Analysis of Steady Flow using HEC-RAS and GIS Techniques

Pallavi H
Post Graduate Student,
Department of Civil Engineering
UVCE Bangalore University, Jnanabharathi
Bengaluru, 560056

A. S Ravikumar
Professor
Department of Civil Engineering
UVCE Bangalore University, Jnanabharathi
Bengaluru, 560056

***Abstract*- Flood is a natural phenomenon which has the capacity of destroying the natural resources, lives and environment; hydraulic modeling and Flood Inundation Mapping (FIM) are to be carried to predict important information from a flood event including the extent of inundation and water surface elevations at specific locations. The U. S. Army Corps of Engineer's Hydrologic Engineering Center's River Analysis System (HEC-RAS) hydraulic model and Remote Sensing(RS) technology along with Geographic Information System (GIS) have become the key tools for flood monitoring in recent years. The central focus in this field revolves delineation of flood zones and preparation of flood hazard maps for the vulnerable areas. For flood hazard map GIS software Arc GIS and HEC-Geo RAS as well as hydraulic software HEC-RAS are used. In the present study an attempt has been made to analyze the flood inundation boundary of the downstream of T.Narsipura, discharge gauging station for a stretch of 37.78 km which is located in the upper Cauvery basin, Karnataka with an integrated approach of ARC-GIS and HEC-RAS. The data products such as SRTM DEM data and the discharge data are of Central Water Commission (CWC), Bengaluru for 21years (1998-2018). Steady flow analysis is carried out using HEC-RAS to detect the change in flooding pattern. The result shows that the maximum and minimum inundated area for the present study is in the year 2018 and 2002 respectively. The flood inundation studies help the decision makers to assess the risk and take necessary actions to mitigate the damages.**

***Keywords*- HEC-RAS, SRTM DEM, FIM, RS, Arc-GIS.**

1. INTRODUCTION

Flood is one of the severe natural disasters and a common occurrence in world due to increase in global temperature. In recent decades, flooding increased profoundly due to hydrological characteristics changes. The consequence of floods usually occurred annually during the monsoon from July to October (Amol et. al, 2016).

Flood is an unpredictable and unexpected event which not only damages the natural resources, lives and environment but also causes health problem and economy loss. When the river banks are overtopped, river water flows over the flood plain and thus causes damage to crops and property within the flood plain of river (Patel et. al, 2016). Flood inundation models are therefore developed to serve this purpose. Flood inundation modeling involves hydrologic modeling to estimate peak flows from storm events, hydraulic modeling to estimate water surface elevations and terrain analysis to estimate the inundated area (Coonrod et.al, 2008).

Water engineers and managers have the option of using various simulation models to determine factors such as flow, velocity, and inundated area of a stream during a flood. There are number of computer models exist to simulate the river flood requirements (depth, velocity, etc.) such as TELEMAC-2D or River-2D, HEC-HMS, HEC-RAS, MIKE11, MIKE SWMM, MIKE FLOOD and InfoWORKS. Based on multiple studies, HEC-RAS was found to be the best for this project due to the fact that it is freely downloadable software, is easy to navigate even for users with minimal modeling experience, and can run quickly for real-time forecasting (Castellarin et al. 2009).

Flood Inundation Mapping (FIM) is required to understand the affects of flooding in a particular area and on important structures such as roadways, railways, streets, buildings and airport which is usual done by ARC-GIS platform.

2. STUDY AREA

River Cauvery originating in the foot hills of Western Ghats, (Talakaveri), Kodagu in Karnataka at an elevation 4340 m, drainage area of 87,000 km^2 of which Kerala has 3.3%, Karnataka 41.2% and Tamilnadu 55.5 %.It flows generally south and east through Karnataka and Tamil Nadu and across the southern Deccan plateau through the southeastern lowlands, emptying into the Bay of Bengal through two principal mouths in Poompuhar, Tamil Nadu. It consist of 21 principal tributaries out of 9 are there in Karnataka 12 are in Tamilnadu. The important tributaries joining from left bank are Harangi, Hemavati, Shimsha and Arkavati; whereas Lakshmanathirta, Kabini, Suvarnavati, Bhavani, Noyil, Amaravati joins from right bank.

