JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

MASTERS OF SCIENCE PROGRAM IN HYDRAULIC ENGINEERING

ESTIMATION OF FLOOD MAGNITUDE AND INUNDATION MAPING OF DAYMA'AD RIVER

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirement for Degree of Masters of Science in Hydraulic Engineering

By

Ahmed Omer Abdulahi

AUGUST, 2021

JIMMA ETHIOPIA

JIMMA UNIVERSITY

SCHOOL OF POST GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

MASTERS OF SCIENCE PROGRAM IN HYDRAULIC ENGINEERING

ESTIMATION OF FLOOD MAGNITUDE AND INUNDATION MAPING OF DAYMA'AD RIVER

A Thesis Submitted to School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirement for Degree of Masters of Science in Hydraulic Engineering

By

Ahmed Omer Abdulahi

Advisor Eng: Mamuye Busier(Associate Professor)

Co-Advisor Mr. Mahmud Mustefa (MSc)

AUGUST, 2021

JIMMA ETHIOPIA

DECLARATION

This Thesis is my original work and has not been presented for a degree award in any other universities

Ahmed Omer

……………… ……………………

Candidate Signature Date

This Thesis has been submitted for examination with May approval as a university supervisor

Eng.Mamuye Busier (Associate Professor)

………………… ………………

Main Advisor Signature Date

Mahmud Mustefa (MSc)

……………… ……………………

Co-Advisor Signature Date

APPROVAL PAGE

The thesis entitled "(**ESTIMATION OF FLOOD MAGNITUDE AND INUNDATION MAPING OF DAYMA'AD RIVER).** "Submitted by **Ahmed Omer Abdulahi** is approved and accepted as a Partial fulfillment of the requirements for the Degree of Masters of Science in Hydrauli Engineering at Jimma Institute of Technology.

Name **Signature Date**

(Main Advisor): Eng Mamuye Busier (Associate Professor) ________________________

(Co-Advisor): Mr. Mahmud Mustafa (M.Sc.) _______________________________

As members of the examining board of MSc. thesis, we certify that we have read and evaluated the thesis prepared by **Ahmed Omer Abdulahi**. We recommend that the thesis could be accepted as a Partial Fulfillment of the Requirements for the Degree of Masters of Science in Hydraulic Engineering.

Name Signature Date

Chairman __________________ _____________ ___________________

External Examiner _________________ _____________ ______________

Internal Examiner ___________________ _____________ ___________

ABSTRACT

Flooding is defined as a natural occurrence caused by an unusually high level of flow over land or along a coastline, resulting in significant damage. A flood happens when water covers a large area of land, usually low-lying. When a river breaches its banks, the worst floods occur. Flood is one of Ethiopia's biggest natural hazards, wreaking havoc on human lives, property, and cattle in many sections of the country. It is common to many parts of Ethiopia every year causing a lot of losses to human lives as well as damage to property. In frequently number of years, in frequently number of years. Dayma'ad River's flood has been caused losses of human lives and property in Jigjiga city. It has taken one event caused by dayma'ad stream On May 30 2008 in Jigjiga town at least 25 people were died after heavy rains that cause flash flood 45 people were hospitalized and the flash floods have swept away several houses and damaged huge properties, The aim of this study is to estimate the amount of peak flood and delineate flood inundation map for the study areas that can be affected by extraordinary floods The data required for this study were obtained from the Ministry of Water, Irrigation & Electricity National Meteorological Agency, Jigjiga City Administration, field survey and Ethiopian Road Authority. The collected data were hydrological and soil data, land use land cover data, Topographic Map, DEM and ERA Manual. The software like Arc View GIS, HEC-HMS, HEC-RAS and HEC-GeoRAS were used for the analysis. The peak discharge were calculated by using Arc GIS, HEC-GeoRAS, HEC-HMS SCS-CN. The basin data is pre-processed by Arc-GIS 10. Arc- hydro and HEC-GeoHMS and exported to HEC-HMS 4.5 that was used for generation of rainfall-runoff model The flood Inundation map shows the area extent to be delineated as buffer zone with using GIS, HEC-GeoRAS and HEC-RAS, The performance of the model was calculated using Nash-Sutcliffe model efficiency coefficient and coefficient determination. The validation result of the model shows that the model is valid for simulation of the rain fall runoff transformation. The result of the calibration of monthly flow showed that there was good agreement between the measured and simulated average monthly low with Nash-Sutcliffe efficiency and coefficient of determination value of 0.684 and 0.697 respectively.. The result model validation coefficient was 0.665 for Nash-Sutcliffe model efficiency coefficient and 0.682 for coefficient determination.

Based on the analysis of the result the peak discharge at the outlet Dayma'ad river was found to be 294.7m^3/s in25 return period. The stream networks are the area that the community living with fear due to an expected flood hazard from the upstream

***Key words:* Flood, GIS, Inundation, Delineate, Peak, Jigjiga**

ACKNOWLEDGMENTS

I would like to thank my Main Advisors Eng. Mamuye Busier /Assistance Professor/ for his priceless support in advising my proposal and thesis work and sharing me valuable comments. And thanks to Co-Advisor Mr. Mahmud Mustefa (MSc) for his guidance feedback and comments on the various draft reports of this thesis as well as in my proposal.

Finally, I would like thanks to my parents for the constant support and encouragement they have given me right from my childhood.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

a.s.l	Above Sea Level
CSA	Central Statics Agency
CN	Curve Number
DEM	Digital Elevation Model
DPPB	Disaster Prevention and Preparedness Bureau
EMA	Ethiopia Mapping Agency
FAO	Food Agricultural Organization
FFA	Flood Frequency Analysis
Geo	Geographical
GIS	Geographical Information System
GeoHMS	Geospatial Hydrologic Modeling Center
Ha	Hectare
HEC	Hydrologic Engineering Center
HMS	Hydrologic Modeling System
Hr.	Hour
HRU	Hydrologic Unit
HSG	Hydrologic Soil Group
IDF	Intensity Duration Curve
JJCA	Jigjiga City Administration
Km	Kilometer
Km^2	Kilometer Square
mm	Millimeter
N	North
NMSA	National Metrological Service Agency
Km	Kilometer
MoARD	Ministry of Agricultural and Rural Development
MoWR	Ministry of Water Resource
PMP	Probable Maximum Precipitation
RAS	River Analysis System
S	South
SCS	Soil Conservation Service
Sec	Second
SRSBIB	Somali Regional State Basin & Irrigation Bureau
USA	United States of America
W	West
Yr	Year

1. INTRODUCTION

1.1. Background

Floods have already had devastating effects on cities and smaller urban centers in many African countries, such as the floods in Mozambique in 2000, which included severe flooding in Maputo, the floods in Algiers in 2001 (which killed around 900 people and affected 45,000), and heavy rains in East Africa in 2002, which caused floods and mudslides, forcing tens of thousands to flee their homes in Rwanda (Habitant, 2015).

Flood waters can wreak havoc on public and private transportation by shutting down roads and railway lines, as well as communication connections if telephone lines are damaged. Floods interrupt city drainage systems, resulting in sewage overflows, which pose a major health risk, as well as standing water and damp objects in the home. Bacteria and viruses cause disease, produce allergic reactions, and destroy materials long after a flood has occurred. Floods can disperse massive amounts of water and suspended silt over large areas, refilling agricultural lands with essential soil nutrients. Large amounts of fast flowing water, on the other hand, can erode soil, spoiling crops, destroying agricultural land or buildings, and drowning farm animals. Severe floods not only destroy homes and businesses, but the water left behind causes additional damage to property and products (Oumer et al., 2011).

A flood occurs when an area of land, usually low-lying, is covered with water. The worst floods usually occur when a river overflows its banks. Flood is one of the major natural hazards in Ethiopia which causes significant damages to human lives, properties and livestock in parts of the countries (Commission, 2018).

Ethiopia is endowed with high surface water potential. There are about 12 major rivers in the country. Some of this rivers cause flood problems in the adjacent areas usually in the rainy season. (Oumer et al., 2011). When it comes to rainfall in the country, the rainy season is focused in the three months between June and September, when approximately 80 percent of the country's rainfall is obtained. In part because the country's terrain is rocky, with well defined watercourses, large-scale flooding is uncommon and restricted to the lowland areas where major rivers flow into neighboring nations. Although infrequent, heavy rainfall in the highlands has the potential to produce floods in villages near any stretch of river flow. (Oumer et al., 2011).

In Somali region when heavy rains in neighboring areas of Oromia usually cause flood in summer season. Unseasonal and above-normal rainfall during October to January could also cause flooding and damages flood prone areas. The study region is found within the Eastern Drainage system of Ethiopia, the Wabi Shebelle river drainage basin. It is located particularly within the upper catchments of Shebelle/Jerer and Fafan Streams which are among the main tributaries of Wabi-shebelle River. Although there is no large perennial river in the study region. There are a number of intermittent streams that drain in to different major tributaries of Wabi-shebelle River (Wondimu, 2010).

Dayma'ad River is found within fafan zone and crosses the center of jigjiga city contributing to flooding during the rainy seasons and providing recharge zones for ground water supplies. No discharges in the streams in dry seasons but the volume of the flood in these rivers/steams drastically increases during summer season (June-September) and inundates the low gradient areas close to their banks. There are also many seasonal/intermittent streams found flowing within Jigjiga City which has created a dense network of natural drainage system (Wondimu, 2010).

The consequences of flood events are significant. Communities who have suffered from heavy flooding require financial resources to seek alternative emergency shelter. Individuals, commercial organizations and municipal organizations all incur significant costs involved in repairing the damage to property and livelihood restoration -crops, farmland etc. This financial burden impacts the poorest families in the catchment most severely, where the loss of vital property such as houses and crops have a devastating long term impact. There were also reports of damage to public property, such as access roads and schools, disrupting inter-town mobility and service delivery in the study area. Living in the constant fear of inundation causes significant psychological stress. Fear for the safety of family members, especially for young children, the sick and the very old becomes intense whenever rain starts to fall, particularly during the night. Living in partially damaged and submerged homes, separation of family when children are moved to another area for their safety is very stressful and depressing for the families concerned. Flood death of a member of a family is obviously a traumatic tragedy to the members of that family. However, if the deceased happens to be the sole income earner, it will have far reaching consequences to the spouse and the children (Blue, 2021).

1.2. Statements of the Problem

A major natural hazard in Ethiopia, flooding is one of the most destructive natural disasters, causing severe damage to human lives, property, and livestock in many parts of the country.

Floods are common to many parts of Ethiopia every year causing a lot of losses to human lives as well as damage to property in frequently number of years (Commission, 2018).

It is common that most often flood affects Jigjiga as the city is very prone to flooding when heavy rain falls in the upper catchment and its surroundings. From the past records three flood events occurred in Jigjiga City. flood have been caused losses of human lives and property in Jigjiga town which last was happened in this year march 2018 at least 3 people were killed and more properties was destroyed by the flood (JCA, 2016).

On April 2016, has claimed many human lives, damaged properties, displaced and left many without shelter and their daily subsistence and livelihood means.23 people were died, 84 people were injured, flood entered on 411 houses affected out of this 262 houses were totally destroyed and few infrastructures including potable water lines were broken and most part of the town have faced shortage of potable water. In total 9 kebeles of Jigjiga town were affected by the flooding (JCA, 2016).

Flooding is a frequent and major hazard to the public as it causes damage to property and death to human beings and livestock. Floods caused dayma.ad river are frequent phenomena and exert multifaceted negative impacts on the residents. Consultations with the town Administration and interviews with residents have revealed significant destruction of private and public property as a result of heavy flooding. The findings of the Key Informant interview exercise showed that the most widespread impact was damage to homes and public infrastructures such as roads and bridges. It was reported that homes in several residential areas are affected by heavy flooding every year during winter season. (Blue, 2021)

Therefore, this research is aimed to estimate the maximum discharge of Dayma'ad River and delineate its inundation area of study through using of relevant application soft wares to take care of such flooding hazards on human being and properties.

1.3. Objectives of the Study

1.3.1. General objectives

The general objective of this study is to estimate the maximum discharge of Dayma'ad River and delineate its inundation area of study.

1.3.2. Specific objectives

1. To evaluate the performance of the HEC-HMS model to estimate flood for the study area.

2. To estimate the peak discharge for different return period of dayma'ad river.
3. To develop flood inundation map of the study area.
4. To recommend mitigation measures of dayma'ad river.

1.4. Research questions

1. Is the performance of the model predicting flood well?
2. How much will be the maximum expected flood discharge on the study area?
3. How much will be the extent of the submergence area along right and left side of the Stream due to the maximum flood?

1.5. Scope of the study

The scope of the work is Hydrological investigation for the flood prone areas/sites and the surrounding area by collecting relevant data. The spatial scope of the study encompassed making flood assessment at entire city as well as at surrounding drainage catchment level (i.e. broader watershed having a common drainage basin with the administrative boundary) like; estimation of peak discharge and developing clear map of flood water way in the town.

2. LITERATURE REVIEW

2.1. Flood

Flooding is the most prevalent and frequent source of natural catastrophe, and it occurs when water submerges land that was previously dry, resulting in a natural disaster. Flood Coastal floods are frequently triggered by severe rainfall, quick snowmelt, or a storm surge from a tropical cyclone or tsunami, all of which occur in conjunction with one another. Floods have the potential to wreak widespread destruction, resulting in the loss of life as well as damage to personal property and important public health facilities. Between 1998 and 2017, floods harmed more than two billion people in over 100 countries around the world.

Most at risk are those who live in floodplains or non-waterproof structures, or who do not have access to flood warning systems or are not aware of the danger of flooding. There are three types of flood that is flash flood, costal flood and river flood 80%-90% of all registered disasters from natural hazards for the last 10 years was from floods, heat waves and extreme storms. Floods are also increasing in frequency and intensity of extreme precipitation is expected to continue to increase due to climate change. (WHO, 2021)

Floods are the most natural hazards caused by the highest impact on society and the flood impact that was recorded shows damages to land and property appear to be increasing due to insufficient prevention, economic growth and a lack of flood-sensitive land use planning. The associated program on flood management promotes an integrated flood management approach so as to reduce the loss of life and effects caused by the livelihoods by increasing the income obtained from the effective use of floodplains (Organization, 2020)

Flash flood is a surface flow of short duration with a relatively high peak discharge. It is a typical example of unsteady non-uniform flow. This flash flood is common feature in the Dire Dawa Administrative region during the rainy season. It is formed as a result of intensive showers, sparse vegetation cover and steep slope of the area. (HABTE, 2009). Floods are a sudden increase in the volume and/or velocity of a body of water that occur at irregular interval anywhere in drainage system of river and streams.

2.2. Hydrology

Hydrology is the basic analysis to be carried out before designing any hydraulic structure. Most researches indicated that the majority of failures were not due to structural weakness rather it is due to non-availability of sufficient hydrological data and insufficient analysis by which design was based. Hydrological data is used in the design of hydraulic and irrigation structures. To deduce from its analysis a few significant figures such as minimum and maximum

Hydrology, which treats all phases of the earth's water, is a subject of great importance for people and their environment, (Chaw, 1964). Knowledge of hydrology is one of the key ingredients in decision-making processes where water is involved. The knowledge of hydrology is not only useful in the field of engineering, but also in agriculture, forest, and other branches of natural science (Chaw, 1964).

2.2,1. Rainfall

Rainfall is the green water resource that is the major input to the system of watershed, which may have different forms, rainfall, storms, dew or any form of water landing from atmosphere. The amount of precipitation can be defined as an accumulated total volume for any selected period. If the watershed contains a large area of lakes or swamps, open channel precipitation may be persistently important (Robinson, Ward et al.1990).

2.2.2. Runoff

Urban areas always present some risk of flooding when rainfall occurs. Buildings, roads, infrastructure and other paved areas hinder precipitation from penetrating the soil and resulting in greater runoff. Heavy and/or extended precipitation generates very significant surface water volumes in any metropolis, which can easily be overrun by drainage systems. Surface runoff begins when soil does not have enough time to absorb the rainwater during a storm. (Huang & Zhan, 2004).

2.2.2.1. Runoff Characteristics of Streams

The stream characteristics depend on: Magnitude intensity, distribution in time, space, soil moisture, slope, vegetation, geology, shape, drainage and climate conditions (Subramanya, 1998).

The intensity of rainfall has a great influence on runoff. Rainfall with higher intensity will generate more runoff than low intensity rainfall. If rainfall continues over an extended period, the water table may rise and reducing the infiltration capacity to zero of that area and there may be chances of serious flood hazard (Shukri, Sanagi et al. 2015).

2.2.3 Rainfall Abstraction

Rainfall abstraction is the part of rainfall which does not turn to the direct runoff. This hydrological abstraction generally includes the following: interception, infiltration, depression storage, evaporation and evapotranspiration (Subramanya, 1998). After the initial abstraction is fulfilled the other rainfall will become the direct runoff. Infiltration is the dominant process of hydrological abstraction, and yet a complicated process whereby its rate is normally to be empirically judged. Infiltration depends upon factors such as tillage, soil structure, antecedent moisture content, soil exchangeable sodium, infiltrating water quality and the soil air status. There is a variety of model used to explain the infiltration process at instantaneous rate, namely Horton model (Horton, 1939).

2.3. Flood Magnitude Estimation

There are many methods developed for calculation of the design flood but their applicability depends mainly on the availability of hydrological data, as most of the methods have parameters which depend on climate and geo-morphological conditions. The climate data (rainfall and intensity) and geo-morphological condition of the project area were collected to determine input data for the methods of flood calculation such as runoff coefficient, curve number, design point rainfall and rainfall intensity of the project. To estimate the magnitude of a flood, peak the following alternative method are available rational method, SCS and unit hydrograph method, Empirical method and Flood Frequency Analysis

2.3.1 Rational method

Rational method estimates the peak runoff at any location in catchment area as a function of the area, runoff coefficient and rainfall intensity for duration equal to the time of concentration. It is best suited to urban storm drain systems and rural ditches. It shall be used with caution if the time of concentration exceeds 30 minutes. This method is used for catchment areas less than 50 hectares (0.5km^2). (Subramanya, 1998).

$Q = 0.00278CIA$ ……………………………..1

Where: Q is maximum rate of runoff, m^3/sec. C is runoff coefficient representing a ratio of runoff to rainfall, I is average rainfall intensity for a duration equal to the time of concentration, for a selected return period, mm/h. A is catchment area tributary to the design location, ha (Subramanya, 1998).

2.3.2. SCS-CN and Unit Hydrograph Method

The United States Soil Conservation Service has developed a synthetic unit hydrograph procedure that has been used widely for developing rural and urban hydrographs. The unit hydrograph employed by the SCS technique is based on an investigation of a large number of hydrographs of natural units from a wide cross-section of geographical and hydrological sites. This approach is suitable for catchment regions beyond 50 hectares (0.5km2). (Habte, 2009). This technique requires the same basic data as the Rational Method: catchment area, a runoff factor, Concentration period and rainfall are also included.

Although more complex than the SCS technique, it takes into account the time distribution of the rainfall, the initial rainfall losses due to interception and depression storage, as well as a decreasing infiltration rate over the course of a thunderstorm. SCS approach can be used to determine direct runoff for any storm, actual or simulated, by subtracting infiltration and other losses from the rainfall to obtain the precipitation surplus (also known as precipitation excess. (Habte, 2009).

SCS used experimental plots to determine a link between accumulated rainfall and accumulated runoff for a variety of hydrologic and vegetative cover variables.

Land-treatment data from experimental catchment regions, such as contouring and terracing, were included. The equation was created primarily for small catchment areas with daily rainfall and catchment area data available. It was created using storm data that contained the total quantity of rain in a calendar day but not the dispersion of that rainfall over time.

As a result, the SCS runoff equation can be used to estimate direct runoff from 24-hour or 1-day storm rainfall. (Habte, 2009).

$$\text{Pe} = \frac{(p-Ia)2}{P-Ia+S} \qquad \text{…… 2}$$

Where Pe denotes accumulated precipitation excess at time t in millimeters, P denotes accumulated rainfall depth (potential maximum runoff) at time t in millimeters, Ia denotes initial abstraction (initial loss) including surface storage, interception, and infiltration prior to runoff in millimeters, and S denotes potential maximum retention, a measure of a watershed's ability to abstract and retain storm precipitation..

$$\boldsymbol{S = \frac{25400}{CN} - 254} \qquad \text{…… 3}$$

$$I_a = 0.2\,S$$

Where: S - is the soil retention (mm), Ia - is the initial loss (mm),CN is the curve number.

The CN for a drainage basin is calculated utilizing a mix of river basin DEM, land use, soil, and Antecedent Soil Moisture Condition data to estimate the CN (AMC). The CN generator requires three files: the drainage basin limits for which CN is generated, the soil type map, and the land use map. The drainage basin limitations are required in the CN generator. The hydrological soil group (HSG), which indicates how much infiltration the soil allows, provides the information essential to determine CN for a given location. There are four types of hydrological soil groupings. The United States of America published this work in 1986.

SCS-CN was modified by substituting 0.5(pIa) for (pIa) in the equation. The current SCS-CN approach and the proposed change are compared and the revised version is more precise than the current one (Singh & Mishra, 1999).

The SCS-CN model was integrated into the GIS/RS system by these researchers to increase model applicability to complicated water bays with significant temporal and spatial soil and soil variability. In addition, a big number of academics conducted GIS research to determine the number of curves and runoffs in the different parts of the world. After the physical parameters of the reaches and sub-basins were derived, the CN was computed using the soil hydrological group, land cover and elevation data. Within Arc-GIS numerous hydrological parameters were derived using HEC-GeoHMS tools. Just like curve number The initial abstraction and duration of concentration were estimated for each sub basin after a grid file from which CN values were obtained for the river basin (Huang & Zhan, 2004).

2.3.3. Empirical method

Empirical formulas are used for the estimation of peak flood is mostly regional formula based on statistical correlation of the observed peak and important catchment properties (Subramanya, 1998).

$Qp = Cn * A^{3/4}$ …………………………………………………………………..………4

Where Qp is peak discharge (m^3/s), A is Catchment Area (Km^2), Cd is Dekens Constant with the value is between 6 – 30.

2.3.4. Flood Frequency Studies

Many available methods of flood frequency analysis have been based on at-site probability distribution functions. The most commonly used are: Gumbel Extreme-Value Distribution, Pearson Type III and Log Normal distributions, have been used for frequency analysis. (Subramanya, 1998)

Gumbel is a special case of Extreme Value Family distribution. Gumbel described the genesis Of the EV-1 distribution and the fitting method which was based on plotting the data on a Double exponential probability scale such that they formed nearly straight line (Nash, 1970). Compared a number of methods fitting EV-1 distribution, such as the method of moments, The method of regression, Gumbel's fitting method and the method of maximum likelihood, In terms of bias, mean square errors and relative efficiency using the same numerical data. Gumbel distribution is a statistical method often used for predicting extreme hydrological Events such as floods (Shaw, 1983).

2.4. Physical Characteristics of the watershed

Physical characteristics of the watershed include the land use, slope of the drainage, and elevation of the area as described below.

2.4.1. Land use and its classification

The land use land cover change has a great effect on the resulting surface runoff. In very broad terms, most of the catchment is under wide cultivation with increased land pressure meaning the expansion of cultivated areas into increasingly marginal lands at the expense of woodlands. Forested areas are now confined to areas too steep and inaccessible to farm. (Darwiche, 2009). Hydrological cycles are highly influenced by changes in land use caused by human disturbances as a result of expansion of agriculture, urbanization and industries (Darwiche, 2009).

