ESTIMATION OF FLOOD ROUTING IN GODAVARI RIVER BASIN

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ABSTRACT

1-D unsteady flood routing is essential to predict the flood at un-gauged stations in a river to acquire the knowledge of variations of flood levels and control on existing structures in natural stream. In this study, 1-D unsteady flood routing simulation using HEC-RAS modeling has been used for Godavari River with a length of 305.5 km upstream from Bay of Bengal. This work has been carried out in fully rainy season (July to August) with calibration of year 2000 & 2005 and validation of year 2013 for reach from Perur to Polavaram (209.9 km). Also, prediction of flood has been carried out after delta formation of year 2000, 2005 & 2013 (July to August) from Polavaram to Bay of Bengal (99.6 km). The obtained results are compared with measured flood hydrograph and found that the right reach (Gautami Godavari) carries more flood than the left reach (Vashista Godavari) of Godavari River basin.

Keywords: *Flood routing, Prediction, HEC-RAS modeling, Simulation, Delta formation*

INTRODUCTION

The river flood routing is important to understand the movement of high flow and calculating the flood hydrograph at any downstream section. This information is very much useful in navigation, assessment of flood effect, channel improvement and designing flood control structures (Hendeson, 1966). It is also observed that, during high flood the sedimentation is high due to rate of erosion; and this can be decreases with decrease in flood peak. The decrease in flood peak causes the deposition in the channel and affect on its channel geometry. Hence, it is necessary to know the variations of the flood in the channel. From the satellite imagery of Godavari River, the geometry of the river reaches observed in the deltaic form which influences the flood in the main channel. Thus, the study for the distribution of flood after the delta formation is needed.

Flood routing has been divided into two catagories: (1) hydraulic methods that are based on numerical solutions of Saint-Venant equations or diffusion wave equations; the numerical solutions of Saint-Venant equations require a fair amount of data which is often not available and can encounter convergence and stability problems (Chaudhry, 1993) and (2) hydrologic methods that are based on conservation of mass principle (Chaudhry, 1993), such as the Rating Curve Method (Barbetta, 2012), Muskingum Method or Non-Linear Muskingum Method (Kundzewicz, 1986). These methods required substantial field data; such as cross-section details, roughness, flow depth and velocity measurements; are time consuming and also costly. Also, the prediction of flood is affected by high uncertainty when the lateral flow becomes important (Barbetta, 2017).

As there are number of difficulties in solving hydrological modeling, the Hydrologic Engineering Center developed the U.S. Army Corps of Engineer's River Analysis System (HEC-RAS) and also expanded to perform 1-D unsteady flow in river hydraulics calculations by solving the Saint-Venant equations or diffusion wave equations. In Canadian practice, HEC-RAS is so widely used for flood forecasting of river reaches affecting the populated areas and also, it is the standard tool for floodplain delineation studies. By considering the simplicity and availability of data in the present study, the HEC-RAS model has been used to perform the unsteady flood routing in Godavari River for reach of length 305.5 km upstream(Perur) from the Bay of Bengal. The objectives of this study include; simulation, calibration, validation of flood routing and prediction of flood after delta formation.

MATERIAL AND METHODS:

Study Area:

In this study, 305.5 km long reach of Godavari River has been considered upstream from nearest of Bay of Bengal to Perur in Andhra-Pradesh, India. This reach has been divided into two parts such as;

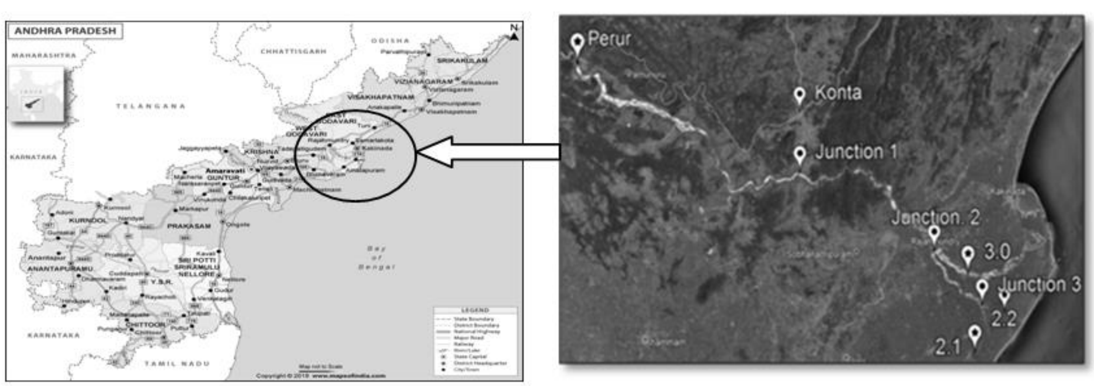


Fig. 1: Satellite Image of study area

Part I- It is between Perur to Polavaram with a length of 209.9 km. Whereas, the Polavaram is 99.6 km upstream from the Bay of Bengal. In between the reach the Sabari tributary has been intersect on the main reach at 55.9 km upstream from Polavaram. The length of Sabari tributary is 31.14 km upstream from the point of intersection.