Due to recent activities of floods in Mysore district a stretch of river for analysis is taken from the river Cauvery over 37.78 km long, while its width varies. The study area falls under the discharge station called Tirumakudal Narsipura of Mysore district, which is considered as the input source of the flow of water into the defined river reach. Geographically it lies between 12º9'30"N and 12º16'0"N and 76º54'0"E and 7º8'0"E in Upper Cauvery basin. The location map of the study area is as shown in Fig.1

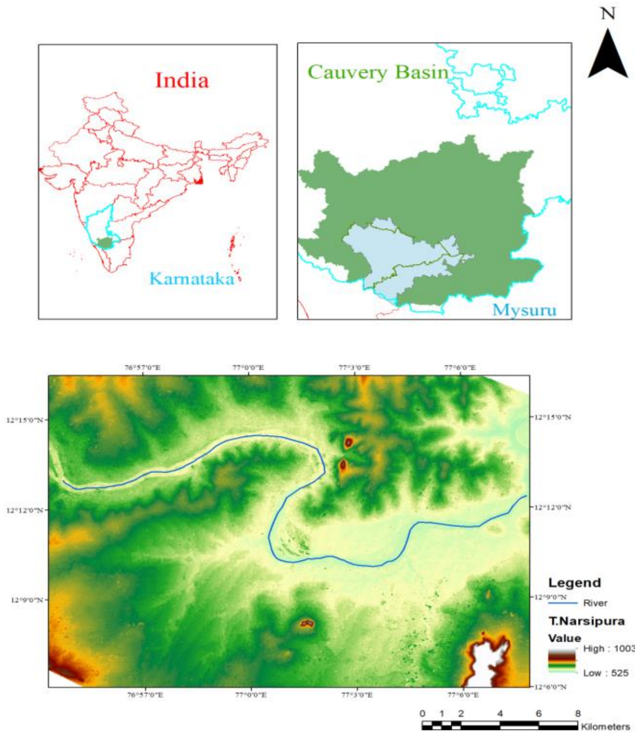


Fig.1 Location map of the study area

3. MATERIALS AND METHODOLOGY

The data sets used in the study area are tabulated in table1.1

Table.1.1 Data sets used in the study

Sl no	Data	Purpose	Source
1	SRTM 30 m DEM data	Extraction of study area	Earth explorer
2	Discharge Data	1D steady flow modeling	CWC
3	Manning's Roughness Co-efficient	For the accuracy of the computed water surface elevation	Hydraulic Reference Manual 2016(Chapter3)
Software used		**Purpose**	**Source**
4	Arc GIS (10.1)	Flood mapping	ESRI website
5	HEC-RAS (5.0.7)	Flow Analysis and Flood Plain Detection	US Army Corps of Engineers

- The Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) is a digital representation of a portion of the earth's surface derived from the interpolation of regularly spaced elevation point measurements. For the study, DEM was obtained from the SRTM of 30m spatial resolution from earth explorer website.
- The discharge data for the study has been obtained from the Central Water Commission (CWC), Bengaluru for the year 1998 to 2018 and the peak flow of the year was input to the modeling to know the variation of flow and flood activities.
- In 1D model, the roughness parameter, Manning's n value, is an important to the solution of the computed water surface profile. The value of Manning's n is highly variable and depends on a number of factors including: surface roughness; vegetation; channel irregularities; channel alignment; scour and deposition; obstructions; size and shape of the channel; stage and discharge; seasonal changes; temperature; and suspended material and bed load. There are several references a user can access that show Manning's n values for typical channels. An extensive compilation of n values for streams and floodplains can be found in Chow's book "Open-Channel Hydraulics"
- Arc GIS developed by Environmental Systems Research Institute (ESRI) is a powerful and easy tool to create and use maps, view spatial data and perform spatial analysis. The processing, modeling, visualization and interpretation of grid based raster data can be performed using the spatial analyst extension. GIS applications in floodplain management has conveyed that GIS is ideally suited for various floodplain management activities such as, base mapping, topographic mapping, and post-disaster verification of mapped floodplain extents and depths.
- The Hydrologic Engineering Centre's River Analysis System (HECRAS, version 4.1.0), a one-dimensional, hydraulic-flow model developed by the U.S. Army Corps of Engineers (USACE), has been used in the present study. HEC-RAS uses a number of input parameters for hydraulic analysis of the stream channel geometry and water flow. These parameters are used to establish a series of cross-sections along the stream. In each cross-section, the locations of the stream banks are identified and used to divide into segments of left flood way, main channel, and right floodway. Flow chart depicting the methodology of study is shown in Figure2.