2.4.2. Effects of land use change on rainfall runoff model

Flooding generation and runoff processes are highly nonlinear systems and depend on many factors such as; natural and spatial or temporal variability of meteorology, topography, climate, soil, vegetation, groundwater conditions and channel drainage (Bárdossy & Bronstert, 2003). On the other hand, human-made activities have caused land use change, and alterations to drainage and river structure. Furthermore, land use is a main boundary condition, in addition to elevation, which may have direct and indirect influences on runoff generation and flooding (Dooge, 1992).

The interaction of the land surface and the atmosphere is important in hydrological processes such as infiltration, evapotranspiration and runoff generation and flooding. However, over time the behavior of a natural catchment system may change due to several factors. Increased growth in human populations has caused increases in demand for residential areas and has led to urbanization. At the same time, increases in food demand have caused deforestation with forests being replaced by other land uses such as agriculture and industry. For example, over-exploitation of resources due to an increase in population and demand for food supply has caused land degradation (Githui, Gitau et al. 2009).

However deforestation and land development for agriculture have not necessarily led to an equal increase in food production, but rather has often led to land erosion in the upstream area and triggered heavy floods in the downstream area (Poesen & Vandaele, 1995).

Many studies have indicated that land use changes such as deforestation and expansion in agricultural land may lead to increases in peak discharge and runoff volume. Rainfall-runoff models have been used widely to study the impact of deforestation and agricultural expansion on runoff generation in hydrological catchments. (Ogaden & Saghafaian, 1997) used the HEC-HMS hydrological model to show that land use change from forest and rangelands to cultivated areas over hill slopes caused substantial land degradation and increased the outflow peak and total runoff volume observed. (Githui, Gitau et al. 2009).

They attributed such changes to decreases in the evapotranspiration rate (due to a reduction in forest area) and infiltration capacity (due to soil compaction caused by agriculture) (Ogaden & Saghafaian, 1997).

2.4.3. Land use land cover change studies in Ethiopia

In Ethiopia most of the land is being used by smallholders who farm for subsistence. With the rapid population growth and in the absence of agricultural intensification, smallholders require more land to grow crops and earn for a living; it results in deforestation and land use conversions from other types of land cover to cropland. The researches that have been conducted in different parts of Ethiopia have shown that there were considerable land use and land cover changes in the country. Most of these studies indicated croplands have expanded at the expense of natural vegetation including forests and shrub lands (Filliol, Driscoll et al. 2003). in this study reported that the decline of natural forests and grazing lands due to conversion to croplands in southern Wello (Bewket, 2003).

The slops of the watershed can affect the rainfall runoff relation. Investigations on experimental runoff plots have shown that steep slope yield more runoff than those with gentle slope. In addition, it was observed that quantity of runoff decreased with increasing slope length. In case of steeper watershed, the velocity of flow will be more and runoff will take lesser time to reach the stream, resulting in higher runoff (Majidi & Vagharfard, 2013).

2.5 Watershed Parameterization

Performing hydrologic modeling involves delineating streams and watersheds, and get some basic watershed properties. This includes the area of watershed, slope, flow length, and stream network density (Venkatesh, 2009). With the availability of digital elevation models (DEM) and Arc Hydro tools in GIS, watershed properties can be extracted by automatic procedures.

2.6. Flood Plain Analysis

Flood plains are flat lands prone to inundation throughout a year. These areas can be used for agricultural development using several irrigation and flood control techniques. Floodplains have several characteristics which make them prone for agricultural development. The combination of surface and ground water together with fertile soil properties allow year round cultivation (Puertas, Po, et, al. 2015).

2.7. Review of GIS Application

Enormous studies have been undertaking following an integrated approach of hydrological modeling with GIS application (Asfaw; and Lindqvist, 2015).

The application of HEC-GeoHMS as an extension of ArcView in HEC-HMS environment; HEC package which is a new generation of software being developed for rainfall-runoff simulation. It is called the Geospatial Hydrologic Modeling Extension (HEC - GeoHMS) and can be used to create basin and meteorological models for use with the program. Therefore, the integration of hydrological model and GIS is quite natural (Bakir, M and Xingnan, Z, 2008)

2.8. Hydrologic Models

Hydrologic models have become crucial tool for the study of hydrological processes and the impact of modern anthropogenic factors on the hydrologic system. The parameters used in the lumped model represent spatially averaged characteristics in a system. The conceptual parameterization in the models is simple and computationally efficient while deterministic semi-distributed models divides the whole catchments in to hydrological units (HRUs) based on other variables in addition to land use, land cover, soil type, slope (Bakir, M and Xingnan, Z, 2008).

2.8.1. Hydrologic Engineering Center–Geospatial Hydraulic Modeling System (HEC – GeoHMS)

HEC-GeoHMS transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the watershed response to precipitation (Maidment & Djokic, 2000).

2.8.2. Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS)

HEC-HMS conceptually represents watershed behavior as different components of runoff processes. It has an appropriate representation of the hydrological system, and its specification depends upon the information needs of the hydrological study. For flood hydraulic modeling and flood inundation mapping, the main objective is to accurately predict catchment outflows from upstream sub catchments and flood wave propagation along the drainage network. (Butts, Overgaard et al. 2006)

2.9. Hydrologic Modeling and Delineation of Flood Prone Area

The Flood Inundation map shows the area extent to be delineated as buffer zone. Two models HEC-GeoRAS and HEC-RAS are used one after another (first HEC-GeoRAS then HEC_RAS then back to HEC-GeoRAS) to accomplish the task. HEC-GeoRAS is a set of procedures, tools, and utilities for processing geographic information systems (GIS) data in Arc GIS using a graphical user interface (GUI). The interface allows preparation of geometric data for import into HEC-RAS and generation of GIS data from exported HEC-RAS simulation results. Automated GIS processing procedures in HEC-GeoRAS provides a valuable and expeditious method for repetitive hydraulic model development during floodplain analysis (Hagos, 2011).

HEC-GeoRAS is used to extract cross-sectional station- elevation data from a digital elevation model (DEM) represented by a triangulated irregular network (TIN). Downstream reach lengths and bank station locations were determined for each cross section. The automated procedures for extracting geometric data proved consistent and efficient for the development of floodplain models. The geometric data was imported into HEC-RAS using a data exchange format developed by HEC-GeoRAS. The resultant water surface elevations exported from HEC-RAS simulations were processed by HEC-GeoRAS for floodplain delineation and water depth calculations. Analysis of cross-sectional velocities exported from HEC-RAS was also performed using HEC-GeoRAS (Hagos, 2011).

2.10. Model Selection Criteria

Hydrological models that we planned to be used should incorporate capabilities that enhance the researcher to meet objectives set for that specific study. Models are selected based on objectives, expected output details and data requirement. (Yuan & Qaiser, 2011).

Considered model experience in hydrologic simulation as a criterion. In addition, its availability for downloading freely, expertise support, easiness to use the software, acceptance by user community and offices were used as criteria of model selection for his study undertaken in Kansas River, United States of America (USA). (Abushandi & Merkel, 2013).

Categorized model selection criteria in two classes, Model functionality and complexity were the two criteria considered while choosing a model to simulate the impact of land use/cover on hydrological processes (Duan, Schaake. et, al. 2006).

Model functionality defined criteria in relation to hydrologic process representation, the equations adopted to simulate these processes and model discretization while used model complexity as model selection criteria's which included data, resources, time, and cost that were required to parameterize and calibrate a model, as well as the professional judgment and experience required to operate these models. Though there are numbers of hydrological models like SWAT, HEC-HMS, AnnAGNPS, GSSHA, HYPE, MIKE-SHE, PRMS, WetSpa, HEC-RAS and WinSRMetc. its detailed results needed, medium-complexity, medium input data requirements, documentation, technical support, easiness to use, availability, previous experience etc(Shan, phanikumar. et, al. 2010).

2.11. Model calibration and validation

Model calibration is the process of adjusting selected model parameters values and other variables in the model in order to match the model outputs with the observed values. The calibration procedure involves a combination of both manual and automated calibrations. The manual calibration proceeds the automate optimization to ensure a physically meaningful set of initial parameters, 10 years' data will be needed for calibration. (Hagos, 2011).

Model Validation is the process of testing the model ability to simulate observed data, Other than those used for the calibration, within acceptable accuracy. During this process, calibrated model parameter values are kept constant. The quantitative measure of the match is again the degree of variation between computed and observed hydrographs. The models are validated for a period of five years (Hagos, 2011).

3. MATERIALS AND METHODS

3.1. Study Area.

3.1.1. Location

The study area is Dayma'ad River which crosses the center of jigjiga town located at 9°30' N latitude and 42°50' E longitude. Relatively speaking it is bounded by towns of Karamarda, chinaksen, Lamadaga and Elbahay vilage in the West, North West, East and north east respectively. The geology of study area being dominantly limestone, there might be a risk of cavity formation in contact with water. The sandstone and basalt geology of the area are good source for construction materials.The topography of the hinterland is dominantly plain with an average altitude of 1700-2000 m.a.s.l. The extent of catchment area is 1072 km^2.

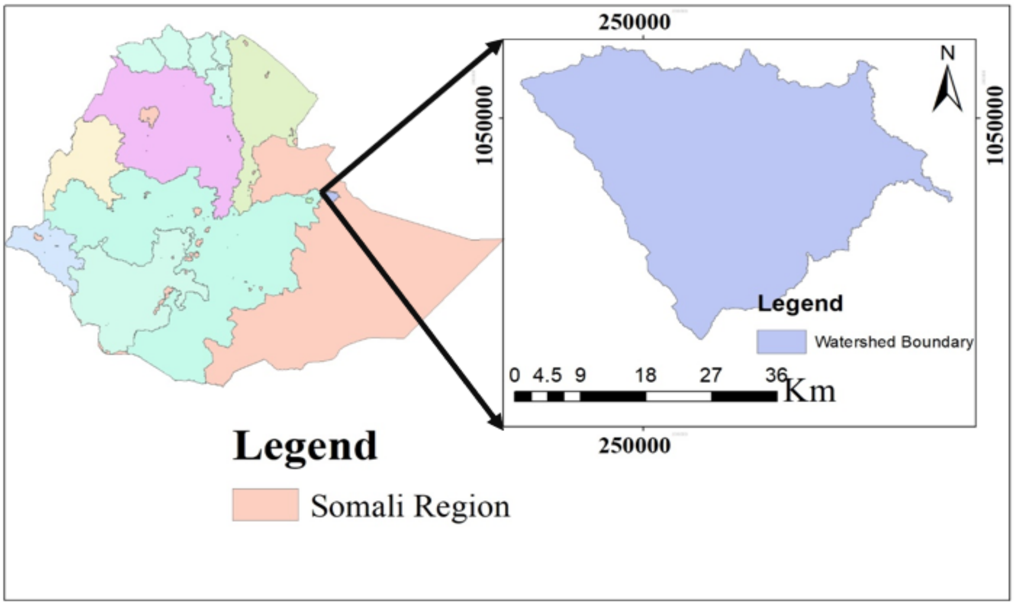


Figure 3.1 Study Area

3.1.2. Topography and Climate

The topography of the study area dominantly plain with an average altitude of 1700-2000m.a.s.l. except the Karamara Ridge that rises up to 2500m.a.s.l. The Hinterland is dominated by plains with minor valley and gully formations. However, the Karamara Ridge has significant ups and downs with steep slopes; particularly the western part of the ridge including Hadew localities has also significant rugged land features. Generally, the topography of the hinterland is appropriate for the provision of physical infrastructures and development of agriculture (crop farming, horticulture and pastoralism).

The mean annual rainfall of study area is just about 598 mm. The mean monthly amount of rainfall varies between 10.2 mm to 102.2 mm in February and April, respectively. It has also an influence on urban land use planning since it influences Drainage typology, extent of green area etc for enhancing human comfort and creating good urban environment.

Dayma'ad River experiences sub-tropical climate which is classified as Tepid to Cool Arid Mid Highland Agro ecological zone with average monthly temperatures between 17ºc and 21.5ºc (CSA, 2007). Moreover, limited pocket area at the peak of Karamardha Ridge has temperate climate. Therefore the temperature is favorable for the development of subtropical crops and to raise animal (dairy and beef).

3.2. Tools and Materials

3.2.1 Soft Wares Used

The major model that was used to estimate the peak discharge were Arc GIS, HEC-GeoRAS, HEC-HMS 4.5 and the data like meteorological data, soil data, and land use land cover data was facilitated to estimate peak discharge. The performance of the model was calculated using Nash-Sutcliffe model efficiency coefficient (NSE) and coefficient determination R^2 and HEC-RAS for Buffer zone. On objectives, expected output details, data requirement and availability for downloading freely, expertise support, easiness to use The software, acceptance by user community and offices were used as criteria of model Selection. Model functionality and complexity is the two criteria considered while choosing a model to simulate the impact of land use/cover on hydrological processes.

3.2.2. Data and Tools Used

The data used for the study were obtained from the MoWIE (hydrological data), NMSA (meteorological data), FAO (soil data), land use land cover data, literature conducted in the study area was other source of data required for the study. The precipitation, maximum and minimum temperature record includes while the stream flow data was gathered, Total Station, Hand GPS and Meters were also the part that was used in this study

3.3. Data Processing and Analysis

3.3.1. Data collection

After the approval of the proposal Jimma Institute of technology, the data collected from the Organizations that data obtained, the data obtained for the research work have been collected from National Meteorological agency, Jigjiga City Administration, MoWIE Field Survey etc. The flowing table below are summarized the data type and source.

Table 3.1 Types and source of data

Targeted Data	Data Source	Purpose
Topographic map of the City 2m interval	JJCA	Generating town part and Stream cross section geo- spatial data using GIS and HEC-GeoRAS
Contour of the stream 1m interval or Surv with Total station	Field Survey	For cross checking JigJiga stream cross section geo-spatial data using GIS and HEC-GeoRAS
Land use Land cover data and Soil data	Downloaded	For curve number computation HEC-HMS,HEC-GeoHMS, HEC-GeoRAS and HEC-RAS.
DEM	Downloaded	Generating catchment geo-spatial data using HEC- GeoHMS
Hydrological data (streams or river flows) gauging stations' data,	MoWIE	Validation
Meteorological data	NMSA	Computing hydrograph using HEC-HMS

3.3.2. Rain fall data consistency

In the hydrologic studies missing data or shortage of data's are among the major problem encountered. Precipitation record from a particular rain gauge station is not complete throughout the year. It may have some missing gap in between a short period or totally without any record in relatively long period. Moreover, some records are not reliable as all the data exhibits same value for a long period. These may due to the failure of instrument or human error while collecting or downloading the data. To remedy the problem, a number of methods were developed to figure out the missing portion of data. These consist of the station average method, the normal ratio method, the quadrant method and the iso-hyetal method as suggested by (Robinson, Ward et al. 1990) According to (Robinson, Ward et al. 1990), the station average method is the easiest to apply as it does not account for the density of rain gauge network. According to this method had been proven to be not accurate if the difference between annual precipitation reading of the rain gauge of interest and total annual precipitation of other rain gauge varies more than 10 per cent. If this occurs, normal ration method is preferred. Similar to the normal ration method, the quadrant method is based on the weighted mean. However, there is a minor difference of weighted mean used by these two methods. The normal ration method is based on annual precipitation of related neighboring raingauge; however quadrant method utilizes the distance between neighboring rain gauge (Robinson, Ward et al. 1990). The disadvantage of using quadrant method is too much time consumed for determining missing rainfall data, and yet its predicted value is not necessary will be accurate.

Some data recorded by rain gauges may be not representing the actual rainfall once they are statistically inconsistent with other nearby gauges According to (McCuen 1989). Therefore, it is vital to exclude such gauges or patch its data with the aid of covariance biplot. The covariance biplot provides graphical interpretation between the data of different gauges and shows the possible outliers. This biplot, however, does not incorporate any physical properties of the gauges, such as spatial location and elevation. It is because these factors may impose significant impact on rainfall and should be taken into consideration when interpreting the biplot (McCuen 1989).

3.3.2.1. Consistency of Recording Stations

The checking for inconsistency of a record were done by double mass curve technique (Subramanya, 1998). The accumulated total of the gauge in question is compared with the corresponding totals for a representative group of nearby gauge. So that, data gap checking, wrong record, negative values and non-dated data recordings which can affect data quality was checked before used for analysis. Figure below shows daily cumulative precipitation of stations with daily cumulative precipitation of group stations.

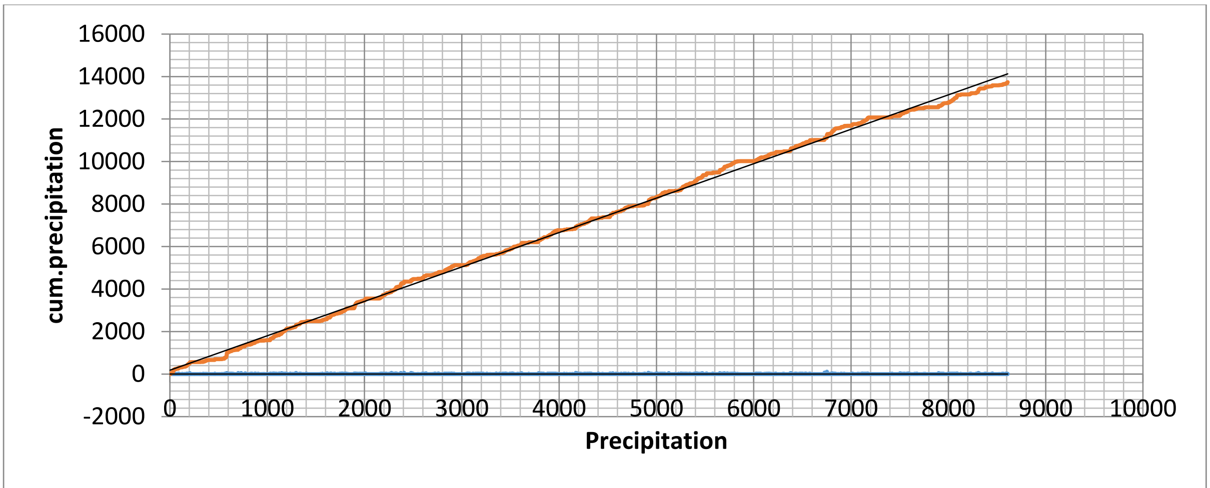


Figure 3.2 Consistency of recording stations

3.3.2.2. Rainfall data gap filling

The meteorological stations for which data collected were located inside the watershed and some are located around it. There was a problem of both hydrological and meteorological data in length of record (quantity) and standard of scientific approach (quality). However, the output of the research is dependent highly on input data quality. Thus before the beginning of data accusation data must have to be filled using appropriate techniques. The techniques of missing data estimation can be grouped as empirical methods, statistical methods and function fitting (Park, Miller, et, al, 1999). After the homogenity and consistency of recording station were assessed, missed values of weather variables were filled using multiple regression. Simillar procedure was used for hydrological data gap filling.

The continuity of a record may be broken with missing data due to many reasons such as damage or fault in a rain gauge during a period. So, it is necessary to first check the homogeneity and consistency of stations. Different methods have been proposed for estimating rainfall data (McCuen 1989). The station average method is the simplest method. The normal ratio method and quadrant methods provide a weighted mean, with the former basing the weights on the mean annual rainfall at each gage and the letter having weight that depend on the distance between the gauges where recorded data are available and the point where a value is required.

The normal-ratio method from the station-average method of that the average annual rainfall was used in deriving weights. If the total annual rainfall at any of the m region gauges differs from the annual rainfall at the point of interest by more than 10%, the normal - ratio method is preferable. Because of this method is more advanced than station average method and simple, for this study considered this method for filling missed rainfall data. The figure below shows the flow duration curve that indicates the occurrence of flow within the relation of time of expedience.

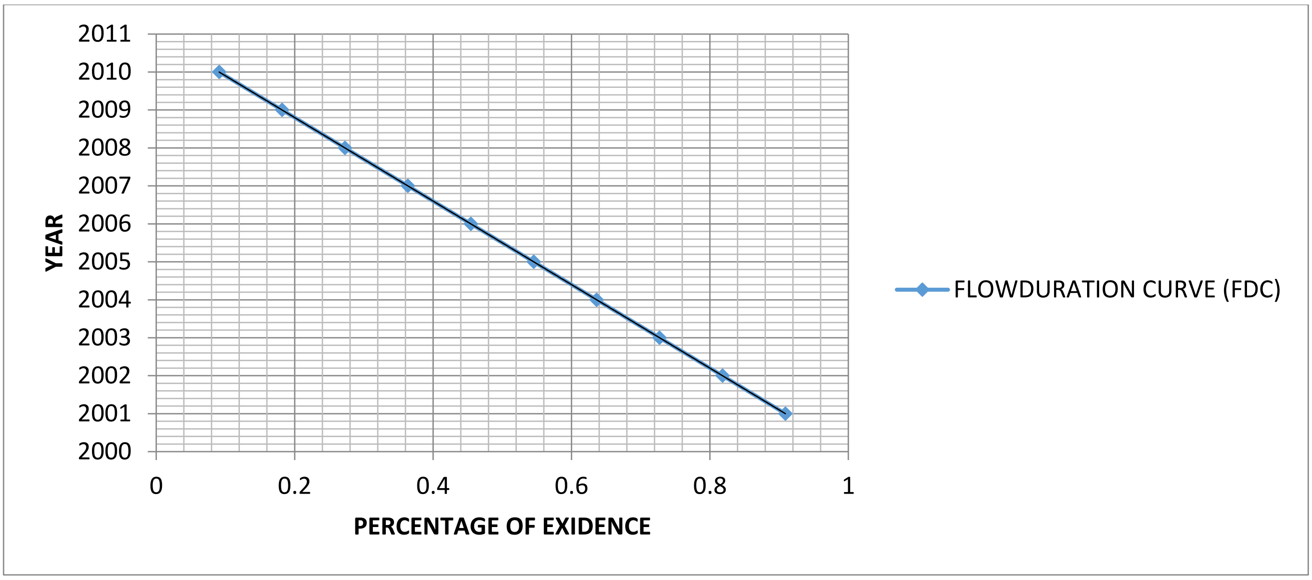


Figure 3.3 Flow duration curve

3.3.3. Soil Data Preparation

Soil in the study area is classified on the basis of the revised FAO/UNESCO-ISWC legend to soil map of the world (1995; 1998; 2002). There are eight major soil types in the study area as described below in the soil map. Out of eight soil types identified in the watershed soil map, more than 90% of the watershed is dominated by dystric nitisols and verticcambisols.

