Steady flood flow analysis for the Godavari River reach in Nashik using HEC-RAS and ArcGIS

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Abstract
Floods have been repetitive phenomenon in the study area. River Godavari flows through Nasik city. The River has almost 10 km reach passing through city. To facilitate the appropriate measures for effective flood mitigation in advance, there is a need to model the flood plain. The present study represents flood simulation of Godavari river reach in Nasik using HEC-RAS as software. Digital Elevation Model (DEM) of Nasik city is used as main input for steady flood flow analysis. Intensity duration frequency (IDF) curve is used to obtain maximum and minimum rainfall intensity for different return periods. From theses intensities discharge is calculated for different return period which is being used as main input for performing steady flood flow analysis. Three discharges are used based upon minimum and maximum rainfall intensity hence three flood flow profiles have been created. The aim of the present study was to create flood flow profiles which can be helpful in suggesting remedial measure against the future flood situations.

Keywords: steady flood flow analysis, DEM, HEC-RAS, IDF

1. Introduction
Floodplain management and mapping is a new and applied method in river engineering and is essential for prediction of flood hazards. Flood inundation maps show the extent of flooding expected spatially over a given area. An easily accessible map graphics will provide users more awareness of the flood hazards in their local community

There are a number of commercial and non-commercial software tools available for numerical modeling and analysis in GIS. The major tools used in this method are one-dimensional numerical model HEC-RAS [1] and ArcView GIS [2] for spatial data processing and HEC-GeoRAS for interfacing between HEC-RAS and ArcView GIS.

Hicks and Peacock studied the suitability of HEC-RAS for flood forecasting. They found that most river flood forecasts were conducted using a two-step procedure. First, flood routing was conducted, normally using hydrological models. The resulting flood peaks were then converted to water level forecasts using a steady flow hydraulic model, such as HEC-RAS. The HEC-RAS model had been extended to facilitate unsteady flow analysis, and while the numerical scheme was not robust enough to handle dynamic events (such as ice jam release floods) or supercritical flows, it did have the capability to route simple open water flows and produce water level forecasts at the same time [3].

Flood Hazard Mapping is a vital component for appropriate land use planning in flood-prone areas. It creates easily read, rapidly-accessible charts and maps which facilitate the identification of areas at risk of flooding and also helps priorities mitigation and response efforts [4].

Khan studied flood inundation mapping of Kaliganga-Dhaleshwari river basin. In his study, an application of HEC-RAS and HEC-GeoRAS model ware applied in the Kaliganga-Dhaleshwari floodplain. He used discharge and water level data in 2004. He prepared floodplain map and the area of inundation within the floodplain during the post monsoon. He found the downstream area of the basin is more vulnerable to flooding then the upstream area. The area of inundation found from the flood map is about 3 to 4 km on both bank of the river. He showed different thanas like Dhamrai, Savar and Saturia were inundated by 11.81, 9.0 and 47.38% of the total area respectively [5].

Abera studied flood mapping and modeling on Fogera flood plain. HEC-HMS, HEC-RAS and HEC-GeoRAS ware used in river basin flood modeling. He found a flow value of 91.8, 202.4, 273.1, and 308.4 cumec for return periods of 2, 10, 50 and 100 respectively by hydrologic model HEC-HMS. This flow value was used to generate water surface profile for flood inundation mapping by hydraulic model HEC-RAS. The 13 flooded areas for the return periods 2, 10, 50 and 100 year was 12.63, 18.63, 21.31 and 22.5 sq.km respectively. He found most of the area flood depth is less than 1.5 m. He also found 88% of agricultural land, 11.6% of agro-pastoral land and 1.36% river inundated by the flood [6].