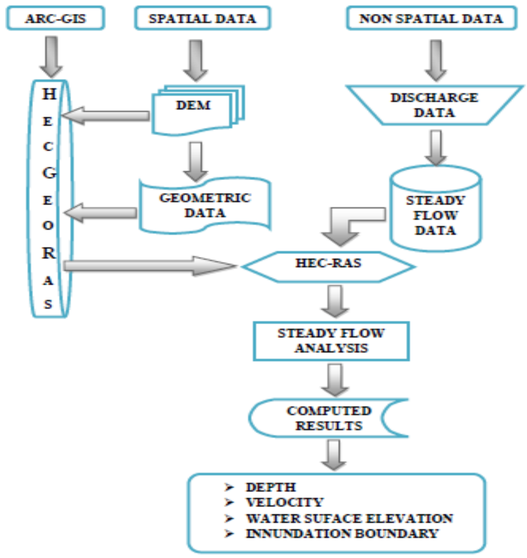


Fig.2 Flow chart of Steady Flow Analysis

3.1 Steps Involved in Creating Steady Flow Hydraulic Model with HEC-RAS and Arc-GIS

a) **Pre-processing Of Data**

Step 1: The SRTM-DEM image downloaded from USGS Earth Explorer is used for delineation of Upper Cauvery Basin on GIS platform.

Step 2: Create the geometry file using HEC-Geo-RAS, click on *RAS Geometry ->Create RAS layers*. Selected attributes were Stream centerline, Bank lines, Flow path

Centre line, and XS Cutline in the study. A geo-database was created by HEC-Geo-RAS in the same folder where the arc-map document was saved. All the features such as river centerline, bank lines, flow paths and cross sections are created in the arc-map is shown in Plate 1.

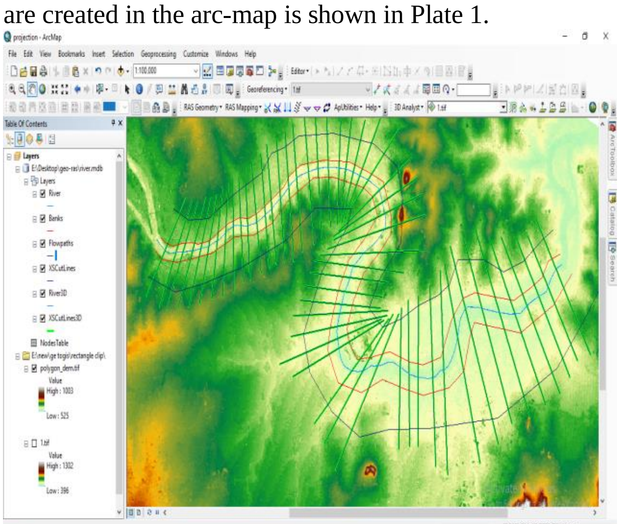


Plate 1 Creation of River Geometry with HEC-Geo-RAS

Step 3: The GIS data was exported to RAS by using HEC Geo-RAS Tool. After completion of export, two files were created as GIS2RAS.xml and GIS2RAS.RASImport.sdf.

b) **HEC--RAS Model Execution**

Step 1: The exported RAS file form GIS is imported to HEC-RAS by geometric data editor tool. Finally Finished Import Data import the Data in HEC-RAS is shown in Plate2.

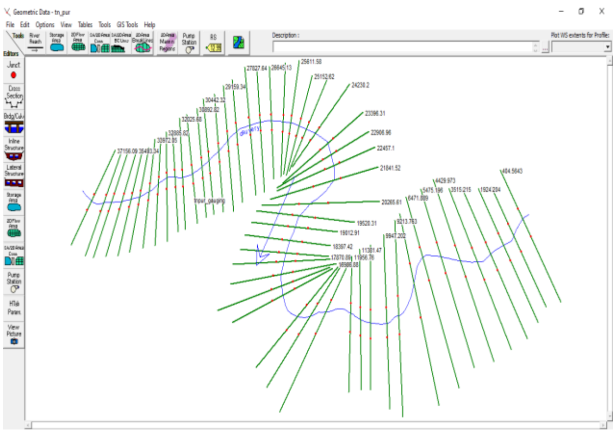


Plate 2 HEC-RAS Geometry view of Steady flow analysis

Step 2: The Manning's n value of 0.05 on LOB & ROB and 0.035 for the channel is provided for the river at al cross sections because it is a natural drain and also depending on the land use, land cover, channel type, slopes of the channel. The reach lengths of all the cross sections are given under the table option in the geometric data, and also the contraction/expansion joints for the steady flow are also provided.

