Addis Ababa University
School of Graduate Studies
Institute of Technology

Hydrologic and Hydraulic Analyses of Drainage Structures In Case of Shishinda-Tepi Road

A thesis submitted and presented to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Degree of Masters of Science in Civil Engineering under Hydraulics Engineering

By
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Advisor
Dr. Daneal Fekersillassie

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Approval by Board of Examiners

Dr. Daneal Fekersillassie

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Internal Examiner	Signature	Date
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External Examiner	Signature	Date
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Chairman (Department of graduate committee)	Signature	Date

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Abstract

Several new road Schemes as well as up-gradation of existing roads are being undertaken by Ethiopian Road Authority for better and faster communication amongst the different parts of the country. Drainage of road is an important aspect of road project for the purposes of safety, speed, maintenance and life span of the road. In early days road drainage structures sized without hydraulic and hydrologic Investigation due to shortage of availability of data as the result; the constructed drainage structure either oversized or in adequate.

This thesis outlines the various data to be collected from different sources for proper planning, design of drainage structures. In this thesis the size of each cross drainage structures are assessed by determining the peak discharges of flood which drains towards the location of cross drainage structures along Shishinda-Tepi road. In this study, based on assumption and limitation behind the formula, for each Cross drainage structures peak discharge is determined by either rational, SCS or frequency analysis method.

The Conveyance capacity of cross drainage structures is determined by Manning Equation.

The study revealed land use/cover hydrological soil group, intensity of rainfall influence that both the peak discharges and runoff volumes reach inlet of drainage structures.

In this thesis HEC-RAS models also used to calculate certain hydraulic parameters at Beko and Bitinwuha River crossing under steady state condition the parameters includes steady state water surface profile for 10, 50,100 years return period, stage-discharge curve, depth scour at abutment and pier of structure for above return periods.

Key words: Beko and Bitinwuha River crossing, sizing of Cross drainage structures, HEC-RAS model, Peak discharge

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I also thank Ethiopia Road Authority, National Metrological Agency Organizations for providing necessary data for me and those who supported me in any aspect for the completion of the study.

I would also like to extend my gratitude and appreciation to U.S. Army Corps of Engineers Hydrologic Engineering Center, HEC and Developer Software and Author of the manual who contributed their time, knowledge and effort during the development of the HEC-RAS and HEC-HMS software and their manual.

Kassahu U.

May, 2016

Addis Ababa,

Ethiopia

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List of abbreviations and their definitions

AASHTO-	American Association of State Highway and Transportation Officials
AMC	Antecedent Moisture Content
ASTEER	Advanced Space born Thermal Emission and Reflection Radiometer
AWW-	Antecedent Watershed Water
CN	Curve Number
DEM	Digital Elevation Model
ENSO	El Niño Southern Oscillation
ERA	Ethiopian Road Authority
FAO	Food and Agricultural orginazation
FEMA	Federal Emergency Management Agency
Fr	Froude number
GIS	Geographical Information System
GUI	Graphical User Interface
HEC- HMS	Hydrological engineering center-Hydrological modeling system
HEC-DSS	Hydrologic Engineering Centre Data Storage System (The U.S. Army corps of Engineers)
HEC-GeoHMS	Hydrologic Engineer center Geospatial Hydrologic Modeling System
HEC-RAS	Hydraulic engineering center-River Analysis system
HSG	Hydrological soil group
IACI	Initial Abstraction Constant Loss
IDF	Intensity flow duration curve
ITCZ	Inter-tropical Convergence Zone
MAP	Mean Areal Precipitation
MAR	Mean Areal Rainfall
MARE	Mean Absolute Relative Error
NMA	National Metrological Agency
NDTP	Net difference of observed time and peak

PET	Potential Evapotranspiration
PEV	Percent Error in Volume
PEP	percentage of error in simulated peak
RMSE	Root Mean Square Error
RE	Rainfall Excess
RRMs	Rainfall-Run-off modeling
SCS	Soil Conservation Service
SCS-CN	Soil Conservation Service Curve Number
SRTM	Shuttle Radar Topographic mission
Tc	Time of concentration
UH	Unit Hydrograph
USA	United States of America
USACE	US Army Corps of Engineers
UTM	Universal Transverse Mercator coordinate system
VDOT	Virginia Drainage of transport manual
WMS	Watershed Modelling System

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Chapter One

1. Introduction

1.1 Back ground

The road network in Ethiopia provides the dominant mode of freight and passenger transport and thus plays a vital role in the economy of country. The network comprises a huge national asset that requires adherence to appropriate standards for design, construction and maintenance in order to provide a high level of service.

Well-functioning road transport system is a critical component of society. Therefore, appropriate management and high capital investment in the design and maintenance of road transport systems are crucially important.

Road is an important infrastructure for the economic development of a mountainous country like Ethiopia. Government of Ethiopia has an ambitious plan of connecting different parts of our country by constructing a network of national highways, state and village roads under various development schemes by ERA and Regional self-Governments. E.g. Addis –Assab , Addis-Jimma and Addis- Nekemt, Butajira-Zway, Asela- Dodola, Agaro-Gera, Gelemso-Mechara, Dejen-Mota, Sodo-Bulki, Nekemte-Bedele and Bonga-MizanTeferi,Nekemt-Bure,Gore-Tepi,Injibara-Beles,Holeta-Muger,Mota-Bahirdar, Shishinda-Tepi. The road route selected for this study is Shishinda-Tepi road route which is crosses many rivers and vegetation. Apart from construction of new roads, the Government‘s policy is to also upgrade the existing roads for developing an efficient road communication system. Roads and similar other infrastructures, built with public money, are our national assets and they must be preserved and protected for the benefit of the people. Drainage of road is one of the many components of a road project that necessitate high cost. The road drainage is used to remove the storm water as rapidly as possible so that traffic may move safely and efficiently without any loss of time. Speedy disposal of the storm water runoff likely to be accumulated due to construction of the road embankment is very important for the success of a road project from technical and environmental points of view. Inadequate drainage invariably results in reduction of life span of a road, increase in maintenance cost and drainage congestion in the countryside leading to submergence of land and consequent loss of agricultural and other properties. Provision of Drainage Structure of adequate size and numbers in a road drainage scheme - whether the road is a new one or an up-gradation of an existing one - is intimately related to the health and safety of the road.

High volume of sediment and water are delivered to a river channel causes Substantial channel modification, silting up structure and channel and finally failure of hydraulic structures. The water can be in the form of ground water, surface water (streams and rivers) or rain and it can damage the road in several ways: by washing away the soil (erosion and scouring), by making the road body less resistant to traffic (i.e. weakening the load bearing capacity), by depositing soils (silting) which may obstruct the passage of water, or by washing away entire sections of the road or its structures. Therefore, storm water and sediment influence the service life of drainage structures. The rain fall intensity and characteristics of catchment area are the major factors for designing and planning road storm water drainage facilities. These facilities have paramount advantage to safely dispose the generated floods to ultimate receiving system.

For sustainable development and management of water resources and mitigation of flood hazards and Similar geo-Hazards a sound Understanding of hydrological process is crucial (Mesay Daniel; 2010). This Leads to are liable representation of rainfall-runoff relation at various spatial and temporal scales. Runoff rates and ground recharge from rainfall event key parameter in most water resources development schemes, such as, storage reservoirs of surface water, diversion weirs, and flood protection structures, hydropower and irrigation projects.

1.2 Study area

1.2.1 Location

The project road of Shishinda-Tepi an existing gravel road having total approximate length of 76.45km located in south western part of Ethiopia.

The road starts at Shishinda town which is located at around 56 km from Bonga town ends at Tepi town. Now days it is administratively located in Southern Nation and Nationalities and peoples National and Regional state. And it links two Zonal administration of Kefa and Sheka and three woredas administration of Chena and Bita in Kefa Zone and Yeki sheka zone.

Hydrologically the project located in Baro-Akobo river Basin and it crosses big rivers like Kieto, Bitinwuha, Beko, Meni and kieto. Different types of culverts and bridges were constructed over these rivers. The general direction of rivers is stream is from the east to west. The rivers within Baro-Akobo basin rise in the high lands (2000m-3500m) situated in the east of the area and flow in to Gambela plain in the West.

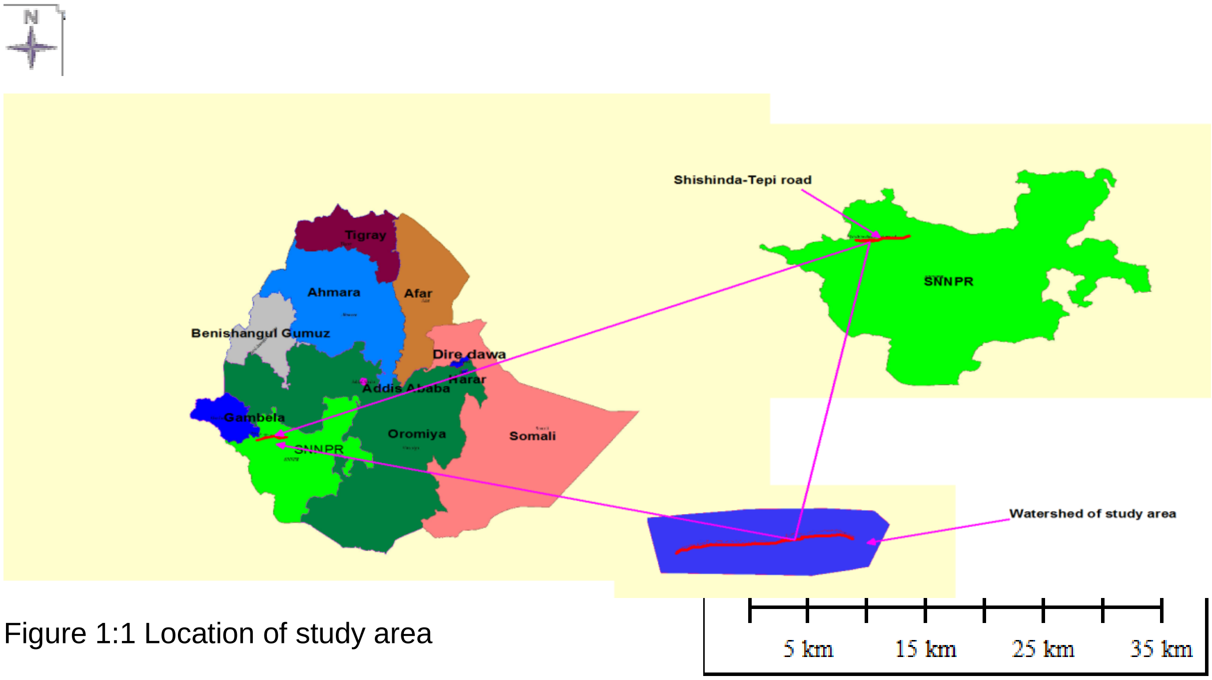


Figure 1:1 Location of study area

1.2.2 Topography

The project passes through generally rolling to mountainous terrain of which 68.41% rolling, 21.58% mountains and 7.6% is flat. The control point in the project are Shishinda town (the starting point of project road with the coordinate of x=818441m, y=802678m) and Tepi town (ending point of the project road with the coordinate x=767336m Y=796033m).

The lowest and highest altitude of study area 1024m and 248m respectively.

According to The Ethiopian Roads Authority‘s Geometric design manual 2013 terrain classification criteria were utilized to distinguish between the terrain types prevalent in the Study area.

1.2.3 Climate

Four geographical aspects largely determine the climate of any region: latitude, distance from sea, direction of prevailing winds and altitude**.**

According Admassu Gebeyehu, the amount of rain fall that prevails at any point in Ethiopia is influenced by location of point relative source of moisture, the direction of winds and topographic relief. High annual rainfalls occur when moist winds forced to rise passing over mountains. Such condition occur especially along the mountains ranges that extend nearly at angles to the prevailing storm movements in Summer (or Kiremt) there is strong movement of air from the South West to the North East direction. That is from the high pressure system over the Gulf of Guinea towards the low pressure center of Arabia. This air stream brings moisture the Gulf of Guinea and results in big rain season in Ethiopia.

Generally the wet season in Ethiopia is mainly from July to September; however there is the variation from place to place within the country that does not fit to this pattern

The Southernmost point of Ethiopia is about 378 km from equator, where tropical climate conditions prevail and Northern most point is only about 50km far from Sahel belt, which is a transitional region to the Sahara desert. Because of its location between the two climatic extremes and high topographic variation, the country is characterized by high spatial heterogeneity of climatic zones. With respect to atmospheric circulation, the climate of study area is mainly controlled by the latitudinal migration of Inter tropical convergence Zone (ITCZ) across the equator (Mesay 2010).

The ITCZ is a zone of low-pressure near the equator, where two easterly trade winds originating from the northern and southern hemispheres converge. Its seasonal northern movement in the period March to June brings moisture-laden air masses from the south west of the tropics into Ethiopia. When the prevailing warm and moist winds reach the western Ethiopian highlands, they are forced to rise, thereby cooling and losing their capacity to hold moisture, so that in July, most of the highlands experience relatively high rainfall, which generally lasts until mid of September and is known as "Kiremt" (Degefu 1988). The *Kiremt* rainfall accounts for 50-80% of the annual total precipitation of the country (Korecha and Barnston 2007). In April and May converging northeast and southeast winds usually produce a brief period of light precipitation, which is known as "Belg". According to Habtemichael and Pedgley (1974), *Belg* rainfall is associated with a southward bend of the northern hemisphere subtropical westerly jet. In contrast, a recent publication by Camberlin and Philippon (2002) stated that this short rain is a northern protrusion of the East African March-May precipitation into northeastern Ethiopia. In addition, El Niño– Southern Oscillation (ENSO), the Atlantic Ocean sea surface temperature and pressure variations (Wang and Eltahir 1999; Camberlin et al. 2001), monsoon activities over India (Camberlin 1997), and the Indian Ocean Dipole Mode (IODM) (Shanko and Camberlin 1998) highly influence the inter-annual rainfall distribution all over the East African regions.

At local scale, these rain producing atmospheric circulations are greatly influenced by the complex topography of the region. The result is a diversified climate ranging from hyper-arid in the eastern lowlands to humid in the southwestern highlands.

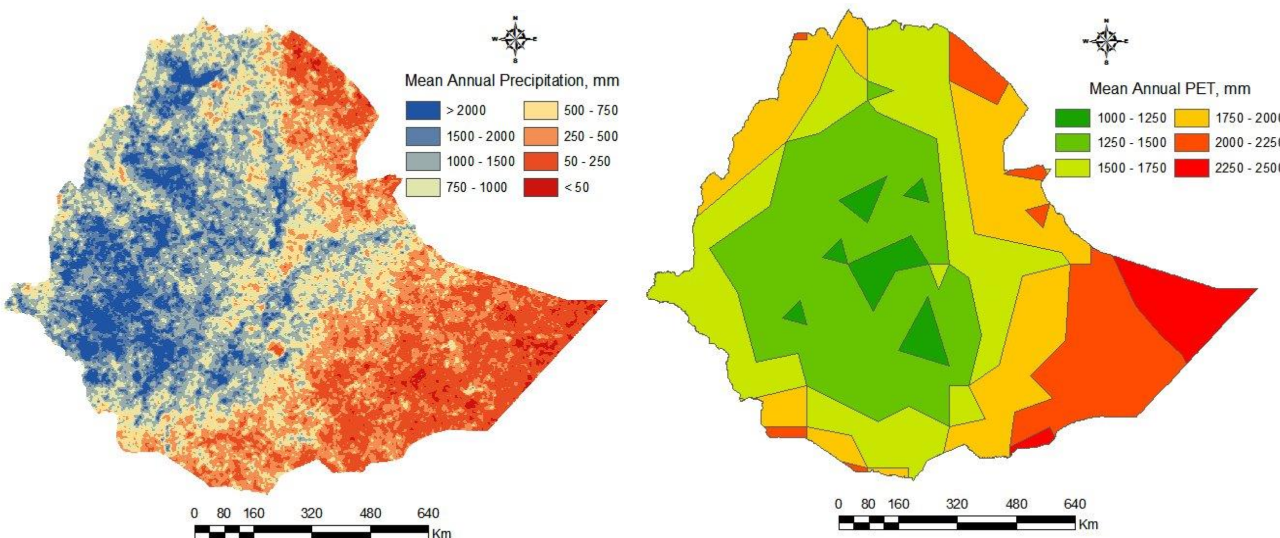
Unlike most of the tropics where two seasons are common (one wet season and one dry season), three seasons are known in Ethiopia, namely Bega (dry season) which extends from October-January, Belg (short rain season) which extends from (February-May), and Kiremt (long rain season) which extends from June-September. In terms of rainfall regions,

Ethiopia can broadly be broken down in three regions, the northern and central, southern and eastern regions.

The climate of the project area is tropical humid with a seasonal variation associated with oscillation of the Inter tropical convergence zone (ITCZ).

The region where this research was carried out exhibits meteorological and hydrological variations over space and time

In the study area, temperature, monthly, hourly & daily rainfall data of Bita, Chena, Shishinda & Tepi station are available from Ethiopian meteorological services agency which would useful in this study



a) b)

Source (Mesay Daniel; 2010 dissertation)

Figure1:2 (a) Mean annual precipitation generated from the Tropical Rainfall Measuring Mission rainfall climatology data (TRMM; TR 2B31, version 6), which was partly processed by King's College (Mulligan 2008) and (b) mean annual Potential Evapotranspiration (PET) in Ethiopia generated from global map of yearly reference evapotranspiration-30 arc minutes data (IIASA 2000)

1.2.4 Drainage system

The area upon which water falls, and the network through which it travels to an outlet, is referred to drainage system. The flow of water through drainage system is only is subset what is commonly referred to us hydrologic cycle, which is also including precipitation, evapotranspiration, and ground water flow. This discussion concerns the movement of water across a surface.

The study area is both in Keffa and in Sheka zone where among the few forest covered region of the country. Broad- leafed forest and mixed forest areas dominate the forest cover of the Keffa and Sheka zone Woredas transversed by road route. However the natural vegetation covers along in the project area distributed by human intervention. Man largely in connection the development of agriculture, settlement and other action has considerably modified the natural vegetation cover area comprising broad-leaf high forest. Pockets of remnants forest and scattered remnant tree species as well as riverine forest along the river crossing are the major natural vegetation covers.

Hydrologically the project is located in Baro- Akobo river basin. Almost all other major/minor streams/Rivers are also finally joining the same River basin. The project road passes through generally rolling to mountainous topography which in turn causes mainly streams/Rivers as concentrated flow. The project area is naturally endowed with many rivers and streams it has high network or density of permanent rivers and streams that drains to Gilo River. The major ones that are crossed by project road include Beko, Meni, Bitinwuha, Kieto and others. Generally, several minor and few major defined streams/Rivers are observed in the section. It was observed that almost most of river crossings of the project road have unstable catchments with very big size transported boulders debris in it. The river regime is closely connected to the climate with stream. The flow is increasing through May to September when they are reach maximum. Both river levels and water discharges are lowest from December through April. The major rivers are perennial although some smaller water courses dry out in most years.

1.3 Statement of Problem

Several new road Schemes as well as up-gradation of existing roads are being undertaken by Ethiopian Road Authority for better and faster communication amongst the different parts of the country. Drainage of road is an important aspect of road project for the purposes of safety, speed, maintenance and life span of the road. In the earliest days of road-building in the Ethiopia, drainage structures were necessarily sized by judgment due to lack of sufficient data. Drainage structures consume high investment cost. Poor hydrologic and hydraulic analysis coupled with lack of sufficient data are common sources of failures of drainage structures. In other words, the hydrologic and hydraulic analysis applied at the planning stage determines the feasibility of the projects

A better understanding of hydrologic and hydraulic phenomena of the area is considerable importance for appropriate design, construction and maintenance of drainage structures in order to provide high level service for both road and drainage structures. Despite the shortage of reliable hydrologic data, the hydrologic and hydraulic factors that affect the sizing of drainage structures appear to have been well understood. Permanence of the road is feasible by designing and constructing effective road drainage systems, which provide water to move away from the road surface as quickly as possible and erosion control on Surrounding Environment of roads can be achieved by keeping water from accumulating and concentrating on the road surface. Effective and proper road drainage controls runoff waters and directs these waters to suitable locations, allows complete use of roads and reduces maintenance and repair costs. To prevent the negative effects of poorly planned, located, designed, constructed and drained roads, the places and sizes of drainage structures should be determined and constructed according to road and watershed conditions. Unfortunately, poorly designed drainage systems deposit sediment directly into streams at road stream crossings and shorten the life of drainage structures and roads. To improve road infrastructure and management activities of drainage system of the Shishinda-Tepi road for potential danger from negative impact of climate change in the future hydraulic and hydrologic analysis of the area very essential. The planning and design of road drainage infrastructure can be quite complicated and involves the consideration of a diverse set of data in order to develop the most appropriate drainage solution for a project. Road construction without adequate provision for drainage is a major cause of erosion. Inadequate drainage systems for roads such as small number of culverts, insufficient capacity of road ditches etc. are some of the causes of scouring, finally failure of structure. Sedimentation is another common cause of failure and is the deposition of soil that has been transported by flowing water. Soil particles settle once the flowing water has slowed or stopped. This often occurs in culvert inlets and outlets as well as creeks and other watercourses. This failure is also termed blockage and reduces the capacity of the drainage structures, which in turn can increase flooding (afflux) upstream. Generally failure of road drainage structures may be caused by any number of problems or combination of problems and can occur during the construction or operation of the road. Erosion at cross drainage structure outlets, undermining of pavement and drainage structures, soil loss on steep batters and sedimentation of drains are all common failures. While flooding of the road corridor is the most common problem as a result of insufficient drainage capacity or a blockage of cross drainage, there are other issues that can occur as a result of failure (reduced performance/capability.)

1.4 Scope of study

1.4.1 Limitation of study

The scope of the MSc research is limited to Shishinda –Tepi road in general and particularly, a case of Rivers which crosses the road and drainage system of the area. In this study the HEC-RAS are used for analysis of hydrologic response and hydraulic property analysis performed in one dimension under steady state condition. Rainfall-runoff modeling event based and hydraulic property are often used to predict stream flow in space and time domain for operational and scientific investigations. For hydraulic analysis HEC- RAS model will be used. In this thesis, it was tried to improve the understanding of the process of institutional and technical adaptation of road drainage structures. The drainage design of roads is aimed at the protection of the road through the prevention of damage due to water to achieve a chosen level of service, without major rehabilitation, at the end of a selected design period. The design procedures take into account factors such as rainfall intensity, catchment areas, land use/land cover, topography, climate change, and run off. In this paper detail investigation surface water included but Sub - face drainage is not included in detail. Longitudinal structure does not consider in this paper because of along Shishinda- Tepi road segment the impact longitudinal drainage is insignificant.

Even though the area is dominated by high rain fall intensity there is no major erosion problem ting or land slide along the existing road length /streets even at ditches and existing cutoff drains. This may be chiefly due to the vegetation cover of the area. The soil in the area is well protected both by crop, fruit, and planted trees and natural vegetation is also on good condition respective to soil erosion.

1.4.2 Significance of study

This directly used for Ethiopian Road Authority when upgrade the road and also can use directly methodology Study area vulnerable with flood. This pepper may also use as a base for further study on the road drainage system. This thesis describes hydrologic and hydraulic Phenomena of drainage structure of Shishinda-Tepi road segment. The analyses include (1) estimates of peak flood discharges corresponding to floods with recurrence intervals of 25 and 50 years so that size of structure is determined based on determined peak discharge and (2) determination of water-surface-elevation profiles and flood-plain boundaries corresponding to the 10,50 100 years of recurrence interval flood. As part of the analyses, the 50-year flood profiles were developed along the major streams on which bridge is constructed in order that local officials may assess various alternatives to mitigate flood damages hazardous. Hydraulic and hydrologic analyses were done for selected reaches of the two streams studied, on which bridge structure is constructed.

1.5 Objective of the study

1.5.1 General objective

The overall objective of this thesis is to investigate hydrologic and hydraulic Property of drainage structures of Shishinda- Tepi road and to model Bridge crossing along the road.

1.5.2 Specific objective

- ✓ To assess adequacy of each drainage structures of the road
- ✓ To analysis back water sur-face effects due to blockage of pier
- ✓ To evaluate hydrologic property drainage structures
- ✓ To evaluate hydraulic property of drainage structure

1.6. Research questions

Follow up to the above objectives, a few question are raised. To achieve the objectives of the current research, the thesis concentrates on the following questions. The research Question will includes,

- ✓ Is the size of cross drainage structures of Shishinda –Tepi road adequate for the corresponding return Period?
- ✓ What is the flow rate at the two Bridges (Bitinwuha and Beko River Crossings) due to selected storm events?
- ✓ What is impact of land use change on the rate of flow at Bridge crossing
- ✓ For selected storm event how peak precipitation related peak run-off for Bitinwuha and Beko River crossing?
- ✓ Which of the design flows inundate the bridge completely?
- ✓ Determine the Water surface elevation at the upstream and downstream of the bridge for the design floods specified.
- ✓ What is the "Pier Scour depth" and Abutment Scour depth Beko and Bitinwuha crossing
- ✓ Determine the Energy Grade Line, Water Surface and Critical Water surface line

elevations at the bridge cross section for 10,50,10 years design flood.

1.7 Structure of thesis

This thesis is structured as follows.

Chapter 1 has presented a research background, general introduction the topography, climate, Drainage system of study area, and Ethiopia in general. It also summarizes the main objectives and the problem statement of this study.

Chapter 2- A literature review covers and gives an overview of typically related references that are applicable for this study. Hydrologic processes are covered in this chapter, which describe the scientific principle governing hydrologic phenomenon that is a system concept. There is also brief overview of commonly used drainage structures for high way engineer and hydraulic concept used in this area.

Chapter 3 describes the research methods to accomplish this study. Discuss the applied methodology to meet the objective set and how to model calibrated and validated is described. In more detail, the model parameters used in calibration, the approach of calibration and in what way model calibration is evaluated are expounded. It shows results of data preparation (rainfall) and model simulation.

Chapter 4 discusses the study area, Collection data necessary for this study and fieldwork activities and includes a description of the main characteristics of the catchment and data collected during the fieldwork period and detail hydrologic analysis and size cross drainage structure along Shishinda –Tepi road route .

Chapter 5 is detailed discussion on the results of model calibration and validation and Hydrologic and hydraulic analyses. The feasibility of the possibility of predicting model parameters from catchment characteristics is examined. It also describes HEC- HMS Calibration and validation in detail.

Chapter 6 concludes this study and achievements and limitations are summarized and few recommendations for further investigation are proposed.

Chapter Two

2. Literature Review

2.1 Introduction

Little literature was found that concerns on hydrologic and hydraulic analysis for drainage structure of road. This research seeks to contribute to the current body of knowledge by addressing this issue. First, however, relevant literature and previous work is reviewed. We drive a long distance every day, while many of this distance involve travel on the same route, say to or from school or a job, the individual traveler will encounter a surprisingly large number of engineering designs where hydrologic and hydraulic analyses were required. Both hydrologic and hydraulic analyses are required for the design of Culverts and Bridge. It should be evident that those involved in road design must understand the basic concepts of hydrologic and hydraulic analysis since the design of every kilometers of highway requires consideration of the fundamental concepts of hydrology and hydraulics. Like most of the basic sciences, hydrology and hydraulics require analysis and synthesis to use the fundamental concepts in the solution of engineering problems. According to Richard H. McCuen the word analysis is derived from the Greek word analusis, which means "a releasing," and from analuein, which means "to undo." In practical terms, it means "to break apart" or "to separate into its fundamental constituents." Analysis should be compared with the word synthesis. The word synthesis comes from the Latin word suntithenai, which means "to put together." In practical terms, it means "to combine separate elements to form a whole."

2.2. Basic Hydrological and Hydraulic Concepts

Because of the complexity of most hydraulic engineering design problems, the fundamental elements of the hydrologic and hydraulic sciences cannot be used directly. Instead, it is necessary to take measurements of the response of a hydrologic process and analyze the measurements in an attempt to understand how the process functions. Quite frequently, a model is formulated on the basis of the physical concepts that underlie the process, and the fitting of the model with the measurements provides the basis for understanding how the physical process varies as the input to the process varies. After the measurements have been analyzed (taken apart) to fit the model, the model can be used to synthesize (put together) design rules. That is, the analysis leads to a set of systematic rules that explain how the underlying hydrologic process will function in the future. Future changes in climate and land use are likely to affect catchment hydrological responses and consequently influence the amount of runoff reaching roads.(Zahra Kalantari

January 2014). The general definition for hydrology according Richard H. McCuen was "Hydrology is the study of the properties, distribution, and effects of water on the earth's surface, and in the soils, underlying rocks, and atmosphere***".*** Specifically for this study hydrology will deal with estimating flood magnitudes as the result of precipitation (drainage manual of ERA 2013). In the design of highway drainage structures, floods are usually considered in terms of peak runoff or discharge in cubic meters per second (m3/s) and hydrographs as discharge per time. For structures that are designed to control volume of runoff, like detention storage facilities, or where flood routing through culverts and Bridge is used, then the entire discharge hydrograph will be of interest.

General hydrologic analysis involves the estimation of Design flow rate based on climatological and watershed Characteristics. This analysis is one the most important aspects of Culvert and Bridge design. Since statistical uncertainties are inherent in hydrological analysis, results of the analysis are not accurate as the result in hydraulic analysis of culvert and Bridge. Nonetheless, both of these analyses are required, and the hydrologic and hydraulic study must be performed first.

According to R.K, Rajput the hydraulics defined as follows. it is the branch of engineering – science which deals water at rest or in motion. In general hydrologic analysis involves the estimation of Design flow rate based on climatological and watershed Characteristics the nature of fluid flow in open channel.

2.2.1 Open Channel Flow

Basically the hydraulic analysis of both natural and artificial channels proceeds according to the basic principles of open channel flow. The basic principles of fluid mechanics continuity, momentum, and energy can be applied to open channel flow with the additional complication that the position of the free surface is usually one of the unknown variables. The determination of this unknown is one of the principle problems of open channel flow analysis and it depends on quantification of the flow resistance. Natural channels display a much wider range of roughness values than artificial channels.

The hydraulic analysis of a channel determines the depth and velocity at which a given discharge will flow in a channel or known geometry, roughness, and slope. The depth and velocity of flow are necessary for the design or analysis of channel lining and highway drainage structures. Open channel flow is defined as the flow of a free surface fluid within a defined channel. Typical examples are flow in natural streams, constructed drainage canals, and storm sewers. The development of effective floodplain management plans requires that engineers understand the hydraulics of open channel flow, which depend upon the flow classification, flow and conveyance, and the energy equation. Open channel flow must have a free surface that is subject to atmospheric pressure (Chow, 1959). The conduit in the case of this research is a open channel on longitudinal drainage, bridge to cross rivers and streams, culvert to cross small streams and ponds. A culvert acts as an open channel only when the culvert is partly full and other structure open channel flow, which applies to this research.

2.2.1.1 Open Channel flow classification

Open channel flow is classified based on time, space, and flow regime:

- ✓ *Time*

Steady flow describes conditions in which depth and velocity at a specific channel location do not change with time. In contrast, *unsteady flow* refers to flow conditions that change with time at a given location.

- ✓ Space

The term *uniform flow* denotes fluid flow in which depth and velocity are constant with distance. Uniform flow conditions require the channel to be straight, with constant cross-sectional geometry, and a water surface that is parallel to the base of the channel. In *varied flow*, water depth and velocity change with distance along the channel.

- ✓ *Flow regime*

The dimensionless Froude number is used to classify flow type:

$Fr = \frac{V}{\sqrt{gy}}$ --- --------------------------- 2.1

Where: Fr = Froude number

V = mean fluid velocity (m/s)

g = gravitational acceleration (m/s^2)

y = water depth (m)

Subcritical flow occurs when the Froude number is less than 1; when the

Froude number exceeds 1, supercritical flow conditions exist. Critical flow, critical depth, and critical velocity are defined at the point where the total energy head is a minimum. At critical conditions, the Froude number equals one.

