Flood Minimization by using Specific Energy and Venturi Flume Concept – Specifically for 'Western Maharashtra Floods in Krishna Sub-Basin 2019'

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Abstract - *The flood situation raised in the year 2019 in Western Maharashtra was very severe and the highest of all times. The water level in the Krishna river near Sangli, had passed the previous HFL (543.29 m) By a significant amount in the month of August. The water thus spread over larger area and brought the surrounding area under inundation for longer time. So, there is need immediate solution to the problem to control the loss of property and lives. This research project will try to design a solution to the flood problem in the Krishna river sub-basins. The idea used in the research is related with the specific energy phenomenon. With some change or modification in the river geometrics and with the use of the fluid mechanics concepts, the water discharge and depth can be controlled. So, this research will try to test the idea for controlling floods. So, this research comprises of the unique idea or solution to minimize the floods in the rivers. The idea is also supported by the river flow model created by the HEC-RAS software and the results are analyzed.*

Key Words: Western Maharashtra floods, specific energy, venturi flume, HEC-RAS, river modelling.

1.INTRODUCTION

During the months of July & August 2019, Sangli & Kolhapur districts in Krishna sub basin experienced extreme floods for long durations. Heavy losses to life, property & crops etc. had been reported. Different opinions at various levels were put forth concerning these flood events. Sangli & Kolhapur districts faced heavy flood situations in past also & floods of 2005 & 2006 were noteworthy. However, 2019 flood event was comparatively much more severe which lasted more than a week & losses experienced were also on higher scale.

During the year 2019, eight cyclonic storms were developed over Indian Seas. Arabian Sea contributed 5 out of these 8 cyclones against the normal of 1 per year, which equals the previous record of 1902 for the highest frequency of cyclones over the Arabian Sea. Out of 5 cyclones developed over Arabian Sea 2 were very severe, one was extremely sever and one was super cyclonic storm. Active spell of South West monsoon started from 27thJuly, 2019 and before it is fully dissipated; low pressure area was formed on the Bay of Bengal, which intensified into deep depression on 7th August. During the first spell catchment was fully saturated. Hence, during second spell almost all the rainfall converted into runoff causing severe inundation.

2. OBJECTIVES

1. Analyze the Western Maharashtra 2019 flood situation at Sangli.
2. Identification of the reasons for the Western Maharashtra floods 2019.
3. Providing the solution for the minimization of the flood effect by studying different concepts related with the specific energy.
4. Identification of the feasibility and the practical constraints or limitations.

3. METHODOLOGY

1. The data collection of regarding the recent floods nearby.
2. Case study of the reports on recent floods in Western Maharashtra in the year 2019.
3. The identification and analysis of the reasons for the floods in the Western Maharashtra.
4. Developing the solutions or techniques for the flood problem by studying different concepts in river engineering and adopting new ideas.
5. Corelating the solutions by the studied and researched concepts with the flood problems in the above region.
6. Finding out the limitations and practical constraints that may affect the proper implementation of the idea.
7. Preparation of the detailed report for the research work.

4. LITERATURE REVIEW

1. Expert study committee (Vadnere Committee) (2019), "Report on Krishna sub-basin floods 2019". [1]

The report comprises of the study and analysis of the Western Maharashtra floods 2019 framed into three volumes (Vol I , II and III). The study was conducted a committee lead by Er. Nandkumar Vadnere who is retired secretory of Water Resource Department, Maharashtra. The objective is to find out the reasons behind the flood situations in Bhima and Krishna Valley in the year 2019. Considering the voluminous work and the huge data compilation required for the studies, it was decided to prepare separate reports for each basin.

2. Shahid Ali, "Flow over weir like obstacles". [4]

In this paper, the flow characteristics of water over weirs is given and the significant energy losses are mentioned. The main objective of paper is to study the hydraulic resistance caused by the vegetated weir-like obstacles in the floodplain during high water stages. This study focuses on the changes in the water depth while passing over a weir. The specific energy concept is explained in the paper which causes the reduction in the depth. A number of processes related to vegetation, weirs and bed forms are studied in order to come to an improved implementation of the physical processes.

Also in this paper, the detailed graphs and results of the changes in water level on the upstream and downstream of the weir are given. The energy losses for the weirs and there effect on the water depth is specifically mentioned.

