drainage problem and the discharge would be calculated. Then give conclusions and recommendations of the results.

Site visit refers to the systematic examination of real-time processes or operations with the goal of identifying needs/challenges or improving processes and practices that is, what can be seen.

A questionnaire is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents.
Site visit refers to the systematic examination of real-time processes or operations with the goal of identifying needs/challenges or improving processes and practices that is, what can be seen.

Field survey is measuring the data from the field by using different material, tape and GPS.

photography is the art, science and practice of creating durable images by recording light or other electromagnetic radiation, either chemically by means of a light-sensitive material such as photographic film, or electronically by means of an image sensor.

3.5 Study population

In order to complete the study it is necessary to under taken the following:
Detailed survey, index properties of the drainage to existing conditions of a road drainage system would be recorded such as an alignment, size, and capacity of peak discharge.

3.6 Sample size and sampling procedures

Sampling procedures are using Random sampling includes choosing subjects from a population through unpredictable means. In its simplest form, subjects all have an equal chance of being selected out of the population being researched (Chambers, 2003). Once the population frame is randomized, the next step is to decide on the sampling interval. The confidence level set in determining the sample size is 95% confidence level of the target population while the response is taken to be within positive or negative 5% (+ or -5%) of the population. Then the existing condition of the drainage system and their causes and effects on the roads are prepared as questionnaires to get information from engineer, road users and residents. The sample size for the population was calculated using the formula below:

$$n=Z^2 pqN/(e^2(N-1)+Z^2 pq)$$

Where:

N – Size of the population
P – Sample proportion
n – Size of the sample
q – 1-P
e – Accepted error (e = 0.05, this is because estimate should be within 5% of the true value)
Z – The value of the standard deviation at a given confidence level.

by used equation above and used random value for (N=600,330,230,40 respectively):

Total sample population n = 65
Road users n = 36
Residents n = 25
Engineers n= 4

3.7 Data collection process

In this study both primary and secondary data would be used.

Primary data source: The research is conducted first by identification of the causes of road drainage problems through literature review and desk study on selected road drainage problem on the study area.

Site visit / observations: site visit was carried out to ascertain current conditions drainage system in *Upper Atbara and Setit Dam Complex Township paved 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 current state of the road and the drainage system, **Field survey** measuring the data by using tape and GPS.

Questionnaire is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents. Was asking the contractors and people living around the study area and interviews means Oral questions were asked to get more information and to clarify the ambiguous response. The study area information that was gathered from the residences and road user.

Secondary data source:

The data from different written documents and topographical map, published and unpublished data, internets

Photography: - Photography is an indirect way of data collection. It was majorly used to capture the current status of the drainage system in *Upper Atbara and Setit Dam Complex Township paved road*. . It was meant to give a visual understanding of the research topic to the readers of this research project, the extent of deterioration, maintenance and the state of the drainage system.

3.8 Data processing and analysis

Data collecting by using different materials, after collecting the data, it would be analyzed using descriptive and exploratory, such as rational and **scs** methods. Qualitative and quantitative methods and MS word and Excel of analysis used for data that are collected and interview.

3.9Ethical considerations

This study is conducted in a manner that is consistent with ethical issues that need to be considered in conducting a Thesis. Accordingly, letter from the Jimma University Institute of technology department of civil engineering is written for the concerned bodies. Hence, most individuals, the researcher visited for interview, accepted and cooperated with the researcher thesis. Moreover, a prior consent of the participants is requested before conducting the interview.

3.10 Data quality assurance

Before data collection all the source populations availability has checked and respondents daily work schedule has respected. All the questions that are put in simple and clear ways, willingness of the respondents to answer the questions and collaborates with the study is test out, all necessary schedule are worked out needed to administrate the observations group interviews and to measurements.

3.11 Limitations of the study

The thesis is limited to the performance assessment of current drainage system and proposing mitigation measures of the problem that are find only on highway drainage system. The research does not include structural design of all types of drainage structures except proposing the type and size of the required drainage system.

3.12 Rational Method

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

3.13 Equation:

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:

$$Q = 0.00278CIA \qquad (3.1)$$

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)

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1 Results from questionnaires analysis

Questionnaires were well-arranged to the engineers from west region and consultants of the west region. Another questionnaire was given to the residents of the area adjacent to *Upper Atbara and Setit Dam Complex Township* and people who use the road, here in referred to as road users. The questionnaire comprised of open ended and structured questions on issues that are related to the study.

Table 4.1 Response rate

Respondent	No. of planned questionnaires	The response	The response rate
Engineers	4	3	75
Road users	36	27	75
Residents	25	15	60
Total	**65**	**45**	**69.23**

A response rate of 50% is acceptable for data analysis and reporting, 60% is good and above 70% is very good (Mugenda, 1999). There was a response rate of 69.23% for this study and therefore good enough for the analysis of the data show table above.

4.2 Causes and effects of drainage system on asphalt pavement road

4.2.1 Causes of drainage on the asphalt pavement road layer.

The improper and no well-maintained of the drainage system are causes the failure of road pavement and it's reduce their life span. This bad condition of the side drain and its structures remains the same throughout the rain season causing the runoff water to flow on the surface of the road and unable to run off through the path far from the failed drain. The resultant effect of this critical situation causes serious distresses and damages on pavement. The road edges suffered from detachment of asphalt layer due to continuous contact of water leading to stripping of asphalt from aggregates resulting in severe pavement distresses of cracking, potholes and failure of edges of the road.

The impact of drainage condition on road pavement is very adverse. It causes pavement distresses and deterioration which affect the safety and riding quality on the pavement. The study investigated cases of pavement failures and damages due to drainage experienced during the rainy season.

4.2.2 The effects of drainage system on the road.

✓ Reducing the load carrying ability of the sub grade, sub base, asphalts and shoulder of the road.

✓ Eroding the road side surface by washing away the top surface of the road.

✓ Runoff the road and block a road by deposited waste material on the road and water leaved debris on the road and thaw weakening and stripping the asphalt in asphalt pavement road.

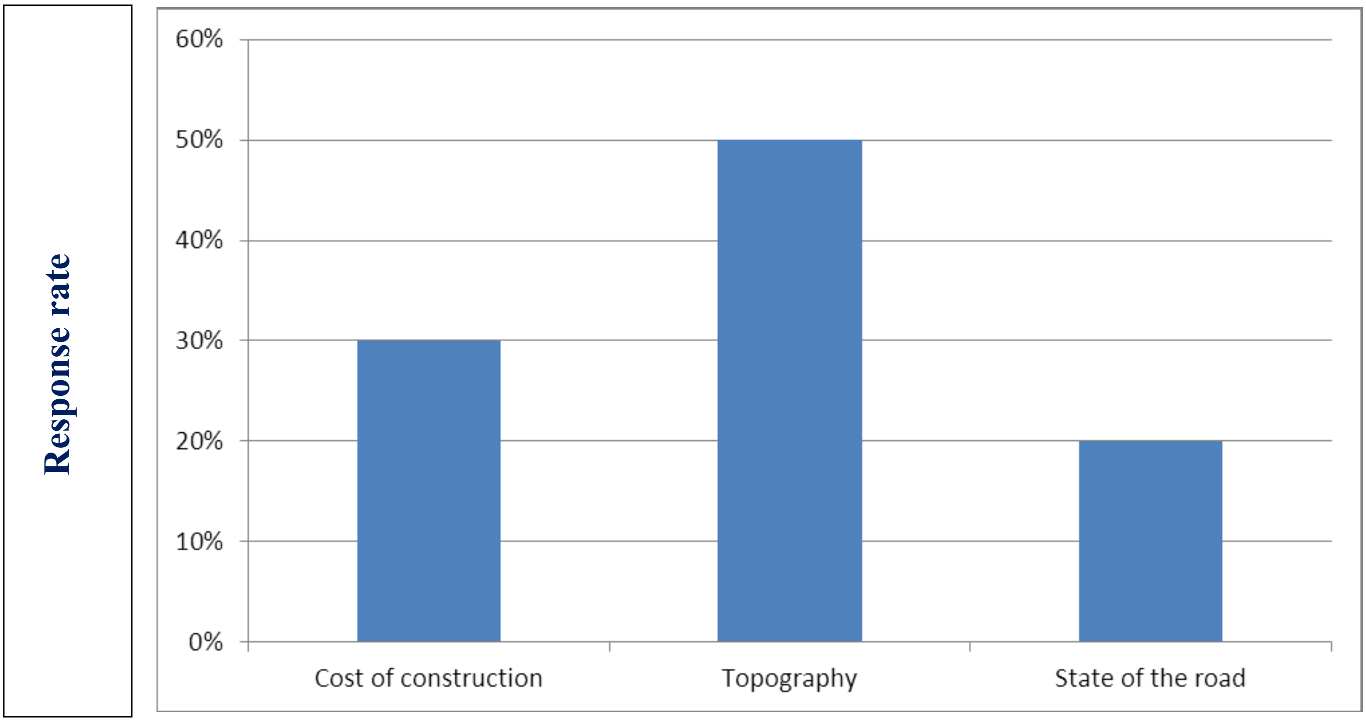


Figure 4.1 Considerations when coming up with a road design.

According to get the information from the engineers and DDM of ERA when design and construction of the road drainage structure it must be consider more on the topography of around the study area based on the location of settlements of road that useful for road user and residents in the way which to control the causes and effects of poor drainage on the road. And also consider the cost of construction and state of the road. It was important to know the critical factors considered when designing a road drainage system. This is because they helped to understand the reasons behind the design of every road show figure 4.1.

Table 4.2 Problems, Causes, effects and actions of the drainage on the road

Problems	Causes	Effects	Solution or action
Poor quality of construction	Lack of improper location of drainage installations	Inefficient planning and performance of measures	Overview of location of existing road drainage facilities in the local area
	Lack of drainage structures	Scouring/eroded shoulder	Properly construct road with all structures
	Number of cross drainage	Over flowing out on road surface	Add necessary crossing drainage at damaged road
construction and design	Lack of drainage capacity/improper design	Water infiltration in cracking which weakening the road	To provide the proper drainage system that increases the life of roads
	Improper depth of drainage installations	Inefficient drainage	Better construction /installation method. Deep drainage
	Limited diameter of pipe or culvert	Insufficient capacity to handle large water volumes	Consideration of the need of locally increased drainage structure dimensions
	Heavy precipitation; flooding	Various kinds of damage	Development and usage of tools to locate vulnerable points and need of action; addition/retrofitting of devices to increase discharge capacity, such as extra culverts, pipes, flushing pipes and subgrade drains

It was important to know the critical factors considered when designing a road drainage system. This is because they helped to understand the reasons behind the design of every road and in this case, *Upper Atbara and Setit Dam Complex Township* and people who use the road show Table 4.2.

4.2.3 Appropriateness of the drainage system

The engineers‟ and consultant indicated that the drainage system provided for *Upper Atbara and Setit Dam Complex Township* and people who use the road.

Drainage was poor and inappropriate. The magnitude of the water from the surrounding the area in which the road is situated was overlooked during design. They also indicated that studies that were carried out before designing the road were not sufficient to satisfactorily ascertain the amount of water that would cross the road at a point in time and therefore the design lacked capacity to adequately drain the runoffs during the rains. However, poor workmanship by the contractor during construction and poor maintenance also contributed to the drainage problems on road. As part of understanding the background of the poor drainage system provisions in the *Upper Atbara and Setit Dam Complex Township* and people who use the road. That lack drainage.

