FLOOD PLAIN MAPPING OF NONOI RIVER THROUGH 2D MODELING USING ARC-GIS AND HEC-RAS

A dissertation submitted in partial fulfilment of the requirements

for the award of degree of

MASTER OF TECHNOLOGY
In
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(With Specialization in Water Resource Engineering)

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Submitted by-

HIMANGSHU SAHARIAH

Registration No. 157306220 of 2020-21

ASTU Roll No : 200620030006

Under the Guidance of

DR. BIPUL TALUKDAR
Professor, Department of Civil Engineering

Assam Engineering College

DEPARTMENT OF CIVIL ENGINEERING

ASSAM ENGINEERING COLLEGE, GUWAHATI, ASSAM - 781013

DECLARATION

I hereby declare that the project entitled ***"Flood Plain Mapping of Nonoi River through 2D modeling using ARC-GIS and HEC-RAS"*** submitted to the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati- 781013 under Assam Science & Technology University is a record of an original work done by me under the guidance of Dr. Bipul Talukdar, Professor, Department of Civil Engineering, Assam Engineering College, Guwahati. This project work is submitted in the partial fulfillment of the requirements for the award of the degree of Masters in Technology in Civil Engineering (With specialization in Water Resource Engineering).

I further declare that none of the work included in this project has been plagiarized or submitted in whole or in part for consideration for any other degree from this or any other university.

Date :

Himangshu Sahariah
Roll No. : 200620030006
Reg. No. 157306220 of 2020-21

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CERTIFICATE FROM THE SUPERVISOR

This is certified that work contained in the report *"Flood Plain Mapping of Nonoi River through 2D modeling using ARC-GIS and HEC-RAS"* has been carried out by **Himangshu Sahariah** (Roll No : 200620030006) a student of 4th Semester, M. Tech in the Department of Civil Engineering, Assam Engineering College, Guwahati in partial fulfilment of the requirements for the award of the Masters of Technology in Civil Engineering with specialization in Water Resources Engineering under Assam Science and Technology University under my guidance and supervision.

Date :

Dr. Bipul Talukdar
Professor
Department of Civil Engineering
Assam Engineering College
Guwahati-781013

CERTIFICATE FROM HEAD OF DEPARTMENT

This is to certify that **Himangshu Sahariah**, bearing Roll No. 200620030006, a student of 4th Semester, M. Tech, Water Resource Engineering (Civil Engineering Department) has submitted his project report on *"Flood Plain Mapping of Nonoi River through 2D modeling using ARC-GIS and HEC-RAS"* in partial fulfilment of the requirements for the award of the Masters of Technology in Water Resources Engineering under Assam Science and Technology University.

Date:

Dr. Jayanta Pathak
Professor & Head
Department of Civil Engineering
Assam Engineering College
Jalukbari, Guwahati-13

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Date :

Himangshu Sahariah

Roll No. : 200620030006

Department of Civil Engineering

Assam Engineering College

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CHAPTER 1
INTRODUCTION

1.1 Flood

When a region is completely or partially covered in water for several days, it can cause floods, which can result in dangerous infections, property loss, and fatalities. Floods can pose a threat to cities, hospitals, factories, and other structures. In areas that are prone to flooding, floods typically happen during the rainy season, and the water level in these areas can change. Of course, prolonged periods of heavy rain might result in flooding as water reserves fill up and overflow into the area. During the monsoon, flooding can occur in some areas of India, resulting in significant damage to natural habitats and human life. However, in certain areas, floods brought on by man-made disasters can occur and result in property destruction as well as fatalities. One of the main causes of man-made disasters can be breaking of river embankments. Crop damage occurs when floodwater builds up in agricultural fields as a result of these floods. More deaths and famine may result from it. As a result of the loss, several farmers have begun taking their own lives. Both the nation's economy and human lives are at risk from flooding. Consequently, it is imperative to take the required actions to lessen the effects of flooding.

1.2 Flood problem in Assam :

Assam is located in the North-Eastern region of India. It share it’s border with seven Indian states and two foreign countries i.e. Bangladesh and Bhutan. The total geographical area of our state is about 78.468 Sq KM which is about 2.39% of total geographical area of our country. Out of this 56,194 Sq km and 22,244 sq km falls under Brahmaputra valley and Barak valley including three hill districts respectively. Assam provides shelter to a people of about 2.58% of country’s total population as per the census of 2011.

The Brahmaputra valley is 80 km wide on average. One of the biggest rivers in the world, the Brahmaputra, flows through the state of Assam. It is the third largest river in the world in terms of discharge. The river originates in the Kailash range of Himalayas at an elevation of about 5300 m. About 2,40,000 square kilometers of the 5,80,000 square kilometers that make up the Brahmaputra River's entire watershed are located in Bhutan and India. The total length of this river around 2880 km and in Assam, its length is about 640 km from Sadia to Dhubri. As many as 64 tributaries from the north and 38 from south joins the river.

In the Barak valley, the local rainfall run off of the valley along with the adjacent hilly areas flow through the river Barak and its various tributaries. Different tributaries of Barak river that are originating in the hilly areas are mainly rain fed and causes flood problems when precipitation occurs.

These two major river Brahmaputra and Barak and its major and minor tributaries have crises-crossed the plans of both the valleys. During the monsoon season both the valley faces the problem of floods, bank erosion and drainage congestion. In every year the state faces several waves of flood which causes major damages to both life and property. The losses due to flood runs into hundreds of crores in every year apart from huge damages to roads, bridges, agricultural land and other facilities. These losses due to flood and erosion diminishes the wealth of the state and it shows an adverse effect in the economy of the state of Assam.

Also, Assam falls under the highest rainfall intensity area of the country. The average rainfall of this region is very high and it is around 1750 mm in the plain region and 6400 mm in the hilly areas. High rainfall in the state and it’s the neighbouring hilly states and Bhutan causes severe floods in Assam almost every year. A huge volume of water rushes through the narrow bowl-shaped valley also causes severe flood and erosion in Assam.

As the state is compasses a number of rivers and tributaries and these tributaries originate from the upper catchments and joins the Brahmaputra from a very high gradient , which causes a very dynamic river system in the state of Assam. This extreme monsoon and the unique physiographic setting of the basin are considered the single most important cause of frequent flood and erosion in Assam.

Flood and erosion are the two major natural disasters which are being faced by the people of Assam in every year. The total flood prone area of Assam is about 31,500 sq km as assessed by the Rastriya Barh Ayog which is about 39.58 percent of the total geographical area of Assam. This area is about 9.40 percent of the total flood prone area of India. It has been assessed that about 92.6 percent of the total cultivated land are affected by flood in Assam. In every year around 9,310 sq km area are affected by flood. Almost every year three to four waves of flood ravage the flood prone areas of Assam.

As a part of National flood Policy government has taken different initiative for control of flood in the state. Out of these initiative, construction of embankment in both the bank of major river is considered as a long term measures of flood control. A total length of 4486.44 km of river embankments has been constructed till the financial year 2019-20. But in every year, these earthen river embankments are facing different problems like erosion, breaching etc. Considering the present status of flood and it's vulnerability in Assam, the embankment system in the state is required to be raised and strengthened so that it can provide flood protection to the state for sustainable socio-economic development.

1.3 Flood Inundation :

Flood destruction likelihood is increasing with urbanization and population rate of growth. To cope with flood problems inland engineering physical measures with their support by computer aided measures in form of flood models are necessary to execute in balance. Physical measures including the reservoirs, retarding basin, flood diversion embankments, etc. that can control or divert the large scale flood diversity. Computer aided flood models are being efficiently used most efficient to evaluate the flood damage to property and people. The model show the extent, depth of flooding to depict the area liable to flooding events of different return periods.

Flood forecast information in a graphical format i.e flood inundation map helps emergency managers and disaster relief officials, to better prepare for potential flood conditions. So it is important to provide easy to read graphical information related to flood hazard to the public, city planners and emergency managers. Flood inundation mapping is the process of defining the area covered by water, a map during a flood event. It can be done by integrating Geographic information system with hydrologic and hydraulic models. Decision-makers can decide how best to deploy resources to prepare for catastrophes and to generally improve the quality of life by having a thorough grasp of the level of flooding and swamping caused by floodwaters.

1.4. Objective of the Study :

1. Development of a Two-Dimensional Hydraulic Model of the Floodplain of the Nonoi River.
2. Assessment of Flood Vulnerability of the Nonoi River to Extreme Flood Events for Return Periods of 50 and 100 Years.
3. Mapping the probable positions and dimensions of different dtructures as preventive measures to reduce the impact of flood hazards.

1.5 Scope of Work :

The scope of this study encompasses a detailed analysis of flood risks within the Nonoi River basin in Darrang District, Assam. The focus lies on conducting comprehensive flood hydraulic modeling and floodplain mapping to assess the region's susceptibility to flooding events, which are predominantly triggered by heavy monsoon rains and flash floods from Bhutan and Arunachal Pradesh. By leveraging advanced tools such as Google Earth Pro, ArcGIS, and HEC-RAS, the study aims to develop accurate 2D models that simulate flood scenarios for 50- and 100-year return periods. These models will visualize potential impacts on infrastructure, residential areas, and agriculture, aiding disaster relief workers and emergency managers in enhancing preparedness strategies tailored to the unique hydro-geomorphic characteristics of the Nonoi River basin. The research also addresses the ongoing challenges of erosion, riverbank instability, and sedimentation, crucial factors influencing flood dynamics in the region.

1.6 Methodology :

- **Define Study Area** : Define the study area by outlining its geographical and hydrological features, including watershed boundaries, topography, and land use patterns.
- **Data Collection :** Gather comprehensive data such as long-term river discharge records, basin characteristics and Digital Elevation Models (DEM) for hydraulic modeling.
- **Data Analysis and Calculation:** Analyze data using statistical methods to assess discharge patterns and quantify basin characteristics. Process DEM data to derive slope and flow parameters crucial for accurate hydraulic simulations.

- **HEC-RAS Model Preparation** : Prepare a detailed hydraulic model using HEC-RAS, inputting cross-sections, flow characteristics, and boundary conditions to simulate water levels, velocities, and flood extents.

- **Analysis of Software Output**: Compare flood extents, water levels, inundation depths, and flow velocities with and without embankments to assess their impact on flood dynamics..

- **Interpretation of Results**: Interpret findings to identify flood-prone areas, manage sediment transport, and inform infrastructure design for flood control and environmental sustainability.

1.7 River Nonoi :

The Nonoi River is North Bank Tributary of mighty River Brahmaputra. This river originates from the Bhutan Hill Tangchar at an Elevation of 1220m which is located at southern part of Bhutan Hill. From the point of origin it flows towards the south direction and enters in Assam through boundary stone No 103 in Udalguri district of Assam. In Assam it passes through two Districts namely Udalguri and Darrang and then finally meet–Brahmaputra. The terrain characteristics of this river basin are quite typical. Because of the geography along the river, as the rivers move from the hills to the plains of the Brahmaputra valley, the valley gradients drop off sharply. Because of its hydro-geomorphic characteristics, the Nonoi river basin, a portion of the Brahmaputra valley's riverine built-up plain made of fine alluvial deposits, experiences nearly yearly channel shifting and river bank erosion as a result of sheet floods. In the southern portion of the Darrang district, the hydro-geomorphic characteristics of the river basin have resulted in significant environmental, hydrologic, and geomorphic issues. The running water, altitude and the adjacent sub-tributaries dominate the basin's nature and play a significant role in making an unstable river basin in the region. Due to the heavy downpour during the monsoon (Annual Mean Rainfall 210 cm.) it carries a huge amount of discharge along with sediments. Therefore, the middle part of the basin is highly volatile to bank erosion and channel shifting during the rainy season.With many small tributaries, the length of the Nanoi River is 104.275 kilometers with a basin area of 577.927 sq. km.

As per the report of National Disaster Management Authority (NDMA) , the River Nonoi has an annual average discharge of 10,281 m^3/sec. Almost every year flood from this river ravages the flood prone areas of Darrang District. The destructive floodwater causes significant damage, including loss of life, extensive damage to infrastructure, road closures, crop destruction, and livestock loss in this District.

1.8 Chapter wise Planning :

Chapter 1 : Introduction : An overview of Flood, Flood in Assam and importance of flood inundation including the Nonoi River and its characteristics.

Chapter 2 : Literature Review Preview of different study related to flood inundation and its necessity for flood risk assessment, methodology adopted for hydraulic modeling etc.

Chapter 3 : Study area and Materials : Details about the study area including basin characteristics, Software used for the preparation of model, theory used for calculation of data etc has been mentioned in this chapter.

Chapter 4 : Data collection and Methodology : Calculation of peak discharge for 50 and 100 years return period using different approach, steps followed in the softwatre for development of the model.

Chapter 5 : Results and discussion : Results obtained from the study which includes flood plain extent, water surface elevation, depth of flow etc.

Chapter 6 : Conclusion : Overall outcome of the study and future scope of study related to this topic.

Chapter 2

LITERATURE REVIEW

In this chapter, an attempt has been made to review some earlier important studies related to Mapping of Flood Plain using different methodology and their results to know the vulnerability of flood.

Sunilkumar P et al. (2017) has conducted a a study on River Mangalam using HEC-RAS and ArcGis for flood Modeling. The study was on River Mangalam on a reach length of 30 km. The river basin is basically spread over Palakkad district of Kerala. The various methodologies of the study include estimation of peak flood discharge, flood analysis using HEC RAS, and the flood inundation mapping using GIS. HEC-RAS and its extension HEC-GeoRAS was used to prepare the flood inundation map of the Mangalam River. HEC-GeoRAS uses the functions associated with Spatial Analyst and 3D Analyst extensions of ArcGIS. The only dataset required in this mapping is the terrain data in TIN o DEM format. HEC-RAS may receive GIS data that has been pre-processed using the tools included in the RAS Geometry menu. To create a flood inundation map, post-processing functions for HEC-RAS findings are available under the RAS Mapping menu.
In the study, the flood inundation map was prepared in ArcGIS by modeling the unsteady flow analysis in HEC-RAS and then exporting the result back in GIS using the extension HEC-GeoRAS. Combining the aforementioned findings can help with flood prevention strategies, particularly as flash floods are a common occurrence in the studied area.
From the study the probable maximum flood occurring in the area was calculated. This value helps in the designing work of a civil structure in the study area,The flood hydrograph was developed, which was further utilized in the flood plain mapping in HEC-RAS. By doing this analysis it was possible to get an idea about how much flood can occur in the study area. Floodplain was also obtained by performing the unsteady flow analysis in the HEC-RAS software using a GIS platform. Flooding was found maximum both at the upstream reach and the lower reach of the Mangalam river compared to the midland region. This is in concurrence with the flood inundation map prepared in the GIS.

A case study was conducted by **Devashish Pradhan et al. (2022)** in the Burhi Gandak River Basin in Bihar, India, in order to provide flood inundation mapping using ArcGIS and the Hydraulic Model (HEC-RAS). The study's main objectives were to locate places where hydrological hazards exist and to develop emergency management strategies. Finding flood-prone areas close to the river is made simple by the flood map.

. For the study of the flood inundation discharge data of 50 years had been analyzed and map was prepared using discharge data for a return period of 5, 10, 20, 50, 100 & 150 years.

The main objective of the study was to prepare HEC-RAS model to find two flow variables i.e. water depth and flow velocity of the above River. Flood inundation map prepared from the study show that the depths of the 5, 10, 20, 50, 100, and 150-year return periods are 12.78 m, 13.11 m, 13.37 m, 13.67 m, 13.89 m, and 14.01 m, respectively. The result of the study reveals that the depth of flow increases with increase in the return period, and the damage is severe even with a short return period. It is also observed that the variation in depth of flow decreases as the return period increases. It was concluded in the study that by knowing the water accommodation capacity of the river and river plain, relation between precipitation and river discharge can be established and from there, a flood frequency and flood inundation map can be prepared. It will help to minimize the affect of flood and save the the life and properties. Hydrologic and hydrologic model structures in the river can be used to improve flood inundation maps by using DEM data with high-resolution and accurately measured cross-sections. By implementing best design practices and raising the height of the embankment could helps in solve the problem of erosion and flood.

Usman Khalil et al. (2017) has done Flood plain mapping for Indus River reach ChashmaTaunsa of length 252 km. Floodplain mapping and flood hydraulic modeling were done in their study to provide a preliminary assessment of flood susceptibility and a plan of action for emergency preparedness. Different tools like HEC-RAS, Arc-GIS and it's extension HEC-GeoRAS were used to obtain the hydraulic modelling and floodplain mapping. HEC-RAS model input cross-sections data were collected from physical survey and extracted from DEM SRTM 90 m by using Hec-GeoRas. Comparison was made between surveyed and SRTM DEM extracted cross-sections; to perform necessary verification and merging the channel data in DEM extracted cross-section. It is observed that by using the DEM data of fine resolution more accurate results can be acquired. The Flood peaks for the extreme flood events were calculated by using Gumbel's and Log Pearson Type III distributions of frequency analysis. The result shows that the flood of 2010 in study area has return period of 180 years and 300 years at Chashma and Taunsa respectively. Cross-sections data and results of frequency analysis were used in HEC-RAS to perform unsteady flow analysis for low to extreme events. The flood plain maps generated from the study shows the extent and depth represents those areas under flood which could be act as an important tool for Engineers, Planners for emergency actions plans and for flood management.

Anjusha K.K. (2021) has done a study on Flood Inundation Modeling of Godavari Reach, Nanded District using Arc Gis and HEC RAS. The study area is Reach of Godavari River in Nanded District, Maharastra which is often flooded when there is a heavy rainfall. In order to facilitate one- and two-dimensional modeling as well as floodplain mapping in Arc GIS, the study offers a simple method for processing the output of the Arc GIS and HEC RAS hydraulic model. The Flow data of 35 Years, Cross Section details and Manning's Coefficient has been used as an input the HEC-RAS and from there unsteady flow stimulation has been done. The output from the simulation is water surface elevation. Twodimensional modelling is also done using HEC RAS. Flood forecasting has been done for a return period of 2,5,10,25,50,100 years using Gumbel's Distribution method. This data has been used for Steady flow analysis and flood inundation mapping has been done for every return period.

The result of the study shows that each cross section has a cross section with water surface elevation, as well as an energy head line (Energy Gradient, Maximum Water Surface) and a critical maximum water surface. For the Water surface elevation profiles, he program will see the water surface rise, energy grade line height, and basic profundity rise in profile plots (otherwise called long parts or longitudinal profiles) of the HEC-RAS consistent stream and flimsy stream computational information.

S. Olaniyan et al. (2017) carried out a study on Inundation and Hazard Mapping of Asa River of Nigeria using Geographic Information System (GIS). This research was aimed at producing an inundation and hazard map using a Geographical Information System across River Asa. Rainfall data of 30 years obtained from Kwara State meteorological station was used to derived hydraulic discharge of the river using Institute of hydrology method of model. Flood frequency distribution was modeled using the log Pearson Type III model. Using GIS, contour values were interpolated from the catchment's contour lines to create a digital elevation model (DEM). The combination of rainfall, land use variation, DEM, and slope—the main elements causing flooding in an area—was analyzed to create the floodplain map. Log Pearson Type III model gave a discharge ranges from (6306 – 10,458) m^3 /s for return period between 2 to 50 years. The flood risk map showed that 56% of existing structure will be at risk at discharge value of 50 years return period. Using data from remote sensing, the study created an inundation and hazard map of River Asa.

Chapter 3

STUDY AREA AND MATERIALS

3.1 Study Area :

The area of interest for the present study is Nonoi River Basin that falls under the area of Darrang district. The Nonoi River is North Bank Tributary of mighty River Brahmaputra. This river originates from the Bhutan Hill Tangchar at an Elevation of 1220m which is located at southern part of Bhutan Hill. From the point of origin it flows towards the south direction and enters in Assam through boundary stone No 103 in Udalguri district of Assam. With many small tributaries, the length of the Nanoi River is about 104.275 kilometers with a basin area of 577.927 sq. km.

For the present study, a reach length of about 25 Km has been selected. The reach of Nonoi river Bridge in Hapamara upto Bridge over NH-15 has been selected for this work. This reach is in between 26°31'24.12"N lattitude and 91°51'56.24"E Longitude upto 26°21'4.91"N lattitude and 91°51'22.03"E Longitude. The last 34 Km of this river upto Brahmaputra is active flood plain with channel gradient of 1.763 m/km. The basin area receives an annual mean rainfall of 210 cm. The major stream i.e. is the Nonoi is fed by numbers of sub tributaries which supply water to the basin mainly during summer season.

Every year area near the Nonoi river faces problems of floods and damages during monsoon season.This is due to the heavy rainfall and flash flood that comes from the Hills of Bhutan and Arunachal Pradesh. To facilitate the appropriate measures for effective flood mitigation, there is a need to model the flood plain. Flood plain modelling using HEC RAS is an effective tool for hydraulic study.