In order to determine the water surface elevations at different cross sections in a channel, the flow rate and velocity must be known or calculated. For river hydraulic analysis, a steady, gradually varied flow assumption is often used for both subcritical and supercritical flow regimes. Steady, gradually varied flow applies to flow in which changes in flow depth and velocity occur gradually over a considerable length of channel. (Eric Tate, 1999)

The continuity equation for steady flow states that flow must be conserved between adjacent cross-sections:

Q = V1A1 = V2A2 ------ ------------- --- 2-2

Where: Q = flow rate/discharge (m^3/s)

Vn = average velocity at cross-section n (m/s)

An = area at cross-section n (m2)

For open channel flow, the momentum equation is used in the form of the

Manning equation:

$Q = K\sqrt{Sf}$ ----------------------------------- ---2.3

$K = \frac{1}{n}AR^{2/3}$ ------------------------------------ ---2.4

Where: R = hydraulic radius (m)

n = Manning roughness coefficient

K = conveyance ($m^{5/3}$)

Sf = average friction slope between adjacent cross-sections

The hydraulic radius is calculated by dividing the cross-sectional area by the wetted perimeter. The Manning coefficient is a parameter that measures the effect of channel roughness on the flow of water through it.

For determination of conveyance, the cross-section is subdivided based on Manning coefficient into the left overbank, main channel, and right over bank. The conveyance for each subdivision is then calculated (Eq. 2-4). The total conveyance for the cross-section is obtained by summing the individual subdivision conveyances (Eric Tate, 1999)

2.2.1.2 Energy Equation

For open channel flow, the total energy per unit weight (energy head) has three components:

elevation head, pressure head, and velocity head (Figure 2-1) below.

$H = Z + Y + \alpha V^2/2g$-- ------------------------2.5

In hydraulic analysis the model HEC –RAS compute the water surface profile one cross section to next by solving energy equation with iterative approach procedure called standard step method. The energy equation is written as follows;

$Z_1 + Y_1 + \frac{\alpha_1 V_1{}^2}{2g} = Z_2 + Y_2 + \frac{\alpha_2 V_2{}^2}{2g} + h_e$ -------------------------- ----------------2.6

Where Z_1, Z_2, = Elevation of main channel inverts

Y_1, Y_2= depth of water at cross sections

V_1, V2= average velocity (total discharge/total flow area

g =gravitational acceleration

h_e= energy head loss

α_1, α_2= Velocity Weight coefficient

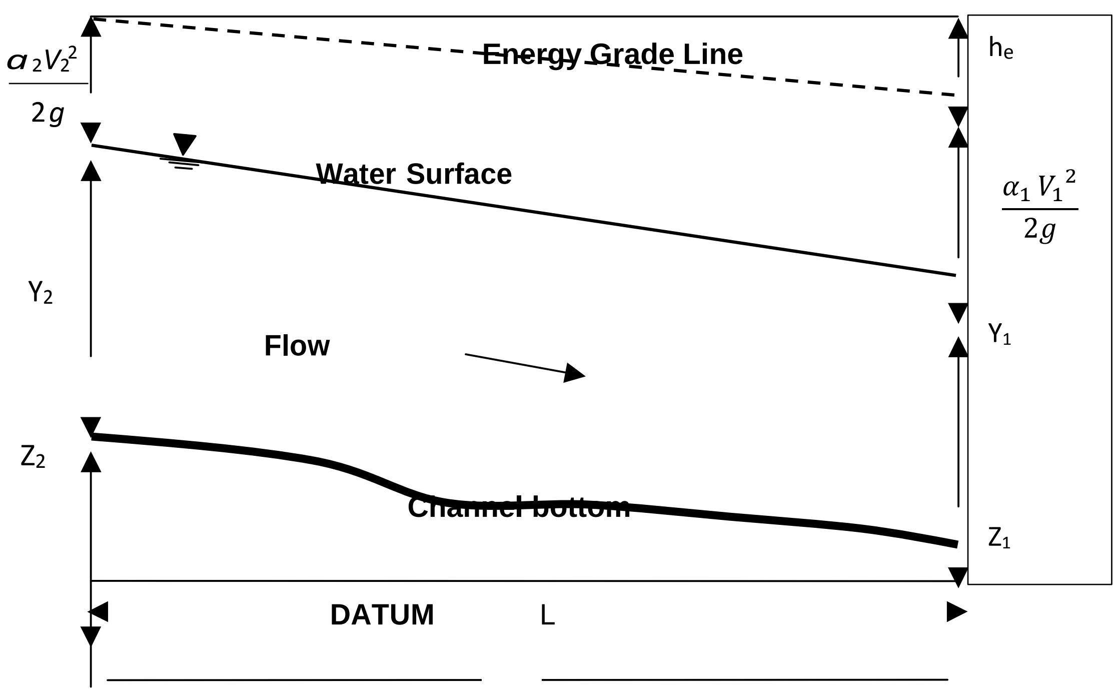


Figure 2:1 Energy equation parameters for gradually varied flow (Source HEC- RAS manual)

2.2.2. The Nature of Hydrologic Cycle over Drainage Area

The area upon which water falls, and the network through which it travels to an outlet, is required to drainage system. The flow of water through drainage system is only a subset of what is what commonly referred to as the hydrologic cycle, which also includes precipitation, evaporation, and ground water flow. (David Maidment.1999)

A drainage basin is an area that drains water and other substances to common outlet concentrated drainage. Other common terms for drainage basins are Watershed, basin, catchment, or contributing area. This area is normally defined as the total area flowing to a given outlet, or pour point, is the point at which water flows out of an area. This is lowest point along the boundary of drainage basin. The boundary between basins referred to as drainage divide or Water shed boundary

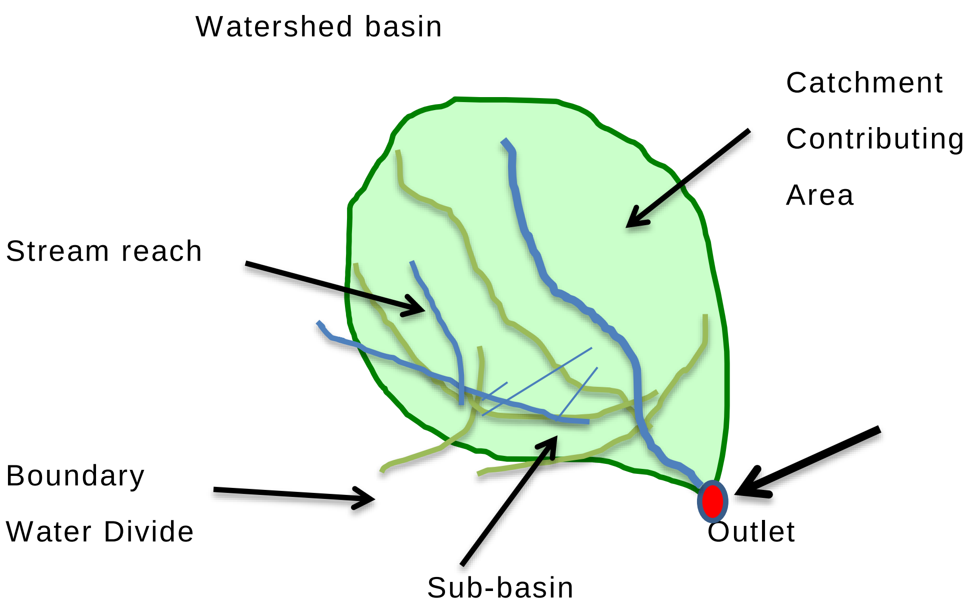


Fig 2.2 Drainage basin terminology

The physical processes controlling the distribution and movement of water are best understood in terms of the hydrologic cycle**.** Catchment modelling requires a clear understanding the hydrologic cycle at catchment scale. The catchment hydrologic cycle involves many processes. Many hydrologists investigated this cycle by a number of studies. A summary of the cycle is given by Chow et al To summary the processes; a brief description is presented and is illustrated in figure 2.3.

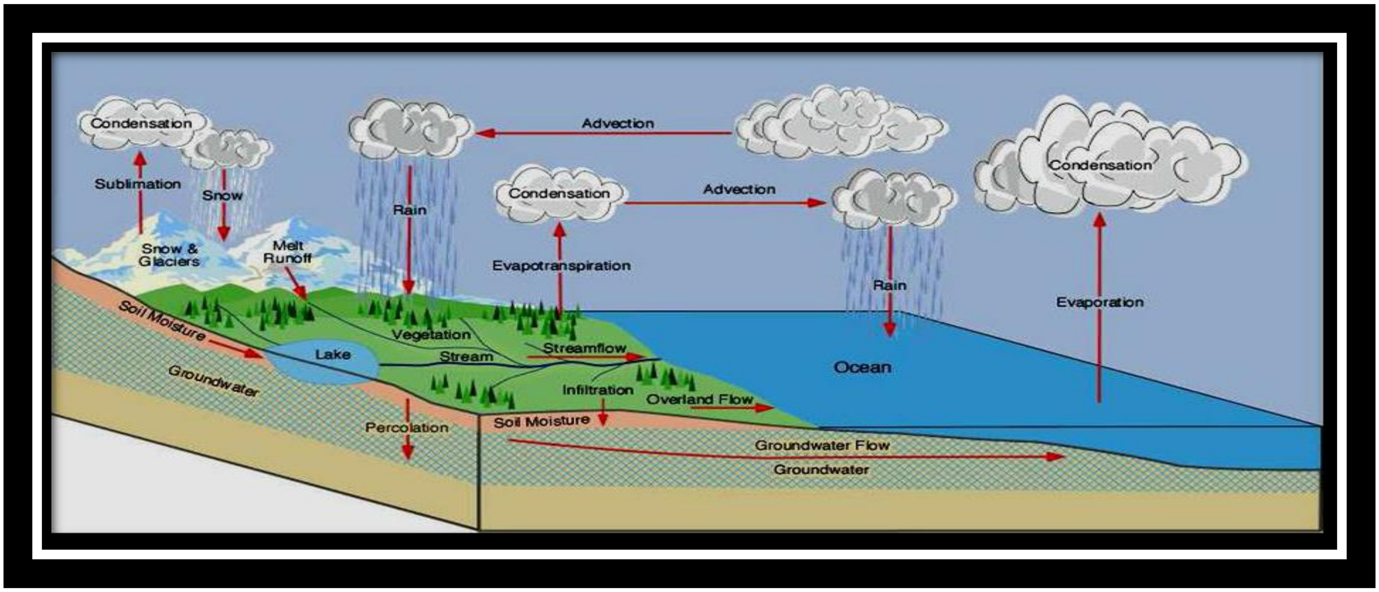


Figure 2.3 hydrological cycle, Chow et al. (1988).

Precipitation is the most essential process for the generation of runoff at a catchment scale. The distribution of precipitation varies spatially and temporally the nature. Precipitation can be in the form of snow, hail, dew, rain and rime. In this study precipitation is considered in the form of rain only.

Rainfall travels in a catchment in different directions. Due to vegetation, part of rainfall is intercepted by vegetation canopy. Interception is known as a loss function to catchment runoff depending on vegetation type, vegetation density. The rest of rainfall moves down the vegetation as stem flow, drip off the leaves, or directly falls to the ground as through fall. Rainfall remains at the land surface as depression storage and either evaporates, infiltrates or is discharged as overland flow. Although there is no real beginning or ending point of the hydrologic cycle, we can begin the discussion with precipitation. For the purposes of this study, we will assume that precipitation consists of rainfall and snowfall. Rain falling on Earth may enter a water body directly, travel over the land surface from the point of impact to a watercourse, or infiltrate into the ground. Some rain is intercepted by vegetation; the intercepted water is temporarily stored on the vegetation until it evaporates back to the atmosphere. Some rain is stored in surface depressions, with almost all of the depression storage infiltrating into the ground. Water stored in depressions, water intercepted by vegetation, and water that infiltrates into the soil during the early part of a storm represent the initial losses. The loss is water that does not appear as runoff during or immediately following a rainfall event. Water entering the upland streams travels to increasingly larger rivers and then to the seas and oceans. The water that infiltrates into the ground may percolate to the water table or travel in the unsaturated zone until it reappears as surface flow.

2.3 Hydrologic Analysis of Road Drainage Structures

In the early days, culverts and bridges were sized by empirical methods developed from experiences with existing structures during floods. No particular recurrence intervals were associated with the resulting designs.(Bruce M. McEnroe, 2007).

But now days Modern hydrologic methods are based on statistical analyses of systematic records of stream flow or rainfall data; the desired recurrence interval is an input to the design.

In the hydrologic analysis for a drainage structure, it must be recognized that there are many variable factors that affect floods. Some of the factors which need to be recognized and considered on an individual site-by-site basis are things such as: Rainfall amount and storm distribution Drainage area size, shape, and orientation, Ground cover Type of soil, Slopes of terrain and stream(s), Antecedent moisture condition, Storage potential (overbank, ponds, wetlands, reservoirs, channels, etc.), as the result. In order to optimize drainage structures design many factors are considered vital. At many sites designers have valid reason for providing safety factor in designs. These reasons include uncertainty in discharge estimate, potentially disastrous results in property damage or damage to highway from headwater elevations which exceed the allowable, potential for development upstream of structure, and the chance that the design frequency flood will be exceed during the life of the structure(Aydagne, 2007).

2.3.1 Rainfall Runoff Process

The surface subsystem of the hydrologic cycle is where the rainfall and runoff interaction takes place. The input to this system is the rainfall and the output taken as the stream flow at the outlet of the system.

2.3.1.1 Rainfall

In the hydrologic cycle, moisture comes from the atmosphere to the surface as precipitation. The rainfall pattern and intensity greatly influences the runoff. If the rainfall intensity is lower than the equilibrium capacity, then all the water reaching the land surface will infiltrate. If the rainfall intensity is greater than the equilibrium infiltration capacity, but less than the initial infiltration capacity, at the beginning all the water will infiltrate, but when the infiltration capacity drops below the rainfall intensity, some of the water will remain on the ground surface. Finally, if the rainfall intensity is greater than the initial infiltration capacity, some water will immediately remain on the land surface.

Therefore, the nature of rainfall pattern is of great importance in dealing with runoff process.

Rainfall is extremely variable both in time and space. The variation is brought about by differences in the type and scale of development of precipitation-producing processes, and is also strongly influenced by local and regional factors, such as topography and wind direction at the time of rainfall. It is, however, assumed that each individual rain-gauge is representative of a very considerable area around it. This assumption is not correct. Because of the very considerable spatial variation of precipitation depth and intensity, particularly for short durations and for sever convectional storms as is the case in most parts of Ethiopia. There is no guarantee that point rainfall will in any way provide a reliable guide to the rainfall of immediate surrounding areas. Hence to account the spatial and time variation of rainfall, one can derivate the areal rainfall from a number of point rainfall data. The simplest and most obvious initial approach to the derivation of areal rainfall is to calculate using the arithmetic-mean method. This method is satisfactory if the gauge is uniformly distributed over the area and the individual gage measurements do not vary greatly about the mean. The Thiessen polygon method is the second and generally more accurate than the arithmetic-mean method. The Isohyetal method is flexible than Theissen polygon but it is more time-consuming, Chow et al. (1988)

2.3.1.2 Runoff

The water that moves in defined channel or all the water that moves over the land in undefined channel is termed as runoff, Chow et al. (1988).

During precipitation, some of the rainfall is intercepted by vegetation before it reaches the land surface. This may later fall to the ground or evaporate. Meteoric water which is not intercepted by the vegetation cover falls on the ground surface, where it evaporates, infiltrates into pervious soils, lies in the ground depression or flows down giving rise to runoff. The runoff process is strongly influenced by infiltration capacity. The infiltration capacity varies not only from soil to soil, but is also different for dry versus moist conditions in the same soil. After a certain time it reaches a regime value which is called equilibrium infiltration capacity, Chow et al. (1988). The water, which does not infiltrate, forms puddles or flows as a thin sheet across the land surface which is called overland flow or surface runoff. Hydrologists refer to the water trapped in puddles as depression storage.

The overland flow, sometimes called Horton overland flow, occurs only when the rainfall intensity exceeds the infiltration capacity. In areas in which soils have a high infiltration capacity, this process may occur only during very intense storms or when the soil is saturated or frozen.

If the unsaturated zone is uniformly permeable, most of the infiltrated water percolates vertically (percolation). If layers of soil with a lower vertical hydraulic conductivity occur beneath the surface, then infiltrated water may move horizontally giving rise to what is called interflow. This interflow is substantial in some drainage basins, and contributes significantly to the total stream flow. Thin permeable soil overlying fractured bedrock of low permeability would provide a geological condition contributing to significant interflow, Chow et al. (1988)

The infiltrated water that percolates into the saturated zone below the water table becomes stored in the groundwater reservoirs or aquifers. This is not a static storage, as groundwater is in constant movement. While freshly infiltrated water is entering the groundwater reservoir, other groundwater, known as base flow, is discharged into a stream.

Water that infiltrates into the soil on a slope can move down slope as lateral unsaturated flow (through flow). The difference between through flow and interflow is that through flow emerges as seepage at the foot of the slope rather than entering a stream, as does interflow.

Thus, through flow appears as overland flow before entering a stream channel. This peculiar overland flow is called return flow which is different from the Horton overland flow. Direct precipitation is also very important for the stream flow, especially when it falls onto the surfaces of large lakes or reservoirs.

For all hydrologic analyses, the following factors should be evaluated and included when they will have a significant effect on the final results: Drainage basin characteristics including: size, shape, slope, land use, geology, soil type, surface infiltration, and storage, Stream channel characteristics including: geometry and configuration, slope, hydraulic resistance, natural and artificial controls, channel modification, aggradation, degradation, and ice and debris, Floodplain characteristics, Meteorological characteristics such as precipitation amount and type (rain, snow, hail, or combinations thereof), rainfall intensity and pattern, areal distribution of rainfall over the basin, and duration of the storm event.

2.3.2. Rainfall-Runoff Relationships

The derivation of relationships between the rainfall over a catchment area and the resulting flow in a river is a fundamental problem for the hydrologist. In most countries, like Ethiopia there are usually Shortage of rainfall records and the more elaborate and expensive stream flow measurements, which are what the engineer needs for the assessment of water resources or of damaging flood peaks, are often limited and are rarely available for a specific river under investigation. Evaluating river discharges from rainfall has stimulated the imagination and ingenuity of engineers for many years, and more recently has been the inspiration of many research workers.

To facilitate comparisons it is usual to express values for rainfall and river discharge in similar terms. The amount of precipitation (rain, snow, etc.) falling on a catchment area is normally expressed in millimetres (mm) depth, but may be converted into a total volume of water, cubic metres (m^3) falling on the catchment. Alternatively, the river discharge (flow rate), measured in cubic metres per second ($m^3/s{-}1$ or cumecs) for a comparable time period may be converted into total volume (m3) and expressed as an equivalent depth of water (in mm) over the catchment area. The discharge, often termed *r*unoff for the defined period of time, is then easily compared with rainfall depths over the same time period.

Estimating runoff or discharge from rainfall measurements is very much dependent on the timescale being considered. For short durations (hours) the complex interrelationship between rainfall and runoff is not easily defined, but as the time period lengthens, the connection becomes simpler until, on an annual basis, a straight-line correlation may be obtained. The time interval used in the measurement of the two variables affects the derivation of any relationship, although with continuously recorded rainfall and stream discharge this constraint is removed and only the purpose of the study influences choice of time interval. Hence, relating a flood peak to a heavy storm requires continuous records, but determining water yield from a catchment can be accomplished satisfactorily using relationships between totals of monthly or annual rainfall and runoff.

Naturally, the size of the area being considered also affects the relationship. For very small areas of a homogeneous nature stretch of motorway, say the derivation of the relationship could be fairly simple; for very large drainage basins on a national or even international scale and for long time periods, differences in catchment effects are smoothed out giving relatively simple rainfall-runoff relationships. However, in general and for short time periods, great complexities occur when spasmodic rainfall is unevenly distributed over an area of varied topography and geological composition.

In the intermediate scale of area and time, other physical and hydrological factors, such as evaporation, infiltration and groundwater flow are very significant and thus any direct relationship between rainfall alone and runoff is not easily determined.

2.3.3. Method of Estimation of Peak Discharge

According to ERA, 2013 drainage design manual, there are many hydrologic flow estimation methods available. If possible, the selected method should be calibrated to local conditions and verified for accuracy and reliability. There is no single method for determining peak discharge that is applicable to all watersheds. It is the researcher's responsibility to examine all methods that can apply to a particular study area and to make the decision as to which is the most appropriate. Consequently, the designer must be familiar with the method sources of the various methods and their applications and limitations.

The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to the design of highway drainage structures. Errors in the estimates will result in a structure that is either undersized and causes more drainage problems or oversized and costs more than necessary. On the other hand, it is important to realize that any hydrologic analysis is only estimation. Although some hydraulics analysis is necessary for all highway drainage structure design, the extent of such studies should be commensurate with the hazards associated with the hydraulics structures and with other concerns, including economic, engineering, social, and environmental factors. Because hydrology is not an exact science, different hydrologic flow estimation methods developed for determining flood runoff may produce different results for a particular situation.

Therefore, the engineer should exercise sound engineering judgment to select the proper flow estimation method or methods in estimation design flows. While performing the hydrological and hydraulics analysis for the design of highway drainage systems, the hydraulic engineer should recognize and evaluate potential environmental problems that would impact the specific design of a drainage structure early in the design process.

a) Empirical Formulae

Many Empirical Formulae have been devised for the purpose of simplifying the methods of estimating flood flows. Some of these formulae relate peak discharge to the total catchment areas while other formulae relate peak discharge to catchment area and slope. For more effective hydrological design, similar Regression Equations for estimation of Design Flood Discharge should be developed for Ethiopia However, if such empirical formulae are to be adopted for Ethiopia, their applicability for a particular area in Ethiopia should first be calibrated and verified with locally available data.

b) Hydrological method

The hydrological methods approved by ERA and limitations on their use are as follows:

i. Rational Method - only for drainage areas less than 50 hectares (0.5 square. km);

ii. SCS and other Unit Hydrograph Methods - for drainage areas greater than 50 and less than 65,000 hectares; As detailed in Highway Hydrology - Hydraulic Design Series -2, The SCS method should be used on watersheds that are homogeneous in CN; where parts of the watershed have CNs that differ by 5, the watershed should be subdivided and analyzed using a hydrograph method, such as SCS, 1984

The SCS method should be used only when the CN is 50 or greater and the tc is greater than 0.1 hour and less than 10 hours. The computed value of Ia/P should be between 0.1 and 0.5

iii. Watershed Regression Equations - for all routine designs at sites where applicable;

iv. Log Pearson III Analyses - preferable for all routine designs provided there are at least 10 years of continuous or synthesized record for 10-year discharge estimates and 25 years for 100-year discharge estimates; and

v. Suitable Computer Programs - such as HEC-HMS and Hydro CAD will be used to aid tedious hydrologic calculation.

"The estimation of the Q-T relation has motivated a multitude of journal articles, reports and conference proceedings, and these reflect a wide variety of approaches. Despite the volume of literature that has resulted from both theoretical and applied investigation, no consensus exists as how to best to proceed." (Admassu, 1989)

The terrain of land features greatly influence the rate of run-off.

Table 2:1 Different classification of terrain

Flat	0 to 10 five- metres contours per km. the natural ground slopes perpendicular to the ground contours Are generally below 3%
Rolling	11 to 50 five- metres contours per km. the natural ground slopes perpendicular to the ground contours Are generally between 3% and 25%.
Mountainous	26 to 25 five- metres contours per km. the natural ground slopes perpendicular to the ground contours Are generally Above 25% .
Escarpment	Escarpment requires special Geometric standards because of engineering risk involved. Typical gradients are greater than those mountainous terrains.

2.4 Rain Fall Intensity and Frequency

The frequency of storms and floods are not necessarily synchronized largely due the effects of antecedent moisture conditions, variability of channel transmission losses, over bank storage, and etc.

When water shed is saturated from recent rains, additional rain fall naturally causes substantial run off. on the other, for example early in rainy season in Ethiopia, rain fall may cause different amount of rain fall, then rainfall frequency and run off frequency cannot always be the same: a 100-year recurrence interval rainfall does not always cause a 100-year peak flow. It in view of this incongruity that in practice run off coefficients are usually adjusted, that is, to reflect postulated fluctuations in run-off frequency. This procedure, while empirical, has seemed to work well.(Ponce,1989)

A rainfall frequency (return period) applicable to given design condition is selected, as frequency varies with type of project and degree of protection desired for specific structure. The size and importance the project as well as design criteria issued by ERA and regional state of design offices have bearing in the selection of design frequency.

It should be understood at the outset that predictions regarding future rainfall or runoff from accumulated records rest on the laws of probability: in other words, the chance that a given event will or will not take place. To illustrate, consider the statement that a culvert is designed to carry a "50-year" flood. This means that, if past experience is repeated, the chances are 1 in 50 that the structure will flow full or be overtaxed once in a particular year. It does not mean that the design flood or a larger one will occur exactly one time in 50 years; in fact, the chances are only 64 in 100 that a flood of this magnitude will occur in a given 50- year period. On the other hand, several floods of this or greater magnitude could occur in successive years or in a single year, but the chance for either combination is extremely small. (Bruce M. McEnroe, 2007).

The longer return period i.e the smaller the frequency, the greater the peak discharge calculated by rational formula. Different methods are used to determine the rain fall intensity to be employed in the rational method of catchment modeling.

The two most commonly used techniques for this purpose in the rational method.

- ✓ IDF (intensity –Duration Frequency) Curve method
- ✓ Rainfall frequency analysis

2.5 Drainage Structures

Two types of drainage systems, surface and sub-surface, are commonly used to conduct water away from the area surrounding the road and to evacuate extra water from the road structure. The design of road drainage systems varies with factors such as road importance and age, traffic load and rural/urban area (Faísca et al., 2009). A surface drainage system (ditch) collects and diverts storm water from the road surface and surrounding areas to avoid flooding. It also prevents damage to sub-surface drains, water supplies (wells) and other sensitive areas adjacent to roads. It decreases the possibility of water infiltration into the road and retains the road bearing capability (Faísca et al., 2009). Subsurface drainage systems drain water that has infiltrated through the pavement and the inner slope, but also groundwater. Subsurface drainage systems usually comprise culverts and have a direct linkage to surface drainage systems (Dawson, 2009).

According to Peter and John (2002), for rill and sheet erosion, road surfaces is the cause; whereas for gully erosion risk, road culverts and ditches are the major cause.

2.5.1 Road Ditches

Ditch is a long narrow channel dug in the ground parallel to a road usually used for drainage and as a boundary marker. Good ditches make good roads. Properly designed and constructed ditches serve a number of essential purposes:

- They collect road surface run-off and drain it away from the road.
- They store large amounts of rainfall.
- With proper turnouts and buffers, they keep pollution from reaching sensitive water resources.
- They collect and drain subsurface water away from the road's base and sub grade soil materials.

Proper ditching involves careful consideration of many factors, including watershed size, degree of slope, width of right-of-way, ditch size and shape, and native soil type. According to Dunham (2001), for unpaved roads, Ditches must be lined with stone and grass, and for paved or asphalt road, Ditches should be constructed from cement and concrete to control erosion.

The constructions such as culverts and bridges outside urban areas are usually dimensioned for 50-year flows (flows with a return period of 50 years). The rational formula is used for predicting maximum discharge levels in rivers and streams when dimensioning culverts and bridges. In that formula, important factors such as topography, soil conditions or land use are not taken into account, which can in some cases lead to incorrect dimensioning. Furthermore, existing drainage structures are mostly designed based on historical precipitation statistics and experiences, whereas today the design needs to include future scenarios (Hansson et al., 2010).

2.5.2 Cross- drainage Structures

Design of an efficient cross-drainage system is a prerequisite for success of new road projects and for rehabilitation projects as well.

Cross drainage involves the conveyance of surface water and stream flow across or from the highway right of way. This is accomplished by providing either a culvert or a bridge to convey the flow from one side of the roadway to the other side or past some form of flow obstruction. In addition to the hydraulic function, a culvert must carry construction and highway traffic and earth loads. Culvert design, therefore, involves both hydraulic and structural design. However, this section of the manual is concerned with the hydraulic design of culverts.

Both the hydraulic and structural designs must be consistent with good engineering practice and economics According to ERA drainage manual there are three main types of cross drainage structures used on roads and each has particular advantages and disadvantages. The three types are bridges, culverts and fords.

Selection of one type of structure based on hydraulic factors such as Flood discharge equation, Water course channel conditions and topography, afflux constraints debris properties, scour risk and other factors like Road alignment, level of serviceability and soil condition.

2.5.2.1 Road Culverts

Culverts hydraulically short conduit which Convey stream flow through roadway embankment or past some other type of flow obstruction. This is accomplished by conveying water under the road through the culvert, or by allowing water to flow over the road using a ford, water bar, or dip. Culverts are constructed from variety of materials and are available in many different Shapes and configuration. According to Federal high way of U.S.A of hydraulic design series No, 5, There are numerous cross –sectional Shapes area available which includes, circular, Box (rectangular), elliptical, Pipe arch, arch. The shape selection shape is based the cost of construction, the limitation on upstream water surface elevation, road way embankment height and, hydraulic performance.

Proper planning of culverts is a very important aspect of road design from the point of view of safety of the road - new or existing one. Planning generally covers selection of location, type, numbers and size of culverts.

To be most effective, location of culverts have to be very carefully decided after studying the terrain and collecting relevant information from topo sheets and other sources. Field visit and consultation with local people and local authorities conversant with local topography and drainage problem of the area is extremely useful.

The hydraulic Capacity of culvert may be improved by appropriate inlet selection. Since the natural channel is usually wider than the culvert barrel, the culvert inlet edge represents flow contraction and primary flow control. The provision of the more gradual Flow transition will lessen the energy loss and thus create the more hydrologically efficient inlet condition.

Selection of culvert type is important in some applications. According to ERA drainage manual the following predominate types are used

- Pipes (any material type);
- Box culverts, including slab link culverts;
- Slab deck culverts (cast in-situ); and Multi-plate arches.

There are two issues of particular concern for selecting the type of culvert. The first relates to the waterway area at low flow depths and the second relates to the extent to which the culvert spreads the flow. Box culverts and slab deck culverts provide for a greater waterway area at shallow depths while pipes need to flow at a greater depth before the maximum flow capacity is reached. The use of pipes however does tend to spread the flow to a greater extent, which is often desirable for consideration of concentration of flow and risk of scour.

One of the earliest American textbooks on road-building stated that culverts should be sized for the worst-case scenario. Their size must be proportioned to the greatest quantity of water which they can ever be required to pass, and should be at least 18 inches square, or large enough to admit a boy to enter to clean them out. However, most early textbooks on highway engineering advocated consideration of then economic trade-offs in the sizing of culverts and bridges The efficiency of the culvert may be materially increased by so arranging the upper end that the water may enter it without being retarded. The discharging capacity of a culvert can also be increased by increasing the inclination of its bed, provided that the channel below will allow the water to flow away freely after having passed the culvert.(Bruce M. McEnroe, 2007) Generally the flow condition Vary from culvert may flow full or partly depending on upstream and downstream condition, barrel Characteristics, and inlet geometry. Many literatures describe the two flow control in Culvert is Inlet and outlet control. Inlet control occurs when Culvert barrel is capable of conveying more flow inlet accept, whereas outflow control occurs when culvert barrel is not capable of conveying as much flow the inlet opening will accept.

2.5.2.2 Bridge

Bridge is Structures that transport traffic over waterways or other obstructions.