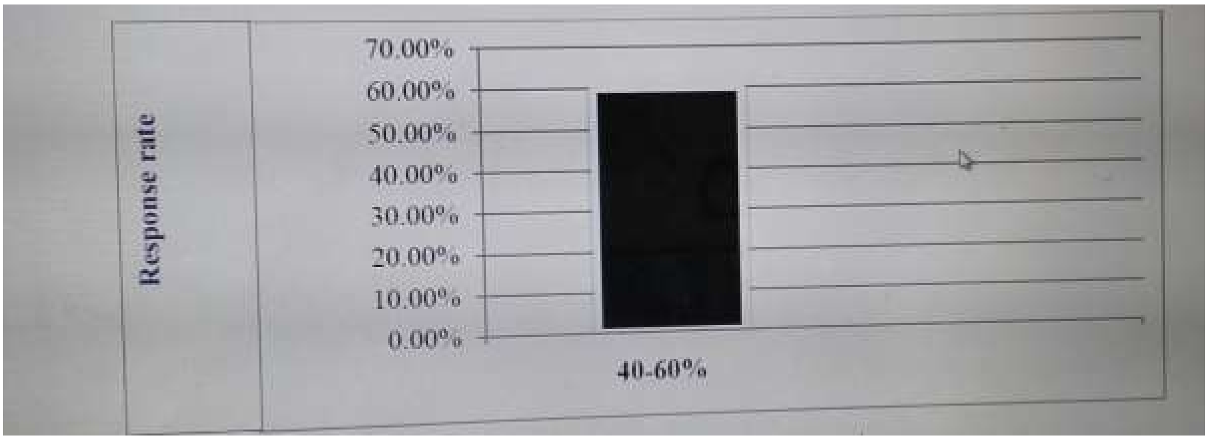


Figure 4.2 Percentage of roads with inadequate drainage system

From Figure 4.2, it can be observed from the project engineers‟ perception, that most of the roads in west region lack sufficient drainage system. Some of the reasons cited were inadequate designs, lack of enough studies to establish the drainage requirements of the road and poor workmanship as a result of reduced road drainage quality. The study also sought to understand whether the washing away of *Upper Atbara and Setit Dam Complex Township* and people who use the road construction was expected; the engineers responded that it was never expected because studies were done before the inception of the road to ascertain the drainage requirements. It was therefore expected that due diligence was observed during the study.

4.2.4 State of the drainage services

The engineers‟ and consultant have carried out a study on the effects of poor drainage system on the surrounding environment. They both agreed that though there was need for redesigning and reconstruction of the drainage system, there was also need to carry out maintenance on the existing drainage facilities to increase their efficiency and effectiveness. They reported that redesigns and reconstruction have been implemented in the future.

4.3 Causes and effects of drainage system on asphalt pavement road that response from road users

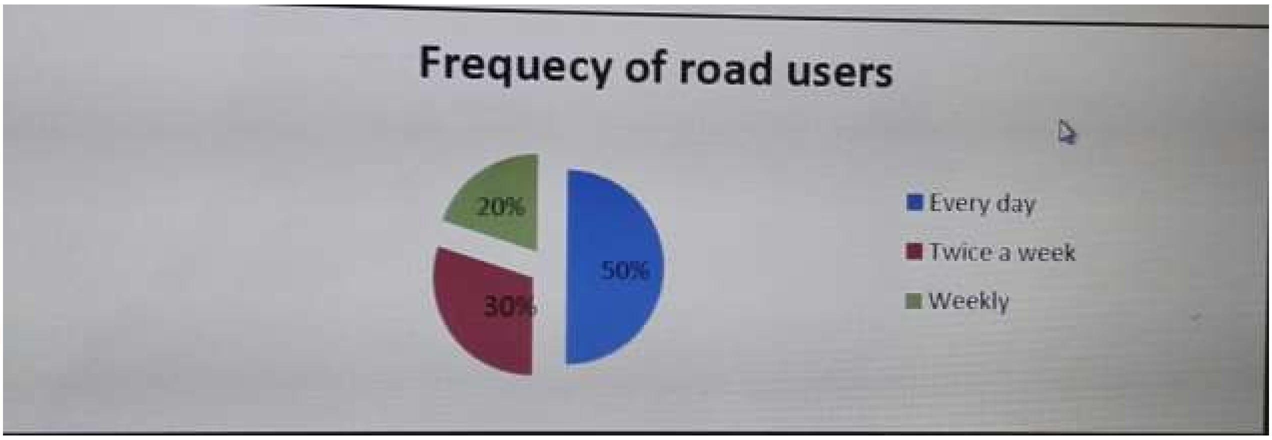


Figure 4.3 Frequency of road usage by road users.

From figure 4.3 A significant proportion of the respondents either use the road every day or twice a week. The data collected shows that 80% of the respondents use the road often. This was important to this study as it showed that the respondents could be relied on to give authentic information to achieve the studies objectives.

The road users were concerned about their safety and the convenience of going through Upper *Atbara and Setit Dam Complex Township* road during the rains. The state of the drainage system compromised their safety as they travelled. Only 20% think the drainage system provided in *Upper Atbara and Setit Dam Complex Township* road is good, whereas, there was none of the respondents who thought the drainage system was very poor that causes the damage of the road eroded, cracking, wash away by over flooding of the water and deposited waste materials on the road.

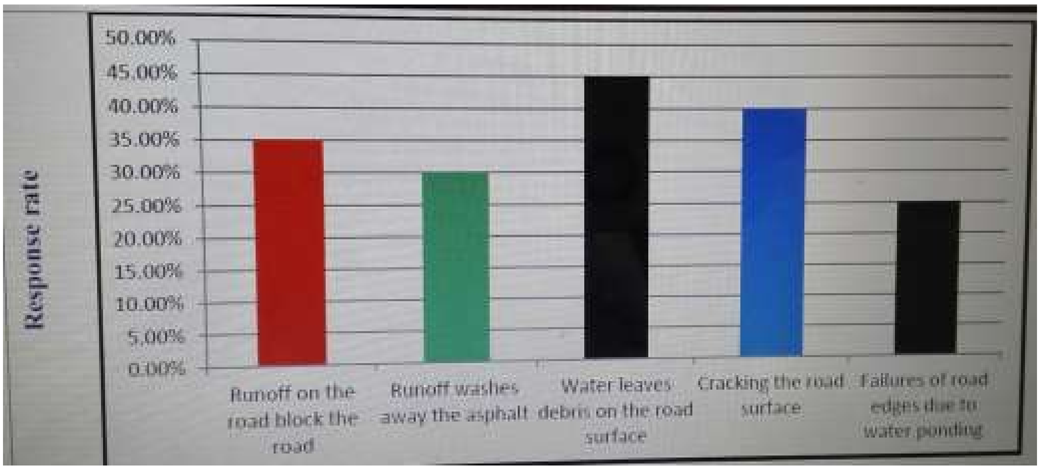


Figure 4.4 Effects of drainage system on the asphalt pavement road.

From figure 4.4 Road users were in consensus when it came to the effects of the poor drainage system on the road. Majority reported that the causes and effects of poor drainage on the road are water leaves debris on the road surface during the rains there by hindering free movements of vehicles on the road. It also washed away the asphalts during the rainy season, therefore totally making it impossible the passage of the road. A significant proportion reported that runoffs on the road block and cracking the through the road and leave debris on the road after the rains; this debris would then hinder movement along the road and therefore inconvenience travelers. The travelers would then become late in their businesses or other engagements.

The causes of flooding are complex. A combination of factors can have an impact on causing flooding and consequences in road drainage systems. According to the clogging of drainage pipes, culverts and ditches by debris flow and fine-grade soil is one of the most import maintenance issues in current drainage systems. Some of the respondents stated that cleaning of drainage pipes, culverts and ditches is not specified at a certain time and is therefore only done when needed. This suggests that it is important to perform operations such as maintenance and cleaning regularly to prevent over flooding of the water on the road.

4.3.1 Level of road users' satisfaction of the drainage system.

From the data given below in figure4.5, there is a clear indication that majority of the road users are not satisfied with the state of drainage system in Upper *Atbara and Setit Dam Complex Township* road. According to understanding from the road users satisfactions the state of the drainage systems are very poor and its affects the road structures, there is need to thus improve on the system in order to obtain road users satisfaction. Road users do not satisfy from the road because asphalt pavement of the roads is affected by drainage system.

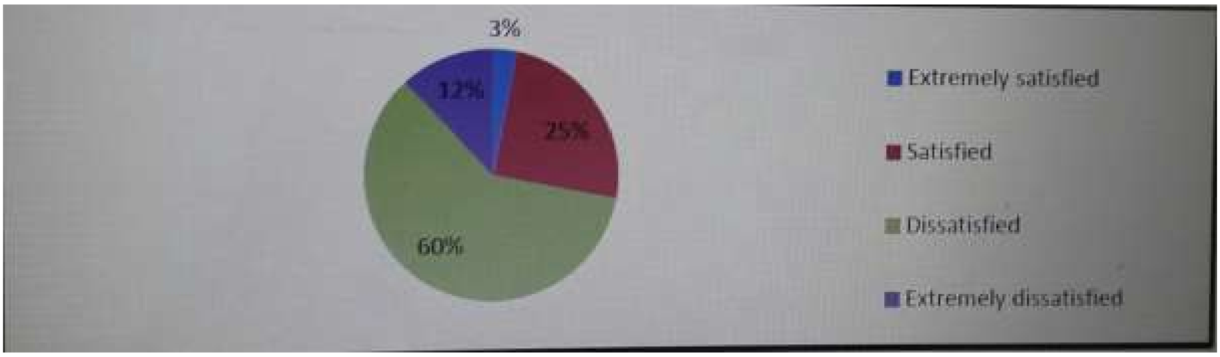


Figure 4.5 Level of road user satisfaction.

4.3.2Causes and effects of drainage system on asphalt road that response from the residents

A good percentage from within 100 meters from the road. According to the data collected 30% come from within a hundred meters from the road and outside the 50 meters mark. This was important because it showed that they could respond to all the issues raised in this study so as to achieve the objectives.

On drainage across the road having inadequate drainage systems, deterioration often begins with the origin of cracks or potholes on the road pavements either at the edges along the drive way which differs by their shapes, configuration, amplitude of loading, movement of traffic and rate of deformation. Figure 4.6 below shows how the residents feel they were affected by the poor drainage in the area. Majority of the respondents reported that runoff had had adverse effects on their road and land. They stated that runoff eroded their land the water that comes from the road there by making the land less productive and affecting the good road satisfactions of the area.

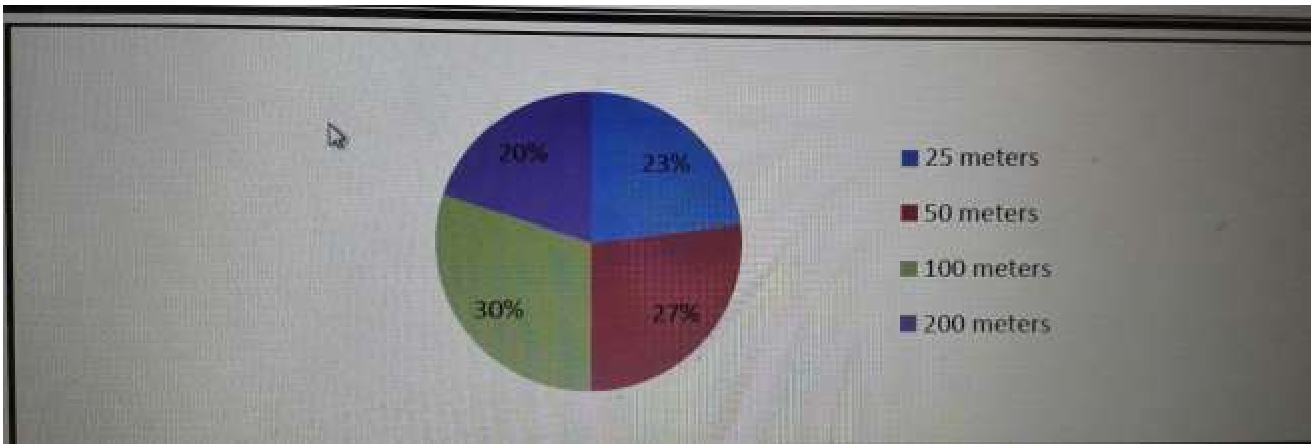


Figure 4.6 proximity of residents

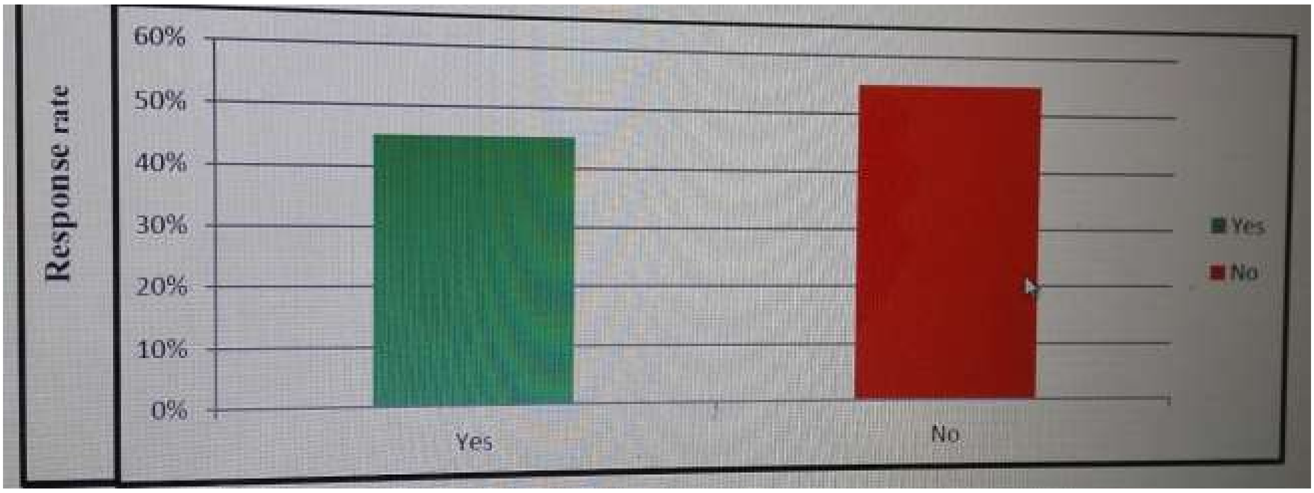


Figure 4.7 Improvement activities.

