CHAPTER 8

RESULTS, CONCLUSIONS AND RECOMMENDATIONS

8 RESULTS, CONCLUSIONS AND RECOMMENDATIONS

In this chapter results, conclusions and recommendations from ARIMA mathematical model study, graphical techniques, revised Ukai reservoir operation, FBRO, flood risk and flood hazard map listed as shown below.

8.1 Results of ARIMA Mathematical Model

ARIMA 1 – D Mathematical Model

Few solutions to minimize Tapi River flood impacts to save Surat City from flood impacts by using ARIMA 1-D Mathematical Model are listed below.

Tapi River flood water surface profile predicted by using ARIMA model. This model gives flood water depth information at various locations across Surat City. Moreover, it is also helpful for different flood frequency operation conditions. Detailed analysis of model results and comparing with observed results. Critical and detail analysis of impact of flood in the various downstream areas of Ukai Dam are also listed below.

As per discussion the water levels predicted along Tapi river for different discharges from 5669 m^3/sec (2 Lac cfs) to 45351 m^3/sec (16 lac cfs) under existing conditions (with Singanpure and Kakrapar weir and existing embankment on bath banks on u/s and d/s of Singanpur weir) for the reach from Tapi river mouth at Hazira to the Ukai Dam are enclosed Table No 4.1 and 4.2.gives the water levels and velocities along the above river reach for different discharges along with river bed and bank levels. Graph.4.1 to 4.6.shows the water level profiles for different discharges along with the river bed profile. The bank top levels are also shown along the reach. It may be mentioned that the results enclosed are with the d/s boundary condition as spring tide with HWL of 5.26 m (GTS). All the levels mentioned are with reference to GTS. The chainages given in table and in Graphs are from the d/s boundary of mathematical model located at 27.4 km d/s of Singanpure weir.

In general it could be seen that the flood water starts spilling on right bank d/s of Nehru Bridge at dischange of 8503 m^3/sec (3 Lac cfs) in the reach between Singanpure weir to Kathor Bridge the water levels will be above existing bank levels beyond 19841 m^3/sec (7 Lac cfs). In the reach from Kathore Bridge to Kakrapar weir the flood up to discharge of 28345 m^3/sec (10 Lac cfs) will be mostly contain with the high banks with some spillage with locally low bank top levels. In general on u/s of

Kakrapar weir also the water levels will be higher than the river bank levels for the discharge beyond 34013.60 m^3/sec (12 Lac cfs).

8.2 Results of Graphical Techniques

8.2.1 Gidhare Rain gauge to Ukai Dam

Catchment area from Gidhare rain gauge station to Ukai is 7500 km^2. Contribution of this area is 38 % of total inflow. The results of analysis are shown in Figure.No.5.1 and 5.2.

8.2.2 Flood Routing Studies

Results of different flood routing alternate studies are listed below.

Alternate as Discussed in Chapter - 5	Results
1 to 6	Flood routing at FRL 105.18 m (345 ft.) with restricted outflow of 11337.86 Cumec (4.0 lac Cusecs). Results indicated that MWL crosses HFL.
7 to 12	Flood routing at FRL 105.18 m (339 ft.) with restricted outflow of 11337.86 Cumec (4.0 lac Cusecs). Results indicated that MWL crosses HFL.
13	To maintain MWL at RL 107.01 m (351 ft.) with restricted outflow of 11337.86 Cumec (4.0 lac Cusecs). Initial reservoir level will have to be kept at RL 100.76 m (330.50 ft.).
14	To maintain MWL at RL 107.01 m (351 ft.) with restricted outflow of 11337.86 Cumec (4.0 lac Cusecs). Initial reservoir level will have to be kept at RL 100.76 m (330.15 ft.).
15	MWL is to be maintained at RL 107.01 m (351.0 ft.) with restricted outflow of 11337.86 Cumec (4.0 lac Cusecs). Discharging capacity at RL 97.86 m (321 ft.) considering all gates as operative is 11564.62 Cumec (4.08 lac Cusecs). Therefore initial RL will have to be kept at RL 97.86 m (321 ft.) and the max. Res. Level reached will be 107.13 m (351.41 ft.) instead of 107.01 m (351 ft.).
16	MWL is to be maintained at RL 107.01 m (351.0 ft.) with restricted outflow of 11337.86 Cumec (4.0 lac Cusecs). Discharging capacity at RL 97.86 m (321 ft.) considering all gates as operative is 11564.62 Cumec (4.08 lac Cusecs). Therefore initial RL will have to be kept at RL 97.86 m (321 ft.) and the max. Res. Level reached will be 107.66 m (353.14 ft.) instead of 107.01 m (351 ft.).
17	MWL is to be maintained at RL 107.01 m (351.0 ft.) with restricted outflow of 11337.86 Cumec (4.0 lac Cusecs). Discharging capacity at RL 97.86 m (321 ft.) considering all gates as operative is 11564.62 Cumec (4.08 lac Cusecs). Therefore initial RL will have to

	be kept at RL. 97.86 m (321 ft.) and the max. Res. Level reached will be 108.16 m (354.78 ft.) instead of 107.01 m (351 ft.).		
18	MWL is to be maintained at RL 107.01 m (351.0 ft.) with restricted outflow of 11337.86 Cumec (4.0 lac Cusecs). Discharging capacity at RL 97.86 m (321 ft.) considering all gates as operative is 11564.62 Cumec (4.08 lac Cusecs). Therefore initial RL will have to be kept at RL. 97.86 m (321 ft.) and the max. Res. Level rached will be 109.76 m (360.02 ft.) instead of 107.01 m (351 ft.).		
Alternate as Discussed in Chapter - 5	**Results**		
19	Routing policy		
20	Reservoir level (ft.)		
21	From	To	Outflow (lac Cusecs)
22	103.35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	105.48 m (346 ft.)	14172.33 Cumecs (5 Lac Cusecs)
	105.48 m (346 ft.)	105.79 m (347 ft.)	17006.80 Cumecs (6 Lac Cusecs)
	105.79 m (347 ft.)	106.09 m (348 ft.)	19841.26 Cumecs (7 Lac Cusecs)
	106.09 m (348 ft.)	106.40 m (349 ft.)	24092.97 Cumecs (8.5 Lac Cusecs)
	Above	106.40 m (349 ft.)	Inflow = Outflow
23	Routing policy		
24	Reservoir level (ft.)		
25	From	To	Outflow (lac Cusecs)
26	103.65 m (340 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	105.48 m (346 ft.)	14172.33 Cumecs (5 Lac Cusecs)
	105.48 m (346 ft.)	105.79 m (347 ft.)	17006.80 Cumecs (6 Lac Cusecs)
	105.79 m (347 ft.)	106.09 m (348 ft.)	19841.26 Cumecs (7 Lac Cusecs)
	106.09 m (348 ft.)	106.40 m (349 ft.)	24092.97 Cumecs (8.5 Lac Cusecs)