Hatipoglu studied on floodplain delineation in Mugla-Dalaman plain using GIS based river analysis system. In his study, an application of HEC-RAS and HEC-GeoRAS model ware applied in Mugla-Dalaman floodplain. Due to its economic and touristic potential, Dalaman floodplain is very important. They studied that area before and delineated the floodplain with traditional methods and found the houses and lands of the local people prices were decreasing because of being in the flood plain. For the determination of flood-plain, first, HEC-RAS simulations were performed to generate water surface profiles throughout the system. Floodplain zones for the design storms were reproduced in three dimensions with HEC-GeoRAS by overlaying the integrated terrain model for the region with the corresponding water surface TIN. As a result it was seen that the floodplain extend that was found by GIS based methods gives considerable better results than by traditional methods [7].

2. Materials and Methods
The objective of the present study was to develop floodplain maps for the segment of the Godavari reach in Nasik. The methodology employed for performing steady flow analysis are given below-
- Flood frequency analysis of the available observed

discharge data to obtain floods corresponding to different return periods.

- Preparation of DEM based on SRTM data.
- Preparation of geometric data using arc geo HEC-RAS.
- Application of HEC-RAS to a number of potential flow scenarios corresponding to different return-period floods.
- To produce flood hazard map for flood preparedness and emergency response.
- Evaluate the impacts of man-made changes in the river basin on the extent of flooding.

2.1 IDF curve
Daily rainfall data for the study area were available for a period of 35 years. From this data base, the maximum values were extracted for each year and were converted into shorter duration (1, 2, 6, 12 and 24-hr) values using the reduction formula suggested by the Indian Meteorological Department [8] which is

$$P_t = P_{24} \left(\frac{t}{24}\right)^{1/3} \qquad (1)$$

Where; P_t = is required precipitation depth for the duration t-hour in mm.
P_{24} =Daily precipitation in mm
t = the time duration in hours for which precipitation depth is required in hours

**Table 1:** Rainfall Intensity (mm/hr) for Different Duration

Year	1 Hour	2 Hour	6 Hour	12 Hour	24 HOUR
2000	22.80226	14.33137	6.86462	4.31446	2.71
2001	38.39735	24.13299	11.55952	7.265237	4.56
2002	35.724	22.45277	10.75471	6.759408	4.24
2003	26.41215	16.60021	7.951377	4.997494	3.14
2004	51.97429	32.66619	15.64686	9.834157	6.18
2005	38.2572	24.0449	11.51733	7.238719	4.54
2006	28.2015	17.72483	8.490062	5.336061	3.35
2007	31.67965	19.91087	9.537159	5.994169	3.76
2008	32.12217	20.189	9.67038	6.077899	3.82
2009	27.38513	17.21174	8.244295	5.181594	3.25
2010	44.30463	27.84576	13.33791	8.382966	5.26
2011	52.1705	32.78951	15.70593	9.871282	6.2
2012	75.24254	47.29044	22.65177	14.23679	8.94
2013	30.20563	18.98444	9.093406	5.715267	3.59
2014	102.8414	64.63651	30.96041	19.45882	12.23

2.2 Preparation of DEM
From the SRTM tile of Maharashtra, DEM of present study area is clipped using clip tool of arc-map software.
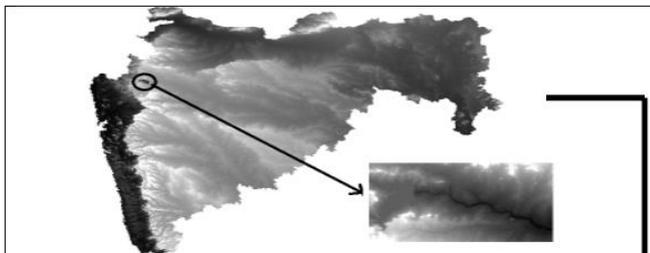
**Fig 1:** Extracting DEM of Study Area from Maharashtra SRTM tile
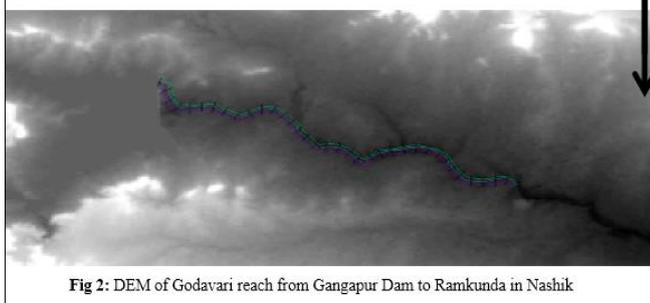
Fig 2: DEM of Godavari reach from Gangapur Dam to Ramkunda in Nashik