The data shows in figure4.7 that there have been ongoing activities geared towards the improvement of the drainage system. A greater percentage of the respondents have not observed improvement activities on the road, however, there is also a significant percentage that have observed these activities being carried out. This shows that though there are efforts to improve the drainage system, enough has not yet been done yet. There is therefore need to improve the facilities to an acceptable standard.

4.4 Results from observation and photography

This research project employed both observation and photography as tools for which data would be collected. This involved observation and taking of photographs to show the current state of the drainage system in Upper *Atbara and Setit Dam Complex Township* road. From observation also; a brief description of what was observed would be given with the help of photographs.

4.4.1 Causes and effects of drainage system on asphalt road Surface due to poor drainage that collected from the field with the photography.

From observation, the state of the drainage system in in Upper *Atbara and Setit Dam Complex Township* road is poor. Figure with definitions from the field survey, it was observed that the road surface experienced potholes, cracking, edge damages and accumulation of soil on a large area of road surface as shown below:

Figure 4.8 Accumulation of soils on the road and Edge of the road erosion

Figure 4.9 the side drain was blocked with soil, debris, vegetation, wheel and solid waste.

The existing drain is located on both side of the road. It is open and earth ditch with 1m width and 0.5 to 1 depth. The condition of this drain is very bad. It was full with soil accumulation and refuse dumps. The side drain was blocked with soil, debris, vegetation, wheel and solid waste as shown in above figure. Therefore from these problems the remedies suggests that it is important to perform operations such as maintenance and cleaning regularly to prevent the over flooding of water on the road.

4.5 Investigations of Design and Construction Performs on the study area.

Road drainage system should be designed by analyzing hydrologic parameters of the catchment area. Adequate hydrologic analysis design is significant for road drainage system to pass peak discharge without distraction, destruction the drainage system and property adjoining the road crossing. Moreover, after acceptable hydrologic analysis design proper construction is very important for the road drainage construction to function properly for the proposed purpose.

In general, most of the side drains provided to roads in *Upper Atbara and Setit Dam Complex Township* are earth drains or ditches. Some drains built from bricks, stones or concrete materials are open drains without covers. Others built drains are covered with concrete slab or blocks. Failures of built drains like collapse of bed, side walls and/or covers caused by improper design and construction, settlement or heave may lead to the development of cracks and subsequent failure.

This leads to a situation where preliminary studies that would help the design and construction decisions are not done.

4.5.1 Design and Construction Application at Station 0+30 (road 3)

The condition of the drain and its structures is very poor and getting deteriorated by the passage of time. The drain suffered from low capacity, natural siltation, and absence of inlets, indefinite drainage outlets, and lack of proper maintenance and over and above disposal of solid waste into the crossing culverts. The drain blocked with silt and sand accumulation, debris and vegetation as shown in figure4.10 .It is clear that the drain and culverts being converted to dumpy place and subsequently obstructed the water flow.

Figure 4.10 Damaged Culverts at Station *0+30 (road 3)*

Problems associated with slab culvert location and construction as shown on Figure 4.10 on *Upper Atbara and Setit Dam Complex Township* can be alleviated by conducting a proper site investigation, paying attention to geomorphic indicators, knowing road template design needs, and understanding how streams and watersheds function. A poor location of the slab culvert on road at station 0+30 as shown on Figure 4.10 makes to be susceptible to failure. Selection of good drainage system site must involve many disciplines that include preliminary engineering, hydrology & hydraulics, geomorphologic concerns, roadway alignment, and environmental & geological concerns in order to make the structure sustainable after In order to serve a road properly for the road users, drainage system should be constructed by considering where the location of the crossing in the watershed is required and how can water, sediment, and wood be transported at that location and how is the catchment configured. The proper construction practice is important after proper design for drainage system to function properly for the road users as intended. Only proper design by itself does not make the drainage structure to serve properly up to its design life but also proper construction practice must be carried out by appropriate personnel according to the design.

4.5.2 Design and Construction Application at Station 0+400(road 2)

On *Upper Atbara and Setit Dam Complex Township* at station 0+400, the surface of the road on the downstream side was eroded by overtopping flood. Initially, one rows of pipe culvert was constructed. The one rows of pipe culvert could not accommodate the peak discharge during the rainy season after constructed because the active channel width is greater than the span of the culvert. In order to mitigate the overtopping problem two row pipe that has one-meter internal diameter on the left side and the right side was important additionally to mitigate the overtopping problem of the peak flood during the rainy season.

Figure 4.11 initially constructed one Rows of Pipe Culvert at Station 0+400

The main cause for the pavement erosion was the lack of detail flood information during rainy season and poor drainage design. The construction of the culvert was carried out without some rational and scs calculation of the expected flow. The hydrologic analysis is required to estimate peak discharge that is a major component of the overall design effort. In general, drainage crossings must be designed to pass the appropriate storm flows and debris or to survive overtopping.

Proper design and construction of drainage structures are dynamic components for road structure to function without traffic disturbance. Appropriate hydrological analysis of the catchment area where the drainage system would be constructed and appropriate drainage parameters should be determined.

4.5.3 Design and Construction Application at Station 0+85(road38)

On *Upper Atbara and Setit Dam Complex Township* at station 0+85, the surface of the road on the downstream side was eroded by overtopping flood. Initially, one rows of pipe culvert was constructed. The one rows of pipe culvert could not accommodate the peak discharge during the rainy season after constructed because the active channel width is greater than the span of the culvert. In order to mitigate the overtopping problem two row pipe that has one-meter internal diameter on the left side and the right side was important additionally to mitigate the overtopping problem of the peak flood during the rainy season. The construction of the culvert was carried out without some rational and scs calculation of the expected flow i.e. the construction was carried out by trial and error rather than considering hydrological analysis calculating parameters during the design stage. The hydrologic analysis is required to estimate peak discharge that is a major component of the overall design effort. In general, drainage crossings must be designed to pass the appropriate storm flows and debris or to survive overtopping.

Proper design and construction of drainage structures are dynamic components for road structure to function without traffic disturbance. Appropriate hydrological analysis of the catchment area where the drainage system would be constructed and appropriate drainage parameters should be determined. Culverts conveying cross drainage flow from outside should be located on the natural drainage path of the flow. When the natural drainage path of the flow is a wide overland flow area, the designer should evaluate the need for multiple culverts in order to prevent concentrated flow at a single location. The proposed cross culvert must be aligned with upstream and downstream channels. The designer must analyze the existing flow conditions of the areas located upstream and immediately downstream of proposed cross culverts. Land use conditions in upstream and downstream areas should be clearly document ted in the Drainage Report, including photo documentation of the areas, if possible. This documentation of the existing conditions on the adjacent drainage areas, prior to construction, could provide useful information for sub (DDM 2011).

Figure 4.12 initially constructed one Rows of Pipe Culvert at Station 0+85

Review is the appraisal of the design and the check list is a very imperative. It's hoped that this road design review would be use full to those engaged upon the design review for the road projects it is the necessary to emphasize the current evaluation of the documents and provided comment at any time to improve can be made in the future. Also the main purpose of review is to check and to ensure the design deliverables consists of the drawing. After sizing a drainage facility using a flood (and the hydrograph) corresponding to the design frequency, it is necessary to review this proposed facility with a base discharge. This is done to insure that there are no unexpected flood hazards inherent in the proposed facility. The review (check) flood shall be at least the 50-100-year event, or as provided.

4.6 Results analysis

4.6.1 Descriptions of Watershed Area Problems in design

Descriptions" of the catchment area for existing drainage systems is tabulated in table 4.3 that are determined by digital elevation model.

Table 4.3 Descriptions of Existing Drainage System.

S.NO	Existing drainage system	
	Station	Area(ha)
1	*0+30 (road 3)*	889
2	*0+400(road 2)*	902
3	*0+85(road38)*	723

4.6.2 Calculation of Catchment Characteristics

4.6.2.1 Catchment Characteristics at Station *0+30 (road 3)* Drainage system

After the watershed areas and properties were described, the land use coverage, soil type and curve number were computed. From the Soils Map and field survey approximately about 70% of the catchment is covered by grass, and the remaining 30% is covered by small trees, and scarcely distributed trees. As presented in Appendix B on Table 16, the runoff curve number for pasture, Fair condition and covered land, without conservation treatment average hydrologic soil group B is

75 and hydrologic soil group C is 83.5 Therefore, average runoff curve number is:

(0.70x75) + (0.30x83.5)
= 77.55 but the nearest CN value is 80.

i. Runoff Curve Number

As per **Appendix B** in Table 11, hydrological characteristics of soil groups, the region is a wet antecedent moisture condition (AMC) region. From **Appendix B** in Table 1,
CN80avg = CN91wet.

ii. 24-hour rainfall depth

Since the drainage system at station 0+30 is culvert that has diameter greater than 2-meter as shown on the 24-hour rainfall depth for years 25 and 50 are 118mm for design and 132mm for checking (**See Appendix B in Table 13**).

iii. Direct runoff depth

Direct runoff (Q) is determined from **Appendix A** on Figure 2, by using rainfall depth of 118mm for design, 132mm for checking and CN of 91. Therefore,
S = 25.4((1000/91)-10) = 25.12mm

Ia = 0.2s = 0.2*25.12 = 5.02mm

Q25= (118-5.02) ^2/ ((118-5.02) +25.12)) =92mm and

Q50= (132-5.02) ^2/ ((132-5.02) +25.12)) =106mm.

iv. Slope of the watershed

The average slope of the overland flow is approximated 2% (0.02) by referring from topography and field reconnaissance. Since the topographical map was produced 24-years ago, there is radical change between the existing topography and the topography from the topographical map. Hence, I used the slope that I obtained from field reconnaissance.

Table 4.4 summary of the watershed properties calculations at station *0+30 (road 3)*

1	Curve number(CN)	91wet
2	Precipitation(p) of 25 years	118mm
3	Precipitation(p) of 50 years	132mm
4	Potential max retention(s)	25.12mm
5	Initial abstraction(Ia)	5.02mm
6	Direct runoff 25 year(Q25)	92mm
7	Direct runoff 50 year(Q50)	106mm
8	Slope of the watershed	0.02

v. Time of concentration

A. sheet flow

The sheet flow occurs up to 100 meters. Sheet flow, natural range, slope of 0.02 m/m, and length of 150m and from Appendix B, Table 2, Manning‟s roughness coefficient is 0.13. The 2-year, 24-hour rainfall depth is determined from **Appendix A** in Figure 3 **or Appendix B** in Table 13 to be 65mm. Hence, from Equation (2.12), travel time for sheet flow is determined as:

Tt = [0.091(nL) ^ 0.8/ (P2) ^0.5S^0.4]

= [0.091(0.13*150) ^0.8 / (65^0.5*0.02^0.4)

= 0.979/1.686

=0.58hr

b. Shallow Concentrated Flow

For shallow concentrated flow, unpaved watershed slope is approximated 0.02m/m and length from topography map is 1000m. From equation (3.12), V= 4.9178(S) ^ 0.5 for unpaved watershed. V= 4.9178(0.02) ^0.5 = 0.70m/sec. From equation (2.9), travel-time is determined as:

Tt = L/ (3600V)

= 1000/ (3600X0.70)

= **0.39hr.**

c. Channel Flow

For channel flow, natural stream channel, curving with hoes and ponds, slope is 0.01m/m, and length is 1100m. By direct measuring the average bottom width of the stream channel is 2.75m, side slopes are 1V:1.6H, 25-year storm depth is observed from flood mark and measured to be 1.25m. From **Appendix B** in Table 2, Manning's roughness coefficient for fallow (no residue) channels is 0.050.
Cross-sectional flow area (A) = by+zx^2
Where b= width, z= depth, y vertical slope and x is horizontal slope
= (2.75 x 1) + 1.25(1.6) ^2
= 5.95m2
Wetted perimeter (Pw) = b+2x (1+z^2) ^0.5
= 2.75+2x1.6 (1+1.25^2)^0.5
= 7.87m

Hydraulic radius (R) = A/P
= 5.95/7.87
= 0.756m
From Equation (2.14), V = (R2/3S1/2)/n
V = (0.756)2/3*(0.01)1/2/0.05 = (0.829*0.1)/0.05
= 1.658m/sec.
From equation (2.9), Tt = L/ (3600V)
= 1100/ (3600*1.658)
= 0.18hr
From equation (2.15)
Total Time of Concentration (Tc) is (0.58 + 0.39+ 0.18) = 1.15 hr.

