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FLOOD MODELING AND FLOOD FORECASTING USING HEC-RAS

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Abstract: - **The flood and drought condition in our country has been more frequent in past few years due to changing climatic conditions of the environment. Prediction of stage of river during the flood requires mathematical modeling of the river. This helps to take decision related to the flood protection and disaster management work in that area. In Maharashtra, Pune city faces problems of floods and damages during monsoon. Many bridges over rivers get submerged, resulting failure of communication facility, inundation of the city and surrounding area during this period. The flood prediction of Mutha River using HEC-RAS has discussed in this paper. This will be helpful for preparation of flood mitigation plan for Pune city as a curative measure for the control of flood in the Mutha River. This model also provides the depth of water, velocity as well as water surface elevation with respect to time. The study represents the importance of 2D modeling of flood problems which helps to develop management strategies to tackle the probable future events by employing flood risk reduction measures.**

Keywords: - Mutha river, Flood modelling, Flood forecasting, HEC-RAS.

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I. INTRODUCTION

1.1 General

Water is an essential ingredient of life. Since the beginning of the existence of mankind, drought and floods have affected human activities throughout the world. River line floods are the floods caused by the water overflowing from the river banks into the flood plains. Flood is the most prominent natural hazard in India and its frequency is higher than any other natural calamities. They have catastrophic impact on lives as well as property. The water carrying capacity of the river has obviously reduced over the years. There are many reasons and factors responsible for it. Due to encroachment, silting and scouring, depth and width are reducing day by day. As the overall carrying capacity has decreased, it causes floods.

During monsoon, when the reservoirs get filled to its maximum limit, the water is discharged from the dam. When the water is released from the dam, the river cannot contain the water inside it and thus the water comes out causing floods. So to calculate the total water carrying capacity, firstly we need to know the nature and depth of river basin. This paper involves the study of the river's cross-section and finds the carrying capacity and other important parameters and also generates warning for the areas under risk that require immediate attention. By reducing carrying capacity on adjoining areas and modifying the channel it will be helpful for preparation of flood mitigation plan for Pune city as a curative measure for the control of flood in the Mula-Mutha River. Thus, modification of river channel should do to increase the carrying capacity of the rivers in Pune and thus reducing the effect of flood in Pune city and surrounding region. In view of that, various flood protective works should carried out by strengthening and raising the height of existing of embankment or retaining wall by 2 to 3 meters so as to protect the city against the heavy flood in future.

1.2 Aim of the study

To analyze the flood carrying capacity of the segment of Mutha river between Mhatre Bridge and Joshi Bridge which are 1.6 km apart by evaluating its capacity in response to discharge and slopes by using the HEC-RAS software.

1.3 Objective of the study

- To compute the different cross-section using past flood data, discharges and HEC-RAS.
- To determine adequacy of existing section to a carry flood of various magnitude.

- To recommend measures to assure safe flood conveyance for the study reach by increasing height of retaining wall, proposing new bunds or retaining wall.
- To identify critical section for the spread of water in the study area.

1.4 Study Area

Pune district lies in Bhima basin. Mula, Mutha, Pawana, Ram and Dev river are the five rivers that flow through Pune city. Mula and Mutha river meet at the College of Engineering, Pune. The origin of Mutha is in the lower hill ranges of eastern flanks of N-S trending Sahyadri ranges, which flows towards eastwards and then SE-wards up to Khadakwasla and then it turns in NE direction to flow in nearby plain area until it meets Mula river at Sangam in Pune city. It is found that flood problem in Pune city is generally caused due to flood water releases from various dams located on upstream side of Pune city on Mutha River. Our study area consists of the part between Mhatre Bridge to Joshi Bridge. This part consists of total 66 river stations which we have studied. Depending on the hydraulic properties of flood water which have generated by software, required changes in design of river basin are mandatory if any.

1.5 Limitations of Study

- Data availability is a major problem for this project. Data has to be collected from the respective government department which is a cumbersome process.
- Handling the software and using it for the project is also quite difficult and time consuming. Handling the software can be very challenging at times.
- Difficulty in understanding information. The data we get from government bodies is raw and not very understandable. Therefore much time is required to understand the data and sort it according to our requirements.
- Learning software is time consuming. It is a very different platform and requires a thorough understanding for being able to use it and derive required outputs.

1.6 Research Methodology

Pune faces the flooding problem each year. So flood forecasting is important. There are many types of software which can use for flood modeling and flood forecasting. Some of the softwares are,

- HEC-RAS (Hydrologic engineering centre river analysis system)
- HEC-HMS(Hydrologic engineering centre hydrologic modeling system)
- ARC-GIS (aeronautical reconnaissance coverage geographic information system).

Due to ease in getting required data and handling of software, we choose HEC-RAS. It is freely available software developed by US Army Corps of Engineers and it can perform one- and two-dimensional hydraulic calculations for a full network of natural and constructed channels.

1.6.1 HEC-RAS

The hydraulic model used for our study is based on Hydraulic Engineering Center's River Analysis System (HEC-RAS), version 5.0.1. It is freely available developed by US Army Corps of Engineers and can perform one- and two dimensional hydraulic calculations for a full network of natural and constructed channels. The HEC-RAS model is one of the most commonly utilized floods modeling software in hydrodynamic simulation. This model has designed to perform 1D steady flow as well as 2D unsteady flow simulations for a river flow analysis, and sediment transport and water temperature/quality modeling. The model uses geometric data representation as well as geometric and hydraulic computation routines for a network of natural and constructed channels of river.

The software that we used i.e. HEC-RAS has ability to make the calculations of water surface profiles for steady and gradually varied flow as well as for subcritical, super critical, and mixed flow regime. HEC-RAS is also capable to do modeling for sediment transport, which is notoriously difficult. In HEC-RAS, there are various boundary conditions available for steady flow and sediments analysis computations.

At each cross-section, HEC-RAS needed various input parameters to describe shape, elevation, and relative location along the river stream:

- River station (cross-section) number
- Reduced levels for each terrain point
- Left and right bank station locations
- Reach lengths between the left floodway, stream Centre line, and right floodway of adjacent cross-sections
- Manning's roughness coefficients
- Channel contraction and expansion coefficients
- Maximum discharge of the stream
- Geometric properties of any hydraulic structure like bridges, culverts, and weirs etc.