	Above	106.40 m (349 ft.)	Inflow = Outflow	
27	Routing policy			
	From	To	Outflow (lac Cusecs)	
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)	
	105.18 m (345 ft.)	Onward	14172.33 Cumecs (5 Lac Cusecs)	
Alternate as Discussed in Chapter - 5	**Results**			
28	From	To	Outflow (lac Cusecs)	
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)	
	105.18 m (345 ft.)	Onward	17006.80 Cumecs (6 Lac Cusecs)	
29	From	To	Outflow (lac Cusecs)	
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)	
	105.18 m (345 ft.)	Onward	19841.26 Cumecs (7 Lac Cusecs)	
30	From	To	Outflow (lac Cusecs)	
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)	
	105.18 m (345 ft.)	Onward	24092.97 Cumecs (8.5 Lac Cusecs)	
31	Routing policy			
	From	To	Outflow (lac Cusecs)	
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)	
	105.18 m (345 ft.)	Onward	14172.33 Cumecs (5 Lac Cusecs)	
32	From	To	Outflow (lac Cusecs)	
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)	
	105.18 m (345 ft.)	Onward	17006.80 Cumecs (6 Lac Cusecs)	
33	From	To	Outflow (lac Cusecs)	

	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	19841.26 Cumecs (7 Lac Cusecs)
34	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	24092.97 Cumecs (8.5 Lac Cusecs)
Alternate as Discussed in Chapter - 5	**Results**		
35	Routing policy		
	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	14172.33 Cumecs (5 Lac Cusecs)
36	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	17006.80 Cumecs (6 Lac Cusecs)
37	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	19841.26 Cumecs (7 Lac Cusecs)
38	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	24092.97 Cumecs (8.5 Lac Cusecs)
39	Routing policy		
	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	14172.33 Cumecs (5 Lac Cusecs)

40	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	17006.80 Cumecs (6 Lac Cusecs)
41	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	19841.26 Cumecs (7 Lac Cusecs)
Alternate as Discussed in Chapter - 5	**Results**		
42	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	24092.97 Cumecs (8.5 Lac Cusecs)
43	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	14172.33 Cumecs (5 Lac Cusecs)
44	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	17006.80 Cumecs (6 Lac Cusecs)
45	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	19841.26 Cumecs (7 Lac Cusecs)
46	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	24092.97 Cumecs (8.5 Lac Cusecs)
47	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)

	105.18 m (345 ft.)	Onward	14172.33 Cumecs (5 Lac Cusecs)
48	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	17006.80 Cumecs (6 Lac Cusecs)
Alternate as Discussed in Chapter - 5	**Results**		
49	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	19841.26 Cumecs (7 Lac Cusecs)
50	From	To	Outflow (lac Cusecs)
	103 35 m (339 ft.)	105.18 m (345 ft.)	11337.87 Cumecs (4 Lac Cusecs)
	105.18 m (345 ft.)	Onward	24092.97 Cumecs (8.5 Lac Cusecs)
51	(a) Upto		
52	105.48 m (346 ft.)		14172.33 Cumecs (5 Lac Cusecs)
53	105.48 m (346 ft.) – 105.79 m (347 ft.)		17006.80 Cumecs (6 Lac Cusecs)
54	105.79 m (347 ft.) – 106.09 m (348 ft.)		19841.26 Cumecs (7 Lac Cusecs)
55	106.09 m (348 ft.) – 106.40 m (349 ft.)		24092.97 Cumecs (8.5 Lac Cusecs)
56	106.40 m (349 ft.) – 106.70 m (350 ft.)		28344.67 Cumecs (10 lac Cusecs)
57	Above 106.70 m (350 ft.)		Inflow = Outflow
58	(b) Upto		
59	105.48 m (346 ft.)		17006.80 Cumecs (6 Lac Cusecs)
60	105.48 m (346 ft.) – 105.79 m (347 ft.)		19841.26 Cumecs (7 Lac Cusecs)
61	105.79 m (347 ft.) – 106.09 m (348 ft.)		24092.97 Cumecs (8.5 Lac Cusecs)

62	106.09 m (348 ft.) – 106.40 m (349 ft.)	28344.67 Cumecs (10 lac Cusecs)
	Above 106.40 m (349 ft.)	Inflow = Outflow
	(c) Upto 105.48 m (346 ft.)	19841.26 Cumecs (7 Lac Cusecs)
	105.48 m (346 ft.) – 105.79 m (347 ft.)	24092.97 Cumecs (8.5 Lac Cusecs)
	105.79 m (347 ft.) – 106.09 m (348 ft.)	28344.67 Cumecs (10 lac Cusecs
	Above 106.09 m (348 ft.)	Inflow = Outflow
Alternate as Discussed in Chapter - 5	**Results**	
63 to 71	1) Flood routing at 1 hr interval 2) Advance deletion of 9 hrs 3) Restrict outflow 5.0 to 8.0 lakh cusecs	
72	1) Flood routing at 1 hr interval	
73	2) Advance depletion of 9.0 hrs	
74	3) Restrict outflow 4.90 to 7.25 lakh cusecs	
75	Advance depletion of 10 hrs	
76	Flood routing at 1 hr interval	
77	Advance depletion of 12.0 hrs	
78	Restrict outflow 4.745 to 6.95 lakh cusecs	
79	Advance depletion of 9 hrs	

8.2.3 Tapi River Carrying Capacity

Result of analysis of discharge carrying capacity at different river channel sections based on hydraulic Modeling between the weir and the Arabian Sea. Surat City lies between sections RD22-LD22 to RD54-LD54 prove that the safe water carrying capacity of the Tapi River near Surat is reported to have been significantly reduced from (10 to 3.5 lacs) due to: encroachment in the flood plain areas, silting in the river-bed, and afflux caused by the Singanpore weir constructed on the river very close to the city.