Step 3: Flows were defined at the upstream location and the flow to be simulated is known as profile. Steady flow analysis was performed in this study. Downstream boundary condition was selected as normal depth (0.001-slope of the river profile) and critical depth is chosen on upstream.

Step 4: Finally the steady flow analysis was performed to get the final output/result, which include depth of the river, the velocity of the flowing water, water surface elevation. There are many output tables where we get the volume of water at each cross section

Step 5: To prepare the map, the results thus obtained in HECRAS are then exported to the Arc GIS using import RAS data under RAS mapping which is a HECRAS tool.

4. RESULTS AND DISCUSSIONS

HEC-RAS model was performed under steady flow condition for 21 years (1998 to 20018) to check the inundation boundary area keeping the constant discharge with time along the cross section of the stream. In this case the flow is assumed as uniform and has an average velocity at every cross section. The inundation boundary from analysis in terms of areal extent for 21 years is shown in Table 1.2

Table 1.2 Inundation boundary of study area

Year	1998	1999	2000	2001	2002
Area(km^2)	31.22	31.27	24.78	22.81	19.32
Year	2003	2004	2005	2006	2007
Area(km^2)	22.18	31.51	24.46	37.41	26.96
Year	2008	2009	2010	2011	2012
Area(km^2)	34.52	24.09	29.35	25.69	21.19
Year	2013	2014	2015	2016	2017
Area(km^2)	39.52	42.17	29.92	22.8	24.85
Year	2018				
Area(km^2)	159.72				

From the table 1.2 the minimum and maximum inundation boundaries are observed in the year 2002 and 2018.

The inundation mapping results are obtained from Arc GIS. Figure 3&4 shows the inundation map of year 2018 and 2002, where the differences of inundation boundary are shown in plates 3 and 4.