Part II- It is between Polavaram to the Bay of Bengal with 99.6 km length. The river gets bifurcate at 65.45 km upstream from Bay of Bengal into Vashista Godavari (left reach) and Gautami Godavari (right reach). Again on the Vashista Godavari at 23.8 km upstream from Bay of Bengal there is a bifurcation.

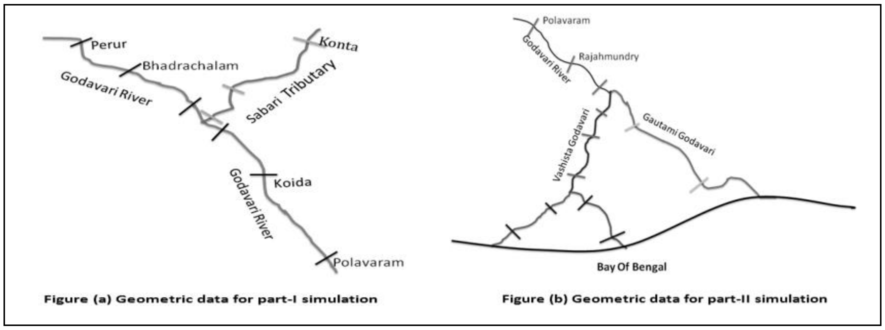


Fig. 2: Line diagram of study area

HEC-RAS Model:

The model developed with U.S. Army corps of engineers by Hydrologic Engineering Center. This model allows performing 1-D unsteady flow simulations through a full network of channel. The equations solver was adopted from Dr. Robert L. Barkau's UNET model (Barkau, 1992 and HEC, 1997). The HEC-RAS model solves the saint Venant equations formulated for natural channels (U.S. Corps of Engineers, 2016)

$$\frac{\partial A}{\partial t} + \frac{\partial S}{\partial t} + \frac{\partial Q}{\partial x} - q_l = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial (VQ)}{\partial x} + gA\left(\frac{\partial z}{\partial x} + S_f\right) = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, x = distance along the channel, t = time, Q= flow, A = cross sectional area, S = storage from non conveying portions of cross section, q_l= lateral inflow per unit distance, g= acceleration due to gravity, S_f = frictional slope, V = velocity, z = elevation of water surface above specified datum. The above equations are solved by using four point implicit box finite difference schemes. Von Neumann stability analysis and convergence analysis are performed; wherein, stability analysis shows the implicit scheme to be unconditionally stable for $0.5< \theta \leq 1.0$; conditional stable for $\theta=0.5$ and unstable $\theta < 0.5$. Convergence analysis shows that numerical damping increased as the ratio $\lambda/\Delta x$ decreased; where λ is the length of wave in the hydraulic systems (Fread, 1974 and Ligget & Cunge, 1975). The other factor such as dramatic changes in channel slope, characteristics of flood wave itself, and abrupt changes in channel slope forms the non-stability of solution scheme and also affected by θ. Therefore the sensitivity study is important; where the accuracy and the stability of the solution are tested with various time and distance intervals.

Data Required:

The input data like channel geometry, boundary conditions, tributary inflow, Manning coefficients are required to simulate the flood routing and water level in HEC-RAS model. In this study the geometric data used were from the department of CWC-India for the simulation of part-I and part-II unsteady flow analysis. For the calibration, validation and prediction of the flow in open channel; the flow hydrograph and frictional slope is required for the downstream reach (HEC, 2016). In the present study, the flow hydrograph of year 2000, 2005 and 2013 (July to August) is given at upstream stations of the main reach and the tributary. The frictional slope has been calculated by using the available geometric data for the downstream reach of the channel. The selection of an appropriate value for Manning's 'n' is very significant for the accuracy of the computed water surface elevation. The manning's n values has been compiled from an extensive tables (Chow, 1959).

