FLOODPLAIN MODELING AND MAPPING USING GIS & HEC- RAS ON DOWNSTREAM REACH OF DIJO RIVER, ALAGE, ETHIOPIA

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CONTENTS

ACRONYMS

AATVETC	Alage Agricultural Technical and Vocational Educational Training Collage
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
GIS	Geographical Information System
HEC- GEORAS	Hydrologic Engineering Center's Geographical River Analysis System
HEC-RAS	Hydrological Engineering Center River Analysis System
MoWIE	Ministry of Water, Irrigation and Energy
SRTM	Shuttle Radar Topography Mission
TIN	Triangulated Irregular Network
USGS	United States Geological Survey
WS	Water Surface
XS	Cross Section
1D	one- dimensional
2D	two-dimensional

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ABSTRACT

Flood is the most dominant common, continuously frequent and destructive natural disaster in the world. It causes loss of life and property, displacement of people, breaking of socio-economic activities and loss of fertile agricultural lands. Dijo River flood affects Alage ATVET Collage during rain seasons. The main objective of this research is to map the flood inundation area on downstream reach (Alage ATVET collage) of Dijo River. GIS 10.3, HEC-Geo RAS, HEC- RAS 5.0.6, excel 2016 and easy fit 5.5 software's are used for this research. primary data's (total station surveying data, field observation) and secondary data (Dijo and furfuro stream flow data and Manning's n value) are used to conduct the research. Flood frequency analysis, pre-processing, processing/model execution and post-processing methods are used and got 101.22m^3/s, 164.6 m^3/s, 175.8 m^3/s, 207.58 m^3/s and 227.83m^3/s peak discharge for 2, 10, 25, 50 and 100- years return period respectively. 27 x-section cut lines are drawn on 4km river reach geometry, among these 55.6 % of the x-sections are severely flood venerable x- sections from all return period peak flood discharges and to both side of the river reach. The flood inundation area of 2, 10, 25, 50 and 100 years return periods were 5702, 8154.71, 8499.96, 9271.9 and 9851.84m^2 respectively. This area includes both Alage ATVET collage and neighboring kebeles of the collage. Therefore, the responsible body makes remedial measures to control the flood like repair and increase the height of the exiting earthen dykes at upstream of alage Bera Bridge, construction of new dykes and levees at the chefe agricultural area, grassland area and desilting siltation-filled x-section, afforestation from upper watershed of the river.

Keywords: - Alage collage, GIS, Hec-RAS, HEC-GeoRAS, Dijo River

1 INTRODUCTION

1.1 BACKGROUND

Flood is an exotic increasing of a river excesses its bank, inundating the nearby areas and it is also one of the grievous natural hazards in the world (El-Naqa & Jaber, 2018; Sunilkumar P & Vargheese, 2017). Floods are a constant threat to life and property(Dutta et al., 2006). When the volume of the coming river water is greater than the carrying capacity of the river the water which is excess from the river is called flood (Franco & Tesfaye, 2020; Marfai, 2003). It is the most dominant common, continuously frequent and destructive natural disaster in the world (Chakraborty & Biswas, 2020; Erena et al., 2018) (Gebre SL, 2015). It cause loss of life and property, displacement of people, breaking of socio-economic activities and loss of fertile agricultural lands (Sunilkumar P & Vargheese K. O, 2017).

In the world 20000 lives and 75 million peoples are affected in each year because of the existence of vast amount of floodplains and suitability of the floodplain areas for settlement (Muianga, 2004). Asian and Africa highly flood affected continents (Erena et al., 2018). The impacts are more of economic impacts rather than death impacts because of it damages infrastructures like roads, bridges, industries, hospitals, schools and agricultural lands, killing of animals and damaging of large amount of food crops(Cronin et al., 2008). The major causes of floods are either natural or manmade. Natural causes may be meteorology, topographical, soil type, overtopping of banks, excessive rainfall in short duration earth quick, tsunamis. Manmade causes include failure of dams or levees, land use, rapid urbanization assisted by deforestation, encroachment of floodplain and several human activities (Abera, 2011; Chakraborty & Biswas, 2020; Erena et al., 2018).

Ethiopia is one of the natural disaster (flood) affected countries in Africa country (Feyissa & Tufa, 2019).To manage floods, it is important to understand hydrological response of the catchment using different hydraulic and hydrologic models that can support to quantify the magnitude of flood , to project and identify the most affected area. HEC-RAS /HEC- GEORAS GIS extension tool is one of the common hydraulic model to solve flood problems (Erena et al., 2018; Feyissa & Tufa, 2019). Floodplain is the normally dry land area next to flooding rivers and side of rivers, which is able to inundation during flood events (Chow,1988). To decrease the catastrophic impact of flooding due to rivers and streams detection of the appropriate cross section, extent of flood inundation area and provide mitigation measure based on the output of the model is essential. To identify the cross section and the extent of flood covering areas need flood modeling and mapping tools. This tool is able to indicate appropriate flooding location and mapping the area of flood extent easily understandable or graphical format. This inundation map significant for executive body and disaster relief officials, to better prepare emergency action plan for potential flood conditions (Sunilkumar & Vargheese . O, 2017). But the impact of flooding still continue in developing countries because implementation of the floodplain management not updated by modern technology (Feyissa & Tufa, 2019).

Downstream reach of Dijo River is a flood affected /floodplain area during rainy seasons (June - September). Excess rainfall is the main cause of flooding (Bekele & Gemi, 2021a) in Dijo River. In the flood prone areas, protection works such like earthen dyke constructed at the local level without preplanning and forecasting the problems. However, such works were not solved the problems for long time. As increasing human activity on watershed of the river increasing flooding and frequency at downstream of rivers (Dutta et al., 2006).mean monthly stream flow of dijo river increased in wet seasons decreased in dry seasons (Nigusie & Dananto, 2020). This increases the probability of happing of flood in Dijo River. Hence, specific floodplain area identification and propose mitigation measure is very significant for Dijo river. The main objective of this research is to map the flood inundation area on downstream reach (Alage ATVET collage) of Dijo river. The purpose of the study is to save lives and properties settling in the collage and/or around the bank of the river.

1.2 STATEMENT OF PROBLEM

Problems associated with flood are diverse. Flooding is a recurrent event at a downstream reach of Dijo River around Alage ATVET collage. During rainy season, Alage ATVET Collage is flooded by the excess flows from Dijo River. This collage is very important collage of our country. However, during rain seasons it is at risk of flooding from Dijo River(Nigusie & Dananto, 2020). Some part of the collage like bee farm area, old administration office, farmlands around entrance, Ogden village animal grazing land, and access roads area inundated by flood in previous years. Old administration office changed the location to Zeray 01 village area b/c of continuous inundation of the area by flood. In this area many researches are did research on watershed of the river on different titles like

(Bekele & Gemi, 2021; Nigusie and Dananto, 2020) their research depend on land use land cover on hydrological process and the risk of soil erosion. But the researchers not include flood inundation area of the alage collage and also there are many researchers conduct the research in the world from their environment from this type of titles but they are no use real topographic data of the area. Hence, for this research real topographic total station surveying data was used. Prevention of flood and prediction of flood pattern in the Dijo River near the collage reach is very important for protecting the collage community and the surrounding areas. This will simplify sustainable the responsibilities in the collage and increasing productivity of the collage. Hence, Flood management for collage is very important task. To manage flood inundation, identify flood inundation area and river x- sections are important inputs.

1.3 OBJECTIVE

1.3.1 General Objective

The main objective of this research is to prepare flood inundation map of an area at downstream reaches of Dijo River Using hec-ras hydraulic model.

1.3.2 Specific objective

Flood frequency analysis

Identification of extremely vulnerable river cross sections

flood plain map Preparation

1.4 RESEARCH QUESTIONS

How much volume of discharges will exist at different return periods?

Which cross sections are extremely vulnerable for flooding?

Which areas are likely inundated by different return period?

1.5 SCOPE OF THE STUDY

Although Alage ATVET collage has been affected by massive seasonal flooding, the range of this study restricted to geographical scope. Based on these facts, geographically the study is limited to downstream reach of Dijo River (alage atvt collage) due to time and resource limitations and the work has been concentrated on extracting geometric data, calculate peak discharge, simulating, measuring water surface profiles, analyzing the flood inundation area with the help of hydraulic model (HEC-RAS) integrated with in GIS environment.

1.6 Limitation of the Study

This study conducts on downstream reach (Alage ATVET collage) of Dijo River through HEC-RAS 1D model integration with GIS and HEC GEORAS. The main objective of study is mapping of flood inundation area at downstream reaches of Dijo River. The study conducted on only 4km of Dijo River at downstream reach and by using steady state analysis. Calibration and validation assure the accuracy of measured data's. But for this research use observed stream flow without hydrological calibration and validation. High resolution Landsat image also not had for this area, hence manning's values from hec-ras manuals.

1.7 Significance of the Research

Practical floodplain maps are the most important tools to prevent the impact of floods at flood plain areas. These floodplain maps also improve public safety. Flood plain maps are an important tool for planning and emergency action plans (El-Naqa & Jaber, 2018). Early selection of flood-prone areas allows public safety organizations, concerned and responsible body has to plan the solution for early warning in the floodplain. It also assists the prioritization of either the maintenance of existing flood defenses or the construction of new ones.

2 LITERATURE REVIEW

2.1 FLOODS IN ETHIOPIA

In our country, the problem of flood continues to be of significant concern to people be located in lowlands, near lakes and river areas. Flood catastrophes are happening further frequently, and having an affected impact on Ethiopia in terms of both the human and economic costs. As a result of the extended and widespread heavy rainfall as of the beginning of 2006 main rainy season, many areas have already experienced devastating damage.

According to UNISDR (2014), United Nations International Strategy for Disaster Reduction report, next to drought flood is hazardous disaster in Ethiopia.

According to (Legese & Gumi, 2020) in 2006, quite 357,000 people were affected by flood (out of this 600 died, 200,000 became displaced from there home) from this our country lost 40 million Ethiopian Birr.

According to (DPPA 2006) altogether 639 people have various other parts of the country. therefore, need for supporting environmental planning choices with simulation, prediction models and early warning of flood exposed or flood plain of the river is very important task.

According to, National Disaster Risk Management Commission (NDRMC, 2020) different region of our country affected by flood of different rivers of our country. From this 470163 people were affected by flooding, out these 301284 people displaced in Somali, Oromia, Afar and SNNP regions and Dire Dawa city council.

Table 1 Population affected and displaced by the floods between April and May 2020

Region	Zone	Woreda	Already affected and displaced population as of mid-May 2020	
			Affected	IDPs
Afar	Zone 1	Dubti	9,000	1,800
		Kori	865	173
		Elidar	375	75
	Zone 2	Bidu	2850	570
	Zone 3	Amibara	5515	1103
Sub total			18605	3721
Oromia	West Guji	Gelana	63601	63601

		Bulle Hora	20687	20687
Sub total			84288	84288
SNNPR	Gamo	Chencha	90	90
		Gerese	537	537
		Gacho baba	781	781
		Kemba	600	600
	South Omo	Jinka	465	118
		Dasenech	10185	10185
		Debub ari	3475	336
		Bako Dawla	2295	0
		Male	4375	0
		Semen Ari	95	0
	Gofa	Geze Gofa	197	197
		Oyda	38	38
	Alaba	Wera dejo	231	175
	Silte	Sankura	305	305
		Silte	90	90
Sub total			23759	13452
Dire Dewa	Dire Dewa	Dire Dewa	1985	1985
Sub Total			1985	1985
Somali	Shabelle	Denan	22380	138
		Gode	10200	5280
		Kelefo	87402	37920
		Imay Bari	28800	13800
		Mustahiil	33276	22824
		Aleele	11100	3642
		Ber'ano and Abkoro	17364	2436
		Adadle	8400	2046
		Ferfer	28542	16920
	Qoraxey	Shilaabo	720	0
		Debeweyeni	324	324
	Afder	Dolo Baye	6918	6918
		Wes Ime	3072	3072
		Kohel	390	390
	Liben	Dolo Dalo	59490	59490
		Guradmole	204	204
	Dawa	Mubarek	1500	1500
		Hudete	2400	2400
	Fafan	Babali	13704	13704
		Gursum	198	198
		Kebri Beyah	1380	1380

	Erer	Mayu muluko	864	864
	Nogob	Ayun	330	330
	Sitti	Gotabiki	648	648
		Gablalalu	1920	1410
Sub total			341526	197838
Total			470163	301284

These indicated that different region of the country had affected by river flood in different time in different extent. The effect of this flooding also so huge.

The overall conceptual approach of flood management in Ethiopia may be outlined around two concepts minimizing the damage of flood water through maximizing the benefits of flood for food security and poverty reduction. And using efficient, cost effective and sustainable flood management System that is institutionally manageable and technologically advanced and flexible. The first framework will form part of a continuous study, research and development to convert the ill effects of floods through deriving the benefit from flood water. In most cases, this involves building structural measures such as reservoirs, diversion structures and directing the flood water to dry areas for the purpose of beneficial use. The second concept focuses on institutionalized flood detection, prediction and issuing early warning to potential flooding area.

These measures can be classified broadly into structural and non-structural measures. Many considerations have to be sought to select suitable flood mitigation measures. Some of the factors such as the type and characteristics of the flood (magnitude, return period, peak, damage, etc.), cost implications and opportunity to maximize the benefit from the flood water must be considered in selecting feasible solution. The structural measures (Engineering or Technical solution) are designed and constructed to modify the characteristics of floods before received to the flood damage area through various physical constructions such as reservoirs, diversions, levees, dykes, or channel modifications and river retaining works. Structural measures may be suitable to prevent the damages of flash floods but the enormity of the financial, economic and ethical requirement undermines the importance of the flood prevention measures

Whereas non-structural measures are designed to modify the damage potential of the flood without interfering to the characteristics of the flood (magnitude, peak, duration, etc.). Such methods focus on software and hardware technological aspects, such as flood proofing, flood warning system, land use control, etc. For instance, through flood inundation mapping and early flood warning mechanism, the potential of flood damage to properties and human lives can be reduced. Early warning system can be implemented to evacuation the population and property at risk before the flood wave reaches to the flood prone area. However, flood warning systems requires efficient communication network to relay information and message from observation stations to Forecasting center and from forecasting to response agencies (like DPPA) and to potential flood affected area.

2.2 FLOOD CHARACTERISTICS

Flood disasters are occurring more frequently, and having an ever more dramatic impact on Ethiopia in terms of the costs on lives, livelihoods and environmental resources. Due to global climate change and local environmental pressures, the occurrence and frequency of flood hazards and the magnitude of destruction from floods are increasing through time. Human activities like urbanization, mass migration, development along the flood plains, industrialization and fragmentation/consolidation of agriculture land are the major driving force in altering the land use pattern and significantly affect the hydrologic processes. The effect of this land transformation is to increase the flood flows. Hence, land use change is a major force altering the hydrological processes over a range of temporal and spatial scales. Land use change can affect the runoff generation and concentration by altering hydrological factors such as interception, infiltration and evaporation. Thus, it causes changes in the frequency and intensity of flooding and produces runoff for shorter return periods and increase the susceptibility to damage. In order to understand the urban impacts on flooding, the total runoff must be quantified. This runoff is used to compute flow profiles and flood depths. Flood damages occur as a result of the particular flood event. The factors that influence the damage are land use pattern, frequency of flooding, characteristics of flood including depth and duration. Flood studies are important because of its effect on health, living conditions and economy of the society and it should consider the anthropogenic factor, which increases the vulnerability to floods.

2.3 GEOGRAPHIC INFORMATION SYSTEM (GIS)

Geographical Information System (GIS) defined as data processing technology (Parker,1988).it is efficient tool in flood risk ,flood hazard, vulnerability and in risk assessment and useful for delineation of flood zones, preparation of flood hazard and risk maps assessment (Gomaa M et. al., 2012; Ali et al. 2016). GIS deals with ideas developed in many areas including the fields of photogrammetry, surveying, Engineering and, geography and other type of fields. It is an information technology, which stores, analyses, and displays both spatial and non-spatial data. Spatial data are data's which represent objects that have physical dimensions it occurs on, in, or above the planet Earth (Parker 1988; DJ MAGUIRE).

According to (Tola Aliy Adem, 2018), the ultimate purpose of GIS is carried out spatial analysis and creating different kinds of maps outputs using all available data. GIS have extensive possibility for improving disaster management as they offer more efficiency and speed in the input, management, manipulation, analysis and output of data/information. The key benefit of using GIS for flood analyses is that it not only generates a visualization of flooding, but also creates potential to further analyze these events to estimate probable damage due to floods. Mostly, studies have applied hydraulic model for simulating flood runoff and runoff in low-lying flood-prone areas, in order to provide flood occurrence, magnitude of the event, location and depth of the inundation for flood management (Booij, 2005). Today state-of-the-art flood forecasting and early warning systems have made a significant impact to reduce the losses. By using these advance technologies, we can better design for flood mitigation measures, forecast earlier and issue possible warnings to the peoples living in low lying areas which will be affected.

2.4 HYDRAULIC MODELING AND FLOODPLAIN MAPPING

Once a design discharge (peak discharge) value has been estimated, it is converted into an estimate of flood water elevation, known as flood stage. There are many hydraulic models that vary significantly in complexity and data requirements (Daniel B. Wright, Ph.D., 2016). The most appropriate models can be select based on the location, and the available data. The two most common classes of hydraulic models are:

2.4.1 1-Dimensional (1D)

1D model are simplified models that characterize the terrain using a series of cross sections. At each cross section, the flow depth and velocity perpendicular to the cross section is computed. These models are well suited for areas where the flow direction is well defined. The best- known 1D model is HEC-RAS from the U.S. Army Corps of Engineers.

2.4.1.1 HEC-RAS

HEC-RAS (Hydrologic engineering center- river analysis system) is the basic Hydraulic software's. It is used to simulate the water flow in natural and manmade channels, estimate the water surface profiles of flash flood events integration with numerical models (Bezabeh, 2018; Brunner, 2016; Feyissa & Tufa, 2019). It is the best-known 1D model. Steady surface profile computations, unsteady flow simulation, movable boundary sediment transport computations and, Water quality analysis are basic component of HEC-RAS. This components use a common geometric data and hydraulic computation routines(Astride M. Adjinacou, 2016). It is the most practical, hydraulic model in the flood studies (Alaghmand et al., 2012). It was allowing (1D), (2D) or combined 1D and 2D river hydraulics calculations. River geometric , stream flow and Manning data's are input of HEC-RAS software (Brunner, 2016). Additionally, it is used to Checking the cross-section, editing and making correction of the river geometry and the generate water surface level for different return periods(Astride M. Adjinacou, 2016; Bezabeh, 2018; Feyissa & Tufa, 2019; Gebre SL, 2015). floodplain modeling on HEC-RAS hydraulic modeling provide more efficient, effective and standardized results and also saves time and resources(Abera, 2011; Alaghmand et al., 2012; Bezabeh, 2018; Gebre SL, 2015). Hydraulic models can be run in two different ways, depending on the application and the nature of the input design discharge. If the design discharge is a peak discharge estimate, then the models must be run in a steady flow mode(Daniel B. Wright, 2016).

2.4.1.1.1 1D Steady Flow

When the flow rate at any cross section constant with respect to time, the flow in a River or, stream is called steady(Gary, 2016). It improves water surface profiles by using the flowing formula.

$$Z_1+Y_1+\frac{a1v12}{2g} = Z_2+Y_2+\frac{a2V22}{2g}+h_e$$

Where

Y_1, Y_2 = Depth of water at cross sections

Z_1, Z_2 = elevation of the main channel inverts

a_1, a_2 = velocity weighting coefficients

v_1, v_2 = average velocity

h_e = energy head loss

2.4.1.2 MIKE 11 MODEL

It is one of the distributed model (Astride M. Adjinacou, 2016). Danish Hydraulic Institute (DHI) develops it in 1987. it was a popular 1D dynamic modeling tool for simple and complex river and channel systems (Alaghmand et al., 2012), the Hydrodynamic (HD) module is the core of the MIKE 11 modeling system and forms the basis for most modules including Flood Forecasting, Advection-Dispersion, Water Quality and Non-cohesive sediment transport modules. Input files are a river network file, a cross-section file, a boundary file, a hydrodynamic parameter file, and a simulation file. But its Limitation is widely require large amount of data and the cost of data collection may be high; the relative complexity of the physics-based solution requires significant execution time (Astride M. Adjinacou, 2016).

2.4.2 2-Dimensional (2D)

2D models calculate the flow both parallel and non-parallel to the main flow. They are useful for modeling areas of complex topography such as wider floodplains or broad estuaries but require high quality data and can require long computation times. Because of their greater complexity, most 2D models are not freely available.

Floodplain model is one of the means to understand the behavior of flood in a particular area. Model simulation can provide flood depth and extent. Floodplain models are the representation of hydraulic and hydrologic processes in the river channel and flood plain. Accurate representation of the actual processes is of paramount significance in predicting flood extent and depth, especially explaining the transient characteristics of river water flow in the model domain (BEZABEH, 2018).

2.5 HEC-GEORAS

HEC-GEORAS is one of the Arc GIS extension tools , which used to prepare geometric data (Ackerman, 2009). It is a free software but not standalone. Its main purpose is preparation of model and map for flooding areas. It have procedures, tools, and utilities for the preparation of river geometry data, which is impute of HEC- RAS (Bezabeh, 2018). Hydraulic modeling encompasses three steps: 1) geometric data preparation, 2) model execution, and 3) post-processing/visualization of results, hence HEC-GeoRAS perform pre- processing and post-processing data (Bezabeh, 2018;

Feyissa & Tufa, 2019a; Gebre SL, 2015; Sudhakar Sharma, 2015). It maps floodplain quickly accurately (Feyissa & Tufa, 2019).Recently, several worldwide and Ethiopian scholars are used HEC GEORAS to preparation of floodplain modeling and mapping of a River . The components of the river geometry are

- ✓ River centerline
- ✓ Bank lines
- ✓ Flow path lines
- ✓ Cross section lines

Gebre, (2015) Conduct research on Awash River. His objective was analyzing flood hazard and inundation area mapping of Awash River Basin. He also uses HEC-RAS Hydraulic modeling for checking, editing imported geometric data and create water surface profile. He also uses the HEC-GEORAS GIS extension tool for the preparation of geometric files, which contains stream centerline, left and right banks, Cross sections and finally export the result as can read from HEC-RAS. He uses this extension tool for preparation of flood inundation area mapping with different flood factors. Finally, he maps different flood areas along Awash River basin. Finally concludes HEC-RAS model is power full tool and able to give satisfied result.

