# Floodplain Mapping of Krishna River at Karad Using Hec-Ras

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**Abstract** - A flood occurs when water overflows and submerges ordinarily dry terrain. When the flow rate of a river exceeds the capacity of the river channel, particularly near bends or meanders, flooding can occur. As a result, settlements are destroyed, human lives are harmed, and infrastructure and public services are lost. It is necessary to model flood plains in order to determine the flood plain and its extent in advance of taking adequate flood mitigation measures. Decision makers can make better decisions about how to effectively deploy resources to prepare for catastrophes and improve the quality of life by assessing the degree of floods and floodwater inundation. The software created models from the HEC-RAS simulations are extremely useful in a variety of ways, including determining the extent of floods, associating high flood levels with the design and planning of hydraulic structures, and generating flood plain maps that can be used in town planning or estimating the approximate amount of damages. The objective of this study was to map flood inundation areas along the Krishna River. Using the HEC-RAS model, ArcGIS for spatial data processing, and Ras mapper for creating geometry, the flooded areas along the Krishna River were mapped based on peak flows for different return periods. For 25, 50, and 100 years, the lands around the Krishna River were simulated to be inundated. Proper land use management and tree plantations are crucial in reducing the negative effects of floods, especially in low-lying flood-prone areas. The findings of this study will assist the responsible agencies in developing plans based on flood plain mapping and hazard levels in the area.

***KeyWords*: Flood,Inundation,HEC-RAS,HEC GeoRas, ArcGIS,Krishna River**

## 1.INTRODUCTION

A flood is an abnormally high level of flow of water caused by run-off, which is usually caused by excessive rainfall. The overflowing river exceeds its banks, flooding the surrounding region. Floods cause substantial harm every year, ranging from property damage to economic disruption to loss of life. Floods are a major threat in India. More than 40 million hectares of the whole geographical area of 329 million hectares is flood-prone. Floods are a common occurrence that result in a significant loss of life and damage to property, infrastructure, and public services each year.

The hydrographs linked with floods are crucial data in the development of various hydrologic schemes. Furthermore, different properties of flood peaks at a specific stream, flood peaks vary every year, and their magnitude is made up of a hydrologic series that allows one to attribute a frequency to a certain magnitude of flood peak. The peak flow that can be expected with a given frequency (for example, once every 100 years) is critical in the construction of any hydraulic systems. In the design of bridges, culverts, canals, and dam spillways, as well as the estimation of scour at a hydraulic structure, flood peak is necessary. Flood in a stream has two attributes: (i) magnitude of the peak (highest discharge flows), and (ii) stage of the peak (elevation of the water surface at the maximum flows). The peak flow rate is important to design the (i) spillways of dams and barrages, and (ii) capacities of bridge and waterways. The stage is used for the (i) estimation of the extent of area flooded, (ii) determining the elevation of bridge decks, and (iii) deciding the minimum elevation for the structures built on the flood plains. The low-lying lands near to the river are known as flood plains. Because these flood plains have become overpopulated as a result of urbanization, the amount of casualties and property destruction has escalated.

After Bangladesh, India is the worst-affected country in the world by floods, accounting for one-fifth of all flood-related deaths worldwide. According to the National Flood Commission, floods damage almost 40 million hectares of land in the country each year, with an average of 18.6 million hectares being affected. Annually, around 3.7 million hectares of agricultural land are impacted. Monsoon flooding is the primary source of floods in India. During the four-month monsoon season (June–September), almost 75 percent of India's rainfall is concentrated. During the monsoon, huge river basins in India such as the Ganga, Brahmaputra, Krishna, Godavari, and Cauvery see heavy flooding as their catchments get strong and heavy rainfall. During heavy floods, there is usually no overflow of the banks in the higher sections, when the river travels through steep terrain or an undulating area. Rivers overflow their banks in low-lying areas, particularly if the terrain is flat, causing inundation of low-lying regions, submerging standing crops and property, and disrupting communications. As a result, important flood episodes in India have been included here.