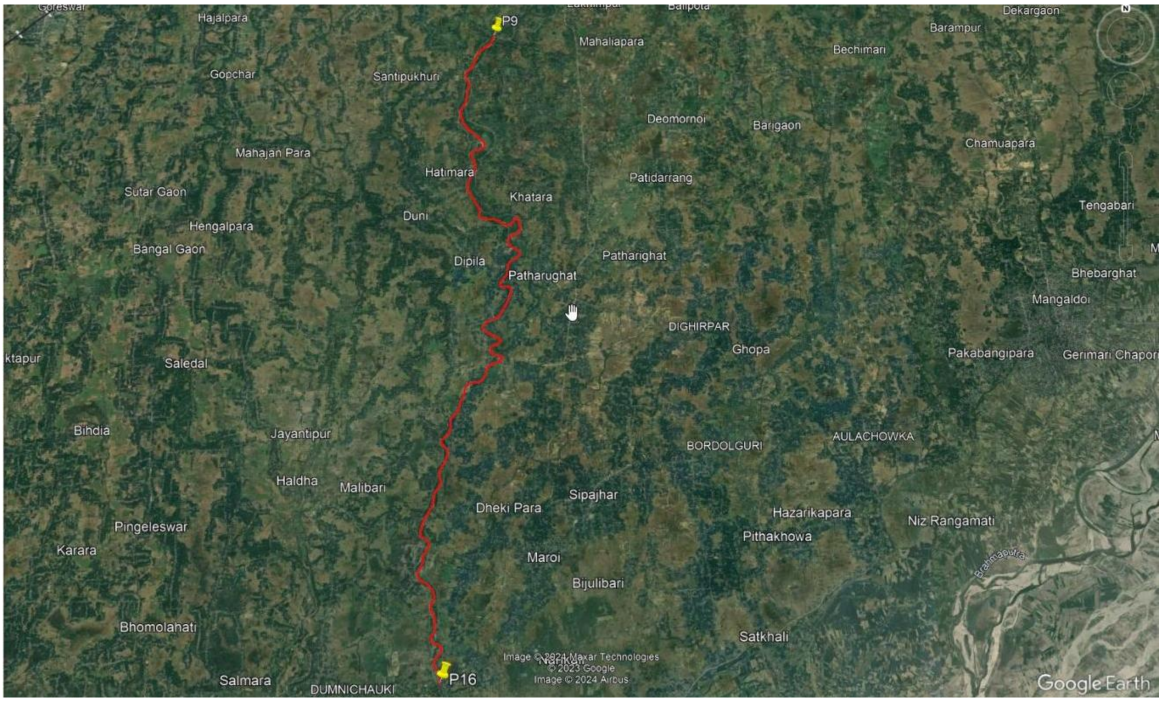


Figure 3.1 : Study Area on Google Earth

3.2 Materials/Software Used

3.2.1 Google Earth Pro : To show the study area of this work Google Earth Pro has been used. The centre line of the river has been drawn by using Google Earth Pro. This line is again used in ArcGIS to converted it as polyline. The free program Google Earth Pro facilitates the creation, overlaying, evaluating, and visualizing of geographic data. For learners who want to start with more fundamental procedures and techniques and are interested in learning more about GIS, this approachable resource is frequently a helpful intermediate. Moreover, Google Earth Pro may be used to locate locations, upload or download geospatial data in its native interoperable file format (KML), and examine its incredibly high-resolution satellite imagery.

3.2.2 HEC HMS : HEC-HMS stands for Hydrologic Engineering Center - Hydrologic Modeling System which enables simulate the complete hydrologic processes of dendritic watershed systems. Numerous conventional hydrologic analysis techniques, like event infiltration, unit hydrographs, and hydrologic routing, are included in the software. Along with these essential processes for continuous modeling, HEC-HMS also includes soil moisture accounting, snowmelt, and evapotranspiration. Furthermore, gridded runoff modeling employing the linear quasi-distributed runoff transform is made possible with advanced capabilities.

In this study, HEC-HMS is basically used for calculation of different Geospatial sub basin characteristics. To compute subbasin characteristics, the basin model must have georeferenced subbasins and the GIS Preprocess Drainage step must be computed. These characteristics is again used for development of Synthetic Unit Hydrographs by Snyder's Method. The Geospatial sub basin characteristics includes Longest Flow Path Length (L), Centroidal Flow Path Length (L_c), Basin Slope, Basin Relief etc. Out of which Longest flow Path Length (L) Centroidal Flow Path Length (L_c) will be required for calculation of different parameters necessary for development of Synthetic Unit Hydrograph.

3.2.3 ArcGIS : An application for displaying geographic data is ArcGIS, a Geographic Information System (GIS). Organizations can be empowered to make more effective data-driven decisions by using ArcGIS, which links maps, apps, data, and people. The way ArcGIS does this is by facilitating map discovery, usage, creation, and sharing for all members of an organization—from any device, anywhere, at any time. In the present study, ArcGIS has been used for development of Land Use Land Cover Map of the study area. This Land use Land cover map is then used for processing the data in HEC-RAS. Land use map processed using ArcGIS to identify the land roughness and derive the flow behaviour.

3.2.4 USGS Earth Explorer : The USGS Earth Explorer (EE) provides users the ability to query, search, and order satellite images, aerial photographs, and cartographic products from several sources. The current study has downloaded the DEM for the study area in Raster format with a resolution of 30m from the website (*https://earthexplorer.usgs.gov*). The downloaded DEM needs to be projected to convert its coordinates from the geological coordinates to Universal Transverse Mercator (UTM) coordinates under the classification of the World Geodetic System (WGS) of the year 1984. The accuracy of the DEMs provided by USGS ranges from (1-90) m, and may sometimes reach even less than 1m, depending on the type of study and the data that need to be provided. The downloaded DEM data in .tiff format then used in HEC RAS for the terrain data.

3.2.5 HEC RAS : The Hydrologic Engineering Center- River Analysis System is a software that is developed by US Army Corps of Engineers. This software enables the user to perform (1) one dimensional steady flow hydraulics (2) one-dimensional or two-dimensional unsteady flow hydraulics (3) Quasi unsteady or fully unsteady flow movable boundary sediment transport computations (1D and 2D) and (4) one dimensional water quality analysis.

3.3 Synthetic Unit Hydrograph :

For development of Unit Hydrograph of a specific catchment, different information such as rainfall data of the catchment and the resulting hydrogpah is required. However, these data is not easily available specially when the catchment area is located in some remote areas. In order to formation of unit hydrograph of such areas, various empirical equations may be used. But, these equations only applicable for a specific region only. The unit hydrograph developed by using these equation is known as *Synthetic Unit Hydrograph* (SUH). There are various methods available like CWC dimensionless approach, Snyder's method, Two parameter Gamma distribution method and Hybrid model. For this study, the traditional method that is Snyder's method has been used.

3.3.1 Snyder's Method :

Snyder developed a set of empirical equations for the formation of Synthetic Unit Hydrograph which are based on study of large number of catchments of United States of America (USA). The most important features of a basin affecting a hydrograph due to storm is basin lag. The basin is basically the time difference between centroid of the input i.e. rainfall excess and output i.e. direct runoff hydrograph. This value is determined based on the features of the topography such as size, shape, stream density, length of the main stream, slope, land use and land cover.

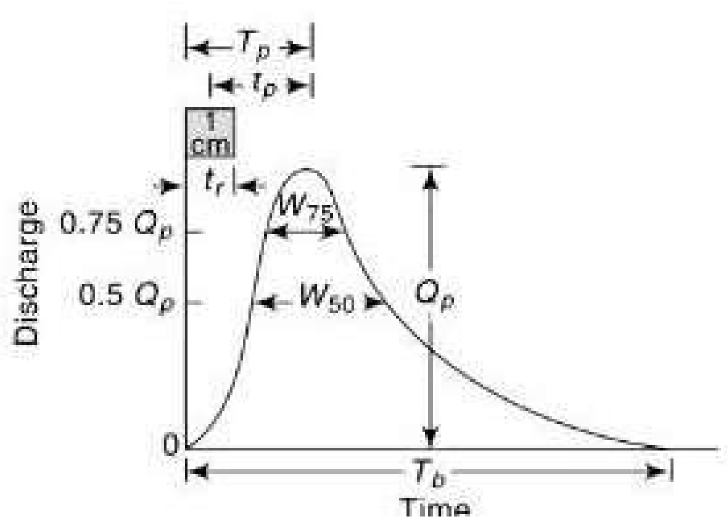


Figure 3.2 : Elements of a Synthetic Unit Hydrograph (SUH)

3.3.2 North Brahmaputra Subzone -2 (a) report by Central water Commission (CWC) :

This report by CWC deals with the estimation of design flood for various return period such as 25, 50, 100 years for small and medium catchment areas of this Sub zone. This sub zone includes the areas mainly of part of Assam and small portion of Sikkim, Arunachal Pradesh and West Bengal. This report is based on the detailed rainfall and runoff studies of 21 representative catchments. The report is recommended for estimation of design flood fpr catchment of small and medium catchments of size 25 to 2500 sq km of area. This report enables the calculation of design flood for the ungauged and inadequately gauged catchments areas of the sub zone.

Detailed Synthetic Unit Hydrograph Approach :

Determination of the Physiographic parameters : From the catchment area of the study area the following parameters are determined.

Area of the catchment in Sq Km. = A

Length of the Longest Stream in Km = L

Length of the Longest Stream from a opposite C.G. of Catchment to the Point of study in km = L_c

Equivalent stream slope in m/Km = S

This data has been calculated from the catchment area of the study region using HEC-HMS Software.

The following equations are used to as per North Brahmaputra Subzone report by Central water Commission (CWC) for formation of the Synthetic Unit Hydrograph (1 Hour) with known values of A, L, L_C & S.

1. $q_p = 2.272\left(\frac{L \times Lc}{S}\right)^{-0.409}$

2. $t_p = 2.164(q_p)^{-(940)}$

3. $W_{50} = 2.084(q_p)^{-1.065}$

4. $W_{75} = 1.028(q_p)^{-1.071}$

5. $W_{R50} = 0.856(q_p)^{-0.865}$

6. $W_{R75} = 0.440(q_p)^{-0.918}$

7. $T_B = 5.428(q_p)^{0.852}$

8. $t_m = t_p + \frac{t_r}{2}$

9. $Q_p = q_p \times A$

Where,

q_p= Peak discharge of unit hydrograph per unit area in m^3/s per sq. km

t_p= Time from the centre of unit rainfall duration to the centre of unit hydrograph (hrs).

W_{50}= Width of the U.G measured at 50% peak discharge ordinate (Q_p) in hrs.

W_{75}= Width of the U.G measured at 75% peak discharge ordinate (Q_p) in hrs.

W_{R50} = Width of the rising side of U.G measured at 50% of peak discharge ordinate (Q_p) in hrs.

W_{R75} = Width of the rising side of U.G measured at 75% of peak discharge ordinate (Q_p) in hrs.

T_B = Base width of unit hydrograph in hrs.

T_m = Time from the start of rise to the peak of unit hydrograph in hrs.

Q_p = Peak discharge of unit hydrograph in m^3/sec.

From the estimated parameter a few points of the unit hydrographs will be available. Plotting those points in the graph paper and joining them through a smooth curve will provide the Synthetic Unit Hydrograph (SUH). The discharge ordinates available from this SUH for rainfall excess of t_r duration when multiplied it with time duration, it will provide the volume of water in the catchment. For the calculation of the volume another standard method is to multiply the area with the depth of flow. From the available area and the calculated volume the depth of flow of 1cm will be calculated.

Estimation Of Design Storm Duration :

The design storm duration is the duration of the storm rainfall which cause the maximum discharge in a drainage basin. As per the section 3.1.0 of North Brahmaputra Subzone -2 (a) report, the design storm duration (T_D) is taken equal to the base width of unit hydrograph (T_B). The design storm duration T_D which is equal to T_B is rounded off to nearest full hour for any specific site study.

Estimation Of Point Rainfall and Areal Rainfall :

Point rainfall is the rainfall at any given time interval or during the storm measured in the gauge station. The 24 hr point rainfall maps for all the station in and around the subzone were plotted on a base map as per the report and isopluvial maps of 50 years and 100 years return period were drawn. From these maps, the 24 hours point rainfall value of 50 years and 100 years corresponding to the study area has to be determined.

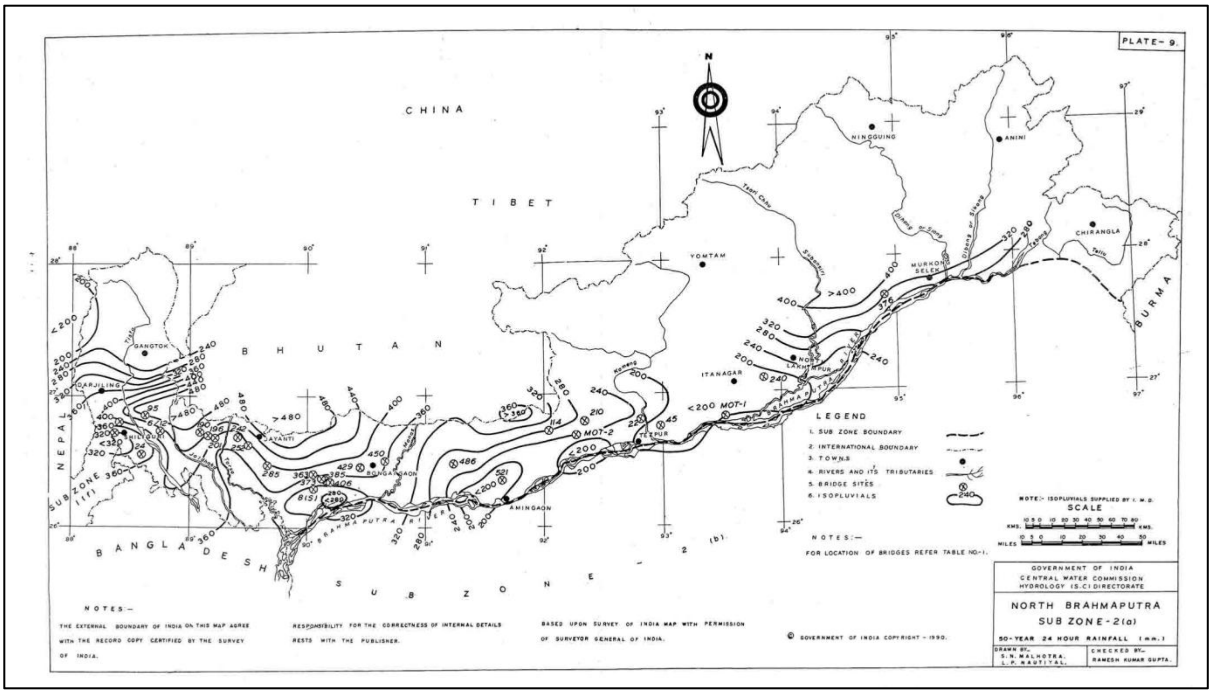


Figure 3.3 : Map Showing 50 Year 24 Hour Rainfall Data

(Source : North Brahmaputra Subzone -2 (a) report by CWC)

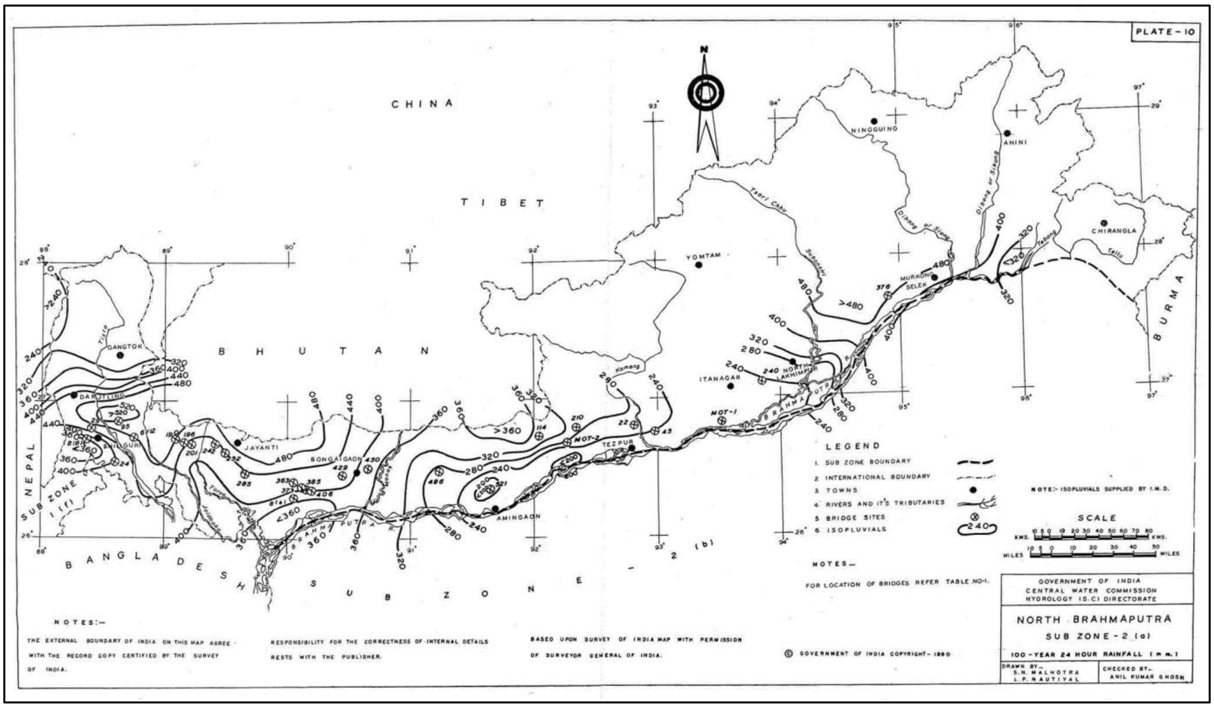


Figure 3.4 :Map Showing 100 Year - 24 Hour Rainfall Data

(Source : North Brahmaputra Subzone -2 (a) report by CWC)

Conversion of point rainfall to areal rainfall :

Rainfall gauges provides point measurement of rainfall amount. But in hydrological applications spatial variation or average depth of rainfall over the given area is needed. This point rainfall data has to be converted to areal rainfall. For this, Sub Zone report provides a series of values as areal reduction factor based on the area of the catchment as given below.

Table - 6

POINT TO AREAL RAINFALL RATIO'S (PERCENTAGE)

Area in sq. km.	1-hr	3-hr	6-hr	12-hr	24-hr
50	83	88	92	97	98
100	74	81	88	94	96
150	67	75	84	91	94
200	63	71	81	89	93
250	60	68	78	87	91
300		65	76	86	89
350		64	74	84	88
400			73	83	87
450			72	82	86
500			71	81	85
600				79	84
700				78	82
800				77	81
900				77	80
1000				76	80
1500					79
2000					78
2500					77

Figure 3.5 : Table for conversion of point rainfall to Areal rainfall

Time Distribution of Areal Rainfall :

The areal rainfall rainfall obtained for the particular study area has to be distributed with different distribution coefficient as provided in the Sub Zone Report corresponding to 24 hours to get the 1-Hour rainfall increments. The distribution coefficient required for this are provided in the report as given below.

TABLE - T - 2

TIME DISTRIBUTION CO-EFFECIENTS OF AREAL RAINFALL
SUB-ZONE 2(a)

TIME	DISTRIBUTION CO-EFFECIENTS FOR DESIGN STORM DURATION OF 2 -24 HOURS																						TIME
HOURS	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	HOURS
24																							1.00	24
23																						1.00	0.98	23
22																					1.00	0.98	0.97	22
21																				1.00	0.98	0.97	0.95	21
20																			1.00	0.98	0.96	0.95	0.93	20
19																		1.00	0.98	0.96	0.95	0.93	0.92	19
18																	1.00	0.98	0.96	0.95	0.93	0.91	0.90	18
17																1.00	0.98	0.96	0.94	0.93	0.90	0.89	0.88	17
16															1.00	0.98	0.96	0.93	0.92	0.90	0.89	0.88	0.86	16
15														1.00	0.98	0.96	0.93	0.92	0.90	0.88	0.87	0.85	0.84	15
14													1.00	0.97	0.95	0.93	0.91	0.89	0.88	0.86	0.84	0.83	0.81	14
13												1.00	0.97	0.95	0.92	0.91	0.89	0.87	0.85	0.83	0.81	0.80	0.79	13
12											1.00	0.97	0.94	0.92	0.90	0.88	0.86	0.84	0.82	0.80	0.78	0.77	0.76	12
11										1.00	0.97	0.94	0.92	0.89	0.87	0.85	0.83	0.81	0.79	0.77	0.76	0.74	0.73	11
10									1.00	0.96	0.94	0.91	0.88	0.86	0.83	0.82	0.80	0.77	0.75	0.74	0.72	0.70	0.69	10
9								1.00	0.97	0.94	0.92	0.87	0.84	0.82	0.80	0.78	0.76	0.73	0.72	0.70	0.68	0.67	0.65	9
8							1.00	0.96	0.93	0.91	0.87	0.83	0.81	0.78	0.76	0.74	0.71	0.70	0.67	0.65	0.64	0.63	0.61	8
7						1.00	0.96	0.93	0.89	0.87	0.83	0.78	0.76	0.74	0.71	0.69	0.67	0.64	0.62	0.60	0.59	0.58	0.56	7
6					1.00	0.95	0.92	0.88	0.84	0.82	0.79	0.73	0.70	0.68	0.65	0.63	0.61	0.59	0.57	0.56	0.54	0.53	0.52	6
5				1.00	0.95	0.90	0.86	0.83	0.79	0.76	0.73	0.67	0.64	0.61	0.58	0.56	0.55	0.53	0.52	0.51	0.49	0.48	0.47	5
4			1.00	0.94	0.89	0.83	0.79	0.75	0.72	0.68	0.66	0.58	0.56	0.53	0.51	0.48	0.47	0.46	0.45	0.44	0.43	0.41	0.40	4
3		1.00	0.93	0.86	0.80	0.74	0.70	0.65	0.63	0.59	0.56	0.49	0.47	0.45	0.44	0.42	0.41	0.40	0.38	0.37	0.36	0.34	0.32	3
2	1.00	0.91	0.80	0.73	0.65	0.62	0.56	0.52	0.49	0.46	0.42	0.38	0.36	0.34	0.32	0.31	0.29	0.28	0.27	0.27	0.26	0.26	0.25	2
1	0.82	0.67	0.56	0.48	0.42	0.38	0.35	0.32	0.30	0.28	0.25	0.23	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.15	0.14	0.13	0.13	1

Note : Hourly rainfall distribution co-effecients are given in the vertical columns for various design storm durations from 2 - 24 hours.