It is structure with a total clear opening above 6.0-m. A structure with a clear span opening less than 6m that is a *culvert and* Small bridge 6-15 m, Medium 15-50 m and Large Bridge above 50 m total length. *(ERA, design manual 2013)*

According to Beza, 210 Bridges that cross the rivers and valleys are vital components of the road network that contributes greatly to the national development and public daily life. Any damage or collapse of bridge can risk the lives of road users as well as create serious influence to the entire country. Furthermore, the reconstruction of the bridges needs considerable amount of money and time. In fact, Ethiopia has experienced many cases of bridge collapse and their serious consequence over decades.

The two main issues in bridge hydraulics are the backwater caused by bridges during floods and scour around bridge piers and abutments during floods.

Proper hydraulic and hydrologic analysis and design is as vital as the structural design.

Stream crossing systems should be designed for:

- Minimum cost subject to criteria
- Desired level of hydraulic performance up to an acceptable risk level
- Mitigation of impacts on stream environment
- Accomplishment of social, economic, and environmental goals

Following are certain American Association of State Highway Transportation Officials (AASHTO) general criteria adopted by the Department related to the hydraulic analyses for bridges as stated in their highway drainage guidelines:

- Backwater will not significantly increase flood damage to property upstream of the crossing

• Velocities through the structure(s) will not damage either the highway facility or increase damages to adjacent property.

• Maintain the existing flow distribution to the extent practicable

• Pier spacing and orientation and abutment designed to minimize flow disruption and potential scour.

• Foundation design and/or scour countermeasures to avoid failure by scour.

• Minimal disruption of ecosystems and values unique to the floodplain and stream. (VDOT, drainage design manual)

2.5.3 Road Drainage Structure's Failure

Adequate maintenance is necessary for the proper operation of the drainage system. Lack of maintenance is one of the most common causes of failure of drainage systems (erosion and sediment controls). This may be attributed to reasons such as a significant reduction in hydraulic or storage capacity (e.g. blockage by debris or sediment).

In principle, there are two different natural causes for the clogging or blockage of drainage structures, namely erosion in the stream caused by high water flows and landslides on the river banks resulting in soil and vegetation being transported with the stream. Regions which have many pipe bridges and culverts may be especially at risk of flooding, as within these structures the space for water and possible transported objects, e.g. tree branches, is limited.

The most common reason for the occurrence of damage is blockage of the pipe/culvert inlet with materials such as fine soil, gravel, stones and tree branches. Since that is normally the result of high water flows, there is commonly not enough time to remove the barrier before the water flows over the road and the whole embankment is destroyed. Hence, insufficient maintenance can often be the cause of road drainage failure. Prior to the destruction of an embankment, it is relatively common for settling in the road to occur, which indicates that soil is being carried away through internal erosion (also called piping). When flow paths then open up through the embankment, the whole process accelerates and results in a more or less violent dam breakage, which has a flood wave of water and soil as its consequence (Magnusson et al., 2009).

Elevated water levels and increased water velocity in watercourses can result in trees, stones, etc. being displaced as well as road culverts and low bridges being clogged during high flows. This can lead to erosion of roads and washing away of roads and embankment.

Chapter Three

3. Research Methodology

3.1 General

The Shishinda-Tepi road projects are found in the Southern part of Ethiopia with SNNP region with starting point of Shishinda town approximately at $7^o15'$ latitude and $35^o52'$ longitude and Tepi town at $7^o12'$latitude and $35^o25'$ longitude.

The research process began with a review of ERA drainage design manual documents and of international literature concerning road drainage systems. There is a dearth of relevant literature explaining and predicting hydrologic and hydraulic failure due to insufficient road drainage systems and too extravagancy of structure by oversize designing.

Upon obtaining the identified problems, conceptual and contextual literature reviews were conducted to have in depth understanding on the issue of hydrologic and hydraulic analysis for road drainage structure in general.

The literature reviewed includes books, dissertations, thesis, magazines, journals, newspapers and informal discussion of professionals. The work continued by examining current practice of road drainage systems in Ethiopia and gathering experience from professionals working with various problems concerning surface and subsurface drainage systems.

3.2 Study Methods

3.2.1 Data Collection

Generally in this paper different data types are collected. Both primary and secondary data were collected from fields and concerned organization. These data are the location of each cross drainage structure which expressed in terms Northing and Easting as indicated Appendix D and each size cross drainage structure. There are around ninety three cross drainage structures on the route which includes two bridges and ninety one different types' culverts. In addition to above data secondary data are collected from different organization.

The work is begun by collecting field data which accomplished using electronic survey equipment and Global positioning system (GPS). Using GPS as data collection tool, the location of each Cross drainage structure is obtained, with little addition processing. This information can be directly used in hydraulic and hydrologic software.

Different datasets were used to build the model. These include the elevation, stream flow, precipitation, soil classification and land use data. The different datasets and their sources are given in Table 3:1

Table 3:1Types of data collected and their sources

Types Data	Sources of Data
Meteorological Data	National Meteorological Service Agency Addis Ababa Ethiopia, Hydrology department
stream flow records for two crossing	Ministry of water and Energy Addis Ababa Ethiopia(hydrology department)
Surveyed High Water M	Site Visit
Topographic Maps	Ethiopian Mapping Authority Addis Ababa, Ethiopia
Geological Maps	Ministry of Mines Addis Ababa, Ethiopia
Soils and Land Use Maps `	Ministry of Agriculture Addis Ababa, Ethiopia
Digital elevation Model(30mx30m resolution)	Ministry of water and Energy Addis Ababa Ethiopia, GIS department
Location of each cross drainage and photo	Collected from field by using GPS and camera
Spot Image	Ethiopian Mapping Authority Addis Ababa, Ethiopia

3.2.2 Different Types Materials used in Research

There are different types of software used in this study. These are Global mapper Version 15.1, Arch GIS version 10.1, Arch hydro which is compatible with Arch GIS10.1 ,HEC –RAS 4.1.0, spread sheet ,Satellite image downloader, Google Earth, AutoCAD 2007 . All these software are used in this study. In This study the analysis of were done using Arc GIS 10.1, Global Mapper 15.1 Excel spread 2010, sheet ,and Topography map of large scale size for the determination of the catchment area is used.

Also for determination catchment characteristics Spot image, Google image downloader 7.47 & Google earth is used. Peak flood determination for the 50 years return periods for each crossing is conducted. The peak discharge for the inlet drainage structures is determined by rational method, SCS method, frequency analysis. Two crossing are where bridge is located is modeled by HEC – RAS 4.0 and other data's were used for the hydraulic analysis.

Table 3:2 Different types of software and their uses in this study

Software	Their uses
Global mapper	To overlay different GIS image with correct projection, to determine catchment area
Arch hydro	To delineate area of catchment for two crossing,
HEC-RAS	To observe water surface profile and depth of scour
Google Earth	To Observe land use and Land cover of Catchments area
Satellite image downloader	To down load image with high resolution
AutoCAD	To coconut profile road route, delineate catchment
Arch GIS	To Geo referencing different images
Spreadsheet	To plot graph and chart and calculation

3.3 Research method

General

The work began by Field visits were made to Shishinda-Tepi road to a collect data needed to do Hydrologic and Hydraulic investigation. Such as determination of stream channel roughness coefficients (Manning's *n*), cross-section elevations, and hydraulic structure geometries, and Location of cross drainage structure obtained from field visit. Drainage-basin divides for the streams, initially defined on topographic maps, were field checked for accuracy. Most of the channel and overbank cross-section elevation data for use in the hydraulic models were obtained from field surveys.

In some cases, elevation data were estimated by interpolation between surveyed cross sections.

3.4 Sizing Cross-Drainage Structure of Shishinda-Tepi Road

The earliest textbooks on road-building stated that culverts and Bridge should be sized for the worst-case scenario. Their size must be proportioned to the greatest quantity of water which they can ever be required to pass. However, most early textbooks on highway engineering advocated consideration of the economic trade-offs in the sizing of culverts and bridges. Especial care is required to provide an ample way for the water to be passed. If the Culvert and

Bridge is too small, it is liable to cause a washout, entailing interruption of traffic and cost of repairs, and possibly may cause accidents that will require the payment of large sums for damages. On the other hand, if the culvert and Bridge is made unnecessarily large, the cost of construction is needlessly increased. Anyone can make a cross drainage large enough, but it is the province of the engineer to design one of sufficient but not extravagant size.

The economy of designing a bridge or culvert to take the maximum discharge from an area should be determined for sizing drainage structures. It would be economical to build the structure to meet maximum conditions if the interest on the first cost was less than the cost to repair whatever damage was incurred by the use of a structure furnishing a smaller waterway. Where a loss of life would be involved, however, the structure should be designed to meet maximum conditions. The first step to take is to decide on what magnitude of flood should be provided for. Extreme floods may occur but once or twice in a century; and the cost of caring adequately for such a contingency is excessive and unwarranted in many instances. Here the best judgment of the engineer will be needed; for the temptation will be to use too rigidly the principle that the loss due to the extreme flood is justified if it does not exceed the capitalized cost of the additional waterway necessary to prevent it. The difficulty in applying this principle is to foresee all the items that will enter into some future loss, and thus arrive at a true.

No historical stream flow data are available for the Ninety one crossing among crossing streams of interest in this study. The most applicable peak discharge estimation method was used to estimate peak flood discharges at selected locations along road route. Based area of catchment and assumption behind derivation of the formula three methods used in this study. these are Rational method for area less than 0.5km^2, SCS curve number method for area less than 65 km^2,Gumbel method used for more area. After determination of peak Discharge the conveyance capacity of cross drainage structures are calculate using Manning Equation. Any drainage installation is sized according to the probability of occurrence of an expected peak discharge during the design life of the installation. This, of course, is related to the intensity and duration of rainfall events occurring not only in the direct vicinity of the structure, but also upstream of the structure.

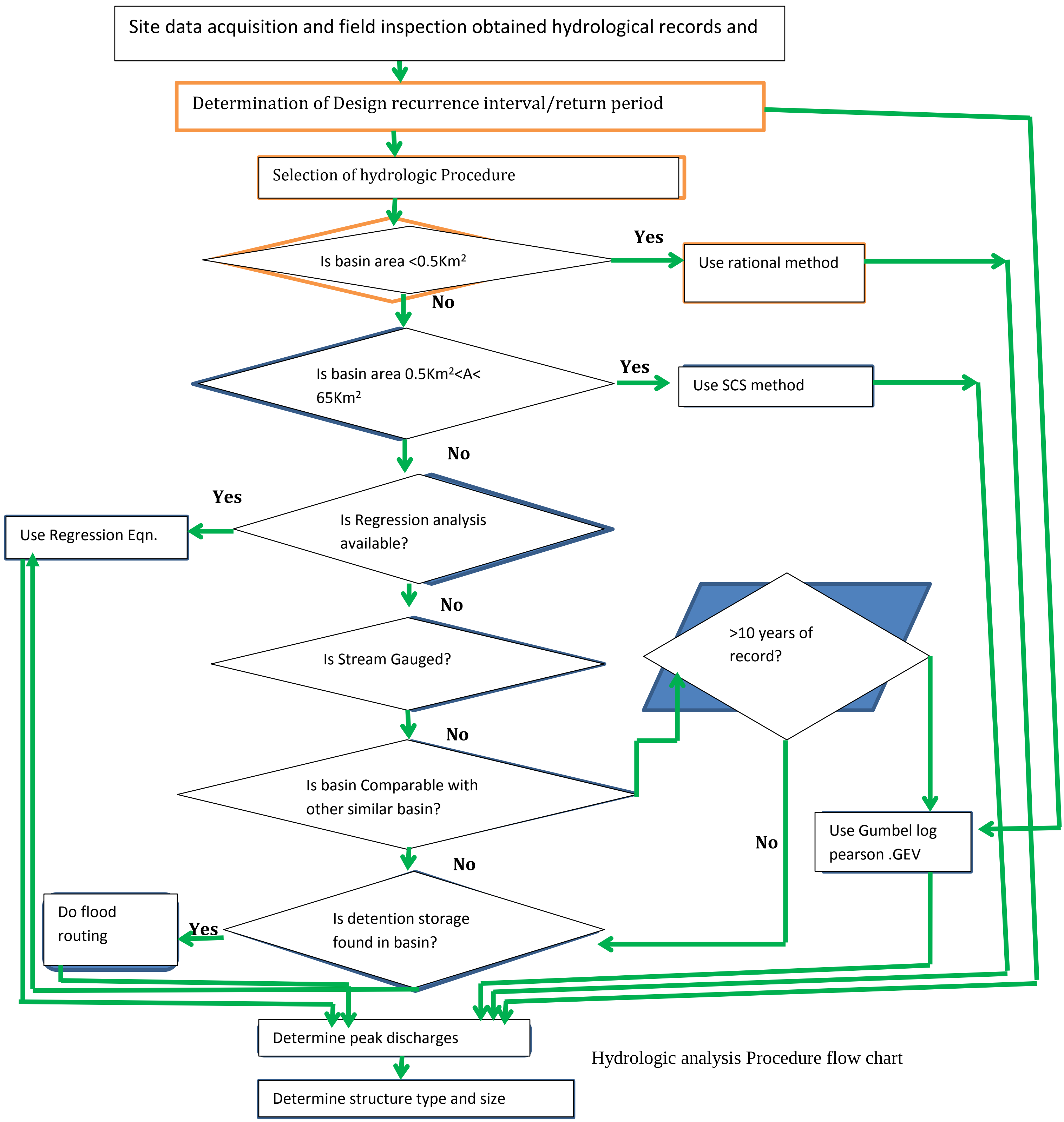
For the Shishinda-Tepi road, the maximum peak flood computed using the return period recommend in ERA Drainage Design Manual 2013 considering the Road standard and the design life span of the structure, 25 and 50 years return period for Sizing structure. According to ERA Drainage manual the rational method is used for area equal or less than 0.5km^2.

In addition to considering intensity and duration of a peak rainfall event, the frequency, or how often the design maximum may be expected to occur, is also a consideration and is most often based on the life of the road, traffic, and consequences of failure. Primary highways often incorporate frequency periods of 50 to 100 years, secondary roads 25 years, and low volume rural roads 10 to 25 years. For study area the road is gravel frequency period incorporated is 25, or 50 years based on span length.

Parameter Calculation

In this thesis different parameters are Investigated to the meet objective set. Once ninety three cross drainage structure is identified delineation of catchment area proceed. Among available watershed only two crossings have gaged stream data. Others are not gauged. For each crossing area of catchment is delineated from detail topographic map, Global mapper, Arch hydro. In this research small catchments are delineated from topographic map. Medium size of drainage catchments are delineated by AutoCAD and Global mapper

Largest sizes of catchments are delineated by Arch hydro. All areas obtained for each crossing catchment in this research are indicated in appendix D.



Hydrologic analysis Procedure flow chart

3.5 Hydrologic and hydraulic Modeling of Beko and Bitiwuha crossing watershed

3.5.1 General

Hydrologic and Hydraulic phenomena are extremely complex, and difficult both to measure and understand in full detail. In the absence of perfect knowledge, however, they may be represented in a simplified way by means of the system concept which is a set of connected parts that forms a whole. For instance the hydrologic cycle may be treated as a system, whose components are precipitation, evaporation, snowmelt, infiltration, runoff and other processes in the hydrologic cycle. The different components can each be grouped together into subsystem or broken down into new sub-processes, depending on the level of detail in the analysis and the purpose of the analysis. For most event based Modeling, only a few processes of the hydrologic cycle are Considered at a time, and only for a small part of the earth's surface, usually in a catchment.

A hydrological system can be defined as a structure or volume in space, surrounded by a boundary that accepts water and other inputs operates on them internally and produces an output. The objective of hydrological system analysis is to study the system operation and predict its internal states and output. Hydrological model is commonly used tool to estimate the basin hydrological response due to precipitation. A hydrological and Hydraulic system model is an approximation of the actual system. A model relates something unknown (output) to something known (input). Inputs and outputs are measurable hydrological variables and the model's structure is a set of equations linking input and output. Central to the model structure is the concept of system transformation. The input and output can be expressed as functions of time I (t) and Q (t) respectively. A system performs transformation of the input into the output by a transformation operator or equation. Because of these great complications, it is not possible to describe all the physical processes within the watershed with exact physical laws. Using the physical system concept the effort is instead directed to the construction of a model representing the most important processes, and their interaction within the total system. A conceptual knowledge of the physical system will still be valuable to determine the main processes, and develop a simplified but useful model. In this study due to absence hourly hydrography in study area for calibration and validation the researcher refrain from using HEC-HMS model.

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3.5.2 Hydrologic Modeling of Beko and Bitinwuha River Crossing

3.5.2.1 Model selection

In hydrologic terms model is a mathematical representation of hydrologic systems of the real world, for instance, the Unit Hydrograph model, the Soil Conservation Service Curve Number (SCS CN) model. A computer program, which contains one or more models, coded in a computer programming language to facilitate the mathematical realizations, such as WMS, HEC-HMS, SWAT, and etc. could also be termed as a hydrologic model. For the sake of clarity, throughout this monograph Hydrologic Model (HM) means any mathematical representation of hydrologic system processes and relations of the real world; and Hydrologic Computer Model (HCM) is a computer program that contains the hydrological mathematical realizations or equations.

Selection of the right HM model depends primarily on the objective of the modeling task for which the model will be evaluated based on certain criteria to meet some requirements.

Based on the hydro-climatological characteristics of study regions described in the previous chapters, different HMs evaluation criteria are proposed and the suitable applicable models are selected. Most of the currently available models do not match the top two basic criteria (empirical and event based) which is very important to deal with the space and time patchiness of rainfall events and the resulting discontinuous catchment responses. With respect to this study, a more attractive choice for the third important criteria would be to pick a semi-distributed model, which will be a good compromise between generally high simplification of the governing hydrologic processes used in lumped models, and extensive data requirements of distributed models.

3.5.2.2Rainfall-Runoff Modeling

Rainfall–runoff modelling may have a broad meaning depending on its objective.

Briefly, the intention of any Rainfall-Runoff Model (RRM) is to estimate the amount of runoff generated from a given rainfall using simple to complex (analytical) techniques applying an enormous number of assumptions and simplifications in representing the actual processes. The term “rainfall-runoff” explains “what runoff?” is generated from a given “rainfall” on a given “land surface”. The term “modeling” represents the mathematical representation used at different stages of the hydrologic system components to relate the rainfall and other hydrological parameters of the watershed with the parameters of the runoff characteristics.

“Rainfall” is the main input in most RRMs. Some models take a single parameter of the rainfall characteristics (in most cases mean areal rainfall depth) with a time resolution, which ranges from days to months, while other models consider multiple parameters of the rainfall (rainfall depth, intensity, and duration) with high time resolution that may range from minutes to hours. Application of the models depends on the purpose of the modelling task, the degree of comprehensiveness and expected accuracy of the model output for the “what runoff?” question. The modeling may be intended to answer the “what runoff?” question either partly or fully. For instance some of the hydrologic models developed in the past five decades try to estimate only the total volume of runoff generated from a given rainfall in a given time horizon. However, more "complete" models, which actually constitute different small models within them, try to give complete answer for the “what runoff?” question. The runoff volume with its characteristic hydrograph is describing the time the runoff has started and ended, the runoff time base, and its peak(s) of volumetric rate(s). These parameters can also be used for detailed characterization of the runoff by separating the surface flow and subsurface (base flow) of the model output.

In general RRMs have been used either to estimate the total runoff volume, the peak discharge or both, together with the runoff hydrograph; based on how the “rainfall”, “what runoff?”, and “land surface” terms are defined in the modelling task. RRMs can be classified in different categories: in terms of the method applied to represent the different hydrologic system components, the analytical approach, or the model structure (some say architecture). The different categories are explained in more detail in the following section. Different studies have been conducted to describe factors, which are related to the rate of overland flow generation. Most of their conclusion can be summarized into three primary factors: rainfall intensity, the instantaneous infiltration rate, and the rate at which the surface water is removed as runoff from the top soil layer (function of slope of the surface)

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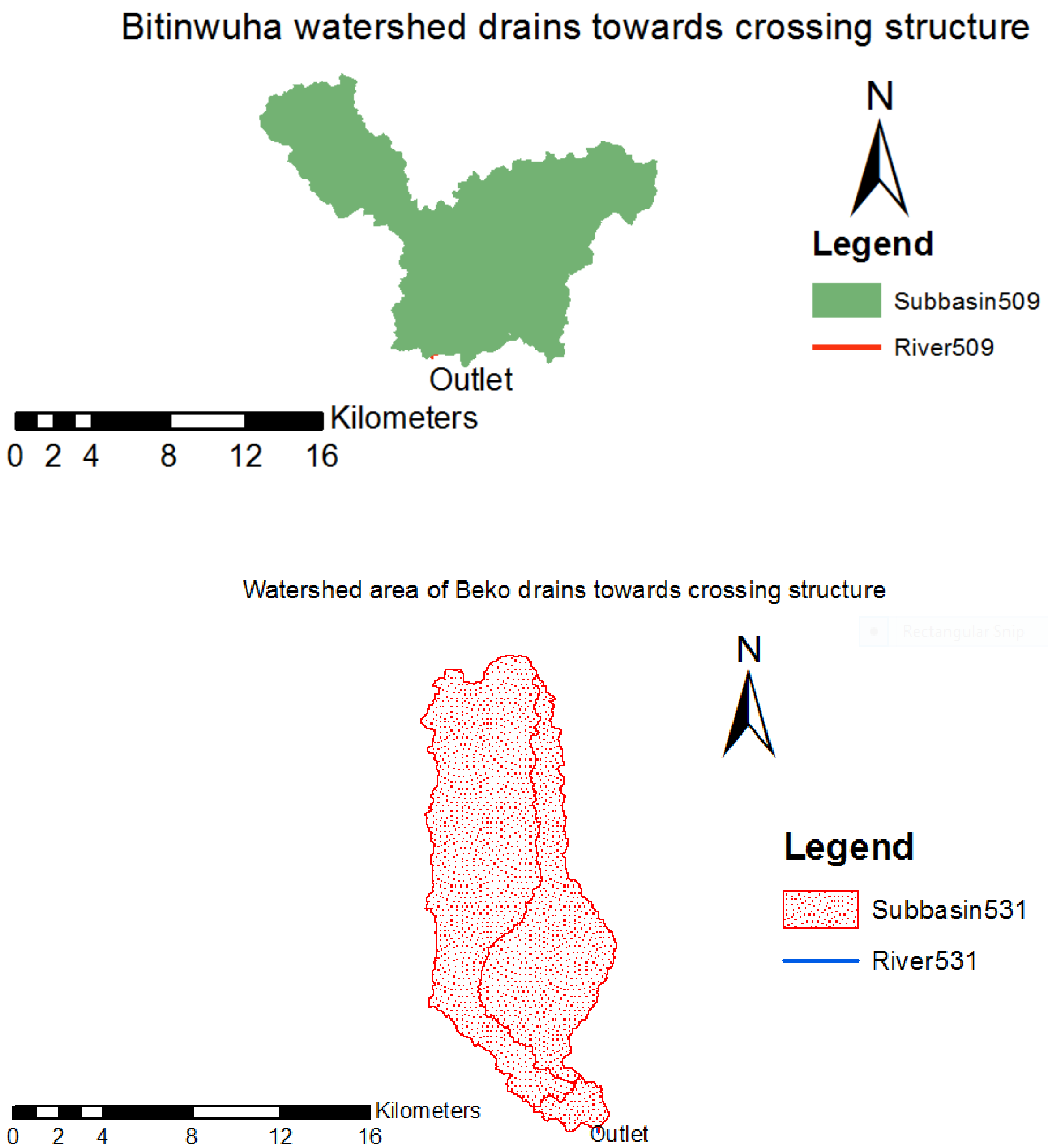

Figure 3:1 a) watershed area of Bitinwuha drains towards crossing Structure

b) Watershed area of Beko drains towards crossing structure

ii. Meteorology models: The meteorological model is responsible for preparing the boundary conditions that act on the watershed during a hydrological parameter calculation. Consequently, a meteorological model is prepared for use with one or more basin models. If the basin model contains sub basin elements, then the meteorological model must specify how precipitation will be generated for each sub basin.

- ✓ Precipitation

Precipitation is one of the three components of a meteorological model, and the one required in almost all meteorological models. The only time precipitation is not required is if a basin model contains no subbasins. Any basin model that contains at least one subbasin can only be used in a simulation with a meteorological model that includes a precipitation method. Some of the method choices are designed to work with statistical data. Others are designed to work with gage data. Regardless of the supporting data source, the precipitation method produces a hyetograph at the correct time step for each subbasin. There are different types of method in which we can work with precipitation in the model; Frequency Storm, Gage Weights, Gridded Standard Project Storm Precipitation, Inverse Distance, SCS Storm and Specified Hyetograph. In this study inverse distance method is used to model precipitation of study area**.**

- ✓ Inverse Distance

The inverse distance method was originally designed for application in real-time fore casting systems. It can use recording gages that report on a regular interval like 15 minutes or 1hour hour.

Because it was designed for real-time forecasting, it has the ability to automatically switch from using close gages to using more distant gages when the closer gages stop reporting data. The latitude and longitude of the gages is used to determine closeness to one or more nodes specified in each subbasin. Optionally, an index depth can be assigned to each gage. The index is used to adjust for regional bias in annual or monthly precipitation. This method uses separate parameter data for each gage used to compute precipitation and also uses separate parameter data for each subbasin in the meteorological model.

The scheme relies on the notion of nodes that are positioned within watershed such that they provide adequate spatial resolution of precipitation. Weight are computed and assigned to gages in inverse from the node to gage.

$$W_C = \frac{\frac{1}{d_C^2}}{\frac{1}{d_C^2}+\frac{1}{d_D^2}+\frac{1}{d_B^2}+\frac{1}{d_A^2}} \quad \text{-------3.1}$$

In which W_C= weight assigned to gage C, d_C=distance from node to gage C, d_D=distance from node to gage D, d_B=distance from node to gage B, d_A=distance from node to gage A.

Weights for gages D, E and A are computed similarly.

With the weight thus compute, the node hyetograph ordinate at time t is computed as;

$P_{node}(t) = W_A P_A(t) + W_C P_C(t) + W_D P_D(t) + W_E P_E(t)$ -- 3.2

Here the gage in figure 3.8 is note used in this example as it is not nearest to the node in the northwest quadrant. However, for any time the precipitation ordinate missing for gage A the data from gage B will be used, in general terms in the nearest gage in the quadrant with a data (including a zero value) will be used to compute the MAP.

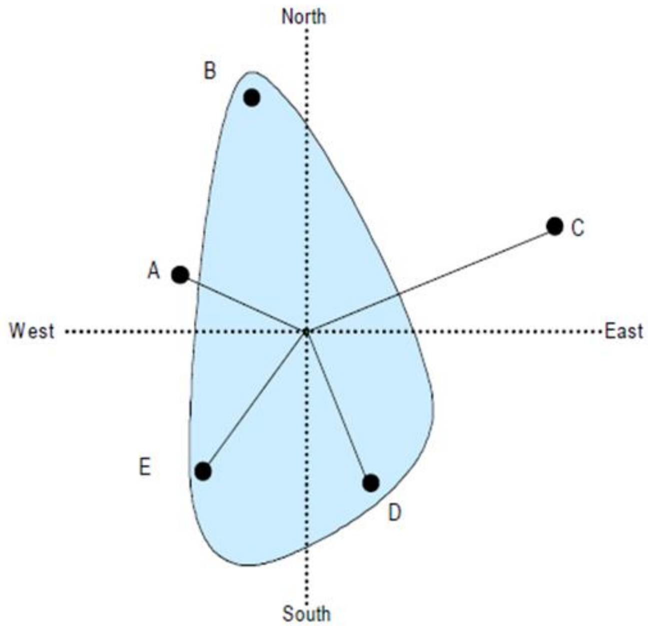

Figure 3:2 *Illustration* of inverse distance Method

- ✓ Evapotranspiration

Evapotranspiration is the second of the three components of a meteorological model.

It is the combination of evaporation from the ground surface and transpiration by vegetation. It is only required if the meteorological model will be used with subbasins that use continuous simulation loss rate methods: deficit constant, gridded deficit constant, soil moisture accounting, and gridded soil moisture accounting. Even if those methods are used in the sub basins, an evapotranspiration method is not required. If a continuous simulation loss rate method is used and no evapotranspiration is specified in the meteorological model, then zero evapotranspiration is used in the subbasins. In general there should be a selected evapotranspiration method for continuous simulation. In all cases, the meteorological model is computing the potential evapotranspiration and subbasins will calculate actual evapotranspiration based on soil water limitations. During storm event, this evapotranspiration is limited.

3.5.3 Hydraulic Modeling of Bitinwuha and Beko Bridge

3.5.3.1General over view of HEC-RAS

Hydrologic Engineering Centers River Analysis System (HEC-RAS) is integrated system software, designed for interactive use in multitasking, multi user network environment.

In HEC-RAS, the stream morphology is represented by a series of cross-sections called river station. Proceeding from downstream to upstream, the river station numbering is increases. The distance between adjacent cross-sections is termed the reach length. Each cross-section is defined by a series of lateral and elevation coordinates, which are typically obtained from land surveys. The numbering of the lateral coordinates begins at the left end of the cross-section, (looking downstream) and increases until reaching the right end.

The value of the starting lateral coordinate is arbitrary, only the distance between points is important. It is a one-dimensional model, intended for hydraulic analysis of river channels. The model is comprised of a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities. The HEC-RAS system includes four river analysis components. They include the steady flow water surface profile computations, unsteady flow simulation, sediment transport computations and water quality analysis. In addition to these components, the model contains several hydraulic design features that can be invoked once the basic water surface profiles are computed. HEC-RAS applications include floodplain management studies, bridge and culvert analysis and design, and channel modification studies (HEC, 2010b).

HEC-RAS has been present in the public realm for more than 15 years and has been peer reviewed (HEC, 2010c). It is freely available for download from the HEC website and is supported by the US Army Corps of Engineers. It is also widely used by many government agencies and private firms. For these reasons, HEC-RAS was selected for this study.

In this paper to meet the objective set steady flow river analysis method used.

3.5.3.2 River Analysis Components Used In this Study

Steady flow analysis water analysis water surface profiles: This component of the modeling system is intended calculating water surface profiles for steady gradually varied flow. The system can handle a full network of channels, dendritic system or single reach. The steady flow component is capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles.

The basic computational procedure is based on the solution of the one dimensional energy equation. Energy losses are evaluated by friction (manning's equation) and contraction/ expansion (coefficient multiplied by the change in velocity head). The momentum equation is utilized in situation where the water surface profile is varied these situations include mixed flow regime calculation (i.e. hydraulic Jumps, hydraulics of bridges, and evaluating profiles at river confluences (stream Junctions).In this assumption is used where two river come together i.e. Meni River and upper Bitinwuha River and at bridges (refer appendix (A.1).

3.5.3.3 Developing Hydraulic Model by using HEC-RAS

In the study two crossing Bitinwuha and Beko Bridge are modeled by using HEC-RAS.

There are five main steps in creating a hydraulic model in with HEC-RAS these are starting a new project, Entering Geometric data, entering flow data and Boundary condition, performing hydraulic calculation and viewing result. For two rivers the river systematic is developed in such that the boundary condition entered for modeling (see appendix A.1 and B.1). After the river systematic is completed, the next step to enter cross section data. Cross sections data represents the geometric boundary of stream. In this study cross sections are located at relatively short intervals along the stream to characterize the flow carrying capacity of stream. Cross sections are taken for each river at representative location through stream and locations where changes occur in discharge, slope, shape, roughness and Bridge. Stream junction data are entered where two streams (Meni and upper Bitinwuha river) comes together. For steady flow hydraulics in HEC-RAS, a junction can be modeled either energy equation or momentum equation. The energy equation does not take into account take into account angle of tributary coming in or leaving, while momentum equation does (HEC-RAS reference manual 2010).as the result in this study amount of energy loss due to angle of tributary flow is not significant, and using energy equation to model Junctions is more than adequate. Once all necessary cross section data have been entered, the next is to add bridge data. HEC –RAS computes energy losses caused by structures such as Bridge and culvert in three parts. One part consists of losses that occur in the reach immediately downstream from the structure where an expansion of flow takes place. The second part is losses at the structure itself, which is can be modeled with several different methods. The third part consists of losses that occur in the reach immediately up stream of the structure where flow contracting to get through opening.