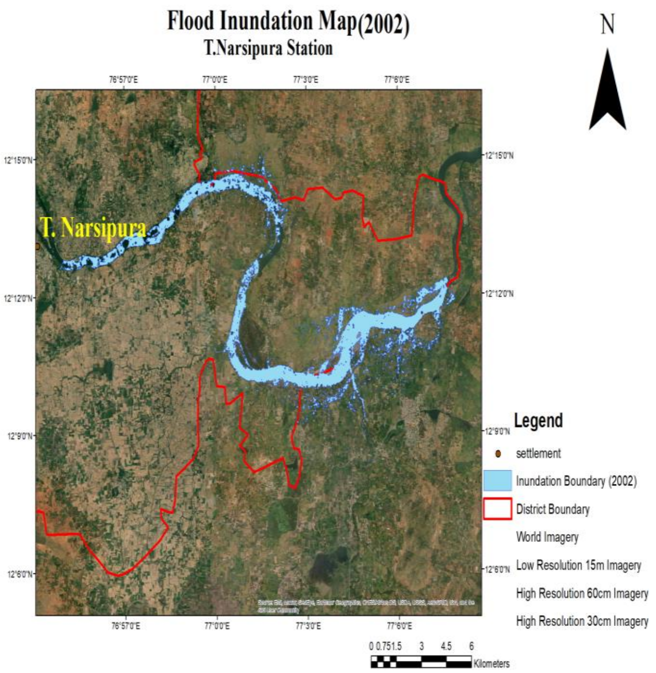


Plate 3 Flood Inundation Map-2002

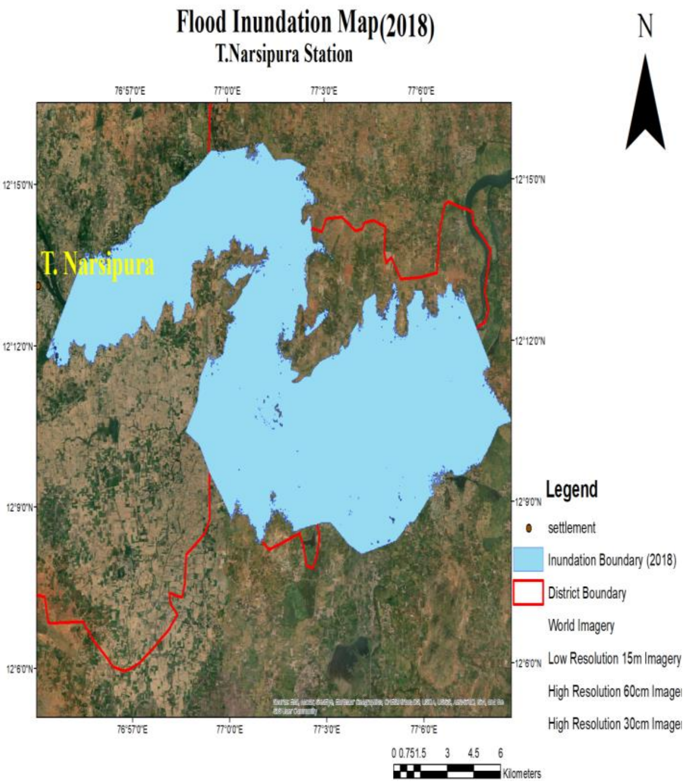


Plate 4 Flood Inundation Map-2018

The upstream (first) and downstream (last) cross sections of the year 2018 and 2002 can be seen in figures 3 to 6.

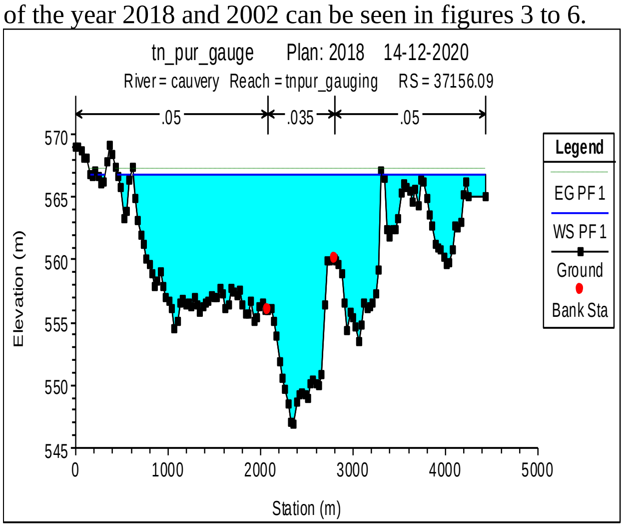


Fig 3 Upstream cross section (2018)

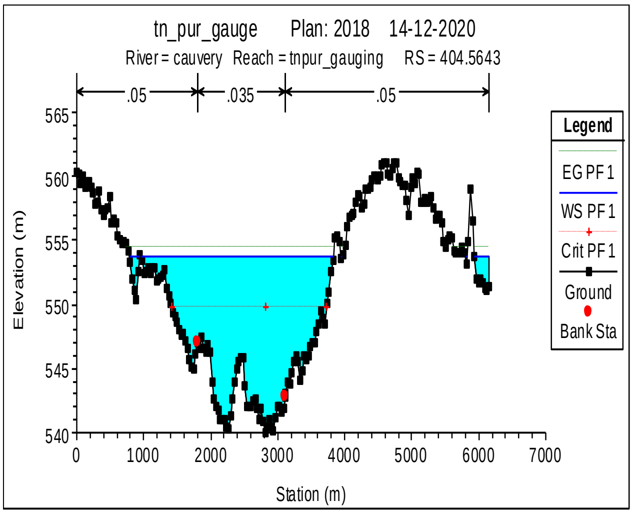


Fig 4 Downstream cross section (2018)

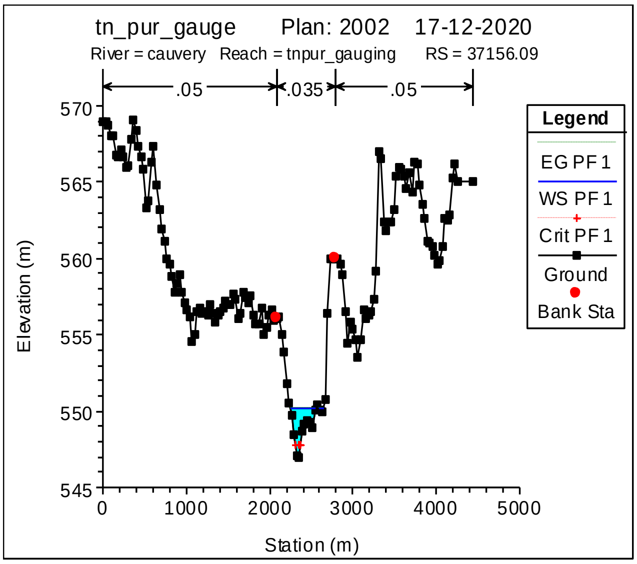


Fig 5 Upstream cross section (2002)

