FLOOD MAPPING THROUGH 1D & 2D MODELLING FOR KULSI RIVER USING HEC - RAS

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DECLARATION

I hereby declare that the work presented in the dissertation **“FLOOD MAPPING THROUGH 1 & 2 D MODELLING FOR KULSI RIVER USING HEC RAS ”** in partial fulfillment of the requirement for the awardof the degree of “MASTER OF TECHNOLOGY” in Civil Engineering (with specialization inWater Resource Engineering), submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13 under Assam Science & Technology University,is a real record of my work carried out in the said college under the supervision of Dr. Bipul Talukdar, Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13.

Do hereby declare that this project report is solemnly done by me and is my effort and that no part of it has been plagiarized without citation.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

Due to its location and numerous hydro-meteorological and topographical factors, Assam is particularly vulnerable to river bank erosion and flooding. The Kulsi River, a significant tributary of the Brahmaputra River, originates in the West Khasi Hills of Meghalaya, where it is known as the Khir River. Flowing for 12 kilometers through the picturesque landscapes of Meghalaya, the river then enters the Kamrup district of Assam, where it is referred to as the Kulsi River. The confluence of the Kulsi with the mighty Brahmaputra River occurs at Nagarbera in the Kamrup district of Assam. This merging of waters not only adds to the grandeur of the Brahmaputra but also plays a crucial role in the ecosystem and livelihoods of the surrounding areas. The journey of the Kulsi River from its humble beginnings in the West Khasi Hills to its ultimate union with the Brahmaputra is a testament to the natural beauty and interconnectedness of the rivers that sustain life in the region. A River Analysis System (HEC-RAS) model for the specified study area was created based on the appropriate circumstance. Simulation models have been utilized to analyze and predict river levels at multiple cross-sections based on the gathered performance data. The primary objective of this analysis is to provide valuable insights for decision-makers, urban planners, and insurance professionals. By offering a comprehensive understanding of potential flood scenarios, these simulations aim to support the development of robust strategies for mitigating flood risks and formulating effective disaster management plans tailored to the specific needs of the study area. Such informed decision-making is essential for minimizing the impact of flooding events and reducing associated financial losses in the region.

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CHAPTER 1

INTRODUCTION

1.1 PROLOGUE

River floods have long been recognized as one of the most devastating natural disasters, particularly in urban areas. The destructive power of floods presents a significant risk to human lives, properties, and assets. Therefore, it is crucial to conduct thorough studies and promptly develop flood risk management strategies that prioritize mitigation efforts. Flooding occurs when an area is inundated by a sudden increase in water levels, often caused by factors such as snowmelt, intense precipitation concentrated in both upper and lower basin areas, or dam failures, putting lives and properties in the affected region at risk. Flooding can be a regular and recurring occurrence for rivers, with approximately eighty percent of precipitation events happening during the monsoon season from June to September. These factors, combined with the limited capacity of river systems to handle water flow, contribute to floods, drainage issues, and erosion along riverbanks. Floods occur when excessive or prolonged rainfall exceeds the soil's ability to absorb water and the river channel's capacity to convey it, leading to the overflow of water onto surrounding lands. While floods most commonly occur in monsoon-affected regions, many areas still lack comprehensive flood hazard maps to prevent or mitigate potential damages. Therefore, it is essential to advance the development of predictive models, enhance monitoring systems, and implement regulatory measures and contingency plans to effectively manage the risks associated with flooding.

The evaluation of the potential for increased stream surges has garnered significant attention worldwide over an extended period. Various approaches to mitigating flood risks have been employed, including floodplain management and the application of scientific data to reduce the adverse effects of flooding. Flood damage reduction measures can be categorized into two main types: structural and nonstructural strategies. Structural flood management tactics encompass the construction of dams, channels, diversion channels, and other physical infrastructure designed to alleviate flooding. Conversely, nonstructural flood management methods focus on minimizing flood impacts without the need for physical interventions. A crucial step in optimizing the utilization of surrounding lands involves the anticipation of flood hazards in river systems and the delineation of their boundaries. River zoning maps play a pivotal role in civil engineering projects, as they provide essential information on flood depths and hazard zones. Therefore, it is imperative to prioritize the development of accurate and up-to-date river zoning maps to support effective flood prevention initiatives.

The implementation of relief measures for development purposes is contingent upon the integration and utilization of engineering tools such as flood modeling. Among the various design tools available, flood modeling stands out as a crucial apparatus that provides precise data regarding flood profiles. Key parameters that govern floods include precipitation, runoff, catchment characteristics, and return period. Floodplain studies play a pivotal role in offering insights into water surface profiles and creating floodplain maps that are essential for land-use planning in flood-prone areas.

In-depth floodplain studies often encompass the analysis of historical floods, which serve as a basis for model calibration to ensure accurate replication of water surface elevations observed during significant flood events. Developing hydrological models that provide a simplified representation of real-world scenarios can be a complex undertaking, particularly in regions with limited data availability, emphasizing the importance of meticulous calibration of such models.

The efficacy of a river flood model hinges on its ability to accurately represent river channel and floodplain geometries, along with precise depiction of model parameters, enabling the precise prediction of flow magnitudes and water levels along the river stretch. Computer modeling plays a crucial role in these analyses by facilitating the prediction of water surface profiles under varying flow conditions. Traditionally, computed water surface elevations are manually transposed onto paper maps to delineate floodplains. However, advancements in computer program tools have streamlined this process by extracting spatial features essential for hydraulic models from both GIS and non-GIS datasets.

By leveraging such simulations, insights into the historical human interventions within the river system can be gained, enabling an examination of the significant impacts of land-use changes on river performance over time. This spatial and temporal data serves as a vital input for flood management strategies and developmental planning initiatives. Software tools that offer a versatile array of options for modeling hydraulic systems have been effectively deployed in similar medium mountain regions, leading to numerous international publications and research endeavors.

River Kulsi, a vital southern tributary of the mighty Brahmaputra, stands as a crucial sanctuary for the endangered Gangetic dolphin (Platanista gangetica) within the scenic landscapes of Assam. Noteworthy studies have documented the presence of 29 individual dolphins in this ecologically significant watercourse. The existence of this top carnivore and indicator species, akin to the tiger's importance in forests, not only underscores the river's ecological value but also paints a vivid picture of a thriving freshwater ecosystem, as seen in the case of Kulsi.

Recent comprehensive surveys have revealed the remarkable abundance and diversity of fish and aquatic invertebrates inhabiting the waters of the Kulsi river. Researchers have identified a rich tapestry of aquatic life, with a total of 63 fish species spanning 8 orders and 21 families. Within this diverse aquatic community, six species are exotic imports, while the remainder comprises indigenous fish species prized for both their ornamental allure and economic significance. Adding to this aquatic tapestry, some have also reported the presence of five distinct crustacean species flourishing within the river's nurturing embrace.

Moreover, the Kulsi river banks not only support a varied array of semi-aquatic macrophytes but also foster a heterogeneous assemblage of these plant species. Thriving under the influence of heavy rainfall, high humidity, and moderate to high temperatures, semi-aquatic macrophytes such as Ipomoea carnea ssp. fistulosa exhibit prolific growth during the monsoon and early autumn seasons, contributing to the river's overall ecological richness and complexity.

Geographically, the Kulsi river originates in Meghalaya (25°38°N, 91°38°E) before traversing approximately 120 kilometers into Assam, where it eventually merges with the Brahmaputra at Nagarbera. Surrounded by a network of wetlands, the likes of Chandubi and Deeporbeel play pivotal roles in nurturing a healthy prey base for the endangered Gangetic dolphin thriving in the Kulsi's waters. Additionally, the river receives sustenance from various tributaries, including Botha, Kharkhari, Boko, Singra, and other smaller streams, further enhancing its structural complexity and ecological significance.

The cultural and societal importance of the Kulsi river extends to the 25 villages dotting its course, with seventy percent of the local populace relying on its waters for essential daily activities such as fishing, sand mining, cattle bathing, and recreation. Serving as a lifeline for the communities it touches, its rich biodiversity and ecosystem services are invaluable to the region's well-being.

Nevertheless, the very existence of the Kulsi river faces imminent threats in the form of rampant sand mining, overfishing, unregulated motorboat traffic, riverbank erosion, and the looming specter of dam construction. Urgent action in the form of strategic planning, continued research efforts, and heightened awareness campaigns are imperative to safeguard the delicate ecological balance of the Kulsi river and ensure its sustained vitality for generations to come.

Therefore, it is important to understand suitable methods to safeguard the delicate ecological balance of the Kulsi river and protect the communities it touches during a major flood like situation.

Program frequently utilized in combination with HEC-RAS is ArcGIS, a powerful tool that enhances the analysis of hydraulic systems. The essential inputs to HEC-RAS in this study incorporate the waterway release, channel, floodplain geometry, and channel resistance, all crucial elements for accurate hydraulic modelling. The HEC-RAS hydraulic model serves as a simplified representation of stream flow, with GIS strategies aiding in the seamless generation of flood visualizations. These visualizations serve a vital purpose in flood relief efforts and basin planning, facilitating various studies such as flood estimation, flood inundation modelling, analysis of different flood control methods, addressing social implications of dam removal, and the development of early flood warning systems.

This study leverages these tools to highlight the flooding potential in the study region due to urbanization and extreme precipitation events, while also evaluating the effectiveness of utilizing wetlands as a mitigation measure. Through the utilization of HEC-RAS, this study demonstrates a comprehensive analysis and simulation of hydraulic flows within the water system network. The accurate portrayal of hydraulic processes provided by HEC-RAS positions it as a fundamental tool in this study, enabling a detailed examination of the impact of urban development and climate events on the water system.

1.2 OBJECTIVE OF THE STUDY

The Objectives of the study are as given below:

i. The development of a hydrological model by a 100year return period rainfall that will generate hydrograph at the upstream boundary of our study area.
ii. Development of hydraulic/ hydrodynamic model for the river Kulsi (Assam region) for assessment of Flood Vulnerability.
iii. Development of Flood Plain map of the study area

1.3 SCOPE OF WORK

The project entails the thorough examination of flood vulnerabilities along the Kulsi River in Assam, a critical task in assessing and managing flood risks. Leveraging the sophisticated 2D modeling capabilities of HEC-RAS, the analysis will yield a wealth of detailed data encompassing water surface elevations, inundation depths, and flow velocities throughout the targeted region. Through meticulous comparisons and analyses, a comprehensive flood map of the area will be crafted, pinpointing specific elevated terrains suitable for serving as evacuation sites in times of severe flooding. Moreover, the project's mandate extends to formulating strategic recommendations aimed at enhancing flood risk management practices, ensuring the implementation of proactive measures to safeguard against potential inundation threats.

1.4 METHODOLOGY

- **Study Area Definition**: Define the geographical scope of the study covering the Kulsi River basin in Assam, including key hydrological and topographical features.
- **Data Collection**: Gather rainfall data, basin characteristics (such as land use, soil type, and slope), and topographic maps necessary for modeling.
- **Flow Hydrograph**: Develop a Flow Hydrograph based on historical data and basin characteristics at the starting of the study area to represent a 100-year return period rainfall event.
- **1D and 2D Modeling**: Implement HEC-RAS for both 1D and 2D modeling to simulate flood scenarios, including peak discharge and flood hydrographs.
- **Scenario Analysis**: Evaluate flood extents, water surface elevations, inundation depths, and flow velocities under different scenarios.

- **Strategies**: Recommend elevated land within a flood prone area that can act as a evacuation point during a major flood event.

1.5 ABOUT KULSI RIVER

The Kulsi River, a significant tributary of the Brahmaputra River, originates in the West Khasi Hills of Meghalaya, where it is known as the Khir River. Meandering through the lush and verdant landscapes of Meghalaya for a distance of approximately 12 kilometers, the river gracefully traverses the picturesque terrain before entering the Kamrup district of Assam, where it assumes the name by which it is widely recognized, the Kulsi River. The merging of the Khir River into the larger water body brings about a transition not only in nomenclature but also in the scale and significance of the river's journey. The confluence of the Kulsi with the mighty Brahmaputra River occurs at Nagarbera in the Kamrup district of Assam, a site where the meeting of waters symbolizes not just a physical union but a blending of destinies.

This juncture between the Kulsi and the Brahmaputra is not merely a geographical phenomenon; it holds profound ecological and socio-economic implications for the region. The convergence of these two water bodies contributes to the magnificence of the Brahmaputra, enhancing its volume and majesty as it continues its onward flow. Moreover, the mingling of waters at this confluence plays a vital role in sustaining the ecosystem and livelihoods of the communities dwelling along the riverbanks. The fertile soils nourished by the merged waters support agriculture and fisheries, providing a source of sustenance for the local populace.

The journey of the Kulsi River, from its humble origins in the West Khasi Hills to its eventual confluence with the Brahmaputra, serves as a poignant reminder of the interconnectedness and interdependence of natural water systems. Through its course, the river epitomizes the harmonious coexistence of various water bodies, each contributing to the vitality and resilience of the broader ecosystem. The story of the Kulsi River encapsulates the inherent beauty and significance of rivers in shaping the landscapes and livelihoods of the regions they traverse, underscoring the profound bond between water, land, and life.

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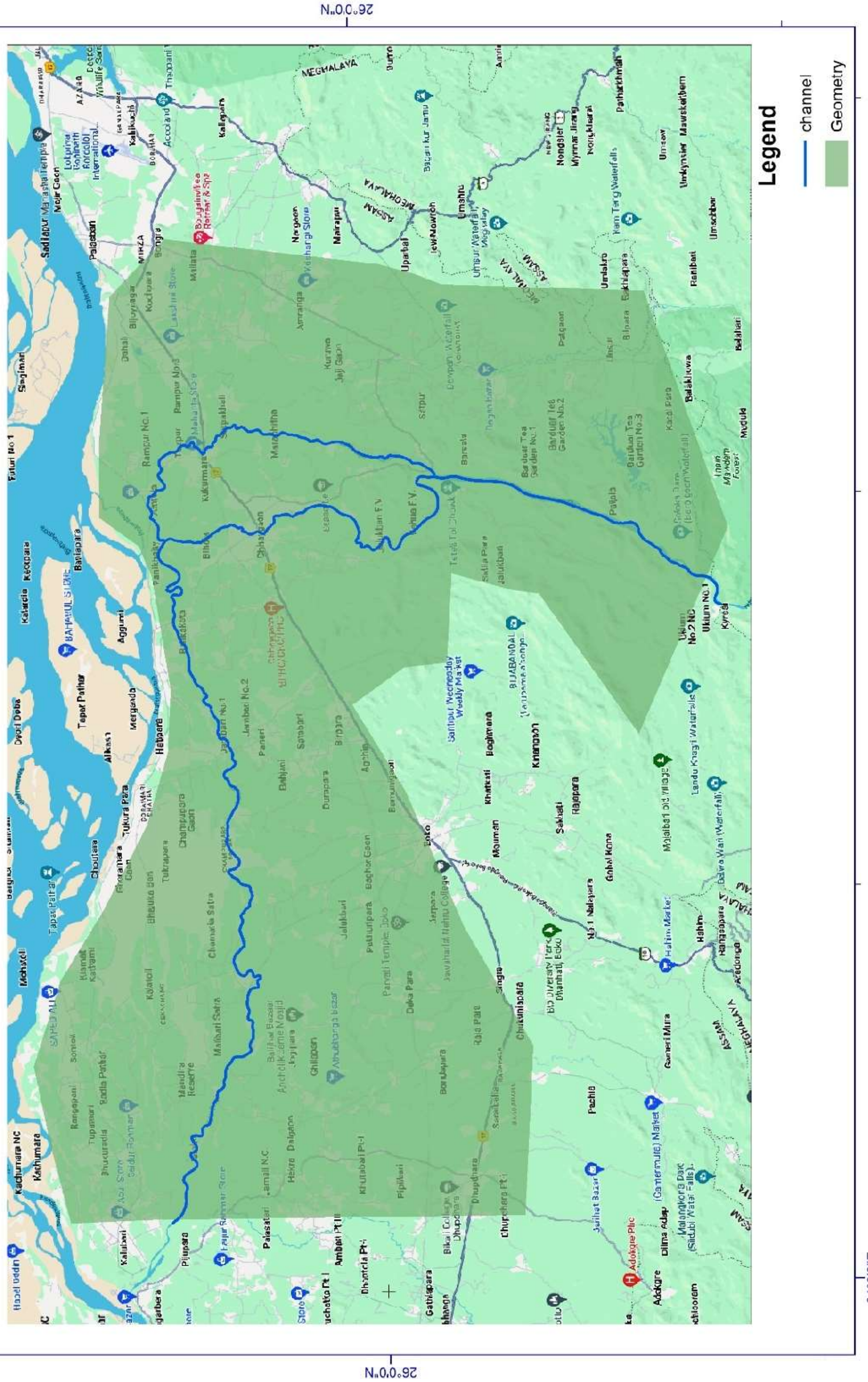
1.6 CHAPTERWISE PLANNING

- **Chapter 1:** Introduction- Overview of the Kulsi River: origin, flow path, and significance. Importance of flood mapping. Objective and scope of the study
- **Chapter 2**: Literature Review- Review of existing studies and Exploration of methodologies and models used for flood vulnerability assessments globally and regionally.
- **Chapter 3**: Study Area and Materials- Description of the study area: geographical extent, topography, and hydrological characteristics. Use of HEC-RAS software for 1D and 2D flood modelling. data collection methods: discharge data, basin characteristics, and topographic maps.
- **Chapter 4**: Methodology- Development of flow Hydrograph for 100-year return period rain. Detailed explanation of 1D and 2D modeling techniques in HEC RAS.
- **Chapter 5**: Results and discussions- Analysis of flood extents, water surface elevations, inundation depths, and flow velocities. Generation of flood maps.
- **Chapter 6**: Conclusion- Summary of findings and key conclusions drawn from the study. Future research directions: areas for further study and improvement in flood modeling and mitigation strategies.
- **Chapter 7**: References- Comprehensive list of sources cited throughout the report and literature review.

Fig 1.1 Map showing the study area of the Kulsi river



<u>**CHAPTER 2**</u>

LITERATURE REVIEW

In continuation with endeavour of exploring the available works related to the topic, some literatures have been reviewed. These literature reviews demonstrate the familiarity of this topic and scholarly context. This study is an effort mainly to focus on the floodplain modeling using hydraulic models. Different researchers used different types of techniques and methods for flood control in order to protect the riverbank. A summary review of previous similar researches dealing with the floodplain modelling using hydrodynamic models is presented in this chapter.

Yi (Frank) Xiong (2011) has done a Dam Break Analysis Using HEC-RAS. Break parameters prediction, the understanding of dam break mechanics, top outflow expectation were shown as the fundamental for the dam break investigation, and inevitably decided the misfortune of the harms. As an application example, Foster Joseph Sayers Dam break was further modeled and analysed utilizing USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) model based on accessible geometry information. Combination of mechanics and case studies, reflection of overwhelming instruments of head cut erosion, more particular categorization of dam, judicious examination and induction of dam break prepare are required in creating a satisfactory dam break recreation model.

From this study it is known that the dam breaks due to piping elongates the time period of high-water surface level, which increments the term of chance. In any case, the dam break does not increment the down stream's most extreme water surface height (Max. W.S. Elev) significantly at past design "Probable Maximum Flood (PMF)". Foster Joseph Sayer dam break has more prominent effect on the downstream area which is closer to the dam in accordance with the comparison of the hydrographs at different areas.

Yongping Yuan et al. (2011) done a project on floodplain Modeling in the Kansas River Basin Using Hydrologic Engineering Center (HEC) Models. In this study, it focused on highlighting the flooding potential for Kansas River region and also for using wetlands as a mitigation option. Various tools such as Hydrologic Engineering center- Hydrologic Modeling system (HEC-HMS) and Hydrologic Engineering center- River Analysis System (HEC-RAS) which is used for various types of studies such as building flood forecasting, flood inundation models, to analyze various flood control, early flood warning system, etc.

A GIS device ICLUS's projections of urban land use densities for 2020 were adjusted to show expanding densification of urban regions, by converting low concentrated improvement to medium concentrated in 2030 and to high concentrated improvements in 2040. The paper concludes that there will be an increase in peak runoff and flood inundation for different storms from baseline scenario to 2040 which is about 15% increase in runoff for all the land use and design storm scenarios.

Ali M. F et al. (2013) has done Integration of HEC-RAS and geographical information system (GIS) in the hydrological study of peak flow response to deforestation on a small watershed in Malaysia. The geological informations were prepared utilizing geographical information system (GIS) to appear the lands utilize alters within the study range. The hydrological information was analyzed through relapse investigation, stream length bend, and soil conservation service (SCS) strategy for analysing runoff for land use change. The relapse investigations have found critical increment of r2 value from 3.1% between year 1990 to 1996, 7.5% between year 1997 to 2000, and 13.2% between the years of 2001 to 2006. The stream length bend has chosen streamflow information event on December 28 to 29, 1996 on the Kinta Stream at outlet of Kinta watershed result which has appeared volume of stream flow that was 2.209 × 106 cumecs.

From the study it is concluded that the precipitation was not the major contributing figure, hence when precipitation condition was kept consistent, the runoff varieties were primarily coming from land use alter of watersheds or land use periods, which too got to be further examined. Estimate of basin is too another factor. Little basins act in an unexpected way from the huge ones in terms of the relative significance of various stages of the runoff phenomenon. In small catchments the overland stream stages are fundamental over the channel stream. Hence, the land use and concentration of rainfall have a critical part within the peak flood.

Sunil Kute et al. (2014) has done a flood modeling of river Godavari using HEC-RAS. The flood discharged for Gangapur dam, which is built on upstream of Nashik city at 14 km separate is considered for the modeling. The surge release is based on the most exceedingly worst discharge of 1969 surge. The stream, 14 bridges over the stream and the flood plain were modeled. The demonstrate encourages to find the surge plain and its degree for compelling surge relief measures.

After giving all the input parameters to the program for the computation, the yield in terms of the table and the graphs is gotten which incorporates: value of ground elevation, velocity head, water surface elevation, total velocity, max channel depth, losses, average velocity, wetted perimeter etc. The rating curve and for the given release, the submergence at the given section is additionally shown which the level of flood appears.

Muhammad Shahzad Khattak et al. (2015) has done a case study on Kabul river using HEC-RAS and ArcGIS. Khyber Pakhtunkhwa Province, which experienced uncommon floods in July/August 2010 uncovering the helplessness of the area to this natural catastrophe were measured. The peak floods from recurrence investigation were input into HECRAS model to discover the corresponding surge levels expected along waterway reaches expanding through Warsak dam to Attock. Results found from HEC-RAS model were utilized in combination with ArcGIS to prepare floodplain maps for different return periods. Through floodplain maps, regions that are vulnerable to flooding dangers have been recognized.

Urban areas such as those of Nowshera are also vulnerable to flooding, which was also evident in July/August 2010 floods. It is clearly visualized from the floodplain maps that with one in 100-year return-period surge, the levels of inundation are generally four times that due to ordinary flow. Therefore, it is greatly vital to supply assurance to cities such as Charsadda and Nowshera on both banks of the stream mainly through raising of embankments.

Vieux Boukhaly Traore et al. (2015) has done a hydraulic analysis of the Kayanga River Basin, Senegal using HEC-RAS. In this paper, the river reach selected which is located between the Niandouba dam and Kounkane threshold and the flow characteristics to analyze the hydraulic behavior of this system is analyzed using HECRAS model. ArcGIS computer program is additionally utilized to extract the bathymetry for the separated cross segment and the distance between two adjoining cross sections which help in creating the river geometry in HEC-RAS.

The study concluded that the HECRAS model is utilized to analyze dynamic of stream in Kayanga waterway basin. The main stream characteristics along the study reach is being calculated which offer assistance the decision makers in finding the high, low and constant flow characteristics regions and also the expansive and contractive area regions. The above results too offer assistance the concerned parties for water assignment, water administration, hydraulic structure execution, natural planning and surge control ministration in Kayanga Stream.

Chandresh G. Patel et al. (2016) has done a case study on Surat city in which floodplain Delineation Using HECRAS Model is done. Stream area near Nehru Bridge is utilized as test case to recreate surge stream. Discharges rise to to food return period for 25 and 32 have been utilized for examination of surge situation. Result of the research clearly demonstrates that most of the zone of the Surat city is submerged for a depth of 2.5 to 4.0 m when the release discharged from Ukai dam rises to to return period of 32 a long time (25768.09 Cumecs).

A few stream cross areas have been recognized which can not contain release that's likely to come for return period of 25 years. It is additionally illustrated that most of the low lying region of the city is submerged at release breaks even with to return period of 32 years. Basic remedial measures have been recommended in arrange to anticipate surge impact in low lying region of Surat city up to a few degree. One of the foremost critical lessons learnt from the study is that the use of GIS for the undertaking of surge recreation can progress precision and can too demonstrate cost-saving for floodplain outline.

Uttam Aryal et al. (2016) have done a study on flood hazard assessment in Dhobi-Khola watershed (Kathmandu, Nepal) using hydrological model. In this study, the flood prone areas of the Dhobi-Khola watershed were identified and using HEC-RAS and GIS, the flood risk area was also delineated. With discharge data of Gaurighat and rainfall data of Sundarijal stations, the model was calibrated and validated in Bagmati river watershed and then transported to Dhobi-Khola watershed using hydrological data of Budhanilkantha station.

The flood risk evaluation makes a difference to decide the high flood risk zones in advance, which helps to require moderation measures effectively and productively. As expressed by diverse consider related to Bagmati, a few destinations that are close Anamnagar, Thapagaun, underneath Bhatkekopul, behind Sukedhara which fall beneath the High Danger, Exceptionally High Hazard, Extremely High Risk category. So, the levee height ought to be remade with detail hydro-engineering survey in arrange to avoid future immersion.

Rahul Agarwal et al. (2016) unsteady flow analysis in lower Dudhana river using HEC-RAS. Calculation of surface water elevations on downstream side of upper catchment of Dudhana Stream for diverse sum of releases additionally incorporates assurance of flooding zone at distinctive amount of the discharge for different time arrangement from dam. Consequently, stimulate the basic circumstance of flood and its affect on Dudhana River basin on downstream side. Study reach consists of 21 cross sections.

Steady and Unsteady flow was effectively run for Dudhana Stream and 3D view of discerning plot for single discharge for given study zones. The execution of calibrated show has been confirmed for previous discharges from dam in last year records. Moreover, model can be geo-referenced with Google earth and flooding can be highlighted on Google map.

Adebayo Kehinde John (2017) has done a case study on Eleyele catchment area. He determined the flood plain map and run off computation using Geographic information system (GIS). Five maps which includes topography map were generated i.e land use map, digital elevation model (DEM) map, Hydrology map, Triangulated irregular network (TIN) map which finally gives us the flood plain area.

The taking after conclusions were made based on the discoveries from this study that the geographical and DEM maps of Eleyele catchments appear that there's notable lower of heights within the southern portion of the catchment outline which has influenced the hydrological design of the catchment, the hydrological maps of Eleyele catchment appears streams were amassing within the lower locale of the catchment range, the surge plain outline created from the TIN of the study region appears that 50% of the Eleyele catchment region are inclined to surge and these ranges are strikingly of moo elevation.

Azhar Husain (2017) has done a Flood Modeling by using HEC-RAS. Right now steady and unsteady streams are available and silt transport is beneath improvement. A key element is that all three components will utilize a common geometric information representation and common geometric and hydraulic computation schedules. In addition to the three hydraulic investigation components, the framework contains a few hydraulic design features that can be conjured once the fundamental water surface profiles are computed. The main objective is to supply an surge control system in which all computations made by the different territorial included in river training.

