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Mapping River Inundation – A Case Study on River Pennar from Penna Ahobilam Balancing Reservoir (PABR) To Mid Pennar Reservoir (MPR)

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ABSTRACT : Anantapur district is situated in semi arid region of Andhra Pradesh, India. Rainfall is scanty, erratic and unpredictable in this region. In most of the years, there is scarcity of water due to scanty rain fall, and at times, there are flash floods due to sudden excess rainfall. Effects of excess and insufficient rainfalls are floods and droughts respectively. Due to the experience of many droughts in succession, people in this region are not able to imagine the floods and are not able to care the ill effects of floods. With this, people are not hesitating to develop agriculture, Industries and habitations on flanks nearby the rivers. But there are some instances of heavy floods though rare occurrences. Such rare floods may result inundation which may cause damages to property, casualties including livestock etc. To avoid this, it is necessary to have some awareness regarding the extent of inundation due to floods so that, the encroachments on the flanks of rivers can be minimised and in turn the ill effects can be reduced. Here an attempt has been made to assess the Inundation along the flanks of the River Pennar from Penna Ahobilam Balancing Reservoir (PABR) to Mid Pennar Reservoir (MPR) in Anantapur district, Andhra Pradesh state, India. From the mapped inundation, certain patches of cultivable lands which may get submerged at MFL condition along the river Pennar have been identified.

KEY WORDS : Maximum Flood Level, Inundation, Manings equation, Google earth image, Encroachments, Habitations, Floods, Droughts. Topo sheets.

Abbreviations : Catchment Area (CA), Maximum Flood Discharge (MFD), Maximum Flood Level (MFL), Longitudinal section (LS), Cross section (CS), Penna Ahobilam Balancing Reservoir (PABR), Mid Pennar Reservoir (MPR), Cubic feet per second (Cusecs), Cubic metres per second (Cumecs).

I. INTRODUCTION

Inundation is defined as 'Rising and spreading of water over grounds'. Such spreading of flood water over flanks of river is termed as 'Flood Inundation'. Rainfall in Anantapur district is erratic and unpredictable. Due to this, some part of the district is receiving insufficient rainfall and some part, normal to excess rain fall. The result of insufficient rainfall is 'Drought' and sudden excess rainfall is flood. In this region, occurrence of drought is common where as flash floods are rare. Hence, people are almost tuned to experience the droughts and are not in position to imagine ill effects of floods. Due to this, there are many encroachments on the flanks of rivers for agriculture, habitations, Industries etc. If a sudden flood occurs it may result in casualties of human lives, livestock and huge loss of property. To minimise such ill effects, it is necessary to have proper awareness about the spreading of water over flanks of the rivers (Inundation) during maximum flood condition. Shuhua Qi et.al modeled the extent of inundation around Poyang Lake, China using, 13 Landsat images and two digital elevation models (DEMs). Satellite-based remote sensing images have been used to map the extent of flood inundation since the early 1970s (Deutsch et al., 1973; Rango and Solomonson, 1974). In order to assess the inundation along the flanks of the River Pennar from Penna Ahobilam Balancing Reservoir (PABR) to Mid Pennar Reservoir (MPR) in Anantapur district maximum Flood Levels (MFL)

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Vol. 3, Issue 12, December 2014

have been computed using 'Manings equation' considering various cross sections along the river. Based on the MFLs, probable inundation has been mapped.

II. STUDY AREA

Penna Ahobilam Balancing Reservoir (PABR) is situated near Korrakodu village, Kudaeru Mandal, Anantapur district, Andhra Pradesh, India. Study area is situated in between 77° 17' 52" East longitude, 14° 47' 29" North latitude and 77° 21' 38" East longitude, 14° 51' 57" North latitude. River Pennar has its origination near Chikkabalapur in Karnataka state. Catchment area at PABR as computed from the topo sheets is 6650 Sq. km. Reach from PABR to MPR which is about 12 km along river Pennar, has been selected for the present study. An Index Map showing the study area is given in figure 1.