2.3 TIN Model
TIN model represents a surface as a set of adjoining, non-overlapping triangles. Within each triangle the surface is represented by a plane. The triangles are made from a set of points called mass point. The TIN model is attractive because of its simplicity and economy and is a significant alternative to the regular raster of the GRID model. With the help of DEM, the triangulated irregular network (TIN) is being created which is shown in the figure below.
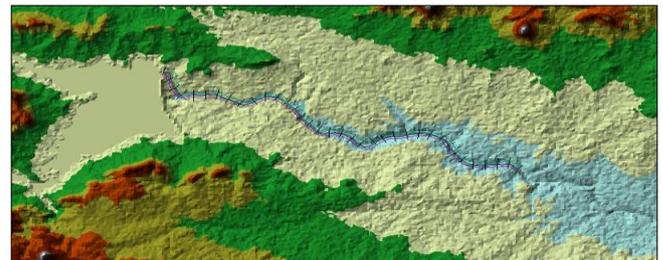
Fig 3: TIN model of Godavari reach from Gangapur Dam to Ramkunda in Nashi

2.4 HEC-RAS Model
Before performing the steady flood flow analysis, certain input parameters such as geometric data, flow data and boundary condition etc. are entered. These parameters are discussed one by one below.

2.4.1 Geometric Data
The value of the cross section describes the section data referring to other section within the reach. The data to be entered is from upstream to downstream direction of the river in geometric data editor of HEC-RAS.in the present study cross-section has been taken at the interval of every 400 meter cross-section, so in this way total length of reach which is 14000 meter is divided into 35 cross-sections.
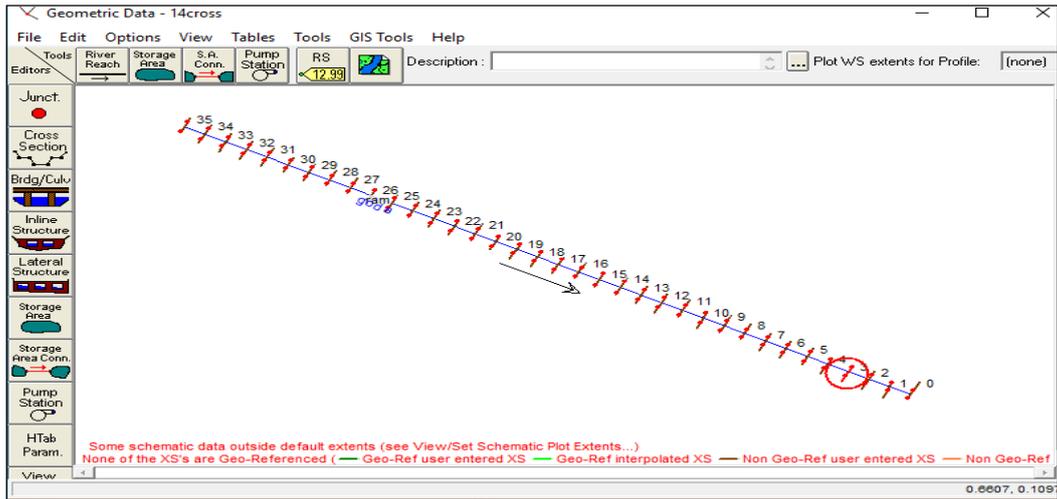
Fig 4: Geometric Data Window (HEC-RAS)