Feyissa & Tufa, (2019) conduct the research on Jima town Awitu River. He uses HEC-RAS and HEC-GEORAS GIS extension tool hydraulic modeling. He was also using log normal distribution for frequency analysis method. Finally identify the flood vulnerable cross sections and map floodplain areas, and he conclude the HEC-RAS and HEC-GEORAS GIS was powerful tool for floodplain modeling.

Andreou et al. (2019) conducted a study on the 'Floodplain Mapping using Hydraulic Simulation HEC-RAS in G.I.S the objective of his study was floodplain mapping along M.Rema stream at Attica, Greecs. As a result, the study delineated floodplain areas along the main stream M.Rema, by using ArcGIS Hec-GeoRas and HEC-RAS. The Water surface profile were also prepared using the HEC-RAS by using three different flow data's, 200 cross-sections cut lines from HEC-GEO RAS and use Manning's n values from HEC-RAS manuals. Finally, the Analysis detects the percentage of extent of flood vulnerable areas across the whole cross-sections cut lines by using three different return period discharges values.

Bezabeh, (2018) conduct research on title of floodplain mapping and modeling for Geray River in Jabi Tehnan Woreda, which is one of the Amhara Region woredas. The objective of his research was analyzing the inundation area along the Geray River by using GIS and HEC-GeoRAS/ HEC-RAS Model. He was use DEM, TIN, google earth surveying data for extraction of river cross section data. He also uses different materials for his study like HEC-RAS, HEC-GEORAS, and HEC-HMS AND GIS. He uses (extreme value 1) Gumbel's method for flood frequency analysis. He prepares flood inundation areas along the Geray River by using 2 and 100 return period peak discharge values and geometric data. Finally, he recommends levees engineering structure for this flood mitigation measures.

Azouagh et al. (2018) has done study to establishment of floodplain maps for Martil River in Morocco. In this research, HEC RAS hydraulic modeling used to investigate flood inundation areas. This research input data is DEM, aerial photograph data and hydro-meteorological data. Aerial photograph data are used for to create the river floodplain map and geometry. This research alters different flood zones, velocities and heights of different cross section of Martil River at Tetuan city, Morocco. Finally concludes HEC RAS is advanced in natural hazard management and mapping by delineating floodplain areas.

El-Naqa & Jaber (2018) has done research to develop floodplain map for a concession area of Attarat Um Al-Ghudran Oil Shale area, Central Jordan. The researcher uses three major methodology stages pre-processing, processing and post processing. The study produces floodplain maps for the major river in the study area at three flow rates and finally concludes HEC-RAS is a powerful, yet easy-to-use software package for determining water surface profiles in a wide variety of streams.

Sunilkumar P & Vargheese K. O, (2017) has done study to estimate the probable maximum flood of the Mangalam River Basin and to create the flood inundation map of Mangalam River Basin in a GIS platform by using 30X30 DEM, flow data and manning coefficient n values from HEC RAS reference manual as input data. The researcher-modelled flood inundated area by using HEC-RAS and prepared flood inundation map by using GIS. At the end, the study finalizes flood inundation maps are used for preparation of flood mitigation plans for study area responsible executive body and HEC RAS is an effective tool for Flood plain modelling.

Hajibayov et al. (2017) conduct research on the title of Floodplain Modeling and Mapping Using the Geographical Information Systems (GIS) and HEC-RAS/HEC-GeoRAS Applications. Case of Edirne, Turkey. In this study, used methodologies were pre-processing, processing and post processing. The study prepared 1D and 2D hydraulic models and compered the result. The researcher compered the result of 1D and 2D models and finally concluded both methods can provide reliable results on Flow Inundation Maps of Floods for Different Return Periods.

Kardavani & Qalehe,(2013) conduct a study to analysis the results of the HEC RAS model and flood zoning in GIS environment with of Different years return periods. In this, research HEC

RAS, HEC -GEO RAS, AND GIS are used for preparation of flood zoning area and to develop HEC RAS model parameters. The researcher prepared flood inundation area of study area. The results of the study indicated that, integration of GIS and hydraulic models can be used for flood inundation area of rivers and determining the mitigated areas.

Khattak et al. (2016) carried out study to develop floodplain maps for the part of Kabul River in Pakistan. For this study used 90mx90m DEM data, stream flow for input, and log Preason type 3-flood frequency analysis method was used to calculate extreme flows with different return periods. Finally, floodplain maps, flooding vulnerable areas, and land use of type of those areas have been identified.

Patel et al. (2018) studied the HEC-RAS one-dimensional hydrodynamic model to analyze prediction of water level and inundation extent along Ambica River in two previously flood vulnerable and Ambica River bordering villages by using the HEC-RAS model and past flood events. Finally, the study provides water levels and inundation areas along the river for different discharges and seat recommendation to construct a new retaining wall or rehabilitate the height of the existing wall at identified flood vulnerable areas.

Jan et al. (2018), carried out study on modeling flood inundation of river kabul using hec-georas in Pakistan. At the end of the research concludes HEC-GeoRAS model can be used to predict water levels at the different reach of rivers on the basis of discharge at recorded its upstream gaging stations, which is the best model used for flood inundation modeling.

2.6 FLOOD FREQUENCY ANALYSIS

Flood frequency analysis is a method used to predict peak discharges with its specific return periods (Bezabeh, 2018). The frequency analysis is one of probability distributions used to relate the magnitude of extreme events to their recurrent period (Chow, 1988). It is one of the methods of studying the number of occurrences and identification of largest flood. It is also a way of preparing the flood events of a certain river or rivers of a specific area. The result of flood frequency analysis is the basic input for floodplain modeling and mapping, design of flood control structures. The development of all design flood estimation procedures starts with the direct statistical analysis of gauged station data's(Alemu, 2007; Alexander, 2002; Bhattacharya, 2010; Roy & De, 2015). Statistical analyses is used to determine the flood discharge and its frequency (Alexander, 2002). According to Al-Mashidani et al.(1978) and Griffis & Stedinger(2009) studies the Pearson type III, the Gumbel extreme value distribution, and lognormal distribution more popularly applicable than any other distributions.

The relationship between the probability of a flood and its intensity gives rise to the concept of return period (also known as recurrence interval), represented by the symbol T and expressed in terms of years. A T-year flood is the flood intensity that has a probability of 1/T of being exceeded in a given year. This probability is called the exceedance probability. It is important to point out that this definition of return period is contrary to what the term "10-year flood" or "100-year flood" would seem to imply, (i.e., the intensity of a flood that would occur once every ten or one hundred years). This is a major source of confusion and misunderstanding around the definition of return periods and can result in improper estimation.

Usually, the highest recorded discharge record from each year is used in the analysis. For example, if there are 30 years of daily discharge measurements available at a particular measuring station, then 30 data points are used in the discharge-frequency analysis, each one corresponding to the largest daily discharge observation from one of the 30 years of record. These data points are referred to as annual discharge maxima. Once these data points have been identified, the analyst fits several statistical distributions (for example: log-normal, log-Pearson, or generalized extreme value) and selects the distribution that most accurately describes the data. It must be emphasized that the proper application and interpretation of statistical procedures requires substantial experience and specialized knowledge (Daniel B. Wright, Ph.D., 2016).

2.6.1 Gumbel Extreme Value Type-I distribution

Gumbel distribution is most applicable and suitable for the Rivers (Bhattacharya, 2010). The Gumbel frequency curve for extreme value distribution was an important application to check the relationship between magnitude maximum discharge and their probabilistic distribution.

Chakraborty & Biswas, (2020) carried out research to analyze the flood risk based on flood hazard and vulnerability using the HEC-RAS model. He use Gumbel Extreme Value Type-I distribution to estimate the peak discharge of River for different return periods.

Chow, (1988) stated that Storm rainfalls are most commonly modeled by the Extreme Value Type I distribution and drought by the Weibull distribution (EVIII distribution).

$X_T=\bar{X}+k\sigma_{n-1}$ $\bar{X}=\frac{\sum_{i=1}^{n} Xi}{n}$

$Y=-\ln(-\ln(q))$ $\sigma_{n-1}=\sqrt{\frac{\sum_{i=1}^{n}(X-\bar{X})^{\wedge}2}{n-1}}$

$q=1-p$ $T=\frac{1}{P}=\frac{1}{1-q}$

$K=-\left(\frac{\mathrm{YT-Yn}}{Sn}\right)$

$Y_T=-ln\left[ln\left(\frac{T}{T-1}\right)\right]$

Where $\bar{X}$= mean of the variate

K=frequency factor

q = the probability of non-exceedance

σ_{N-1}= standard deviation of the variant

T= Return Period

P= Probability of occurrence

Yn = Reduced mean

Sn = Reduced standard deviation

3 MATERIALS AND METHODS

3.1 STUDY AREA DESCRIPTION

This study is conduct on Dijo River along Alage ATVET Collage, which is one of the oldest and important collages of Ethiopia, which has been, Established in the 1980. The collage contains Plant science, Animal science, natural resource and animal health department; the departments are located on average 3-5km with each other. The collage provides courses and training on animal health, dairy, poultry, bee farm, fruits, vegetables, and water harvesting and alternatives energy sources. It is located 41 km from worabe town and 215 km South of Addis Ababa around Abiata and shalla rift valley lakes. Geographically the collage is lies between in latitude 7°34’30 and 7°37’30 and longitude 38°23'30'E and 38°30'30'E. It covers total area of 2948 Hectare (29.48km^2).

3.1.1 Topography

The elevation of the catchment ranges from 1573.80 m to 3194m amsl at northern ridge of Alicho wuriro. The upper part of the catchment is highly mountainous, undulating, rugged and hilly topography but the downstream area is very flat.

3.1.2 Soil

soil types of the watershed are Chromic Luvisols, Chromic Vertisols, Chromic Vertisols, Eutric Cambisols, Luvic Phaeozems, Pellic Vertisols and Vitric Andosols.

3.1.3 Land use

The watershed contains many types of land uses. According to (Bekele & Gemi, 2021; Nigusie & Dananto, 2020) the watershed mainly dominated by diverse land use land cover; includes forest, agriculture and settlement, shrub and grassland, barren land, settlement and water bodies, which comprises about 5.9, 60.1, 31.9, 1.8 and 0.3%, respectively, based on 2018 LULC.

3.1.4 Rainfall distribution

Five stations (Halaba, Wulbareg butajira and ziway) are inside the watershed. As a result annual average rainfall of the study area 975.5 mm/yr. The rainfall is bi-modal type I,e heavy rainfall from June to September and low rainfall from March to May. Mean maximum temperature of the watershed is 26.9°C and the mean minimum temperature is 13.2°C. The mean annual potential evapotranspiration (PET) 153.5 mm/yr.

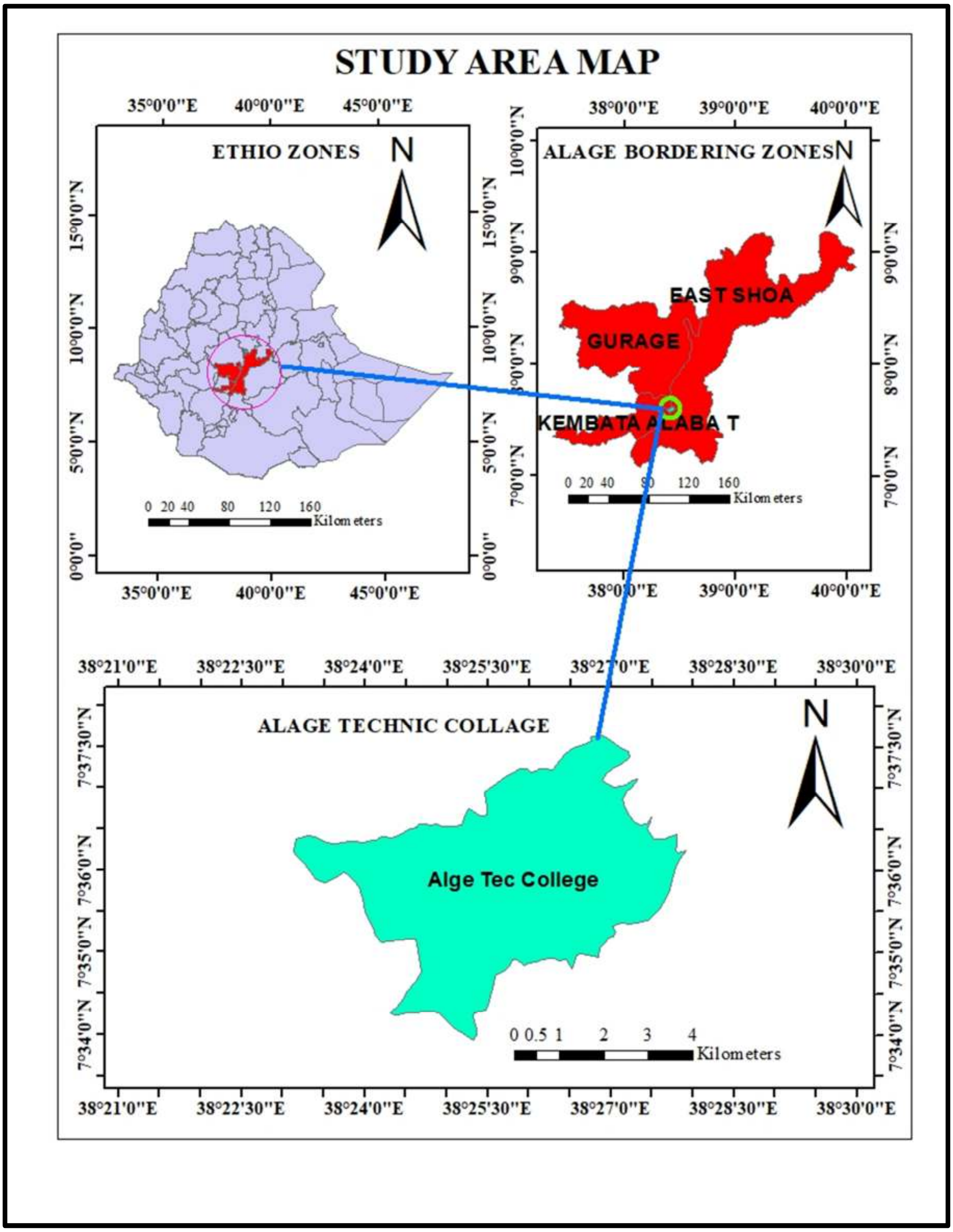

Figure 1 Study area map

3.2 DIJO RIVER

Dijo River is one of the seasonal rivers in southern part of Ethiopia. The length of the river is around 75.19km in length. The starts from Alicho wuriro Woreda Mountains areas and it cross five woredas (Alicho wuriro, worabe town administration, Dalocha, Sankura, Mitto) of silte zone, one Halaba zone woreda Finally joining Shalla Lake along Alage ATVET collage. Kalid, Limaza and furfuro rivers are tributary of the River. The largest part of the river is located in the silte zone in the Southern part of Ethiopia.

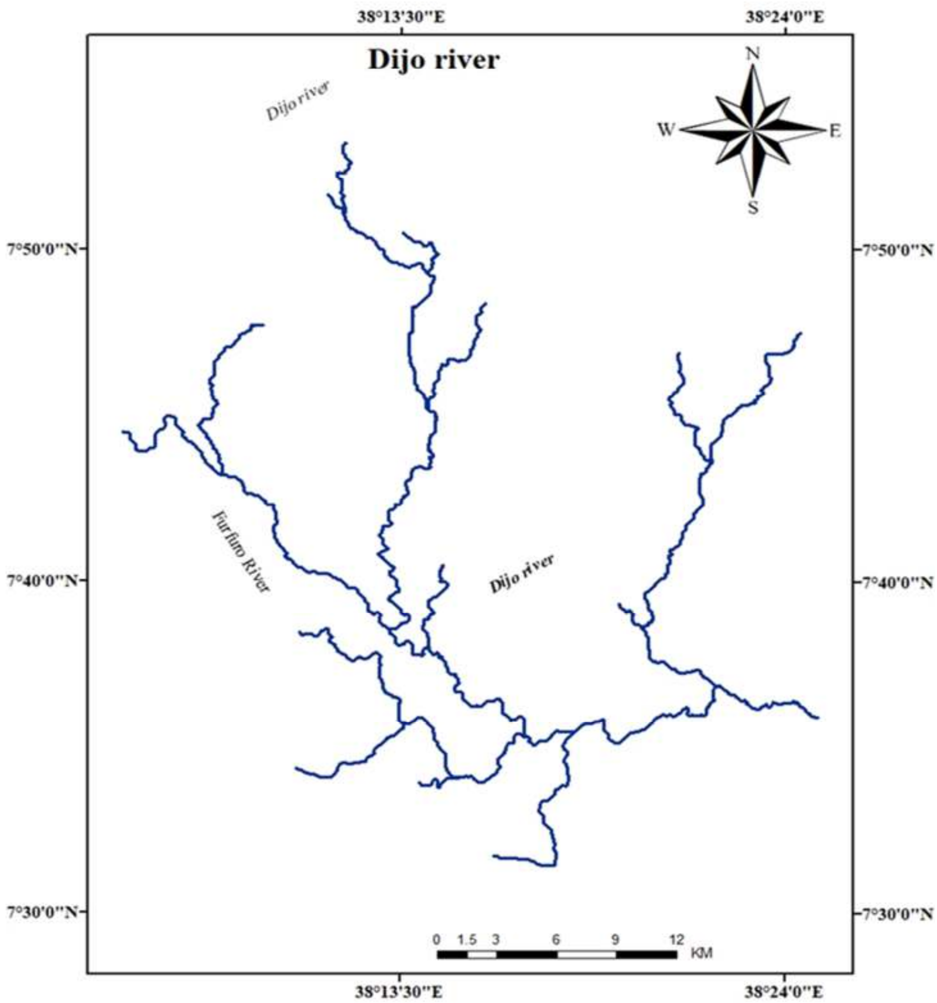

Figure 2 Dijo River network

3.3 AVAILABLE DATA'S

The result of expected objective of the study and the efficiency of models are depending on the reliability, Accuracy and availability of the geometric and hydrological data(BEZABEH, 2018; Hajibayov et al., 2017). I use primary data's and secondary data's for this research. The primary data's are total station surveying/field observation/site visit data from the Dijo River in Alage ATVET collage. The secondary data's are Dijo and furfuro stream flow data and collect from the Ministry of Water, Irrigation and Energy (MoWIE) and Manning's (n) value from hec-res manual.

3.3.1 Geometric Data

Geometric data is the geometrical information of a specific river reach. The geometrical data of river was prepared using a tool called HEC-Geo RAS. The river centerline, flow path, left and right banks, and cross section cut lines are essential information of the river. Finally, these geometric data were used as input for HEC RAS.

3.3.2 Hydrological Data

The hydrological data is required as input for HEC RAS model to steady river flow analysis of this research. For this study, daily hydrological data of (1987-2008) and (1990-2008) of Dijo and furfuro river gaging station was collected respectively with some missing data of stream flow from the hydrology department of Ministry of Water, Irrigation, and Energy (MoWIE) of Ethiopia. The calibration and validation of observed and simulated data of the rivers are very essential for checking the quality of the stream flow data.

Table 2 Hydrological stations in Dijo watershed

s/no	Station Name	data type	data availability	no years
1	Jidu Children Village	daily	1987-2008	22
2	Furfuro Wulbareg	daily	1990-2007	18

3.4 METHODOLOGY

This section provides a detailed description of the methodology, which is applied to obtain the floodplain modeling and mapping results. General methods for doing flood plain mapping for a water bodies like river and stream have Four major stages fill missing data's, check consistency, hydrological data preparation (flood frequency analysis), pre-processing, processing/model execution and post processing. Microsoft excel 2016 tool, Easy fit tool, HEC-RAS and HEC-GeoRAS GIS extension are tools used to prepare the flood inundation map of the 4km downstream (Alage AVTET collage) reach of Dijo River. The Preprocessing stage consists input data preparation by using HEC-GeoRAS GIS extension tool, which helps in creation of the data needs for the HEC-RAS model and the transfer of data between ArcGIS and HEC-RAS processing stage did completely within HEC-RAS using the river geometry prepared in the Preprocessing stage.