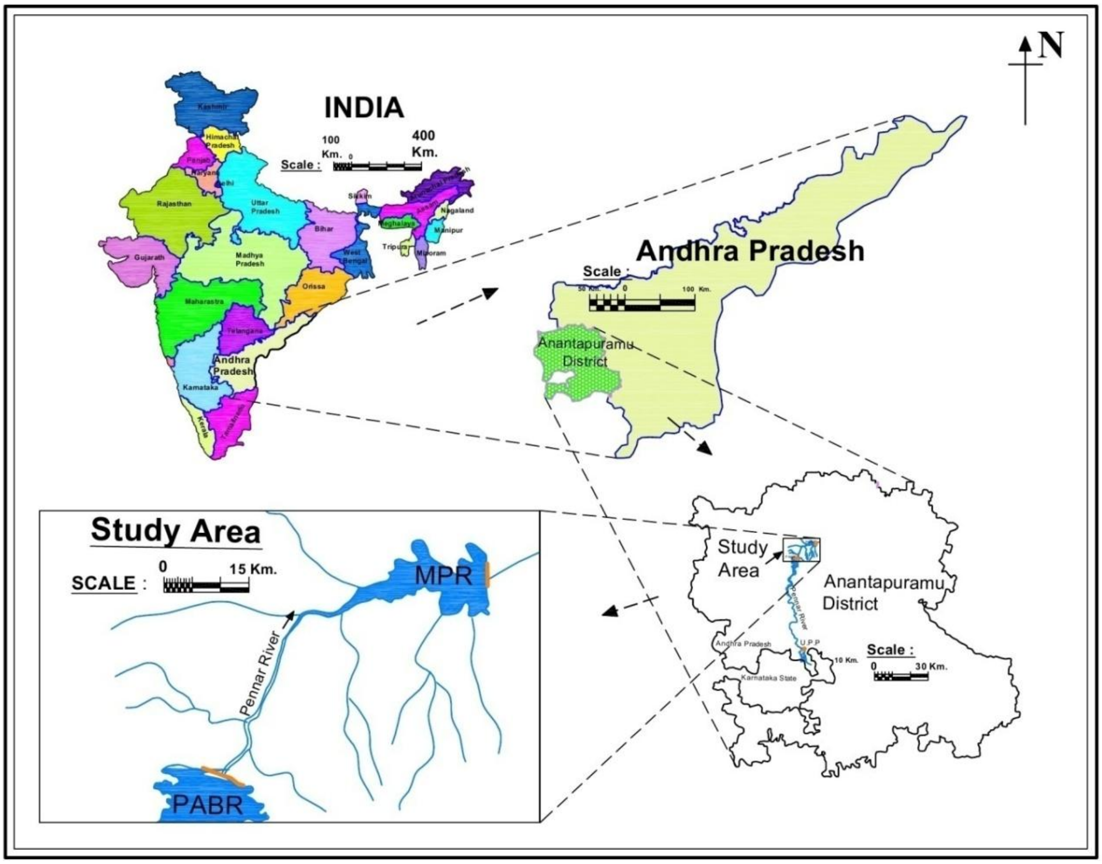

Fig 1 Index Map showing the study area

III. DATA

Following data is required for the present study

(i) Topo sheets with numbers 57E, 57F and 57G of scale 1:2,50,000 have been used for computation of catchment area.

(ii) Levels along the longitudinal section of river Pennar at every 1 km interval have been extracted using 'Google earth'.

(iii) Based on the terrain, cross section levels at 30 m intervals for every cross section have been extracted from the 'Google earth'.

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Vol. 3, Issue 12, December 2014

IV. METHODOLOGY

Taking levels on field using conventional methods, is time consuming and a difficult task. Hence, Google earth has been utilized for extracting required levels. Extracted levels from Google earth have been used for computation of MFL at every cross section. Catchment area at PABR as per the topo sheets is 6650 Sq. km. A Map showing the entire catchment area upto PABR is shown in figure 2.