2.4.2 Steady Flow Data

The type of flow data entered depends upon the type of analysis to be performed in the project. In present paper, the steady flow analysis is performed. It includes the flow data, number of profiles computed and river system boundary conditions. Three profiles with different discharge like 582.162, 203.33 and 10.94 cubic meter per second for return periods of 100, 50 and 2 years have been created. Steady flow data window is shown in the figure below.
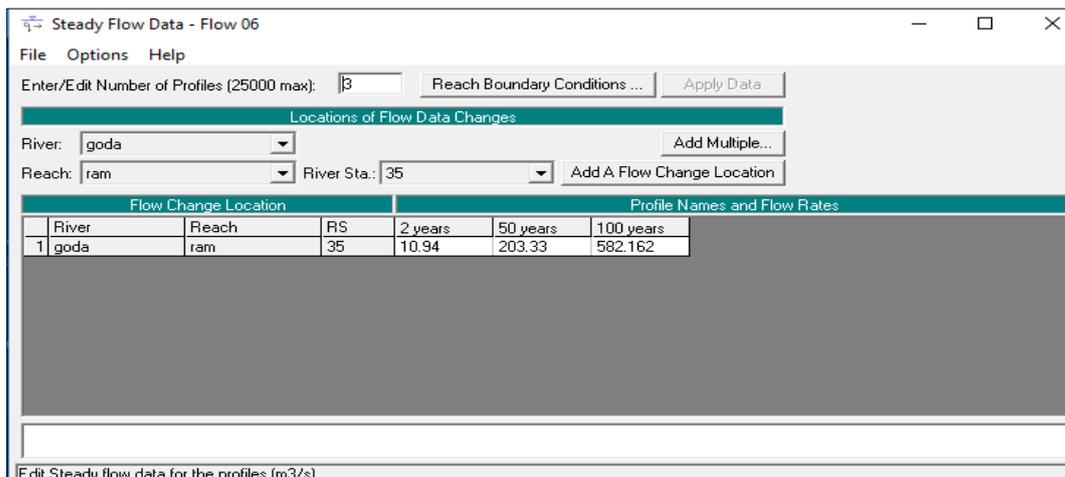
Fig 5: steady flow data window (HEC-RAS)

2.4.3 Boundary Conditions

Boundary conditions are required to perform the calculations. In this study, the normal depth is used as a boundary condition with slope of 0.003.steady flow boundary condition window is shown in figure below
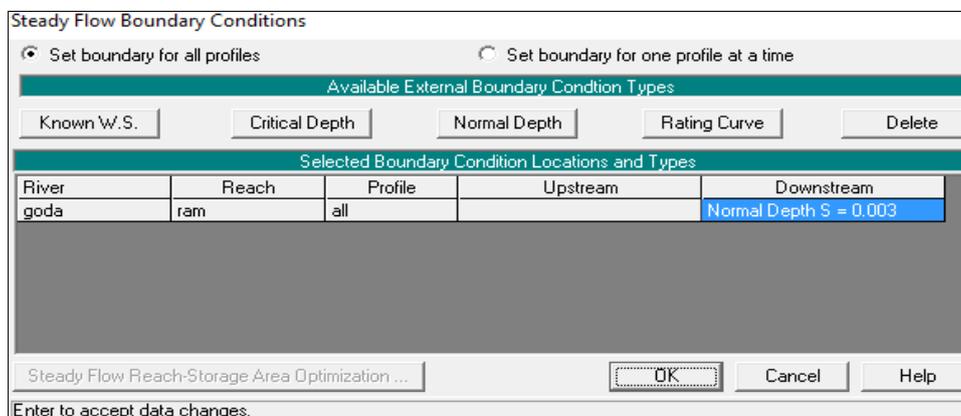