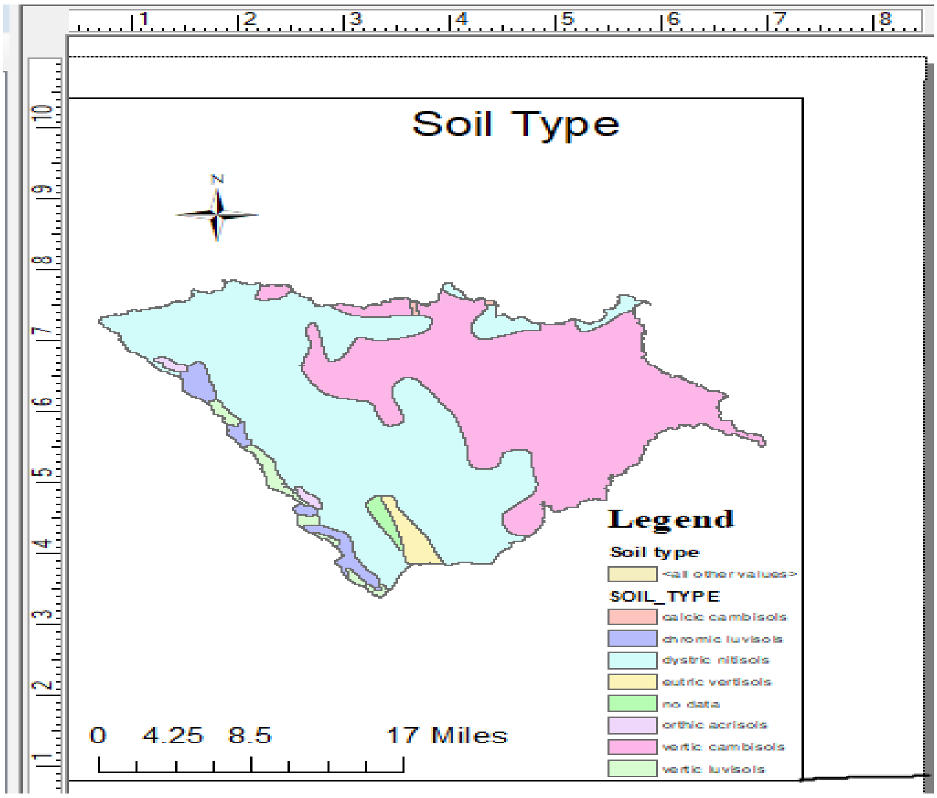


Figure 3.4 soil map of dayma'ad river watershed

The soil data of Jigjiga watershed was analyzed by using ArcGIS. For this analysis, the hydrological soil group one the important input in estimation of runoff has been extracted from satellite earth data of TIFF format of Africa hydrological soil group which has been downloaded from (https://daac.ornl.gov/). After this, the physical and chemical properties of the soil determined from FAO (2002) soil data base. Following this analysis, the map of Jigjiga soil hydrological soil group is provided below.

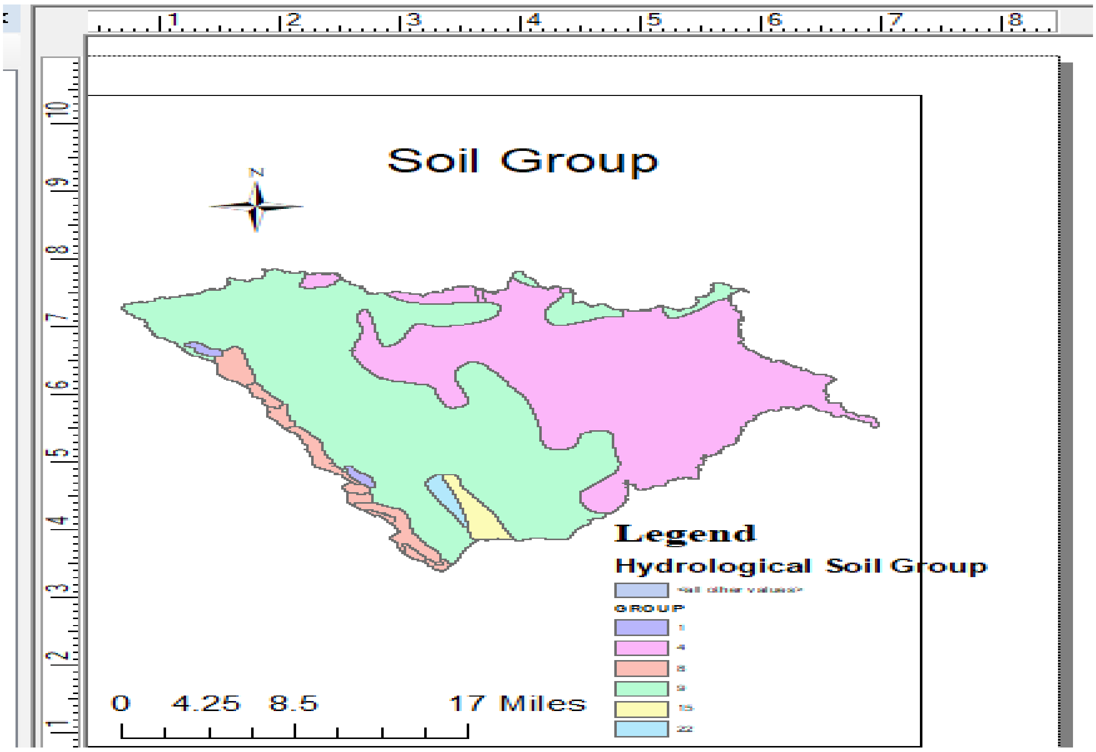


Figure 3.5 Hydrological soil group of dayma'ad area watershed

3.3.4. Land Use Map

The land use map of the study area was collected the land use land cover (LULC) spatial map from organizations. land use land cover (LULC) determines the amount of soil entering to the reservoir. The trapping efficiency of the LULC is based on its density and variety. The land use land cover (LULC) of the study area includes the woodland, cultivation land, wet land, shrub land and settlement.

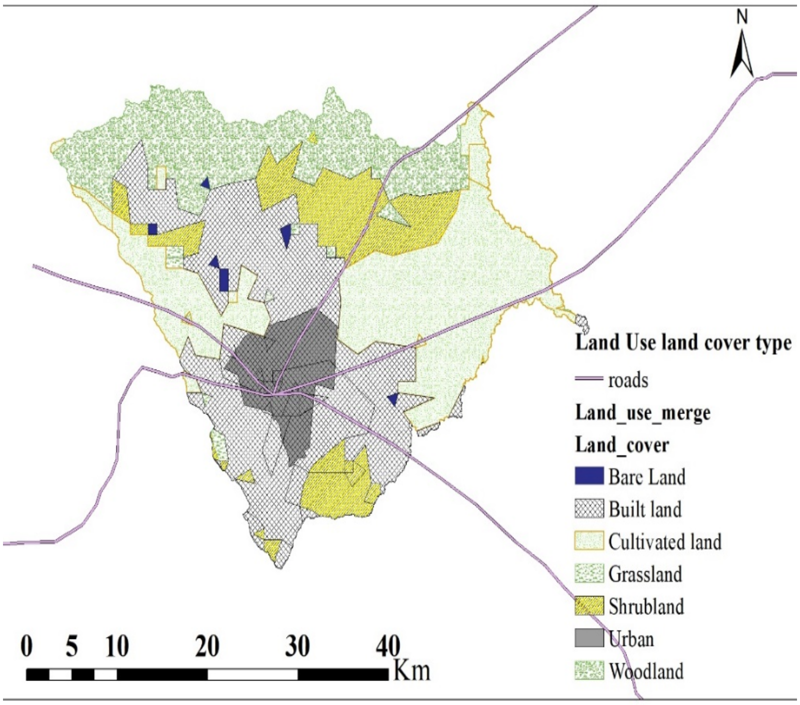


Figure 3.6 land use land cover of dayma'ad area watershed

3.3.5. Digital Elevation Model Data Preparation

The SRTM supplied an Earth's near-global Digital Elevation Model (DEM) based on DEM data to build a dayma'ad watershed method. The first step is to develop a Digital Elevation Model (DEM), from the region's SRTM data. The DEM data includes pits or ponds to be eliminated before hydrological modeling is utilized. These are cells in which water accumulates when drainage patterns are extracted. Pits are an indication of interpolation mistakes in the DEM. These boxes were deleted by a sink filling algorithm. This method has been constructed on the ARC Hydro interface.

The physical properties of HEC-HMS were used to prepare the hydrological networks. Preprocessing has been divided into three major phases in Arc-GIS software; a) preprocessing in the field, b) basin processing, and c) set-up of HMS-projects. Once the DEM sinks were filled, a flow direction map was calculated by finding the sharpest slope and by encrypting the possible flow directions to the adjacent cells in each cell. The flow direction is then used to produce the accumulation map of the flow. The accumulation of flow, formed by addressing each DEM cell, measures how many upstream cells contribute to the cell flow. Flow guidance and accumulation maps are then utilized to outline the network stream.

The stream network can be separated into parts that determine the basin outflows. The penultimate phase is the process of delineation of the basin, which depends on the generated flow direction and map accumulation.

In addition, a user-specified quantity known as the threshold depends on it. This threshold determines the minimum number of pixels within each delineated sub-basin.

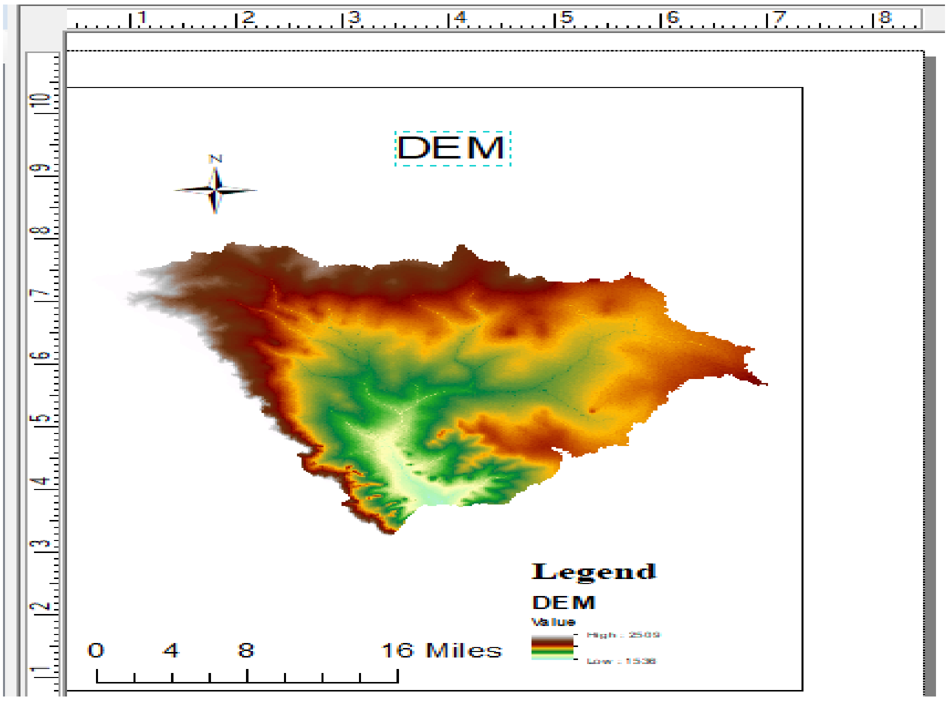


Figure 3.7 Dayma'ad River DEM

3.3.6 HEC-GeoHMS and HEC-HMS

The first step is preparing a Digital Elevation Model (DEM), from the SRTM data of the region. HEC-GeoHMS was utilized for preparing hydrological networks derive the physical characteristics in the HEC-HMS model. In Arc-GIS software the preprocessing was divided into three main stages are; terrain preprocessing, Hydrologic is processing (basin processing. Stream, Watershed Characteristics, HMS Model Files) and HMS project.

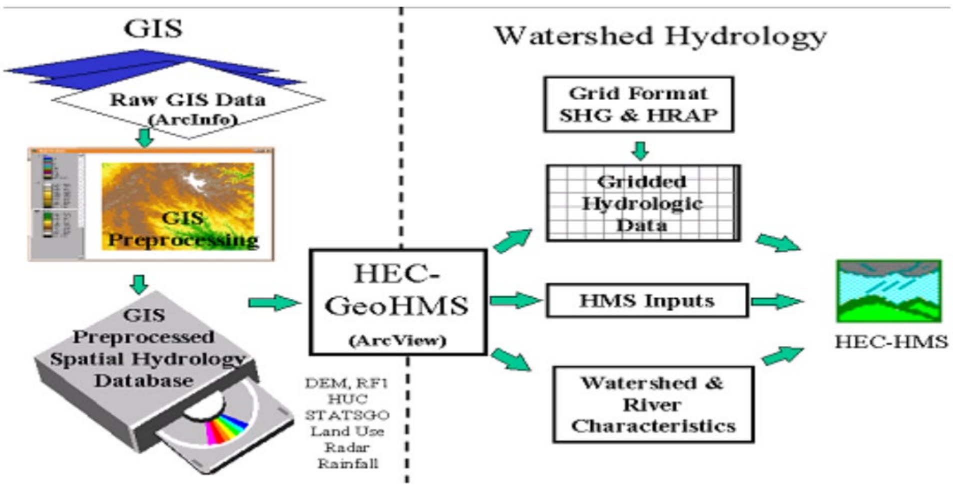


Figure 3.8 GIS HEC-GeoHMS and HEC-HMS

Once the DEM sinks were filled, a flow direction map was calculated by finding the sharpest slope and by encrypting the possible flow directions to the adjacent cells in each cell.
The flow direction is then used to produce the accumulation map of the flow.
The accumulation of flow, formed by addressing each DEM cell, measures how many upstream cells contribute to the cell flow. Flow guidance and accumulation maps are then utilized to outline the network stream. The stream network can be separated into parts that determine the basin outflows. The penultimate phase is the process of delineation of the basin, which depends on the generated flow direction and map accumulation.

HEC-HMS is a basin model that simulates dendritic watershed systems in the precipitation-runoff process. It describes the physical characteristics of the watercourse and the structure of the stream network. It is designed to be applied to solve a wide variety of problems in a wide range of geographical areas. This comprises water supply for vast river basin areas and hydrology for tiny, urban or natural rivers.

3.3.6.1. SCS Curve Number (CN) Analysis

The next stage is the analysis of the CN. The CN of a drainage basin is computed using a combination of the DEM river basin, land use, soil condition and previous soil humidity. The CN generator requires three files of form: the boundaries of drainage basins for which CN is generated, the map of the soil type and the map of land use. The information required to determine CN is the hydrological soil group (HSG), which shows how much infiltration the soil allows. There are four hydrological soil groups: A; soil with a high rate of infiltration; B; soils with a moderate rate of infiltration; C; soil with a slow rate of infiltration; D; soils with extremely slow rate of infiltration. (United States of America, 1986).

Once the data has been collected, the standard CN estimation method for a drainage region is carried out as follows: Define and map the drainage basin(s) boundaries for which CN(s) are calculated. Determine the drainage basin area (s), Map the types of soil and land use for the interest drainage basin(s), Transform soil types into hydrological soil groups, Overlaying land use and soil group hydrology maps, identifying each unique polygon land use soil group and determining the area of each polygon, Assign a CN to every single polygon (USDA, 1986)

Identification and estimation of missed data: Missing values in the series are a real handicap to the hydrologic data users; the estimation of these missing values is often desirable prior to the use of the data. In this assessment, the years that had inadequate daily records for selecting the annual maximum were identified and considered to be missed.

The annual maximum would be extracted for daily durations if at least 50% of the months in the assigned wet season and at least 50% of the data for the accumulated period were present. The highest value in each year was extracted as the annual maximum for that particular year. In addition, for 1- day if all the days in the month were missing or if more than 10 days of the month were missing and the maximum precipitation for that month was 0.00 that month would be set to missing. Alternatively, if more than 15 days were missing and the maximum for the month was less than 30% of the average 1-day maximum precipitation for that month over the period of record at that station, that month be would also set to missing (NOAA, 2006). Hence, they were needed for reconstruction to make them at least relatively complete for the estimation of PMP. The missed data were estimated and reconstructed by normal ratio method. This method is preferable compared to other methods because it is simple and can be used when the average annual catches between neighbouring stations differ by more than 10%. Such difference might occur in regions where there are larger differences in elevation (regions where orographic effects are present) or in regions where average annual rainfall is low, but annual variability is high (Viessman and Lewis, 1996).

Test for consistency and homogeneity: before using the rainfall record of the data it is necessary to check the data for its consistency and continuity. The consistency of the data set of the given stations was cheeked by the double mass-curve method with in-reference to their neighborhoods stations to cumulative of average. The double mass curve was plotted by using the annual cumulative total rainfall of the station under study as ordinate and the average annual cumulative total of neighboring stations (base stations) as abscissa. By adding successive values, it was assumed that the random error would tend to cancel each other while the linear relationship was reinforced by repetition. Significant change in the slope or trend the resulting line was a clue as to break in homogeneity (Shahn, 2002).

3.3.7. Meteorological stations and precipitations

The meteorological stations are provided below as one manual operated station and the other four are satellite stations tabulated below.

Table 3.2 metrological stations

ID	UTM		Name of Station
	X(m)	Y(m)	
1	238999.00	1052802,27	Chinaksen Station (ST 1_92425)
2	251223.14	1029465.97	Jigjiga Station
3	280750.70	1030418.48	Lamadaga Station (ST 3_95431)

Precipitation is the falling to the earth as water it might be rainfall or snow. In arid or semiarid area, the precipitation is rainfall. Rainfall is precious resource in arid area that is the major input to the system of watershed; it makes life as easy to increase product and other incomes. The amount of precipitation can be defined as an accumulated total volume for any selected period. If the watershed contains a large area of lakes or swamps, open channel precipitation may be important. The precipitation reaching the ground surface may in order to form surface runoff, it may infiltrate into the ground or it evaporates back up into the atmosphere. After infiltration of the precipitation into the soil, the flow process becomes unpredictable since the catchment runoff behaviour is closely related to the subsurface physiographic, geometry and geology of the watershed. (Robinson, Ward et al. 1990).

A total of 20 years of three rain gauge stations are available in Jigjiga watershed station named as Jigjiga and two satellite stations used for this assessment. The rain gauge stations are shown below around Jigjiga watershed of the Thiessen Polygon map.

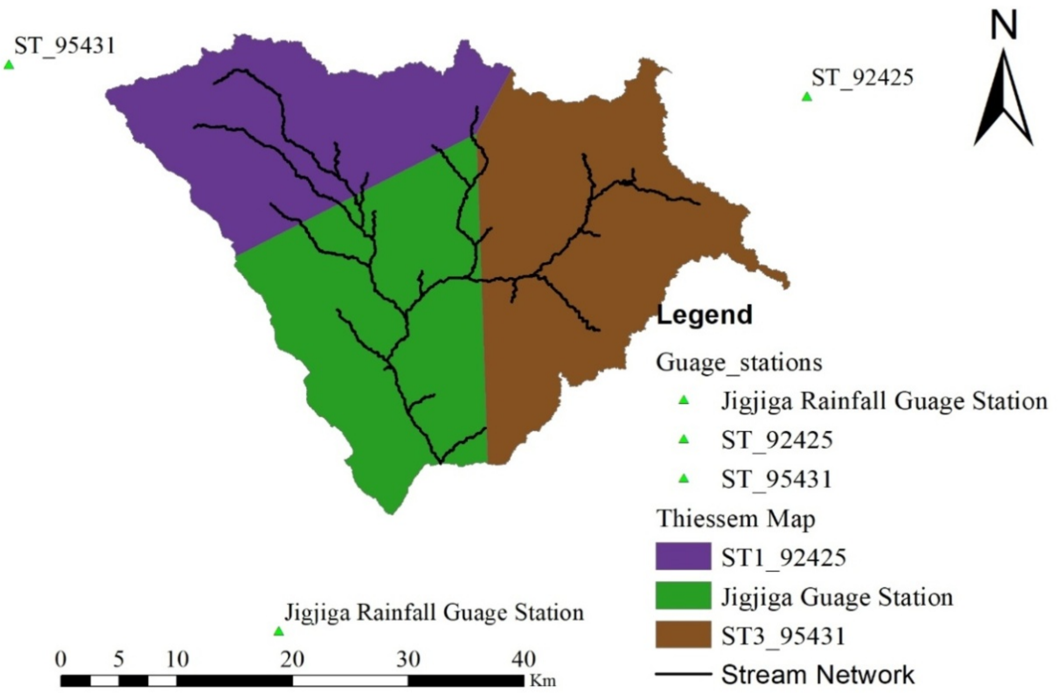


Figure 9: Theissen Polygon of Dayma'ad/Jigjiga Watershed for Rainfall

3.3.8. Probable Maximum Precipitation Estimation Procedure

For each station, the annual maximum series of one-day maximum amount of rainfall was selected and an array of annual maximum values of rainfall was formed. For each station the daily maximum was selected for all the months and the month with the maximum daily rainfall was selected i.e. the annual daily maximum rainfall and the annual total is the summation of annual rainfall of the year. Finally, the annual daily and annual total rainfall was arranged in pivot table of Excel-2019 spreadsheet and used as tool for analyzing and interpreting the data. For the frequency analysis of rainfall was used for PMP computation. One-day annual maximum rainfall values of all stations were analyzed to extract the station based PMP estimates.

$$X_{PCP} = \bar{X} + K_{PCP}\delta_{PCP} \quad \text{.....1}$$

$$K_{PCP} = \frac{Y_{PCP} - 0.5772}{\frac{\pi}{\sqrt{6}}} \quad \text{.....2}$$

$$y_{PCP} = -\left[ln * ln\frac{T}{T-1}\right] \quad \text{.....3}$$

Using the rainfall analysis equation, the tabular PMP of the dayma'ad river watershed is provided below to understand the characteristics of rainfall in the watershed.