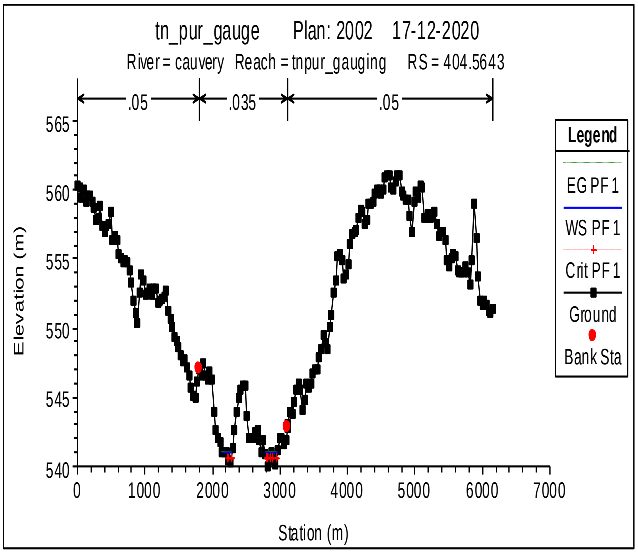
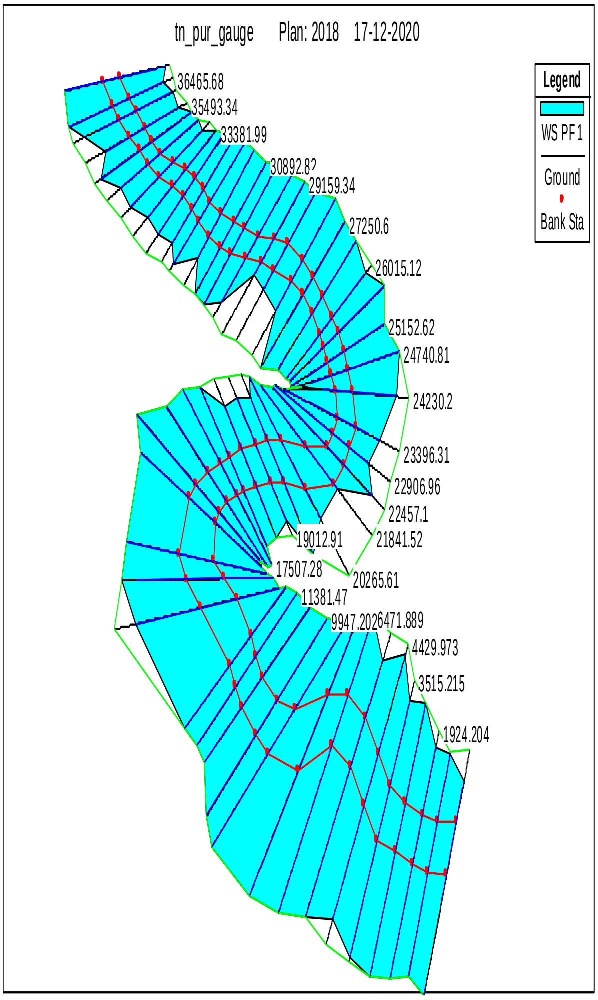