Table 4.5 summary of time concentration at station *0+30 (road 3)*.

1	**sheet flow**	length	150m
		Manning roughness coefficients(n)	0.13
		Slope	0.02
		Precipitation of 2 year(p2)	65mm
		Travel time	0.58hr
2	**shallow concentrated flow**	length	1000m
		Slope	0.02
		unpaved watershed	0.70m/sec
		Travel time	0.39hr
3	**channel flow**	length	1100
		Slope	0.01
		width of the stream channel(b)	2.75m
		Depth of the stream channel(z)	1.25m
		side slope	1V:1.6H
		Manning roughness coefficients(n)	0.05
		Cross section area	5.95m^2
		Wetted perimeter	7.87m
		Hydraulic radius®	0.756m
		Velocity	1.658M^3
		Travel time	0.18hr
4	**Total of time concentration**		1.15hr

Using the time concentration and the year to find intensity (I) from appendix A figure 1 and Runoff Coefficient (c) based on the soil group find from appendix B table 12

Unit peak discharge (Qu25) = 0.00278*C*I*A= 0.00278*0.13*60*8.89 = 0.193

(Qu50) = 0.00278*C*I*A= 0.00278*0.13*68*8.89 = 0.218

Peak discharge (Qp25) = Qu25*Q25*A → Qp25 = 0.193*92*8.89 = 157.85

(Qp50) = Qu50*Q50*A → Qp50 = 0.218*106*8.89 = 205.88

4.6.2.2 Catchment **Characteristic** *at Station0+400(road 2) Drainage System*

After the watershed areas description, watershed properties like the land use coverage, soil type and curve number are computed. From the Soils Map of Ethiopia and from the field survey approximately about 70% of the catchment is cultivated, and the remaining 30% is covered by small trees, shrubs, and scarcely distributed trees. From **Appendix B** on Table 16, the runoff curve number for pasture, Fair condition and cultivated land, without conservation treatment average hydrologic soil group B is 75 and hydrologic soil group C is 83.5. Therefore, average runoff curve number is:

(0.70x75) + (0.30x83.5)

= 77.55 but the nearest CN value is 80.

i. Runoff Curve Number

As per **Appendix B** in Table 11, hydrological characteristics of soil groups, the region is a wet antecedent moisture condition (AMC) region. From **Appendix B** in Table 1,

CN80avg = CN91wet.

ii. 24-hour rainfall depth

Since the drainage system at station 24+200 is culvert that has diameter greater than 2-meter as shown on 24-hour rainfall depth for years 10 and 25 are 98mm for design and 118mm for checking (**See Appendix B in Table 13**).

iii. Direct runoff depth

Direct runoff (Q) is determined from **Appendix A** on Figure 2, by using rainfall depth of 98mm for design, 132mm for checking and CN of 91. Therefore,

S = 25.4((1000/91)-10) = 25.12mm

Ia = 0.2s =0.2*25.12 = 5.02mm

Q_{10}= (98-5.02) ^2/ (98-5.02) +25.12 =73mm and

Q_{25}= (118-5.02) ^2/ (118-5.02) +25.12 =92mm

iv. Slope of the watershed

The average slope of the overland flow is approximated 2% (0.02) by referring from topography and field reconnaissance. Since the topographical map was produced 24-years ago, there is radical change between the existing topography and the topography from the topographical map. Hence, I used the slope that I obtained from field reconnaissance.

Table 4.6 Summaries of the watershed properties calculated at station *0+400(road 2)*

1	Curve number(CN)	91wet
2	Precipitation(p) of 10 years	98mm
3	Precipitation(p) of 25 years	118mm
4	Potential max retention(s)	25.12mm
5	Initial abstraction(Ia)	5.02mm
6	Direct runoff 10 year(Q10)	73mm
7	Direct runoff 25 year(Q25)	92mm
8	Slope of the watershed	0.02

V. Time of concentration

A. sheet flow

The sheet flow occurs up to 50meters. Sheet flow, natural range, slope of 0.02 m/m, and length of 100m and from Appendix B, Table 2, Manning's roughness coefficient is 0.13. The 2-year, 24-hour rainfall depth is determined from **Appendix A** in Figure 3 **or Appendix B** in Table 13 to be 65mm. Hence, from Equation (3.12), travel time for sheet flow is determined as:

Tt = [0.091(nL)0.8/ (P2)0.5S0.4]

= [0.091(0.13*100)0.8 / (650.5*0.020.4)

= 0.708/1.686

0.42hr.

B. Shallow Concentrated Flow

For shallow concentrated flow, unpaved watershed slope is approximated 0.02m/m and length from topography map is 900m. From equation (3.12), V= 4.9178(S) 0.5 for unpaved watershed. V=4.9178(0.02)0.5 =0.70m/sec. From equation (3.9), travel-time is determined as:

Tt = L/ (3600V)

= 900/ (3600X0.70)

= **0.36hr.**

C. Channel Flow

For channel flow, natural stream channel, curving with hoes and ponds, slope is 0.01m/m, and length is 1000m. By direct measuring the average bottom width of

the stream channel is 2.5m, side slopes are 1V:1.5H, 25-year storm depth is observed from flood mark and measured to be 1.5m. From **Appendix B** in Table 2, Manning's roughness coefficient for fallow (no residue) channels is 0.050.
Cross-sectional flow area (A) = by+zx^2
Where b= width, z= depth, y vertical slope and x is horizontal slope
= (2.5 x 1) + 1.5(1.52)
= 5.875m2
Wetted perimeter (Pw) = b+2x (1+z2)^0.5
= 2.5+2x1.5 (1+1.52)^0.5
= 7.91m
Hydraulic radius (R) = A/P
= 5.875/7.91
= 0.743m
From Equation (3.14), V = (R2/3S1/2)/n
V = (0.743)2/3*(0.01)1/2/0.05 = 1.64m/sec.
From equation (3.9), Tt = L/ (3600V)
= 1000/ (3600*1.64) = **0.17hr.**
From equation (3.15)
Total Time of Concentration (Tc) is (0.42 + 0.36+ 0.17) = 0.95 hr.
Table 4.7Summary of time concentration at station *0+400(road 2)*

1	**σηεετ φλοω**	λενγτη	100μ
		Μαννινγ ρουγηνεσσχοεφφιχιεντσ(ν)	0.13
		Σλοπε	0.02
		Πρεχιπιτατιον οφ 2 ψεαρ(π2)	65μμ
		Τραϖελ τιμε	0.42ηρ
2	**σηαλλοω χονχεντρατεδ φλοω**	λενγτη	900μ
		Σλοπε	0.02
		υνπαϖεδ ωατερσηεδ	0.70μ/σεχ
		Τραϖελ τιμε	0.36ηρ
3	**χηαννελ φλοω**	λενγτη	1000
		Σλοπε	0.01
		ωιδτη οφ τηε στρεαμ χηαννελ(β)	2.5μ
		Δεπτη οφ τηε στρεαμ χηαννελ(ζ)	1.5μ
		σιδε σλοπε	1ς:1.5H
		Μαννινγ ρουγηνεσσ χοεφφιχιεντσ(ν)	0.05
		Χροσσ σεχτιον αρεα	5.875μ⊥2
		Ωεττεδ περιμετερ	7.91μ
		Ηψδραυλιχ ραδιυσ□	0.743μ
		ςελοχιτψ	1.645Μ⊥3
		Τραϖελ τιμε	0.17ηρ
4	**Τοταλ οφ τιμε χονχεντρατιον**		0.95ηρ

Using the time concentration and the year to find intensity from appendix A figure1 and Runoff Coefficient(c) based on the soil group to find the from appendix B table 12

Unit peak discharge (Qu10) = 0.00278*C*I*A= 0.00278*0.13*58*9.02 = 0.189

(Qu25) = 0.00278*C*I*A= 0.00278*0.13*70*9.02 = 0.228

Peak discharge (Qp10) = Qu*Q*A → Qp10 = 0.189*73*9.02 = 124.500

(Qp25) = Qu*Q*A → Qp25 = 0.261 *92*9.02 = 189.359

By the same procedures, catchment parameters of the rest stations are

determined.

4.7 Peak Discharge Computation

4.7.1 Peak Discharge at Station 0+85(road38) Drainage System

After the watershed areas description, watershed properties like the land use coverage, soil type and curve number are computed. From the Soils Map of Ethiopia and from the field survey approximately about 70% of the catchment is cultivated, and the remaining 30% is covered by small trees, shrubs, and scarcely distributed trees. From **Appendix B** on Table 16, the runoff curve number for pasture, Fair condition and cultivated land, without conservation treatment average hydrologic soil group B is 75 and hydrologic soil group C is 83.5. Therefore, average runoff curve number is:

(0.70x75) + (0.30x83.5)

= 77.55 but the nearest CN value is 80.

i. Runoff Curve Number

As per **Appendix B** in Table 11, hydrological characteristics of soil groups, the region is a wet antecedent moisture condition (AMC) region. From **Appendix B** in Table 1,

CN80avg = CN91wet.

ii. 24-hour rainfall depth

Since the drainage system at station 0+85(road38) is culvert that has diameter greater than 2-meter as shown on 24-hour rainfall depth for years 10 and 25 are 98mm for design and 118mm for checking (**See Appendix B in Table 13**).

iii. Direct runoff depth

Direct runoff (Q) is determined from **Appendix A** on Figure 2, by using rainfall depth of 98mm for design, 132mm for checking and CN of 91. Therefore,

S = 25.4((1000/91)-10) = 25.12mm

Ia = 0.2s =0.2*25.12 = 5.02mm

Q25= (118-5.02) ^2/ ((118-5.02) +25.12)) =90mm and

Q50= (132-5.02) ^2/ ((132-5.02) +25.12)) =105mm.

iv. Slope of the watershed

The average slope of the overland flow is approximated 2% (0.02) by referring from topography and field reconnaissance. Since the topographical map was produced 24-years ago, there is radical change between the existing topography and the topography from the topographical map. Hence, I used the slope that I obtained from field reconnaissance.

v. Time of concentration

A. sheet flow

The sheet flow occurs up to 100 meters. Sheet flow, natural range, slope of 0.02 m/m, and length of 150m and from Appendix B, Table 2, Manning‟s roughness coefficient is 0.13. The 2-year, 24-hour rainfall depth is determined from **Appendix A** in Figure 3 **or Appendix B** in Table 13 to be 65mm. Hence, from Equation (2.12), travel time for sheet flow is determined as:

Tt = [0.091(nL) ^ 0.8/ (P2) ^0.5S^0.4]

= [0.091(0.13*150) ^0.8 / (65^0.5*0.02^0.4)

= 0.979/1.686

=0.25 hr

b. Shallow Concentrated Flow

For shallow concentrated flow, unpaved watershed slope is approximated 0.02m/m and length from topography map is 1000m. From equation (3.12), V= 4.9178(S) ^ 0.5 for unpaved watershed. V= 4.9178(0.02) ^0.5 = 0.70m/sec. From equation (2.9), travel-time is determined as:

Tt = L/ (3600V)

= 1000/ (3600X0.70)

= **0.39hr.**

c. Channel Flow

For channel flow, natural stream channel, curving with hoes and ponds, slope is 0.01m/m, and length is 1100m. By direct measuring the average bottom width of the stream channel is 2.75m, side slopes are 1V:1.6H, 25-year storm depth is observed from flood mark and measured to be 1.25m. From **Appendix B** in Table 2, Manning's roughness coefficient for fallow (no residue) channels is 0.050.