Table 3.3 Statistical Analysis of Probable Maximum Precipitation of Dayma'ad River

Name	Mean	Standard Deviation	CV (%)	PMP
Lamadaga Station (ST1_92425)	18.18666	9.768827	53.71423	101.2217
Jigjiga Station	28.74152	19.93791	69.3697	198.2138
Chinacksen Station (ST3_95431)	29.65042	19.44988	65.5973	194.9744

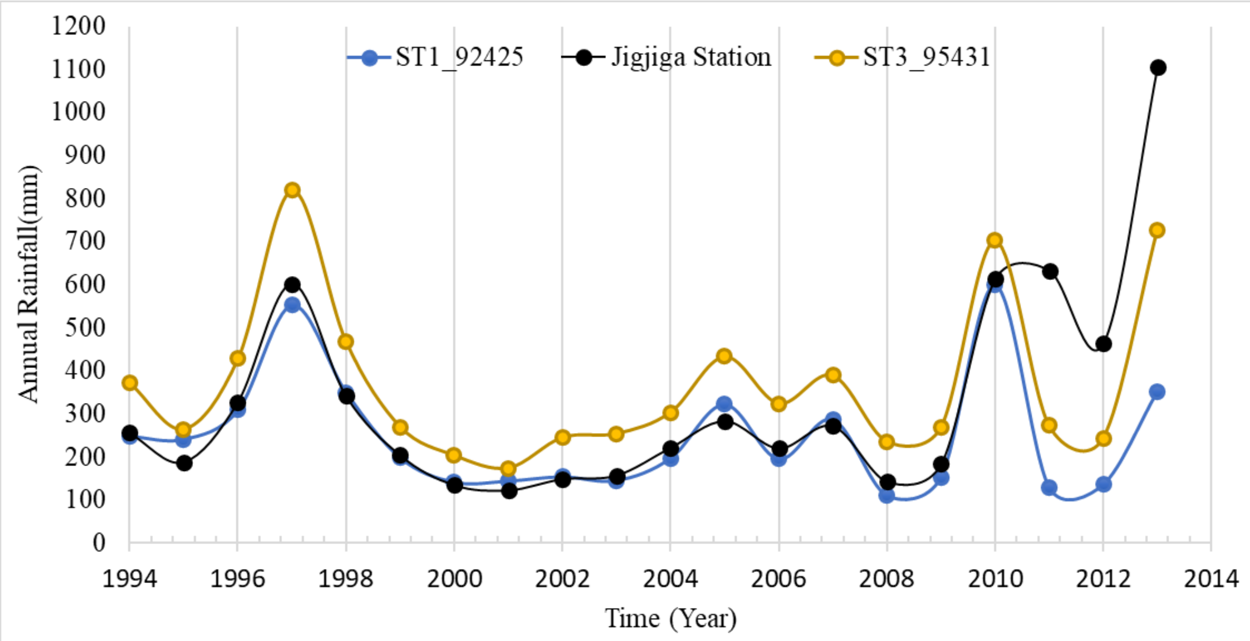


Figure 10 long term rainfall distribution of dayma'ad river watershed

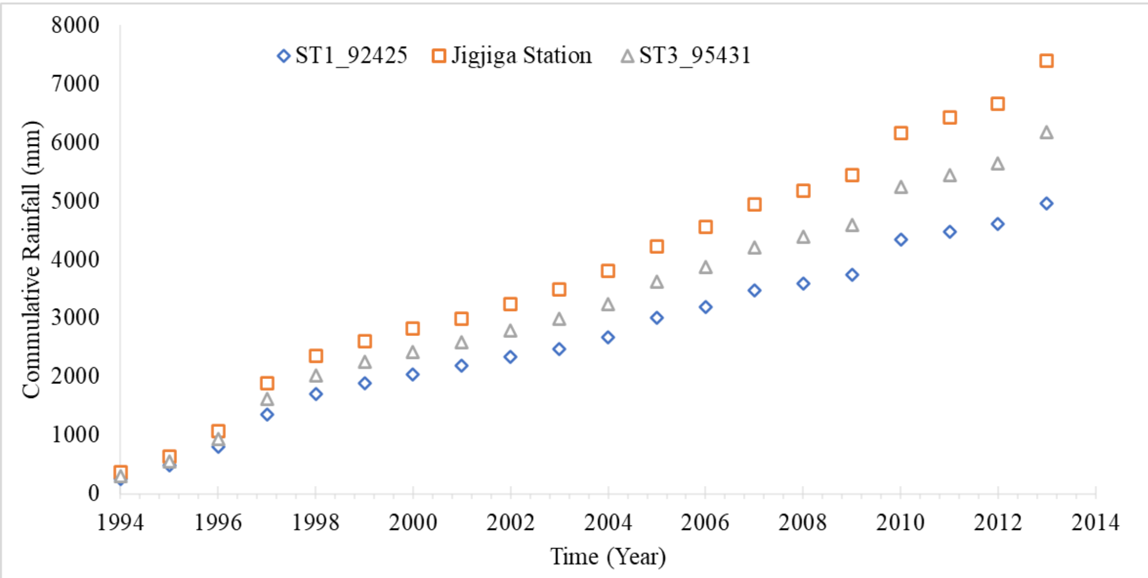


Figure 3.11 double mass curve of selected for dayma'ad river watershed

3.3.9. Homogeneity Test

The homogeneity of the annual rainfall data from 1994 to 2013 was tested for all stations using the excel spreadsheet of the Pivot analysis and PI-one-dimensional equation. The result of homogeneity test for the weather generator (climate) data shows that maximum rainfall appears in April for the last 20 years.

Non-dimensional values of the monthly precipitation of each station can be computed by the following equation.

$$P_i = \frac{P_{i,avg}}{P_{avg}} * 100 \quad \ldots\ldots 4$$

Where, P_i is non-dimensional value of precipitation for the month in station i, $P_{i,avg}$ over years averaged monthly precipitation for station i and P_{avg} is over year's averaged yearly precipitation of the station i.

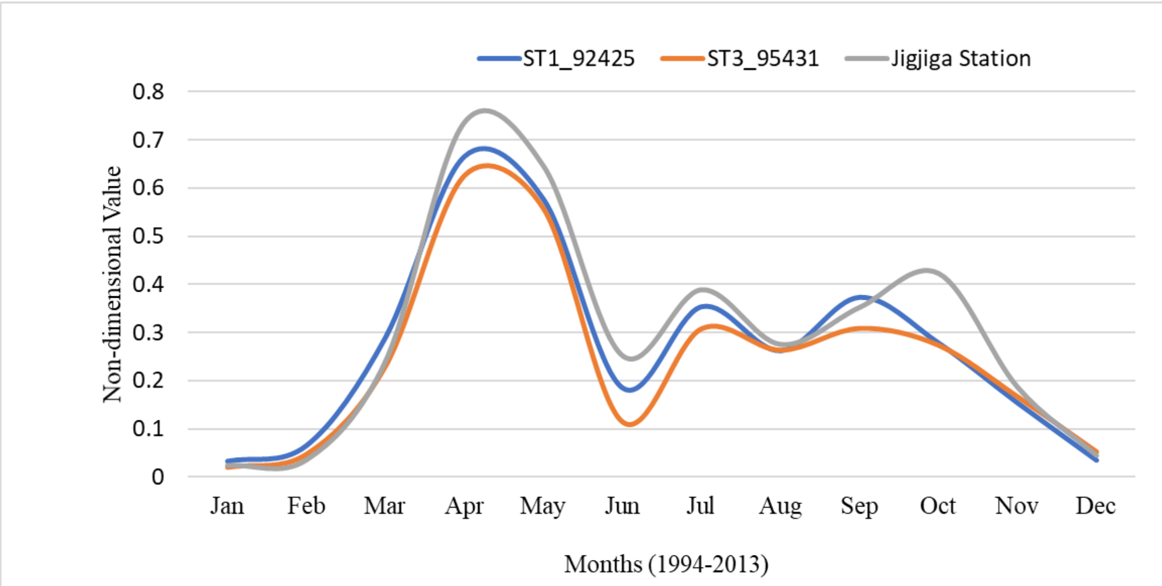


Figure 3.12 Homogeneity Text of Selected Stations for dayma'ad river Watershed

3.3.10. Computation for Maximum Frequency Factor (Km)

The highest observed (HO) values from 1-day annual maximum rainfall series of 3 stations, considered under the assessment, were analyzed and used with $\overline{X}_{N-1}$ and σ_{N-1}, for N years and thereafter station based maximum frequency factors (K_m) were derived.

Table 3.4 Frequency Factor Determination(Km)

No	Station Name	HO	$\overline{X}_{N-1}$	σ_{N-1}	K_m
1	ST1_92425	38.57	0.68	2.18	7
2	Jigjiga Station	91.52	0.92	3.24	8
3	ST3_95431	91.64	1.01	3.02	9
Mean					8
Sn					1
CV					0.667

Mean, standard deviation and coefficient of variation for selected station-based K_m values were calculated and found to vary from 8, 1 and 0.667 respectively. This variation may be due to the variability of climatic conditions of the watershed satellite and discontinues recording gauging stations.

3.3.11. Testing of GEVI PDF of Jigjiga

This distribution was achieved by plotting the ranked annual maximum rainfall values and was calculated for excedance probability. GEVI PDF plays the significant role in prediction of the rainfall variability from its probability occurrence in the region.

Table 3.5 Fitting EVI Distribution and Estimating rainfall of jigjiga station in (mm)

Year	RF	RF Order	Rank	P=m/(n+1)	T=1/p	Y_T	K_T	X_T
1994	22.00	91.64	1.00	0.05	21.00	3.02	1.90	66.72
1995	11.77	68.16	2.00	0.10	10.50	2.30	1.34	55.55
1996	12.73	44.69	3.00	0.14	7.00	1.87	1.01	48.84
1997	91.64	39.73	4.00	0.19	5.25	1.55	0.76	43.93
1998	68.16	33.48	5.00	0.24	4.20	1.30	0.57	40.01
1999	33.48	32.23	6.00	0.29	3.50	1.09	0.40	36.70
2000	20.74	25.69	7.00	0.33	3.00	0.90	0.25	33.80
2001	13.55	24.24	8.00	0.38	2.63	0.73	0.12	31.19
2002	22.73	22.98	9.00	0.43	2.33	0.58	0.00	28.79
2003	21.72	22.73	10.00	0.48	2.10	0.44	-0.11	26.55
2004	18.36	22.00	11.00	0.52	1.91	0.30	-0.22	24.41
2005	22.98	21.72	12.00	0.57	1.75	0.17	-0.32	22.34
2006	24.24	20.74	13.00	0.62	1.62	0.04	-0.42	20.32
2007	44.69	19.12	14.00	0.67	1.50	-0.09	-0.52	18.31
2008	15.63	18.36	15.00	0.71	1.40	-0.23	-0.63	16.26
2009	39.73	15.63	16.00	0.76	1.31	-0.36	-0.73	14.15
2010	25.69	13.63	17.00	0.81	1.24	-0.51	-0.84	11.91
2011	19.12	13.55	18.00	0.86	1.17	-0.67	-0.97	9.42
2012	13.63	12.73	19.00	0.90	1.11	-0.86	-1.12	6.48
2013	32.23	11.77	20.00	0.95	1.05	-1.11	-1.32	2.46
	$\bar{X}$	28.74						
	S_n	19.94						

Note: RF=Rainfall, P=Probability, T=Returning period, Y_T= reduced variate and X_T=predicted rainfall

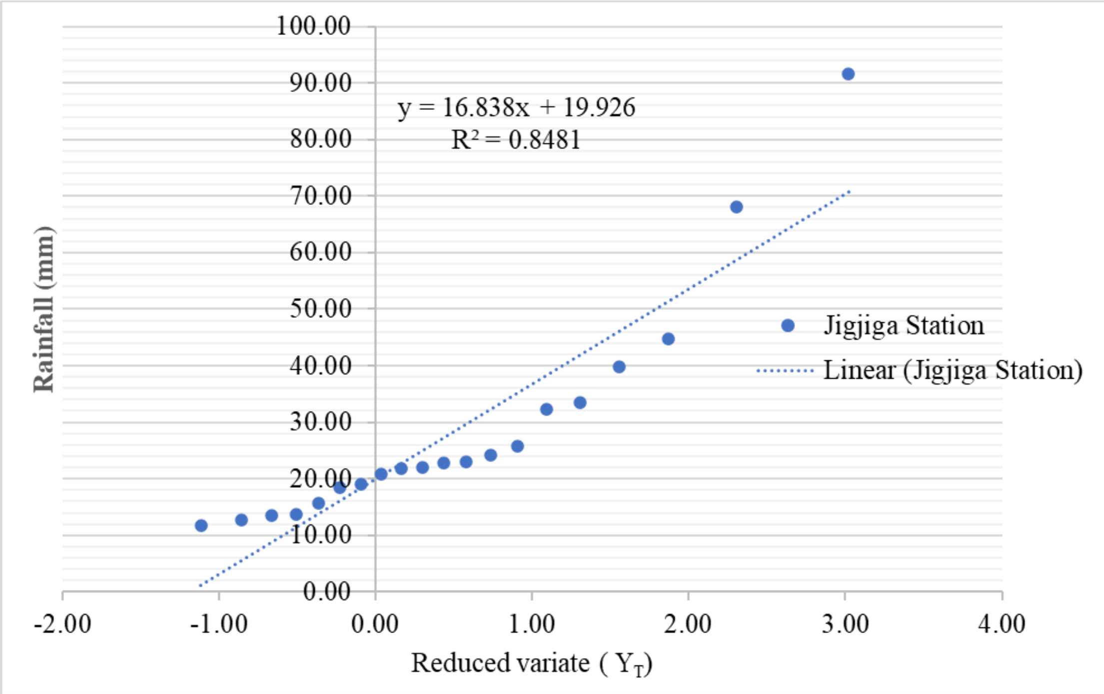


Figure 3.13 Fitting the reduced variance verses maximum annual rainfall value for EVI probability distribution of jigjiga station

3.3.12. Computation for PMP Return Period Jigjiga station

The annual exceedances for the predicted 1-day PMP depths (PMP) were calculated from the respective EV1 distribution of each station and the corresponding return period was computed and presented in Table 3.5.The PMP return period computed for the next coming 25, 50 and 100 years of Jigjiga rainfall station. To compute the returning period (T) of rainfall of Jigjiga Station the following equation was applied.

$$X_T = \mu + \alpha Y_T \quad \text{.........5}$$

Table 3.6 The annual exceedance and PMP jigjiga station with return period

Recurrence Interval (T) in years	X_T=μ+αYT
10	48.675
25	52.639
50	60.101
100	67.519

3.4. Watershed Runoff Modeling

Hydrological models that planned to be used should incorporate capabilities that enhance the researcher to meet objectives set for that specific study or assessment. To model the Jigjiga watershed runoff the Hydrological Engineering Center (HEC) family called Hydrologic Engineering Center-Geospatial Hydrologic Modeling System (HEC-GeoHMS) was used. It transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the watershed response to precipitation and runoff (Abushandiand Merkel, 2013). This model an interface of GIS creates a background map file; physical characteristics of the watershed are computed.

3.4.1. Rainfall Runoff Modeling

For this assessment, the SCS Curve Number method was used because SCS-CN method was developed by soil conservation service (SCS) of USA in 1969,is a simple predictable, and stable conceptual method for estimation of direct runoff from the rainfall depth. It relies on only one parameter, CN. The SCS-CN method is based on the water balance equation of the rainfall change with time, which can be expressed as

$$P = I_a + F + Q \quad \ldots\ldots 6$$

where P = total precipitation, Ia = initial abstraction, F = cumulative infiltration excluding Ia and Q = direct surface runoff occurring in the time change.

$I_a = \lambda S$, but it needs to be understood that λ=0.1, 0.2 or 0.3 based on the moisture characteristics.

$$Q = \frac{(P-\lambda S)^2}{P+\lambda S} \quad \ldots\ldots 7$$

The parameter S representing the potential maximum retention depends upon the soil-vegetation-land use complex of the catchment and antecedent soil moisture condition in the catchment just prior to the commencement of rainfall event and given below as in metric system.

$$S = 254(\frac{100}{CN} - 1) \quad \ldots\ldots 8$$

$$CN = \frac{25400}{S+254} \quad \ldots\ldots 9$$

The CN has the range of 100 ≥ CN ≥ 0. A CN value of 100 represents a condition of zero potential retention (i.e. impervious catchment) and CN = 0 represents an infinitely abstracting catchment with S = ∞. This CN depends upon soil type, land use/cover, antecedent moisture condition. In this assessment, the SCS curve number method was used to transform precipitation to run off(Bedient, 2008).

3.4.2. Peak runoff rate

The peak runoff rate is an indicator of the erosive power of a storm and is used to predict soil loss. To calculates the peak runoff rate with a modified rational method for each sub-basin can be estimated based on equation provided below.

$$Q_{peak} = \frac{\alpha_{tc} * Q_{surf} * A}{3.6 * t_{conc}} \quad \text{……10}$$

Where, $Q_{peak}$is peak runoff rates in m^3/s, α_{tc} is the fraction of daily rainfall that occurs during the time of concentration, Q_{surf} is the surface runoff (mm); A is the sub-basin area (km^2), t_{conc} time of concentration (hr) and 3.6 is conversion factor.

$$\alpha_{tc} = 1 - exp\,[2 * t_{conc} * ln\,(1 - \alpha_{0.5})] \quad \text{……11}$$

Where, $\alpha_{0.5}$ is the fraction of daily rain falling in the half-hour highest intensity rainfall, t_{conc} is the time of concentration for the sub basin (hr). The time of concentration, t_{conc} is which the entire sub basin area is discharging at the outlet point. It is the summation of the overland flow time of the furthest point in the sub basin to reach the stream channel (t_{ov}) and the upstream channel flow time needed to reach the outlet point (t_{ch}) and computed by equation (4.16).

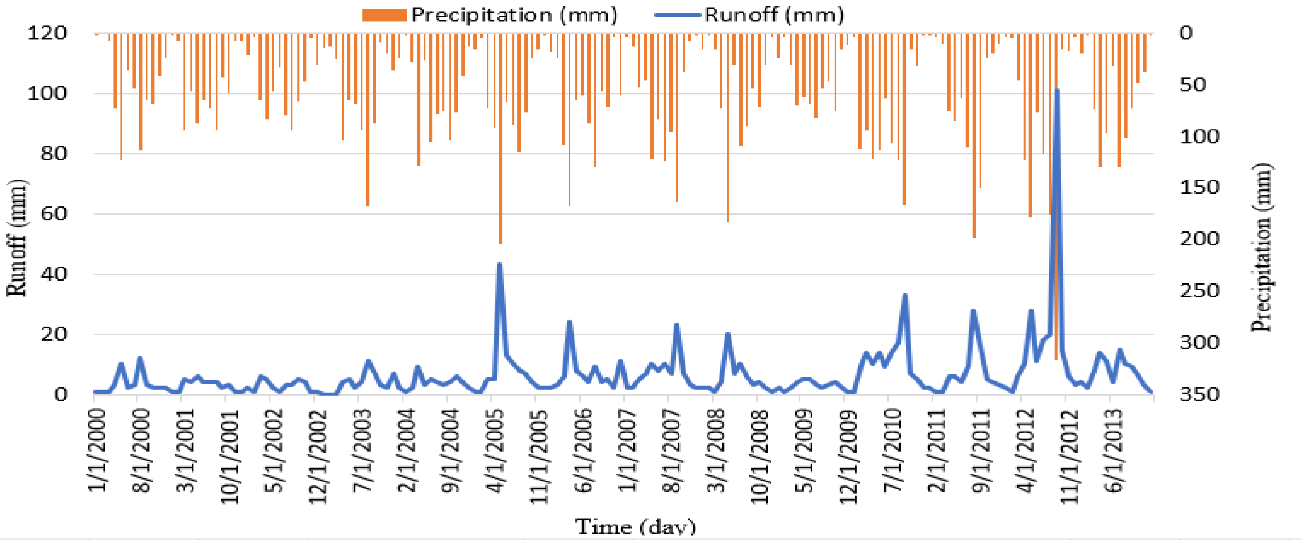
$$t_{conc} = t_{ov} + t_{ch} \quad \text{……12}$$

The overland flow time (t_{ov}) and the channel flow (t_{ch}) is computed by using equation given below.

$$t_{ov} = \frac{L_{slp}}{3600 * V_{ov}} \quad \text{……13}$$

$$t_{ch} = \frac{L_c}{3.6 * V_{cv}} \quad \text{……14}$$

Where; L_{slp} the average sub basin slope length (m), V_{ov} is the overland flow velocity (m/s), L_c the average flow channel length (km), V_c the average flow velocity (m/s), and 3.6 and 3600 are the unit conversion factor.



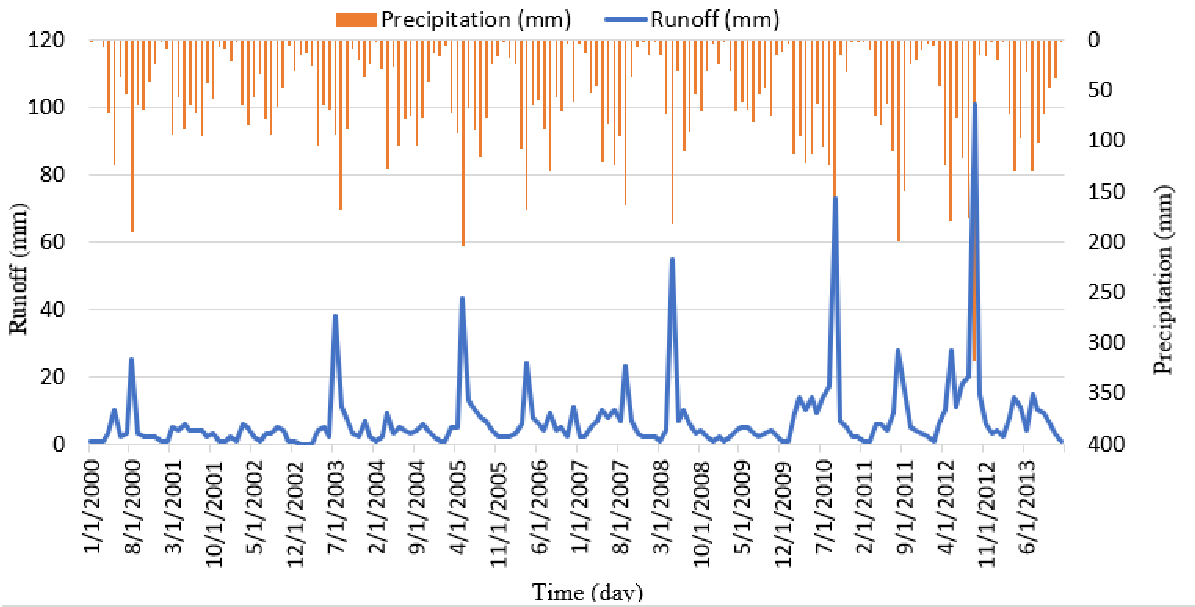


Figure 3.14 Runoff and precipitation rate daymaad river sub-watershed

3.4.3. Curve Number (CN) Analysis for Dayma'ad river Watershed

The CN was calculated from the soils and the land use, within Arc-GIS using HEC-GeoHMS. The land Cover of the assessment area was extracted from 2008 land use land cover for land cover type categories. These seven-land cover categories are presented below as built and wood and are the dominant coverage in percent (%).

In order for the CN generator to function properly, three shape files must be provided: the drainage basin boundaries for which CN will be produced, a soil type map of the catchment, and a land use map of the catchment. The hydrologic soil group (HSG) provides the information required to determine a CN since it reflects the amount of infiltration that the soil allows for. According to the USDA (1986), there are four hydrologic soil groups: A, which contains soils with high infiltration rates and low runoff potential, B, which contains soils with moderate infiltration rates and moderately low flow potential, C, which contains soils with slow infiltration rates and moderately high runoff potential, and D, which contains soils with very slow infiltration rates and high runoff potential. Using the hydrologic soil group of the Dayma'ad river/Jigjiga watershed as a guide, we were able to identify the soil class that was discovered, as shown in the table below.

Table 3.6 Curve number determination of Dayma'ad River

ID	Land Cover Type	Hydrological Soil Group and Curve Number			
		A	B	C	D
1	Bare Land	39	61	79	80
2	Built Land	98	98	98	98
3	Cultivated Land	76	86	91	96
4	Grass Land	49	69	77	84
5	Shrub Land	49	68	76	84
6	Urban Land	82	88	90	93
7	Wood Land	28	44	57	64

In most cases, once the necessary data has been collected, the following procedure is followed in order to generate the CN for a drainage area: Identify the drainage basin(s) for which CN(s) will be calculated and map the boundaries of the drainage basin(s). (2) Calculate the size of the drainage basin's catchment area (s). Make a map of the soil types and land use in the drainage basin(s) that you are interested in. (3) Convert the soil types into hydrologic soil groups using the soil type conversion table. Fourth, overlaid on each other, the land use and hydrologic soil group maps are used to identify each unique land use-soil group polygon and calculate the area of each polygon. (5) Using the SCS curve number, overlay the drainage basin map on top of the land use-soil group polygons to create a drainage system. In each drainage basin, calculate the total number of CN by area-weighting the land use-soil group polygons contained inside the drainage basin boundaries using the following equation for total number of CN computation..

$$CN_{weightege} = \frac{\sum_{i=1}^{n} (CN_i * A_i)}{\sum_{i=1}^{n} A_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 15$$

Where CN is the area-weighted CN for the drainage basin, CN_i and A_i are CN and area respectively for each land use-soil group polygon, and n is the number of polygons in each drainage basin.