8.2.4 Probability Analysis for Flood forecasting

The peak flood data used 73 years (from 1939-2012) for this research study. Peak flood will occur after nineteen years according to Hazen's method. Peak flood will occur after fourteen years according to Well Weibull's method. Peak flood will occur after eight years according to California method.

Flood Frequency at Selected Stations

The flood frequency analysis of the water level and discharge data shows that there was a likelihood of a flood hazard once in eight years till 1998, but that has increased during the recent decade to one in five years. Flood frequency analysis at Ghala discharge station for 5, 10, 15, 20 and 25-year return periods. It is estimated that discharge will exceed or equal 2834.47 Cumecs (1.0 Lac Cusecs) at every 17 years, 5668.93 Cumecs (2.0 Lac Cusecs) at every 21 years and 11337.87 Cumecs (4.0 Lac Cusecs) at every 25 years. The 25-year flood will result in several areas being under flood and river bank breaching at several locations.

8.3 Results of Revised Rule level Ukai Reservoir Gate Operation

Results of analysis from revised reservoir operation are listed in Table No.8.1 and 8.2. Calculated revised rule level compared with existing rule level and flood absorption volume 4890.1 Mm^3 are determined for Ukai multipurpose dam. Table.No.8.1 shows suggested revised rule level for flood absorption during monsoon months. Table.No.8.2 shows revised gate operation schedule of Ukai dam. Moreover, this revised operation suggests each quantity of flood releases by indicating Ukai dam radial Gate opening height and numbers save downstream people and property.

Table.8.1 Suggested Rule Level for Flood Absorption

Month	Rule Level (Year 2000) by Task Manager in m. (AC)	Suggested Revised Rule Level in m. (AB)	Difference in m. (AC-AB)	Flood absorption Volume Mm^3
JUNE	90	89.92	0.08	484.73
JULY	97.86	94.67	3.19	1145.79
AUGUST	101.52	101.10	0.42	207.85
SEPTEMBER	104.55	103.07	1.48	834.24
OCTOMBER	105.18	101.06	4.12	2217.49
			Total	**4890.1**

Table.8.2 Revised Gate operation schedule of Ukai dam

Sr. No.	Overflow in Cumecs / (Cusecs)	Gate Nos. to be opened	Total Nos. of gates to be opened	Opening of gates when RWL is 345 Feet m. (ft.)	Opening of gates when RWL is 339 Feet m. (ft.)
1	2834.47 (1.00 lac)	1 to 22	22	0.30 m. (1.00)	0.30 m. (1.00)
2	5668.93 (2.00 lac)	3 to 9,11 to 20	17	1.2 m. (4.00)	1.5 m. (5.00)
		1,2,10,21,22	5	0.6 (2.00)	1.5 m. (5.00)
3	8503.40 (3.00 lac)	3 to 9,11 to 20	17	2.1 m. (7.00)	2.7 m. (9.00)
		1,2,10,21,22	5	0.90 m (3.00)	0.90 m. (3.00)
4	12755.10 (4.50 lac)	3 to 20	18	4 m. (12.00)	4.2 m. (14.00)
		1,2,21,22	4	1.8 m. (6.00)	1.8 m. (6.00)
5	14172.33 (5.00 lac)	3 to 20	18	7.2 m. (24.00)	7.5 m. (25.00)
		1,2	2	3.9 m. (13.00)	4.5 m. (15.00)
		21,22	2	2.1 m. (7.00)	2.7 m. (9.00)

8.4 Result of Excel Program for Forecast Based Reservoir Operation (FBRO)

FBRO prepared for real time reservoir operation with help of Microsoft excel program. By writing Ukai Dam reservoir water level numerical value as an input, reservoir gate release as an output instructions are obtained for different flood conditions. Suggested operation schedule for real time shown in Table.No.8.3 for conditions: N, N1, N2, N3, N4 and N5.

Table.8.3 Suggested Operation Schedule for Real Time

Situation		Operation
No	The water level after 12 hrs not likely to exceed the rule level.	Gates not to be opened
N	The water level after 12 hrs likely to exceed the rule level	Gates not to be opened
N1	Water level after 6 hrs is not likely to exceed rule level and C<5 lac cusecs OR Water level after 6 hrs is likely to exceed rule level, forecasted inflow in 12-24 hrs is less than that in 0-12 hrs and C<5 cusecs.	The rule curve level for conservation of storage during monsoon period as mentioned in Para 9.1 may be followed and the reservoir filled up to the designated rule curve level. Once the reservoir reached the designated rule level, the gates may be opened so as to release outflow equal to average inflow, based on forecast from CWC coming regularly at 12 hrs.
N2	Water level after 6 hrs is likely to exceed rule level, forecasted inflow in 12-24 hrs is less than that in 0-12 hrs and C>5 lac cusecs.	The gates may be operated so as to release outflow computed on the basis of inflow expected in 0-6 hrs (A) or on the basis of 0-12 hrs (B), whichever is lower. The rate of outflow may be revised after 6 hrs based on the level reached and revised forecast received if any, so as not to cross the rule level.
N3	Water level after 6 hrs is likely to exceed rule level, forecasted inflow in 1224 hrs is more than that in 0-12 hrs and the trend in the river after 24 hrs is indicated as "Falling".	The gates may be operated so as to release outflow computed on the basis of inflow expected in 0-6 hrs (A), or on the basis of 0-12 hrs (B), whichever is higher. However, if the release is on the basis of previous FBRO is (A or B or D) and reservoir level is still RISING, then it should not be reduced till the reservoir level starts falling.The rate of outflow may be revised after 6 hrs, based on the level reached and revised forecast received if any, so it does not cross the rule level.

