JIMMA UNIVERSITY
SCHOOL OF POST GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
HYDROLOGY AND HYDRAULIC ENGINEERING CHAIR

Flood Prediction and Modeling: A Case Study of Jimma Town

A Thesis Submitted to School of Post Graduate Studies of Jimma Institute of Technology in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Hydraulic Engineering.

By: Milko Abishu

May, 2019
Jimma, Ethiopia

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Main Advisor: Zeinu Ahmed (PhD)
Co-Advisor: Mohammed Hussen (Msc.)

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DECLARATION

I hereby declare that, this thesis is my original work and that has not been presented and will not be presented by me to other university for similar or any other degree award.

Name: Milko Abishu Signature…………………….

Date………………………….

This thesis has been submitted for Examination with my approval as University Main advisor and Co-advisor

Main advisor:	Signature	Date
Zeinu Ahmed (PhD)	…………………….	…………….
Co-Advisor:		
Mohammed Hussen (Msc.)	……………………..	…………..

APPROVAL SHEET

They undersigned approve that they have read the title entitled: **Flood Prediction and Modeling A Case Study of Jimma town** and here by recommend for acceptance by the Jimma University in partial fulfillment of the requirements for the degree of Master of Science in Hydraulic Engineering.

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ABSTRACT

Nowadays, Floods are the most critical among all natural calamities to many parts of Ethiopia that causes tremendous losses in terms of property and life, particularly in the lowland areas. Jimma town, around bishishe because of heavy rainfall flash floods was occurred it damages homes, and market places with their property. Hence, the core objective of this study was to model and predict flood with respect to rainfall and to find depth and extent flood inundation. Modeling was done by integrating Arc view GIS, Hydrologic Engineering Center-River Analysis System, and related software's. The data used to accomplish those task were secondary data such as (daily stream flow and Rainfall of 15 years), (Soil map and Landuse land cover) was collected from Ministry of Water Resource, irrigation and Electricity, National Meteorological Service Agency, and Ethiopia Mapping Agency respectively. Normal Ratio Method was used for filling missing value of precipitation and using double mass curve consistency of rainfall was checked. Other parameter like Curve Number and basin lag time were generated using Hydrologic Engineering Centers Geo-Spatial Hydrological Modeling System which is an interface between ArcGIS and HEC-HMS. Soil Conservation service curve number, Soil Conservation Service Unit-hydrograph, Monthly constant, and Muskingum were chosen for precipitation loss modeling ,excess precipitation transformation to direct runoff, base flow modeling, and flood routing respectively. Among collected 15 years hydro-meteorological data, 8 events (1995-2002) were used for model calibration and 7 events (2003-2010) were used for model validation. The model performance was evaluated using Nash Sutcliffe Efficiency (NSE) and Coefficient of Determination (R^2).Nash Sutcliffe during calibration and validation was 0.75 and 0.7 respectively where as Coefficient of determination during these two processes are 0.94 and 0.89 respectively. Flood frequency analysis was conducted using HEC-HMS frequency storm method for2,5,10,25,50,and 100 year return period and corresponding results are 19.6m^3/s,28.8m^3/s,35.4m^3/s,44.3m^3/s, 51.2m^3/s, and 58.5m^3/s for respective return period. Flood inundation mapping was modeled for peak discharge of each return period using HEC-RA S and inundation area 71.46ha, 71.66ha, 71.92ha, 90.46ha, 90.68ha, and 90.73ha respectively. Based on the result downstream dwellers of the stream were found to be vulnerable area.

Key Words: Flash Flood, Flood Modeling, HEC-HMS, HEC-RAS, TIN

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ABBREVIATION

a.m.s.l	above mean sea level
CN	Curve Number
DEM	Digital Elevation Model
DTM	Digital Terrain Model
DPPA	Disaster Prevention and Preparedness Agency
EMA	Ethiopia Mapping Agency
ERA	Ethiopia Road Authority
FEMA	Federal Emergency Management Agency
FDPPA	Federal Disasters Prevention and Preparedness Agency
GIS	Geographical Information Systems
HEC	Hydrologic Engineering Center
HEC-HMS	Hydrologic Engineering Centre-Hydrologic Modeling System
HEC-GeoHMS	Hydrologic Engineering Center Geo-Spatial Hydrological Modeling System
HEC-RAS	Hydrologic Engineering Centre-River Analysis System
HEC-GeoRAS	Hydrologic Engineering Centre- Geospatial River Analysis System
IDF	Intensity Duration Frequency
IPCC	Intergovernmental panel Climate Change
MOWRE	Ministry of Water Resource and Energy.
NMSA	National Metrological Service Agency
OFDA/CRED	Office of Foreign Disaster Assistance/ Centre for the Epidemiology of Disaster
1D	One-Dimensional
SRTM	Shutter Radar Topography Mission
TIN	Triangular Irregular Network
USACE	United State Army Corps of Engineers
USGS	United State Geological Survey

1. INTRODUCTION

1.1. Background of the Study

Floods are the costliest natural disasters in the word's accounts for 31 percent of economic loss resulting from natural catastrophes (Munich, 2007).Compared with other natural disaster (drought, volcanic eruptions, Landslides, forest fires…etc) floods have greatest destructive potential and affect people through the world. It is the most common natural hazard that can happen any time in wide variety of location due to high intensity rainfall events, hurricanes, tidal waves and melting ice/snow. Such floods are the most frequent and devastating natural disasters in both developed and developing countries. Between 2000 and 2008 East Africa has experienced many episodes of flooding (OFDA/CRED, 2008).Such high intensity rainfall events along the change in the land use patterns are expected to have inferences on the intensity of river flooding and local flash flooding in a flood plain region can substantially alter the spatial extent of future floods . According to OFDA/CRED (2008) data base, 119, 156, and 952 flood deaths have been occurred in 2003, 2005, and 2006 respectively in different parts of Ethiopia.

Flooding is common in Ethiopia during its four months of rainy seasons (June-September) (FDPPA, 2007). Our country, Ethiopia experiences two types of floods: - flash floods and river floods. Flash floods are one formed from excess rains falling on upstream watershed and gush downstream with massive concentration, speed and force, often resulting in considerable losses of human life and property. It is a short duration event caused by high peak discharge and they are short -term inundation of small area such as a town or part of a city, usually by tributaries and creeks (Few, 2006).The basic cause of flash floods are intensity, duration and distributions of rainfall, steep slope and sedimentations of reservoir channels, absence of vegetation, poor soil infiltration capacity, failure of hydraulic structure (dam, reservoir…etc), sudden release of water from dams, landslides (Samson, 2008). Therefore, such floods often results considerable toll, damages became especially pronounced and devastating when they pass across or along human settlements and infrastructure. The incident 2006 Diredawa city experienced is the most typical example of flash flood in which 9,956 people were displaced and 256 people killed (FDPPA, 2007).

Jimma town also faced such problems in August 2017. Flash floods occurred in this town is because of heavy rainfall from Limu highlands and surrounding mountains. Floods at that time have destroyed homes, public institutions, market places with their property, and infrastructures but human death was not occurred. In addition to that, flash floods were also hits Dippo Condominium in July 2016 and also in May, 27, 2018 the homes of dwellers found on the floor was affected by this floods. The reason why floods occurred was as a result of excess rains falling on the upstream of Abba Jifar mountains and very steep mountains surrounding the town and take to downstream, it collects various solid waste that close drainage ditch.

On the other hand, much of flood disasters in Ethiopia are attributed to rivers that overflow or burst their banks and inundate downstream plain lands. It usually occurs in lowland part of Ethiopia as a result of heavy rains in the highland parts of the country. The magnitude of these types of floods depends on many factors such as catchment size, intensity of rainfall and amount of precipitation that fall in to watershed and tributaries, topography, anthropogenic activities in the catchment area, drainage basin(Bonaci et al. ,2008).

Natural hazard in Ethiopia are strongly related to climate change and have great impact on food security of large part of population. Ongoing climate change might greatly impact on the occurrence and severity of hazard and increase people vulnerability. The (Fourth Assessment report, 2007) of the Intergovernmental panel of climate change (IPCC) predicts that heavy precipitation events, which are very likely to increase frequency, will augment/increase/ flood risk. Flood in urban areas causing several problems, as urban areas mostly consists impervious surfaces, they even more prone to the negative effects of flash floods. These floods are associated with short and intensive precipitation and mostly impact small basins (less than $1000km^2$) (Marchi et al., 2010). Flash floods in Jimma town is a serious problem that have to be considered since it regularly occur in the city within less than 3 years shortest intervals and damages property. Even though it is impossible to avoid damage risk or prevent their occurrence but can reduce their effects by various engineering techniques. Hence, the core objective of this study is to model and predict flood with respect to rainfall and to find depth and extent of flood inundation. This was accomplished by collecting necessary secondary data from different organization and Modeling was done in this study by integrating ArcGIS, HEC-GeoHMS, HEC-RAS, HEC-HMS, and HEC-GeoRAS modeling software's.

Flood hazard maps can also be prepared at high resolution with better accuracy for preparedness planning. Therefore, the necessity of understanding the phenomena of flooding of the river and flash floods and, to identify and map vulnerable areas for proper management and mitigation of floods is becoming essential to minimize damage occurred annually. By using geographic information system (GIS) software and remote sensing technique flash flood hazard maps can be generated which are an important tool for municipal, urban growth planning and emergency action plans (Elkhrachy,2017).For this study, integrating of HEC-GeoRAS, HEC-RAS, and Arc-GIS was used to prepare inundation map (inundation extent and depth) within the area for floods of different return periods and also HEC-HMS and its extension were used to determine peak discharge of the stream for different return period.

1.2. Statement of the Problem

Floods are the costliest natural disasters in the word's accounts for 31 percent of economic loss resulting from natural catastrophes (Munich, 2007). Such floods are among the most devastating and frequent natural hazard in Africa, where as Flash floods are among the greatest hazard arising from tropical cyclone and severe storms of unusual metrological combination sometimes combined with melting snow on the catchment. The problem is more acute in highland areas like Ethiopia under strong environmental degradation due to population pressure. The damage caused by Flash floods and floods include loss of life and property, displacement of people, disruption of socio economic activities, loss of valuable agricultural lands, famine, spread of epidemic disease such as Malaria, Cholera, Dysentery. The economic loss due to flash floods are one of the most considerable natural hazard and concern hydrological, climate or natural hazard sciences due to their frequency, amount of people affected on global scale and actual fatalities (Marchi et.al,2010).

In last decades the frequency of flash floods markedly increased, all over Ethiopia, which caused a number of fatalities and large amount of property damage. The occurrence of such flood is recorded mainly a in semi-arid area which is associated with climate change, and with monsoon like rainfall distribution a typical of Ethiopia and an annual rainfall around 500-700mm. Jimma town which is surrounded by steeply or hilly topography is subjected to frequent flooding in rainy seasons. The occurrence of road over flooding on Oct.7, 2013 in the town which was forced to stop vehicles for some hours (Getachow, et al., 2015).

Also flash floods was occurred in the town in July, 2016 (Dippo Condominium), August 23, 2017 around Hirmata Bishishe market due to heavy rainfall Awetu stream overflows also May, 27, 2018 (Dippo Condominium and Kochi home) as a result of heavy rainfall a lot of public property were damaged, market places with their property were also damaged, So flash floods in Jimma town occurs yearly (within less than 3 years) it is a serious problems have to be considered. With the advancement of new technology on flood modeling such as the hydrologic and hydraulic modeling, and GIS these days, it is possible to model flood extent, depth, and distribution etc.

Figure 1.1: Picture Showing Flood Damage occurred May, 27, 2018 Dippo Condominium.

1.3. Objectives of the Study

1.3.1. General Objective

The overall objective of this study was to predict; model flood and flood inundation areas of the streams in the Jimma town.

1.3.2. Specific Objectives

The specific objectives were outlined as follows:-

1. To estimate Peak discharge of the streams for different return periods.
2. To identify areas most prone to flooding problems
3. To identify causative factors of floods in the towns

1.4. Research Questions

The researchers seek out answer to the following basic questions.

1. How much is Peak discharge of the stream for different return period?
2. Which part and how much of the town area is vulnerable to flood hazard? , and who are more affected by this flooding, upstream dwellers or downstream dwellers?
3. What is the main cause (source) of floods in Jimma town?

1.5. Significance of the Study

The primarily purpose of this study was requirement of partial fulfillment of Masters of Science in Hydraulic Engineering. In addition, the study may serve as an input for the planners, decision makers, and any concerned body to understand consequence of flood on hydrological variables and their impact on Jimma water resource planning and management. Also it serves as pave way for those who want to do further research on areas under investigation. The finding from the study can be used for city planners, Policy makers, and Environmental planners. Also it can be useful to the government to control flood during monsoon season.

1.6. Scope and Limitation of the Study

The study was geographically limited to Awetu and Kito stream catchment which are found in Jimma town. Also the study was limited to analysis of 15 years rainfall data of four stations (1995-2010) and, stream flow data, and then computing the peak runoff discharge that cause damages by the help of selected software. Generally, the study investigates flood problems which have been occurred in the town. So, conclusion and recommendation were also made.

1.7. Thesis Outline

This thesis was organized in to five chapters and it is organized as follows. Chapter one gives a general introduction of the study area with its background, statement of problem, objectives and research questions, significance of the study, and scope and limitation of the study. Chapter two describes the literature review related to the study. In Chapter three each Materials and Methodology was discussed in detail and also gives brief description of the study area, includes location, Topography, climate ,rainfall, hydrology, land use land cover, Soil type , data collection , data preparation and analysis, filling missed data and Checking consistency of rainfall data ,Hydrologic modeling, and Hydraulic modeling were presented in detail. Chapter four concerned with Result and Discussion of the study, model calibration and Validation result, as well as Model performance was described in detail. Conclusions and recommendations of the thesis are discussed in chapter five. Finally, references and appendix in the form of tables and figures and serving as supporting document for this thesis are attached to make a work a complete.

2. LITERATURE REVIEW

2.1. Flood Modeling

Flood modeling comprises two components, the hydrologic and hydraulic modeling which makes use of modeling programs HEC-HMS and HEC-RAS of the US Army Corps. Hydrologic modeling which refers to rainfall-runoff simulation give rise to a discharge hydrograph as a result of particular rainfall event while hydraulic modeling refers to the simulation of flood water movement through waterways and flood plain along with the computed flood height and flow patterns using the HMS simulated flow data (US Army Corps of Engineering,2010).

Flood modeling is one of the engineering tools which provide accurate information of the flood profile also, it is one of means to understand the behavior of flood in particular area where as, Model simulation can provide flood depth and extent so, Flood model can either be used in planning and design, land use zoning or flood forecasting. Government authority usually use flood models in the determining flood hazard zone and flood extent in their locality (Roy, 2008).The flood hazard is especially related to flood risk, source area, rainfall intensity, and main drainage area as pathways and the most important part of flood risk identification and management is the flood prone area (extent) delineation; which are subjected to inundation as a result of flooding with certain frequency (USACE, 2006).

2.2. Hydrologic and Hydraulic Flood Modeling.

The Hydrologic modeling is done by using HEC-HMS (Hydrologic Engineering Centers-Hydrologic Modeling Systems) model by giving the meteorological data and other necessary data as input and flood hydrograph is derived from specific rainfall event. Hydrologic modeling develop rainfall-runoff hydrograph from a design rainfall or historic rainfall event (USACE, 2010). The output from HEC-HMS model is given as input to HEC-RAS (River Analysis System) along with necessary geometric data and boundary conditions for generating water surface profile also, Hydraulic model, used to route the runoff from river channel to determine water surface profiles and flow velocity (USACE, 2006).

2.3. Selection of Model

Selecting the best and appropriate model is an essential part in any research work. There are various criteria for choosing the most suitable model. According to Cunderlik and Simonovic (2003), the choice depends mainly on the requirement and needs of the research. Cunderlik and Simonovic put the following criteria:

a) Required output of the model
b) Availability of input data
c) Prices and availability of the model
d) The model structure

There are different flood modeling tools which have their own distinct model structure and solution procedures. Most widely used 1D flood modeling tools are: HEC-RAS and MIKEII .etc. Although today's researchers prefer 1D interaction flood models, the use of one dimensional flood model has also great significance in the research areas (Dhondia and Stelling, 2002). In this thesis 1D hydraulic model with ArcGIS was used, the model has capability to simulate flood plain areas with great accuracy. Also, HEC-HMS was used which is freely available from United States Army Corps of Engineers (USACE).Model has strong focus on flood modeling and engineering design (acknowledged by Federal Emergency Management Agency, FEMA) and it has linkage to other HEC models. The Models selected for this particular thesis are discussed as follows:

2.3.1. Hydrologic Model (HEC-HMS)

HEC-HMS is a physically based, semi-distributed hydrologic model developed by the US Army Corps of Engineers to simulate the hydrologic response of a watershed subject to a given hydro metrological input and It is a software is specifically designed to simulate precipitation-runoff process of watershed systems (USACE, 2010).It is comprised of a graphical user interface (GUI), integrated hydrologic analysis components, data storage and management capabilities, graphics and reporting facilities (USACE, 2010).HEC-HMS was used as hydrologic model which is linked to GIS using HEC-GeoHMS extension to extract geospatial input data. HEC-HMS modeling is dependent on three components: the basin model, metrological model, and a set of control specification indicating the time step and simulation period. The model uses DEM information to partition the sub basins in to sub watersheds and can simulate individual storm events as well as continuous precipitation input at minute, hourly, or daily time steps. The HEC-HMS offers a variety of model options to simulate runoff production, at the hill slope scale and flow channels. This includes SCS curve number, SCS unit hydrograph, and Base flow estimation methods which are necessary to calculate water losses, runoff transformation, and base flow rates respectively.

a). Basin model

The basin model defines the hydrologic connectivity of the watershed, how rainfall is converted to runoff, and how water is routed from one location to another. Its principal purpose is to convert atmospheric conditions in to stream flow at specific locations in the catchment. The basin model is responsible for describing physical properties of the watershed and the topology of the stream network. It contains hydrologic elements (Sub basin, reach, junction, reservoir, diversion, source and sink) and their connectivity that represents the movement of water through drainage system (USACE-HEC, 2006).It also contains the modeling components that describe catchment area, infiltration, surface runoff and channel routing. Outflow is computed from meteorological data by subtracting losses of basin and transforming excess precipitation through the basin.

b).Meteorological model

Meteorologic models are one of the main components in an HEC-HMS project that is used to specify how much precipitation will be generated for each sub basin. The meteorological model stores precipitation data that defines when, where, and how much it rains over the watershed. It is a set of information required to define historical or hypothetical precipitation to be used in conjunction with basin model. In meteorological model, the Specified hyetograph was used to produce runoff from a given precipitation data. The meteorologic model can utilize both point and gridded precipitation and has capability to model frozen and liquid precipitation along with evapotranspiration. The newly added snowmelt method uses a temperature index algorithm to calculate the accumulation and melt of snow pack. The evapotranspiration methods include the monthly average method and the new priestly Taylor and gridded priestly Taylor methods. An evapotranspiration method only required when simulating the continuous or long term hydrologic response in a watershed (USACE-HEC-1, 2010).

c).Control Specification

The control Specification defines time-related information for a simulation, including the starting and ending dates and the time interval for the computations. The time step for HEC-HMS model calibration for the catchment is divided into different time steps as calibration, simulation, and verification (USACE, 2006).After creating basin module then, HEC-HMS model was runned to obtain output peak discharge then; each model run combines a basin model, meteorological model, and control specification with run options to obtain results (Choudhari et al., 2014).

2.3.2. HEC-GeoHMS

HEC-GeoHMS is a set of Arc GIS tools specifically designed to process geospatial data and create input files for the Hydrological Engineering Centers Hydrological Modeling Systems (HEC-HMS). It includes integrated data management and graphical user interface (GUI).Through the GUI, which consists of menu, tools, and buttons, the user can analyze the terrain information, delineate sub basins and streams, and prepare hydrological inputs. In HEC-GeoHMS basin was disintegrated into sub basins (USACE, 2003). HEC-HMS takes basin module created by HEC-GeoHMS to derive flood hydrograph and peak flood discharge for specific rainfall event.

2.3.2.1. Terrain Processing using HEC-GeoHMS

Terrain processing is used to generate hydrologic parameters using DEM. Hydrologic derivatives including fill sink, flow direction, flow accumulations, watershed sub delineations and stream segmentations, and every stream segment defined by stream segmentation grid and following delineation of corresponding watershed. In HEC-GeoHMS basin was disintegrated into sub basins. Then the physical characteristics of watersheds such as river length slope and longest flow path for each sub basin was extracted. The result from terrain processing can be used to create input files for hydrologic models using HEC-GeoHMS. HEC-HMS accepts these hydrological inputs as a starting point for hydrologic modeling (USACE, 2003).

2.3.3. Hydraulic Model Data (HEC-RAS)

HEC-RAS is an integrated package of hydraulic analysis programs, in which user interacts with the system through the use of Graphical user interface(GUI).The flood plain visualization was carried out using one dimensional numerical model HEC-RAS. HEC-GeoRAS, which is an

ArcGIS extension, is used as the interface between HEC-RAS and GIS for preprocessing and post processing of the data in GIS. The output from HEC-HMS model is given as input to HEC-RAS (River Analysis System) along with the necessary geometric data and boundary conditions for generating water surface profile. The geometric data of the flood plain and river is obtained from the digital elevation model (DEM) for the points where the plain showing less number of cross- sections. Water surface profiles along the river reach, floods of various return periods were computed with sub critical flow, super critical or mixed simulation and these profiles were exported to GIS and water surface Triangular Irregular Network (TIN) was generated then, An intersection of the terrain TIN and water surface TIN results in flood inundation map (USACE, 2010).HEC-RAS uses a number of input parameters for analysis of the stream channel geometry and water flow. These parameters are used to establish a series of cross-sections along the stream. In each cross-section, the locations of the stream banks are identified and used to divide in to segments of left floodway (overbank), main channel, and right floodway .At each cross section, HEC-RAS uses several input parameters to describe shape, elevation, and relative location along the stream: River station (cross-section) number, Left and right bank station locations, Manning's roughness coefficients (may vary horizontally or vertically), Channel contraction expansion coefficients, Geometric description of any hydraulic structures such as bridges, culverts, and weirs(USACE,2010).

2.3.4. HEC-GeoRAS and TIN

HEC-GeoRAS, an extension of ArcGIS (USACE, 2009) is used for the preparation of spatial data for input in to a HEC-RAS hydraulic model and the generation geographic information system (GIS) data from the output of HEC-RAS for use in flood plain mapping. The GEORAS software assists in the preparation of geometric data for import in to HEC-RAS and generation of GIS data from exported HEC-RAS simulation results. GeoRAS is an ArcGIS extension developed by the US Army Corps of Engineers designed specifically to improve the data input process for HEC-RAS. Operating within the ArcGIS, GeoRAS uses spatial data to develop, organize, and automatically enter input data in to the HEC-RAS model. One of the limitations of HEC-GeoRAS is that the modeler are forced to use the stream geometry data extraction preprocessing in HEC-GeoRAS to ultimately use the post processing visualization tools. Even when surveyed data is accurate and geo-referenced by the stream network, the geometry extraction from the terrain model is still required (USACE, 2009).

2.4. Remote Sensing and Geographic Information System in Flood Modeling

Remote sensing is the process of gathering catchment information and hydrologic state variable using measured electromagnetic spectrum (Maidment, 1993). In Remote sensing electromagnetic energy is measured through use of sensors. The sensors that are used for hydrological application can be either passive or active and it covers a broad range of the electromagnetic spectrum. Data acquired through remote sensing tremendously trigger advancements in flood modeling. Geographic information system is a system that facilitates the preparation and analysis of georeferenced data (Roy, 2008). With the use of GIS, data handling and pre-processing in Flood modeling can be done systematically. Many GIS integrated modeling applications have capitalized on using the GIS as a database manager and visualization tools.

2.4.1. Watershed Delineation

The catchment area or drainage basin that drains in to a common outlet defines a watershed. Simply watershed of a particular outlet is defined as an area, which collects the rainwater and drain through gullies to a single outlet. Delineation of watershed means determining the boundary of the watershed i.e. ridgeline. GIS uses DEM as inputs to delineate watershed with integration of Arc SWAT or by hydrology tool in Arc GIS spatial analysis (Winchell, 2008).

2.5. Flood Magnitude Estimation Method

Hydrology deals with estimating magnitude of floods because of precipitation. Many hydrological methods are available to estimate the magnitude of peak floods discharge and runoff hydrograph for the given site. Each method has a range of applications and limitation. Among them Rational method, Soil Conservation Service (SCS), and other Unit Hydrograph methods, Regression equations, and analysis of stream gage data were explained below. The choice of these methods depends on data available and practical existing situations. If possible the method shall be calibrated to local condition and tested for accuracy and reliability (ERA Drainage Manual, 2002).

2.5.1. Rational Method

The Rational Method is more accurate for estimating the design storm peak runoff for areas up to 50ha (0.5km^2). It provides peak runoff rates for small and rural catchment areas, but least suited to urban storm drain systems and rural ditches. It shall be used with caution if the time of concentration used exceeds 30 minutes. A rational approach used to obtain yield of catchment by assuming a suitable runoff coefficient.

It estimates peak runoff at any location in catchment area as a function of catchment areas, runoff coefficient, and rainfall intensity for duration equal to the time of concentration. The Rational formula is expressed by:-

Q=0.0278CIA ………………………………………………………………………………. (2.1)

Where, Q- Maximum rate of runoff(m^3/s);C-Runoff Coefficient representing ratio of runoff to rainfall; I-Average rainfall intensity for a duration equal to the time of concentration for selected return period(mm/hr);A-Catchment area for tributary to design location(ha).

2.5.2. Soil Conservation Service (SCS) Synthetic Unit Hydrograph

The U.S. Soil Conservation Service has developed a synthetic unit hydrograph procedure to that has been used widely for developing rural and urban hydrograph. The Unit hydrograph used by SCS method is based on an analysis of large number of natural unit from broad cross section of geographic locations and hydrologic regions. It is used for catchment area greater than 50ha (0.5km^2). This technique requires the same basic data as rational method: Catchment area, runoff factors, time of concentration, and rainfall. With Soil Conservation Service method, the direct runoff can be calculated for any storm either real or fabricated by subtracting infiltration and other losses from rainfall to obtain excess precipitation. It is based on 24-hour storm event. The relationship between accumulated rainfall and accumulated runoff was derived by SCS from of experimental plots of numerous hydrologic and vegetative cover conditions. Data for land treatment measures such as contours and terracing from experimental catchment areas for which daily rainfall and catchment area data that included total amount of rainfall in a calendar day but not its distributions with respect to time. The SCS runoff equation is therefore a method of estimating direct runoff from 24-hours or 1-day storm rainfall. The equation is:-

$$P_e = \frac{(P- Ia)2}{P-I_a+ S}$$ ……………………………………………………………………...….. (2.2)

Where, P_e = accumulated precipitation excess at time t, (mm), P = accumulated rainfall depth (potential maximum runoff) at time t, (mm), I_a =the Initial abstraction (initial loss) including surface storage, interception, and infiltration prior to runoff, (mm), S = Potential maximum retention, a measure of ability of watershed to abstract and retain storm precipitation

Analysis of results from many experimental watersheds, the SCS developed an empirical relationship of I_a and S:

I_a= 0.2S, therefore, cumulative excess at time t is:

$$P_e = \frac{(P-0.2S)^2}{P+0.8S} \quad \text{.....................} (2.3)$$

The maximum retention, S, and watershed characteristics are related through an intermediate parameter the curve number (CN) it is given as:

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \quad \text{.....................} (2.4)$$

Where S in, (mm).

2.5.3. Regression Equations

Peak flow can be calculated using regression equation developed for specific geographic regions. Where dependent variable would be the peak flow for the given frequency, and the independent variable may be area, slope, channel geometry and other metrological, physical or site specific data. Regression equations commonly accepted method for estimating peak flow at ungaged site or site with insufficient data (ERA Drainage Manual, 2002).This method is accurate, reliable, and easy as well as provide consistent finding. It is one of the preferred methods for estimating peak flow for larger catchment areas and should be used routinely in design. This equation is used to relate parameters such as the peak flow or some other flood characteristics at specified recurrence interval to the catchment area's physiographic, hydrologic, meteorological characteristics or as alternatives, to the channel geometry characteristics at site. A regional approach to estimating floods at ungaged sites can be adapted using regression model to predict flood.

2.5.4. Analysis of Stream Gauge Data

They can be used to develop Peak discharges and hydrograph. The analysis of gauged data permits an estimate of Peak discharge for the desired return period at a site. If a project is located near one of gauging station record is sufficient length, flood estimation has to be made. The most important aspect of applicable station record is the series of annual peak discharge. The stream gauge analysis used for design, when there sufficient years of measured or synthesized recorded discharge data. Two methods are used for estimating flood frequency curves from stream gauge data these are Gumbel method and Statistical method, which makes use of the Log Pearson Type III frequency distribution. Which is more representative of naturally occurring floods and reliable when used for prediction (ERA Drainage Manual, 2002).

2.6. Concepts and Practices of Flood Mitigations Alternatives

The hazard of flooding is receiving increasing attention in both public and professional arenas. Flooding is a disastrous natural phenomenon, producing many socio economic and environmental consequences within the affected flood plain. Flood risk are rising many parts of the world owing to continually increasing populations and rapidly escalating land development (Walker and Maidment, 2006).Studies have shown that more than one third of the world's land area is flood prone, and about 196 million people in more than 90 countries are exposed to catastrophic flooding (United Nation Development Programme (UNDP), 2004).As a result of, the frequency, extent, and subsequent hazard associated with flooding are global concerns. Flood hazard mitigation plans could be implemented as either Structural or Non structural measures, depending on the particular case (Correia et al., 1999).These measures involve managing the effects of flooding and preventing the negative consequences. Structural measures, including Levees, high flow diversion, channel modifications and dams, could be implemented to mitigate flood risk by reducing the volume of runoff, water level or extent of the of area flooding. However, Non structural methods, such as flood insurance, land use regulation and flood forecasting, serve as preventive measures for reducing flood hazards. Structural measures are favored in situations in which portions of adjacent residential areas are situated about the maximum flood level, or when it is important to protect land adjoining a river from inundations due to an existing flood risk. By implementing structural measures, flood hazards for these kind of areas are reduced. However, structural flood control methods like channelization have some predictable negative effects. Studies have shown that sediment loads may increase below channelization works and other river training measures (Hill, 1976). Moreover, changes may occur in discharge characteristics below channelization works; in particular, flood level may be increased downstream (Brookes, 1987). Interaction between river flow and stream channel is dynamic, constantly responding to natural and human induced river and flood plain changes. Finding sustainable mitigation measures for flood hazards is made difficult by complex and dynamic interrelationships of environmental, technical, economic and managerial factors in river systems. Therefore, accurate simulation of water surface profiles and reliable delineation of flood extents and depths within flood plain (Pappenberger et al., 2005), as well as understanding of the complex interaction between flood mitigation measures and river systems, combined with socio economic impacts(Tefera,2015) are necessary for flood mitigation planning and flood plain management.