3.4.4. Rainfall runoff modeling processes

The main objective of calculating precipitation loss process in a sub basin is to determine what percentage of precipitation is infiltrates and what percentage becomes runoff contributing to the river flow. For this study, the SCS Curve Number method was selected because the parameters that we need are available. The SCS CN method uses soil cover, land use, and antecedent soil moisture to determine precipitation excess the model calculates the volumes of runoff, the precipitation excess is a function of cumulative precipitation, soil type, land use/cover and antecedent moisture. Considering the initial loss and the potential maximum retention, the precipitation excess can be calculated

3.4.5. Rainfall Runoff Equation

The direct runoff from 24-hour or 1-day storm rainfall using the expression below:

$$Q_u = \frac{(P - 0.2\,S)^2}{P + 0.8\,S}$$

Where

Q_u = Direct runoff (mm)

P = Design rainfall (mm) (P_{10}=58mm P_{25}=65mm, P_{50}=70mm and P_{100}=75mm)

S = Potential Infiltration or Potential maximum soil water retention

After determination of the various input parameters as discussed above, the peak unit discharge, q_u read from a graph as function of ratio of I_a& P and T_c. I_a = initial abstraction including surface storage, interception, and infiltration prior to runoff in mm and P is design point rainfall.

Then peak discharge was then computed from the following expression:

$$Q_p = q_u A Q$$

Where: Q_p = Peak flow (m^3/s)

q_u = Unit peak flow ($m^3/s/km^2/mm$)

A = Drainage area (km^2)

Q = Accumulated direct runoff (mm)

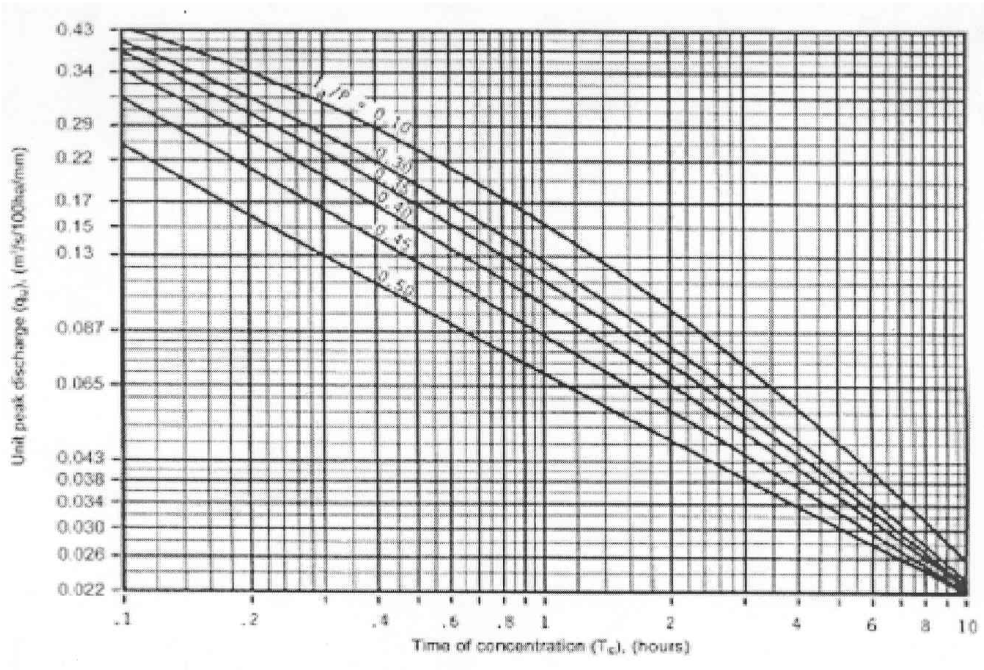


Figure 3.15 Unit Peak Discharge, Type II Rainfall

Table 3.7 The runoff estimation using SCS method is summarized and presented in the table below. Design Flood Estimation Table Using SCS Method

Cat. ID	Area	Stream Length	H max	H min	River Slope	T_c	CN	S	24 HOUR DESIGN POINT RAINFALL [mm]				DIRECT RUNOFF [mm]				PEAK DISCHARGE [m³/s]			
	Km2	m	m	m	m/m	hr			P_{10}	P_{25}	P_{50}	P_{100}	P_{C10}	P_{C25}	P_{C50}	P_{C100}	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Out let	993.2	3,794	1,870	1,825	0.012	1.01														
		17,598	1,825	1,725	0.006	4.35														
		10,695	1,725	1,680	0.004	3.33														
		10,695	1,680	1,630	0.005	3.20														
		741	1,630	1,627	0.004	0.43														
	993.2					11.88	69	114	48.68	52.64	60.10	67.52	8	11	14	16	194	294.4	322	383

3.4.6. River basin Delineation

The first step in this analysis is to delineate the Dayma'ad/Jigjiga River basin and sub-basin using the HEC-GeoHMS. Data needed in this step is DEM data. Jigjiga catchment outlet will be determined in the downstream as per the map will show the catchment has a number of sub basins.

3.5. Sub-Watershed Delineation

A watershed is today defined as all the land and water areas which contribute runoff to a common point. The watershed above any point on a defined drainage channel is therefore all the land and water areas which drain through that point (often the outlet). It is marked by an elevated line that forms a division between two areas drained by separate streams, river systems or lakes. A watershed that can be further subdivided into smaller sub-watershed as shown below.

Historically, watersheds have been differentiated from sub watersheds on the basis of stream order. In this context, a watershed would be an area drained by a primary stream or river which flows directly into a lake or ocean, while a sub watershed would be an area drained by a tributary. With the beginnings of more ecologically/community-based approaches to planning, these terms have taken on a new meaning. Stream order is no longer the main determinant in differentiating a watershed from a sub watershed, instead it is the level of detail addressed in a plan. Watershed plans provide a comprehensive approach towards the management of water and other natural resources. They articulate broad future visions for the watershed and outline general strategies for achieving them. Sub watershed plans are more site specific and focus on local environmental issues in dealing with watershed management.

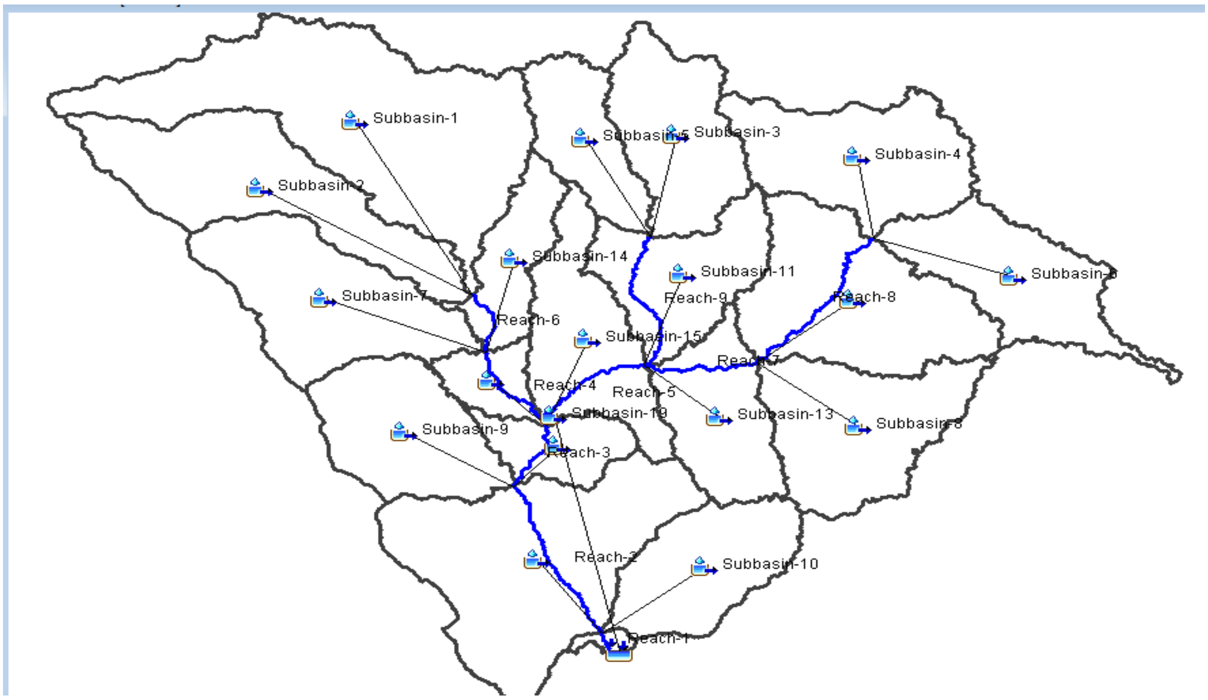


Figure 3.16 Sub-basin and Stream Network of Dayma'ad River Watershed

3.5.1. Flow direction and Terrain Analysis

Flow direction determines which direction water will flow in a given cell. Based on the direction of the steepest descent in each cell, we measure flow direction. In addition, the z-value difference and slope are calculated between neighboring cells.

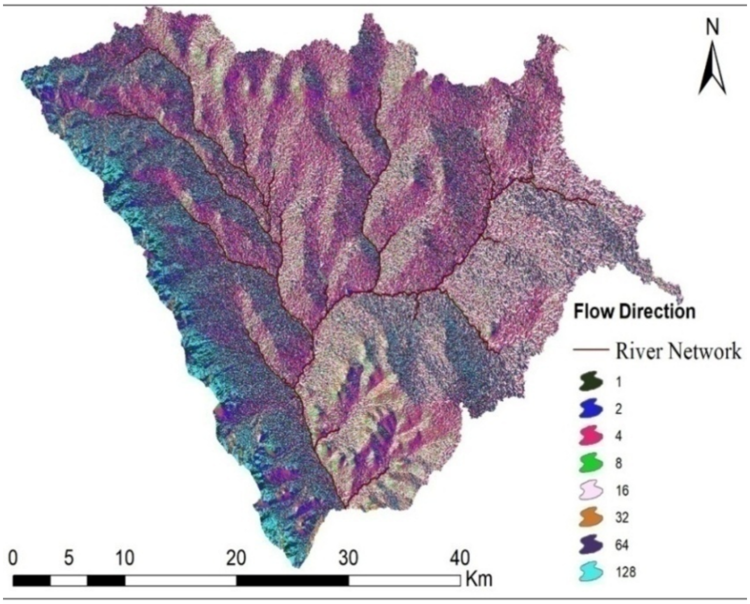


Figure 3.17 flow directions of dayma'ad river watershed

3.6. Dayma'ad River/Jigjiga Watershed Runoff

To understand watershed runoff, it important to define watershed as it is referring to an area of land that drains to a common draining point called as outlet. Based on the outlet location the watershed characteristics are predefined for further analysis of the watershed morphology such as Watershed shape area, stream density, flow directions, basin slope and the sub-watersheds. Stream density determines the runoff volume coming from each sub-watershed. And, runoff is affected by slope, soil type, rainfall and land cover. As depicted below on the runoff map, the runoff distribution flows the stream network and it show maximum at the joining of streams of that is flowing from Daymaad on the North West direction and from Elbahay Dam North East direction. Around the outlet of the watershed, which is below Dayma'ad river/Jigjiga City the runoff amount is low this may probably as a result of slope and soil characteristics. The runoff output is collated Dayma'ad River/ Jigjiga City as in figure below shown.

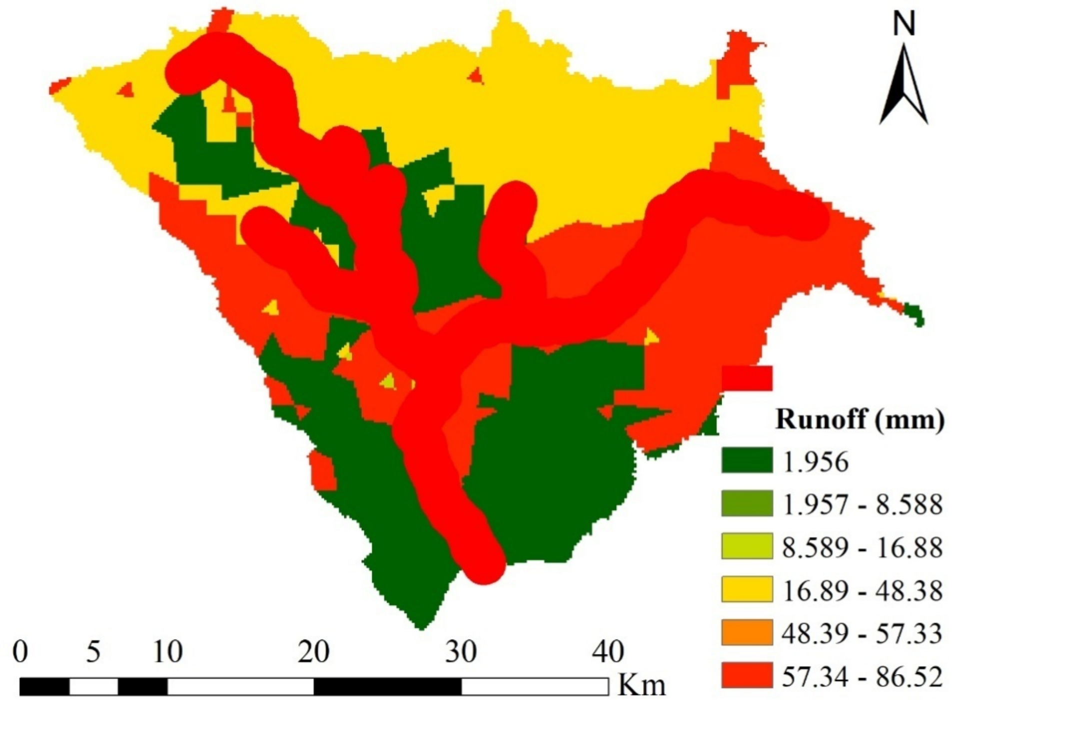


Figure 3.18 Runoff map of Dayma'ad river watershed

3.7. Delineation and Identification of Flood Risk Areas

The flood Inundation map shows the area extent to be delineated as buffer zone. Two models HEC-GeoRAS and HEC-RAS are used one after another (first HEC-GeoRAS then HEC-RAS then back to HEC-GeoRAS) to accomplish the task. Contour map of the town. Contour map cross section of stream,DEM, Land use and Soil map.HEC-GeoRAS is a set of procedures, tools and utilities for processing geographic information systems (GIS) data in ArcView GIS, using a graphical user interface (GUI). The interface allows preparation of geometric data for import into HEC-RAS and generation of GIS data from exported HEC-RAS simulation results.

The automated procedures for extracting geometric data proved consistent and efficient for the development of floodplain models. The geometric data was imported into HEC- RAS using a data exchange format developed by HEC-GeoRAS. The resultant water surface elevations exported from HEC-RAS simulations were processed by HEC-GeoRAS for floodplain delineation and water depth calculations. Analysis of cross-sectional velocities exported from HEC-RAS was also performed using HEC-GeoRAS.

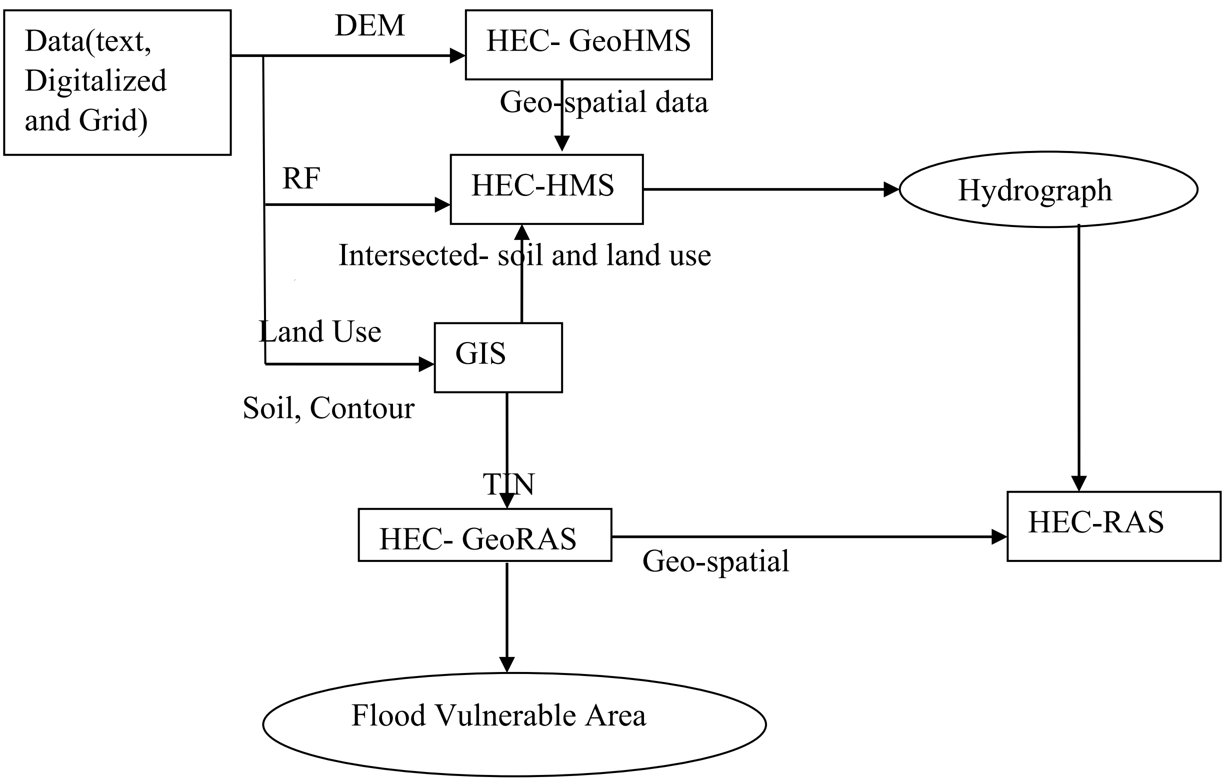


Figure 3.19 Flow chart mapping inundation

3.8. Calibration and Validation performance of the model

In order to evaluate the performance of the model to determine the quality and reliability of prediction compared to the observed values the following methods for goodness of-fit measures of model predictions used during the calibration and validation periods. These numerical model performance measures are coefficient of determination (R^2) and Nash-Sutcliffe simulation efficiency (NSE) (Nash and Sutcliffe, 1970),

The coefficient of determination (R^2) is the square of the Pearson product moment correlation coefficient. It describes the proportion of the total variance in the observed data i.e. explained by the model. Based on the result of equation (1), the value of R^2 greater than 0.6 and closer to one is the higher of the agreement between the simulated with the observed flows an.

$$R^2 = \left(\frac{\sum_{i=1}^{n}\left(Q_i^{ob} - Q_{ave}^{ob}\right)\left(Q_i^{pred} - Q_{ave}^{pred}\right)}{\left[\sum_{i=1}^{n}\left(Q_i^{ob} - Q_{ave}^{ob}\right)^2 \sum_{i=1}^{n}\left(Q_i^{pred} - Q_{ave}^{pred}\right)^2\right]^{0.5}} \right)^2 ----------1$$

Where, $Q^{ob}{}_i$ is observed value (flow in m^3/s), $Q^{ob}{}_{ave}$is the average observed of n value, $Q^{pred}{}_i$ simulated value (flow in m^3/s), $Q^{pred}{}_{ave}$ averaged predicted of n value and n is number of observations.

Nash-Sutcliffe efficiency (NSE): NSE is a normalized statistic that determines the relative magnitude of the residual variance compared to the measured data variance. NSE indicates that the plot of observed values to simulated values of the data fits the 1:1 line and it is estimated as equation (2).

$$\text{NSE} = 1 - \frac{\sum_{i=1}^{n}\left(Q_i^{ob} - Q_i^{pred}\right)^2}{\sum_{i=1}^{n}\left(Q_i^{ob} - Q^{ave}\right)^2} - - - - - - - - - - - - - - - - - - 2$$

NSE ranges between −∞ and 1 (1 inclusive), NSE> 0.5 is good model performance; NSE equal to 1 is being the optimal value. Values between 0 and 1 are generally viewed as acceptable levels of performance, whereas values<0 indicates that the mean observed value is a better predictor than the simulated value, which indicates unacceptable performance level.

4. RESULT AND DISCUSSION

4.1. HEC-HMS Performance Evaluation

The model components, data requirements for each the model types used in this study and calibration and validation results along with error measures are presented subsequently

4.1.1. Calibration of HEC-HMS

The Calibration of Hydrological Model HEC-HMS was done at Jigjiga watershed on the basis of monthly peak flow model outputs. The calibration was done using the data of 1/1/2000 to 12/1/2004 of the monthly basis. The calibration result of the monthly flow is shown in the below figure. By using coefficient of determination (R^2) measure gives good agreement between recorded and predicted values of model. The result of the calibration of monthly flow showed that there was good agreement between the measured and simulated average monthly flow with Nash-Sutcliffe efficiency (NSE) and coefficient of determination (R^2) value of 0.684 and 0.697 respectively. This result indicated that the model over predicted the flow values for some of the months, for instance, 2000 and 2001 months are over predicted by the model outputs.