II. LITERATURE SURVEY

Literature survey is the most important part in any kind of research. Before starting any paper, we need to study different previous year research papers of our domain. It helps us to predict and minimize the drawbacks in our study. In this section we will thoroughly review previous year's research papers.

In the paper of flood inundation simulation of Mahanadi River, Odisha during September 2008 by using HEC-RAS 2d model the sensitivity analysis carried out for different manning's coefficient 'n'. Flood hazard maps prepared based on the flood depth of the Mahanadi River. HEC-RAS 2D is a hydraulic model used to simulate water flowing through rivers and open channels. It observed that the model performed well for channel roughness coefficient of 0.020.

In the paper of prediction of flood for lower tapi river using HEC-RAS, analysation of stability of segment of Lower River performed. This helped for preparation of Flood Mitigation Plan for Surat city. As the Surat city needed curative measure for the control of flood in the river Tapi. In this paper, uniform flow computed for past five year's peak flood discharge data. It concluded that, as the slope of river increases, velocity of water also increases and hence the discharge carrying capacity of river also increases.

In the paper, flood modeling by using HEC-RAS, the main goal was to provide flood control system .They used outputs to determine extent of overtopping of bridges. Flood modeling system here presented copes with a basic need of standardization of the databases system. The use of HEC-RAS provided capability to simulate flood depth in different part of the floodplain.

In the paper, floodplain mapping and management of urban catchment using HEC-RAS: a case study of Hyderabad city, a methodology for developing a flood model in urban environment carried out. The hydraulic modeling with GIS integration made the modeling process easy and produced more easily understandable results. The flood inundation maps were further processed in Arc-GIS to develop flood risk map and papered on Google Earth imagery.

In the paper of river flood modeling using GIS, HEC-Geo-RAS and HEC-RAS for Purna river, Navsari district, Gujarat, India, the first part of the study followed by the Arc-GIS and HEC-Geo RAS software in which pre-processing completed which contain to develop D.E.M (digital elevation model), Geo referencing, Shape file, Mosaic, Extract by mask of Navsari district and Purna river. Then from the HEC-Geo RAS geometry stream centerline, bank line, flow path and its centerline and cross-section cut lines is defined.

III. METHODOLOGY

This chapter explains how to perform hydraulic analysis study with the HEC-RAS software. It describes the methodologies used in performing the one-dimensional flow calculations within HEC-RAS. Steps for performing steady flow analysis of Mutha river basin have explained below.

The terms used in software have explained in user manual of the HEC-RAS software. User manual gives the clear idea about what parameter is to enter in which block.

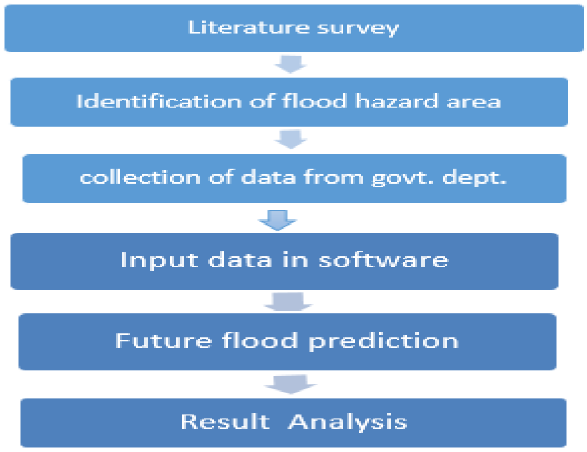

Figure 1: Flowchart of methodology

Step 1: To start a new HEC-RAS paper.

In the main window, open HEC-RAS click on the File, then click on New Paper. In the window of New Paper, type in Title and File name then click OK.

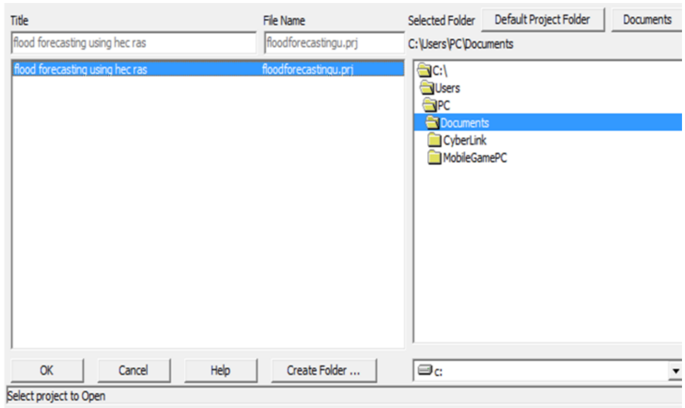

Figure 2: Project title window

Step 2: To set up river reach.

For a subcritical flow, which is very common in natural and man-made channels, step computations will begin at the downstream end of the reach, and progress upstream between adjacent cross-sections. For supercritical flow, the computations will begin at the upstream end of the reach and proceed downstream.

In main window, click on Edit, then Geometric Data.

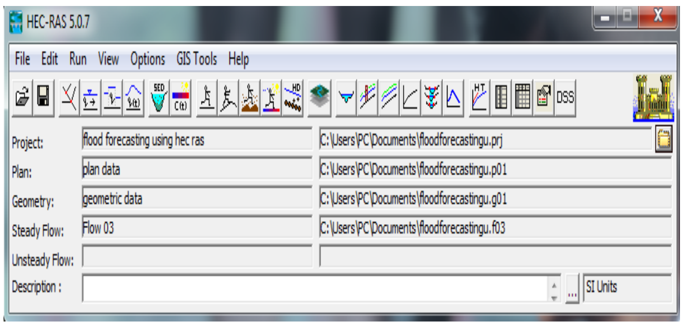

Figure 3: Main window

Step3: Plan cross-sections

Figure out where to position the cross-sections, and then scratch on the paper on the screen.