3. Dennis A. Davis, Robert A. Halliday, "Guidelines for reducing flood losses".[3]

In this article, the different guidelines for the reducing the flood effect are given. The Socio-Economic Aspects of Water-Related Disaster Response is also mentioned. The different techniques for reducing the flood damage is specifically given in this article. The different case studies related with the disaster management are mentioned with the given techniques for reducing the flood effects.

4. Books on open channel flow [5,6]

1. K Subramanya, "Flow in open channels (third edition)",Tata McGraw-Hill Publication.

2. M. Hanif Chaudhary, " Open channel flow (second edition)", Springer Publication.

The concepts related with specific energy and open channel (river) hydraulics are mentioned in these books. The actual part of research work is based on the date given in these books. The analyzation of the data and concepts and application of those concepts in this research is the core outcome. The concepts such as rapidly and gradually varied flow, specific energy, flow over weirs are the core study areas for this research.

5. ANALYSIS OF THE REASONS BEHIND THE FLOODS

Rainfall data indicates that Konkan and adjoining Madhya Maharashtra experienced very heavy rainfall. In the beginning of the flood period i.e. from 27th Jul to 3rd Aug, the heavy rainfall events were localized in the northern part of the Konkan and adjoining North Madhya Maharashtra. Many stations in Pune and Nasik districts, recorded rainfall more than 150 mm/day during the period 3rd to 5th Aug. Towards the latter part of the week, rainfall belt shifted towards south Madhya Maharashtra. Mahabaleshwar recorded highest rainfall of 380 mm on 5th Aug.

Rainfall records in dam catchments

It was seen that the observed actual rainfall in various catchments to the upstream of dams varies from 5 to 19 times the normal. Average actual rainfall was about 6 times the normal rainfall in all these catchments bringing abnormal flood to downstream areas.

Rainfall records in Free catchments

The actual rainfall during the first 56 days of the monsoon (starting from 1st June 2019) was measured at 6 rain gauge stations, situated in the free catchments of these three districts. It is observed that the total rainfall during the peak period of 18 days (27th July to 13thAugust) measured at the same stations, was about 1.6 times the total rainfall during the previous 56 days (1st June to 26th July). Also, the actual rainfall during the event in free catchments was varied from 13 to 29 times the normal rainfall. The overall observed rainfall over the normal was about 18 times. Such abnormal high occurrence of rainfall even in free catchments also aggravated floods in Sangli & Kolhapur districts.

6. DATA COLLECTION

6.1 Physical characteristics of the krishna river near sangli

Cross section of the river at different locations at Sangli

For any type of analysis of flood, we require the channel cross section details for which we are going to study. I have used the HEC RAS software for the terrain preparation and extracting the river geometry. Also, the same software is used for further modelling of the river. The software requires the Digital Elevation Model (DEM) which is referred from the SRTM and bhuvan.nrsc.gov.in and which gives all the satellite surveyed date for India.

Also I have used the Google Earth Profile tool for getting the geometrical details of the Krishna river.

General profile of the ground across the river flow on both sides of the river (2019 flood water reach)

As mentioned in above para, I also collected the general profile of the ground by using HEC RAS and Google Earth software.

Surface characteristics of the river

Surface characteristics in terms of channel roughness factor or friction slope are collected from the 'Western Maharashtra 2019 flood report' by Vadnere committee (Vol I – 5.3.4, page 109). The manning's roughness coefficient 'n' is given as 0.031 for the channel section and 0.07 for the overbank portion. The higher values 0.07 is because of the presence of crops on both side of the river.

Longitudinal slope of the river at Sangli

The longitudinal profile of the Krishna river is referred from the 'Western Maharashtra 2019 flood report' by Vadnere committee (Vol III – drawing 7). The bed slope of the Krishna river is **0.00017** from village Brahmanal to Sangli. and from Sangli to N. Wadi it is **0.00021**.