- In 2004, Bihar had its worst flood in the state when the Ganges River surpassed the danger level for the first time at Farakka Barrage, killing 885 humans and 3272 animals and affecting over 21 million people in 20 districts throughout the state. Another flood catastrophe hit the state in 2008, when the Kosi River overflowed, affecting more than 2.3 million people.

- Floods have plagued Assam since 1998. During monsoon seasons, the Brahmaputra River overflows its banks, inflicting massive damage to public property and infrastructure. Assam, for example, was hit by severe flooding in 1998 and 2012.

- Floods hit various parts of India in 2005. Gujarat was flooded in June as a result of severe monsoon rainfall. Over 250,000 people had been evacuated and 123 individuals have perished across the state. At least 5,000 people perished in Maharashtra, with Metropolis Mumbai being the most impacted by the rain and the day when the city came to a halt. During the North-East monsoon season in Chennai, the maximum rainfall was recorded in November-December, and 50 people were killed as a result of floods and stampedes.

- The Indian floods of 2008 wreaked havoc across the country. Floods struck the western states of Maharashtra and Andhra Pradesh, as well as northern Bihar, in 2008, as a result of high rainfall during the monsoon season.

- Flooding hit numerous Indian states in 2009, including Orissa, Kerala, Karnataka, Andhra Pradesh, and the North-East. It was one of the worst floods in the area in 100 years, with at least 299 people killed and 500,000 more displaced.

- Due to a huge cloud burst and substantial overnight rainfall in the region, Lehin Ladakh, a part of the northernmost Indian state of Jammu and Kashmir, saw flash floods and debris flow in 2010. At least 255 people are said to have perished, with many more displaced as a result of the flooding, which wreaked havoc on property and infrastructure.

- In 2012, Himalayan flash floods occurred in the Himalayan states of India at midnight on August 3rd, 2012, as a result of a cloud burst, killing 31 people. Another large flood was caused by high flows in the Brahmaputra River and its tributaries as a result of heavy monsoon rainfall. 124 people were murdered, with the worst-affected location being Kaziranga National Park, where 13 great India rhinos and about 500 animals perished.

- The 2013 North India floods produced large landslides and severe rains in nine districts of Uttarakhand, resulting in flash floods across the state.

- Thousands of people perished as a result of this disaster, which ruined Lord Shiva's famed temple in Kedarnath and a portion of the Char Dhamyatra. It is one of India's most devastating floods in its history.

The enormous number of people impacted by flood catastrophes in India shows that a lack of resilience to cope with the occurrence in terms of infrastructure, properties, adaptability, awareness, and planning may be a crucial issue.