The bridge routines in HEC-RAS allow the modeler to analyze the bridge with several different methods without changing th bridge geometry. The routine have the ability to model low flow (Class A, B, and C) low flow and weir flow (with adjustments for submergence),pressure flow(orifice and sluice gate equations), pressure and weir flow, and high flows with energy equation only.

In steady flow analysis the inputs to the model are

- ✓ River geometric data: width, elevation, shape, location, length,
- ✓ River floodplain data: length, elevation,
- ✓ The distance between successive river cross-sections,
- ✓ Manning 'n' value for the land use type covering the river and the floodplain area,
- ✓ Boundary conditions e.g. slope, critical depth, • Stream discharge values

Outputs from models for two crossings includes the flowing See appendix (A.1-B.4)

- ✓ Water surface elevations
- ✓ Rating curves
- ✓ Hydraulic properties i.e. energy grade line slope and elevation, flow area, velocity
- ✓ Visualization of stream flow, which shows the extent of flooding

The step-backwater hydraulic analysis model HECRAS 4.1 (U.S. Army Corps of Engineers) was used to determine steady-state water-surface profiles for each of the two station streams on which bridge is constructed based on the10, 50 and 100-year peak discharges determined in the hydrologic analyses.

Input data for the models included stream cross section and hydraulic-structure geometries, 10-years, 50 years, 100years peak discharges and roughness coefficients.

The two streams have narrow channels, generally ranging from about 5 to 30m in width. Typically, flows in small streams may encounter rapid transitions in channel geometry, likely leading to abrupt changes in cross sectional area and conveyance between sections. To help diminish abrupt transitions of area and conveyance, the maximum distance between open-channel cross sections was held to less than 150m; however, the distance between sections in the models is typically much less than 500m. The hydraulic geometry of the river is essential for accurate model simulations and is basically dependent on the DEM. DEMs are available mainly in two resolutions; 90 m and 30m.

Thirty meter profile DEMs capture more geomorphologic detail and have better elevation accuracy than the 90 m DEM Consequently 30 m DEM was used for the study

HEC-RAS default values for expansion and contraction coefficients were used for most of the cross sections in the model. At select locations, typically upstream and downstream from hydraulic structures, default values for the coefficients were modified on the basis of engineering judgment. At structures with abrupt flow transitions, contraction- and expansion-loss coefficients were typically increased from the HEC-RAS default values to account for the additional losses. Starting water-surface elevations for all four streams were established using the normal depth2 (slope conveyance) option in HEC-RAS. A main channel slope was computed using the average of main-channel streambed elevations from two surveyed cross sections near the downstream limit of each stream reach. These main-channel slopes were assumed to approximate the respective energy slopes for the purposes of normal depth calculations.

Two Catchments were modeled, a hydrologic model using HEC-HMS and a hydraulic model using HEC-RAS. Then using stream gage the hydrologic Models were calibrated and validated for different historic storm events. Future land use scenarios can be developed in for the future years. To evaluate the impact of land use changes on runoff, the hydrologic model was used to generate runoff for the SCS 50year 24-hour design storms for different land use scenarios. The hydrologic model runoff estimates were used in the hydraulic model, to generate the flooding extents for the different land use scenarios. Finally, the potential of wetlands for flood mitigation were evaluated. Wetlands were simulated using the hydrologic model.

Chapter Four

4. Hydro-Metrological data processing and analysis

Previous chapters give general overview of drainage structures and some important concept of hydrology and hydraulics. This chapter deals with collection of data suitable for the application of the methods and the output result of HEC-HMS and HEC-RAS models for the area. According to the theories discussed, three basic data sets are necessary for the modeling work. These are:

- ✓ Meteorological data (rainfall , temperature, wind speed, relative humidity and solar radiation)
- ✓ Hydrological data (stream flow) and
- ✓ Catchment physiographic data such as land use, land cover DEM of the area

4.1 Meteorological Data Collection and Analysis

4.1.1 Meteorological Data Collection

In Ethiopia, the source of raw metrological data is the National metrological service agency (NMA). A request of metrological data such as rainfall, temperature, wind speed and relative humidity of study area was made to the agency. Following the approval of the agency‘s higher official daily data of existing years period is collected. From the entire available automatic recording stations those which are in or proximate to the watersheds considered for the research work were selected. As a result a total of four station rainfall stations were selected for use in the research work.

The four stations are collected for this study; those are Shishinda, Bita, Chena, and Tepi.

The data available at Tepi station start in1956 to1959, and missed from 1960 to 1980. The daily metrological data exist at this station from 1981 to 2014 with missed certain monthly and daily data. At Chena and Shishinda stations metrological data available from 1980 with missed gap with certain daily and monthly data. At the Bita Woshi station the metrological data available from 1977. These rainfall stations are used in conjunction with stream flow stations, and the location of these rainfall stations is shown in Table 4.1

The rainfall records that obtained from NMA cover the length of years from 1956 to 2014 depending on the available stream flow records particular to catchment being considered. Besides, record years and mean annual rainfall (mm) are listed in Table 4.1. The collected data stretched over these years to obtain adequate match between the rainfall events and the resulting stream flow records. In the basin, for the watersheds considered, rainfall records are scarcely available; with sudden interruptions of records occur in the rainy season. The search for good match between the rainfall and stream flow records called for a big effort due to the gaps encountered. Table 4.1 shows the description of the rainfall stations with years of average annual rainfall recordings selected for the modeling work.

Table 4:1 Summary of the rainfall stations

No	Station name	Latitude (dms.)	Longitude (dms.)	Elevation (m)	Years of data available	Mean annual rainfall (mm)
1	Tepi	071200	0355300	1205	1956-2014	1576.4
2	Chena	070900	0354900	2203	1980-2014	1857.2
3	Bita Woshi	071900	0360200	1836	1977-2014	1639.6
4	Shishinda	071500	0355300	2000m	1980-2014	1408.2

4.1.2 Meteorological Data Analysis

4.1.2.1 Rainfall Data Screening

Hydrological modelling and water resources development project designs need sophisticated procedures that require continuous meteorological data for better water resource management.

Hydro-Metrological analysis forms an important analysis and integral part of hydrological research. Rainfall is one of these important meteorological variables that determine water availability and the hydrological processes in the hydrosphere. In addition, rainfall is more variable with in short distance in space than other meteorological variables. However, input data from most of the meteorological stations are missing and there is shortage of long-term continuous database in important watersheds of developing countries like Ethiopia. Rainfall data is collected by number of organization. It is common experience the rain fall data in its new form contain many gaps and inconsistent values. As such Preliminary Processing of this data is essential before it put to further use in the analysis. Process of data is two main objectives. One is to evaluate the data for its accuracy and other to prepare the data in the most usable form to the users.

Rough rainfall data screening of the four metrological stations in the study area was first done by visual inspection of daily rainfall data. Because of long braking in rainfall records of some stations and absence of lengthy overlapping period of record this inspection was done in the record of the hydrologic years of 1980 to 2014. Four methods arithmetic mean, normal ratio, inverse distance weighting, used to fill missing data. Arithmetic mean method gave better daily rainfall estimates for meteorological stations found near study area.

Graphical comparison of the rainfall data done by creating time series plotting of monthly rainfall data showed that the four stations show similar periodic pattern of records. A summary of th

rainfall stations with years of record used in the thesis is given in Table 4.1The rainfall data used in the model is given in Appendix D for the station.

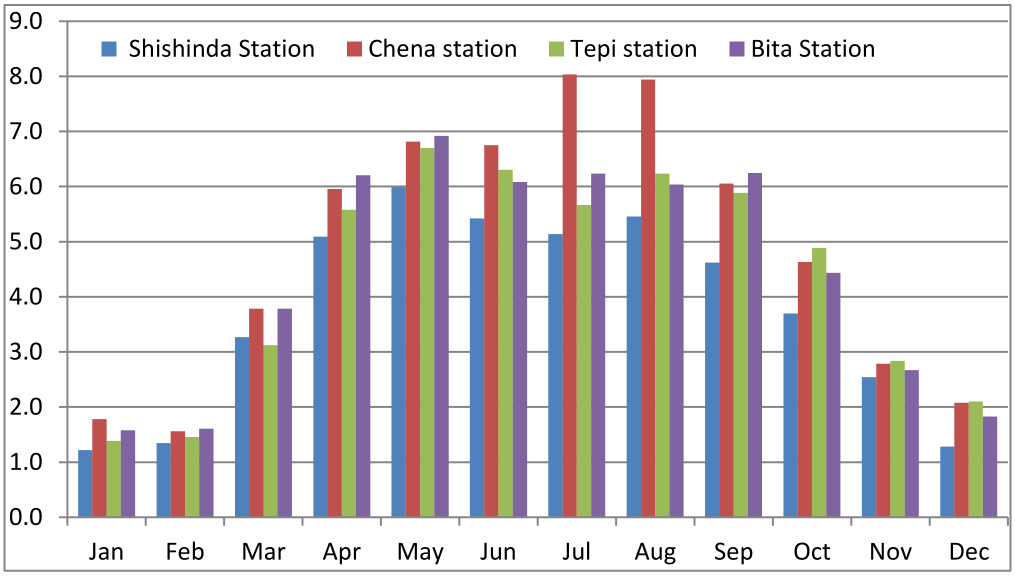

Figure 4:1 Average monthly Rainfall data (mm/day) series of 1980-2013)

4.1.2.2 Filling in Missing Rainfall Data

A number of methods have been proposed for estimate missing rainfall data (Richard H.McCuen (1989). the station average method is the simplest method. The normal-ratio and quadrant methods provide a weighted mean, with the former basing the weights on the mean annual rainfall at each gauge and the latter having weights that depend on the distance between the gauges where recorded data are available and the point where a value is required. The station average method for filling missing data is conceptually the same as the station average method for estimating a mean precipitation. This method may not be accurate when the total annual rainfall at any of the n region gauges differs from the annual rainfall at the point of interest by more than 10%. The normal-ratio method is conceptually simple; it differs from the station-average method of that the average annual rainfall is used in deriving weights. If the total annual rainfall at any of the n region gauges differs from the annual rainfall at the point of interest by more than 10%, the normal-ratio method is preferable. This thesis uses both Average and Regression method for filling the missing rainfall data. For total annual rainfall at station less than 10%, Average method and for more than10% regression method used.

4.1.2.3 Consistency of recording stations

If the conditions relevant to the recording of a rain gauge station have undergone a significant change during the period of record, inconsistency would arise in the rainfall data of that station. This inconsistency would be felt from the time the significant change took place. The checking for inconsistency of a record is done by double mass curve technique (Subramanya.K, 1998).

The accumulated total of the individual gauge is compared with the corresponding totals for a representative group of nearby gauge. If a decided change in the regime of the curve is observed it should be corrected. However, as all the selected stations in this study were consistent, there is no need of further correction.

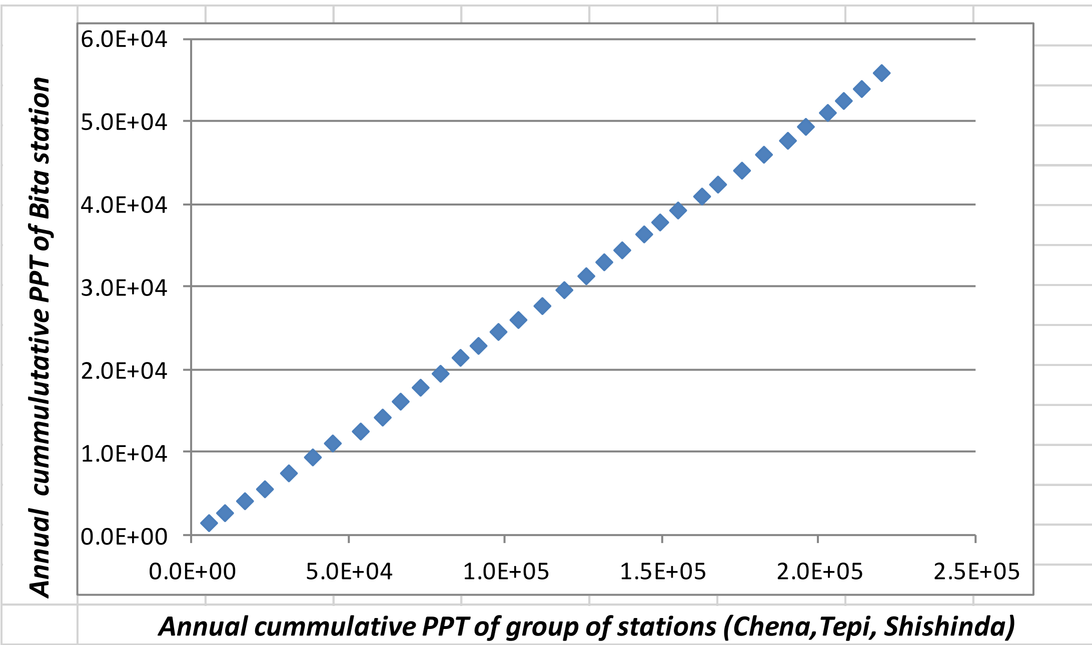

Figure 4:2 Consistency of Bita station with other cumulative station

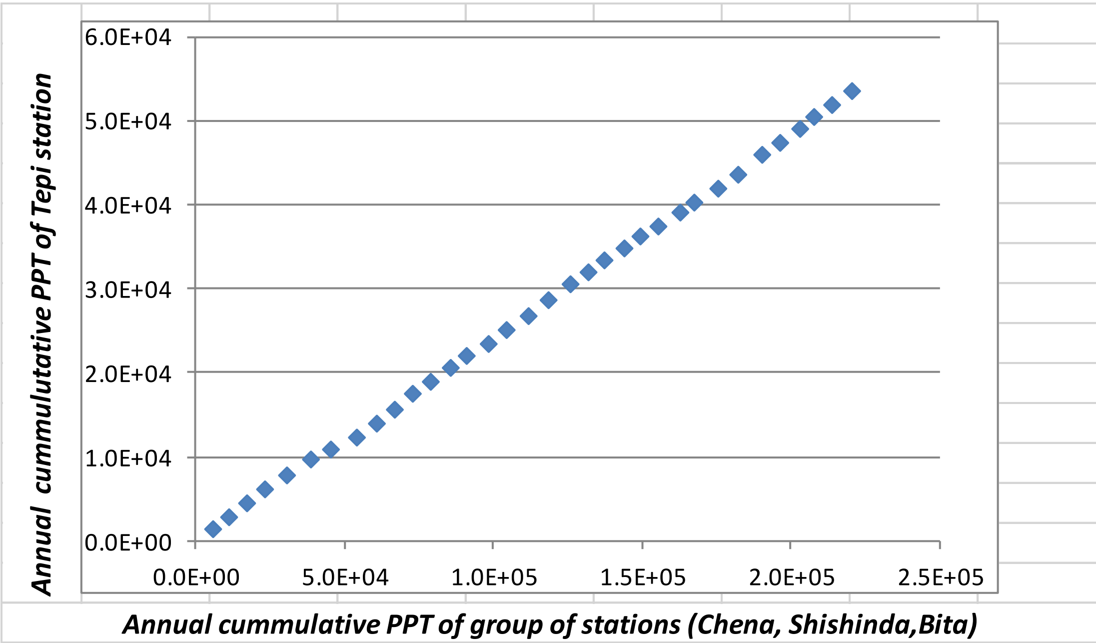

Figure 4:3 Consistency of Tepi station with other cumulative station

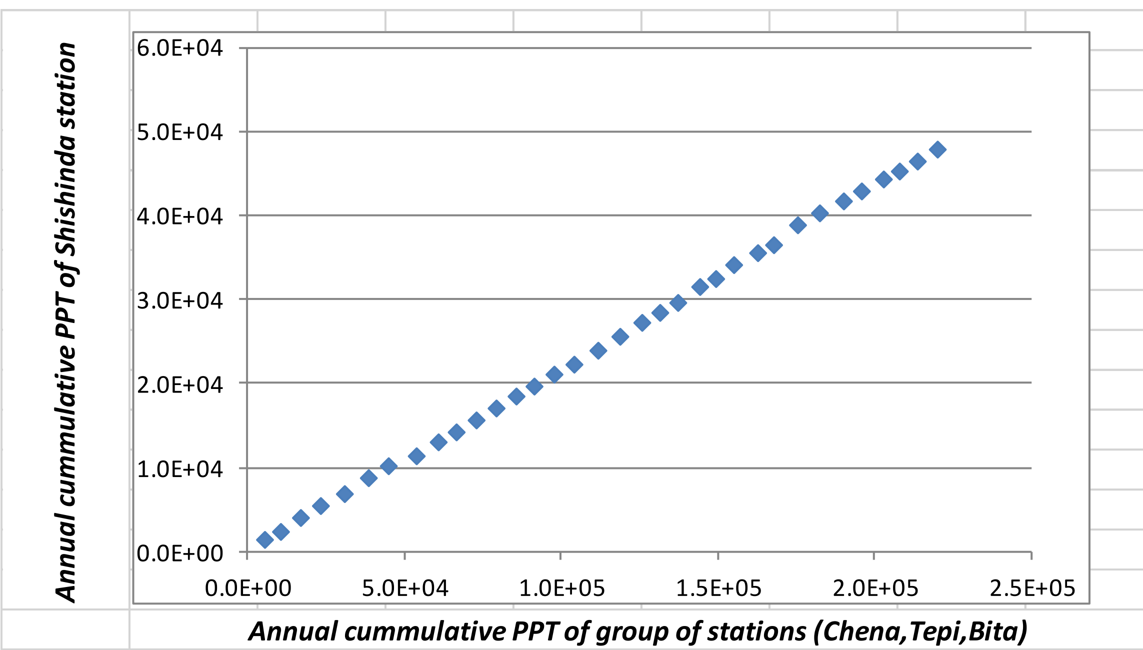

Figure 4:4 consistency of Shishinda station with other cumulative station

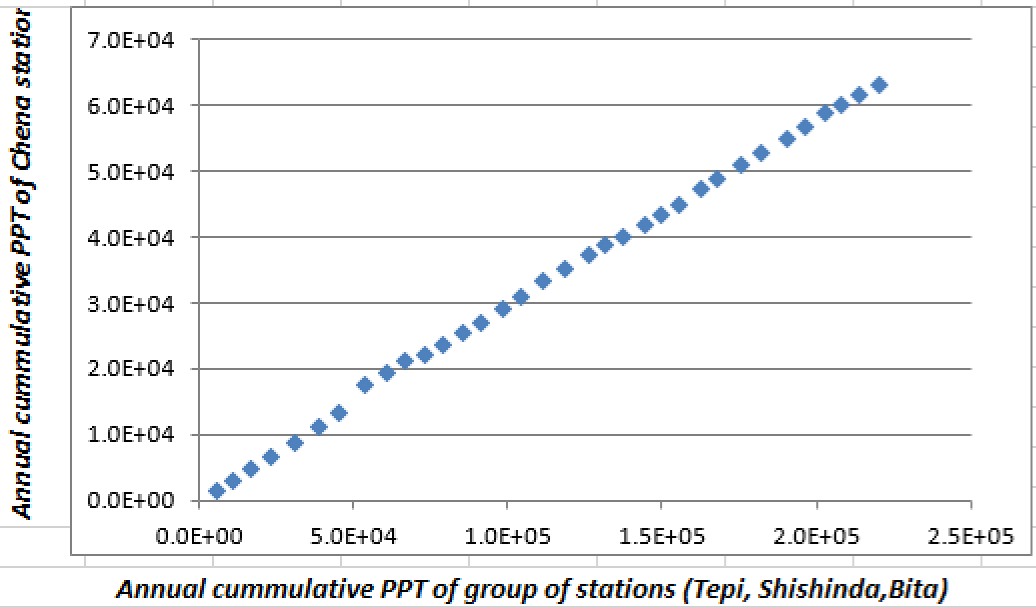

Figure 4:5 consistency of Chena station with other cumulative station

The above graphs showed all points set on or form almost the straight lines, which was plotted for checking of consistency of rainfall, all stations were consistence and have more or less acceptable homogeneity. Therefore, the stations did not need further adjustment.

4.2 Hydrological Data Collection and Analysis

4.2.1 Hydrological Data Collection

General

Hydrological modeling to a large extent depends on hydro-meteorological (precipitation, temperature, relative humidity and sunshine hours) and hydrological (stream flow) data. Reliability of the collected raw hydro-meteorological and hydrological data significantly affects quality of the model input data and, as a result, the model simulation. This chapter sequentially presents, rough data screening of raw hydro-meteorological and hydrological data, completion of identified missing data, estimation of areal rainfall for the study area

Hydrological data were the principal data set in the research work. Other sets of data were all collected depending on the availability and suitability of data from the hydrological stations. The two hydrologic gauging stations in the drainage basin with automatic water level recordings are exist.

The chart readings of these continuous water level recording stations were obtained from the Ministry of Water and Energy, Hydrology Directorate. Generally, data were preliminarily collected for gauging stations with catchment size not exceeding 2800km^2, following the recommendation of Shaw, 1999. Then, depending on the availability of rainfall recording station in or near the boundary of the stream-gauged catchment, the station was considered for further analyses and data acquisition. Based on this criterion; out of the two gauging stations, plus meteorological data‘s were adequately selected and used in the modeling work.

4.2.2. Hydrologic Data Analysis

Two main factors influence runoff from a watershed: precipitation and abstractions. Precipitation in Ethiopia is represented as rainfall. Rainfall rate distributions within a watershed vary both temporally and spatially. For most determinations of peak flows for use in road drainage design and analysis efforts, it is commonly assumed that rainfall rates not to vary within the watershed during the rainfall event. However, this assumption only holds true for small and medium size catchments.

The analysis of the peak rate of runoff, volume of runoff, and time distribution of flow is fundamental to the design of highway drainage structures. Errors in the estimates will result in a structure that is either undersized and causes more drainage problems or oversized and costs more than necessary. On the other hand, it is important to realize that any hydrologic analysis is only estimation. Because hydrology is not an exact science, different hydrologic flow estimation methods developed for determining flood runoff may produce different results for a particular situation. Therefore, the engineer should exercise sound engineering judgment to select the proper flow estimation method or methods in estimation design flows. While performing the hydrological and hydraulics analysis for the design of highway drainage systems, the hydraulic engineer should recognize and evaluate potential environmental problems that would impact the specific design of a drainage structure early in the design process.

Estimating peak discharges for various recurrence intervals is one of the most common engineering challenges faced by drainage structure designers. This is the main challenge in Ethiopia where there is no adequate primary data to base the analysis. In study area, it was noted during site visit that some of structures either are overtopped or washed away by floods by being unable to accommodate the flow generated by the catchment upstream of the crossing and others are too extravagant. Therefore, flow estimation methods should be calibrated with locally collected data. Discharge determination can be divided into two general categories:

Gauged sites - the site is at or near a gauging station and the stream flow record is of sufficient length, then statistical analysis should be used to estimate peak flows.
Ungauged sites - the site is not near a gauging station and no stream flow record is available.

Stream flow Data

Two stations Gaged among Streams which is crosses the road crosses these are on Beko and Bitinwuha river road the basin have incomplete records. Such gaps in the record are filled by developing correlations between the station with missing data and any of the adjacent stations with the same hydrological features and common data periods.

4.3 Physiographic Data Collection and Processing

4.3.1 Physiographic Data Collection

4.3.1.1 Digital Elevation Model (DEM)

The catchment physiographic data were generally collected from topographic maps and DEM. Other data pertinent to the modeling process– which include the watershed area (A), Land use, land cover, soil type and geology of the catchments were obtained from GIS data that found in Ministry of Water and Energy directorate of GIS. In this study watershed for larger area is delineated by using Arc hydro tools from Digital elevation model of study area. A DEM at 30-by-30-meter resolution is generally used for modeling the terrain because of its widespread availability and more accurate than 90mx90m resolution.

The preparation of "hydrologically corrected" terrain data often requires much iteration through drainage path computations. To represent the movement of water through the watershed, the "hydrologically corrected" DEM must have the proper accuracy and resolution to capture details of the stream network. The problems often arise when the watershed has low relief and the resolution is not fine enough to delineate the stream network. In contrast to the effort required for the "hydrologically corrected" DEM, the "depressionless" DEM is simply constructed using automated algorithms to fill in the sinks or depressions in the assembled DEM. In a depression less DEM, water moves across the terrain model towards the edge. A depressionless DEM does not address closed basins or substantial non-contributing areas. Because of the complexity and effort required for constructing a hydrologically corrected terrain model, a depressionless terrain model often serves as a simpler substitute in the analysis. For study regions with moderate to high topographic relief, the depressionless terrain model may be adequate for the analysis. For low-relief regions, however, the depressionless terrain model often needs additional work to adequately represent the terrain. For example, a watershed with flat terrain often requires editing to force proper drainage.

Transforming spatial data into a common coordinate system ensures proper alignment of various datasets for spatial analysis. Coordinate system transformation often leads to map distortions of direction, distance, shape, and area. From a hydrologic perspective, where the terrain and precipitation are important, a suitable coordinate system should preserve area. The terrain data analyzed is in a number of coordinate systems and projections which includes Albers-Equal Area, Universal Transverse Mercator (UTM), Transverse Mercator, Lambert, and the State Plane Coordinate System. The terrain data has been projected into a compatible projection before using HEC-GeoHMS. UTM projection is used in this study.

Watershed is the upslope area contributing flow to an outlet or pour point, which is usually the lowest point along the boundary of the watershed. The place of each drainage structure is thought as an outlet or pour point, the boundary and size of the watershed area should be firstly determined to decide the type of the structure. GPS and GIS technologies are used for these processes in this study. The size of each watershed area (watershed area), topography (average slope of the basin), soil characteristic (permeability) of the land, plant cover type and the ratio of plant canopy are effective factors while calculating the cross-sectional area and defining the type of drainage structure, so we determined all mentioned characteristics for each watershed in this study. DEM of the study area was used to delineate a drainage system. Flow direction of water was firstly determined. Then, creation of stream networks (delineated from a DEM using the output from the flow accumulation function and delineation of watersheds by using pour points were done by using Arc hydro tools. A total of 93 watersheds were appears.

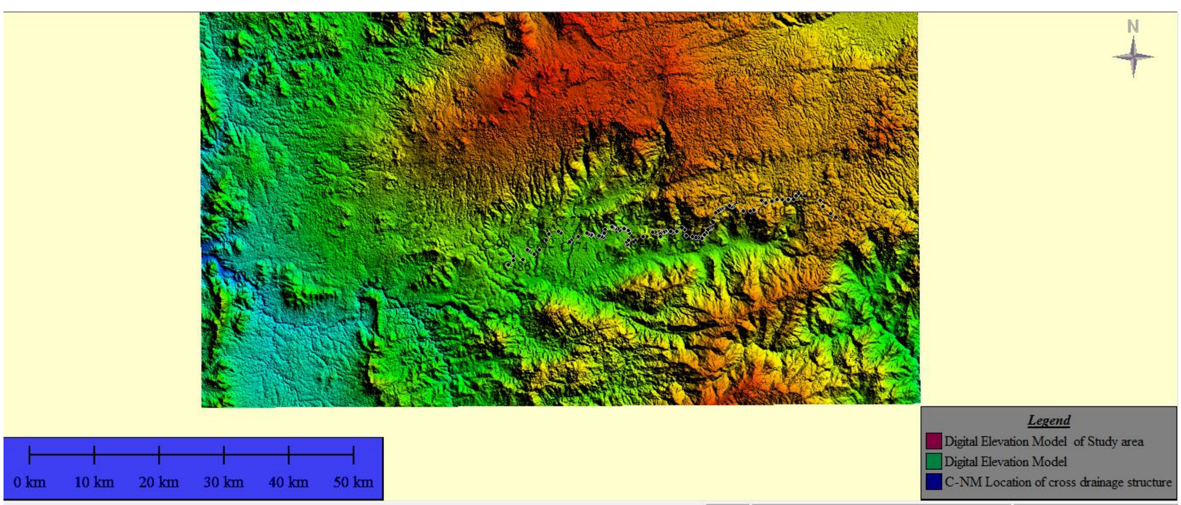

Fig 4.6 Digital Elevation Model of study area with 30mx30m resolution

4.3.1.2 Land cover and Soil type

a. Land Cover

An accurate Land cover map is required to assess its role in the rainfall-runoff relation.

There is no currently prepared land use and Land use /land cover in Ethiopia. However,

In this paper Land use was produced using ASTEER true color (Spot image), Satellite image down loader software and Field investigation.

Most runoff estimation techniques use the size of the contributing watershed as a principal factor. Generally, runoff rates and volumes increase with increasing drainage area. The size of a watershed will not usually change over the service life of the road drainage facility. However, agricultural activity and land development may cause the watershed area to change over time. Flow diversions and catchment area changes due to urbanization and other development inevitably will also occur at some point in the future. Some hydrologic methods accommodate watershed shape explicitly or implicitly; others may not. If a drainage area is unusually irregular extremely narrow, the designer should consider using a hydrologic method that explicitly accommodates this watershed shape.