6.2 Hydrological data of the 2019 flood

Date	Water level m	Total Discharge Cumecs	Discharge from dams Cumecs
30-07-19	534.30	1107	2
31-07-19	537.73	2088	2
01-08-19	537.58	2039	167
02-08-19	537.58	2039	198
03-08-19	538.21	2283	388
04-08-19	539.36	2792	514
05-08-19	540.60	3728	1716
06-08-19	542.23	4712	4252
07-08-19	543.58	5665	4536
08-08-19	544.36	5900	4610
09-08-19	544.57	6324	3967
10-08-19	544.29	5955	2692
11-08-19	543.65	5575	2870
12-08-19	542.66	4976	2073
13-08-19	541.41	4302	1788
14-08-19	539.64	3044	1180
15-08-19	537.40	2015	854
16-08-19	535.90	1552	1033
17-08-19	534.53	1193	794

. **Fig -1**: Discharge and water levels at Irwin bridge Sangli

The flood level in the Krishna River Observation point at Irwin Bridge, Sangli on 05/08/2019 at 11.00 am exceeded the Danger level 540.77m.

The maximum flood level observed at this observation point was **544.57m** (57 feet 5 inches) on 09/08/2019. And the water level started to recedes below danger level on 14/08/19. Sangli city area from 05th August to 13th Aug. thus Sangli town was inundated for about 9 days. Maximum Flood discharge observed was **6324 Cumecs** on 09/08/19 and out of this discharge released from above dams is 3967 Cumecs.

The data is referred from Vadnere committee report (Vol II)

6.3 Information about surrounding area near Sangli

Extent of city area

This is the area where we are not going to widen the river. It is kept as it is and which will act as a throat portion of Venturi flume. The upstream point is at 16°52'28.55"N, 74°33'11.23"E. and downstream point is at 16°50'24.74"N , 74°32'26.93"E.

Fig-2 : Analyzed portion of Krishna river

7. DESIGN SOLUTION

7.1 Concept

The flood situation that is arising periodically in the Western Maharashtra is very severe. So, there is need to have immediate solution to this problem.

There are many concepts and ideas that are at the experimental level to control the floods. The concept that is used in this research to control the floods is related to the specific energy and the Venturi flume. Venturi flume is the portion of the open channel that has reduced cross section (specifically width is reduced) and again the cross section is enlarged as it was initially. The depth of liquid flowing through the reduced cross section is lowered. This phenomenon of the Venturi flume is used to design the flood control concept in this research.

The reason behind the lowering of the depth is related with the concept of specific energy possessed by the flowing liquid.

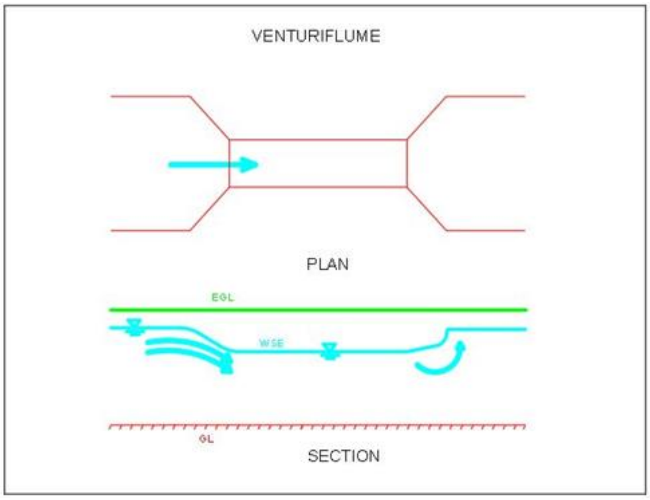

Fig- 3: Venturi Flume

6.4 Idea description

The idea behind the concept is to enlarge the areas of the river reach at regular intervals so that the entire reach will act as a big Venturi Flume. The undisturbed portion of the river will act as the throat between two enlarged portions. The extent of the enlargement or the width of the enlargement is decided such that the water level in the river is kept below the alert level as fixed by the Water Resource Department, Maharashtra. The various water levels at the Irwin bridge, Sangli which are fixed by the WRD, Maharashtra are shown in fig.4.

The following figure shows the cross section of the Krishna river at the Irwin bridge, Sangli. The blue line shown is the water level of the river in the Western Maharashtra 2019 floods. This is the highest flood level recorded ever in the history of the Krishna River.