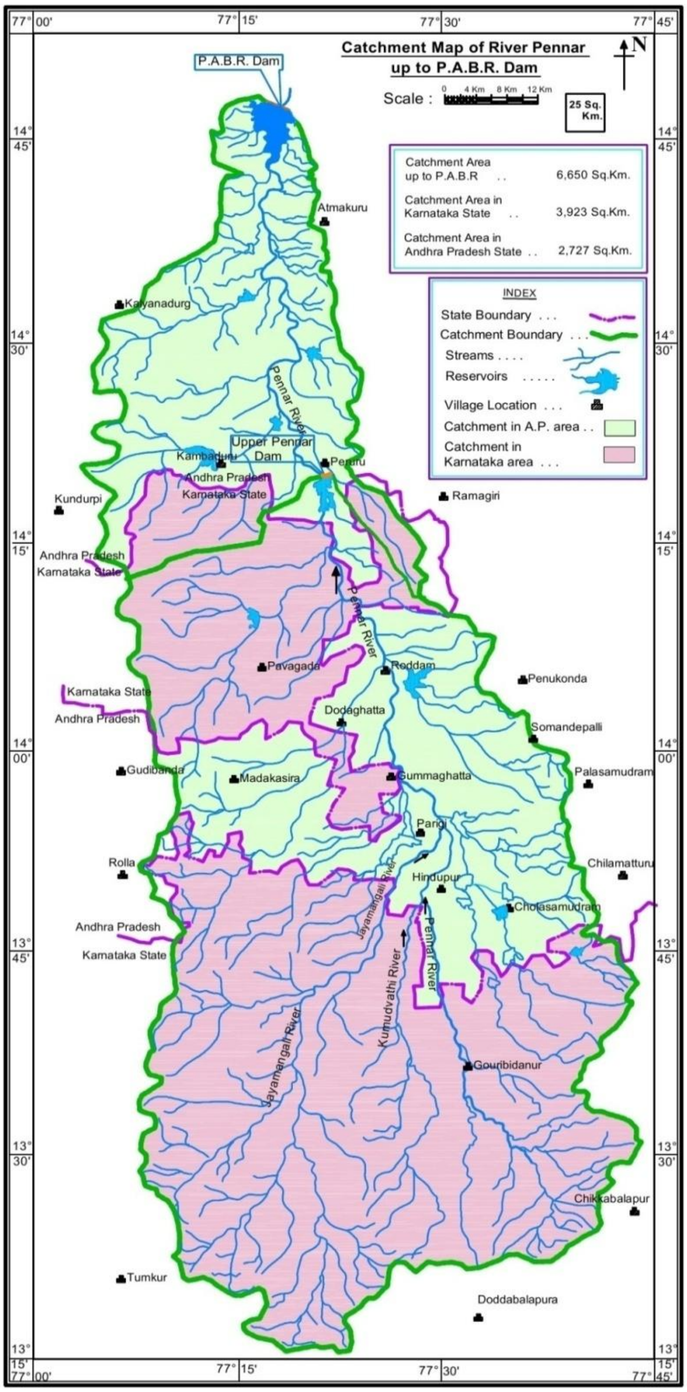

Fig 2 Catchment area Map

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(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Procedure followed for computation of MFL at respective cross sections of river Pennar is as follows.

(i) Computation of Maximum Flood Discharge (MFD)

MFD at PABR has been computed using Dicken's formula (Eq.1).

$Q = CM^{3/4}$ . . . (Eq. 1)

Where, Q = Discharge in Cumecs

C = Constant = 12.5

M = Catchment Area in Sq. km

By substituting the known values, MFD obtained is 9205.05 Cumecs. With this discharge, MFL at every cross section has been computed (Case–I). But, the discharge obtained from the Irrigation department (ie. TBP. HLC. Circle, Anantapur) is 4595.78 Cumecs. MFL at every cross section has been computed by considering this discharge also (Case-II). Discharge from intermittent streams has also been considered where ever the streams are joining the river. Map showing the intermittent streams joining the river is given in figure 3.