Figure 3.6 : Table for Distribution Coefficient for Time Distribution of Areal Rainfall

Estimation of Effective Rainfall Unit:

Effective Rainfall or Excess Rainfall is that part of Rainfall which becomes direct runoff at the outlet of the catchment. It is the total rainfall for a given duration from which abstraction such a initial losses and infiltration are subtracted. So, Effective rainfall is that rainfall which is neither retained on the surface nor infiltrated into the soil. As per section 2.3.0 the Report of Sub Zone, a design loss of 0.18 cm/hr has been adopted for this study. Thus, the reduction of the loss rate from the hourly rainfall increment provides the effective rainfall for the basin.

Design Base flow :

The base flow is the flow of water that comes from below the surface of the earth due to presence of some water sources. As per the clause 2.4 of the Sub Zone Report an average base flow rate of 0.05 cumec/sq km may be adopted.

Estimation of Peak Discharge :

For the estimation of Peak Discharge if required return period, the effective rainfall units has to be rearranged against the ordinates such that the maximum effective rainfall is placed against the Maximum Unit Hydrograph ordinate, the next lower value of effective rainfall against the next lower value of Unit Hydrograph ordinates and so on upto T_D hour duration. The sequence of effective rainfall then reversed so as to obtain the critical sequence of the effective rainfall.

The SUH then drawn against the reversed effective rainfall and this provides direct surface runoff hydrograph (DSRO) for required return period. The DSRO with addition of base flow rate provides the flood hydrograph.

3.4 Gumbel's Distribution Method:

Gumbel's Distribution is one of the commonly used frequency distribution function for the prediction of Extreme flood values. It is a consistent and exact flow forecasting method. It is a probability distribution functions for extreme values in hydrologic and meteorological studies for prediction of peak flood, maximum rainfall etc. Gumbel defined flood as the largest of the 365 daily flows and the annual series of flood flows constitute a series of largest values of flow.

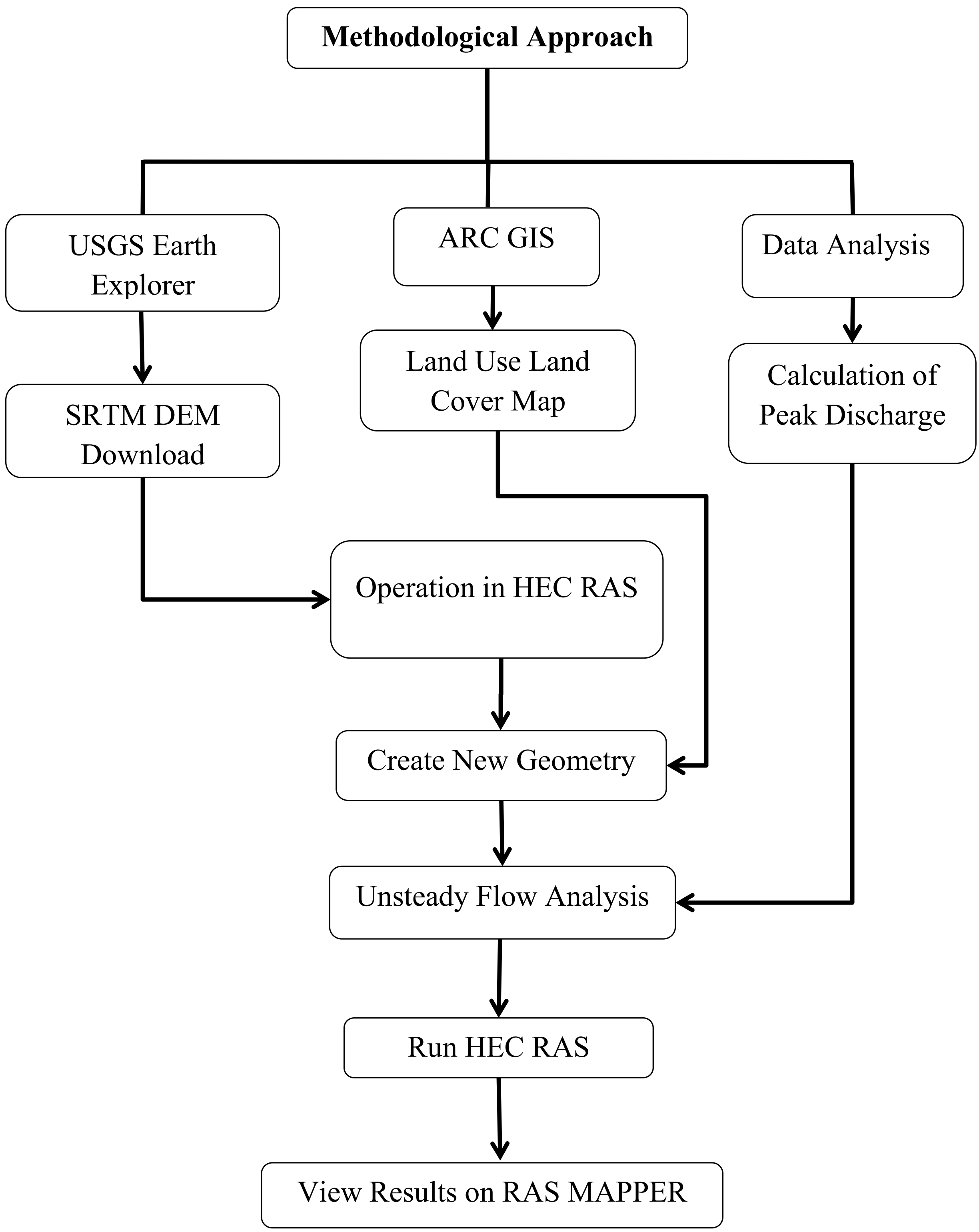
For the estimation of peak flood discharge of a return period of 50 and 100 years rainfall data of last 20 years has been collected and calculated.

From both the Synthetic Unit hydrograph and the Gumbel distribution method the hydrographs that is producing maximum flood peak will be used as input for the Hydraulic Model of the study area.

Chapter 4

DATA COLLECTION AND METHODOLOGY

4.1 Methodological Approach



4.2. Design Flood By Synthetic Unit Hydrograph (SUH) Approach:

4.2.1 Derivation of 1 hour synthetic unit hydrograph parameters:

For the formation of synthetic unit hydrograph, the following physiographic parameters corresponding to the study area has been calculated by using HEC-HMS Software.

Table 4.1 : Physiographic Parameters for Synthetic Unit Hydrograph (SUH)

Available Data		
Parameter	Values	Unit
A	778.0947	Sq. KM
L	100.62	KM
L_c	57.86	KM
S	9.62	M/KM

Where,

A = Area of the catchment in Sq Km.

L = Length of the Longest Stream in Km

L_c = Length of the Longest Stream from a opposite C.G. of Catchment to the Point of study in km

S = Equivalent stream slope in m/Km

The following equations are used as per North Brahmaputra Subzone report (2-a) by Central water Commission (CWC) for formation of the Synthetic Unit Hydrograph (1 Hour) with known values of A, L, L_C & S.

Table 4.2 : Parameters of Synthetic Unit Hydrograph (SUH)

Sl No	Parameter	Formula
1	$q_p =$	$2.272\left(\frac{L \times Lc}{S}\right)^{-0.409}$
2	$t_p =$	$2.164(q_p)^{-(940)}$
3	$W_{50} =$	$2.084(q_p)^{-1.065}$
4	$W_{75} =$	$1.028(q_p)^{-1.071}$

5	W_{R50} =	$0.856(q_p)^{-0.865}$
6	W_{R75} =	$0.440(q_p)^{-0.918}$
7	T_B =	$5.428(q_p)^{0.852}$
8	t_m =	$t_p + \frac{t_r}{2}$
9	Q_p =	q_p x A

Where,

q_p= Peak discharge of unit hydrograph per unit area in m^3/s per sq. km

t_p= Time from the centre of unit rainfall duration to the centre of unit hydrograph (hrs).

W_{50}= Width of the U.G measured at 50% peak discharge ordinate (Q_p) in hrs.

W_{75}= Width of the U.G measured at 75% peak discharge ordinate (Q_p) in hrs.

W_{R50} = Width of the rising side of U.G measured at 50% of peak discharge ordinate (Q_p) in hrs.

W_{R75} = Width of the rising side of U.G measured at 75% of peak discharge ordinate (Q_p) in hrs.

T_B = Base width of unit hydrograph in hrs.

T_m = Time from the start of rise to the peak of unit hydrograph in hrs.

Q_p = Peak discharge of unit hydrograph in m^3/sec.

By using the above Equations, the parameters required for formation of Synthetic Unit Hydrograph has calculated as mentioned below.

Table 4.3 : Derivation of parameters of Synthetic Unit Hydrograph (SUH)

Sl No	Parameter	Formula	Values	Value Considered
1	$q_p =$	$2.272\left(\frac{L \times Lc}{S}\right)^{-0.409}$	0.17	0.17
2	$t_p =$	$2.164(q_p)^{-(940)}$	11.74	11.50
3	$W_{50} =$	$2.084(q_p)^{-1.065}$	14.16	14.16
4	$W_{75} =$	$1.028(q_p)^{-1.071}$	7.06	7.06
5	$W_{R50} =$	$0.856(q_p)^{-0.865}$	4.06	4.06
6	$W_{R75} =$	$0.440(q_p)^{-0.918}$	2.29	2.29
7	$T_B =$	$5.428(q_p)^{0.852}$	44.27	44.00
8	$t_m =$	$t_p + \frac{t_r}{2}$	12.00	12.00
9	$Q_p =$	q_p x A	128.72	128.72

4.2.2 Ordinates Of 1 Hour Synthetic Unit Hydrograph

Above parameters are drawn to scale on graph paper and joining them through a smooth curve will provide the Synthetic Unit Hydrograph (SUH). The ordinates of Unit Hydrograph so obtained are listed below.

Table 4.4 : Ordinates Of Synthetic Unit Hydrograph

Time (Hr)	Unit Hydrograph ordinates (m^3/s)	Time(Hr)	Unit Hydrograph Ordinates (m^3/s)
0	0	23	60
1	4	24	56
2	8	25	52
3	14	26	48
4	21	27	44

5	29	28	40
6	39	29	37
7	51	30	34
8	65	31	31
9	83	32	28
10	104	33	25
11	124	34	22
12	128.27	35	19
13	127	36	16
14	120	37	13
15	111	38	10
16	103	39	7
17	95	40	5
18	88	41	3
19	82	42	2
20	76	43	1
21	70	44	0
22	65	**Total**	**2160.27**

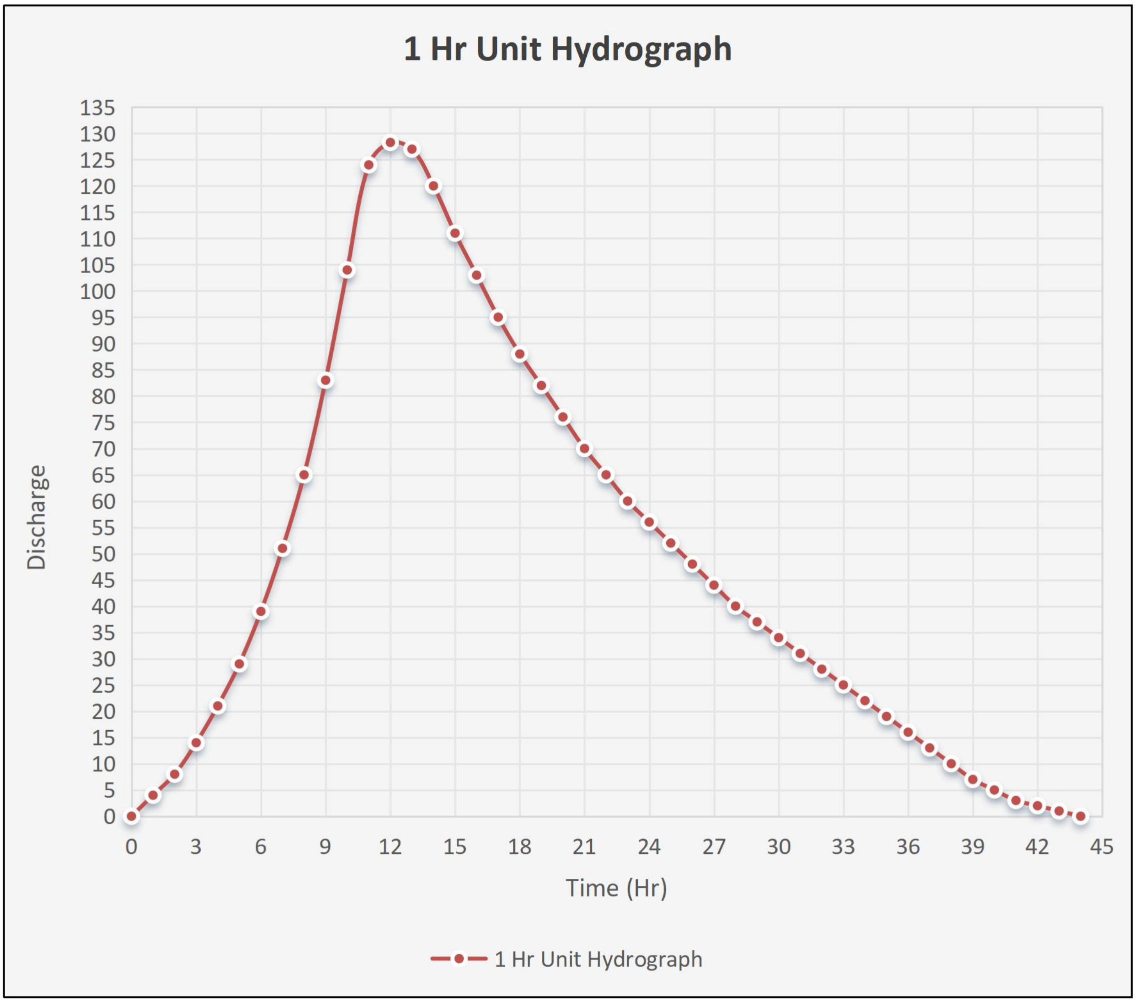


Figure 4.1. : Synthetic Unit Hydrograph

The estimated parameters as per the Report of CWC of Synthetic Unit Hydrograph are plotted to scale. The plotted points are then joined to draw the synthetic unit hydrograph (SUH) and ordinates corresponding to every unit hours are presented in Table No. The Discharge ordinates (Q_i) of the Unit Hydrograph at $t_i = t_r = 1$ Hr interval are added and multiplied by t_r (=1) i.e. $\Sigma Q_i t_i = 2160.27$ m^3/s as shown in Fig.

Now comparing the above value with the volume of 1 cm Direct Runoff Depth over the catchment area with the formula $\frac{A \times d}{0.36 \times tr}$ = 2166.11 m^3/s.

4.3. Calculation of 50 Years Peak Discharge :

4.3.1 Estimation Of Design Storm Duration :

As per the section 3.1.0 of North Brahmaputra Subzone -2 (a) report, the design storm duration (T_D) is taken equal to the base width of unit hydrograph (T_B).

In the present study, adjusting the design storm duration is limited to 24 hours. Hence, adopted design Storm duration T_D =24 Hrs.

4.3.2 Estimation Of Point Rainfall and Areal Rainfall :

Based on the Sub Zone Report,

50 Years 24 Hours Rainfall = 24 Cm (As per plate 9 of North Brahmaputra Subzone-2a report)

Considering area reduction factor the study area = 0.81 (As per Table 6 of North Brahmaputra Subzone report)

Hence, 50 Years 24 Hours Rainfall = 24 cm x 0.81 = 19.44 cm.

4.3.3 Time Distibution of Areal Rainfall :

50 Year 24 Hours areal rainfall = 19.44 cm is distributed with different distribution coefficient as provided in the Sub Zone Report corresponding to 24 hours to get the 1-Hour rainfall increments. The distribution coefficient required for this are provided in the report as per Column 24 of Table T-2 of Subzone Report.

Table 4.5 : Calculation of Hourly rainfall increment

Rainfall Duration (In Hrs)	Distribution Coefficient	24 hr rainfall(cm)	Areal Rainfall (In Cms)	Hourly rainfall Increment (cm)
1	0.13	19.44	2.53	2.53
2	0.25	19.44	4.86	2.33
3	0.32	19.44	6.22	1.36
4	0.4	19.44	7.78	1.56
5	0.47	19.44	9.14	1.36
6	0.52	19.44	10.11	0.97
7	0.56	19.44	10.89	0.78
8	0.61	19.44	11.86	0.97
9	0.65	19.44	12.64	0.78

10	0.69	19.44	13.41	0.78
11	0.73	19.44	14.19	0.78
12	0.76	19.44	14.77	0.58
13	0.79	19.44	15.36	0.58
14	0.81	19.44	15.75	0.39
15	0.84	19.44	16.33	0.58
16	0.86	19.44	16.72	0.39
17	0.88	19.44	17.11	0.39
18	0.90	19.44	17.50	0.39
19	0.92	19.44	17.88	0.39
20	0.93	19.44	18.08	0.19
21	0.95	19.44	18.47	0.39
22	0.97	19.44	18.86	0.39
23	0.98	19.44	19.05	0.19
24	1	19.44	19.44	0.39
			Total	19.44

4.3.4. Estimation of Effective Rainfall Unit:

As per section 2.3.0 the Report of Sub Zone, a design loss of 0.18 cm/hr has been adopted for this study.

The design loss rate subtracted from the 1 hr rainfall increment to obtain the 1 hr effective rainfall.

Table 4.6 : Calculation of Effective rainfall

Rainfall Duration (In Hrs)	Rainfall Increments (In Cm)	Design Loss Rate (cm/hr)	Effective Rainfall (In Cms)
1	2.53	0.18	2.35

2	2.33	0.18	2.15
3	1.36	0.18	1.18
4	1.56	0.18	1.38
5	1.36	0.18	1.18
6	0.97	0.18	0.79
7	0.78	0.18	0.60
8	0.97	0.18	0.79
9	0.78	0.18	0.60
10	0.78	0.18	0.60
11	0.78	0.18	0.60
12	0.58	0.18	0.40
13	0.58	0.18	0.40
14	0.39	0.18	0.21
15	0.58	0.18	0.40
16	0.39	0.18	0.21
17	0.39	0.18	0.21
18	0.39	0.18	0.21
19	0.39	0.18	0.21
20	0.19	0.18	0.01
21	0.39	0.18	0.21
22	0.39	0.18	0.21
23	0.19	0.18	0.01
24	0.39	0.18	0.21

4.3.5 Estimation of Design Base flow :

As per the clause 2.4 of the Sub Zone Report an average base flow rate of 0.05 cumec/sq km may be adopted.

Total Base Flow = Area x Rate of Base Flow

= 778.0947 Sq Km x 0.05 cumec/sq km

= 38.90 Cumec.

4.3.6. Estimation of 50 Years Peak Discharge :

For the estimation of Peak Discharge if required return period, the effective rainfall units has to be rearranged against the ordinates such that the maximum effective rainfall is placed against the Maximum Unit Hydrograph ordinate, the next lower value of effective rainfall against the next lower value of Unit Hydrograph ordinates and so on up to T_D hour duration. The sequence of effective rainfall then reversed so as to obtain the critical sequence of the effective rainfall.