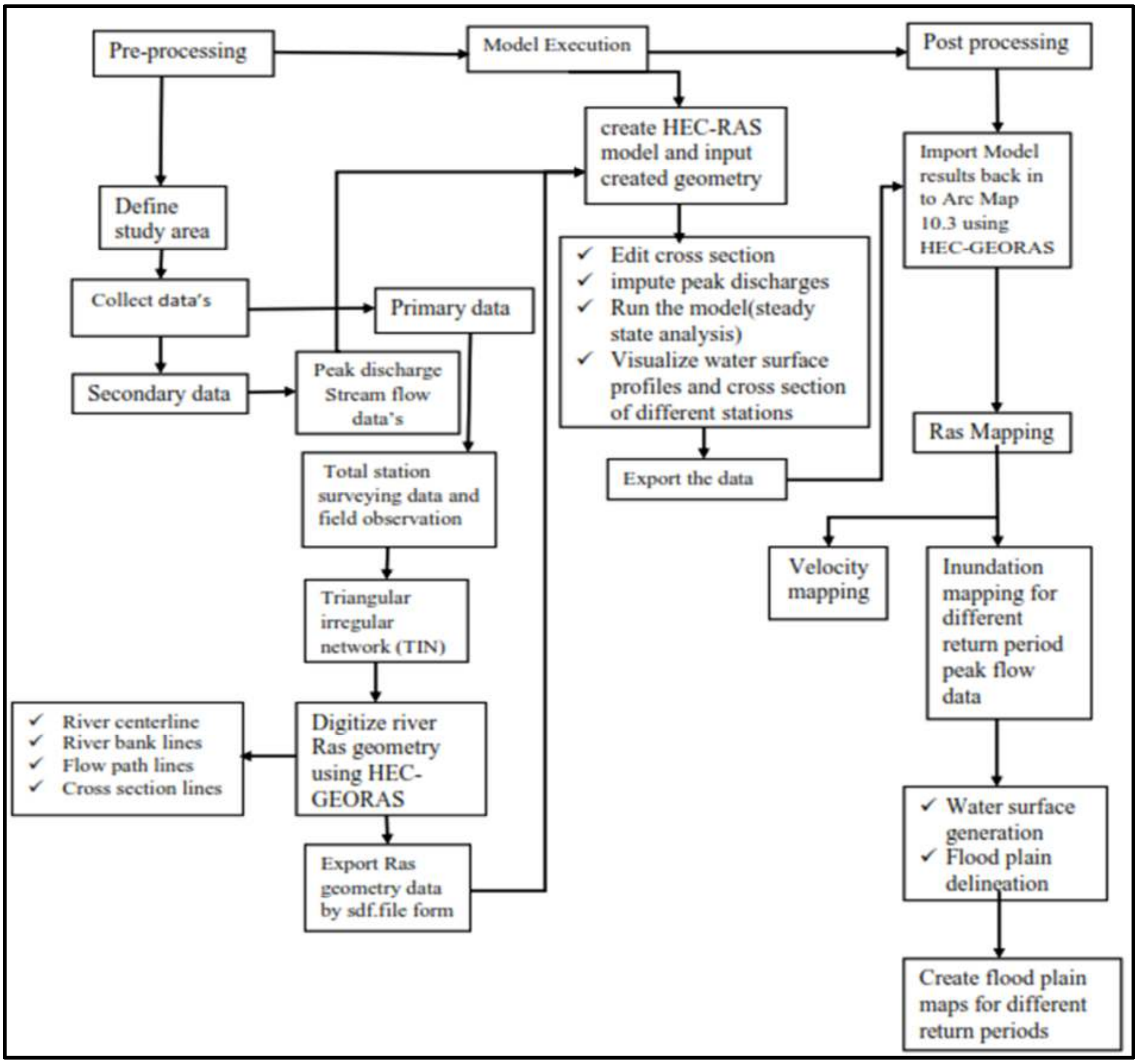

Figure 3 Methodology

3.4.1 Missing data

Full and latest hydrological time series data are very essential for water resources planning, management and reliable hydrological& hydraulic modeling. The hydrological data gaps serious in any data shortage areas of the world particularly in developing countries. The disorder model calibration results, unreliable timing of peak flows, and biased statistics are the result of missing data (Dembélé et al., 2018). The cause of missing data is the failure of monitoring equipment, extreme weather conditions, limited accessibility to measurement sites, negligence/ absence of observers, human-induced errors, budget constraints, and political conflicts (Dembélé et al., 2018).

The missing data were filled by linear regression using Microsoft excel 2016 tool After the consistency of hydrological data was checked.

3.4.2 Hydraulic Analysis

HEC-RAS and its extension HEC-GeoRAS, which is used to prepare the flood inundation map of the downstream reach of Dijo River. HEC-RAS was used to compute water surface elevations from a specified flow rate (steady flow simulation). It requires two basic inputs for flow analyses: geometric data and flow data. The geometric data file includes all the information related to cross-sectional station and elevation data, reach lengths, bank stations, stream junctions, and the geometry of hydraulic structures. The flow data requires defining boundary conditions, peak discharges for steady type simulation. The pre- processing of the geometric data is used to extract the physical characteristics of the study area /river reach of Dijo River and the post-processing of the outputs (to visualize the flooding impact) that analysis by the HEC-GeoRAS. This GIS extension tool allows the preparation of geometric data import into HEC-RAS and processes simulation results exported from HEC-RAS in a geospatial environment. To create the geometric file, the total station instrument collected surveying river cross section data converted to a TIN (Triangulated Irregular Network).

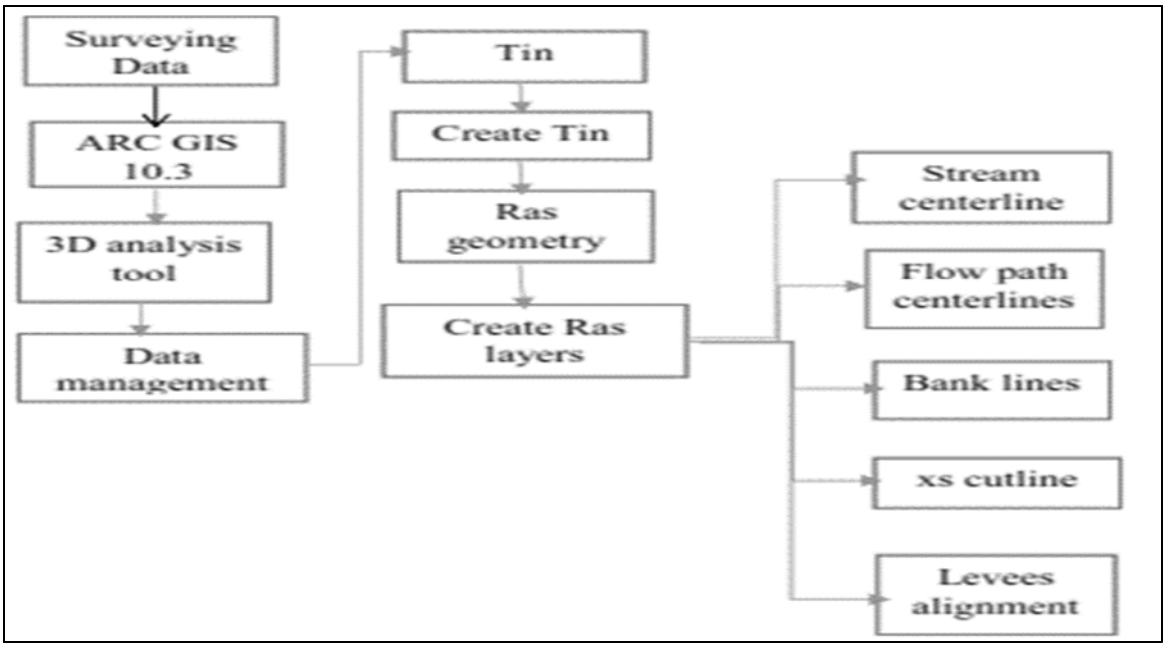

Figure 4 procedure of TIN data

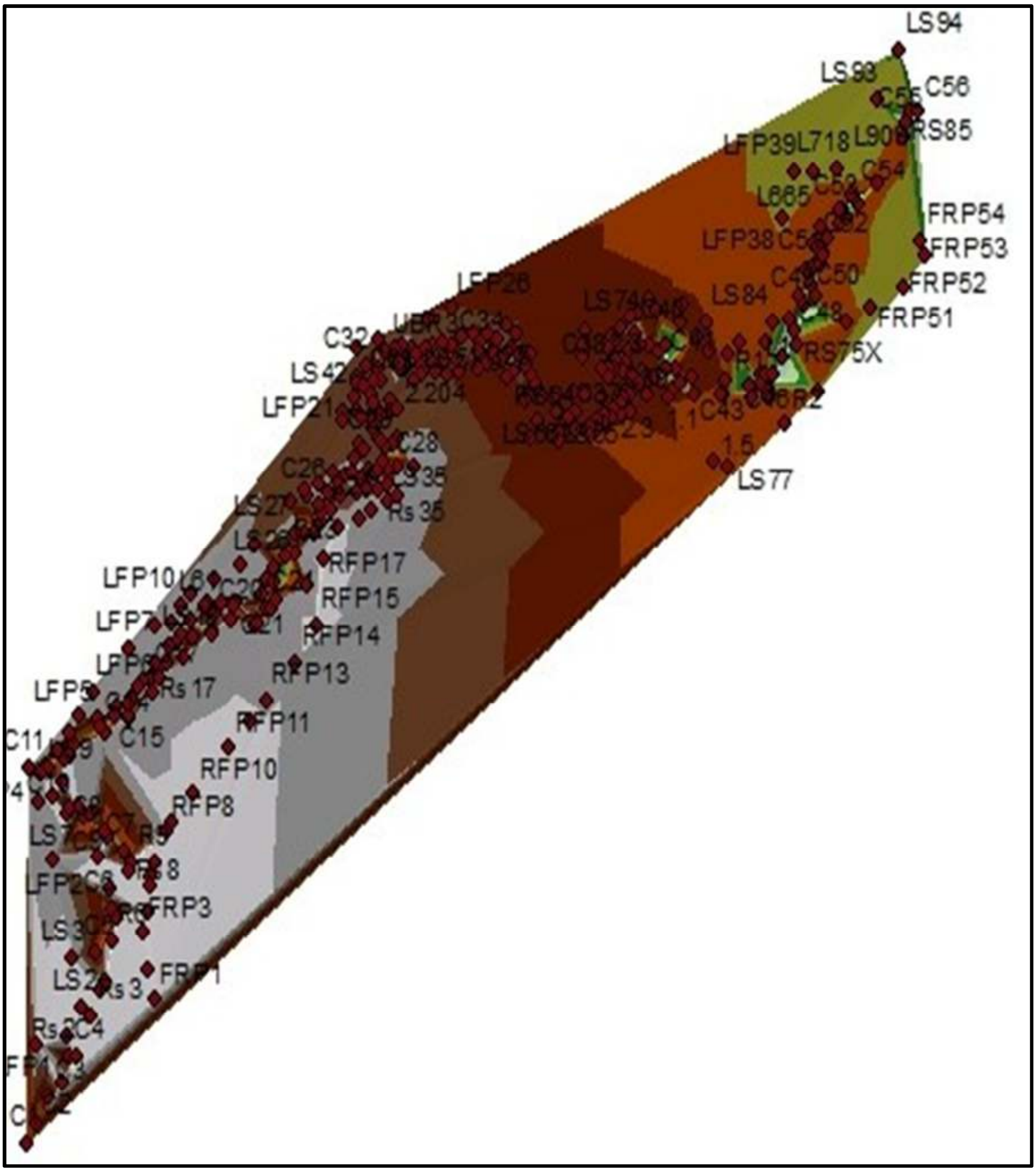

Figure 5 Dijo River Alage reach TIN

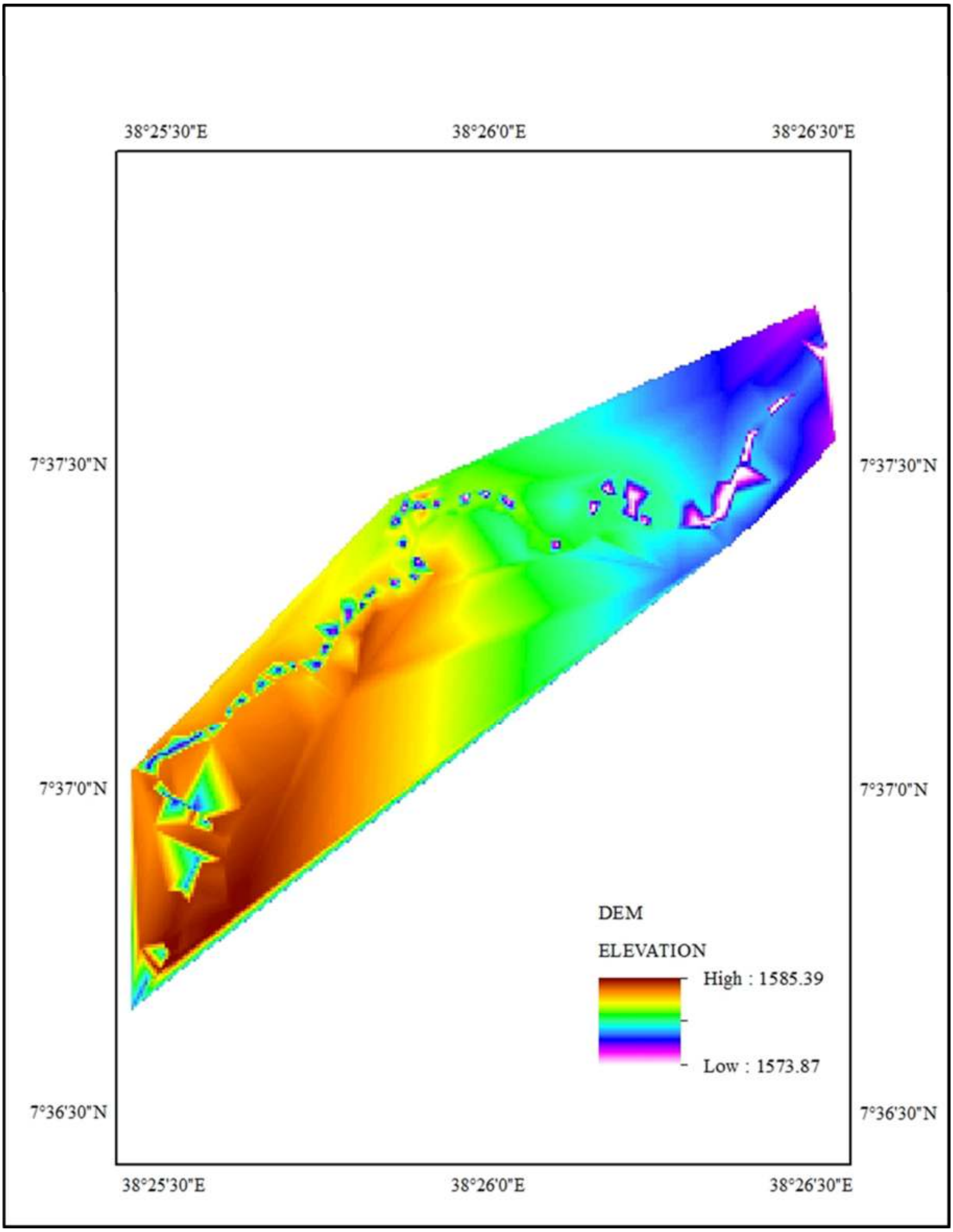

Figure 6 Downstream reach DEM of dijo River

3.4.3 Pre-processing data

Preprocessing is the first stage in preparing floodplain maps.

Procedures of Geometric data preparation/ pre processing

Open GIS 10.3

Add surveying data

Convert the data in to TIN data

Click on RAS Geometry

Then click on create RAS layers

- ✓ Stream center line
- ✓ Left and right bank lines
- ✓ Flow path centerlines
- ✓ XS cut lines
- ✓ Levee alignment

Click on each RAS layers and start editing

Select and click on line and draw

- ✓ 1st stream centerline
- ✓ 2nd bank lines
- ✓ 3rd flow path lines
- ✓ 4th XS cut lines it will draw from left to right

Assign River code, reach code and flow path left and right line type

Click on RAS Geometry then click

stream centerline attributes

Xs cut lines Attributes

Finally go back to RAS Geometry and export RAS data in to HEC-RAS by sdf. File format.

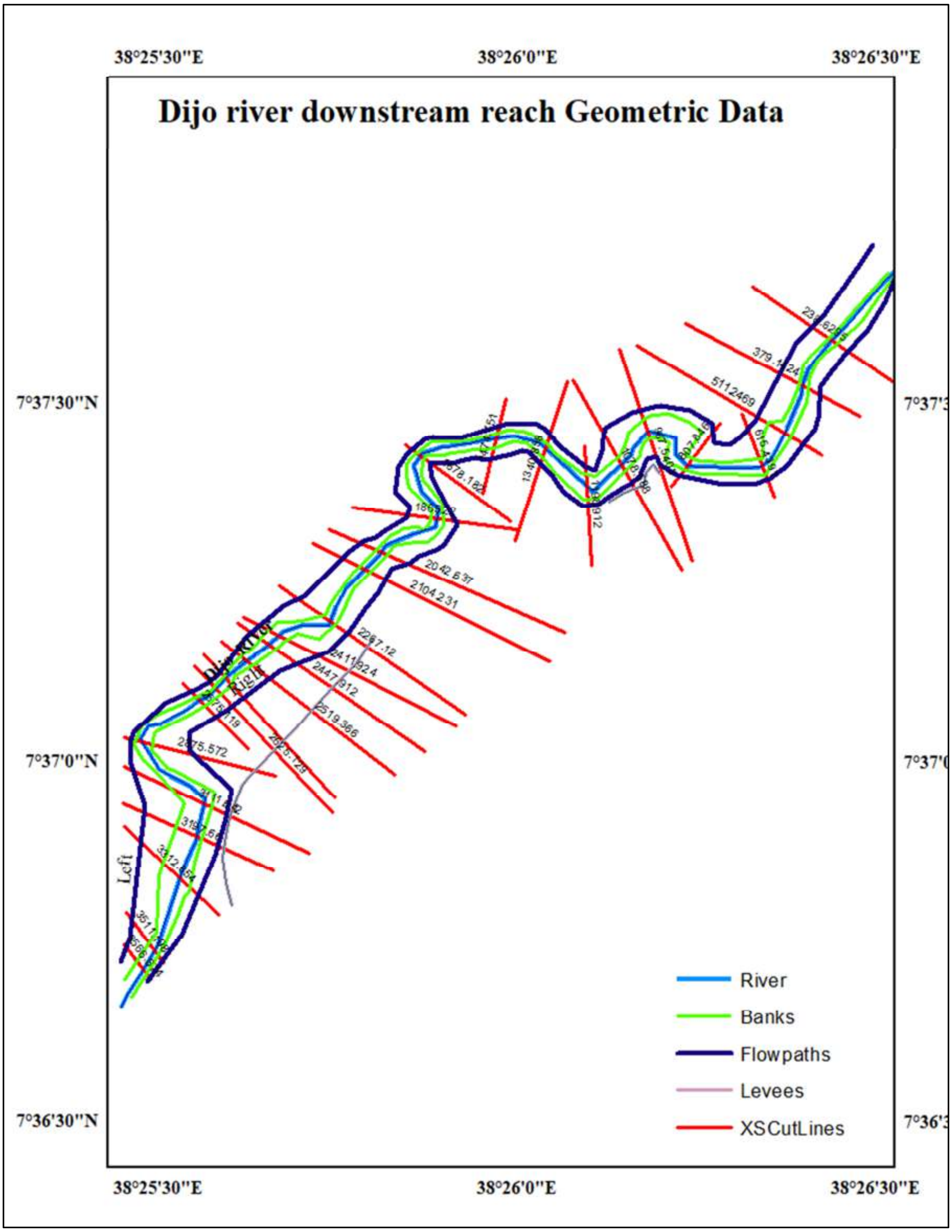

Figure 7 dijo River D/s reach geometric data

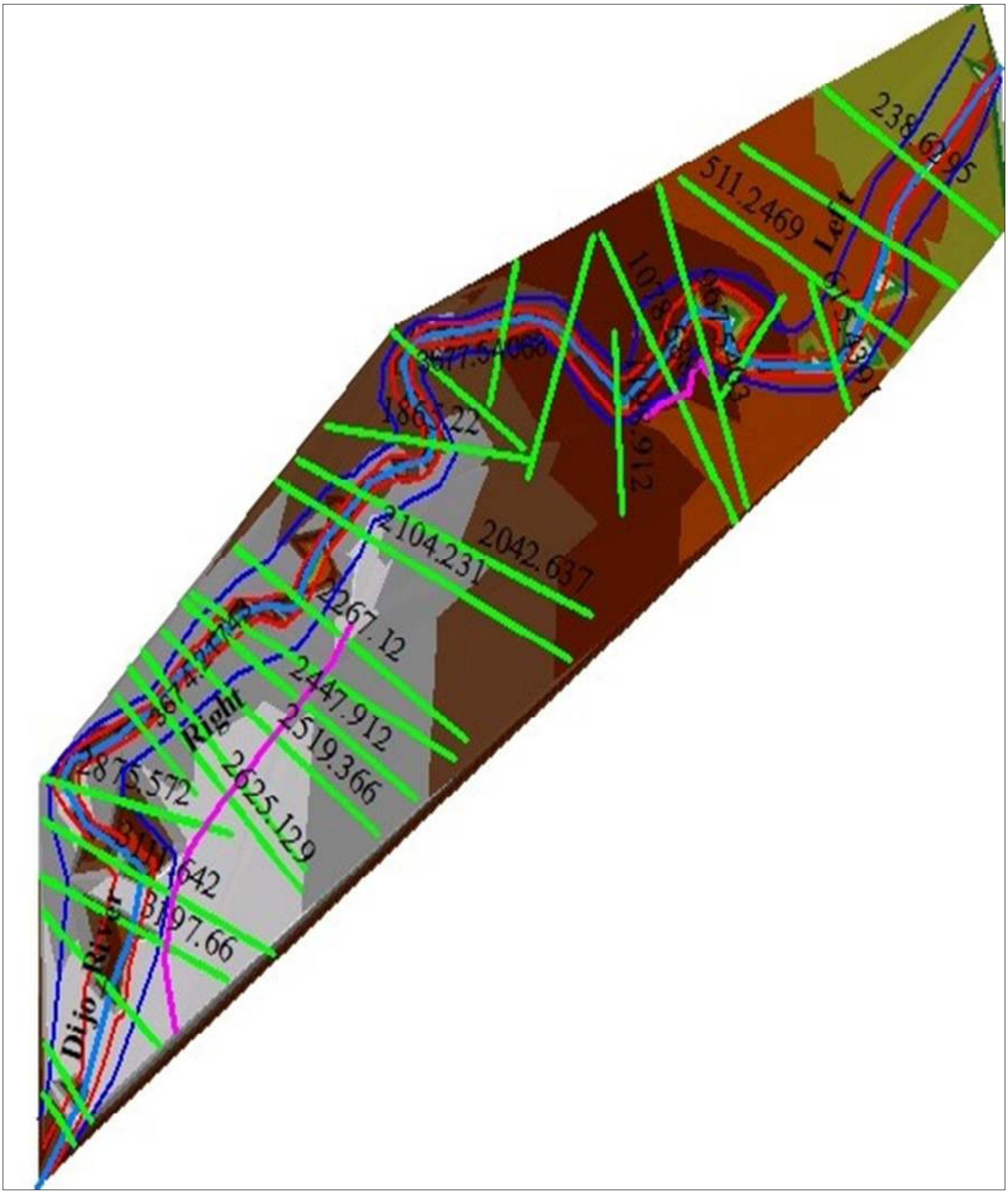

Figure 8 Tin with geometric data

3.4.4 Processing/Model Execution

Now open HEC-RAS then new project would save in the specific name in the particular folder. GIS data will import into HEC-RAS by clicking on Edit -> Geometric Data. In the geometric data editor, select File -> Import Geometry Data -> GIS Format. Import. sdf file which was created in GIS will select and ok. Finally click to import the Data to HEC-RAS.

Click on Edit -> steady flow data in HEC-RAS key window. Downstream Boundary conditions are also defined by clicking Reach Boundary Conditions. Downstream is select, critical depth. The file would be saved. Finally, the virtual data will be transfer to ArcGIS, by clicking on File -> Export GIS Data in the main HEC-RAS window. Clicking on Export Data button, a sdf file will create. The project will be saved and execute.