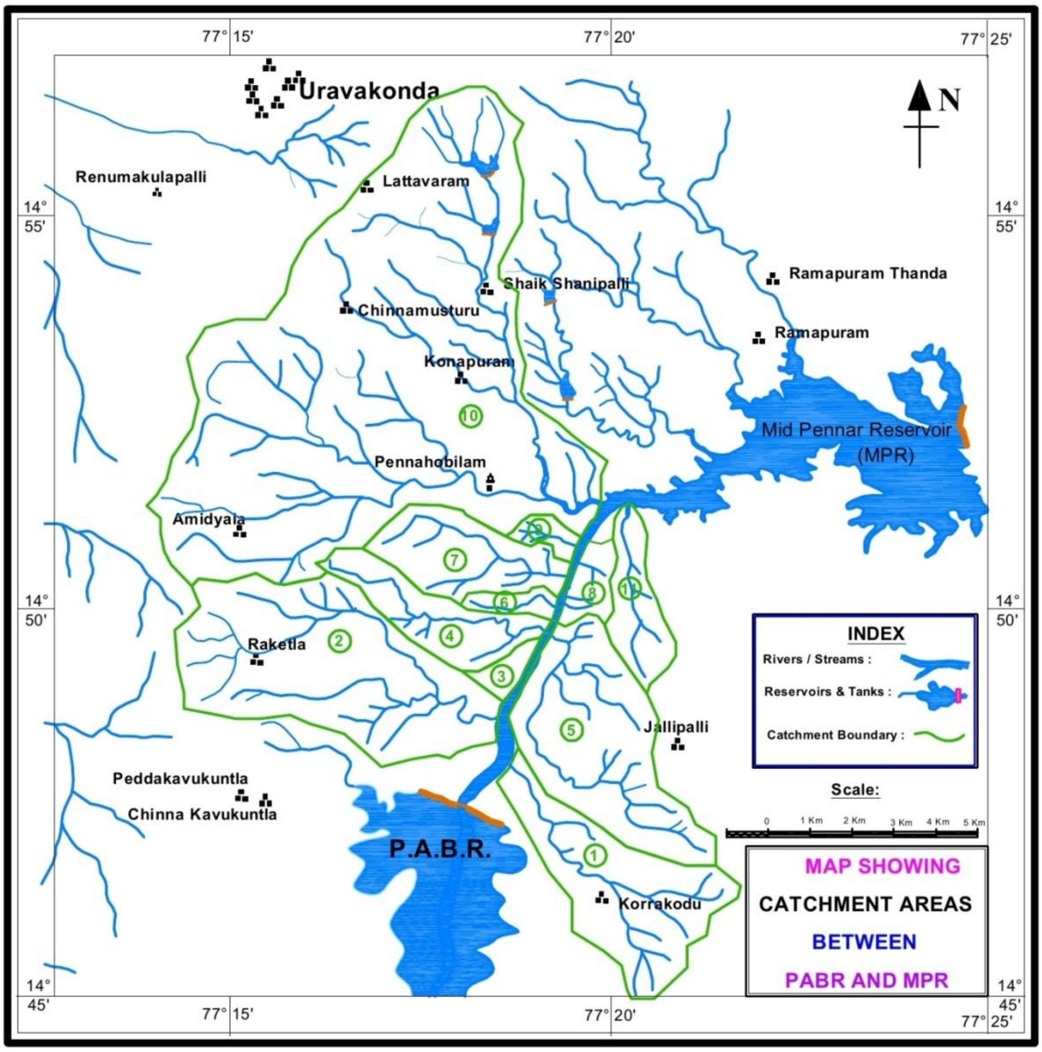

Fig. 3 Intermittent streams joining the river

Details of Catchment area and discharge at each Cross section are presented in table 1.

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Table 1. Details of Catchment area and discharge at each Cross section

Sl. No	Chainage on D/s of PABR	Description	Catchment Area (C.A) in Sq. Km	Case-I		Case-II	
				Computed Discharge in Cumecs	Cumulative Discharge in Cumecs	Computed Discharge in Cumecs	Cumulative Discharge in Cumecs
At PABR		Upto PABR Dam	6650.00	9205.05	9205.05	4595.78	4595.78
1	1.67 Km	Right side streams	12.58	83.50	9288.55	83.50	4679.28
2	2.77 Km	Left side streams	22.35	128.49	9417.04	128.49	4807.77
3	3.99 Km	Left side streams	1.04	12.87	9429.91	12.87	4820.64
4	4.98 Km	Right side stream	5.99	47.86	9477.77	47.86	4868.50
5	4.99 Km	Left side stream	14.86	94.61	9572.38	94.61	4963.11
6	5.60 Km	Left side stream	1.13	13.70	9586.08	13.70	4976.81
7	6.43 Km	Left side stream	6.91	53.27	9639.35	53.27	5030.08
8	6.75 Km	Right side stream	1.84	19.75	9659.10	19.75	5049.83
9	7.16 Km	Left side stream	1.04	12.87	9671.97	12.87	5062.70
10	8.37 Km	Left side stream near MPR Fore shore	70.43	303.90	9975.87	303.90	5366.60
11	8.98 Km	Right side stream near MPR Fore shore	4.06	35.75	10011.62	35.75	5402.35

(ii) Extraction of Levels for Longitudinal and Cross sections of river Pennar

For computation of MFL at a cross section, levels along and across the river are required. These levels have been extracted from the 'Google earth' (a computer application works with internet). For extracting levels, a line along and center of the river has been marked on the 'Google earth' image. Chainages at intervals of 1 km have been indicated on the same image. At every chainage, perpendicular lines have been marked, so as to extract the cross section levels. An image showing the location of PABR, Longitudinal and Cross sections of river Pennar along the river course upto foreshore of MPR as extracted from the 'Google earth' is presented in figure 4.

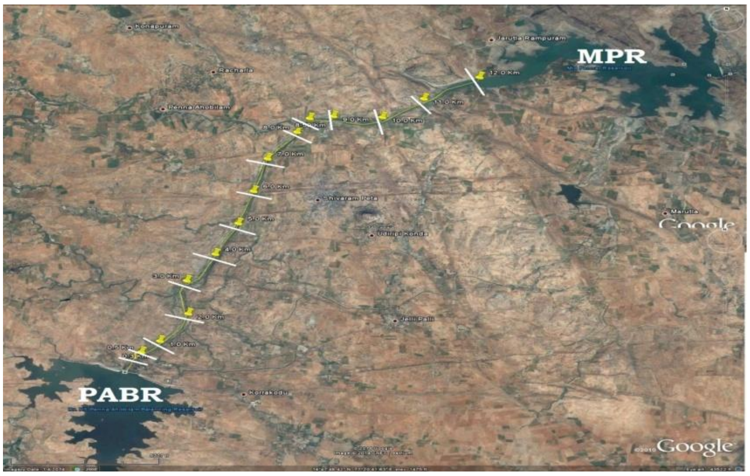

Fig 4. Arial view showing the Cross sections along the river course of Pennar

With the help of curser, points of cross section chainages were located and the elevations indicated at the respective locations have been noted down. The intervals of cross section levels were selected as 30 m to 60 m, depending upon the slope of the terrain on either flanks of the river. The lowest level in every Cross section has been identified and considered for plotting Longitudinal section of the river. Accordingly reach wise fall of the river bed has been computed. Levels along the cross sections of river were plotted to view the profile of the cross section of the river course. A typical cross section of the river Pennar is given in figure 5.