Cross-sectional flow area (A) = by+zx^2

Where b= width, z= depth, y vertical slope and x is horizontal slope

= (2.75 x 1) + 1.25(1.6) ^2

= 5.95m2

Wetted perimeter (Pw) = b+2x (1+z^2) ^0.5

= 2.75+2x1.6 (1+1.25^2)^0.5

= 7.87m

Hydraulic radius (R) = A/P
= 5.95/7.87
= 0.756m
From Equation (2.14), V = (R2/3S1/2)/n
V = (0.756)2/3*(0.01)1/2/0.05 = (0.829*0.1)/0.05
= 1.658m/sec.
From equation (2.9), Tt = L/ (3600V)
= 1100/ (3600*1.658)
= 0.18hr
From equation (2.15)
Total Time of Concentration (Tc) is (0.25 + 0.39+ 0.18) = 0.82 hr.

Using the time concentration and the year to find intensity from appendix A figure1 and Runoff Coefficient(c) based on the soil group to find the from appendix B table 12
Unit peak discharge (Qu10) = 0.00278*C*I*A= 0.00278*0.13*58*9.02 = 0.209
(Qu25) = 0.00278*C*I*A= 0.00278*0.13*70*9.02 = 0.235
Peak discharge (Qp10) = Qu*Q*A → Qp10 = 0.189*73*9.02 = 135.996
(Qp25) = Qu*Q*A → Qp25 = 0.261 *92*9.02 = 178.359

4.8 Existing culvert design:

general characteristic for culverts design show in the tables below:

Table 4.8: Catchment Parameters for Design and Check (Station *0+30(road3)*

Parameters of Design and Review	Design data	Review data
Return Periods (years)	25	50
Time of Concentration (hr)	1.15	1.15
Curve Number (CN)	91	91
Potential Maximum Retention (mm)	25.12	25.12
Initial Abstraction Ia	5.02	5.02
Design Storm (24-hr maximum rainfall)	118	132
Ia/P	0.043	0.038
Direct Runoff (mm)	92	106
Unit Peak Discharge (m3/s/km2/mm)	0.193	0.218
Peak Discharge (m3/sec)	157.85	205.88

Table 4.9: Catchment Characteristics for Design and Check (Station *0+400(road2*)

Parameters of Design and Review	Design data	Review data
Return Periods (years)	10	25
Time of Concentration (hours	0.95	0.95
Curve Number (CN)	91	91
Potential Maximum	25.12	25.12
Retention (mm) Initial Abstraction Ia (mm)	5.02	5.02
Design Storm (24-hr maximum rainfall)	98	118
Ia/P	0.051	0.043
Direct Runoff (mm)	73	92
Unit Peak Discharge (m3/s/km2/mm)	0.189	0.228
Peak Discharge (m3/sec)	124.500	189.359

Table 4.10: Catchment Characteristics for Design and Check at Station *0+85(road38*)

Parameters of Design and Review	Design data	Review data
Return Periods (years)	20	50
Time of Concentration (hours)	0.82	0.82
Curve Number (CN)	91	91
Potential Maximum Retention (mm)	25.12	25.12
Initial Abstraction Ia (mm)	5.02	5.02
Design Storm (24-hr maximum rainfall)	118	132
Ia/P	0.045	0.038

Direct Runoff (mm)	90	105
Unit Peak Discharge (m3/s/km2/mm	0.209	0.235
Peak Discharge (m3/sec)	135.996	178.400

4.9 Analysis design:

On the above tables the design peak discharge calculated and the review peak discharge calculated of the return period is not equal. From this the road around this is damaged by over flooding of the water on the road because the calculated peak discharge for the design was less than the calculated peak discharge for the review at station, 0+30(road3), 0+85(road38) and 0+400(road2)the difference between them are: 48.03 , 64.859 and 42.404 values. Therefore before the culverts are constructing the design and the review data must be checked. Because based on these values the more volume of runoff is very high on the culvert stations. Initially, one rows of pipe culvert was constructed. The one rows of pipe culvert could not accommodate the peak discharge during the rainy season after constructed because the active channel width is greater than the span of the culvert. In order to mitigate the overtopping problem two row pipe that has one-meter internal diameter on the left side and the right side was important additionally to mitigate the overtopping problem of the peak flood during the rainy season. Always when its design the road it must be follow the drainage design manual. A flood event larger than the specified review flood might be used for analysis to ensure the safety of the drainage structure and downstream development.

The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to the design of drainage structures. Errors in the estimates would result in a structure that is either undersized and causes more drainage problems or oversized road at station 0+30(road3), 0+85(road38) and 0+400(road2), the surface of the road on the downstream side was eroded by overtopping flood. Therefore when construct the road drainage it consider hydraulic analysis. Also maintenance and cleaning of the block drainage system are important.

4.10 comparison between new culverts and old culverts:

They are many different between culverts as show in the table below:

4.11 culverts dimension:

4.11.1 Station 0+400

4.11.1.1 design data :

from design:

Q = 0.189 m^3/sec

S = 0.02

n =0.03

Form manning's equation:

Q =((1/n)*A*(R)^2/3*(S)^1/2)

R = A/P

Type of culvert is pipe culvert

A = π r^2

P = 2π r

0.189 = ((π r^2/n)*(π r^2/2π r)^2/3*(0.02)^1/2)

0.189 = 9.3 r^2.67

r = 0.23 m

To calculate velocity from manning's equation:

V =((1/n)*(R^2/3)*(S^1/2))

A = π*0.23^2 = 0.166 m^2

P = 2π*.23 =1.45 m

R = 0.166/1.45 = 0.11 m

V = ((1/0.03)*(0.11^2/3)*(0.02^1/2))

$V = 1.2$ m/sec

4.11.2 Station 0+30

4.11.2.1 design data :

$Q = 0.193$ m^3/sec

$S = 0.02$

$n = 0.03$

Form manning's equation:

$Q =((1/n)*A*(R)^{2/3}*(S)^{1/2})$

$R = A/P$

Type of culvert is pipe culvert

$A = \pi r^2$

$P = 2\pi r$

$0.193 = ((\pi r^2/n)*(\pi r^2/2\pi r)^{2/3}*(0.02)^{1/2})$

$0.193 = 9.3 r^{2.67}$

$r = 0.23$ m

To calculate velocity from manning's equation:

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

$A = \pi*0.23^2 = 0.166$ m^2

$P = 2\pi*.23 =1.45$ m

$R = 0.166/1.45 = 0.11$ m

$V = ((1/0.03)*(0.11^{2/3})*(0.02^{1/2}))$

$V = 1.2$ m/sec

4.11.2.2 review data :

$Q = 0.218\ m^3/sec$

$S = 0.02$

$n = 0.03$

Form manning‘s equation:

Q =((1/n)*A*(R)^2/3*(S)^1/2)

R = A/P

Type of culvert is pipe culvert

A = π r^2

P = 2π r

0.218 = ((π r^2/n)*(π r^2/2π r)^2/3*(0.02)^1/2)

0.218 = 9.3 r^2.67

r = 0.24 m

To calculate velocity from manning‘s equation:

V =((1/n)*(R^2/3)*(S^1/2))

A = π*0.24^2 = 0.181 m^2

P = 2π*.24 =1.51 m

R = 0.181/1.51 = 0.12 m

V = ((1/0.03)*(0.12^2/3)*(0.02^1/2))

V = 1.3 m/sec

$Qd < Qr$

4.11.3 Station 0+85

4.11.3.1 design data :

$Q = 0.209\ m^3/sec$

$S = 0.02$

$n = 0.03$

Form manning's equation:

Q =((1/n)*A*(R)^2/3*(S)^1/2)

R = A/P

Type of culvert is pipe culvert

A = π r^2

P = 2π r

0.209 = ((π r^2/n)*(π r^2/2π r)^2/3*(0.02)^1/2)

0.209 = 9.3 r^2.67

r = 0.239 m

To calculate velocity from manning's equation:

V =((1/n)*(R^2/3)*(S^1/2))

A = π*0.239^2 = 0.179 m^2

P = 2π*.239 =1. 5 m

R = 0.179/1. 5 = 0.12 m

V = ((1/0.03)*(0.12^2/3)*(0.02^1/2))

V = 1.3 m/sec

4.11.3.2 review data :

Q = 0.235 m^3/sec

S = 0.02

n =0.03

Form manning‘s equation:

Q =((1/n)*A*(R)^2/3*(S)^1/2)

R = A/P

Type of culvert is pipe culvert

A = π r^2

P = 2π r

0.235 = ((π r^2/n)*(π r^2/2π r)^2/3*(0.02)^1/2)

0.235 = 9.3 r^2.67

r = 0.27 m

To calculate velocity from manning‘s equation:

V =((1/n)*(R^2/3)*(S^1/2))

A = π*0.27^2 = 0.229 m^2

P = 2π*.24 =1.70 m

R = 0.229/1.70 = 0.135 m

V = ((1/0.03)*(0.135^2/3)*(0.02^1/2))

V = 1.4 m/sec

Qd < Qr

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

Conclusions are for warded from the investigations of the results of the research and Recommendations are provided based on the findings of the results of the research.

5.1 Conclusions

1. The design peak discharge calculated and the review peak discharge calculated of the return period is not equal. From this the road around this is damaged by over flooding of the water on the road because the calculated peak discharge for the design were less than the calculated peak discharge for the review at station, 0+30(road3), 0+85(road38) and 0+400(road2)the difference between them are: 48.03 , 64.859 and 42.404 values. Therefore before the culverts are constructing the design and the review data must be checked always when its design the road, it must be the design peak discharge is greater than the review peak discharge to control the floods that over follow on the road.

2. The most common causes of road drainage problem were found related to improper road geometry, insufficient capacity of drainage structures, poor construction, and lack of proper maintenance. There was a general feeling that the type of drainage system is not adequate .Also the drain suffered from low capacity, soil accumulation, absence of inlets, lack of proper maintenance and disposal of solid waste into the drain and the crossing culverts. For these problems remedies suggests that it is important to perform operations such as when its design and construct the road drainage it must be follow the drainage design manual. Maintenance and cleaning regularly the drainage structures and waste solids remove to prevent these problems.

5.2 Recommendations

1. The following are the recommendations are involved on study area:
A hydrologic analysis is prerequisite to identifying flood hazard areas and determining those locations where construction and maintenance would be unusually expensive or hazardous. Since many levels of government plan, design, and construct highway and water resource projects that might affect each other, interagency coordination is desirable and often necessary. In addition, agencies can share data and experiences within project areas to assist in the completion of accurate hydrologic analysis.

2. Improvement of drainage facilities through maintenance redesign and reconstruction, to improve the role of poor workmanship in the construction of drainage and roads and provision of proper connections or integrations between the road network and drainage network systems is required always when construction of the road.

3. The designer and contractor should follow the minimum requirement set by ERA regarding to the drainage structure, size, length and alignments of road drainage structure so as to prevent the impact of poor drainage on the road pavement. Therefore selection of good drainage system site must involve many disciplines that include preliminary engineering, hydrology & hydraulics, geomorphologic concerns, roadway alignment, and environmental & geological concerns in order to make the structure sustainable and a program for cleaning out the surface drainage system is essential.

4. For future study, it is recommended that detailed in drainage structure investigation should be approved out on related project; experience with quality of man work and construction of methods in accordance with ERA DDM Standard Specifications in order to avoid future problem of the drainage and need to clean out open drains and culverts by using manpower or machine.

REFERENCES

REFERENCES

[1] Achleitner S. (2006). Modular conceptual modeling in urban drainage - development and application of city drain. PhD thesis. Unit of Environmental Engineering, Institute of infrastructure, University of Innsbruck, Faculty of Civil Engineering Science, Innsbruck.

[2] American Association of State Highway and Transportation Officials (AASHTO) Drainage Manual. AASHTO Task Force on Hydraulics and Hydrology (1990).

[3] Aitken, A.P., (1975), "Hydrologic Investigation and Design of Urban Storm water Drainage Systems", Australian Water Resources Council, Technical Paper No.10, Canberra, Australia.

[4] Arizona Department of Transportation, Highway Drainage Design Manual Hydraulics Final Report (2007).

[5] Boller M. (1997). Tracking heavy metals reveals sustainability deficits of urban drainage systems. Water science and Technology, 35 (9), 77-87.

[6] Chiew, F.H.S. and McMahon, T.A., (1993), "Data and Rainfall-Runoff Modelling in Australia", Hydrology and Water Resources Symposium, Newcastle, Australia, 1993, pp. 305-316.

[7] Choi, K. and Ball, J.E., (1999), "Estimation of Control Parameters for Urban Runoff Modeling by Using a Hydro informative System", Proceedings of 8th International Conference on urban Storm Drainage, Sydney, pp 1776-1783.