RESULTS AND DISCUSSIONS:

HEC-RAS model is used for calibration, validation and prediction of flood in Godavari River from Perur to Bay of Bengal. The required geometric data for various stations, upstream boundary conditions for Perur, Konta, Polavaram, downstream boundary conditions for Polavaram, downstream end of Vashista Godavari and Gautami Godavari were collected from Central Water Commission, India.

Initially model analysis is carried out for calibration and validation of 1-D unsteady flow by using Saint-Venant equation. Simulated results were compared with measured data at station Polavaram for the year 2000, 2005 and 2013 of rainy season (July-August).

Graphical representation of the results for the year 2000, 2005 and 2013 are shown in fig 3; which shows simulated results very well matches with measured data. In calibration of model, the 92 days of simulation period in year 2000 obeserved the highest flood peak in 4 days shown in fig 3 (a). The flood discharge on 22nd day & 61st day is 24% and 10% higher, whereas on 45th day and 53rd day, it is 2% and 15% less than measured data respectively. The average result in the year 2000 shows 96 % accuracy for calibration of the model.

Similarly, results obtained for year 2005 were shown in fig.3 (b). The result shows that the flood increases on day 14, 31, 38, 55 and 82; and found the variations in the flood as -2%, -15%,-4%, +3%, -32%

respectively. Average result shows that the simulated data is 6% less than the measured data; and the 94% calculated flood data matched with measured data. Previous studies by different authors concluded that up to 30% variations in the model results are acceptable [Abebe Thadase, 2018] with this the variations in the above results are within a limit and hence the model is run for the validation of the year 2013. The flood is simulated for the same geometric data conditions used in calibration of the model.

On the basis of data sets used the results obtained for validation of the flood are shown in fig.3 (c); represents the high flood on the day 13, 21, 25, 34, 49 and 86. The variations in the results obtained for these days were 13%, 22%, 34%, 62%, 1% and 17% respectively. On day 34 the flood is much higher; but the average variations in the results found 19% and the accuracy is 81%. The results obtained during simulations are depends on geometric parameters of the river. The variations in geometric parameter are increased in rainy season due to high flood, sedimentation and vegetation in the river which affect much on the water body.