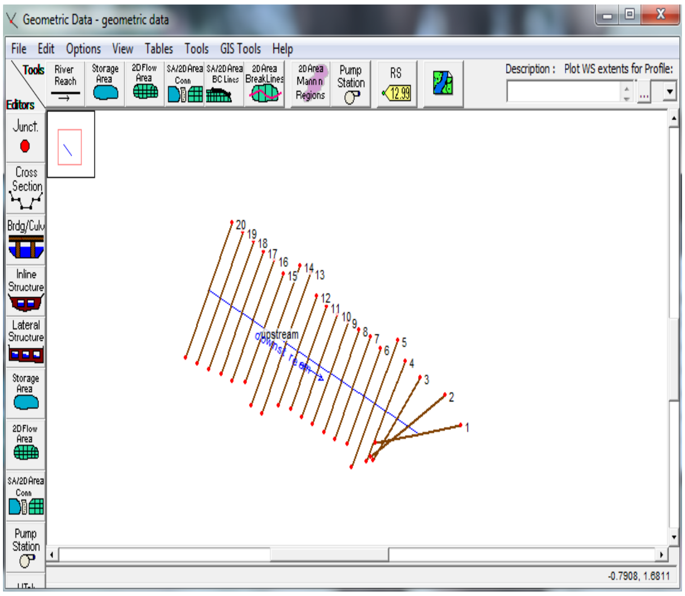

Figure 4: Geometric data view

Step 4: Enter cross-section data

Click on the cross-section. Click the Options. Choose "Add a new cross-section."

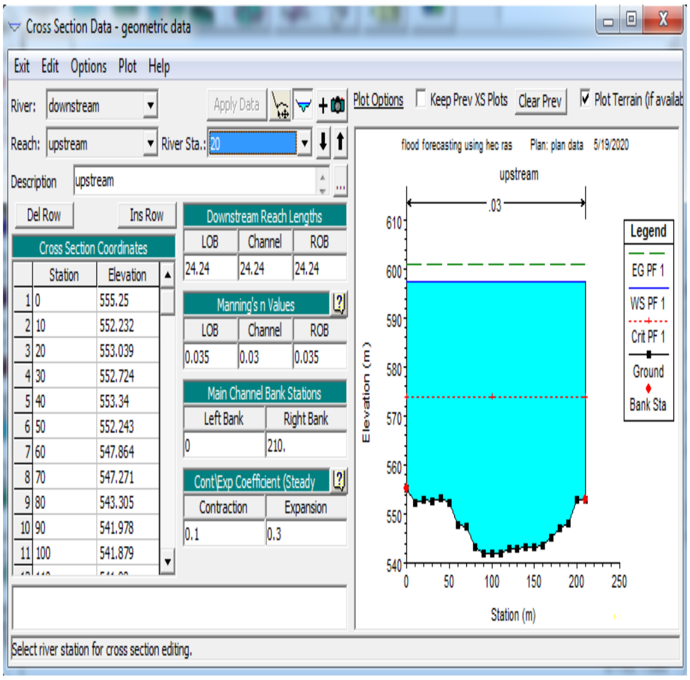

Figure 5: Cross-Section Data view

Step 5: Enter steady flow data

In main menu, click on Edit, then choose Steady Flow Data. Enter the number of profiles. Ex. for 50-year flow enters 1.

Reach boundary conditions are the two most common options used are normal depth and known water surface. For normal depth condition, click Normal Depth, enter stream slope.

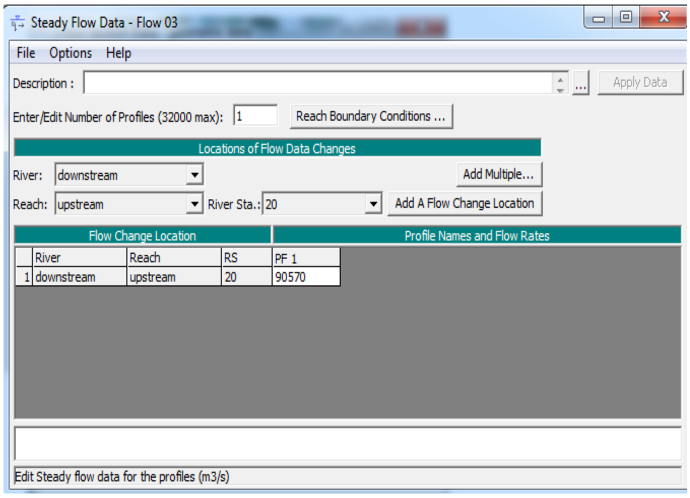

Figure 6: Steady flow data

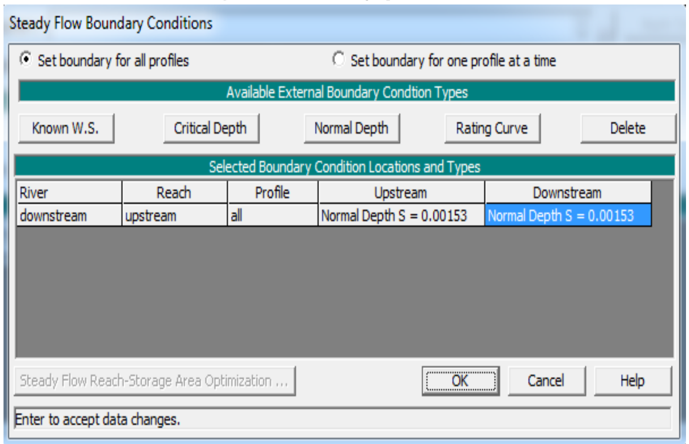

Figure 7: Steady flow boundary conditions

Step 6: Steady Flow Analysis

On main window, click on Run option, after that click on Steady Flow Analysis. After that in flow regime, select mixed and the click on Compute.