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Vol. 3, Issue 12, December 2014

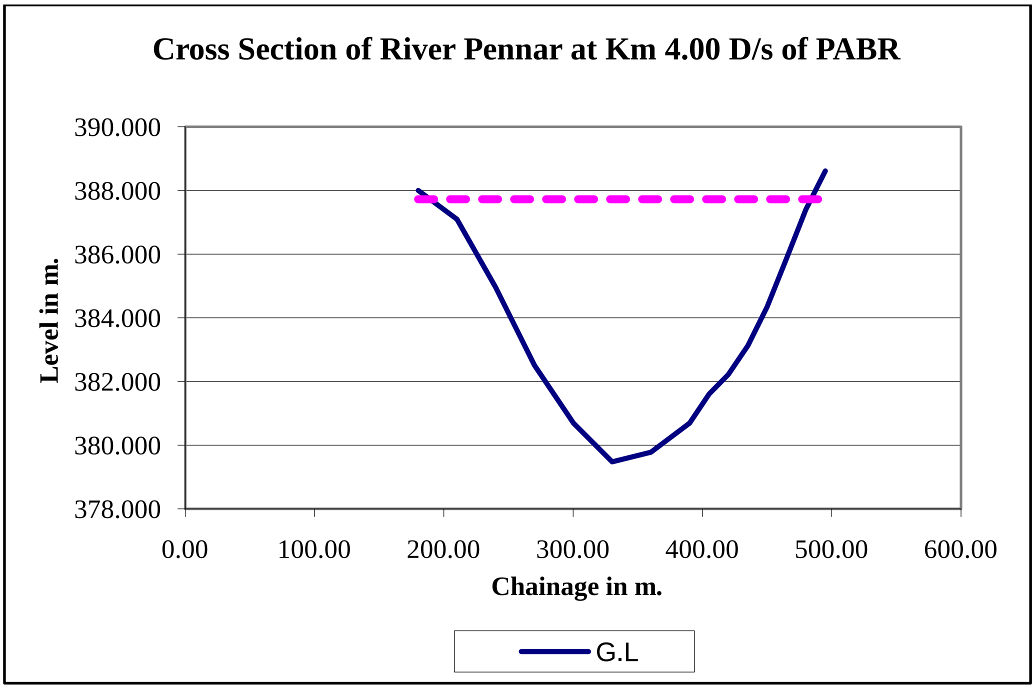

Fig. 5. Typical Cross section of river Pennar (at 4 Km downstream of PABR)

(iii) Computation of Maximum Flood Level (MFL) at each cross section a

(iv) cross river Pennar

MFL at each cross section is computed using 'Mannings formula' by adopting the following procedure.

After plotting the levels at suitable intervals along the cross section of the river, approximate level of MFL has been assumed. With the assumed MFL, ordinate distances upto ground level at each interval points of the cross section have been calculated. Taking mean of successive ordinates and multiplying with the horizontal distance between them, area of each segment of cross section has been obtained. Sum of all these segment areas is the area of flow 'A'. Using 'Pythagoras' rule, sloped distance along the ground of the cross section has been computed. Adding all such sloped distances, the Wetted perimeter 'P' has been obtained. A Sample calculations of MFL for cross section at 2.00 km downstream of PABR has been presented in table 2.

Table 2. Sample calculations of Maximum Flood Level (MFL)

MFL Calculations for CS at 2.00 Km Downstream of PABR (For Case-I)									
MFD at the previous section =			9205.05	Cumecs					
Discharge from Right at 1.67 km =			83.50	Cumecs					
Total Maximum Flood discharge =			9288.55	Cumecs	MFL considered : 399.60 m				
Ch. in m	M.F.L considered in m.	Ground Level in m.	Bed Level considered in m.	Reach Distance in m.	Actual Distance in m.	Depth in m.	Average Depth in m.	Area in Sq. m. 'A'	Wetted perimeter 'P'
330 Left	399.600	402.64	399.600			0			
				30	0.098		0.005	0.0	0.099
300 Left	399.600	399.59	399.590			0.01			
				30	30		0.77	23.1	30.038
270 Left	399.600	398.07	398.070			1.53			
				30	30		2.14	64.2	30.025
240 Left	399.600	396.85	396.850			2.75			
				30	30		2.905	87.2	30.002
210 Left	399.600	396.54	396.540			3.06			