2.7. Previous Studies in the Area

In Ethiopia several studies have been carried out on: - Assessment of flood risk in Diredawa using GIS by (Daniel, 2007) he analyze flood risk using Multi Criteria Evaluation (MCE). To run Multi Criteria Evaluation the selected flood disasters causative factors such as elevation, Slope, drainage density, road density and land use were developed and weighted, and then weighted overlay technique was computed in ArcGIS9.1 model builder to generate flood hazard map., there were also other title entitled on ‘Socio- Economic impact of flooding in Diredawa’ (Alemu, 2009).He focused on flood causative factors and impacts of flooding on socio-economic of Diredawa. The study employed on trend analysis: - SCS-CN, inundation analysis of high intensity rainfall by severe forest degradation caused increased flood damage in impact area. The study entitled on ‘Drought and Flood over upper catchment of Blue Nile’. It focuses on factors which affect severity of flood includes terrain slope, Soil type, and amount of water in the soil. However, in Jimma area the title entitled on ‘Community Awareness and Perception on Natural hazard in Jimma zone south west Ethiopia (Kifle, 2013). The objective of the study was to asses ‘level of awareness to rural community’. It was community based cross sectional survey. The study entitled on ‘Assessment of Effect of Urban road drainage at Ginjo Guduru Keble of Jimma town’ (Getachow et.al, 2015). Based on cross sectional studies they focused on damage to road in surface material and flooding in the area. Awetu river basin which is part of Omo river basin, even considered as main source of flood water in the low- lying areas. So, along Awetu and Kitto stream must requires more studies. Most studies conducted on the area are about Assessment of Drinking Water Quality and Pollution profiles along Awetu stream (Israel, 2007).But, flood

Modeling and Prediction with updated data has not fully studied in the sub basin. Normally area is susceptible to high flood due to topography of the area which varies from very mountainous to very plate land, which greatly enhances the creation of flood with heavy rainfall. Looking at these problems different bodies have high lightly revised the area concerning flood protection but not on the detail flood modeling and prediction that is why the problem has stayed without any solution up to now.

Even though the Jimma town is characterized as high flood prone area during rainy seasons, there are still few studies applied. In the town due to blockage by debris around the stream and the flooding extended to the surrounding residential building causing damage to life and property. Now, the target of this paper is to update the previous studies, use the recent data and giving attention on the flood problem of the area to predict and model flood.

3. MATERIALS AND METHODS

3.1. General Description of the Study area

3.1.1. Location

Jimma town is found in Oromia regional state, which is the largest city in southwestern part of Ethiopia at about 345km from Addis Ababa, capital city of Ethiopia. Geographically, it is located in between 7˚40'N and 7º45’ Latitude, and 36º45’and 36º50’E longitude. The town has surface area of 4623ha from this total area of study area in this particular work is 215km^2.Based on the 2007 Ethiopia population Census conducted by Central Statistical Agency of Ethiopia, the town has total population of 120,960 of which 60824 are men and 60136 are women. The town was located on gentle to irregular slopes with altitude varying between 1718-1842m a.m.s.l .Topographically it exhibits features of upper part of omo-gibe river basin made up of gentle slope. The city lies on a low hill on the left side of the wide alluvial plain of the river Gibe and it is crossed by small streams and it is surrounded by high steeply mountain in north and northeast. It was found in the upper part of Omo-Gibe river basin which drains in to Lake Turkana (Getachow, et.al, 2015).

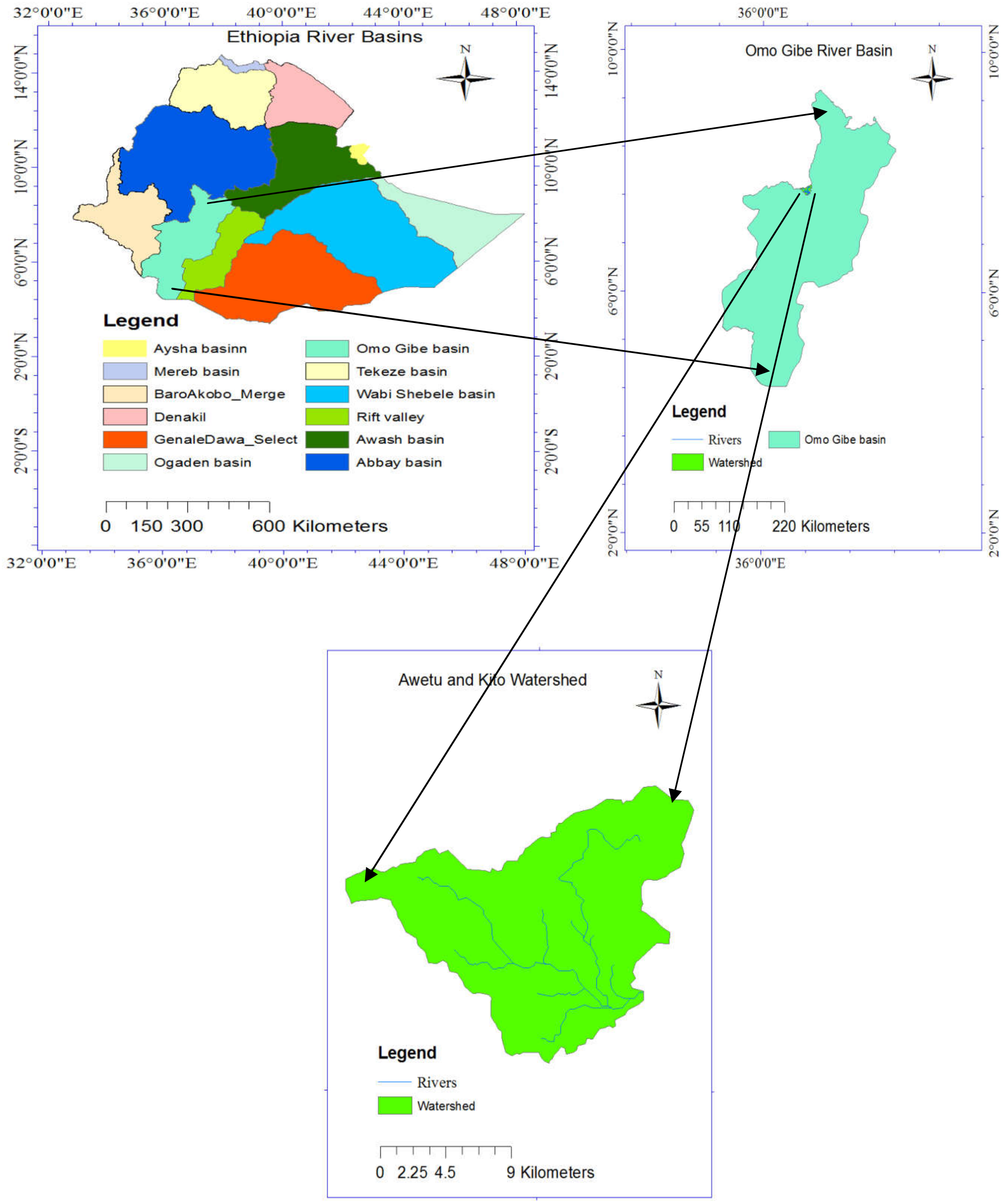

Figure 3.1: Map of the Study area.

3.1.2. Climate and Hydrology

Jimma town has tropical rainforest climate. The town was generally characterized by warm climate with mean annual maximum temperature of 30ºc and mean annual minimum temperature of 14ºc. The highest mean temperature was always in February or March. The annual average rainfall ranges from 1800mm-2300mm. Maximum precipitation occurs during four month period of rainy seasons June to September with minimum December and January. The town was drained by two streams, Awetu and Kito, which subsequently join Gilgelgibe. Kito sub basins drains by kito stream finally join Awetu stream at the dedo bridge (Israel, 2007). Kito stream passes through kito wetland. At the downstream direction, Awetu stream, which is known to carry Jimma town's domestic solid and liquid waste, joins with the Kito stream. Awetu stream is a perennial stream originate from north of the town and flows along the middle of the valley in the south direction. After the confluence area of Kito and Awetu streams, Boye wetland is located and it is continuously fed by Awetu stream which passing through this wetland and finally joins the Gilgelgibe River. Near the town slopes are gentle and land adjacent to some rivers and streams tends to swampy. Furthermore, these area floods during rainy season.

3.1.3. Digital Elevation Model (DEM)

Topography is defined by a Digital Elevation Model (DEM), which describes the elevation of any point in a given area at a specific spatial resolution. DEM describes the elevation of any point in the study area in digital format (raster cell) and contains information on drainage, crest and breaks of slope.DEM is used to analyze the drainage pattern of watershed, slope, stream length, and width of channel within the watershed.DEM used for this study was downloaded from United State Geological Survey, (USGS) website.

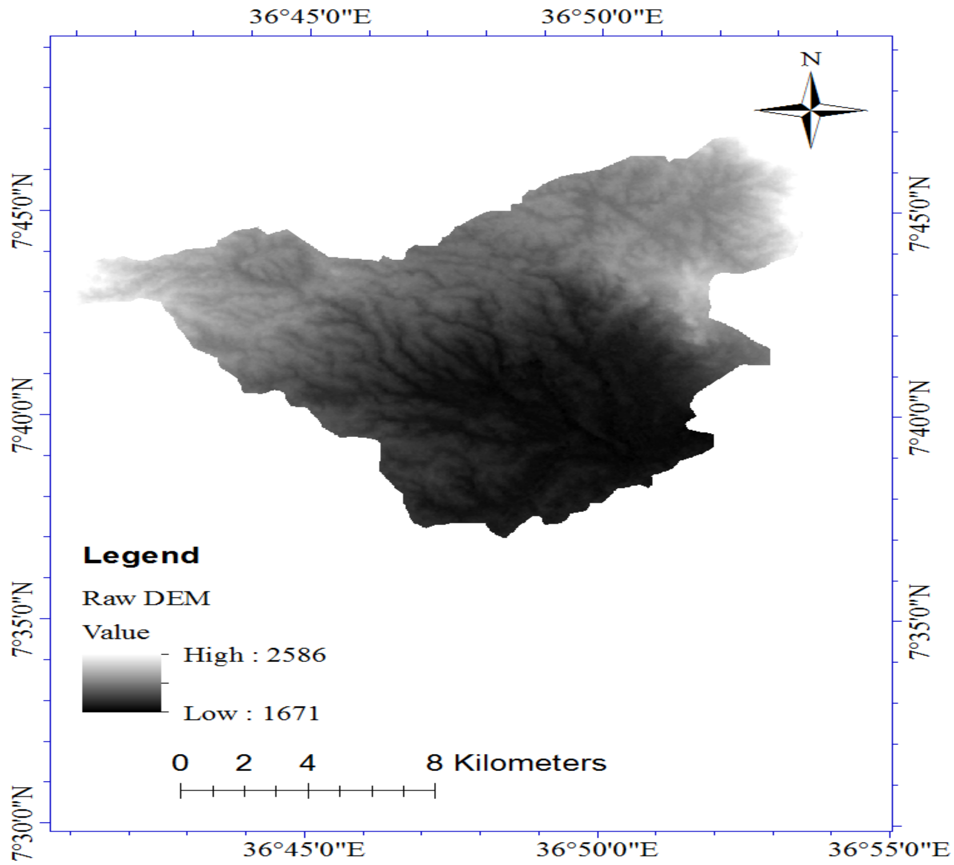

Figure 3.2: 30m by 30m resolution DEM of the study area

3.1.4. Land use Land cover of the Catchment

Land use/cover types of the watershed was classified as Forest land, Grass land, Shrub land, Agricultural land, Bare land ,Wet land, and Wood land. Most of the catchment area is mainly dominated by forest and Agricultural (cultivated land).Small part of the study area was covered by Wood land and bare land as it was shown below from map.

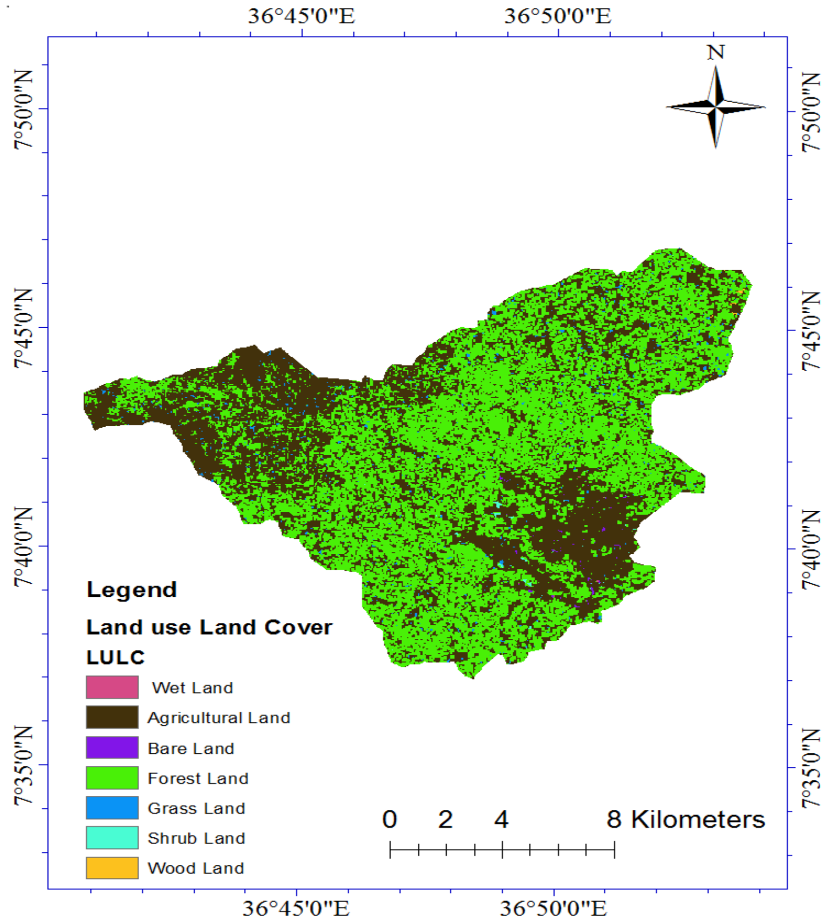

Figure 3.3: Land use Land cover of the Study area.

3.1.5. Soil type of the Catchment

The soil types of the study area are mainly classified as: - dystric nitisols, dystric fluvisols, chromic vertisols, eutric nitisols, orthic acrisols, and eutric fluvisols. As it is shown below from soil map; the catchment was dominated by dystric nitisols and eutric fluvisols. These two soil types cover almost 50% of the area.

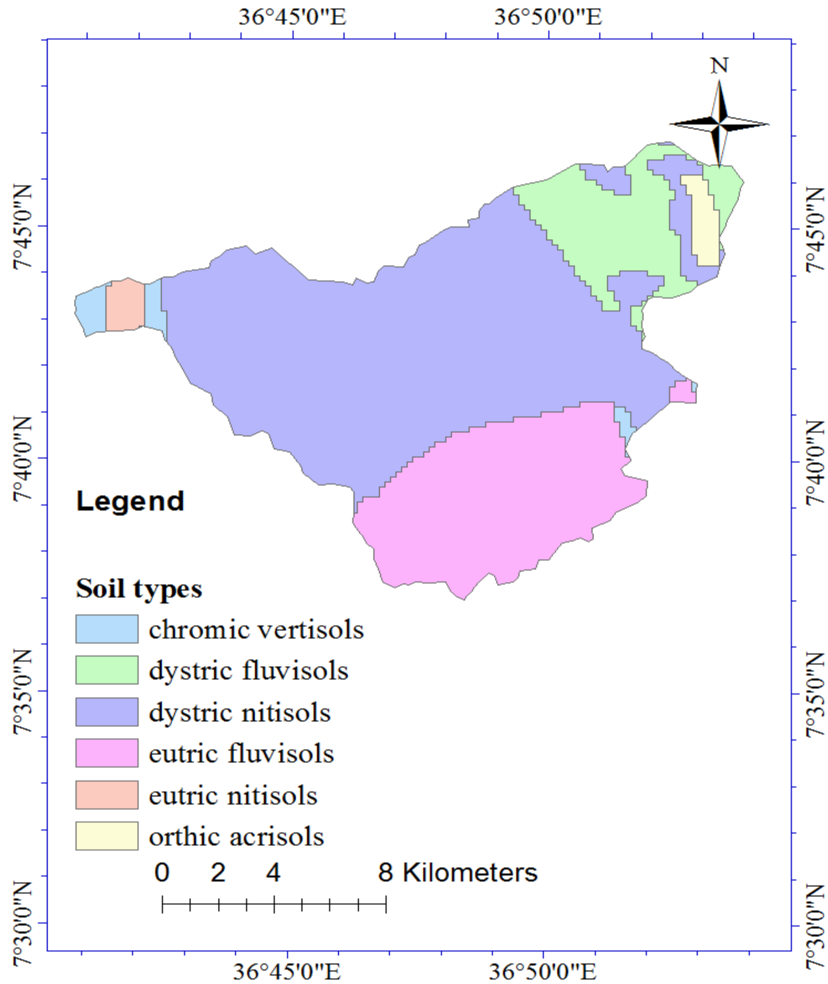

Figure 3.4: Soil type of the Study area

3.2. Materials Used

The materials used for this particular study include some important Software such as:-

A).Arc-GIS 10.2 Version

Arc-GIS were used to clip Omo-gibe basin from Ethio basins; also it was used for mapping and spatial analysis.

B).Microsoft excel spread sheet:-MS-excel used for transposing daily hydrological data.

C). HEC-HMS Version 4.2.1.

HEC-HMS is used to simulate precipitation-runoff process, for estimation of discharge hydrograph as a result of particular rainfall event, to estimate Peak flow rates (Peak discharge).

D) HEC-GeoHMS Version 10.2:-HEC-GeoHMS is used for generation of input data for HEC-HMS.

E).HEC-GeoRAS VERSION 10.2(Pre and PostRAS) and HEC-RAS (Hydrologic Engineering Center River Analysis System):-is used to assists in the preparation of geometric data for import in to HEC-RAS, to generate GIS data from exported HEC-RAS simulation results, for flood inundation mapping.

HEC-RAS is used:-to know Water surface elevation visualization of stream flow, which shows extent of flooding, to obtain flood extent and depth.

In addition to the above listed software spatial data such as (DEM, Land use land cover map, Soil map) and Meteorological and hydrological (RF, Stream flow) was used.

A).Digital Elevation Model (DEM):- DEM of 30m by 30m was downloaded from the United States Geological Survey (USGS) website by path and row search of the study area via dataset of a digital elevation of Shutter Radar Topography Mission (SRTM) and it has been used as main input data to delineate watershed of the study area.

B).Land use land cover map: - Ethiopia Land use land cover classification of 2013 was used as input for Land use land cover classification of the study area which was used to know land cover categories and also Ethio soil was used to know the soil type of the area.

C) Meteorological and Hydrological Data: - Data like rainfall and temperature has been taken from National Meteorological Service Agency (NMSA) and stream flow data from (MOWRE) were used.

3.3. Methods

3.3.1. Data Collection/Acquisition/

Before conducting any research, it is imperative to make tough search for data. After collection of data to begin any hydrological data it is important to make sure that data are homogenous, correct, sufficient, and complete with no missing values. Errors resulting from lack of appropriate data processing are serious because they lead to bias in the final answers (Vedula, 2005). Generally, data should be appropriately adjusted for inconsistency, corrected for errors, extended for insufficient, and filled for missing using different techniques before using them.

The data used in this study were: Secondary data, from different organizations including :- daily Rainfall data for Jimma and nearby station from (1995-2010) which was collected from National

Meteorological Service Agency (NMSA) , daily stream flow data for Awetu and Kito stream (1995-2010) was collected from MOWIRE. Only Digital Elevation Model (DEM) was downloaded from USGS.

Table 3.1: Secondary Data and their Sources.

Data Type	Purpose	Source
(30mx30m)DEM	For generating catchment geo-spatial data using Hec-GeoHMS	From USGS website
Land use map(2013)	For Curve number computation	EMA
Ethio Soil map	For CN computation	MOWIRE
Stream flow(Awetu, Kito(1995-2010)	To compute hydrograph using HEC-HMS	MOWIRE
Daily rainfall data for station (Jimma, Limu Genet, Shebe Sombo, Seka Coqorsa(1995-2010)	To compute hydrograph using HEC-HMS	NMSA
ERA ,IDF curve for the region	To compute hydrograph using HEC-HMS	ERA manual

3.3.2. Data Preparation and Analysis

After data was collected, the next step is data preparations that is transposing daily hydro-metrological data in proper order using MS-excel and then, make sure that data is complete with no missing value before using them. Basically a clear understanding of the hydro-metrological conditions of the area is one of the basic requirements of any water resource management study.

3.3.2.1. Filling Missing Rainfall and Discharge data

In some of the meteorology stations, due to various reasons sometimes the records cannot be kept properly and therefore, cause to missing records. Among the main causes are the broken instruments, unreachable locations due to heavy meteorology conditions such as floods, intensive snow fall, terrorist activities, and alike. The stability of record may be broken with missing data due to many reasons such as: absence of recorder, carelessness of the observer, break or failure of instruments. It is often necessary to estimate these missing records. Missing data can be estimated by using the data of neighboring stations (Sine, 2004). Different methods used for filling of missing Rainfall data for a given gauging station. Among this Arithmetic Average method is simplest one and it is used when the annual precipitation value at each of the neighboring gauges differs by less than 10% from that gauge with missing data. Normal Ratio Method was used in this research paper. The method is used when the normal annual precipitation of the index stations differ by more than 10% of the missing stations (Maidment, 1993). This is the case for the stations near the study area. The general formula for computing missing precipitation by this method was;

$$P_x = \frac{Nx}{M}\left[\frac{P1}{N1} + \frac{P2}{N2} + \ldots\frac{Pm}{Nm}\right] \ldots\ldots (3.1)$$

Where: N_x – Annual Average Precipitations at the gauge with missing values.

N_1, N_2 …N_m - Annual average Precipitation at the neighboring gauges, and M- number of the stations surrounding the station X.

3.3.2.2. Checking Consistency of Rainfall Data

Estimating missing precipitation is one of the problem that hydrologist need to address. A second problem occurs when the catchment rainfall at rain gauge is inconsistent over a period of time and adjustment of the measured data is necessary to provide a consistent record. A consistent record is one where the characteristics of the record have not changed with time. In consistency may result from: change in gauge location, exposure, instrumentations, or observational procedure is not real or on time. To overcome the problem in consistency a technique most widely applied called double mass curve is used. Double Mass Curve is a graphical method for identifying or adjusting inconsistencies in a station record by comparing its time trend with those of other stations nearby (ERA Drainage manual, 2002). A change in proportionality between the measurements at the suspect station and those in the region is reflected in a change in slope in the slope of the trend of the plotted points. The data series, which is inconsistent, adjusted to consistent values by proportionality. Double mass curve plot made for all four stations. The curve is a plot of rainfall record of a station and cumulative rainfall collected at a gauge where measurement condition may have changed significantly against the average of the cumulative rainfall for the same period of record collected at several gauges in the same region. The data is arranged in the reverse order that is the latest record as the first entry and the oldest record as the last entry in the list. The use of the double-mass curve for checking the consistency of precipitation records is explained by proceeding the following steps in which the annual records of four precipitation stations. First the annual precipitation data for each year are tabulated and then cumulated in chronological order. The cumulative precipitation for each station is then plotted against the cumulative precipitation of the pattern. Double mass curve plot made for all four metrological stations shown on figure below. From the graph of Double mass curve the stations are consistent each other.

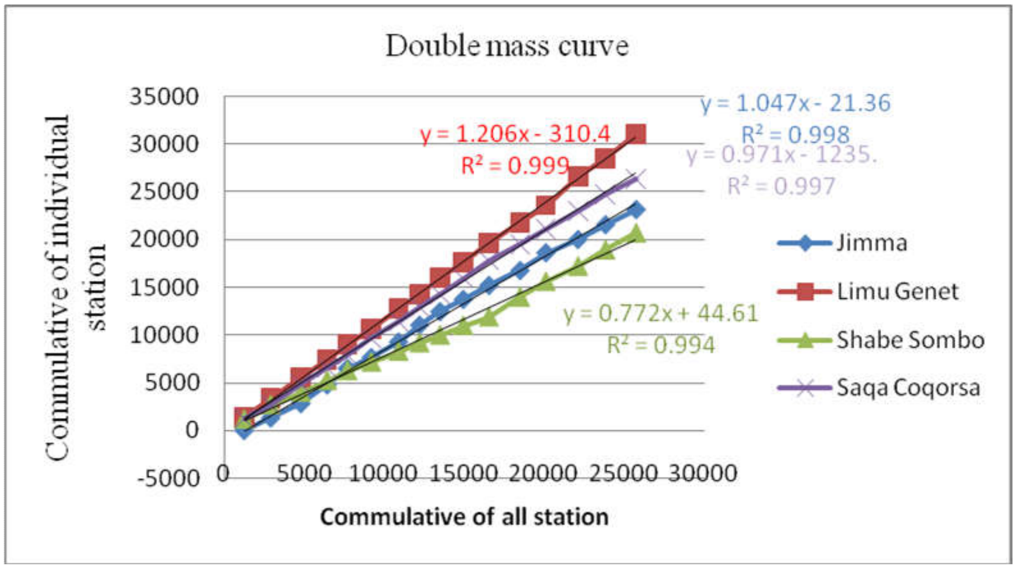

Figure 3.5: Double Mass Curve for Consistency Check

3.3.2.3. Filling Missing Flow data

The daily stream flow data (Awetu and Kito River) of the study area for 15 years was collected from the Ministry of Water, Irrigation and Energy. The discharge gage is located at the outlet of Awetu and Kito river downside where the downstream end is considered as flood prone. The daily discharge of Awetu has full data composition for the considered stations to represent the study area; while daily discharge of Kito River has missed data. Missing flow data records for the sub basin is filled by developing correlation station by scatter plot between the station with missing data and any of the adjacent stations with the same hydrological features and common data points. Linear Regression Analysis commonly used technique for estimation of significant missing observation as accurate as possible (Elshorbagy et al., 2000).Reference variable for regression analysis may be of the same type (e.g. flow vs. flow) or different (e.g. flow vs. climate variables or flow vs. physical catchment characteristics). Simple Linear regression has been applied to fill missing stream flow values using nearby flow gauging station observations. The equation for linear regression is given as:

y = ax + b .... ………….. (3.2)

Where, X- average monthly run-off depth (mm).

Y- Average monthly stream flow (m^3/se) and A and B are coefficient. In this study, regression with correlated Stations by scatter plot is used to obtain missing daily flow using nearby flow (Awetu flow vs. Kito flow) by deriving a common equation using scatter graph, $0.6 \leq r \leq 1$.

3.4. Peak Flood Discharge Estimation Using Hydrologic Modeling

There are different types of peak discharge estimation methods as it were discussed in Chapter 2. The choice of these methods depends on data available and practical existing situations. Each method has a range of application and limitations. The preferred methodology for this study is SCS method with the help of suitable Computer program ArcGIS and SCS models used to facilitate the calculations. To accomplish this objective 30m by 30m DEM of the study area is used as input dataset. It is fundamental dataset used for development of basin model component in the HEC-HMS model and the geometrical data model in the HEC-RAS model. This dataset is therefore useful in hydrological modeling, hydraulic modeling, and flood inundation mapping.

3.4.1. Terrain Preprocessing using HEC-GeoHMS

The processing of DEM to delineate watershed is referred to as terrain pre-processing. Terrain preprocessing is used to generate hydrologic parameters using DEM. DEM is primary spatial data source based on which GeoHMS extract catchment boundary, topographic variables such as basin geometry, stream networks, slope, aspect, flow direction .etc. HEC-GeoHMS is a set of Arc GIS tools specifically designed to process geospatial data and create input files for the Hydrological Engineering Centers Hydrological Modeling Systems (HECHMS).It includes integ rated data management and graphical user interface (GUI).Through the GUI, which consists of menu, tools, and buttons, the user can analyze the terrain information, delineate sub basins and streams, and prepare hydrological inputs. Stream and watershed delineation are generated using HEC-GeoHMS extension. In HEC-GeoHMS basin was disintegrated into sub basins then, the physical characteristics of watersheds such as river length slope and longest flow path for each sub basin was extracted. Therefore, Hec-GeoHMS operates on the DEM to derive sub basins delineation and prepare a number of hydrological inputs. The result from terrain processing can be used to create input files for hydrologic models using HEC-GeoHMS. HEC-HMS accepts these hydrological inputs as a starting point for hydrologic modeling. In this paper it is intended to derive parameters like: Curve number, Basin Lag, and Time of concentration and Loss. Using terrain data as input, the terrain preprocessing is a series of steps to derive the drainage networks. A 30m by 30m DEM was extracted for the respective sub basins then, the steps consists of; Fill sinks, Flow direction, Flow accumulation, Stream definition, Stream segmentation, Catchment grid delineation, Catchment polygon processing, Drainage Line processing, Adjoint catchment processing ,Longest flow path of the catchment, HMS Legend and Schematic performed in sequential order. Once these datasets are developed, they are used in the later steps for the sub basins and stream delineation. The terrain data is processed and analyzed using the eight-pour point approach to determine flow paths. This approach uses the steepest slope to define the direction that water flows from one grid cell to one of its eight neighbors. Terrain analysis is computer intensive and some steps require several hours, depending on the amount of data and computer resources.

3.4.2. Basin Processing

After terrain preprocessing is completed and a new project has been created the project point or outlet point of the catchment was defined. Then, Basin processing menu used to revise the sub basin delineations. Customized sub basin and routing reach delineations should include point where information is needed, i.e., stream flow gage locations, flood damage centers, environmental concerns, and hydrologic and hydraulic controls. The tools allow user to interactively combine or subdivide sub basins as well as to delineate sub basins to a set of points. Under the Basin processing menu, the Basin merge menu item merges multiple sub basins in to one sub basins. Then, HEC-HMS input file such as Background shape file, Basin model file, Meteorological model file, and Create HEC-HMS project was prepared using HEC-GeoHMS.

3.4.3. Physical Description of Sub basin (HEC-GEOHMS).

Hydrologic elements are used to break the sub basin into manageable pieces. They are connected together in a dendritic (branched extension or shape of a tree branch) network to form a representation of the stream system. The base map was prepared in Arc-view with the help of HEC-GeoHMS and used as input in the Basin module of HEC-HMS. After the successful completion of HEC-GeoHMS; back ground shape file, Basin model file, Met model file and Gage model file together with watershed hydrologic elements were exported to HEC-HMS to use as an input file for further analysis as shown in figure below.

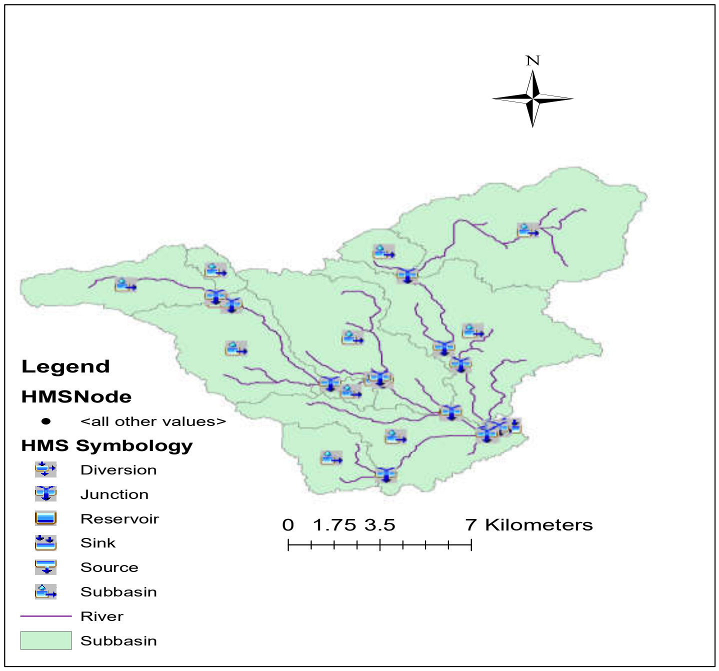

Figure 3.6: HEC-HMS Legend and Schematic.