	Situation	Operation
N4	Water level after 6 hours is likely to exceed rule level, forecasted inflow in 12-24 hrs is more than that in 0-12 hrs and the trend in the river after 24 hrs is indicated as 'Rising'.	The gates may be operated so as to release outflow computed on the basis of inflow expected in 0-6 hrs (A), or on the basis of 0-12 hrs (B), or on the basis of 0-24 hrs (D), whichever is higher.The rate of outflow may be revised after 6 hrs, based on the level reached and revised forecast received if any, so as not to cross the rule level.
N5	Water level after 6 hrs is likely to exceed rule level, forecasted inflow in 12-24 hrs is less than that in 0-12 hrs and the trend in the river after 24 hrs is indicated as 'Falling'.	The gates may be operated so as to release outflow computed on the basis of inflow expected in 0-6 hrs (A), or on the basis of 0-12 hrs (B), whichever is higher. However, if the release is on the basis of previous FBRO is (A or B or D) AND reservoir level is still RISING, then it should not be reduced till the reservoir level starts falling.The rate of outflow may be revised after 6 hrs, based on the level reached and revised forecast received if any, so as not to cross the rule level.

8.5 Result of Flood Risk and Flood hazard map for whole Surat city

The result of embankment also reduces the extent of the spread from 80 sq.km of the area with SMC limit to about 40-54 Sq.km in the simulated data sets. The zone flooding data shows lesser damage in Katargam area due to construction of the embankment. However, the impact of the embankment would be lesser in the South and South west part of the city due to poorly conceived length of the protection structures. The high density of the development on the Western part of Surat and development along Hazira restricts the movement of the flood water there by resultant spread in upstream.

The depth of water in west zones area was 2 m to 4 m, which demarcated in flood hazard map. Out of 23.34 km^2 area 23.30 km^2 would be under water in West zone if river reaches to 12 m height near Nehru Bridge. South zone, South-West zone, South-East zone and Central zone are also low rise area of the city all this zone would not survive longer for flood of equal frequency as 2006. North and East zone are high rise area of the city and most of its parts are settled at higher level than 12.5 meter. Accordingly these two zones can survive against danger of flood up to some extent compare to other zone of the city. Plate.No.8.1 shows TIN (DEM) of whole Surat City. The graph of submerge area versus water level of different zone is shown in Graph.No.8.1.

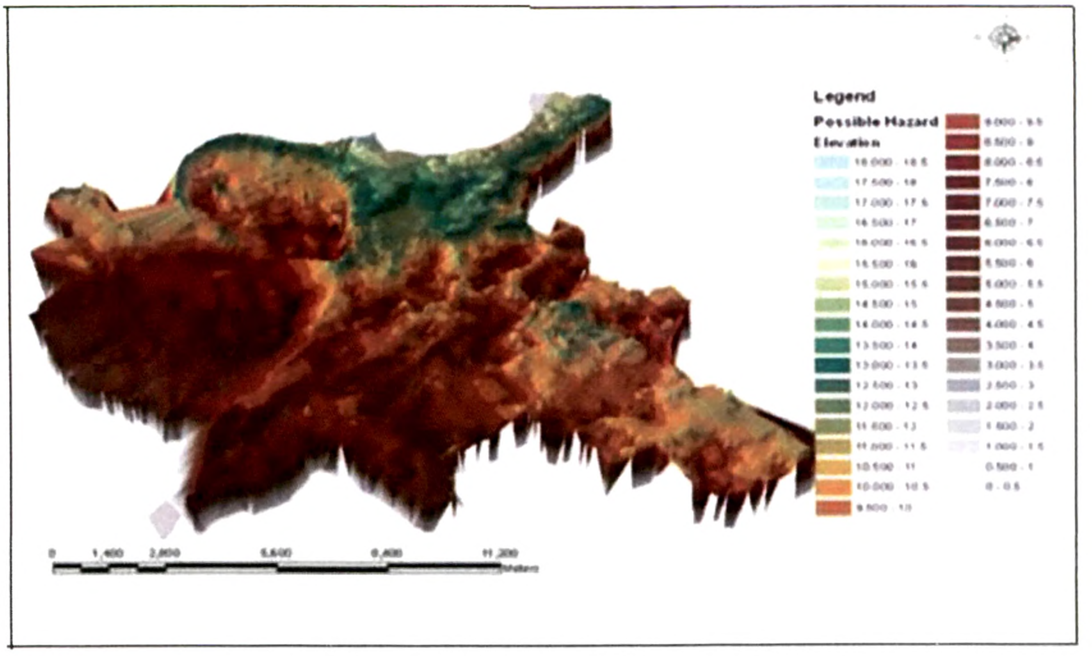
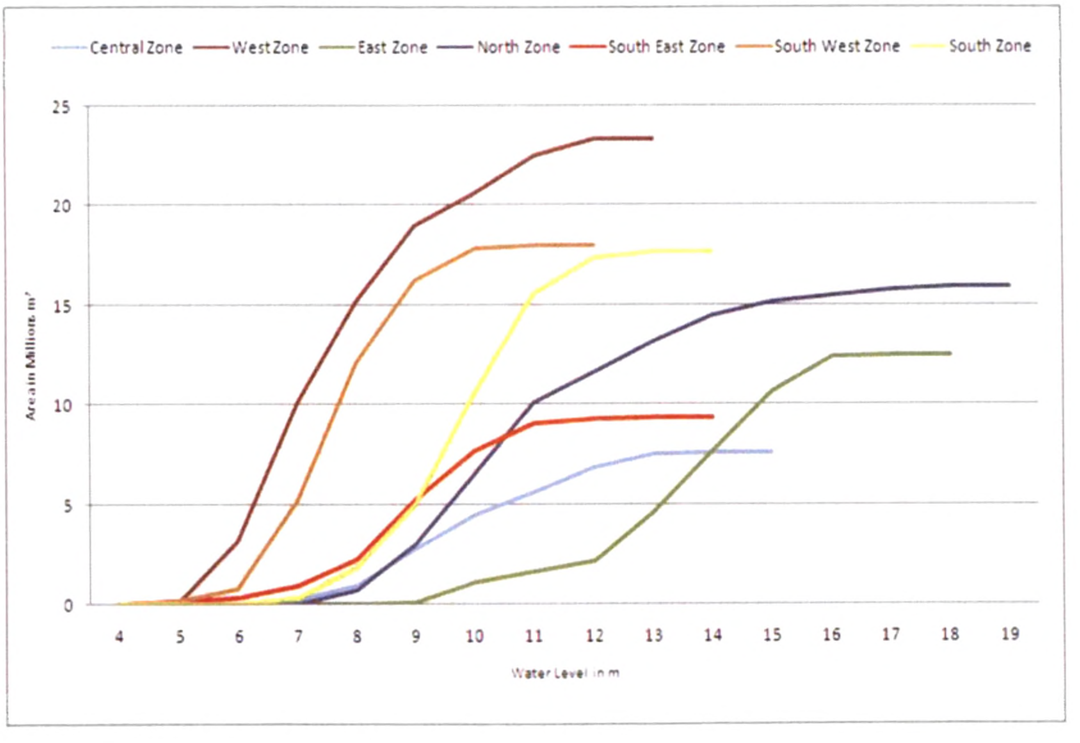