Agriculture with dense Forest or with woodland (cultivated area with perennial crop) is largely the land property of Catchment, where they are either under active conversion to cultivation or are protected through serving as shade for coffee trees

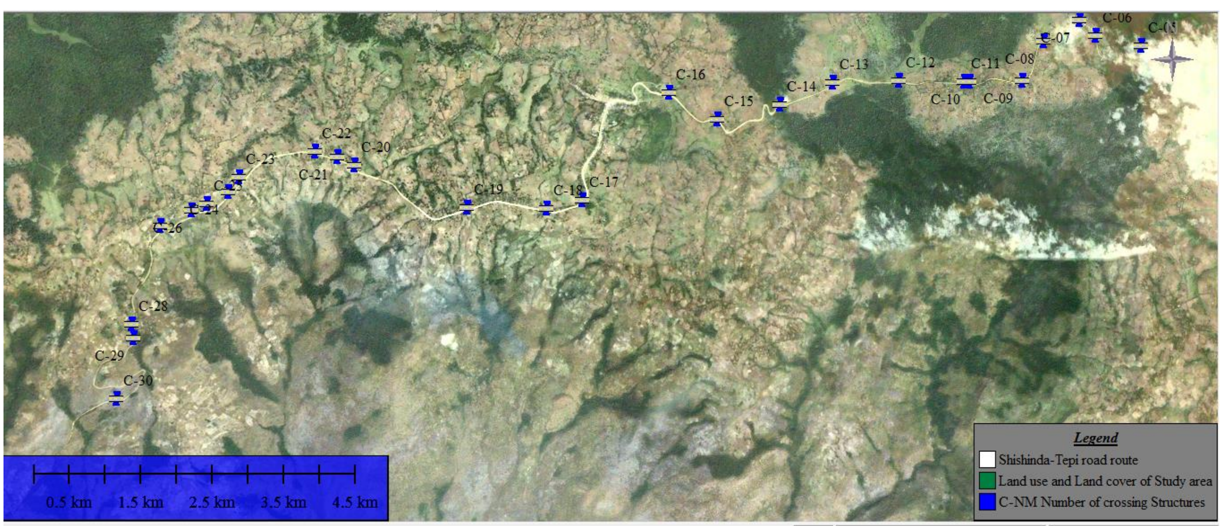

Figure 4.7 the location of cross drainage structures overlaid with spot Image

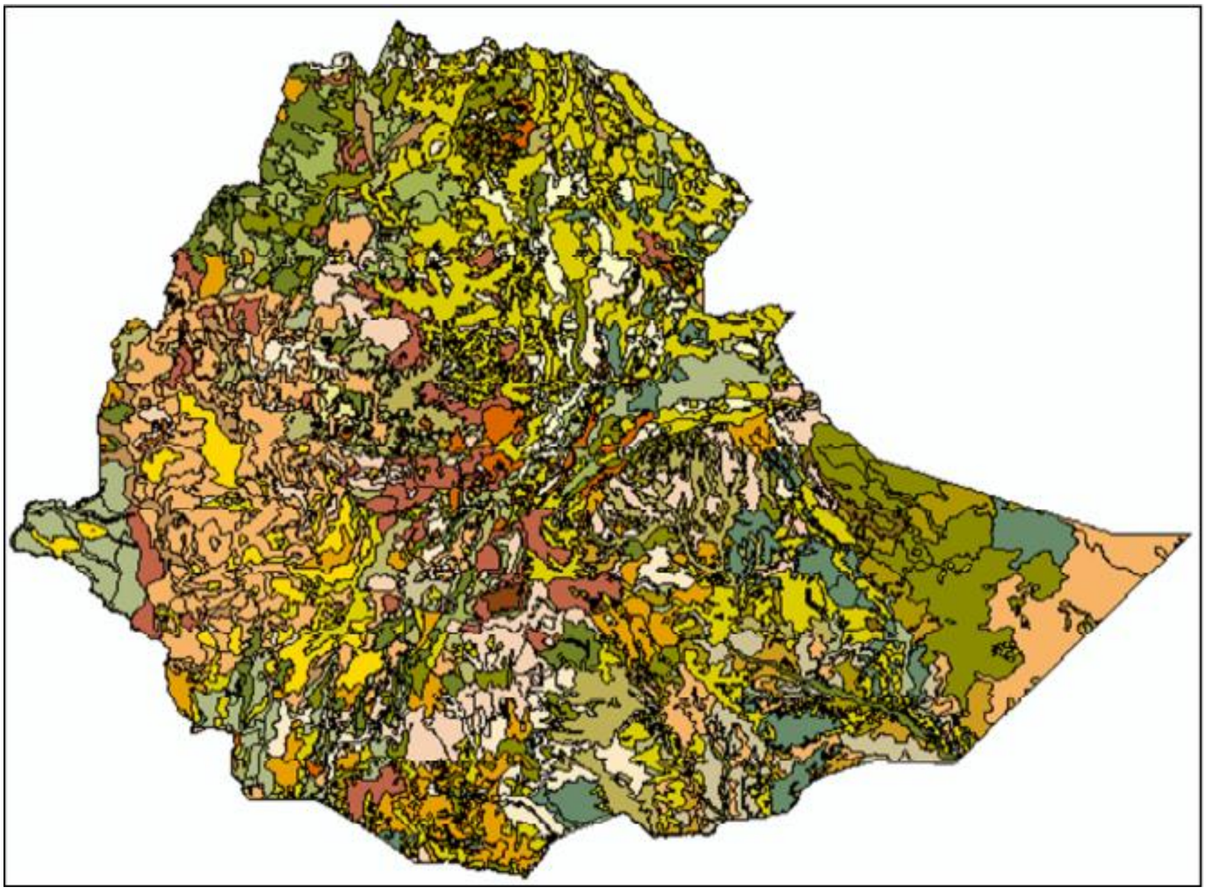

Fig 4.8 Soil Map of Ethiopia Source (Ministry of Agriculture)

b. Soil data Analysis

The soil data used in study is collected from Ministry of Agriculture. Soil within watershed is classified based on Soil map of Ethiopia and FAO.

Soil physical and chemical properties are also among the main factors that affect the rainfall-runoff relation. In order to have these important soil characteristics, soil map (figure below) of study area is produced. Soil type can have considerable effect on the discharge rates of the runoff hydrograph; the soil type directly affects the permeability of the soil and thus the rate of rainfall infiltration. The output of the land suitability evaluation will include description of land utilization types; land suitability, and land resource. In the land suitability study, land uses that are being considered are rain-fed agriculture, forestry, irrigation, wildlife conservation and livestock production. Besides, soil association is one of the major aspects of land suitability. Generally, the soil which dominate the study area is the following. The most important soil texture within the basin is Dystric Nitosols, and cambisols soil being highest abundant All the above illustration of the basin soil type gives a broad-spectrum optimistic picture of soils within the study area. On the other hand, 34 % of the basin is covered by shallow and moderately profound soils with undulating topography, good drainage and fertility, i.e. dystric Nitosols (21.5 %), orthic Acrisols (15.5%), dystric Cambisols (45%), Lithosols(15%), district gleysols (8%). The effects of soil on the discharge at outlet represent by the hydrological soil group.

Table 4:2 Hydrological soil group of study area

Soil type	***Hydrological soil group***
Dystric cambisols	B
Dystric Nitosols	B
Orthic Acrosols	B
Lithosols	D
District gleysols	D

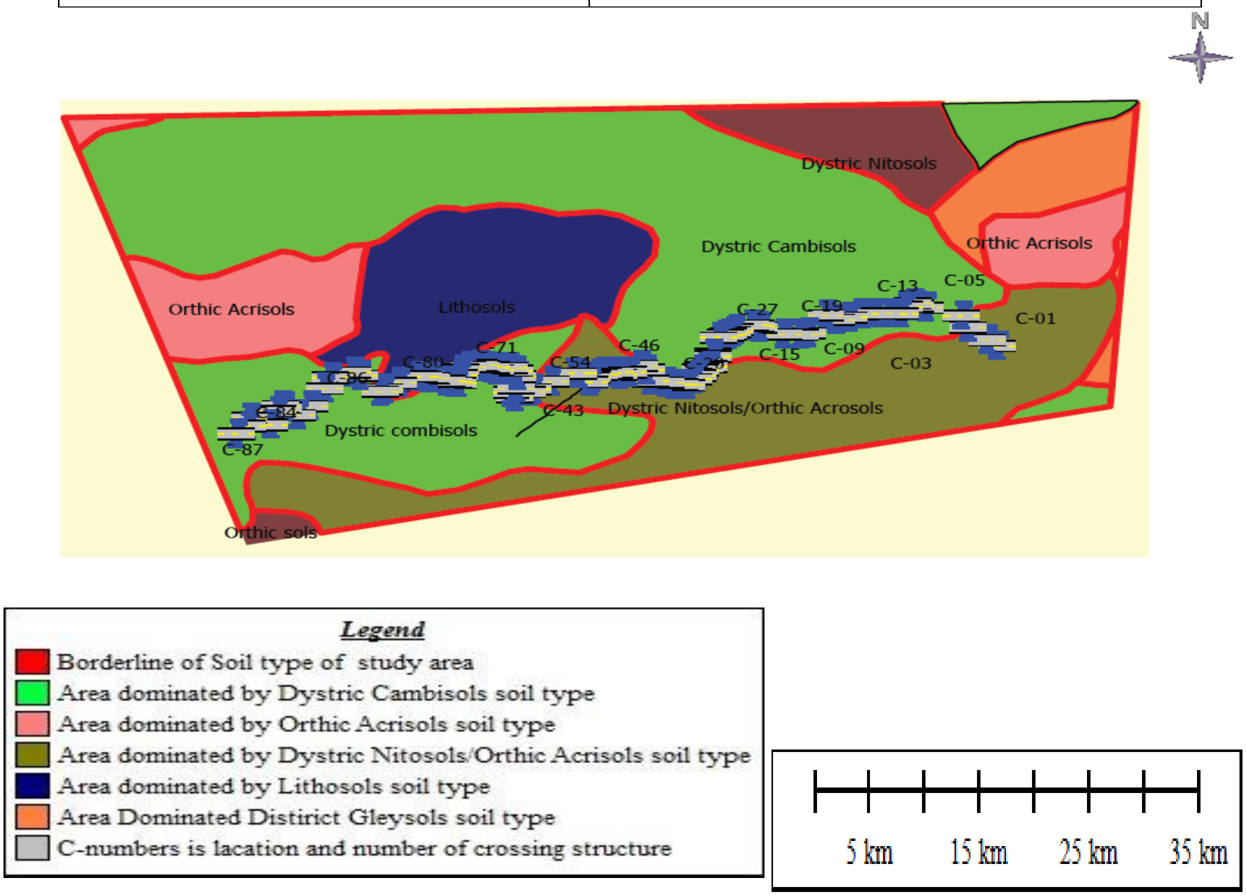

Figure 4:9 Soil type of study area

4.3.1.3 Hydrological Soil Groups for Ethiopia

Soil properties influence the relationship between runoff and rainfall since soils have differing rates of infiltration. Permeability and infiltration are the principal data required to classify soils into Hydrologic Soils Groups (HSG).

According to ERA drainage manual of 2013 the hydrological soil group in Ethiopia in four categories

Based on infiltration rates, the Soil Conservation Service (SCS) has divided soils into four hydrologic soil groups as follows:

Group A: Sand, loamy sand or sandy loam. These are Soils which have a low runoff potential due to high infiltration rates. These soils primarily consist of deep, well-drained sands and gravels.

Group B: Silt loam, or loam. These Soils are having a moderately low runoff potential due to moderate infiltration rates. These soils primarily consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

Group C: Sandy clay loam. These Soils are having a moderately high runoff potential due to slow infiltration rates. These soils primarily consist of soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.

Group D: Clay loam, silty clay loam, sandy clay, silty clay or clay. These Soils are having a high runoff potential due to very slow infiltration rates. These soils primarily consist of clays with high swelling potential, soils with permanently-high water tables, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.

As the slope of the drainage basin increases, the selected runoff coefficient C should also increase. This is caused by the fact that as the slope of the catchment area increases, the velocity of overland and channel flow will increase allowing less opportunity for water to infiltrate the ground surface. Thus, more of the rainfall will become runoff from the catchment are

Slope

There are various ways in which slope can be computed depending on the nature of the information available and the method to be used. To define slope in hydrology, we are interested in the pathway of water lowing downhill. This means that slope is considered a positive quantity if pointing downhill. The D8 flow direction is a special case, because although it is being defined on a continuously gridded elevation surface, only 8 discrete flow directions are possible, and so effectively, the D8 Slope is computed as

$$D8slope = \frac{\boldsymbol{Drop}}{\boldsymbol{Run}}$$

Where drop refers to the difference in elevation between the “from cell” and the “to cell”, with downwards considered positive, and the run is equal to the cell size for flow along the coordinate directions, and equal to$\sqrt{2}$ x cell size for flow in the diagonal directions. So, in effect, the D8 flow direction is a slope computation on a set of eight 3D lines like the lines connecting the survey benchmarks in the example described above, where the one giving the maximum downward slope is selected as the direction of steepest descent and its corresponding value (1, pa2, 4,…., 64, 128) is encoded in the flow direction grid.

In this study the river slope is obtained by dissolving the river length in to segments.

Along the flow path the maximum and minimum elevation is obtained from Digital Elevation Model (DEM).

Therefore here overall river slope **S_R** is computed as

$$S_R = \frac{\sum_{i=1}^{n} LiSi}{\sum_{i}^{n} Li} \text{ --- } \quad 4.6$$

4.4 Time of Concentration

This section provides use of time concentration in rational method and how it was calculated in this paper Hydrologic and hydraulic analysis requires an estimation of the time of concentration. The time of concentration (Tc) is used in the Rational Method to determine the critical rainfall duration, which can then be combined with an appropriate rainfall intensity duration frequency (IDF) relation to establish the required design rainfall intensity.

The Tc is the time required for water to flow from the most remote point of the basin to the location being analyzed.

A storm equal to this duration will permit direct runoff to arrive from all points in the watershed concentrating at the outlet. This time measure is taken to be the critical time by many flood-estimating approaches, in that it is assumed that the use of any other time would result in a lower flood estimate. A shorter time, although resulting in higher rainfall intensity, will not permit the entire basin to contribute flow simultaneously. A longer duration allows the entire basin to contribute, but with a lower intensity. Many different Tc formulas are available, and it is through the selection and use of these formulas result in greatest error that typically occurs in applying the Rational Formula to non-urban watersheds. While some error occurs in assigning runoff coefficients, as there is a large range of possible values for each surface condition, the realistic determination of the response time of the basin is the greatest challenge, particularly for natural (rural) basins. Bondelid et al (1982) found that upwards of 75% of errors in peak flow estimates can be attributed to errors in the time of concentration.

Examples of popular Tc equations can be found in most hydrology texts books, such as those by Chow et al (1988), Maidment (1993), and McCuen (1989), and the different equations generally give a wide range of estimates for any particular set of basin parameters. This situation reflects differences in the data sets used in deriving the equations, and illustrates that most equations are generally unreliable when applied to areas that are different from those used for their development.

The Kirpich and Hathaway equations are widely used to estimate time of concentration.

However, the one should be aware that both equations have been developed from limited data for a specific site. The Kirpich equation was developed from data for six agricultural watersheds in Tennessee, USA (ranging in size from 0.4 ha to 45 ha), with well-defined channels and slopes ranging from 3% to 10% (Viessman and Lewis 1996). The Hathaway formula was developed on the basis of data from very small watersheds (<1.8ha), where the slopes were less than 1% and storm runoff was dominated by surface low (MaCuen 1989). In this paper formula used selected Based on limitation and assumption behind formula.

4.5 Longest Flow path Calculation

There may be a number of possible paths to consider in determining the longest travel time. Identify the flow path along which the longest travel time is likely to occur. This is a trial and error process. Generally, it is reasonable to consider the three following components of flow that can characterize the progression of runoff along a travel path: overland flow (sheet flow), shallow concentrated flow, and conduit and open channel flow (or concentrated channel flow).For each drainage area, determine the distance (L) from the outlet of the drainage area to the most remote point. Determine the average slope (S) for the same distance. For a specific drainage basin, the time of concentration consists of an inlet time plus the time of flow in a closed conduit or open channel to the design point. Inlet time is the time required for runoff to flow over the surface to the nearest inlet and is primarily a function of the length of overland flow, the slope of the drainage basin, and surface cover. Pipe or open channel flow time can be estimated from the hydraulic properties of the conduit or channel. For each catchment area, the distance is determined from the inlet to the most remote point in the tributary area. From a topographic map, the average slope is determined for the same distance by Equation 4.6.

In this Paper to obtain the total time of concentration, the open channel flow time must be calculated and added to the inlet time. After first determining the average flow velocity in channel, the travel time is obtained by dividing velocity into channel length. Open channel flow time can be estimated from the hydraulic properties of the channel. Generally, from ERA drainage manual application, it is reasonable to assume uniform flow and employ Manning's Equation for Uniform Flow for open channel and conduit flow considerations.

For open channel flow, consider the uniform flow velocity based on bank-full flow conditions. That is, the main channel is flowing full without flow in the overbanks. This assumption avoids the significant iteration associated with other methods that employ rainfall intensity or discharges (because rainfall intensity and discharge are dependent on time of concentration). For conduit flow, in a proposed storm drain system, compute the velocity at uniform depth based on the computed discharge at the upstream. Otherwise, if the conduit is in existence, determine full capacity flow in the conduit, and determine the velocity at capacity flow. It is necessary to compare this velocity later with the velocity calculated during conduit analysis. If there is a significant difference and the conduit is a relatively large component of the total travel path, re-compute the time of concentration using the latter velocity estimate.

Since my study area rural area time of concentration is calculated as follows in two sections;

i) Calculation of the Time of Concentration for Overland Flow

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

$$T_{c1}=0.604\left(\frac{rl}{S^{0.5}}\right)^{0.467} \quad \text{………………………………………. ………………………… 3.7}$$

Where:

Tc = time of concentration (hours)

r = roughness coefficient obtained from Table ERA manual

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

S = Slope of the catchment

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

$$\mathrm{T_{c2}}=\left(\frac{087l^{2}l}{1000\mathrm{S_{av}}}\right)^{0.385} \quad \text{-- } \mathit{4.8}$$

Where: Tc = time of concentration (hours).

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

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

Then time of Concentration is equal to the sum of the two concentrations

$T_c = T_{c1} + T_{c2}$---4.9

4.6 Estimation of Discharge for Checking Adequacy of Structures

In this paper Cross drainage structure includes both Bridge and culvert. Culvert is structure that used to convey surface run off through embankment. It should be usually designed hydraulically to take advantage of submergence to increase hydraulic capacity. The culvert can be a structure as distinguished from bridges that is usually covered with an embankment and is composed of structure materials around the entire parameter, the requirement of culvert is where Bridge is hydraulically not required and debris is tolerable. There are around 91 Culverts are installed along the road the route.

Figure 4.10 photo of Culvert taken from site

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 subgrades 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 for a road.

Hydrologic factors to consider in locating roads are number of stream crossings, side slope, and moisture regime. For example, at the lowest point on the slope, only one or two stream crossings may be required. Likewise, side slopes generally are not as steep, thereby reducing the amount of excavation. However, side cast fills and drainage requirements will need careful attention since water collected from upper positions on the slope will concentrate in the lower positions. In general, roads built on the upper one-third form of water in the natural environment (precipitation, stream flow, soil moisture, etc.) while the latter deals with the engineering properties of fluids in motion. Based on the criteria set by ERA's design manual different section of the project road are distinguished among terrain types. The following table indicates the over labels terrain types along the road alignments.

Table 4:3 Terrains along the road alignment

Chain age		Terrain Type	Length(km)	Percent (%)
From	To			
0+000	11+000	Rolling	11.00	14.39%
11+000	13+000	Flat	2.00	2.62%
13+000	23+000	Rolling	10.00	13.08%
23+000	29+500	Mountainous	6.5	8.50%
29+500	36+000	Rolling	6.50	8.50%
36+000	46+000	Mountainous	10.00	13.08
46+000	58+000	Rolling	12.00	15.70%
58+000	62+500	Flat	4.5	5.89
62+500	75+300	Rolling	12.80	16.74%
75+300	76+450	Flat	1.15	1.5%

4.6.1 Rational Method

The rational formula estimates the peak rate of runoff at any location in a catchment area as a function of the catchment area; runoff coefficient; and mean rainfall intensity, for duration equal to the time of concentration. The rational formula is expressed as

$$Q = 0.00278CIA \quad \text{..........} 4.6.1.$$

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

C = runoff coefficient representing a ratio of runoff to rainfall

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

A = catchment area which contribute to inlet of the structure, ha

The peak discharge needs to be modified for actual use in study area. Runoff coefficient may express a function of frequency factor, Slope ranges, hydrological soil groups, land uses. The result of using the rational formula to estimate peak discharges very sensitive to the parameters that are used. Run-off coefficient for rural i.e study area is product of rainfall intensity factor and the summation of other factors. The frequency factor for 50 years return period is 1.2.The run off coefficient for other factors is summation of average slope of catchment permeability of soil, and Vegetation (Appendix E)Therefore in this paper runoff coefficient is estimated based on above factor for each catchment. The Rainfall intensity (I) is the average rainfall rate in mm/hr for duration equal to the time of concentration for selected return period. My study area falls in region of rainfall B1 and there is already developed IDF curve for region. Manning's formula is perhaps the most widely used empirical equation for estimating discharge since it relies solely on channel characteristics that are easily measured. Manning's formula is:

$$Q = n^{-1} A R^{2/3} S^{1/2} \text{ ---------- } 4.6.2$$

Where: Q = discharge (m^3/s)

A = cross sectional area of the structure (m^2)

R=hydraulic radius (m), (area/wetted perimeter of the channel)

n =roughness coefficient of the channel

S = slope of the structure

The selection of Manning's 'n' is generally based on observation; however, considerable experience is essential in selecting appropriate 'n' values. For a given channel geometry, slope, and roughness, and a specified value of discharge Q, a unique value of depth occurs in steady uniform flow. It is called the normal depth. The normal depth is used to design artificial channels in steady, uniform flow and is computed from Manning's Equation.

For drainage basins where no runoff has been measured, the SCS Curve Number is another way to estimate the depth of direct runoff from the rainfall depth, given an index describing runoff response characteristics. The SCS Method was originally developed by the Soil Conservation Service (Soil Conservation Service 1964; 1972) for conditions prevailing in the United States. According to ERA drainage manual, The SCS –method is most for computing flood peaks and run-off volumes for catchments smaller 65KM^2, with slope of less than 30% and a time of concentration(T_c) less than 10 hours. For area greater than 0.5km^2 SCS Peak Discharge Estimation Method is used in this paper. The following equation was used for the estimation of the peak discharge in SCS method.

4.6.2 SCS-Curve Number Method

The SCS method has an index, which is called curve numbers (CN) to represent the combined hydrologic effect of soil, land use; agricultural land treatment class hydrologic conditions and ant The CN have been estimated based on Ministry of Water Resources ETHIO-GIS digital soil map, land use and land cover obtained from different topographic map field observations and antecedent soil moisture.

$q_p = q_u A\, Q$ …………………………………………………………………. *4.6.3*

Where

q_p = peak discharge, m^3/s

q_u = unit peak discharge, m^3/s/km^2/mm

A = drainage area, Km^2

Q = depth of runoff, mm

The unit peak discharge is obtained from the following equation, which requires the time of concentration (t_c) in hours and the initial abstraction rainfall (Ia/p) ration as input:

$q_u = \alpha 10^{C_o + C_1 \log t_c + C_2 (\log t_c)^2}$ -- 3.6.4

Where C_0, C_1 and C_2 = regression coefficients for various Ia/p ratios:
α= unit conversion factor equal to 0.000431 in SI unit.

A relationship between accumulated rainfall and accumulated runoff was derived by SCS from experimental plots for numerous hydrologic and vegetative cover conditions. The equation was developed mainly for small catchment areas for which daily rainfall and catchment area data are ordinarily available. It was developed from recorded storm data that 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 or 1-day storm rainfall.

$$Q=\frac{(p-I_a)^2}{(p-I_a)+S} \quad \text{--}4.6.5$$

Where: Q = accumulated direct runoff, mm
P = accumulated rainfall (potential maximum runoff), mm
Ia = initial abstraction including surface storage, interception, and infiltration prior to runoff, mm,
S = potential maximum retention, mm. The relationship between I_a and S was developed from experimental area data. It removes the necessity for estimating the I_a for common usage. The empirical relationship used in the SCS run off equation is
I_a =0.2S--4.6.6

The accumulated direct runoff expressed as

$$Q=\frac{(P-0.2S)^2}{(P+0.8S)} \quad \text{--}4.6.7$$

S is related to the soil and cover conditions of the catchment area through the CN. CN has a range of 0 to 100, and S is related to CN by:

$$S=\frac{25400}{CN}-254 \quad \text{--}4.6.8$$

According ERA, drainage manual for antecedent moisture conditions (AMC) in Ethiopia, dry for region D1, wet for region B1, and average AMC for other region is used.
In this study the for area greater than 65km^{2}frequency analysis used

4.6.3 Flood Frequency Analysis

In this research the method the observed data's of past record floods is used to predict the futures floods of a particular probability of return period. The analysis is based on the premise that the flood is random phenomena and therefore the mathematical theory of probability is used. Frequency analysis in compasses different methods.

4.6.3.1 Parameter Estimation

The most commonly used parameter estimator are:

- ❖ The method of L-moment
- ❖ The method of Maximum Likelihood
- ❖ The probability of weight moment

To select and evaluate the parent distribution, L-moment is recent method and it gives efficiency result as compared with other method of evaluation of parent distribution.

4.6.3.2 Probability distributions

There are many distributions which could be used in hydrology. For this analysis the following frequency distribution methods were applied: Log-Pearson type III, Gumbel Type I Extremal, Normal, 2 parameter Log Normal, 3 parameter Log Normal and Pearson type III distributions. Accordingly, for annual daily highest Stream flow analysis of determined return period T years. A probability distribution is a function representing the probability of occurrence of a random variable. By fitting a distributions to a set of hydrologic data, a great deal of the probabilistic information in the sample can be compactly summarized in the function and its associated parameters.

4.6.3.3 Estimation of L-Moment

Hosking (1986 and 1990) introduced the L-moments, which are linear functions of PWMs.

L-moments are summary statistics for probability distributions and data samples. They are analogous to ordinary moments -- they provide measures of location, dispersion, skewness, kurtosis, and other aspects of the shape of probability distributions or data samples -- but are computed from linear combinations of the ordered data values (hence the prefix *L*).

L-moments have the following theoretical advantages over ordinary moments:

- ➢ For *L*-moments of a probability distribution to be meaningful, we require only that the distribution have finite mean; no higher-order moments need be finite [J. R. M. Hosking, *J. R. Statist. Soc. B*, **52** (1990), Theorem 1].
- ➢ For standard errors of *L*-moments to be finite, we require only that the distribution have finite variance; no higher-order moments need be finite [Hosking, 1990, Theorem 3].
- ➢ Although moment ratios can be arbitrarily large, sample moment ratios have algebraic bounds [J. Dalen, *Statistics and Probability Letters*, **5** (1987)]; sample *L*-moment ratios can take any values that the corresponding population quantities can [Hosking, 1990, page 115].

The L-moments are more convenient than PWMs because they can be directly interpreted as measures of scale and shape of probability distributions. In this respect they are analogous to conventional moments. L-moments are defined by Hosking in terms of the PWMs α and β as

L-moments are ways of Summarize the statistical properties of hydrological data. The first L-moment estimator is the mean.

l_1=E[X]

Let X $_{(1/n)}$ be the ith the largest observation in simple size n(i=1 corresponding to the largest). Then, for any distribution the second L- moment is description of scale based on expected difference between two randomly selected observations:

$L_{1/2}$=1/2*E[X $_{(1/2)}$-X$_{(2/2)}$]

Similarly L-moments measures of skewness and kurtosis use;

l_3=1/3*E[X $_{(1/3)}$-2*(X $_{(2/3)}$) +X $_{(3/3)}$]

l_4=1/4*E[X $_{(1/4)}$-3*(X $_{(2/4)}$) +3*X $_{(3/4)}$ - X$_{(4/4)}$]

L-moment estimator: L-moment ca be written as function of probability weighted moment

b_r= E{X[F(X)]^r}

When unbiased ness is important one can employ unbiased PWW estimator: for Bitinwuha River crossing is

$b_o=\bar{X}$=6.781

$b_1=\frac{\sum_{j=1}^{n-1}(n-j)(X_j)}{n(n-1)}$ =2.524

$b_2=\frac{\sum_{j=1}^{n-2}(n-j)(n-j-1)(X_j)}{n(n-1)(n-2)}$ =1.584

$b_3=\frac{\sum_{j=1}^{n-3}(n-j)(n-j-1)(n-j-2)(X_j)}{n(n-1)(n-2)(n-3}$ =1.166

For any distribution, L-moment are easily calculated in terms of PWWs from;

L_1=b $_o$= 6.781

$L_2=2b_1-b_0$=0.4323

$L_3=6b_2-6b_1+b_0$=0.3694

$L_4=20b_3$-30b2 +$12b_1-b_0$=0.0269

When unbiased ness is important one can employ unbiased PWW estimator: for Beko River crossing is

$b_o=\bar{X}$=22.6124

$b_1 = \frac{\sum_{j=1}^{n-1}(n-j)(X_j)}{n(n-1)}$ =248.9305

$b_2 = \frac{\sum_{j=1}^{n-2}(n-j)(n-j-1)(X_j)}{n(n-1)(n-2)}$ =8.68345

$b_3 = \frac{\sum_{j=1}^{n-3}(n-j)(n-j-1)(n-j-2)(X_j)}{n(n-1)(n-2)(n-3}$ =6.689

For any distribution, L-moment are easily calculated in terms of PWWs from;

$L_1 = b_o$= 22.6124

$L_2 = 2b_1 - b_0$=475.2486

$L_3 = 6b_2 - 6b_1 + b_0$=1418.87

$L_4 = 20b_3 - 30b2 + 12b_1 - b_0$=2837.831

Estimate of the L, are obtained by replacing the unknown, by simple estimator. The l-moment ratios, which are analogous to convectional moment ratio defined by Hosking as L- moment estimation was tabulated.

Table 4:3 L moment Estimation Parameters

Name of variable	Formula for variable	Bitinwuha	Beko
L- coefficient of Variation	Z_2=L2/L1	0.296	0.896
L-Coefficient of Skewness	Z3= L3/L2	0.355	0.552
L-Coefficient Kurtosis	Z4 =L4/L2	0.295	0.435

To select the type of distribution, which fit to the given data, is using the following equations.

Uniform, $Z_3 = Z_4 = 0$

Exponential, Z3=1/3 and Z4 =0.1226

Gumbel Z3= 0.1699 and Z4 =0.1504

Normal; Z3=0 and Z4= 0.1226

- For Bitinwuha river crossing

Gumbel Z_4=0.10701+0.1109Z_3+0.84838Z_3^2+$0.06669Z_3^3$+ $0.00567Z_3^4-0.04208Z_3^5+0.03763Z_3^6$ = 0.8567

Pearson Type distribution, Z_4= 0.1224+0.30115Z_3^2+0.95812Z_3^4 -0.57488Z_3^6 +0.19383Z_3^8 =1.0542

Log normal, Z_4=0.12282+0.7751Z_3^2 +0.12279Z_3^4 -0.133683Z_3^6+0.11386 Z_3^8 =1.0255

- For Beko River crossing

Gumbel Z_4=0.10701+0.1109Z_3+0.84838Z_3^2+$0.06669Z_3^3$+ $0.00567Z_3^4-0.04208Z_3^5+0.03763Z_3^6$ = 0.8253

Pearson Type distribution, Z_4= 0.1224+0.30115Z_3^2+0.95812Z_3^4 -0.57488Z_3^6 +0.19383Z_3^8 =1.00042

Log normal, Z_4=0.12282+0.7751Z_3^2 +0.12279Z_3^4 -0.133683Z_3^6+0.11386 Z_3^8 =1.000075

Based on the l moment estimator, the value of sample Z_4 is close to value of Z4 that is computed using Gumbel method of estimation. Therefore the most fitted probable distribution for this specific study area is Gumbel distribution method is used

The *L*-moment ratio diagram can be used to compare the *L*-skewness--*L*-kurtosis relations of different distributions and data samples. This gives a visual indication of which distribution may be expected to give a good fit to a data sample or samples.

Chapter Five

5. Result and Discussion

5.1 General

The main objective of this thesis is to investigate hydraulic and hydrologic problem of drainage structure long Shishinda-Tepi road.

Transport infrastructure is a vital part of society and involves high capital investment, so proper management and design of the system is very important. For continued function of the road transport system, the road infrastructure should be robust and capable of withstanding strains from a variety of weather. During the study, the researcher examined current practice for road drainage systems in Ethiopia and gathered information from professionals working with road drainage management, maintenance and construction. Nowadays there is no careful hydrologic and hydraulic analysis even in area flood affected region in Ethiopia.

Related to the preceding recommendations and suggestions for appropriate adaptation measures, the researcher coupled historical data, local hydrology models and land use measures to carry out modeling simulations that could evaluate the hydrologic and hydraulic parameters near roads.

Modeling the hydrological and hydraulic response is useful for analyzing the impacts of possible measures to reduce peak flow, total runoff, and scour depth in order to avoid damage to roads downstream and road structure itself. This studies demonstrated the potential of using hydrological models to examine the mechanisms regulating catchment responses to different land use measures in relation to their spatial distribution and to storm characteristics.

The traditional approach in road construction has been to make sure culverts and bridges are large enough for specific storm events, where discharge is calculated from the rational equation. The studies illustrated one approach for estimating potential reduction of peak flows whereby more robust landscape measures and their location were analyzed.

Different parameters which is essential to estimate are calculate based on the assumption.

The location of each cross drainage structure which expressed in terms of Northing and Easting were indicated in appendix. Based on the location of drainage structures the land use, land cover for catchment which drain towards the crossing of the road determine indicated in the appendix. The land use and land cover of the area greatly influence the rate of run-off which reach inlet off drainage structures. In addition to this hydrological soil group of study area also affects the rate off run-off that reach the inlet drainage structure. Discharge of runoff at inlet of drainage structures is calculated by either rational, SCS curve number method or frequency analysis method.