3.4.4. HEC-HMS Modeling Development Using HEC-GEOHMS

3.4.4.1. HEC-HMS Model Description

HEC-HMS is hydrologic modeling software developed by US Army Corps of Engineers Hydrologic Engineering Centers (HEC).The Hydrologic Engineering Centers- Hydrologic Modeling System (HEC-HMS) is designed to simulate precipitation-runoff process dendritic watershed systems (USACE-HEC, 2006).It is the physically based and conceptual semi distributed model designed to simulate rainfall-runoff processes in a wide range of geographic areas such as large river basin water supply and flood hydrology to small urban and natural watershed runoff. The system encompasses losses, runoff transform, open channel routing, Analysis of meteorological data, rainfall-runoff simulation, and parameter estimation. HEC-HMS uses separate models to represent each component of runoff process, including models that compute runoff volume, models of direct runoff, and model of base flow. Each model run combines a basin model, meteorological model, and control specification with run option to obtain results.

3.4.4.2. Hydrologic Model Parameter Selection and Hydrological modeling

HEC-HMS offers a variety of options to simulate runoff production. This include SCS curve number, SCS unit hydrograph, and Base flow method. Depending up on the situation that was being modeled and the availability of data, an adequate mathematical model for each of four components (Loss, transform, Routing, and Base flow) process needs to be chosen.

Table 3.2: Hydrological Model selection and Catchment basin model parameters

S/NO	Model	Method	Parameter value required and units
1	Loss	SCS Curve Number	Initial abstraction (mm), Curve number, Impervious (%)
2	Transform	SCS Unit hydrograph	Lag time(min)
3	Routing	Muskingum	Travel time K(hrs) and Weighting factor X

i).SCS Curve Number method/Loss method/

While a sub basin element conceptually represents infiltration, surface runoff, and subsurface process interacting together, the actual calculations are performed by a loss method. Due to the available data type SCS Curve Number Loss method is adopted for loss computation. After selecting the method, three parameters were required to compute loss. These are: - Curve number, Initial abstraction (I_a), and Impervious (%).The relationship between Ia and S were developed from experimental catchment area data. The empirical relationship used in the SCS runoff equation is:

$$I_a = 0.2S \quad \text{(3.3)}$$

S – Potential maximum retention; it is related to soil and cover conditions of the catchment area obtained from generated curve number. The CN has a range of 0 to 100, and S is related to CN by:

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \quad \text{(3.4)}$$

Where, S is in (mm)

Soil Conservation Service (SCS) curve number is implemented for the precipitation loss calculations. In this study curve number for each sub basin was generated with Land use Land cover and Soil type data. In SCS-CN method, accumulated precipitation excess is estimated as a function of cumulative precipitation, Soil cover, land use, and Initial abstraction is:

$$P_e = \frac{(P-0.2S)^2}{P+0.8S} \quad \text{……………………………………………………………………… (3.5)}$$

Where, P_e= Accumulated precipitation excess at time't'; P= Accumulated rainfall depth at time t; I_a= Initial abstraction and S= Potential maximum retention.

ii).SCS unit hydrograph method/Transform method/

SCS unit hydrograph is applied for estimating direct runoff by transformation of runoff from precipitation .The basin lag time (T_{lag}) is the parameter of SCS UH model which is 0.6 times the time of concentration (T_c). Lag time (basin lag) is the time difference between the center mass of rainfall excess and the time to peak of the UH and Time of concentration indicates the time for runoff to travel the distance from hydraulically most distant point in the watershed to the outlet.

iii).Base Flow Method

Base flow models are used to simulate the fraction of the runoff contributed by groundwater. While a sub basin element conceptually represents infiltration, surface runoff, and subsurface process interacting together, the actual subsurface calculations are performed by a base flow method contained within the sub basin. A total of four different base flow methods are provided, those are Bounded recession, Constant monthly, linear reservoir, Nonlinear Boussinesq, and Recession method. Some of the methods are designed primarily for simulating events while are intended for continuous simulation. For this study Constant Monthly base flow method was chosen, which is average minimum of respective months because it is easy than other method.

iv).Muskingum method

It is used for routing of flow from outlet of each sub basin to the outlet of entire watershed. In this method X and K must be evaluated. Theoretically, K parameter is time passing of a wave in reach length and X parameter is constant coefficient that its value varies between 0-0.5. Curve number is the parameter that quantifies the infiltration capacity and theoretically ranges between

0(100% of the total rainfall infiltrate) to 100(0% of the total rainfall infiltrate).Basin Curve Number parameter value for each sub basin were estimated during data processing using HEC-GeoHMS software in Arc GIS environment and for each sub basins Basin curve number is given in Appendix. The values of Sub basin curve number were then extracted from the attribute table of sub basin data layer. Percentage impervious area is taken as 0%, if there is no urban settlement inside the Sub basin. But in this paper, there was urban area which contains asphalt so percentage impervious has to be considered.

3.5. Creation of CN Grid in Arc Map

HEC-GeoHMS uses the merged (soil_ lu) and the lookup table (CNLookup) to create Curve number grid. Look-up table of CN use land-cover classes under different Hydrologic Soil Group to estimate the values of curve number.

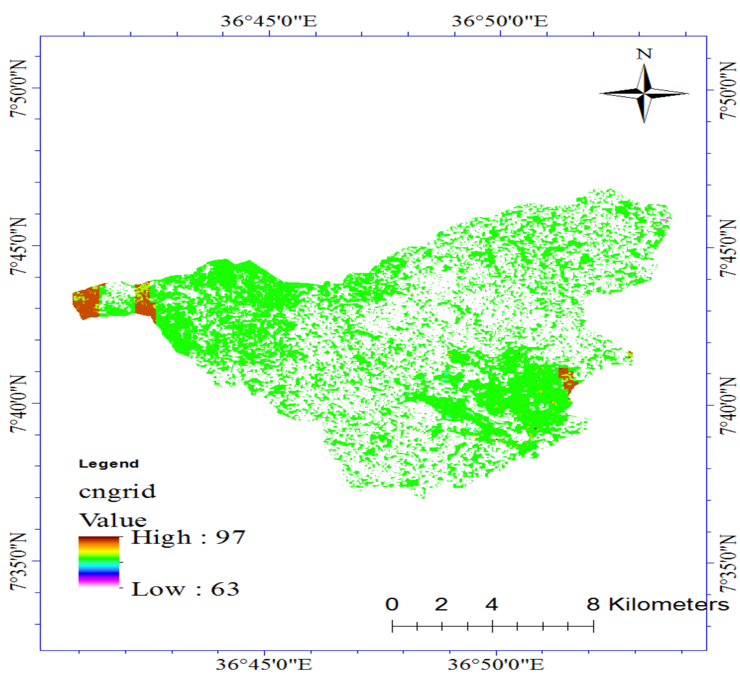

Figure 3.7: Curve Number grid map

To compute the Curve Number (CN), soil and land use are required as shown in Table below. Then, the land use data obtained from Ethiopia Mapping Agency (EMA, 2013) it was reclassified in Arc-GIS in to seven major groups based on hydrological soil group criteria (ERA manual, 2013).

Table 3.3: Soil type and the respective Hydrologic group.

S.No.	Soil type	HSG/Soil group/	Area(Km^2)	%Area
1.	Dystric nitisols	B	129.794	60.37
2.	Chromic vertisols	D	3.842	1.78
3.	Eutric fluvisols	B	50.984	23.72
4.	Dystric fluvisols	B	23.946	11.14
5.	Orthic acrisols	B	3.279	1.52
6.	Eutric nitisols	B	3.156	1.47

Table 3.4: Land Use and Land Cover of the Catchments

S.No.	LULC type	Area(Km^2)	%Area
1	Agricultural Land	53.8	25.02
2	Bare Land	13.44	6.25
3	Forest Land	42.08	19.57
4	Grass Land	28.31	13.17
5	Shrub Land	32.17	14.96
6	Wet Land	37.23	17.32
7	Wood Land	7.97	3.71
Total		215	100

Table 3.5: Curve Numbers for Hydrological Soil Group and Landuse Land cover of the study.

S.NO	Land use land cover type	Curve numbers for hydrological Soil groups			
		A	B	C	D
1	Agricultural Land	70	80	87	90
2	Bare Land	77	86	90	94
3	Forest Land	38	63	75	82
4	Grass Land	68	79	86	89
5	Shrub Land	63	77	86	89
6	Wet Land	97	97	97	97
7	Wood Land	40	66	77	85

The Weighted curve number for each sub basin was created by giving land use information and soil type. For a watershed that consists of several soil types and land uses, a composite CN is calculated as suggested by Panigrahi (2013).

$$CN_{composite} = \frac{\sum Ai\ CNi}{\sum Ai} \quad \text{...} (3.6)$$

Where, $CN_{composite}$ = the composite curve number used for runoff volume computations.

CN_i = an index of watershed subdivisions of uniform land use and soil type

A_i = the CN for subdivision i; and i= the drainage area of subdivision

3.6. HEC-HMS Model Set up (Components)

HEC-HMS model components are used to simulate the hydrological response of a watershed subjected to a given hydrometeorological input. The model can simulate individual storm events as well as continuous precipitation inputs at minute, hourly, or daily time steps. HEC-HMS model components has four main components, which are created for developing a HEC-HMS project these are: Basin model manager, Meteorological model manager ,Control Specifications manager and input data(time series, paired data, gridded data). A simulation calculates the precipitation-runoff response in the model given the input from meteorological model. Control Specifications manager are one of the main component, and it is principally used to control time interval of simulation. It controls when simulation start and drop and what time interval is used in simulation i.e. it is used to define time period and time interval. The time interval was about one day to run the model taken in this study. Input data components are often required as parameter or boundary conditions in basin and meteorological models.

In this study the basin model, which represents the physical watersheds was created using the HEC-GeoHMS and then imported in to the HEC-HMS with all its hydrologic elements: 15 Sub basins, 15 junctions, 15 reaches, and Sink are used to represent the outlet of the sub basin and to relate the simulated flow to the historical observed flow of the sub basins. Hydrologic elements use mathematical models to describe physical process in the watershed. For this particular study for all respective sub basins, depending on the availability of time and data requirement, simulation was done with SCS curve number loss method, SCS unit hydrograph, Constant monthly base flow conditions has been used.

3.6.1. Rainfall Runoff Modeling

HEC-HMS modeling may be taken considering different time series values such as daily, hourly, and even in minute. Accuracy of the model output is high if it is in reverse order (i.e. the model was more performed for hourly data than daily data). Although most flood studies are undertaken considering hourly time steps, there are cases where daily data are taken. For this particular study since hourly data was not available the daily rainfall data was used.

3.6.2. Model Calibration and Validation

Model Calibration is the process of adjusting model parameter values and other variables in the model in order to much the model outputs with the observed values (until model result match historical data). Automated calibration (optimization) was found to give optimum and reliable model parameters. HEC-HMS has capabilities to process automated calibration in order to minimize a specific objective function such as sum of absolute error, sum of squared error, percent error in peak, and Peak- weighted root mean square error. The objective function measures the goodness-of-fit between the computed outflow and observed stream flow at the selected element. Six different functions are provided that measure the goodness of fit in different ways HEC-HMS user's manual (USACE, 2003).Among them Peak-Weighted root mean square error was used for this thesis work. The calibration procedure involves a combination of both manual and automated calibrations. The manual calibration proceeds the automate optimization to ensure meaningful set of initial parameters. Eight (8) years of data (1995-2002) are used for calibration. Each model that has been added to HEC-HMS has parameters. The value each parameter must be specified to use the model for estimating runoff.

Calibration was commonly done manually by optimizing parameters values, starting from initial values, until the simulated variable fits with the observations. Constant monthly base flow method was adopted for calibration area. That is base flow by a constant flow for each month and for this work average of the minimum of respective months are used for eight years of data(1995-2002) .It uses hydro-meteorological data in a systematic search for parameters that yield best fit of the computed result to the observed flow. This search method is referred to as Optimization. Model Validation was done after completion of Calibration and all model parameters were adjusted. Validation is the process of testing the model ability to simulate observed data, other than those used for calibration, within acceptable accuracy. During validation process, the calibrated model parameters values are kept constant. Seven (7) years of data (2003-2010) are used for validation of model.

3.6.3. Simulation Run and Search Methods

Two search methods are available for minimizing the objective function and finding the optimal parameter values. The univarient gradient method evaluates and adjusts one parameter at a time holding other parameters constant. The Nealder and Mead method uses a downhill simplex to evaluate all parameters simultaneously and determine which parameters to adjust (HEC-HMS, User's manual, 2003). For this thesis Univarient gradient Evolution Search method was adopted as it resulted in a better result.

3.6.4. Model Performance Evaluation

The performance of HEC-HMS was evaluated by using statistical measures to determine the quality and reliability of predictions when compared to observed values. Coefficient of determination (R^2) and Nash-Sutcliffe Simulation Efficiency (E_{NS}) were the goodness of fit measures used to evaluate model prediction.

3.6.4.1. Coefficient of Determination

Coefficient of determination is used to measure how well trend in the measure data were reproduced by simulated result over specified period. The R^2 value is an indicator of strength of relationship between observed and simulated values. Its value ranges between 0 and 1. With 0 values no correlation at all and value 1 is perfect correlation. Determination of coefficient for n time step was calculated as:

$$R^2 = \frac{[\sum_{i=1}^{n}(Q_{si} - Q_S)(Q_{oi} - Q_O)]2}{\sum_{i=1}^{n}(Q_{si} - Q_s)^2 \sum_{i=1}^{n}(Q_{oi} - Q_o)^2} \quad \text{(3.7)}$$

Where: n = is the number of sample data

Q_{si} = the Simulated value at i^th^ time interval, Q_{oi} = Observed value at the ith time interval.

Q_o = average value of observed discharge; Q_s= average value of simulated discharge.

3.6.4.2. Nash-Sutcliffe Simulation Efficiency (E_{NS})

The Nash-Sutcliffe simulation efficiency (ENS) indicates how well the plot of observed versus simulated value fits the 1:1 line. If ENS value is between 0 and 1, it indicates deviation between measured and predicted value. ENS is negative, prediction are very poor, the average value of output is better estimate than the model prediction (Nash and Sut-cliffe, 1970).The disadvantage of this efficiency criteria is an overestimation of the model performance during peak flows and an underestimation during low flow conditions. The E_{NS} simulation efficiency for n time steps is calculated as:

$$E_{NS} = 1 - \frac{\sum_{i=1}^{n}(Q_{si} - Q_{s})2}{\sum_{i}^{n}(Q_{oi} - Q_{o})2} \quad \text{.......... (3.8)}$$

Where: Q_{oi} =observed discharge Q_s=Simulated value at ith time interval

Q_{si} = simulated discharge Q_o = average value of observed discharge value.

3.6.5. Flood Frequency Analysis

Flood frequency analysis is used to relate the magnitude of extreme events to their frequency of occurrence through the use of probability distributions. Rainfall frequency analysis was used as a key input to the calculation of flood frequency and magnitude. Certain hydrologic procedures use rainfall and rainfall frequency as the basic input instead of flood frequency. It is commonly assumed that the 10-year rainfall will produce the 10-year flood. Depending up on antecedent soil moisture conditions, and other hydrologic parameters, there may not direct relationship between rainfall and flood frequency (ERA, Drainage Design Manual, 2013).The rainfall frequency analysis was carried out using the 24-hour annual maximum rainfall data for rain gauge stations situated in the nearby areas. It was necessary to combine data from different stations in order to attain an acceptable representative's record. The rainfall intensity determined from Rainfall-Intensity-Duration curves. The rainfall intensity at any required time using the 24-hr rainfall depth, which is known as a rainfall intensity-durations-frequency (IDF) relationship.

Precipitation for frequency analysis in HEC-HMS was chosen as 24-hr (1-day). In addition to this HEC-HMS also requires a depth of 5,15, 30, 60, 120, 360, 720, and 1440 minute's durations or 0.083, 0.25,1,2,3,6,12,and 24 hour duration.

The depth of the rainfall for the listed duration was computed using the 24-hr rainfall depth, using IDF relationship. From ERA, Drainage Design Manual, 2013 the relationship is given as:

$$R_{Rt} = \frac{t}{24}\frac{(b+24)^n}{(b+t)^n} \quad \text{.......... (3.9).}$$

Where: R_{Rt} = Rainfall depth ratio R_t: R_{24} R_t = Rainfall depth in a given duration't' R_{24} = 24 hr rainfall depth, b and n are coefficients b= 0.3 and n= (0.78-1.09). Input data for HEC-HMS model to frequency analysis given in table below using equation above.

Table3.6: IDF table for the Study area (ERA Drainage manual, 2013).

Intensity-Duration-Frequency-Curves						
Return period(years)	2	5	10	25	50	100
RF intensity	2.45mm/hr	2.97mm/hr	3.30mm/hr	3.72mm/hr	4.04mm/hr	4.35mm/hr
Duration(hr)	Depth(mm)	Depth(mm)	Depth(mm)	Depth(mm)	Depth(mm)	Depth(mm)
0.083	8.53	10.32	11.48	12.94	14.03	15.12
0.25	18.55	22.45	24.98	28.15	30.51	32.88
1	34.21	41.41	46.08	51.93	56.28	60.65
2	40.95	49.56	55.15	62.14	67.35	72.59
3	44.38	53.72	59.77	67.36	73.00	78.68
6	49.59	60.04	66.80	75.28	81.58	87.93
12	54.32	65.76	73.16	82.45	89.36	96.31
24	58.87	71.26	79.29	89.35	96.84	104.37

3.6.6. Modeling by Frequency Storm.

Within the input from HEC-GeoHMS and some edition from the main HEC-HMS, the model is simulated for rainfall intensity of 2, 5, 10, 25, 50, and 100 year return periods as shown in (Table 3.6). The frequency intensity are found from the Ethiopia Road Authority drainage manual (ERA, 2013).The design hyetograph for different return periods were derived from IDF curves using the frequency storm method in HEC-HMS. The main input data for frequency – based design storm to specified return period is the total storm duration, the precipitation depths for the number of given durations within the total storm duration. The intensity duration defines the duration of maximum and constant intensity within the storm.

3.7. Delineation of Most Flood Prone Areas (Hydraulic Modeling)

Delineation of flood extent and depth within the flood plain was carried out based on the integration of hydraulic simulation results and GIS analysis using HEC-GeoRAS extension of Arc view GIS and HEC-RAS. So two models HEC-GeoRAS and HEC-RAS are used one after the another (i.e. first HEC-GeoRAS then HEC-RAS and then back to HEC-GeoRAS) to achieve the objective.

Procedures followed: DEM of study area is first converted to terrain TIN (Triangular Irregular Network) in ArcGIS extensions HEC-GeoRAS. Then the following main procedures are applied:-

i).Pre processing of geometric data for HEC-RAS, using HEC-GeoRAS.

ii).hydraulic analysis in HEC-RAS; and

iii).Post processing of HEC-RAS results and flood inundation mapping, using HEC-GeoRAS and flood inundation map delineate most flood prone area.

3.7.1. General Hec-GeoRAS or HEC-RAS Model Description

The Hydrological Engineering Centers Geographical River Analysis System (HEC-GeoRAS) is the set of Arc GIS tools specifically designed to process geospatial data for use with Hydrologic Engineering Centers- River Analysis System (HEC-RAS) .The GEORAS software assists in the preparation of geometric data for import in to HEC-RAS and generation of GIS data from exported HEC-RAS simulation results. GeoRAS is an ArcGIS extension developed by the US Army Corps of Engineers designed specifically to improve the data input process for HEC-RAS. Operating within the ArcGIS, GeoRAS uses spatial data to develop, organize, and automatically enter input data in to the HEC-RAS model. In this study, HEC-GeoRAS version 10.2 is used to extract cross-sectional- station elevation data from Digital Elevation Model (DEM) represented by Triangular irregular network(TIN) .The key element that GeoRAS uses as input data is terrain data, commonly referred to as a Triangular Irregular Network (TIN). To create the import file, the user must have an existing digital terrain model (DTM) of the river system in TIN or GRID format. The user creates a series of lines to develop geometric data for HEC-RAS. The HEC-GeoRAS extension was used to set up the necessary features that would be needed for HEC-RAS model (i.e. stream centerline, bank lines, Flow path center lines, Cross section cut lines etc.). HEC-RAS uses these features to obtain an accurate layout of the river and establish the cross-sectional elevations of the potential floodplains. After that the developed geometric data was imported in to HEC-RAS version 5.0.1 using a data exchange format developed by HEC-GeoRAS.

3.7.2. Development of DTM

The key element that GeoRAS uses as input data is terrain data, commonly referred to as a Triangular Irregular Network (TIN).One source of data used to develop TIN is a Digital Elevation Model (DEM) .DEMs exist in grid (raster cell) format which can be displayed within ArcGIS, if the proper extensions are installed. The quality of this data is based on its resolution, or cell size. The smaller the cell is the greater the resolution and accuracy .However, the smaller the cell size, the greater computational requirements. The usefulness of DEMs for developing terrain models should be determined based on the cell size and level of hydraulic analysis to be performed. So to create the import file, the user must have an existing digital terrain model (DTM) of the river system in TIN or GRID format

3.7.2.1. TIN of the Study area

The representation of the river and floodplain is by the use of the TIN generated from the existing DEM of the study area using 3D analyst of ArcGIS. The generated TIN serves in the delineation of flood plain boundaries; calculation of inundation depths, and also for extraction of cross sectional data of river schematics and flood plain. After generating TIN, river was digitized in HEC-GeoRAS.

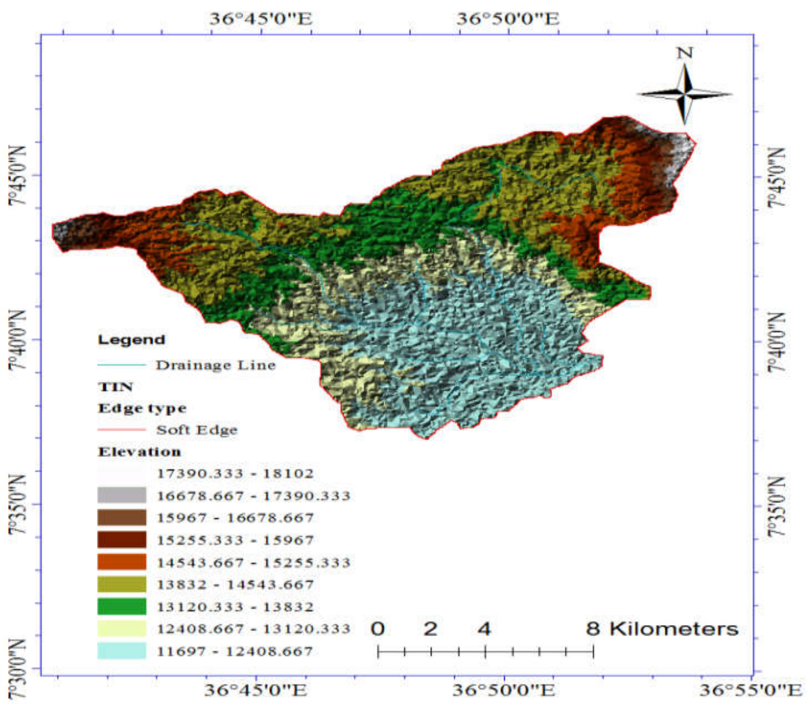

Figure 3.8: TIN of the Study area

3.7.3. Preprocessing of Geometric Data Using HEC-GeoRAS.

The goal of Pre-processing was to develop the basic spatial data required to generate the HEC-RAS Geometry Import file. The first stage in determining floodplains for the study area was preprocessing and the first step in the preprocessing stage is the creation of digital terrain model (DTM) of the river system in the Triangular Irregular Network (TIN) format. The TIN also serves in the delineation of flood plain boundaries and calculation of inundation depths. The Pre-processing start with the development of the geometry data files for use with HEC-RAS. After completion of preprocessing stage, the hydraulic analysis is performed using the HEC-RAS modeling program for the computations of water surface profiles. The analysis starts by importing geometric data (RAS layers).

3.7.4. Creating RAS (Geo-spatial) layers

For this particular study TIN was created from DEM with cell size 30mX30m using 3D Spatial Analyst, which makes it appropriate for use in hydraulic analysis and floodplain modeling. After that, RAS layers was created, which are used to create geometric data sets that used in HEC-RAS. These layers includes: Stream centerlines, Bank, Flow path centerlines, Cross-section Cut-lines, Land use, Levee Alignment, Ineffective flow Areas, and Storage Areas. For this work, the layers were created for stream centre lines, bank lines, flow path lines, and (cross-section) XS cut lines. In editor mode each layers were then digitized. The attributes for all layers were computed and the data was then exported to HEC-RAS.

3.7.5. Hydraulic Analysis Using HEC-RAS

The Hydraulic Engineering Center-River Analysis System (HEC-RAS) is developed by Hydraulic Engineering Center of United States Army Corps of Engineers. HEC-RAS system is comprised of a graphical user interface (GUI), separate analysis components, data storage and management capabilities, graphics and reporting facilities (USACE, 2006).The most recent version of HEC-RAS supports steady and unsteady flow water surface profile calculations, Sediment transport computations and water temperature analysis(USACE,2006).HEC-RAS is currently capable of performing one dimensional water surface profile calculations for steady gradually varied flow in natural or constructed channels. In this study Steady Flow analysis was done due to availability of data, in HEC-RAS software based on Open channel flow and mixed flow regime. Flow cross section, flow profile, and 3D cross section with depth of water were generated. For this study HEC-RAS model was developed to create the geometric data, which can be accomplished by using ArcGIS 10.2, and HEC-GeoRAS, which was specifically designed to process geo-spatial data for use with HEC-RAS. The geometric files include information about river centerlines, flow path lines, stream bank lines, cross-sections, and other physical attributes of river channels. Hydraulic analysis is performed using flow data and steady flow data.

i).Creating Cross-sections

Cross-sections are one of the key inputs to HEC-RAS. Cross section cut lines are used to extract the elevation data from the terrain to create a ground profile across channel flow. The intersection of cut lines with other RAS layers such as center lines and flow path lines are used to compute HEC-RAS attributes such as bank stations (locations that separate main channel from the flood plain), downstream reach lengths(distance between cross sections) and Manning’s number. Therefore, creating adequate number of cross sections to produce good representation of channel bed and flood plain is critical. Certain guidelines must be followed in creating cross section cut lines: (1) they are digitized perpendicular to the direction of flow; (2) must span over the entire flood extent to be modeled; and (3) always digitized from left to right (looking downstream).

Data required for HEC-RAS model include:

a. Geometry Data

It consists of a description of size, shape, and connectivity of stream cross sections. While generating HEC-RAS geometric input data using HEC-GeoRAS first, the Triangular Irregular Network (TIN) data was obtained from the DEM data using 3D analyst of Arc-GIS. Cross section data represent the geometric boundary of the stream. Cross sections are located at relatively short intervals along the stream to characterize the flow carrying capacity of the stream and its adjacent floodplain. Cross sections are required at representatives locations throughout the stream and at locations where changes occur in discharge, slope, shape, roughness; at locations where levees begin and end; and at hydraulic structures (bridges, culverts, and weirs).The required information for a cross sections consists of: the river, reach and river station identifiers description; X and Y coordinates(station and elevation points) ,downstream reach lengths, manning's roughness coefficients, main channel bank stations, contraction and expansion coefficients. To create geometric model, importing the geometry file is needed. So the HEC-RAS geometry file contains physical parameters describing cross sections.

b.Flow Data

It contains discharge rates. Once the geometric data is entered, the necessary flow data (steady or unsteady flow) can be entered. Steady Flow Data consist of: the number of profiles to be computed; the flow data; and the river system boundary conditions. At least one flow must be entered for every reach within the system. Additionally, flow can be changed at any location within the river system. Flow values must be entered for all profiles. The Flow data has been extracted /imported/ directly from HEC-HMS hydrologic model run for different design storms or entered manually from model run results. Unsteady flow condition is adopted since it is rare to find the steady flow in the natural channel flow condition.

c. Plan Data

Plan data contains information pertinent to the run specifications of the model, including descriptions of flow regime. The plan data defines which geometry and flow data are to be used, as well as provide a description and short identifier for the run.

3.7.6. Post-Processing of Hydraulic Results (HEC-GeoRAS) and Flood Inundation Mapping

The post-processing of the water surface profiles is performed using the same maps that were used for the preprocessing of geometric data. Flood plain mapping is performed with the limits of the bounding polygon using the water surface elevations generated by the HEC-RAS. Post-RAS processing is the one which uses HEC-RAS output for flood plain inundation mapping and delineation. Flow data from HEC-HMS is imported in to hydraulic model HEC-RAS along with necessary geometric data to develop water surface profiles. The data is once again used in ArcGIS with HEC-GeoRAS extensions from HEC-RAS to delineate flood plains. The output from HEC-RAS is imported to HEC-GeoRAS for post processing from where flood inundation map was prepared. From flood inundation map, the flood vulnerable areas were identified.

3.8. Identification of Causative Factors of Flood in the Town

Urban areas always present some risk of flooding when rainfall occurs. Buildings, roads, infrastructure and other paved areas prevent rainfall from infiltrating in to soil and so produce more runoff. Heavy and/or prolonged rainfall produces very large volume of surface water in any city, which can easily over flow drainage systems. So, urban floods are caused by natural events and anthropogenic activities.