The output from the HEC-RAS model was utilized to decide the degree of overtopping of bridges/barrages within the study reach when subjected to surge of a given magnitude. With increased stream flows at distinctive areas within the future, the vulnerability of the basin to high magnitude flooding events is likely to extend beneath future climatic change within the River basin framework.

Thet Hnin Aye et al. (2017) has developed a Flood Inundation Map for Bago River Basin, Myanmar. In arrange to perform waterway flood risk mapping, HECHMS and HEC-RAS were utilized as hydrological and hydraulic models, individually. Three flood events were connected to calibrate and approve the come about. The most elevated profundity of immersion can seriously affect the upper portion of Bago city zones and downstream country ranges counting the paddy areas.

In this study, the investigation embraced illustrated that the model is right now at the restrain of prescient capacity for flood immersion, but the results of calibration and approval indicated acceptable comes about in recreating the surge occasions. The results of the hydrologic demonstrate may be encourage moved forward by installing a thick arrange of gaged stations. They accept the data inferred from this study can contribute to evaluating the plausibility of surge harm for the neighborhood population and for those locations where information is constrained, such as in Myanmar.

Amina Azouagh et al. (2018) has done a study on Integration of GIS and HEC-RAS in Floods Modeling of Martil River (Northern Morocco) using HEC-RAS. This investigation, therefore, presents flood mapping and classification of hazard regions utilizing the Hec-GeoRas and Hec-Ras hydraulic demonstrating devices integrated into the Arcgis information framework. The outcome demonstrate that the utilize of aerial photographs provides a great information of the morphology and physical characteristics of the waterway, which is able offer assistance choice creators to prevent flooding in the urban range of Tetuan, Morocco.

The overall outcomes permitted to find flood zones, velocities and heights of water, etc. These results are dependable and are steady with the morphology of the field. The study region has experienced significant rebuilding amid the last twenty a long time in parallel with the improvement of mindfulness of the flood issue: bridges, dams, tunnels, recovery of the river and its tributaries have been built, however it only takes a stormy day for the roads and neighborhoods to be submerged in water permitting panic to set in again.

Shayannejad M et al. (2018) has done an analysis on open channel networks using HEC-RAS. In this paper, an illustration was solved in unsteady stream utilizing HEC-RAS. In this procedure, the energy and duration equations are chosen for consistent, gradually differing stream by the Newton–Raphson procedure and the advertised technique is utilized to tree-type and looped-channel systems.

Results obtained from HEC-RAS model were connected in compound with ArcGIS to provide floodplain maps for variation return cycles. Hydrologic procedures are strategies that clarify the computation of flow circumstances in a channel reach. Routed hydrographs for standard and composed channels are at that point contrasted with a river analysis system model (HEC-RAS). Those output obtained shows that the recommended model (HEC-RAS) procedure is useful in directing a organize hydrograph.

Avanti Waghchaure et al. (2020) have done a flood modeling and flood forecasting using HEC-RAS. The flood prediction of Mutha Stream utilizing HEC-RAS has talked about in this paper. In Maharashtra, Pune city faces issues of floods and harms amid rainstorm. Forecast of stage of stream amid the surge requires scientific modeling of the river. The study speaks to the significance of 2D modeling of surge issues which makes a difference to create administration techniques to handle the likely future occasions by employing flood chance reducing measures.

This paper presents a technique for modeling and forecasting of surge caused due to numerous reasons like heavy rainfall, destitute stream basin, and need of space for water flow in riverbed due to urbanization. The result table of hydraulic properties and all profile plots can too be utilized in future arranging of developmental works. Display circumstance of stream basin shows that it will not be able to carry tremendous surge. So it is very critical to extend estimate of waterway.

Raymond Diedhiou et al. (2020) has done a case of Senegal River Estuary Downstream Diama Dam. The study carries out the hydraulic modeling of the estuary of Senegal stream downstream of the Diama Dam in transitory mode by the HEC-RAS computer program. The primary geometric model, of which the regions of Senegal stream downstream Diama Dam have been represented by cross-section, is one-dimensional. The second one is also one dimensional in which the region of the Senegal Stream estuary downstream Diama Dam is presented as water capacity zones.

The outcomes obtained from HEC-RAS simulations are the varieties of the water levels, the transient variations of the flow rates for each segment, the most extreme stream velocities and the engendering times of the flood waves. These results are solid and steady with the morphology of the estuary. To oversee flood circumstances amid water discharges at the Diama dam, real-time water level checking and estimation gear should be introduced upstream of the dam. This demonstrates may be at that point can be utilized as a decision instrument by the concerned authorities.

CHAPTER 3

STUDY AREA AND MATERIALS

3.1 STUDY AREA

The River Kulsi, known as Khri in the upper catchments in Meghalaya, is a major southern tributary of Brahmaputra in Assam, India. The river originates from the northern slopes of the Khasi Hill ranges, enters Assam at Ukiam and after flowing through the plains of Kamrup District, Assam outflows into the river Brahmaputra near Nagarbera. It is composed of three rivers, namely Khri, Krishniya and Umsiri, all of which originate from West Khasi Hill range and flow north and finally join the Brahmaputra. The hill range is covered with evergreen forests and gets high rainfall during the monsoon. The river has total catchments of 3231sq. km out of which about 1666sq. km is in Khasi hills in Meghalaya and the rest is in the plains of Assam. The total length of Kulsi from its source to outfall is about 220km out of which 100km is in Meghalaya and the rest 120 km is in Assam. Climatically, the study area falls under sub-tropical monsoonal type of climate with an average temperature of 23ºC and around 10ºC during summer and winter seasons respectively. The study area has a population density of 489 persons / km^2. Surrounded by a network of wetlands, the likes of Chandubi and Deeporbeel play pivotal roles in nurturing a healthy prey base for the endangered Gangetic dolphin thriving in the Kulsi's waters. Additionally, the river receives sustenance from various tributaries, including Botha, Kharkhari, Boko, Singra, and other smaller streams, further enhancing its structural complexity and ecological significance.

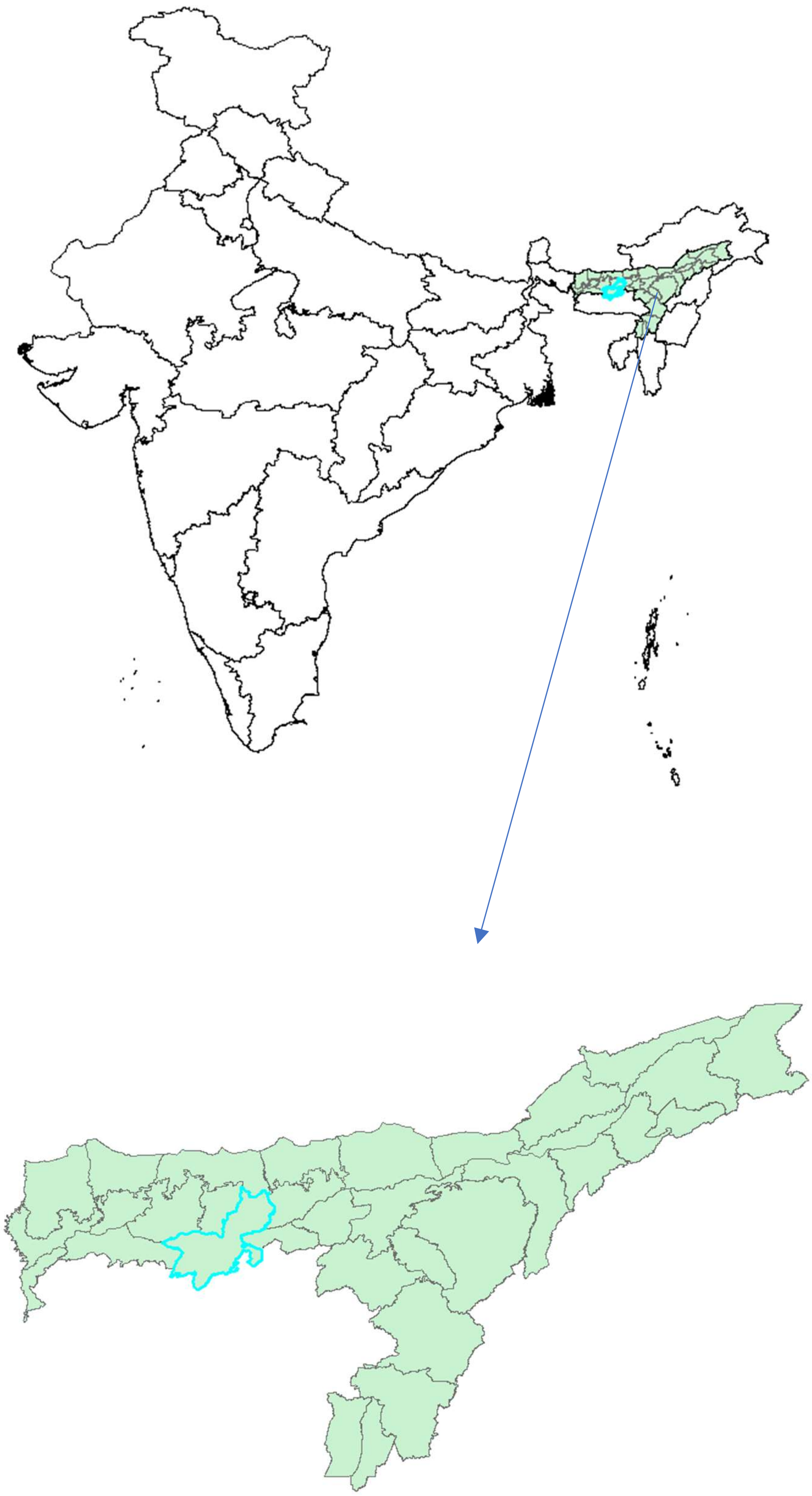


Fig 3.1: Map showing India and the state of Assam

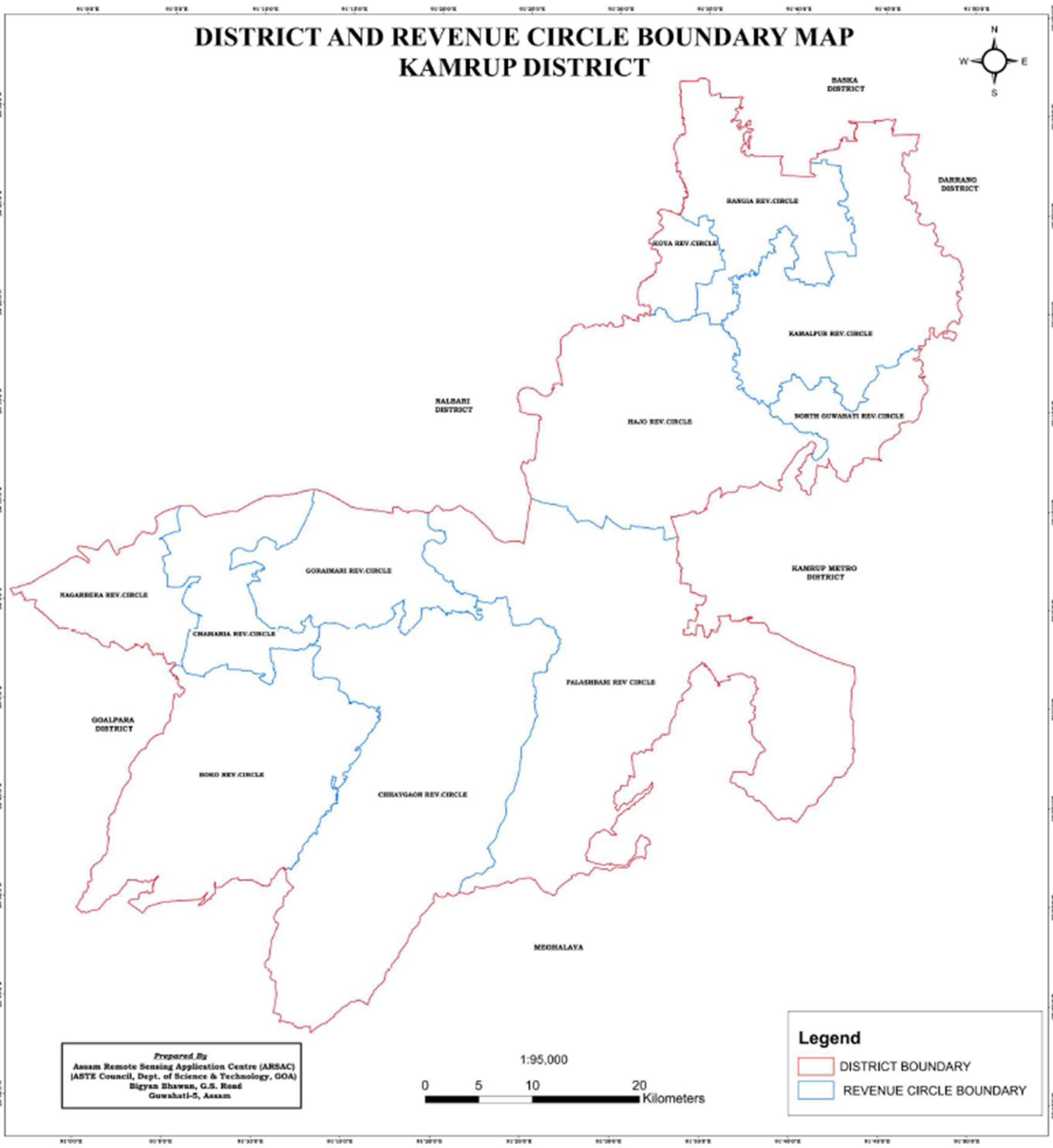


Fig: 3.2 Map showing Kamrup district where our study area lies

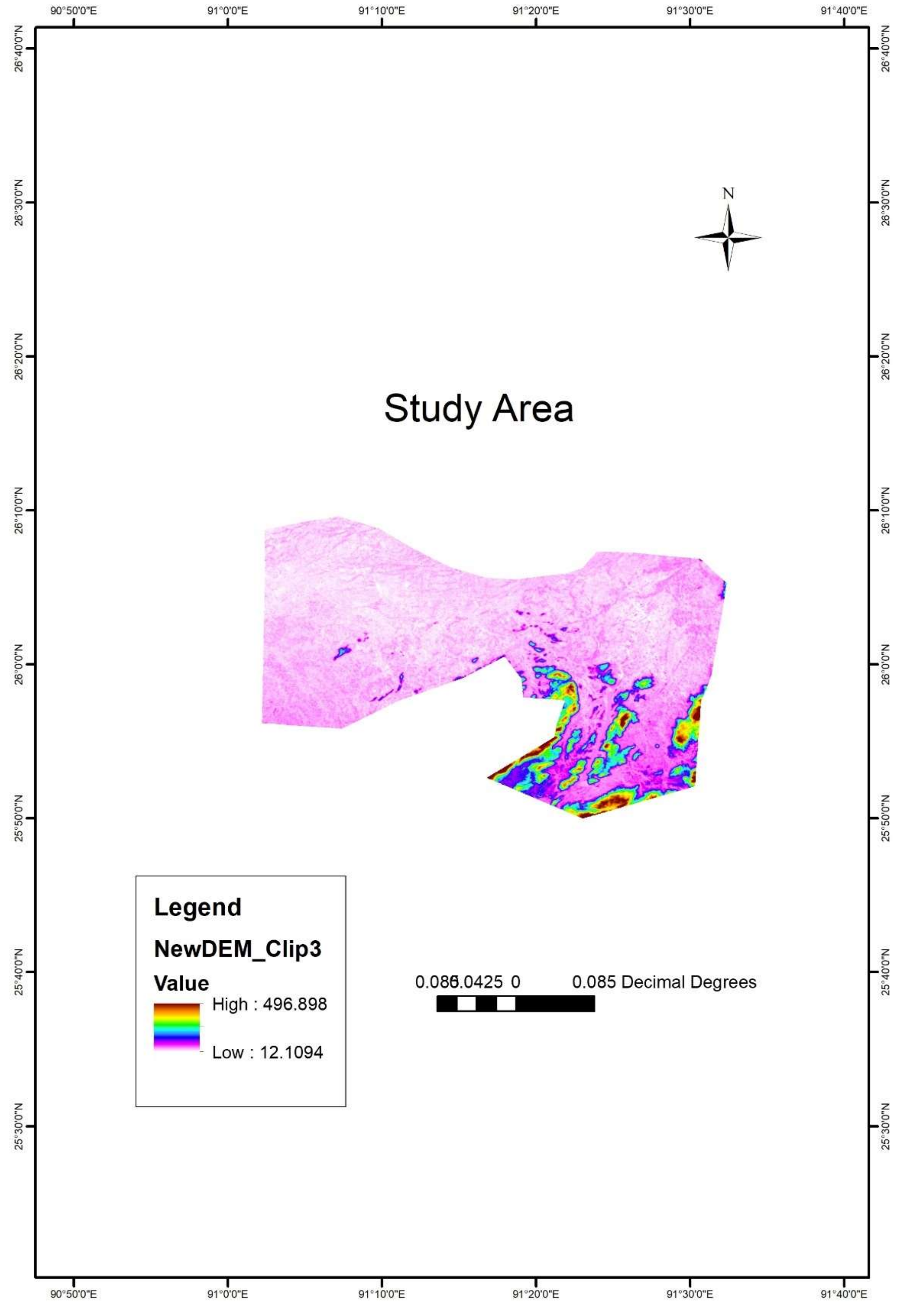


Fig 3.3: Study Area

3.2 MATERIALS:

3.2.1 Google Earth Pro- Google Earth Pro is a versatile geospatial desktop application renowned for its comprehensive features that enable users to traverse the globe and craft intricate maps with precision. Facilitating a seamless exploration experience, Google Earth Pro now grants all users unrestricted access to top-tier aerial photography and detailed ground imagery, enhancing the ability to delve into various geographical regions. Complementing its bird's eye view of the Earth, this cutting-edge application boasts a diverse array of tools and layers to aid in the investigation of our planet's landscapes. Undoubtedly, Google Earth Pro stands out as a proficient and sophisticated software solution readily available to consumers. In the course of this research endeavor, a specific study area will be delineated, focusing on establishing accurate river centerlines that will subsequently be exported to ArcGIS for further analysis and utilization.

3.2.2 ArcMAP- ArcGIS is a powerful geographic information system (GIS) developed and maintained by the Environmental Systems Research Institute (ESRI). This sophisticated software is specifically designed to handle maps and geographic information, offering a wide array of functionalities to assist users in various geospatial tasks. Among its many capabilities, ArcGIS enables users to create and utilize maps, compile geographic data, analyze mapped information, share and discover geographic data, integrate maps and geographic information into diverse applications, and effectively manage geographic information within a comprehensive database system.

3.2.3 HEC-RAS– This software, HEC-RAS, is a hydraulic model developed by the Hydrologic Engineering Centre as a primary adaptation of the steady flow model HEC-2, which was first introduced in 1966. The evolution of the software took place in 1990, marking a significant advancement in the field of hydraulic engineering. With the progression of computer technology, the original HEC-2 program underwent a transformation into the more sophisticated and user-friendly HEC-RAS program, which operates on Windows-based systems and offers a graphical user interface (GUI) for hydraulic modeling. HEC-RAS is a comprehensive system designed for interactive use in a multitasking environment, incorporating a GUI, distinct analysis components, data storage and management capabilities, as well as graphical visualization and reporting features. Being developed by U.S Federal Government resources, HEC-RAS is in the public domain and can be freely used, copied, distributed, or redistributed. Nonetheless, users are kindly requested to provide appropriate acknowledgment to the Hydrologic Engineering Centre in any subsequent application of this software.

The fundamental computational strategy is based on the solution of the one-dimensional energy equation. Energy losses are assessed by friction (Manning's condition) and contraction and expansion. The Momentum equation is used in circumstance where the water surface profile is rapidly varied and Energy equation is only valid for gradually varied. These circumstances incorporate mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and assessing profiles at stream confluences (stream intersections).

HEC-RAS models can viably utilize to improve and simplify the forecasts of regions likely to be immersed beneath a given flood. The HEC-RAS model was at first utilized for calculating water surface profiles for 1D steady state flow. It provides the modeler with an option to utilize either the steady flow or unsteady flow option. Along with the unsteady and steady flow choices, the HEC-RAS model too gives the various capabilities such as modeling of open channel systems and single streams (both unsteady and steady flow alternatives), analysis of bridges, weirs, and culverts (unsteady and steady stream choices), displaying capacity zones, route dams, tunnels, pumping stations, and levee failures (unsteady flow option only), handling of subcritical, supercritical, and mixed-flow administrations (steady flow option only). In this study, the stream geometry has been imported from ArcGIS to HEC-RAS and after that it'll be further utilized to consider the stream characteristics for both steady and unsteady conditions such as finding discharge at distinctive cross section of the river, velocity of the river at distinctive areas, etc which can offer assistance in flood mapping.

3.2.3 HEC-HMS The Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) stands as a prominent software solution meticulously crafted by the Hydrologic Engineering Center (HEC) under the auspices of the United States Army Corps of Engineers. Revered for its robust capabilities, HEC-HMS serves as an indispensable tool in the realm of hydrological modeling, exhibiting a specialized focus on replicating the intricate hydrologic processes occurring within a given watershed. Widely embraced by a spectrum of professionals including engineers, hydrologists, and researchers, HEC-HMS plays a pivotal role in the analysis and prediction of watershed and river system behaviors across an array of hydrological scenarios. Its sophisticated functionality empowers users to delve deep into the dynamics of water flow, enabling a comprehensive understanding of the complex interactions within hydrological systems and contributing significantly to informed decision-making in water resource management.

HEC-HMS allows users to simulate various hydrological processes, including rainfall, runoff, evapotranspiration, snowmelt, and more. The software provides a comprehensive platform for building watershed models and assessing the impact of different factors on the water cycle.

3.3 DATA:

3.3.1 Rainfall Data:

The Rainfall data of the Study Area in obtained from the website of India water Resource Information System.

Table 3.1: Rainfall Data from year 2005 to 2020

Year	Maximum rainfall in a single day (mm)
2005	250.65
2006	188.45
2007	120.33
2008	90.48
2009	85.55
2010	166.70
2011	250.37
2012	101.62
2013	180.63
2014	190.57
2015	155.43
2016	71.27
2017	142.07
2018	169.57
2019	353.16
2020	370.00

CHAPTER 4

METHODOLOGY

4.1 INTRODUCTION: The methodology used for preparation and assessment of Model is illustrated through the following FLOW CHART.

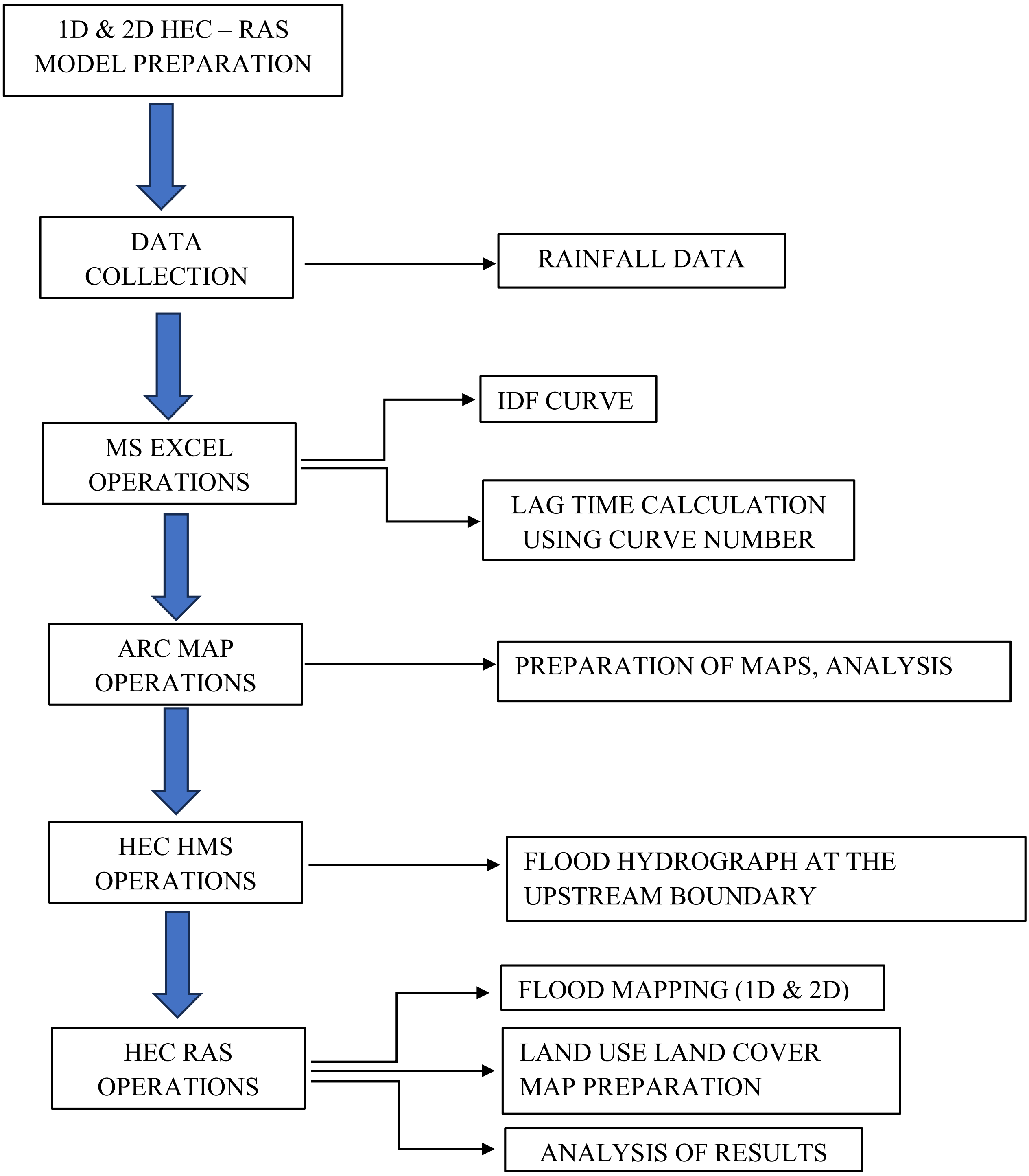


Fig 4.1: Operational Flowchart

4.2 OPERATIONS IN GOOGLE EARTH PRO:

Firstly, the DEM is downloaded from www.opentopography.org. After that, by using Google Earth Pro software, the study area is selected and the center line of the river is marked.

