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Flood Analysis of Wainganga River by using HEC-RAS model

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Abstract: Bhandara city lies on the bank of Wainganga River which is flood prone area. The floods of Wainganga River affects the normal life in the city very frequently. In the present study, USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS 5.0.3) Model is used for the analysis of the flood. The water surface elevation are computed for various flood discharges and return period (25 years, 50 years and 100 years). Total 19 cross sections along the river near the city are considered for the steady and unsteady flow simulations. The flow hydrograph which is generated from previous available data is used for unsteady flow simulation. The output from a HEC-RAS model shows that at cross section 2,3 for steady flow conditions and cross section 19 for unsteady flow conditions are critical and subjected to the flooding of the adjoining area disturbing the normal life, for reducing the losses the protective measures needs to be undertaken.

Keywords: Wainganga River, HEC-RAS, Flood Analysis, Flood Protection.

1 Introduction:

Floods are recurrent events caused by overflowing of water from the main drainage system to the adjoining areas, capture coastal areas and floodplains. The flood disturbs human activities, impacted to society and it is considered as a natural disaster. The Wainganga River having a large catchment area about 43,500km² whenever severe rainfall occurs the water overflows the bank of river and surrounding area gets flooded. Bhandara is the most affected flood area, which is located on the bank of Wainganga River. The historical recorded event of flooding in Bhandara city are observed during 2005, 2007, 2012, 2013, 2014 and 2016. Among these, 2005 event was severe which cause lots of damages to the low-lying area nearby bank. For preventing such damages or to take preventive measures, it is necessary to analyze the flow of the river and predict flood surface elevation. Various models are available for analysis of flow and flood in rivers like HEC-HMS, HEC-RAS, HEC-Geo HMS, HEC-SSP, FLO-2D, MIKE-21, MIKE Food, MIKE SHE etc. The HEC-RAS is most popular software used for flow and flood analysis in rivers. Various studies are carried out and it is observed that it is gives most appropriate results and model is suitable for flow and flood analysis in river. HEC-RAS is a hydraulic model developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers. It is an open source software and analyzes the flood from the basin with different discharge condition for the urban area, it determines water surface elevation. It is a combination of Hydrology and Hydraulics. Hydrology calculates information such as probable maximum flood flow (PMF), 100-year flood flow, etc., by using this in HEC-RAS, it is possible to find out hydraulic conditions for the given study area. HEC-RAS is capable to simulate steady and unsteady flow in river. The model is able to simulate subcritical, supercritical and mixed flow regime water surface profile. It uses a various parameters for hydraulic analysis of the stream channel, geometry, and channel flow. By using these parameters the stream divided into segments in left floodway, right floodway and main channel. In HEC-RAS, river reach is subdivided in cross section because of difference in hydraulic parameter.

Hydraulic model, HEC-RAS was used to evaluate flood and also uniform flow computation was carried out by Agrawal (2016). The study area consists of 21 cross sections to stimulate the critical situation of flood and its impact on Dudhana River basin on downstream side. Modak (2015), predicted Flood using HEC-RAS model in Surat. One dimensional hydrodynamics model was used for calculating flood event and Cross-sections of the lower Tapi River which was extracted from Auto-Cad file. After simulation of the model, inundation maps of possible floods were created by RAS Mapper which were useful for emergency action plans during the floods. Silva *et al* (2014), created maps by using GIS and HEC-RAS model. Flood extent of Rio dos Cedros city urban area, Medium Itajaí River Valley – Santa Catarina, has been mapped using this software. Study conclude that HEC-RAS model and GIS used high resolution spatial data for mapping flood area. The calibration of most sensitive parameter of hydraulic model, on the basis of their simulation model was the most effective single Manning's roughness co-efficient for the reach Khairmal to Munduli of the Mahanadi River. From the given study Parhi1 (2012) proves that for flood forecasting and flood Plane mapping HEC-RAS gives the best result. Ahmad (2016) used peak flood records as input for HEC RAS model was used to find out calculate flood levels in the river Jhelum Kashmir valley. Head losses was determined by using Manning's equation and contraction/expansion coefficients. HEC-RAS was used to construct the hydraulic model for flow and flood analysis of river.

1.2 Objective:

1. To find the flood level in Zone of Wainganga River for various return period flood.
2. To Analyze the flood and
3. To prepare simulated hydrograph of given cross section.