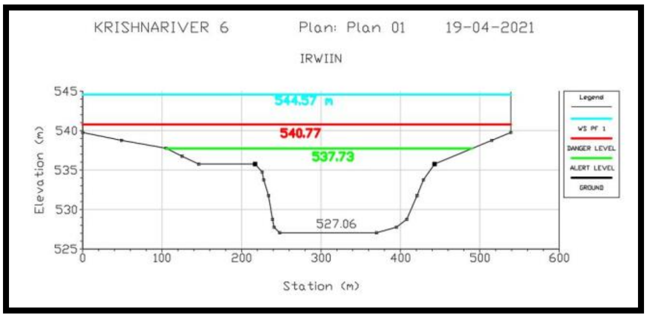

Fig- 4: Irwin water levels

For fixing the width of the enlargement, no of trials are taken on the HEC-RAS software to get the required depth of the water in the Krishna river. Further the depth in the throat portion is again reduced as the area of the throat is minimum. This lowering of the depth is due to the specific energy theory. The theory is supported by the specific energy curve which gives the conclusion that when the specific energy of the water is reduced by increasing the bed level, the velocity of the water is increased and the depth is reduced.

The enlargements are made at regular intervals up to the point where the river starts overflowing. The point at which river is not able to carry the discharge is expanded to maintain the water within the river banks. And the similar expansions are made at regular intervals. So, by this method we do not need to expand all the river section throughout the length. Thus, the entire river reach will act as no of Venturi Flumes. The general overview is shown in fig. 5.

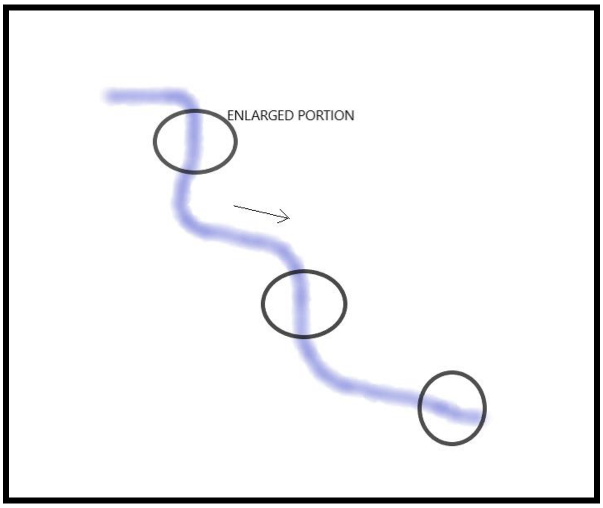

Fig- 5: General overview

6.5 Analysis using HEC-RAS

The analysis flow through the natural geometry and modified geometry is carried out using HEC- RAS river modelling software. The preparation of river geometry is first of all carried out. Then all the required input data related with Krishna river characteristics is entered to analyse the depth of water attained by the water. Then, same process is carried out for the modified geometry and the results are interpreted..

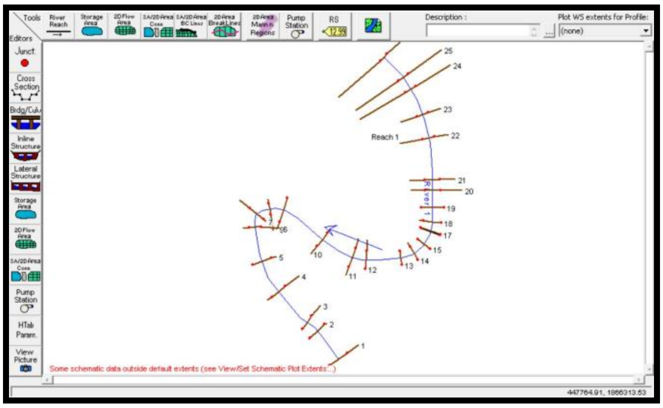

Fig- 6:. Geometry in HEC-RAS

8. RESULTS AND DISCUSSIONS

After carrying out the steady flow analysis for the given flow data and the river geometrics, the water level in the river is reduced considerably. The corresponding water levels at all the cross sections are tabulated in the output tables as given in fig. 12,13,14. The water levels are lowered up to alert level after widening of 100 m on each side of the river. The velocities are increased for the modified section due to lowering of the depth.

8.1 Cross sections of the river carrying flow

Following are the changes in the water level for the sections-

CS 26 (most upstream section) :

The change in the water level from 545.08 m to 539.06 m is observed at the section i.e. 6.02 m. This change is enough for maintaining the water within the river banks, so that the water could not expel out of the river.