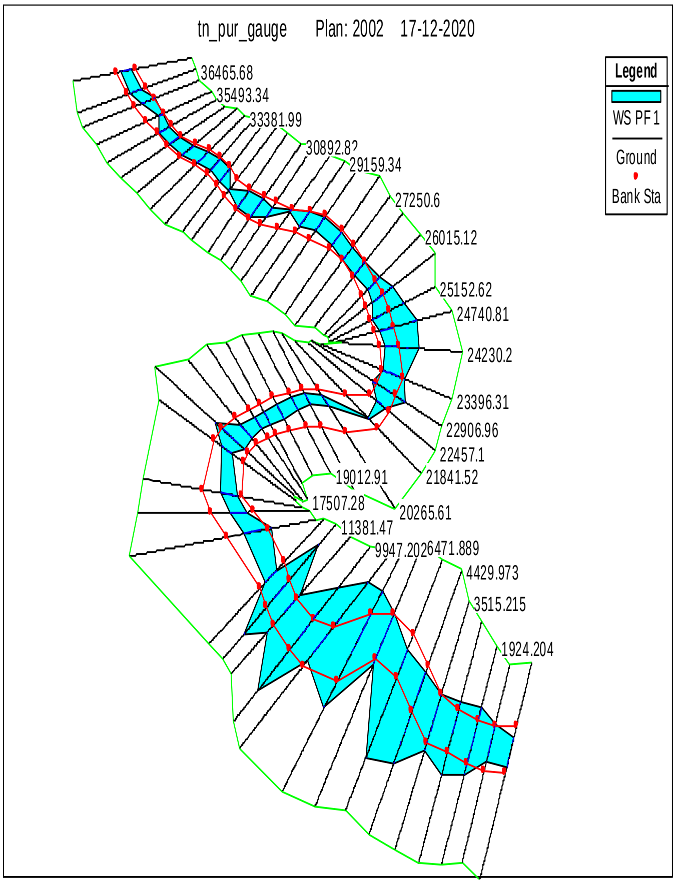
Fig 6 Downstream cross section (2002)

X-Y-Z perspective plot

The inundation figures below shows the X-Y-Z perspective plot of water surface area for 2018 and 2002 respectively.



XYZ Plot-2018



XYZ Plot-2002

Ground truth verification of the inundated boundary are shown in the Plates 5 and 6.

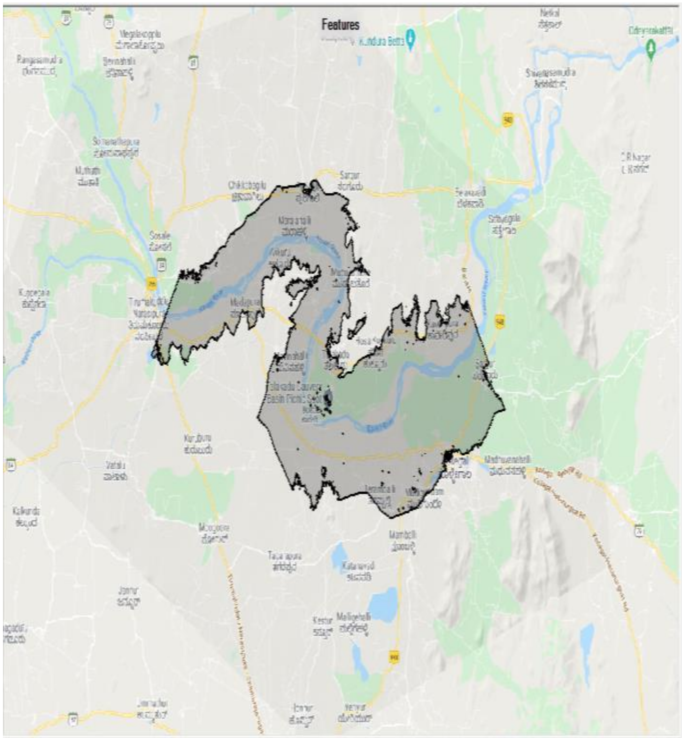


Plate 5 View on Google maps of downstream of T.Narsipura Station-2018 (RAS Mapper)