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2. Study Area : In a present study 14 km long Wainganga river reach is selected nearby Bhandara, which lies between 21°13’17.94”N to 21°07’25.33”N latitude and 79°41’38.33”E to 79°37’28.96”E longitude. Bhandara city is located at 21.17°N 79.65°E with an average elevation of 244 meters (800 feet) in north eastern part of Maharashtra state. The total area of Bhandara is about 3716.65 square meters having 1198810 population (Census 2011). The Wainganga River divides Bhandra city in two parts. The study area is shown in fig.1.

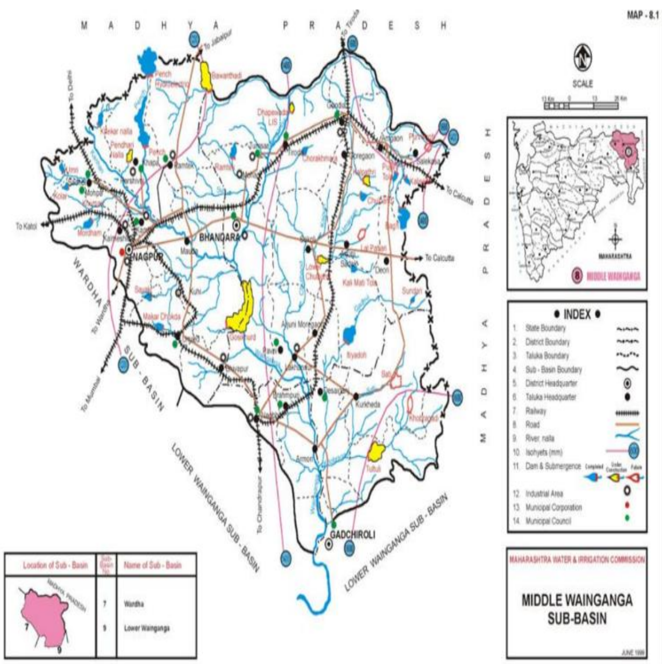

Fig 1. Location of Wainganga River nearby Bhandara city

3. Methodology:

In order to study flood scenario, discharge calculated for various return period of 25 year, 50 year, and 100 year. For both steady and unsteady simulation, downstream condition is used as normal depth having value 0.01. In unsteady simulation at upstream boundary condition, flow hydrograph is used as input.

In the present study, whole reach of Waingangā River is subdivided into 19 cross section (fig. 3) according to cross section data availability from Water Resource Department, Nagpur. Previous 20 year flow data has been collected from Hydrology Project Department, Nashik. In HEC-RAS at each cross section river station, left and right bank location, segment length between two adjacent cross section, Manning’s coefficient, contraction and expansion coefficient are provided. Manning’s coefficient 0.04 for each cross section is taken from the reference report of Water Resource Department, Nagpur and contraction and expansion coefficient is taken from reference manual of HEC-RAS. After selecting the particular flow type with a regime condition, construct the model and compute outputs.

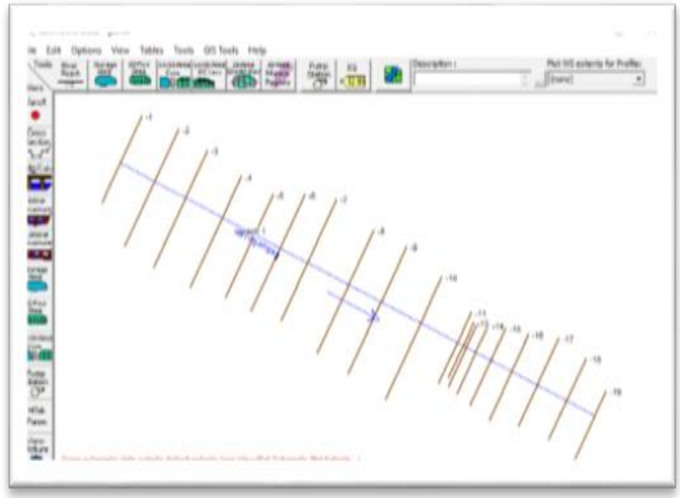

Fig 2. Cross section on river stream

4. Performance Analysis:

4.1 Steady flow analysis:

Gumble’s Extreme Value Distribution method is used for deciding the design flood from the last 20 year discharge data of river for 25 year, 50 year and 100 year return period is 20996.77743 m³/s, 24269.4726 m³/s, 27518.00283 m³/s respectively which are uses as input for model. The Gumble’s method is one of the most appropriate and popular method for determination of design flood. Gumble’s Extreme Value Distribution is given as,

$$Q_T = X + K_T\, S$$

Where,

Q_T = design flood for return period T,

X = mean of data

S = standard deviation

K_T = frequency factor = $-\frac{\sqrt{6}}{\pi}\{0.5772 + \ln[\ln(\frac{T}{T-1})]\}$

The steady flow simulation is done by using energy equation and head loss is calculated by using Manning’s equation, contraction and expansion coefficient in HEC-RAS model. From the simulation of whole reach having 19 cross section, critical water level is given for total cross section. The steady flow simulation of cross sections 2 and cross section 3 which are severe among total cross section are as shown in figure.