The following figures gives the change in the water level.(fig. 7 and fig. 8)

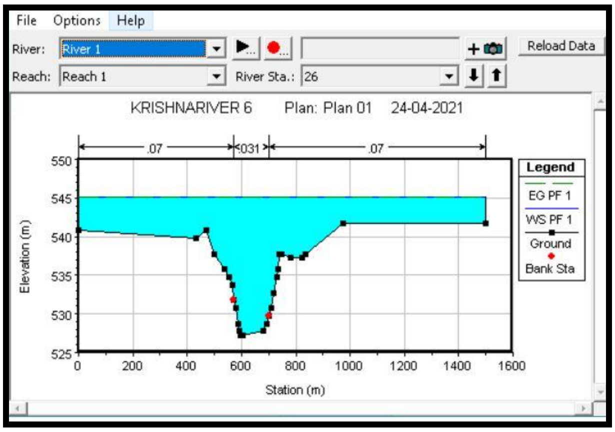

Fig-7 : CS 26, natural geometry

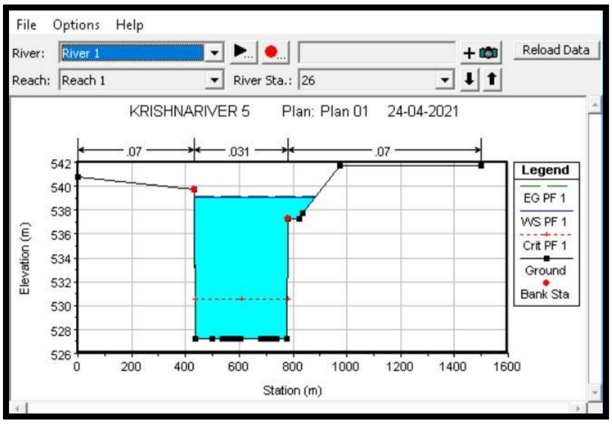

Fig- 8: CS 26, modified geometry

CS 20 (Irwin bridge, Sangli) :

The change in the water level from 544.91 m to 536.90 m is observed at the section i.e. 8.01 m. This change is enough for maintaining the water within the river banks, so that the water could not expel out of the river. Is can also clearly seen that due to the Venturi effect the change in water level in the CS 26 and CS20 has the difference of about 2m (6.02 m for CS26 and 8.01 m for CS20).

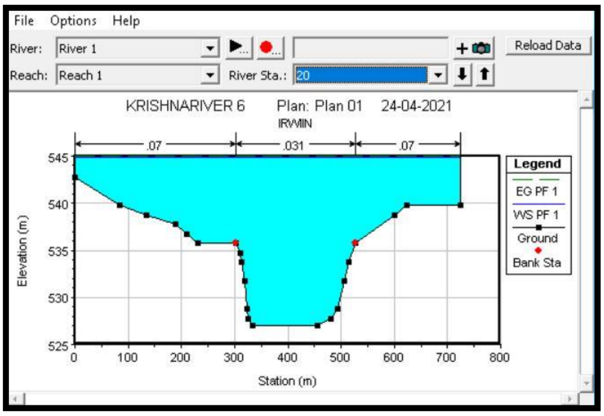

Fig- 9: CS 20, natural geometry

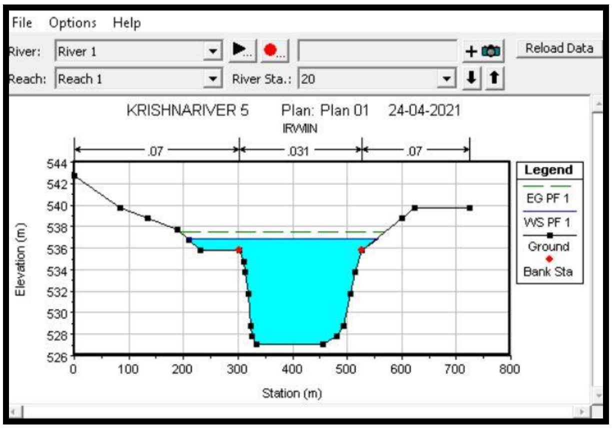

Fig.-10 : CS 20, Modified geometry

8.2 Water surface profile

The water surface elevation profile shows the changes in the flow depth over the length of reach. Fig. 11 shows the water profile for the modified section having enlarged widths. The sudden drop in the water surface elevation can be seen clearly due to the effect of width transition in the channel. The reduction of about 2 m is observed in the profile at the downstream side of enlarged section. Again the water depth is increased at the second enlargement situated downstream to the reach.