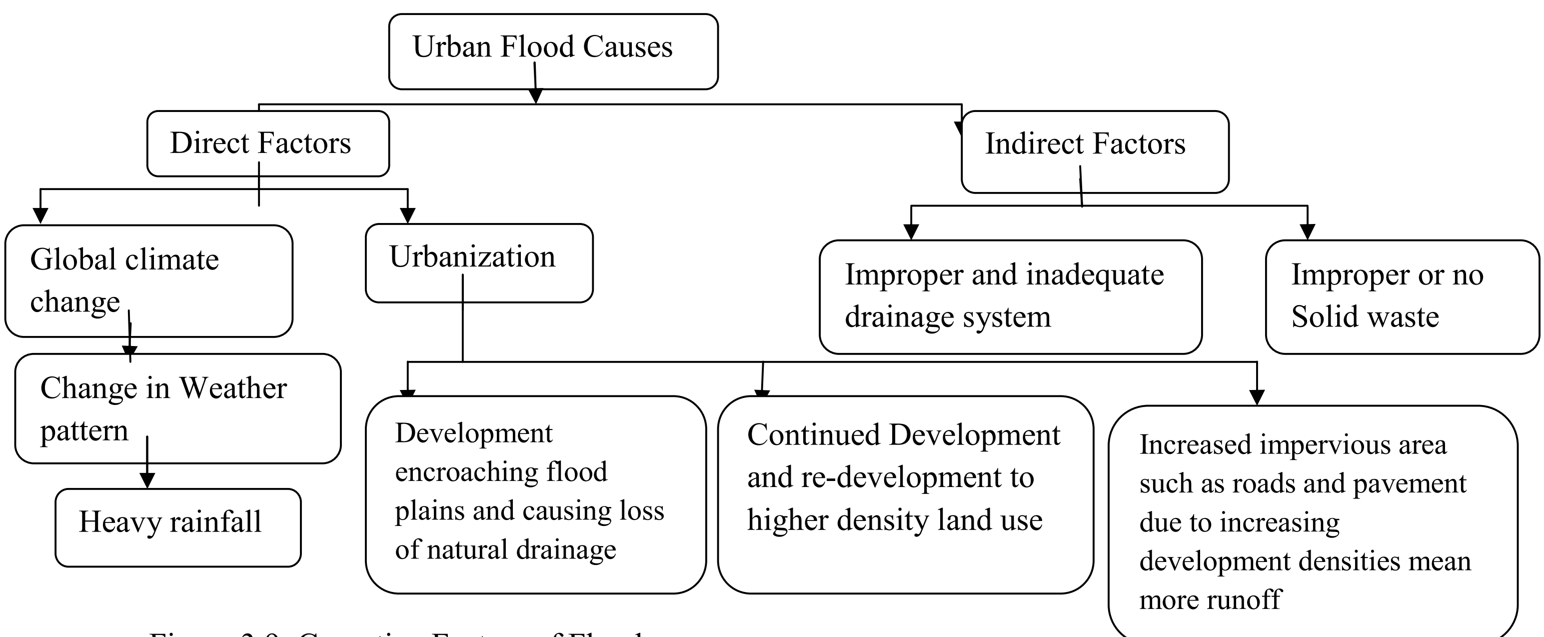

Figure 3.9: Causative Factors of Floods

For this particular study factors that contribute flood hazard can be directly, from heavy rainfall over short duration since the town is surrounded by steeply or hilly topography. Flash flood occurred as a result of excess rains falling on the upstream of Abba Jifar Mountains and very steep mountains surrounding the town and takes it to downstream, and mostly affects downstream community by collecting various solid waste that close drainage ditch. Indirectly, the town has poor sewerage system due to improper and inadequate drainage system, and improper solid waste where, the runoff from roads and waste water from different sources finally end-up in to Awetu stream. Solid waste is found all along the streets, market places, and riparian zones of Awetu stream. So this makes the stream to overflow and cause flooding at downstream and damages settlement to any section of stream. Urbanization is also one of the cause of floods since due to urbanization tarmac and concrete surfaces are increased which are impermeable that lead to increase in surface runoff. After urbanization the lag time is shortened, Peak flow is greatly increased, and total runoff is compressed in to a shorter time interval favorable conditions for intense flooding. To protect communities from the damage caused by flooding, before flood is occurred raise community awareness about floods and flood protection measures including flood awareness and preparedness as well as conduct risk assessment which means distributing flood hazard maps so that people know where there is a risk of flooding.

4. RESULTS AND DISCUSSION

4.1. HEC-HMS Model Results

The HEC-HMS project requires five model data components: Basin Model, Precipitation Model, Control Specifications, Time Series Data, and Paired Data. The basin boundary and drainage line layers prepared as background map files for HEC-HMS are imported in to the model in Arc-view with the help of HEC-GeoHMS 10.2 and used as input in the Basin module of HEC-HMS. The background map files represent the physical watershed. For this particular study background map files that contains 15 sub basins was generated using HEC-GeoHMS 10.2 in ArcGIS 10.2 in figure below. It contains Basin model file, Met model file, Gage model file, and Time series data. They are imported in to HEC-HMS and used as input data for HEC-HMS. The Basin model files contains sub watersheds, reaches, Junctions, and outlet with method of rainfall loss modeling such as loss methods, transform methods, and channel routing methods.

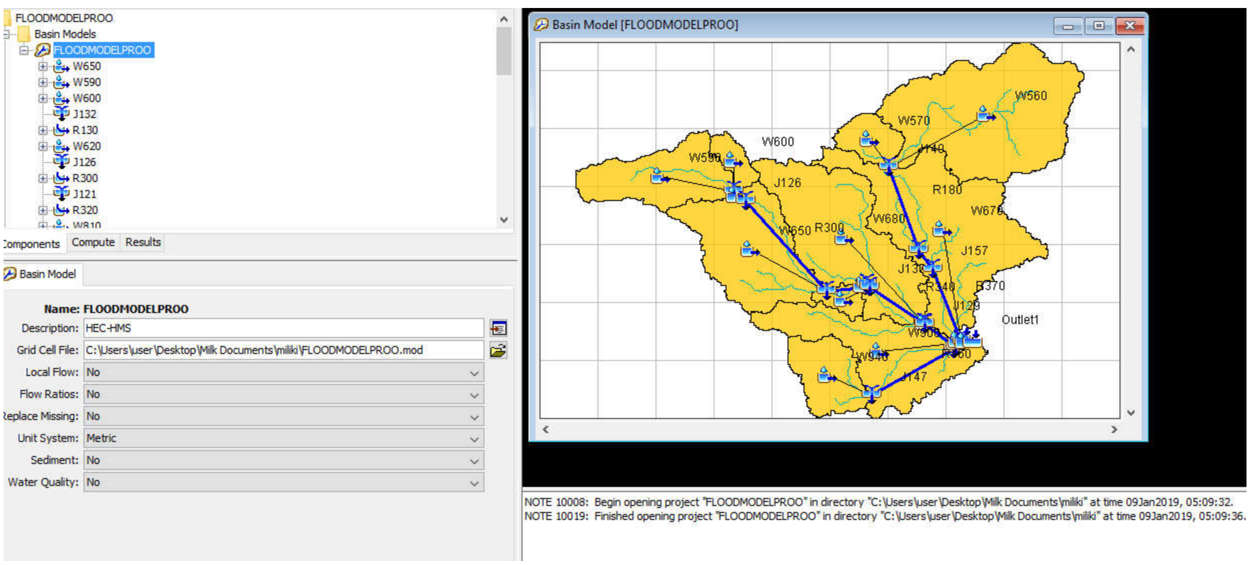

Figure 4.1: Basin Model.

4.2. HEC-HMS Calibration Results

HEC-HMS has an optimization feature which can be used to match the simulated flow with observed flow. The optimization feature was used to carry out the calibration process. It allows multiple calibration parameters at the same time. Three parameters were selected for calibration. They were the curve number, Muskingum K and X parameters, and constant monthly base flow. Calibration is tuning of model parameters based on checking result against observations to ensure the same response over time. This involves comparing the model results, generated with the use of historical meteorological data, recorded stream flow. For this particular study calibration of HEC-HMS was carried out using Eight years from 1995 to 2002 daily rainfall and daily stream flow of Awetu and Kito River.

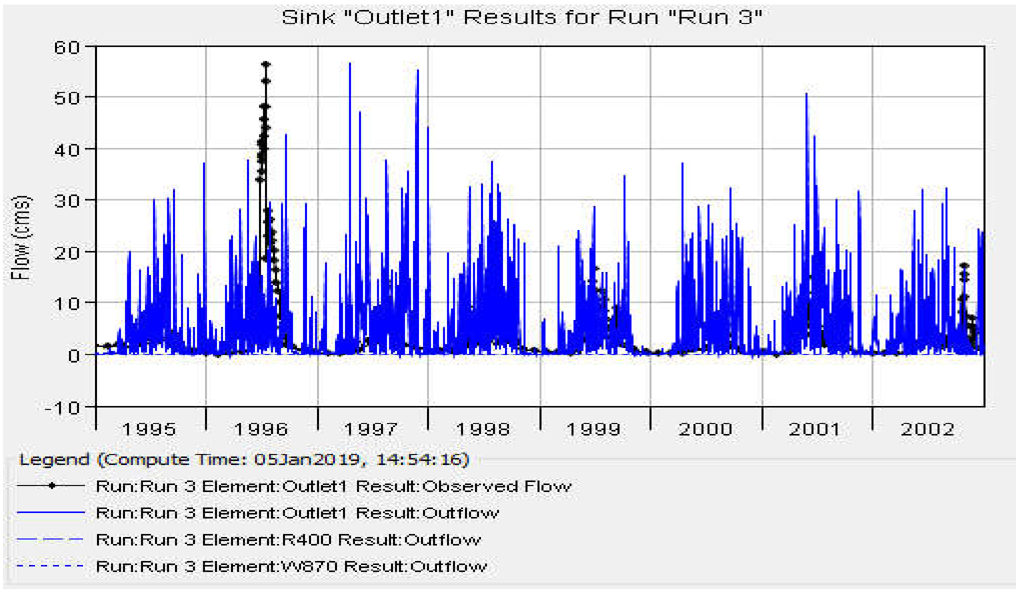

Figure 4.2: Daily Simulated and Observed flow hydrograph taken from HEC-HMS Calibration.

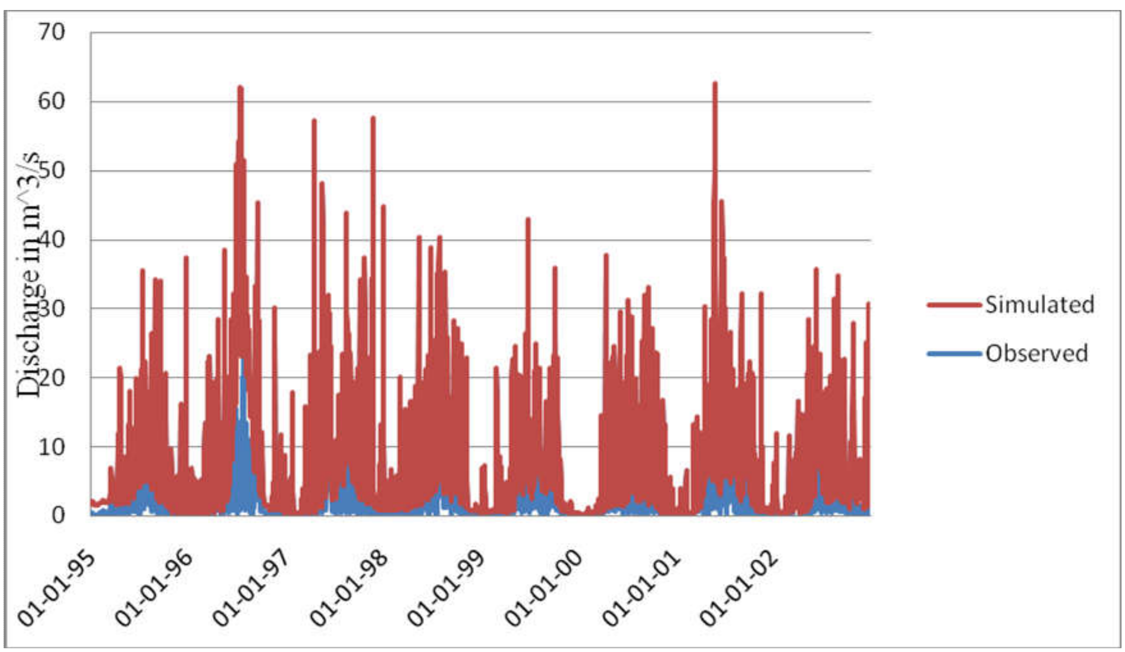

Figure 4.3:Observed and Simulated comparision Flow hydrograph during Calibiratio(1999-2002)

4.3. Model Performance Evaluation

Coefficient of determination (R^2) and Nash-Sutcliffe Simulation Efficiency (ENS) were the goodness of fit measures used to evaluate model prediction. Coefficient of determination (R^2) during calibration was found to be 0.94 and Nash Sutcliffe Simulation Efficiency (ENS) was 0.78.

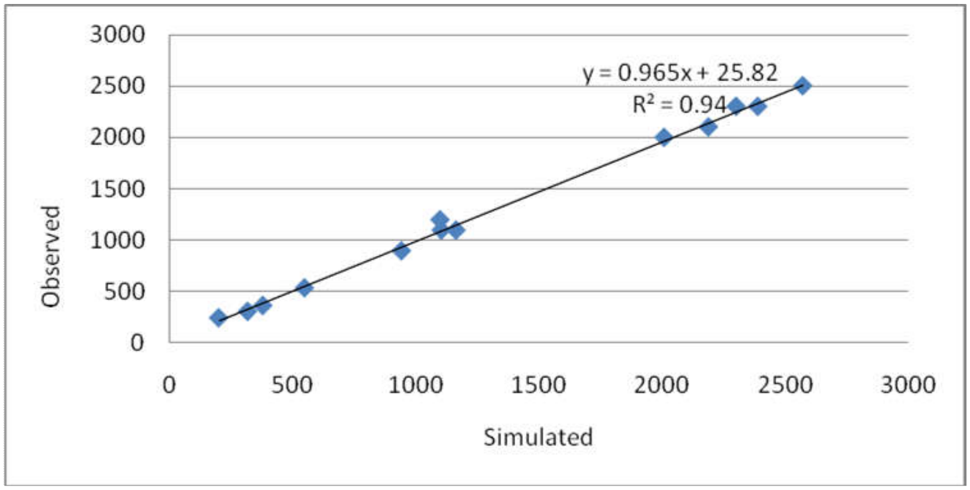

Figure 4.4: Coefficient of determination between Simulated and Observed flow during Monthly Calibration.

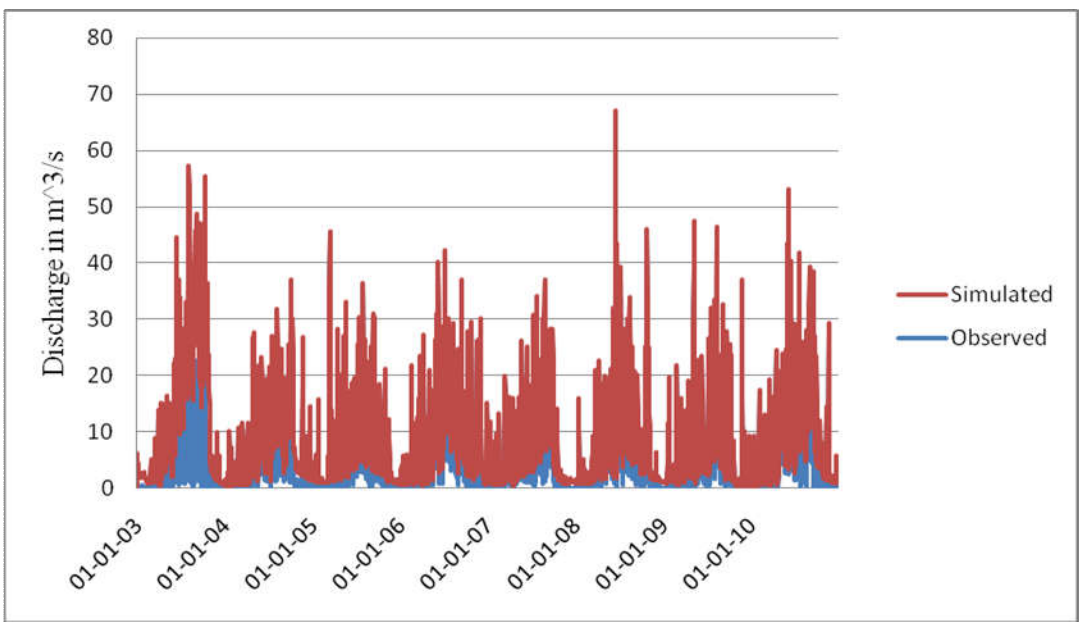

Figure 4.5: Flow Hydrograph during Validation (2003-2010)

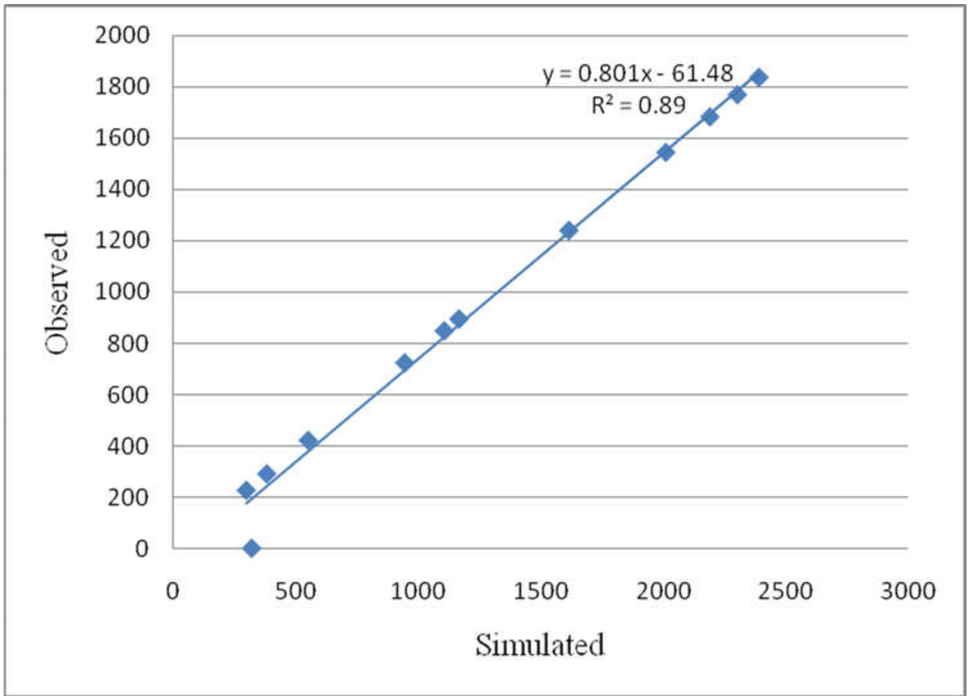

Figure 4.6: Coefficient of determination between Simulated and Observed flow during Validation.

From Calibration and Validation results we can conclude that the model is valid for simulation of the rainfall runoff transformation method to generate the peak discharge. The calibration performance of HEC-HMS has determination coefficient value (R^2) and Nash-Sut-cliffe efficiency evaluation value of 0.94and 0.78 respectively. Also the Validation performance has coefficient of determination value (R^2) and Nash-Sutcliffe (ENS) value of 0.89 and 0.75 respectively.

4.4. Meteorological Modeling Using Frequency Storm

4.4.1. Output of HEC-HMS by Frequency Storm

Table 4.1: Peak Discharge Result of HEC-HMS

Estimated Peak Flood	Return Period(years)					
	2 Years	5 Years	10 Years	25 Years	50 Years	100 Years
Peak Flood(m^3/se)	19.6	28.8	35.4	44.3	51.2	58.5

From the Table above we can conclude minimum peak flow for the town was occurred for 2 year return period for 24 hr storm duration and the maximum peak flow was obtained with 100 year frequency storm for the same duration. The value being 19.6m^3/s and 58.5m^3/s for 2 year and 100 year frequency storm respectively. Then, the Peak discharge results from HEC-HMS model were used as input to the HEC-RAS model inorder to produce levels of inundation.

4.5. HEC-RAS and HEC-GeoRAS (Pre and Post processing) Results

4.5.1. Hydraulic Modeling Output

HEC-RAS use data such as flow rate with different return periods that were obtained using HEC-HMS, Manning's n- value for land use covering the river and flood plain area, river geometric data, river flood plain data, distance between successive river cross section, etc as input. The results of simulated runoff for the precipitation event were obtained from HEC-HMS and the flood plain model was generated with the aid of HEC-RAS and HEC-GeoRAS. The water surface profiles discharge and velocities along with Froude number at different cross sections, water surface elevation, Rating curves, Hydraulic properties i.e. EGL Slope and Elevation, flow area, and velocity, Visualization of stream flow, which shows the extent of flooding, etc. was obtained with the aids of HEC-RAS . In addition to this, HEC-RAS produces different results such as: Minimum channel elevation, Critical water surface elevation for a model with critical flow regime, Elevation of energy and slope gradient, Channel velocity and flow area, Top width of the channel and Froude number for each river station developed during preprocessing using HEC-Geo RAS and for each HEC-RAS profile given in Appendix. After importing, the HEC-

RAS output data into Arcview and create link the HEC-RAS stream representation to the digital representation of the stream in Arcview. Then using a TIN terrain model raster flood mapping was developed to know Peak water level in the river.

4.6. HEC-RAS Model Result

4.6.1. Geometric Data

The river geometry file and stream flow data are the inputs file to HEC-RAS to generate the water surface level along the river. The result of HEC-RAS model simulation will be entered in to GIS environment and further analysis will be performed using HEC-Geo RAS tool. HEC-RAS has ability to import three dimensional (3D) river schematic cross section data created in a GIS/ Arc-view HEC-GeoRAS/while HEC-RAS utilize two dimensional data. Surface profiles exported back to the GIS/Arc-view HEC-GeoRAS/ system for development of flood inundation map.

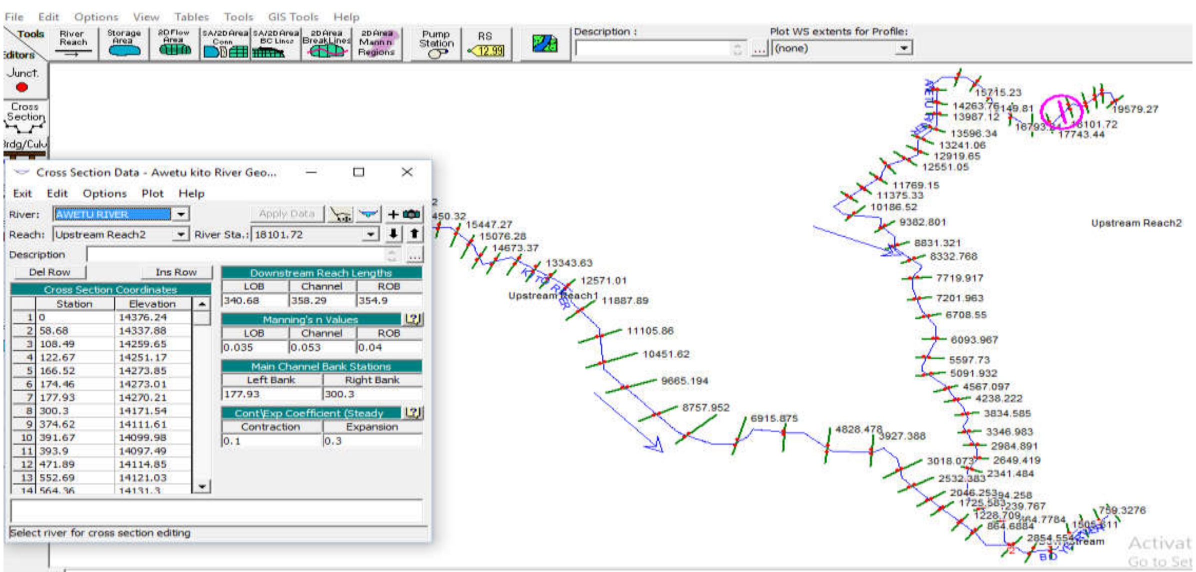

Figure 4.7: Geometric Schematic Data imported to HEC-RAS Cross-section

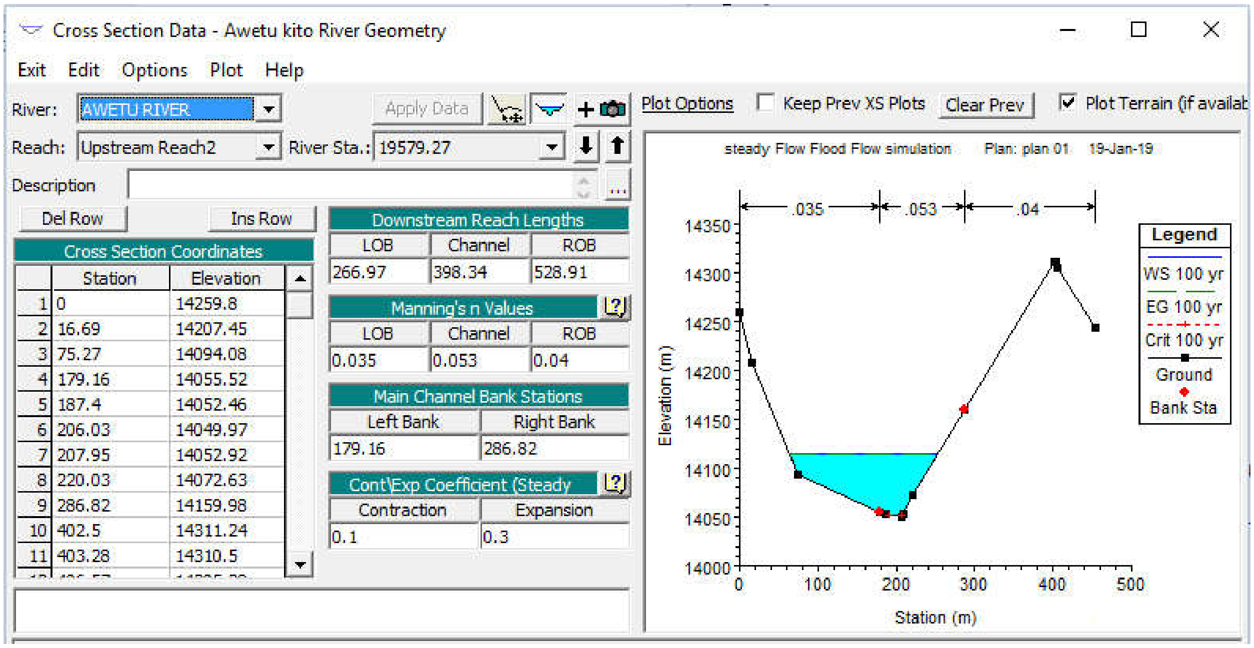

Figure 4.8: Stream Crossections

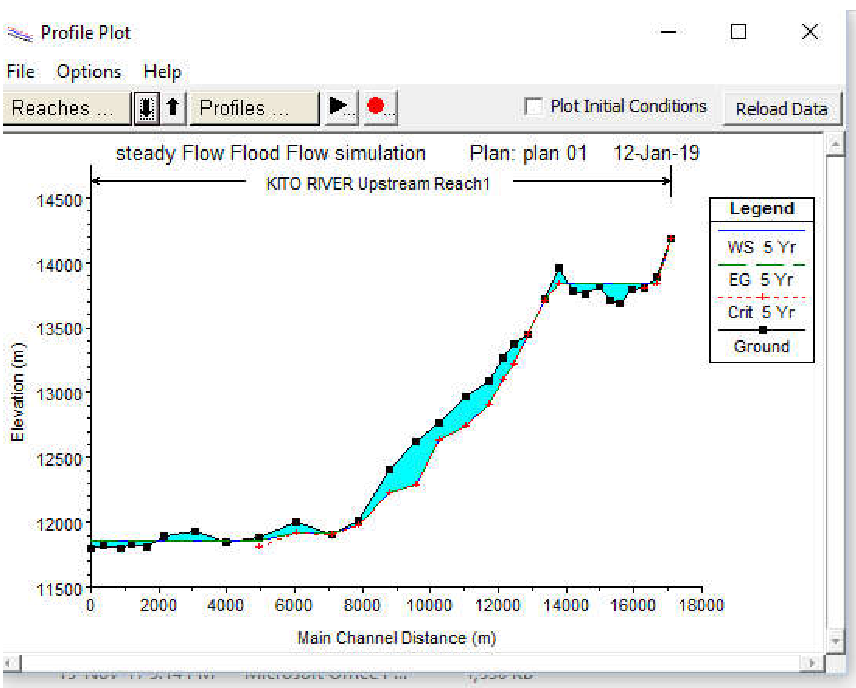

Figure 4.9: Stream Profile of Kito River for PF (2).

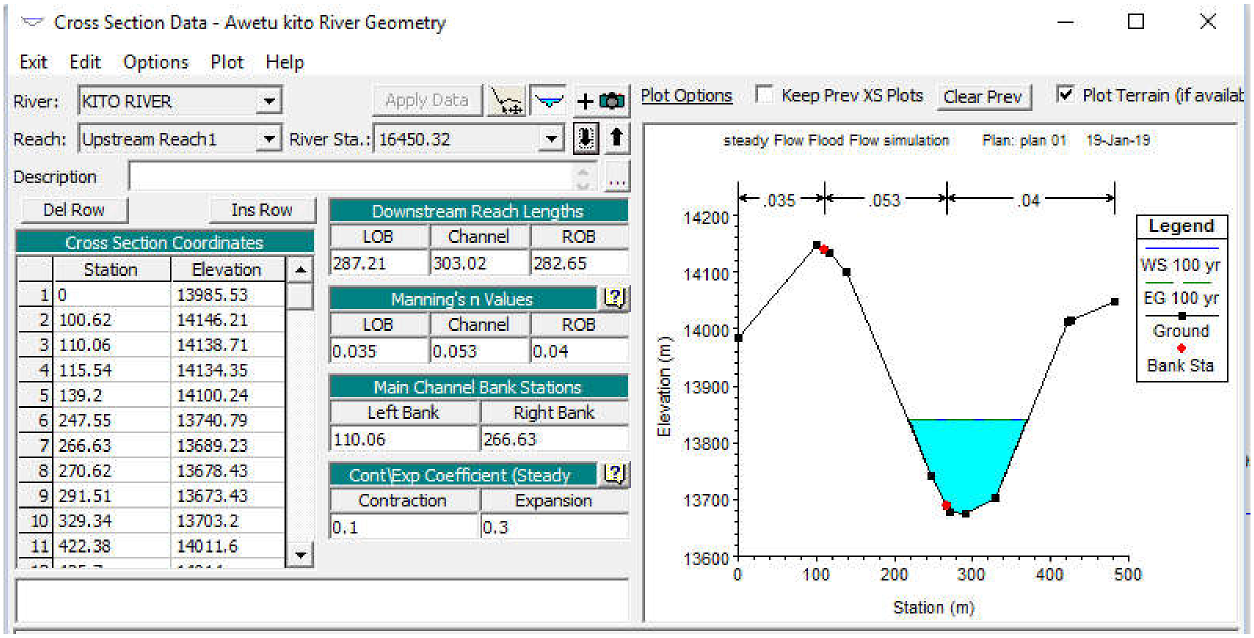

Figure 4.10: Kito river cross section profile for 100-year return period

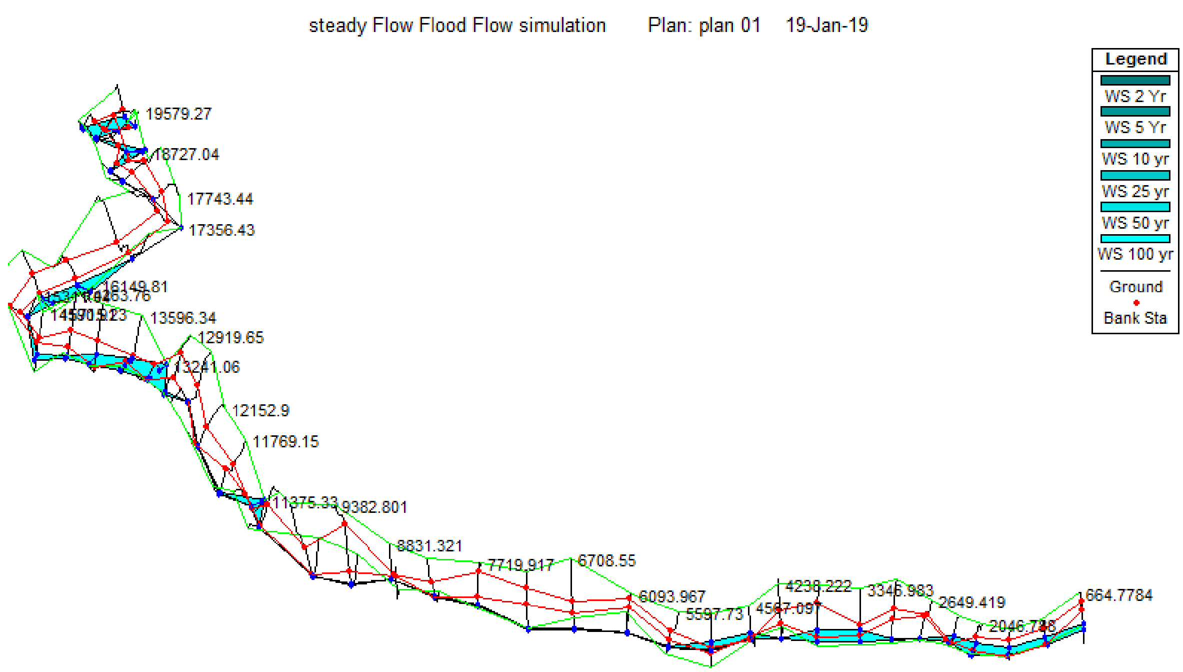

Figure 4.11: 3D x-y-z Perspective plot of the flood plain and the channel in the HEC-RAS.