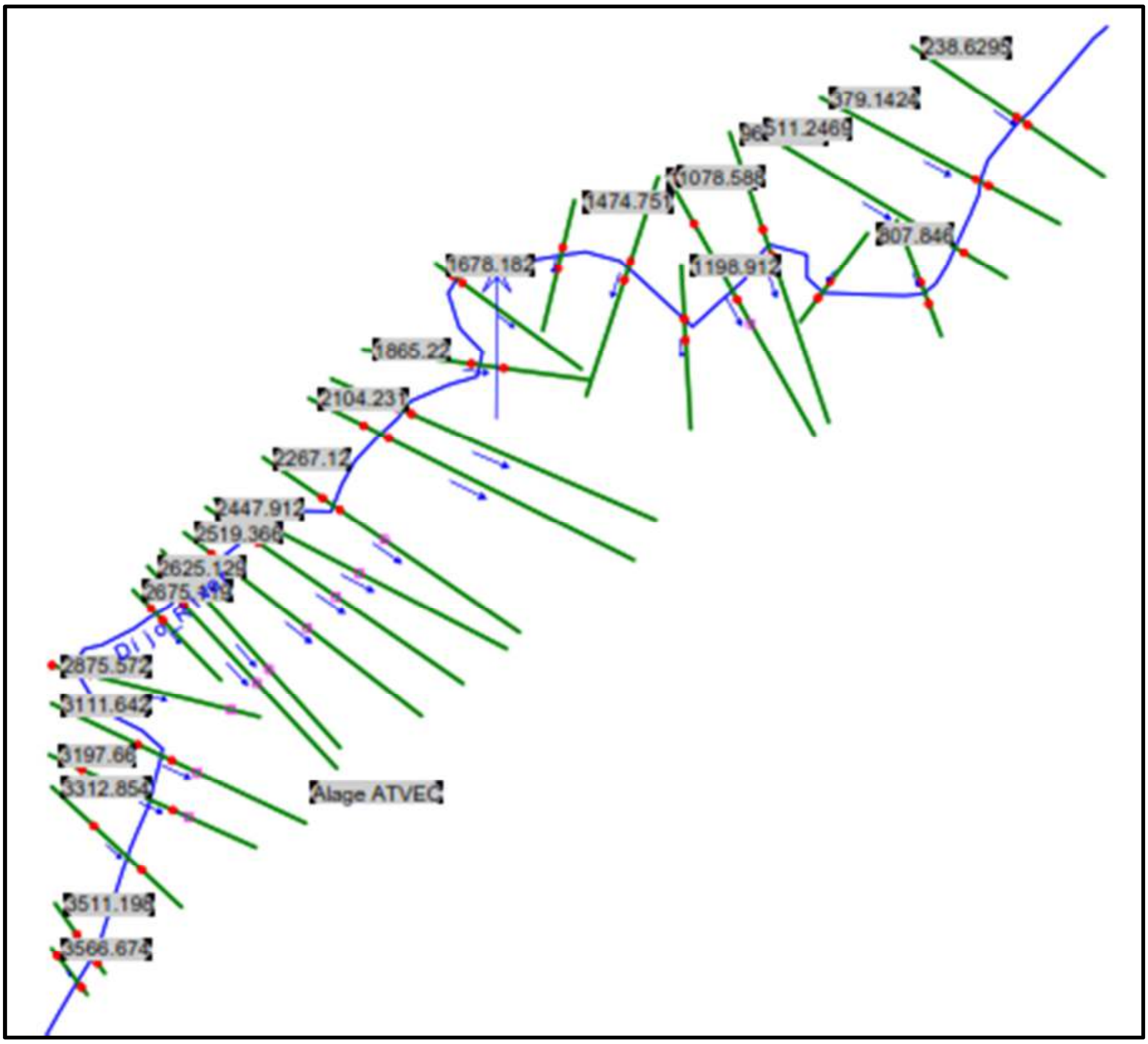

Figure 9 selected x- sections along the reach

3.4.5 Post processing of data

In ArcGIS, clicking on Import RAS SDF file button, the .sdf file can be convert to xml file. The process is complete when a dialogue box appears stating the conversion is done. The layer setup for floodplain mapping is performing by selecting RAS Mapping -> Layer Setup. In the layer setup, New Analysis option will select and name as Steady flow. Single terrain type is select and browses to tin. Working folder. OK will click. In the next step, click on RAS Mapping -> Import RAS Data. During Importing of the data, a series of execution messages will be seen. After completing of this a bounding polygon is, improve which defines the analysis extent for inundation mapping, obtained by connecting the ends of XS cut lines. After defining the analysis extent, the inundation extent can be mapping. Here the inundation extent is will map with maximum water surface. Click on RAS Mapping -> Inundation Mapping -> Water Surface Generation. Select max WS and click ok. Then Click on RAS Mapping-> Inundation Mapping -> Floodplain Delineation using Raters. Select max WS (profile with highest flow), and click ok.

To estimate water surface profiles and extent of inundation under different flood intensities, peak discharges for different return periods are required. Flood frequency analysis was carried out to obtain flood peaks for different return periods.

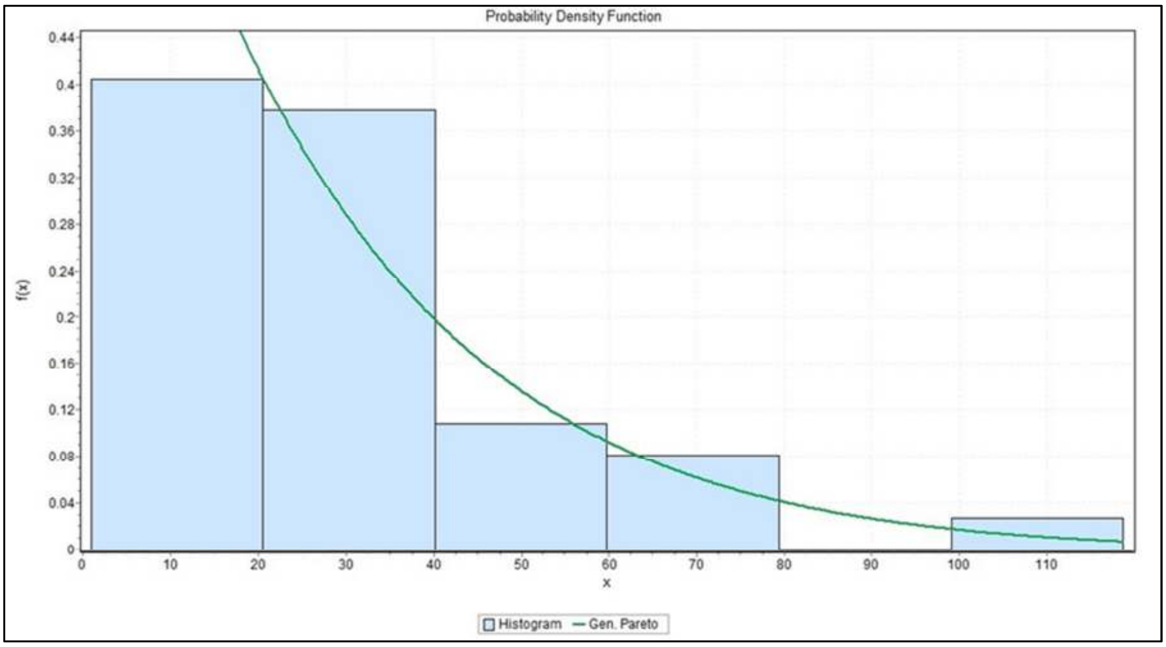

Figure 10 probability distribution curve

3.4.6 Fitting a Flood Probability Distribution

Different probability distribution methods are considered to test the goodness of fit. Normal, Log- Pearson type three, Gen. Extreme value and Gumbel distribution methods were estimated. Then sample data has were simulated and fit with statistical distributions by using easy fit software. Goodness of fit tests such as Kolmogorov- Smirnov, Anderson-Darling and Chi-square were conducted at significance level (α=0.09829) for choosing the best probability distribution. The distribution with minimum statistics value was the value that is best fit with the data.

Using Kolmogrov-Smirnov test (D) and Anderson Darling test (A^2) test was observed that the General Extreme value distribution provides good fit to the yearly discharge data at the exit. Using Chi-squared test (X^2), the result displayed that Log-Pearson 3 provides good fit at the exit. Comparing the three goodness of fit tests, the Kolmogrov-Smirnov test (D) has been found to provide a good fit for selected discharge at the exit.

Table 3 Goodness fit test

No	**Distribution**	**Kolmogorov Smirnov**		**Anderson Darling**		**Chi-Squared**	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Gen. Extreme Value	0.09829	1	0.28006	1	0.47615	4
2	Log-Pearson 3	0.10096	2	0.29188	3	0.11678	2
3	Johnson SB	0.10279	3	0.28579	2	0.5357	6

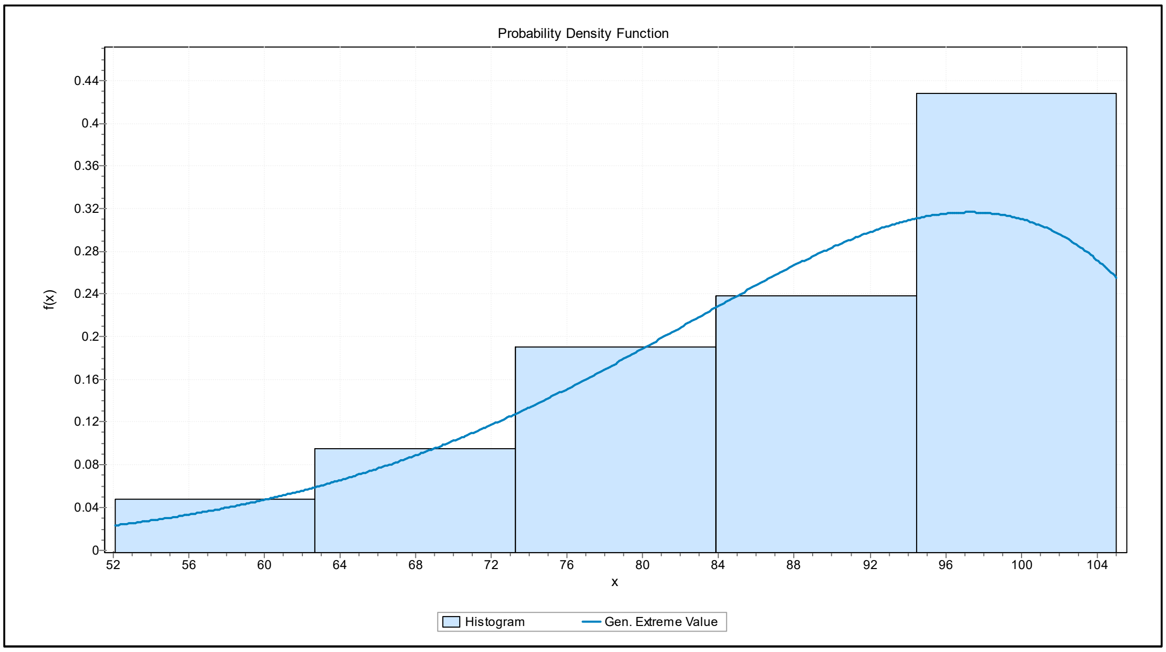

Figure 11 probability density function

4 RESULTS AND DISCUSSION

4.1 FLOOD FREQUENCY ANALYSIS

Prior to flood frequency analysis, gaging stream flow data is filled its missing data using linear regression by using the data of furfuro stream flow gaging station. The result of the regression shows that R^2 of the two-stream flow gaging station data are 0.91, since they have good relation. Extrapolation of yearly data are also important for extension of insufficient year data to sufficient year data. Therefore, in this research I used extrapolation to determine peak discharge of 2009-2020 years and get the goodly approached result from previous years recorded data. After completion of filling missing data and extrapolation, flood frequency analysis performed using the Gumbel's (Gen. Extreme Value) distribution by using Microsoft excel 2016. Since the results of 2, 10, 25, 50 and 100 return period years show the table 2 below.

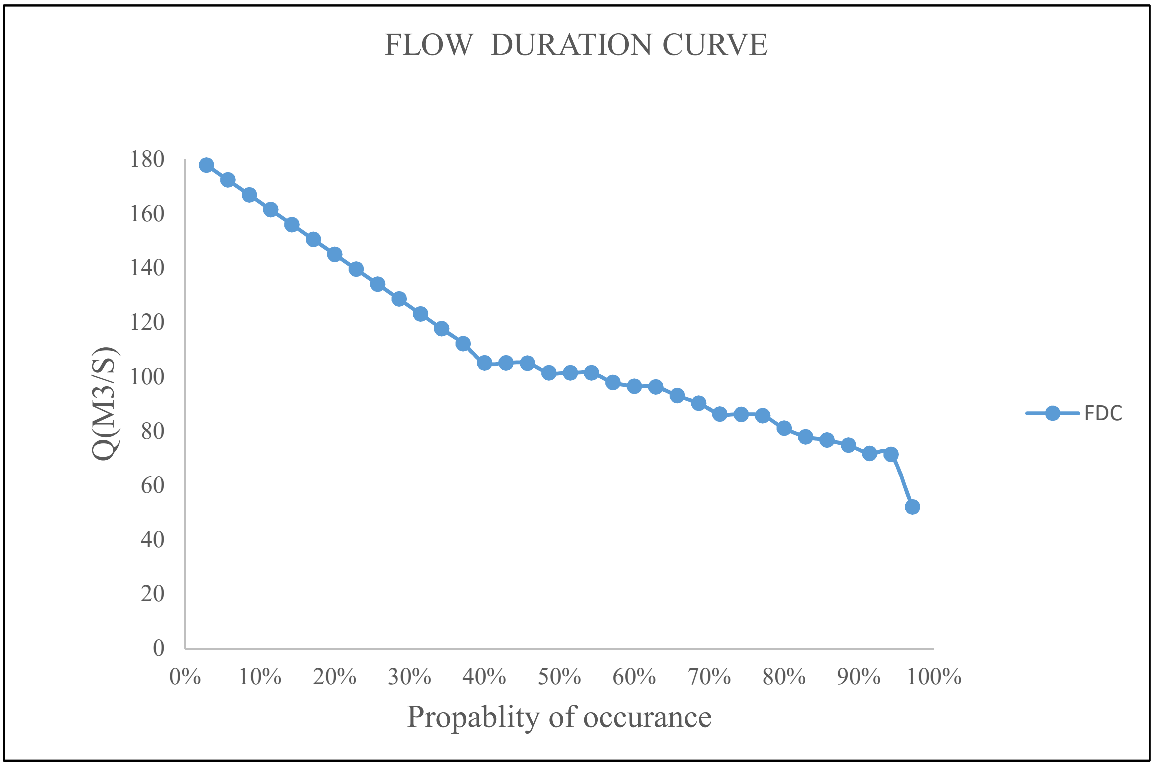

Figure 12 Flow duration curve

Table 4 Return periods & Peak flows

T	$X_t(m^3/s)$
2	101.2
10	164.60
25	175.80
50	207.58
100	227.83

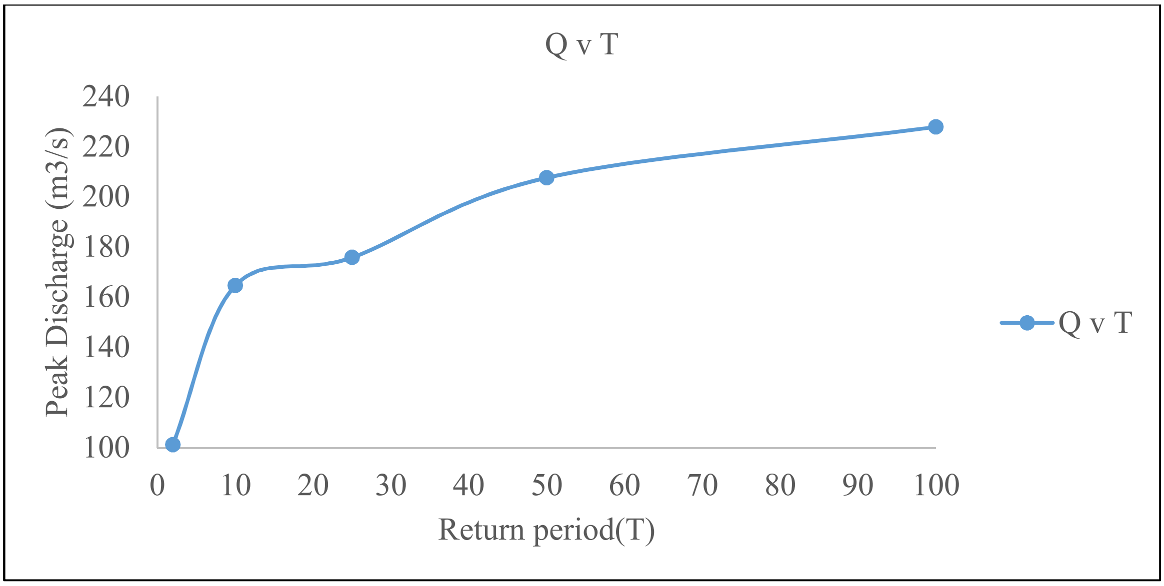

Figure 13 Peak discharge versus return periods

These Gumbel's distribution function calculated values are used for HEC-RAS input.

To check the annual peak discharge of return period data are normal status or abnormal status seat the threshold value is very essential. I use residual mean plot method by using Microsoft excel and easy fit 5.5 tool. Since the result of threshold, value is $62m^3/s$. The result of all annual return period data is greater than threshold value so it is possible to conclude that there is flood at Dijo downstream reach.

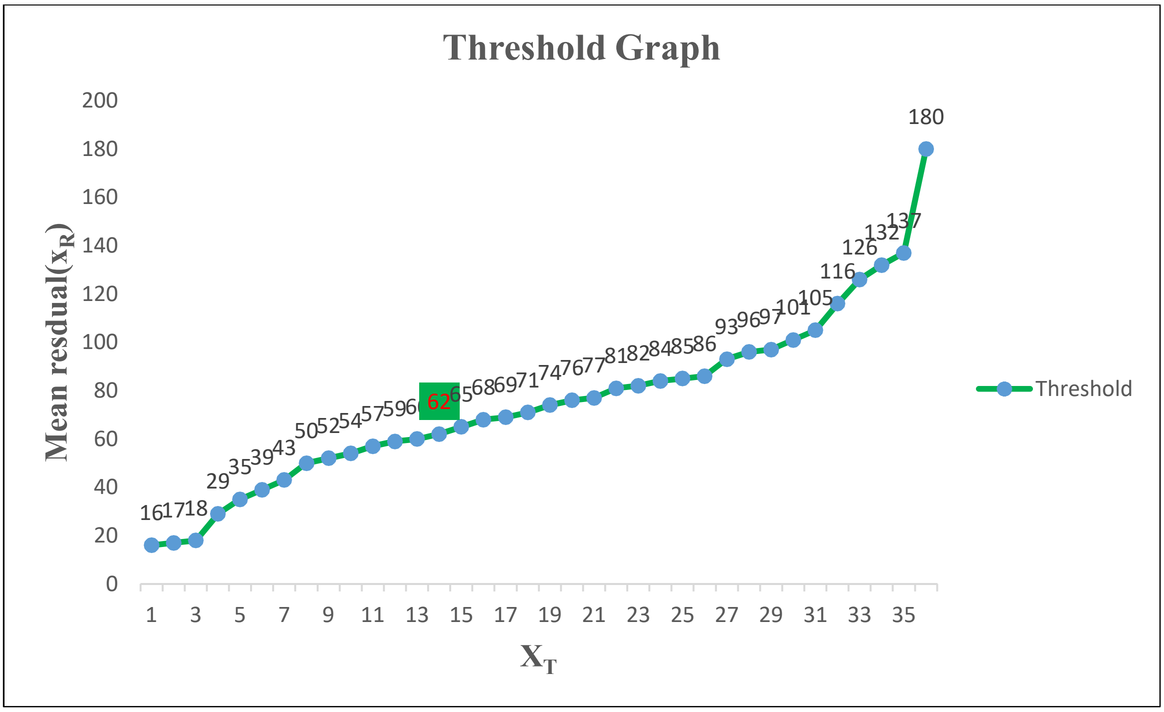

Figure 14 Threshold Graph

4.2 FLOODPLAIN MODELING

The Quality of geographic data of the river and the flood plain areas are very crucial to meet the objective of the research. Since quality is depend on its source of the data. Different researchers fetches different (DEM/TIN) from USGS, Alaska, google earth and GPS instrument (Abera, 2011; Feyissa & Tufa, 2019; Franco & Tesfaye, 2020; Gebre SL, 2015; Hajibayov et al., 2017; Khattak et al., 2016) with different resolution. However, the quality of DEM/TIN data's are depend on their resolution. The cross section of downstream reach of dijo river is not seen by 90m*90m, 30m*30m, 20m*20m, 12.5m*12.5m DEM, google earth and GPS data. Hence, to answer these issues I use total station instrument take surveying data of the reach and obtain 8m*8m DEM/TIN for this research. This data represents the cross section of Dijo River.

To identify flood venerable cross sections and to map flood plain of Dijo River downstream reach 27 x- section cut lines have been drawn on river geometric data. Among these cross-sections 3566.674, 3511.198, 3312.854, 3197.66, 3111.642, 2875.572, 2675.119, 2625.129, 2587.403, 2519.366, 2447.911, 678.182, 1474.751, 1340.8582, 1078.580, 615.4391m, 511.2469, 2267.12, 2104.231, 2042.637, 1865.22 (77.8%) of the total x-sections are severely flood venerable x-section stations from 10, 25, 50 and 100 return period peak flood discharges to both side the river. These listed stations are around bee farm area, old administration residential area, church, nok, 01 residential areas, chefe Agricultural and grassland areas.