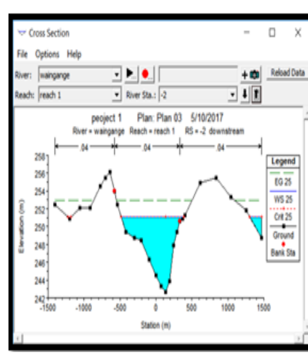

Fig. 3 (i)

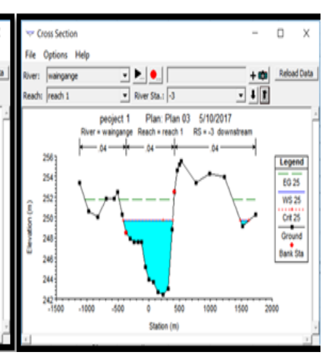

Fig.3 (a)

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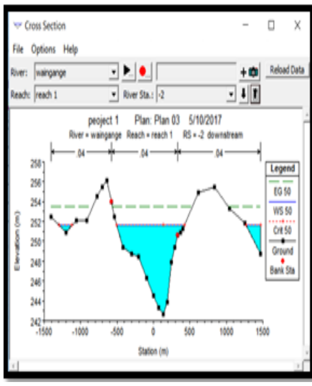


Fig. 3 (ii)

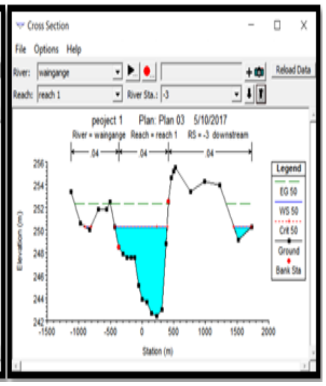


Fig. 3 (b)

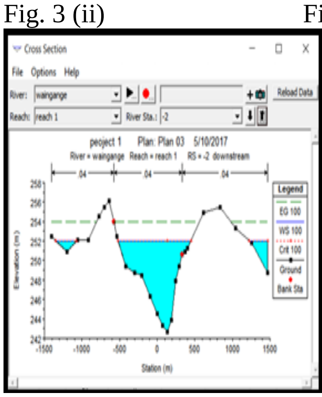


Fig.3 (iii)

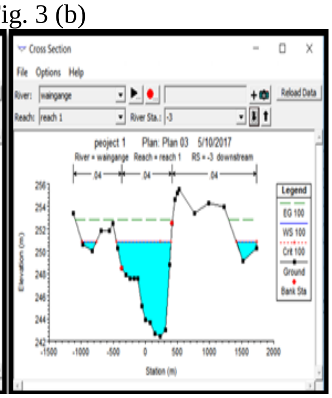


Fig. 3 (c)

Fig 3. Graphical representation of cross sections for different discharges
(i), (ii) and (iii) C/S 2 for discharge 25yr, 50yr and 100yr respectively.
(a), (b) and (c) C/S 3 for discharge 25yr, 50yr and 100yr respectively.

The section defines the flow boundary condition. Values of the critical depth, the water surface (WS) and the energy (EG) can be observed for the defined return periods of 25, 50 and100 years flood for a cross section 2 and 3. At the cross section 2 for a given discharge, the water surface level increases above 250 m, then area along the section having a flood at both the left and right bank. At the cross section 3, for a given discharge the water level increases above 249 m then area along the section having flood at right bank. The water surface profile for all return period and discharges are given in the following fig. 4

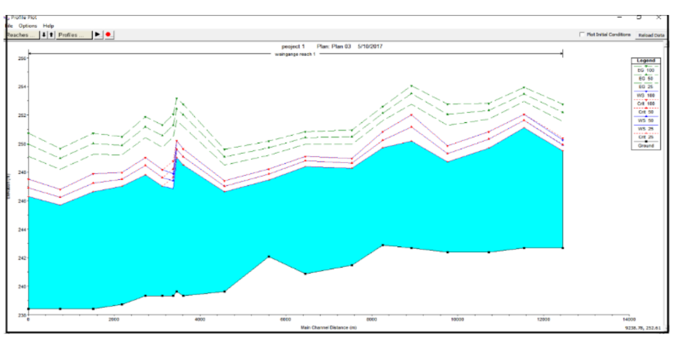


Fig 4. Water surface profile

The longitudinal profile in a section between the banks can be obtained for all profile. In these profile water depth are seen in better way. The profile shows the critical level and energy grade line.