[8] Department of Planning, (New South Wales) (1993), Better Drainage: Guidelines for the Multiple Use of Drainage Systems, Sydney

[9] Ethiopian Roads Authority Drainage Design Manual (2002).

[10] Ethiopian Roads Authority Drainage Design Manual (2011).

[11] Ethiopian Roads Authority Geometric Design Manual (2011).

[12] Giancarro, F.B., (1995), "Management of a Storm water Drainage System within an Established Urban Area", The Second International Symposium on Urban Storm water Management, Melbourne, Australia, pp 21-25.

[13] G.K. Warati, T.A. Demissie, Assessment of the Effect of Urban Road Surface Drainage: A Case Study at Ginjo Guduru Kebele of Jimma Town, International Journal of Science, Technology and Society (IJSTS), 2015, 3(4), pp. 164-173.

[14] G. Shailendra and Veeraragavan, A., "Research Need in Sub-Surface Drainage for Long Lasting Pavements," Highway Research Journal, January - June 2010.

[15] Hagen and Cochran,(1996);comparison of pavement drainage systems, transportation of Hershfied D.M., (1961), "Rainfall Frequency atlas of the United

States for durations from research recording 1519,TRB National Research Council ,Washington, D.C.1996,pp110.
[16] Highway Drainage Guidelines, American Association of State Highway and Transportation Officials, 2003.
[17] Hydrologic Engineering Centre (HEC), (2000), “HEC-RAS User‟s Manual”, Internet, http://www.wrc.hec.usace.army.mil/software-distib/hec-ras/hecrasprogram.html.
[18] IRC: SP 42-1994, “Guidelines on Road Drainage”, Special Publication, Indian Roads Congress, New Delhi 1994.
[19] Larson, C. L. and Straub, L. G. Grate inlets for surface drainage of streets and highways, univ. of Minnesota, st. Anthony falls hydr. Lab, bull. no.2, (June 1949).
[20] L.M. Nyuyo, Maintenance of drainage systems in nairobi‟s Bahati estate, B.A Land Ecomics, University of Nairobi, 1993.
[21] Mina, H.L., Sethi, N.K. (2007) “Road Maintenance of Drainage, Shoulders and Slopes “Journal of Indian Highways, 37(6), 35-38.L.
[22] Mutual C.K (2005), A Study On Participatory Maintenance and Its Impacts on Performance of Ground Storm Water Drainage Systems in Residential Areas
[23] 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.
[24] NAASRA (National Association of Australian State Road Authorities), (1986), Guide to the Design of Road Surface Drainage, Sydney.
[25] NCHRP Synthesis 237, (1997).pavement subsurface drainage systems, TRB National Research Council, Washington, D.C.
[26] O'Flaherty, C.A. (2002). Chapter 7 - Surface drainage for roads. Highways (Fourth Edition), C. A. O‟Flaherty, ed., Butterworth- Heinemann, Oxford, 185-209.

[27] R.J.Sevenhuijsen, 1994. Surface Drainage Systems. In: H.P.Ritzema (ed.), Drainage Principles and Applications, ILRI Publication 16, p.799-826. International Institute for Land Reclamation and Improvement (ILRI), Wageningen, the Netherlands.
[28] Thair Jabbar Mizhir Alfatlawi, Study on Roadway Subsurface Drainage System and Related Performance Using Fem, International Journal of Civil Engineering and Technology, 6(9), 2015, pp. 128–138.
[29] Urban Hydrology for Small Watersheds", Technical Release 55, June 1986, United States Department of Agriculture, Soil Conservation Service, Washington, D.C.
[30] U.S. Department of Transportation, Federal Highway Administration (2001), Hydraulic

Engineering Circular No. 22, Second Edition “Urban Drainage Design Manual,” FHWA- NHI-01-021.
[31] U.S. Natural Resources Conservation Service (2004), National Engineering Handbook “Estimation of Direct Runoff from Storm Rainfall”.
[32] Wyatt et al, (2000); effectiveness of subsurface drainage features based on design adequacy, of transportation research recording 1709,TRB National Research Council ,Washington, D.C.2000,pp69-76.
[33] Zumrawi, M.(2013),“Pavement design for roads on expansive clay subgrades,”University of
Khartoum Engineering Journal (UOFKEJ), Vol.3 Issue 1, pp.52-58.

Appendix: A, B and C

Appendix: A

Appendix A: Time of Flow, Unit Peak Discharge, Velocity of flow and SCS CN Charts.

Figure 1 Intensity –duration –frequency regions of B, C and D (ERA2002 and 2011)

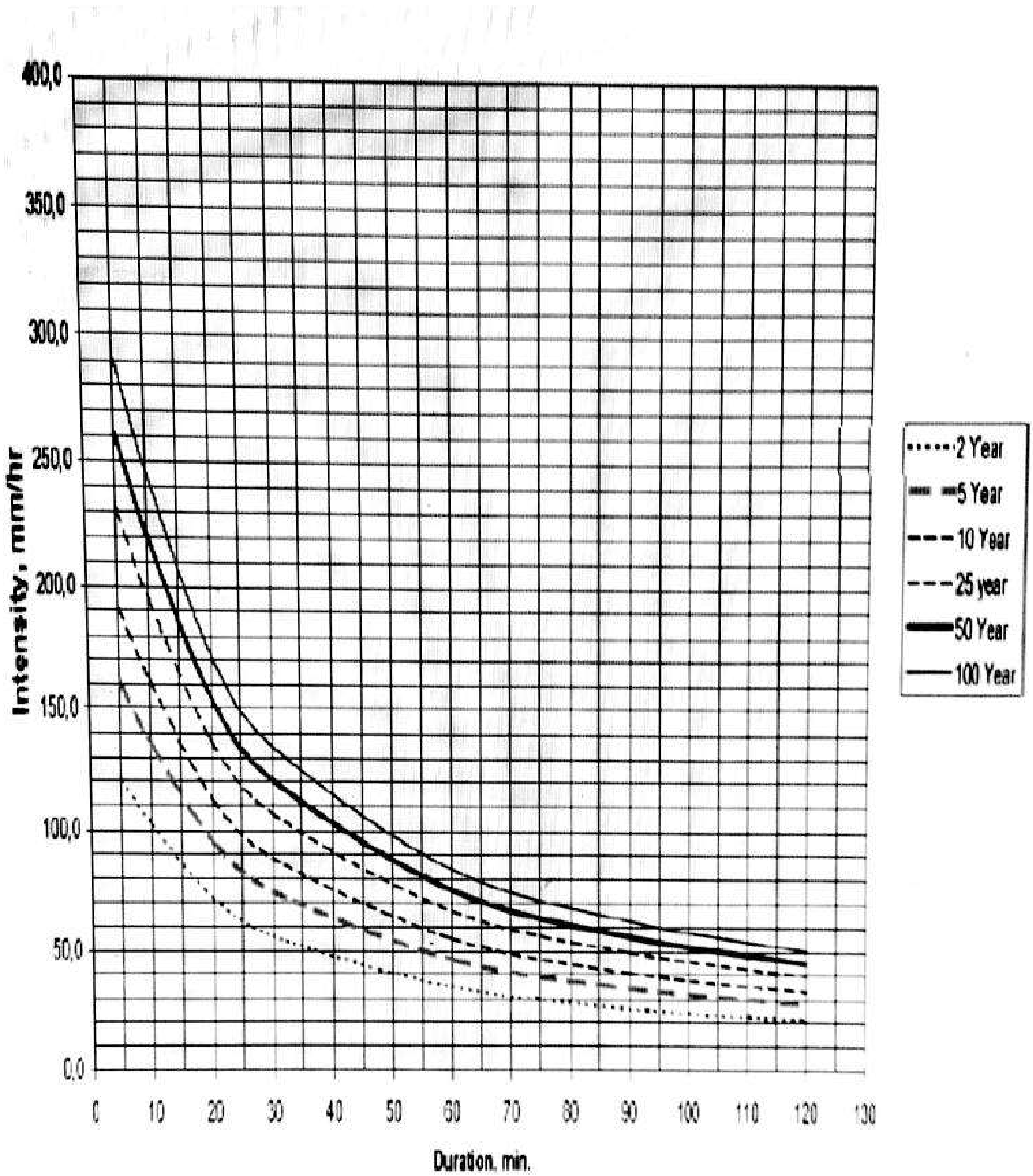


Figure 2: the relation between direct run off, curve number and precipitation (ERA 2002 and 2011)