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International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

				30	30		3.21	96.3	30.001
180 Left	399.600	396.24	396.240			3.36			
				30	30		3.36	100.8	30
150 Left	399.600	396.24	396.240			3.36			
				30	30		3.815	114.5	30.014
120 Left	399.600	395.33	395.330			4.27			
				30	30		4.88	146.4	30.025
90 Left	399.600	394.11	394.110			5.49			
				30	30		5.49	164.7	30
60 Left	399.600	394.11	394.110			5.49			
				30	30		5.185	155.6	30.006
30 Left	399.600	394.72	394.720			4.88			
				30	30		4.73	141.9	30.001
0 Center	399.600	395.02	395.020			4.58			
				30	30		4.275	128.3	30.006
30 Right	399.600	395.63	395.630			3.97			
				30	30		3.665	110.0	30.006
60 Right	399.600	396.24	396.240			3.36			
				15	15		2.905	43.6	15.028
75 Right	399.600	397.15	397.150			2.45			
				15	15		1.99	29.9	15.028
90 Right	399.600	398.07	398.070			1.53			
				15	15		0.92	13.8	15.05
105 Right	399.600	399.29	399.290			0.31			
				15	3.811		0.155	0.6	3.824
120 Right	399.600	400.51	399.600			0			
				Total :	408.909			1420.9	409.153

Area 'A' = 1420.90 Sq.m
Wetted Perimeter 'P' = 409.153 m
Hydraulic mean depth 'R' = A/P = 3.473 m
Slope of the river has been computed based on the bed levels at upstream and downstream cross sections.
Bed levels at 1000 m Upstream and at this cross section are 399.90 m and 394.11 m respectively.
Bed fall in upstream reach = 1000 ÷ (399.90-394.11) = 173 m (1 in 173 m)
Similarly, Bed levels at the cross section and at 1000 m Downstream are 394.11 m and 384.05 m respectively.
Bed fall in upstream reach = 1000 ÷ (394.11-384.05) = 99 m (1 in 99 m)
Overall Bed fall at the cross section, 's'= (173+99) ÷ 2 = 136 (1 in 136 m)
Velocity 'V' has been calculated using Maning's equation (Eq.2)

$$V = {}^{1}/_{n} \times R^{2/3} \times s^{1/2} \quad \text{. . . (Eq.2)}$$

Where, n = Co-efficient of rugosity (0.030)
R = Hydraulic mean depth =A÷P
s = surface fall of flow (assuming bed fall is parallel to the surface fall)
V = Velocity of flow in m/sec

By substitution, Velocity 'V'= 6.550 m/ sec.
Discharge 'Q' has been computed using equation Eq.3.

Discharge 'Q' = A x V . . . (Eq.3)
= 9306.90 Cumecs against 9288.55 Cumecs.

Since, computed discharge is nearer to considered discharge, assumed MFL may be applicable to the cross section. If not, the calculations have to be repeated by changing the assumed MFL till the computed discharge is nearer to considered discharge. Similarly MFL calculations have been carried out for all the cross sections (at 1 km interval) from PABR to MPR. Details of MFLs at various intervals along the river are presented in table 3.

ISSN: 2319-8753

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 12, December 2014

Table 3. Details of MFLs at various intervals along the river from PABR to MPR

S. No.	Chainage in Km.	Bed Level of the River Pennar in m.	Computed MFL in m for Case-I	Computed MFL in m for Case-II
1	0.30	403.560	411.135	409.205
2	0.50	401.420	409.025	407.100
3	1.00	399.900	406.080	404.400
4	2.00	394.110	399.600	398.260
5	3.00	384.050	392.260	390.260
6	4.00	379.480	387.730	385.530
7	5.00	374.600	381.425	379.850
8	6.00	371.860	380.050	377.995
10	7.00	369.420	376.190	374.340
11	8.00	366.980	374.505	374.780
12	8.50	365.460	373.845	372.610
13	9.00	364.540	372.620	371.605
14	10.00	362.710	370.695	370.655
15	11.00	358.750	367.960	368.850
16	12.00	357.230	364.625	366.675

River bed levels, MFLs for case-I and case-II along the river are shown in figure 6.