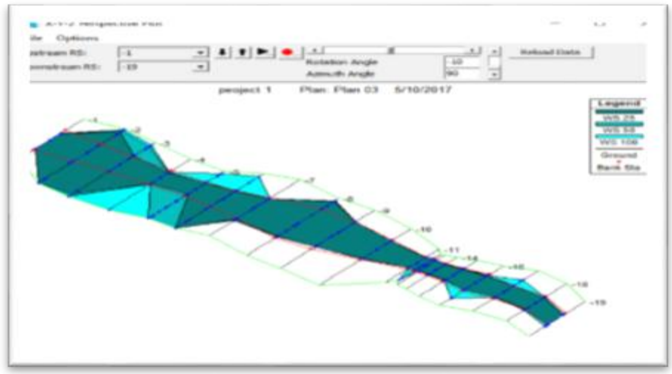


Fig 7. Perspective plot view

The perspective view is represented in a fig 7 for different discharges at all the cross section for different return period. It gives the 3-D view with an animation of different water level. The difference in the water level shown in figure and represents the flood prone area where the preventive measures should be taken place.

4.2 Unsteady flow analysis:

For unsteady flow simulation, flow hydrograph is used upstream boundary condition. Flow hydrograph is generated by using previous 20 years flow data which are collected from Hydrology Project Department, Nasik. CWC method is used for the generation of flow hydrograph (Flood Estimation Report for lower Godavari subzone-3f), as shown in fig. 8.

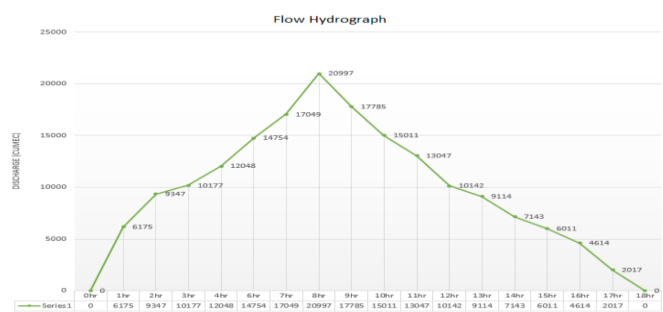
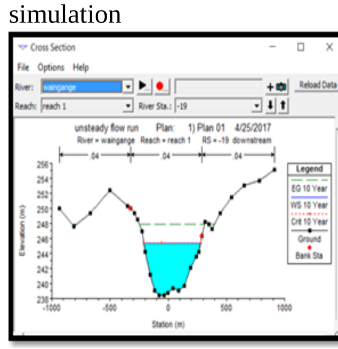
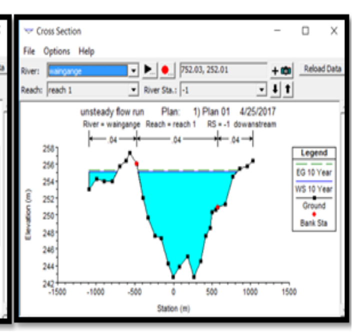


Fig 8. Flow hydrograph of study area

After input of flow hodograph the model is run for unsteady simulation





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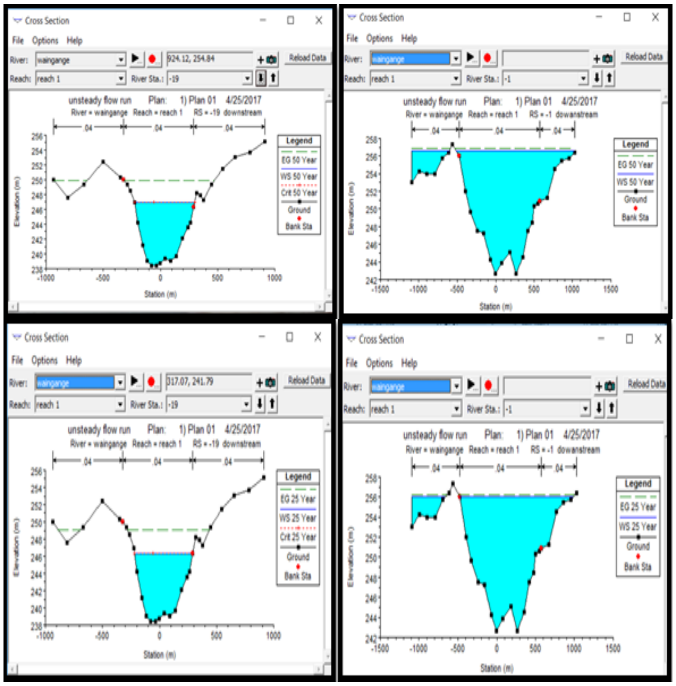