## 2. STUDY AREA, DATA &METHODOLOGY:

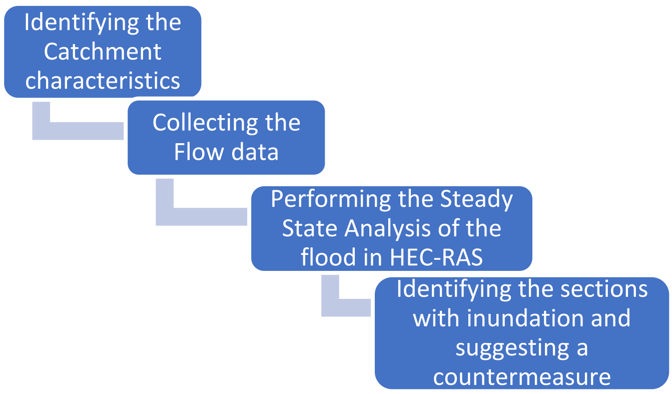


**Fig.1**Methodology to be followed to perform flood analysis

### 2.1 Study Area And Data collection :

The Krishna basin (Fig. 3.1) includes the Upper Krishna basin, which has an aerial size of 55,537.60 km². Within the states of Maharashtra and Karnataka, the basin is located between 15°3'20" and 18° 6'20" north latitudes and 73°39'30" and 77°23'10" east longitudes. The basin region is made up of 12 districts from both states, with 9 districts in Karnataka (Bagalkot, Belgaum, Bijapur, Dharwad, Gadag, Gulbarga, Haveri, Koppal, Raichur) and 3 districts in Maharashtra (Kolhapur, Sangli, Satara). The basin is generally triangular in shape, with the Western Ghats forming its western boundary, the ridges parted by the Bhima basin forming its northern boundary, and the Tungabhadra basin forming its southern boundary. The main Krishna River begins near Mahabaleswar in Maharashtra's Western Ghats at an elevation of 1360 metres above sea level and flows for 642.22 kilometers until joining the Bhima River at Sangam village in Gulbarga district.

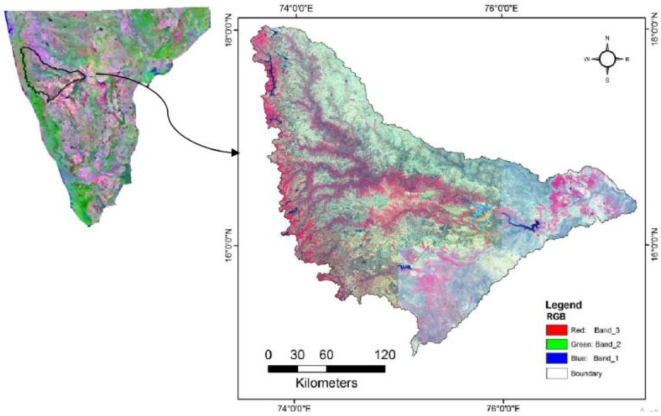


**Fig 2.** Location of Upper Krishna Basin

**2.2 Data Collection:**

**Table No.1** Data collection and software used.

| Sr.No | Data | Purpose | Source |
|---|---|---|---|
| 1 | 30 m resolution DEM | To extract elevation data of the study area | bhuvan.nrsc.gov.in |
| 2 | Projection file | To give downloaded DEM projection | Spatialreference.org |
| 3 | Flow data | To perform 1-D steady state analysis | CWC.gov.in |
| 4 | Manning's Roughness coefficient | To create similar condition as of present in actual river bed | Literature review |
| | **Software used** | **Purpose** | **Source** |
| 5 | HEC-RAS (6.1) | Flow Analysis | US Army Corps of Engineers |
| 6 | Ras Mapper | Floodplain mapping | US Army Corps of Engineers |

**2.2.1 Terrain Data**: To accurately determine the catchment features, a complete terrain model is required. The accuracy of the computed catchment parameters is influenced by the resolution and clarity of the topography data. Terrain data may be gathered from a variety of sources, in a variety of forms, and at various levels of detail. The accuracy and quality of the data are determined by the data gathering source used by the user. The catchment border is easily accessible as a shape file on the Bhuvan website's 2D-Map geoportal's Catchment tool. It is up to the user to collect data from any source and examine it in GIS software. Over GIS-based tools, this catchment file may be overlaid on contours and a digital elevation model.

**2.2.2 Projection file:** The projection file was downloaded from the spatial reference organisation website. The projection file is used to create terrain in RAS Mapper.

**2.2.3 Discharge data**: The discharge data was obtained from the website of the Central Water Commission. The hydro-meteorological water year book is used to collect maximum discharge data. The Krishna basin's water year book for 2019-2020 was retrieved from the Central Water Commission's website. The HEC-RAS uses the peak discharge as an input to perform a 1-D steady flow analysis.

**2.2.4 Manning's roughness co-efficient:** Manning's n value is a critical variable. It is very changeable and is affected by a variety of elements such as vegetation, channel irregularities, surface roughness, scour and deposition, channel alignment, channel size and form, temperature, and so on. The manning's roughness coefficient for banks has been set at 0.05 and for channels at 0.025, based on a prior research in the same location.

**2.2.5 HEC-RAS:** HEC-RAS software is used to perform one-dimensional steady flow analysis.

**2.2.6 Ras Mapper:** RAS Mapper tool is used to create a geometry file, in which stream centre line, bank lines, flow path lines, and cross-section cut lines were digitized.