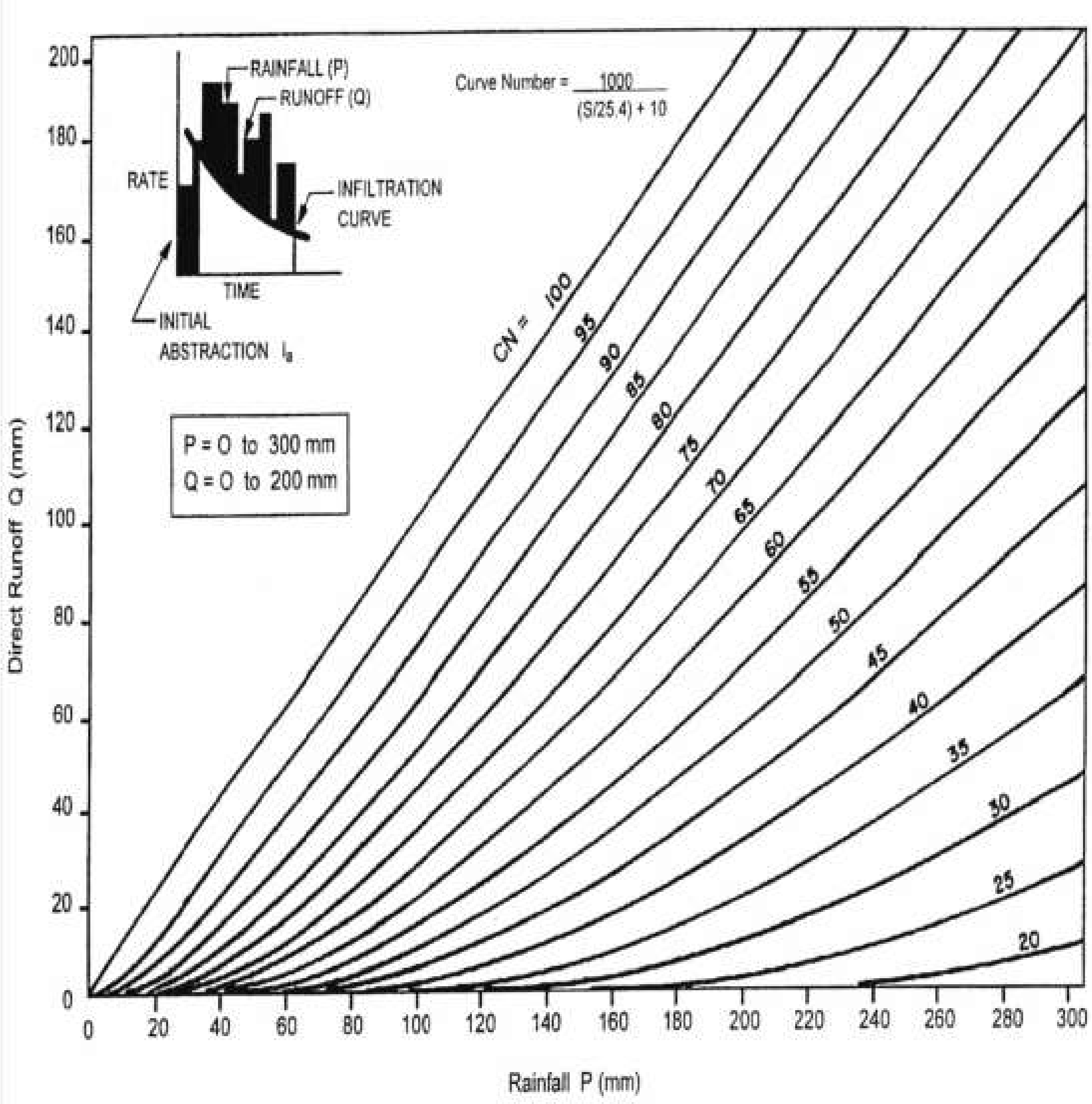


Figure 3 - 24 Hour Depth – Frequency curves

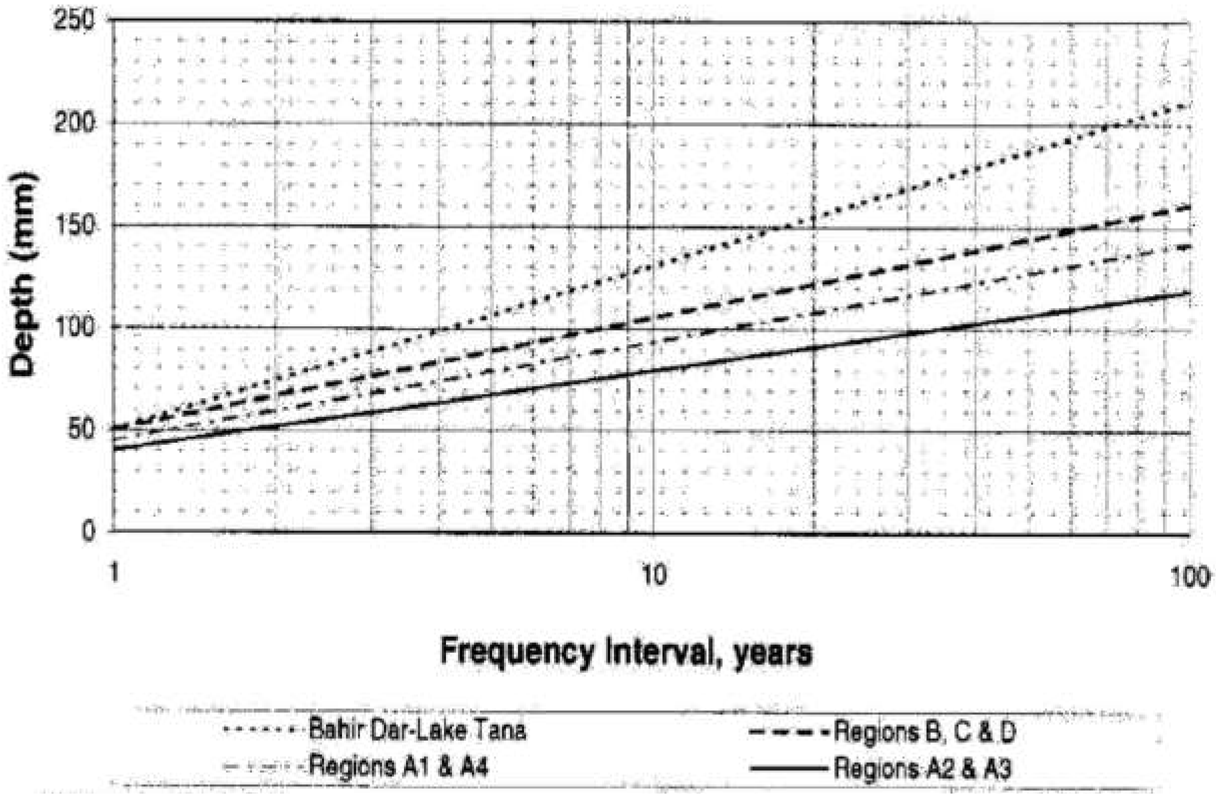


Figure 4: Relationships between Precipitation, Direct Runoff and Curve Number (ERA, 2011)

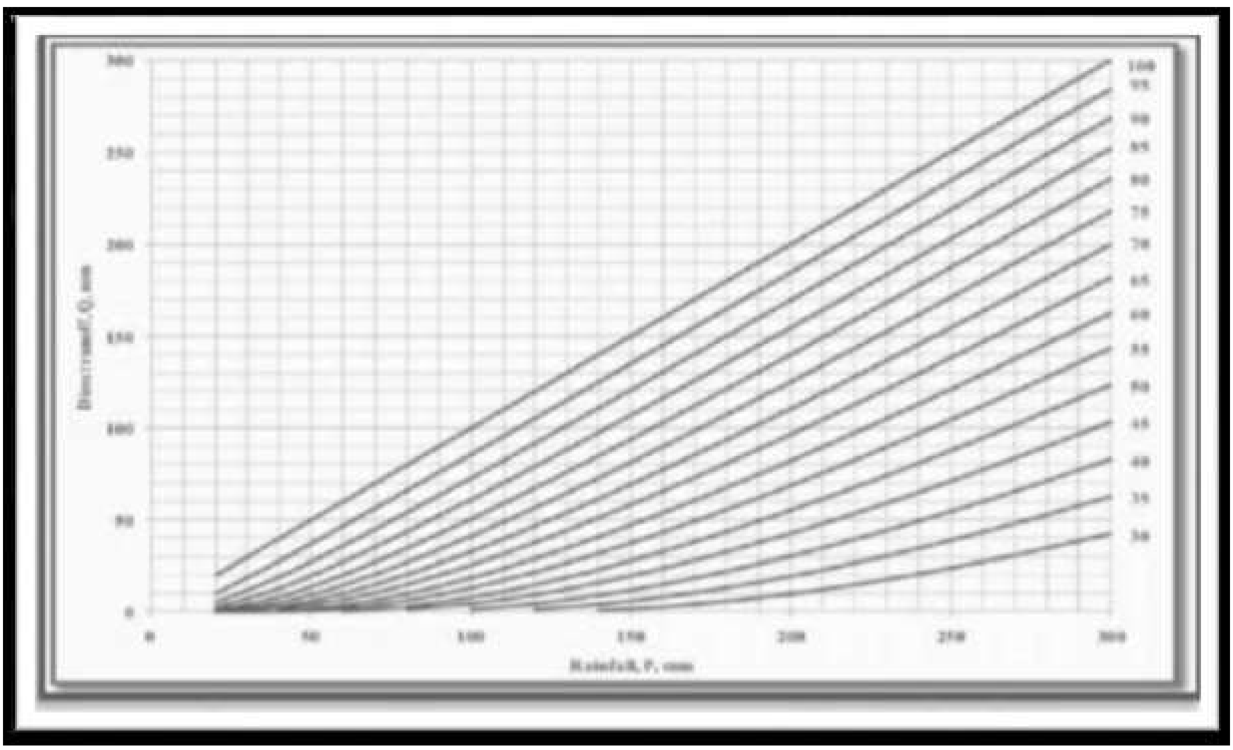


Figure 5: Unit Peak Discharge, Type II rainfall

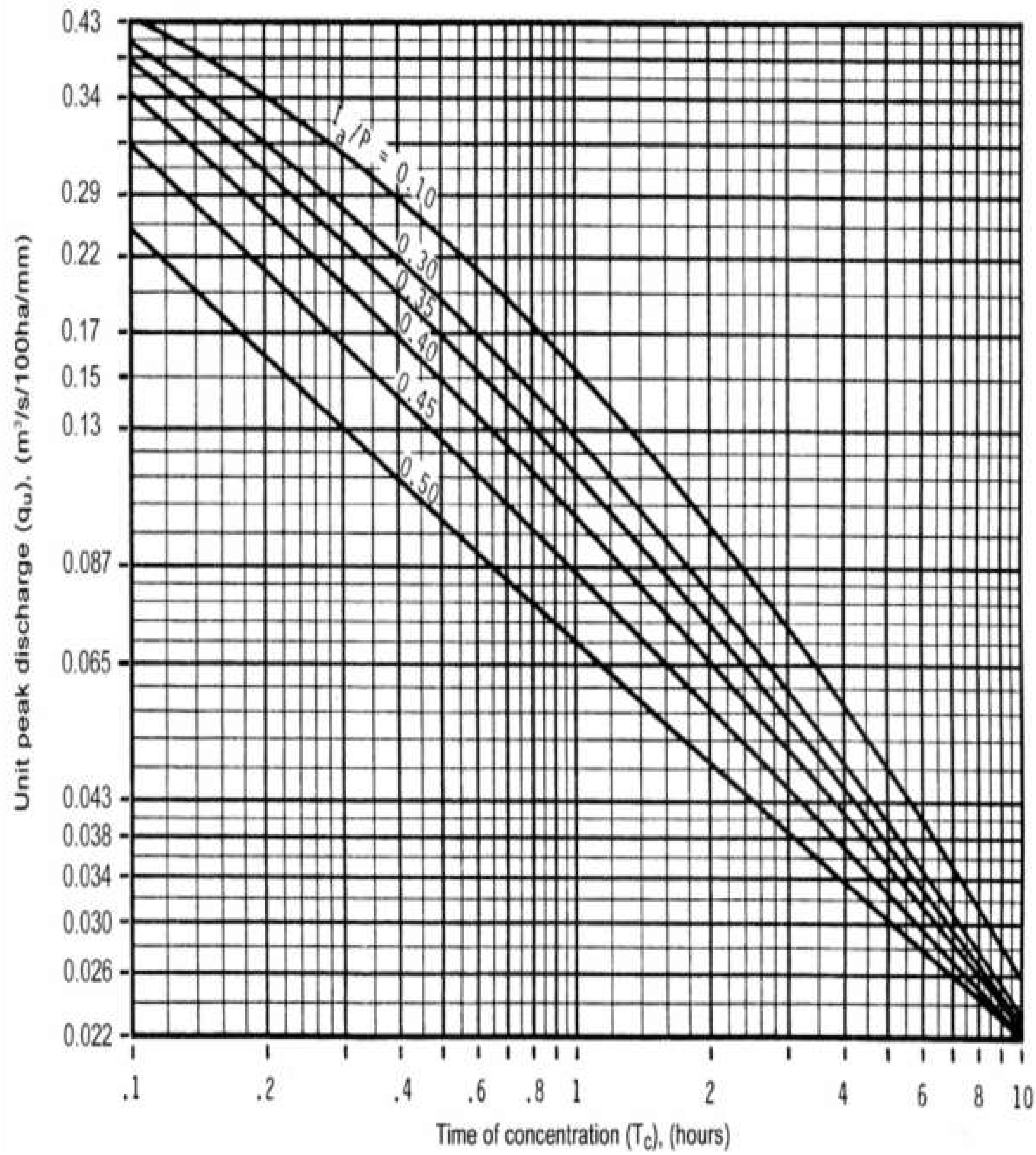


Figure 6: Overland Time of Flow (ERA 2002 and 2011)