Plate.8.1 TIN (DEM) of Surat City



Graph.8.1 Different zones of Surat city submerged in water

During the monsoon of 2006 water level in the Tapi was observed 12.5 m near Nehru Bridge due to release of discharge 25768 m^3/s (9.1 Lac Cusecs), comparing observed Gauge level 12.5m and left, hand side top bank R. L. 8.34 m, about 4.16 m depth of water could spilled the left hand side zone severely. Top bank R.L. of right hand side bank is 7.59 m, so the condition would be more serious in the West zone. Taking 12.5 m observed Gauge level near Nehru Bridge during last event. Flood hazard map of the city as shown in Plate. 8.2 clearly indicate that most parts of the city would be under water by different amount. Table 8.4 shows Calculated probable submerged area in different zone for the flood of equal frequency as 2006.

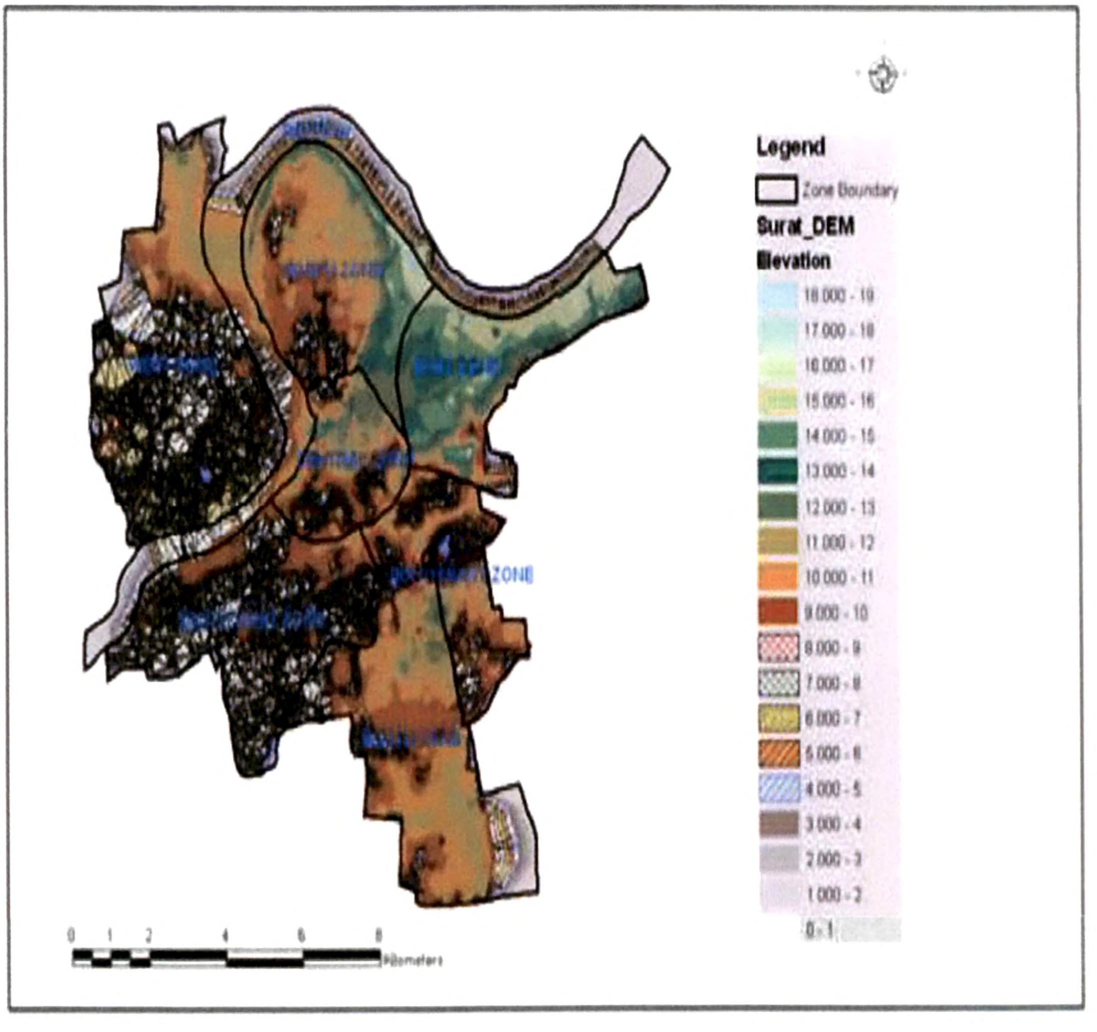


Plate.8.2 Flood hazard map of Surat city (Flood 2006)