Table 4.7 : Estimation of 50 Yrs Flood

Time	U.G ordinate (m^3/s)	1 Hr Effective Rainfall (In Cms)	Direct Runoff (In Cumec)
6	39	0.01	0.39
7	51	0.21	10.71
8	65	0.4	26.00
9	83	0.6	49.80
10	104	0.79	82.16
11	124	1.38	171.12
12	128.27	2.35	301.43
13	127	2.15	273.05
14	120	1.18	141.60
15	111	1.18	130.98

16	103	0.79	81.37
17	95	0.6	57.00
18	88	0.6	52.80
19	82	0.6	49.20
20	76	0.4	30.40
21	70	0.4	28.00
22	65	0.21	13.65
23	60	0.21	12.60
24	56	0.21	11.76
25	52	0.21	10.92
26	48	0.21	10.08
27	44	0.21	9.24
28	40	0.21	8.40
29	37	0.01	0.37
		Total	1563.03
		Base Flow	38.90
		50 years Flood Peak	1601.93

Table 4.8 : Critical 1 hr effective rainfall sequence

Time	Critical 1 hr effective rainfall sequence cms
1	0.01
2	0.21
3	0.21
4	0.21
5	0.21

6	0.21
7	0.21
8	0.21
9	0.4
10	0.4
11	0.6
12	0.6
13	0.6
14	0.79
15	1.18
16	1.18
17	2.15
18	2.35
19	1.38
20	0.79
21	0.6
22	0.4
23	0.21
24	0.01

		1 Hr Effective Rainfall																								
Time	UH Ordinates (Cumec)	0.01	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.4	0.4	0.6	0.6	0.6	0.79	1.18	1.18	2.15	2.35	1.38	0.79	0.6	0.4	0.21	0.01	Total	Base Flow	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0	0	0																								0	38.9	38.9
1	4	0.04	0																							0.04	38.9	38.94
2	8	0.08	0.84	0																						0.92	38.9	39.82
3	14	0.14	1.68	0.84	0																					2.66	38.9	41.56
4	21	0.21	2.94	1.68	0.84	0																				5.67	38.9	44.57
5	29	0.29	4.41	2.94	1.68	0.84	0																			10.16	38.9	49.06
6	39	0.39	6.09	4.41	2.94	1.68	0.84	0																		16.35	38.9	55.25
7	51	0.51	8.19	6.09	4.41	2.94	1.68	0.84	0																	24.66	38.9	63.56
8	65	0.65	10.71	8.19	6.09	4.41	2.94	1.68	0.84	0																35.51	38.9	74.41
9	83	0.83	13.65	10.71	8.19	6.09	4.41	2.94	1.68	1.6	0															50.1	38.9	89
10	104	1.04	17.43	13.65	10.71	8.19	6.09	4.41	2.94	3.2	1.6	0.00														69.26	38.90	108.16
11	124	1.24	21.84	17.43	13.65	10.71	8.19	6.09	4.41	5.6	3.2	2.40	0.00													94.76	38.90	133.66
12	128.27	1.28	26.04	21.84	17.43	13.65	10.71	8.19	6.09	8.4	5.6	4.80	2.40	0.00												126.43	38.90	165.33
13	127	1.27	26.94	26.04	21.84	17.43	13.65	10.71	8.19	11.6	8.4	8.40	4.80	2.40	0.00											161.67	38.90	200.57
14	120	1.2	26.67	26.94	26.04	21.84	17.43	13.65	10.71	15.6	11.6	12.60	8.40	4.80	3.16	0.00										200.64	38.90	239.54
15	111	1.11	25.2	26.67	26.94	26.04	21.84	17.43	13.65	20.4	15.6	17.40	12.60	8.40	6.32	4.72	0.00									244.32	38.90	283.22
16	103	1.03	23.31	25.2	26.67	26.94	26.04	21.84	17.43	26	20.4	23.40	17.40	12.60	11.06	9.44	4.72	0.00								293.48	38.90	332.38
17	95	0.95	21.63	23.31	25.2	26.67	26.94	26.04	21.84	33.2	26	30.60	23.40	17.40	16.59	16.52	9.44	8.60	0.00							354.33	38.90	393.23
18	88	0.88	19.95	21.63	23.31	25.2	26.67	26.94	26.04	41.6	33.2	39.00	30.60	23.40	22.91	24.78	16.52	17.20	9.40	0.00						429.23	38.90	468.13
19	82	0.82	18.48	19.95	21.63	23.31	25.2	26.67	26.94	49.60	41.6	49.80	39.00	30.60	30.81	34.22	24.78	30.10	18.80	5.52	0.00					517.83	38.90	556.73
20	76	0.76	17.22	18.48	19.95	21.63	23.31	25.2	26.67	51.31	49.6	62.40	49.80	39.00	40.29	46.02	34.22	45.15	32.90	11.04	3.16	0.00				618.11	38.90	657.01
21	70	0.7	15.96	17.22	18.48	19.95	21.63	23.31	25.20	50.80	51.308	74.40	62.40	49.80	51.35	60.18	46.02	62.35	49.35	19.32	6.32	2.40	0.00			728.45	38.90	767.35
22	65	0.65	14.7	15.96	17.22	18.48	19.95	21.63	23.31	48.00	50.8	76.96	74.40	62.40	65.57	76.70	60.18	83.85	68.15	28.98	11.06	4.80	1.60	0.00		845.35	38.90	884.25
23	60	0.6	13.65	14.7	15.96	17.22	18.48	19.95	21.63	44.4	48	76.20	76.96	74.40	82.16	97.94	76.70	109.65	91.65	40.02	16.59	8.40	3.20	0.84	0.00	969.30	38.90	1008.20
24	56	0.56	12.6	13.65	14.7	15.96	17.22	18.48	19.95	41.2	44.4	72.00	76.20	76.96	97.96	122.72	97.94	139.75	119.85	53.82	22.91	12.60	5.60	1.68	0.04	1098.75	38.90	1137.65
25	52	0.52	11.76	12.6	13.65	14.7	15.96	17.22	18.48	38	41.2	66.60	72.00	76.20	101.33	146.32	122.72	178.45	152.75	70.38	30.81	17.40	8.40	2.94	0.08	1230.47	38.90	1269.37
26	48	0.4	10.9	11.7	12.6	13.6	14.7	15.9	17.2	35.2	38	61.8	66.6	72.0	100.3	151.3	146.3	223.6	195.0	89.70	40.29	23.4	11.6	4.41	0.1	1357.0	38.9	1395.99

		8	2	6		5		6	2			0	0	0	3	6	2	0	5			0	0		4	9	0	
27	44	0.44	10.08	10.92	11.76	12.6	13.65	14.7	15.96	32.8	35.2	57.00	61.80	66.60	94.80	149.86	151.36	266.60	244.40	114.54	51.35	30.60	15.60	6.09	0.21	1468.92	38.90	1507.82
28	40	0.4	9.24	10.08	10.92	11.76	12.6	13.65	14.7	30.4	32.8	52.80	57.00	61.80	87.69	141.60	149.86	275.78	291.40	143.52	65.57	39.00	20.40	8.19	0.29	1541.45	38.90	1580.35
29	37	0.37	8.4	9.24	10.08	10.92	11.76	12.6	13.65	28	30.4	49.20	52.80	57.00	81.37	130.98	141.60	273.05	301.43	171.12	82.16	49.80	26.00	10.71	0.39	1563.03	38.90	1601.93
30	34	0.34	7.77	8.4	9.24	10.08	10.92	11.76	12.6	26	28	45.60	49.20	52.80	75.05	121.54	130.98	258.00	298.45	177.01	97.96	62.40	33.20	13.65	0.51	1541.46	38.90	1580.36
31	31	0.31	7.14	7.77	8.4	9.24	10.08	10.92	11.76	24	26	42.00	45.60	49.20	69.52	112.10	121.54	238.65	282.00	175.26	101.33	74.40	41.60	17.43	0.65	1486.90	38.90	1525.80
32	28	0.28	6.51	7.14	7.77	8.4	9.24	10.08	10.92	22.4	24	39.00	42.00	45.60	64.78	103.84	112.10	221.45	260.85	165.60	100.33	76.96	49.60	21.84	0.83	1411.52	38.90	1450.42
33	25	0.25	5.88	6.51	7.14	7.77	8.4	9.24	10.08	20.8	22.4	36.00	39.00	42.00	60.04	96.76	103.84	204.25	242.05	153.18	94.80	76.20	51.31	26.04	1.04	1324.98	38.90	1363.88
34	22	0.22	5.25	5.88	6.51	7.14	7.77	8.4	9.24	19.2	20.8	33.60	36.00	39.00	55.30	89.68	96.76	189.20	223.25	142.14	87.69	72.00	50.80	26.94	1.24	1234.01	38.90	1272.91
35	19	0.19	4.62	5.25	5.88	6.51	7.14	7.77	8.4	17.6	19.2	31.20	33.60	36.00	51.35	82.60	89.68	176.30	206.80	131.10	81.37	66.60	48.00	26.67	1.28	1145.11	38.90	1184.01
36	16	0.16	3.99	4.62	5.25	5.88	6.51	7.14	7.77	16	17.6	28.80	31.20	33.60	47.40	76.70	82.60	163.40	192.70	121.44	75.05	61.80	44.40	25.20	1.27	1060.48	38.90	1099.38
37	13	0.13	3.36	3.99	4.62	5.25	5.88	6.51	7.14	14.8	16	26.40	28.80	31.20	44.24	70.80	76.70	150.50	178.60	113.16	69.52	57.00	41.20	23.31	1.20	980.31	38.90	1019.21
38	10	0.1	2.73	3.36	3.99	4.62	5.25	5.88	6.51	13.6	14.8	24.00	26.40	28.80	41.08	66.08	70.80	139.75	164.50	104.88	64.78	52.80	38.00	21.63	1.11	905.45	38.90	944.35
39	7	0.07	2.1	2.73	3.36	3.99	4.62	5.25	5.88	12.4	13.6	22.20	24.00	26.40	37.92	61.36	66.08	129.00	152.75	96.60	60.04	49.20	35.20	19.95	1.03	835.73	38.90	874.63
40	5	0.05	1.47	2.1	2.73	3.36	3.99	4.62	5.25	11.2	12.4	20.40	22.20	24.00	34.76	56.64	61.36	120.40	141.00	89.70	55.30	45.60	32.80	18.48	0.95	770.76	38.90	809.66
41	3	0.03	1.05	1.47	2.1	2.73	3.36	3.99	4.62	10	11.2	18.60	20.40	22.20	31.60	51.92	56.64	111.80	131.60	82.80	51.35	42.00	30.40	17.22	0.88	709.96	38.90	748.86
42	2	0.02	0.63	1.05	1.47	2.1	2.73	3.36	3.99	8.8	10	16.80	18.60	20.40	29.23	47.20	51.92	103.20	122.20	77.28	47.40	39.00	28.00	15.96	0.82	652.16	38.90	691.06
43	1	0.01	0.42	0.63	1.05	1.47	2.1	2.73	3.36	7.6	8.8	15.00	16.80	18.60	26.86	43.66	47.20	94.60	112.80	71.76	44.24	36.00	26.00	14.70	0.76	597.15	38.90	636.05
44	0	0	0.21	0.42	0.63	1.05	1.47	2.1	2.73	6.4	7.6	13.20	15.00	16.80	24.49	40.12	43.66	86.00	103.40	66.24	41.08	33.60	24.00	13.65	0.70	544.55	38.90	583.45
45			0	0.21	0.42	0.63	1.05	1.47	2.1	5.2	6.4	11.40	13.20	15.00	22.12	36.58	40.12	79.55	94.00	60.72	37.92	31.20	22.40	12.60	0.65	494.94	38.90	533.84
46				0	0.21	0.42	0.63	1.05	1.47	4	5.2	9.60	11.40	13.20	19.75	33.04	36.58	73.10	86.95	55.20	34.76	28.80	20.80	11.76	0.60	448.52	38.90	487.42
47					0	0.21	0.42	0.63	1.05	2.8	4	7.80	9.60	11.40	17.38	29.50	33.04	66.65	79.90	51.06	31.60	26.40	19.20	10.92	0.56	404.12	38.90	443.02
48						0	0.21	0.42	0.63	2	2.8	6.00	7.80	9.60	15.01	25.96	29.50	60.20	72.85	46.92	29.23	24.00	17.60	10.08	0.52	361.33	38.90	400.23
49							0	0.21	0.42	1.2	2	4.20	6.00	7.80	12.64	22.42	25.96	53.75	65.80	42.78	26.86	22.20	16.00	9.24	0.48	319.96	38.90	358.86
50								0	0.21	0.8	1.2	3.00	4.20	6.00	10.27	18.88	22.42	47.30	58.75	38.64	24.49	20.40	14.80	8.40	0.44	280.20	38.90	319.10
51									0	0.4	0.8	1.80	3.00	4.20	7.90	15.34	18.88	40.85	51.70	34.50	22.12	18.60	13.60	7.77	0.40	241.86	38.90	280.76
52										0	0.4	1.20	1.80	3.00	5.53	11.80	15.34	34.40	44.65	30.36	19.75	16.80	12.40	7.14	0.37	204.94	38.90	243.84
53											0	0.60	1.20	1.80	3.95	8.26	11.80	27.95	37.60	26.22	17.38	15.00	11.20	6.51	0.34	169.81	38.90	208.71
54												0.00	0.60	1.20	2.37	5.90	8.26	21.50	30.55	22.08	15.01	13.20	10.00	5.88	0.31	136.86	38.90	175.76
55													0.00	0.60	1.58	3.54	5.90	15.05	23.50	17.94	12.64	11.40	8.80	5.25	0.28	106.48	38.90	145.38
56														0.00	0.79	2.36	3.54	10.75	16.45	13.80	10.27	9.60	7.60	4.62	0.2	80.03	38.9	118.93

																									5		0	
57															0.00	1.18	2.36	6.45	11.75	9.66	7.90	7.80	6.40	3.99	0.22	57.71	38.90	96.61
58																0.00	1.18	4.30	7.05	6.90	5.53	6.00	5.20	3.36	0.19	39.71	38.90	78.61
59																	0.00	2.15	4.70	4.14	3.95	4.20	4.00	2.73	0.16	26.03	38.90	64.93
60																		0.00	2.35	2.76	2.37	3.00	2.80	2.10	0.13	15.51	38.90	54.41
61																			0.00	1.38	1.58	1.80	2.00	1.47	0.10	8.33	38.90	47.23
62																				0.00	0.79	1.20	1.20	1.05	0.07	4.31	38.90	43.21
63																					0.00	0.60	0.80	0.63	0.05	2.08	38.90	40.98
64																						0.00	0.40	0.42	0.03	0.85	38.90	39.75
65																							0.00	0.21	0.02	0.23	38.90	39.13
66																								0.00	0.01	0.01	38.90	38.91
67																									0.00	0.00	38.90	38.90

Figure 4.2: Determination of 50 years flood Hydrograph

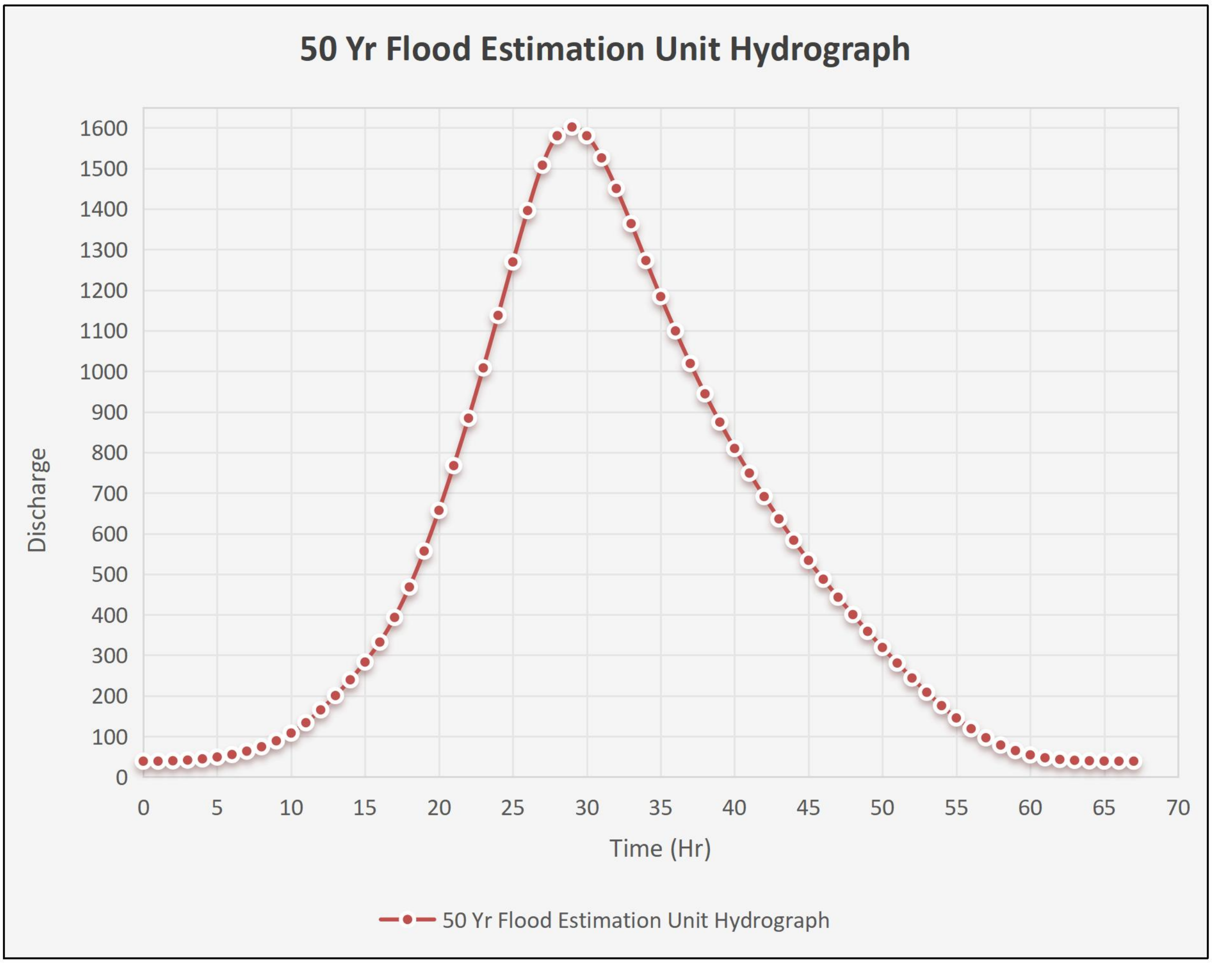


Figure 4.3 : 50 years Flood Hydrograph

4.4 Calculation of 100 Years Peak Discharge :

4.4.1 Estimation Of Design Storm Duration :

As per the section 3.1.0 of North Brahmaputra Subzone -2 (a) report, the design storm duration (T_D) is taken equal to the base width of unit hydrograph (T_B).

In the present study, adjusting the design storm duration is limited to 24 hours. Hence, adopted design Storm duration T_D =24 Hrs.

4.4.2 Estimation Of Point Rainfall and Areal Rainfall :

Based on the Sub Zone Report,

50 Years 24 Hours Rainfall = 28 Cm (As per plate 10 of North Brahmaputra subzone report)

Considering area reduction factor the study area = 0.81 (As per Table 6 of North Brahmaputra subzone report)

Hence, 50 Years 24 Hours Rainfall = 28 cm x 0.81 = 22.68 cm.

4.4.3 Time Distribution of Areal Rainfall :

100 Year 24 Hours areal rainfall = 22.68 cm is distributed with different distribution coefficient as provided in the Sub Zone Report corresponding to 24 hours to get the 1-Hour rainfall increments. The distribution coefficient required for this are provided in the report as per Column 24 of Table T-2 of Subzone Report.

Table 4.9 : Calculation of Hourly rainfall increment

Rainfall Duration (In Hrs)	Distribution Coefficient	24 hr rainfall(cm)	Areal Rainfall (In Cms)	Hourly rainfall Increment (cm)
1	0.13	22.68	2.95	2.95
2	0.25	22.68	5.67	2.72
3	0.32	22.68	7.26	1.59
4	0.4	22.68	9.07	1.81
5	0.47	22.68	10.66	1.59
6	0.52	22.68	11.79	1.13
7	0.56	22.68	12.70	0.91
8	0.61	22.68	13.83	1.13
9	0.65	22.68	14.74	0.91
10	0.69	22.68	15.65	0.91
11	0.73	22.68	16.56	0.91
12	0.76	22.68	17.24	0.68
13	0.79	22.68	17.92	0.68
14	0.81	22.68	18.37	0.45
15	0.84	22.68	19.05	0.68

16	0.86	22.68	19.50	0.45
17	0.88	22.68	19.96	0.45
18	0.90	22.68	20.41	0.45
19	0.92	22.68	20.87	0.45
20	0.93	22.68	21.09	0.23
21	0.95	22.68	21.55	0.45
22	0.97	22.68	22.00	0.45
23	0.98	22.68	22.23	0.23
24	1	22.68	22.68	0.45
			Total	22.66

4.4.4 Estimation of Effective Rainfall Unit:

As per section 2.3.0 the Report of Sub Zone, a design loss of 0.18 cm/hr has been adopted for this study.

The design loss rate subtracted from the 1 hr rainfall increment to obtain the 1 hr effective rainfall.

Table 4.10 : Calculation of Effective rainfall

Rainfall Duration (In Hrs)	Rainfall Increments (In Cm)	Design Loss Rate (cm/hr)	Effective Rainfall (In Cms)
1	2.95	0.18	2.77
2	2.72	0.18	2.54
3	1.59	0.18	1.41
4	1.81	0.18	1.63
5	1.59	0.18	1.41
6	1.13	0.18	0.95
7	0.91	0.18	0.73

8	1.13	0.18	0.95
9	0.91	0.18	0.73
10	0.91	0.18	0.73
11	0.91	0.18	0.73
12	0.68	0.18	0.50
13	0.68	0.18	0.50
14	0.45	0.18	0.27
15	0.68	0.18	0.50
16	0.45	0.18	0.27
17	0.45	0.18	0.27
18	0.45	0.18	0.27
19	0.45	0.18	0.27
20	0.23	0.18	0.05
21	0.45	0.18	0.27
22	0.45	0.18	0.27
23	0.23	0.18	0.05
24	0.45	0.18	0.27

4.4.5 Estimation of Design Base flow :

As per the clause 2.4 of the Sub Zone Report an average base flow rate of 0.05 cumec/sq km may be adopted.

Total Base Flow = Area x Rate of Base Flow

= 778.0947 Sq Km x 0.05 cumec/sq km

= 38.90 Cumec.

4.4.6 Estimation of 100 Years Peak Discharge :

For the estimation of Peak Discharge if required return period, the effective rainfall units has to be rearranged against the ordinates such that the maximum effective rainfall is placed against the Maximum Unit Hydrograph ordinate, the next lower value of effective rainfall against the next lower value of Unit Hydrograph ordinates and so on upto T_D hour duration. The sequence of effective rainfall then reversed so as to obtain the critical sequence of the effective rainfall.