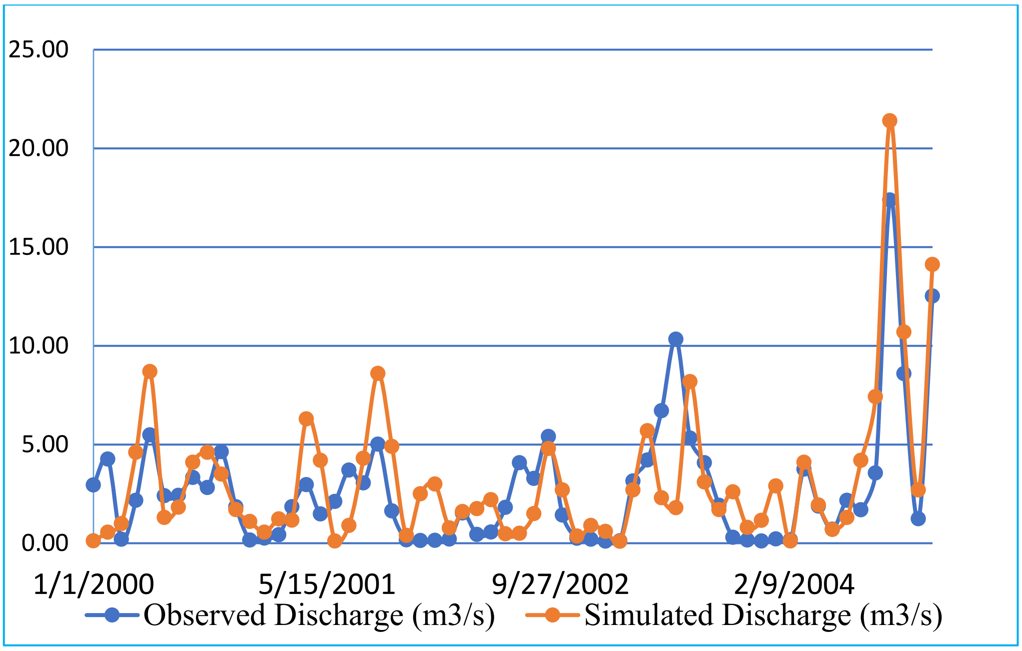


Figure 20 Model Calibration Hydrograph of Jigjiga Watershed by HEC-HMS

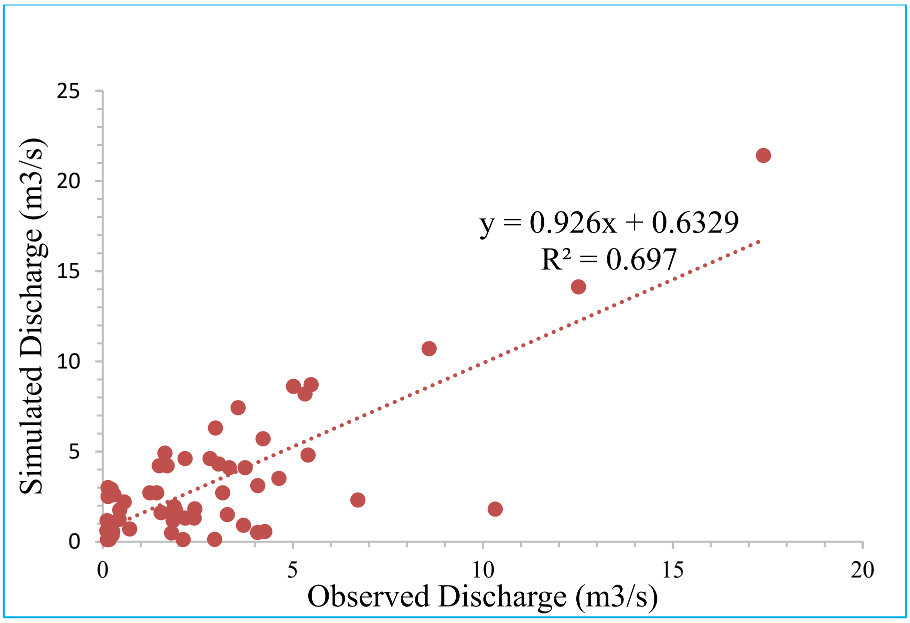


Figure 21 Coefficient of determination of HEC-HMS model performance evaluation result during calibration period

4.1.2. Model Validation

The model validation was also made by using the monthly data, 3 years monthly data from January 2005 to December 2007 was implemented. The validation result for monthly flow is shown in the figure below. The validation of model also showed good agreement between the predicted and measured daily flow with the NSE and R^2 value of 0.664 and 0.682. During the validation period, the model result is under estimated than recorded values of Jigjiga watershed Dayma'ad stream flow.

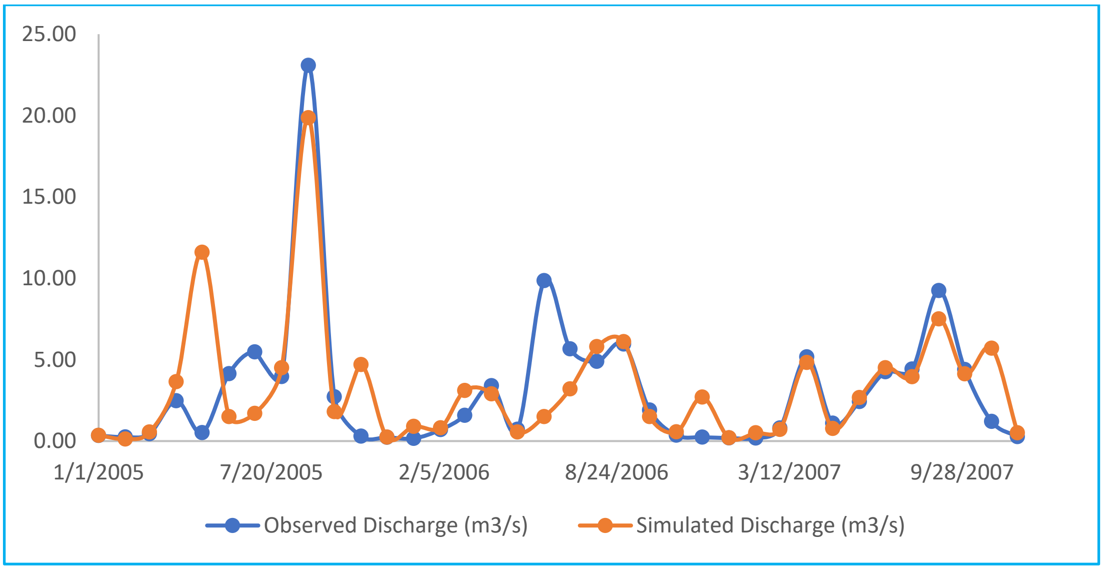


Figure 22 Model Validation Hydrograph of Jigjiga watershed by HEC-HMS

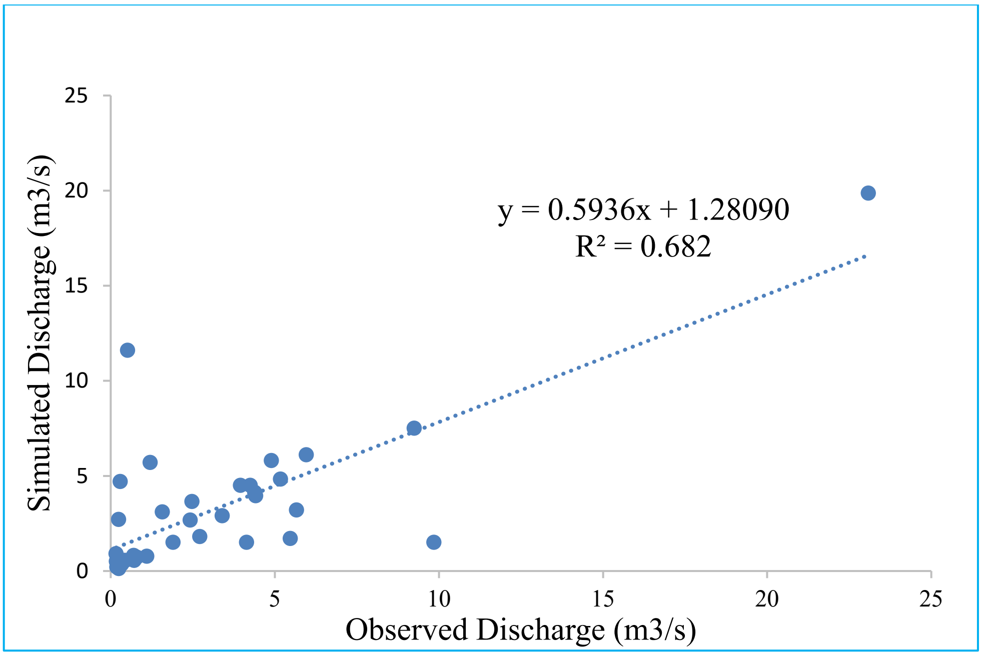


Figure 23 Coefficient of determination of HEC-HMS model performance evaluation result during calibration period

Table 4.1 Model Performance Evaluation

Period	Observed flow (m3/s)	Predicted flow (m3/s)	NSE	R2	Relationship
Calibration Period	3.275	3.486	0.684	0.697	Good agreement
Validation Period	3.138	3.226	0.664	0.682	Good agreement

4.2. Determination of Peak Discharge

The catchment area at the crossing is 993km^2. The design flood estimated are 322m^3/s and 383m^3/s for 50 and 100 years returning period respectively.

Table 4.2 All Basins Peak Discharge and flow volume

PEAK DISCHARGE		[m^3/s]	
Q_{10}	Q_{25}	Q_{50}	Q_{100}
194	294.7	322	383

Hydrologic Element	Drainage Area (km^2)	Peak Discharge (m^3/s)	Volume (m^3)
Subbasin-1	165.43	135.8	4579.96
Subbasin-10	57.272	48.1	4854.75
Subbasin-11	56.148	19.7	3349.52
Subbasin-12	94.822	33.1	3287.54
Subbasin-13	51.713	18.1	3295.24
Subbasin-14	33.906	28.2	4706.88
Subbasin-15	64.041	22	3184.49
Subbasin-16	18.063	15.2	4852.85
Subbasin-17	26.842	22.5	4842.89
Subbasin-18	132.28	46.6	3390.27
Subbasin-19	3.2707	2.7	4807.22
Subbasin-2	93.769	77	4579.96
Subbasin-3	62.466	21	3047.61
Subbasin-4	75.707	26.3	3245.27
Subbasin-5	40.445	14.2	3337.06
Subbasin-6	64.112	22.3	3245.27
Subbasin-7	84.142	69.2	4593.83
Subbasin-8	76.218	26.7	3317.04
Subbasin-9	64.096	53.8	4852.85
Outlet	1071.92	294.7	3888.35

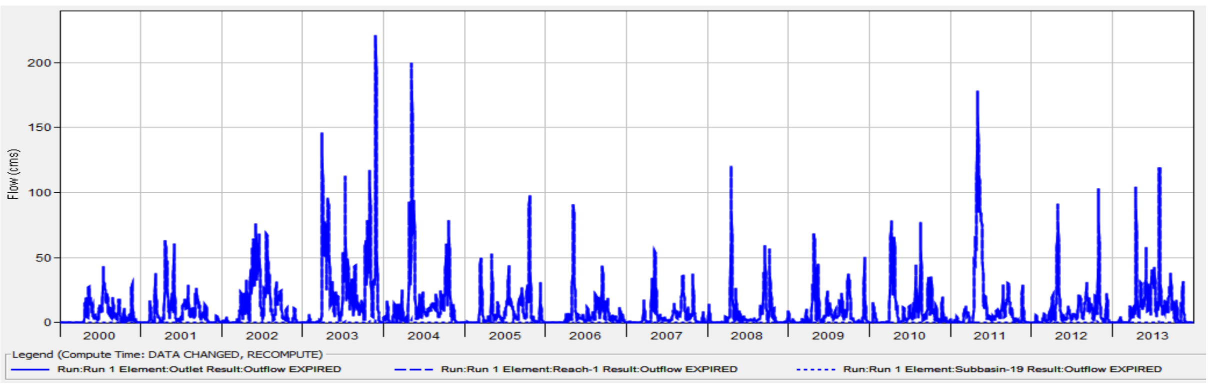


Figure 24 Hydrograph of flow at outlet

4.3. Buffer Zone

The cross-sectional profile of Dayma'ad stream has been shown below for all cross sections from upstream to the downstream. From the figure 4.6 we can see that the water surface profile for the peak discharge for 25 years of return period 294.7 m^3/s.

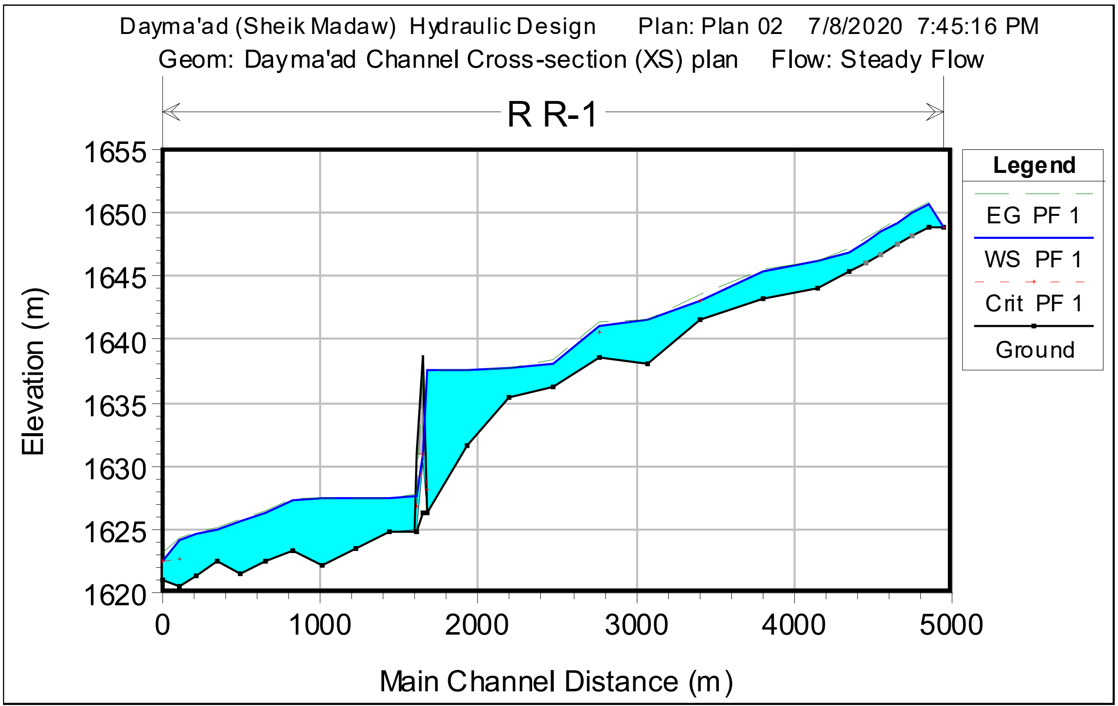


Figure 25. Dayma'ad river Water Profile

During the computations, the three-dimensional information is used in the program for display purpose. Surface profiles exported back to the GIS /ArcView HEC-GeoRAS/ system for development and display of a flood inundation map.

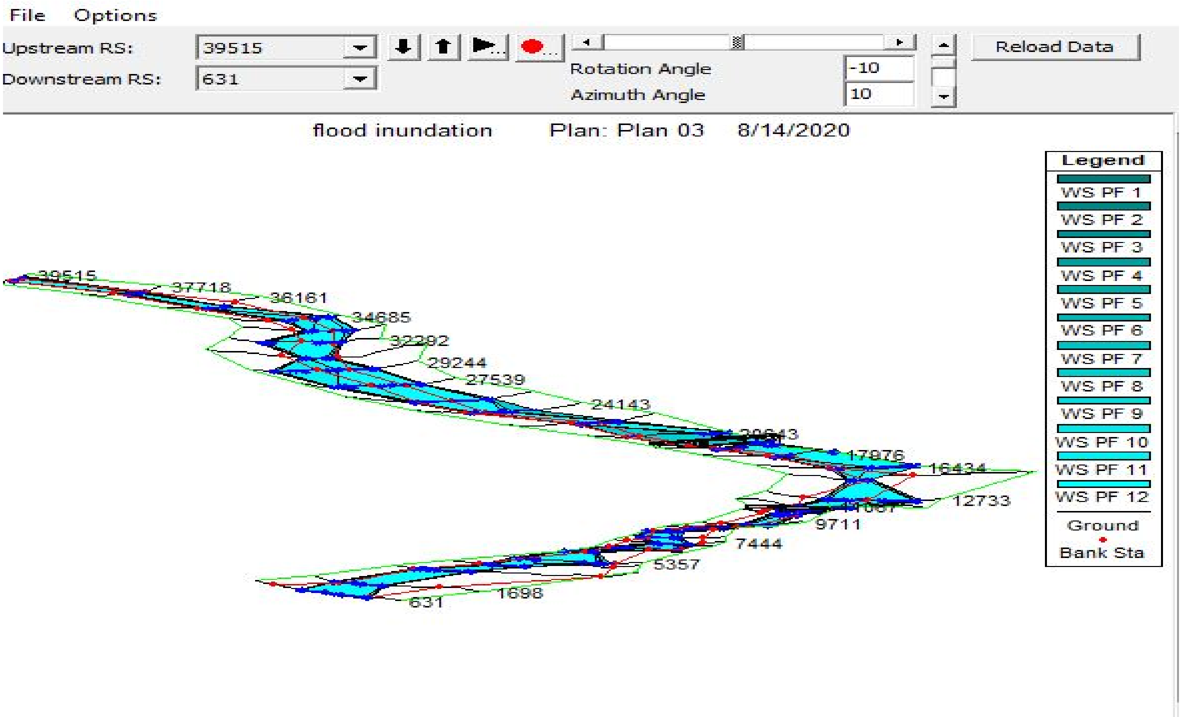
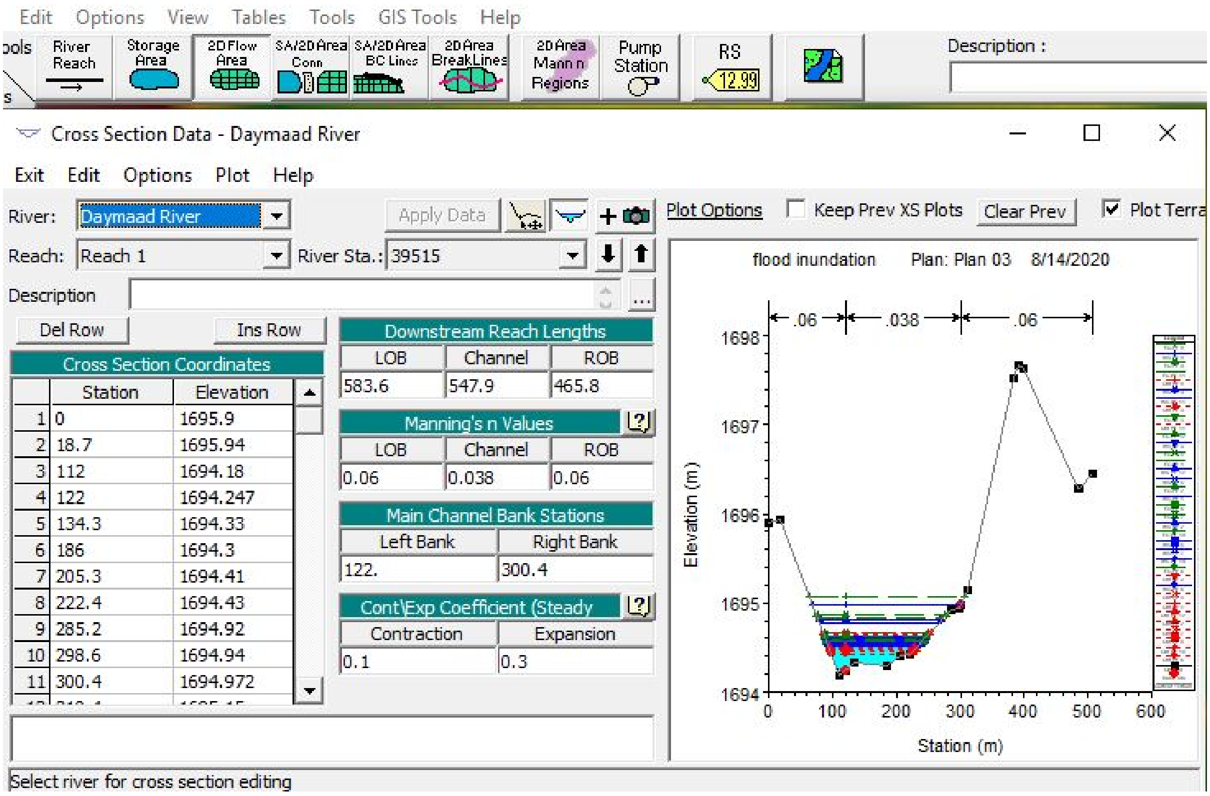


Figure 26 Daymaad Geometric Schamatic Data Improved to HEC-RAS

Cross-Section:- Cross sections are taken perpendicular to the stream and extended to achieve the maximum watershed elevation so as to identify areas where flood overtops



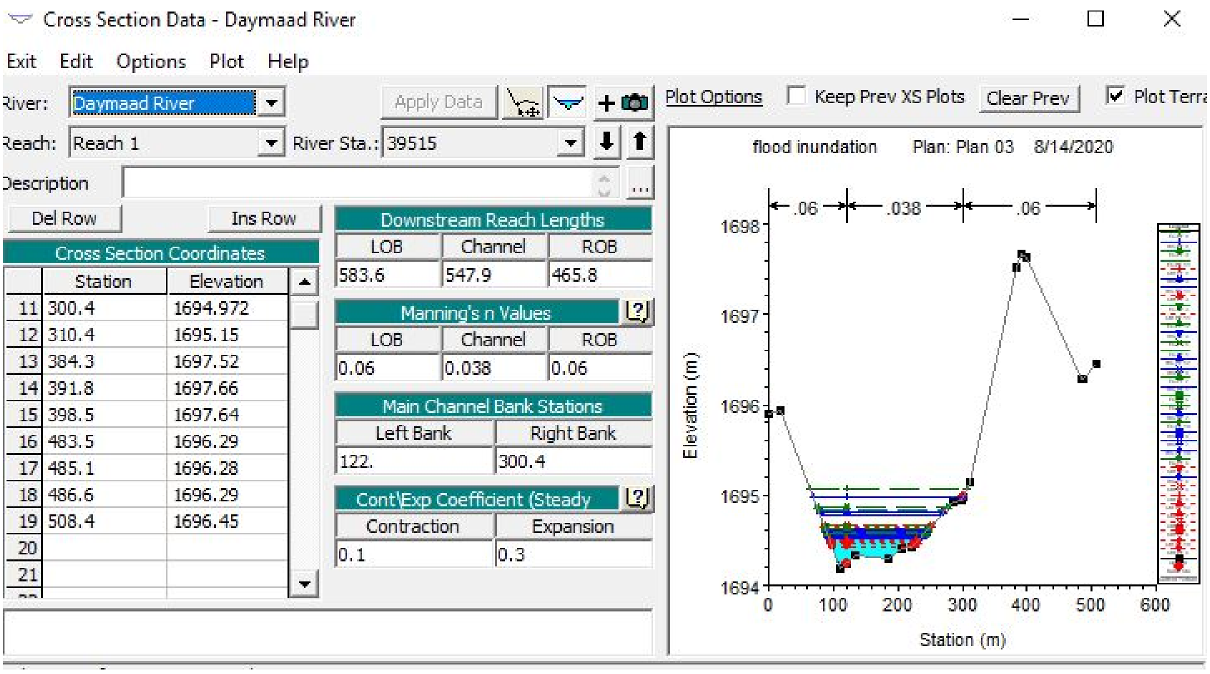


Figure 27 Daymaad Cross Section data improved to HEC-RAS

Flood plain delineation is performed using HEC-GeoRAS Post processing and the result is shown below.