Table.8.4 Calculated Probable Submerged Area for Different Zone for the Flood of Equal Frequency as 2006

R.L. in m.	Central Zone	West Zone	East Zone	North Zone	South Zone	South West Zone	South Zone
	Area in m^2	Area in m^2	Area in m^2	Area in m^2	Area in m^2	Area in m^2	Area in m^2
1	0	16459.8931	0	0	0	0	0
2	0	82685.7784	0	0	125204.4521	144157.84	0
3	35505.7137	3148877.841	0	0	309496.1909	733934.2222	10170.2584
4	218075.0861	10087669.98	0	23947.3616	932935.9305	5177583.488	340280.2013
5	909142.2165	15174263.9	4975.9088	724519.5648	2179847.015	12081565.46	1829098.736
6	2770571.703	19010774.62	69214.0399	3012504.379	5216316.875	16197165.4	4961610.873
7	4458378.64	20579900.4	1045504.081	6518841.898	7630186.822	17815792.9	10546086.5
8	5584819.726	22467947.47	1570872.928	10057721.87	9038917.745	17972520.79	15533632.09
9	6821422.009	23309406.67	2139519.887	11644490.98	9281470.812	17979211.44	17351842.98
10	7553971.397	23343323.55	4557964.053	13145141.06	9323525.22	0	17658427.94
11	7605169.701	0	7620681.004	14424795.18	9327802.941	0	17686694.4
12	7623753.748	0	10665881.83	15114343.94	0	0	0
13	0	0	12370449.75	15403339.84	0	0	0
14	0	0	12474629.8	15751534.07	0	0	0
15	0	0	12475711.15	15871592.54	0	0	0
16	0	0	0	15886591.83	0	0	0

8.6 Concluding Remarks of ARIMA Mathematical Model Study

1. The September 1998 maximum flood levels around Hazira Industrial Area and Surat city were about 7.5 m at ONGC, 7.0 m at KRIBHCO colony and 7.9 m at GAIL complex. Along Tapi river the flood levels were 6.8 m at Magdalla Bridge, 7.9 m at Bhatpur, 8.55 m at Umra, 11.4 m at Nehru Bridge, 13.9 m at Singanpur, 14.23 m at Variav and 18.29 m at Kathor.
2. The main reasons for flooding in Surat and surrounding Urban area and Hazira Industrial Area in 1998 were as given below :
   - The reservoir operation during September 1998 flood indicated that the incoming flood discharge flood discharges of about 29820 m^3/s (1053000 cfs). The high flood of 19057 m^3/s (6.73 lac cfs) was released on downstream as the reservoir level was at FRL. in 1994 the discharge of 13815 m^3/s (4.87 lac cfs) also flooded the entire area. The maximum outflow could

have been restricted to 8495 m^3/s (3 lac cfs) as shown in reservoir operation studies. The storage space between FRL and MWL was not utilized for flood moderation.

- Absence of any protection wall along low level right bank (with levels of 6.5 m to 4.5 m) between Bhata and Magdalla Bridge from where flood water spilled all along the right bank.
- Incomplete protection works / embankment / sluice regulators along right bank between Nehru Bridge to Kathor which allowed entry of flood water which ultimately found its way towards urban and industrial areas near Bhatpur and Hazira on west along right bank
- Raising height of flood embankments in the reach upstream of Singanpur weir was delayed.
- Rise in flood levels due to encroachments along Tapi River by private construction.
- Low natural ground levels (4.0 m to 4.5 m) as well 1 as low finished ground levels (5.5 m to 6.0 m) in the industrial area and high level embankment for roads, canals and railways creating obstruction to the flow of flood water. In particular the railway embankment on north of ONGC and KRIBHCO colonies obstructed flow of flood water to Tena creek.
- Inadequate waterways of many Bridges on natural drains between Bhata and Icchapur and also Bridges on Tena River.

3. There is no adequate data to show that how much silting of river bed contributed to the increased flood levels.

4. The mathematical model developed for Tapi river reach from mouth to about 15 km upstream of Kathor Bridge (total 66 km reach) is capable of handling unsteady flows in looped river channel network with tide and flood hydrograph as boundary conditions. The predicted water surface profile for the peak discharge of 19057 m^3/s (6.7 lac cfs) in September 1998 closely follow the observed high flood levels at various locations along Tapi river reach between Magdalla Bridge to Kathor Bridge. The mathematical model was thus adequately validated for 1998 flood.

5. Predicated water levels versus time curve at Bridge also shows good predicted velocities for 1998 Hood vary between 1.5 m/s lo 2.5 m/s in the reach downstream of Magdalla aim between 2.0 m/s to 3.0 in the upstream reach up to Kathor. The How remained unidirectional towards sea.
6. Model studies with flood hydrograph with peak discharge of 28315 m^3/s (10 lac cfs) as upstream boundary condition and Spring tide (with HWL of 5.3 in) or Neap tide (with HWL of 2.0 in) as downstream boundary condition indicate that on upstream of

Magdalla Bridge the water levels remain more or less unchanged irrespective of tidal condition. The maximum flood levels under these conditions will be 10.66 m at Umra / hata. 12.93 m at Nehru Bridge 15.24 m at Singanpur weir 17.43 m at Variav 18.29 m at Amroli and 21.76 m at Kathor At Magdalla Bridge. The water levels will be 7.86 m and 7392 m and 7.92 m for neap tide and spring tide condition respectively.