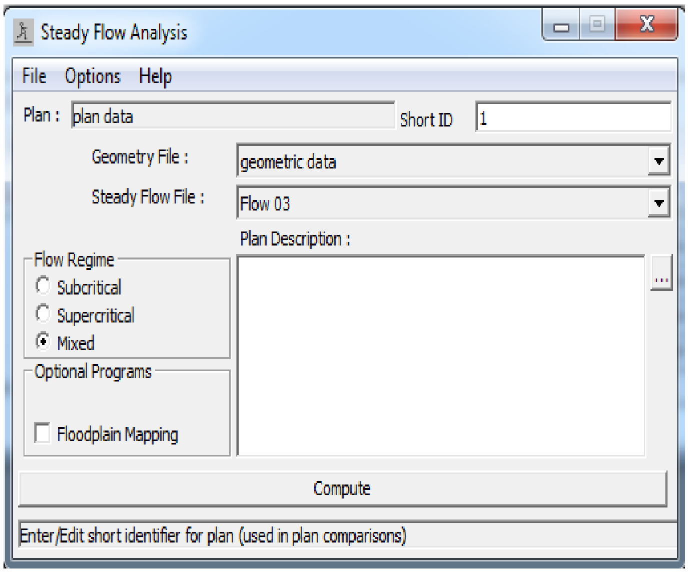

Figure 8: Steady Flow Analysis

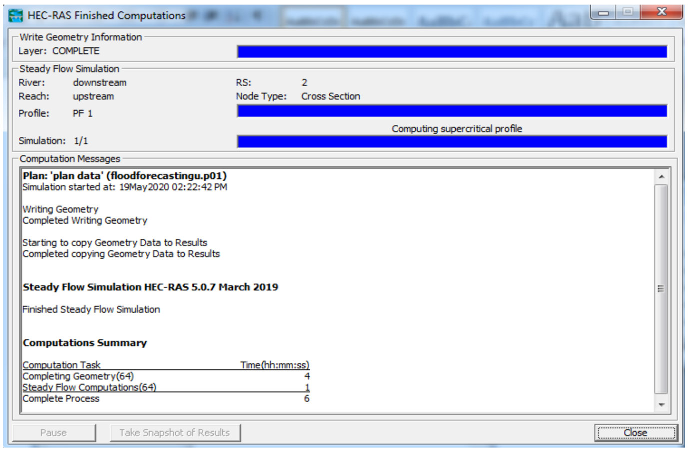

Figure 9: HEC-RAS finished computations

Step 7: View Output

Click on View option on main window. There will be various options as follows:

- Cross Sections
- General Profile Plot
- XYZ Perspective Plot
- Hydraulic Property Table
- Detailed Output Table
- Profile Summary Table
- Summary Error, Warning, Notes

IV. RESULT

Results of the study consist of various profile plots, output tables of hydraulic properties, XYZ perspective view which we can rotate to any desired angle. From this result, we can design the river basin as per requirements.

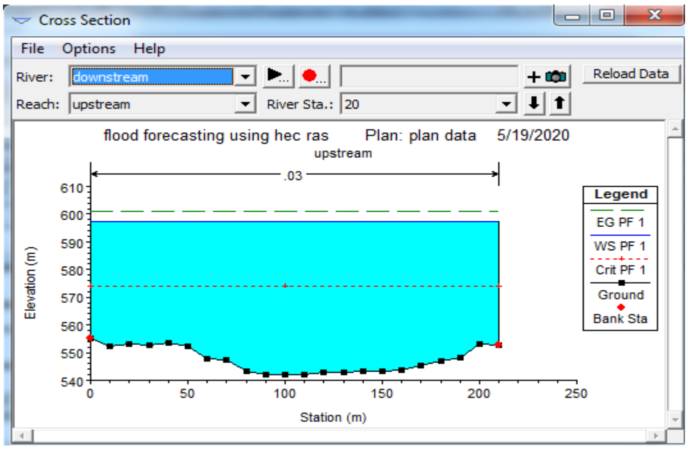

Figure 8: Cross section

The software can generate profile plots also called long sections or longitudinal profiles of the HEC-RAS steady flow and unsteady flow computational results, displaying the water surface elevation, energy grade line elevation, critical depth elevation, channel invert, bank stations, structures and more.