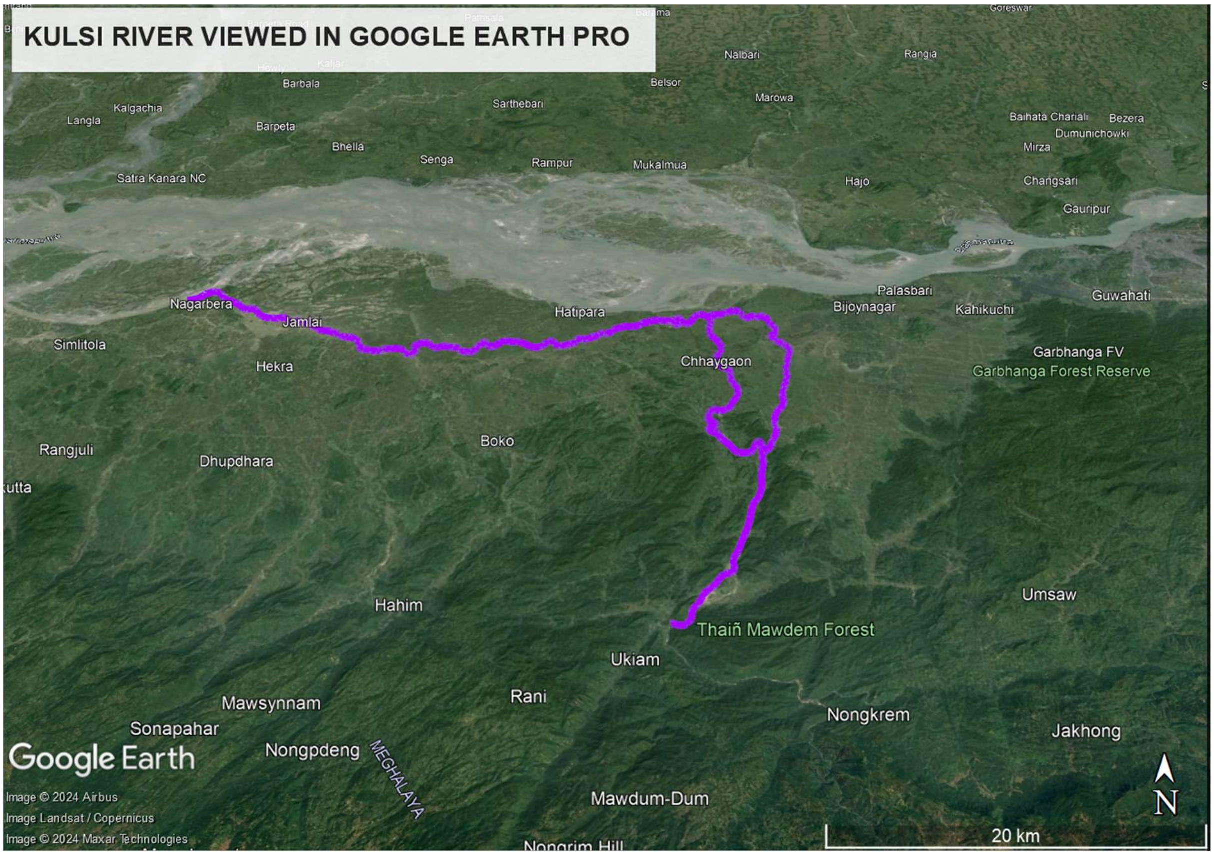


Fig 4.2: Kulsi River in Google Earth Pro

4.3 OPERATIONS IN ARC MAP:

1) The DEM is downloaded from USGS Earth explorer.

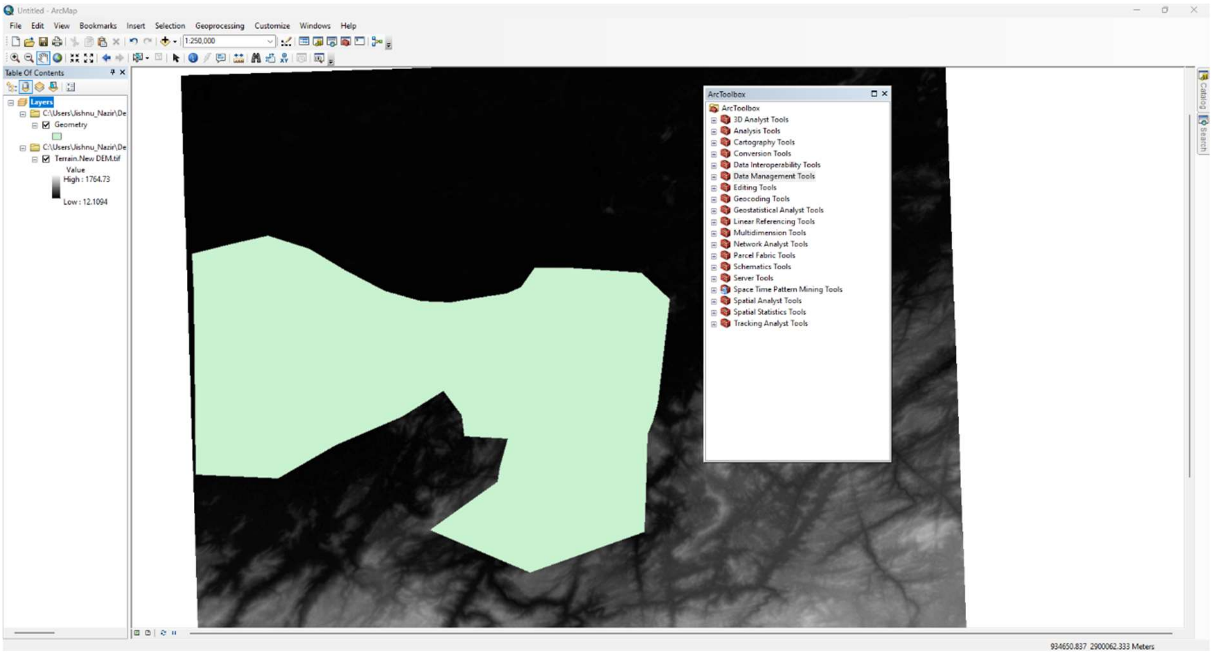


Fig 4.3: Arc Map Window displaying DEM and the study area in the form of shape file

2) To clip a digital elevation model (DEM) in ArcMap, we have followed these steps:

I. Open ArcMap and add the DEM layer that you want to clip.
II. Add the layer that you want to use as the clip feature. This can be a polygon, a shapefile, or any other feature layer.
III. Make sure that the two layers have the same projection.
IV. Click on the ArcTool Box – Data Management Tools – Raster – Raster processing – “Clip”.
V. In the Clip tool dialog box, select the input raster layer (the DEM layer) and the clip feature layer.
VI. Choose the output raster location and name, and make sure that the "Use Input Features for Clipping Geometry" option is selected.
VII. Click OK to run the tool.
VIII. Once the clip operation is completed, you will have a new clipped DEM layer.

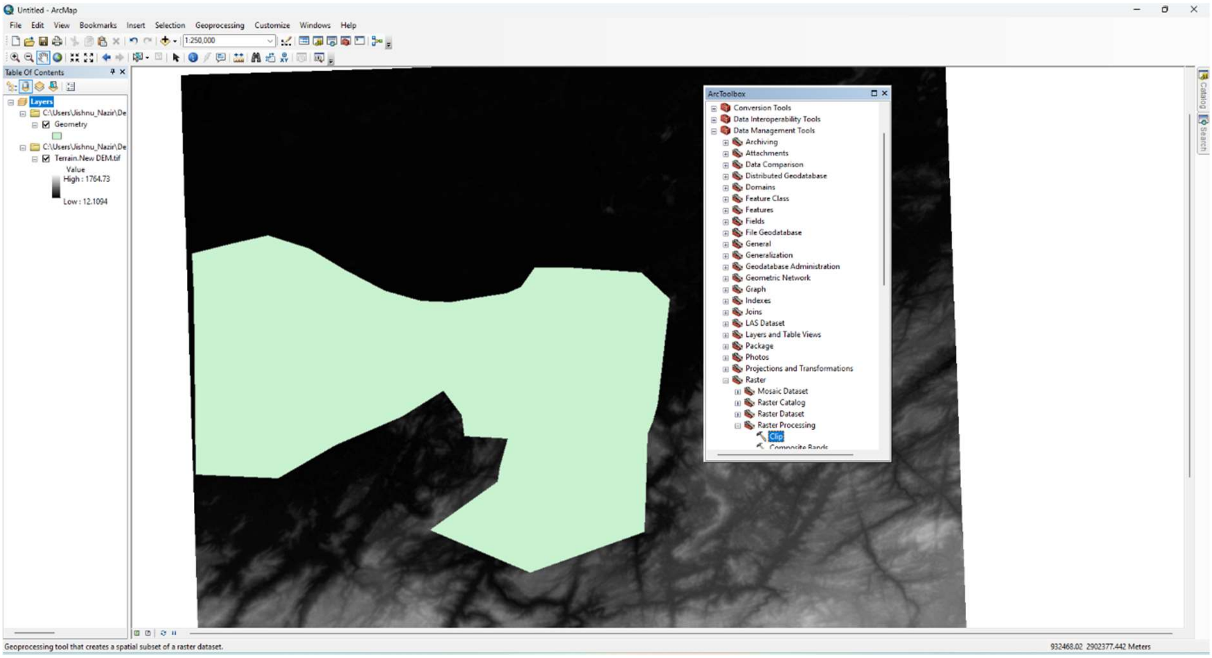


Fig 4.4: Clipped DEM Steps 1

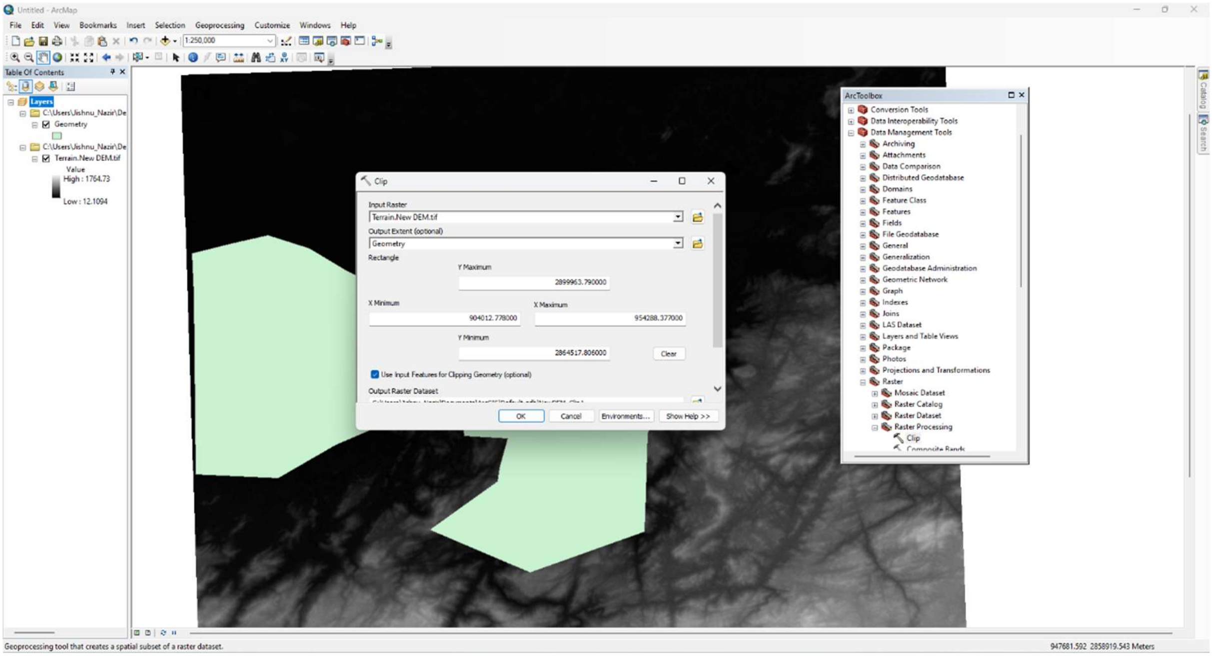


Fig: 4.5 Clipped DEM Steps 2

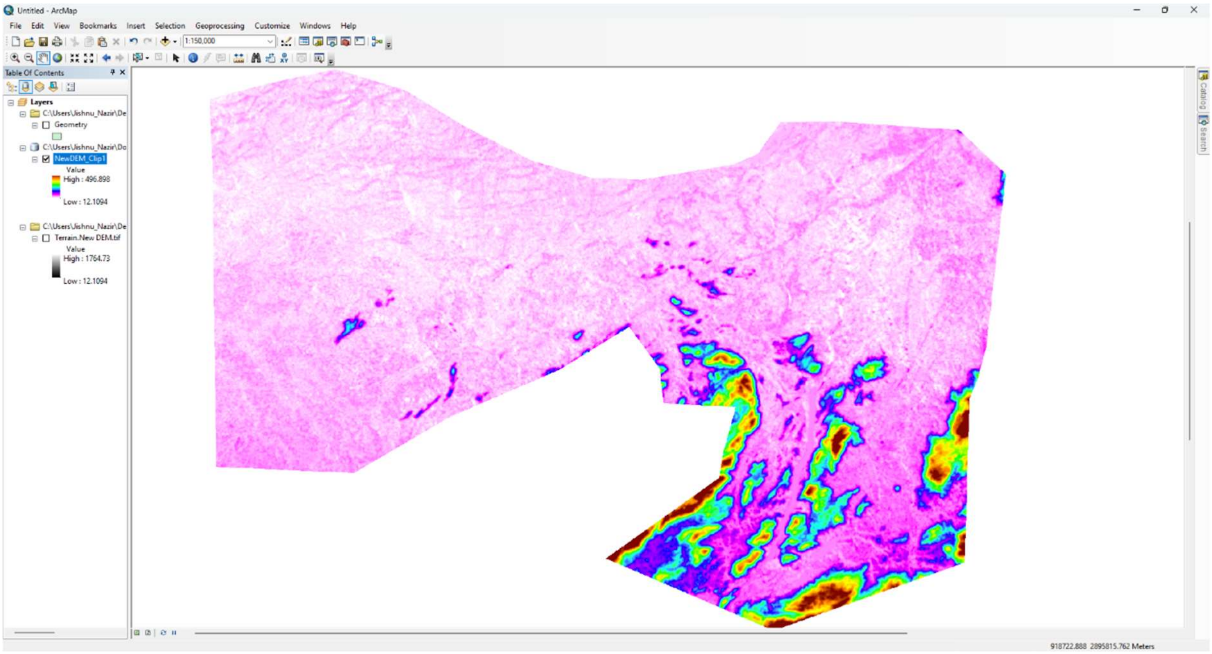


Fig: 4.6 Clipped DEM

4.4 LAND USE LAND COVER:

Land use and land cover are terms used in geography and environmental studies to describe the way land is utilized by humans and the type of natural and artificial features that cover the Earth's surface.

1. **Land Use**: This refers to the human activities and purposes that land is designated for. It includes various categories such as residential, commercial, industrial, agricultural, recreational, and more. Land use helps us understand how different areas are developed and utilized based on societal and economic needs.

2. **Land Cover**: This term describes the physical and biological material found on the Earth's surface, including both natural and artificial elements. Examples of land cover categories are forests, grasslands, water bodies, urban areas, barren land, and more. Land cover data helps us understand the extent of various types of surfaces on the planet.

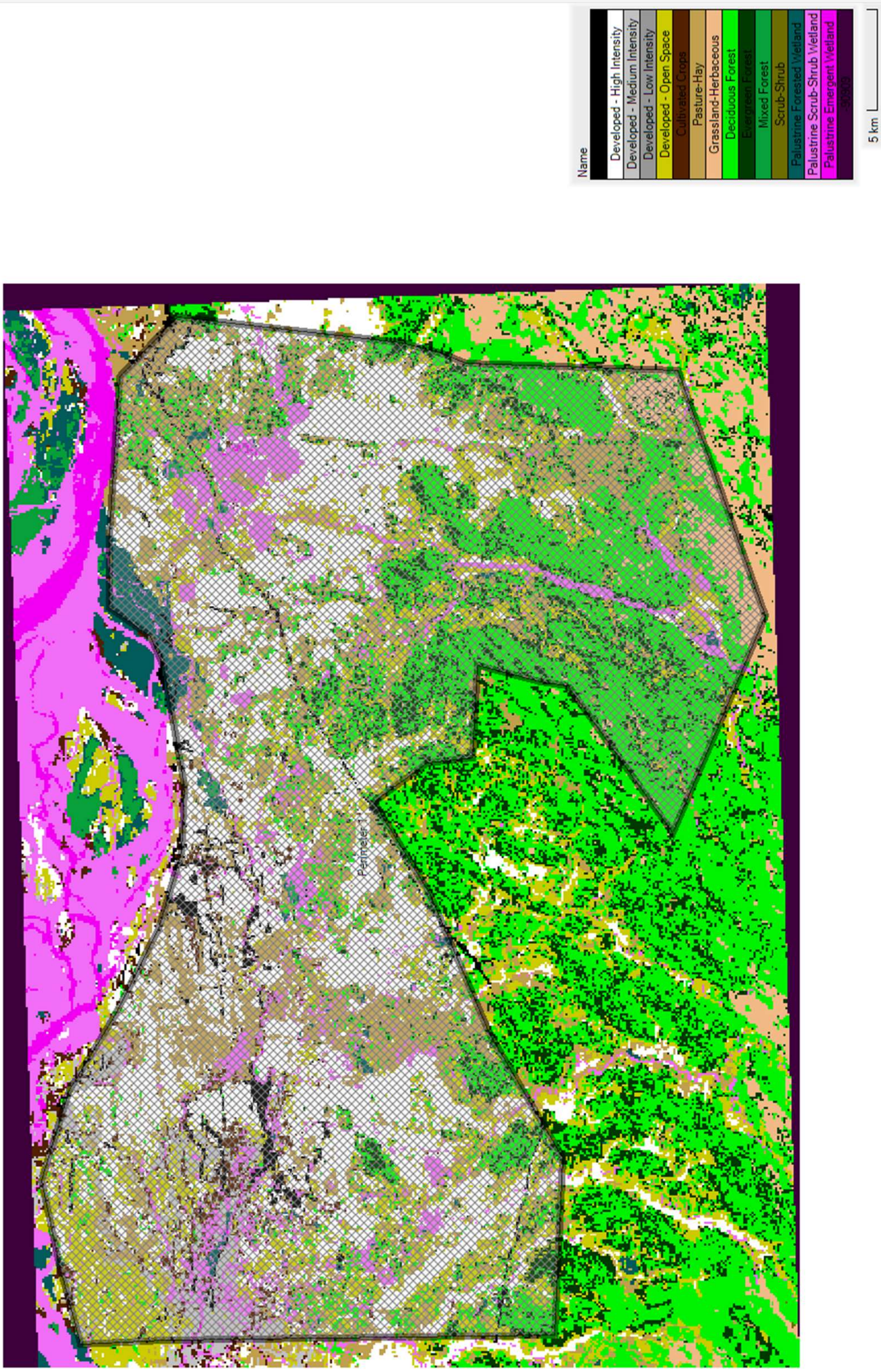


Fig 4.7: Land Use Land Cover Map of study area

4.5 OPERATION IN MS EXCEL:

1) Gumbel Method for Rainfall Frequency Analysis:

The 2D hydrodynamic simulation provides information on hydraulic parameters such as water surface elevation, velocity, and flow depth at a different location in the computational domain. The rainfall frequency analysis is done by using Gumbel's method to calculate the maximum rainfall in a single day at six different return periods, mainly 2 years, 10 years, 25 years, 50 years, 75 years and 100 years. It is also known as the Generalized Extreme Value distribution method. The data is fitted to Gumbel's distribution and the rainfall is calculated using the general equation of frequency analysis, given by

$x_T = x + K_T \times S$ …………………….. Eq 1

Where, x_T = Design intensity for a particular duration and a particular return period

x = Mean of the annual maximum for a particular duration

S = Standard Deviation of the annual maximum for a particular duration

K_T = Frequency factor

Extreme value type I (EV-I) distribution, also known as Gumbel's distribution, is a limiting probability distribution which is used to model the maximum or minimum values from a sample of independent, identically distributed random variables, as the size of the sample increases. Frequency factor (K_T) is determined by the standard equation derived from Gumbel's distribution function as,

$K_T = -\frac{\sqrt{6}}{\pi}\{0.5772 + ln\,(ln\,(\frac{T}{T-1}))\}$ or ……………………………………. Eq 2

$K_T = (Y_T - \tilde{y}_n)/\sigma_n$ …………………………………………………. EQ 3

$Y_T = ln(ln(\frac{T}{T-1}))$ …………………………………………………. EQ 4

$\tilde{y}_n$ and σ_n values are obtained from the table under for different numbers of n (n=16 in our case as we have 16 years of rainfall data)

$\tilde{y}_n = 0.5157$

$\sigma_n = 1.0316$

Table 4.1: $\tilde{y}n$ and σn values for different numbers of observation n

n	$\bar{y}_n$	σ_n	n	$\bar{y}_n$	σ_n	n	$\bar{y}_n$	σ_n
8	0.4843	0.9043	35	0.5403	1.1285	64	0.5533	1.1793
9	0.4902	0.9288	36	0.5410	1.1313	66	0.5538	1.1814
10	0.4952	0.9497	37	0.5418	1.1339	68	0.5543	1.1834
11	0.4996	0.9676	38	0.5424	1.1363	70	0.5548	1.1854
12	0.5035	0.9833	39	0.5430	1.1388	72	0.5552	1.1873
13	0.5070	0.9972	40	0.5436	1.1413	74	0.5557	1.1890
14	0.5100	1.0095	41	0.5442	1.1436	76	0.5561	1.1906
15	0.5128	1.0206	42	0.5448	1.1458	78	0.5565	1.1923
16	0.5157	1.0316	43	0.5453	1.1480	80	0.5569	1.1938
17	0.5181	1.0411	44	0.5458	1.1499	82	0.5572	1.1953
18	0.5202	1.0493	45	0.5463	1.1519	84	0.5576	1.1967
19	0.5220	1.0566	46	0.5468	1.1538	86	0.5580	1.1980
20	0.5236	1.0628	47	0.5473	1.1557	88	0.5583	1.1994
21	0.5252	1.0696	48	0.5477	1.1574	90	0.5586	1.2007
22	0.5268	1.0754	49	0.5481	1.1590	92	0.5589	1.2020
23	0.5283	1.0811	50	0.5485	1.1607	94	0.5592	1.2032
24	0.5296	1.0864	51	0.5489	1.1623	96	0.5595	1.2044
25	0.5309	1.0915	52	0.5493	1.1638	98	0.5598	1.2055
26	0.5320	1.0961	53	0.5497	1.1653	100	0.5600	1.2065
27	0.5332	1.1004	54	0.5501	1.1667	150	0.5646	1.2253
28	0.5343	1.1047	55	0.5504	1.1681	200	0.5672	1.2360
29	0.5353	1.1086	56	0.5508	1.1696	250	0.5688	1.2429
30	0.5362	1.1124	57	0.5511	1.1708	300	0.5699	1.2479
31	0.5371	1.1159	58	0.5515	1.1721	400	0.5714	1.2545
32	0.5380	1.1193	59	0.5518	1.1734	500	0.5724	1.2588
33	0.5388	1.1226	60	0.5521	1.1747	750	0.5738	1.2651
34	0.5396	1.1255	62	0.5527	1.1770	1000	0.5745	1.2685

Table 4.2: Frequency factor (K_T) values for different return periods.

	2 YEAR	10 YEAR	25 YEAR	50 YEAR	75 YEAR	100 YEAR
Y_T	0.366513	2.250367	3.198534261	3.901938658	4.310784111	4.600149227
K_T	-0.14462	1.681531	2.600654	3.282511	3.678833	3.959334

Table 4.3: GUMBEL DISTRIBUTION

Year	Maximum rainfall in a single day (mm)	PRECIPITATION							
		5 min	10 min	15 min	30 min	60 min	120 min	720 min	1440 min
2005	250.65	37.95511	47.82044	54.74074	68.96901	86.8955	109.4815	198.941	250.65
2006	188.45	28.53636	35.95357	41.15656	51.85402	65.33197	82.31312	149.5729	188.45
2007	120.33	18.22118	22.95724	26.27948	33.11008	41.71608	52.55897	95.50598	120.33
2008	90.48	13.70109	17.26229	19.76039	24.89653	31.36766	39.52078	71.81402	90.48
2009	85.55	12.95456	16.32172	18.6837	23.53999	29.65853	37.3674	67.90108	85.55
2010	166.7	25.24283	31.80398	36.40647	45.86927	57.79166	72.81293	132.3099	166.7
2011	250.37	37.91271	47.76702	54.67959	68.89196	86.79843	109.3592	198.7188	250.37
2012	101.62	15.38798	19.38764	22.19331	27.96182	35.22969	44.38662	80.65585	101.62
2013	180.63	27.35221	34.46162	39.44871	49.70226	62.62092	78.89742	143.3661	180.63
2014	190.57	28.85739	36.35803	41.61956	52.43736	66.06693	83.23911	151.2555	190.57
2015	155.43	23.53625	29.65382	33.94515	42.76821	53.88457	67.89031	123.3649	155.43
2016	71.27	10.79218	13.5973	15.56502	19.6107	24.70793	31.13004	56.56704	71.27
2017	142.07	21.51319	27.10493	31.02739	39.09207	49.25292	62.05479	112.761	142.07
2018	169.57	25.67743	32.35153	37.03326	46.65898	58.78664	74.06652	134.5878	169.57
2019	353.16	53.47786	67.37788	77.12842	97.17572	122.4337	154.2568	280.3033	353.16
2020	370	56.02788	70.59071	80.80619	101.8094	128.2718	161.6124	293.6692	370

MEAN	27.32164	34.42311	39.40462	49.64671	62.55094	78.80924	143.2059	180.4281
STANDARD DEVIATION	13.37348	16.84953	19.2879	24.30123	30.61763	38.5758	70.09688	88.31654

Table 4.4: Rainfall Intensity for Different Return Period

Time (hours)	Time (minutes)	Mean	Standard Deviation	2 YEARS		10 YEARS		25 YEARS		50 YEARS		75 YEARS		100 YEARS	
				Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)	Rainfall (mm)	Rainfall (mm/hr)
0.08	5.00	27.322	13.373	25.388	304.651	49.810	597.715	62.101	745.217	71.220	854.643	76.520	918.245	80.272	963.261
0.17	10.00	34.423	16.850	31.986	191.918	62.756	376.537	78.243	469.457	89.732	538.391	96.410	578.458	101.136	606.816
0.25	15.00	39.405	19.288	36.615	146.461	71.838	287.351	89.566	358.263	102.717	410.869	110.362	441.446	115.772	463.087
0.50	30.00	49.647	24.301	46.132	92.265	90.510	181.020	112.846	225.692	129.416	258.832	139.047	278.094	145.863	291.727
1.00	60.00	62.551	30.618	58.123	58.123	114.035	114.035	142.177	142.177	163.054	163.054	175.188	175.188	183.776	183.776
2.00	120.00	78.809	38.576	73.231	36.615	143.676	71.838	179.132	89.566	205.435	102.717	220.723	110.362	231.544	115.772
12.00	720.00	143.206	70.097	133.069	11.089	261.076	21.756	325.504	27.125	373.300	31.108	401.081	33.423	420.743	35.062
24.00	1440.00	180.428	88.317	167.656	6.986	328.935	13.706	410.109	17.088	470.328	19.597	505.330	21.055	530.103	22.088