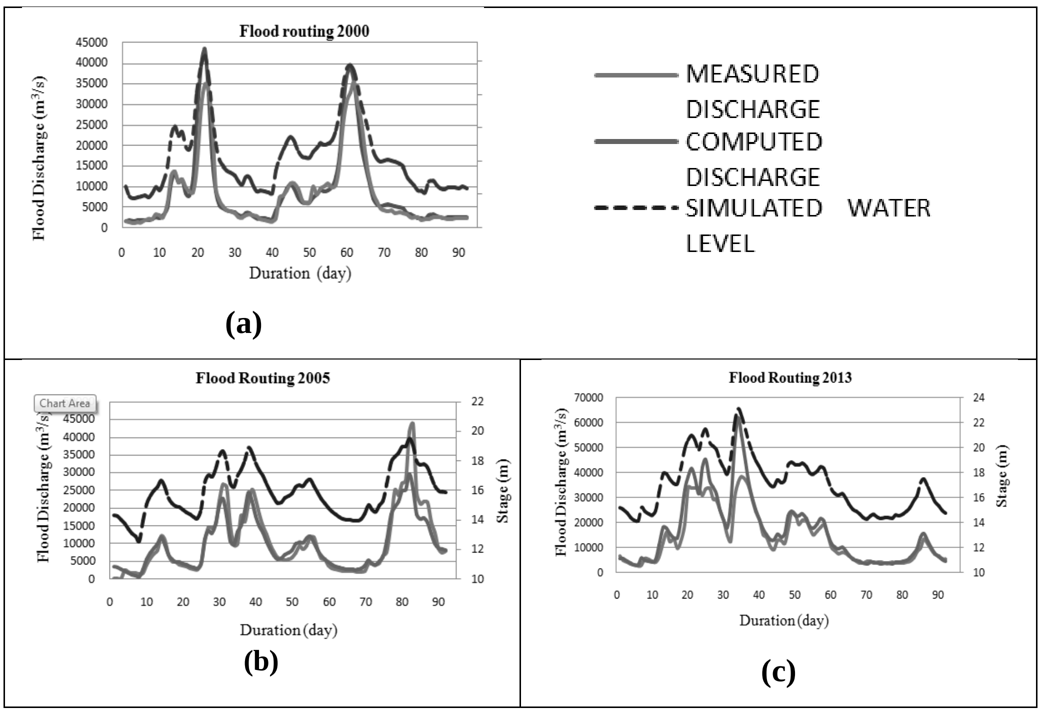


Fig. 3: Computed Discharge vs. Measured Discharge

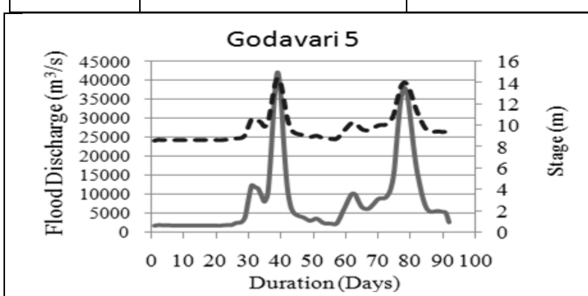
The HEC-RAS model has an ability to distribute the flood in bifurcated network of channel and combines at the junctions of the channel. The bifurcation and confluences of flood in the channel depends on the geometric data and slope of the network [HEC-2016]. In natural channel the formation of delta is itself the bifurcation of the channel network. Therefore, the model used to simulate and prediction is given for the flood after the formation of delta in the Godavari river. The following main reach gets bifurcate into Vashista Godavari and Gautami Godavari. Again Vashista Godavari bifurcated at 23.5km downstream from Polavaram and Gautami Godavari as found in meandering pattern. The simulated results for calibration and validations of the model are used as upstream boundary conditions at Polavaram and geometric data is collected from the Central Water Commission, India.

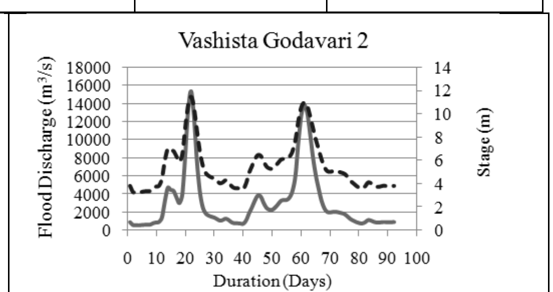
The results are predicted at various sections shown in fig 2, before and after the formation of delta in the river reach. These simulated results shows that, after the formation of delta the flood in the main channel get distributed into Vashista (right reach) and Gautami (left reach) Godavari. It is found that, the flood in Vashista Godavari is less than the flood in Gautami Godavari for the simulations of year 2000, 2005 and 2013. For the same duration, right reach carrying 35%, 37% & 34% flood in the channel while 65%, 63% & 64% carrying by left reach. Gautami Godavari carrying 20% to 26% high flood than the Vashista Godavari. The graphical representation is shown in fig 4, 5, & 6.

The main focus of this study is on the distribution of flood after delta formation. The distribution of flood is found in main channel and in the Vashista Godavari. The Gautami Godavari observed in meandering pattern. Due to its meandering nature, the flood observation in Gautami Godavari is not considered. The results simulated in following Vashista Godavari for year 2000, 2005 and 2013 shows that, left reach carrying 45%, 40% & 46% of the flood and right reach carrying 55%, 60% & 54% of the flood respectively. It is found that, right reach of the Vashista Godavari carries 8% to 20% high flood than that of left reach.

Table-1: Distribution of flood in reach after delta formation

Year	Vashista Godavari (%)	Gautami Godavari (%)	Left Reach (%)	Right Reach (%)
2000	35	65	45	**55**
2005	37	63	40	60
2013	34	64	46	54