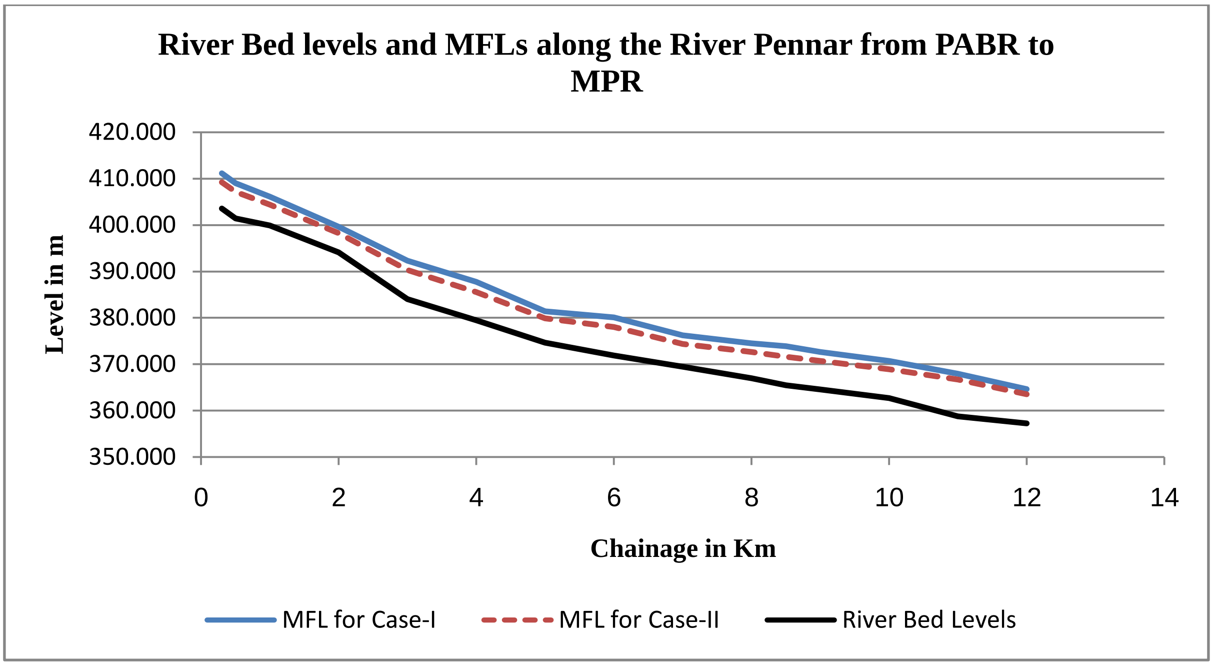

Fig 6. River bed levels, MFLs for case-I and case-II along the river

Using the above MFLs, probable width of inundation on either flanks of the river Pennar has been marked by tracing the levels with the help of curser on 'Google earth' image. The probable inundation area is shown in figure 7.

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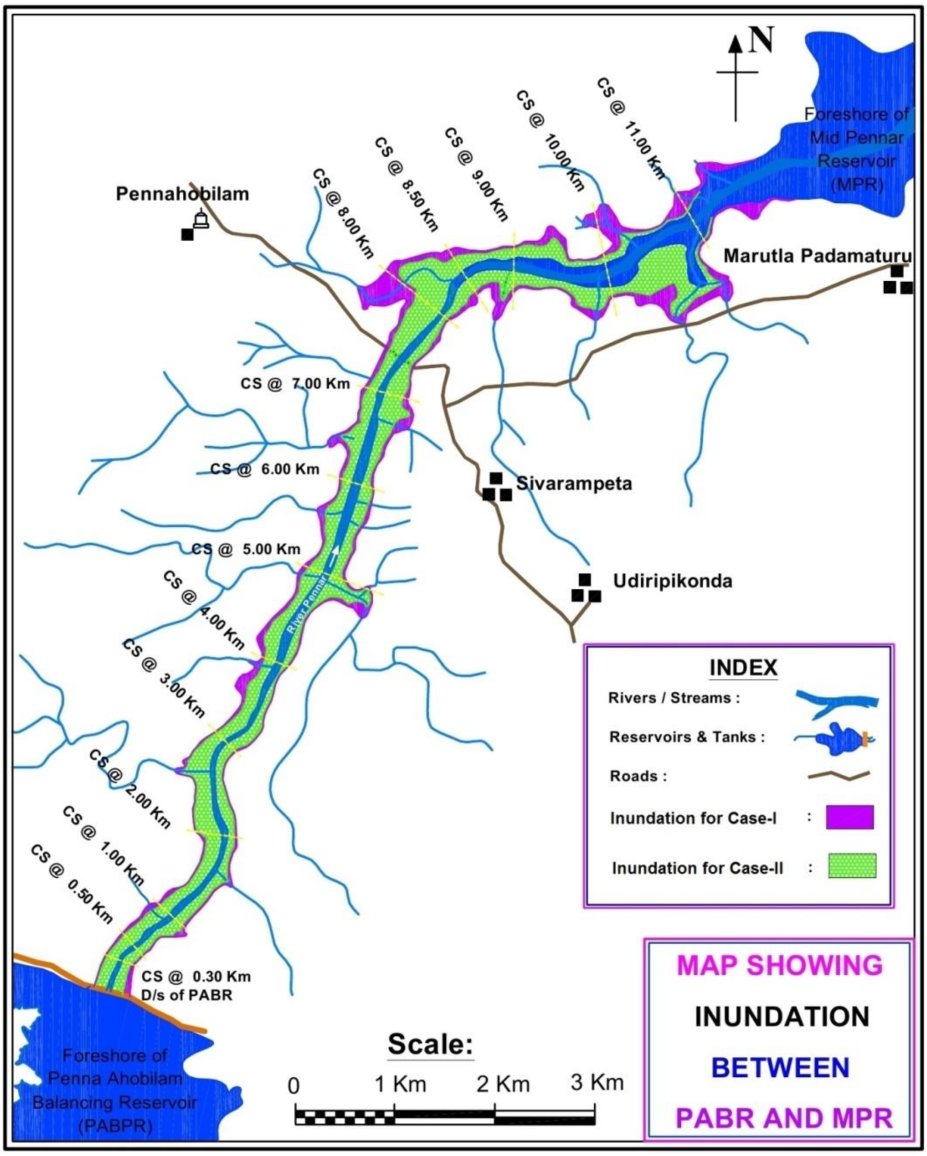