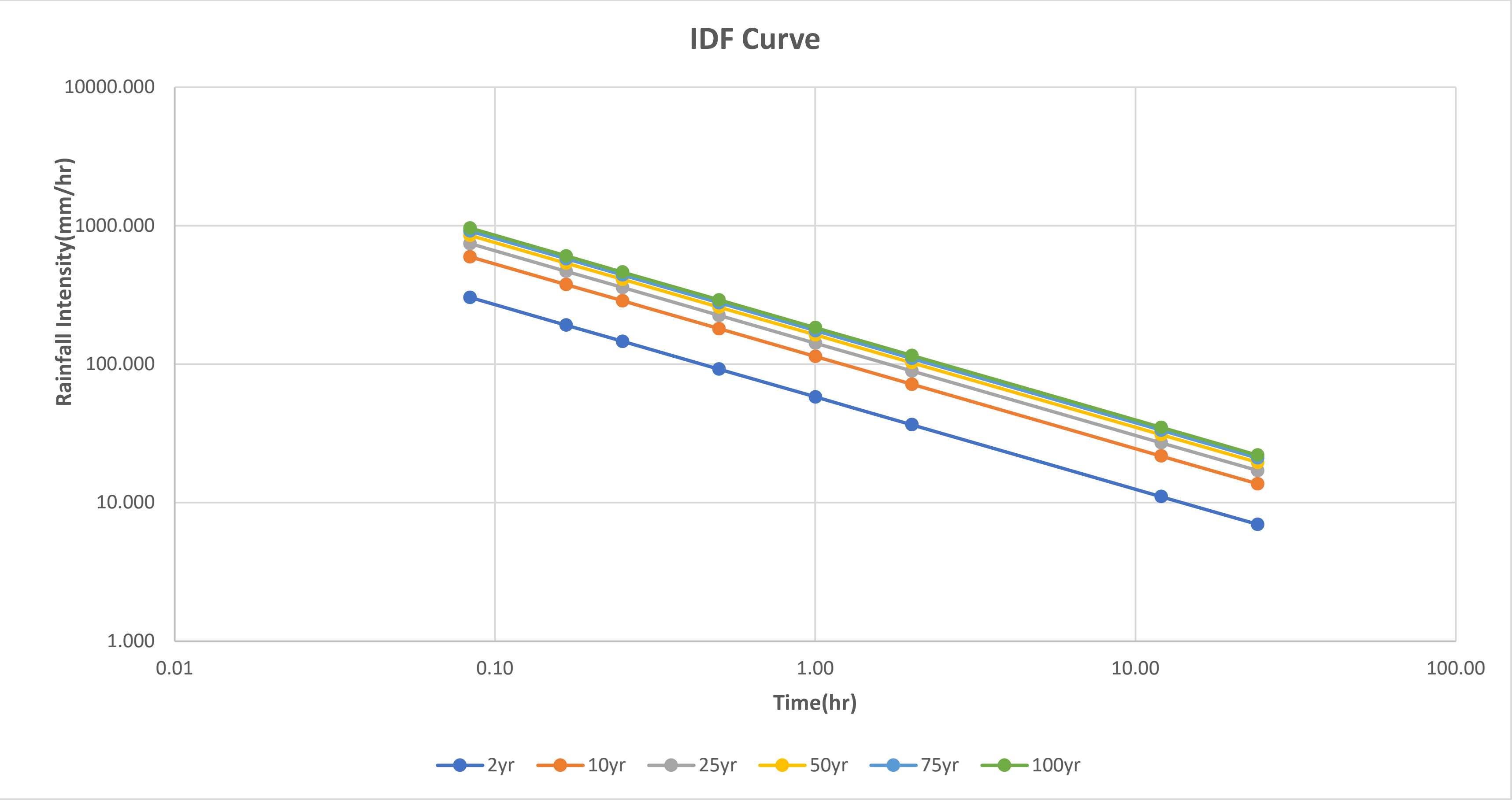


Fig 4.8: IDF Curve

2) Lag Time Calculation: LAG Time is computed for different Sub Basins using Curve Number

Table 4.5: Lag Time Calculation

Sub Basins	Hydraulic Length (l) Km	Average Basin Slope (S) m/m	Average Basin Slope (Y)%	Curve Number (CN)	S=[(1000/CN)-10] inch	Time of concentration (T_c) hour	Lag Time (L) min
Subbasin-1	8.93141	0.38682	38.682	73.636	3.580314	1.50585042	54.21062
Subbasin-10	23.72181	0.26936	26.936	74.376	3.445197	3.860548742	138.9798
Subbasin-11	24.49598	0.27755	27.755	74.183	3.480177	3.923606864	141.2498
Subbasin-12	21.63578	0.30575	30.575	73.292	3.644054	3.471014987	124.9565
Subbasin-13	14.95044	0.27654	27.654	73.257	3.650573	2.718143005	97.85315
Subbasin-14	0.51846	0.10192	10.192	80	2.5	0.249266392	8.97359
Subbasin-15	13.932	0.30519	30.519	73.63	3.581421	2.419910689	87.11678
Subbasin-16	13.95116	0.22141	22.141	73.771	3.555462	2.832930694	101.9855
Subbasin-17	2.50883	0.36181	36.181	74.361	3.44791	0.552356494	19.88483
Subbasin-18	8.6359	0.26374	26.374	74.247	3.468558	1.744812796	62.81326
Subbasin-19	12.05801	0.25969	25.969	73.27	3.648151	2.360818696	84.98947
Subbasin-2	28.94718	0.25915	25.915	72.894	3.71855	4.812259173	173.2413
Subbasin-20	25.06366	0.24757	24.757	73.365	3.630478	4.330103169	155.8837
Subbasin-21	15.17941	0.30991	30.991	72.403	3.811582	2.661713247	95.82168
Subbasin-22	13.25663	0.25606	25.606	73.063	3.686818	2.579668576	92.86807
Subbasin-23	33.64615	0.23947	23.947	76.576	3.058922	5.081405183	182.9306
Subbasin-24	2.12201	0.46083	46.083	76.958	2.994101	0.397003626	14.29213
Subbasin-25	2.92632	0.30511	30.511	72.446	3.803385	0.717936416	25.84571
Subbasin-26	9.10827	0.34739	34.739	72.828	3.730983	1.651123673	59.44045
Subbasin-27	15.22452	0.22029	22.029	73.464	3.612109	3.072138638	110.597
Subbasin-28	10.49	0.28297	28.297	72.92	3.713659	2.043028816	73.54904

Subbasin-29	16.91068	0.23056	23.056	73.228	3.655979	3.28789664	118.3643
Subbasin-3	22.55162	0.25539	25.539	74.578	3.40878	3.785617713	136.2822
Subbasin-30	13.35143	0.34603	34.603	73.621	3.583081	2.197096925	79.09549
Subbasin-31	16.10219	0.25745	25.745	73.888	3.533997	2.93678393	105.7242
Subbasin-32	28.91041	0.20404	20.404	74.678	3.390825	5.151593714	185.4574
Subbasin-33	23.80892	0.25134	25.134	73.901	3.531617	4.062672018	146.2562
Subbasin-34	20.3504	0.42904	42.904	73.139	3.672596	2.802036775	100.8733
Subbasin-35	7.8823	0.29535	29.535	73.706	3.567416	1.556312875	56.02726
Subbasin-36	0.80683	0.41674	41.674	73.25	3.651877	0.214292218	7.71452
Subbasin-37	16.31806	0.27638	27.638	74.039	3.506395	2.852565408	102.6924
Subbasin-4	15.58835	0.26672	26.672	74.201	3.476907	2.786574117	100.3167
Subbasin-5	17.58153	0.25657	25.657	74.504	3.422098	3.101386259	111.6499
Subbasin-6	34.26421	0.24193	24.193	73.475	3.610071	5.607853691	201.8827
Subbasin-7	28.69663	0.25793	25.793	73.886	3.534364	4.658529371	167.7071
Subbasin-8	18.46876	0.23209	23.209	73.921	3.527956	3.448474994	124.1451
Subbasin-9	21.53195	0.3017	30.17	72.561	3.781508	3.552614245	127.8941
Subbasin-1	8.93141	0.38682	38.682	73.636	3.580314	1.50585042	54.21062

$$T_c = \frac{\ell^{0.8}(S+1)^{0.7}}{1{,}140Y^{0.5}} \qquad Lag = 0.6T_c$$

where:

L = lag, h

T_c = time of concentration, h

ℓ = flow length, ft

Y = average watershed land slope, %

S = maximum potential retention, in

………………………………………………………………………… Eq 5 and Eq 6 respectively

4.6 OPERATION IN HEC-HMS:

Developing a flood study model with HEC-HMS (Hydrologic Engineering Center's Hydrologic Modeling System) involves several steps to simulate rainfall-runoff processes and analyze the resulting hydrographs. HEC-HMS is commonly used for hydrologic modeling to estimate streamflow in watersheds. Here's a general outline of the process:

1. Data Collection and Preparation:
    - Obtain topographic data: You will need Digital Elevation Models (DEMs) or other elevation data to define the watershed boundaries and flow directions. (Source: NASA SRTM 30m resolution)
    - Gather meteorological data: Obtain rainfall data, such as observed precipitation records or design storm data for various return periods. (Source: India-WRIS)
2. Set Up the Project:
    - Launch HEC-HMS: Open the HEC-HMS software and create a new project.
    - Define the watershed: Digitize or import the watershed boundary based on the topographic data.
    - Divide the watershed into sub-basins: Define sub-basins within the main watershed based on hydrologic characteristics and flow patterns.

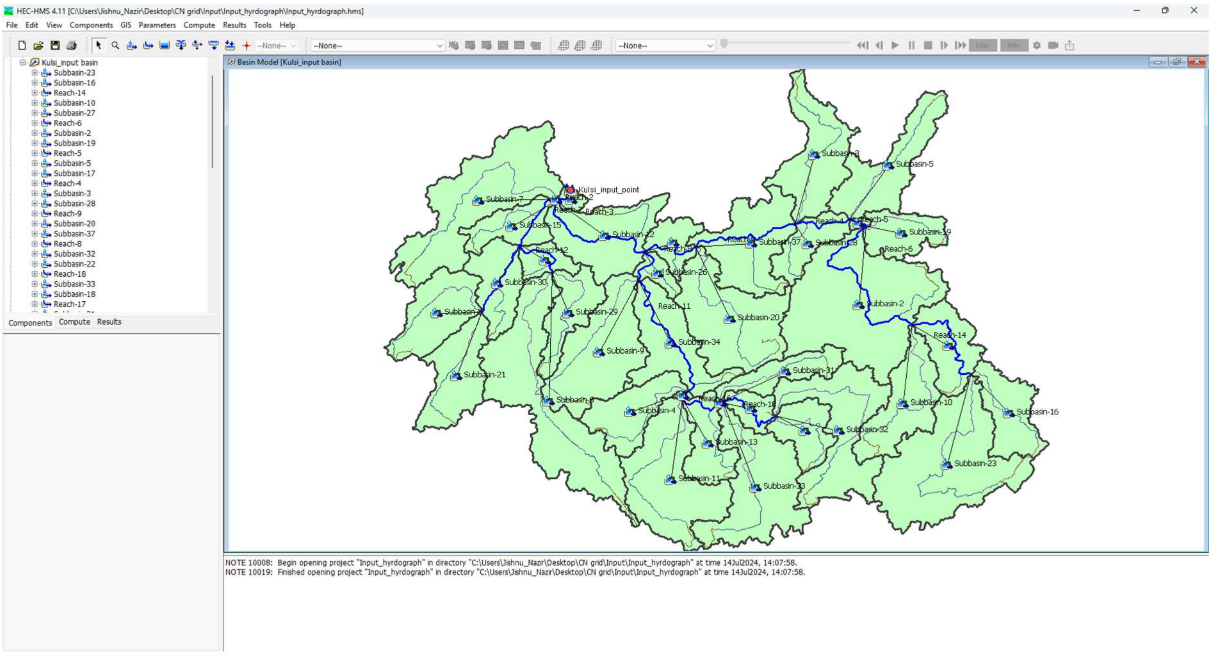


Fig 4.9: HEC HMS interface showing Sub Basin & Junctions

- Delineate hydrologic response units (HRUs): Divide each sub-basin into smaller HRUs representing distinct land use and soil combinations.

3. Hydrologic Model Setup:
    - Select a hydrologic method: Choose an appropriate hydrologic method, such as SCS-CN (Soil Conservation Service Curve Number) or SCS Unit Hydrograph, to estimate runoff.
    - Set up rainfall data: Input the rainfall data for the simulation period, including rainfall depths and durations.
4. Model Calibration and Parameters:
    - Calibrate the model: Adjust the model parameters (e.g., CN values, time to peak, lag time) to match observed streamflow data from gauged locations within the watershed.
    - Validate the model: Verify the model's performance by comparing simulated results with independent observed data.
5. Run the Simulation:
    - Configure simulation settings: Set the simulation duration and time step, as well as any other relevant simulation parameters.
    - Initiate the simulation: Run the HEC-HMS model to compute the rainfall-runoff process for the selected events or storm periods.
6. Post-Processing and Analysis:
    - Review the results: Analyze the output hydrographs generated by HEC-HMS for each sub-basin or outlet point in the watershed.
    - Assess flood characteristics: Examine the peak flow rates, hydrograph shapes, and other relevant parameters to understand the hydrologic response.

4.7 OPERATIONS IN HEC-RAS (1D MODEL):

The following are the general steps for performing a one-dimensional (1D) hydraulic modelling using HEC-RAS:

1) <u>Create a new project in HEC-RAS</u>: Launch the HEC-RAS program and create a new project. Select SI units of measurement. We then digitize the river centreline, and specify the river reach that we want to model. The DEM which is saved using ARC Map is imported in HEC RAS using the RAS Mapper feature of the software.

2) Assigning Projection to the DEM: Projection File is also downloaded from spatialreference.org and applied in the terrain model.

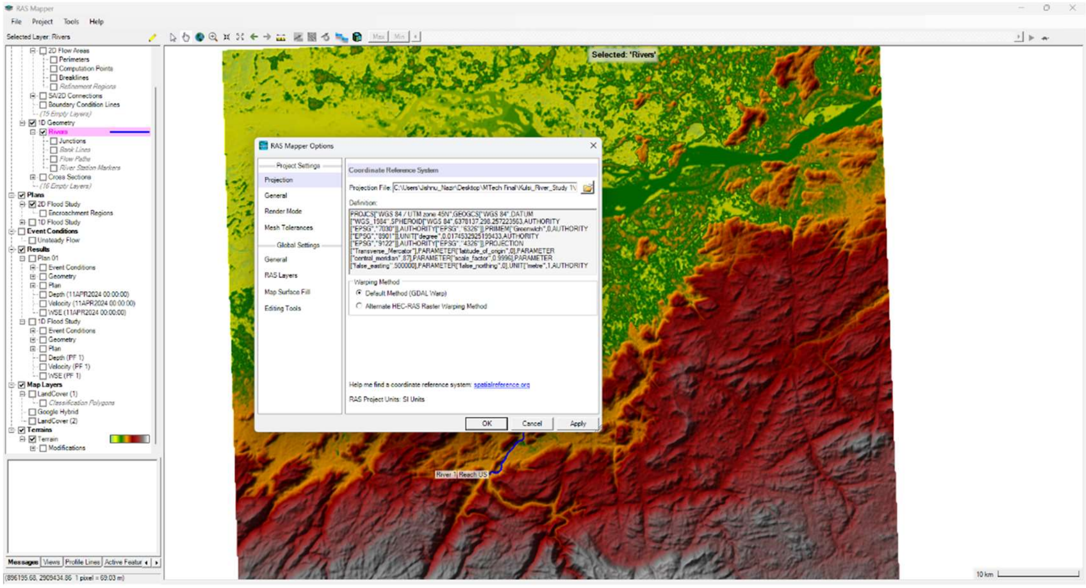


Fig 4.10: Applying Projection to the Terrain in RAS Mapper

3) Define the geometry of the river: The RAS Mapper of HEC-RAS allows us to define cross-sections, banks, and floodplains for your river. After defining the cross-sections, we can set the channel shape, bank stations, and the floodplain geometry.

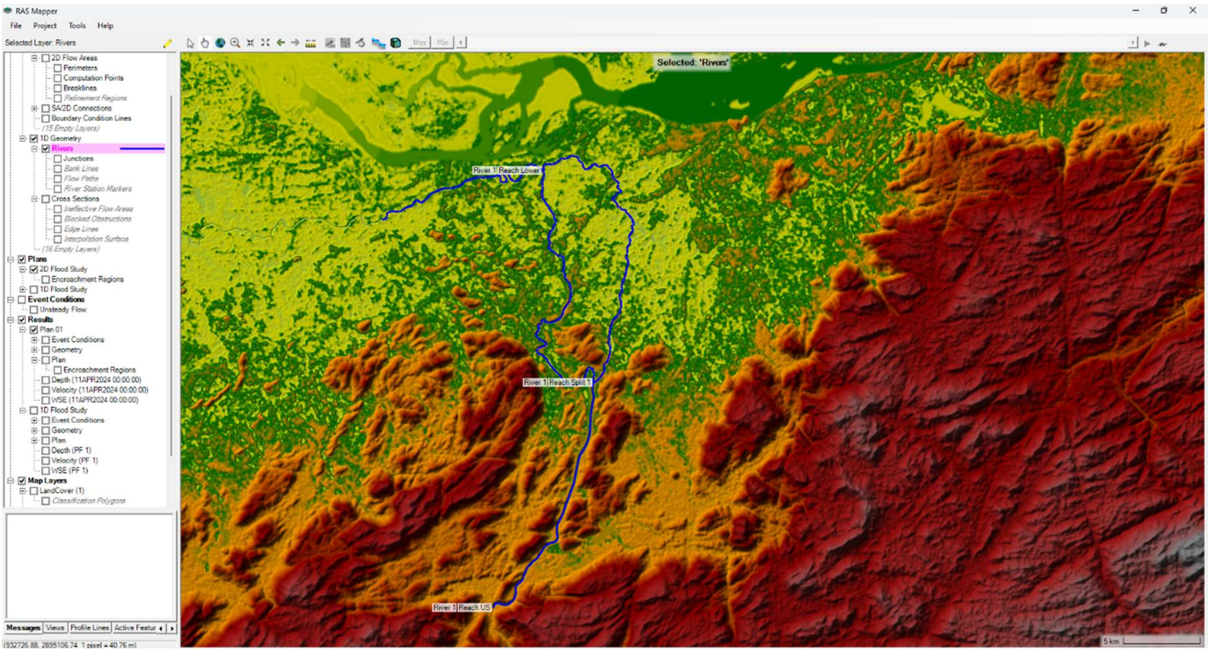


Fig 4.11: Marking centreline of the river in RAS Mapper

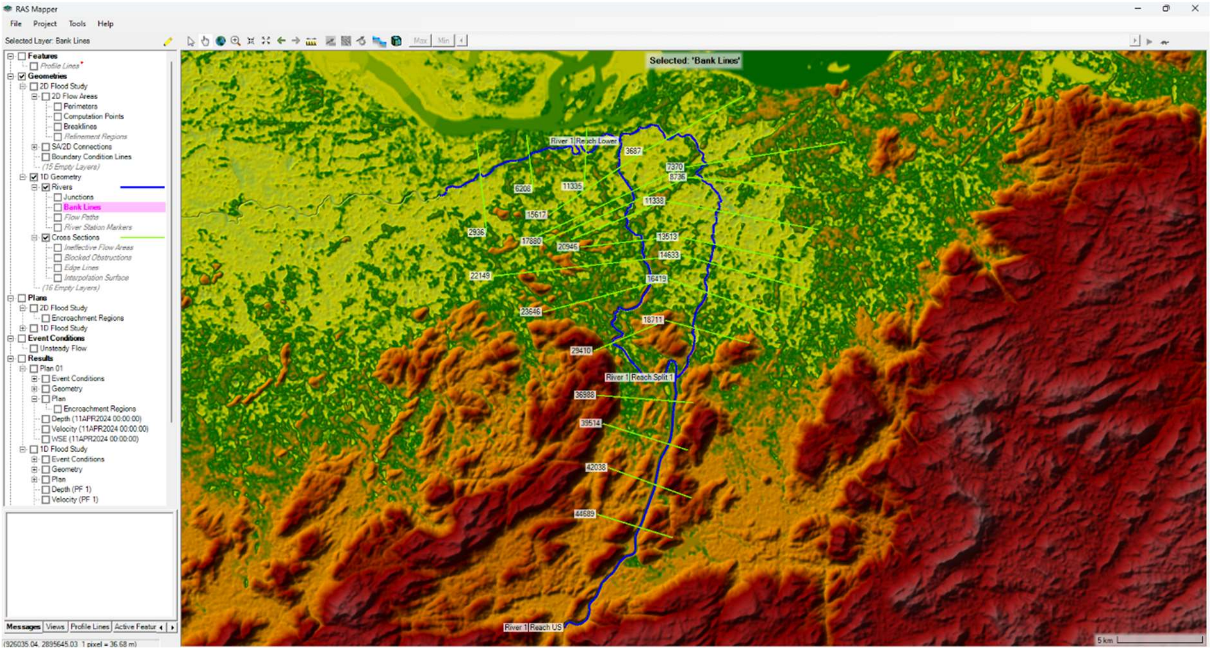


Fig 4.12: Marking Bank Lines, Flow Paths and cross sections in the RAS Mapper

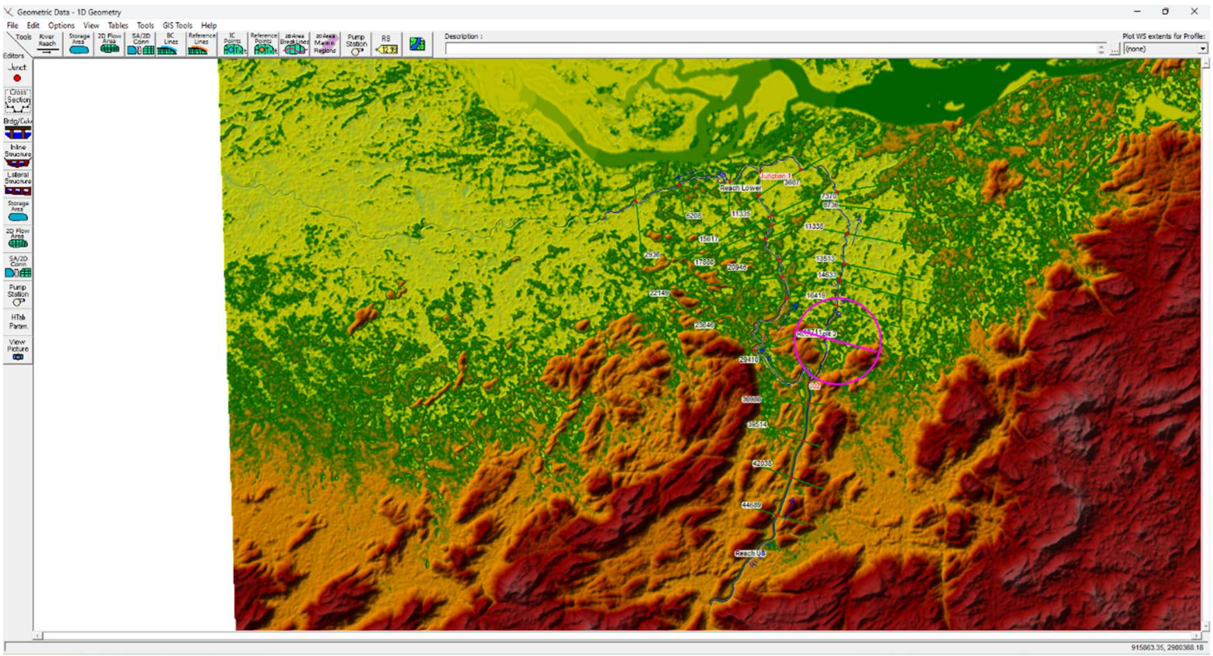
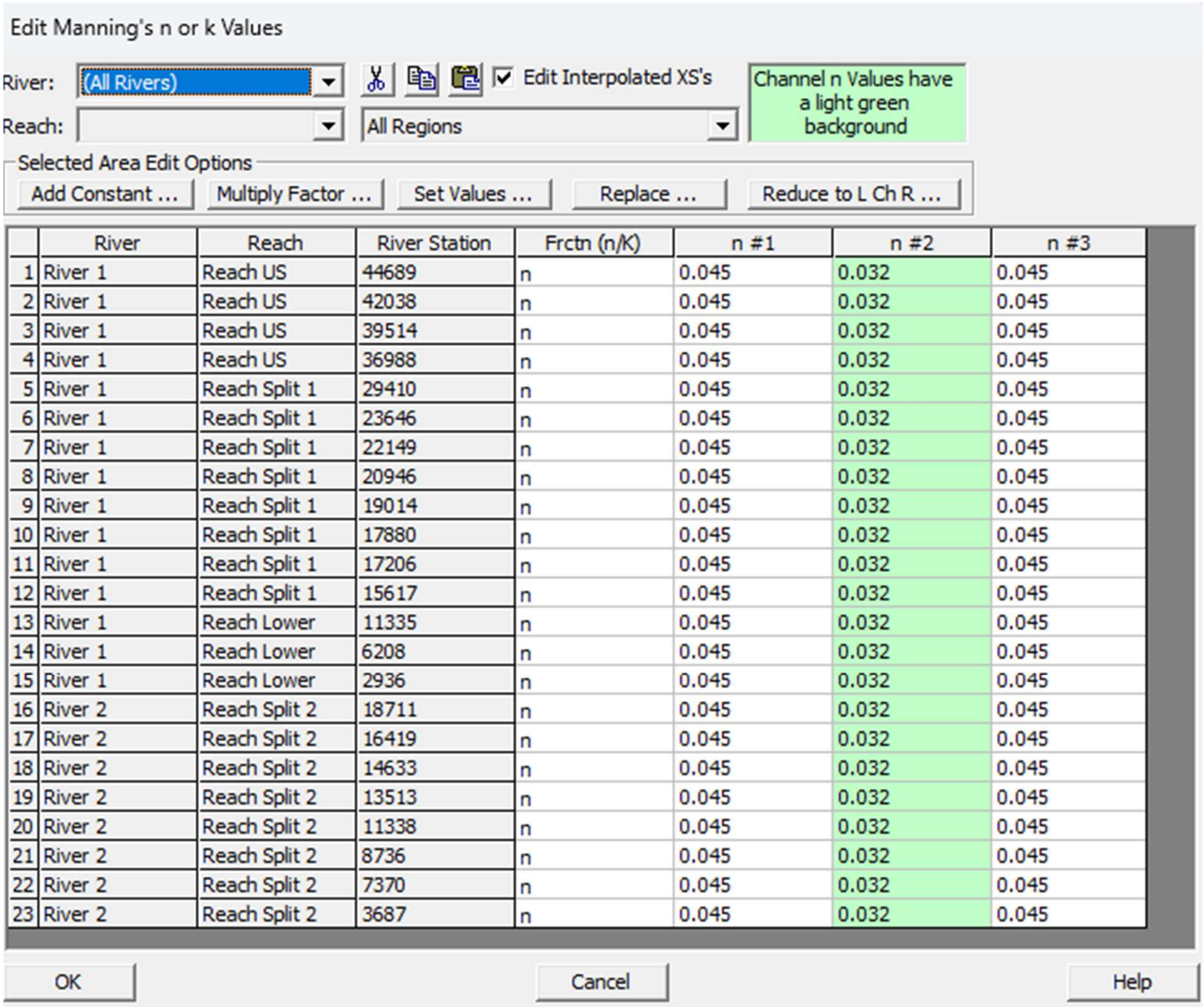


Fig 4.13: Cross Section Window of HEC RAS

4) <u>Define the boundary conditions</u>: We need to specify the upstream and downstream boundary conditions for our model, including the flow rate, water surface elevation, and boundary geometry. We can also add hydraulic structures such as bridges, culverts, and weirs.

5) Assigning roughness values: We need to specify the Manning's n (0.04 avg) values for each cross-section to define the channel roughness. The Manning's n values can be assigned based on the channel material, vegetation, or other factors that influence the channel roughness.