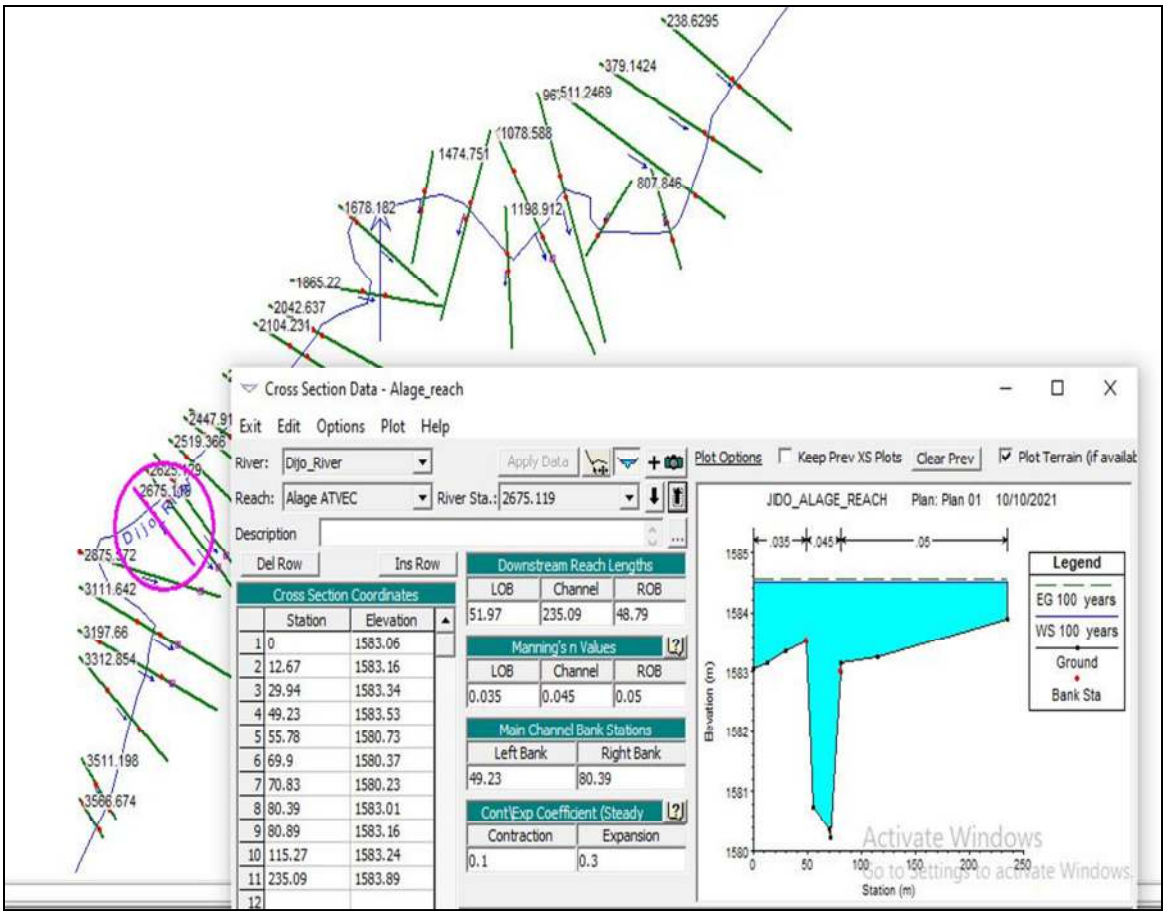

Figure 15 Dijo River x- section 2675.119m

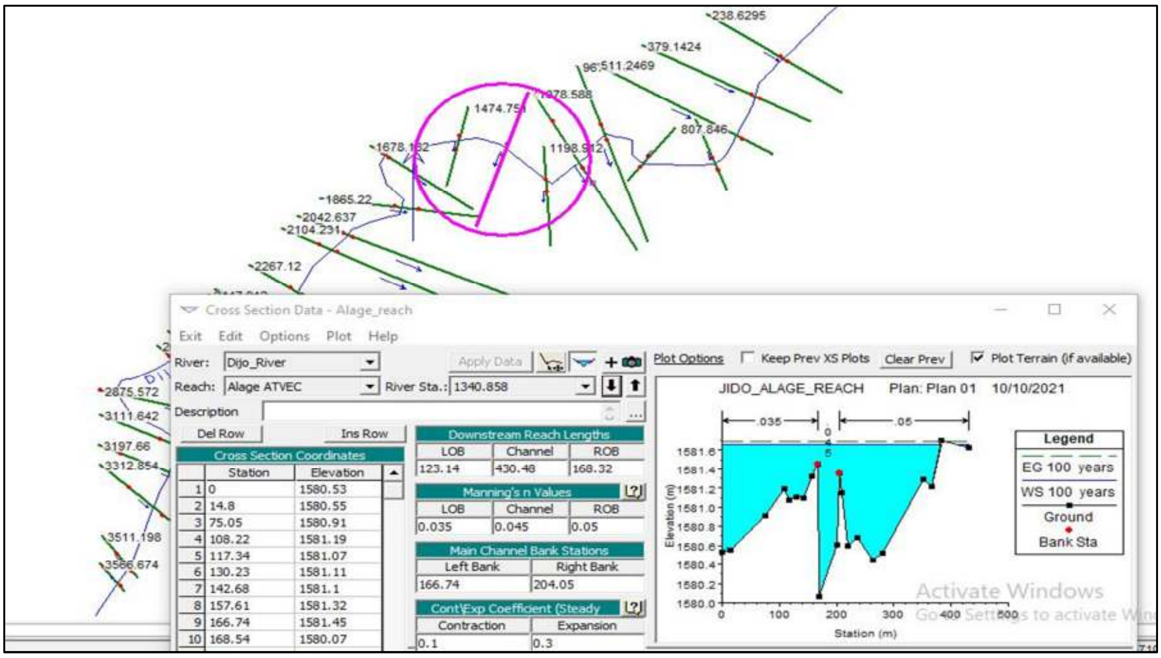

Figure 16 Dijo river x- section 1340.858m

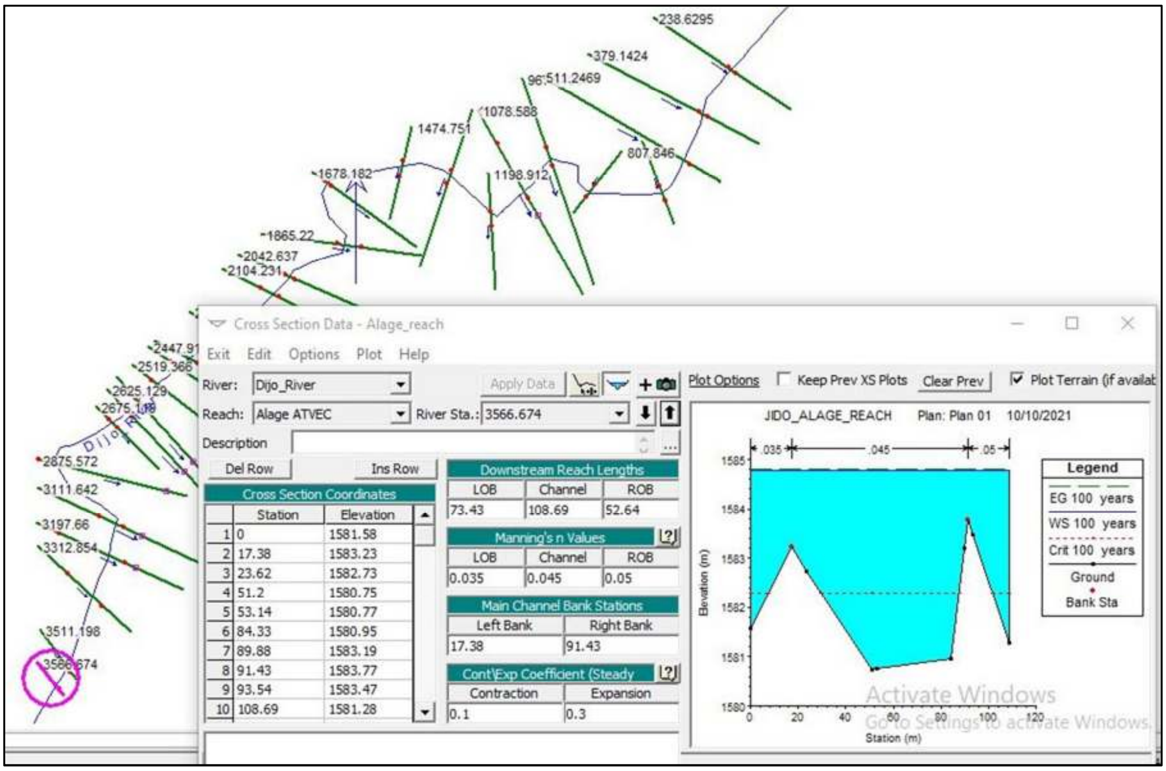

Figure 17 Dijo River x- section of 3566.674m

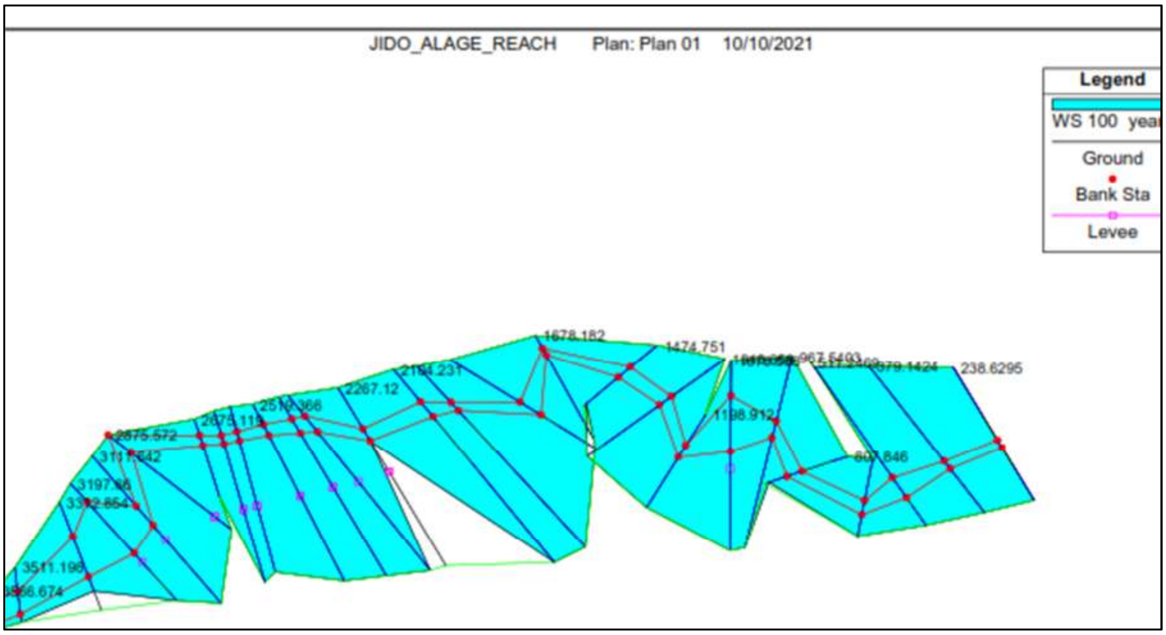

Figure 18 100 years return period directional plot.

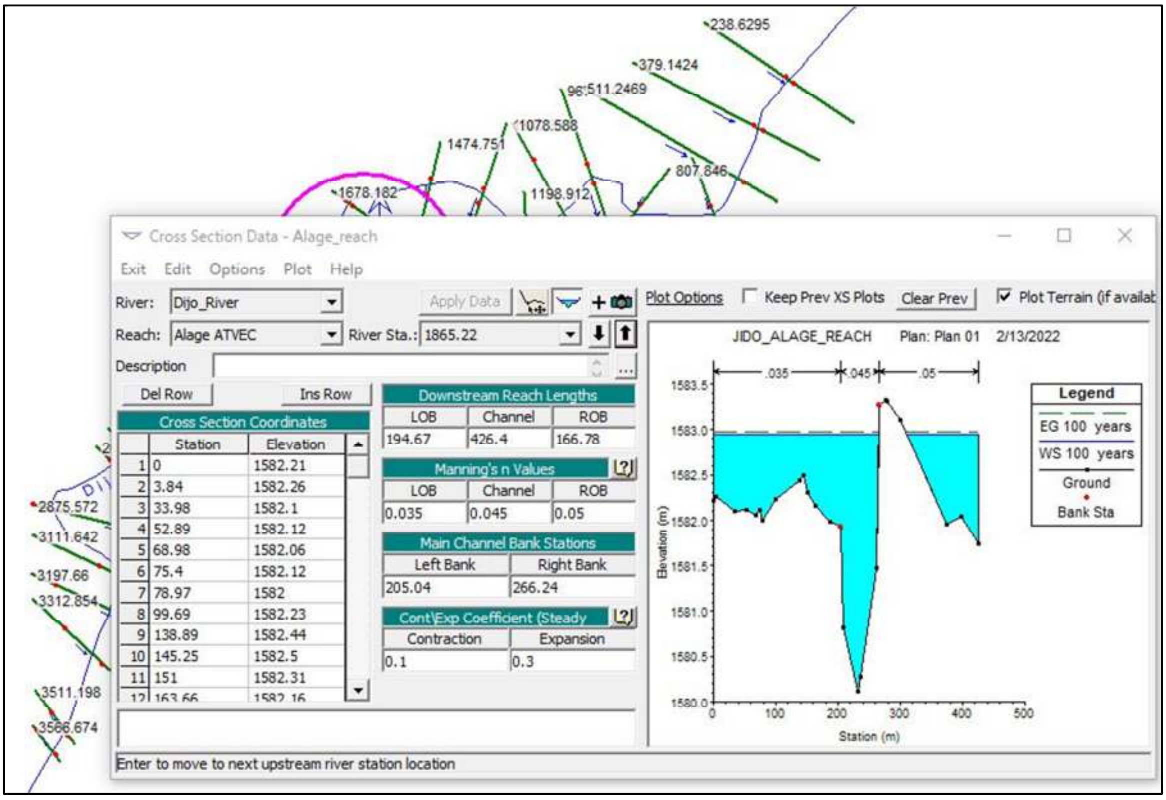

Figure 19 Dijo River x- section of 1865.22m

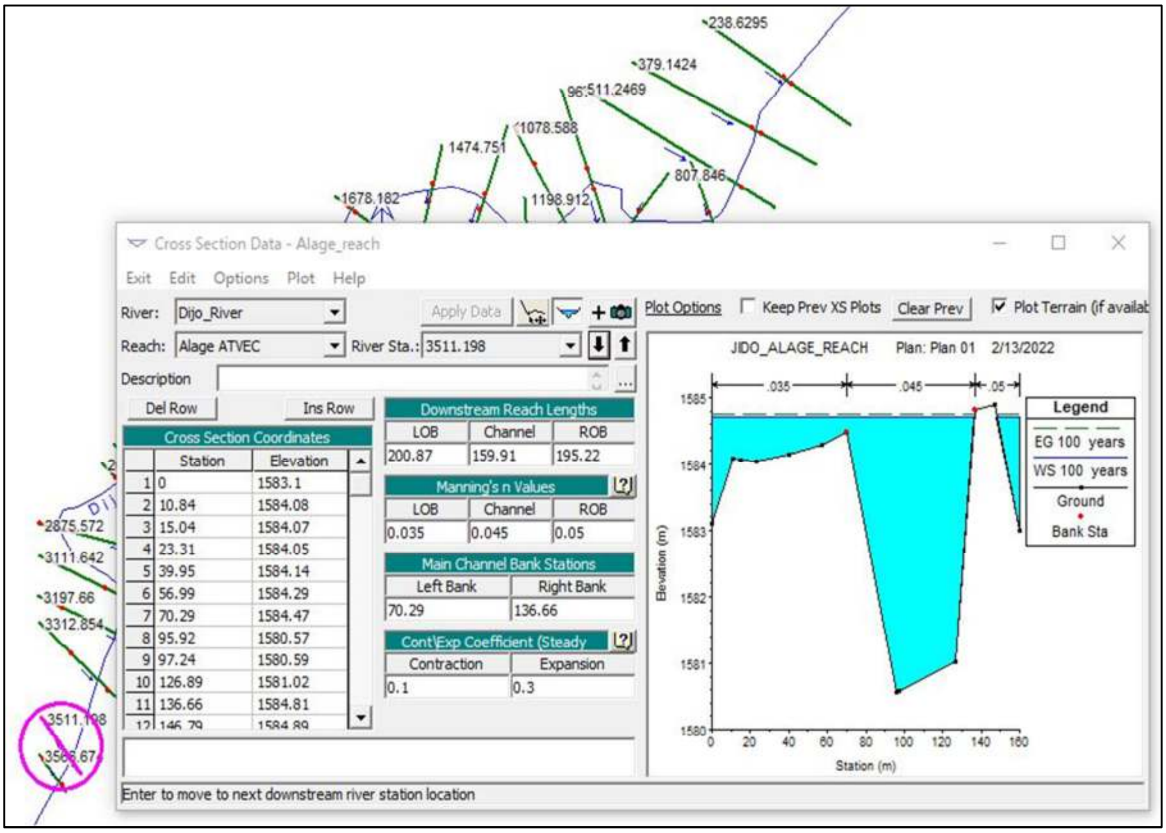

Figure 20 Dijo River x- section of 3511.198m

Figure 21 flood venerable bee farm area cross section

Figure 22 old administration area cross section

In 2-years, return period peak flood discharge only 40.74% of river x-sections are flash flood to the collage and to naqa kebele. This river flood not approach to the existing earthen levee. 59.3% of the x-sections are not disperse the flood to the collage and naqa kebele. See fig. (19, 20). Generally, if the peak discharges increase the venerable x-section of the river is also increase.