4.7. Post-Processing of Hydraulic Results and Flood plain Mapping

Once HEC-RAS computed values are completed with no errors, the next step is exporting the output to ArcGIS for post-RAS processing. Post-RAS processing is the one which uses HEC-RAS output for floodplain inundation mapping and delineation.

4.7.1. Generation of Water Surface TIN

With the bounding polygon created, water surface TIN is created from the given profiles and underlying DTM/TIN. The water surface TIN consequently gives to flood plain delineation. Flood plain delineation is performed using HEC-GeoRAS post processing, in which water surface TIN was generated.

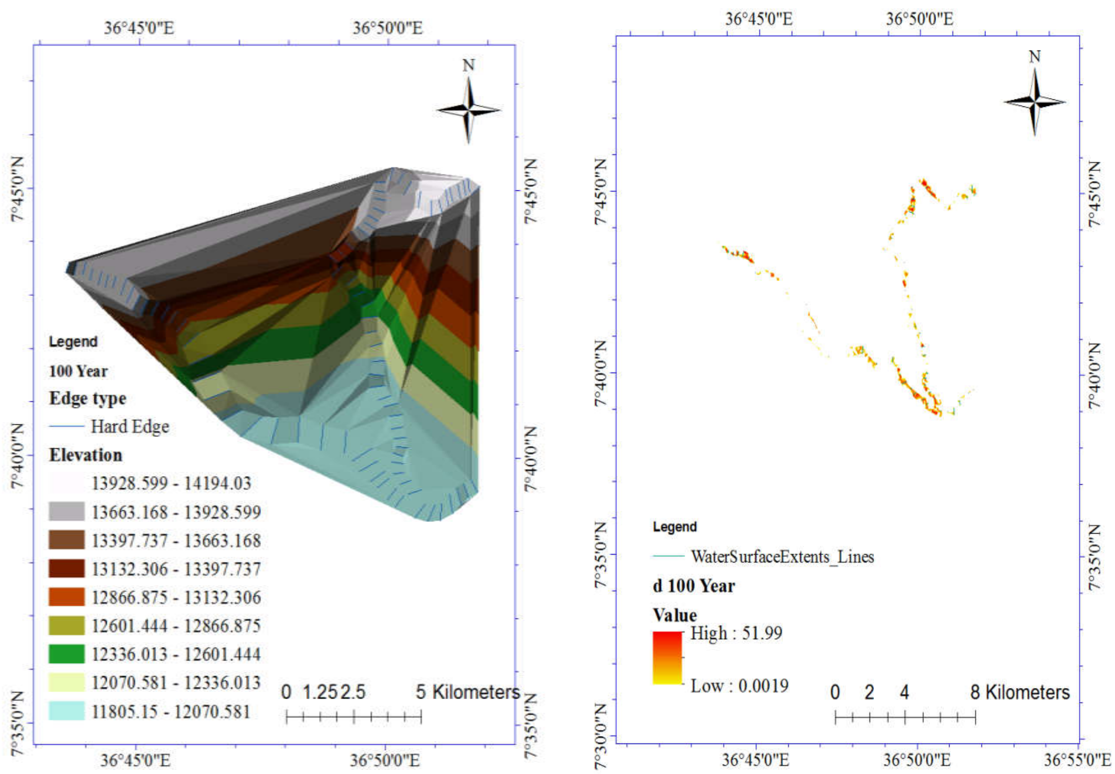

Figure 4.12: Bounding polygon for water surface TIN and Surface extent for 100 Year return period.

4.7.2. Flood Inundation Mapping

Flood inundation map shows the area extent that can be delineated as buffer zone.The water surface TIN consequently gives rise to flood plain delineation. ArcGIS with an extension of HEC-GeoRAS then delineates flood plain for different flow conditions. Flood plain map for each return period differ in depth and area. After steady flow analysis being done in HEC-RAS, GIS data was exported and imported in to Arc-GIS for inundation analysis using RAS Mapping. Imported GIS data need to be converted from SDF format in to XML format. Inundation for profile with flood extend was generated and mapped. For this particular study area inundated by flood hazard and the Maximum depth of water level was obtained by using Hec-GeoRAS (Post processing).After converting the file to Arc GIS compatible using 'Import RAS SDF File' which is one of the HEC-Geo RAS menus, HEC-Geo RAS layer setup was adjusted and the RAS data was imported and then flood inundation running was take place. The result indicated that a 2 year return period frequency storm inundates 71.46 ha of the total area flood plain with the minimum water depth 0.005 and maximum water depth of 51.49 m. Maximum flood coverage resulted for 100 years return period frequency storm and it inundates about 90.73ha that is 90.73ha of the land is vulnerable to flood hazard in 100 years with a minimum and maximum water depth of 0.007 m to 52.36 m respectively. The inundated area and maximum water level given by HEC-RAS during 2, 5,10,25,50 and 100- year flood in the study area is tabulated in Table (4.2) to have an idea of water level indifferent design floods.

Table 4.2: Area inundated and Maximum Water Level

Return period(years)	Area Inundated(ha)	Maximum Water level(m)
2	71.46	51.49
5	71.66	51.64
10	71.92	51.74
25	90.46	51.84
50	90.68	51.92
100	90.73	52.36

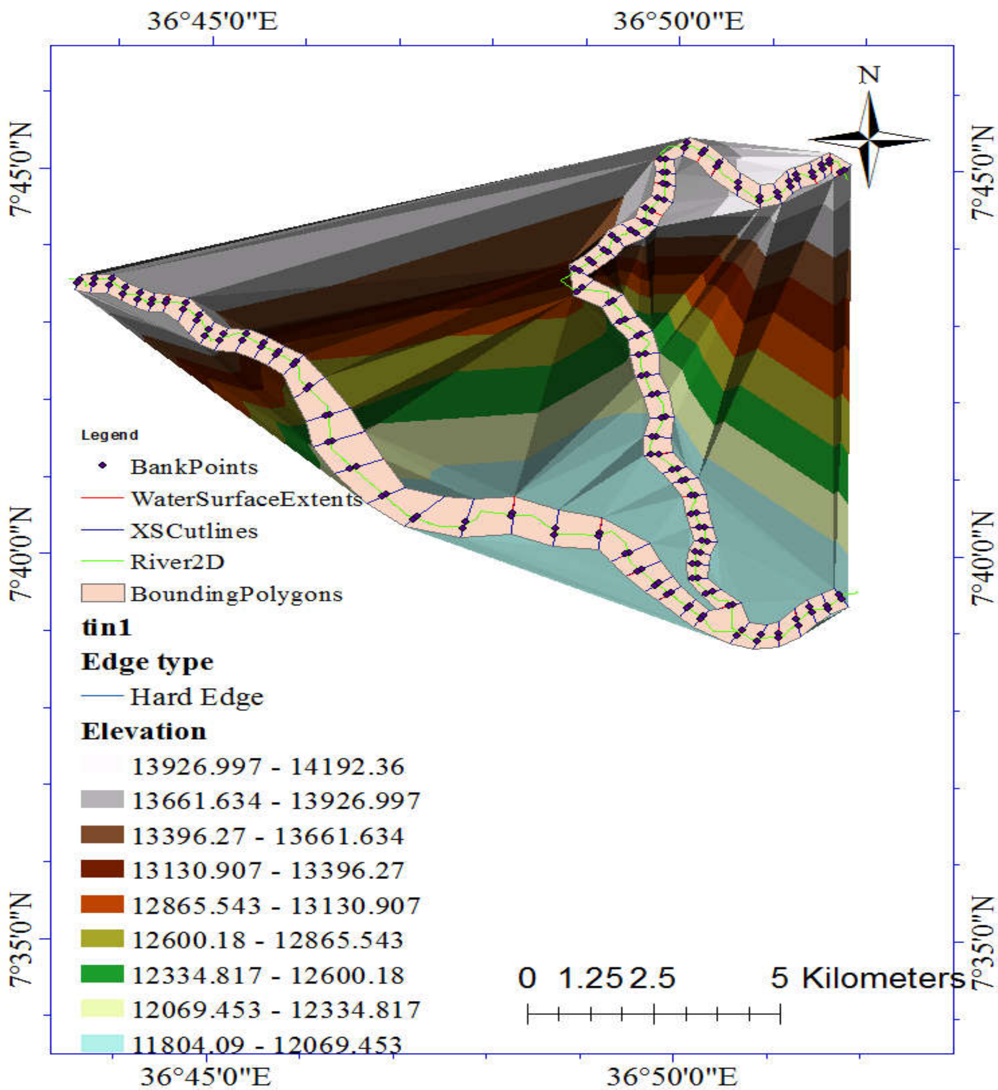

Figure 4.13: Inundation and Flood extend map

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The principal source of flooding in Jimma town is as a result of flash flood originating from high intensity of rainfall on southern highlands and surrounding mountains. It is formed as a result of steep slope of the area and also poor soil infiltration capacity. The data requirement for the study includes Rainfall data and Discharge data. Rainfall data collected from National Meteorological Service Agency, and discharge data was collected from Ministry of Water, Irrigation and Energy. The study presents a systematic approach in the preparation of flood inundation map and delineates vulnerable area, estimation of peak discharge for different return period with application of HEC software models and GIS. The peak flood discharge for different return period was estimated using Computer programs HEC-HMS .The study was carried out with DEM (30X30-resolution cell size) as base data to generate TIN which was further used for analysis in HEC-GeoRAS and HEC-RAS. Flood inundation mapping for different return period are delineated using HEC-GeoRAS and HEC-RAS one after another (first HEC-GeoRAS then HEC-RAS then back to HEC-GeoRAS).The model was calibrated and the parameter lag time and curve number was optimized and validation was done. Flood zone mapping forms the foundation for flood risk and disaster management by providing essential information about the nature and characteristic of flooding. From Hydraulic model results indicate that the flood depth of 52.36m for 100 year return period. This is helps to identify area that is affected by the flood. Nonstructural remedial measures have been suggested in order to prevent flood effect in low-lying areas. Therefore, development of flood inundation map is important in implementing flood hazard management.

5.2. Recommendation

There is a need for more accurate and recent data sets as flooding is becoming a more frequently occurring phenomenon in the town. Without appropriate data, flood modeling and prediction is limited, increasing the vulnerability of poor communities. The availability of adequate data sets for hydraulic modeling has restricted the scale of flood hazard and selection of demonstration area. One-dimensional model, HEC-RAS can provide good result in case of proper defined river course once it overtops the channel top level. For solving flood problem of the study area the non structural measures such as land use planning, and an integrated water shade management also adopted to strengthen flood hazard mitigations. Thus, this study was conducted under major constraint of limited data availability. Therefore, the following recommendations are made for further studies on the area.

- Flow data: The major hydrologic parameter, flow data of long time duration is necessary for the calibration and validation of hydrological model. Unavailability of hourly meteorological data should be addressed.
- Concerning flood mitigation measures Government/ the concerned body/ should take the measures to reduce flood impacts.
- Town administrative have prepare for this unexpected action.
- Societies of the town have to clean their environment by preparing solid waste disposal that make drainage ditch close during rainy season.
- Modified Land use land cover should be adapted since LULC is dynamic.
- Economic oriented criteria will be suggested

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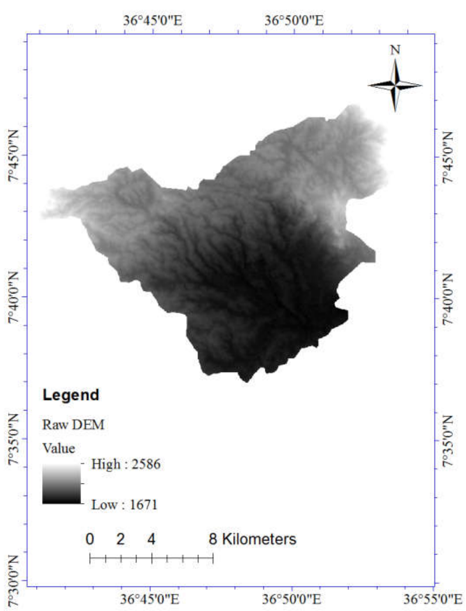
APPENDIXES

APPENDIX A: Terrain Preprocessing for the Sub basin using HEC-GeoHMS



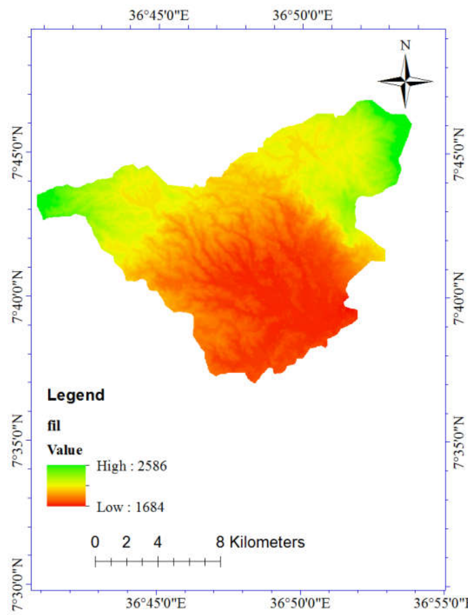
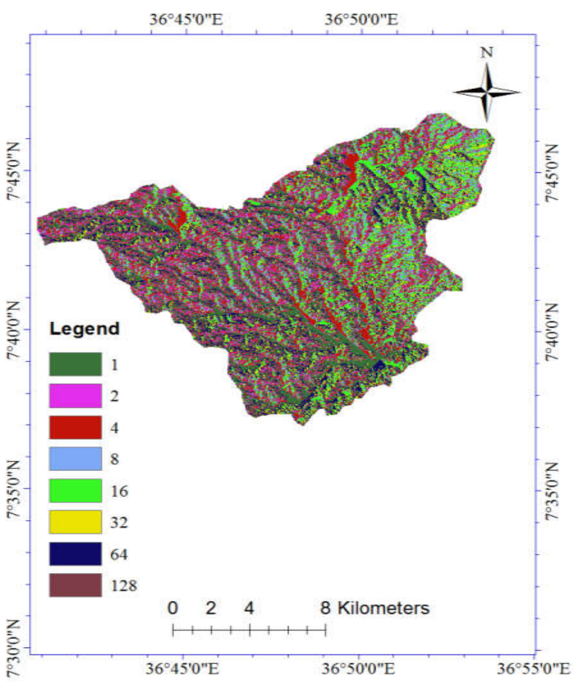
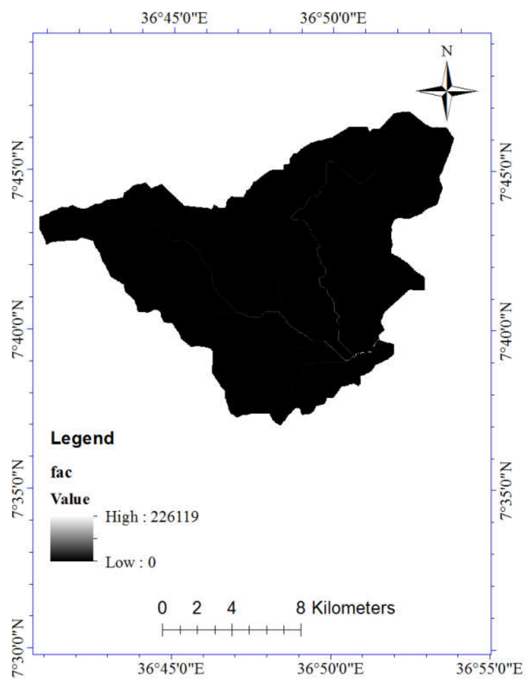


Fig (a).Raw DEM





Fig(c).Flow direction

Fig (d).Flow accumulation

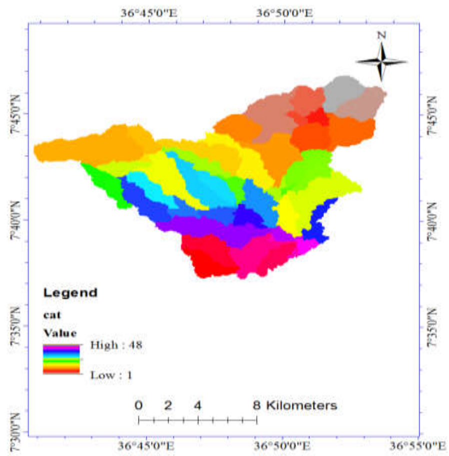


Figure (e). Catchment

APPEDIX B: Catchment characteristics.

Table B1: Catchment Basin characteristics of the Study area.

Sub basin name	Basin Shape Length	Basin Shape Area(Km^2)	Basin CN	Longest FL(Km)
W650	34.5	23.9939	71.091	11.35
W590	27.18	17.2962	77.305	10.01
W600	12.06	5.1590	78.628	3.83
W620	3.66	1.3281	76.968	1.41
W810	10.92	4.6244	68.212	3.31
W780	2.4	0.0918	69.833	0.81
W680	44.76	32.575	69.960	15.35
W840	0.36	0.0036	63	0.12
W940	19.44	11.2043	67.689	7.15
W560	43.92	42.643	69.118	14.67
W570	13.86	6.3605	68.831	4.77
W670	58.08	42.881	70.308	13.87
W900	44.52	26.5943	69.153	12.85
W880	1.68	0.0739	77.914	0.53
W870	3.36	0.1710	80.263	1.107

Table B2: Loss and Transform model parameter estimates

S.NO.	Sub basin Name	Basin Areas (Km^2)	Basin CN	Maximum retention ,S(mm)	Initial abstraction ,I_a(mm)	Impervious, I_m(%)	Basin Lag(min)	Time of Concentration (hr)
1	W_{650}	23.9939	71.091	103.288	20.657	11	106.02	2.945
2	W590	17.2962	77.305	74.568	14.914	8	75.658	2.101
3	W600	5.1590	78.628	69.040	13.808	2	38.104	1.058
4	W620	1.3281	76.968	76.007	15.201	0.6	17.385	0.483
5	W810	4.6244	68.212	118.368	23.673	2	56.635	1.573
6	W780	0.0918	69.833	109.724	21.944	0.0	28.273	0.785
7	W680	32.575	69.960	109.064	21.813	15	147.95	4.109
8	W840	0.0036	63	149.174	29.834	0.0	3.4498	0.096
9	W940	11.2043	67.689	121.245	24.249	5	92.146	2.559
10	W560	42.643	69.118	113.487	22.697	19	134.34	3.731
11	W570	6.3605	68.831	115.019	23.004	3	62.132	1.726
12	W670	42.881	70.308	107.267	21.453	20	131.90	3.664
13	W900	26.5943	69.153	113.301	22.660	12	153.97	4.277
14	W880	0.0739	77.914	72.000	14.40	0.0	20.108	0.558
15	W870	0.1710	80.263	62.459	12.492	0.08	22.767	0.6324

Table B3: Channel Routing Characteristics.

River Reach	Shape Length	Slope	Ele.U.S	Ele.D.S	River Length(m)
R130	1004.558	0.0099	1988	1978	1004.558
R300	6862.935	0.0382	1978	1716	6862.935
R320	2286.396	0.0057	1716	1703	2286.396
R270	169.705	0	1703	1703	169.705
R410	1899.777	0	1703	1703	1899.777
R340	3418.599	0	1703	1703	3418.599
R350	42.426	0	1703	1703	42.426
R460	5206.173	0.0038	1723	1703	5206.173
R430	127.279	0	1703	1703	127.279
R420	459.411	0	1703	1703	459.411
R180	5844.701	0.034	1915	1716	5844.701
R210	1333.675	0.00375	1716	1711	1333.675
R370	4110.731	0.0019	1711	1703	4110.731
R390	169.705	0	1703	1703	169.705
R400	611.984	0.0049	1703	1700	611.984

APPENDIX C: HEC-RAS Outputs

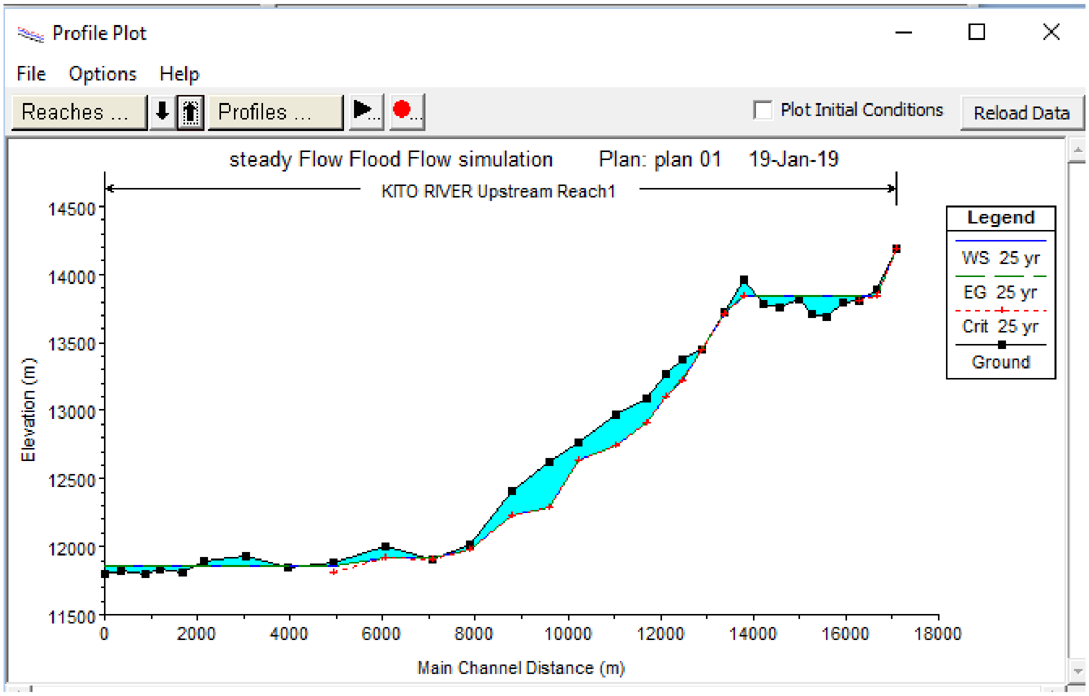
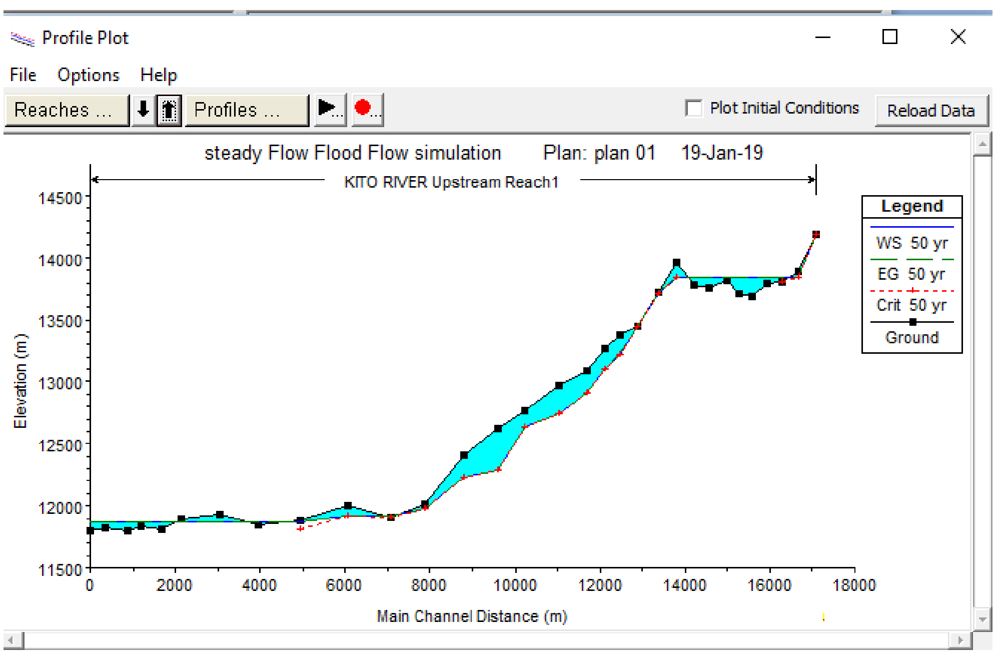
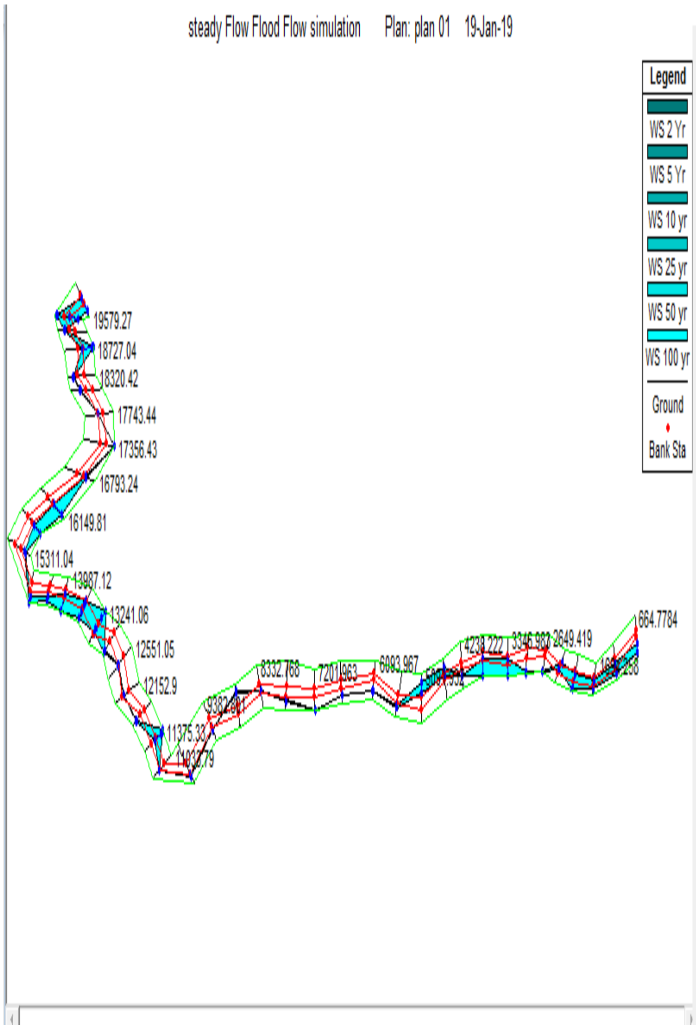
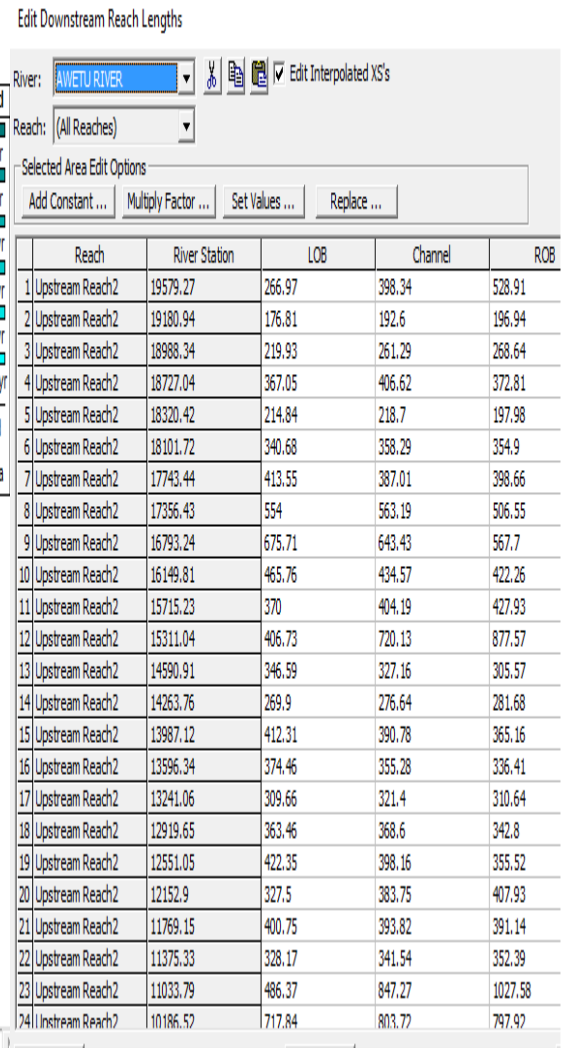


Figure C1: water surface profile of 25 year



FigureC2: Water surface Profile of 50-year




Edit Downstream Reach Lengths

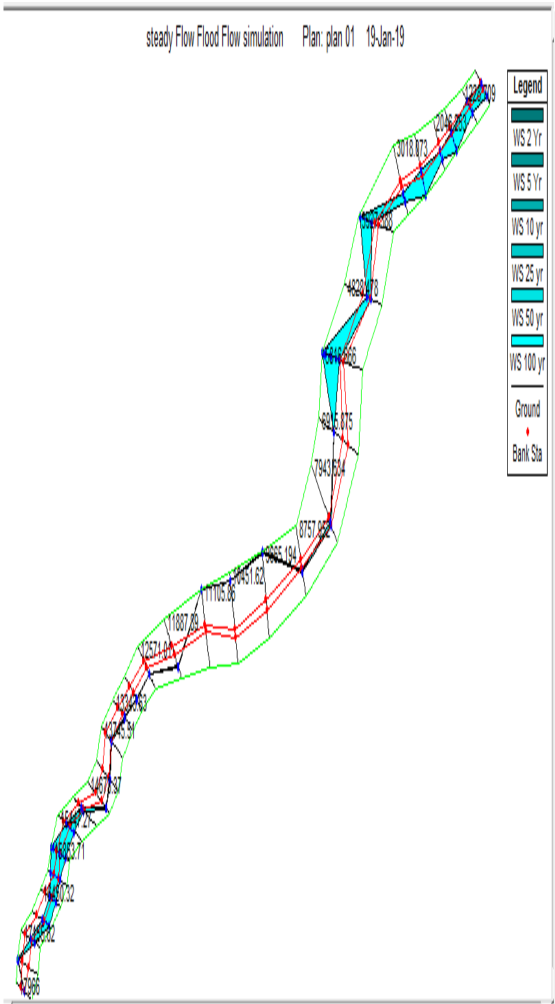
River: AWETU RIVER ☑ Edit Interpolated XS's

Reach: (All Reaches)

Selected Area Edit Options: Add Constant ... | Multiply Factor ... | Set Values ... | Replace ...