Fig 7. Map showing probable inundation from PABR to MPR

V. RESULTS

It has been observed that there are rising flanks on either side of the river and hence, width of inundation is not much. There are no habitations on the flaks of the river except some patches of cultivable lands depending on lean flows. Based on the inundation boundaries, the patches which may get affected at Maximum Flood condition have been identified and are presented in figure 8.

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International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 3, Issue 12, December 2014

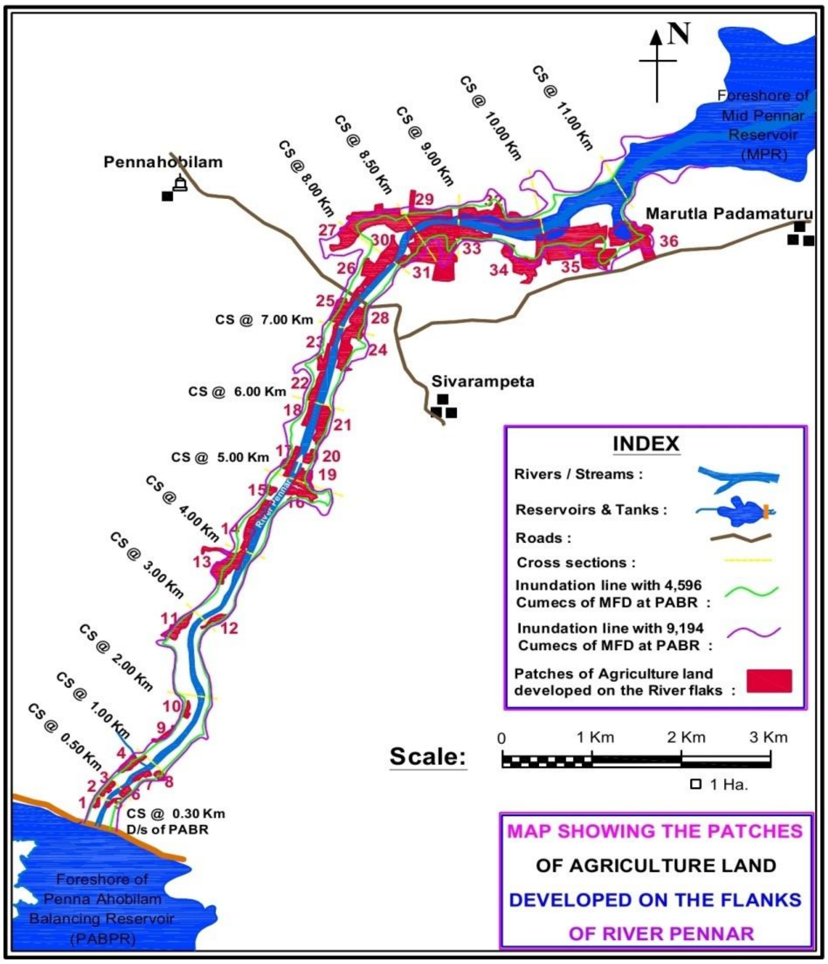

Fig 8. Patches of cultivable lands affected at MFL condition

Extent of patches affected due to inundation have been shown in table 4.

Table 4. Extent of patches affected due to inundation

S. No.	Description	No. of patches	Total Area in Ha.	Area affected due to inundation in Ha.	
				Case-I	Case-II
1	Left flank	20	82.74	75.96	58.11
2	Right flank	16	107.8	83.49	57.41
	Total :	36	190.54	159.45	115.52

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