5.2 Result of Discharge Obtained from Rational Method

As indicated in appendix the discharge calculated by this method for area less than $0.5km^2$. The parameters involved in this calculation were run-off coefficient, rainfall intensity from IDF curve which developed for this region. To use the IDF for region time concentration and return is specified. The calculated rainfall intensity is indicated in appendix. Return period is fixed based on ERA drainage manual. According ERA drainage manual of 2013 the recurrence design frequency 25 years for culvert of span length less than 2m, for culvert of span length between 2m and 6m 50 years design storm frequency and for bridge short span between 6m -15m 50 years design frequency is used(refer ERA drainage manual 2013). Therefore the researcher uses 25 and 50 years design storm frequency for both bridge and culvert depend on span length.

The run-off coefficient is very sensitive parameter which can change the value of run-off discharges at inlet of drainage structures. In the study the run-off coefficient were calculated based on return period, slope of catchment vegetation and hydrological soil group as indicate in tabulated table of appendix E.

Conveyance of the structure and run off at inlet were compared to check adequacy of structure using manning formula. The result obtained in the analysis indicated for certain sample in the table 5:1 below. For all drainage structured along the road the calculated discharge compared to know whether the structure adequate, oversized or inadequate as indicated in appendix D.

5.3 Result of discharge Obtained from SCS Curve Number Method

As mentioned in methodology for area between $0.5km^2$to 65 km^2 SCS curve number method was used in this thesis. Using SCS curve number discharge of crossing is estimated.

Most runoff estimation techniques use the size of the contributing watershed as a principal factor. Generally, runoff rates and volumes increase with increasing drainage area. The size of a watershed will not usually change over the service life of the road drainage facility. However, agricultural activity and land development may cause the watershed area to change over time. As indicated in table 5:2 blow many parameters were calculated obtain value of discharge at crossing site. In addition location of crossing which is expressed in terms of Easting and Northing the catchment area delineated from Global mapper as indicated in table 5:2. The other important parameters in calculation of discharge in SCS curve number method were time of concentration, accumulated direct runoff, mm ,accumulated rainfall (potential maximum runoff), mm initial abstraction including surface storage, interception, and infiltration prior to runoff, mm ,potential maximum retention, mm.

Runoff is rainfall excess or effective rainfall - the amount by which rainfall exceeds the capability of the land to infiltrate or otherwise retain the rainwater. The principal physical catchment area characteristics affecting the relationship between rainfall and runoff are land use, land treatment, soil types, and land slope.

Land use is the catchment area cover, and it includes both agricultural and nonagricultural uses. Items such as type of vegetation, water surfaces, roads, roofs, etc. are all part of the land use. 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 uses a combination of soil conditions and land-use (ground cover) to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CN), indicate the runoff potential of an area. The higher the CN, the higher is the runoff potential. For each crossing the catchment hydrological soil group, land use and cover indicate in appendix.

Table 5.1 Calculated discharges at inlet and conveyance capacity of drainage structures for area less than 0.5 km^2

No	***Easting***	***Northing***	***Catchment area (km^2)***	***Existing Structure***					***catchment Property***				***Intensity(mm/hr)***	***Runoff coefficient***	***Discharge from catchment(m^3/s)***	***Conveyance Capacity Of structure (m^3/s)***	**Remark**
				Type of structure	***No. Cell***	***Width (m)***	***Height (m)***	***Dia. (m)***	***Soil type***	***Longest flow path(km)***	***land Cover***	***Hydrological Soil group***					
1	818385.8	802740.498	0.071	PC	1			0.914	Drystic Nitosols	0.894	cultivation	**B**	**77.5**	**0.6**	0.92	3.15	over sized
2	817709.7	803224.177	0.053	PC	1			0.914	Drystic Nitosols	0.5678	cultivation	**B**	**79**	**0.6**	0.70	0.77	adequate
3	816422.3	804241.121	0.061	PC	1			0.914	Drystic Nitosols	0.79856	Sparse Forest	**B**	**98**	**0.48**	0.80	1.4	adequate
4	816021.1	805217.276	0.265	B/SC	1	0.98	2		Drystic Nitosols	8.5698	cultivation	**B**	**95**	**0.56**	70.36	72.56	adequate
5	813654	805878.075	0.5	B /SC	1	1	4		Drystic Cambisols	5.239	dense forest	**B**	**98**	**0.67**	259.70	230	Inadequate
6	813015	806024.551	0.026	PC	1			0.914	Drystic Cambisols	0.35678	dense forest	**B**	**83.5**	**0.42**	0.25	0.37	adequate
7	812789.8	806237.154	0.04	PC	1			0.914	Drystic Cambisols	0.4598	cultivation	**B**	**51.4**	**0.6**	0.34	0.07	Inadequate
8	812285.3	805949.911	0.076	PC	1			0.914	Drystic Cambisols	1.256	cultivation	**B**	**76.5**	**0.6**	0.97	0.12	Inadequate
9	811988.8	805406.214	0.052	PC	1			0.914	Drystic Cambisols	0.45687	cultivation	**B**	**60**	**0.6**	0.52	0.97	adequate

Table 5.2 Calculated discharges at inlet and conveyance capacity of drainage structures for area greater than 0.5 km^2

No `	**Easting**	**Northing**	**Area (km^2)**	**Time of concentration. (min.)**	**Normal curve No.**	**Wet region Curve No.**	**Potential Max. retention**	**Accum. Prec.(P) mm**	**accumulated run-off(Q)**	**qu**	**peak discharge m^3/s**	**conveyance capacity m^3/s**	**Remark**
1	816021.1	805217.3	12.5	371.0	57.0	88.0	34.6	96.8	64.9	0.09	70.4	72.56	adequate
2	813654.0	805878.1	50.4	202.9	45.0	82.0	55.8	97.6	52.6	0.1	259.7	230.00	inadequate
3	810259.3	805411.6	5.4	296.7	45.0	82.0	55.8	96.8	51.9	0.08	23.3	22.45	Inadequate.
4	808604.8	805079.6	60.1	320.0	57.0	73.0	93.9	98.6	36.6	0.1	215.7	210.00	adequate
5	807046.5	805246.2	3.8	250.2	70.0	94.0	16.2	96.8	79.8	0.09	26.1	25.00	inadequate
6	798747.5	800795.1	1.0	14.1	57.0	73.0	93.9	96.8	35.4	0.09	3.1	3.00	adequate
7	797350.8	799612.4	2.7	17.2	57.0	73.0	93.9	96.8	35.4	0.09	8.4	12.50	adequate
8	796415.3	799749.9	2.0	121.4	45.0	82.0	55.8	96.8	51.9	0.08	8.6	8.63	adequate
9	795140.6	800798.5	1.1	71.0	71.0	95.0	13.4	96.8	82.5	0.08	7.1	5.23	inadequate
10	794741.6	801122.1	15.2	280.9	71.0	95.0	13.4	97.8	83.4	0.08	106.5	112.23	adequate
11	792349.3	800562.0	2.3	89.7	71.0	95.0	13.4	96.8	82.5	0.08	15.1	15.96	adequate
12	792206.5	800524.4	1.3	74.8	62.0	90.0	28.2	96.8	69.6	0.08	7.2	7.30	adequate
13	786666.4	800252.2	1.8	64.4	71.0	95.0	13.4	96.8	82.5	0.08	11.8	12.23	adequate
14	786055.5	800960.4	11.8	299.5	71.0	95.0	13.4	96.8	82.5	0.08	81.9	83.00	adequate
15	785796.7	800936.7	23.7	240.6	71.0	95.0	13.4	97.6	83.2	0.09	167.3	152.63	inadequate
16	783986.4	801191.7	1.6	65.5	63.0	91.0	25.1	96.8	72.1	0.08	9.2	12.50	adequate
17	782385.5	799771.5	5.4	15.5	83.0	97.0	7.9	96.8	88.0	0.08	39.7	40.23	adequate
18	780821.7	800109.4	0.9	103.5	83.0	97.0	7.9	96.8	88.0	0.08	6.6	7.23	adequate
19	780096.6	800257.3	1.8	102.4	83.0	97.0	7.9	96.8	88.0	0.08	12.7	13.56	adequate
20	778785.1	799736.9	0.8	76.5	83.0	97.0	7.9	96.8	88.0	0.08	5.5	4.00	inadequate

21	777806.0	799205.5	67.1	502.0	83.0	97.0	7.9	98.6	89.7	0.09	3055.0	300.00	inadequate
22	776212.0	800316.9	3.0	88.2	57.0	88.0	34.6	96.8	64.9	0.08	15.7	14.52	inadequate
23	775727.3	800584.1	0.7	76.8	83.0	97.0	7.9	96.8	88.0	0.08	5.3	4.56	inadequate
24	772061.4	797090.7	27.8	302.9	48.0	84.0	48.4	97.9	56.9	0.09	870.7	820.00	inadequate
25	770959.6	797812.4	5.4	24.5	48.0	84.0	48.4	96.8	56.1	0.08	25.3	25.60	adequate
26	770263.8	796304.3	41.5	2520.8	60.0	89.0	31.4	97.8	68.2	0.09	240.5	245.00	adequate
27	768888.6	796864.9	0.7	88.3	47.0	83.0	52.0	96.8	54.0	0.08	3.1	4.00	adequate
28	768778.2	796204.1	32.1	558.8	82.0	97.0	7.9	98.6	89.7	0.09	885.1	823.00	Inadequate.

. *5.4 Result of Discharge Obtained from Gumbel's Method*

As discussed in previous chapters in frequency analysis there are number of probability distribution for gauged condition. In this study for the two bridge crossing discharge of two rivers is measured for 20 years. By using L- moments the curve fits with Gumbel extreme value.

Table 5.3 Calculation of L- moment parameters for Bitinwuha River

No	Year	Q_{max}	n-j-2	n-j	n-j-1	bo	b1	b2	b3
1	1987	4.404	17	19	18	6.8	83.7	1506.17	25605
2	1988	5.06	16	18	17	6.8	91.1	1548.36	24774
3	1989	5.208	15	17	16	6.8	88.5	1416.58	21249
4	1990	3.765	14	16	15	6.8	60.2	903.6	12650
5	1991	4.767	13	15	14	6.8	71.5	1001.07	13014
6	1992	3.695	12	14	13	6.8	51.7	672.49	8069.9
7	1993	5.208	11	13	12	6.8	67.7	812.448	8936.9
8	1994	4.118	10	12	11	6.8	49.4	543.576	5435.8
9	1995	3.625	9	11	10	6.8	39.9	398.75	3588.8
10	1996	6.093	8	10	9	6.8	60.9	548.37	4387
11	1997	8.19	7	9	8	6.8	73.7	589.68	4127.8
12	1998	5.387	6	8	7	6.8	43.1	301.672	1810
13	1999	3.911	5	7	6	6.8	27.4	164.262	821.31
14	2000	4.085	4	6	5	6.8	24.5	122.55	490.2
15	2001	7.724	3	5	4	6.8	38.6	154.48	463.44
16	2002	6.399	2	4	3	6.8	25.6	76.788	153.58
17	2003	8.991	1	3	2	6.8	27	53.946	53.946
18	2004	11.387	0	2	1	6.8	22.8	22.774	0
19	2005	11.91	-1	1	0	6.8	11.9	0	0
20	2006	21.693	-2		20	6.8	0	0	0
	Mean	6.781					959	10837.6	135630
	St. dev.	4.29					2.52	1.58444	1.1664
	Skewness	0.998							

Table 5.4 Calculation of L- moment parameters for Beko River

No	year	Q_{max}	n-j-2	n-j	n-j-1	bo	b1	b2	b3
1	1987	33.928	17	19	18	22.612	33.928	11603	197257
2	1988	29.928	16	18	17	22.612	28.353	9158	146527
3	1989	22.498	15	17	16	22.612	20.13	6119.5	91792
4	1990	25.423	14	16	15	22.612	21.409	6101.5	85421
5	1991	23.728	13	15	14	22.612	18.733	4982.9	64777
6	1992	22.498	12	14	13	22.612	16.577	4094.6	49136
7	1993	22.095	11	13	12	22.612	15.118	3446.8	37915
8	1994	20.91	10	12	11	22.612	13.206	2760.1	27601
9	1995	20.523	9	11	10	22.612	11.882	2257.5	20318
10	1996	19.012	8	10	9	22.612	10.006	1711.1	13689
11	1997	51.22	7	9	8	22.612	24.262	3687.8	25815
12	1998	35.3	6	8	7	22.612	14.863	1976.8	11861
13	1999	15.497	5	7	6	22.612	5.7094	650.87	3254.4
14	2000	11.48	4	6	5	22.612	3.6253	344.4	1377.6
15	2001	11.48	3	5	4	22.612	3.0211	229.6	688.8
16	2002	11.753	2	4	3	22.612	2.4743	141.04	282.07
17	2003	15.086	1	3	2	22.612	2.382	90.516	90.516
18	2004	19.177	0	2	1	22.612	2.0186	38.354	0
19	2005	23.426	-1	1	0	22.612	1.2329	0	0
20	2006	17.287	-2	0	0	22.612	0	0	0
	Mean	22.612					248.93	8.6835	6.6891
	St. dev	9.47							
	Skewness	0.0806							

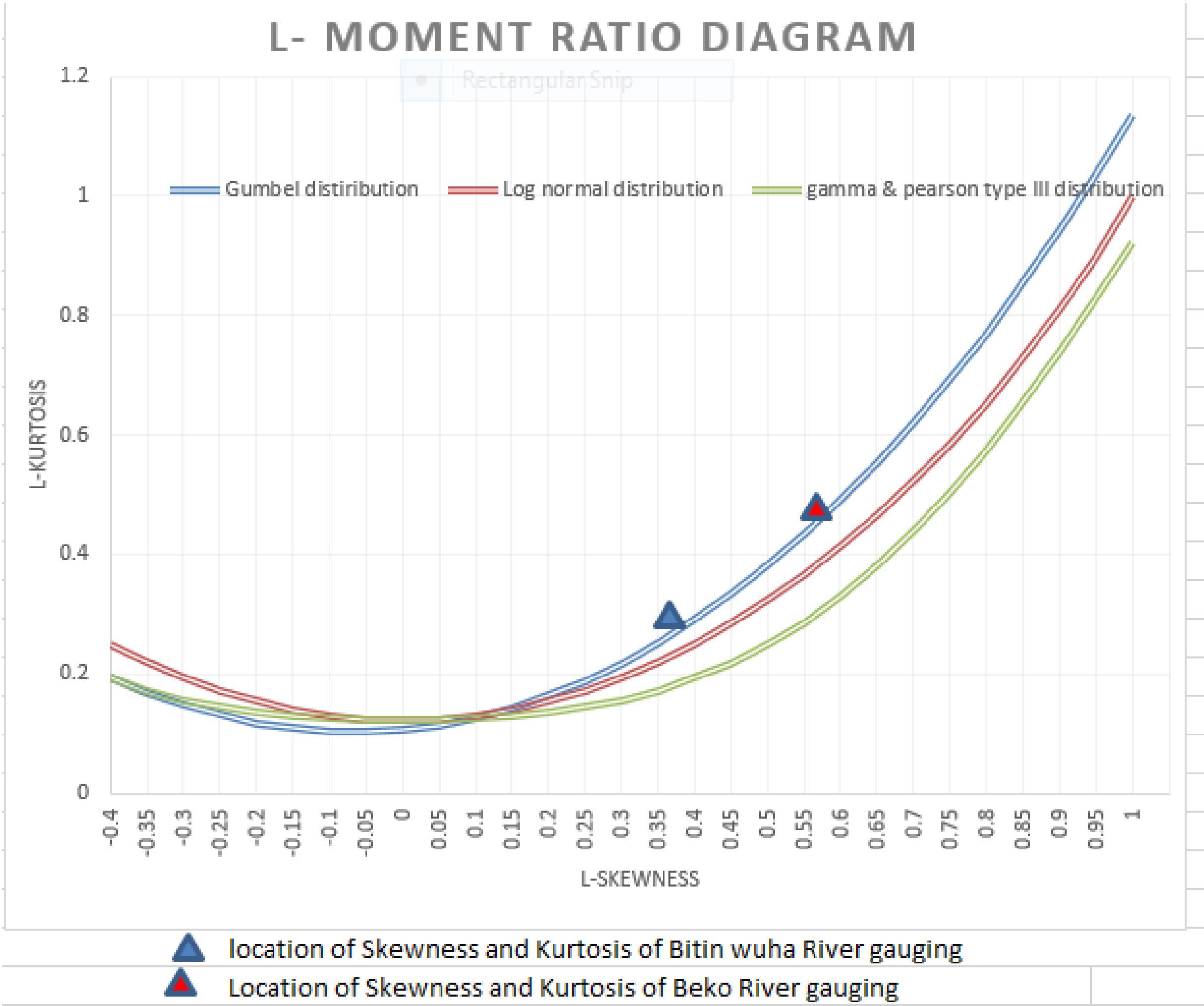

Fig 5.1 L-moment ratio diagram in order to check its fitness of distribution

5.4.1 Gumbel method

Gumbel method the most widely used distribution for the estimation of floods of various recurrence intervals. The calculation are follows.

Probability of exceedance and recurrence interval is determined from the given data set using P=1/T we will compute Y(T)= -(ln .ln T/1-T) for recurrence interval of 50 years

For number samples we will find Y_n and S_n from Gumbel's table.

$X_T = \bar{X} + K\sigma_{n-1}$ --- Equation 5.1

$\bar{X} = mean\ of\ sample$

Where σ_{n-1} - standard deviation of sample

$\sigma_{n-1} = \frac{\sqrt{\sum_{i=1}^{n}(Xi-\overline{X})}}{n-1}$ -- Equation 5.2

K frequency factor

$K = \frac{Y_T - \overline{Y_n}}{S_n}$ -- equation 5.3

Y_{T-} $reduce$ Variate function of table of T and is given by

$Y_{T = -[ln.ln\frac{T}{T-1}]}$ -- Equation 5.4

From a table the value of $\bar{y}_n$ and s_n for 20 samples 0.5236 and 1.0628 respectively

$Y_{T = -\left[ln.ln\frac{50}{50-1}\right] = 3.9}$

$K = \frac{3.9 - 0.53636}{1.0628}$ = 3.165

Now design discharge for two crossing calculate asfollows

Q_d of Bitinwuha river crossing

=6.781+4.29*3.165=25m^3/s

Q_d of Beko river crossing

22.612+3.165*4.29=37m^3/s

5.5 Result Obtained on Assessment of Size Cross Drainage Structures

In this study I was used different approach to calculate peak discharge for each crossing based catchment area, Slope of river, rainfall intensity in order to size each cross drainage structure. The risk of roads being washed away could be significantly reduced at a reasonable cost by identifying and rectifying weak points in the infrastructure system. Novel statistical and Empirical methods were developed based on the relationship between road-related floods without focusing on complex hydrological modelling. Therefore in this study three methods are to assess the size cross drainage to estimate peak discharge. These are rational method; SCS curve number method, statistical method.

In this research thesis the location and type of existing cross drainage structure is identified. Box culvert, pipe culverts, bridges are exist along the road. Generally ninety three cross drainage structure exists along Shishinda-Tepi road. Among this 91 are culverts others are bridges. In my study I assessed the peak discharge for each crossing from determined catchment area and flood frequency analysis. The conveyance capacity of drainages structures determined from Manning formula. In my finding the adequacy of each cross drainage structures compared with peak discharge. The result obtained indicates that among existing cross drainage structures, 22 crossing structure are oversized which means too extravagant, which is not economical, 29 crossing are adequate and 42 crossing are in ad inadequate. In this case there is probability of overtopping with 50 years return period. There no such effects of longitudinal drainage because of topography and Vegetated area.

In this thesis Hydraulic and hydrologic modeling is conducted for two crossings on Bitinwuha and Beko River.

5.6 HEC-RAS Result and Discussion

In this Thesis HEC –RAS model is used hydraulic phenomena of two bridges over Bitinwuha and Beko River. Along the Shishinda –Tepi road the two bridge existing over these river crossing of Bitinwuha and Beko River. As indicated in river below there no pier for Bitinwuha and there is Pier for Beko Bridge. The modeling of the two Bridge structures starts by collecting detail survey data. For Bitinwuha Bridge on upstream the side two rivers upper reach of Bitinwuha and Meni River come together join at upstream side a few kilometer away from bridge. Beko Rive on has only one reach on upstream side there is tributary that join river. Both River crossing of Schematic model indicated in appendix A.1 and B.1 for Bitinwuha and Beko rivers respectively.

The nature of topography is rolling in case of Bitinwuha crossing and hilly on Beko River. The schematic description, the longitudinal profiles, the cross sectional profile and the bridge detail data are Indicated in Appendix A.1 and B.1.

For two crossing the detail hydraulic property were of at bridge is investigated.

The water sur-face profile for 10, 50,100 years return period calculated for two crossing as indicated in appendix. Stage-discharge of relation at Bitinwuha and Beko Bridge crossing were analyzed as indicated in appendix.

For case of Beko river Crossing The reach is divided in to 10 river stations, station 10 being the upper most station and station 1 the lower most. Intermediate stations and cross sections are interpolated by 20m maximum distance from 10 river station data Cross-sectional data collected.

The river bed material varies from gravels and cobbles to boulders. An average Manning Roughness of 0.035 can be considered. The Bridge is located between station 8 and station 7 in Beko River whereas Bitinwuha Bridge located between station 4 and station 3

Fig 5.2 Photo of Beko Bridge

Fig 5.3 photo of Bitinwuha Bridge

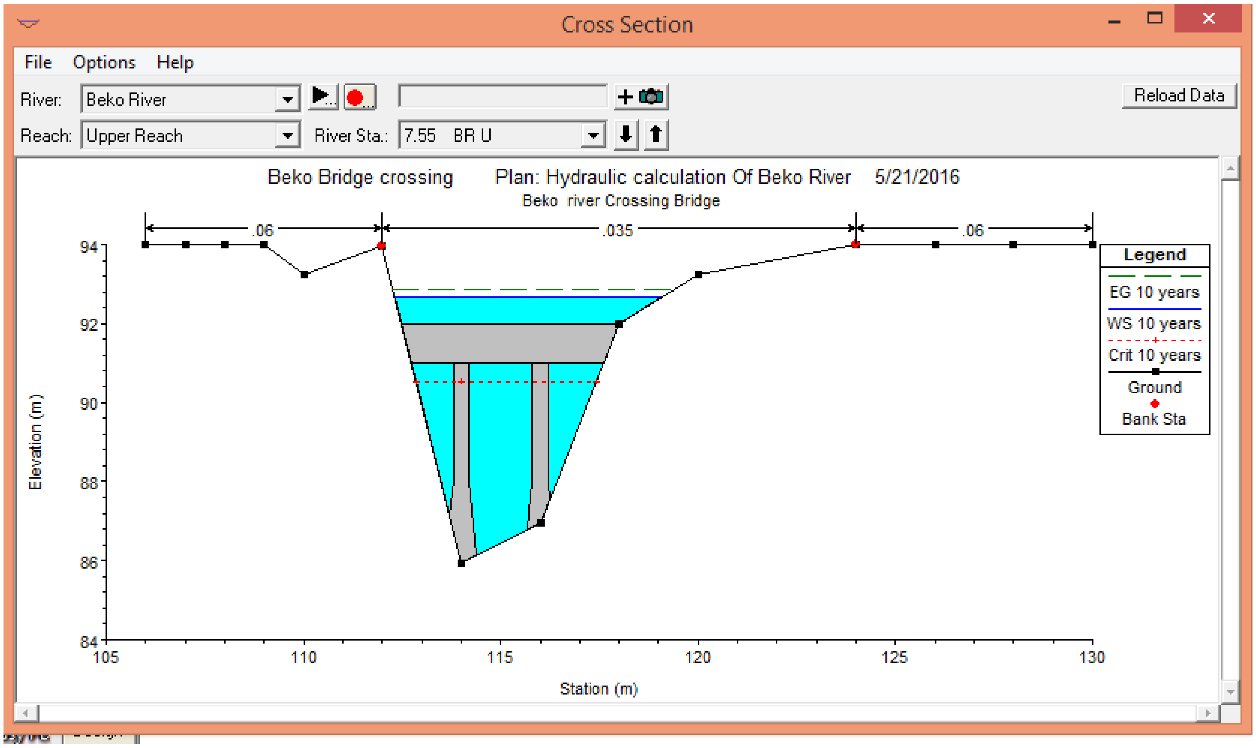

Figure 5.4 Depth of water surface for 10 years return period at Beko Bridge

The computation of depth scour at bridge abutment and piers with HEC- RAS is calculated. The model result indicates that great depth of bridge scour at pier and abutment. For instance for 10 years return period the depth scour 5.34m at left abutment and 7.91 m Right abutment and 3.67m at bridge pier, for 50 years return period the depth scour 5.71m at left abutment and 10.08 m Right abutment and 4.57m at bridge pier, for 100 years return period the depth scour 17.14m at left abutment and 23.6 m Right abutment and 1.54m at bridge pier. The sour depth of Left and right abutment of Bitinwuha Bridge is 2.11m and 7.11m for 10 years period, 3.14m and 9.12m for 50 years return period, 5.23m and 11.52m for 100 years.

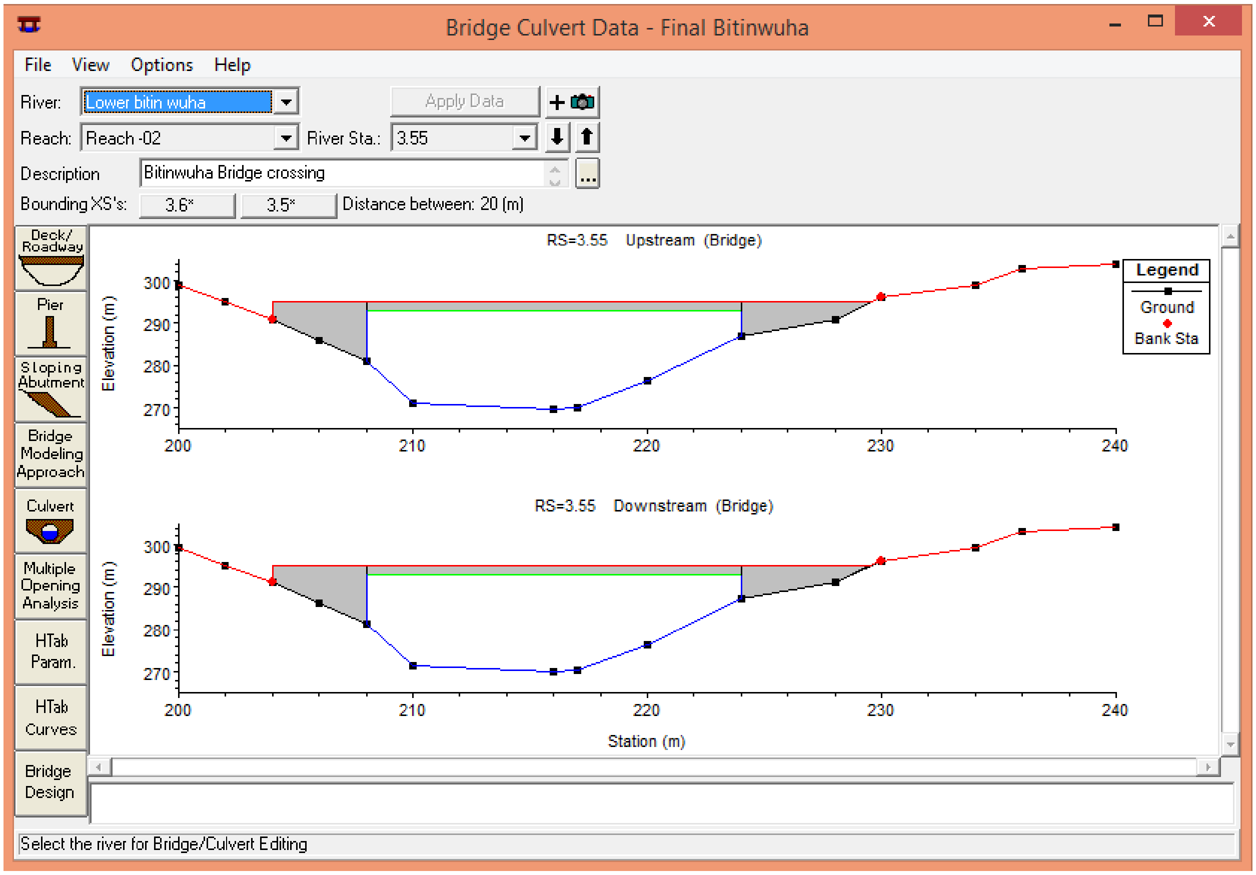

Figure 5.5 upstream and downstream Bridge section of Bitinwuha River

It is required to model the river in order to carry out investigation work on flood protection, adequacy of the bridge openings to accommodate the design floods and the magnitude of scour at the piers and abutments.

Chapter Six

6. Conclusion and Recommendation

6.1 Conclusion

In this research, attempt has been made to assess adequacy of size of existing drainage Structures along Shishinda-Tepi road, peak discharge and hydraulic calculation at bridge crossing.

Thus, based on the applied methodology and results obtained, the following conclusions are drawn

- ✓ There are ninety three drainage structures along the Shishinda-Tepi road. Among these forty two are inadequate, twenty nine are adequate and twenty two are oversized.
- ✓ The growth of weeds, brush, and trees in a drainage channel can effectively reduce its hydraulic efficiency. The result being that a portion of the design flow may overflow the channel banks causing flooding and possible erosion.
- ✓ Under-dimensioned drainage structures and mismanaged outlet ditches can sometimes complicate the maintenance and operation of the dewatering system and increase the risk of flooding and waterlogging along the road infrastructure.
- ✓ This is major problem for road of Shishinda-Tepi. In this thesis, the limited diameter of road drainage structures such as pipe, bridges and culverts and their resulting insufficient capacity or oversized to handle water volumes in future and clear-cutting scenarios indicates a need for increases in specific drainage structure dimensions and reduce to be economical.
- ✓ An increase in the occurrence of extreme weather events will impose greater strain on the facilities for dewatering and drainage of roads. Undersized or non-functional culverts, poorly cleaned ditches and structures with limited capacity may lead to serious damage to the entire road transport system already today; many culverts, trenches and other drainage facilities lack the capacity to deal with the current frequency of extreme flows along the road route.
- ✓ Poorly designed drainage systems deposit sediment directly into streams at road stream crossings and shorten the life of drainage structures and roads.
- ✓ Good drainage design in rural roads is critical to the success of road construction. If

drainage is inadequate, maintenance costs can be increased, the life span of the road can be reduced, and adverse impacts on the environment and local communities can result such as increased health risks, damage to food and water supplies, and depletion of natural resources.

- ✓ From performed hydraulic calculation in Steady state river analysis condition there great depth of scour and the probability over toping in case of Beko Bridge for 50 years return period but not in case of Bitinwuha River.
- ✓ Changes in hydrological and hydraulic conditions due to changes in climate conditions, Land cover, land use and scouring of abutment and pier of Cross drainage structures in the adjacent area and where drainage structures placed have a significant impact on the function and efficiency of road drainage systems.
- ✓ Culvert which installed along the road structure that used to convey surface runoff through embankment is no designed hydraulically to take advantage of submergence to increase hydraulic capacity
- ✓ This thesis clearly shows that the appropriate choice of hydrological and Hydraulic modelling tool and also needs to consider the type of flood to be estimated. In the thesis context, where the focus was on all season of randomly selected events, the 'best' model varied depending on the prevailing subsurface conditions. The subjectivity of the modeler and the calibration approach also had an influence.