	River	Reach	River Station	Frctn (n/K)	n #1	n #2	n #3
1	River 1	Reach US	44689	n	0.045	0.032	0.045
2	River 1	Reach US	42038	n	0.045	0.032	0.045
3	River 1	Reach US	39514	n	0.045	0.032	0.045
4	River 1	Reach US	36988	n	0.045	0.032	0.045
5	River 1	Reach Split 1	29410	n	0.045	0.032	0.045
6	River 1	Reach Split 1	23646	n	0.045	0.032	0.045
7	River 1	Reach Split 1	22149	n	0.045	0.032	0.045
8	River 1	Reach Split 1	20946	n	0.045	0.032	0.045
9	River 1	Reach Split 1	19014	n	0.045	0.032	0.045
10	River 1	Reach Split 1	17880	n	0.045	0.032	0.045
11	River 1	Reach Split 1	17206	n	0.045	0.032	0.045
12	River 1	Reach Split 1	15617	n	0.045	0.032	0.045
13	River 1	Reach Lower	11335	n	0.045	0.032	0.045
14	River 1	Reach Lower	6208	n	0.045	0.032	0.045
15	River 1	Reach Lower	2936	n	0.045	0.032	0.045
16	River 2	Reach Split 2	18711	n	0.045	0.032	0.045
17	River 2	Reach Split 2	16419	n	0.045	0.032	0.045
18	River 2	Reach Split 2	14633	n	0.045	0.032	0.045
19	River 2	Reach Split 2	13513	n	0.045	0.032	0.045
20	River 2	Reach Split 2	11338	n	0.045	0.032	0.045
21	River 2	Reach Split 2	8736	n	0.045	0.032	0.045
22	River 2	Reach Split 2	7370	n	0.045	0.032	0.045
23	River 2	Reach Split 2	3687	n	0.045	0.032	0.045

Fig 4.14: Applying Manning's n value

6) Run the HEC-RAS model: After setting up your geometry, boundary conditions, and roughness values, you can run the model to calculate the water surface elevation, velocity, and other hydraulic parameters for each cross-section. The HEC-RAS model uses the Saint Venant equations to simulate the hydraulic behavior of the river.

HEC-RAS model use the energy equation to compute a water solution based on given discharge.

$$Z_2 + Y_2 + \alpha_2 \frac{V_2^2}{2g} = Z_1 + Y_1 + \alpha_1 \frac{V_1^2}{2g} + h_e \text{ .... Eq 7}$$

Where: Z_1 and Z_2 are the elevation of the main channel invert, h_1 and h_2 are depth of water at cross section, V_1 and V_2 are average velocities, α_1 and α_2 are the velocity weighting coefficient, g and he are gravitational acceleration and head loss respectively. The head loss between two cross sections is comprised of friction losses and contraction or expansion losses.

7) Review the results: After running the HEC-RAS model, you can review the results to ensure that they are reasonable and make any necessary adjustments to the model inputs or parameters. We can visualize the results using graphs, tables, and maps.

4.7.1 STEDY FLOW ANALYSIS

We analyse the results for steady flow of the river. For that the steady flow option is selected. The discharge value corresponds to the peak discharge that we get in our hydrograph (obtained through HEC-HMS) at the upstream of the study area.

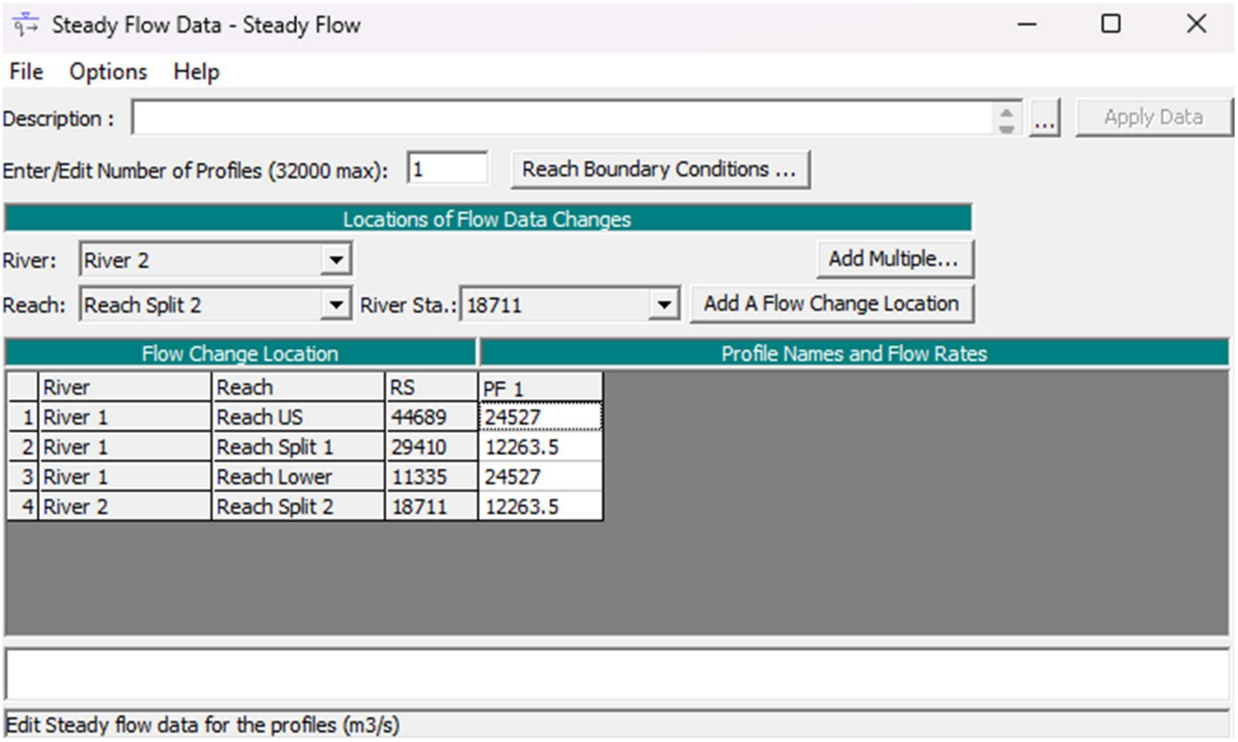


Fig 4.15: Entering Steady Flow Data

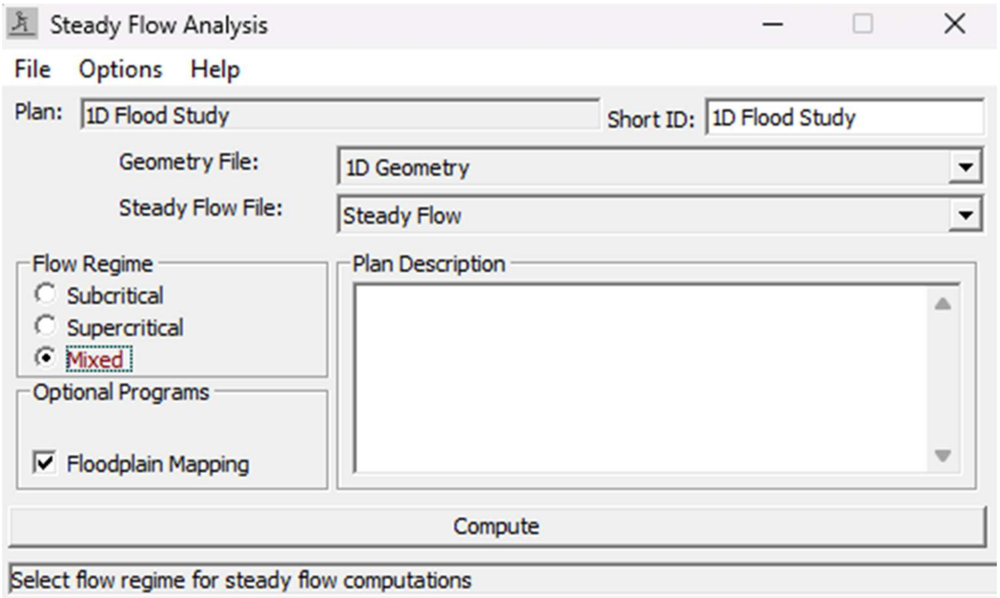


Fig 4.16: Steady Flow Analysis

4.8 OPERATIONS IN HEC-RAS (2D MODEL):

The 2D modeling capability of HEC-RAS allows for more accurate representation of complex hydraulic conditions, such as flow patterns, water levels, and velocities. Here's a step-by-step guide to performing a HEC-RAS 2D modeling analysis:

1. **Project Setup:**
   - Launch HEC-RAS and create a new project.

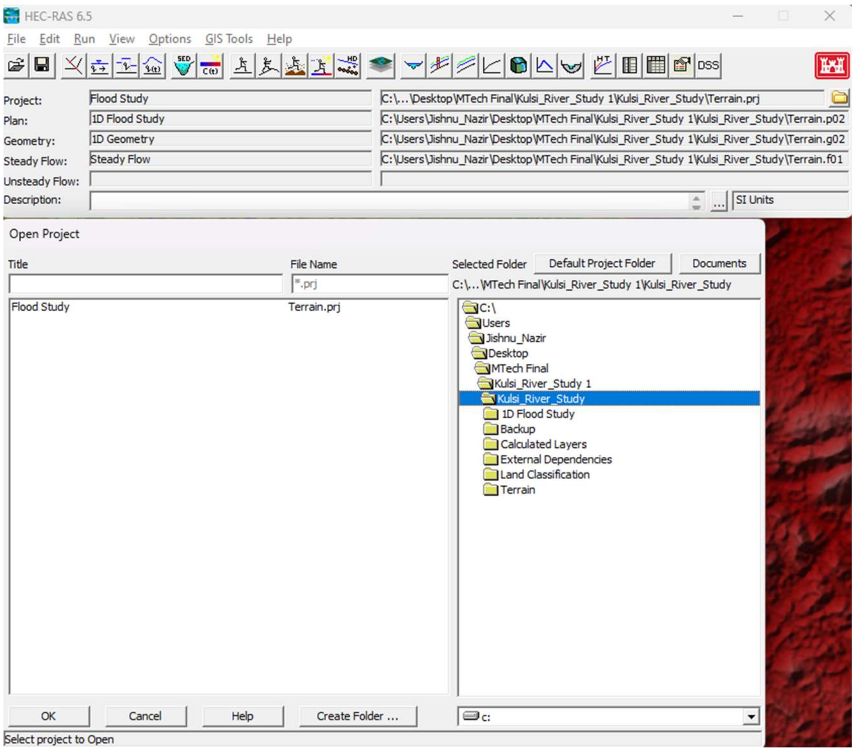


Fig 4.17: Opening a project

▪ Define the project's geographical location and coordinate system.

▪ Set up a 2D modeling analysis by selecting the "2D Flow Area" option.

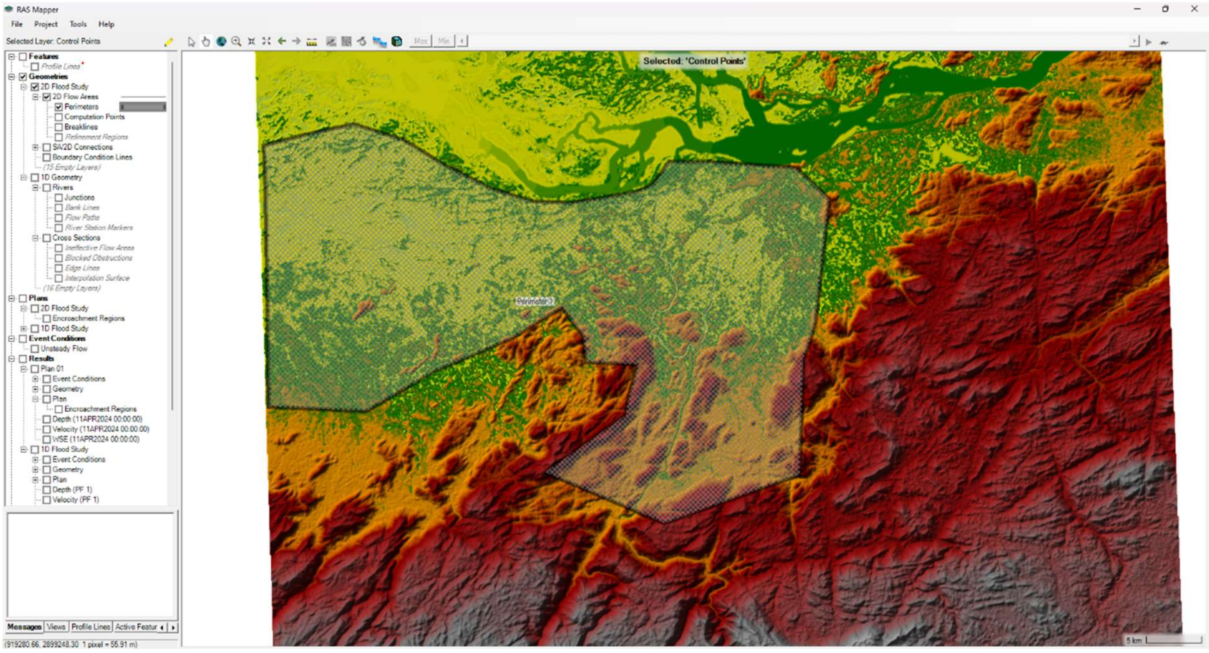


Fig 4.18: Setting up of 2D Flow Area

2. Add Breaklines:

▪ Import or create a terrain elevation dataset (e.g., Digital Elevation Model or DEM) that represents the topography of the study area.

▪ Add breaklines to create the geometry of the river or channel.

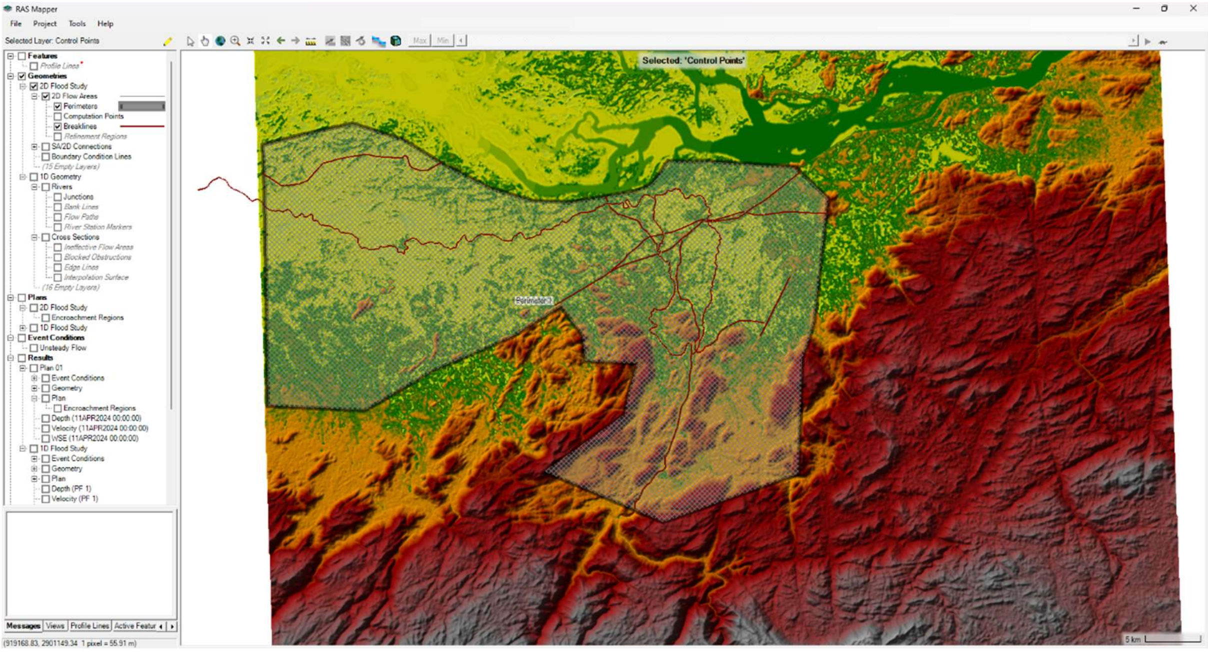


Fig 4.19: Adding breaklines to the Geometry

3. **Define Hydraulic Structures:**
   - Add any structures that impact the flow, such as bridges, culverts, weirs, and levees.

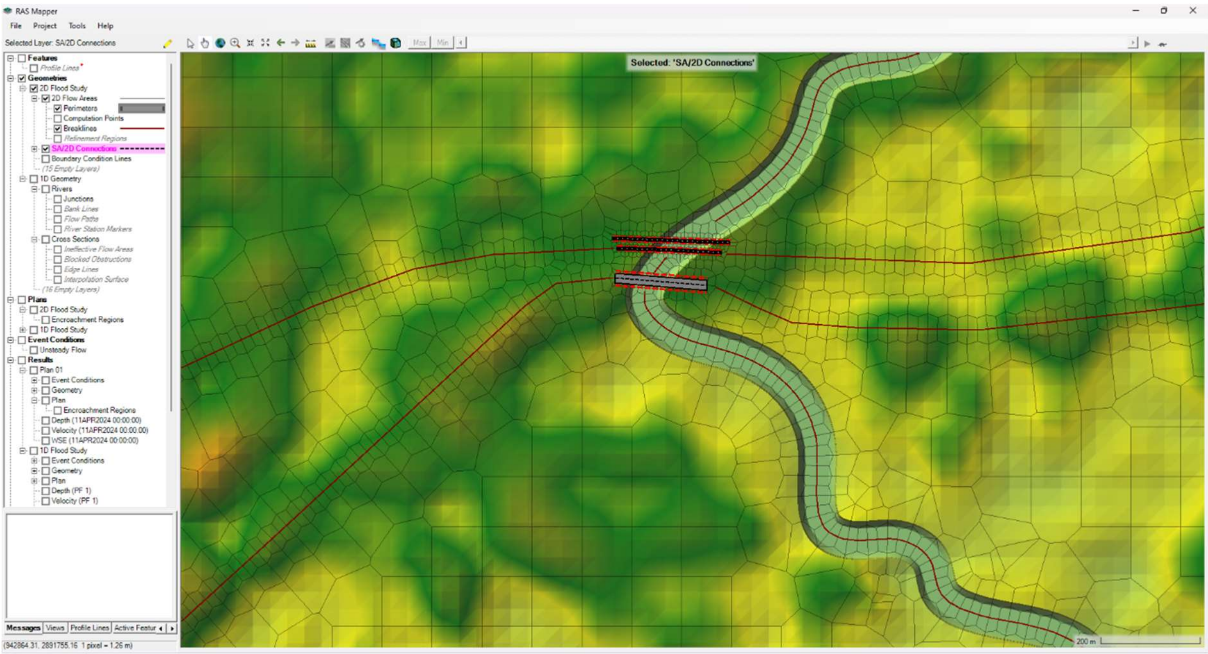


Fig 4.20: Setting up of Bridges

   - Specify the characteristics of these structures, including dimensions, openings, and flow behavior.

4. **Define Boundary Conditions:**
   - Set up upstream and downstream boundary conditions by specifying water levels, discharges, or hydrographs.

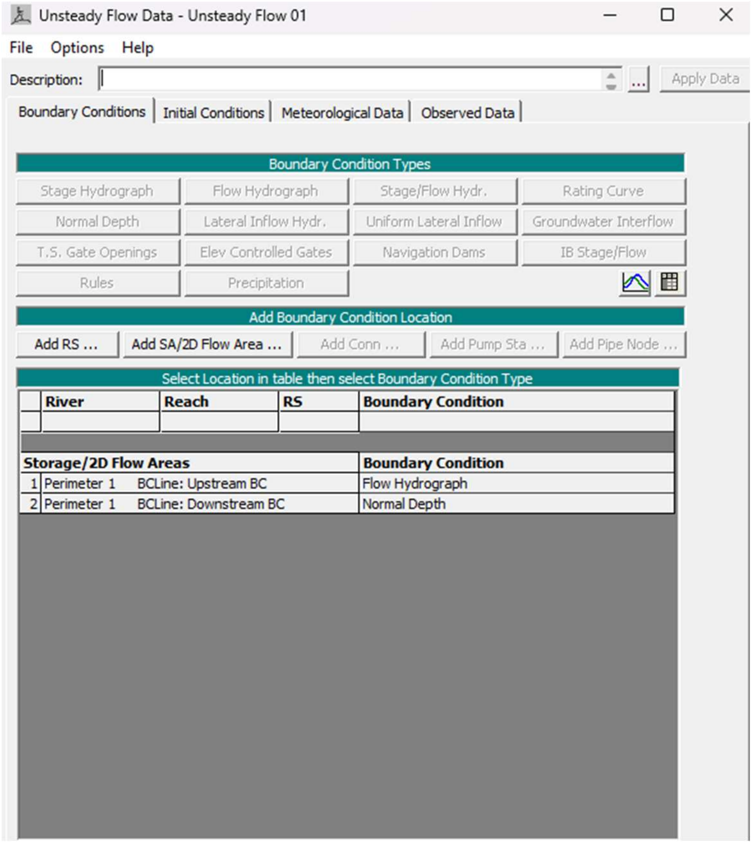


Fig 4.21: Defining Boundary Conditions

5. Define Initial Conditions:

- Specify the initial water surface elevations within the modeling domain.
- This step is crucial to provide a starting point for the analysis.

6. Mesh Generation:

- Create a mesh or grid that discretizes the 2D modeling area.

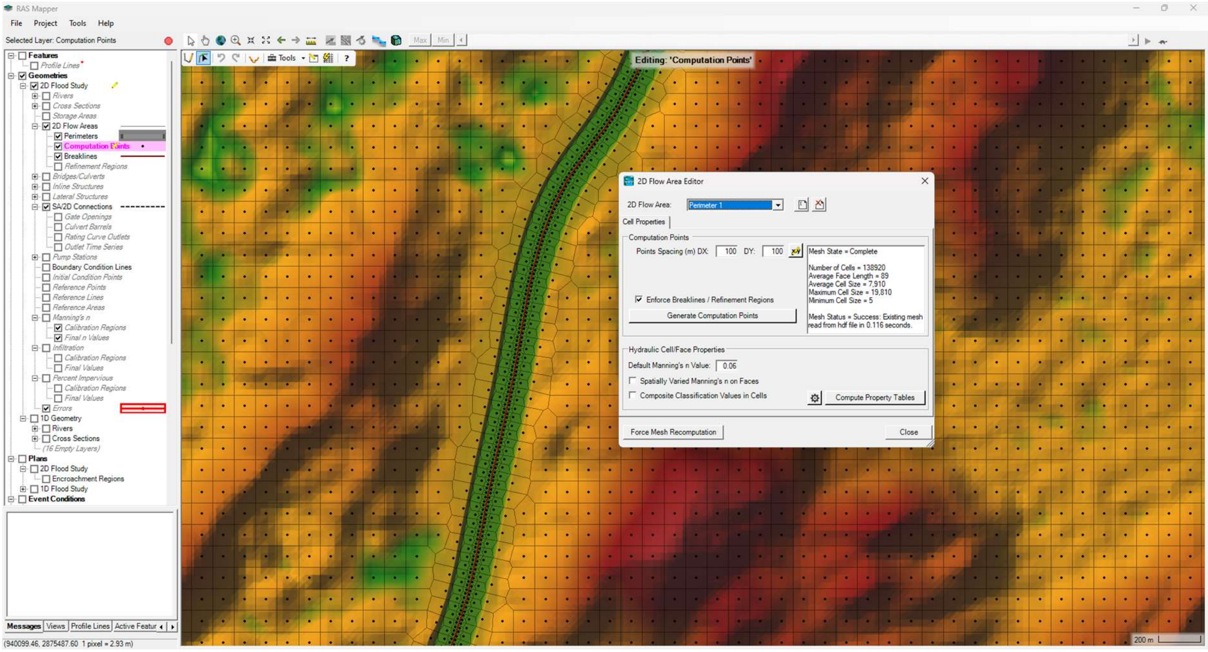


Fig 4.22: Generation of Mesh

- HEC-RAS uses this mesh to solve the governing equations for flow.