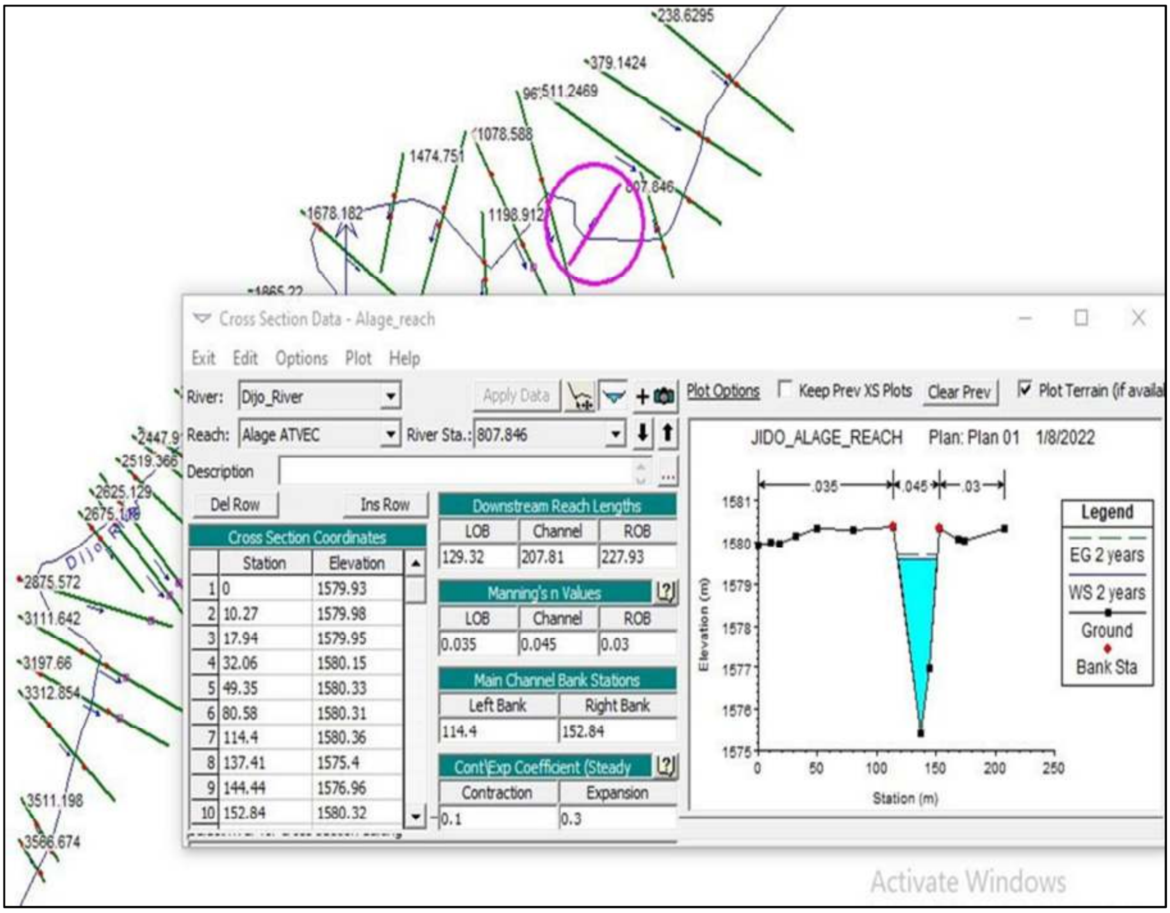

Figure 23 Dijo River x- section 807.846m

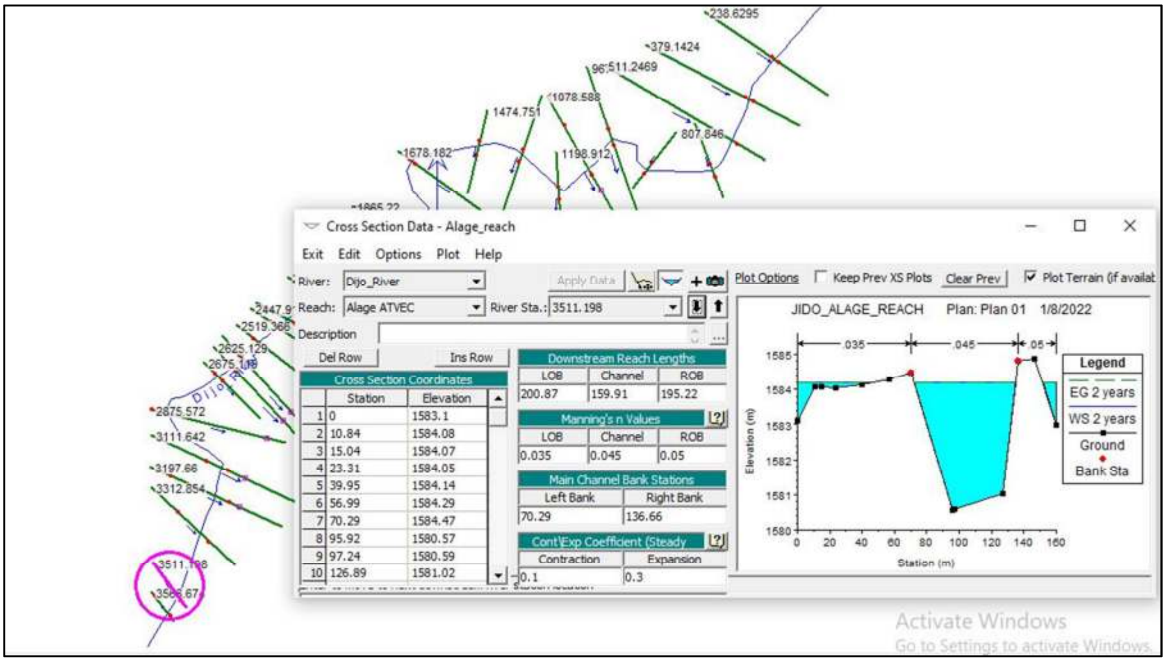

Figure 24 Dijo river x- section 3511.198m

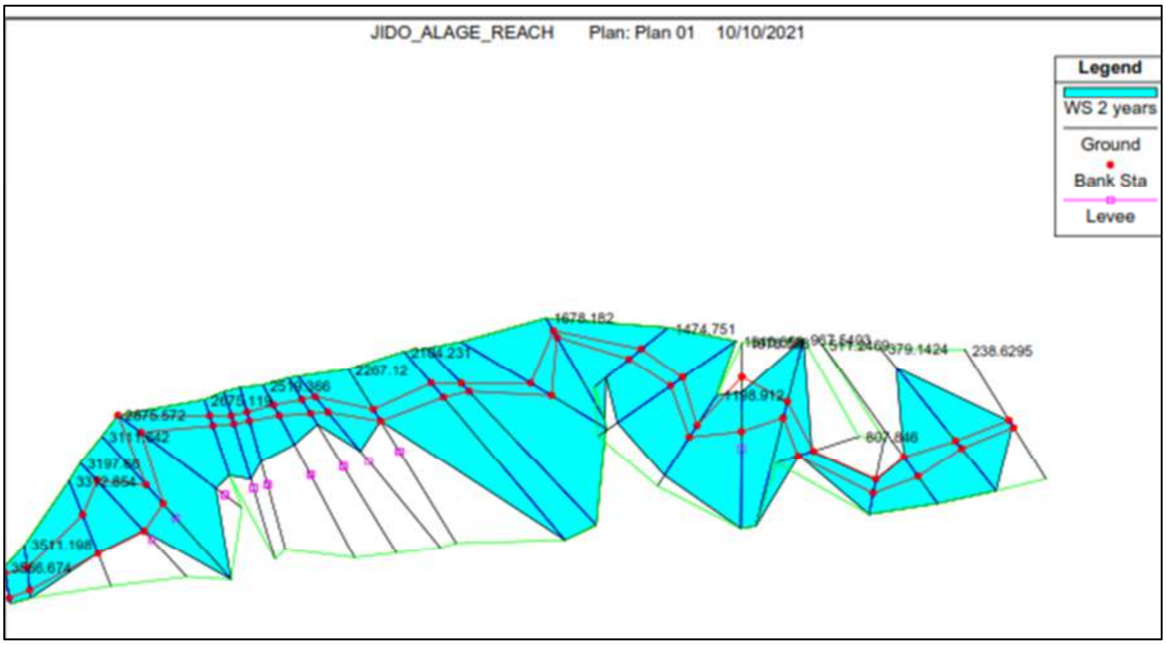

Figure 25 2-years return period X-Y-Z perspective Water surface profile

4.3 Flood Inundation Mapping

Flood Inundation Mapping is significant tool for designers, planners, and responsible body's emergency action plans and ecological studies. Flood venerable x-section and the amount of flooded area is very important to planning, set mitigation measure and management the collage and naqa kebele. The inundation area of 2, 10, 25, 50 and 100-year floods are 5702, 8154.71, 8499.96, 9271.9 and 9851.84m^2. Most of the areas are at the Alage ATVEC. This flood reaches Bee farm area, 01 teacher's residential areas, old administration residential area, church, nok, 01 residential areas, chefe Agricultural and grassland areas are more inundating area. It can be occurred due to a narrow of the river channel, meandering of the river and exceed of peak flood discharges. I prepared flood inundation map of Dijo River downstream (Alage ATVEC) reach by using 2, 10, 25, 50 and 100 return period peak flows.

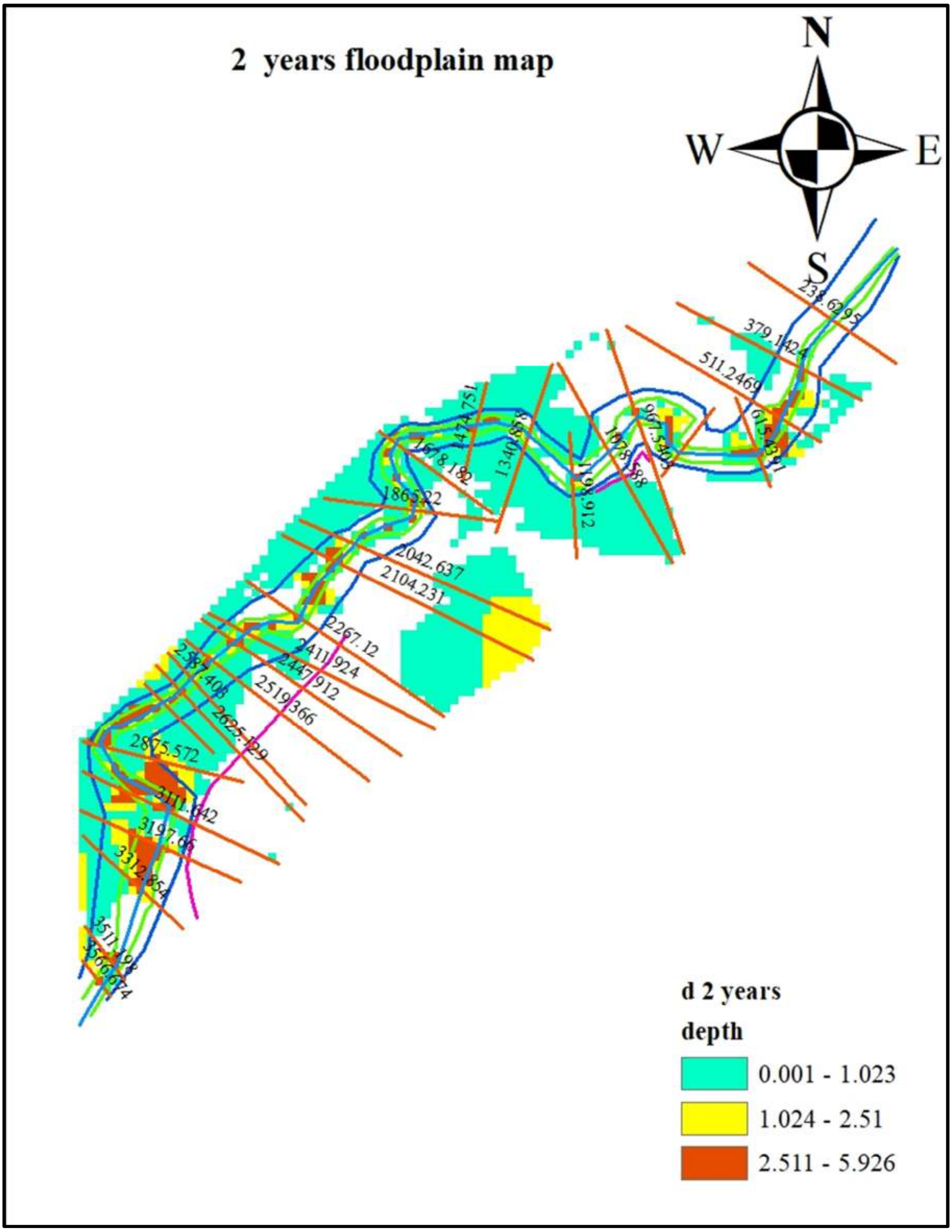

Figure 26 2 years return period flood map

This 2-year return period flood plain map has covers 5702m ^{2}, which is the result of 101.19 m^3/s peak discharge of the river. The map covers small area near the riverbanks. The exiting earthen levee is free from flooding. Flood is spread near to riverbanks. I.e., in this flood plain map 59.3% of the x-sections, not flash the flood neither to the collage nor to the Naqa kebele. Hence, the flood-affected area is also small.

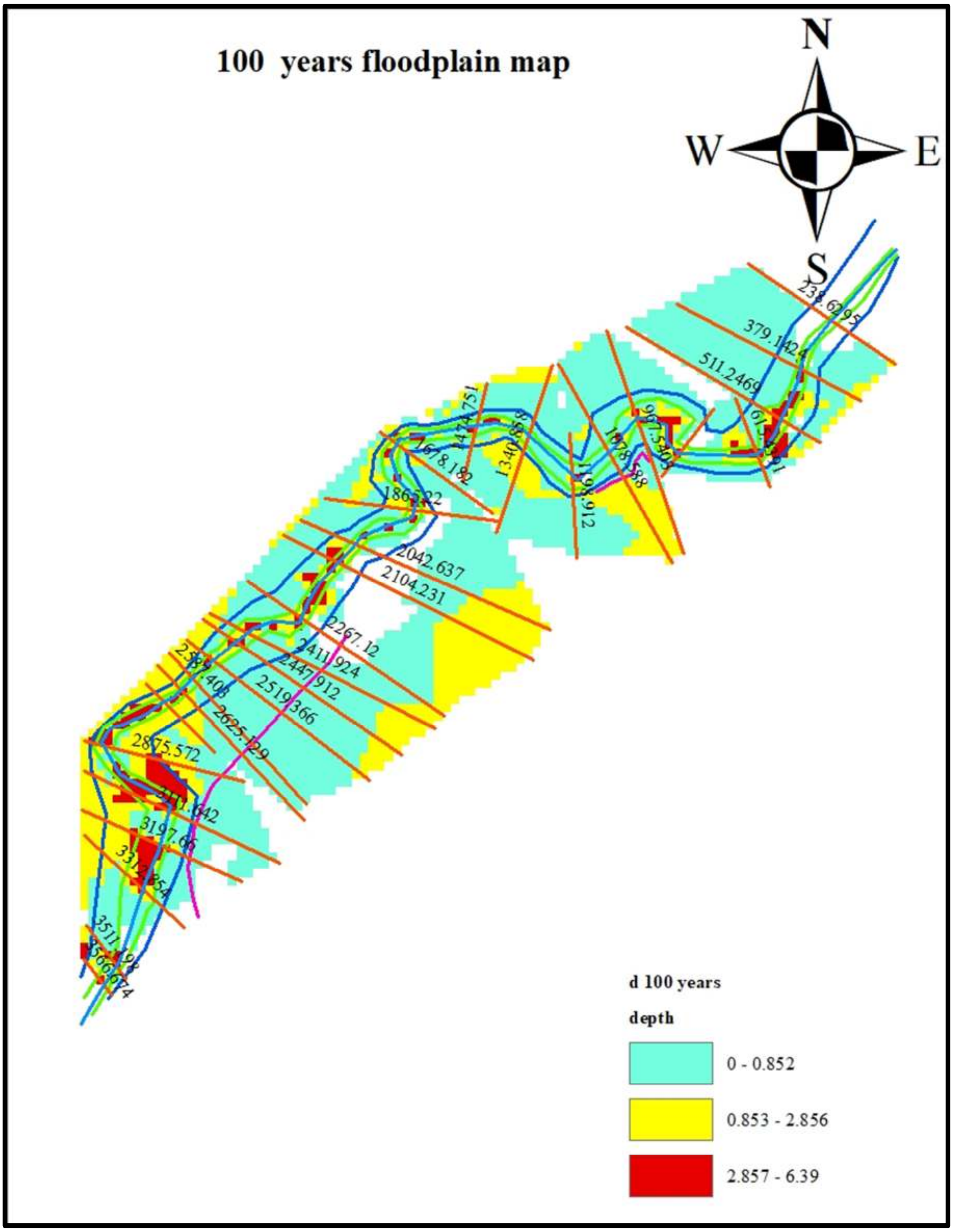

Figure 20 flood Plain map of 100 years return period

This 100-year return period flood plain map shows that out of the right and left riverbanks. Bee farm area, arefe ayne grazing and agricultural area,ortodox church, nock, chefe agricultural area, ogaden grass area, the main entrance road from bera town to zeray 01 administration area road and bera town to old administration and mosque road areas are affected by flood. In general, the above listed areas are the basic valuable area of the collage and continuously flood-affected area from10, 25, 50, and 100 -years return period but flood depth depend on the peak discharge of return periods. The inundation area of 2, 10, 25, 50 and 100-year floods are 5702, 8154.71, 8499.96, 9271.9 and 9851.84m2 respectively.

Table 5 Area of inundated and water level

			Depth		
Return periods (year)	Peak Discharges(m^3/s)	Inundated area (m^2)	Minimum	Mean	Maximum
2	101.217	5702	0	0.8	2.511
10	164.6	8154.71	0	0.802	2.62
25	175.8	8499.96	0	0.81	2.66
50	207.58	9271.9	0	0.839	2.717
100	227.83	9851.84	0	0.859	2.857

Previously made earthen dyke/ levee from alage-Bera Bridge to kuba village to prevent the collage from dijo river flooding, the villagers also used as an access road. The minimum and the maximum height of the dyke are 0.1 and 0.45m respectively. This indicates the height of the dyke is less than the depth of a flood.

Figure 27 locally made earthen dyke

5 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The aim of the research was preparation of floodplains map of the downstream reach of Dijo River. The prepared data were incorporated with HEC-RAS, GIS and its extension tool called HEC-GEORAS software programs to identify the planed floodplains. This study uses the steady state analysis and GIS. Topographic analysis using Arc GIS and surveying data has a greatly effectiveness to represent terrain nature exactly. The total station surveying data have advanced and the most accurate for the floodplain map.

In this study, HEC-RAS, Arc GIS 10.3, HEC-Geo RAS and excel 2016, extension models were used for flood modelling of dijo River. HEC Geo RAS used to prepare and process geometric input from surveying data and delineate floodplain map. The geometric data prepared has 27x- sections. In addition, the flood frequency analysis of dijo River is conducted to estimate peak flood magnitude of the river. Flood mapping was done properly and inundation area and flood depth were interrelated. From the result of this study, it is possible to conclude that there are several x-sections, which are continuously venerable to flooding along Dijo riverbank against to the return periods. The result indicates that not only Alage ATVEC /right side/ the left side/Naqa kebele/ of the river is also exposed to flooding at all return period peak discharges but the extent flood occupied area are vary . Old Administration residential area, nock area, church area, bee farm area, chefe cultivated and grassland areas in the college and residential and agricultural area of Neqa kebele are flood venerable areas. The 2, 10, 25, 50 and 100 years return period peak discharges are 101.22, 164.6, 175.8, 207.58, 227.83m3/s and flood occupied area are 5702, 8154.71, 8499.96, 9271.9 and 9851.84m2 respectively.

5.2 RECOMMENDATION

- ✓ Flood inundation map is primary precondition to protect the downstream reach of Dijo River. B/c it indicates the affected areas of the collage.
- ✓ Concerned body increase the height and width of exiting levee at the upstream of alage-Bera Bridge and construction of new levee on downstream of alage- Bera Bridge and naqa kebele and de-silting at vulnerable x-sections to prevent loss life and property damage.
- ✓ The responsible bodies also actively and cooperatively work together with dijo river upper watershed areas responsible bodies for watershed management works.
- ✓ The recommended flood remedial measures prioritize from any other works.
- ✓ The coming new researcher's conduct the research on selection of appropriate remedial measures with its detail designs depending on land use land cover and return period peak discharges.
- ✓ Use other hydraulic models in order to know flooding pattern more effectively.
- ✓ The coming researchers focus on flood risk analysis based identifies flood risk area based on detail survey of the collage area and set the mitigation area of venerable areas.

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7 APPENDICES

Appendix- I Manning's n coefficient

Types of channel and Description	Manning's Roughness (n) Values		
	Minimum	Normal	Maximum
Natural Streams			
1. Main channels			
1.1. Clean ,straight ,full ,no rifts or deep pools	0.025	0.030	0.033
1.2. Same as above ,but more stones and weeds	0.030	0.035	0.040
1.3. Clean ,winding ,some pools and shoals	0.033	0.040	0.045
1.4. Same as above ,but some weeds and stones	0.035	0.045	0.050
1.5. Same as above ,lower stage ,more ineffective slopes and sections	0.040	0.048	0.055
1.6. Same as "d" but more stones	0.045	0.050	0.060
1.7. Sluggish reaches ,weedy ,deep pools	0.050	0.070	0.080
1.8. Very weedy reaches ,deep pools or floodways with heavy stands of timber and brush	0.070	0.100	0.150
2. Flood plains			
2.1. Pasture no brush			
2.1.1. Short grass	0.025	0.030	0.035
2.1.2. High grass	0.030	0.035	0.050
2.2. Cultivated areas			
2.2.1. No crop	0.020	0.030	0.040
2.2.2. Mature row crops	0.025	0.035	0.045
2.2.3. Mature field crops	0.030	0.040	0.050
2.3. Brush			

2.3.1. Scattered brush ,heavy weeds	0.035	0.050	0.070
2.3.2. Light brush and trees ,in winter	0.035	0.050	0.060
2.3.3. Light brush and trees ,in summer	0.040	0.060	0.080
2.3.4. Medium to dense brush, in winter	0.045	0.070	0.110
2.3.5. Medium to dense brush, in summer	0.070	0.100	0.160
2.4. Trees			
2.4.1. Cleared land with tree stumps ,no sprouts	0.030	0.040	0.050
2.4.2. Same as above ,but heavy sprouts	0.050	0.060	0.080
2.4.3. Heavy stands of timber ,few down trees ,little under growth ,flow below branches	0.080	0.100	0.120
2.4.4. Same as above , but with flow into branches	0.100	0.120	0.160
2.4.5. Dense willows, ,straight ,straight	0.110	0.150	0.200
3. Mountain streams ,no vegetation in channel banks usually steep ,with trees and brush on banks submerged			
3.1. Bottom : gravels ,cobbles ,and few boulders	0.030	0.040	0.050
3.2. Bottom : cobbles with large boulders	0.040	0.050	0.070

Appendix- II Table flood frequency analysis

Years	Yearly peak flow(m^3/s)	Descending order	Rank(m)	probability of occurrence(m/n+1)	Return period(TP)
1987	93.003	177.874	1	0.0286	35
1988	81.052	172.4003	2	0.0571	17.5
1989	52.11	166.9266	3	0.0857	11.67
1990	74.763	161.4529	4	0.1143	8.75
1991	101.418	155.9792	5	0.1429	7
1992	90.25	150.5055	6	0.1714	5.833
1993	96.25	145.0318	7	0.2000	5
1994	71.35	139.5581	8	0.2286	4.375
1995	76.623	134.0844	9	0.2571	3.889
1996	97.868	128.6107	10	0.2857	3.5
1997	105.031	123.137	11	0.3143	3.182
1998	101.418	117.6633	12	0.3429	2.917
1999	96.466	112.1896	13	0.3714	2.692
2000	71.712	105.031	14	0.4000	2.5
2001	86.264	105.031	15	0.4286	2.333
2002	86.14	105	16	0.4571	2.188
2003	77.876	101.418	17	0.4857	2.059

Years	Yearly peak flow(m^3/s)	Descending order	Rank(m)	probability of occurrence(m/n+1)	Return period(TP)
2004	85.603	101.418	18	0.5143	1.944
2005	101.418	101.418	19	0.5429	1.842
2006	105.031	97.868	20	0.5714	1.75
2007	105	96.466	21	0.6000	1.667
2008	112.1896	96.25	22	0.6286	1.591
2009	117.6633	93.003	23	0.6571	1.522
2010	123.137	90.25	24	0.6857	1.458
2011	128.6107	86.264	25	0.7143	1.4
2012	134.0844	86.14	26	0.7429	1.346
2013	139.5581	85.603	27	0.7714	1.296
2014	145.0318	81.052	28	0.8000	1.25
2015	150.5055	77.876	29	0.8286	1.207
2016	155.9792	76.623	30	0.8571	1.167
2017	161.4529	74.763	31	0.8857	1.129
2018	166.9266	71.71	32	0.9143	1.094
2019	172.4003	71.35	33	0.9429	1.061
2020	177.874	52.11	34	0.9714	1.029
Mean		110.06057			

Years	Yearly peak flow(m^3/s)	Descending order	Rank(m)	probability of occurrence(m/n+1)	Return period(TP)
s_d		32.64			
Y_N		0.5396			
S_N		1.1255			
R_T	Y_T	k	$X_t(m^3/s)$		
2	0.37		101.217		
10	2.25	1.5200	164.6		
25	3.20	2.3624	175.8		
50	3.90	2.9874	207.58		
100	4.60	3.6078	227.83		

NB: Yn =Reduced mean, N = sample size

Appendix- III Threshold values

Threshold	Mean
16	59.0769
17	59.1004
18	59.1511
29	49.2163
35	44.1193
39	40.9406
43	38.5425
50	32.2994
52	30.9468
54	31.6879
57	29.3917
59	31.1091
60	30.9269
62	29.7591
65	27.5598
68	25.3245
69	25.048

Threshold	Mean
71	23.7975
74	23.106
76	23.5886
77	24.4258
81	22.4737
82	22.4928
84	21.5169
85	25.5112
86	26.0679
93	20.7882
96	19.2729
97	21.4073
101	19.2745
105	22.3457
116	18.784
126	18.0555
132	18.0177
137	21.998
180	0.66