6.2 Recommendation

- ✓ The cross drainage structures which exist along the Shishinda-Tepi road need to be upgrade because of the size of existing cross not adequate for 50 years return period.
- ✓ Adapting hydrologic and hydraulic analysis for future change scenarios is very important in order to ensure safe road transport function in the long-term perspective. In this, it is essential that the Ethiopian Road Authority understands the required adaptation process and Common causes of damage to roads and existing problems in road systems should be identified early during planning.
- ✓ The existing drainage along Shishinda-Tepi road did not function properly due aggradation of boulders and debris as the result, regular maintenance should be practiced for having long span life road and drainage structure.
- ✓ For some drainage structure along the road there great depth of scouring which may cause failure of the structure. Therefore to prevent scour, scour resistance mechanisms should be provided in areas vulnerable to scouring effects.
- ✓ Culvert should be designed hydraulically to take advantage of submergence to increase hydraulic capacity.
- ✓ There is no organized data regarding road drainage structures in Ethiopia which is essential to investigate the structure in detail therefore data should be organized.
- ✓ To prevent the negative effects of poorly planned, located, designed, constructed and drained forest roads, the places and sizes of drainage structures should be determined and constructed according to road and watershed conditions, with correct Hydraulic and Hydrologic analyses and road management practices.
- ✓ This thesis shows that forestation/reforestation is an important factor in controlling peak flow and total runoff. With respect to the effect of clear-cutting on increasing peak flow and the influence of reforestation and transforming open land to forest on decreasing peak flow, there should be a need for strategies that improve communication between road managers and the forestry and agriculture sectors and other organization to manage effect coming flood on the road drainage structure.
- ✓ Many of these problems stated above can be avoided if consideration is given to the design, construction and maintenance of adequate road drainage. The time and expense needed to implement adequate road drainage more than off-sets the greater costs of trying to mitigate problems.

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References

1) Admassu Gebeyehu, Regional Flood Frequency Analysis, the Royal institute of Technology,Stockholm,1989
2) ASCE TaskCommittee. 2000. Application of artificial neural networks in hydrology. J. Hydrol Eng. 5: 115-123
3) Aydagne Zeleke, Software development for hydraulic analysis and hydraulic design of minor highway drainage structures, Addis Ababa University Institute of Technology, Addis Ababa,2007
4) Bruce M. McEnroe, sizing of highway culverts and bridges: a historical review of methods and criteria The University of Kansas,2007 Lawrence, Kansas
5) Camberlin, P. and N. Philippon (2002). "The East African March–May RainySeason: Associated Atmospheric Dynamics and Predictability over th1968–97 Period." Journal of Climate **15**(9): 1002-1019
6) Central oregon storm water manual chapter five page no 1 august 2010
7) Chow Ven Te, D.R Maidment, and L.W Mays (1988). Applied Hydrology. McGraw hill, New, York.
8) Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.
9) Degefu, W. (1988). Drought & Hunger in Africa:Denying famine aFuture. M. H.
10) Elizabeth M.Shaw, Hydrology in practice, third edition, Taylor &Francis e. Library, 1994
11) Eric Tate, M.S.E., Floodplain Mapping Using HEC-RAS and ArcView GIS, 1999
12) Ethiopian Roads Authority. (2013). "Drainage Design Manual", Federal Democratic Republic of Ethiopia.
13) Glantz, Cambridge University Press.
14) Habtemichael, A. and D. E. Pedgley (1974). "Synoptic case-study of spring rains in Eritrea " Meteorology and Atmospheric Physics **23**(3-4): 285-296

15 Hosking J.R.M and J.R. Wallis, some statistical useful in regional frequency analysis, Res, Rep. Rc 17096,22pp.IBM Res Div J.S Watson res. Cent Yorktown height N.Y

16 Hydraulic Effects of Safety End Treatments on Culvert Performance by Kathryn Shirley Benson, B.S., B.S. Master of Science in Engineering The University of Texas at Austin May, 2004

17 Korecha, D. and A. G. Barnston (2007). "Predictability of June– September Rainfall in Ethiopia." Monthly Weather Review **135**(2): 628-650.

18 McEnroe Bruce M. 2010. Guidelines for Continuous Simulation of Streamflow in Johnson County, Kansaswith HEC-HMS. Report to Johnson County Public Works and Infrastructure Stormwater Management Program.June

19 16.Motovilov Y.G., Gottschalk L., Engeland K. andBelokurov A. 1999. ECOMAG: Regional model of

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hydrological cycle. Application to the NOPEX region Department of Geophysics, University of Oslo P.O. Box

20 Ponse, V.M, Engineering Hydrology (principles and practices),1989

21 Road structures under climate and land use change by Zahra Kalantari, January 2014

22 Subramenaya K.1998 applied hydrology first edition

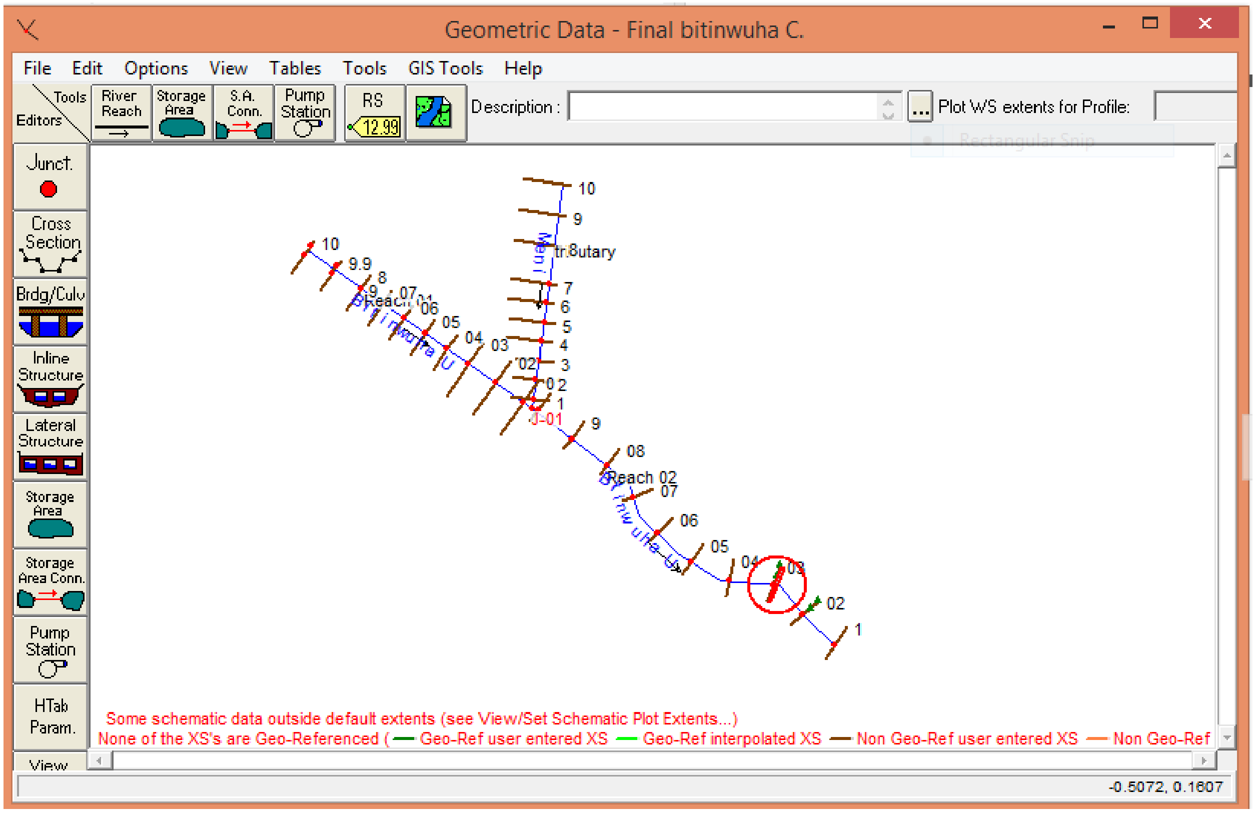
23 U.S. Army Corps of Engineers, Hydrologic Engineering Center, 1997b, HEC-RAS River Analysis System, hydraulic reference manual, Version 2.0: 251 p.

24 U.S. Army Corps of Engineers, Hydrologic Engineering Center, 1997c, HEC-RAS River Analysis System, applications guide, Version 2.0: 283 p.

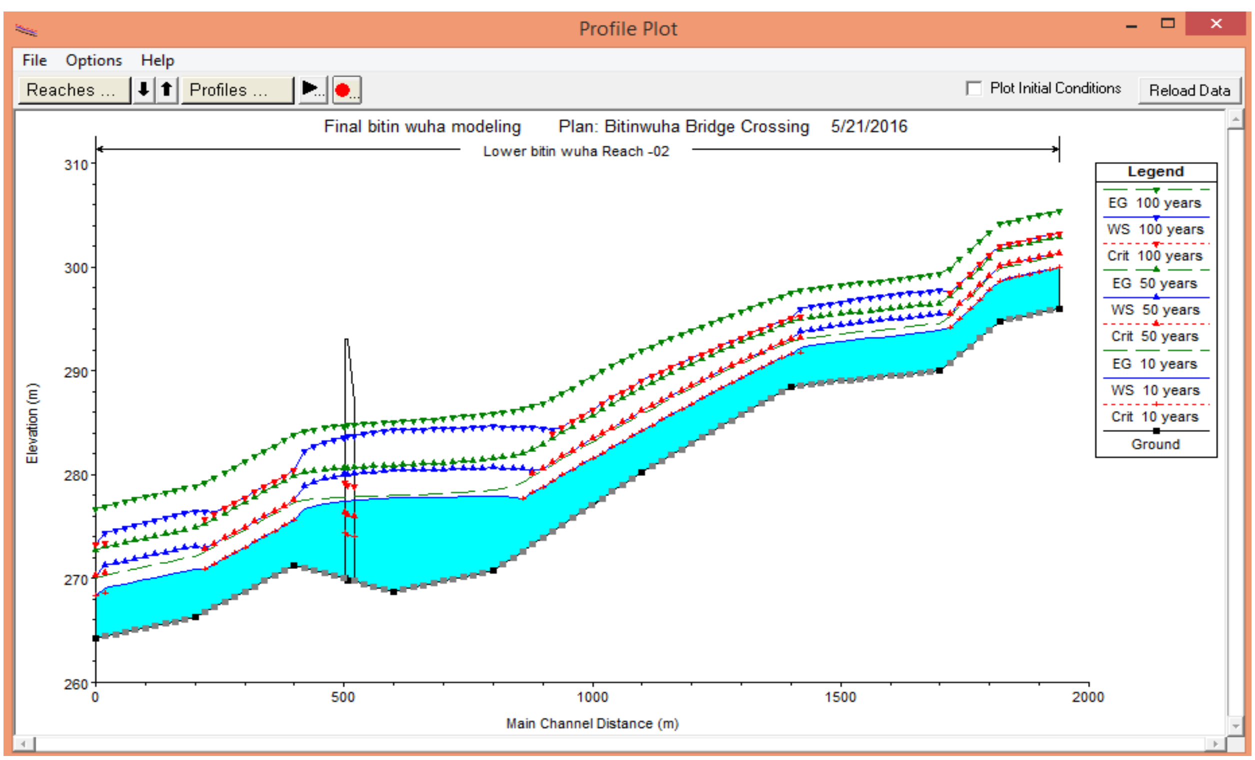
25 USACE-HEC, (2008), Hydrologic modeling system (HEC-HMS)- application guide, US Army Corps of Engineers, Hydrologic Engineering Center, Davis, Calif

Appendices

Appendix A.1 *Schematic of Bitiwuha crossing Modeling using Hydraulic Modeling HEC –RAS*



Appendix A.2 *Profile of Water sur-face for 10,50,100 years return period*



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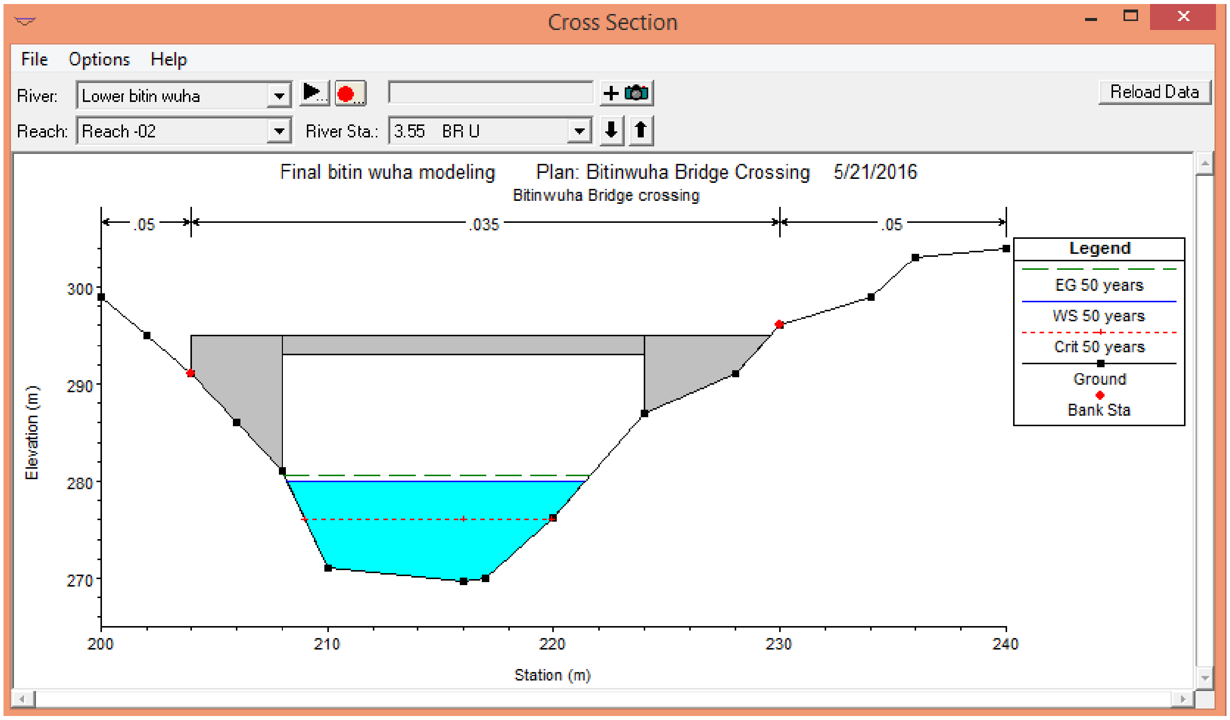
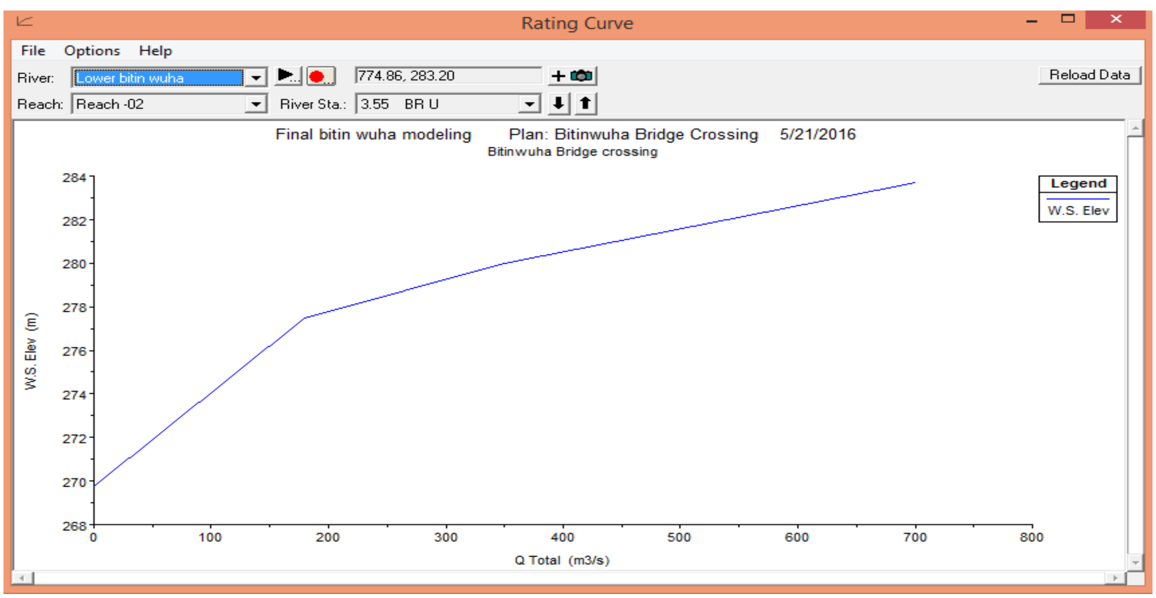
Appendix A.3 Depth water surface at Bitinwuha Bridge crossing for ten years return period



Appendix A.4 Stage-Discharge curve at Bitinwuha crossing



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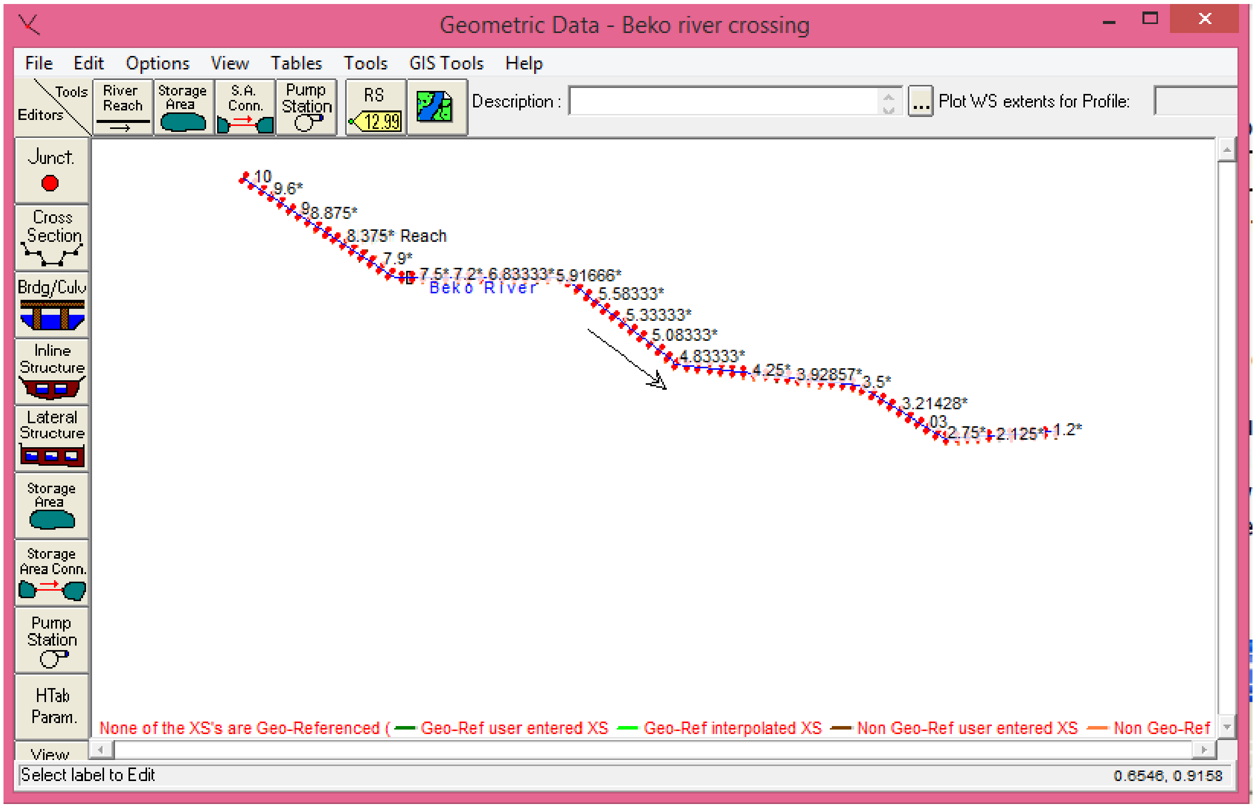
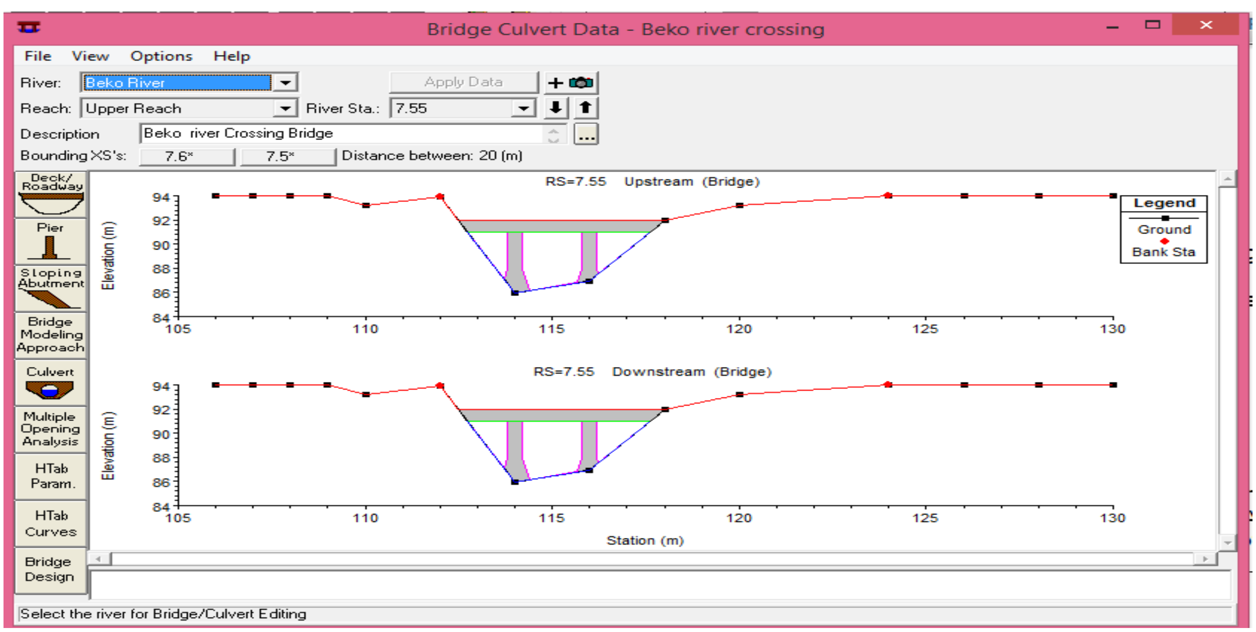
Appendix B.1 Schematic of Beko crossing by using Hydraulic Modeling HEC –RAS



Appendix B.2 upstream and downstream of Bridge of Beko



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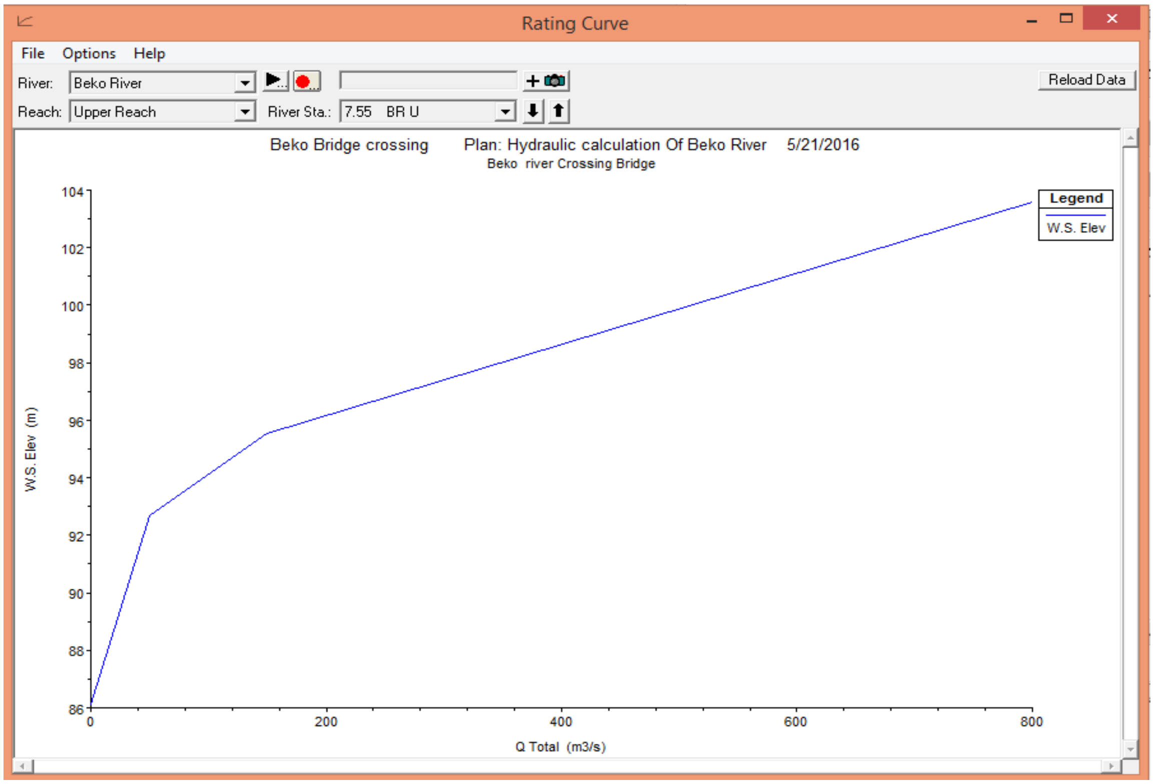
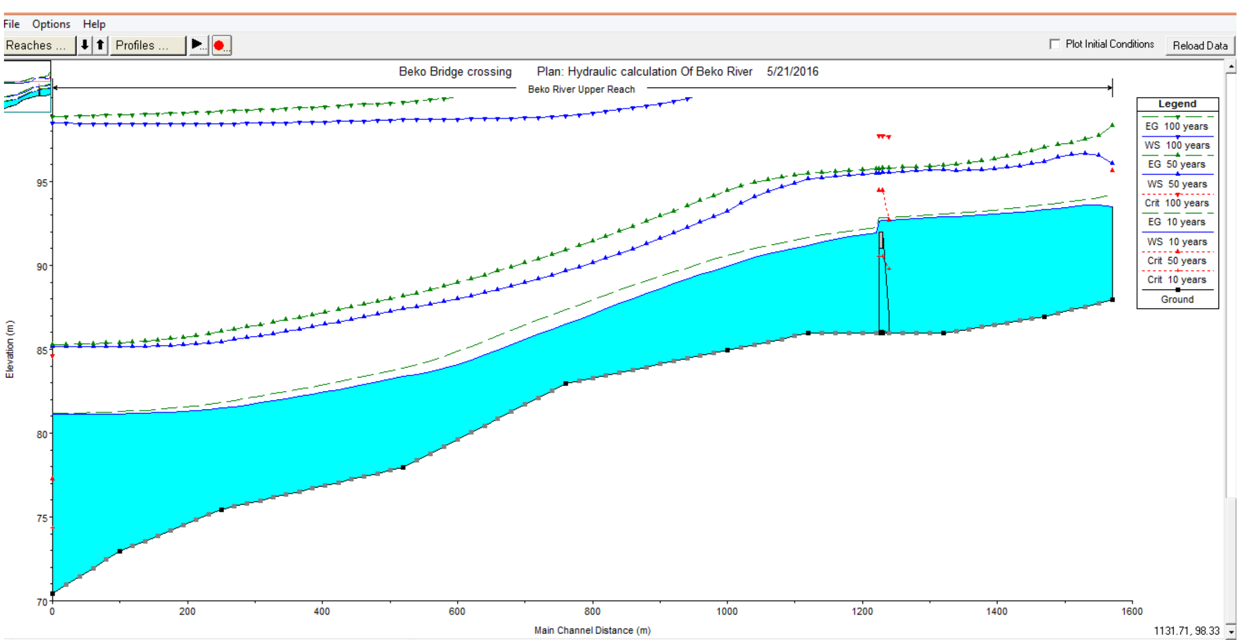
Appendix B.3 Stage –Discharge Curve at Beko Crossing



Appendix B.4 Water surface at Beko River Crossing



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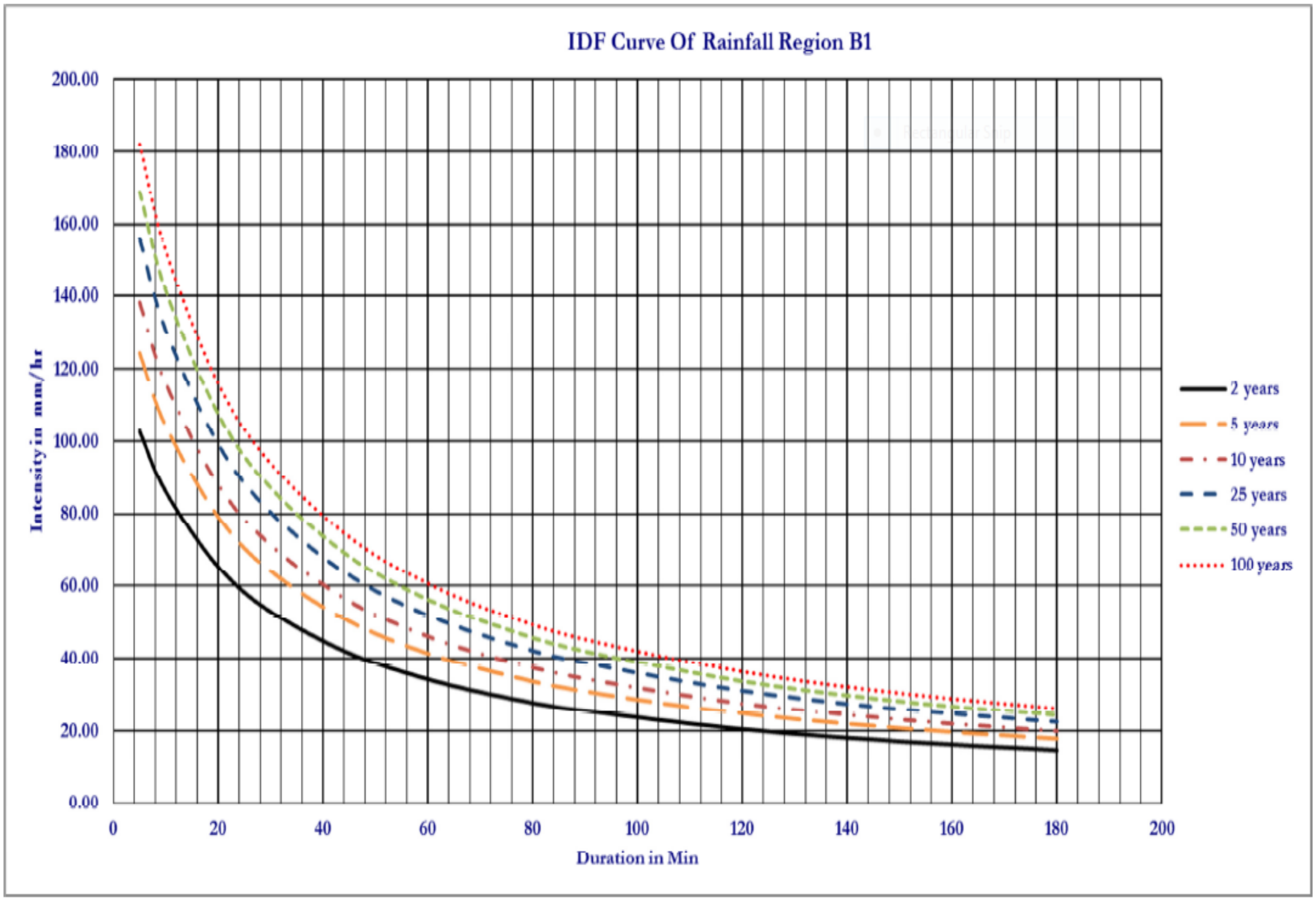
Appendix C: Intensity depth frequency curve of study area



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Appendix D Hydrologic and Hydraulic parameter of Cross drainage structure of Shishinda-Tepi road