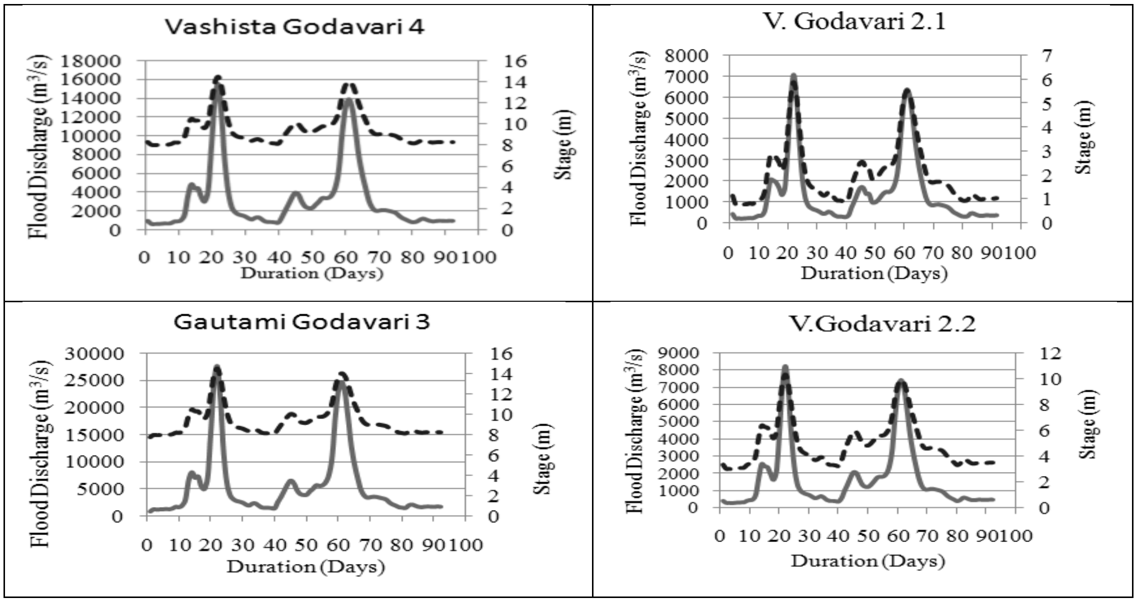


Fig. 4: Computed flood discharge for year 2000 after delta formation

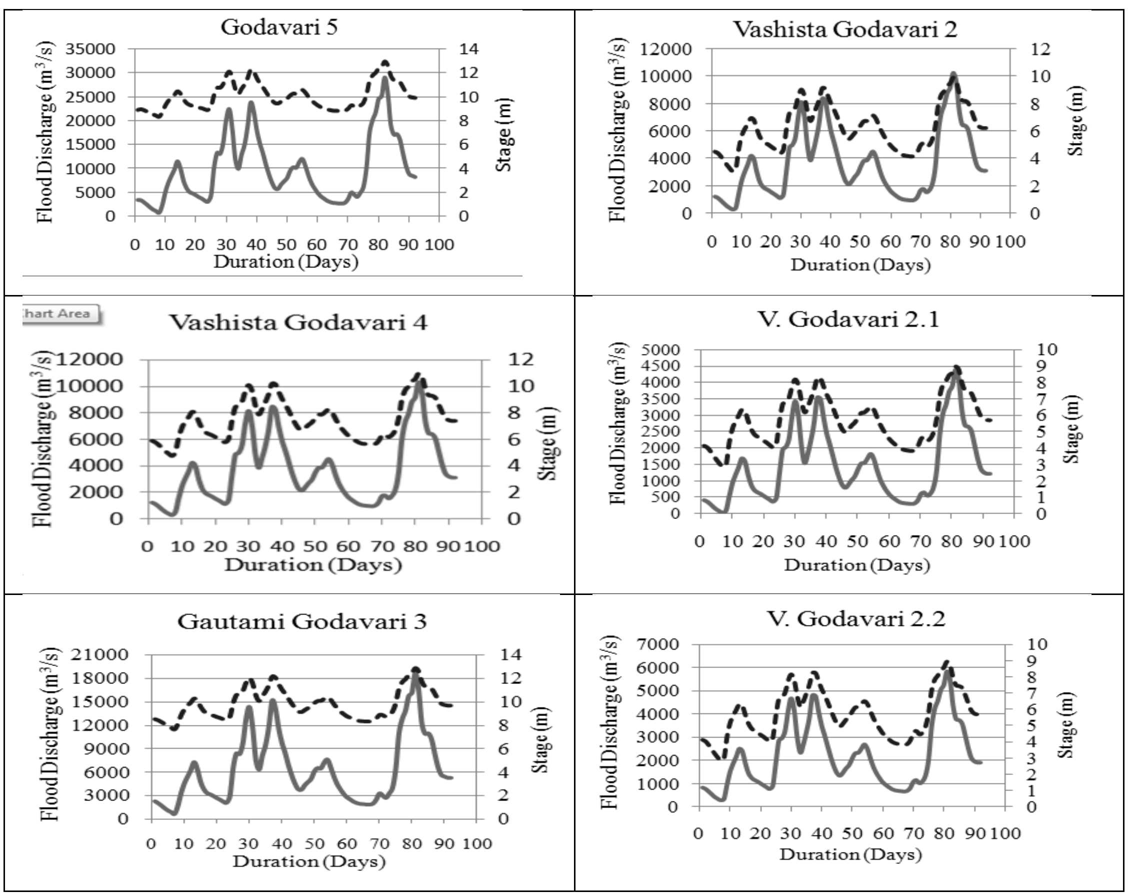


Fig. 5: Computed flood discharge for year 2005 after delta formation

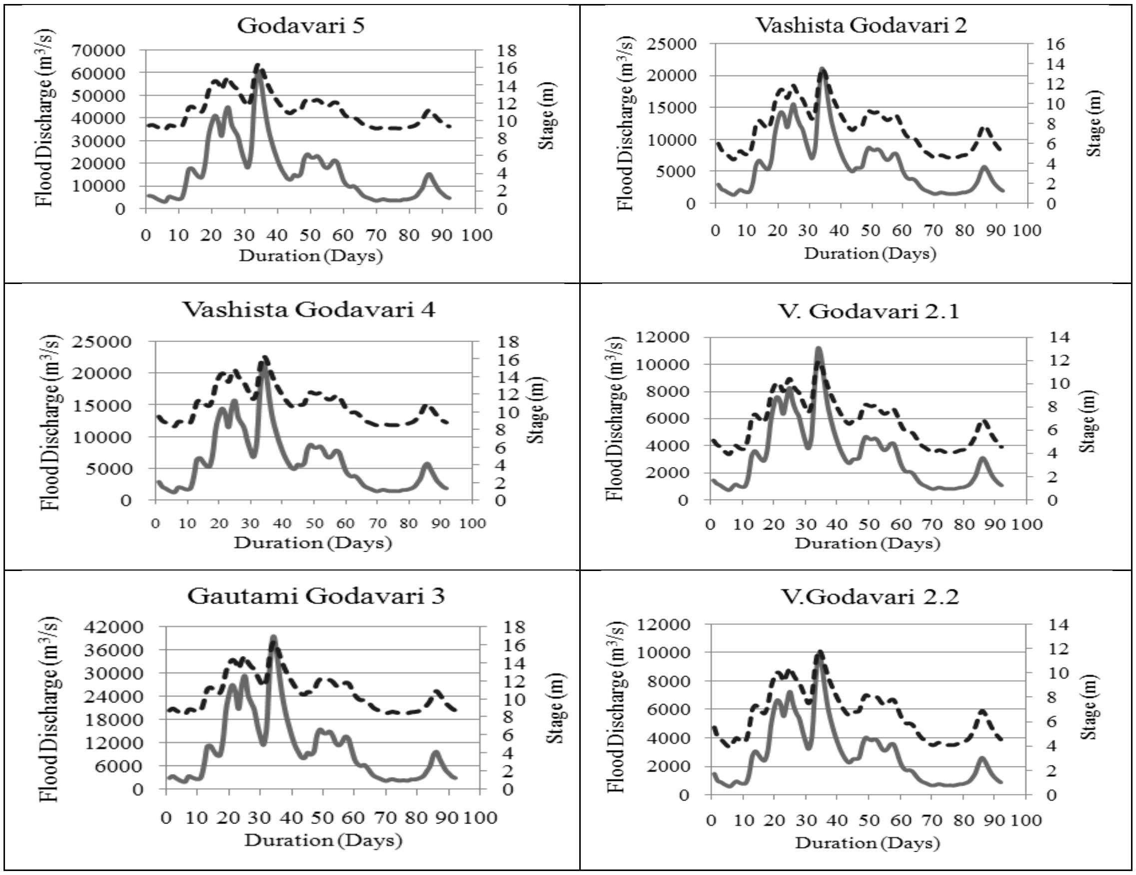


Fig. 6: Computed flood discharge for year 2013 after delta formation

CONCLUSIONS:

The calibration and validation of the model used to confluence of flood at the tributary joint in main channel and the computed results compared with measured flood. The computed results are in close agreement with measured values. The accuracy of computed discharge with respect to measured discharge for the year 2000, 2005 and 2013 is 96%, 94% and 81%. On the basis of accuracy obtained from the simulations, prediction of flood is carried out in the river reach after the delta formation. The right reach (Gautami Godavari) carries 30%, 26% and 30% high flood in year 2000, 2005 and 2013 respectively than the flood carried by the left reach (Vashista Godavari). The prediction is calculated in the Vashista Godavari after delta formation and is 10%, 20% and 8% higher than the left reach in year 2000, 2005 and 2013. The flood carrying in the river reaches; the reaches carrying fewer floods observed in deltaic form. It may be the reason of sediment deposition during less flood.

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