7. **Run the Simulation:**
   - Configure simulation settings: Set simulation parameters such as the simulation duration and time step.
   - Run the 2D simulation: Initiate the simulation and allow HEC-RAS to calculate the flood flows and water levels

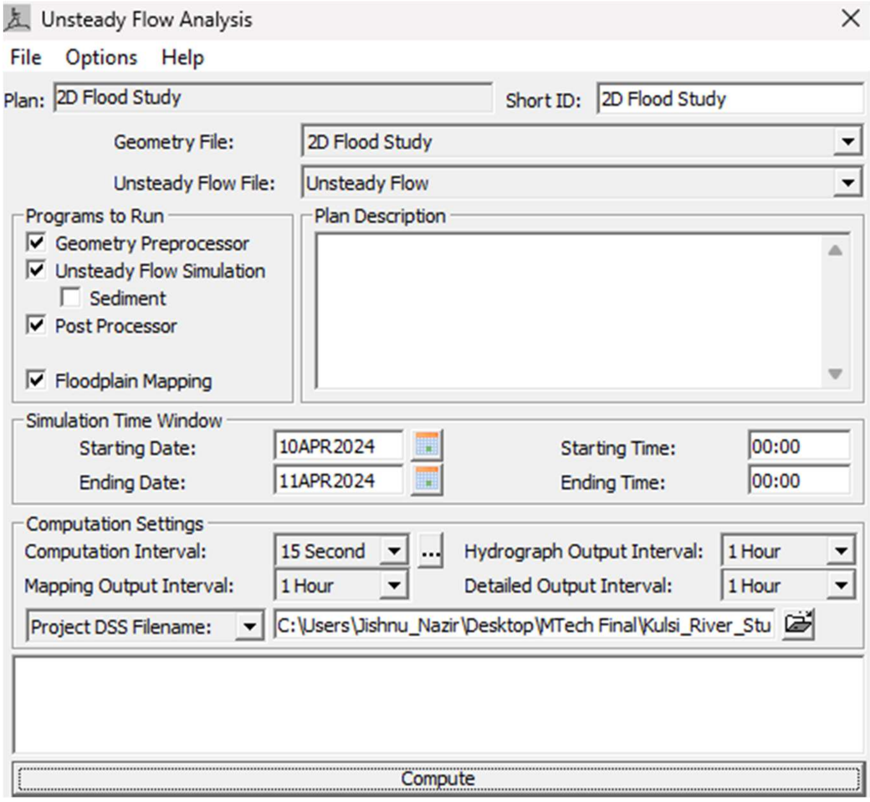


Fig 4.23: Simulation Run

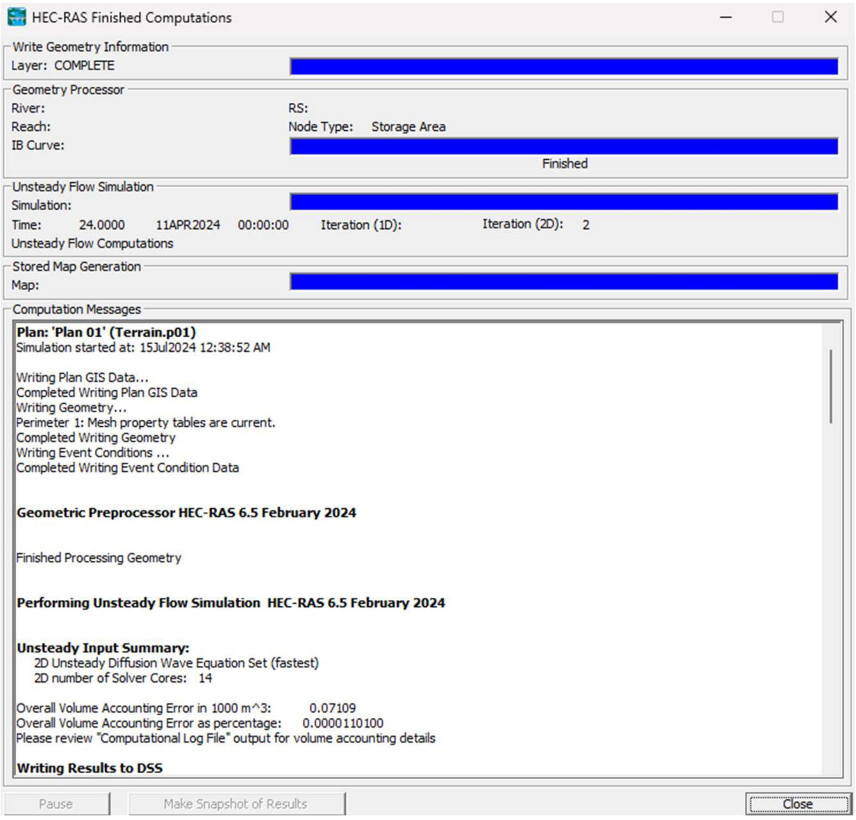


Fig 4.24: Successful simulation run with very negligible errors

CHAPTER 5

RESULTS AND DISCUSSION

5.1: RESULTS FROM HEC HMS: Time Series Plot of 3days at 5 min interval is obtained from HEC HMS

Table 5.1: Time Series Plot

Date	Time	Inflow from Reach-1(M3/S)	Inflow from Sub-25 (M3/S)	Outflow (M3/S)
11Jul2024	00:00	0.0	0.0	0.0
11Jul2024	01:00	0.0	0.0	0.0
11Jul2024	02:00	0.0	0.0	0.0
11Jul2024	03:00	0.0	0.0	0.0
11Jul2024	04:00	1.1	0.3	1.5
11Jul2024	05:00	10.6	1.4	12.0
11Jul2024	06:00	48.0	2.8	50.8
11Jul2024	07:00	142.8	4.4	147.2
11Jul2024	08:00	323.1	6.1	329.2
11Jul2024	09:00	607.0	9.0	616.1
11Jul2024	10:00	1011.7	13.1	1024.8
11Jul2024	11:00	1578.7	22.5	1601.2
11Jul2024	12:00	2776.0	189.5	2965.5
11Jul2024	13:00	6040.6	102.6	6143.2
11Jul2024	14:00	12152.1	46.5	12198.6
11Jul2024	15:00	18976.1	26.5	19002.6
11Jul2024	16:00	23479.9	18.4	23498.3
11Jul2024	17:00	24512.3	14.7	24527.0
11Jul2024	18:00	22642.4	12.6	22655.0
11Jul2024	19:00	19184.3	11.0	19195.3
11Jul2024	20:00	15190.4	9.5	15199.9
11Jul2024	21:00	11593.9	8.3	11602.2
11Jul2024	22:00	8851.6	7.9	8859.5
11Jul2024	23:00	6918.6	7.5	6926.1
12Jul2024	00:00	5579.5	7.2	5586.7
12Jul2024	01:00	4634.3	1.8	4636.1
12Jul2024	02:00	3903.8	0.4	3904.2
12Jul2024	03:00	3231.8	0.1	3231.8
12Jul2024	04:00	2556.3	0.0	2556.3
12Jul2024	05:00	1908.1	0.0	1908.1

Continued in Appendix I

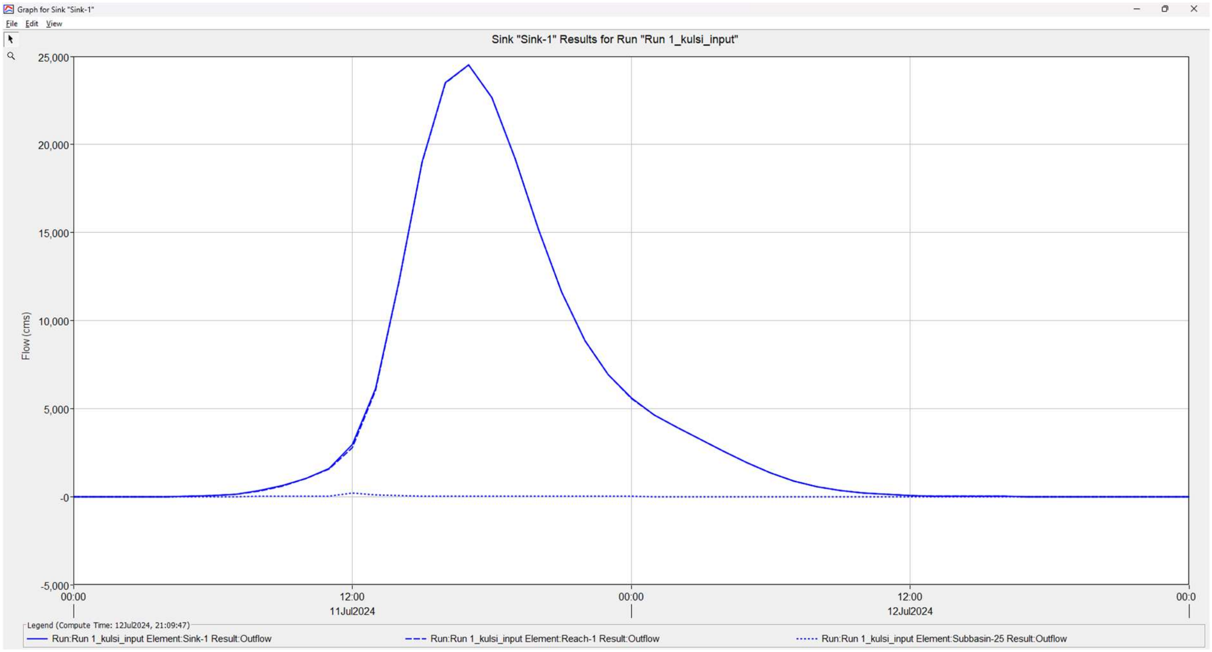


Fig 5.1: Hydrograph of Sink (U/S of the study area) obtained from HEC HMS

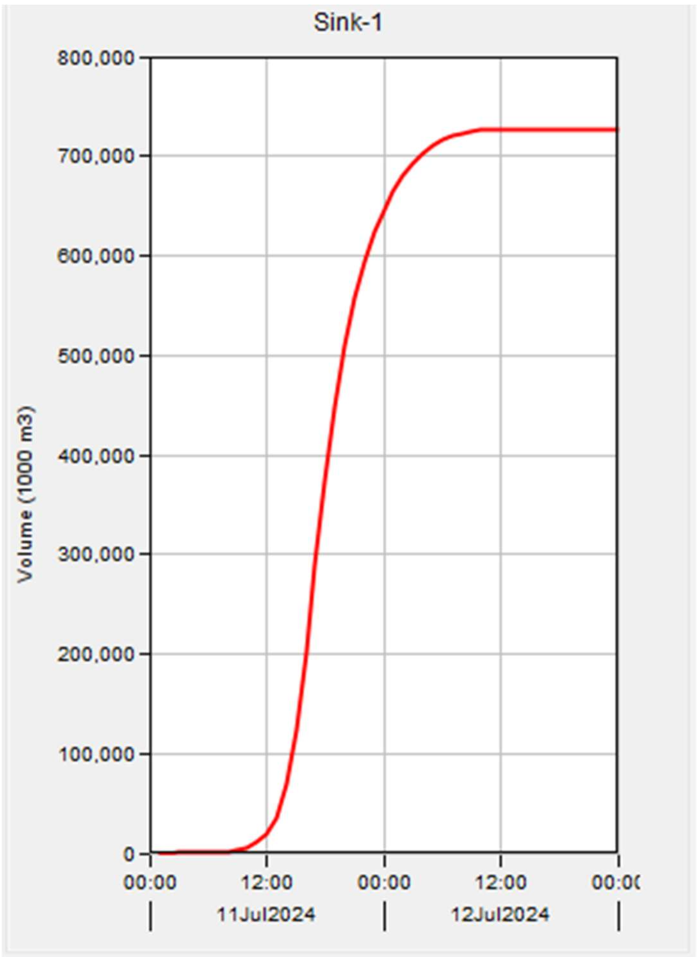


Fig 5.2: Cumulative outflow at the Sink (U/S of the study area) obtained from HEC HMS

5.2: RESULTS FROM HEC RAS (1D MODEL):

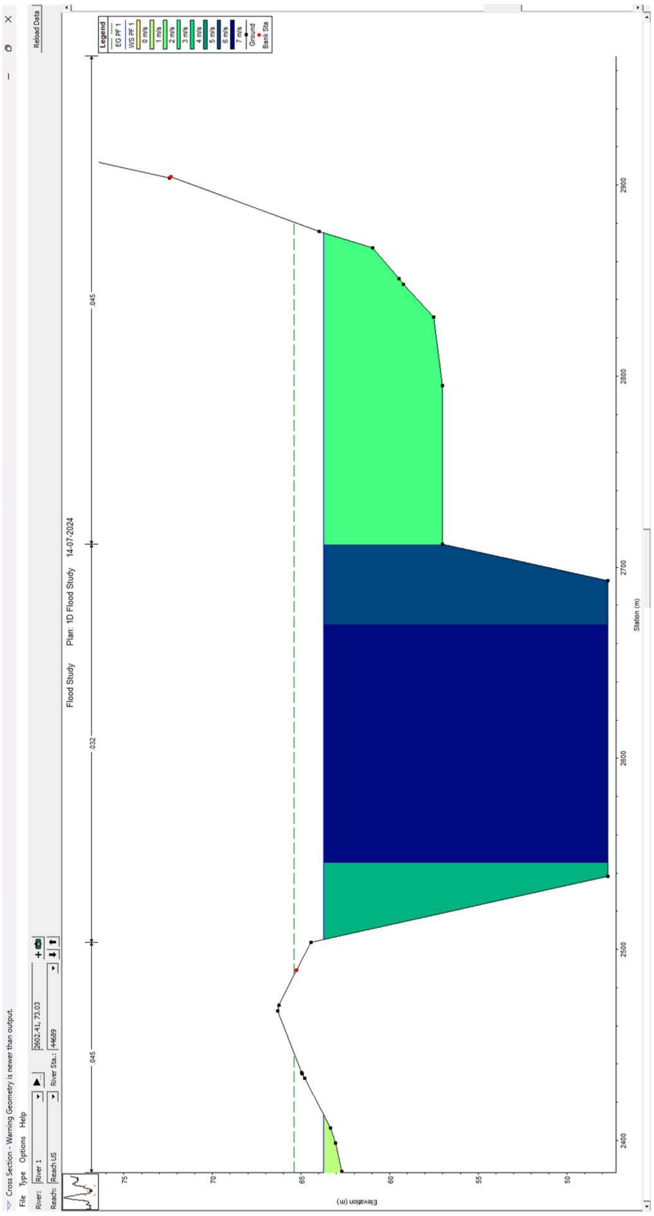


Fig 5.3: Upstream Elevation Velocity Depth Graph

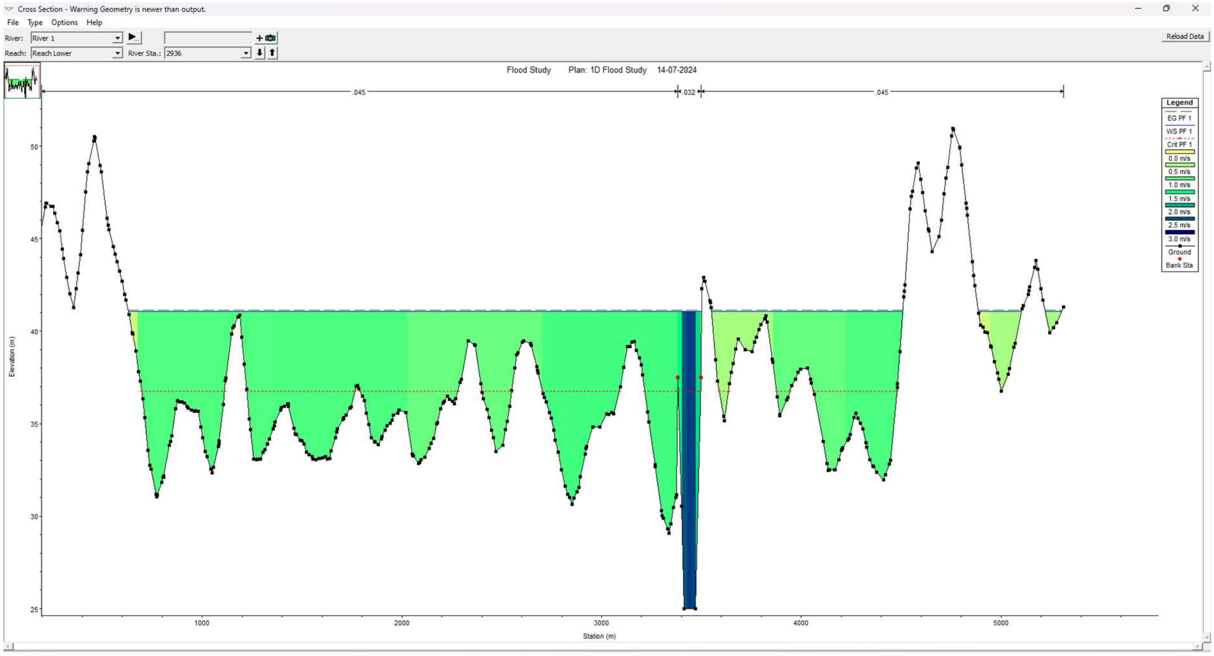


Fig 5.4: Downstream Elevation Velocity Depth Graph

After providing all the input parameters to the software for the computation, various outputs in terms of the table and the graphs are obtained such as the value of ground elevation, velocity head, water surface elevation, total velocity, max channel depth, losses, average velocity, wetted perimeter, etc.

The profile output table of the steady flow analysis are shown below:

Table 5.2**:** Profile output table for steady flow analysis for peak discharge

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
River 2	Reach Split 2	18711	PF 1	12263.5	20	46.14		46.25	0.000065	1.95	11592.8	1248.43	0.13
River 2	Reach Split 2	16419	PF 1	12263.5	20	46.18		46.19	0.000005	0.49	54208.47	6272.12	0.04
River 2	Reach Split 2	14633	PF 1	12263.5	20	46.17		46.18	0.000007	0.53	52454.7	6912.58	0.04
River 2	Reach Split 2	13513	PF 1	12263.5	20	46.17		46.17	0.000005	0.34	59491.12	7057.33	0.03
River 2	Reach Split 2	11338	PF 1	12263.5	20	46.16		46.17	0.000002	0.34	83104.28	7795.47	0.02
River 2	Reach Split 2	8736	PF 1	12263.5	20	46.15		46.16	0.000005	0.52	55976.55	6362.37	0.04
River 2	Reach Split 2	7370	PF 1	12263.5	20	46.14		46.15	0.000013	0.82	37749.91	6099.42	0.05
River 2	Reach Split 2	3687	PF 1	12263.5	20	46.1		46.11	0.000008	0.65	48153	6687.35	0.04
River 1	Reach US	44689	PF 1	24527	47.68	63.72		65.39	0.001254	6.41	5672.21	928.32	0.54
River 1	Reach US	42038	PF 1	24527	46.93	57.38	56.76	59.99	0.003686	8.38	3925.61	647.22	0.87
River 1	Reach US	39514	PF 1	24527	46.22	53.58		54.06	0.001352	4.05	8284.31	1608.44	0.5
River 1	Reach US	36988	PF 1	24527	45.51	47.29		48.34	0.004398	2.98	5426.05	1336.06	0.72
River 1	Reach Split 1	29410	PF 1	12263.5	25	46.44		46.82	0.00025	3.23	6079.87	866.68	0.25
River 1	Reach Split 1	23646	PF 1	12263.5	25	46.2		46.23	0.000041	1.26	22316.89	3897.89	0.1
River 1	Reach Split 1	22149	PF 1	12263.5	25	46.18		46.19	0.000016	0.78	37358.85	6312.83	0.06

River 1	Reach Split 1	20946	PF 1	12263.5	25	46.1		46.15	0.000074	1.61	17822.16	3582.51	0.13
River 1	Reach Split 1	19014	PF 1	12263.5	25	46.07		46.08	0.000017	0.83	31702.92	4316.42	0.06
River 1	Reach Split 1	17880	PF 1	12263.5	25	46.06		46.06	0.000008	0.55	48938.31	6766.6	0.04
River 1	Reach Split 1	17206	PF 1	12263.5	25	46.05		46.06	0.000008	0.46	50774.64	7426.14	0.04
River 1	Reach Split 1	15617	PF 1	12263.5	25	46.04		46.04	0.00001	0.63	41753.2	5167.09	0.05
River 1	Reach Lower	11335	PF 1	24527	25	45.68		45.85	0.000196	2.98	18720.19	2914.77	0.22
River 1	Reach Lower	6208	PF 1	24527	25	41.51	41.51	43.34	0.00201	7.55	6508.37	1926.5	0.66
River 1	Reach Lower	2936	PF 1	24527	25	41.07	36.77	41.15	0.0002	2.34	22904.25	4164.61	0.21

Continued in Appendix II

5.3: RESULTS FROM HEC RAS (2D MODEL):

- **Water Surface Profiles**: The most fundamental result is the water surface profile, which shows how the water level changes along the length of the river or channel.
- **Flood Extent Maps**: HEC-RAS 2D modelling allows us to generate floodplain maps that illustrate the extent of flooding for various water levels. These maps can be useful for emergency planning, land-use decisions, and risk assessment.
- **Velocity and Flow Distribution**: The model can provide information about flow velocity and direction across the study area. This can be important for assessing the potential for erosion, sediment transport, and habitat changes.
- **Inundation Depth**: HEC-RAS can calculate the depth of inundation at various locations within the floodplain. This information is useful for understanding the potential impact of a flood event on structures and infrastructure.
- **Animation**: Some visualization tools within HEC-RAS allow you to create animations of the simulated flow, which can be useful for presentations and conveying the results to stakeholders.

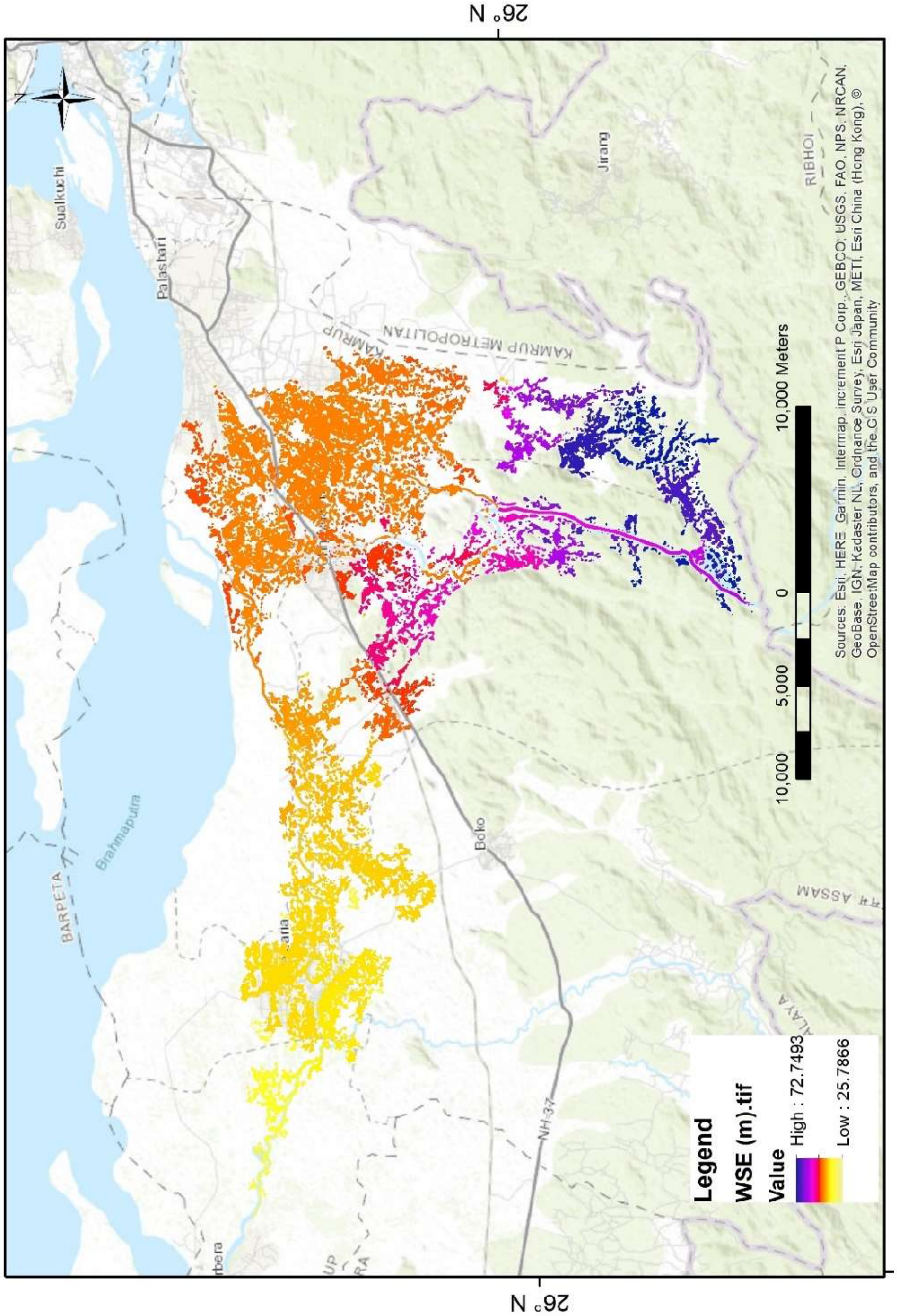


Fig 5.5: Map showing Water Surface Elevation during peak flood

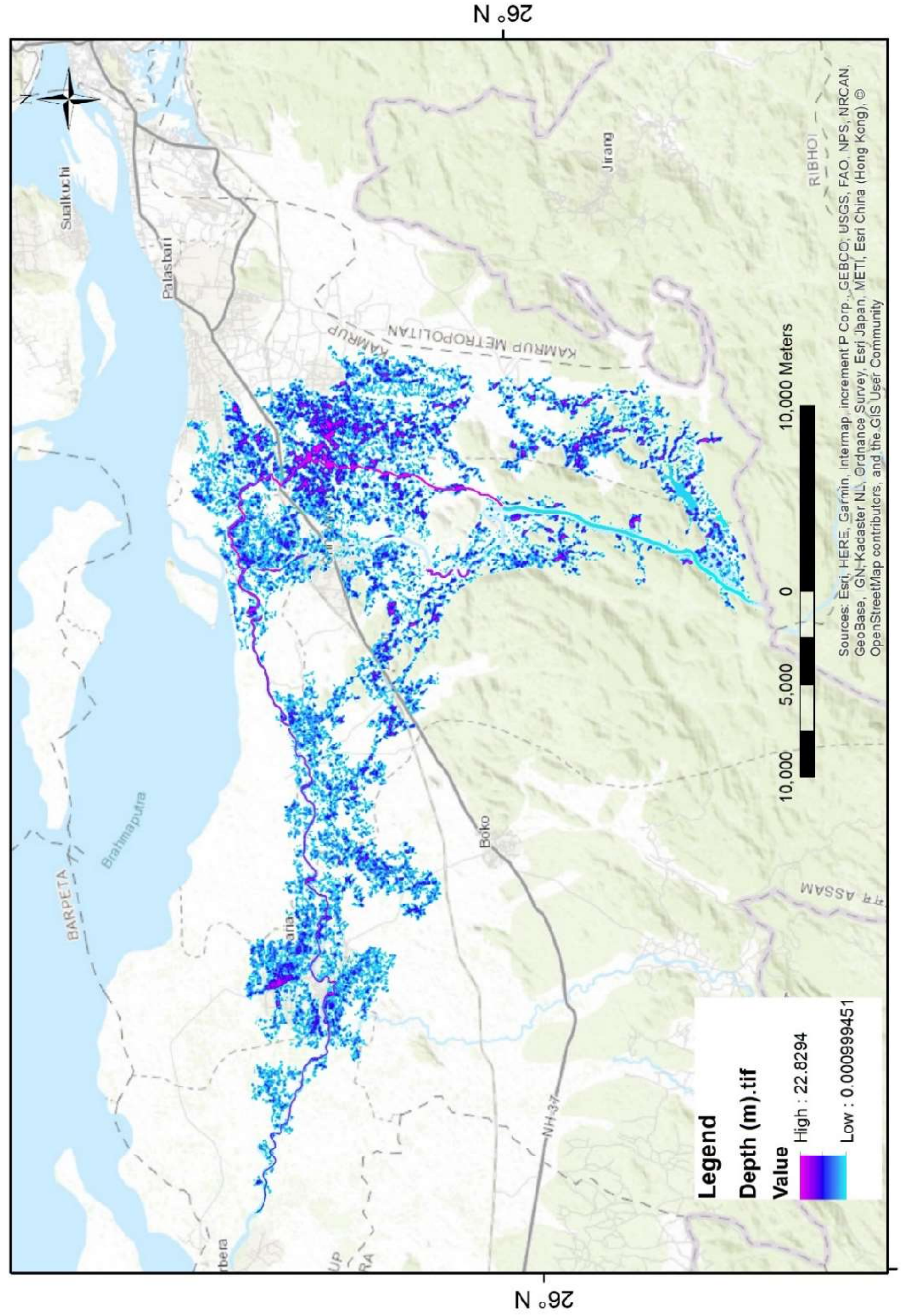


Fig 5.6: Depth Profile During peak flood

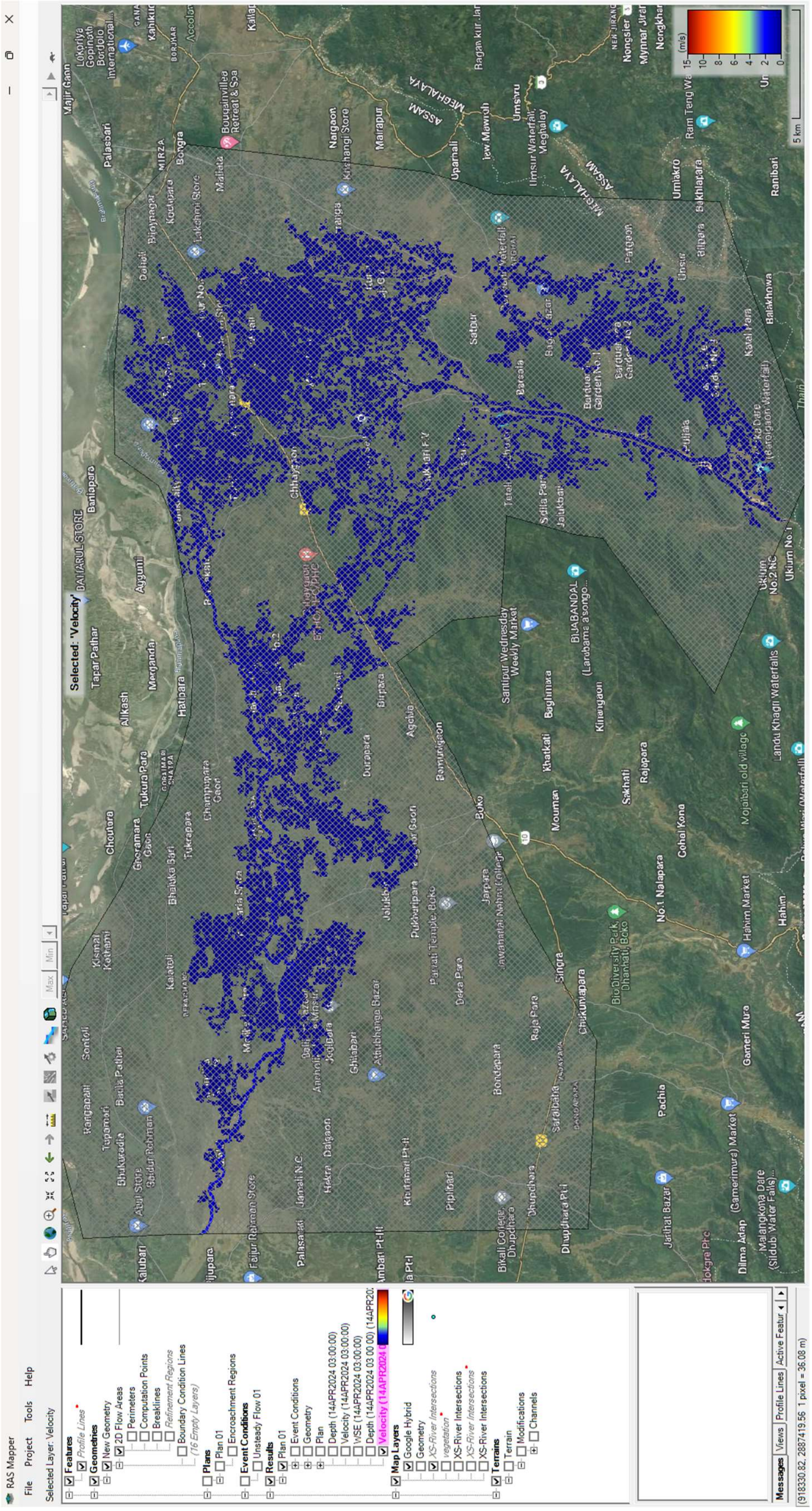


Fig 5.7: Velecity profile during peak plood

5.4 SALIENT FEATURES:

Total Area inundated in the study area for the 100-year Return period: 52656 Hectare