Table 4.11 : Estimation of 100 Yrs Flood

Time	U.G ordinate (m^3/s)	1 Hr Effective Rainfall (In Cms)	Direct Runoff (In Cumec)
6	39	0.05	1.95
7	51	0.27	13.77
8	65	0.5	32.50
9	83	0.73	60.59
10	104	0.95	98.80
11	124	1.63	202.12
12	128.27	2.77	355.31
13	127	2.54	322.58
14	120	1.41	169.20
15	111	1.41	156.51
16	103	0.95	97.85
17	95	0.73	69.35
18	88	0.73	64.24
19	82	0.73	59.86
20	76	0.5	38.00
21	70	0.5	35.00
22	65	0.27	17.55

23	60	0.27	16.20
24	56	0.27	15.12
25	52	0.27	14.04
26	48	0.27	12.96
27	44	0.27	11.88
28	40	0.27	10.80
29	37	0.05	1.85
		Total	1878.03
		Base Flow	38.90
		100 years Flood Peak	1916.93

Table 4.12 : Critical 1 hr effective rainfall sequence

Time	Critical 1 hr effective rainfall sequence cms
1	0.05
2	0.27
3	0.27
4	0.27
5	0.27
6	0.27
7	0.27
8	0.27
9	0.5
10	0.5
11	0.73
12	0.73
13	0.73

14	0.95
15	1.41
16	1.41
17	2.54
18	2.77
19	1.63
20	0.95
21	0.73
22	0.5
23	0.27
24	0.05

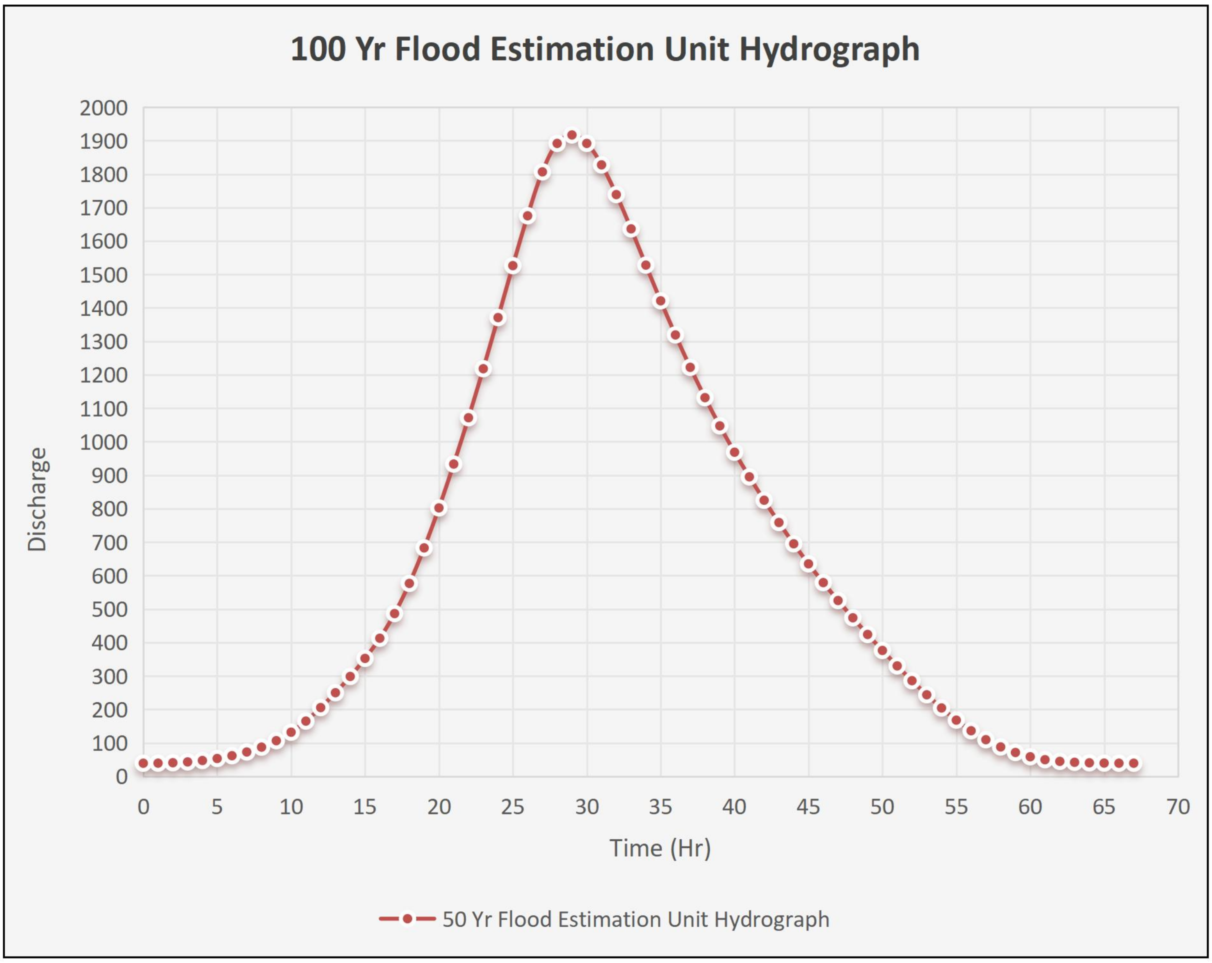


Figure 4.4 : 100 years Flood Hydrograph

		1 Hr Effective Rainfall																								
Time	UH Ordinates (Cumec)	0.05	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.5	0.5	0.73	0.73	0.73	0.95	1.41	1.41	2.54	2.77	1.63	0.95	0.73	0.5	0.27	0.05	Total	Base Flow	Total
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
0	0	0																								0	38.9	38.9
1	4	0.2	0																							0.2	38.9	39.1
2	8	0.4	1.08	0																						1.48	38.9	40.38
3	14	0.7	2.16	1.08	0																					3.94	38.9	42.84
4	21	1.05	3.78	2.16	1.08	0																				8.07	38.9	46.97
5	29	1.45	5.67	3.78	2.16	1.08	0																			14.14	38.9	53.04
6	39	1.95	7.83	5.67	3.78	2.16	1.08	0																		22.47	38.9	61.37
7	51	2.55	10.53	7.83	5.67	3.78	2.16	1.08	0																	33.6	38.9	72.5
8	65	3.25	13.77	10.53	7.83	5.67	3.78	2.16	1.08	0																48.07	38.9	86.97
9	83	4.15	17.55	13.77	10.53	7.83	5.67	3.78	2.16	2	0															67.44	38.9	106.34
10	104	5.2	22.41	17.55	13.77	10.53	7.83	5.67	3.78	4	2	0.00														92.74	38.90	131.64
11	124	6.2	28.08	22.41	17.55	13.77	10.53	7.83	5.67	7	4	2.92	0.00													125.96	38.90	164.86
12	128.27	6.41	33.48	28.08	22.41	17.55	13.77	10.53	7.83	10.5	7	5.84	2.92	0.00												166.32	38.90	205.22
13	127	6.35	34.63	33.48	28.08	22.41	17.55	13.77	10.53	14.5	10.5	10.22	5.84	2.92	0.00											210.78	38.90	249.68
14	120	6	34.29	34.63	33.48	28.08	22.41	17.55	13.77	19.5	14.5	15.33	10.22	5.84	3.80	0.00										259.40	38.90	298.30
15	111	5.55	32.4	34.29	34.63	33.48	28.08	22.41	17.55	25.5	19.5	21.17	15.33	10.22	7.60	5.64	0.00									313.35	38.90	352.25
16	103	5.15	29.97	32.4	34.29	34.63	33.48	28.08	22.41	32.5	25.5	28.47	21.17	15.33	13.30	11.28	5.64	0.00								373.60	38.90	412.50
17	95	4.75	27.81	29.97	32.4	34.29	34.63	33.48	28.08	41.5	32.5	37.23	28.47	21.17	19.95	19.74	11.28	10.16	0.00							447.41	38.90	486.31
18	88	4.4	25.65	27.81	29.97	32.4	34.29	34.63	33.48	52	41.5	47.45	37.23	28.47	27.55	29.61	19.74	20.32	11.08	0.00						537.58	38.90	576.48
19	82	4.1	23.76	25.65	27.81	29.97	32.4	34.29	34.63	62.00	52	60.59	47.45	37.23	37.05	40.89	29.61	35.56	22.16	6.52	0.00					643.67	38.90	682.57
20	76	3.8	22.14	23.76	25.65	27.81	29.97	32.4	34.29	64.14	62	75.92	60.59	47.45	48.45	54.99	40.89	53.34	38.78	13.04	3.80	0.00				763.21	38.90	802.11
21	70	3.5	20.52	22.14	23.76	25.65	27.81	29.97	32.40	63.50	64.135	90.52	75.92	60.59	61.75	71.91	54.99	73.66	58.17	22.82	7.60	2.92	0.00			894.24	38.90	933.14
22	65	3.25	18.9	20.52	22.14	23.76	25.65	27.81	29.97	60.00	63.5	93.64	90.52	75.92	78.85	91.65	71.91	99.06	80.33	34.23	13.30	5.84	2.00	0.00		1032.75	38.90	1071.65
23	60	3	17.55	18.9	20.52	22.14	23.76	25.65	27.81	55.5	60	92.71	93.64	90.52	98.80	117.03	91.65	129.54	108.03	47.27	19.95	10.22	4.00	1.08	0.00	1179.27	38.90	1218.17
24	56	2.8	16.2	17.55	18.9	20.52	22.14	23.76	25.65	51.5	55.5	87.60	92.71	93.64	117.80	146.64	117.03	165.10	141.27	63.57	27.55	15.33	7.00	2.16	0.20	1332.12	38.90	1371.02
25	52	2.6	15.12	16.2	17.55	18.9	20.52	22.14	23.76	47.5	51.5	81.03	87.60	92.71	121.86	174.84	146.64	210.82	180.05	83.13	37.05	21.17	10.50	3.78	0.40	1487.37	38.90	1526.27
26	48	2.4	14.04	15.12	16.2	17.55	18.9	20.52	22.14	44	47.5	75.19	81.03	87.60	120.65	180.86	174.84	264.16	229.91	105.95	48.45	28.47	14.50	5.67	0.70	1636.35	38.90	1675.25
27	44	2.2	12.96	14.04	15.12	16.2	17.55	18.9	20.52	41	44	69.35	75.19	81.03	114.00	179.07	180.86	314.96	288.08	135.29	61.75	37.23	19.50	7.83	1.05	1767.68	38.90	1806.58
28	40	2	11.8	12.9	14.0	15.1	16.2	17.5	18.9	38	41	64.2	69.3	75.1	105.4	169.2	179.0	325.8	343.4	169.5	78.85	47.4	25.5	10.5	1.4	1852.7	38.9	1891.6

			8	6	4	2		5				4	5	9	5	0	7	1	8	2		5	0	3	5	4	0	4
29	37	1.85	10.8	11.88	12.96	14.04	15.12	16.2	17.55	35	38	59.86	64.24	69.35	97.85	156.51	169.20	322.58	355.31	202.12	98.80	60.59	32.50	13.77	1.95	1878.03	38.90	1916.93
30	34	1.7	9.99	10.8	11.88	12.96	14.04	15.12	16.2	32.5	35	55.48	59.86	64.24	90.25	145.23	156.51	304.80	351.79	209.08	117.80	75.92	41.50	17.55	2.55	1852.75	38.90	1891.65
31	31	1.55	9.18	9.99	10.8	11.88	12.96	14.04	15.12	30	32.5	51.10	55.48	59.86	83.60	133.95	145.23	281.94	332.40	207.01	121.86	90.52	52.00	22.41	3.25	1788.63	38.90	1827.53
32	28	1.4	8.37	9.18	9.99	10.8	11.88	12.96	14.04	28	30	47.45	51.10	55.48	77.90	124.08	133.95	261.62	307.47	195.60	120.65	93.64	62.00	28.08	4.15	1699.79	38.90	1738.69
33	25	1.25	7.56	8.37	9.18	9.99	10.8	11.88	12.96	26	28	43.80	47.45	51.10	72.20	115.62	124.08	241.30	285.31	180.93	114.00	92.71	64.14	33.48	5.20	1597.31	38.90	1636.21
34	22	1.1	6.75	7.56	8.37	9.18	9.99	10.8	11.88	24	26	40.88	43.80	47.45	66.50	107.16	115.62	223.52	263.15	167.89	105.45	87.60	63.50	34.63	6.20	1488.98	38.90	1527.88
35	19	0.95	5.94	6.75	7.56	8.37	9.18	9.99	10.8	22	24	37.96	40.88	43.80	61.75	98.70	107.16	208.28	243.76	154.85	97.85	81.03	60.00	34.29	6.41	1382.26	38.90	1421.16
36	16	0.8	5.13	5.94	6.75	7.56	8.37	9.18	9.99	20	22	35.04	37.96	40.88	57.00	91.65	98.70	193.04	227.14	143.44	90.25	75.19	55.50	32.40	6.35	1280.26	38.90	1319.16
37	13	0.65	4.32	5.13	5.94	6.75	7.56	8.37	9.18	18.5	20	32.12	35.04	37.96	53.20	84.60	91.65	177.80	210.52	133.66	83.60	69.35	51.50	29.97	6.00	1183.37	38.90	1222.27
38	10	0.5	3.51	4.32	5.13	5.94	6.75	7.56	8.37	17	18.5	29.20	32.12	35.04	49.40	78.96	84.60	165.10	193.90	123.88	77.90	64.24	47.50	27.81	5.55	1092.78	38.90	1131.68
39	7	0.35	2.7	3.51	4.32	5.13	5.94	6.75	7.56	15.5	17	27.01	29.20	32.12	45.60	73.32	78.96	152.40	180.05	114.10	72.20	59.86	44.00	25.65	5.15	1008.38	38.90	1047.28
40	5	0.25	1.89	2.7	3.51	4.32	5.13	5.94	6.75	14	15.5	24.82	27.01	29.20	41.80	67.68	73.32	142.24	166.20	105.95	66.50	55.48	41.00	23.76	4.75	929.70	38.90	968.60
41	3	0.15	1.35	1.89	2.7	3.51	4.32	5.13	5.94	12.5	14	22.63	24.82	27.01	38.00	62.04	67.68	132.08	155.12	97.80	61.75	51.10	38.00	22.14	4.40	856.06	38.90	894.96
42	2	0.1	0.81	1.35	1.89	2.7	3.51	4.32	5.13	11	12.5	20.44	22.63	24.82	35.15	56.40	62.04	121.92	144.04	91.28	57.00	47.45	35.00	20.52	4.10	786.10	38.90	825.00
43	1	0.05	0.54	0.81	1.35	1.89	2.7	3.51	4.32	9.5	11	18.25	20.44	22.63	32.30	52.17	56.40	111.76	132.96	84.76	53.20	43.80	32.50	18.90	3.80	719.54	38.90	758.44
44	0	0	0.27	0.54	0.81	1.35	1.89	2.7	3.51	8	9.5	16.06	18.25	20.44	29.45	47.94	52.17	101.60	121.88	78.24	49.40	40.88	30.00	17.55	3.50	655.93	38.90	694.83
45			0	0.27	0.54	0.81	1.35	1.89	2.7	6.5	8	13.87	16.06	18.25	26.60	43.71	47.94	93.98	110.80	71.72	45.60	37.96	28.00	16.20	3.25	596.00	38.90	634.90
46				0	0.27	0.54	0.81	1.35	1.89	5	6.5	11.68	13.87	16.06	23.75	39.48	43.71	86.36	102.49	65.20	41.80	35.04	26.00	15.12	3.00	539.92	38.90	578.82
47					0	0.27	0.54	0.81	1.35	3.5	5	9.49	11.68	13.87	20.90	35.25	39.48	78.74	94.18	60.31	38.00	32.12	24.00	14.04	2.80	486.33	38.90	525.23
48						0	0.27	0.54	0.81	2.5	3.5	7.30	9.49	11.68	18.05	31.02	35.25	71.12	85.87	55.42	35.15	29.20	22.00	12.96	2.60	434.73	38.90	473.63
49							0	0.27	0.54	1.5	2.5	5.11	7.30	9.49	15.20	26.79	31.02	63.50	77.56	50.53	32.30	27.01	20.00	11.88	2.40	384.90	38.90	423.80
50								0	0.27	1	1.5	3.65	5.11	7.30	12.35	22.56	26.79	55.88	69.25	45.64	29.45	24.82	18.50	10.80	2.20	337.07	38.90	375.97
51									0	0.5	1	2.19	3.65	5.11	9.50	18.33	22.56	48.26	60.94	40.75	26.60	22.63	17.00	9.99	2.00	291.01	38.90	329.91
52										0	0.5	1.46	2.19	3.65	6.65	14.10	18.33	40.64	52.63	35.86	23.75	20.44	15.50	9.18	1.85	246.73	38.90	285.63
53											0	0.73	1.46	2.19	4.75	9.87	14.10	33.02	44.32	30.97	20.90	18.25	14.00	8.37	1.70	204.63	38.90	243.53
54												0.00	0.73	1.46	2.85	7.05	9.87	25.40	36.01	26.08	18.05	16.06	12.50	7.56	1.55	165.17	38.90	204.07
55													0.00	0.73	1.90	4.23	7.05	17.78	27.70	21.19	15.20	13.87	11.00	6.75	1.40	128.80	38.90	167.70
56														0.00	0.95	2.82	4.23	12.70	19.39	16.30	12.35	11.68	9.50	5.94	1.25	97.11	38.90	136.01
57															0.00	1.41	2.82	7.62	13.85	11.41	9.50	9.49	8.00	5.13	1.10	70.33	38.90	109.23
58																0.00	1.41	5.08	8.31	8.15	6.65	7.30	6.50	4.32	0.95	48.67	38.90	87.57

59																	0.00	2.54	5.54	4.89	4.75	5.11	5.00	3.51	0.80	32.14	38.90	71.04
60																		0.00	2.77	3.26	2.85	3.65	3.50	2.70	0.65	19.38	38.90	58.28
61																			0.00	1.63	1.90	2.19	2.50	1.89	0.50	10.61	38.90	49.51
62																				0.00	0.95	1.46	1.50	1.35	0.35	5.61	38.90	44.51
63																					0.00	0.73	1.00	0.81	0.25	2.79	38.90	41.69
64																						0.00	0.50	0.54	0.15	1.19	38.90	40.09
65																							0.00	0.27	0.10	0.37	38.90	39.27
66																								0.00	0.05	0.05	38.90	38.95
67																									0.00	0.00	38.90	38.90

Figure 4.5: Determination of 100 years flood Hydrograph

4.5 Peak Discharge by Gumbel's Distribution Method:

It is a probability distribution functions for extreme values in hydrologic and meteorological studies for prediction of peak flood, maximum rainfall etc.

For the estimation of peak flood discharge of a return period of 50 and 100 years rainfall data of last 20 years has been collected and calculated as below.

Table 4.13 : Discharge Data of 20 Years

Sl No	Year	Discharge (Cumec)
1	2003	68.841
2	2004	100.352
3	2005	91.250
4	2006	86.953
5	2007	63.626
6	2008	101.219
7	2009	74.538
8	2010	67.327
9	2011	87.219
10	2012	65.872
11	2013	76.121
12	2014	73.443
13	2015	108.846
14	2016	71.969
15	2017	84.616
16	2018	60.913
17	2019	102.068
18	2020	102.524
19	2021	60.156
20	2022	82.834

Value of X with a recurrence interval T is given by

$$x_T = x + K\sigma_{n-1}$$

σ_{n-1} = Standard Deviation of the Sample Size N = $\sqrt{\frac{\sum (x - \bar{x})^2}{N-1}}$

K = Frequency Factor expressed by , K = $\frac{y_T - y_n}{S_n}$

y_T = Reduced Variate, a function of T given by,

Y_t = -(ln.ln(T/T-1))

Table 4.14 : Calculation of Parameters for Gumbel Distribution

Sl No	Year	Discharge	Rank No m	Tp	$(x-X)^2$	Log T_p
1	2015	108.846	1	21.00	745.945	1.322219295
2	2020	102.524	2	10.50	440.580	1.021189299
3	2019	102.068	3	7.00	421.645	0.84509804
4	2008	101.219	4	5.25	387.499	0.720159303
5	2004	100.352	5	4.20	354.117	0.62324929
6	2005	91.250	6	3.50	94.401	0.544068044
7	2011	87.219	7	3.00	32.319	0.477121255
8	2006	86.953	8	2.63	29.366	0.419129308
9	2017	84.616	9	2.33	9.499	0.367976785
10	2022	82.834	10	2.10	1.690	0.322219295
11	2013	76.121	11	1.91	29.301	0.28082661
12	2009	74.538	12	1.75	48.944	0.243038049
13	2014	73.443	13	1.62	65.464	0.208275942
14	2016	71.969	14	1.50	91.489	0.176091259

15	2003	68.841	15	1.40	161.112	0.146128036
16	2010	67.327	16	1.31	201.839	0.118099312
17	2012	65.872	17	1.24	245.298	0.091770373
18	2007	63.626	18	1.17	320.696	0.06694679
19	2018	60.913	19	1.11	425.226	0.043465694
20	2021	60.156	20	1.05	457.019	0.021189299
		1630.687			4563.450	

Now, x = 81.534

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	1.1480	1.1499	1.1519	1.1538	1.1557	1.1574	1.1590
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	1.1770	1.1782	1.1793	1.1803	1.1814	1.1824	1.1834	1.1844
70	1.1854	1.1863	1.1873	1.1881	1.1890	1.1898	1.1906	1.1915	1.1923	1.1930
80	1.1938	1.1945	1.1953	1.1959	1.1967	1.1973	1.1980	1.1987	1.1994	1.2001
90	1.2007	1.2013	1.2020	1.2026	1.2032	1.2038	1.2044	1.2049	1.2055	1.2060
100	1.2065									

Figure 4.6 : Reduced standard deviation S_n in Gumbel's Extreme value Distribution

N	0	1	2	3	4	5	6	7	8	9
10	0.4952	0.4996	0.5035	0.5070	0.5100	0.5128	0.5157	0.5181	0.5202	0.5220
20	0.5236	0.5252	0.5268	0.5283	0.5296	0.5309	0.5320	0.5332	0.5343	0.5353
30	0.5362	0.5371	0.5380	0.5388	0.5396	0.5402	0.5410	0.5418	0.5424	0.5430
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	0.5530	0.5533	0.5535	0.5538	0.5540	0.5543	0.5545
70	0.5548	0.5550	0.5552	0.5555	0.5557	0.5559	0.5561	0.5563	0.5565	0.5567
80	0.5569	0.5570	0.5572	0.5574	0.5576	0.5578	0.5580	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	0.5600									

Figure 4.7 :Reduced mean (y_n) in Gumbel's Extreme value distribution

Now, for this study, N = 20

$y_n = 0.5236$

$S_n = 1.0628$

$\sigma_{n-1} = 15.49$

From calculation, the following data has been found.