Fig 6: steady flow boundary condition window (HEC-RAS

2.4.4 Flow Regime
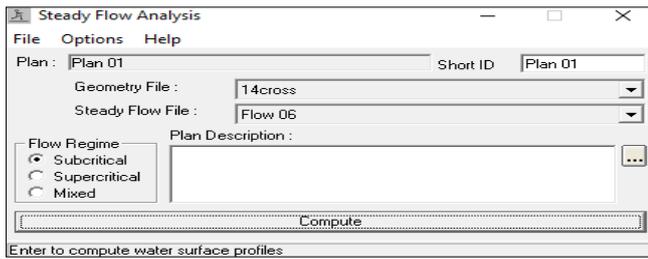For computing the flood flow profile, subcritical flow regime is assumed at upstream.

Fig 7: Steady Flow Analysis Window (HEC-RAS)

2.4.5 Performing Steady Flow Analysis
After giving all the input parameters to the software for the computation, the output in terms of the table and the graphs is obtained. Flood depth profile for the return period of 100 years is shown in the figure.
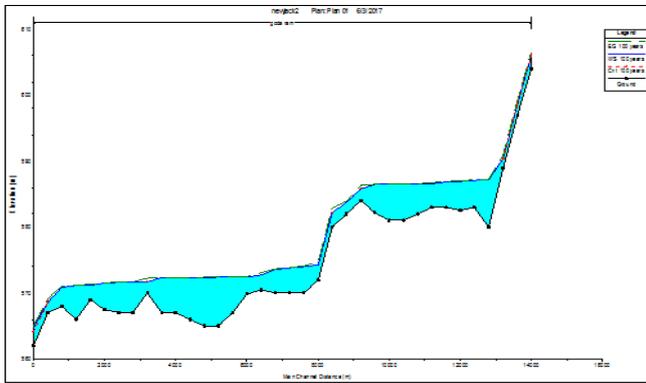

Fig 8: Flood flow profile with a return period of 100 years

3. Conclusions
Intensity duration curve have been created for different return period, floodplain profile obtained for different duration including various cross-section profile and general velocity profile plot are given below.

3.1 IDF
For the present study an intensity duration frequency curve have been developed using Gumble's probability distribution for the return period of 2,5,10,50 and 100 years. From this graph maximum rainfall intensity and minimum rainfall intensity is being calculated and used further to calculate peak flow for certain duration and for certain return period.
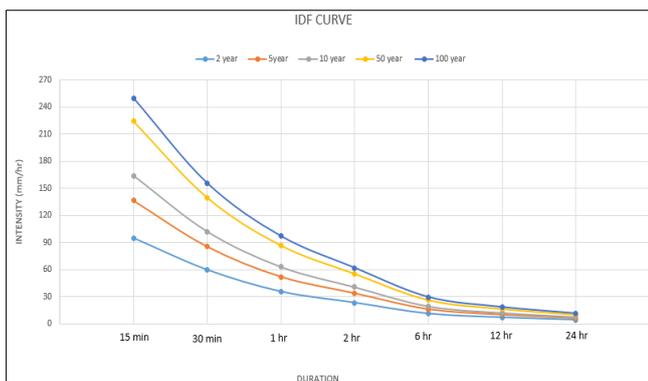

Fig 9: Intensity Duration Frequency Curve for Return Period of 2, 5, 10, 50 And 100

The study showed maximum intensities occur at shout duration having large variations with return period. From the graph it is clear that as the rainfall duration is increasing the rainfall intensity is decreasing for a given return period. As far as return period is concerned the rainfall intensity values are decreasing as the return period is decreasing.