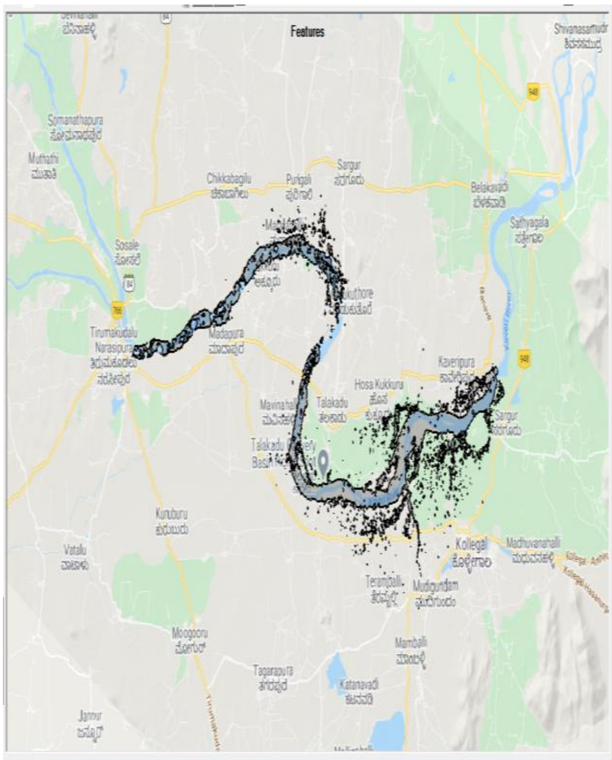


Plate 6 View on Google maps of downstream of T.Narsipura Station-2002 (RAS Mapper)

As it was an extreme flood situation in 2018 due to heavy flow from Kabini and KRS reservoir which have resulted in over flow of Cauvery cutoff over 30 villages at T.Narsipura and lower lying of Kabini river.

Since the study area is also a part of this flood zone, it reveals some of the inundated boundaries of flood prone areas at T.Narsipura, Madapura, Mudukuthore, Marahalli, Mavinahalli, Talakadu, Hosa Kukkur, Kavripura, Sargur, Teramballi, and Kollegala.

CONCLUSION

Flood modeling using HEC-RAS is an effective tool for hydraulic study in handling of disaster and helps in management measures. The output from the HEC-RAS model will be utilized to determine the extent of overtopping of bridges/barrages in the study reach, when subjected to flood of a given magnitude or with increased stream flows at different locations in future.

The study has shown clearly that, HEC-RAS model coupled with remotely sensed data (DEM) is vital in geospatial analysis of the hydrologic cycle including inundation mapping, watershed and flood plain delineation. This profile will facilitate to adopt appropriate flood disaster mitigation measures and reducing the impact of flood, loss of lives and damage.

REFERENCES

[1] USACE, (2009). GIS Tools for support of HEC-RAS using Arc-GIS, HEC-Geo-RAS User's Manual, U.S Army Corps of Engineers (USACE), Accessed on 25th August 2015.

[2] Patel, (2016). "Floodplain Delineation Using HEC-RAS Model- a Case Study of Surat City" Modern Journal of Hydrology, Volume 6, pp.34-42.

[3] Sunil et. al, (2014). "Flood Modeling of River Godavari using HEC-RAS." Civil Engineering department, International Journal of Research in Engineering and Technology (IJRET), pp. 81-87.

[4] Edwin (2019) Steady flow Analysis of Gurupura River Using HEC-RAS Software IJIRASE vol 3 issue 6 jul 2001.

[5] Chidinma et. al, (2015). "Mapping of Flood prone area in surelurlagos, Nigeria a GIS approach". Journal of Geographic Information System, Volume 7, pp. 158-176.

[6] Sandhyarekha and Shivapur (2007) Floodplain Mapping of River Krishnana using HEC-RAS Model at two Stretches Namely Kudachi and Ugar Villages of Belagavi District, Karnataka Volume: 04 Issue: 08 Aug -2017

[7] Goodell, C. Warren, C. Flood Inundation Mapping using HEC-RAS, WEST Consultants, 2601 25th St SE, Suite 450, Salem, OR 9730

[8] Dasallas et. al, (2019) Case Study of HEC-RAS 1D–2D Coupling Simulation: 2002 Baeksan Flood Event in Korea Water Article 30 September 2019

[9] Hakim et. All, (2016) One Dimensional Steady Flow Analysis Using HECRAS– A case of River Jhelum, Jammu and Kashmir European Scientific Journal November 2016 vol. 12 2016.

[10] Castellarin, et. al, (2009) Probability-weighted hazard maps for comparing different flood risk management strategies: a case study, Nat Hazards50, pp-479–496.

[11] Younghun et. al, (2014), Simplified Flood Inundation Mapping Based on Flood Elevat

[12] Chow's book "Open-Channel Hydraulics" Textbook. USACE, (2002). HEC-RAS River Analysis System, Hydraulic Reference Manual, U.S Army Corps of Engineers (USACE), Accessed on 10th August 2015.