## 2.3.Stream centre line:

First and foremost, a stream centreline should be established. The centreline of the stream under investigation is referred to as the stream centreline. With the routine edit tool in Ras Mapper, you may digitise the centreline. The river name and reach names are assigned once this layer is created, and the following properties are computed using the relevant choices.

- Topology of the centreline
- Lengths/Stations
- Elevations along the centreline

**Bank lines:** Bank lines are needed to georeference the location of river banks. Bank lines are useful to differentiate the river from the floodplain areas.

**Flow path lines:** The direction of water flow is shown by flow path lines. It is used to measure the distance between cross-sections in the overbank zones and should be digitised inside the floodplain.

**Cross-section cut lines:** The DEM's elevation data can be retrieved using cross-section cut lines. It must be digitised perpendicular to the flow direction. It must cross the river's centre line, as well as its bank and flow route lines.

### 2.4.5 One-dimensional steady flow water surface profiles (Basic profile calculation equation)

The water profiles are analysed from one cross-section to the next using an iterative approach known as the standard step method, which involves solving the energy equation. The Energy Equation is represented by the following equation.

$$z_2 + y_2 + \frac{a_1 {v_2}^2}{2g} = z_1 + y_1 + \frac{a_1 {v_1}^2}{2g} + h_e$$

Where:

$y_1, y_2$: depth of water at cross-sections

$Z_1, Z_2$: elevation of the main channel inverts

$a_1$, $a_2$: velocity weighting coefficients

$v_1, v_2$: average velocities

g:gravitational acceleration

$h_e$: energy head loss between cross sections.

## 3. RESULTS AND DISCUSSION:

The result of 1-D steady flow analysis includes profile output tables for different values of maximum discharges calculated by flood frequency analysis. Using flood frequency analysis maximum discharge values for 25, 50, and 100-year return periods have been calculated. For these values profile output tables are shown below. From tables given below water surface elevation values at each cross sections can be easily identified.

### 3.1 Floodplain maps

The result of the 1-D steady flow analysis includes floodplain maps for different return periods calculated using flood frequency analysis. Floodplain maps for 25, 50, and 100-year return period is given below.

#### 3.1.1 Floodplain map for 25 years return period

For discharge calculated for 25-year return period using flood frequency analysis, the inundation boundary length is 647km and inundation area is 45.01 $km^2$.

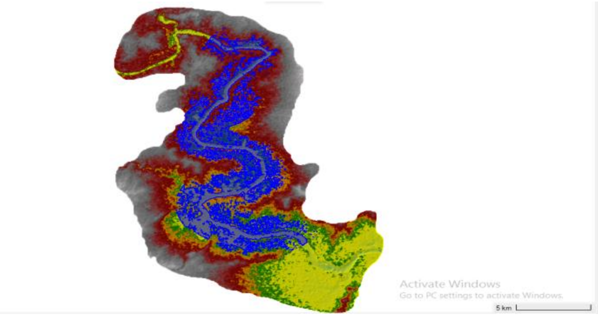

**Fig 3** Floodplain map of 25 years return period

#### 3.1.2 Floodplain map for 50 years return period

For discharge calculated for 50-year return period using flood frequency analysis, the inundation boundary length is 663 km and inundation area is 52.21$km^2$ .

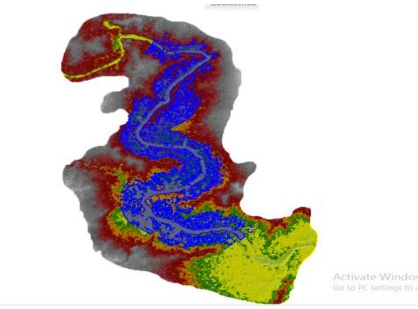

**Fig .4** Floodplain map of 50 years return period.

#### 3.1.3 Floodplain map for 100 years return period

For discharge calculated for 100-year return period using flood frequency analysis, the inundation boundary length is 656 km and inundation area is 58.42 $km^2$.