Table 4.15 : Peak Discharge For 50 & 100 Years Return Period

Return Period (Years)	Discharge (Cumec)
50	130.63
100	140.86

Since, Synthetic unit hydrograph method provided the highest value of Peak Discharge between the two methods, hence , 1601.93 m^3/sec and 1916.93 m^3/sec may be considered for 50 year and 100 year return period flood respectively for this present study.

4.6 Methodology in the Software :

1. Google Earth Pro :

The study area for the present study has been selected in the Google Earth Pro software. Then the river centreline is drawn as a polyline for the selected river reach of this study. The required Lattitude and Longitude of the study area is alsp derived from this map.

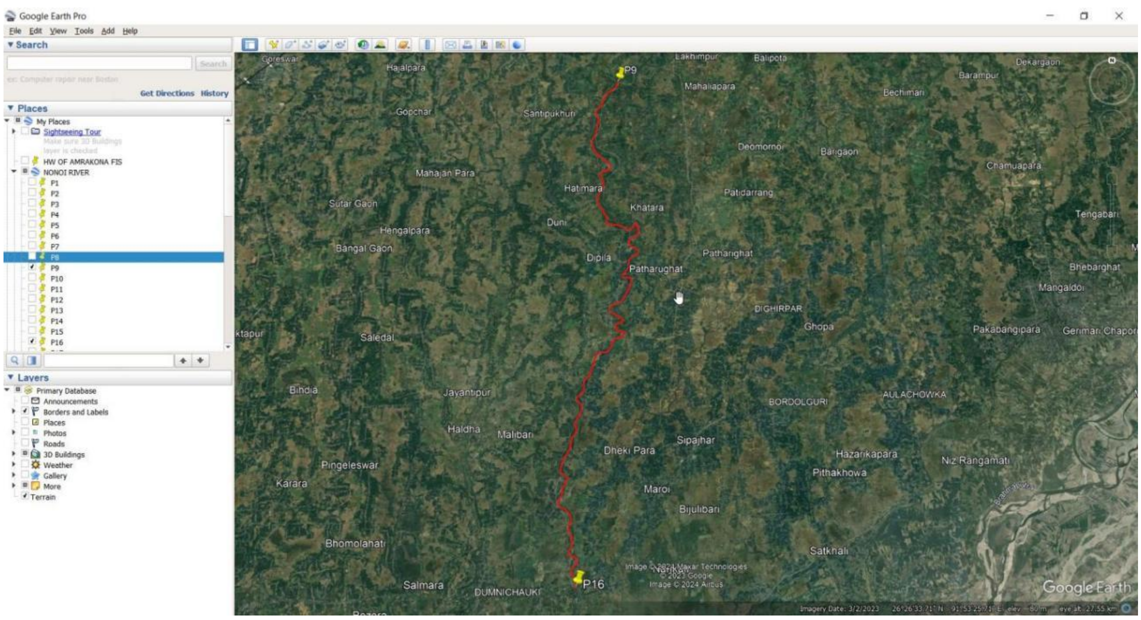


Figure 4.8 : Study Area and River Centreline in Google Earth Pro

2. Methodology USGS Earth Explorer :

The required Digital Elevation Model(DEM) data has been downloaded from the USGS Earth Explorer. It provide DEM data from the Shuttle Radar Topography Mission (SRTM). SRTM is a global research shuttle owned by the United States Geological Survey (USGS) that provides a geological, topographic and meteorological database for the Earth in a high-resolution digital format represented by digital elevation models (DEM). The accuracy of the DEMs provided by USGS ranges from (1-90) m, and may sometimes reach even less than 1m, depending on the type of study and the data that need to be provided. For the present work, DEM data of 30m resolution has been downloaded for the selected study area. The file downloaded is available in .tiff format.

3. ArcGIS

For the development of the Hydraulic Model of Study Area, Land Use Land Cover map is required. The map is prepared using ArcGIS software. Land use map processed using ArcGIS to identify the land roughness and derive the flow behaviour.

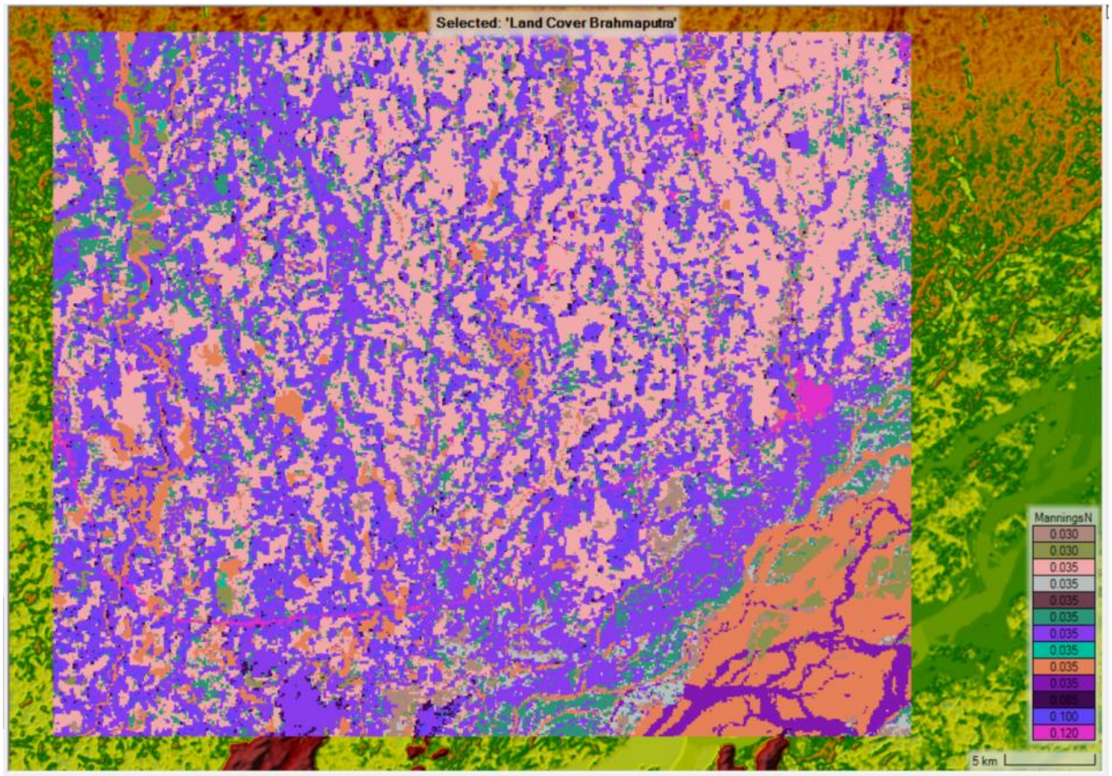


Figure 4.9 : Land Use Land Cover Map of Study Area.

4. Methodology adopted in HEC-RAS:

The 2D modeling capability of HEC-RAS allows for more accurate representation of complex hydraulic conditions, such as flow patterns, water levels, and velocities. For this study the latest version of HEC-RAS *6.5* has been used. The detailed steps for the development of 2D Hydraulic Model analysis has been mentioned in below.

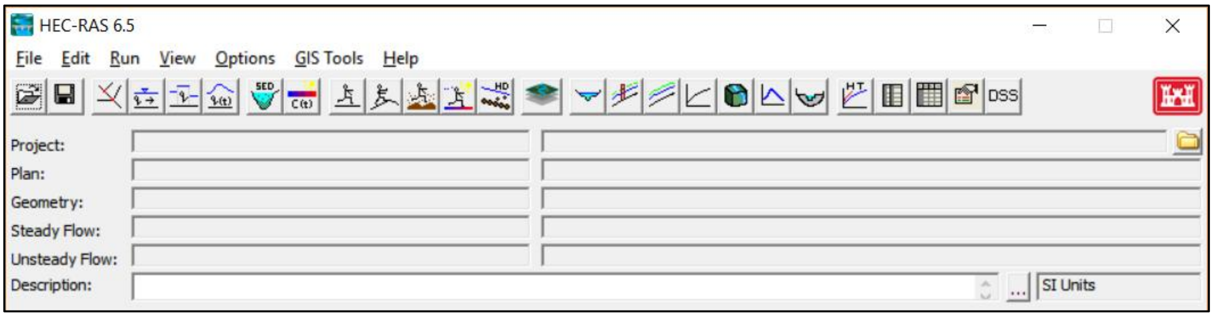


Figure 4.10: Initial Interface of the HEC RAS *6.5*

1. <u>Create a New Project</u> :

Launch the HEC-RAS *6.5* software for the setting up a new project. In the File of the menu a new project can be created and existing project can also be opened. Every file created in the HEC RAS has an extension of .prj. A new project is created for this study. Along with the creation of New Project, the Unit system of the project work has to be defined. HEC RAS enables to work with Two Unit System - US Customary and System International (Metric System). For this modeling of our study area, SI unit system has been considered.

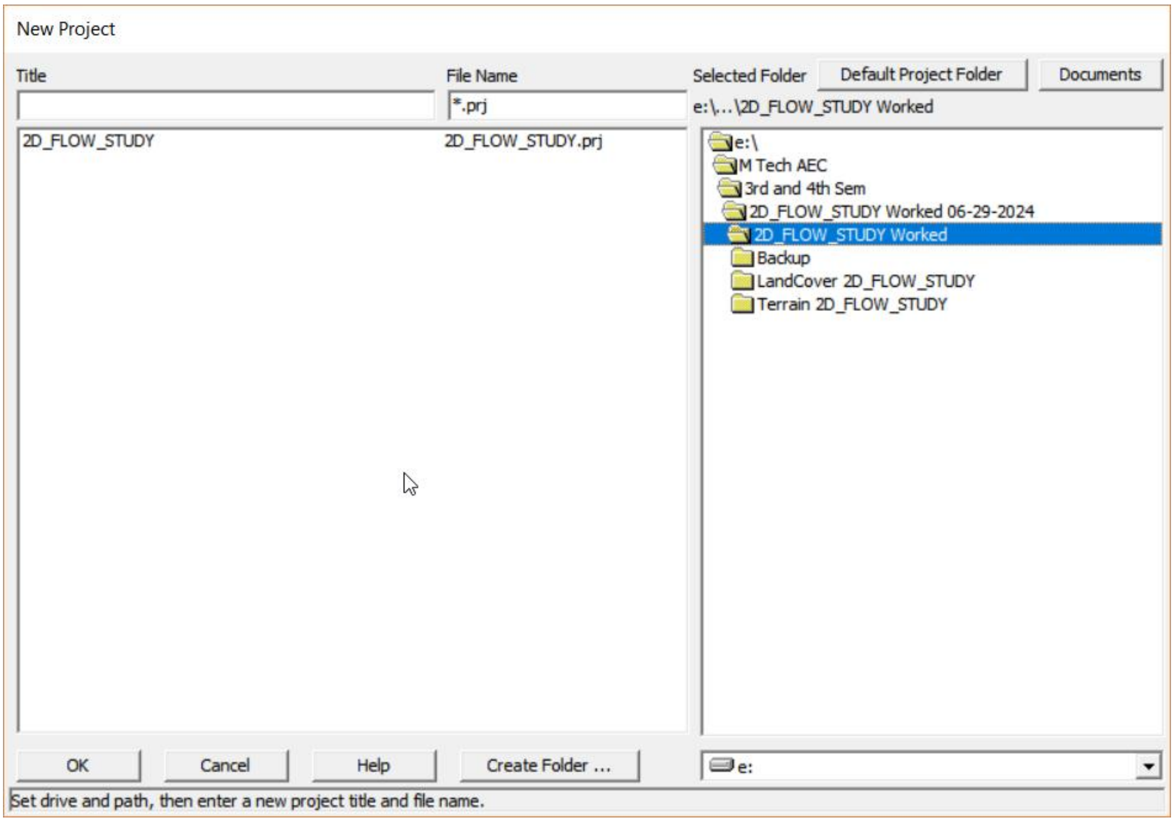


Figure 4.11 : New Project in HEC RAS *6.5*

2. <u>Set the Projection and Create New RAS terrain</u>:

For working with the new project for the selected study area, the coordinate reference system has to be defined. For this, open the RAS mapper of the HEC RAS and in the *project* menu, new projection has been set up based on the study area. This can be done based on the downloaded DEM of the study area. For our study area, WGS 1984 having a UTM Zone of 45 N has been assigned.

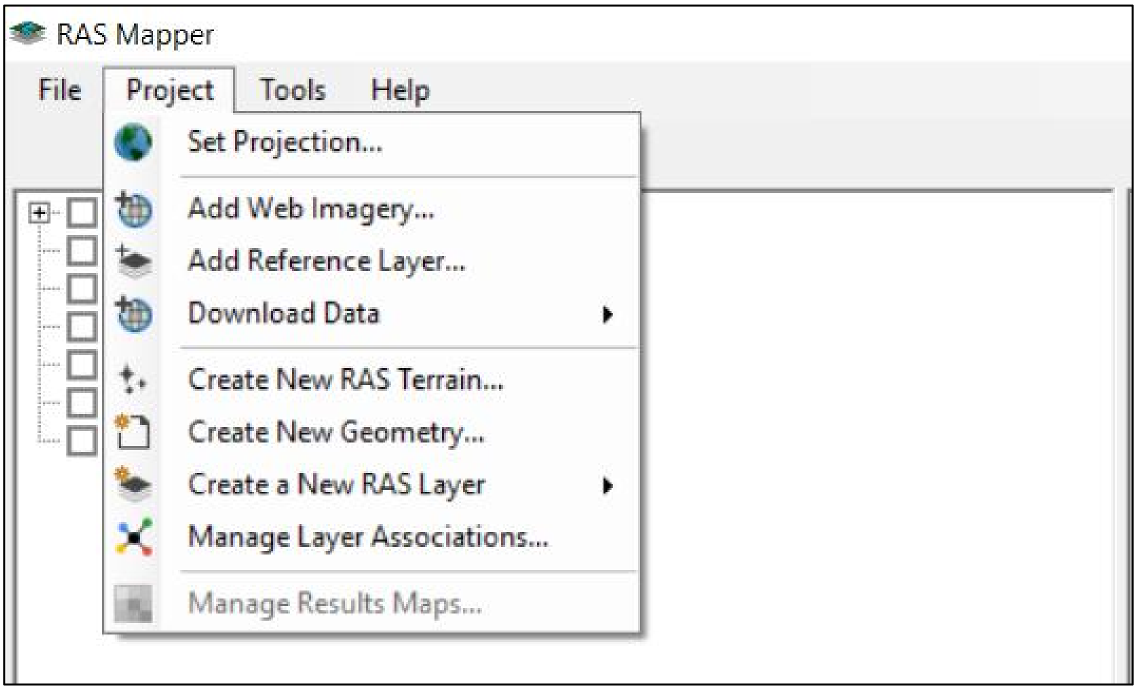


Figure 4.12 : For Projection of Coordinate System and New RAS terrain

After setting up the projection a new RAS terrain has to be created. For this, the downloaded DEM has been imported.

3. Create New Geometry :

A new Geometry File has to be created and the imported terrain is to be selected for this Geometry. On the new geometry, the *2D flow areas* is selected for defining the perimeter of the study area and breakline on the river centreline. Based on the study area, *perimeter* and the *breakline* along the river centreline is drawn on the terrain. Along with it, the Upstream and downstream boundary condition line is also drawn on the terrain from the *Boundary Condition lines* menu.

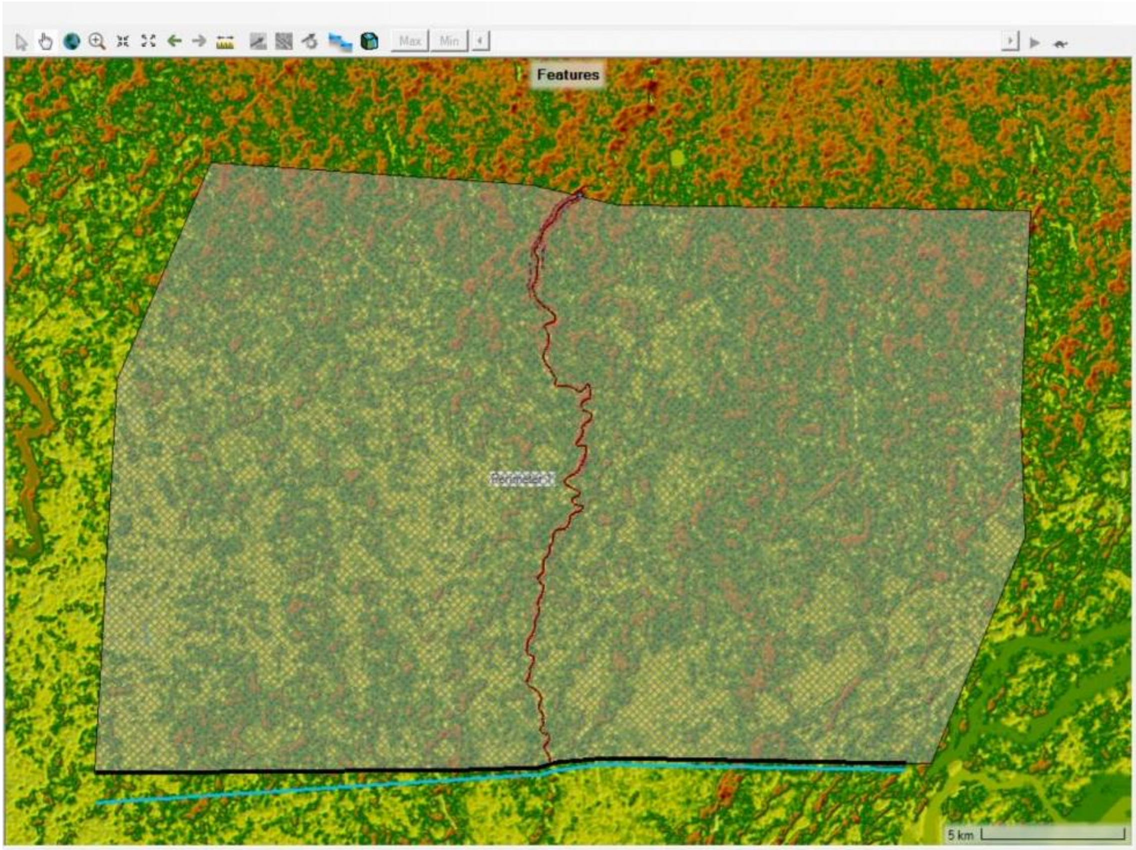


Figure 4.13 : Terrain Showing Perimeter, Breakline and Boundary Condition

4. <u>Assigning Unsteady Flow Data</u> :

After assigning the boundary condition, close the RAS Mapper window and again back to the HEC RAS initial interface. For the 2D Flow analysis, unsteady flow analysis is to be done. For this, unsteady flow data has to be assigned for the study area based on the calculated data. On the *Edit* menu of HEC RAS, *Unsteady Flow Data* is selected for assigning the boundary condition of the study area.

For the upstream boundary condition, Flow Hydrograph is selected and required data is provided by specifying water levels, discharges, or hydrographs as per calculation for the study area. For the downstream boundary condition, Normal depth is considered and friction slope of 0.0002 has been assigned.