Appendix- IV Total station surveying data

PtID	East	North	Elevation
R1	438132	842710	1579.96
L1	438113	842738	1579.84
C45	438120	842717	1574.25
R2	438170	842645	1579.05
LS82	438069	842793	1579.76
1.1	438034	842728	1579.96
RS70	438028	842699	1579.77
LS77	438042	842567	1578.78
LS81	438040	842773	1579.68
1.5	438010	842578	1579.14
RS68	437964	842698	1580
1.7	437963	842732	1580.24
LS80	437999	842779	1580.27
RS67	437920	842709	1580.35
1.1	437907	842696	1580.06
RS66	437925	842748	1580.5
C42	437933	842719	1574.99
RFP47	437877	842732	1580.6
1.16	437860	842700	1580.35
LS79	437971	842804	1580.4
LFP37	437994	842830	1580.03
RS65	437885	842780	1580.26
RFP46	437850	842745	1580.53
LS78	437934	842831	1580.51
LFP36	437938	842862	1580.19
C41	437902	842791	1574.87
1.27	437902	842747	1575.32
RS64	437868	842789	1580.38
1.29	437844	842724	1580.58
1.3	437884	842854	1580.46
RS63	437842	842791	1580.52
LFP35	437865	842874	1580.3
RS62	437829	842789	1580.5
RS61	437819	842777	1580.58
LS76	437839	842850	1580.01
RS60	437811	842757	1580.7
LS75	437823	842840	1580.6
LS74	437802	842823	1580.71
C40	437831	842810	1575.13
LS73	437781	842805	1580.78
LS72	437775	842783	1580.49

LS71	437776	842752	1580.51
RS59	437809	842743	1580.73
RFP45	437830	842736	1580.54
RFP44	437813	842705	1580.63
2.21	437825	842702	1580.54
LFP34	437722	842818	1580.22
RFP43	437809	842694	1580.58
2.24	437820	842669	1581.12
LFP33	437716	842790	1579.99
RFP42	437800	842684	1580.64
2.27	437801	842664	1579.94
LFP32	437715	842769	1579.87
RFP41	437785	842673	1580.66
2.3	437783	842656	1580.1
RFP40	437766	842663	1580.78
2.32	437764	842649	1580.05
C39	437792	842765	1574.84
C38	437787	842745	1575.01
LS70	437777	842747	1580.22
2.3	437760	842746	1580.52
RFP39	437749	842651	1580.86
2.32	437746	842637	1580.01
RFP38	437733	842643	1581.06
2.34	437732	842628	1579.73
LS69	437774	842731	1580.54
RS58	437758	842692	1580.74
RFP37	437677	842630	1581.14
RS57	437704	842637	1581
LS68	437724	842700	1580.62
LS67	437704	842669	1581.03
LFP31	437695	842707	1580.57
RS56	437666	842633	1581.12
LS66	437664	842670	1581.1
RFP36	437664	842617	1580.31
LFP30	437659	842701	1580.78
RFP34	437615	842651	1581.09
RFP35	437600	842620	1580.21
RS55	437594	842699	1581.05
RFP33	437588	842692	1580.69
C37	437687	842656	1575.24
LS65	437658	842670	1581.11
LS64	437626	842693	1581.22

LS63	437611	842721	1581.08
LS62	437602	842737	1581.21
LS61	437591	842752	1581.56
LFP29	437599	842773	1580.89
LS60	437576	842775	1581.37
LFP28	437571	842811	1581.19
LFP27	437546	842826	1581.33
RS54	437562	842740	1581.37
RFP33	437550	842732	1580.59
C36	437552	842778	1575.29
RS 53	437537	842763	1581.26
RFP31	437523	842757	1581.67
RS52	437517	842778	1581.2
RFP30	437508	842759	1580.98
C35	437487	842796	1575.3
RS51	437483	842781	1581.43
RFP29	437482	842748	1580.66
RFP28	437444	842740	1580.95
Rs50	437438	842764	1581.52
C34	437428	842787	1575.39
Rs49	437410	842762	1581.71
RFP27	437415	842736	1581.29
RS48	437384	842760	1581.63
RFP26	437390	842741	1580.86
Rs47	437355	842755	1581.84
RFP25	437359	842735	1581.6
LS59	437558	842785	1581.7
LS58	437527	842802	1581.34
LS57	437507	842809	1581.39
LS56	437473	842813	1581.52
LS55	437450	842805	1581.53
LS54	437382	842789	1581.46
LS53	437406	842795	1581.59
LS52	437369	842785	1581.43
LS50	437338	842782	1582
LFP26	437424	842858	1581.32
LFP25	437372	842835	1581.11
LS51	437345	842773	1575.63
RS 46	437327	842753	1581.6
RFP24	437339	842727	1581.3
DBR1	437319	842750	1582.42
DBR2	437318	842754	1580.01

DBR3	437313	842773	1580.1
DBR4	437314	842791	1583.46
UDR1	437310	842748	1583.1
C33	437299	842766	1575.94
UBR1	437304	842772	1579.09
UBR2	437308	842756	1577.69
UBR3	437299	842782	1583.15
C32	437252	842753	1575.6
Rs43	437262	842747	1581.27
2.151	437270	842725	1581.75
Rs42	437252	842728	1582.13
2.153	437290	842692	1581.73
Rs41	437248	842700	1582.53
RS40	437251	842685	1582.26
2.156	437290	842666	1582.01
LS46	437277	842781	1582.09
LS45	437237	842753	1581.66
LS44	437216	842732	1582.05
LS43	437212	842723	1581.62
LS42	437211	842693	1582.38
LS41	437217	842668	1582.02
LS40	437225	842655	1582.15
LFP24	437262	842801	1581.57
LFP23	437216	842784	1581.79
C31	437230	842718	1576.08
C30	437250	842655	1576.15
LFP22	437185	842671	1581.89
LFP21	437182	842655	1581.72
LFP20	437220	842612	1582.39
Rs39	437269	842664	1582.57
2.204	437303	842675	1582.16
LFP19	437212	842585	1582.55
Rs38	437302	842622	1582.53
LS39	437251	842635	1582.36
Rs37	437305	842567	1582.54
LS38	437263	842621	1582.25
RFP23	437341	842567	1583.43
C29	437294	842609	1575.87
C28	437285	842562	1576.62
Rs36	437285	842538	1582.65
RFP22	437307	842515	1583.41
Rs35	437264	842523	1582.5

RFP21	437284	842503	1583.35
C27	437227	842546	1575.77
Rs34	437238	842523	1582.12
RFP20	437244	842487	1583.38
Rs 33	437215	842522	1582.49
RFP19	437220	842472	1583.55
C26	437158	842516	1576.63
Rs32	437178	842514	1581.69
1.271	437149	842522	1582.69
LS29	437173	842542	1582.62
LS30	437189	842552	1582.86
LS31	437204	842560	1582.85
1.275	437242	842561	1582.53
LS32	437250	842555	1582.44
LS33	437257	842557	1582.47
LS34	437264	842562	1582.32
LS35	437273	842580	1581.96
LS36	437275	842604	1581.85
LS37	437269	842617	1581.97
1.282	437229	842601	1582.03
LFP18	437159	842557	1582.61
LFP17	437131	842535	1582.66
1.285	437105	842514	1582.56
Rs31	437156	842487	1582.56
Rs30	437137	842464	1582.79
Rs29	437119	842448	1582.58
Rs28	437078	842407	1582.86
RFP18	437171	842455	1584.03
RFP17	437139	842396	1584.28
C25	437136	842485	1576.75
C24	437096	842447	1576.73
RFP16	437105	842353	1582.26
C23	437056	842405	1576.71
LS28	437128	842497	1582.7
LFP16	437100	842526	1582.39
LFP15	437069	842502	1582.31
LS27	437075	842446	1582.89
LS26	437028	842382	1582.99
LFP14	436988	842426	1582.42
LFP13	436954	842388	1582.64
LS21	436881	842319	1583.27
RFP15	437125	842278	1584.09

RFP14	437079	842209	1583.62
LS25	437016	842363	1582.97
C22	437030	842358	1576.76
C21	437011	842309	1576.72
RFP13	437011	842140	1583.65
LS24	437003	842336	1583
Rs24	436988	842276	1582.53
Rs25	436994	842284	1583.06
Rs26	437024	842307	1583.11
Rs27	437035	842322	1583.13
RFP12	436975	842101	1583.97
Rs50	436933	842290	1583.27
LS23	436943	842321	1583.33
RFP11	436931	842052	1584.04
Rs22	436894	842265	1583.37
LS22	436912	842319	1583.42
L61	436874	842311	1583.32
LS20	436844	842288	1583.31
LS19	436825	842259	1583.36
LS18	436810	842244	1583.43
LFP9	436803	842283	1583.02
LFP10	436822	842313	1583
LFP11	436846	842335	1583.02
LFP12	436896	842360	1583.03
C21	436942	842311	1577.23
C20	436897	842296	1577.57
RS21	436889	842260	1583.37
CX19	436848	842255	1577.5
Rs20	436827	842216	1583.35
Rs19	436773	842182	1583.34
C18	436789	842209	1577.73
R80	436705	842110	1583.04
C17	436752	842179	1578.03
LS15	436739	842174	1583.44
LS16	436767	842210	1583.46
LS17	436797	842238	1583.37
LFP8	436765	842277	1582.8
LFP7	436706	842234	1582.72
Rs18	436775	842183	1583.42
Rs17	436759	842152	1583.48
LS14	436728	842166	1583.45
RFP10	436851	841969	1584.14

L100	436705	842111	1583.51
Rs16	436706	842110	1583.52
LS13	436712	842145	1583.44
Rs15	436655	842081	1583.66
LS12	436682	842131	1583.52
LS11	436636	842110	1583.55
Rs14	436572	842040	1583.81
LS10	436574	842081	1583.86
C16	436707	842131	1577.47
C15	436674	842113	1577.76
C14	436641	842089	1577.67
C13	436582	842059	1577.94
C11	436528	842019	1578.11
LFP5	436594	842111	1583.46
LFP6	436627	842156	1583.06
RFP9	436801	841914	1584.32
RFP7	436766	841841	1584.14
RFP6	436756	841814	1583.97
C12	436548	842051	1577.94
LS9	436509	842005	1583.71
Rs13	436565	842033	1583.79
LS8	436537	841964	1584.06
LFP4	436482	842015	1583.51
Rs12	436558	841989	1583.8
LS7	436569	841933	1584.08
LFP3	436504	841955	1583.42
Rs11	436596	841944	1583.78
C10	436575	841942	1577.91
C9	436606	841925	1578.02
LS6	436657	841890	1584.18
Rs10	436623	841933	1583.37
C8	436656	841899	1578.34
LS5	436640	841853	1583.86
C7	436695	841865	1578.22
LFP2	436540	841847	1583.4
LS4	436666	841794	1584.44
RFP8	436791	841900	1584.18
RFP5	436753	841802	1584
RFP4	436747	841755	1584.44
C5	436635	841679	1578.99
C6	436669	841759	1579.03
R9	436713	841844	1584.42

Rs8	436707	841829	1584.08
R6	436667	841702	1584.28
Rs7	436680	841744	1584.29
FRP3	436739	841714	1584.16
FRP2	436749	841647	1584.57
FRP1	436764	841593	1585.03
Rs5	436654	841625	1584.43
LS3	436577	841670	1584.08
Rs4	436641	841612	1584.48
LS2	436601	841580	1584.68
C1	436478	841330	1579.18
Rs3	436623	841564	1584.58
LS1	436570	841524	1584.81
C2	436500	841368	1578.87
C3	436528	841415	1578.79
C4	436573	841489	1578.81
LFP1	436502	841510	1584.15
Rs2	436591	841490	1584.73
Rs1	436558	841439	1584.87
C43	438085	842713	1575.2
C44	438117	842721	1575.31
RS69	438024	842700	1579.82
RSCROS71	438094	842695	1579.8
RS73	438131	842706	1580.29
RS72 X	438129	842697	1579.08
RS75X	438194	842789	1580.14
RS76	438237	842882	1579.56
L600	438124	842738	1579.78
FRP50	438307	842832	1579.44
LS85	438176	842836	1579.67
LS83	438125	842794	1579.39
LS86	438200	842880	1579.59
LS84	438140	842833	1579.35
LS88	438217	842926	1579.44
FRP49	438241	842706	1578.58
LS87	438216	842925	1579.39
RS79	438250	842957	1579.18
C46	438143	842735	1574.13
C47	438164	842768	1574.12
C48	438186	842819	1574.17
C49	438208	842865	1574.21
C50	438223	842901	1574.16

C51	438228	842933	1574.06
LS89	438230	842977	1579.28
C52	438240	842967	1573.92
LS90	438248	843005	1579.26
RS77	438245	842940	1579.35
LFP38	438163	843024	1578.59
FRP51	438359	842860	1578.41
FRP52	438431	842896	1577.97
LFP39	438189	843108	1578.3
L665	438230	843108	1578.5
FRP53	438477	842951	1577.41
FRP54	438470	842981	1577.54
L718	438285	843113	1578.32
RS78	438250	842956	1579.32
RS80	438264	842986	1578.93
RS81	438287	843010	1579.2
RS82	438303	843021	1579.26
C53	438296	843037	1573.73
LS91	438288	843040	1579.32
RS83	438332	843050	1579.14
C54	438322	843060	1574.01
LS92	438315	843067	1579.19
RS84	438376	843089	1578.97
L909	438448	843218	1579.08
C55	438439	843196	1573.94
RS85	438432	843169	1579.11
C56	438464	843217	1573.67
LS94	438421	843332	1577.35
LS93	438376	843241	1578.08

Appendix- V Reduced mean (Yn) Table

N	0	1	2	3	4	5	6	7	8	9
10	0.4952	0.4996	0.5035	0.507	0.51	0.5128	0.5157	0.5181	0.5202	0.522
20	0.5236	0.5252	0.5268	0.5283	0.5296	0.5309	0.532	0.5332	0.5343	0.5353
30	0.5362	0.5371	0.538	0.5388	0.5396	0.5402	0.541	0.5418	0.5424	0.543
40	0.5436	0.5442	0.5448	0.5453	0.5458	0.5463	0.5468	0.5473	0.5477	0.5481
50	0.5485	0.5489	0.5493	0.5497	0.5501	0.5504	0.5508	0.5511	0.5515	0.5518
60	0.5521	0.5524	0.5527	0.553	0.5533	0.5535	0.5538	0.554	0.5543	0.5545
70	0.5548	0.555	0.5552	0.5555	0.5557	0.5559	0.5561	0.5563	0.5565	0.5567
80	0.5569	0.557	0.5572	0.5574	0.5576	0.5578	0.558	0.5581	0.5583	0.5585
90	0.5586	0.5587	0.5589	0.5591	0.5592	0.5593	0.5595	0.5596	0.5598	0.5599
100	0.56									

yn =Reduced mean in Gumbel's extreme value distribution, N = sample size

Appendix- VI Reduced standard deviation (Sn) Table

N	0	1	2	3	4	5	6	7	8	9
10	0.9496	0.9676	0.9833	0.9971	1.0095	1.0206	1.0316	1.0411	1.0493	1.0565
20	1.0628	1.0696	1.0754	1.0811	1.0864	1.0915	1.0961	1.1004	1.1047	1.1086
30	1.1124	1.1159	1.1193	1.1226	1.1255	1.1285	1.1313	1.1339	1.1363	1.1388
40	1.1413	1.1436	1.1458	1.148	1.1499	1.1519	1.1538	1.1557	1.1574	1.159
50	1.1607	1.1623	1.1638	1.1658	1.1667	1.1681	1.1696	1.1708	1.1721	1.1734
60	1.1747	1.1759	1.177	1.1782	1.1793	1.1803	1.1814	1.1824	1.1834	1.1844
70	1.1854	1.1863	1.1873	1.1881	1.189	1.1898	1.1906	1.1915	1.1923	1.193
80	1.1938	1.1945	1.1953	1.1959	1.1967	1.1973	1.198	1.1987	1.1994	1.2001
90	1.2007	1.2013	1.202	1.2026	1.2032	1.2038	1.2044	1.2049	1.2055	1.206
100	1.2065									

Sn = Reduced standard deviation in Gumbel's extreme value distribution, N = sample size

Appendix- VII-Years Return Period Hec-Ras Report

HEC-RAS Plan: Plan 01 River: Dijo_River Reach: Alage ATVEC Profile: 2 years

Reach	River Sta	Profile	Q Total	W.S. Elev	Flow Area
			(m3/s)	(m)	(m2)
Alage ATVEC	3566.674	2 years	101.22	1584.21	260.76
Alage ATVEC	3511.198	2 years	101.22	1584.19	175.57
Alage ATVEC	3312.854	2 years	101.22	1584.17	279.25
Alage ATVEC	3197.66	2 years	101.22	1584.16	528.77
Alage ATVEC	3111.642	2 years	101.22	1584.15	501.51
Alage ATVEC	2875.572	2 years	101.22	1584.14	493.85
Alage ATVEC	2675.119	2 years	101.22	1584.10	225.27
Alage ATVEC	2625.129	2 years	101.22	1584.03	168.14
Alage ATVEC	2587.403	2 years	101.22	1583.86	157.82
Alage ATVEC	2519.366	2 years	101.22	1583.66	139.76
Alage ATVEC	2447.912	2 years	101.22	1583.48	163.92
Alage ATVEC	2411.924	2 years	101.22	1583.29	173.20
Alage ATVEC	2267.12	2 years	101.22	1582.72	68.67
Alage ATVEC	2104.231	2 years	101.22	1582.71	456.37
Alage ATVEC	2042.637	2 years	101.22	1582.68	356.90
Alage ATVEC	1865.22	2 years	101.22	1582.56	228.99
Alage ATVEC	1678.182	2 years	101.22	1582.27	133.13
Alage ATVEC	1474.751	2 years	101.22	1581.65	102.61
Alage ATVEC	1340.858	2 years	101.22	1581.32	181.04
Alage ATVEC	1198.912	2 years	101.22	1580.81	115.72
Alage ATVEC	1078.588	2 years	101.22	1580.19	113.10
Alage ATVEC	967.5403	2 years	101.22	1579.95	173.69
Alage ATVEC	807.846	2 years	101.22	1579.59	82.25
Alage ATVEC	615.4391	2 years	101.22	1579.37	95.45
Alage ATVEC	511.2469	2 years	101.22	1579.32	176.90
Alage ATVEC	379.1424	2 years	101.22	1579.09	124.50
Alage ATVEC	238.6295	2 years	101.22	1577.09	24.86

Appendix- VIII 50-Years Return Period Hec-Ras Report

HEC-RAS Plan: Plan 01 River: Dijo_River Reach: Alage ATVEC Profile: 50 years

Reach	River Sta	Profile	Q Total	W.S. Elev	Flow Area
			(m3/s)	(m)	(m2)
Alage ATVEC	3566.674	50 years	207.58	1584.72	315.35
Alage ATVEC	3511.198	50 years	207.58	1584.66	241.02
Alage ATVEC	3312.854	50 years	207.58	1584.63	389.87
Alage ATVEC	3197.66	50 years	207.58	1584.61	654.37
Alage ATVEC	3111.642	50 years	207.58	1584.59	670.48
Alage ATVEC	2875.572	50 years	207.58	1584.57	659.22
Alage ATVEC	2675.119	50 years	207.58	1584.49	317.89
Alage ATVEC	2625.129	50 years	207.58	1584.43	355.42
Alage ATVEC	2587.403	50 years	207.58	1584.27	313.73
Alage ATVEC	2519.366	50 years	207.58	1583.98	216.00
Alage ATVEC	2447.912	50 years	207.58	1583.80	409.89
Alage ATVEC	2411.924	50 years	207.58	1583.69	508.45
Alage ATVEC	2267.12	50 years	207.58	1583.09	113.88
Alage ATVEC	2104.231	50 years	207.58	1583.08	628.80
Alage ATVEC	2042.637	50 years	207.58	1583.03	540.22
Alage ATVEC	1865.22	50 years	207.58	1582.90	353.67
Alage ATVEC	1678.182	50 years	207.58	1582.60	241.54
Alage ATVEC	1474.751	50 years	207.58	1581.92	162.95
Alage ATVEC	1340.858	50 years	207.58	1581.62	291.00
Alage ATVEC	1198.912	50 years	207.58	1581.08	190.67
Alage ATVEC	1078.588	50 years	207.58	1580.76	336.09
Alage ATVEC	967.5403	50 years	207.58	1580.64	437.66
Alage ATVEC	807.846	50 years	207.58	1580.17	111.36
Alage ATVEC	615.4391	50 years	207.58	1579.84	165.80
Alage ATVEC	511.2469	50 years	207.58	1579.71	253.00
Alage ATVEC	379.1424	50 years	207.58	1579.43	275.85
Alage ATVEC	238.6295	50 years	207.58	1578.57	117.72

Appendix- IX 100-Years Return Period Hec-Ras Report

HEC-RAS Plan: Plan 01 River: Dijo_River Reach: Alage ATVEC Profile: 100 years

Reach	River Sta	Profile	Q Total	W.S. Elev	Flow Area
			(m3/s)	(m)	(m2)
Alage ATVEC	3566.674	100 years	227.83	1584.77	321.24
Alage ATVEC	3511.198	100 years	227.83	1584.71	248.07
Alage ATVEC	3312.854	100 years	227.83	1584.67	401.83
Alage ATVEC	3197.66	100 years	227.83	1584.65	668.46
Alage ATVEC	3111.642	100 years	227.83	1584.63	690.61
Alage ATVEC	2875.572	100 years	227.83	1584.61	673.90
Alage ATVEC	2675.119	100 years	227.83	1584.52	324.01
Alage ATVEC	2625.129	100 years	227.83	1584.45	364.89
Alage ATVEC	2587.403	100 years	227.83	1584.24	302.47
Alage ATVEC	2519.366	100 years	227.83	1584.03	358.61
Alage ATVEC	2447.912	100 years	227.83	1583.85	440.28
Alage ATVEC	2411.924	100 years	227.83	1583.74	542.14
Alage ATVEC	2267.12	100 years	227.83	1583.15	124.34
Alage ATVEC	2104.231	100 years	227.83	1583.14	658.02
Alage ATVEC	2042.637	100 years	227.83	1583.09	569.35
Alage ATVEC	1865.22	100 years	227.83	1582.95	373.06
Alage ATVEC	1678.182	100 years	227.83	1582.65	258.46
Alage ATVEC	1474.751	100 years	227.83	1581.96	173.03
Alage ATVEC	1340.858	100 years	227.83	1581.66	307.25
Alage ATVEC	1198.912	100 years	227.83	1581.12	203.26
Alage ATVEC	1078.588	100 years	227.83	1580.83	369.95
Alage ATVEC	967.5403	100 years	227.83	1580.72	480.81
Alage ATVEC	807.846	100 years	227.83	1580.24	118.81
Alage ATVEC	615.4391	100 years	227.83	1579.90	179.60
Alage ATVEC	511.2469	100 years	227.83	1579.76	275.68
Alage ATVEC	379.1424	100 years	227.83	1579.47	296.20
Alage ATVEC	238.6295	100 years	227.83	1578.60	127.51