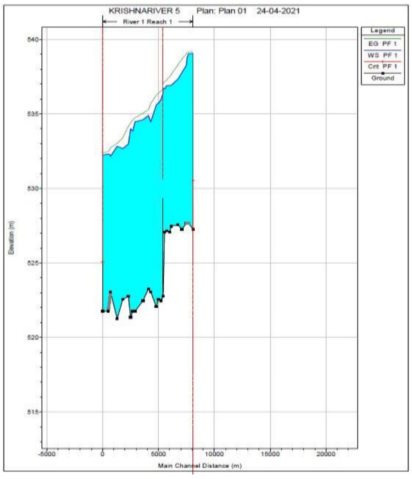

Fig.- 11 : Water surface profile, modified geometry

8.3 Profile output tables

The output tables are obtained after performing the steady flow analysis in HEC-RAS software. The changes in water surface elevation, velocities, Froude numbers, etc. are shown in the profile tables. The profile output tables in fig. 12, 13, 14 show the reduction in the water surface table below alert level (537.73 m) for all the cross sections of the river.

Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: 2 River: River 1 Reach: Reach 1 Profile: PF 1

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)	
Reach 1	26	PF 1	6350.00	527.26	545.08		545.18	0.000071	1.80	8997.01	1500.00	0.14
Reach 1	25	PF 1	6350.00	527.66	545.06		545.15	0.000063	1.61	8922.36	1500.00	0.13
Reach 1	24	PF 1	6350.00	527.66	545.06		545.14	0.000057	1.54	9373.82	1500.00	0.12
Reach 1	23	PF 1	6350.00	527.26	544.92		545.10	0.000099	2.00	4571.96	482.33	0.16
Reach 1	22	PF 1	6350.00	527.56	544.93		545.05	0.000075	1.76	6256.92	700.00	0.14
Reach 1	21	PF 1	6350.00	527.46	544.90		545.01	0.000061	1.58	6080.45	650.00	0.13
Reach 1	20	PF 1	6350.00	527.06	544.91		544.99	0.000049	1.44	6818.31	725.00	0.11
Reach 1	19	PF 1	6350.00	527.16	544.89		544.98	0.000047	1.31	4862.51	324.40	0.11
Reach 1	18	PF 1	6350.00	527.06	544.86		544.97	0.000055	1.48	4669.55	322.00	0.12
Reach 1	17	PF 1	6350.00	522.76	544.87	530.62	544.96	0.000042	1.29	4919.01	300.00	0.10
Reach 1	16.5		Inl Struct									
Reach 1	16	PF 1	6350.00	522.76	544.82		544.90	0.000033	1.22	5187.95	283.00	0.09
Reach 1	15	PF 1	6350.00	522.46	544.74		544.88	0.000066	1.65	3841.63	226.00	0.13
Reach 1	14	PF 1	6350.00	522.56	544.73		544.87	0.000064	1.65	4361.59	293.00	0.13
Reach 1	13	PF 1	6350.00	522.06	544.69		544.85	0.000069	1.78	3627.65	203.00	0.13
Reach 1	12	PF 1	6350.00	523.06	544.69		544.80	0.000063	1.51	5079.22	410.00	0.12
Reach 1	11	PF 1	6350.00	523.26	544.72		544.78	0.000027	1.14	7065.20	555.00	0.09
Reach 1	10	PF 1	6350.00	522.46	544.68		544.76	0.000032	1.28	6158.64	454.00	0.09
Reach 1	9	PF 1	6350.00	521.76	544.69		544.74	0.000019	0.94	7548.23	463.00	0.07
Reach 1	8	PF 1	6350.00	521.76	544.62		544.72	0.000042	1.57	6167.24	453.00	0.11
Reach 1	7	PF 1	6350.00	521.36	544.65		544.70	0.000023	1.13	7247.21	476.00	0.08
Reach 1	6	PF 1	6350.00	522.76	544.59		544.69	0.000046	1.55	6512.51	536.00	0.11
Reach 1	5	PF 1	6350.00	522.56	544.59		544.67	0.000034	1.23	5700.17	350.00	0.09
Reach 1	4	PF 1	6350.00	521.26	544.61		544.64	0.000014	0.89	10288.74	563.00	0.06
Reach 1	3	PF 1	6350.00	523.06	544.58		544.63	0.000024	1.16	7657.75	448.00	0.08
Reach 1	2	PF 1	6350.00	521.76	544.56		544.62	0.000024	1.12	6165.64	346.00	0.08
Reach 1	1	PF 1	6350.00	521.76	544.57	527.98	544.61	0.000016	0.91	8815.48	550.00	0.07