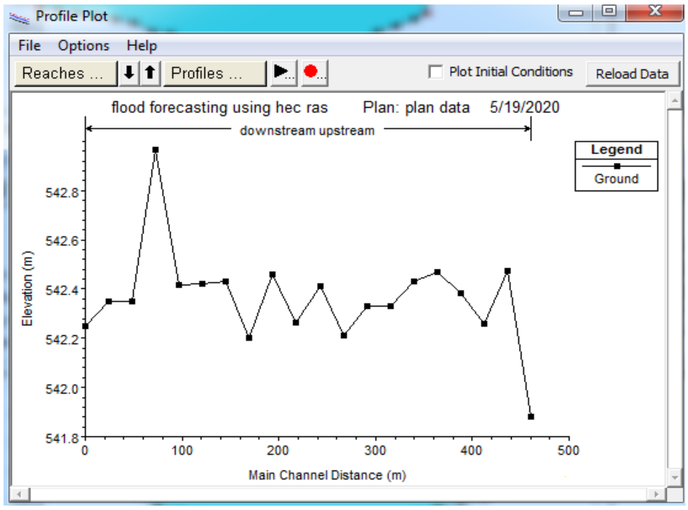

Figure 9: Profile Plot

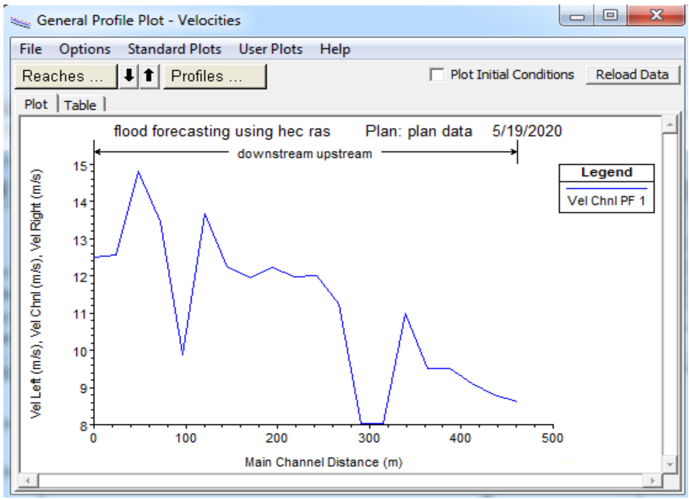

Figure 10: General Profile Plot- Velocities

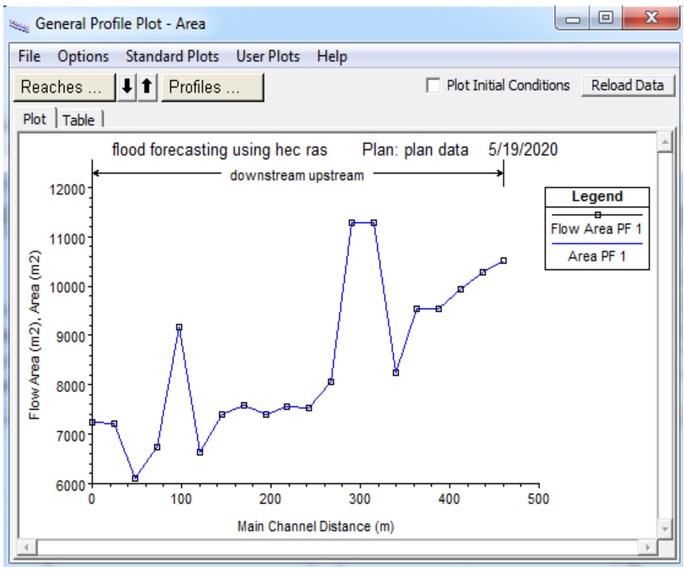

Figure 11: General Profile Plot- Area

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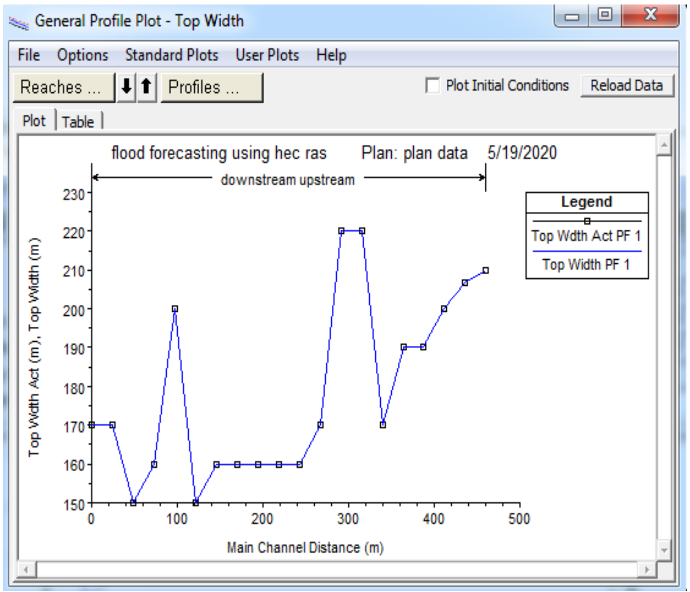


Figure 12: General Profile Plot- Top width

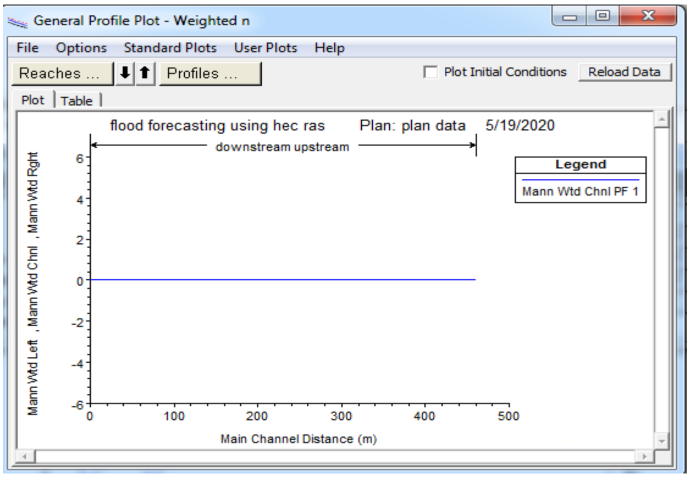


Figure 13: General Profile Plot- Weighted n

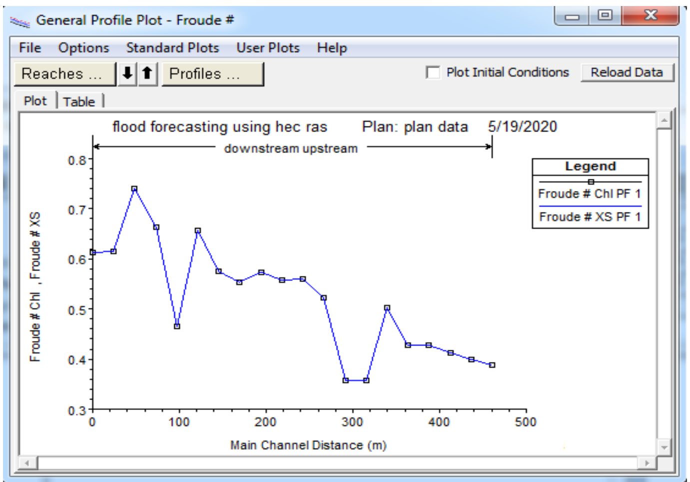


Figure 14: General Profile Plot- Froude number

The user can define the starting and ending location for extent of the plot. In order to get different perspectives of the river reach, the plot can rotate left or right, and up or down.