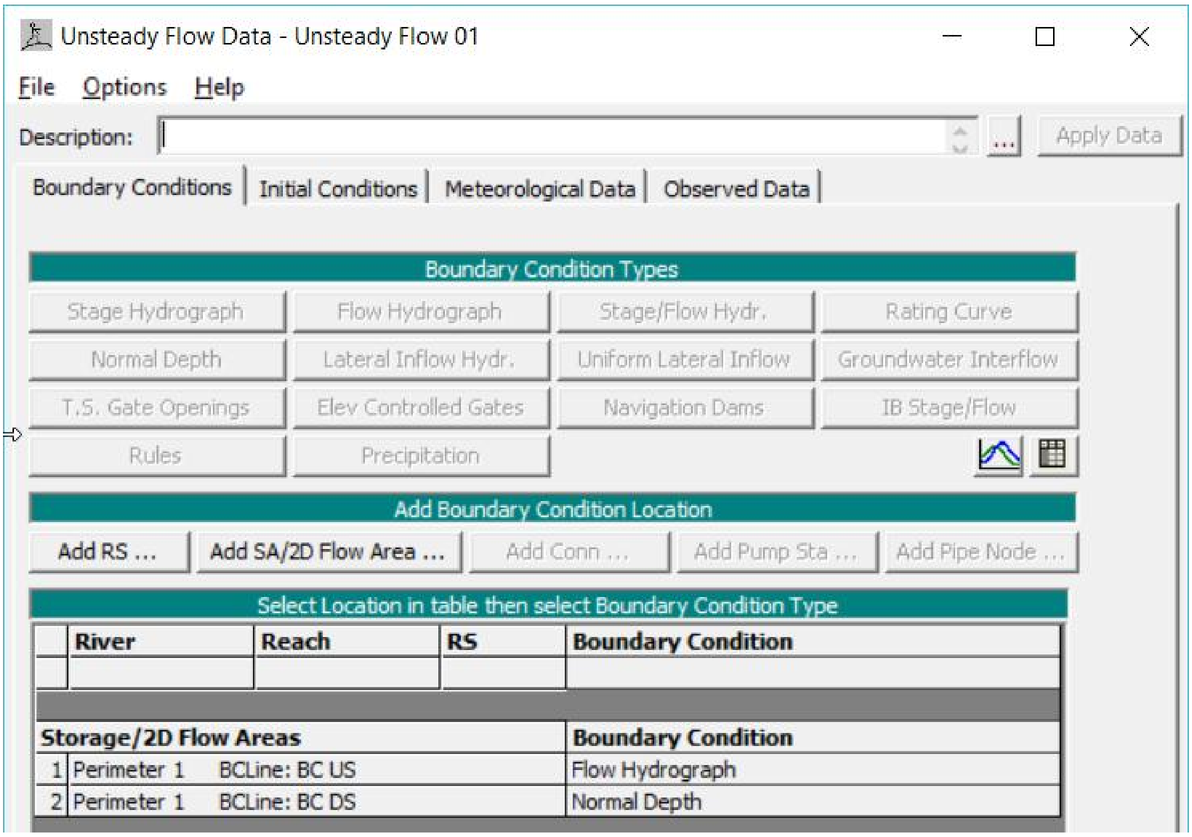


Figure 4.14 : Defining Upstream and Downstream Boundary Condition

5. Unsteady Flow Analysis :

After assigning the Unsteady Flow data as per the study area, the data is to be run in *Run* menu. For this, *Unsteady Flow Analysis* from the *Run* menu is selected. A short ID will created for this analysis without this ID the analysis can not be completed. Here, the program to be run is selected. Geometry pre processor, Unsteady Flow Stimulation, Post Processor and Floodplain Mapping has been selected. The time duration for run the file is selected and click on the *Comput*e menu.

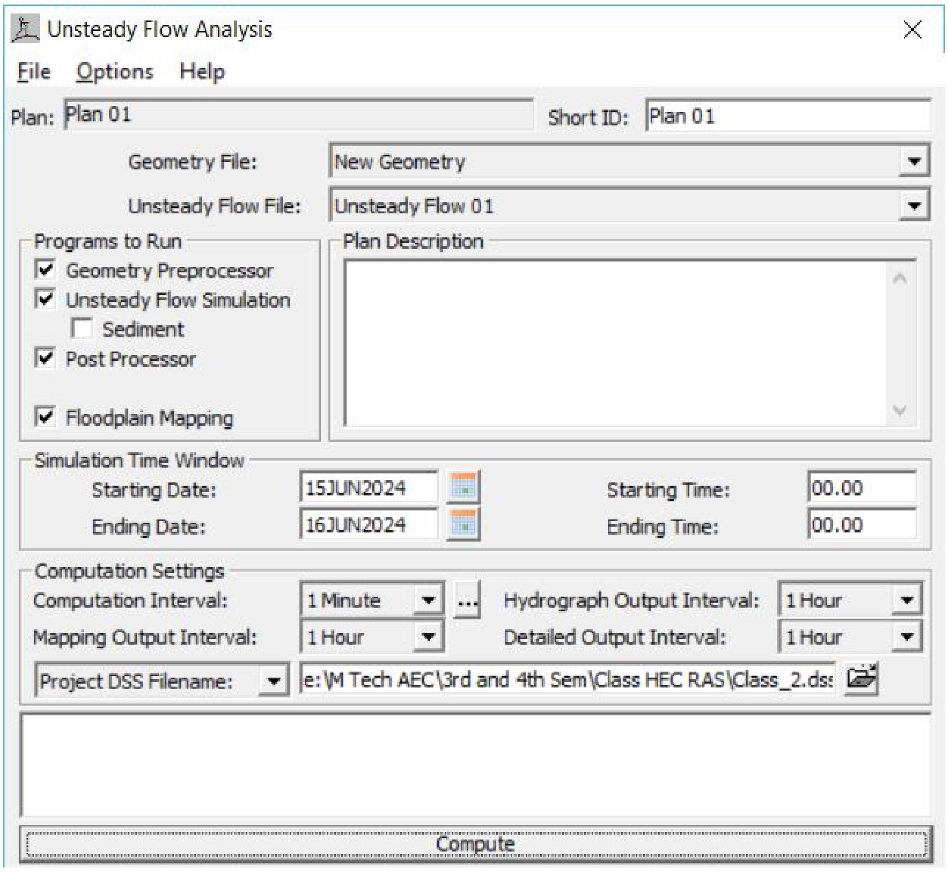


Figure 4.15 : Unsteady Flow Analysis

6. Analysis of Result :

After completing the computation of the Unsteady Flow Analysis, again open the RAS Mapper for viewing the results of the study.

Chapter 5

RESULT AND DISCUSSION

5.1. Results from Data Analysis and HEC RAS (2D Model)

1. Extent of Flood: The hydraulic model results depict the extent of flooding for different peak discharges and return periods. This analysis provides crucial insights into potential flood levels within the study area, offering clear graphical information essential for public awareness, urban planning, and emergency management.

2. **Flood Control Measures:** Utilizing the flood extent data derived from hydraulic modeling, strategic placement and sizing of various flood control structures can be planned. These measures are pivotal in mitigating damages caused by severe floods, safeguarding communities and infrastructure.

3. **Peak Discharge Analysis:** Using available data, the probable maximum flood for the study area has been computed. This information is invaluable for designing structural elements and infrastructure resilient to potential flood events.

4. Depth of Flow Assessment: Analysis of unsteady flow data using RAS Mapper yields insights into the depth of water flow under various flood conditions. This depth information serves multiple purposes in flood risk assessment and preparedness.

The results corresponding to the 50-year and 100-year flood hydrographs obtained from HEC-RAS are illustrated in the following figure. Additionally, to minimize flood impacts, the proposed positions of embankments are delineated in the figure. This visualization aids in understanding flood dynamics and planning effective flood mitigation strategies.