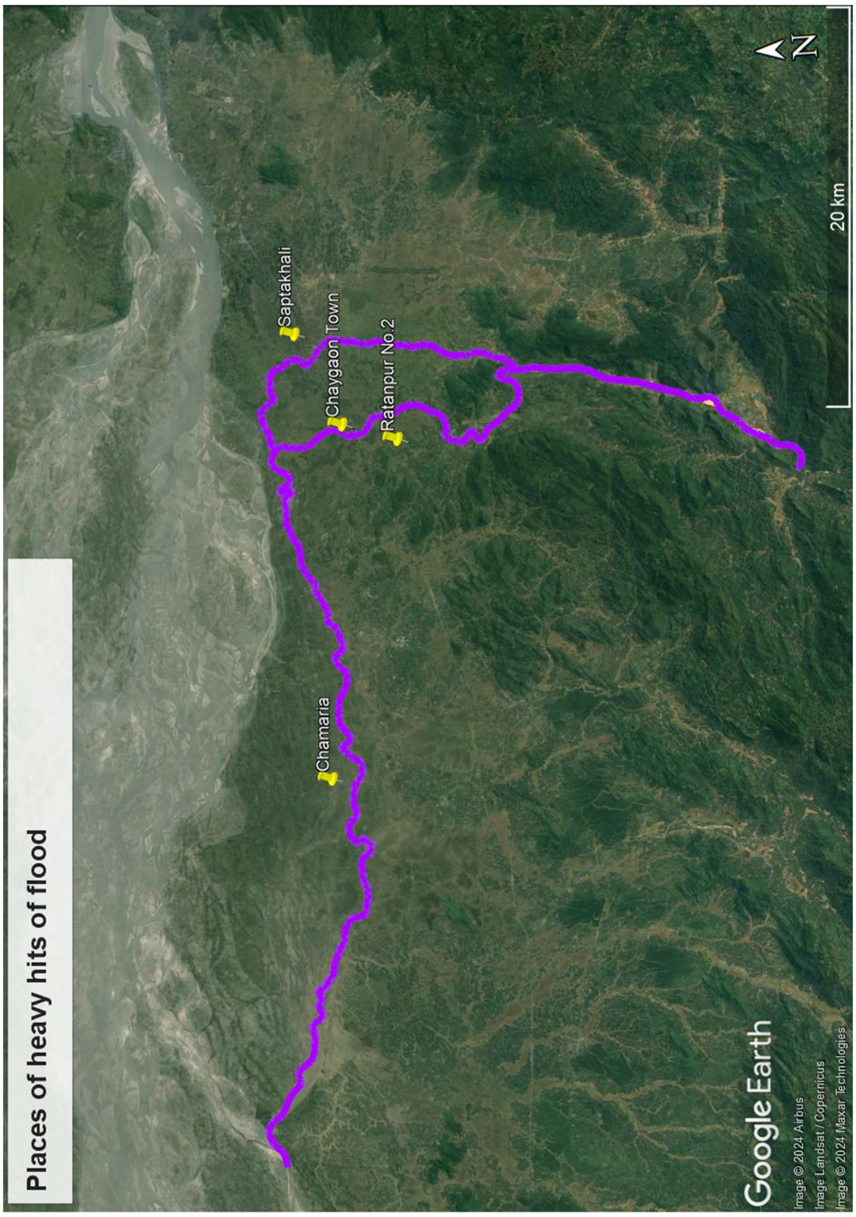


Fig 5.8: Prominent Locations of Flooding

Table 5.3: Coordinates of Various Prominent Locations

Prominent Points	Coordinates	Flood Inundation Depth (m)
Chaygaon Town	Lat: 26° 2'59.78"N Long: 91°23'33.72"E	6.3
Saptakhali	Lat: 26° 4'19.47"N Long: 91°26'46.49"E	7.1
Ratanpur No.2	Lat: 26° 1'18.58"N Long: 91°22'52.59"E	5.2
Chamaria	Lat: 26° 4'1.95"N Long: 91°11'49.00"E	4.6

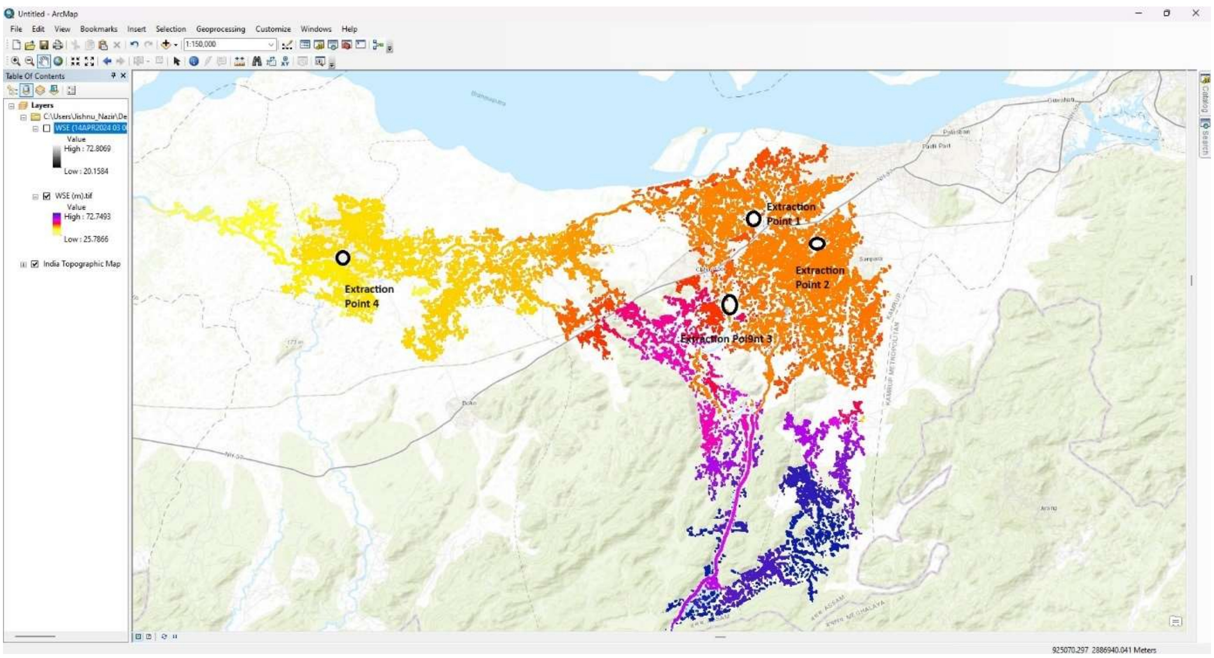


Fig 5.9: Possible Extraction Points

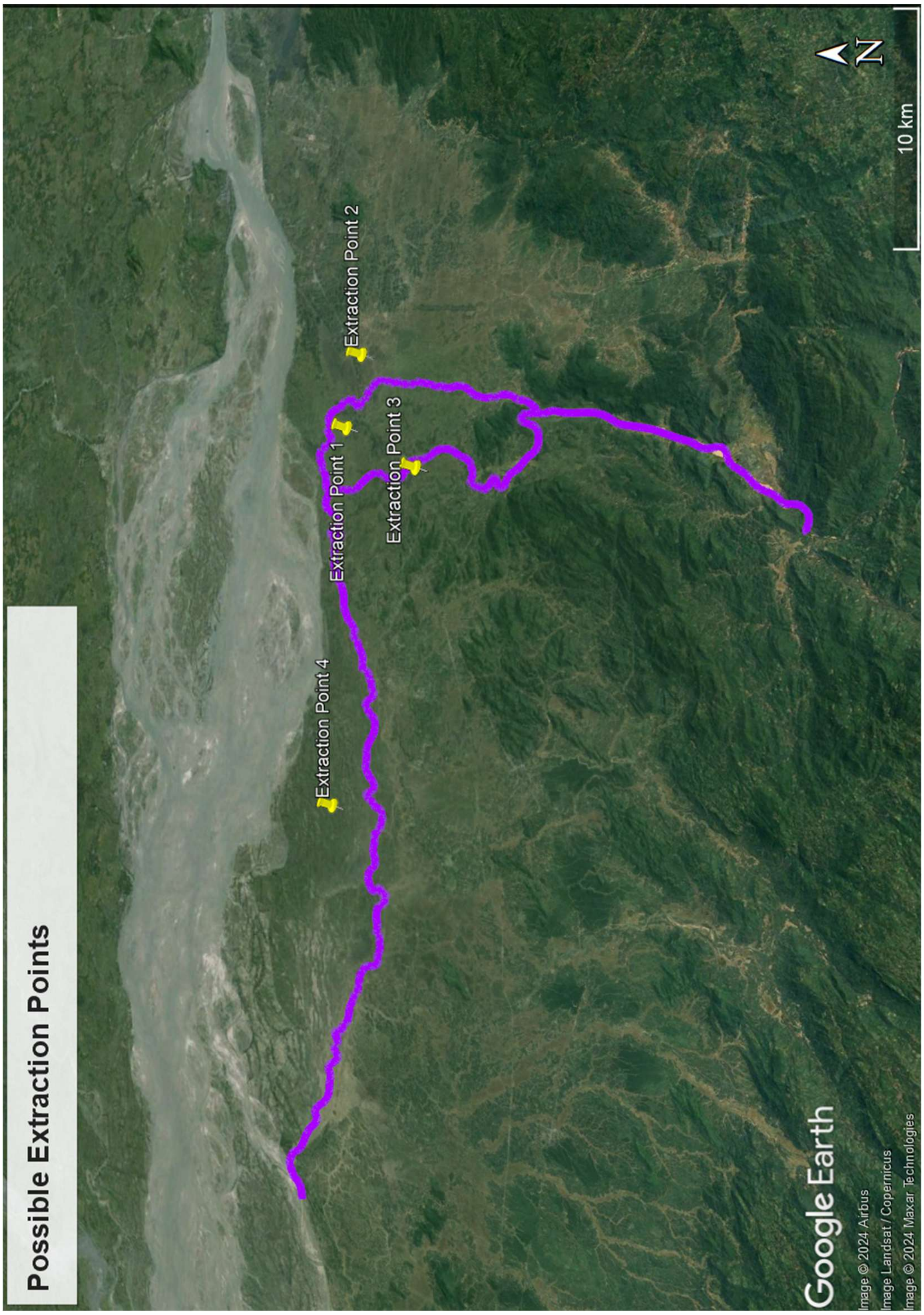


Fig 5.10: Possible Extraction point viewed in Google Earth Pro

Table 5.4: Possible Extraction Points Coordinates

Possible Extraction Points	Coordinates
Extraction Point 1	Lat: 26° 4'21.76"N Long: 91°24'59.56"E
Extraction Point 2	Lat: 26° 3'47.03"N Long: 91°27'20.25"E
Extraction Point 3	Lat: 26° 1'43.68"N Long: 91°23'26.07"E
Extraction Point 4	Lat: 26° 4'54.77"N Long: 91°12'25.56"E

CHAPTER 6

CONCLUSION

The river Kulsi, located in Assam, is sadly one of the many rivers in the region that faces chronic losses due to frequent flooding. The abundance of rich biodiversity and fragile ecosystem along the riverbanks are often threatened when floodwaters rise. Recognizing the importance of understanding the flood vulnerability of the Kulsi River, a comprehensive Flood Vulnerability Assessment has been deemed essential.

In order to assess the flood vulnerability in the area, a sophisticated 1D & 2D model has been meticulously developed utilizing the HEC-RAS Software. This advanced modeling approach enables a more comprehensive visualization of potential flooding scenarios along the river. The primary objective of this model is to simulate a flood event with a 100-year Return Period, with the ultimate goal of mapping out flood-prone areas. By doing so, it aims to provide valuable insights to the administration for devising effective flood mitigation strategies and emergency response plans during catastrophic flood situations.

Two distinct models, namely 1D and 2D, have been constructed in the HEC-RAS software to facilitate the generation of flood maps and various critical results such as water surface elevations, inundation depths, and flow velocities at different key locations within the study area. Furthermore, a HEC-HMS model has also been developed using rainfall data to generate a flood hydrograph spanning 48 hours for a 100-year return period, projecting a peak discharge of 24,527 cubic meters per second.

The study revealed that out of the total study area of 109,890 hectares, a substantial 52,656 hectares of land are susceptible to inundation during significant flood events. To address the challenge of reaching relief effectively to the most affected regions during such crises, strategic elevated lands have been identified within the severely impacted areas. These elevated sites are proposed as potential locations for the administration to develop as designated centers for relief and rescue operations, ensuring a more efficient and coordinated response in minimizing the adverse impacts of major flooding incidents.

FUTURE STUDY

Further studies on this project may encompass a comprehensive validation of hydraulic models utilized for precise flood prediction, thereby enhancing the reliability and accuracy of flood forecasting systems. Additionally, there is a crucial need to delve into the assessment of climate change impacts on flood frequency and intensity within the Kulsi basin to anticipate future challenges and develop adaptive strategies.

Moreover, in-depth evaluations are warranted to understand the economic and social repercussions of flooding, including the assessment of infrastructure damage, community displacement, and overall societal vulnerabilities. It is imperative to analyze the ecological ramifications of flood control measures, specifically examining how structures like embankments may affect habitats and biodiversity in the region.

Furthermore, active engagement with local communities is essential to foster effective flood risk management practices and bolster resilience-building efforts at the grassroots level. By adopting an integrated approach that blends structural and non-structural measures, stakeholders can better address the multifaceted challenges posed by flooding events.

To ensure the long-term sustainability of flood risk management strategies, the implementation of robust monitoring programs is vital. These programs should be designed to continuously assess flood vulnerability, measure the efficacy of mitigation measures, and inform evidence-based decision-making processes aimed at enhancing community resilience and minimizing flood-related damages in the Brahmaputra Basin.

CHAPTER 7

REFERENCES

1. **“Application of 1-D HEC-RAS model in design of Channels”.International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Volume 1 Issue 7 (August 2014**): Darshan J. Mehta, Mr. Manthan Ramani, Mr. Maulik Joshi (2014)
2. **“Determination of floodplain map and runoff computation using geographic information system (GIS)”.** Department of Civil engineering, faculty of engineering the polytechnic, Ibadan. A. Kehinde John (2017)
3. **“Flood modeling and flood forecasting using HEC-RAS”. International journal of advance scientific research andf engineering trends, Volume 5 || Issue 6 || June 2020 || ISSN 2456-0774:** Avanti Waghchaure , Aarti Patil , Pragati Bachhav , Rajashri Bodhai .
4. **“Flood modeling of river Godavari using Hec-Ras”. International Journal of Research in Engineering and Technology, eISSN: 2319-1163 | ISSN: 2321-7308:**Muhammad Shahzad Khattak, Faizan Anwar, Tariq Usman Saeed, Mohammed Sharif, Khurram Sheraz, Anwaar Ahmed.
5. **“Flood Modelling by using HEC-RAS”. International Journal of Engineering Trends and Technology (IJETT) – Volume 50 Number 1 August 2017**:Azhar Hussain (2017).
6. **“Floodplain Delineation Using HECRAS Model—A Case Study of Surat City”, Open Journal of Modern Hydrology, 2016, 6, 34-42:** Chandresh G. Patel, Pradip J. Gundaliya
7. **“Floodplain Modeling in the KansasRiver Basin Using Hydrologic Engineering Center (HEC) Models Impacts of Urbanization and Wetlands for Mitigation”,** Y. Yuan Kamal Qaiser (2011): U.S. Environmental Protection Agency National Exposure Research Laboratory Environmental Sciences Division Landscape Ecology Branch Las Vegas, NV 89119
8. **“Floodplain Zoning Simulation by Using HEC-RAS and CCHE2D Models in the Sungai Maka River”,** Ahmad Shahiri Parsa, Mohammad Noori, Mohammad Heydari and Mahmood Rashidi**.**

9. **“GIS mapping algorithm for floodway modeling”. Journal of flood engineering Vol. 10 No. 1 (January-June, 2019)** : Sivasankkar Selvanathan and Randel L. Dymond
10. **“Integration of GIS and HEC-RAS in Floods Modeling of Martil River (Northern Morocco)”. European Scientific Journal April 2018 edition Vol.14, No.12 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431Amina :** Azouagh, Rabei El Bardai, Ismael. Hilal, Jamal. Stitou el Messari, PhD (2018)
11. **“Integration of HEC-RAS and geographical information system (GIS) in the hydrological study of peak flow response to deforestation on a small watershed in Malaysia”. International Journal of Water Resources and Environmental Engineering, Vol. 5(3), pp. 146-151, March, 2013 :**Ali M. F, Kamarudin A. F, Khalid K. and Abd Rahman N. F.
12. **“One Dimensional Steady Flow Analysis Using HECRAS – A case of River Jhelum, Jammu and Kashmir”. European Scientific Journal November 2016 edition vol.12, No.32 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431:** Hakim Farooq Ahmad, Akhtar Alam, M. Sultan Bhat, Shabir Ahmad (2016):
13. **“River Flood Modeling Using GIS, HEC-GeoRAS And HECRAS For Purna River, Navsari District, Gujarat, India”, International Journal of Scientific Development and Research (IJSDR) :** Azazkhan I.Pathan, 2Prof.B.M Vadher, 3Dr.P.G Agnihotri.

APPENDIX I

Table 5.1: Time Series Plot

Date	Time	Inflow from Reach-1 (M3/S)	Inflow from Sub-25 (M3/S)	Outflow (M3/S)
11-Jul-24	00:00	0	0	0
11-Jul-24	00:05	0	0	0
11-Jul-24	00:10	0	0	0
11-Jul-24	00:15	0	0	0
11-Jul-24	00:20	0	0	0
11-Jul-24	00:25	0	0	0
11-Jul-24	00:30	0	0	0
11-Jul-24	00:35	0	0	0
11-Jul-24	00:40	0	0	0
11-Jul-24	00:45	0	0	0
11-Jul-24	00:50	0	0	0
11-Jul-24	00:55	0	0	0
11-Jul-24	01:00	0	0	0
11-Jul-24	01:05	0	0	0
11-Jul-24	01:10	0	0	0
11-Jul-24	01:15	0	0	0
11-Jul-24	01:20	0	0	0
11-Jul-24	01:25	0	0	0
11-Jul-24	01:30	0	0	0
11-Jul-24	01:35	0	0	0
11-Jul-24	01:40	0	0	0
11-Jul-24	01:45	0	0	0
11-Jul-24	01:50	0	0	0
11-Jul-24	01:55	0	0	0
11-Jul-24	02:00	0	0	0
11-Jul-24	02:05	0	0	0
11-Jul-24	02:10	0	0	0
11-Jul-24	02:15	0	0	0
11-Jul-24	02:20	0	0	0
11-Jul-24	02:25	0	0	0
11-Jul-24	02:30	0	0	0
11-Jul-24	02:35	0	0	0
11-Jul-24	02:40	0	0	0
11-Jul-24	02:45	0	0	0
11-Jul-24	02:50	0	0	0
11-Jul-24	02:55	0	0	0

11-Jul-24	03:00	0	0	0
11-Jul-24	03:05	0	0	0
11-Jul-24	03:10	0	0	0
11-Jul-24	03:15	0	0	0
11-Jul-24	03:20	0	0	0
11-Jul-24	03:25	0	0	0
11-Jul-24	03:30	0	0	0.1
11-Jul-24	03:35	0	0.1	0.1
11-Jul-24	03:40	0	0.1	0.1
11-Jul-24	03:45	0	0.2	0.2
11-Jul-24	03:50	0	0.2	0.3
11-Jul-24	03:55	0.1	0.3	0.4
11-Jul-24	04:00	0.1	0.4	0.5
11-Jul-24	04:05	0.1	0.5	0.6
11-Jul-24	04:10	0.2	0.6	0.8
11-Jul-24	04:15	0.3	0.7	0.9
11-Jul-24	04:20	0.4	0.8	1.1
11-Jul-24	04:25	0.5	0.9	1.4
11-Jul-24	04:30	0.7	1	1.7
11-Jul-24	04:35	1	1.1	2.1
11-Jul-24	04:40	1.3	1.2	2.5
11-Jul-24	04:45	1.8	1.3	3.1
11-Jul-24	04:50	2.3	1.4	3.8
11-Jul-24	04:55	3	1.5	4.6
11-Jul-24	05:00	3.9	1.6	5.5
11-Jul-24	05:05	4.9	1.8	6.6
11-Jul-24	05:10	6.1	1.9	7.9
11-Jul-24	05:15	7.5	2	9.5
11-Jul-24	05:20	9.1	2.1	11.2
11-Jul-24	05:25	11	2.2	13.2
11-Jul-24	05:30	13.1	2.4	15.5
11-Jul-24	05:35	15.6	2.5	18.1
11-Jul-24	05:40	18.3	2.6	21
11-Jul-24	05:45	21.4	2.8	24.2
11-Jul-24	05:50	24.9	2.9	27.8
11-Jul-24	05:55	28.8	3	31.8
11-Jul-24	06:00	33	3.1	36.2
11-Jul-24	06:05	37.7	3.3	41
11-Jul-24	06:10	42.9	3.4	46.3
11-Jul-24	06:15	48.5	3.5	52
11-Jul-24	06:20	54.6	3.7	58.3
11-Jul-24	06:25	61.3	3.8	65.1

11-Jul-24	06:30	68.4	4	72.4
11-Jul-24	06:35	76.2	4.1	80.3
11-Jul-24	06:40	84.5	4.2	88.7
11-Jul-24	06:45	93.4	4.4	97.8
11-Jul-24	06:50	103	4.5	107.5
11-Jul-24	06:55	113.1	4.7	117.8
11-Jul-24	07:00	124	4.8	128.7
11-Jul-24	07:05	135.4	4.9	140.4
11-Jul-24	07:10	147.6	5.1	152.7
11-Jul-24	07:15	160.4	5.2	165.6
11-Jul-24	07:20	174	5.4	179.3
11-Jul-24	07:25	188.2	5.5	193.7
11-Jul-24	07:30	203.2	5.6	208.9
11-Jul-24	07:35	218.9	5.8	224.7
11-Jul-24	07:40	235.4	6	241.3
11-Jul-24	07:45	252.6	6.1	258.7
11-Jul-24	07:50	270.5	6.2	276.8
11-Jul-24	07:55	289.2	6.4	295.6
11-Jul-24	08:00	308.7	6.5	315.2
11-Jul-24	08:05	328.9	6.7	335.6
11-Jul-24	08:10	349.9	6.8	356.7
11-Jul-24	08:15	371.7	7	378.7
11-Jul-24	08:20	394.2	7.2	401.4
11-Jul-24	08:25	417.5	7.4	424.9
11-Jul-24	08:30	441.6	7.7	449.2
11-Jul-24	08:35	466.4	7.9	474.3
11-Jul-24	08:40	492	8.2	500.2
11-Jul-24	08:45	518.4	8.6	527
11-Jul-24	08:50	545.5	9	554.5
11-Jul-24	08:55	573.4	9.3	582.7
11-Jul-24	09:00	602.1	9.7	611.8
11-Jul-24	09:05	631.5	10.1	641.6
11-Jul-24	09:10	661.7	10.6	672.3
11-Jul-24	09:15	692.7	11	703.7
11-Jul-24	09:20	724.5	11.4	735.8
11-Jul-24	09:25	757.1	11.7	768.8
11-Jul-24	09:30	790.5	12	802.5
11-Jul-24	09:35	824.8	12.3	837.1
11-Jul-24	09:40	860	12.6	872.5
11-Jul-24	09:45	896	12.8	908.8
11-Jul-24	09:50	933	13.1	946.1
11-Jul-24	09:55	971	13.4	984.5

11-Jul-24	10:00	1010	13.9	1023.9
11-Jul-24	10:05	1050.1	14.3	1064.4
11-Jul-24	10:10	1091.2	14.9	1106.1
11-Jul-24	10:15	1133.5	15.5	1149
11-Jul-24	10:20	1176.8	16.2	1193
11-Jul-24	10:25	1221.4	16.9	1238.3
11-Jul-24	10:30	1267.1	17.8	1284.9
11-Jul-24	10:35	1314.1	18.6	1332.7
11-Jul-24	10:40	1362.3	19.6	1381.9
11-Jul-24	10:45	1411.8	20.6	1432.4
11-Jul-24	10:50	1462.6	21.8	1484.4
11-Jul-24	10:55	1514.8	23	1537.9
11-Jul-24	11:00	1568.5	24.4	1592.9
11-Jul-24	11:05	1623.6	25.9	1649.6
11-Jul-24	11:10	1680.4	27.6	1708
11-Jul-24	11:15	1738.8	29.5	1768.3
11-Jul-24	11:20	1799.1	31.7	1830.7
11-Jul-24	11:25	1861.3	34.2	1895.4
11-Jul-24	11:30	1925.5	37.1	1962.6
11-Jul-24	11:35	1992	40.9	2032.8
11-Jul-24	11:40	2060.7	47.3	2108
11-Jul-24	11:45	2132	59.4	2191.4
11-Jul-24	11:50	2206.2	82.8	2289
11-Jul-24	11:55	2283.7	123.7	2407.4
11-Jul-24	12:00	2365.8	182.6	2548.4
11-Jul-24	12:05	2453.5	251.1	2704.7
11-Jul-24	12:10	2546.7	311.4	2858.1
11-Jul-24	12:15	2645.4	344.2	2989.6
11-Jul-24	12:20	2751.9	344	3095.9
11-Jul-24	12:25	2869	319.3	3188.2
11-Jul-24	12:30	2998.8	280.3	3279.1
11-Jul-24	12:35	3143.9	235.5	3379.4
11-Jul-24	12:40	3308.2	193.9	3502.1
11-Jul-24	12:45	3497	161.2	3658.2
11-Jul-24	12:50	3716.7	136	3852.7
11-Jul-24	12:55	3973.2	115.6	4088.7
11-Jul-24	13:00	4271.2	98.9	4370.1
11-Jul-24	13:05	4613.6	85.5	4699.1
11-Jul-24	13:10	5001.7	74.8	5076.5
11-Jul-24	13:15	5435.8	66.2	5502
11-Jul-24	13:20	5914.6	59.3	5973.9
11-Jul-24	13:25	6435.8	53.6	6489.5