No	***Easting***	***Northing***	***Catchment area (km^2)***	***Existing Structure***					***catchment Property***				***Intensity(mm/hr)***	***Runoff coefficient***	***Discharge from catchment(m^3/s)***	***Conveyance Capacity Of structure (m^3/s)***	**Remark**
				Type of structure	***No. Cell***	***Width (m)***	***Height (m)***	***Dia. (m)***	***Soil type***	***Longest flow path(km)***	***land Cover***	***Hydrological Soil group***					
1	818385.8	802740.498	0.071	PC	1			0.914	Drystic Nitosols	0.894	cultivation	**B**	**77.5**	**0.6**	0.92	3.15	over sized
2	817709.7	803224.177	0.053	PC	1			0.914	Drystic Nitosols	0.5678	cultivation	**B**	**79**	**0.6**	0.70	0.77	adequate
3	816422.3	804241.121	0.061	PC	1			0.914	Drystic Nitosols	0.79856	Sparse Forest	**B**	**98**	**0.48**	0.80	1.4	adequate
4	816021.1	805217.276	12.46	B/SC	1	5	4		Drystic Nitosols	8.5698	cultivation	**B**			70.36	72.56	adequate
5	813654	805878.075	90.4	Bridge	1	18	5		Drystic Cambisols	5.239	dense forest	**B**			259.70	230	Inadequate
6	813015	806024.551	0.026	PC	1			0.914	Drystic Cambisols	0.35678	dense forest	**B**	**83.5**	**0.42**	0.25	0.37	adequate
7	812789.8	806237.154	0.04	PC	1			0.914	Drystic Cambisols	0.4598	cultivation	**B**	**51.4**	**0.6**	0.34	0.07	Inadequate
8	812285.3	805949.911	0.076	PC	1			0.914	Drystic Cambisols	1.256	cultivation	**B**	**76.5**	**0.6**	0.97	0.12	Inadequate
9	811988.8	805406.214	0.052	PC	1			0.914	Drystic Cambisols	0.45687	cultivation	**B**	**60**	**0.6**	0.52	0.97	adequate

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10	811256.3	805390.29	0.1	PC	1			0.914	Drystic Cambisols	0.9856	cultivation	**B**	**77.5**	**0.6**	1.29	1	Inadequate
11	811176.4	805393.787	0.073	PC	1			0.914	Drystic Cambisols	0.4589	cultivation	**B**	**78.5**	**0.6**	0.96	1.01	Inadequate
12	810259.3	805411.629	5.4	B/SC	1	4	3		Drystic Cambisols	3.56	cultivation	**B**			23.27	22.45	Inadequate
13	809344.8	805378.599	0.088	PC	1			0.914	Drystic Cambisols	0.2569	cultivation	**B**	**59.75**	**0.6**	0.88	0.08	Inadequate
14	808604.8	805079.554	211.1	Bridge	1	30	6		Drystic Cambisols	14.968	sparse forest	**B**			215.7 5	210	Inadequate
15	807728.5	804887.3	0.049	PC	1			0.914	Drystic Cambisols	0.356	cultivation	**B**	**76.5**	**0.6**	0.63	1.06	adequate
16	807046.5	805246.176	3.76	B/SC	1	4	3		Drystic Cambisols	2.369	cultivation	**B**			26.10	25	Inadequate
17	805843.6	803787.941	0.048	PC	1			0.914	Drystic Cambisols	0.569	cultivation	**B**	**96.5**	**0.6**	0.77	0.39	inadequate
18	805339.8	803674.312	0.03	PC	1			0.914	Drystic Cambisols	0.369	cultivation	**B**	**58.5**	**0.6**	0.29	0..67	adequate
19	804218.7	803686.165	0.034	PC	1			0.914	Drystic Cambisols	0.2569	cultivation	**B**	**72.5**	**0.6**	0.41	1.12	adequate
20	802642.3	804252.2	0.055	PC	1			0.914	Drystic Cambisols	0.369	cultivation	**B**	**65**	**0.6**	0.60	0.44	Inadequate
21	802411.5	804366.227	0.047	PC	1			0.914	Drystic Cambisols	0.3556	cultivation	**B**	**78.5**	**0.6**	0.62	0.33	Inadequate
22	802092	804448.856	0.08	PC	1			0.914	Drystic Cambisols	0.236	cultivation	**B**	**90.5**	**0.6**	1.21	0.23	Inadequate

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23	801030.1	804092.186	0.087	PC	1			1.22	Drystic Cambisols	0.3698	cultivation	**B**	**40**	**0.6**	0.58	0.63	adequate
24	800886.7	803900.626	0.08	PC	1			1.22	Drystic Cambisols	0.3568	cultivation	**B**	**59.5**	**0.6**	0.79	0.53	Inadequate
25	800588.4	803728.298	0.031	PC	1			1.06	Drystic Cambisols	0.269	cultivation	**B**	**80**	**0.72**	0.50	1.96	over sized
26	800366.5	803639.193	0.06	PC	1			1.22	Drystic Cambisols	0.3596	cultivation	**B**	**92.5**	**0.72**	1.11	1.53	adequate
27	799933.2	803433.893	0.058	PC	1			1.22	Drystic Cambisols	0.3598	cultivation	**B**	**118.5**	**0.72**	1.38	1.41	adequate
28	799540.2	802098.501	0.3	B/SC	1	2	2	0.914	Drystic Cambisols	0.236	cultivation	**B**	**104.5**	**0.72**	6.28	8.03	over sized
29	799561.9	801905.105	0.2	B/SC	1	2	1.5	0.914	Drystic Cambisols	0.3598	cultivation	**B**	**100**	**0.72**	4.00	11.92	oversized
30	799327.9	801075.726	0.25	B/SC	1	2	1.5	0.914	Drystic Cambisols	0.369	cultivation	**B**	**138.5**	**0.72**	6.93	11.92	over sized
31	799048	801006.788	0.18	B/SC	1	2	1.5	0.914	Drystic Cambisols	0.125	cultivation	**B**	**110**	**0.72**	3.96	13.7	oversized
32	798747.5	800795.08	1.02	B/SC	1	4	2	0.914	Drystic Cambisols	2.369	sparse forest	**B**			3.11	3	Inadequate
33	798529.5	800341.99	0.23	PC	1	2		0.914	Drystic Cambisols	0.8967	cultivation	**B**	**122.5**	**0.72**	5.64	1.67	inadequate
34	798277.1	800044.078	0.23	PC	1			0.914	Drystic Cambisols	0.9666	cultivation	**B**	**99.5**	**0.6**	3.82	2.36	Inadequate
35	797857.5	799539.67	0.11	PC	1			0.914	Drystic Cambisols	0.7569	cultivation	**B**	**112.5**	**0.6**	2.06	1.42	Inadequate

36	797350.8	799612.389	2.73	B/SC	1	4	3		Drystic Cambisols	3.75	Sparse Forest	**B**			8.41	12.5	adequate
37	796950.5	799604.814	0.28	B/SC	1			0.914	Drystic Cambisols	0.8596	cultivation	**B**	**138.5**	**0.6**	6.47	0.62	Inadequate
38	796415.3	799749.904	1.98	B/SC	1	3	3		Drystic Cambisols	1.25	cultivation	**B**			8.63	8.63	adequate
39	795455.7	799887.574	0.24	B/SC	1	2	1.5	0.914	Drystic Cambisols	0.2369	cultivation	**B**	**110**	**0.6**	4.40	0.52	Inadequate
40	795140.6	800798.539	1.05	B/SC	1	4	2		Drystic Cambisols	3.69	cultivation	**B**			7.10	5.23	Inadequate
41	794741.6	801122.071	15.2	B/SC	3	4	4		Drystic Cambisols	9.269	cultivation	**B**			106.54	112.23	adequate
42	794017.6	800609.443	0.09	PC	1			1.22	Drystic Cambisols	0.369	cultivation	**B**	**120**	**0.6**	1.80	0.59	Inadequate
43	793372.1	800403.839	0.19	PC	1			1.22	Drystic Cambisols	0.56	cultivation	**B**	**130**	**0.72**	4.94	3.16	Inadequate
44	793047.4	800585.403	0.23	B/SC	1	2	1.5		Drystic Cambisols	1.25	cultivation	**B**	**132.5**	**0.72**	6.10	6.2	adequate
45	792349.3	800562.015	2.26	B/SC	1	4	3		Drystic Cambisols	2.369	cultivation	**B**			15.10	15.96	Inadequate
46	792206.5	800524.399	1.3	B/SC	1	3	3		Drystic Cambisols	1.369	cultivation	**B**			7.24	7.3	adequate
47	792022.8	800417.794	0.48	B/SC	1	2	2		Orthic Acrosols	1.096	cultivation	**B**	**120**	**0.72**	11.53	23.61	over sized
48	791612.2	800272.297	0.17	PC	1			1.22	Orthic Acrosols	0.996	cultivation	**B**	**138.5**	**0.72**	4.71	4.81	adequate

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49	791485.8	800140.098	0.29	PC	1			1.22	Orthic Acrosols	0.695	cultivation	**B**	**142.5**	**0.72**	8.27	2.63	Inadequate
50	791439.4	799796.706	0.06	PC	1			1.06	Orthic Acrosols	0.1267	cultivation	**B**	**135**	**0.72**	1.62	3.9	oversized
51	790644	800505.153	0.07	PC	1			1.06	Orthic Acrosols	0.365	cultivation	**B**	**98.5**	**0.72**	1.38	3.22	oversized
52	790260.1	800502.324	0.055	PC	1			1.06	Orthic Acrosols	0.2369	cultivation	**B**	**118.5**	**0.72**	1.30	3.6	oversized
53	788823.8	799837.042	0.12	PC	1			1.22	Orthic Acrosols	0.966	cultivation	**B**	**119**	**0.72**	2.86	2.94	adequate
54	787626.1	799209.246	0.06	PC	1			1.06	Orthic Acrosols	0.2566	cultivation	**B**	**70**	**0.72**	0.84	4.09	oversized
55	787331.3	799002.438	0.06	PC	1			1.06	Orthic Acrosols	0.369	cultivation	**B**	**110**	**0.72**	1.32	3.87	oversized
56	786426.2	798562.047	0.056	PC	1			1.06	Orthic Acrosols	0.5698	cultivation	**B**	**112.5**	**0.72**	1.26	2.27	adequate
57	786211.3	798948.726	0.087	PC	1			1.06	Orthic Acrosols	0.369	cultivation	**B**	**128**	**0.72**	2.23	5.44	oversized
58	786510	799291.015	0.36	B/SC	1	2	2		Orthic Acrosols	1.25	sparse forest	**B**	**113.5**	**0.48**	5.45	9.06	oversized
59	786666.4	800252.243	1.77	B/SC	2	3	2		Orthic Acrosols	3.459	sparse forest	**B**			11.82	12.23	adequate
60	786464.1	800722.515	0.28	PC	2			1.22	Orthic Acrosols	0.896	cultivation	**B**	**90**	**0.6**	4.20	0.6	Inadequate
61	786055.5	800960.371	11.83	B/SC	3	4	3		Orthic Acrosols	12.569	cultivation	**B**			81.94	83	Inadequate

62	785796.7	800936.673	23.67	B/SC	3	5	4		Orthic Acrosols	13.69	cultivation	**B**			167.33	152.63	Inadequate
63	785221.5	800773.347	0.155	PC	1			1.22	Orthic Acrosols	0.785	sparse forest	**B**	**102.5**	**0.48**	2.12	2.47	adequate
64	784916	800970.402	0.12	PC	1			1.22	Orthic Acrosols	0.692	sparse forest	**B**	**120**	**0.38**	1.52	0.98	Inadequate
65	784503.1	801009.49	0.4	B/SC	1	2	2		Orthic Acrosols	0.569	sparse forest	**B**	**120**	**0.38**	5.07	9.49	oversized
66	784300.4	801065.19	0.022	PC	1			1.06	Orthic Acrosols	0.236	sparse forest	**B**	**119.5**	**0.38**	0.28	1.99	0versized
67	784101.4	801157.431	0.044	PC	1			1.06	Orthic Acrosols	0.569	sparse forest	**B**	**110**	**0.38**	0.51	0.82	adequate
68	783986.4	801191.653	1.56	B/SC	1	3	3		Orthic Acrosols	1.25	grass land	**B**			9.22	12.5	oversized
69	782878.3	800809.423	0.078	PC	1			1.06	Orthic Acrosols	0.369	grass land	**B**	**110**	**0.42**	1.00	4.65	oversized
70	782792.3	800347.641	0.05	PC	1			1.06	Orthic Acrosols	0.369	grass land	**B**	**110.5**	**0.42**	0.65	3.75	oversized
71	782658.3	799708.731	0.072	PC	1			1.06	lithosols	0.963	grass land	**D**	**120**	**0.54**	1.30	0.30	inadequate
72	782385.5	799771.51	5.44	B/SC	2	3	3		lithosols	4.96	grass land	**D**			39.74	40.23	Inadequate
73	781976.2	799865.678	0.28	PC	1			1.22	lithosols	0.8569	grass land	**D**	**90**	**0.54**	3.78	0.13	Inadequate
74	780919.6	800089.395	0.16	PC	1			1.22	lithosols	0.68777	grass land	**D**	**121.5**	**0.54**	2.92	0.74	Inadequate
75	780821.7	800109.381	0.93	B/SC	1	3	2		lithosols	1.563	grass land	**D**			6.63	7.23	adequate
76	780390.5	800197.322	0.45	B/SC	1	2	2		lithosols	1.0965	grass land	**D**	**118**	**0.54**	7.97	4.5	Inadequate
77	780096.6	800257.282	1.76	B/SC	1	3	3		lithosols	1.26	grass land	**D**			12.70	13.56	adequate
78	778785.1	799736.946	0.76	B/SC	1	3	2		lithosols	1.698	grass land	**D**			5.48	4	Inadequate

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79	777806	799205.46	370.1	Bridge	2	20	6		lithosols	2556.3	dense forest	**D**			305.96	300	Inadequate
80	777538.9	799020.233	0.19	PC	1			1.22	lithosols	0.9065	dense forest	**D**	**110.5**	**0.42**	2.45	0.92	Inadequate
81	776212	800316.904	2.95	B/SC	1	4	3		lithosols	2.56	dense forest	**D**			15.70	14.52	Inadequate
82	775727.3	800584.099	0.74	B/SC	1	3	2		lithosols	1.236	grass land	**D**			5.28	4.56	Inadequate
83	774262.9	800142.604	0.06	PC	1			1.06	lithosols	0.965	sparse grass land	**D**	**80**	**0.66**	0.88	2.31	oversized
84	773854.3	799276.393	0.13	PC	1			1.22	lithosols	1.089	sparse grass land	**D**	**85**	**0.66**	2.03	0.89	Inadequate
85	772886.4	797818.869	0.04	PC	1			1.06	lithosols	0.466	sparse forest	**D**	**50**	**0.78**	0.43	0.32	Inadequate
86	772061.4	797090.676	171.8	Bridge	1	24	6		lithosols	19.56	sparse forest	**D**			870.67	820	Inadequate
87	771165	797715.09	0.083	PC	1			1.06	Drystic cambsols	0.698	sparse forest	**B**	**118**	**0.66**	1.80	1.8	adequate
88	770959.6	797812.414	5.38	B/SC	1	4	3		Drystic cambsols	4.75	sparse forest	**B**			25.33	25.6	adequate
90	770263.8	796304.281	41.5	B/SC	3	5	3		Drystic cambsols	12.5	grass land	**B**			240.48	245	oversized
91	768888.6	796864.928	0.71	B/SC	1	2	2		Drystic cambsols	1.236	sparse forest	**B**			3.14	4	adequate
92	768778.2	796204.083	112.1	Bridge	1	20	6		Drystic cambsols	6.59	suburban	**B**			885.09	823	Inadequate
93	768007.6	795563.321	0.37	B/SC	1	2	2		Drystic cambsols	1.056	suburban	**B**	**90**	**0.66**	6.11	12	oversized

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Appendix E Run-off coefficient and time of concentration of each of Cross-drainage structure

No	*Easting*	*Northing*	*land Cover*	*H soil*	*Catchment area (km²)*	Slope of river	Slope of Catchment	TC1(hr)	TC2(hr)	TC(min)	Nature of Land scape	Run off coefficient			
												CS	Cp	Cv	C
1	818385.8	802740.498	cultivation	**B**	0.071	0.027490119	0.016436702	0.47963238	0.296061	46.54	Rolling	0.15	0.15	0.2	0.6
2	817709.7	803224.177	cultivation	**B**	0.053	0.062804878	0.005926158	0.2336784	0.438482	40.33	Rolling	0.15	0.15	0.2	0.6
3	816422.3	804241.121	Sparse Forest	**B**	0.061	0.210191083	0.011740501	0.09038797	0.337008	25.64	Rolling	0.15	0.15	0.1	0.48
4	816021.1	805217.276	cultivation	**B**	12.46	0.000223214	0.003354429	5.64831883	0.545891	371.65	Rolling	0.15	0.15	0.2	0.6
5	813654	805878.075	dense forest	**B**	90.4	0.00037122	0.00195675	2.70991888	0.671781	202.90	Rolling	0.15	0.15	0.05	0.42
6	813015	806024.551	dense forest	**B**	0.026	0.004065041	0.012299573	0.2026399	0.331026	32.02	Rolling	0.15	0.15	0.05	0.42
7	812789.8	806237.154	cultivation	**B**	0.04	0.102752294	0.000559071	0.17212454	1.088164	75.62	Rolling	0.15	0.15	0.2	0.6
8	812285.3	805949.911	cultivation	**B**	0.076	0.020283976	0.007827001	0.2399044	0.393944	38.03	Rolling	0.15	0.15	0.2	0.6
9	811988.8	805406.214	cultivation	**B**	0.052	0.227272727	0.001297046	0.09993151	0.787012	53.22	Rolling	0.15	0.15	0.2	0.6
10	811256.3	805390.29	cultivation	**B**	0.1	0.711462451	0.002236286	0.05538571	0.638118	41.61	Rolling	0.15	0.15	0.2	0.6
11	811176.4	805393.787	cultivation	**B**	0.073	0.246857143	0.005590715	0.13784064	0.44843	35.18	Rolling	0.15	0.15	0.2	0.6
12	810259.3	805411.629	cultivation	**B**	5.4	0.000444733	0.005031643	4.47727997	0.466994	296.66	flat	0.05	0.15	0.2	0.48
13	809344.8	805378.599	cultivation	**B**	0.088	0.048780488	0.001118143	0.09386453	0.833293	55.63	Flat	0.05	0.15	0.2	0.48
14	808604.8	805079.554	sparse forest	**B**	211.1	0.000234962	2.018527629	5.28719313	0.046455	320.02	Rolling	0.15	0.15	0.1	0.48
15	807728.5	804887.3	cultivation	**B**	0.049	0.02259887	0.01118143	0.2926668	0.343398	38.16	Rolling	0.15	0.15	0.2	0.6
16	807046.5	805246.176	cultivation	**B**	3.76	0.000559701	0.002795357	3.5850075	0.585586	250.24	Rolling	0.15	0.15	0.2	0.6
17	805843.6	803787.941	cultivation	**B**	0.048	0.157211538	0.02236286	0.21075331	0.262967	28.42	Rolling	0.15	0.15	0.2	0.6
18	805339.8	803674.312	cultivation	**B**	0.03	0.066481481	0.001375316	0.22927719	0.769457	59.92	Rolling	0.15	0.15	0.2	0.6
19	804218.7	803686.165	cultivation	**B**	0.034	0.103107345	0.003354429	0.14059839	0.545891	41.19	Rolling	0.15	0.15	0.2	0.6
20	802642.3	804252.2	cultivation	**B**	0.055	0.110497238	0.001900843	0.15514946	0.679321	50.07	Rolling	0.15	0.15	0.2	0.6

21	802411.5	804366.227	cultivation	**B**	0.047	0.070480828	0.006708858	0.16470816	0.418032	34.96	Rolling	0.15	0.15	0.2	0.6
22	802092	804448.856	cultivation	**B**	0.08	0.093150685	0.011293244	0.1620846	0.342085	30.25	Rolling	0.15	0.15	0.2	0.6
23	801030.1	804092.186	cultivation	**B**	0.087	0.088480392	0.000268354	0.11264384	1.443499	93.37	Rolling	0.15	0.15	0.2	0.6
24	800886.7	803900.626	cultivation	**B**	0.08	0.03671875	0.001118143	0.11126657	0.833293	56.67	Rolling	0.15	0.15	0.2	0.6
25	800588.4	803728.298	cultivation	**B**	0.031	0.541574391	0.006149786	0.08088812	0.432273	30.79	mountainous	0.25	0.15	0.2	0.72
26	800366.5	803639.193	cultivation	**B**	0.06	0.294102857	0.025216361	0.12151815	0.251085	22.36	mountainous	0.25	0.15	0.2	0.72
27	799933.2	803433.893	cultivation	**B**	0.058	1.730103806	0.022429948	0.04789249	0.262664	18.63	mountainous	0.25	0.15	0.2	0.72
28	799540.2	802098.501	cultivation	**B**	0.3	0.592105263	0.017890288	0.07612011	0.286557	21.76	mountainous	0.25	0.15	0.2	0.72
29	799561.9	801905.105	cultivation	**B**	0.2	0.252197452	0.102415189	0.14912129	0.146379	17.73	mountainous	0.25	0.15	0.2	0.72
30	799327.9	801075.726	cultivation	**B**	0.25	1.546640889	0.03354429	0.04205868	0.22496	16.02	mountainous	0.25	0.15	0.2	0.72
31	799048	801006.788	cultivation	**B**	0.18	0.590932247	0.027969349	0.15057667	0.241266	23.51	mountainous	0.25	0.15	0.2	0.72
32	798747.5	800795.08	sparse forest	**B**	1.02	0.404984424	0.097345133	0.08532053	0.149269	14.08	mountainous	0.25	0.15	0.1	0.6
33	798529.5	800341.99	cultivation	**B**	0.23	0.285714286	0.198630137	0.11766966	0.113428	13.87	mountainous	0.25	0.15	0.2	0.72
34	798277.1	800044.078	cultivation	**B**	0.23	0.931506849	0.032505224	0.06171685	0.227702	17.37	Rolling	0.15	0.15	0.2	0.6
35	797857.5	799539.67	cultivation	**B**	0.11	0.347533632	0.030507736	0.11792763	0.23333	21.08	Rolling	0.15	0.15	0.2	0.6
36	797350.8	799612.389	Sparse Forest	**B**	2.73	0.302677532	0.04593741	0.08657707	0.199313	17.15	Rolling	0.15	0.15	0.1	0.48
37	796950.5	799604.814	cultivation	**B**	0.28	0.440394837	0.103485839	0.06312601	0.145794	12.54	Rolling	0.15	0.15	0.2	0.6
38	796415.3	799749.904	cultivation	**B**	1.98	0.006060606	0.0015625	1.29105009	0.732569	121.42	Rolling	0.15	0.15	0.2	0.6
39	795455.7	799887.574	cultivation	**B**	0.24	0.343147208	0.042103239	0.12388479	0.206114	19.80	Rolling	0.15	0.15	0.2	0.6
40	795140.6	800798.539	cultivation	**B**	1.05	0.008841463	0.004759519	0.70566512	0.477098	70.97	Rolling	0.15	0.15	0.2	0.6
41	794741.6	801122.071	cultivation	**B**	15.2	0.001055966	0.001085633	3.83868397	0.842813	280.89	Rolling	0.15	0.15	0.2	0.6
42	794017.6	800609.443	cultivation	**B**	0.09	0.387878788	0.076551468	0.11082594	0.163737	16.47	Rolling	0.15	0.15	0.2	0.6
43	793372.1	800403.839	cultivation	**B**	0.19	0.738993711	0.078431373	0.08443156	0.162215	14.80	mountainous	0.25	0.15	0.2	0.72
44	793047.4	800585.403	cultivation	**B**	0.23	0.29296875	0.115006905	0.08532716	0.139988	13.52	mountainous	0.25	0.15	0.2	0.72

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45	792349.3	800562.015	cultivation	**B**	2.26	0.006696429	0.002371542	0.87098643	0.623853	89.69	mountainous	0.25	0.15	0.2	0.72
46	792206.5	800524.399	cultivation	**B**	1.3	0.003514938	0.006337136	0.8189994	0.427307	74.78	mountainous	0.25	0.15	0.2	0.72
47	792022.8	800417.794	cultivation	**B**	0.48	0.940520446	0.035907666	0.05339871	0.21914	16.35	mountainous	0.25	0.15	0.2	0.72
48	791612.2	800272.297	cultivation	**B**	0.17	0.790816327	0.108736175	0.0479624	0.143043	11.46	mountainous	0.25	0.15	0.2	0.72
49	791485.8	800140.098	cultivation	**B**	0.29	0.872340426	0.165060082	0.05102188	0.121808	10.37	mountainous	0.25	0.15	0.2	0.72
50	791439.4	799796.706	cultivation	**B**	0.06	0.62639821	0.107465253	0.05384755	0.143691	11.85	mountainous	0.25	0.15	0.2	0.72
51	790644	800505.153	cultivation	**B**	0.07	0.344	0.010471661	0.04721593	0.352179	23.96	mountainous	0.25	0.15	0.2	0.72
52	790260.1	800502.324	cultivation	**B**	0.055	0.234042553	0.040355125	0.06937074	0.209507	16.73	mountainous	0.25	0.15	0.2	0.72
53	788823.8	799837.042	cultivation	**B**	0.12	0.882352941	0.040322581	0.03941605	0.209572	14.94	mountainous	0.25	0.15	0.2	0.72
54	787626.1	799209.246	cultivation	**B**	0.06	0.030674847	0.002427184	0.1299053	0.618308	44.89	mountainous	0.25	0.15	0.2	0.72
55	787331.3	799002.438	cultivation	**B**	0.06	0.550847458	0.019695895	0.05691635	0.276143	19.98	mountainous	0.25	0.15	0.2	0.72
56	786426.2	798562.047	cultivation	**B**	0.056	0.650793651	0.024626866	0.04083683	0.253383	17.65	mountainous	0.25	0.15	0.2	0.72
57	786211.3	798948.726	cultivation	**B**	0.087	0.816326531	0.073654391	0.05283702	0.166187	13.14	mountainous	0.25	0.15	0.2	0.72
58	786510	799291.015	sparse forest	**B**	0.36	0.414507772	0.05918619	0.11740817	0.180786	17.89	Rolling	0.15	0.15	0.1	0.48
59	786666.4	800252.243	sparse forest	**B**	1.77	0.011682243	0.01300813	0.74871377	0.323964	64.36	Rolling	0.15	0.15	0.1	0.48
60	786464.1	800722.515	cultivation	**B**	0.28	0.09202454	0.009669523	0.10051227	0.363152	27.82	Rolling	0.15	0.15	0.2	0.6
61	786055.5	800960.371	cultivation	**B**	11.83	0.002002549	0.000374204	3.72194873	1.270055	299.52	Rolling	0.15	0.15	0.2	0.6
62	785796.7	800936.673	cultivation	**B**	23.67	0.0025	0.000412088	2.7856463	1.223765	240.56	Rolling	0.15	0.15	0.2	0.6
63	785221.5	800773.347	sparse forest	**B**	0.155	0.435705669	0.025536443	0.10810139	0.249869	21.48	Rolling	0.15	0.15	0.1	0.48
64	784916	800970.402	sparse forest	**B**	0.12	0.437389771	0.0520969	0.0654361	0.189888	15.32	flat	0.05	0.15	0.1	0.36
65	784503.1	801009.49	sparse forest	**B**	0.4	0.487744227	0.050761421	0.06358161	0.191796	15.32	flat	0.05	0.15	0.1	0.36

66	784300.4	801065.19	sparse forest	**B**	0.022	0.807588076	0.081654872	0.06413431	0.159719	13.43	flat	0.05	0.15	0.1	0.36
67	784101.4	801157.431	sparse forest	**B**	0.044	0.867208672	0.031594578	0.06307647	0.230207	17.60	flat	0.05	0.15	0.1	0.36
68	783986.4	801191.653	grass land	**B**	1.56	0.016741071	0.008130081	0.70322192	0.388224	65.49	flat	0.05	0.15	0.15	0.42
69	782878.3	800809.423	grass land	**B**	0.078	0.346137611	0.027063599	0.04597738	0.244343	17.42	flat	0.05	0.15	0.15	0.42
70	782792.3	800347.641	grass land	**B**	0.05	2.034235669	0.111218569	0.02260755	0.141805	9.86	flat	0.05	0.15	0.15	0.42
71	782658.3	799708.731	grass land	**D**	0.072	0.114854518	0.009489917	0.09551175	0.365783	27.68	flat	0.05	0.25	0.15	0.54
72	782385.5	799771.51	grass land	**D**	5.44	0.573712256	0.047444408	0.06121661	0.196851	15.48	flat	0.05	0.25	0.15	0.54
73	781976.2	799865.678	grass land	**D**	0.28	0.549363057	0.026422288	0.03069078	0.24661	16.64	flat	0.05	0.25	0.15	0.54
74	780919.6	800089.395	grass land	**D**	0.16	0.103092784	0.010089642	0.10302062	0.357254	27.62	flat	0.05	0.25	0.15	0.54
75	780821.7	800109.381	grass land	**D**	0.93	0.005	0.001282051	0.93441479	0.790543	103.50	flat	0.05	0.25	0.15	0.54
76	780390.5	800197.322	grass land	**D**	0.45	0.007163324	0.010044643	0.66708747	0.357869	61.50	flat	0.05	0.25	0.15	0.54
77	780096.6	800257.282	grass land	**D**	1.76	0.002737226	0.001923077	1.03098189	0.676286	102.44	flat	0.05	0.25	0.15	0.54
78	778785.1	799736.946	grass land	**D**	0.76	0.010141988	0.003252033	0.72274041	0.552446	76.51	flat	0.05	0.25	0.15	0.54
79	777806	799205.46	dense forest	**D**	370.1	0.000369458	0.000311405	7.0036328	1.363134	502.01	flat	0.05	0.25	0.05	0.42
80	777538.9	799020.233	dense forest	**D**	0.19	0.062230216	0.005011275	0.13711316	0.467723	36.29	flat	0.05	0.25	0.05	0.42
81	776212	800316.904	dense forest	**D**	2.95	0.006369427	0.003021148	0.90207425	0.568333	88.22	flat	0.05	0.25	0.05	0.42
82	775727.3	800584.099	grass land	**D**	0.74	0.004444444	0.003348214	0.73416054	0.546281	76.83	flat	0.05	0.25	0.15	0.54
83	774262.9	800142.604	sparse grass land	**D**	0.06	0.0968523	0.004731582	0.06321579	0.47818	32.48	flat	0.05	0.25	0.25	0.66
84	773854.3	799276.393	sparse grass land	**D**	0.13	0.0335097	0.000433369	0.144068	1.200269	80.66	flat	0.05	0.25	0.25	0.66
85	772886.4	797818.869	sparse forest	**D**	0.04	0.175746924	0.034027361	0.05866946	0.223725	16.94	Rolling	0.15	0.25	0.25	0.78

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86	772061.4	797090.676	sparse forest	**D**	171.8	0.000369198	0.000339806	3.73036468	1.318091	302.91	Rolling	0.15	0.25	0.25	0.78
87	771165	797715.09	sparse forest	**B**	0.083	0.052724077	0.002527566	0.07771489	0.608736	41.19	Rolling	0.15	0.15	0.25	0.66
88	770959.6	797812.414	sparse forest	**B**	5.38	0.017574692	0.028435121	0.16777517	0.239737	24.45	Rolling	0.15	0.15	0.25	0.66
90	770263.8	796304.281	grass land	**B**	41.5	0.001508296	0.002266484	41.3783479	0.634831	2520.79	Rolling	0.15	0.15	0.15	0.54
91	768888.6	796864.928	sparse forest	**B**	0.71	0.010111223	0.003252033	0.91941149	0.552446	88.31	Rolling	0.15	0.15	0.25	0.66
92	768778.2	796204.083	suburban	**B**	112.1	0.000294811	0.000290948	7.91367541	1.399265	558.78	Rolling				0.48
93	768007.6	795563.321	suburban	**B**	0.37	0.105448155	0.013163091	0.14016279	0.32249	27.76	Rolling				0.48