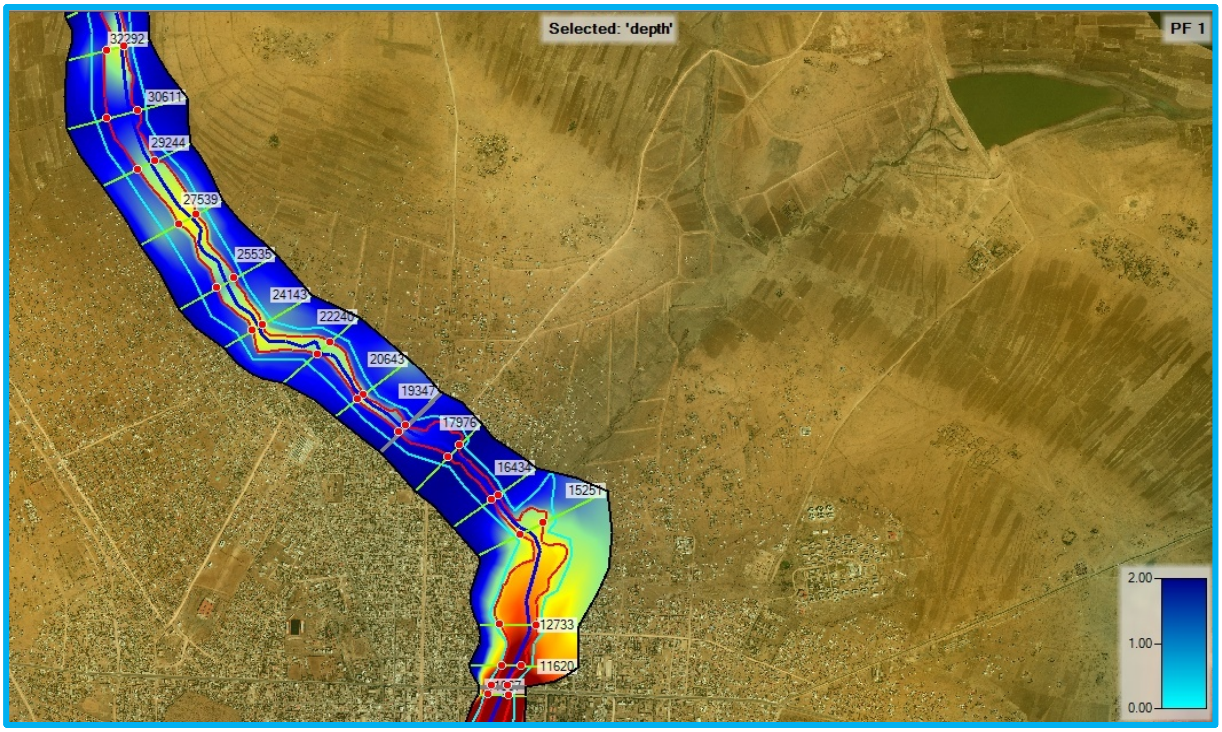


Figure 28 Dayma'ad River flood plain

5. CONCULUTION AND RECOMMENDATION

5.1. Conclusion

In Jigjiga city dayma'ad river is the main problem in loses of lives, damages in humans and properties and also erosion occurred by runoff from upstream watershed. As stated in this thesis the eroded area of the watershed area those found following the stream networks. The stream networks are the area that the community living with fear due to an expected flood hazard from the upstream. The peak runoff of the area happens in different years and buffering zone, even though it showed a good relation with precipitation of the area; that was high in March and April every year. And, in August it is summer season but during this time it shows that the climatic variability has been occurring throughout the study period.

Optimization trail of the model was conducted using a basin model generated by the Arc-GIS extension of HEC-GeoHMS. The SCS CN loss method is a useful tool to simulate the rainfall runoff relationship. The model pointed out that CN was the most sensitive parameter that controls the stream flow of the studied watershed. On the other hand, the calibration and validation have showed that the HEC-HMS model simulated good enough. Performance of the model for both the calibration and validation of the watershed were found to be reasonably good with Nash-Sutcliffe coefficient and R^2 value of 0.684 and 0.697 respectively and calibration were as the validation result Nash-Sutcliffe coefficient and R^2 value were 0.664 and 0.682 respectively.

Before the evaluation of the impacts of land use land cover change on the stream flow of Jigjiga watershed data preparation, calibration, validation and evaluation of model performance were performed on the selected HEC-HMS model. The catchment has peak discharge 294.7 m^3/s at its outlet for 25years of return period; the sub basin of the catchment has an area of 1071.92Km^2.

5.2. Recommendations

- Weather stations should be improved both in quality and quantity in order to improve the performance of the model. Hence, it is highly recommended to established good hydrological and meteorological stations.
- The flood is estimated and vulnerable areas are identified, a flood damage analysis follows. analysis like the hydrologic Engineering Center's Flood damage Reduction Analysis (HEC-FDA, or FDA) as a mitigation measure can be used
- Constructions of retaining wall Structure for flood protection in corner of buffer zone areas, construction of dam and dikes are recommended.
- A forestation is highly recommended, In case of inside the city dumping of solid waste in to the drainage to aware the community,
- The drainage should be removed and maintained periodically by the concerned body.
- Community living inside the buffer zone should be relocated for the safety

REFRENCE

Abushandi, E., & Merkel, B. (. (2013). Modelling rainfall runoff relations using HEC-HMS and IHACRES for a single rain event in an arid region of Jordan. *Water resources management , 27(7),*, 2391-2409.

Asfaw; and Lindqvist. (2015). Extending minimal repair models for repairable systems A comparison of dynamic and heterogeneous extensions of a nonhomogeneous Poisson process. *Journal of Reliability Engineering & System Safety , 140*, 53-58.

Bakir, M and Xingnan, Z. (2008). GIS and remote sensing applications for rainwater harvesting in the Syrian Desert (al-badia). Alexandria, Egypt: Paper presented at the Proceedings of Twelfth International Water Technology Conference, IWTC 12.

Bárdossy, & Bronstert. (2003). Uncertainty of runoff modelling at the hillslope scale due to temporal variations of rainfall intensity. *Journal Physics and Chemistry of the Earth, , Parts A/B/C 28(6)*, 283-288.

Bewket, W. (2003). *Towards integrated watershed management in highland Ethiopia the Chemoga watershed case study.* Ethioia ,Adiss Ababa.

Blue, N. O. (2021). *Sanitation Plan and Waste Water Management System.* Jigjiga.

Chaw, V. (1964). *Applied Hydrology* (ED ed.). New Yokk: McGraw.

Commission, F. D. (2018). *Flood Alert.* Adiss Ababa.

CSA. (2007). *Statics.* Addis Ababa.

Darwiche. (2009). Modeling and reasoning with Bayesian networks. London: Cambridge University Press.

Dooge. (1992). Sensitivity of runoff to climate change. *Bulletin of the American Meteorological Society , 73(12)*, 2013-2024.

Duan, Q., Schaake, J., Andreassian, V., Franks, S., Goteti, G., & Gupta, H. V. (2006). Model Parameter Estimation Experiment (MOPEX): An overview of science An overview of science strategy and major results. *Journal of hydrology , 32(1)*, 3-17.

Faith, G., Gitau, W., Bauwens, F. M., & Willy. (2009). Climate change impact on SWAT simulated streamflow in western Kenya. *International Journal of Climatology , 29(12)*, 1823-1834.

Filliol, Jeffery, Dic, & Barry. (2003). Snapshot of moving and expanding clones of Mycobacterium tuberculosis and their global distribution assessed by spoligotyping in an international study. *Journal of Clinical Microbiology , 41(5)*, 1963-1970.

Habitant, U. (2015). *Enhancing Urban Safety and Security.* London: Earthscan Publications.

Habte. (2009). *Dechatu Flood Study.* Dire Dawa: Adiss Ababa University.

Habte, T. (2006). *DECHATU CATCHMENT (Dire Dawa Town) FLOOD STUDY.* Addis Ababa: Addiss Ababa University.

HABTE, T. (2009). *DECHATU CATCHMENT (Dire Dawa Town) FLOOD STUDY.* Addis Ababa.

Hagos. (2011). *Hydraulic Modeling and Flood Mapping Of Fogera Flood Plain A Case Study of Gumera River .* Adiss Ababa.

Hagos, B. (2011). *Hydraulic Modeling and Flood Mapping Of Fogera Flood Plain .* Adiss Ababa.

Halcrow. (1989). *Master Plan for the development of surface water resources in the Awash Basin.* Adiss Ababa.

Horton. (1939). Analysis of runoff- plat experiments with varying infiltration- capacity. *Eos, Transactions American Geophysical Union , 20(4*, 693-711.

Huang, & Zhan. (2004). ArcCN-Runoff: an ArcGIS tool for generating curve number and runoff maps. *Journal Environmental Modelling & Software , 19(10)*, 875-879.

JCA. (2016). *dayma'ad river risk.* Jigjiga: SRTV.

Maidment, D. R., & Djokic, D. (2000). *Hydrologic and hydraulic modeling support: With geographic information systems: ESRI, Inc.*

Majidi, A., & Vagharfard, H. (2013). Surface Run-off Simulation with Two Methods Using HEC-HMS Model (Case Study: Abnama Watershed, Iran)). *Current Advances in Environmental Science , 1(1*, 7-11.

McCuen. (1989). *Hydrologic analysis and design.*

Nash, L. a. (1970). A comparison of methods of fitting the double exponential distribution. *J. Hydrol.* , 10, 259-275.

Ogaden, & Saghafaian. (1997). Green and Ampt infiltration with redistribution. *Journal of Irrigation and Drainage Engineering , 123(5)*, 386-393.

Organization, W. M. (2020). *Flood Managment.* Stockholm.

Oumer et al. (2011). *AWASH RIVER BASIN FLOOD CONTROL.* Arbaminch.

Poesen, & Vandaele. (1995). Watershed and stream network delineation.

Puertas, D. G.-L., Pol, B. v., Kumsa, A., Steenbergen, F. v., Haile, A. M., & Embaye, T.-a. G. (2015). *stutus and potential of ground water use in ethiopian floodplain.* Adiss Ababa.

Robinson. Ward.J, K., P.Eaton, R., & Haaland. (1990). *Method and Apparatus for Abiological Analyte From ModelConstructed From knowen Biological.* New Mexico.

Shaw, H. a. (1983). Statistical Methods in Hydrology. *Lowa State University*, (p. 378). Lowa.

Shen, C., Phanikumar, M. S., Verma, & Mahana. (2010). A process-based, distributed hydrologic model based on a large-scale method for surface-subsurface coupling. *Journal of Advances in Water Resources , 33(12)*, 1524-1541.

Shukri; Sanagi; Ibrahim; and Abdin. (2015). Liquid Chromatographic Determination of NSAIDs in Urine After Dispersive Liquid-Liquid Microextraction Based on Solidification of Floating Organic Droplets. *Chromatographia , 78(15-16)*, 987-994.

Singh, & Mishra. (1999). Another look at SCS-CN method. *Journal of Hydrologic Engineering 4(3)* , 257-264.

Subramanya, K. (1998). *Engineering Hydrology* (1st Ed ed.). New Dalhi.

USDA. (1986). *Natural Resources Conservation Service Urban hydrology for small watersheds.* New Yok.

Venkatesh, M. (2009). *Watershed and stream network delineation.* School of Civil Engineering Purdue University.

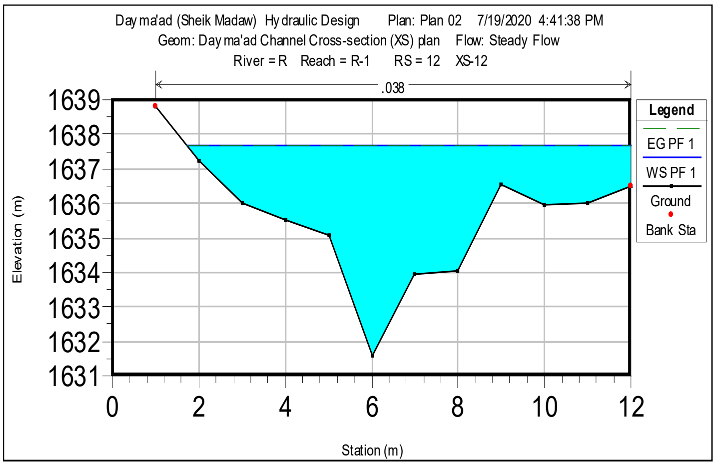
WHO. (2021). *Health tropics Flood* . Geneva.

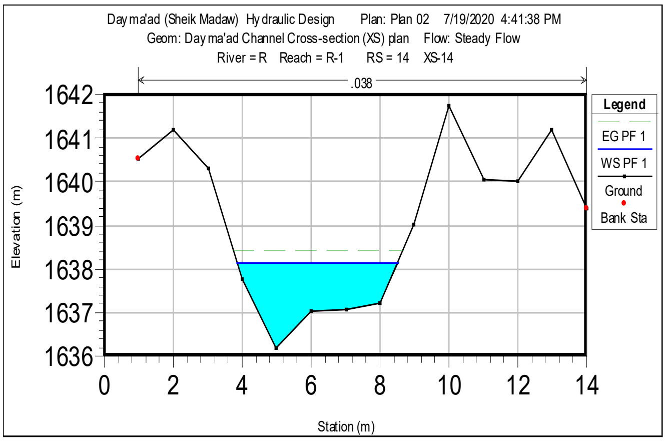
Wondimu. (2010). *Jigjiga city Structural plan report.* Jigjiga.

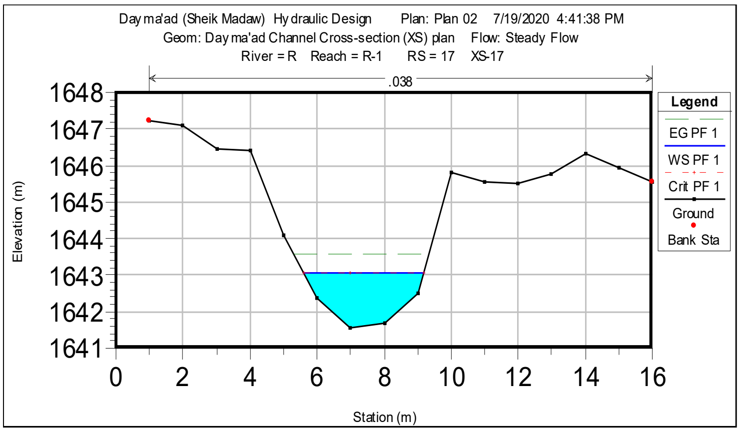
Yuan, Y., & Qaiser, K. (2011). *Floodplain Modeling in the Kansas River Basin Using Hydrologic Engineering Center (HEC) Models.* Impacts of Urbanization and Wetlands for Mitigation: US Environmental Protection Agency, Office of Research and Development.

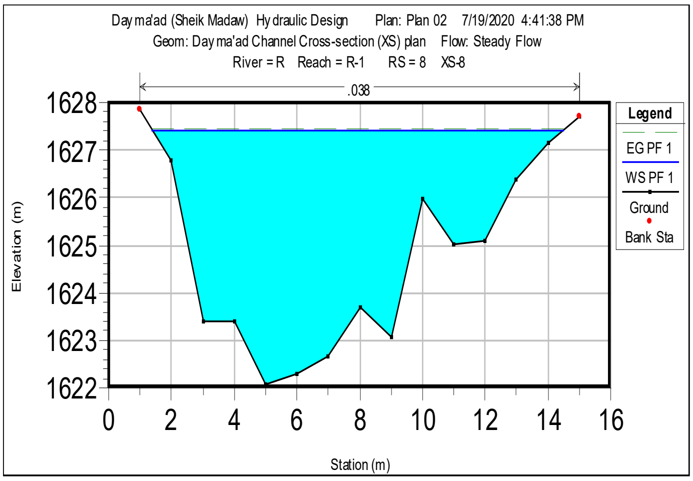
APPENDIX

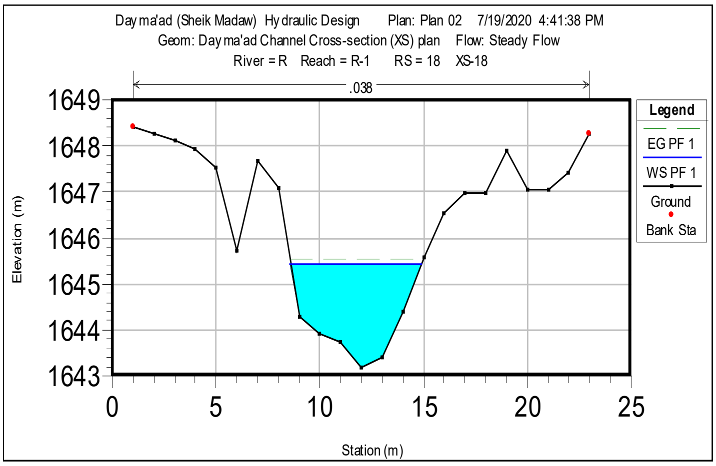
Appendix 1: Cross Sectional (XS) view of Dayma'ad stream

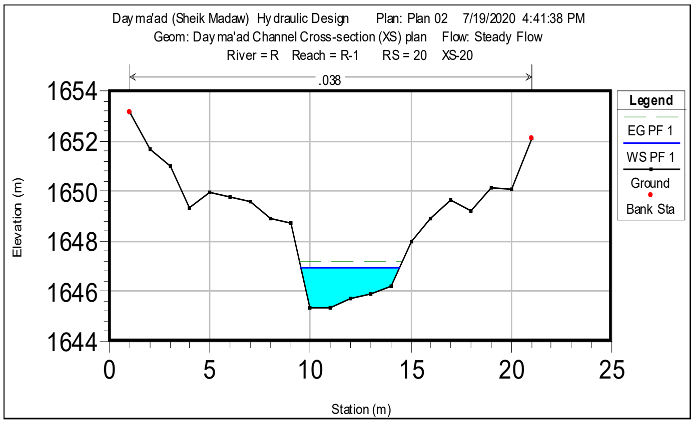












Appendix 2: Topographical channel elevation with coordinate system

East UTM (m)	North UTM (m)	Elevation (m)	Nomenclature
256272.459	1038461.95	1652.809	TOPO98
256293.99	1038565.833	1651.063	TR3
256304.578	1038489.027	1652.589	TOPO99
256327.425	1038557.35	1649.911	TR1
256346.322	1038534.359	1651.705	EGE 3
256351.926	1038402.66	1653.684	TOPO97
256354.205	1038542.202	1648.956	CL M R 01
256367.16	1038519.408	1651.57	EGE12R
256370.823	1038632.466	1652.341	TOPO100
256375.873	1038523.3	1648.848	CL M R AND GR STAR
256385.694	1038533.278	1651.268	EGE13R
256389.788	1038394.309	1652.115	TOPOgj
256398.802	1038563.331	1649.527	GORGE 1
256409.061	1038647.998	1650.778	GRG1
256423.762	1038628.256	1650.367	GORGE 01
256425.056	1038650.175	1650.811	GRG2
256434.233	1038666.603	1651.034	TR2
256444.406	1038408.228	1650.495	TOPO92
256457.582	1038565.973	1652.587	TOPO98
256496.311	1038441.805	1651.15	EGER80
256498.003	1038217.393	1651.165	TOPO58
256505.629	1038447.094	1648.333	CL M R 90
256518.552	1038453.822	1651.697	EGE91
256524.906	1038225.689	1651.148	TOPO57
256534.651	1038398.567	1650.968	EGE R 72
256534.877	1038351.707	1650.702	TOPO72
256542.656	1038404.404	1648.104	CL M R 73
256547.42	1038300.108	1651.004	TOPO 65
256551.257	1038460.2	1652.213	TOPO93
256551.732	1038407.072	1651.057	EGE R 73
256561.376	1038356.236	1650.218	EGE R 71
256564.784	1038146.999	1649.704	TOPO53
256576.166	1038355.314	1648.212	CL M R 69
256580.01	1038422.338	1651.97	TOPO74
256581.615	1038490.504	1653.147	TOPO94
256584.918	1038361.363	1650.575	EGE R 70
256585.802	1038311.193	1650.121	EGE R 201
256590.657	1038107.142	1649.605	TOPO44
256598.656	1038308.376	1647.246	CL M R 62
256606.294	1038310.525	1650.032	EGE R 61
256607.747	1038093.459	1649.932	TOPO32
256611.475	1038176.809	1650.06	TOPO50

256615.495	1038240.1	1650.532	EGE R 56
256627.214	1038369.071	1651.762	TOPO71
256633.312	1038241.169	1646.715	CL M R 55
256634.827	1038129.69	1649.793	TOPO42
256637.192	1038314.01	1651.049	TOPO60
256640.142	1038243.507	1649.799	EGE R 55
256654.735	1038196.589	1649.194	EGE R 48
256658.293	1038135.095	1648.551	GORG40
256663.26	1038056.551	1649.282	TOPO22
256666.402	1038251.104	1648.705	GORG 56
256666.631	1038123.98	1648.9	TOPO29
256674.833	1038195.888	1646.231	CL M R 54
256686.331	1038200.45	1649.415	EGE R 51
256691.321	1038138.14	1649.653	EGE R 37
256697.642	1037998.961	1648.979	GORG7EGE
256701.372	1038145.516	1645.908	CL M R 39
256702.963	1038062.081	1648.849	R EGE 2
256703.362	1037995.231	1645.369	GORG17
256707.834	1038211.047	1650.145	TOPO49
256711.598	1037980.115	1648.924	EGE4
256714.909	1038113.709	1649.092	R EGE 27
256716.059	1038048.582	1645.368	CL M R 20
256716.384	1037755.835	1647.938	TOPO6
256716.512	1038152.677	1649.376	R EGE 1
256719.161	1037962.333	1648.863	TOPO16
256725.947	1038164.055	1648.974	GORG41
256726.135	1038052.543	1648.608	R EGE 1
256726.456	1037985.609	1644.832	EGE4
256728.43	1038110.376	1645.723	CL M R 36
256729.826	1037759.079	1648.131	TOPO5
256730.51	1037953.659	1648.472	TOPO15
256733.641	1037990.634	1648.148	EGE2
256736.719	1038114.326	1648.935	EGE R 35
256736.755	1038114.307	1648.958	EGE R 31
256744.921	1037824.461	1647.516	TOPO6
256749.479	1037862.789	1648.276	TOPO10
256749.571	1037895.093	1648.399	TOPO13
256757.374	1038116.092	1649.361	TOPO30
256758.771	1037681.758	1645.726	GORG1
256762.03	1037822.044	1647.948	TOPO9
256765.546	1038058.587	1648.917	TOPO23
256773.903	1037777.781	1647.825	TOPO3
256776.478	1038000.715	1648.418	EGE1
256777.208	1037819.812	1643.917	CL M R 4
256780.92	1037779.985	1643.739	CLM R 3

256787.138	1037706.081	1647.678	TOPO2
256789.492	1037950.402	1644.588	CL M R 26
256790.783	1037785.852	1647.098	TOPO7
256795.721	1037927.938	1647.714	EGE3
256798.001	1037601.478	1647.216	TOPO 199
256805.169	1037940.205	1644.497	CL M R 25
256806.842	1037884.989	1644.306	CL M R 3
256811.088	1037881.467	1647.406	EG2
256811.094	1037911.054	1644.41	CL M R 5
256813.16	1037595.179	1647.107	TOPO 198
256813.403	1037930.918	1648.039	EGE1
256815.957	1037673.026	1647.061	TOPO 202
256816.668	1037602.755	1647.042	TOPO200
256824.656	1037559.353	1647.069	TOPO 193
256827.936	1037645.275	1646.55	TOPO 201
256835.523	1037749.893	1646.221	EG1
256838.945	1037753.847	1643.42	CL M R 2
256842.345	1037879.027	1648.267	TOPO9
256843.012	1037987.208	1647.975	GORG3
256846.658	1037831.647	1647.88	TOPO8
256848.861	1037517.671	1646.817	TOPO 177
256849.477	1037598.603	1645.528	EGE RIGHT
256850.4	1037930.58	1648.536	TOPO11
256851.61	1037625.589	1646.74	TOPO EG RIGHT
256852.058	1037569.42	1646.747	TOPO 192
256856.592	1037514.754	1647.595	TOPO 175
256867.51	1037533.356	1647.536	TOPO 179
256872.765	1037464.904	1646.454	TOPO 167
256879.53	1037678.972	1643.198	CL M R 1
256885.148	1037553.847	1646.235	EGE 180
256889.991	1037421.584	1646.32	TOPO 161
256890.391	1037941.487	1648.758	TOPO12
256892.319	1037558.703	1642.521	CL M R 172
256892.82	1037689.562	1646.97	TOPO1
256892.973	1037524.338	1645.933	TOPO 173
256893.201	1037471.927	1646.418	TOPO 168
256909.214	1037572.016	1645.539	TOPO 174
256909.386	1037487.526	1645.573	EGE 171
256915.758	1037531.833	1642.39	CL M RIVER 170
256921.432	1037789.938	1646.993	GORGE 1
256932.024	1037598.295	1644.078	GORGE 176
256932.153	1037426.905	1645.781	TOPO 159
256935.359	1037484.352	1641.695	CL M RIVER 164
256939.134	1037442.617	1641.561	CL M R 158
256940.263	1037602.829	1646.539	TOPO 178