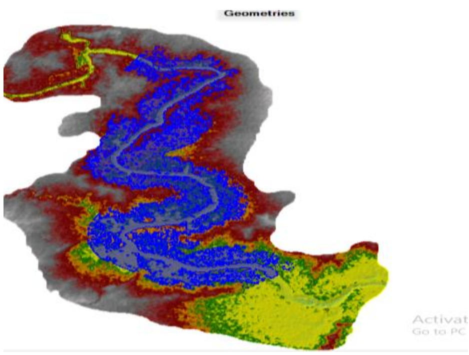


**Fig. 5** Floodplain map of 100 years return period

| Return period | Inundation area | Inundation length |
|---|---|---|
| 25-year return period | 45.01 km$^2$ | 647 km |
| 50-year return period | 52.21 km$^2$ | 663 km |
| 100-year return period | 58.42 km$^2$ | 656 km |

**Table1.** Inundation area and length for corresponding return period

### 3.2 Graphical representation of cross-sections

HEC-RAS also gives output in the form of graph. This graph contains cross-section and water elevation in that cross section for different time period. Some of the cross-sections are given below which are in urgent need of repair because of over toppling of water from banks.

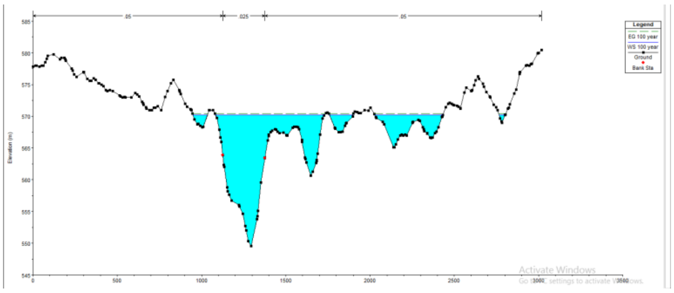

**Fig.5** Water profile of cross section at station number 34132.

Above graphical representation shows water profile of cross-section on Krishna River. The station number of cross-section is 34132 that mean it is situated at upstream. In this cross-section water profile is created by a flood of 100-year return period. From the figure it is observed that the banks are overtopped. The maximum water surface elevation is found to be 568.88 m.

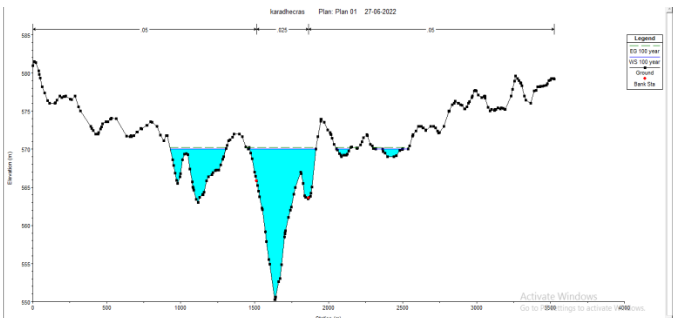

**Fig.6** Water profile of cross section at station number 32698.

Above graphical representation shows water profile of cross-section on Krishna River. The station number of cross-section is 32698 that mean it is situated at upstream. In this cross-section water profile is created by a flood of 100-year return period. From the figure it is observed that the banks are overtopped. The maximum water surface elevation is found to be 570.04 m.

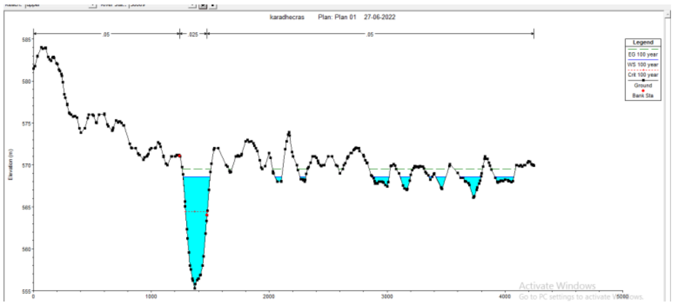

**Fig.7** Water profile of cross section at station number 30009.

Above graphical representation shows water profile of cross-section on Krishna River. The station number of cross-section is 30009 that mean it is situated at upstream. In this cross-section water profile is created by a flood of 100-year return period. From the figure it is observed that the banks are overtopped. The maximum water surface elevation is found to be 568.57 m.