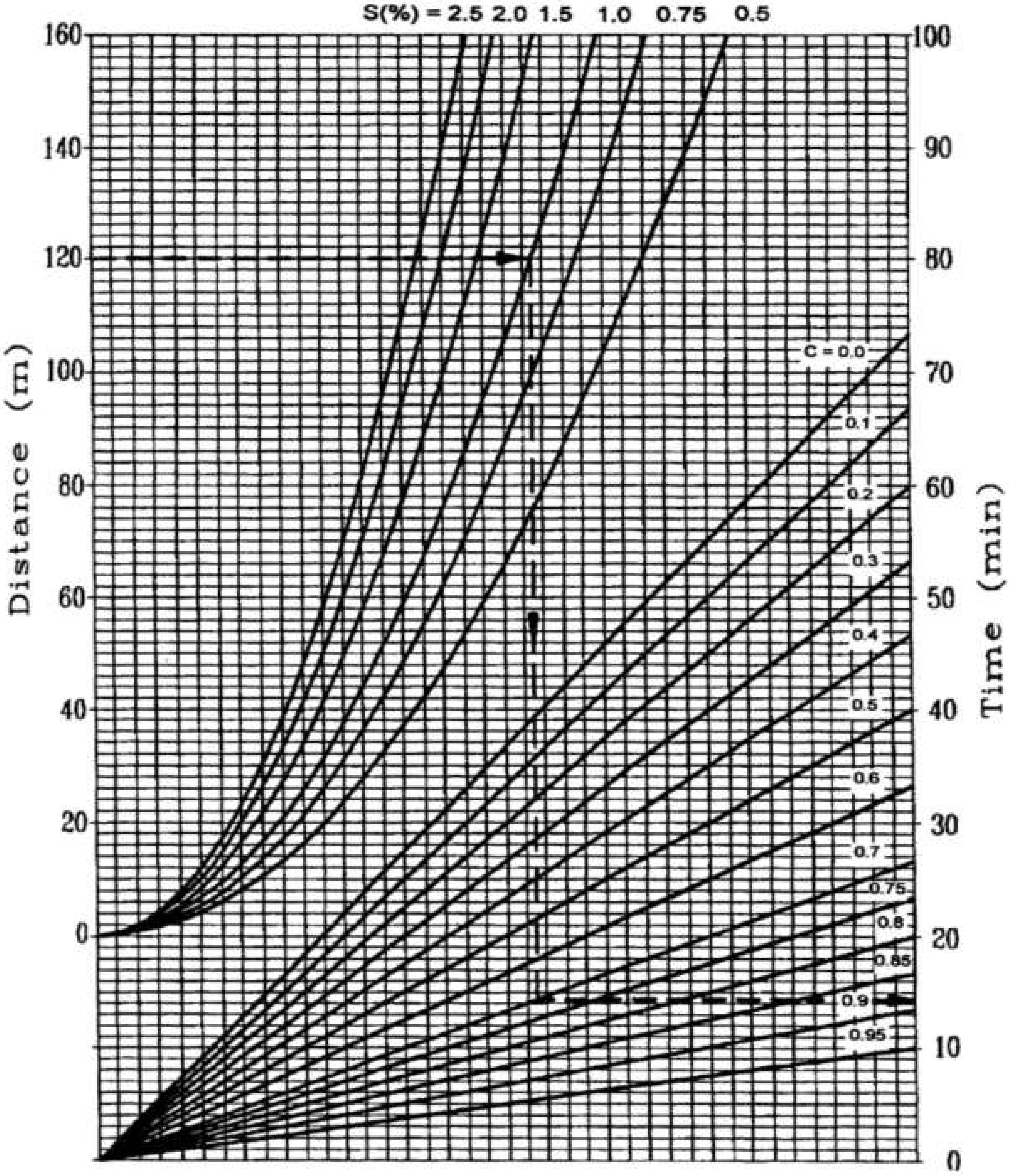
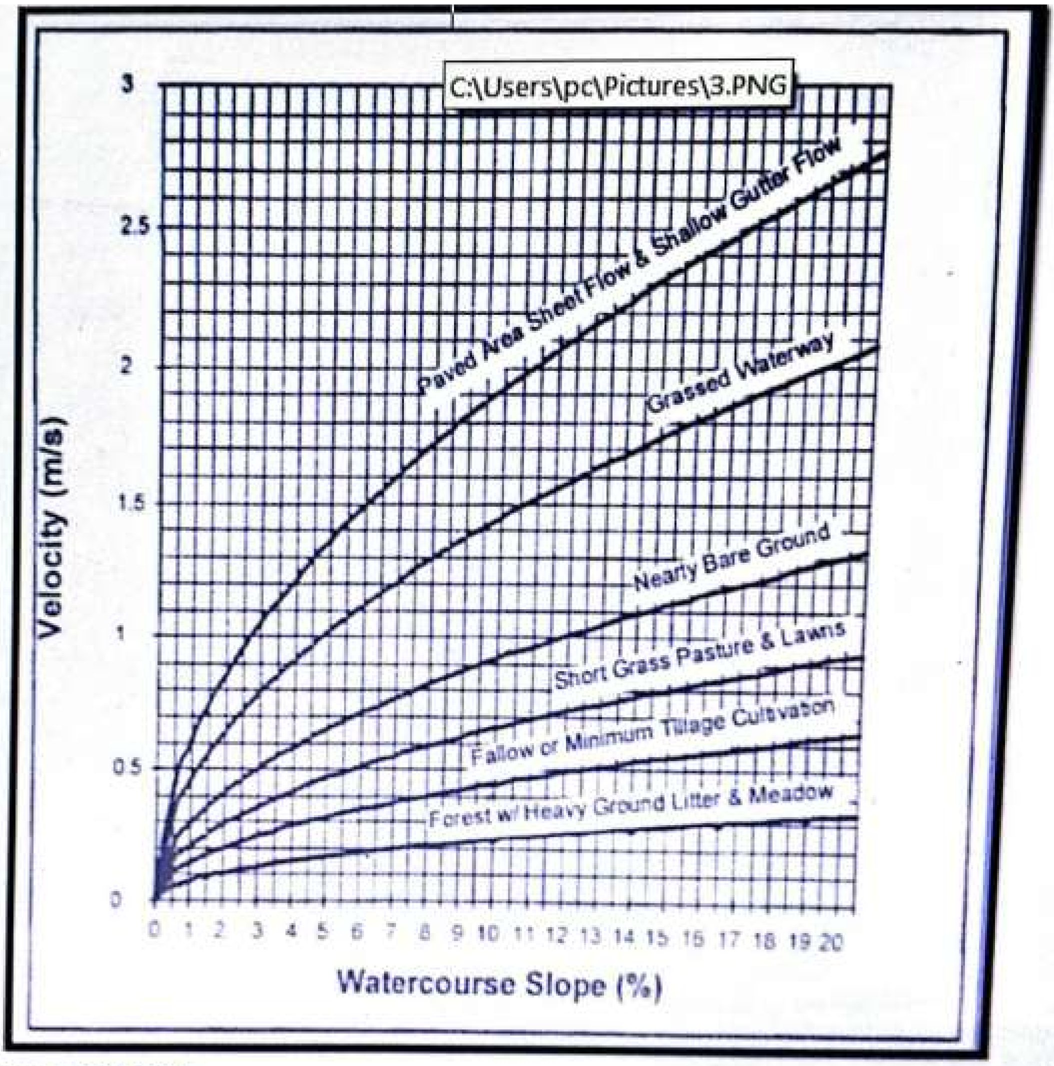


Figure 7: Velocities for Upland Method of Estimating Time of Concentration



Source ERA DDM

APPENDEX B

APPENDEX B: Roughness and Runoff Coefficient Values and Parameters for the Design of Drainage Structures.

Table 1: Conversion from average antecedent moisture conditions to dry and wet conditions.

CN For Average Conditions	Corresponding CN"s For	
	Dry	Wet
100	100	100
95	87	98
90	78	96
85	70	94
80	63	91
75	57	88
70	51	85
65	45	82
60	40	78
55	35	74
50	31	70
45	26	65
40	22	60
35	18	55
30	15	50
25	12	43
15	6	30
5	2	13

Table 2: Roughness Coefficients (Manning's n) For Sheet Flow

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

Table 3: values of roughness coefficient n (uniform flow) (ERA DDM 2002)

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 4: Ia Value for runoff curve numbers (ERA DDM 2002)

Curve Number	I_a (mm)	Curve Number	I_a (mm)	Curve Number	I_a (mm)
40	76.2	60	33.9	80	12.7
41	73.1	61	32.5	81	11.9
42	70.2	62	31.1	82	11.2
43	67.3	63	29.8	83	10.4
44	64.6	64	28.6	84	9.7
45	62.1	65	27.4	85	9.0
46	59.6	66	26.2	86	8.3
47	57.3	67	25.0	87	7.6
48	55.0	68	23.9	88	6.9
49	52.9	69	22.8	89	6.3
50	50.8	70	21.8	90	5.6
51	48.8	71	20.6	91	5.0
52	46.9	72	19.8	92	4.4
53	45.1	73	18.8	93	3.8
54	43.3	74	17.9	94	3.3
55	41.6	75	16.9	95	2.7
56	39.9	76	16.1	96	2.1
57	38.3	77	15.2	97	1.6
58	36.8	78	14.3	98	1.0
59	35.3	79	13.5	99	0.4

Table 5: Recommended Runoff Coefficient (C) for Various Selected Land Uses (ERA DDM 2002)

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 6: values of roughness coefficient n (uniform flow) (ERA DDM 2002)

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

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: Storm Design Return Period –years (ERA DDM, 2011)

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 8: Runoff Coefficient: Humid Catchment (ERA Drainage Design Manual, 2011)

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 9: Runoff Coefficient: Semi-arid Catchment (ERA DDM, 2011)

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 10: Hydrological Characteristics of Soil Groups (ERA DDM, 2011)

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 11: Antecedent Moisture Conditions (ERA DDM, 2011 for LVRs)

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

Table 12: Recommended runoff coefficient C for previous surfaces by selected hydrologic soil groupings and slope 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

Table 13: 24 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 14: Coefficient for composite runoff analysis

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

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

Table 15 Design Storm Frequency (Yrs) by Geometric Design Criteria

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

Table 16: Runoff curve numbers (ERA DDM 2002)

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 storm drains, 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

Appendix: C

Appendix C: Questionnaire Type One

Causes and Effects of Poor Drainage System on the Flexible Pavement Layers: a Case Study in Upper Atbara & Setit Dam Complex, a township Road.
This questionnaire is being administered for the collection of data to investigate in the study of the Causes and Effects of Poor Drainage System on the Upper Atbara & Setit Dam Complex, a township Road. The information collected is confidential and will strictly be used for related data with the study.
Sector: Practical Perspective.
Practical Aspect
1 What is your academic background or field of training?
A Engineer
B Any other (specify)
…………………………………………………………………………………

2 What are some of the considerations that are made when coming up with road design and appropriate drainage facility in Upper Atbara & Setit Dam Complex, a township road?
A. State of road
B. Cost of construction
C. Class of the road
D. Period of construction
E .Topography

3 From your design experience, was the design appropriate?
A Yes
B No

4 Do you think the contractor observed due diligence in the construction of the road drainage systems?

A Yes

B No
If your answer above is yes, why do you think so?
……………………………………………
5 If your answer is no, in your opinion what percentage of roads in Ethiopia are not provided with adequate drainage system?
A 0 – 20%
B 20 – 40%
C 40 – 60%
D 60 – 80%

E 80 – 100%

6 From your engineering experience and practice, how can you rate the state of the drainage system in Upper Atbara & Setit Dam Complex, a township road?
A Excellent
B Very good
C Good
D Poor
E Any other (specify) ………………………………………………………….

7 How often do you carry out inspection to ascertain the state of the drainage system in Upper Atbara & Setit Dam Complex, a township road?
A Monthly
B Every three months
C Every six months

D Once a year
E Any other (specify) ……………………………………………………….

8 Have you carried out a research on the effects of the poor drainage system on the surrounding environment?
A Yes
B No

9 What did you find the causes and effects of poor drainage system on flexible road and their solution?
A …………………………
B …………………………
C …………………………
D …………………………

10 What do you think is the remedy to the solution state of the drainage system in Upper Atbara & Setit Dam Complex, a township road?
Maintenance
B Redesigning
C Reconstruction
D Any other (specify)
……………………………………………………………………

11 Why do you think has hindered the above mentioned measures from being implemented?
A Lack of resources
B Lack of awareness

C Poor planning
D Lack of commitment by the government

12 Which of the following descriptions is the best suitable type of drainage system existing in Upper Atbara & Setit Dam Complex, a township road? More than one answer may be ticked.
A Separate system
B Combined system
C Open channel drainage
D Subsurface drainage
E Any other (please specify) ---

13 In your own opinion based on the professional experience, is the type of drainage facility installed in Upper Atbara & Setit Dam Complex, a township road with enough capacity to satisfactorily drain the water from the road?
A) Yes
B) No
If your answer above is no, why do you think so?

Appendix C: **Questionnaire Two**

Causes and Effects of Poor Drainage System on the Flexible Pavement Layers: a Case Study in Upper Atbara & Setit Dam Complex, a township Road. This questionnaire is being administered for the collection of data to investigate in the study of the Causes and Effects of Poor Drainage System on the Upper Atbara & Setit Dam Complex, a township Road. The information collected is confidential and will strictly be used for related data.
Sector: General Perspective.
1) How often do you use Upper Atbara & Setit Dam Complex, a township road?
A Every day
B Twice a week
C One's a week

D Any other (please specify) --

2) In your opinion how do you find the condition of the drainage system in Upper Atbara & Setit Dam Complex, a township road?
A Very good condition
B Good condition
C Fair condition
D Poor condition
3) How does poor drainage affect the road?

A Runoff on the road block the road
B Runoff washes away the asphalt
C Cracking of road surface
D Water leaves debris on the road surface
E Any other (specify) --
4) What are the main challenges faced by solving over flooding hazards in Upper Atbara & Setit Dam Complex, a township road?
A …………………
B …………………
C …………………
D ………………
5) How does poor drainage of the road affect you as the resident?
A Runoff erodes the land
B Runoff create valleys on your land

C Runoff washes away yields
D Runoff washes away asphalt road
E Any other (specify)
………………………………………………………………………………
6) Have you observed any improvements on the drainage system?
A Yes
B No
7) In your own view, how satisfied are you as a road user or resident with the state of drainage of the road?
A Extremely satisfied
B Satisfied
C Dissatisfied
D Extremely dissatisfied
8) Which one of the following has not responsibility about highway drainage problems awareness?
a) The commercial sector
b) Service organizations
c) Non-Governmental Organizations
d) All
9) What is your opinion on the responsibility of highway drainage system problems?
a) Strong responsibility
b) Faire responsibility
c) Limited responsibility

d) No responsibility

10) In your opinion, which of the following problem is the most serious that needs immediate Solution?
A). Lack of good drainage systems
B). high traffic accidents due to drainage
C). high soil erosions
D). Other (If any) --

11) How do you perform the assessment taken to solve the drainage problems?

A). Very good
B). God
C). Fair
D). Poor
E). Very poor