Appendix- X property of cross section

Cross Section Output

File Type Options Help

River: Dijo_River Profile: 2 years

Reach Alage ATVEC RS: 3566.674 Plan: Plan 02

Plan: Plan 02 Dijo_River Alage ATVEC RS: 3566.674 Profile: 2 years

		Element	Left OB	Channel	Right OB
E.G. Elev (m)	1584.22	Wt. n-Val.	0.035	0.045	0.050
Vel Head (m)	0.01	Reach Len. (m)	73.43	108.69	52.64
W.S. Elev (m)	1584.21	Flow Area (m2)	31.43	200.23	29.10
Crit W.S. (m)		Area (m2)	31.43	200.23	29.10
E.G. Slope (m/m)	0.000092	Flow (m3/s)	11.62	82.50	7.09
Q Total (m3/s)	101.22	Top Width (m)	17.38	74.05	17.26
Top Width (m)	108.69	Avg. Vel. (m/s)	0.37	0.41	0.24
Vel Total (m/s)	0.39	Hydr. Depth (m)	1.81	2.70	1.69
Max Chl Dpth (m)	3.46	Conv. (m3/s)	1210.0	8587.3	738.3
Conv. Total (m3/s)	10535.6	Wetted Per. (m)	20.09	74.68	20.37
Length Wtd. (m)	104.19	Shear (N/m2)	1.42	2.43	1.29
Min Ch El (m)	1580.75	Stream Power (N/m s)	0.52	1.00	0.32
Alpha	1.05	Cum Volume (1000 m3)	105.82	1226.77	204.78
Frctn Loss (m)	0.01	Cum SA (1000 m2)	225.00	555.07	353.83
C & E Loss (m)	0.00				

Errors, Warnings and Notes

Appendix- XI property of cross section

Cross Section Output

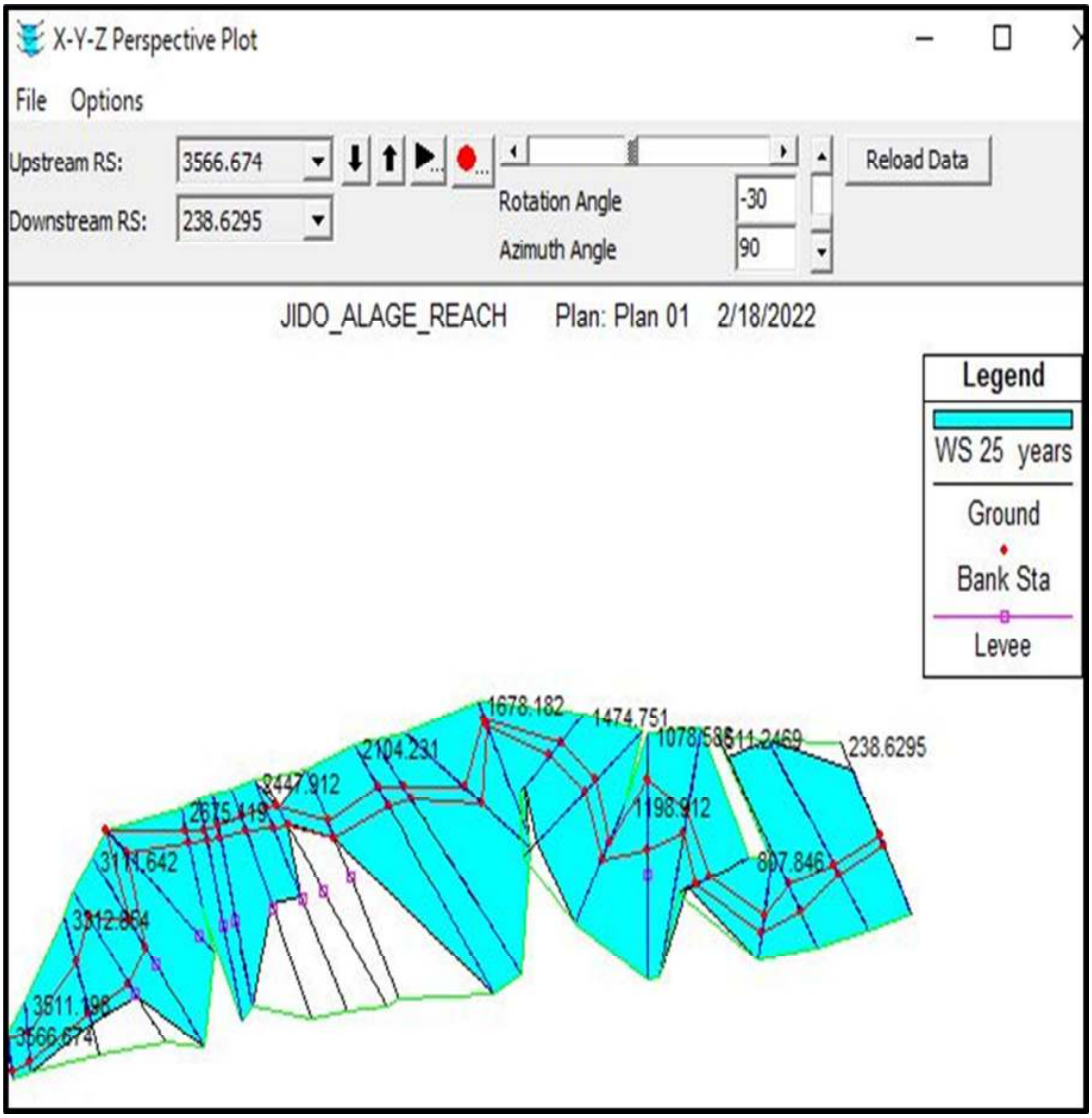
File Type Options Help

River: Dijo_River Profile: 100 years

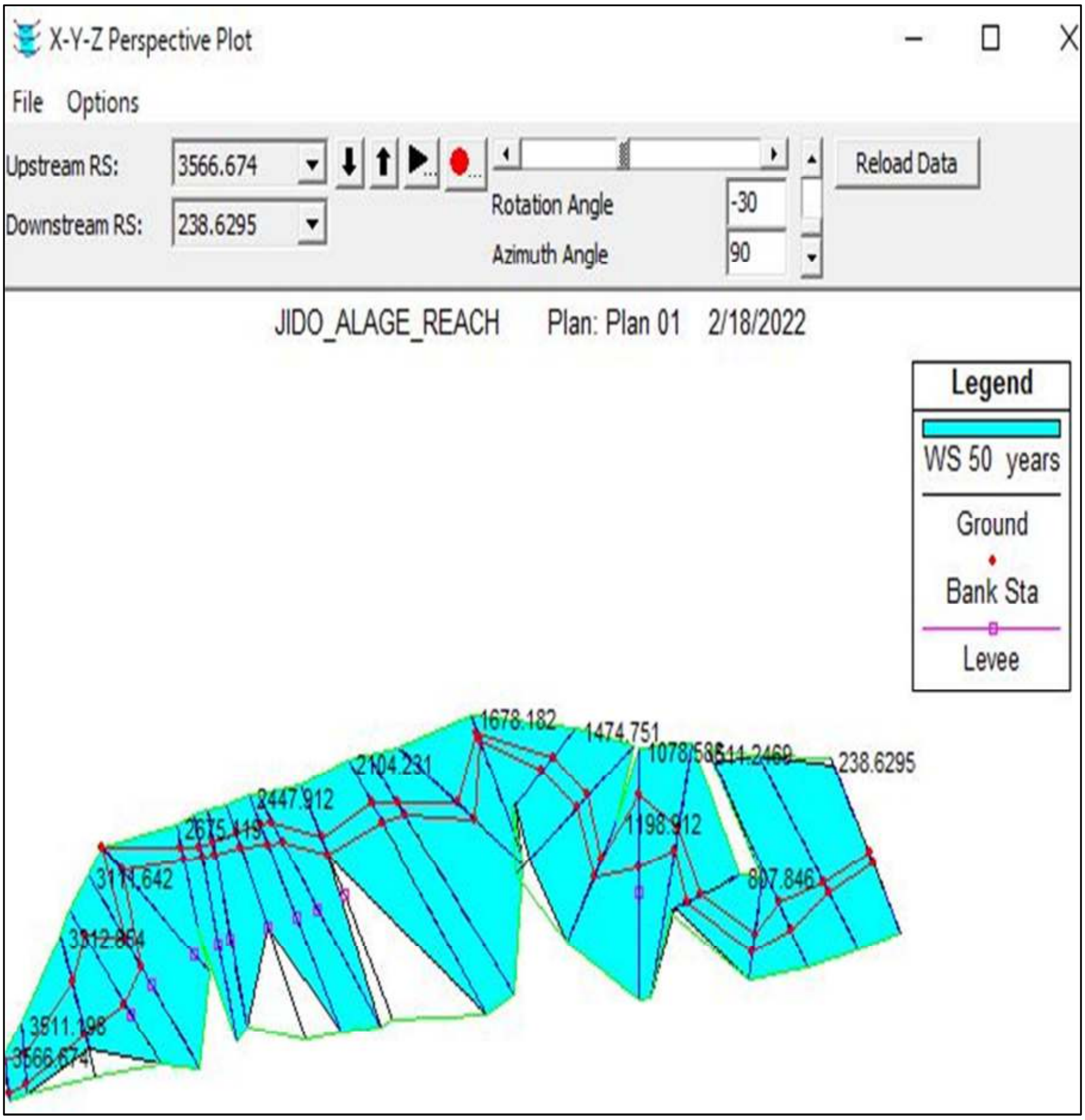
Reach Alage ATVEC RS: 3566.674 Plan: Plan 02

Plan: Plan 02 Dijo_River Alage ATVEC RS: 3566.674 Profile: 100 years

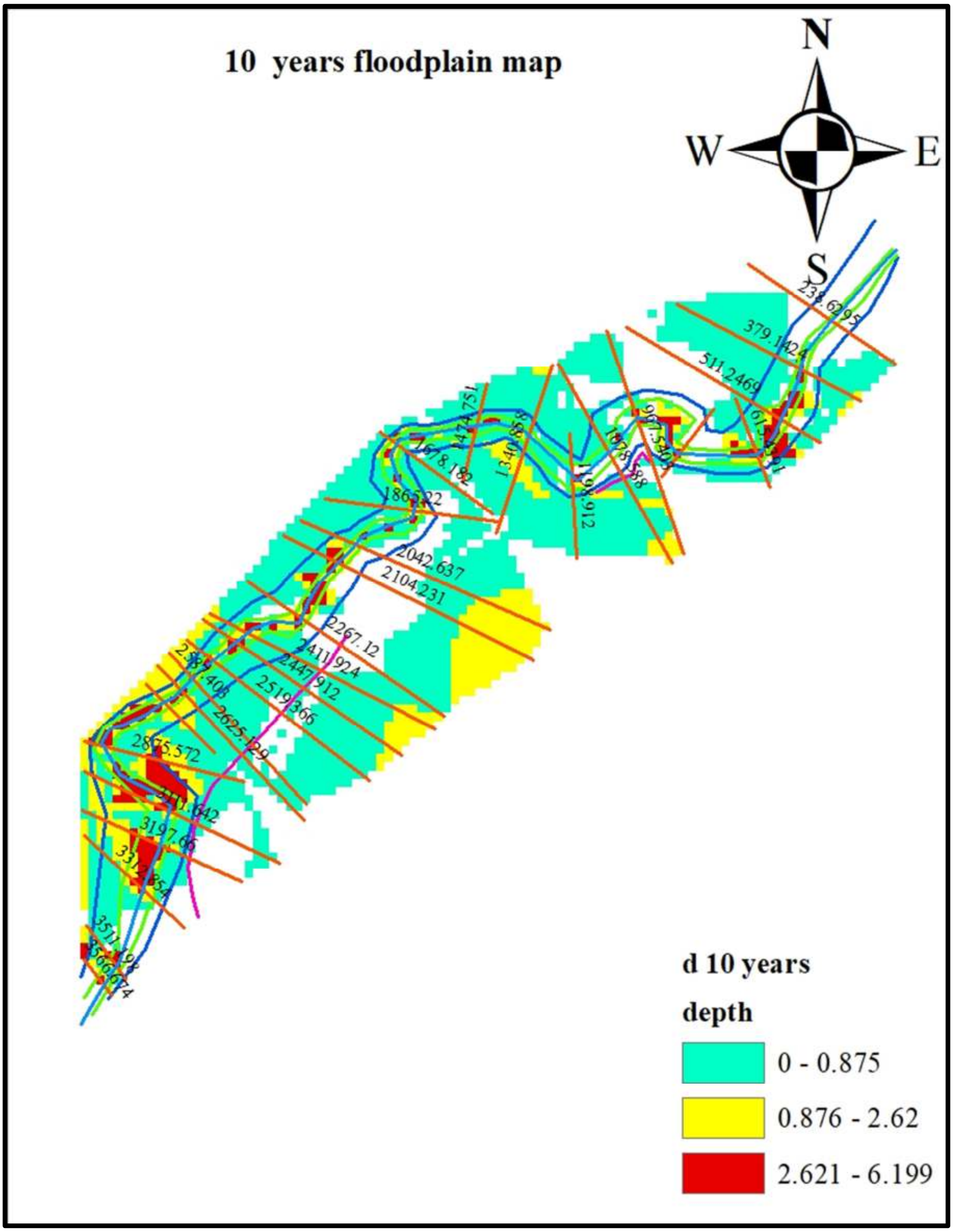
		Element	Left OB	Channel	Right OB
E.G. Elev (m)	1584.80	Wt. n-Val.	0.035	0.045	0.050
Vel Head (m)	0.03	Reach Len. (m)	73.43	108.69	52.64
W.S. Elev (m)	1584.77	Flow Area (m2)	41.10	241.44	38.71
Crit W.S. (m)		Area (m2)	41.10	241.44	38.71
E.G. Slope (m/m)	0.000238	Flow (m3/s)	28.69	181.13	18.01
Q Total (m3/s)	227.83	Top Width (m)	17.38	74.05	17.26
Top Width (m)	108.69	Avg. Vel. (m/s)	0.70	0.75	0.47
Vel Total (m/s)	0.71	Hydr. Depth (m)	2.36	3.26	2.24
Max Chl Dpth (m)	4.02	Conv. (m3/s)	1858.1	11730.4	1166.5
Conv. Total (m3/s)	14755.0	Wetted Per. (m)	20.65	74.68	20.93
Length Wtd. (m)	102.21	Shear (N/m2)	4.65	7.56	4.32
Min Ch El (m)	1580.75	Stream Power (N/m s)	3.25	5.67	2.01
Alpha	1.05	Cum Volume (1000 m3)	236.35	1510.42	450.95
Frctn Loss (m)	0.04	Cum SA (1000 m2)	364.62	616.66	624.11
C & E Loss (m)	0.00				



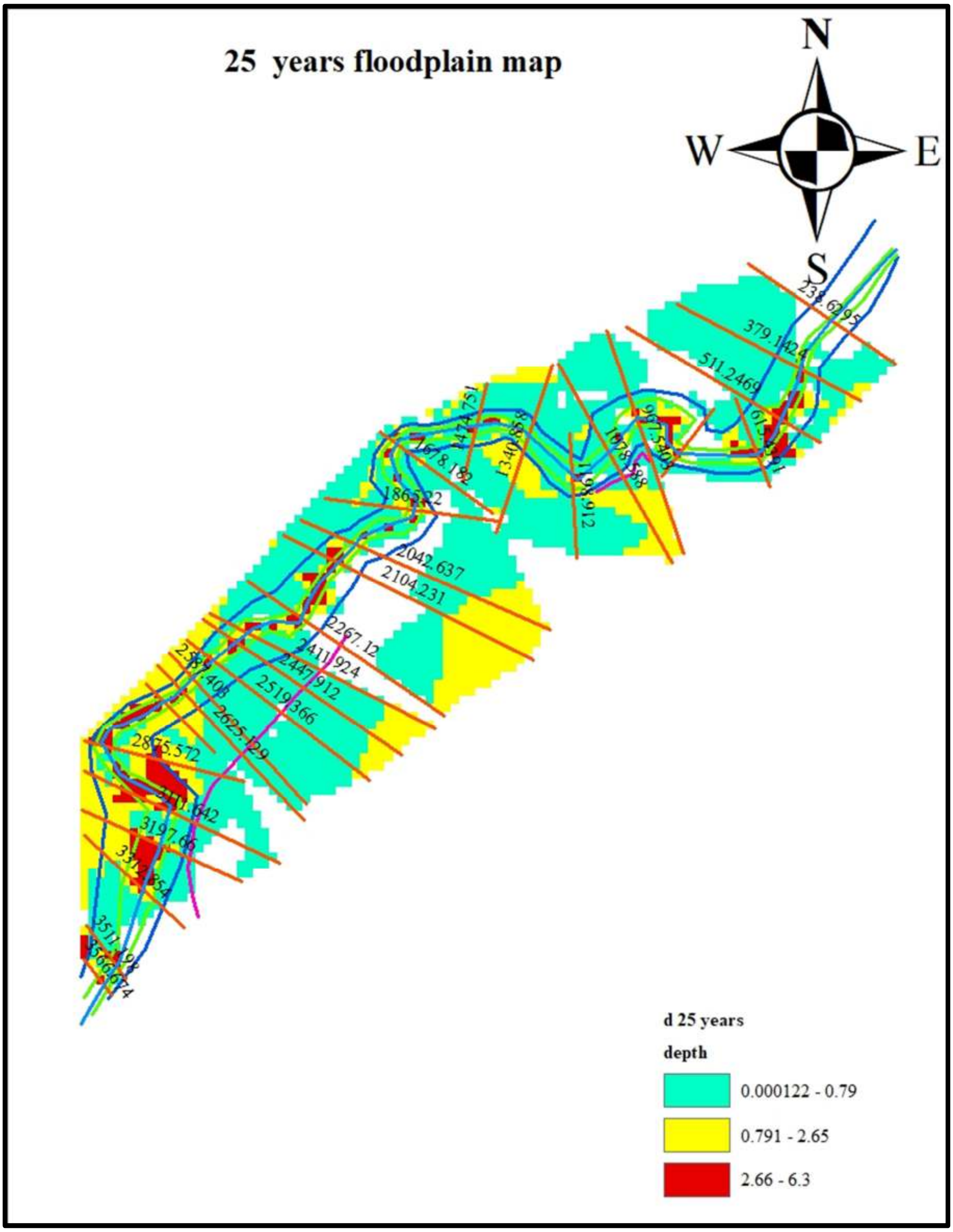
Appendix- I 25 years WS direction plot



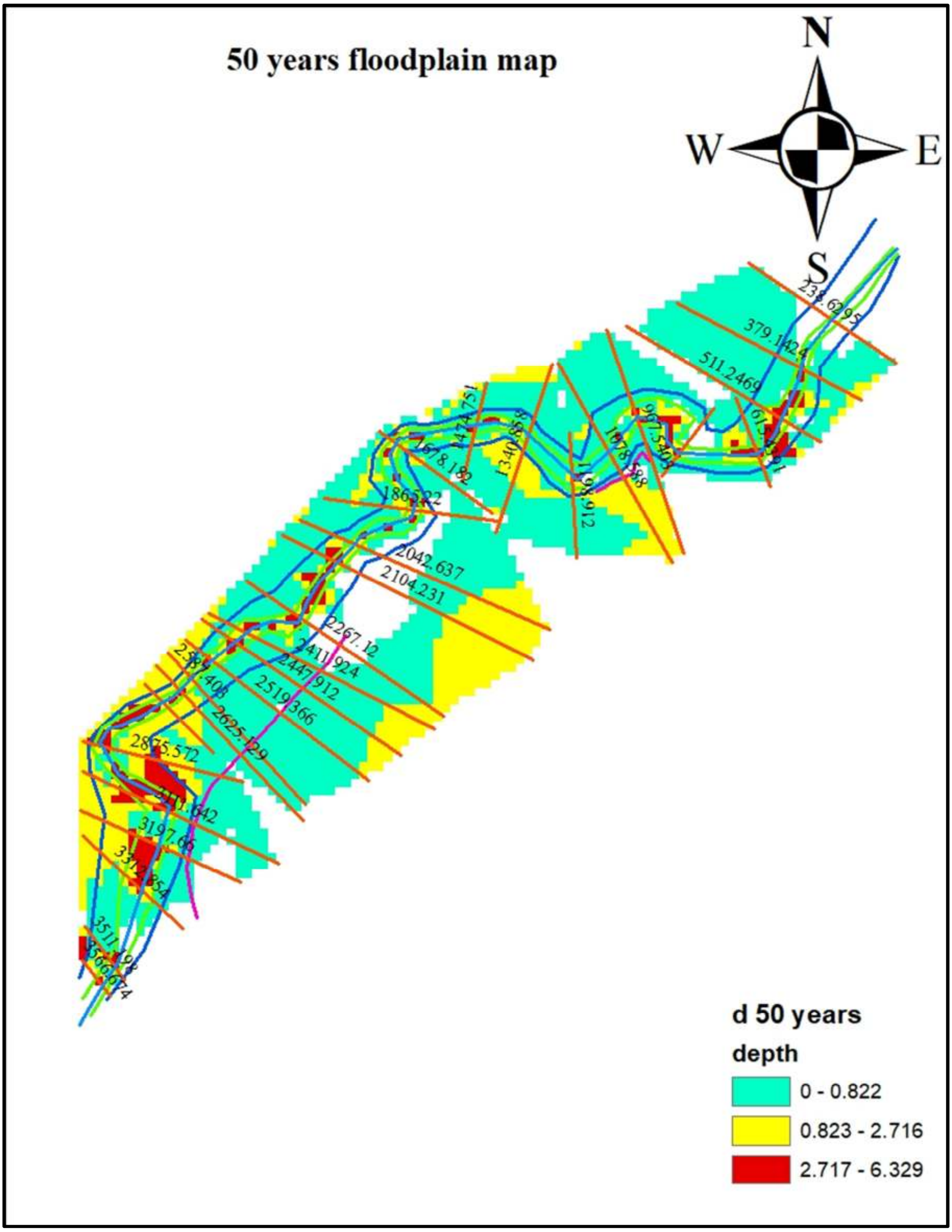
APPENDEX-II 50 years WS direction plot



Appendix-III 10 year’s floodplain map



Appendix-V 25 year's floodplain map



Appendix-VI 50 years floodplain map