11-Jul-24	13:30	6996.4	49	7045.4
11-Jul-24	13:35	7593	45.1	7638
11-Jul-24	13:40	8221.1	41.8	8262.9
11-Jul-24	13:45	8875.9	39	8914.9
11-Jul-24	13:50	9552.1	36.6	9588.8
11-Jul-24	13:55	10245.4	34.5	10279.9
11-Jul-24	14:00	10952	32.5	10984.5
11-Jul-24	14:05	11668.5	30.7	11699.1
11-Jul-24	14:10	12392.1	29.1	12421.1
11-Jul-24	14:15	13120.3	27.7	13148
11-Jul-24	14:20	13849.9	26.6	13876.5
11-Jul-24	14:25	14577.3	25.6	14603
11-Jul-24	14:30	15299	24.8	15323.8
11-Jul-24	14:35	16012	24.1	16036.1
11-Jul-24	14:40	16714.3	23.4	16737.7
11-Jul-24	14:45	17404.4	22.8	17427.2
11-Jul-24	14:50	18081	22.3	18103.3
11-Jul-24	14:55	18742.2	21.9	18764.1
11-Jul-24	15:00	19385.8	21.4	19407.2
11-Jul-24	15:05	20008.8	21	20029.9
11-Jul-24	15:10	20608.4	20.6	20629
11-Jul-24	15:15	21182.1	20.2	21202.4
11-Jul-24	15:20	21728	19.8	21747.8
11-Jul-24	15:25	22244.7	19.5	22264.1
11-Jul-24	15:30	22731.1	19.1	22750.2
11-Jul-24	15:35	23186.5	18.7	23205.2
11-Jul-24	15:40	23610.3	18.3	23628.6
11-Jul-24	15:45	24002.1	18	24020
11-Jul-24	15:50	24361.6	17.6	24379.2
11-Jul-24	15:55	24688.7	17.3	24705.9
11-Jul-24	16:00	24983.1	16.9	25000
11-Jul-24	16:05	25244.9	16.6	25261.5
11-Jul-24	16:10	25474.1	16.2	25490.3
11-Jul-24	16:15	25670.9	15.8	25686.7
11-Jul-24	16:20	25835.7	15.5	25851.2
11-Jul-24	16:25	25969.4	15.2	25984.6
11-Jul-24	16:30	26073.1	14.9	26088
11-Jul-24	16:35	26147.9	14.7	26162.6
11-Jul-24	16:40	26195	14.5	26209.5
11-Jul-24	16:45	26215.6	14.3	26229.9
11-Jul-24	16:50	26210.6	14.1	26224.8
11-Jul-24	16:55	26181.1	14	26195.1

11-Jul-24	17:00	26127.6	13.8	26141.5
11-Jul-24	17:05	26050.9	13.7	26064.6
11-Jul-24	17:10	25951.6	13.6	25965.2
11-Jul-24	17:15	25830.4	13.4	25843.9
11-Jul-24	17:20	25688.2	13.3	25701.5
11-Jul-24	17:25	25525.9	13.1	25539
11-Jul-24	17:30	25344.3	12.9	25357.3
11-Jul-24	17:35	25144.5	12.8	25157.3
11-Jul-24	17:40	24927.2	12.7	24939.8
11-Jul-24	17:45	24693.2	12.6	24705.8
11-Jul-24	17:50	24443.6	12.4	24456
11-Jul-24	17:55	24179	12.3	24191.3
11-Jul-24	18:00	23900.3	12.2	23912.4
11-Jul-24	18:05	23608.2	12.1	23620.3
11-Jul-24	18:10	23303.8	11.9	23315.7
11-Jul-24	18:15	22987.6	11.8	22999.4
11-Jul-24	18:20	22660.8	11.7	22672.5
11-Jul-24	18:25	22324.2	11.5	22335.8
11-Jul-24	18:30	21978.9	11.4	21990.3
11-Jul-24	18:35	21625.8	11.3	21637.1
11-Jul-24	18:40	21266	11.2	21277.2
11-Jul-24	18:45	20900.5	11	20911.5
11-Jul-24	18:50	20530.3	10.9	20541.2
11-Jul-24	18:55	20156.4	10.7	20167.1
11-Jul-24	19:00	19779.6	10.6	19790.2
11-Jul-24	19:05	19400.9	10.5	19411.4
11-Jul-24	19:10	19021	10.4	19031.3
11-Jul-24	19:15	18640.7	10.2	18650.9
11-Jul-24	19:20	18260.7	10.1	18270.8
11-Jul-24	19:25	17881.7	10	17891.7
11-Jul-24	19:30	17504.4	9.9	17514.2
11-Jul-24	19:35	17129.3	9.7	17139
11-Jul-24	19:40	16757	9.6	16766.6
11-Jul-24	19:45	16388.2	9.5	16397.6
11-Jul-24	19:50	16023.2	9.3	16032.5
11-Jul-24	19:55	15662.5	9.2	15671.7
11-Jul-24	20:00	15306.6	9	15315.6
11-Jul-24	20:05	14955.8	8.9	14964.7
11-Jul-24	20:10	14610.4	8.8	14619.2
11-Jul-24	20:15	14270.8	8.7	14279.5
11-Jul-24	20:20	13937.1	8.6	13945.7
11-Jul-24	20:25	13609.5	8.5	13618

11-Jul-24	20:30	13288.4	8.4	13296.8
11-Jul-24	20:35	12973.7	8.3	12982.1
11-Jul-24	20:40	12665.7	8.3	12674
11-Jul-24	20:45	12364.4	8.2	12372.6
11-Jul-24	20:50	12070	8.2	12078.1
11-Jul-24	20:55	11782.3	8.1	11790.4
11-Jul-24	21:00	11501.6	8.1	11509.6
11-Jul-24	21:05	11227.7	8	11235.8
11-Jul-24	21:10	10960.8	8	10968.8
11-Jul-24	21:15	10700.7	8	10708.7
11-Jul-24	21:20	10447.5	7.9	10455.4
11-Jul-24	21:25	10201.1	7.9	10209
11-Jul-24	21:30	9961.4	7.9	9969.3
11-Jul-24	21:35	9728.4	7.9	9736.3
11-Jul-24	21:40	9502	7.9	9509.9
11-Jul-24	21:45	9282.1	7.8	9290
11-Jul-24	21:50	9068.6	7.8	9076.5
11-Jul-24	21:55	8861.4	7.8	8869.2
11-Jul-24	22:00	8660.4	7.8	8668.2
11-Jul-24	22:05	8465.4	7.7	8473.1
11-Jul-24	22:10	8276.3	7.7	8284
11-Jul-24	22:15	8092.9	7.7	8100.6
11-Jul-24	22:20	7915.2	7.6	7922.8
11-Jul-24	22:25	7743	7.6	7750.6
11-Jul-24	22:30	7576	7.6	7583.6
11-Jul-24	22:35	7414.3	7.6	7421.8
11-Jul-24	22:40	7257.6	7.5	7265.1
11-Jul-24	22:45	7105.8	7.5	7113.2
11-Jul-24	22:50	6958.8	7.4	6966.2
11-Jul-24	22:55	6816.4	7.4	6823.8
11-Jul-24	23:00	6678.6	7.4	6686
11-Jul-24	23:05	6545.2	7.4	6552.6
11-Jul-24	23:10	6416.1	7.3	6423.4
11-Jul-24	23:15	6291.1	7.3	6298.4
11-Jul-24	23:20	6170.1	7.3	6177.4
11-Jul-24	23:25	6053	7.3	6060.3
11-Jul-24	23:30	5939.7	7.3	5947
11-Jul-24	23:35	5830.1	7.3	5837.4
11-Jul-24	23:40	5724	7.2	5731.3
11-Jul-24	23:45	5621.4	7.2	5628.6
11-Jul-24	23:50	5522	7.2	5529.2
11-Jul-24	23:55	5425.9	7.2	5433.1

12-Jul-24	00:00	5332.9	7.1	5340
12-Jul-24	00:05	5242.9	7	5250
12-Jul-24	00:10	5155.9	6.8	5162.7
12-Jul-24	00:15	5071.6	6.3	5077.9
12-Jul-24	00:20	4990.1	5.5	4995.6
12-Jul-24	00:25	4911.2	4.6	4915.7
12-Jul-24	00:30	4834.8	3.6	4838.4
12-Jul-24	00:35	4760.8	2.8	4763.6
12-Jul-24	00:40	4689.1	2.1	4691.2
12-Jul-24	00:45	4619.7	1.5	4621.2
12-Jul-24	00:50	4552.4	1.1	4553.5
12-Jul-24	00:55	4487.1	0.9	4487.9
12-Jul-24	01:00	4423.6	0.6	4424.2
12-Jul-24	01:05	4361.9	0.5	4362.3
12-Jul-24	01:10	4301.7	0.4	4302
12-Jul-24	01:15	4242.8	0.3	4243.1
12-Jul-24	01:20	4185.2	0.2	4185.4
12-Jul-24	01:25	4128.6	0.1	4128.8
12-Jul-24	01:30	4072.9	0.1	4073
12-Jul-24	01:35	4017.9	0.1	4017.9
12-Jul-24	01:40	3963.4	0.1	3963.5
12-Jul-24	01:45	3909.4	0	3909.4
12-Jul-24	01:50	3855.6	0	3855.7
12-Jul-24	01:55	3802.1	0	3802.1
12-Jul-24	02:00	3748.7	0	3748.7
12-Jul-24	02:05	3695.3	0	3695.3
12-Jul-24	02:10	3642	0	3642
12-Jul-24	02:15	3588.6	0	3588.6
12-Jul-24	02:20	3535.2	0	3535.2
12-Jul-24	02:25	3481.7	0	3481.7
12-Jul-24	02:30	3427.9	0	3427.9
12-Jul-24	02:35	3374	0	3374
12-Jul-24	02:40	3319.9	0	3319.9
12-Jul-24	02:45	3265.5	0	3265.5
12-Jul-24	02:50	3210.9	0	3210.9
12-Jul-24	02:55	3156.1	0	3156.1
12-Jul-24	03:00	3101	0	3101
12-Jul-24	03:05	3045.7	0	3045.7
12-Jul-24	03:10	2990.1	0	2990.1
12-Jul-24	03:15	2934.3	0	2934.3
12-Jul-24	03:20	2878.3	0	2878.3
12-Jul-24	03:25	2822.2	0	2822.2

12-Jul-24	03:30	2765.8	0	2765.8
12-Jul-24	03:35	2709.4	0	2709.4
12-Jul-24	03:40	2652.9	0	2652.9
12-Jul-24	03:45	2596.3	0	2596.3
12-Jul-24	03:50	2539.8	0	2539.8
12-Jul-24	03:55	2483.3	0	2483.3
12-Jul-24	04:00	2426.9	0	2426.9
12-Jul-24	04:05	2370.7	0	2370.7
12-Jul-24	04:10	2314.6	0	2314.6
12-Jul-24	04:15	2258.8	0	2258.8
12-Jul-24	04:20	2203.3	0	2203.3
12-Jul-24	04:25	2148	0	2148
12-Jul-24	04:30	2093.2	0	2093.2
12-Jul-24	04:35	2038.7	0	2038.7
12-Jul-24	04:40	1984.7	0	1984.7
12-Jul-24	04:45	1931.2	0	1931.2
12-Jul-24	04:50	1878.3	0	1878.3
12-Jul-24	04:55	1825.9	0	1825.9
12-Jul-24	05:00	1774	0	1774
12-Jul-24	05:05	1722.9	0	1722.9
12-Jul-24	05:10	1672.3	0	1672.3
12-Jul-24	05:15	1622.5	0	1622.5
12-Jul-24	05:20	1573.3	0	1573.3
12-Jul-24	05:25	1524.9	0	1524.9
12-Jul-24	05:30	1477.2	0	1477.2
12-Jul-24	05:35	1430.3	0	1430.3
12-Jul-24	05:40	1384.2	0	1384.2
12-Jul-24	05:45	1338.9	0	1338.9
12-Jul-24	05:50	1294.4	0	1294.4
12-Jul-24	05:55	1250.8	0	1250.8
12-Jul-24	06:00	1208.1	0	1208.1
12-Jul-24	06:05	1166.2	0	1166.2
12-Jul-24	06:10	1125.3	0	1125.3
12-Jul-24	06:15	1085.2	0	1085.2
12-Jul-24	06:20	1046.1	0	1046.1
12-Jul-24	06:25	1008	0	1008
12-Jul-24	06:30	970.8	0	970.8
12-Jul-24	06:35	934.5	0	934.5
12-Jul-24	06:40	899.2	0	899.2
12-Jul-24	06:45	864.8	0	864.8
12-Jul-24	06:50	831.4	0	831.4
12-Jul-24	06:55	799	0	799

12-Jul-24	07:00	767.5	0	767.5
12-Jul-24	07:05	737	0	737
12-Jul-24	07:10	707.4	0	707.4
12-Jul-24	07:15	678.7	0	678.7
12-Jul-24	07:20	651	0	651
12-Jul-24	07:25	624.2	0	624.2
12-Jul-24	07:30	598.3	0	598.3
12-Jul-24	07:35	573.2	0	573.2
12-Jul-24	07:40	549.1	0	549.1
12-Jul-24	07:45	525.7	0	525.7
12-Jul-24	07:50	503.3	0	503.3
12-Jul-24	07:55	481.6	0	481.6
12-Jul-24	08:00	460.7	0	460.7
12-Jul-24	08:05	440.7	0	440.7
12-Jul-24	08:10	421.4	0	421.4
12-Jul-24	08:15	402.8	0	402.8
12-Jul-24	08:20	385	0	385
12-Jul-24	08:25	367.8	0	367.8
12-Jul-24	08:30	351.4	0	351.4
12-Jul-24	08:35	335.6	0	335.6
12-Jul-24	08:40	320.5	0	320.5
12-Jul-24	08:45	306	0	306
12-Jul-24	08:50	292.1	0	292.1
12-Jul-24	08:55	278.7	0	278.7
12-Jul-24	09:00	266	0	266
12-Jul-24	09:05	253.8	0	253.8
12-Jul-24	09:10	242.1	0	242.1
12-Jul-24	09:15	230.9	0	230.9
12-Jul-24	09:20	220.2	0	220.2
12-Jul-24	09:25	210	0	210
12-Jul-24	09:30	200.2	0	200.2
12-Jul-24	09:35	190.9	0	190.9
12-Jul-24	09:40	182	0	182
12-Jul-24	09:45	173.5	0	173.5
12-Jul-24	09:50	165.3	0	165.3
12-Jul-24	09:55	157.6	0	157.6
12-Jul-24	10:00	150.2	0	150.2
12-Jul-24	10:05	143.1	0	143.1
12-Jul-24	10:10	136.3	0	136.3
12-Jul-24	10:15	129.9	0	129.9
12-Jul-24	10:20	123.8	0	123.8
12-Jul-24	10:25	117.9	0	117.9

12-Jul-24	10:30	112.3	0	112.3
12-Jul-24	10:35	107	0	107
12-Jul-24	10:40	101.9	0	101.9
12-Jul-24	10:45	97.1	0	97.1
12-Jul-24	10:50	92.5	0	92.5
12-Jul-24	10:55	88.1	0	88.1
12-Jul-24	11:00	83.9	0	83.9
12-Jul-24	11:05	79.9	0	79.9
12-Jul-24	11:10	76.1	0	76.1
12-Jul-24	11:15	72.5	0	72.5
12-Jul-24	11:20	69	0	69
12-Jul-24	11:25	65.7	0	65.7
12-Jul-24	11:30	62.6	0	62.6
12-Jul-24	11:35	59.6	0	59.6
12-Jul-24	11:40	56.8	0	56.8
12-Jul-24	11:45	54	0	54
12-Jul-24	11:50	51.5	0	51.5
12-Jul-24	11:55	49	0	49
12-Jul-24	12:00	46.6	0	46.6
12-Jul-24	12:05	44.4	0	44.4
12-Jul-24	12:10	42.3	0	42.3
12-Jul-24	12:15	40.2	0	40.2
12-Jul-24	12:20	38.3	0	38.3
12-Jul-24	12:25	36.5	0	36.5
12-Jul-24	12:30	34.7	0	34.7
12-Jul-24	12:35	33	0	33
12-Jul-24	12:40	31.4	0	31.4
12-Jul-24	12:45	29.9	0	29.9
12-Jul-24	12:50	28.5	0	28.5
12-Jul-24	12:55	27.1	0	27.1
12-Jul-24	13:00	25.8	0	25.8
12-Jul-24	13:05	24.5	0	24.5
12-Jul-24	13:10	23.3	0	23.3
12-Jul-24	13:15	22.2	0	22.2
12-Jul-24	13:20	21.1	0	21.1
12-Jul-24	13:25	20	0	20
12-Jul-24	13:30	19.1	0	19.1
12-Jul-24	13:35	18.1	0	18.1
12-Jul-24	13:40	17.2	0	17.2
12-Jul-24	13:45	16.4	0	16.4
12-Jul-24	13:50	15.6	0	15.6
12-Jul-24	13:55	14.8	0	14.8

12-Jul-24	14:00	14.1	0	14.1
12-Jul-24	14:05	13.4	0	13.4
12-Jul-24	14:10	12.7	0	12.7
12-Jul-24	14:15	12.1	0	12.1
12-Jul-24	14:20	11.4	0	11.4
12-Jul-24	14:25	10.9	0	10.9
12-Jul-24	14:30	10.3	0	10.3
12-Jul-24	14:35	9.8	0	9.8
12-Jul-24	14:40	9.3	0	9.3
12-Jul-24	14:45	8.8	0	8.8
12-Jul-24	14:50	8.4	0	8.4
12-Jul-24	14:55	8	0	8
12-Jul-24	15:00	7.6	0	7.6
12-Jul-24	15:05	7.2	0	7.2
12-Jul-24	15:10	6.8	0	6.8
12-Jul-24	15:15	6.5	0	6.5
12-Jul-24	15:20	6.1	0	6.1
12-Jul-24	15:25	5.8	0	5.8
12-Jul-24	15:30	5.5	0	5.5
12-Jul-24	15:35	5.2	0	5.2
12-Jul-24	15:40	4.9	0	4.9
12-Jul-24	15:45	4.7	0	4.7
12-Jul-24	15:50	4.4	0	4.4
12-Jul-24	15:55	4.2	0	4.2
12-Jul-24	16:00	3.9	0	3.9
12-Jul-24	16:05	3.7	0	3.7
12-Jul-24	16:10	3.5	0	3.5
12-Jul-24	16:15	3.3	0	3.3
12-Jul-24	16:20	3.1	0	3.1
12-Jul-24	16:25	3	0	3
12-Jul-24	16:30	2.8	0	2.8
12-Jul-24	16:35	2.6	0	2.6
12-Jul-24	16:40	2.5	0	2.5
12-Jul-24	16:45	2.3	0	2.3
12-Jul-24	16:50	2.2	0	2.2
12-Jul-24	16:55	2	0	2
12-Jul-24	17:00	1.9	0	1.9
12-Jul-24	17:05	1.8	0	1.8
12-Jul-24	17:10	1.7	0	1.7
12-Jul-24	17:15	1.6	0	1.6
12-Jul-24	17:20	1.5	0	1.5
12-Jul-24	17:25	1.4	0	1.4

12-Jul-24	17:30	1.3	0	1.3
12-Jul-24	17:35	1.2	0	1.2
12-Jul-24	17:40	1.1	0	1.1
12-Jul-24	17:45	1	0	1
12-Jul-24	17:50	1	0	1
12-Jul-24	17:55	0.9	0	0.9
12-Jul-24	18:00	0.8	0	0.8
12-Jul-24	18:05	0.8	0	0.8
12-Jul-24	18:10	0.7	0	0.7
12-Jul-24	18:15	0.6	0	0.6
12-Jul-24	18:20	0.6	0	0.6
12-Jul-24	18:25	0.5	0	0.5
12-Jul-24	18:30	0.5	0	0.5
12-Jul-24	18:35	0.5	0	0.5
12-Jul-24	18:40	0.4	0	0.4
12-Jul-24	18:45	0.4	0	0.4
12-Jul-24	18:50	0.4	0	0.4
12-Jul-24	18:55	0.3	0	0.3
12-Jul-24	19:00	0.3	0	0.3
12-Jul-24	19:05	0.3	0	0.3
12-Jul-24	19:10	0.2	0	0.2
12-Jul-24	19:15	0.2	0	0.2
12-Jul-24	19:20	0.2	0	0.2
12-Jul-24	19:25	0.2	0	0.2
12-Jul-24	19:30	0.2	0	0.2
12-Jul-24	19:35	0.2	0	0.2
12-Jul-24	19:40	0.1	0	0.1
12-Jul-24	19:45	0.1	0	0.1
12-Jul-24	19:50	0.1	0	0.1
12-Jul-24	19:55	0.1	0	0.1
12-Jul-24	20:00	0.1	0	0.1
12-Jul-24	20:05	0.1	0	0.1
12-Jul-24	20:10	0.1	0	0.1
12-Jul-24	20:15	0.1	0	0.1
12-Jul-24	20:20	0.1	0	0.1
12-Jul-24	20:25	0.1	0	0.1
12-Jul-24	20:30	0	0	0
12-Jul-24	20:35	0	0	0
12-Jul-24	20:40	0	0	0
12-Jul-24	20:45	0	0	0
12-Jul-24	20:50	0	0	0
12-Jul-24	20:55	0	0	0

12-Jul-24	21:00	0	0	0
12-Jul-24	21:05	0	0	0
12-Jul-24	21:10	0	0	0
12-Jul-24	21:15	0	0	0
12-Jul-24	21:20	0	0	0
12-Jul-24	21:25	0	0	0
12-Jul-24	21:30	0	0	0
12-Jul-24	21:35	0	0	0
12-Jul-24	21:40	0	0	0
12-Jul-24	21:45	0	0	0
12-Jul-24	21:50	0	0	0
12-Jul-24	21:55	0	0	0
12-Jul-24	22:00	0	0	0
12-Jul-24	22:05	0	0	0
12-Jul-24	22:10	0	0	0
12-Jul-24	22:15	0	0	0
12-Jul-24	22:20	0	0	0
12-Jul-24	22:25	0	0	0
12-Jul-24	22:30	0	0	0
12-Jul-24	22:35	0	0	0
12-Jul-24	22:40	0	0	0
12-Jul-24	22:45	0	0	0
12-Jul-24	22:50	0	0	0
12-Jul-24	22:55	0	0	0
12-Jul-24	23:00	0	0	0
12-Jul-24	23:05	0	0	0
12-Jul-24	23:10	0	0	0
12-Jul-24	23:15	0	0	0
12-Jul-24	23:20	0	0	0
12-Jul-24	23:25	0	0	0
12-Jul-24	23:30	0	0	0
12-Jul-24	23:35	0	0	0
12-Jul-24	23:40	0	0	0
12-Jul-24	23:45	0	0	0
12-Jul-24	23:50	0	0	0
12-Jul-24	23:55	0	0	0
13-Jul-24	00:00	0	0	0

APPENDIX - II

Table 5.2: Profile output table for steady flow analysis for Peak Discharge

River	Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
				(m)	(m)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m)
River 2	Reach Split 2	18711	PF 1	46.25	46.14	0.11	0.03	0.03	220.8	5729.01	6313.69	1248.43
River 2	Reach Split 2	16419	PF 1	46.19	46.18	0	0.01	0	4495.26	2155.82	5612.43	6272.12
River 2	Reach Split 2	14633	PF 1	46.18	46.17	0	0.01	0	2292.74	1079.41	8891.35	6912.58
River 2	Reach Split 2	13513	PF 1	46.17	46.17	0	0.01	0	1565.93	954.04	9743.52	7057.33
River 2	Reach Split 2	11338	PF 1	46.17	46.16	0	0.01	0	3724.99	768.63	7769.88	7795.47
River 2	Reach Split 2	8736	PF 1	46.16	46.15	0	0.01	0	612.93	1242.56	10408.02	6362.37
River 2	Reach Split 2	7370	PF 1	46.15	46.14	0.01	0.04	0	1032.66	1977.03	9253.81	6099.42
River 2	Reach Split 2	3687	PF 1	46.11	46.1	0.01	0.24	0.02	2571.66	1496.1	8195.75	6687.35
River 1	Reach US	44689	PF 1	65.39	63.72	1.67	5.31	0.09	3100.95	18963.37	2462.69	928.32
River 1	Reach US	42038	PF 1	59.99	57.38	2.61	5.29	0.64	9229.3	15130.6	167.1	647.22
River 1	Reach US	39514	PF 1	54.06	53.58	0.48	5.65	0.06	19594.28	4932.72		1608.44
River 1	Reach US	36988	PF 1	48.34	47.29	1.06	1.81	0.29	23703.41	823.59		1336.06
River 1	Reach Split 1	29410	PF 1	46.82	46.44	0.38	0.48	0.1	3133.33	8016.56	1113.61	866.68
River 1	Reach Split 1	23646	PF 1	46.23	46.2	0.03	0.04	0.01	6567.98	3456.32	2239.21	3897.89
River 1	Reach Split 1	22149	PF 1	46.19	46.18	0.01	0.04	0	8914.09	1939.54	1409.88	6312.83
River 1	Reach Split 1	20946	PF 1	46.15	46.1	0.05	0.06	0.01	3291.94	4182.11	4789.46	3582.51
River 1	Reach Split 1	19014	PF 1	46.08	46.07	0.01	0.01	0	4867.46	2028.98	5367.06	4316.42
River 1	Reach Split 1	17880	PF 1	46.06	46.06	0	0.01	0	6037.1	2155.97	4070.43	6766.6
River 1	Reach Split 1	17206	PF 1	46.06	46.05	0	0.01	0	5022.32	1498.21	5742.98	7426.14
River 1	Reach Split 1	15617	PF 1	46.04	46.04	0.01	0.18	0.02	6811.24	1566.26	3886	5167.09
River 1	Reach Lower	11335	PF 1	45.85	45.68	0.17	2.34	0.17	12837.19	7123.68	4566.13	2914.77
River 1	Reach Lower	6208	PF 1	43.34	41.51	1.83	1.51	0.53	7594.65	14673.98	2258.38	1926.5
River 1	Reach Lower	2936	PF 1	41.15	41.07	0.08			16591.81	3442.63	4492.56	4164.61