Fig 9 (a) Fig 9(b)

Fig 9.Graphical representation of C/S for unsteady simulation for different return period

Fig (a) shows C/S 19 and fig (b) shows C/S 1

In fig 9 shows the output obtained from the simulation of unsteady flow for cross section 19 and c/s 1 for a different return period by the HEC-RAS model. It shows that the water level is at a critical level about 238m for a cross section 19 (fig. 9a) and the area along that get flooded if the water surface level exceeds above it. At a cross section 1, the water level is normal as shows in fig 9(b).

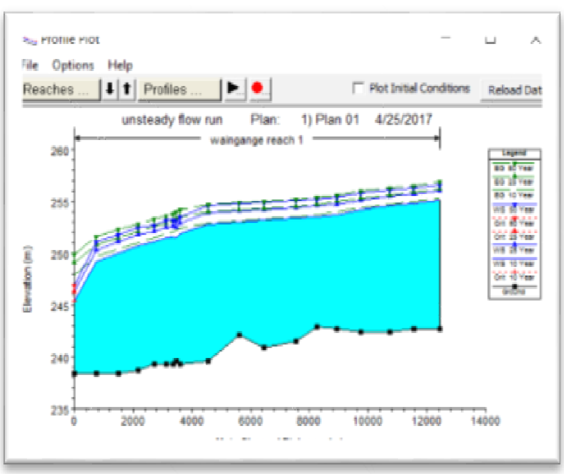

Fig 10. Water surface profile for unsteady flow

The fig.10 represents the HEC-RAS output for a water surface profile which are seen in better manner. At the end of profile, the water level reaches to the critical level and the surrounded area get flooded at a same time the area around other remaining cross section of a reach is at safe side.

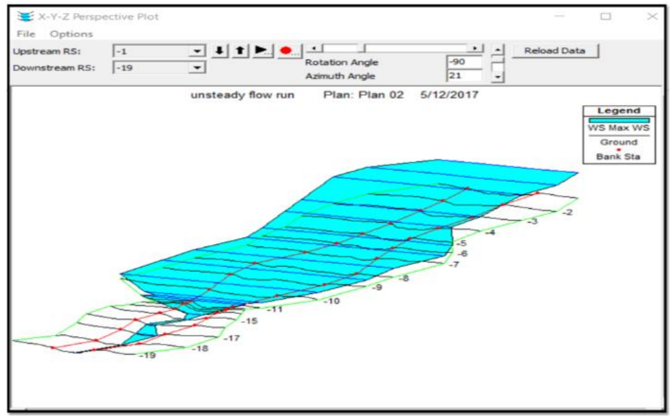

Fig 12. XYZ Perspective plot for unsteady flow simulation of river reach

The fig.11 shows graphical representation of a velocity, flow, area, and top width for different return period for both left bank, right bank and main channel. The results give the velocity of water along the reach. The fig.12 shows the 3D perspective plot for a given reach which shows different water level for different return period for a river basin for all cross section. These water levels are shown by the animation in a HEC-RAS model.

4.3 Result and Discussion: From all the output which are obtained after simulation of steady and unsteady flow by HEC-RAS gives some result for particular cross section. In a steady flow analysis at the cross section 2 and 3, the water level achieved the critical level because of which the area surrounded get affected by flood , where some preventive measures have to be taken. In unsteady flow analysis at cross section 19, the critical level achieved by the water and left the bank of river and area get flooded. For reducing losses, the protective measures need to be undertaken for area. At a same time, remaining reach is safe from flood in unsteady flow analysis.

5.CONCLUSION: The flood anlysis is carried out by using the HEC-RAS model by giving the input of river cross section and hydologic data of river. The steady flow and unsteady flow anlysis is carried out succesfully for Wainganga River located along a Bhandara city for all the cross sections of a reach. Among them, cross section 2 and 3 for steady and 19 for unsteady flow analyis gives the critial water level and area get flooded surronded by it. It is necessary to provide some prevention such as create a spongy city, sepearting rainwater from sewage system, install water infiltration and attenduation system, impermeable surfaces replaced with permeable materials, improve flood warning system, provide protection wall to the city etc. For a river, create floodplains and overflow areas for river. Different cross sections with different water levels of a stream help to provide preventive measures for the respective cross section and prevent them from damage.

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