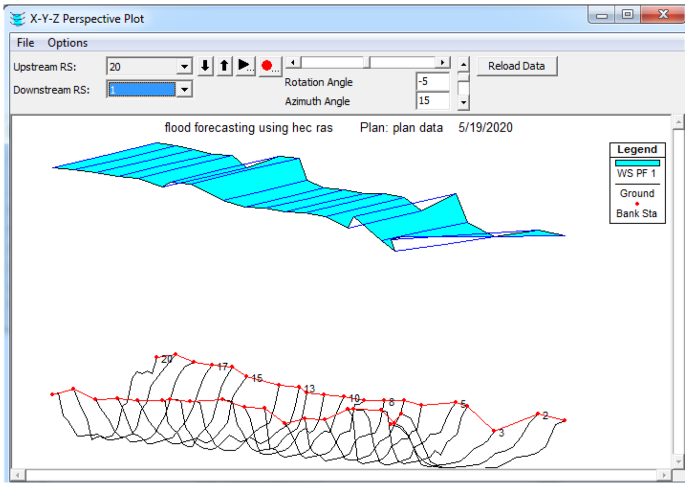
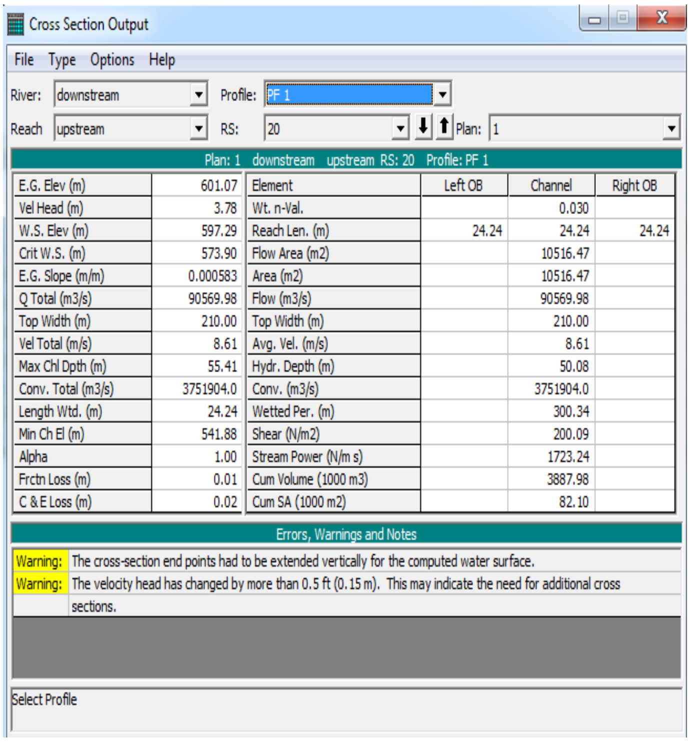


Figure 15: XYZ Perspective plot



		Element	Left OB	Channel	Right OB
E.G. Elev (m)	601.07	Wt. n-Val.		0.030	
Vel Head (m)	3.78	Reach Len. (m)	24.24	24.24	24.24
W.S. Elev (m)	597.29	Flow Area (m2)		10516.47	
Crit W.S. (m)	573.90	Area (m2)		10516.47	
E.G. Slope (m/m)	0.000583	Flow (m3/s)		90569.98	
Q Total (m3/s)	90569.98	Top Width (m)		210.00	
Top Width (m)	210.00	Avg. Vel. (m/s)		8.61	
Vel Total (m/s)	8.61	Hydr. Depth (m)		50.08	
Max Chl Dpth (m)	55.41	Conv. (m3/s)		3751904.0	
Conv. Total (m3/s)	3751904.0	Wetted Per. (m)		300.34	
Length Wtd. (m)	24.24	Shear (N/m2)		200.09	
Min Ch El (m)	541.88	Stream Power (N/m s)		1723.24	
Alpha	1.00	Cum Volume (1000 m3)		3887.98	
Frctn Loss (m)	0.01	Cum SA (1000 m2)		82.10	
C & E Loss (m)	0.02				

Errors, Warnings and Notes

Warning: The cross-section end points had to be extended vertically for the computed water surface.
Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.

Select Profile

Figure 16: Cross section output

Distribution of flow in three subdivisions of the cross-section is as follows:

- Left overbank
- Main channel
- Right overbank

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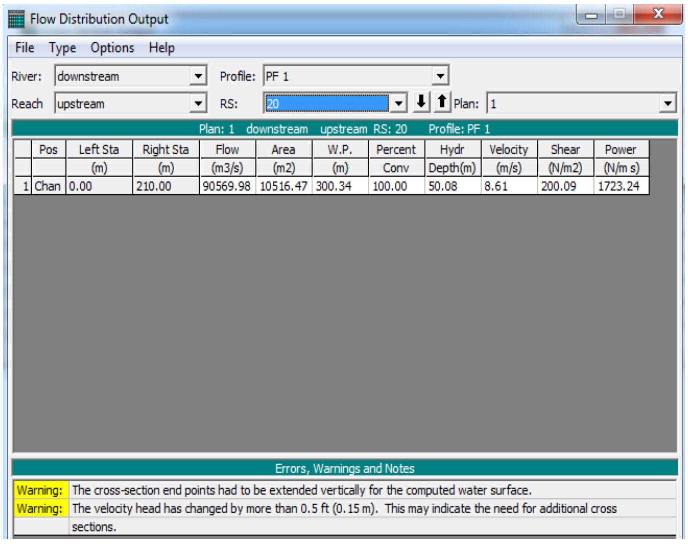
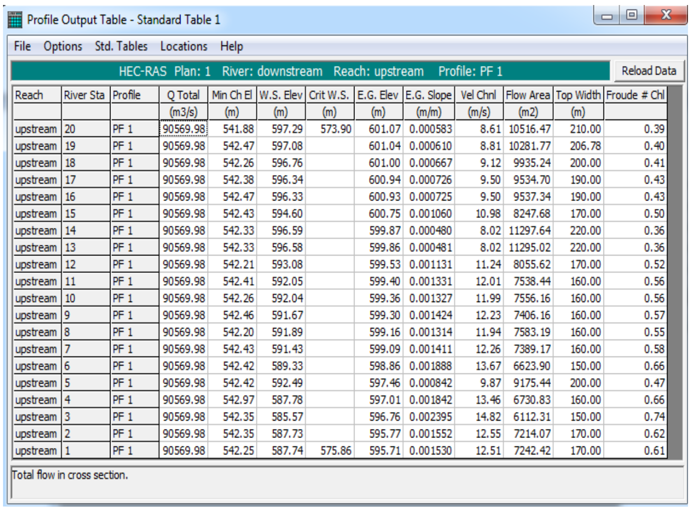

Flow Distribution Output
File Type Options Help
River: downstream Profile: PF 1
Reach upstream RS: 20 Plan: 1
Plan: 1 downstream upstream RS: 20 Profile: PF 1

	Pos	Left Sta	Right Sta	Flow	Area	W.P.	Percent	Hydr	Velocity	Shear	Power
		(m)	(m)	(m3/s)	(m2)	(m)	Conv	Depth(m)	(m/s)	(N/m2)	(N/m s)
1	Chan	0.00	210.00	90569.98	10516.47	300.34	100.00	50.08	8.61	200.09	1723.24

Errors, Warnings and Notes
Warning: The cross-section end points had to be extended vertically for the computed water surface.
Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.