	Reach	River Station	LOB	Channel	ROB
1	Upstream Reach2	19579.27	266.97	398.34	528.91
2	Upstream Reach2	19180.94	176.81	192.6	196.94
3	Upstream Reach2	18988.34	219.93	261.29	268.64
4	Upstream Reach2	18727.04	367.05	406.62	372.81
5	Upstream Reach2	18320.42	214.84	218.7	197.98
6	Upstream Reach2	18101.72	340.68	358.29	354.9
7	Upstream Reach2	17743.44	413.55	387.01	398.66
8	Upstream Reach2	17356.43	554	563.19	506.55
9	Upstream Reach2	16793.24	675.71	643.43	567.7
10	Upstream Reach2	16149.81	465.76	434.57	422.26
11	Upstream Reach2	15715.23	370	404.19	427.93
12	Upstream Reach2	15311.04	406.73	720.13	877.57
13	Upstream Reach2	14590.91	346.59	327.16	305.57
14	Upstream Reach2	14263.76	269.9	276.64	281.68
15	Upstream Reach2	13987.12	412.31	390.78	365.16
16	Upstream Reach2	13596.34	374.46	355.28	336.41
17	Upstream Reach2	13241.06	309.66	321.4	310.64
18	Upstream Reach2	12919.65	363.46	368.6	342.8
19	Upstream Reach2	12551.05	422.35	398.16	355.52
20	Upstream Reach2	12152.9	327.5	383.75	407.93
21	Upstream Reach2	11769.15	400.75	393.82	391.14
22	Upstream Reach2	11375.33	328.17	341.54	352.39
23	Upstream Reach2	11033.79	486.37	847.27	1027.58
24	Upstream Reach2	10186.52	717.84	803.72	797.92

Figure C3:3D Plan River Stations of Left, Main,and Right Channel.



Edit Downstream Reach Lengths

River: KITO RIVER ☑ Edit Interpolated XS's

Reach: (All Reaches)

Selected Area Edit Options

Add Constant ... | Multiply Factor ... | Set Values ... | Replace ...

	Reach	River Station	LOB	Channel	ROB
1	Upstream Reach1	17966	319.91	425.32	327.98
2	Upstream Reach1	17540.68	361.2	385.05	350.19
3	Upstream Reach1	17155.62	332.2	360.75	334.6
4	Upstream Reach1	16794.88	334.89	344.56	326.03
5	Upstream Reach1	16450.32	287.21	303.02	282.65
6	Upstream Reach1	16147.29	289.17	293.58	296.21
7	Upstream Reach1	15853.71	416.66	406.45	411.16
8	Upstream Reach1	15447.27	395.31	370.99	359.33
9	Upstream Reach1	15076.28	380.55	402.91	340.69
10	Upstream Reach1	14673.37	397.83	436.81	320.76
11	Upstream Reach1	14236.56	470.85	491.05	423.11
12	Upstream Reach1	13745.51	404.95	401.88	409
13	Upstream Reach1	13343.63	365.4	353.3	330.07
14	Upstream Reach1	12990.33	439.05	419.32	388.13
15	Upstream Reach1	12571.01	654.81	683.12	581.62
16	Upstream Reach1	11887.89	846.93	782.03	679.78
17	Upstream Reach1	11105.86	649.54	654.24	627.38
18	Upstream Reach1	10451.62	751.82	786.42	774.38
19	Upstream Reach1	9665.194	808.1	907.24	927.28
20	Upstream Reach1	8757.952	907.84	814.32	881.24
21	Upstream Reach1	7943.634	671.53	1027.76	1129.4
22	Upstream Reach1	6915.875	799.41	1099.21	1058.33
23	Upstream Reach1	5816.666	962.79	988.19	909.39
24	Upstream Reach1	4828.478	894.09	901.09	885.89

Figure C4:3D Plan River station of Left, Main, and Right Channel

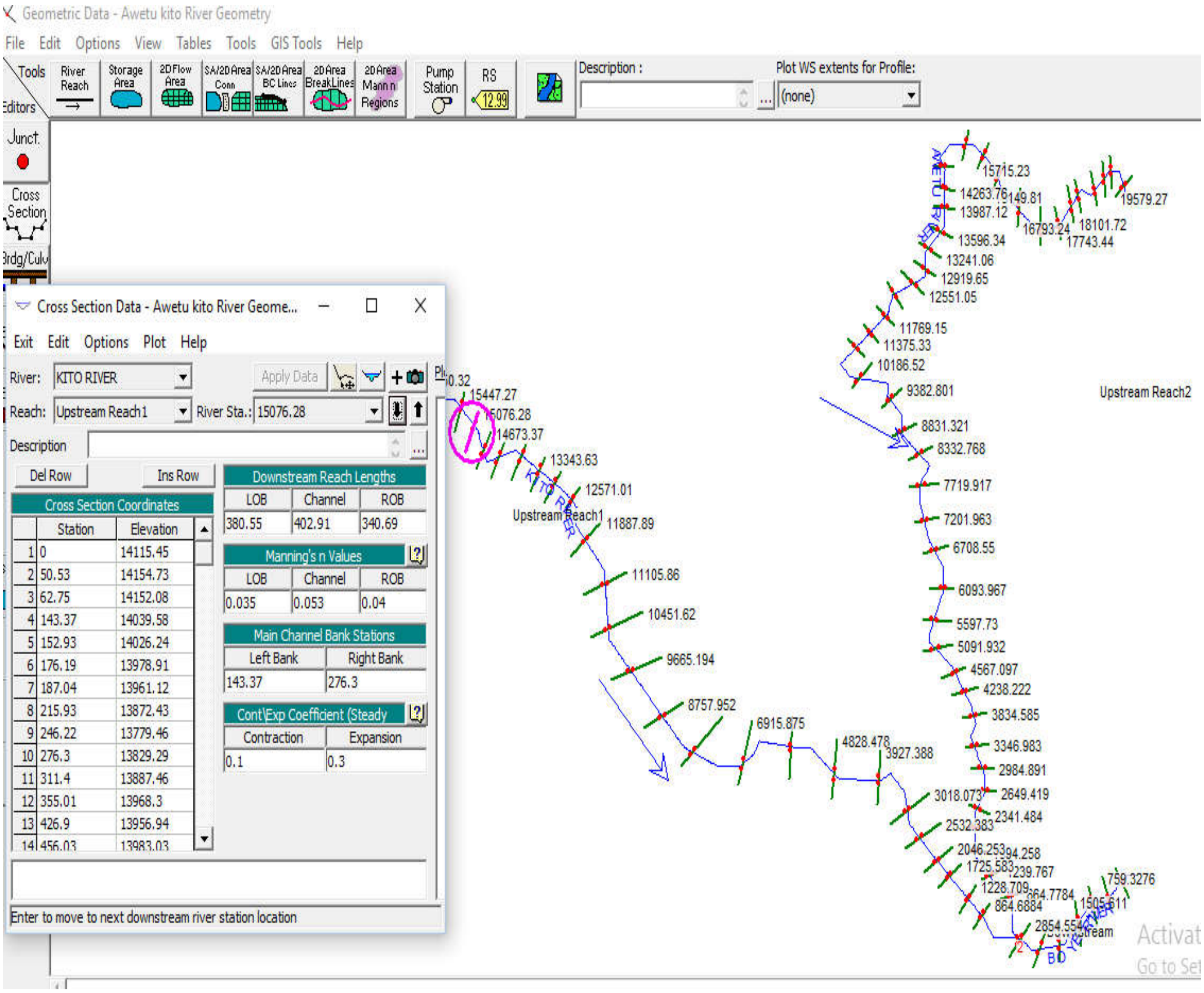
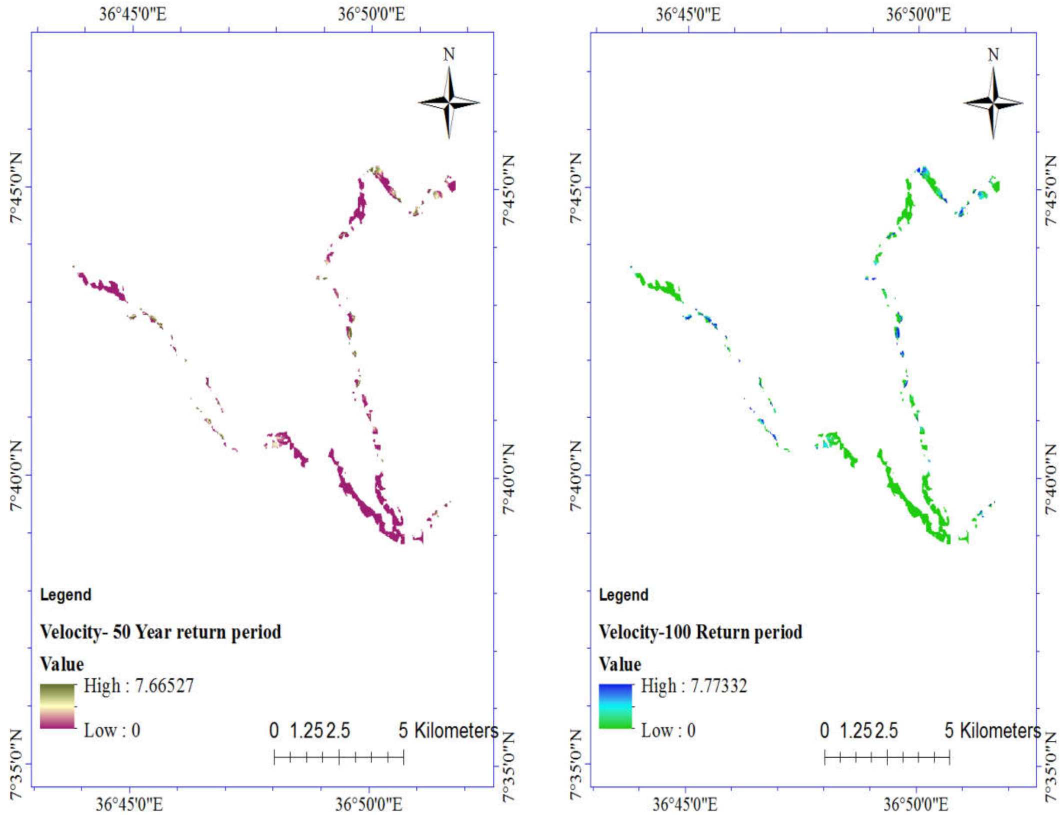


Figure C6: Geometric data.

APPENDIX D: Flood Velocity results.



FigureD1: Flood Velocity of 50 and 100 Year return period.

APPENDIX E: Flood Inundation Map Results.

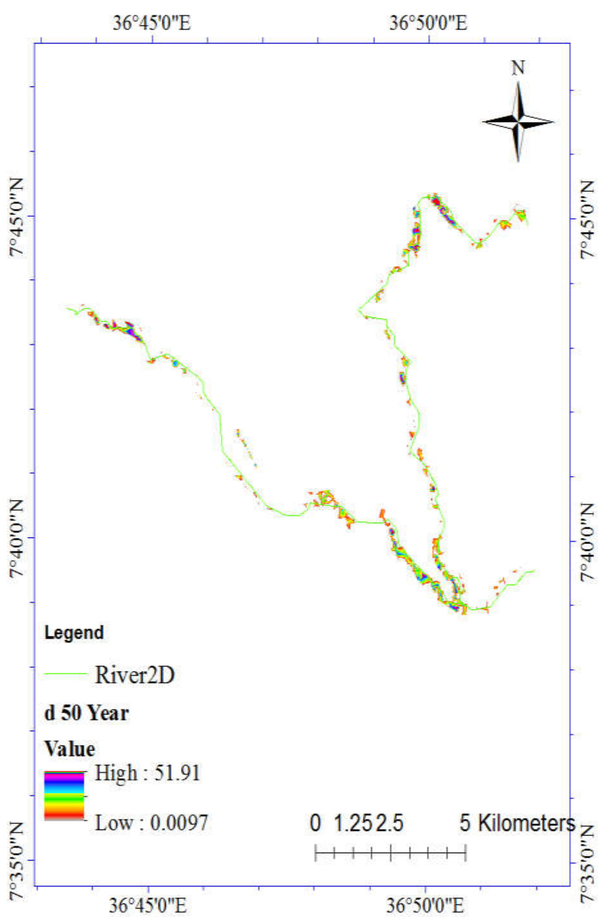


Fig E1: 50 year flood map

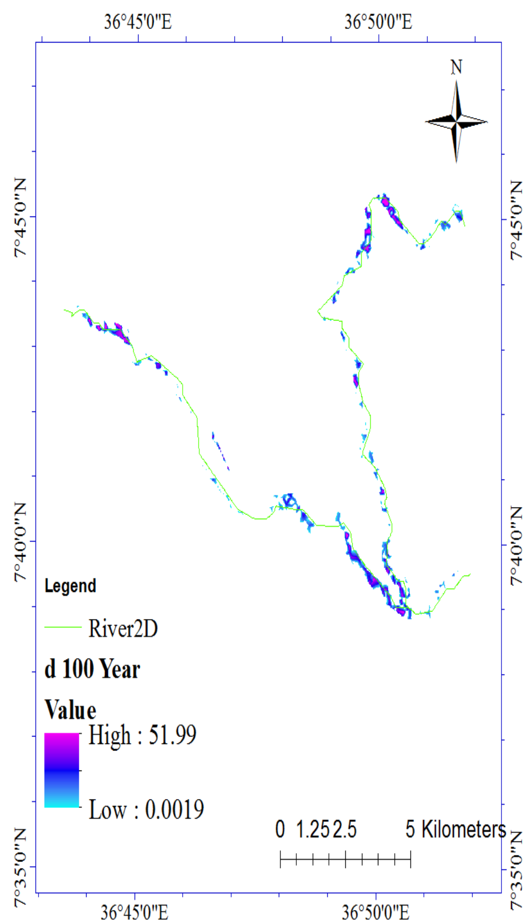
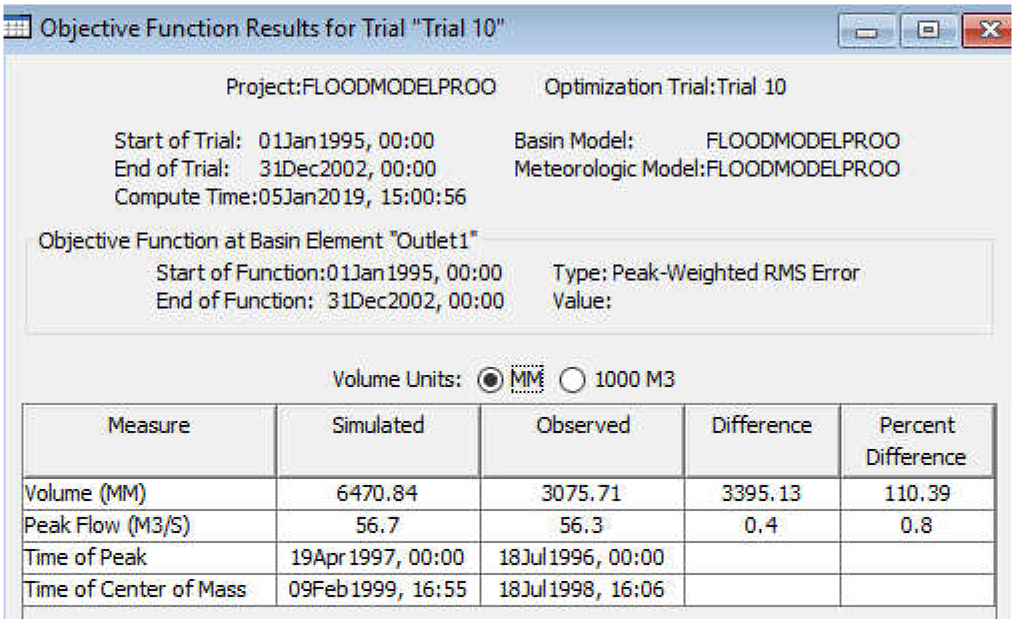


Fig E2: 100 year flood map

APPENDIX F: Objective Function Result of the Catchment


Objective Function Results for Trial "Trial 10"

Project:FLOODMODELPROO   Optimization Trial:Trial 10

Start of Trial: 01Jan1995, 00:00   Basin Model: FLOODMODELPROO
End of Trial: 31Dec2002, 00:00   Meteorologic Model:FLOODMODELPROO
Compute Time:05Jan2019, 15:00:56

Objective Function at Basin Element "Outlet1"
Start of Function:01Jan1995, 00:00   Type: Peak-Weighted RMS Error
End of Function: 31Dec2002, 00:00   Value:

Volume Units: MM 1000 M3

Measure	Simulated	Observed	Difference	Percent Difference
Volume (MM)	6470.84	3075.71	3395.13	110.39
Peak Flow (M3/S)	56.7	56.3	0.4	0.8
Time of Peak	19Apr1997, 00:00	18Jul1996, 00:00		
Time of Center of Mass	09Feb1999, 16:55	18Jul1998, 16:06		

APPENDIX G: HEC-RAS Output Summary table by profile

Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
Upstream Reach2	19579.27	2 Yr	19.60	14049.97	14113.23	14051.32	14113.23	0.000000	0.00	7088.63	185.70	0.00
Upstream Reach2	19579.27	5 Yr	28.80	14049.97	14113.71	14051.56	14113.71	0.000000	0.00	7177.66	186.31	0.00
Upstream Reach2	19579.27	10 yr	35.40	14049.97	14114.00	14051.70	14114.00	0.000000	0.00	7231.84	186.68	0.00
Upstream Reach2	19579.27	25 yr	44.30	14049.97	14114.34	14051.86	14114.34	0.000000	0.00	7295.26	187.12	0.00
Upstream Reach2	19579.27	50 yr	51.20	14049.97	14114.58	14051.97	14114.58	0.000000	0.01	7339.85	187.42	0.00
Upstream Reach2	19579.27	100 yr	58.50	14049.97	14114.81	14052.08	14114.81	0.000000	0.01	7383.40	187.72	0.00
Upstream Reach2	19180.94	2 Yr	19.60	14105.50	14113.23		14113.23	0.000000	0.00	4214.78	171.37	0.00
Upstream Reach2	19180.94	5 Yr	28.80	14105.50	14113.71		14113.71	0.000000	0.00	4297.24	173.19	0.00
Upstream Reach2	19180.94	10 yr	35.40	14105.50	14114.00		14114.00	0.000000	0.00	4347.72	174.30	0.00
Upstream Reach2	19180.94	25 yr	44.30	14105.50	14114.34		14114.34	0.000000	0.00	4407.08	175.59	0.00
Upstream Reach2	19180.94	50 yr	51.20	14105.50	14114.58		14114.58	0.000000	0.00	4449.00	176.49	0.00
Upstream Reach2	19180.94	100 yr	58.50	14105.50	14114.81		14114.81	0.000000	0.00	4490.08	177.38	0.00
Upstream Reach2	18988.34	2 Yr	19.60	14188.49	14112.60	14112.60	14113.17	0.021984		5.88	5.22	0.00
Upstream Reach2	18988.34	5 Yr	28.80	14188.49	14112.98	14112.98	14113.64	0.020987		7.99	6.08	0.00
Upstream Reach2	18988.34	10 yr	35.40	14188.49	14113.19	14113.19	14113.92	0.020916		9.34	6.58	0.00
Upstream Reach2	18988.34	25 yr	44.30	14188.49	14113.47	14113.47	14114.26	0.019883		11.26	7.22	0.00
Upstream Reach2	18988.34	50 yr	51.20	14188.49	14113.65	14113.65	14114.49	0.019583		12.62	7.65	0.00
Upstream Reach2	18988.34	100 yr	58.50	14188.49	14113.82	14113.82	14114.72	0.019516		13.97	8.04	0.00
Upstream Reach2	18727.04	2 Yr	19.60	14091.53	14109.49	14065.74	14109.49	0.000000	0.00	4246.25	183.35	0.00
Upstream Reach2	18727.04	5 Yr	28.80	14091.53	14109.81	14066.01	14109.81	0.000000	0.00	4305.43	184.83	0.00
Upstream Reach2	18727.04	10 yr	35.40	14091.53	14110.01	14066.19	14110.01	0.000000	0.00	4341.61	185.72	0.00
Upstream Reach2	18727.04	25 yr	44.30	14091.53	14110.24	14066.37	14110.24	0.000000	0.00	4384.40	186.78	0.00
Upstream Reach2	18727.04	50 yr	51.20	14091.53	14110.40	14066.52	14110.40	0.000000	0.00	4414.26	187.51	0.00
Upstream Reach2	18727.04	100 yr	58.50	14091.53	14110.56	14066.65	14110.56	0.000000	0.00	4443.56	188.23	0.00
Upstream Reach2	18320.42	2 Yr	19.60	14161.62	14109.07	14109.07	14109.46	0.019144		7.13	9.44	0.00
Upstream Reach2	18320.42	5 Yr	28.80	14161.62	14109.33	14109.33	14109.77	0.017938		9.75	11.03	0.00
Upstream Reach2	18320.42	10 yr	35.40	14161.62	14109.47	14109.47	14109.96	0.017724		11.43	11.95	0.00
Upstream Reach2	18320.42	25 yr	44.30	14161.62	14109.65	14109.65	14110.19	0.017403		13.62	13.04	0.00
Upstream Reach2	18320.42	50 yr	51.20	14161.62	14109.78	14109.78	14110.34	0.016758		15.40	13.87	0.00
Upstream Reach2	18320.42	100 yr	58.50	14161.62	14109.90	14109.90	14110.50	0.016424		17.14	14.63	0.00
Upstream Reach2	18101.72	2 Yr	19.60	14171.54	14098.56	14099.10	14100.64	0.172323		3.07	5.75	0.00
Upstream Reach2	18101.72	5 Yr	28.80	14171.54	14098.70	14099.37	14101.40	0.188337		3.96	6.53	0.00
Upstream Reach2	17743.44	2 Yr	19.60	14080.01	14081.88	14081.88	14082.34	0.034291	3.03	6.47	6.94	1.00
Upstream Reach2	17743.44	5 Yr	28.80	14080.01	14082.18	14082.18	14082.73	0.032730	3.28	8.79	8.09	1.00
Upstream Reach2	17743.44	10 yr	35.40	14080.01	14082.36	14082.36	14082.96	0.032625	3.45	10.27	8.75	1.02
Upstream Reach2	17743.44	25 yr	44.30	14080.01	14082.59	14082.59	14083.24	0.031212	3.58	12.36	9.59	1.01
Upstream Reach2	17743.44	50 yr	51.20	14080.01	14082.73	14082.73	14083.44	0.031047	3.71	13.80	10.14	1.02
Upstream Reach2	17743.44	100 yr	58.50	14080.01	14082.89	14082.89	14083.62	0.029905	3.79	15.44	10.72	1.01
Upstream Reach2	17356.43	2 Yr	19.60	14066.18	14030.25	14030.25	14030.79	0.019505		6.03	5.69	0.00
Upstream Reach2	17356.43	5 Yr	28.80	14066.18	14030.60	14030.60	14031.23	0.018628		8.18	6.63	0.00
Upstream Reach2	17356.43	10 yr	35.40	14066.18	14030.81	14030.81	14031.50	0.018181		9.64	7.20	0.00
Upstream Reach2	17356.43	25 yr	44.30	14066.18	14031.06	14031.06	14031.81	0.017614		11.54	7.88	0.00
Upstream Reach2	17356.43	50 yr	51.20	14066.18	14031.24	14031.24	14032.03	0.017163		12.99	8.35	0.00
Upstream Reach2	17356.43	100 yr	58.50	14066.18	14031.42	14031.42	14032.25	0.016764		14.48	8.82	0.00

Upstream Reach2	16793.24	2 Yr	19.60	13989.36	13945.07	13945.07	13945.92	0.035898		4.79	2.86	0.00
Upstream Reach2	16793.24	5 Yr	28.80	13989.36	13945.61	13945.61	13946.62	0.034529		6.49	3.33	0.00
Upstream Reach2	16793.24	10 yr	35.40	13989.36	13945.96	13945.96	13947.04	0.033258		7.68	3.63	0.00
Upstream Reach2	16793.24	25 yr	44.30	13989.36	13946.36	13946.36	13947.54	0.032055		9.22	3.97	0.00
Upstream Reach2	16793.24	50 yr	51.20	13989.36	13946.63	13946.63	13947.88	0.031496		10.34	4.21	0.00
Upstream Reach2	16793.24	100 yr	58.50	13989.36	13946.91	13946.91	13948.22	0.030905		11.51	4.44	0.00
Upstream Reach2	16149.81	2 Yr	19.60	13928.40	13883.09	13782.39	13883.09	0.000000		10226.65	180.46	0.00
Upstream Reach2	16149.81	5 Yr	28.80	13928.40	13883.42	13782.80	13883.42	0.000000		10284.70	180.69	0.00
Upstream Reach2	16149.81	10 yr	35.40	13928.40	13883.61	13783.04	13883.61	0.000000		10319.35	180.82	0.00
Upstream Reach2	16149.81	25 yr	44.30	13928.40	13883.84	13783.33	13883.84	0.000000		10360.92	180.98	0.00
Upstream Reach2	16149.81	50 yr	51.20	13928.40	13884.00	13783.52	13884.00	0.000000		10389.59	181.10	0.00
Upstream Reach2	16149.81	100 yr	58.50	13928.40	13884.15	13783.72	13884.15	0.000000		10417.84	181.21	0.00
Upstream Reach2	15715.23	2 Yr	19.60	13909.87	13883.09		13883.09	0.000000		5962.14	146.79	0.00
Upstream Reach2	15715.23	5 Yr	28.80	13909.87	13883.42		13883.42	0.000000		6009.38	147.07	0.00
Upstream Reach2	15715.23	10 yr	35.40	13909.87	13883.61		13883.61	0.000000		6037.58	147.24	0.00
Upstream Reach2	15715.23	25 yr	44.30	13909.87	13883.84		13883.84	0.000000		6071.44	147.44	0.00
Upstream Reach2	15715.23	50 yr	51.20	13909.87	13884.00		13884.00	0.000000		6094.80	147.58	0.00
Upstream Reach2	15715.23	100 yr	58.50	13909.87	13884.15		13884.15	0.000000		6117.83	147.72	0.00
Upstream Reach2	15311.04	2 Yr	19.60	13896.23	13882.68	13882.68	13883.06	0.015095		7.22	9.55	0.00
Upstream Reach2	15311.04	5 Yr	28.80	13896.23	13882.92	13882.92	13883.37	0.014779		9.71	11.08	0.00
Upstream Reach2	15311.04	10 yr	35.40	13896.23	13883.08	13883.08	13883.56	0.014175		11.52	12.06	0.00
Upstream Reach2	15311.04	25 yr	44.30	13896.23	13883.25	13883.25	13883.78	0.013907		13.72	13.17	0.00
Upstream Reach2	15311.04	50 yr	51.20	13896.23	13883.38	13883.38	13883.94	0.013617		15.42	13.95	0.00
Upstream Reach2	15311.04	100 yr	58.50	13896.23	13883.50	13883.50	13884.09	0.013510		17.09	14.69	0.00
Upstream Reach2	14590.91	2 Yr	19.60	13896.78	13814.17	13718.11	13814.17	0.000000		6283.83	98.32	0.00
Upstream Reach2	14590.91	5 Yr	28.80	13896.78	13814.43	13718.50	13814.43	0.000000		6309.02	98.47	0.00
Upstream Reach2	14590.91	10 yr	35.40	13896.78	13814.58	13718.73	13814.58	0.000000		6324.26	98.56	0.00
Upstream Reach2	14590.91	25 yr	44.30	13896.78	13814.76	13719.02	13814.76	0.000000		6342.23	98.66	0.00
Upstream Reach2	14590.91	50 yr	51.20	13896.78	13814.89	13719.21	13814.89	0.000000		6354.92	98.74	0.00
Upstream Reach2	14590.91	100 yr	58.50	13896.78	13815.02	13719.40	13815.02	0.000000		6367.74	98.81	0.00
Upstream Reach2	14263.76	2 Yr	19.60	13866.49	13814.17		13814.17	0.000000		432.69	59.65	0.00
Upstream Reach2	14263.76	5 Yr	28.80	13866.49	13814.43		13814.43	0.000001		448.01	60.03	0.00
Upstream Reach2	14263.76	10 yr	35.40	13866.49	13814.58		13814.58	0.000001		457.32	60.26	0.00
Upstream Reach2	14263.76	25 yr	44.30	13866.49	13814.76		13814.76	0.000001		468.32	60.52	0.00
Upstream Reach2	14263.76	50 yr	51.20	13866.49	13814.89		13814.89	0.000001		476.11	60.71	0.00
Upstream Reach2	14263.76	100 yr	58.50	13866.49	13815.02		13815.02	0.000002		483.93	60.90	0.00
Upstream Reach2	13987.12	2 Yr	19.60	13715.56	13814.17		13814.17	0.000000	0.00	13926.33	205.18	0.00
Upstream Reach2	13987.12	5 Yr	28.80	13715.56	13814.43		13814.43	0.000000	0.00	13978.86	205.28	0.00
Upstream Reach2	13987.12	10 yr	35.40	13715.56	13814.58		13814.58	0.000000	0.00	14010.64	205.34	0.00
Upstream Reach2	13987.12	25 yr	44.30	13715.56	13814.76		13814.76	0.000000	0.00	14048.05	205.41	0.00
Upstream Reach2	13987.12	50 yr	51.20	13715.56	13814.89		13814.89	0.000000	0.00	14074.47	205.45	0.00
Upstream Reach2	13987.12	100 yr	58.50	13715.56	13815.02		13815.02	0.000000	0.00	14101.13	205.50	0.00
Upstream Reach2	13596.34	2 Yr	19.60	13783.33	13814.17		13814.17	0.000000	0.00	2984.52	158.68	0.00
Upstream Reach2	13596.34	5 Yr	28.80	13783.33	13814.43		13814.43	0.000000	0.01	3025.27	159.73	0.00
Upstream Reach2	13596.34	10 yr	35.40	13783.33	13814.58		13814.58	0.000000	0.01	3050.05	160.36	0.00
Upstream Reach2	13596.34	25 yr	44.30	13783.33	13814.76		13814.76	0.000000	0.01	3079.32	161.10	0.00
Upstream Reach2	13596.34	50 yr	51.20	13783.33	13814.89		13814.89	0.000000	0.01	3100.07	161.62	0.00
Upstream Reach2	13596.34	100 yr	58.50	13783.33	13815.02		13815.02	0.000000	0.01	3121.08	162.15	0.00