7. With flood discharge of 28315 m^3/s (10 lac cfs) the expected rise in water levels above September 1998 flood levels will be about 1.12 m at Magdalla Bridge, 2.0 m at Umra, 1.5 m at Nehru Bridge, 1.7 m at Singanpur weir, 2.4 m at Variav and about 3.0 m at Kathor Bridge. The flood levels around ONGC will be about 10.6 m i.e. about 2.0 m above 1998 flood levels.
8. For the flood discharge of 28315 m^3/s (10 lac cfs) the predicted flood levels vary between 10.66 m at hata, 7.92 m at Magdalla Bridge, 6.0 m at KRIBHCO jetty to about 5.65 m at L & T jetty. The natural right bank levels in this reach vary from 6.4 m. This lead to heavy flooding under this situation. Therefore, either the Ukai outflows need to be restricted to 8500 to 9910 m^3/s or there is necessity of flood protection works along right bank at least in the reach right from Nehru Bridge to Magdalla Bridge and further downstream up to KRIBHCO/ L & T jetty. Provision of protection works along right bank from Nehru Bridge to Magdalla Bridge has been made in the proposal of Surat Irrigation Circle.
9. Mathematical model studies for floods discharge of 28315 m^3/s with flood embankments on both banks in the reach from Nehru Bridge to river mouth at Hazira predicted flood levels of 8.0 m at KRIBHCO jetty, 9.55 m at Magdalla Bridge. 11.28 m at Umra / hata. 14.85 m at Nehru Bridge, 16.37 m at Singapur weir, 18.18 m at Variav, 18.81 m at Amroli Bridge and 21.88 m at Kathor Bridge. There will be Substantial rise of about 1.2 m to 1.6 m in flood levels in the reach from Singanpur weir to Magdalla Bridge over the flood levels predicted without flood embankments as seen from comparison of flood levels.
10. With partial flood embankments between Nehru Bridge to Magdalla Bridge and flood discharge of 28315 m^3/s the flood reduce to 8.26 m at Magdalla Bridge, 10.76 m at Umra. 14.02 m, at Nehru Bridge 16.27 m, at Siganpur weir However, in the reach downstream of Magdalla Bridge flood levels near L & T / KRIBHCO jetty will be about 7.50m.
11. With partial flood embankment from Nehru to Magdalla Bridge and flood discharge of 19057 m^3/s (6.73 lac cfs) . The rise in flood levels above 1998 HFLs will be relatively low (less than 0.60 m) as seen from comparison of predicted flood level under condition I and V.
12. The preliminary reservoir operation studies conclude following ;

- The floods similar to 1998 flood could be moderated effectively by restricting outflow of about 8500 to 9910 m^3/s (3 to 3.5 lac cfs) and with initial reservoir level of 102.11 m (334.92 ft) to 104.17 m (341.75 ft) respectively. The reservoir level close to FRL could have been maintained with these restricted outflows.
- The floods upto 28315 m^3/s (10 lac cfs) could be managed by restricting outflow to 9910 m^3/s (3.5 lac cfs) with maximum reservoir level close to FRL.
- If the present MWL is not allowed to be exceeded then during flood similar to that of 1968 the Ukai outflow Level of 100.58 m (330 ft). This high release will cause flooding similar to that in 1998 in the downstream, reaches.
- The PMF flood discharge of 72490 m^3/s (25.6 lac cfs) cannot take care of Ukai reservoir with outflows restricted below 11330 m^3/s (4 lac cfs). Even with outflow of 24069 m^3/s (8.5 lac cfs) the reservoir will reaches water level of 110.35 m (364.04 ft) and 109.19 m (358.25 ft) with initial levels of 103.63 m (340 ft) and 100.58 m (330 ft) respectively. The release of discharge of 24069 m^3/s on downstream will result in flooding situation worse than that in 1998.
- In view of the high flood levels experienced during the recent of 1994 and 1998 as well as predicted high flood levels for the discharge of 28315 m^3/s (10 lac cfs) and the result of preliminary operational studies there is need to take review of Ukai flood reservoir operation. Along with general operational policy on seasonal basis an emergency policy to deal the floods above 28315 m^3/s (10 lac cfs) need to be evolved. The existing rainfall and gauging network Tapi basin upstream of Ukai need to be modernized / updated and expanded (if necessary) so as to get adequate from 72490 m^3/s (25.6 lac cfs). In view of all these factors detailed reservoir operation studies including power generation and irrigation aspect are required to be carried out to evolve an effective seasonal as well emergency operational policies to minimize flooding of urban and industrial area around Surat city by keeping Ukai outflows preferably between 8500 m^3/s to 9910 m^3/s (3.0 to 3.5 lac cfs)
- There is need to develop a mathematical model for predicting time dependent flows (discharges and water levels) in river channel network of entire api basin upstream of Ukai reservoir to get adequate and timely information of flood discharge approaching Ukai reservoir. The data acquired by hydrological network will provide necessary input data for this model. This mathematical model could also be used to make quick trials on Ukai reservoir operation to decide appropriate outflow as function of time deal with incoming

flood. This mathematical model of Tapi basin network will also be useful to study rise in flood levels in the upstream reaches.

8.7 Conclusion from Graphical Techniques

The estimation of runoff due to rainfall in the catchment between Sarangkheda to Ukai will further improve if 2 new wireless stations are opened.

It is assessed that the river at Surat can carry only between 2 to 4 Lac cusecs without causing significant damage to urban dwellings and infrastructures. Analysis shows that after the flood of 2006 safe carrying capacity of river near Surat is reduced to 4531 m^3/s to 5660 m^3/s (1.60 to 2.0 Lac Cusecs). Right side embankment of the river Tapi from section RD20 to RD83 is very low in height; West Zone is developed in this reach and affected severely in recent flood events.

Out of three method used for peak flood probability, peak flood will occur after every eight years according to California method and this method prove good agreement with observed peak flood value along with suitable for Indian climate. For quantification of the flood-prone area, the thematic map based on Google-Earth and IRS-1D data reveals that more than 80% of the urban area in Surat City could be flooded by an event of 50-year return period.

8.8 Conclusion of Revised Ukai Reservoir Operation

Simulation model is developed to simulate reservoir operation using monthly available historical inflow. Month end storage and canal releases obtained from simulation model. Month end storage overlaid over a simulation period. Ultimately, calculation of rule level obtained for revised Ukai dam reservoir operation. In this revised reservoir operation has minimize the deficiency of Irrigation and maximizing the hydro power generation without flooding downstream in existing condition.