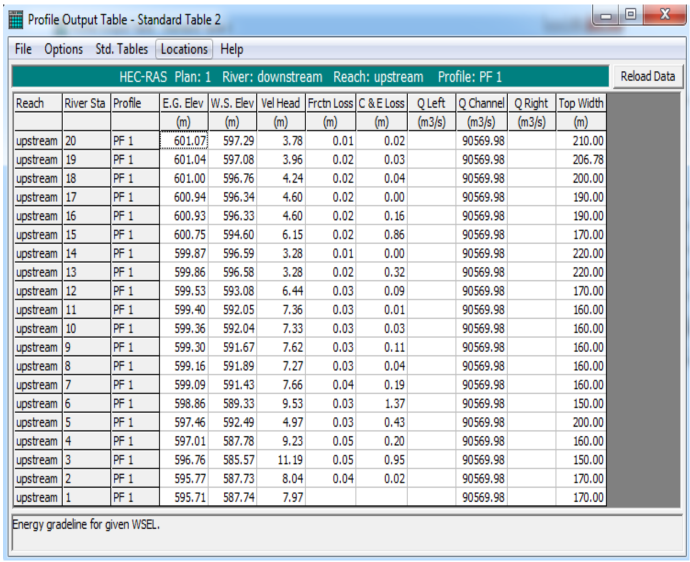
Figure 17: Flow Distribution Output


Profile Output Table - Standard Table 1
File Options Std. Tables Locations Help
HEC-RAS Plan: 1 River: downstream Reach: upstream Profile: PF 1 Reload Data

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
upstream	20	PF 1	90569.98	541.88	597.29	573.90	601.07	0.000583	8.61	10516.47	210.00	0.39
upstream	19	PF 1	90569.98	542.47	597.08		601.04	0.000610	8.81	10281.77	206.78	0.40
upstream	18	PF 1	90569.98	542.26	596.76		601.00	0.000667	9.12	9935.24	200.00	0.41
upstream	17	PF 1	90569.98	542.38	596.34		600.94	0.000726	9.50	9534.70	190.00	0.43
upstream	16	PF 1	90569.98	542.47	596.33		600.93	0.000725	9.50	9537.34	190.00	0.43
upstream	15	PF 1	90569.98	542.43	594.60		600.75	0.001060	10.98	8247.68	170.00	0.50
upstream	14	PF 1	90569.98	542.33	596.59		599.87	0.000480	8.02	11297.64	220.00	0.36
upstream	13	PF 1	90569.98	542.33	596.58		599.86	0.000481	8.02	11295.02	220.00	0.36
upstream	12	PF 1	90569.98	542.21	593.08		599.53	0.001131	11.24	8055.62	170.00	0.52
upstream	11	PF 1	90569.98	542.41	592.05		599.40	0.001331	12.01	7538.44	160.00	0.56
upstream	10	PF 1	90569.98	542.26	592.04		599.36	0.001327	11.99	7556.16	160.00	0.56
upstream	9	PF 1	90569.98	542.46	591.67		599.30	0.001424	12.23	7406.16	160.00	0.57
upstream	8	PF 1	90569.98	542.20	591.89		599.16	0.001314	11.94	7583.19	160.00	0.55
upstream	7	PF 1	90569.98	542.43	591.43		599.09	0.001411	12.26	7389.17	160.00	0.58
upstream	6	PF 1	90569.98	542.42	589.33		598.86	0.001888	13.67	6623.90	150.00	0.66
upstream	5	PF 1	90569.98	542.42	592.49		597.46	0.000842	9.87	9175.44	200.00	0.47
upstream	4	PF 1	90569.98	542.97	587.78		597.01	0.001842	13.46	6730.83	160.00	0.66
upstream	3	PF 1	90569.98	542.35	585.57		596.76	0.002395	14.82	6112.31	150.00	0.74
upstream	2	PF 1	90569.98	542.35	587.73		595.77	0.001552	12.55	7214.07	170.00	0.62
upstream	1	PF 1	90569.98	542.25	587.74	575.86	595.71	0.001530	12.51	7242.42	170.00	0.61

Total flow in cross section.

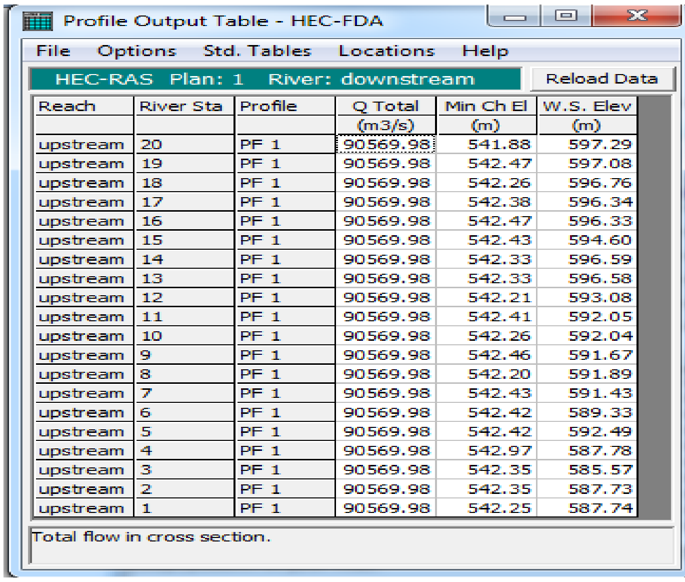
Figure 18: Standard Table 1


Profile Output Table - Standard Table 2
File Options Std. Tables Locations Help
HEC-RAS Plan: 1 River: downstream Reach: upstream Profile: PF 1 Reload Data

Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
			(m)	(m)	(m)	(m)	(m)	(m3/s)	(m3/s)	(m3/s)	(m)
upstream	20	PF 1	601.07	597.29	3.78	0.01	0.02		90569.98		210.00
upstream	19	PF 1	601.04	597.08	3.96	0.02	0.03		90569.98		206.78
upstream	18	PF 1	601.00	596.76	4.24	0.02	0.04		90569.98		200.00
upstream	17	PF 1	600.94	596.34	4.60	0.02	0.00		90569.98		190.00
upstream	16	PF 1	600.93	596.33	4.60	0.02	0.16		90569.98		190.00
upstream	15	PF 1	600.75	594.60	6.15	0.02	0.86		90569.98		170.00
upstream	14	PF 1	599.87	596.59	3.28	0.01	0.00		90569.98		220.00
upstream	13	PF 1	599.86	596.58	3.28	0.02	0.32		90569.98		220.00
upstream	12	PF 1	599.53	593.08	6.44	0.03	0.09		90569.98		170.00
upstream	11	PF 1	599.40	592.05	7.36	0.03	0.01		90569.98		160.00
upstream	10	PF 1	599.36	592.04	7.33	0.03	0.03		90569.98		160.00
upstream	9	PF 1	599.30	591.67	7.62	0.03	0.11		90569.98		160.00
upstream	8	PF 1	599.16	591.89	7.27	0.03	0.04		90569.98		160.00
upstream	7	PF 1	599.09	591.43	7.66	0.04	0.19		90569.98		160.00
upstream	6	PF 1	598.86	589.33	9.53	0.03	1.37		90569.98		150.00
upstream	5	PF 1	597.46	592.49	4.97	0.03	0.43		90569.98		200.00
upstream	4	PF 1	597.01	587.78	9.23	0.05	0.20		90569.98		160.00
upstream	3	PF 1	596.76	585.57	11.19	0.05	0.95		90569.98		150.00
upstream	2	PF 1	595.77	587.73	8.04	0.04	0.02		90569.98		170.00
upstream	1	PF 1	595.71	587.74	7.97				90569.98		170.00

Energy gradeline for given WSEL.

Figure 19: Standard Table 2


Profile Output Table - HEC-FDA
File Options Std. Tables Locations Help
HEC-RAS Plan: 1 River: downstream Reload Data

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev
			(m3/s)	(m)	(m)
upstream	20	PF 1	90569.98	541.88	597.29
upstream	19	PF 1	90569.98	542.47	597.08
upstream	18	PF 1	90569.98	542.26	596.76
upstream	17	PF 1	90569.98	542.38	596.34
upstream	16	PF 1	90569.98	542.47	596.33
upstream	15	PF 1	90569.98	542.43	594.60
upstream	14	PF 1	90569.98	542.33	596.59
upstream	13	PF 1	90569.98	542.33	596.58
upstream	12	PF 1	90569.98	542.21	593.08
upstream	11	PF 1	90569.98	542.41	592.05
upstream	10	PF 1	90569.98	542.26	592.04
upstream	9	PF 1	90569.98	542.46	591.67
upstream	8	PF 1	90569.98	542.20	591.89
upstream	7	PF 1	90569.98	542.43	591.43
upstream	6	PF 1	90569.98	542.42	589.33
upstream	5	PF 1	90569.98	542.42	592.49
upstream	4	PF 1	90569.98	542.97	587.78
upstream	3	PF 1	90569.98	542.35	585.57
upstream	2	PF 1	90569.98	542.35	587.73
upstream	1	PF 1	90569.98	542.25	587.74

Total flow in cross section.

Figure 20: Profile Output Table

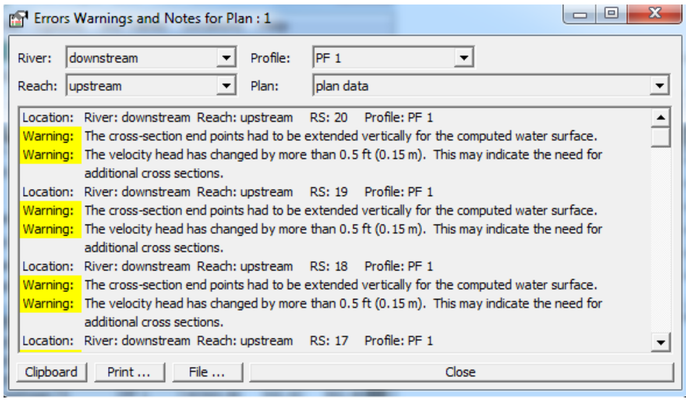

Errors Warnings and Notes for Plan : 1
River: downstream Profile: PF 1
Reach: upstream Plan: plan data
Location: River: downstream Reach: upstream RS: 20 Profile: PF 1
Warning: The cross-section end points had to be extended vertically for the computed water surface.
Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.
Location: River: downstream Reach: upstream RS: 19 Profile: PF 1
Warning: The cross-section end points had to be extended vertically for the computed water surface.
Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.
Location: River: downstream Reach: upstream RS: 18 Profile: PF 1
Warning: The cross-section end points had to be extended vertically for the computed water surface.
Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.
Location: River: downstream Reach: upstream RS: 17 Profile: PF 1
Clipboard Print ... File ... Close

Figure 21: Errors, Warning and Notes for Plan

V. CONCLUSION

This paper presents a methodology for modeling and forecasting of flood caused due to many reasons like heavy rainfall, poor river basin, and lack of space for rainwater flow in riverbed due to urbanization. The use of HEC-RAS software made the forecasting & modeling process easy and also produced more easily understandable results. The cross-sections of river bed were cross sections prepared in HEC-RAS. The areas susceptible to flood have recognized by analyzing XYZ perspective view and warning table simultaneously which are developed by software itself. It is clearly seen that the cross-section end points should extend vertically for the computed water surface. Otherwise it will cause overflow of flood water through river basin. Thus, our study area needs immediate attention during flooding situations & should assign high priority. The result table of hydraulic properties and all profile plots can also be used in future planning of developmental works. Present situation of river basin is not that capable to carry huge flood. So it is very important to increase size of river basin horizontally as well as vertically. Following are warnings developed by HEC-RAS:

Location:

River: downstream

Reach: upstream

RS: 20 Profile: PF 1

Warning: End points of the cross-section end points should extend vertically for the computed water surface.

Warning: There is a need for additional cross sections because the velocity head has changed by more than 0.5 ft (0.15 m).

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