Upstream Reach2	13241.06	2 Yr	19.60	13812.20	13814.17		13814.17	0.000000	0.00	720.22	148.08	0.00
Upstream Reach2	13241.06	5 Yr	28.80	13812.20	13814.43		13814.43	0.000000	0.01	758.35	149.47	0.00
Upstream Reach2	13241.06	10 yr	35.40	13812.20	13814.58		13814.58	0.000000	0.01	781.53	150.08	0.00
Upstream Reach2	13241.06	25 yr	44.30	13812.20	13814.76		13814.76	0.000000	0.01	808.94	150.79	0.00
Upstream Reach2	13241.06	50 yr	51.20	13812.20	13814.89		13814.89	0.000001	0.01	828.36	151.29	0.00
Upstream Reach2	13241.06	100 yr	58.50	13812.20	13815.02		13815.02	0.000001	0.02	848.03	151.80	0.00
Upstream Reach2	12919.65	2 Yr	19.60	13880.41	13814.17		13814.17	0.000000		336.87	36.57	0.00
Upstream Reach2	12919.65	5 Yr	28.80	13880.41	13814.43		13814.43	0.000001		346.29	37.08	0.00
Upstream Reach2	12919.65	10 yr	35.40	13880.41	13814.58		13814.58	0.000001		352.06	37.39	0.00
Upstream Reach2	12919.65	25 yr	44.30	13880.41	13814.76		13814.76	0.000002		358.86	37.75	0.00
Upstream Reach2	12919.65	50 yr	51.20	13880.41	13814.89		13814.89	0.000003		363.73	38.00	0.00
Upstream Reach2	12919.65	100 yr	58.50	13880.41	13815.02		13815.02	0.000003		368.68	38.26	0.00
Upstream Reach2	12551.05	2 Yr	19.60	13814.34	13813.84	13813.84	13814.14	0.020115		8.03	13.41	0.00
Upstream Reach2	12551.05	5 Yr	28.80	13814.34	13814.03	13814.03	13814.39	0.019320		10.88	15.61	0.00
Upstream Reach2	12551.05	10 yr	35.40	13814.34	13814.16	13814.16	13814.54	0.018698		12.86	16.97	0.00
Upstream Reach2	12551.05	25 yr	44.30	13814.34	13814.30	13814.30	13814.72	0.018042		15.42	18.58	0.00
Upstream Reach2	12551.05	50 yr	51.20	13814.34	13814.39	13814.39	13814.84	0.017674	0.15	17.12	19.58	0.31
Upstream Reach2	12551.05	100 yr	58.50	13814.34	13814.48	13814.48	13814.97	0.016848	0.30	18.94	20.58	0.36
Upstream Reach2	12152.9	2 Yr	19.60	13619.26	13621.75	13621.75	13622.38	0.083566	3.50	5.59	4.49	1.00
Upstream Reach2	12152.9	5 Yr	28.80	13619.26	13622.16	13622.16	13622.89	0.080638	3.81	7.57	5.22	1.01
Upstream Reach2	12152.9	10 yr	35.40	13619.26	13622.40	13622.40	13623.21	0.079298	3.98	8.89	5.66	1.01
Upstream Reach2	12152.9	25 yr	44.30	13619.26	13622.70	13622.70	13623.58	0.076045	4.15	10.68	6.21	1.01
Upstream Reach2	12152.9	50 yr	51.20	13619.26	13622.90	13622.90	13623.83	0.075287	4.28	11.95	6.57	1.01
Upstream Reach2	12152.9	100 yr	58.50	13619.26	13623.11	13623.11	13624.09	0.072686	4.37	13.39	6.95	1.01
Upstream Reach2	11769.15	2 Yr	19.60	13510.81	13372.43	13360.69	13372.43	0.000004		143.51	18.61	0.00
Upstream Reach2	11769.15	5 Yr	28.80	13510.81	13372.85	13361.14	13372.86	0.000008		151.47	19.06	0.00
Upstream Reach2	11769.15	10 yr	35.40	13510.81	13373.11	13361.42	13373.11	0.000012		156.41	19.33	0.00
Upstream Reach2	11769.15	25 yr	44.30	13510.81	13373.41	13361.74	13373.42	0.000017		162.28	19.65	0.00
Upstream Reach2	11769.15	50 yr	51.20	13510.81	13373.62	13361.96	13373.63	0.000021		166.40	19.87	0.00
Upstream Reach2	11769.15	100 yr	58.50	13510.81	13373.83	13362.19	13373.83	0.000025		170.49	20.09	0.00

Upstream Reach2	11375.33	2 Yr	19.60	13349.35	13372.43		13372.43	0.000000	0.00	3951.62	135.99	0.00
Upstream Reach2	11375.33	5 Yr	28.80	13349.35	13372.86		13372.86	0.000000	0.00	4009.59	137.53	0.00
Upstream Reach2	11375.33	10 yr	35.40	13349.35	13373.11		13373.11	0.000000	0.00	4044.91	138.46	0.00
Upstream Reach2	11375.33	25 yr	44.30	13349.35	13373.42		13373.42	0.000000	0.00	4086.95	139.56	0.00
Upstream Reach2	11375.33	50 yr	51.20	13349.35	13373.63		13373.63	0.000000	0.00	4116.28	140.33	0.00
Upstream Reach2	11375.33	100 yr	58.50	13349.35	13373.83		13373.83	0.000000	0.00	4145.09	141.07	0.00
Upstream Reach2	11033.79	2 Yr	19.60	13379.68	13371.88	13371.88	13372.38	0.020021		6.24	6.27	0.00
Upstream Reach2	11033.79	5 Yr	28.80	13379.68	13372.21	13372.21	13372.80	0.018981		8.50	7.32	0.00
Upstream Reach2	11033.79	10 yr	35.40	13379.68	13372.41	13372.41	13373.05	0.018693		9.98	7.93	0.00
Upstream Reach2	11033.79	25 yr	44.30	13379.68	13372.64	13372.64	13373.35	0.018202		11.93	8.67	0.00
Upstream Reach2	11033.79	50 yr	51.20	13379.68	13372.81	13372.81	13373.55	0.017690		13.44	9.20	0.00
Upstream Reach2	11033.79	100 yr	58.50	13379.68	13372.97	13372.97	13373.75	0.017390		14.95	9.70	0.00
Upstream Reach2	10186.52	2 Yr	19.60	12994.83	12992.19	12992.19	12992.46	0.020503		8.62	16.54	0.00
Upstream Reach2	10186.52	5 Yr	28.80	12994.83	12992.37	12992.37	12992.67	0.019455		11.74	19.30	0.00
Upstream Reach2	10186.52	10 yr	35.40	12994.83	12992.47	12992.47	12992.80	0.018921		13.85	20.96	0.00
Upstream Reach2	10186.52	25 yr	44.30	12994.83	12992.58	12992.58	12992.96	0.017954		16.22	21.26	0.00
Upstream Reach2	10186.52	50 yr	51.20	12994.83	12992.65	12992.65	12993.08	0.018053		17.72	21.35	0.00
Upstream Reach2	10186.52	100 yr	58.50	12994.83	12992.74	12992.74	12993.19	0.017179		19.55	21.46	0.00
Upstream Reach2	9382.801	2 Yr	19.60	12755.84	12668.10	12668.10	12668.69	0.025075		5.78	5.01	0.00
Upstream Reach2	9382.801	5 Yr	28.80	12755.84	12668.48	12668.48	12669.17	0.024104		7.83	5.83	0.00
Upstream Reach2	9382.801	10 yr	35.40	12755.84	12668.71	12668.71	12669.46	0.023468		9.24	6.33	0.00
Upstream Reach2	9382.801	25 yr	44.30	12755.84	12668.99	12668.99	12669.80	0.022652		11.07	6.93	0.00
Upstream Reach2	9382.801	50 yr	51.20	12755.84	12669.18	12669.18	12670.04	0.022099		12.46	7.35	0.00
Upstream Reach2	9382.801	100 yr	58.50	12755.84	12669.37	12669.37	12670.28	0.021711		13.86	7.75	0.00

Upstream Reach2	8831.321	2 Yr	19.60	12619.25	12504.63	12504.63	12504.92	0.015453		8.19	14.28	0.00
Upstream Reach2	8831.321	5 Yr	28.80	12619.25	12504.80	12504.80	12505.17	0.014452		10.66	14.61	0.00
Upstream Reach2	8831.321	10 yr	35.40	12619.25	12504.92	12504.92	12505.34	0.013665		12.38	14.84	0.00
Upstream Reach2	8831.321	25 yr	44.30	12619.25	12505.06	12505.06	12505.54	0.013280		14.43	15.11	0.00
Upstream Reach2	8831.321	50 yr	51.20	12619.25	12505.16	12505.16	12505.68	0.013057		15.93	15.30	0.00
Upstream Reach2	8831.321	100 yr	58.50	12619.25	12505.25	12505.25	12505.83	0.013128		17.34	15.48	0.00
Upstream Reach2	8332.768	2 Yr	19.60	12356.10	12357.44	12357.44	12357.77	0.065269	2.58	7.61	11.37	1.01
Upstream Reach2	8332.768	5 Yr	28.80	12356.10	12357.66	12357.66	12358.05	0.062780	2.80	10.30	13.23	1.01
Upstream Reach2	8332.768	10 yr	35.40	12356.10	12357.79	12357.79	12358.22	0.060288	2.90	12.21	14.40	1.01
Upstream Reach2	8332.768	25 yr	44.30	12356.10	12357.95	12357.95	12358.42	0.058443	3.03	14.61	15.76	1.01
Upstream Reach2	8332.768	50 yr	51.20	12356.10	12358.06	12358.06	12358.56	0.057487	3.12	16.39	16.69	1.01
Upstream Reach2	8332.768	100 yr	58.50	12356.10	12358.17	12358.17	12358.69	0.056364	3.21	18.25	17.61	1.01
Upstream Reach2	7719.917	2 Yr	19.60	12377.18	12336.05	12336.05	12336.49	0.019680		6.66	7.76	0.00
Upstream Reach2	7719.917	5 Yr	28.80	12377.18	12336.33	12336.33	12336.85	0.018753		9.05	9.04	0.00
Upstream Reach2	7719.917	10 yr	35.40	12377.18	12336.37	12336.51	12337.09	0.025464		9.42	9.22	0.00
Upstream Reach2	7719.917	25 yr	44.30	12377.18	12336.55	12336.71	12337.36	0.025208		11.19	10.05	0.00
Upstream Reach2	7719.917	50 yr	51.20	12377.18	12336.66	12336.86	12337.55	0.026417		12.25	10.52	0.00
Upstream Reach2	7719.917	100 yr	58.50	12377.18	12336.80	12337.00	12337.72	0.025169		13.79	11.16	0.00
Upstream Reach2	7201.963	2 Yr	19.60	12327.13	12190.26	12190.26	12190.96	0.032271		5.28	3.82	0.00
Upstream Reach2	7201.963	5 Yr	28.80	12327.13	12190.71	12190.71	12191.54	0.030905		7.17	4.44	0.00
Upstream Reach2	7201.963	10 yr	35.40	12327.13	12190.99	12190.99	12191.89	0.030071		8.45	4.83	0.00
Upstream Reach2	7201.963	25 yr	44.30	12327.13	12191.32	12191.32	12192.30	0.029191		10.11	5.28	0.00
Upstream Reach2	7201.963	50 yr	51.20	12327.13	12191.54	12191.54	12192.58	0.028760		11.34	5.59	0.00
Upstream Reach2	7201.963	100 yr	58.50	12327.13	12191.78	12191.78	12192.86	0.027944		12.67	5.91	0.00
Upstream Reach2	6708.55	2 Yr	19.60	12199.83	12108.74	12108.74	12109.34	0.023830		5.71	4.86	0.00
Upstream Reach2	6708.55	5 Yr	28.80	12199.83	12109.13	12109.13	12109.83	0.022508		7.78	5.67	0.00
Upstream Reach2	6708.55	10 yr	35.40	12199.83	12109.37	12109.37	12110.13	0.021958		9.17	6.16	0.00
Upstream Reach2	6708.55	25 yr	44.30	12199.83	12109.65	12109.65	12110.48	0.021346		10.96	6.73	0.00
Upstream Reach2	6708.55	50 yr	51.20	12199.83	12109.84	12109.84	12110.72	0.021019		12.29	7.13	0.00
Upstream Reach2	6708.55	100 yr	58.50	12199.83	12110.04	12110.04	12110.96	0.020421		13.73	7.53	0.00
Upstream Reach2	6093.967	2 Yr	19.60	12203.40	12054.67	12054.67	12055.45	0.038526		4.99	3.26	0.00
Upstream Reach2	6093.967	5 Yr	28.80	12203.40	12055.18	12055.18	12056.09	0.036321		6.81	3.80	0.00
Upstream Reach2	6093.967	10 yr	35.40	12203.40	12055.50	12055.50	12056.48	0.035156		8.05	4.14	0.00
Upstream Reach2	6093.967	25 yr	44.30	12203.40	12055.85	12055.85	12056.94	0.034427		9.60	4.52	0.00
Upstream Reach2	6093.967	50 yr	51.20	12203.40	12056.11	12056.11	12057.26	0.033482		10.82	4.79	0.00
Upstream Reach2	6093.967	100 yr	58.50	12203.40	12056.35	12056.35	12057.57	0.033183		11.99	5.05	0.00
Upstream Reach2	5597.73	2 Yr	19.60	12064.85	12017.22	12017.22	12017.46	0.021819		8.99	19.17	0.00
Upstream Reach2	5597.73	5 Yr	28.80	12064.85	12017.38	12017.38	12017.66	0.020269		12.34	22.46	0.00
Upstream Reach2	5597.73	10 yr	35.40	12064.85	12017.47	12017.47	12017.77	0.019657		14.57	24.40	0.00
Upstream Reach2	5597.73	25 yr	44.30	12064.85	12017.59	12017.59	12017.92	0.019091		17.43	26.69	0.00
Upstream Reach2	5597.73	50 yr	51.20	12064.85	12017.66	12017.66	12018.01	0.018674		19.59	28.30	0.00
Upstream Reach2	5597.73	100 yr	58.50	12064.85	12017.74	12017.74	12018.11	0.018480		21.74	29.81	0.00
Upstream Reach2	5091.932	2 Yr	19.60	11967.37	11926.10	11897.11	11926.10	0.000000		2760.57	129.56	0.00
Upstream Reach2	5091.932	5 Yr	28.80	11967.37	11926.68	11897.28	11926.68	0.000000		2835.19	130.48	0.00
Upstream Reach2	5091.932	10 yr	35.40	11967.37	11927.02	11897.37	11927.02	0.000000		2880.49	131.03	0.00
Upstream Reach2	5091.932	25 yr	44.30	11967.37	11927.44	11897.49	11927.44	0.000000		2934.61	131.69	0.00
Upstream Reach2	5091.932	50 yr	51.20	11967.37	11927.72	11897.57	11927.72	0.000000		2972.15	132.15	0.00
Upstream Reach2	5091.932	100 yr	58.50	11967.37	11928.00	11897.64	11928.00	0.000000		3008.71	132.59	0.00

Upstream Reach2	4567.097	2 Yr	19.60	11894.44	11926.10		11926.10	0.000000	0.01	1641.14	99.90	0.00
Upstream Reach2	4567.097	5 Yr	28.80	11894.44	11926.68		11926.68	0.000000	0.01	1698.69	100.66	0.00
Upstream Reach2	4567.097	10 yr	35.40	11894.44	11927.02		11927.02	0.000000	0.01	1733.64	101.11	0.00
Upstream Reach2	4567.097	25 yr	44.30	11894.44	11927.44		11927.44	0.000000	0.02	1775.41	101.66	0.00
Upstream Reach2	4567.097	50 yr	51.20	11894.44	11927.72		11927.72	0.000000	0.02	1804.39	102.04	0.00
Upstream Reach2	4567.097	100 yr	58.50	11894.44	11928.00		11928.00	0.000000	0.02	1832.63	102.40	0.00
Upstream Reach2	4238.222	2 Yr	19.60	12017.21	11925.35	11925.35	11926.04	0.029073		5.35	3.96	0.00
Upstream Reach2	4238.222	5 Yr	28.80	12017.21	11925.80	11925.80	11926.60	0.027459		7.29	4.63	0.00
Upstream Reach2	4238.222	10 yr	35.40	12017.21	11926.07	11926.07	11926.94	0.026995		8.56	5.02	0.00
Upstream Reach2	4238.222	25 yr	44.30	12017.21	11926.38	11926.38	11927.34	0.026387		10.22	5.48	0.00
Upstream Reach2	4238.222	50 yr	51.20	12017.21	11926.61	11926.61	11927.62	0.025624		11.52	5.82	0.00
Upstream Reach2	4238.222	100 yr	58.50	12017.21	11926.83	11926.83	11927.89	0.025140		12.82	6.14	0.00
Upstream Reach2	3834.585	2 Yr	19.60	11843.03	11893.88	11799.69	11893.88	0.000000	0.00	13802.32	196.53	0.00
Upstream Reach2	3834.585	5 Yr	28.80	11843.03	11894.50	11799.83	11894.50	0.000000	0.00	13923.12	196.72	0.00
Upstream Reach2	3834.585	10 yr	35.40	11843.03	11894.87	11799.92	11894.87	0.000000	0.00	13996.22	196.84	0.00
Upstream Reach2	3834.585	25 yr	44.30	11843.03	11895.31	11800.02	11895.31	0.000000	0.00	14082.96	196.97	0.00
Upstream Reach2	3834.585	50 yr	51.20	11843.03	11895.61	11800.09	11895.61	0.000000	0.00	14143.48	197.07	0.00
Upstream Reach2	3834.585	100 yr	58.50	11843.03	11895.91	11800.15	11895.91	0.000000	0.00	14202.39	197.16	0.00
Upstream Reach2	3346.983	2 Yr	19.60	11876.76	11893.88		11893.88	0.000000	0.00	3627.93	214.32	0.00
Upstream Reach2	3346.983	5 Yr	28.80	11876.76	11894.50		11894.50	0.000000	0.00	3759.71	214.67	0.00
Upstream Reach2	3346.983	10 yr	35.40	11876.76	11894.87		11894.87	0.000000	0.01	3839.49	214.89	0.00
Upstream Reach2	3346.983	25 yr	44.30	11876.76	11895.31		11895.31	0.000000	0.01	3934.21	215.14	0.00
Upstream Reach2	3346.983	50 yr	51.20	11876.76	11895.61		11895.61	0.000000	0.01	4000.33	215.32	0.00
Upstream Reach2	3346.983	100 yr	58.50	11876.76	11895.91		11895.91	0.000000	0.01	4064.70	215.49	0.00
Upstream Reach2	2984.891	2 Yr	19.60	11981.56	11893.88		11893.88	0.000004		174.40	14.81	0.00
Upstream Reach2	2984.891	5 Yr	28.80	11981.56	11894.49		11894.50	0.000007		183.61	15.19	0.00
Upstream Reach2	2984.891	10 yr	35.40	11981.56	11894.87		11894.87	0.000010		189.30	15.42	0.00
Upstream Reach2	2984.891	25 yr	44.30	11981.56	11895.30		11895.31	0.000015		196.13	15.70	0.00
Upstream Reach2	2984.891	50 yr	51.20	11981.56	11895.61		11895.61	0.000019		200.97	15.89	0.00
Upstream Reach2	2984.891	100 yr	58.50	11981.56	11895.91		11895.91	0.000023		205.75	16.08	0.00
Upstream Reach2	2649.419	2 Yr	19.60	11970.60	11893.08	11893.08	11893.80	0.036933		5.20	3.63	0.00
Upstream Reach2	2649.419	5 Yr	28.80	11970.60	11893.55	11893.55	11894.40	0.035347		7.06	4.23	0.00
Upstream Reach2	2649.419	10 yr	35.40	11970.60	11893.84	11893.84	11894.76	0.034292		8.33	4.59	0.00
Upstream Reach2	2649.419	25 yr	44.30	11970.60	11894.17	11894.17	11895.19	0.033828		9.91	5.01	0.00
Upstream Reach2	2649.419	50 yr	51.20	11970.60	11894.42	11894.42	11895.49	0.032793		11.18	5.32	0.00
Upstream Reach2	2649.419	100 yr	58.50	11970.60	11894.65	11894.65	11895.77	0.032232		12.43	5.61	0.00
Upstream Reach2	2341.484	2 Yr	19.60	11818.70	11863.70	11821.00	11863.70	0.000000	0.01	2268.01	103.57	0.00
Upstream Reach2	2341.484	5 Yr	28.80	11818.70	11864.00	11821.38	11864.00	0.000000	0.01	2299.81	104.31	0.00
Upstream Reach2	2341.484	10 yr	35.40	11818.70	11864.19	11821.61	11864.19	0.000000	0.01	2319.10	104.76	0.00
Upstream Reach2	2341.484	25 yr	44.30	11818.70	11864.41	11821.89	11864.41	0.000000	0.01	2342.11	105.30	0.00
Upstream Reach2	2341.484	50 yr	51.20	11818.70	11864.56	11822.08	11864.56	0.000000	0.02	2358.06	105.67	0.00
Upstream Reach2	2341.484	100 yr	58.50	11818.70	11864.71	11822.25	11864.71	0.000000	0.02	2373.82	106.03	0.00
Upstream Reach2	2046.788	2 Yr	19.60	11788.97	11863.70		11863.70	0.000000	0.00	5779.86	195.90	0.00
Upstream Reach2	2046.788	5 Yr	28.80	11788.97	11864.00		11864.00	0.000000	0.00	5839.97	196.91	0.00
Upstream Reach2	2046.788	10 yr	35.40	11788.97	11864.19		11864.19	0.000000	0.01	5876.34	197.27	0.00
Upstream Reach2	2046.788	25 yr	44.30	11788.97	11864.41		11864.41	0.000000	0.01	5919.60	197.68	0.00
Upstream Reach2	2046.788	50 yr	51.20	11788.97	11864.56		11864.56	0.000000	0.01	5949.52	197.97	0.00
Upstream Reach2	2046.788	100 yr	58.50	11788.97	11864.71		11864.71	0.000000	0.01	5979.00	198.25	0.00

Upstream Reach2	1694.258	2 Yr	19.60	11783.14	11863.70		11863.70	0.000000	0.00	4249.11	116.84	0.00
Upstream Reach2	1694.258	5 Yr	28.80	11783.14	11864.00		11864.00	0.000000	0.01	4285.03	117.91	0.00
Upstream Reach2	1694.258	10 yr	35.40	11783.14	11864.19		11864.19	0.000000	0.01	4306.84	118.55	0.00
Upstream Reach2	1694.258	25 yr	44.30	11783.14	11864.41		11864.41	0.000000	0.01	4332.90	119.31	0.00
Upstream Reach2	1694.258	50 yr	51.20	11783.14	11864.56		11864.56	0.000000	0.01	4350.98	119.83	0.00
Upstream Reach2	1694.258	100 yr	58.50	11783.14	11864.71		11864.71	0.000000	0.01	4368.85	120.35	0.00
Upstream Reach2	1239.767	2 Yr	19.60	11831.27	11863.70		11863.70	0.000000	0.01	1875.33	129.18	0.00
Upstream Reach2	1239.767	5 Yr	28.80	11831.27	11864.00		11864.00	0.000000	0.01	1915.00	130.11	0.00
Upstream Reach2	1239.767	10 yr	35.40	11831.27	11864.19		11864.19	0.000000	0.01	1939.06	130.66	0.00
Upstream Reach2	1239.767	25 yr	44.30	11831.27	11864.41		11864.41	0.000000	0.02	1967.76	131.32	0.00
Upstream Reach2	1239.767	50 yr	51.20	11831.27	11864.56		11864.56	0.000000	0.02	1987.65	131.78	0.00
Upstream Reach2	1239.767	100 yr	58.50	11831.27	11864.71		11864.71	0.000000	0.02	2007.29	132.22	0.00
Upstream Reach2	664.7784	2 Yr	19.60	11940.76	11863.70		11863.70	0.000000		6372.56	100.53	0.00
Upstream Reach2	664.7784	5 Yr	28.80	11940.76	11864.00		11864.00	0.000000		6403.37	100.82	0.00
Upstream Reach2	664.7784	10 yr	35.40	11940.76	11864.19		11864.19	0.000000		6421.99	101.00	0.00
Upstream Reach2	664.7784	25 yr	44.30	11940.76	11864.41		11864.41	0.000000		6444.14	101.21	0.00
Upstream Reach2	664.7784	50 yr	51.20	11940.76	11864.56		11864.56	0.000000		6459.45	101.36	0.00
Upstream Reach2	664.7784	100 yr	58.50	11940.76	11864.71		11864.71	0.000000		6474.55	101.50	0.00

HEC-RAS Plan: plan 01

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
KITO RIVER	Upstream Reach1	17966	2 Yr	19.60	14189.28	14192.36	14192.36	14193.13	0.067525	3.90	5.02	3.27	1.01
KITO RIVER	Upstream Reach1	17966	5 Yr	28.80	14189.28	14192.86	14192.86	14193.78	0.064588	4.23	6.81	3.80	1.01
KITO RIVER	Upstream Reach1	17966	10 yr	35.40	14189.28	14193.17	14193.17	14194.16	0.062926	4.41	8.03	4.13	1.01
KITO RIVER	Upstream Reach1	17966	25 yr	44.30	14189.28	14193.54	14193.54	14194.62	0.061129	4.61	9.61	4.52	1.01
KITO RIVER	Upstream Reach1	17966	50 yr	51.20	14189.28	14193.79	14193.79	14194.94	0.060129	4.75	10.78	4.78	1.01
KITO RIVER	Upstream Reach1	17966	100 yr	58.50	14189.28	14194.03	14194.04	14195.25	0.059246	4.89	11.97	5.04	1.01
KITO RIVER	Upstream Reach1	17540.68	2 Yr	19.60	13896.09	13844.89	13844.89	13845.79	0.044277		4.66	2.63	0.00
KITO RIVER	Upstream Reach1	17540.68	5 Yr	28.80	13896.09	13845.48	13845.48	13846.53	0.041854		6.35	3.07	0.00
KITO RIVER	Upstream Reach1	17540.68	10 yr	35.40	13896.09	13845.83	13845.83	13846.98	0.040789		7.49	3.33	0.00
KITO RIVER	Upstream Reach1	17540.68	25 yr	44.30	13896.09	13846.26	13846.26	13847.50	0.039659		8.95	3.64	0.00
KITO RIVER	Upstream Reach1	17540.68	50 yr	51.20	13896.09	13846.56	13846.56	13847.87	0.038483		10.09	3.87	0.00
KITO RIVER	Upstream Reach1	17540.68	100 yr	58.50	13896.09	13846.83	13846.83	13848.23	0.038381		11.16	4.07	0.00
KITO RIVER	Upstream Reach1	17155.62	2 Yr	19.60	13806.71	13837.61	13806.19	13837.61	0.000000	0.01	2563.15	109.74	0.00
KITO RIVER	Upstream Reach1	17155.62	5 Yr	28.80	13806.71	13838.11	13806.34	13838.11	0.000000	0.01	2617.85	110.61	0.00
KITO RIVER	Upstream Reach1	17155.62	10 yr	35.40	13806.71	13838.41	13806.42	13838.41	0.000000	0.01	2650.85	111.13	0.00
KITO RIVER	Upstream Reach1	17155.62	25 yr	44.30	13806.71	13838.76	13806.56	13838.76	0.000000	0.01	2690.26	111.75	0.00
KITO RIVER	Upstream Reach1	17155.62	50 yr	51.20	13806.71	13839.00	13806.62	13839.00	0.000000	0.01	2717.72	112.18	0.00
KITO RIVER	Upstream Reach1	17155.62	100 yr	58.50	13806.71	13839.25	13806.70	13839.25	0.000000	0.02	2744.75	112.60	0.00
KITO RIVER	Upstream Reach1	16794.88	2 Yr	19.60	13798.61	13837.61		13837.61	0.000000	0.00	5783.26	159.78	0.00
KITO RIVER	Upstream Reach1	16794.88	5 Yr	28.80	13798.61	13838.11		13838.11	0.000000	0.00	5862.81	160.65	0.00
KITO RIVER	Upstream Reach1	16794.88	10 yr	35.40	13798.61	13838.41		13838.41	0.000000	0.00	5910.70	161.18	0.00
KITO RIVER	Upstream Reach1	16794.88	25 yr	44.30	13798.61	13838.76		13838.76	0.000000	0.00	5967.81	161.80	0.00
KITO RIVER	Upstream Reach1	16794.88	50 yr	51.20	13798.61	13839.00		13839.00	0.000000	0.00	6007.54	162.23	0.00
KITO RIVER	Upstream Reach1	16794.88	100 yr	58.50	13798.61	13839.25		13839.25	0.000000	0.00	6046.61	162.65	0.00
KITO RIVER	Upstream Reach1	16450.32	2 Yr	19.60	13689.23	13837.61		13837.61	0.000000	0.00	16116.33	151.53	0.00
KITO RIVER	Upstream Reach1	16450.32	5 Yr	28.80	13689.23	13838.11		13838.11	0.000000	0.00	16191.63	151.82	0.00
KITO RIVER	Upstream Reach1	16450.32	10 yr	35.40	13689.23	13838.41		13838.41	0.000000	0.00	16236.85	152.00	0.00
KITO RIVER	Upstream Reach1	16450.32	25 yr	44.30	13689.23	13838.76		13838.76	0.000000	0.00	16290.64	152.22	0.00
KITO RIVER	Upstream Reach1	16450.32	50 yr	51.20	13689.23	13839.00		13839.00	0.000000	0.00	16327.99	152.37	0.00
KITO RIVER	Upstream Reach1	16450.32	100 yr	58.50	13689.23	13839.25		13839.25	0.000000	0.00	16364.66	152.51	0.00