Fig- 12: Profile output table, natural geometry

File Options Std. Tables Locations Help

HEC-RAS Plan: 2 River: River 1 Reach: Reach 1 Profile: PF 1

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)	
Reach 1	25	PF 1	6350.00	527.66	539.02		539.14	0.000095	1.53	4142.58	369.13	0.15
Reach 1	24.857*	PF 1	6350.00	527.66	538.99		539.14	0.000116	1.69	3762.50	341.07	0.16
Reach 1	24.714*	PF 1	6350.00	527.66	538.95		539.13	0.000146	1.87	3390.87	318.56	0.18
Reach 1	24.571*	PF 1	6350.00	527.66	538.90		539.12	0.000187	2.10	3030.73	302.37	0.21
Reach 1	24.429*	PF 1	6350.00	527.66	538.82		539.11	0.000247	2.38	2683.76	290.28	0.24
Reach 1	24.286*	PF 1	6350.00	527.66	538.71		539.09	0.000338	2.74	2357.57	309.29	0.28
Reach 1	24.143*	PF 1	6350.00	527.66	538.54		539.06	0.000488	3.22	2045.94	309.74	0.33
Reach 1	24	PF 1	6350.00	527.66	538.25		539.02	0.000765	3.91	1725.61	289.87	0.41
Reach 1	23	PF 1	6350.00	527.26	537.78		538.67	0.000973	4.18	1559.31	262.20	0.45
Reach 1	22	PF 1	6350.00	527.56	537.34		538.30	0.001068	4.36	1496.30	293.21	0.48
Reach 1	21	PF 1	6350.00	527.46	536.92		537.64	0.000902	3.78	1722.36	298.07	0.43
Reach 1	20	PF 1	6350.00	527.06	536.90		537.48	0.000674	3.39	1972.00	348.23	0.38
Reach 1	19	PF 1	6350.00	527.16	536.89		537.28	0.000500	2.78	2286.37	301.05	0.32
Reach 1	18	PF 1	6350.00	527.06	536.67		537.16	0.000593	3.11	2066.58	290.00	0.35
Reach 1	17	PF 1	6350.00	522.76	536.72	530.62	537.05	0.000383	2.57	2473.28	299.26	0.29