256951.731	1037731.674	1645.573	GORG 2 CL
256953.044	1037511.382	1642.075	CL M R 165
256954.949	1037496.652	1645.793	EGE 162
256961.603	1037728.827	1647.053	TOPO2
256968.502	1037347.177	1644.496	TOPO 144
256971.498	1037389.996	1643.301	TOPO 156
256991.63	1037504.466	1646.268	TOPO 160
256992.141	1037409.858	1640.944	CL M R 152
256993	1037615.858	1646.16	TR EGE LIFT
256995.109	1037371.963	1644.09	TOPO 155
256996.03	1037325.367	1640.656	CL M R 147
257002.263	1037619.076	1644.405	TR CL 1
257009.328	1037622.915	1646.779	TR RIGHT 1
257013.927	1037354.496	1640.766	CL M R 148
257015.275	1037390.845	1643.809	TOPO 154
257019.948	1037414.122	1640.781	CL M R 151
257024.862	1037306.949	1644.567	EGE 134
257033.265	1037375.657	1640.834	CL M R 149
257035.087	1037634.711	1645.152	GORGE 190
257035.332	1037514.787	1646.135	TR L 03
257041.987	1037408.119	1641.097	CL M R 150
257044.539	1037323.96	1640.479	CL R M 1
257049.579	1037334.324	1643.418	EGE 137
257051.407	1037520.26	1643.4	TR C L03
257052.925	1037417.451	1643.993	GORGE 140
257057.72	1037351.952	1644.156	TOPO 153
257060.514	1037524.976	1646.003	TR R 03
257070.564	1037265.899	1643.631	GORGE 16
257074.009	1037431.18	1643.249	TR CL 3
257079.261	1037305.162	1640.216	RIVER CL 1
257080.326	1037322.078	1643.707	EGE 136
257086.337	1037441.156	1645.298	TR R 3
257101.758	1037334.596	1644.249	TR L 3
257110.824	1037337.748	1641.313	TR CL 3
257113.503	1037460.987	1645.902	TR R 4
257115.077	1037257.401	1643.445	EGE 121
257122.645	1037339.982	1644.876	TOPO 131
257129.053	1037282.363	1639.942	D RIVER CL 2
257133.811	1037255.146	1640.001	CL M R 120
257140.135	1037212.202	1643.314	TOPO 114
257148.951	1037491.375	1646.061	TR R 5
257151.409	1037259.629	1642.996	RIVER EGE 22
257170.442	1037148.143	1644.358	TOPO 110
257182.177	1037162.801	1643.661	TOPO 108
257184.64	1037185.364	1641.97	EGE 107

257202.928	1037197.323	1638.987	CL M R 109
257214.944	1037218.237	1641.754	GORGE 111
257216.311	1037124.824	1643.226	TOPO 101
257235.728	1037245.984	1644.064	TOPO 112
257242.614	1037145.603	1638.497	CL M R 103
257254.407	1037159.05	1642.41	EGE 104
257257.229	1037013.764	1643.683	TOPO 18
257272.684	1037043.113	1643.317	TOPO 19
257283.955	1037192.414	1643.58	TOPO 105
257291.695	1037051.536	1638.579	CL M R SHARPC2
257297.096	1037070.201	1640.832	TOPO 20
257304.188	1037076.314	1640.247	GORGE 15
257338.321	1037073.692	1642.2	EGE 30
257345.162	1037051.665	1638.639	CL M R 69
257347.486	1037033.551	1642.977	TOPO 55
257348.158	1037105.722	1642.922	TOPO 54
257350.072	1037148.561	1643.114	TOPO 17
257351.917	1037032.954	1641.763	EGE 29
257356.946	1037137.009	1642.978	TOPO 56
257418.377	1037016.746	1642.085	TOPO 99
257427.932	1037035.873	1640.055	EGE 38
257446.199	1037061.242	1638.115	CL M R 96
257460.002	1037097.395	1640.791	GORGE 99
257471.211	1037030.465	1639.516	GORGE 98
257502.879	1037085.783	1641.166	GORGE 97
257556.378	1037040.451	1640.259	EGE 25
257556.827	1037015.567	1637.754	CL M R SHARP 2
257573.95	1036965.929	1640.296	TOPO 48
257586.791	1036975.822	1640.04	TOPO 50
257626.195	1037110.364	1639.382	TR CL 2
257650.856	1036973.568	1638.088	EGE 22
257652.989	1037052.045	1637.224	SHARP CL CURVY
257656.925	1037074.239	1639.618	GORGE 011
257658.106	1036991.174	1637.025	RIVER CL 12
257660.231	1037063.307	1640.607	EGE 54
257671.397	1036998.85	1639.241	EGE 21
257685.591	1037090.334	1641.745	TOPO 49
257704.808	1036934.648	1639.998	TOPO 74
257716.912	1037025.343	1641.189	TOPO 87
257735.674	1037029.487	1640.481	GORGE 23
257745.278	1036962.347	1637.06	RIVER CL 14
257755.133	1037046.713	1641.192	TOPO 47
257759.661	1036911.797	1639.031	TOPO 32
257768.47	1036921.101	1638.722	EGE 66
257784.188	1036933.843	1636.175	CL RIVER 1

257797.678	1036950.736	1639.783	EGE 67
257821.989	1036974.264	1640.511	TOPO 33
257823.029	1036821.173	1637.006	BED RIVER 55
257836.24	1036828.39	1636.385	BED RIVER 56
257840.309	1036831.447	1635.602	RIVER CL 1
257853.363	1036845.441	1638.204	EGE 25
257860.636	1036763.133	1636.861	RIVER M CL
257864.363	1036751.612	1637.372	TOPO R 55
257866.176	1036783.191	1635.837	TR START 1
257866.504	1036766.449	1635.549	GORGE 33
257867.383	1036806.661	1637.361	TR LIFT
257869.31	1036751.431	1636.57	BED R 66
257869.768	1036838.869	1638.938	TR LIFT
257871.146	1036806.794	1635.915	TR CL
257873.758	1036861.675	1639.858	TR LIFT 2
257873.835	1036836.132	1636.46	TR CL 1
257874.516	1036807.764	1637.458	TR RIGHT
257876.415	1036753.327	1635.462	CL M R 269
257876.764	1036887.532	1640.122	TR LIFT 4
257879.011	1036835.105	1637.647	TR RIGHT
257882.378	1036860.307	1636.808	TR RIGHT 2
257884.49	1036889.421	1637.079	TR CL 14
257887.484	1036852.675	1638.667	TR RIGHT 3
257892.466	1036885.147	1638.729	TR RIGHT 99
257901.645	1036693.667	1637.313	TOPO 268
257911.206	1036733.035	1636.532	EGE RIGHT
257916.125	1036704.578	1635.487	CL M R 261
257929.244	1036742.134	1638.478	TOPO 77
257973.718	1036655.049	1637.211	TOPO 66
257976.221	1036595.501	1636.305	BED R 055
257985.967	1036608.699	1635.598	GORGE 021
257987.292	1036676.541	1638.802	TOPO 67
257996.878	1036616.04	1635.195	CL M R 260
258003.108	1036629.565	1637.103	EGE R 25
258036.052	1036576.651	1636.034	EGE R 2014
258037.128	1036582.003	1634.46	CL M R 2154
258058.891	1036550.297	1635.06	BED R 2147
258076.211	1036525.324	1635.996	BED R 01
258080.447	1036534.322	1635.513	BED R 02
258090.158	1036543.64	1634.034	CL M R 221
258094.492	1036554.458	1634.962	TOPO 225
258179.648	1036468.786	1633.541	CL M R 214
258194.146	1036483.162	1635.335	TOPO 219
258214.809	1036503.632	1635.58	TOPO 220
258231.046	1036411.183	1634.067	EGE R 211

258231.142	1036523.125	1635.313	GORGE 200
258236.053	1036416.84	1635.176	CL M R 210
258236.17	1036417.356	1634.18	CL M R 214
258273.715	1036372.453	1634.058	CL M R 204
258278.595	1036384.67	1633.966	CL M R 208
258282.487	1036396.28	1634.7	EGE R 201
258345.873	1036296.273	1635.996	TOPO 203
258361.054	1036292.292	1636.509	TOPO 201
258364.992	1036291.028	1636.561	TOPO 196
258379.552	1036273.184	1635.15	TOPO 200
258388.658	1036319.556	1631.612	CL M R 198
258394.55	1036331.094	1635.944	TOPO 200
258404.696	1036360.492	1634.555	TOPO 202
258474.157	1036287.512	1632.982	EGE RIVER 1
258478.664	1036256	1635.073	TOPO 193
258490.307	1036310.233	1628.774	CL M R 195
258504.176	1036338.751	1633.64	TOPO 195
258517.401	1036384.076	1634.223	TOPO 194
258554.788	1036238.181	1632.697	TOPO 188
258559.016	1036247.22	1629.994	SLOPE 1
258566.208	1036263.205	1628.709	CL M R 186
258572.603	1036274.821	1631.594	TOPO 189
258581.827	1036303.588	1632.432	GORGE 1
258584.885	1036250.879	1628.529	CL M R 185
258605.536	1036168.086	1633.066	TOPO 178
258616.927	1036191.355	1632.714	TOPO 177
258637.198	1036224.976	1628.082	CL M RIVER 210
258648.828	1036270.788	1632.144	TOPO 182
258651.723	1036232.506	1631.633	TOPO 208
258702.988	1036151.401	1630.179	TOPO 201
258708.534	1036159.865	1626.446	CL M RIVER 202
258718.683	1036165.238	1631.164	TOPO 204
258744.584	1036109.74	1630.426	TOPO 193
258755.911	1036114.217	1626.281	CL M RIVER 190
258765.969	1036120.095	1631.305	TOPO 191
258815.769	1036030.699	1629.858	TOPO 182
258832.025	1036058.645	1629.863	TOPO 186
258853.29	1035993.579	1629.596	TOPO 178
258866.698	1036001.201	1625.914	CL M RIVER 171
258875.772	1036006.825	1629.254	TOPO 170
258898.733	1035929.036	1628.757	TOPO 167
258914.619	1035943.738	1625.655	CL M RIVER 163
258924.433	1035952.066	1629.479	TOPO 166
258935.323	1035889.498	1629.027	TOPO 155
258937.892	1035938.526	1630.374	TP

258938.034	1035889.792	1629.187	L
258947.581	1035899.871	1625.578	CL M RIVER 160
258951.337	1035898.989	1625.119	B
258957.749	1035907.87	1629.05	TOPO 161
258959.601	1035905.861	1628.744	R
258977.437	1035812.353	1628.917	TOPO 151
258986.392	1035810.999	1627.541	TOPO 150
258991.81	1035799.352	1627.976	L
259003.432	1035819.779	1624.848	CL M RIVER 145
259010.99	1035809.252	1624.178	B
259012.185	1035752.32	1628.696	TOPO 142
259016.253	1035816.953	1629.01	TOPO 146
259021.723	1035805.836	1628.361	R
259027.115	1035761.23	1624.253	CL M RIVER 102
259041.033	1035760.698	1627.964	TOPO 143
259043.739	1035708.554	1628.224	TP
259062.359	1035701.74	1623.93	CL M RIVER 101
259067.613	1035678.768	1628.305	TOPO 83
259069.964	1035709.864	1627.508	TOPO 78
259085.397	1035675.041	1623.857	CL M RIVER 100
259086.605	1035690.417	1627.843	TOPO 84
259096.19	1035645.502	1628.527	L
259102.335	1035655.646	1624.604	B
259115.149	1035657.173	1626.853	R
259116.938	1035638.796	1623.645	CL M RIVER 68
259120.654	1035618.308	1628.438	TOPO 82
259152.698	1034821.52	1624.018	BJ
259152.702	1034797.877	1624.039	BJ
259155.675	1035637.178	1626.546	TOPO 81
259157.762	1034824.684	1620.97	BJ
259158.92	1034852.927	1625.498	L
259162.898	1035598.746	1623.492	CL M RIVER 67
259172.329	1034832.887	1620.527	CL M RIVER 1
259178.214	1035134.336	1624.508	TOPO 19
259178.708	1034942.43	1627.664	TOPO 14
259179.21	1034942.284	1628.035	TOPO 13
259180.011	1034821.03	1624.021	BM
259182.176	1034943.323	1628.923	TOPO 12
259183.212	1034822.663	1621.173	BJ
259184.621	1034840.722	1620.941	B
259185.684	1034942.218	1628.498	L
259188.95	1034943.287	1626.121	TOPO 11
259191.012	1035028.002	1625.248	TOPO 68
259192.647	1034942.717	1622.328	EGE 4
259192.958	1035026.579	1626.021	TOPO 67

259192.986	1035029.772	1625.989	TOPO 66
259195.27	1034834.549	1620.823	BED R 1
259199.487	1034830.063	1621.152	BJ
259200.635	1034821.482	1624.036	BJ
259201.559	1035613.847	1626.952	TOPO 80
259201.767	1035236.677	1624.877	TOPO 24
259202.398	1034829.012	1622.861	EGE 2
259202.486	1035126.185	1624.591	TOPO 17
259202.894	1034797.922	1624.032	BJ
259203.863	1035028.669	1622.115	EGE 7
259206.173	1035124.326	1625.756	TOPO 16
259208.88	1034835.645	1625.34	R
259209.01	1035453.095	1625.8	TOPO 147
259211.007	1034932.208	1621.101	B
259211.162	1034937.867	1620.808	CL M R 3
259212.337	1035133.425	1623.077	BED R 17
259212.749	1035618.751	1626.199	TOPO 79
259213.983	1035026.558	1621.368	CL M RIVER 4
259215.886	1035620.171	1624.108	GORGE 1
259220.836	1035036.567	1621.343	B
259223.964	1035130.177	1622.555	CL M RIVER 15
259224.3	1035235.421	1626.792	TOPO 22
259224.69	1034929.974	1622.284	EGE 4
259227.792	1035027.515	1623.905	EGE 8
259228.734	1035244.385	1627.982	L
259230.282	1035231.071	1623.89	BED R 20
259230.484	1034927.832	1625.509	EGE 3
259232.843	1035595.359	1626.272	TOPO 78
259233.19	1034918.319	1627.637	R
259234.498	1035051.849	1623.419	R
259236.777	1035061.79	1625.939	BM
259236.786	1035061.788	1625.886	BM
259236.808	1035337.138	1627.961	TOPO 30
259237.391	1035129.482	1623.323	BED R 15
259238.185	1035534.817	1623.202	CL M RIVER 66
259239.443	1035510.902	1627.795	TOPO 48
259242.563	1035127.069	1626.415	EGE 18
259243.229	1035504.895	1627.26	L
259246.654	1035225.883	1622.714	CL M RIVER 19
259246.764	1034920.535	1625.685	TOPO 3
259247.613	1035215.246	1621.57	B
259253.511	1034822.775	1623.817	TOPO 1
259255.546	1035125.958	1625.256	TOPO 18
259255.692	1035515.822	1622.509	B
259256.031	1035327.612	1623.954	CL M RIVER 27

259257.955	1035449.558	1625.658	TOPO 45
259261.039	1035533.482	1625.663	TOPO 77
259266.316	1035430.665	1627.178	L
259267.198	1035525.788	1625.717	R
259270.201	1035226.903	1626.962	R
259271.397	1035642.53	1627.002	TOPO 1454
259271.784	1035507.344	1623.25	CL M RIVER 001
259271.971	1035452.793	1625.153	L
259273.224	1035530.18	1626.081	TP
259273.279	1035530.136	1626.075	TP
259277.43	1035223.693	1625.37	TOPO 23
259278.441	1035447.487	1624.838	TOPO 40
259281.131	1034827.994	1624.229	TOPO 2
259282.634	1035393.808	1623.401	CL M RIVER 101
259284.498	1035445.941	1623.406	B
259285.379	1035328.606	1625.076	BED RIVER 29
259286.28	1035447.571	1623.284	CL M RIVER 35
259289.052	1035457.632	1622.652	B
259289.989	1035393.217	1625.975	CL M RIVER 69
259292.761	1035446.934	1623.05	BED RIVER 41
259299.196	1035457.832	1625.019	R
259301.85	1035447.103	1625.088	R
259309.276	1035444.386	1626.398	TOPO 46
259313.633	1035560.963	1626.8	TOPO 14
259337.981	1035445.571	1627.165	TOPO 47
259345.795	103529.431	1624.7	GORGE 11
259384.157	1035446.12	1627.7	TOPO 102

Appendix 3: Annual and monthly discharge of Dayma'ad River

Year Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1990	28.2	29.0	29.4	27.8	29.8	28.3	27.6	27.5	28.0	28.9	28.8	27.5	28.4
1991	29.7	29.9	29.2	28.5	29.7	28.8	25.3	27.6	28.6	29.6	28.1	27.0	28.5
1992	27.4	28.6	31.0	29.7	30.3	28.0	27.2	28.2	29.1	29.4	29.2	28.2	28.8
1993	29.1	28.7	30.4	29.5	31.1	29.1	29.0	28.9	29.5	29.1	30.2	29.4	29.5
1994	29.6	29.7	30.2	30.1	29.4	29.3	26.7	27.0	27.5	27.2	27.2	26.9	28.4
1995	28.8	29.4	30.1	30.1	28.7	28.4	25.6	26.2	27.5	26.2	27.2	27.1	27.9
1996	27.9	29.0	29.9	30.0	27.9	27.4	27.0	26.1	27.3	28.2	27.2	27.3	27.9
1997	25.9	29.3	29.2	30.2	28.9	28.4	26.7	26.5	28.0	28.3	27.4	28.0	28.1
1998	26.2	29.1	30.0	28.8	29.2	28.4	27.8	27.3	27.4	28.4	28.4	27.6	28.2
1999	27.1	30.0	30.8	29.5	30.0	27.2	26.5	26.8	26.9	28.9	28.2	26.7	28.2
2000	27.6	28.4	29.5	28.0	29.7	28.3	27.4	27.7	27.6	27.4	27.6	26.8	28.0
2001	27.4	30.2	29.6	29.1	27.2	26.7	26.0	26.9	27.2	27.9	27.4	26.5	27.7
2002	27.4	29.0	29.2	27.5	28.6	28.6	27.6	26.6	26.6	27.8	26.8	25.6	27.6
2003	26.8	29.2	30.5	29.1	28.6	27.3	27.4	27.6	27.4	28.5	27.5	27.0	28.1
2004	28.4	28.0	30.5	30.6	29.4	27.9	27.3	27.4	28.6	28.3	26.8	27.1	28.4
2005	27.1	29.1	30.2	28.8	30.0	29.9	28.2	29.1	29.4	28.1	28.6	28.2	28.9
2006	28.0	28.1	28.0	28.5	28.6	28.1	25.1	26.4	27.4	29.7	27.8	27.1	27.7
2007	28.0	29.4	30.7	31.2	29.3	28.2	28.0	27.1	27.2	28.6	28.1	26.5	28.5
2008	27.5	28.5	30.4	29.4	30.0	28.6	26.5	28.1	28.1	28.9	28.8	28.3	28.6
2009	27.5	29.8	29.0	28.5	28.4	28.2	26.6	26.0	27.7	27.2	27.0	26.0	27.7
2010	28.0	28.9	29.1	30.5	29.6	31.5		27.0	26.5	28.5		26.5	28.6
2011	28.6	29	30	31	31.30	28	0	25	25,4	29			

Appendix 4: Observed Flow Dayma'ad River

Year Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	0.31	0.21	0.11	3.17	2.78	1.80	1.90	4.06	5.76	12.13	1.75	0.24
1991	0.11	0.14	0.12	0.13	0.91	0.60	3.15	3.57	8.11	1.00	0.28	0.13
1992	0.13	0.11	0.15	3.91	6.07	0.25	1.41	4.46	2.16	2.48	0.82	0.18
1993	0.10	0.15	0.91	3.59	4.73	3.37	2.09	6.93	4.65	2.10	0.37	0.56
1994	0.15	0.13	0.41	1.73	11.49	3.79	0.30	0.36	2.23	3.70	1.10	0.11
1995	0.09	0.10	0.10	1.60	0.72	0.90	12.81	7.41	3.39	7.35	0.39	0.11
1996	0.09	0.08	2.60	4.07	1.03	0.67	6.12	4.97	2.60	2.62	0.88	3.68
1997	0.49	0.48	2.51	1.57	0.84	0.20	0.60	1.90	2.28	3.48	0.34	0.86

1998	0.15	0.13	0.21	1.74	6.67	0.56	5.92	6.66	6.41	1.82	0.43	0.68
1999	0.32	0.27	0.54	1.39	3.43	0.56	2.76	3.95	2.85	9.05	3.07	4.67
2000	2.95	4.27	0.20	2.17	5.48	2.41	2.42	3.33	2.82	4.63	1.85	0.09
2001	0.16	0.26	0.43	0.71	2.17	1.69	2.42	4.25	4.42	4.60	6.96	3.24
2002	0.14	0.14	0.21	1.53	0.45	0.57	1.81	4.08	3.28	5.41	1.42	0.25
2003	0.20	0.10	0.12	3.15	4.22	6.71	10.33	5.32	4.08	1.92	0.30	0.16
2004	0.11	0.22	0.17	3.75	1.88	0.71	2.17	1.69	3.56	17.39	8.59	1.24
2005	12.52	0.33	0.25	0.45	2.48	0.52	4.14	5.47	3.96	23.08	2.72	0.29
2006	0.23	0.16	0.70	1.57	3.40	0.72	9.85	5.66	4.90	5.96	1.90	0.36
2007	0.24	0.19	0.18	0.80	5.17	1.10	2.42	4.25	4.42	9.25	4.39	1.20
2008	0.27	0.24	1.51	12.33	8.03	1.60	1.51	8.81	11.89	6.95	6.42	3.16
2009	0.46	0.24	1.48	13.77	2.30	1.45	2.52	4.04	2.40	6.96	3.24	1.93
2010	4.01	0.40	0.60	2.17	1.94	2.01	8.00	14.14	2.85	4.34	1.23	5.00
2011	0.68	0.60	0.39	1.40	1.19	0.60	4.43	14.42	11.00	10.19	1.53	1.06

Appendix 5: Field Survey Conducting of Dayma'ad River Data with Total station