3.2 Cross-Section Attribute Window
In this window on left hand attribute of cross-section are tabled in terms of station and their corresponding elevation. On right side a profile plot is plotted based on the given data. The red marks in the profile plot are showing the banks point.
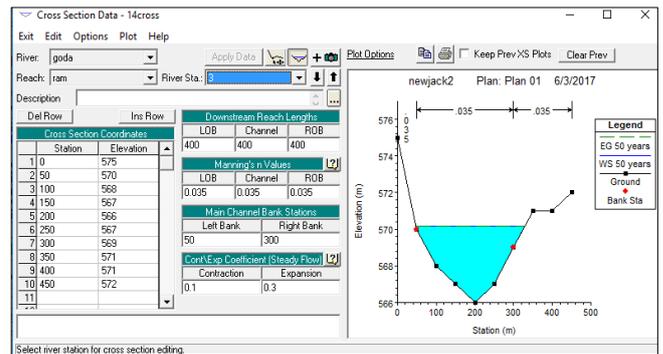

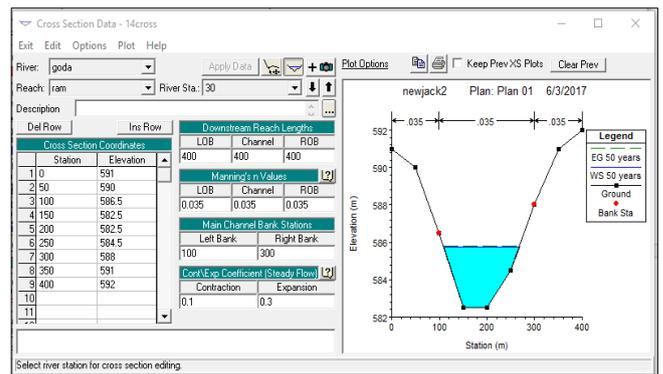**Fig 10:** Cross-Sectional Attribute of River Station 3

Fig 11: Cross-Sectional Attribute of River Station 30

3.3 Flood Depth Analysis
For comparing the difference in depth of water for different return period, a flood depth profile has been plotted which is shown in the figure. From the graph it is clear that the depth of water surface elevation is maximum for 15 min duration and 100 return period and lowest water surface elevation is obtained for 24 hour and 2 year return period.
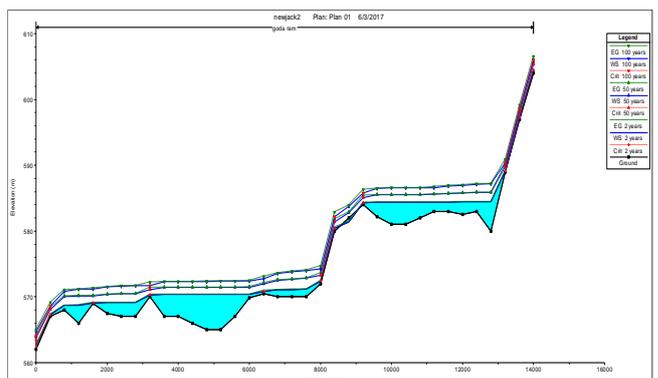

Fig 12: Comparison of Flood Water Depth for Different Return Periods

3.4 1-D Flood Plain Model for a return period of 100 Years

From the flood profile plot it is clear that at some cross-section water is spreading out of the river banks to a larger extent (at sections between 33-32 27, 26.25.24 at upstream side and on downstream side 14-9) which can cause flooding in the nearby areas of river banks
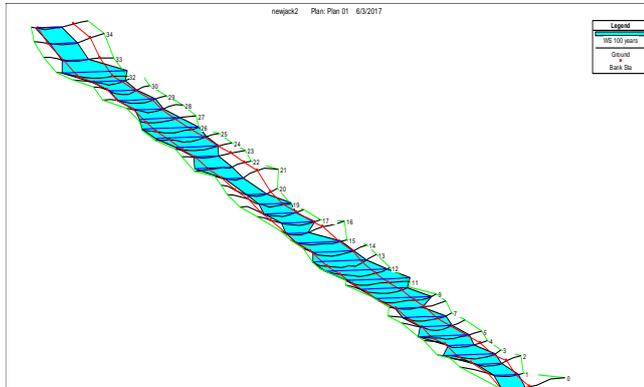
Fig 13: Flood Flow Profile for 100 year return period having X, Y, Z perspective

4. References

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