Fig- 13: Profile output table, modified geometry

Reach 1	16.5		Inl Struct									
Reach 1	16	PF 1	6350.00	522.76	536.37		536.63	0.000240	2.27	2795.84	283.00	0.23
Reach 1	15	PF 1	6350.00	522.46	535.94		536.53	0.000605	3.40	1868.70	207.69	0.36
Reach 1	14	PF 1	6350.00	522.56	535.72		536.39	0.000693	3.63	1788.64	228.19	0.39
Reach 1	13	PF 1	6350.00	522.06	535.60		536.25	0.000625	3.57	1788.21	194.27	0.37
Reach 1	12	PF 1	6350.00	523.06	534.46		535.69	0.001854	4.92	1291.31	190.32	0.60
Reach 1	11	PF 1	6350.00	523.26	534.89		535.28	0.000433	2.75	2305.53	273.25	0.30
Reach 1	10	PF 1	6350.00	522.46	534.59		535.05	0.000473	2.98	2129.39	238.45	0.32
Reach 1	9	PF 1	6350.00	521.76	534.48		534.73	0.000291	2.25	2910.50	375.78	0.25
Reach 1	8	PF 1	6350.00	521.76	533.84		534.60	0.000690	3.90	1866.88	275.29	0.39
Reach 1	7	PF 1	6350.00	521.36	534.00		534.39	0.000376	2.75	2415.85	327.01	0.29
Reach 1	6	PF 1	6350.00	522.76	532.97		534.17	0.001593	4.89	1384.39	212.45	0.57
Reach 1	5	PF 1	6350.00	522.56	532.67		533.39	0.001029	3.75	1691.94	242.97	0.45
Reach 1	4	PF 1	6350.00	521.26	532.82		533.01	0.000243	2.18	4031.79	482.32	0.23
Reach 1	3	PF 1	6350.00	523.06	532.15		532.73	0.000806	3.56	2280.46	394.79	0.41
Reach 1	2.8571*	PF 1	6350.00	522.87	532.22		532.67	0.000819	3.12	2428.52	389.45	0.35
Reach 1	2.7143*	PF 1	6350.00	522.69	532.26		532.62	0.000785	2.77	2585.34	384.11	0.30
Reach 1	2.5714*	PF 1	6350.00	522.50	532.28		532.58	0.000776	2.49	2758.14	379.07	0.27
Reach 1	2.4286*	PF 1	6350.00	522.32	532.29		532.54	0.000736	2.25	2945.24	369.70	0.24
Reach 1	2.2857*	PF 1	6350.00	522.13	532.30		532.51	0.000723	2.06	3146.67	360.76	0.21
Reach 1	2.1429*	PF 1	6350.00	521.95	532.30		532.48	0.000695	1.90	3362.19	352.32	0.19
Reach 1	2	PF 1	6350.00	521.76	532.31		532.47	0.000139	1.77	3597.35	344.52	0.17
Reach 1	1	PF 1	6350.00	521.76	532.24	525.07	532.40	0.000140	1.77	3755.34	454.85	0.18

Fig-14: Profile output table, modified geometry

8.4 Results summery

Table-1: Design details

Sr. no.	Specification	Details	Remarks
1.	Most upstream point on river geometry along length	(CS 26) 16°52'35.15"N, 74°33'5.42"E	
2.	Most downstream point on river geometry along length	(CS 1) 16°50'10.89"N, 74°32'38.43"E	
3.	Length of enlarged sections	200 m each	
4.	Width of enlargement	100 m each from river banks both sides	Banks are decided in the software
5.	Length of undisturbed portion	7500 m / 7.5 Km	Throat area
6.	Area of land required	80000 m² / 20 Acre	For one set
7.	Volume of earthwork excavation	264203 +177440 + 146650+168000=756294 m³	For one set

9. PRACTICAL CONSTRAINTS

The land alongside Krishna river is required for the widening. So, there is agricultural land and built area in the city and near city available along both sides of river. One thing is taken care about while deciding the position of enlargement is that the land of enlargement has no built area. So, the only agricultural land is to be acquired.

10. REVENUE GENERATION

The enlarged area can be used for developing the water sports activities, boating centre or water zoo. The development of these types of tourist places will provide employment for people and develop the surrounding area.

11. CONCLUSIONS

The results of the flood analysis and implementation of the research idea are as per the expectation and satisfactory. The output tables and cross sections obtained after analysis are tabulated and studied. After, observing and analysing the results the final conclusions are decided.

Following conclusions are drawn from the results obtained after performing flood analysis using HEC-RAS to design the research idea-

- An unprecedented & unexpected extremely heavy rainfall (+200 mm) per day continuously for 6-7 days over Western Maharashtra within a span of 20 days duration (26th July to 15th of August, 2019) caused flood inundation in Kolhapur and Sangli.
- By analysing the concept specified in this research, there is reduction in the depth of water up to 8.01 meters in the Krishna river.
- The depth of water is reduced from 544.57 m (which is maximum flood level observed during 2019 floods) to 537.73 m (which is alert level of Krishna river).
- The velocity of the water in the modified section has increased by about 2.5 m/s which ensures speedy passage of flow in the section without increasing the depth of flow.
- The project seems to be feasible financially having the Benefit / cost ratio of about 2.5 which will compensate the damage caused by floods in future.
- The floods with intensity similar to the year 2019 can be controlled by this research idea.

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13. BIOGRAPHIES

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