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
KITO RIVER	Upstream Reach1	16147.29	2 Yr	19.60	13705.85	13837.61		13837.61	0.000000	0.00	16715.43	232.97	0.00
KITO RIVER	Upstream Reach1	16147.29	5 Yr	28.80	13705.85	13838.11		13838.11	0.000000	0.00	16831.27	233.68	0.00
KITO RIVER	Upstream Reach1	16147.29	10 yr	35.40	13705.85	13838.41		13838.41	0.000000	0.00	16900.89	234.11	0.00
KITO RIVER	Upstream Reach1	16147.29	25 yr	44.30	13705.85	13838.76		13838.76	0.000000	0.00	16983.77	234.62	0.00
KITO RIVER	Upstream Reach1	16147.29	50 yr	51.20	13705.85	13839.00		13839.00	0.000000	0.00	17041.36	234.97	0.00
KITO RIVER	Upstream Reach1	16147.29	100 yr	58.50	13705.85	13839.25		13839.25	0.000000	0.00	17097.91	235.32	0.00
KITO RIVER	Upstream Reach1	15853.71	2 Yr	19.60	13821.46	13837.61		13837.61	0.000000	0.00	7157.76	190.53	0.00
KITO RIVER	Upstream Reach1	15853.71	5 Yr	28.80	13821.46	13838.11		13838.11	0.000000	0.00	7252.64	191.69	0.00
KITO RIVER	Upstream Reach1	15853.71	10 yr	35.40	13821.46	13838.41		13838.41	0.000000	0.00	7309.80	192.38	0.00
KITO RIVER	Upstream Reach1	15853.71	25 yr	44.30	13821.46	13838.76		13838.76	0.000000	0.00	7377.98	193.21	0.00
KITO RIVER	Upstream Reach1	15853.71	50 yr	51.20	13821.46	13839.00		13839.00	0.000000	0.00	7425.44	193.78	0.00
KITO RIVER	Upstream Reach1	15853.71	100 yr	58.50	13821.46	13839.25		13839.25	0.000000	0.00	7472.11	194.34	0.00
KITO RIVER	Upstream Reach1	15447.27	2 Yr	19.60	13759.13	13837.61		13837.61	0.000000	0.00	12206.44	182.34	0.00
KITO RIVER	Upstream Reach1	15447.27	5 Yr	28.80	13759.13	13838.11		13838.11	0.000000	0.00	12297.16	183.09	0.00
KITO RIVER	Upstream Reach1	15447.27	10 yr	35.40	13759.13	13838.41		13838.41	0.000000	0.00	12351.72	183.55	0.00
KITO RIVER	Upstream Reach1	15447.27	25 yr	44.30	13759.13	13838.76		13838.76	0.000000	0.00	12416.72	184.08	0.00
KITO RIVER	Upstream Reach1	15447.27	50 yr	51.20	13759.13	13839.00		13839.00	0.000000	0.00	12461.92	184.45	0.00
KITO RIVER	Upstream Reach1	15447.27	100 yr	58.50	13759.13	13839.25		13839.25	0.000000	0.00	12506.32	184.82	0.00
KITO RIVER	Upstream Reach1	15076.28	2 Yr	19.60	13779.46	13837.61		13837.61	0.000000	0.01	1571.52	54.05	0.00
KITO RIVER	Upstream Reach1	15076.28	5 Yr	28.80	13779.46	13838.11		13838.11	0.000000	0.02	1598.47	54.51	0.00
KITO RIVER	Upstream Reach1	15076.28	10 yr	35.40	13779.46	13838.41		13838.41	0.000000	0.02	1614.74	54.78	0.00
KITO RIVER	Upstream Reach1	15076.28	25 yr	44.30	13779.46	13838.76		13838.76	0.000000	0.03	1634.17	55.11	0.00
KITO RIVER	Upstream Reach1	15076.28	50 yr	51.20	13779.46	13839.00		13839.00	0.000000	0.03	1647.71	55.34	0.00
KITO RIVER	Upstream Reach1	15076.28	100 yr	58.50	13779.46	13839.25		13839.25	0.000000	0.04	1661.05	55.56	0.00
KITO RIVER	Upstream Reach1	14673.37	2 Yr	19.60	13963.23	13836.97	13836.97	13837.55	0.023888		5.79	4.97	0.00
KITO RIVER	Upstream Reach1	14673.37	5 Yr	28.80	13963.23	13837.35	13837.35	13838.04	0.023096		7.82	5.78	0.00
KITO RIVER	Upstream Reach1	14673.37	10 yr	35.40	13963.23	13837.58	13837.58	13838.33	0.022549		9.21	6.27	0.00
KITO RIVER	Upstream Reach1	14673.37	25 yr	44.30	13963.23	13837.86	13837.86	13838.68	0.021740		11.05	6.87	0.00
KITO RIVER	Upstream Reach1	14673.37	50 yr	51.20	13963.23	13838.05	13838.05	13838.92	0.021211		12.43	7.28	0.00
KITO RIVER	Upstream Reach1	14673.37	100 yr	58.50	13963.23	13838.23	13838.23	13839.15	0.021209		13.74	7.66	0.00

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River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
KITO RIVER	Upstream Reach1	14236.56	2 Yr	19.60	13718.40	13716.20	13716.21	13716.54	0.020167		7.64	11.76	0.00
KITO RIVER	Upstream Reach1	14236.56	5 Yr	28.80	13718.40	13716.42	13716.42	13716.81	0.019044		10.41	13.73	0.00
KITO RIVER	Upstream Reach1	14236.56	10 yr	35.40	13718.40	13716.55	13716.55	13716.97	0.018217		12.36	14.96	0.00
KITO RIVER	Upstream Reach1	14236.56	25 yr	44.30	13718.40	13716.71	13716.71	13717.17	0.017822		14.75	16.34	0.00
KITO RIVER	Upstream Reach1	14236.56	50 yr	51.20	13718.40	13716.82	13716.82	13717.30	0.017272		16.63	17.35	0.00
KITO RIVER	Upstream Reach1	14236.56	100 yr	58.50	13718.40	13716.92	13716.92	13717.43	0.017246		18.39	18.25	0.00
KITO RIVER	Upstream Reach1	13745.51	2 Yr	19.60	13448.73	13450.07	13450.07	13450.41	0.035334	2.60	7.53	11.28	1.02
KITO RIVER	Upstream Reach1	13745.51	5 Yr	28.80	13448.73	13450.30	13450.30	13450.69	0.032720	2.78	10.35	13.22	1.00
KITO RIVER	Upstream Reach1	13745.51	10 yr	35.40	13448.73	13450.43	13450.43	13450.86	0.031730	2.90	12.22	14.36	1.00
KITO RIVER	Upstream Reach1	13745.51	25 yr	44.30	13448.73	13450.58	13450.58	13451.06	0.031339	3.05	14.52	15.66	1.01
KITO RIVER	Upstream Reach1	13745.51	50 yr	51.20	13448.73	13450.69	13450.69	13451.20	0.030927	3.15	16.27	16.57	1.01
KITO RIVER	Upstream Reach1	13745.51	100 yr	58.50	13448.73	13450.81	13450.81	13451.33	0.029404	3.19	18.32	17.59	1.00
KITO RIVER	Upstream Reach1	13343.63	2 Yr	19.60	13377.30	13225.24	13225.24	13225.93	0.030798		5.32	3.91	0.00
KITO RIVER	Upstream Reach1	13343.63	5 Yr	28.80	13377.30	13225.68	13225.68	13226.50	0.029666		7.20	4.54	0.00
KITO RIVER	Upstream Reach1	13343.63	10 yr	35.40	13377.30	13225.96	13225.96	13226.84	0.028602		8.53	4.94	0.00
KITO RIVER	Upstream Reach1	13343.63	25 yr	44.30	13377.30	13226.29	13226.29	13227.25	0.027476		10.24	5.42	0.00
KITO RIVER	Upstream Reach1	13343.63	50 yr	51.20	13377.30	13226.52	13226.52	13227.53	0.026920		11.50	5.74	0.00
KITO RIVER	Upstream Reach1	13343.63	100 yr	58.50	13377.30	13226.73	13226.73	13227.80	0.026776		12.74	6.04	0.00
KITO RIVER	Upstream Reach1	12990.33	2 Yr	19.60	13265.96	13095.73	13095.73	13096.56	0.043601		4.86	2.99	0.00
KITO RIVER	Upstream Reach1	12990.33	5 Yr	28.80	13265.96	13096.29	13096.29	13097.24	0.040775		6.65	3.50	0.00
KITO RIVER	Upstream Reach1	12990.33	10 yr	35.40	13265.96	13096.65	13096.65	13097.65	0.037966		7.97	3.83	0.00
KITO RIVER	Upstream Reach1	12990.33	25 yr	44.30	13265.96	13096.99	13096.99	13098.14	0.039127		9.33	4.15	0.00
KITO RIVER	Upstream Reach1	12990.33	50 yr	51.20	13265.96	13097.25	13097.25	13098.47	0.038386		10.47	4.39	0.00
KITO RIVER	Upstream Reach1	12990.33	100 yr	58.50	13265.96	13097.51	13097.51	13098.80	0.037718		11.65	4.64	0.00
KITO RIVER	Upstream Reach1	12571.01	2 Yr	19.60	13090.93	12904.31	12904.31	12904.99	0.028320		5.38	4.06	0.00
KITO RIVER	Upstream Reach1	12571.01	5 Yr	28.80	13090.93	12904.75	12904.75	12905.54	0.026809		7.33	4.74	0.00
KITO RIVER	Upstream Reach1	12571.01	10 yr	35.40	13090.93	12905.01	12905.01	12905.87	0.026252		8.62	5.14	0.00
KITO RIVER	Upstream Reach1	12571.01	25 yr	44.30	13090.93	12905.33	12905.33	12906.27	0.025320		10.34	5.63	0.00
KITO RIVER	Upstream Reach1	12571.01	50 yr	51.20	13090.93	12905.55	12905.55	12906.54	0.024913		11.60	5.96	0.00
KITO RIVER	Upstream Reach1	12571.01	100 yr	58.50	13090.93	12905.77	12905.77	12906.81	0.024357		12.93	6.30	0.00

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River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
KITO RIVER	Upstream Reach1	11887.89	2 Yr	19.60	12974.10	12743.10	12743.10	12743.82	0.031476		5.24	3.72	0.00
KITO RIVER	Upstream Reach1	11887.89	5 Yr	28.80	12974.10	12743.57	12743.57	12744.40	0.029791		7.13	4.35	0.00
KITO RIVER	Upstream Reach1	11887.89	10 yr	35.40	12974.10	12743.85	12743.85	12744.76	0.029044		8.41	4.72	0.00
KITO RIVER	Upstream Reach1	11887.89	25 yr	44.30	12974.10	12744.19	12744.19	12745.18	0.028231		10.05	5.16	0.00
KITO RIVER	Upstream Reach1	11887.89	50 yr	51.20	12974.10	12744.41	12744.41	12745.47	0.027867		11.26	5.46	0.00
KITO RIVER	Upstream Reach1	11887.89	100 yr	58.50	12974.10	12744.64	12744.64	12745.75	0.027363		12.53	5.76	0.00
KITO RIVER	Upstream Reach1	11105.86	2 Yr	19.60	12764.18	12629.45	12629.45	12630.50	0.064620		4.32	2.10	0.00
KITO RIVER	Upstream Reach1	11105.86	5 Yr	28.80	12764.18	12630.14	12630.14	12631.36	0.061089		5.88	2.45	0.00
KITO RIVER	Upstream Reach1	11105.86	10 yr	35.40	12764.18	12630.54	12630.54	12631.88	0.060031		6.91	2.65	0.00
KITO RIVER	Upstream Reach1	11105.86	25 yr	44.30	12764.18	12631.03	12631.03	12632.49	0.058173		8.28	2.90	0.00
KITO RIVER	Upstream Reach1	11105.86	50 yr	51.20	12764.18	12631.37	12631.37	12632.92	0.056903		9.30	3.08	0.00
KITO RIVER	Upstream Reach1	11105.86	100 yr	58.50	12764.18	12631.72	12631.72	12633.33	0.055068		10.41	3.26	0.00
KITO RIVER	Upstream Reach1	10451.62	2 Yr	19.60	12626.30	12291.71	12291.71	12292.43	0.025206		5.21	3.66	0.00
KITO RIVER	Upstream Reach1	10451.62	5 Yr	28.80	12626.30	12292.19	12292.19	12293.03	0.023827		7.11	4.27	0.00
KITO RIVER	Upstream Reach1	10451.62	10 yr	35.40	12626.30	12292.47	12292.47	12293.39	0.023405		8.35	4.63	0.00
KITO RIVER	Upstream Reach1	10451.62	25 yr	44.30	12626.30	12292.80	12292.80	12293.81	0.022913		9.96	5.06	0.00
KITO RIVER	Upstream Reach1	10451.62	50 yr	51.20	12626.30	12293.04	12293.04	12294.11	0.022313		11.21	5.36	0.00
KITO RIVER	Upstream Reach1	10451.62	100 yr	58.50	12626.30	12293.27	12293.27	12294.39	0.021897		12.48	5.66	0.00
KITO RIVER	Upstream Reach1	9665.194	2 Yr	19.60	12408.52	12231.01	12231.01	12231.63	0.022421		5.63	4.66	0.00
KITO RIVER	Upstream Reach1	9665.194	5 Yr	28.80	12408.52	12231.42	12231.42	12232.14	0.021316		7.66	5.44	0.00
KITO RIVER	Upstream Reach1	9665.194	10 yr	35.40	12408.52	12231.67	12231.67	12232.44	0.020370		9.09	5.93	0.00
KITO RIVER	Upstream Reach1	9665.194	25 yr	44.30	12408.52	12231.95	12231.95	12232.80	0.019837		10.86	6.48	0.00
KITO RIVER	Upstream Reach1	9665.194	50 yr	51.20	12408.52	12232.15	12232.15	12233.05	0.019628		12.16	6.86	0.00
KITO RIVER	Upstream Reach1	9665.194	100 yr	58.50	12408.52	12232.33	12232.33	12233.29	0.019484		13.47	7.22	0.00
KITO RIVER	Upstream Reach1	8757.952	2 Yr	19.60	12010.93	11980.39	11980.39	11981.07	0.034091		5.35	3.98	0.00
KITO RIVER	Upstream Reach1	8757.952	5 Yr	28.80	12010.93	11980.84	11980.84	11981.63	0.031606		7.34	4.78	0.00
KITO RIVER	Upstream Reach1	8757.952	10 yr	35.40	12010.93	11981.16	11981.16	11981.96	0.027794		8.97	5.36	0.00
KITO RIVER	Upstream Reach1	8757.952	25 yr	44.30	12010.93	11981.47	11981.47	11982.34	0.027169		10.69	5.90	0.00
KITO RIVER	Upstream Reach1	8757.952	50 yr	51.20	12010.93	11981.65	11981.65	11982.61	0.028029		11.77	6.22	0.00
KITO RIVER	Upstream Reach1	8757.952	100 yr	58.50	12010.93	11981.85	11981.85	11982.87	0.027432		13.09	6.59	0.00

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River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
KITO RIVER	Upstream Reach1	7943.634	2 Yr	19.60	11904.51	11920.20	11906.15	11920.20	0.000001	0.05	392.61	43.99	0.01
KITO RIVER	Upstream Reach1	7943.634	5 Yr	28.80	11904.51	11920.71	11906.42	11920.71	0.000001	0.07	415.60	45.19	0.01
KITO RIVER	Upstream Reach1	7943.634	10 yr	35.40	11904.51	11921.02	11906.58	11921.02	0.000001	0.08	429.75	45.92	0.01
KITO RIVER	Upstream Reach1	7943.634	25 yr	44.30	11904.51	11921.39	11906.77	11921.39	0.000002	0.10	446.81	46.78	0.01
KITO RIVER	Upstream Reach1	7943.634	50 yr	51.20	11904.51	11921.65	11906.90	11921.65	0.000002	0.11	458.86	47.38	0.01
KITO RIVER	Upstream Reach1	7943.634	100 yr	58.50	11904.51	11921.90	11907.04	11921.90	0.000003	0.12	470.78	47.97	0.01
KITO RIVER	Upstream Reach1	6915.875	2 Yr	19.60	11998.57	11919.52	11919.52	11920.13	0.018682		5.64	4.68	0.00
KITO RIVER	Upstream Reach1	6915.875	5 Yr	28.80	11998.57	11919.93	11919.93	11920.64	0.017581		7.70	5.47	0.00
KITO RIVER	Upstream Reach1	6915.875	10 yr	35.40	11998.57	11920.16	11920.16	11920.94	0.017336		9.04	5.93	0.00
KITO RIVER	Upstream Reach1	6915.875	25 yr	44.30	11998.57	11920.46	11920.46	11921.30	0.016555		10.88	6.50	0.00
KITO RIVER	Upstream Reach1	6915.875	50 yr	51.20	11998.57	11920.65	11920.65	11921.55	0.016371		12.18	6.88	0.00
KITO RIVER	Upstream Reach1	6915.875	100 yr	58.50	11998.57	11920.84	11920.84	11921.79	0.016244		13.50	7.24	0.00
KITO RIVER	Upstream Reach1	5816.666	2 Yr	19.60	11887.21	11863.70	11814.14	11863.70	0.000000		4606.51	232.56	0.00
KITO RIVER	Upstream Reach1	5816.666	5 Yr	28.80	11887.21	11864.00	11814.53	11864.00	0.000000		4677.98	234.57	0.00
KITO RIVER	Upstream Reach1	5816.666	10 yr	35.40	11887.21	11864.19	11814.76	11864.19	0.000000		4721.38	235.78	0.00
KITO RIVER	Upstream Reach1	5816.666	25 yr	44.30	11887.21	11864.41	11815.03	11864.41	0.000000		4773.19	237.22	0.00
KITO RIVER	Upstream Reach1	5816.666	50 yr	51.20	11887.21	11864.56	11815.22	11864.56	0.000000		4809.14	238.22	0.00
KITO RIVER	Upstream Reach1	5816.666	100 yr	58.50	11887.21	11864.71	11815.40	11864.71	0.000000		4844.67	239.19	0.00
KITO RIVER	Upstream Reach1	4828.478	2 Yr	19.60	11850.81	11863.70		11863.70	0.000000	0.03	576.57	91.17	0.00
KITO RIVER	Upstream Reach1	4828.478	5 Yr	28.80	11850.81	11864.00		11864.00	0.000001	0.05	604.72	92.85	0.01
KITO RIVER	Upstream Reach1	4828.478	10 yr	35.40	11850.81	11864.19		11864.19	0.000001	0.06	621.95	93.87	0.01
KITO RIVER	Upstream Reach1	4828.478	25 yr	44.30	11850.81	11864.41		11864.41	0.000001	0.07	642.65	95.07	0.01
KITO RIVER	Upstream Reach1	4828.478	50 yr	51.20	11850.81	11864.56		11864.56	0.000001	0.08	657.08	95.90	0.01
KITO RIVER	Upstream Reach1	4828.478	100 yr	58.50	11850.81	11864.71		11864.71	0.000002	0.09	671.42	96.72	0.01
KITO RIVER	Upstream Reach1	3927.388	2 Yr	19.60	11926.58	11863.70		11863.70	0.000000		3934.24	267.47	0.00
KITO RIVER	Upstream Reach1	3927.388	5 Yr	28.80	11926.58	11864.00		11864.00	0.000000		4016.37	269.30	0.00
KITO RIVER	Upstream Reach1	3927.388	10 yr	35.40	11926.58	11864.19		11864.19	0.000000		4066.17	270.40	0.00
KITO RIVER	Upstream Reach1	3927.388	25 yr	44.30	11926.58	11864.41		11864.41	0.000000		4125.55	271.71	0.00
KITO RIVER	Upstream Reach1	3927.388	50 yr	51.20	11926.58	11864.56		11864.56	0.000000		4166.70	272.62	0.00
KITO RIVER	Upstream Reach1	3927.388	100 yr	58.50	11926.58	11864.71		11864.71	0.000000		4207.34	273.50	0.00

HEC-RAS Plan: plan 01

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
KITO RIVER	Upstream Reach1	3018.073	2 Yr	19.60	11893.02	11863.70		11863.70	0.000000		4231.21	113.08	0.00
KITO RIVER	Upstream Reach1	3018.073	5 Yr	28.80	11893.02	11864.00		11864.00	0.000000		4265.87	113.43	0.00
KITO RIVER	Upstream Reach1	3018.073	10 yr	35.40	11893.02	11864.19		11864.19	0.000000		4286.82	113.64	0.00
KITO RIVER	Upstream Reach1	3018.073	25 yr	44.30	11893.02	11864.41		11864.41	0.000000		4311.74	113.89	0.00
KITO RIVER	Upstream Reach1	3018.073	50 yr	51.20	11893.02	11864.56		11864.56	0.000000		4328.97	114.06	0.00
KITO RIVER	Upstream Reach1	3018.073	100 yr	58.50	11893.02	11864.71		11864.71	0.000000		4345.96	114.23	0.00
KITO RIVER	Upstream Reach1	2532.383	2 Yr	19.60	11809.78	11863.70		11863.70	0.000000	0.00	17866.71	315.85	0.00
KITO RIVER	Upstream Reach1	2532.383	5 Yr	28.80	11809.78	11864.00		11864.00	0.000000	0.00	17963.40	316.12	0.00
KITO RIVER	Upstream Reach1	2532.383	10 yr	35.40	11809.78	11864.19		11864.19	0.000000	0.00	18021.76	316.29	0.00
KITO RIVER	Upstream Reach1	2532.383	25 yr	44.30	11809.78	11864.41		11864.41	0.000000	0.00	18091.07	316.48	0.00
KITO RIVER	Upstream Reach1	2532.383	50 yr	51.20	11809.78	11864.56		11864.56	0.000000	0.00	18138.93	316.62	0.00
KITO RIVER	Upstream Reach1	2532.383	100 yr	58.50	11809.78	11864.71		11864.71	0.000000	0.00	18186.06	316.75	0.00
KITO RIVER	Upstream Reach1	2046.253	2 Yr	19.60	11831.25	11863.70		11863.70	0.000000	0.00	4993.70	114.80	0.00
KITO RIVER	Upstream Reach1	2046.253	5 Yr	28.80	11831.25	11864.00		11864.00	0.000000	0.00	5028.88	115.16	0.00
KITO RIVER	Upstream Reach1	2046.253	10 yr	35.40	11831.25	11864.19		11864.19	0.000000	0.00	5050.15	115.38	0.00
KITO RIVER	Upstream Reach1	2046.253	25 yr	44.30	11831.25	11864.41		11864.41	0.000000	0.00	5075.46	115.64	0.00
KITO RIVER	Upstream Reach1	2046.253	50 yr	51.20	11831.25	11864.56		11864.56	0.000000	0.00	5092.95	115.82	0.00
KITO RIVER	Upstream Reach1	2046.253	100 yr	58.50	11831.25	11864.71		11864.71	0.000000	0.00	5110.20	115.99	0.00
KITO RIVER	Upstream Reach1	1725.583	2 Yr	19.60	11799.54	11863.70		11863.70	0.000000	0.00	11952.89	253.62	0.00
KITO RIVER	Upstream Reach1	1725.583	5 Yr	28.80	11799.54	11864.00		11864.00	0.000000	0.00	12030.54	253.87	0.00
KITO RIVER	Upstream Reach1	1725.583	10 yr	35.40	11799.54	11864.19		11864.19	0.000000	0.00	12077.40	254.03	0.00
KITO RIVER	Upstream Reach1	1725.583	25 yr	44.30	11799.54	11864.41		11864.41	0.000000	0.00	12133.07	254.21	0.00
KITO RIVER	Upstream Reach1	1725.583	50 yr	51.20	11799.54	11864.56		11864.56	0.000000	0.00	12171.52	254.33	0.00
KITO RIVER	Upstream Reach1	1725.583	100 yr	58.50	11799.54	11864.71		11864.71	0.000000	0.00	12209.38	254.46	0.00
KITO RIVER	Upstream Reach1	1228.709	2 Yr	19.60	11821.14	11863.70		11863.70	0.000000	0.00	5589.67	170.75	0.00
KITO RIVER	Upstream Reach1	1228.709	5 Yr	28.80	11821.14	11864.00		11864.00	0.000000	0.00	5642.06	171.67	0.00
KITO RIVER	Upstream Reach1	1228.709	10 yr	35.40	11821.14	11864.19		11864.19	0.000000	0.00	5673.79	172.22	0.00
KITO RIVER	Upstream Reach1	1228.709	25 yr	44.30	11821.14	11864.41		11864.41	0.000000	0.01	5711.59	172.88	0.00
KITO RIVER	Upstream Reach1	1228.709	50 yr	51.20	11821.14	11864.56		11864.56	0.000000	0.01	5737.77	173.34	0.00
KITO RIVER	Upstream Reach1	1228.709	100 yr	58.50	11821.14	11864.71		11864.71	0.000000	0.01	5763.60	173.78	0.00
KITO RIVER	Upstream Reach1	864.6884	2 Yr	19.60	11802.69	11863.70		11863.70	0.000000	0.00	8933.98	194.10	0.00
KITO RIVER	Upstream Reach1	864.6884	5 Yr	28.80	11802.69	11864.00		11864.00	0.000000	0.00	8993.54	195.21	0.00
KITO RIVER	Upstream Reach1	864.6884	10 yr	35.40	11802.69	11864.19		11864.19	0.000000	0.00	9029.63	195.88	0.00
KITO RIVER	Upstream Reach1	864.6884	25 yr	44.30	11802.69	11864.41		11864.41	0.000000	0.00	9072.63	196.68	0.00
KITO RIVER	Upstream Reach1	864.6884	50 yr	51.20	11802.69	11864.56		11864.56	0.000000	0.00	9102.41	197.23	0.00
KITO RIVER	Upstream Reach1	864.6884	100 yr	58.50	11802.69	11864.71		11864.71	0.000000	0.01	9131.80	197.77	0.00

BOYE RIVER	Downstream	2854.554	2 Yr	19.60	11798.45	11863.70		11863.70	0.000000	0.01	2628.12	89.18	0.00
BOYE RIVER	Downstream	2854.554	5 Yr	28.80	11798.45	11864.00		11864.00	0.000000	0.01	2655.55	90.13	0.00
BOYE RIVER	Downstream	2854.554	10 yr	35.40	11798.45	11864.19		11864.19	0.000000	0.01	2672.24	90.71	0.00
BOYE RIVER	Downstream	2854.554	25 yr	44.30	11798.45	11864.41		11864.41	0.000000	0.02	2692.19	91.39	0.00
BOYE RIVER	Downstream	2854.554	50 yr	51.20	11798.45	11864.56		11864.56	0.000000	0.02	2706.04	91.86	0.00
BOYE RIVER	Downstream	2854.554	100 yr	58.50	11798.45	11864.71		11864.71	0.000000	0.02	2719.75	92.32	0.00
BOYE RIVER	Downstream	2414.522	2 Yr	19.60	11861.86	11863.29	11863.29	11863.66	0.114875	2.69	7.28	10.16	1.02
BOYE RIVER	Downstream	2414.522	5 Yr	28.80	11861.86	11863.53	11863.53	11863.96	0.108867	2.90	9.92	11.86	1.01
BOYE RIVER	Downstream	2414.522	10 yr	35.40	11861.86	11863.68	11863.68	11864.14	0.104401	3.01	11.76	12.91	1.01
BOYE RIVER	Downstream	2414.522	25 yr	44.30	11861.86	11863.85	11863.85	11864.36	0.102496	3.16	14.01	14.09	1.01
BOYE RIVER	Downstream	2414.522	50 yr	51.20	11861.86	11863.97	11863.97	11864.51	0.098605	3.23	15.85	14.99	1.00
BOYE RIVER	Downstream	2414.522	100 yr	58.50	11861.86	11864.08	11864.08	11864.65	0.098894	3.34	17.49	15.75	1.01
BOYE RIVER	Downstream	2027.422	2 Yr	19.60	11826.93	11860.83	11821.80	11860.83	0.000000	0.00	6194.57	323.38	0.00
BOYE RIVER	Downstream	2027.422	5 Yr	28.80	11826.93	11861.41	11822.01	11861.41	0.000000	0.00	6385.72	333.25	0.00
BOYE RIVER	Downstream	2027.422	10 yr	35.40	11826.93	11861.76	11822.15	11861.76	0.000000	0.00	6504.21	339.22	0.00
BOYE RIVER	Downstream	2027.422	25 yr	44.30	11826.93	11862.18	11822.31	11862.18	0.000000	0.00	6646.27	343.57	0.00
BOYE RIVER	Downstream	2027.422	50 yr	51.20	11826.93	11862.47	11822.42	11862.47	0.000000	0.00	6746.37	345.57	0.00
BOYE RIVER	Downstream	2027.422	100 yr	58.50	11826.93	11862.75	11822.52	11862.75	0.000000	0.01	6843.33	347.49	0.00
BOYE RIVER	Downstream	1505.611	2 Yr	19.60	11845.47	11860.83		11860.83	0.000000	0.01	965.50	91.89	0.00
BOYE RIVER	Downstream	1505.611	5 Yr	28.80	11845.47	11861.41		11861.41	0.000000	0.01	1019.70	94.29	0.00
BOYE RIVER	Downstream	1505.611	10 yr	35.40	11845.47	11861.76		11861.76	0.000000	0.01	1053.18	95.74	0.00
BOYE RIVER	Downstream	1505.611	25 yr	44.30	11845.47	11862.18		11862.18	0.000000	0.01	1093.32	97.48	0.00
BOYE RIVER	Downstream	1505.611	50 yr	51.20	11845.47	11862.47		11862.47	0.000000	0.01	1121.82	98.74	0.00
BOYE RIVER	Downstream	1505.611	100 yr	58.50	11845.47	11862.75		11862.75	0.000000	0.02	1149.62	99.97	0.00
BOYE RIVER	Downstream	1098.235	2 Yr	19.60	11882.44	11860.07	11860.07	11860.76	0.026211		5.32	3.89	0.00
BOYE RIVER	Downstream	1098.235	5 Yr	28.80	11882.44	11860.52	11860.52	11861.33	0.025087		7.22	4.53	0.00
BOYE RIVER	Downstream	1098.235	10 yr	35.40	11882.44	11860.79	11860.79	11861.67	0.024699		8.48	4.91	0.00
BOYE RIVER	Downstream	1098.235	25 yr	44.30	11882.44	11861.12	11861.12	11862.08	0.023551		10.21	5.38	0.00
BOYE RIVER	Downstream	1098.235	50 yr	51.20	11882.44	11861.34	11861.34	11862.37	0.023467		11.40	5.69	0.00
BOYE RIVER	Downstream	1098.235	100 yr	58.50	11882.44	11861.56	11861.56	11862.64	0.022824		12.73	6.01	0.00
BOYE RIVER	Downstream	759.3276	2 Yr	19.60	12009.27	11812.19	11812.19	11812.66	0.015422		6.43	7.03	0.00
BOYE RIVER	Downstream	759.3276	5 Yr	28.80	12009.27	11812.51	11812.51	11813.05	0.014263		8.84	8.24	0.00
BOYE RIVER	Downstream	759.3276	10 yr	35.40	12009.27	11812.69	11812.69	11813.28	0.013805		10.45	8.96	0.00
BOYE RIVER	Downstream	759.3276	25 yr	44.30	12009.27	11812.91	11812.91	11813.55	0.013565		12.45	9.77	0.00
BOYE RIVER	Downstream	759.3276	50 yr	51.20	12009.27	11813.05	11813.05	11813.74	0.013384		13.94	10.34	0.00
BOYE RIVER	Downstream	759.3276	100 yr	58.50	12009.27	11813.21	11813.21	11813.93	0.013002		15.58	10.93	0.00
BOYE RIVER	Downstream	393.0777	2 Yr	19.60	11831.63	11804.09	11804.44	11805.25	0.043613		4.11	3.93	0.00
BOYE RIVER	Downstream	393.0777	5 Yr	28.80	11831.63	11804.40	11804.84	11805.85	0.045586		5.39	4.50	0.00
BOYE RIVER	Downstream	393.0777	10 yr	35.40	11831.63	11804.59	11805.10	11806.19	0.045025		6.32	4.87	0.00
BOYE RIVER	Downstream	393.0777	25 yr	44.30	11831.63	11804.83	11805.38	11806.60	0.044350		7.52	5.31	0.00
BOYE RIVER	Downstream	393.0777	50 yr	51.20	11831.63	11805.00	11805.58	11806.88	0.043664		8.43	5.63	0.00
BOYE RIVER	Downstream	393.0777	100 yr	58.50	11831.63	11805.15	11805.78	11807.17	0.043934		9.30	5.91	0.00

APPENDIX H: Rating curves