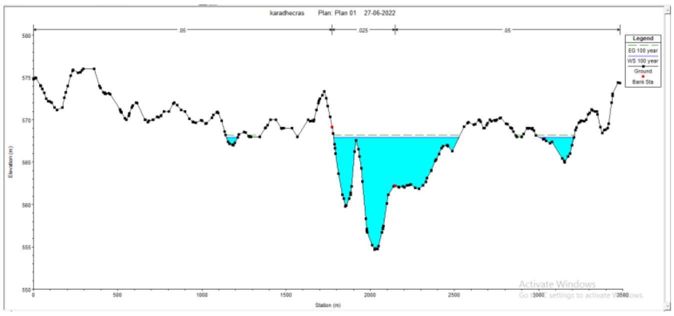

**Fig.8** Water profile of cross section at station number 27367.

Above graphical representation shows water profile of cross-section on Krishna River. The station number of cross-section is 27367 that mean it is situated at upstream. In this cross-section water profile is created by a flood of 100-year return period. From the figure it is observed that the banks are overtopped. The maximum water surface elevation is found to be 567.91 m.

From above cross sections it is evident that overtopping of banks is mostly happening in upstream region of the river. That mean concerned authority should give more attention to this area while doing repairs.

## 4. Conclusion:

- The HEC-RAS program, developed by the US Army Corps of Engineers at the Hydrologic Engineering Center (HEC), allows one to do one-dimensional steady flow calculations. The goal of this project was to generate a flood inundation map for the 34-kilometer Krishna River stretch. The study's most important findings are summarized as follows:

- Flood Inundation Mapping is a key component of nonstructural measures, and data provided by remote sensing and geographic information systems (GIS) can be valuable in hydraulic research.
- The procedures for creating the model may be utilised to re-create a functioning model comparable to it at any location.
- The flood frequency study yielded 6280, 7410, and 8530 cumec Krishna, for the 25, 50, and 100 year return periods, respectively
- For the aforementioned 25, 50, and 100-year return period floods, the flooded areas estimated using HEC-RAS were of the order of 45.01, 52.21, and 58.42 square kilometres, respectively.
- The 1-D steady flow study yields water surface elevation data for each river cross-section during floods, as well as minimum channel elevation, energy grade line elevation, energy grade line slope, channel velocity, flow area, top width, and Froude number, among other things.
- The water surface elevation upstream has been found higher than down streams.
- Floodplain maps have been developed for the 25, 50, and 100-year return periods. After looking at all of the floodplain maps, it was discovered that as the return period value grows, so does the flood inundation area.
- Following an examination of floodplain maps and cross section graphs, it was discovered that cross sections on the upstream side were unable to absorb flood, resulting in a greater likelihood of water overtopping. The river stretch near Krishna nagar in Sangli needs to be repaired immediately. It can be accomplished by reducing encroachment on the river's floodplain or by constructing a levee along the river's bank.
- It can be observed that left bank of river is capable of handling the increased discharge but right bank is in need of repair.
- The upper Krishna basin requires river channelization. It improves river channel capacity by deepening and expanding the channel, lowering floodwater levels. Straightening the river channel will help eliminating the rivers' severe meandering issues and boost flow velocity.
- Levees can be built along river banks in sensitive locations to reduce agricultural losses and flooding damage. The findings of this study may be valuable to flood-control agencies. They might take the required steps to protect the research area from flood damage and agricultural losses. These findings may be relevant in the research area for water management and allocation.

The floodplain maps were made without the need of the pricey ARC-GIS and HEC-GeoRAS extension, demonstrating the usability of the RAS Mapper tool. In addition, the flood inundation area and length of the inundation border may be easily determined.

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