5.2 Results for 50 Yrs Flood Hydrograph

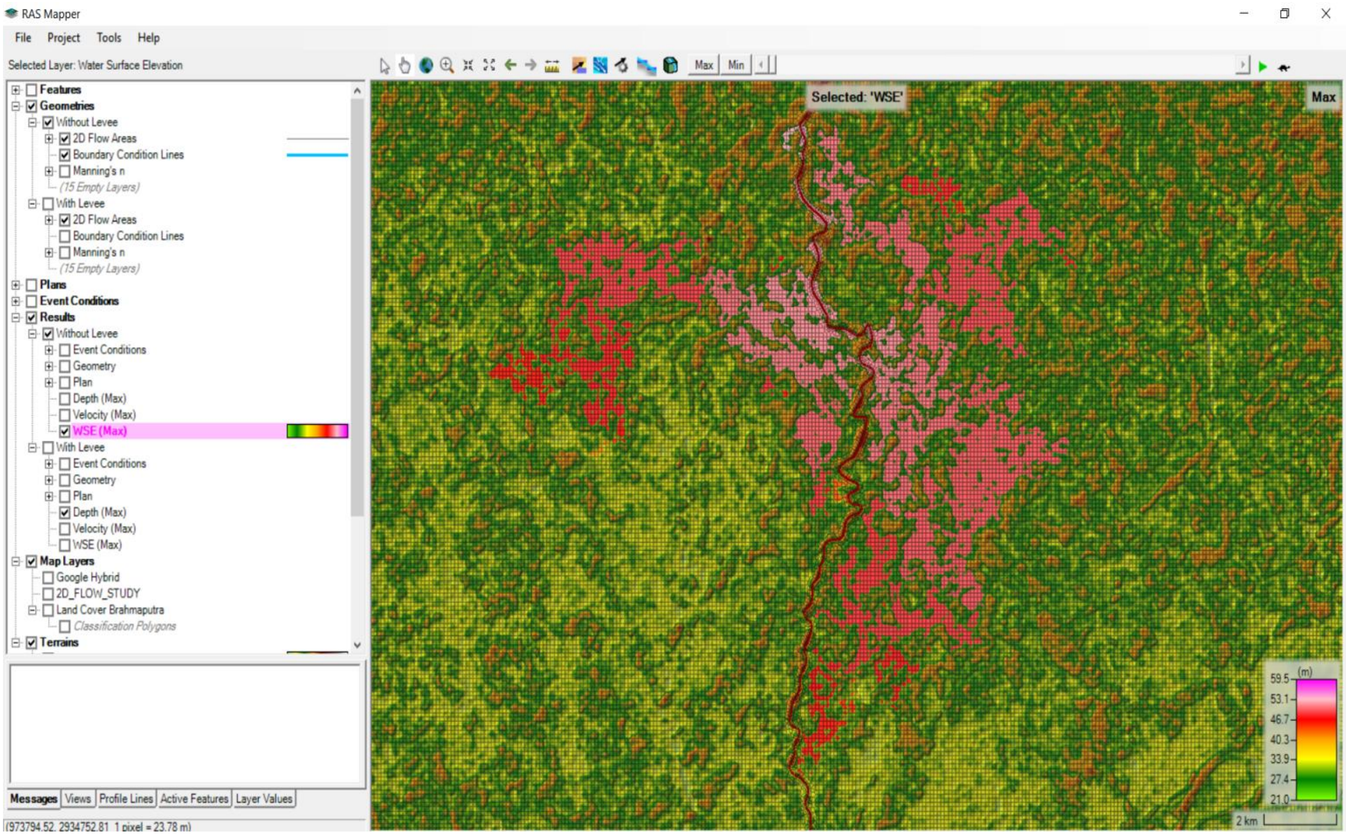


Figure 5.1 : Results showing Water Surface Elevation without Embankment

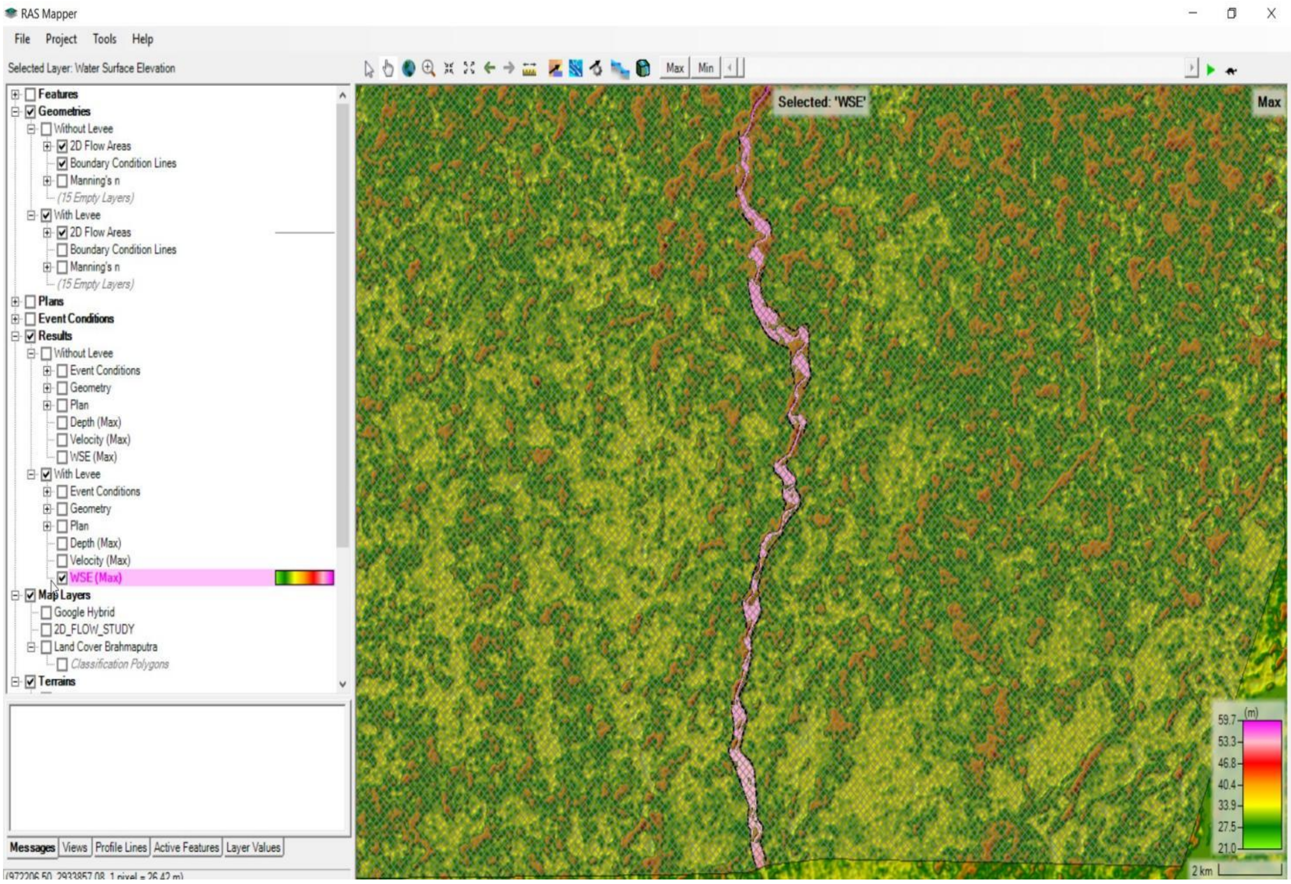


Figure 5.2 : Results showing Water Surface Elevation with Embankment

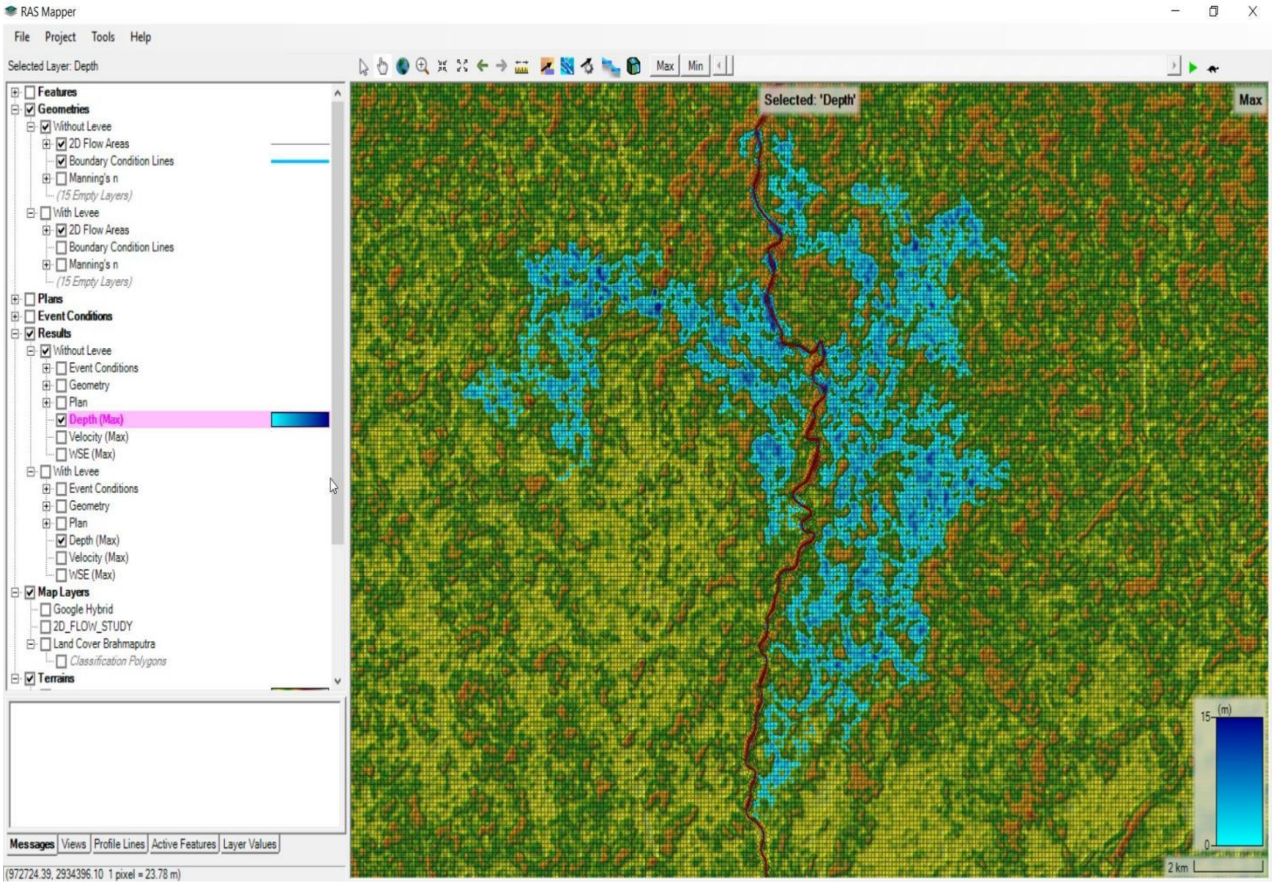


Figure 5.3 : Results showing Depth Profile without Embankment

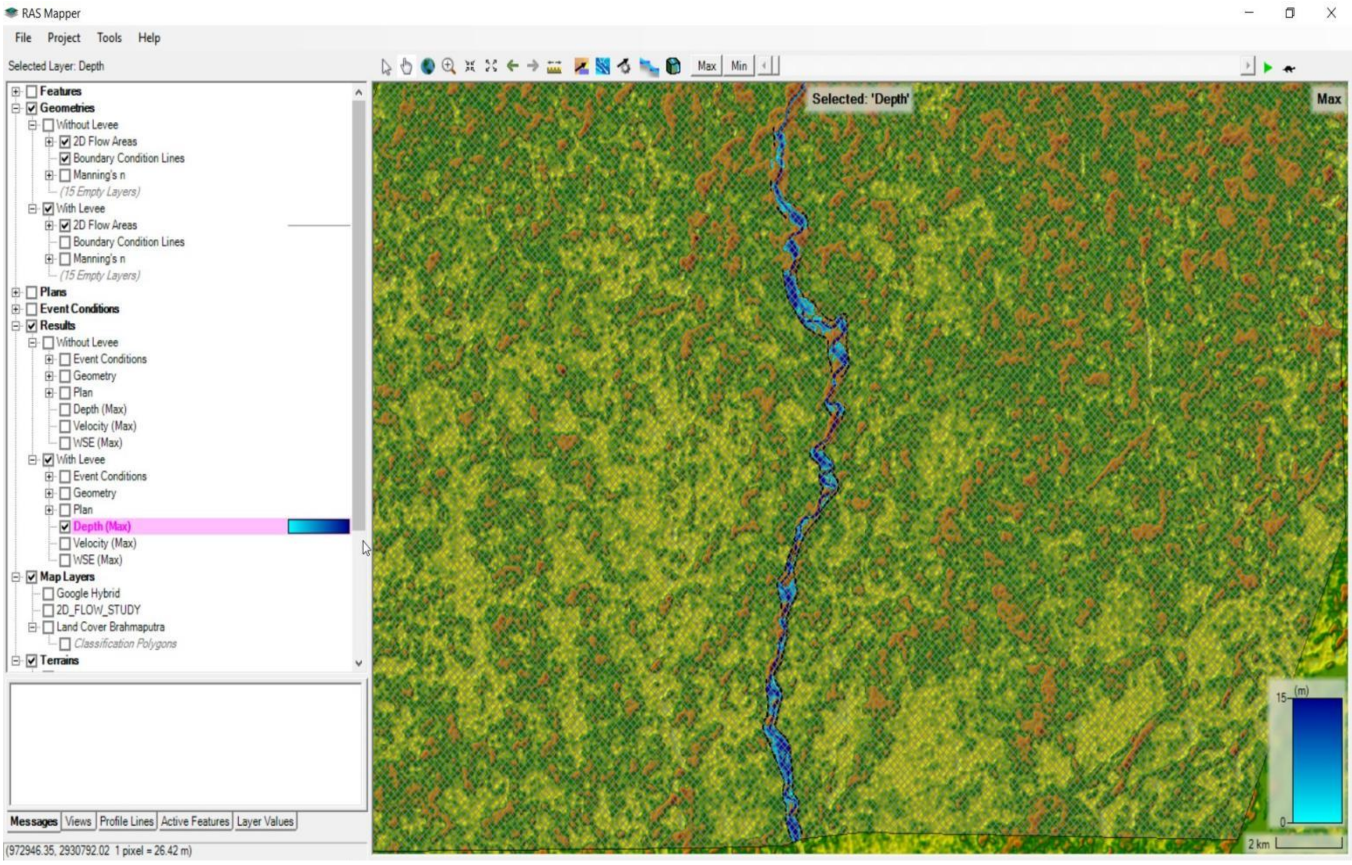


Figure 5.4 : Results showing Depth Profile with Embankment

5.2 Results for 100 Yrs Flood Hydrograph

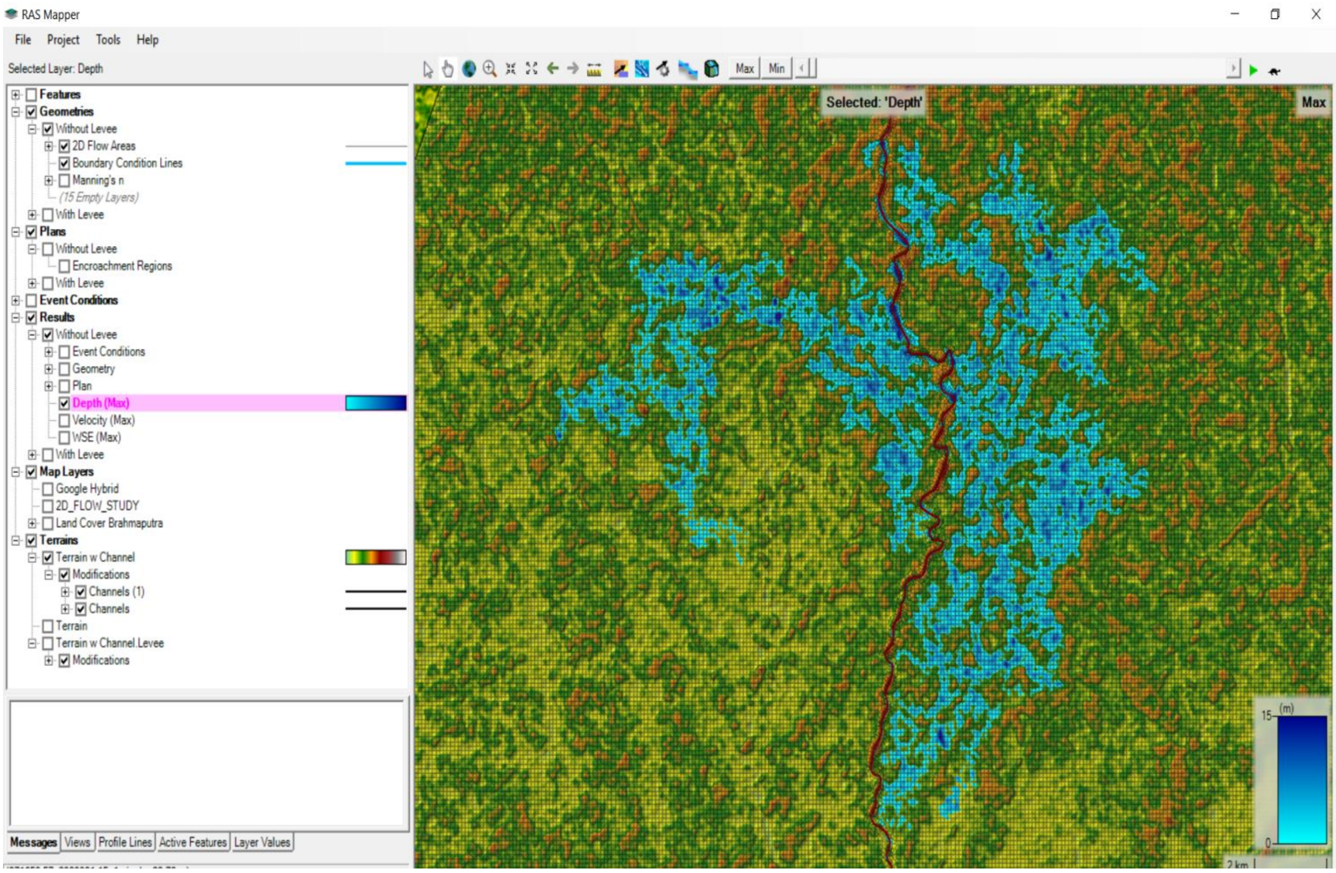


Figure 5.5 : Results showing Depth Profile without Embankment

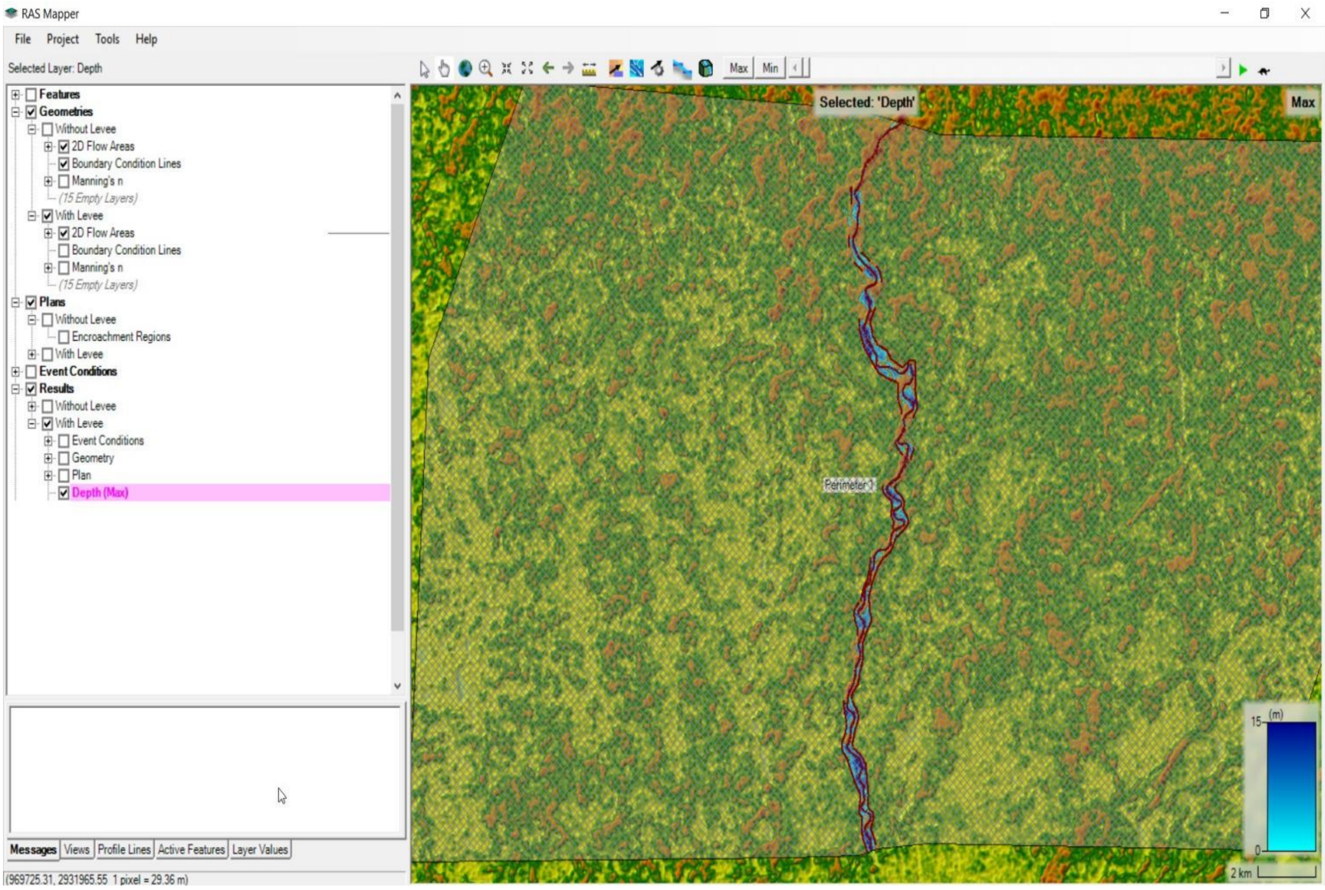


Figure 5.6 : Results showing Depth Profile with Embankment

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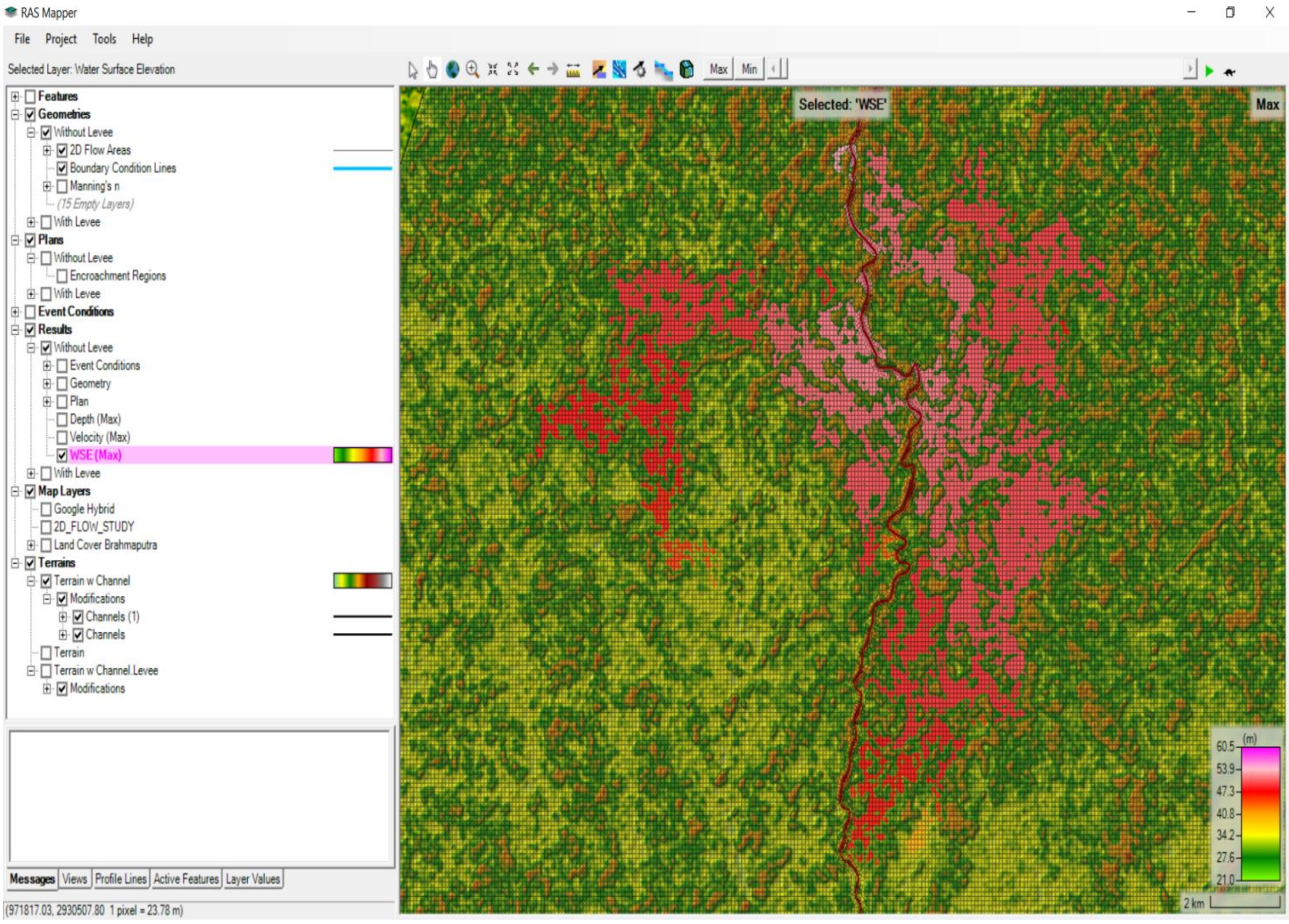

Figure 5.7 : Results showing Water Surface Elevation without Embankment

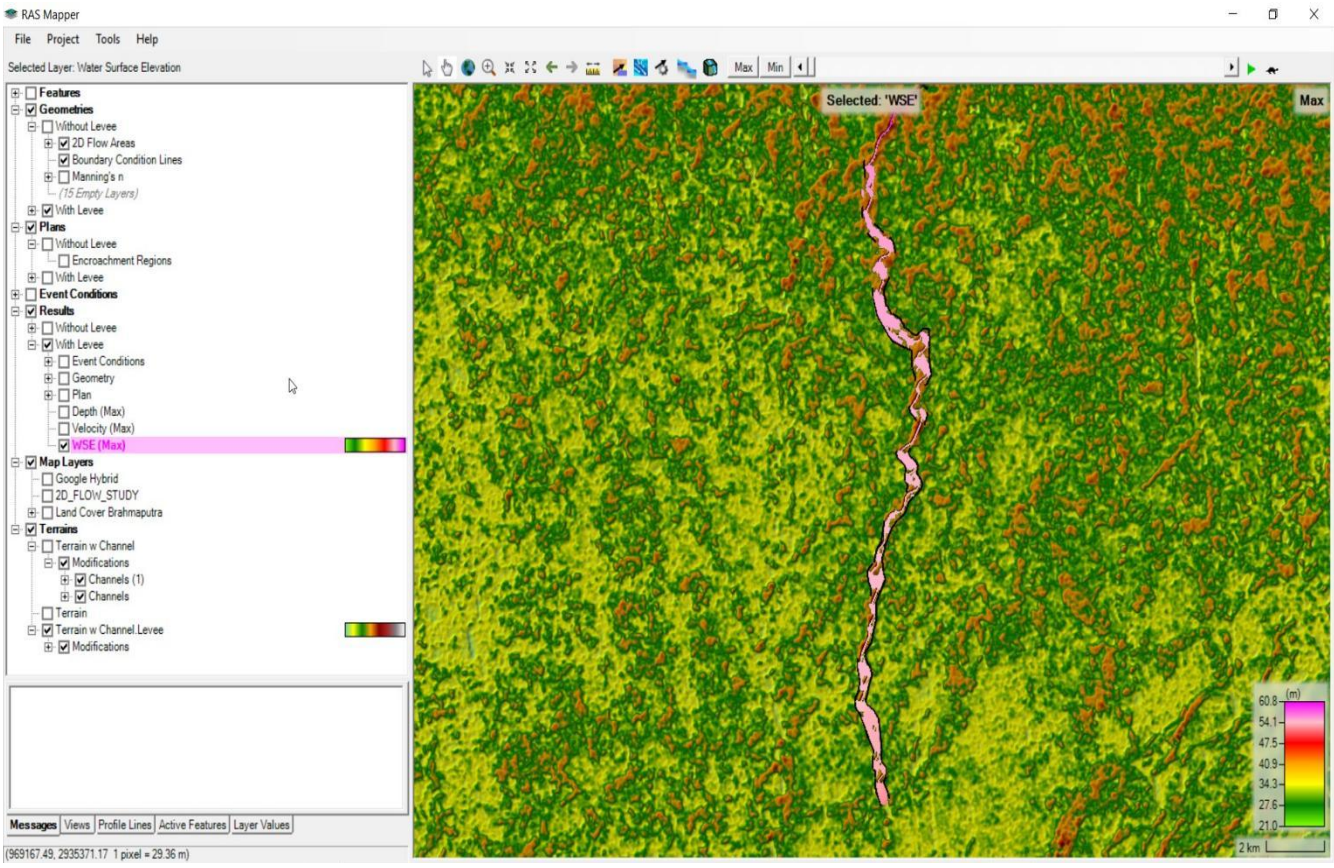

Figure 5.8 : Results showing Water Surface Elevation with Embankment

Chapter 6

CONCLUSION

The Nonoi River, traversing the western part of Darrang district, spans an active floodplain in its final 34 kilometers. This region is particularly vulnerable to bank erosion and channel shifting, exacerbated during the monsoon season. Nearly every year, floods originating from the Nonoi River wreak havoc on the flood-prone areas of Darrang District, resulting in tragic loss of life and extensive damage to infrastructure. The destructive force of floodwaters also leads to road closures, crop devastation, and significant losses in livestock, impacting the livelihoods of local communities.

In response to these recurrent challenges, there is an urgent need to undertake comprehensive floodplain modeling. Utilizing advanced tools such as HEC-RAS, floodplain modeling serves as a critical approach for conducting hydraulic studies and formulating effective flood mitigation strategies.

The primary objective of this modeling effort is to illustrate the extent of flood inundation for different return periods and flood events. By simulating various scenarios, the model identifies optimal locations for constructing embankments along both sides of the river, particularly crucial during extreme flood events. Comparative analysis between scenarios with and without embankments provides insights into the potential effectiveness of such structures in mitigating flood impacts.

Detailed outputs from the modeling include maximum water surface profiles and depth profiles, offering essential data for understanding flood dynamics and assessing risks. These profiles serve as valuable resources for emergency preparedness and infrastructure planning, guiding decisions on where to implement protective measures and enhance resilience against future flood events.

Through a thorough examination of flood inundation modeling and strategic placement of embankments, it is possible to significantly reduce the area prone to flooding. This proactive approach not only aims to safeguard lives and property but also promotes sustainable development in Darrang District by minimizing the adverse impacts of recurring floods.

Further Study :

Here are concise study points derived from floodplain modeling and flood mitigation efforts along the Nonoi River in Darrang District:

1. Hydrological Analysis : Analyze flow patterns, peak discharges, and flood frequency to assess flood intensity and recurrence for effective flood control measures.

2. Geomorphological Assessment : Study channel morphology, sediment dynamics, and erosion-prone areas to identify vulnerabilities during floods.

3. Infrastructure Impact: Evaluate flood impacts on critical infrastructure and recommend resilience-enhancing solutions.

4. Multi-Hazard Risk Assessment : Integrate flood modeling with assessments of other hazards (e.g., landslides, earthquakes) to develop holistic risk management strategies.

5. Monitoring Systems : Establish real-time monitoring systems based on flood modeling outputs to enhance early warning and response capabilities.

6. Social Vulnerability Mapping : Map communities at highest risk during floods considering demographics, socioeconomic factors, and disaster coping capacity.

These study points aim to strengthen floodplain modeling efforts, guiding the development of comprehensive flood risk management strategies for the Nonoi River basin in Darrang District.

References :

1. Usman Khalil, Noor Muhammad Khan, Habib-ur-Rehman (2017) : **"Floodplain Mapping for Indus River: Chashma –Taunsa Reach"**, *Pak. J. Engg. & Appl. Sci. Vol. 20 January, 2017 (p. 30–48)*

2. Anjusha K.K.(2021) : **"Flood Inundation Modelling Using Arc GIS and HECRAS of Godavari Reach, Nanded District"**, *United International Journal for Research & Technology , Volume 02, Issue 07, 2021 , ISSN: 2582-683.*

3. Sravani Duvvuri, Balaji Narasimhan (2013) : **"Flood Inundation Mapping of Thamiraparani River Basin Using HECGeo RAS and SWAT"** *International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 7, July - 2013, ISSN: 2278-0181.*

4. Devashish Pradhan, Ramgopal T. Sahu, and Mani Kant Verma (2022) : **"Flood Inundation Mapping Using GIS and Hydraulic Model (HEC-RAS) : A Case Study of the Burhi Gandak River, Bihar, India".**

5. O. S. Olaniyan , O.M. Olaniyan , I. A. Azeez , A. S. Akolade (2017) : **"INUNDATION AND HAZARD MAPPING ON RIVER ASA"**, USING GIS, *Arid Zone Journal of Engineering, Technology and Environment, December, 2017; Vol. 13(6):868-877*

6. Sunilkumar P. , Vargheese K. O.(2017): **"FLOOD MODELLING OF MANGALAM RIVER USING GIS AND HEC-RAS"**, *International Journal of Advanced Research in Scienec and Engineering, Vol No 6, Issue No 6, June 2017.*

7. Avanti Waghchaure , Aarti Patil , Pragati Bachhav , Rajashri Bodhai (2020): "**Flood modeling and flood forecasting using HEC-RAS"** *International Journal of Advance Scientific Research and Engineering Trends*, *Volume 5, Issue 6, June 2020, ISSN 2456-0774.*

8. T. Siva Subramanian, Tharini Cheyapalan, T. Selvaraj, Dr. V. E. Nethaji Mariappan (2014) : **"Mapping Storm Water Sewer System and using GIS"**, *J. Adv. Res. Civil Env. Eng. 2014; 1(3&4): 23- 32.*

9. Dr. Niranjan Bhattacharjee (2017): **"MORPHOMETRY AND ITS IMPACT ON LANDUSE IN NANOI RIVER BASIN, ASSAM, USING GEOINFORMATICS TOOL"**, *International Journal of Advanced Research 5(4), 1369-1376, ISSN: 2320-5407.*

10. Nilotpal Kalita, Niranjan Bhattacharjee (2024) : **"Estimation of Soil Loss in the Nanoi River Basin using Geospatial Techniques",** *Indian Journal of Science and Technology 2024;17(18):1845–1853*

11. B.Kaviya, Om kumar,Ram Chandra verma, Ramesh kumar ram, Ritesh pal singh (2017) : **"WATERSHED DELINATION USING GIS IN SELAIYUR AREA"***International Journal of Pure and Applied Mathematics, Volume 116 No. 13 2017, 417-423.*