8.9 Conclusion of Excel Program for FBRO

- Data related to stage-discharge of Burhanpur (base station) and Dedtalai (forecasting station) as well as Gopalkheda (base station) and Yerli (forecasting station) can be utilized to develop better correlation using ANN to forecast inflow at Hathnur dam.
- The relationship between the outflow from Hathnur dam and inflow at Gidhade station can be established for better understanding of flood movement and present 12 hour warning time can be enhanced up to 24 hours.

- Relationship between Kakrapar weir outflow and stage at hope Bridge in Surat can be established, giving due consideration to tidal level, using ANN which would be helpful in flood forecasting to user agencies like Surat Municipal Corporation.
- Hydrodynamic modeling for Tapi River using MIKE 11 can improve the flood forecasting accuracy for Surat City.

8.10 Conclusion of Flood Risk and Flood Hazard Map

Result of analysis indicates that when water level starts increasing 8 m and above surrounded area start submerging by different amount. DEM shows that West zone is low lying area of the city and the slope of the city is from East to West. Table.No.8.5 shows Water Levels ft (Simulated over the Banks of Tapi: Surat).

Table.8.5 Water Levels ft (Simulated Over the Banks of Tapi: Surat)

ID	FE_1_3	FE_EM2_5	OVERSPILL	BANK_HT	PROP_BLD_P	RISK_LVL
1	2.500	0.000	5.500	2.500	-3.000	LOW
2	2.000	-0.500	4.500	1.500	-3.000	LOW
3	2.244	-0.256	4.988	1.988	-3.000	LOW
4	2.122	-0.378	4.744	1.744	-3.000	LOW
5	1.876	-0.624	4.252	1.252	-3.000	LOW
6	1.430	-1.070	3.360	0.360	-3.000	LOW
7	1.870	-0.630	4.240	1.240	-3.000	LOW
8	2.034	-0.466	4.568	1.568	-3.000	LOW
9	2.320	-0.180	5.140	2.140	-3.000	LOW
10	7.540	5.040	15.580	12.580	-3.000	HIGH
11	4.320	1.820	9.140	6.140	-3.000	MID
12	7.540	5.040	15.580	12.580	-3.000	HIGH
13	7.540	5.040	15.580	12.580	-3.000	HIGH
14	7.540	5.040	15.580	12.580	-3.000	HIGH
15	4.320	1.820	9.140	6.140	-3.000	MID
16	7.540	5.040	15.580	12.580	-3.000	HIGH
17	8.340	5.840	17.180	14.180	-3.000	HIGH
18	7.540	5.040	15.580	12.580	-3.000	HIGH
19	4.320	1.820	9.140	6.140	-3.000	MID
20	7.540	5.040	15.580	12.580	-3.000	HIGH
21	7.540	5.040	15.580	12.580	-3.000	HIGH
ID	FE_1_3	FE_EM2_5	OVERSPILL	BANK_HT	PROP_BLD_P	RISK_LVL
22	4.320	1.820	9.140	6.140	-3.000	MID
23	8.340	5.840	17.180	14.180	-3.000	HIGH
24	8.340	5.840	17.180	14.180	-3.000	HIGH
25	2.690	0.190	5.880	2.880	-3.000	MID

26	8.340	5.840	17.180	14.180	-3.000	HIGH
27	8.340	5.840	17.180	14.180	-3.000	HIGH
28	5.910	3.410	12.320	9.320	-3.000	MID
29	8.340	5.840	17.180	14.180	-3.000	HIGH
30	2.690	0.190	5.880	2.880	-3.000	MID
31	8.340	5.840	17.180	14.180	-3.000	HIGH
32	8.340	5.840	17.180	14.180	-3.000	HIGH
33	5.910	3.410	12.320	9.320	-3.000	MID
34	6.900	4.400	14.300	11.300	-3.000	MID
35	8.340	5.840	17.180	14.180	-3.000	HIGH
36	5.910	3.410	12.320	9.320	-3.000	MID
37	8.340	5.840	17.180	14.180	-3.000	HIGH
38	6.900	4.400	14.300	11.300	-3.000	MID
39	6.100	3.600	12.700	9.700	-3.000	MID
40	10.580	8.080	21.660	18.660	-3.000	HIGH
41	10.580	8.080	21.660	18.660	-3.000	HIGH
42	7.910	5.410	16.320	13.320	-3.000	HIGH
43	10.580	8.080	21.660	18.660	-3.000	HIGH
44	9.350	6.850	19.200	16.200	-3.000	HIGH
45	7.910	5.410	16.320	13.320	-3.000	HIGH
46	10.580	8.080	21.660	18.660	-3.000	HIGH
47	9.350	6.850	19.200	16.200	-3.000	HIGH
48	9.350	6.850	19.200	16.200	-3.000	HIGH
49	9.140	6.640	18.780	15.780	-3.000	HIGH
50	9.350	6.850	19.200	16.200	-3.000	HIGH
51	9.350	6.850	19.200	16.200	-3.000	HIGH
52	9.140	6.640	18.780	15.780	-3.000	HIGH
53	9.350	6.850	19.200	16.200	-3.000	HIGH
54	9.350	6.850	19.200	16.200	-3.000	HIGH
55	7.910	5.410	16.320	13.320	-3.000	HIGH
56	10.580	8.080	21.660	18.660	-3.000	HIGH
57	9.350	6.850	19.200	16.200	-3.000	HIGH
58	9.350	6.850	19.200	16.200	-3.000	HIGH
59	7.910	5.410	16.320	13.320	-3.000	HIGH
60	9.140	6.640	18.780	15.780	-3.000	HIGH
61	9.350	6.850	19.200	16.200	-3.000	HIGH
62	9.350	6.850	19.200	16.200	-3.000	HIGH
63	10.580	8.080	21.660	18.660	-3.000	HIGH
64	9.350	6.850	19.200	16.200	-3.000	HIGH
65	10.580	8.080	21.660	18.660	-3.000	HIGH
66	9.350	6.850	19.200	16.200	-3.000	HIGH
67	7.800	5.300	16.100	13.100	-3.000	HIGH

Detailed calculations for probable submergence area of the different zone according to water level are given in Table.No 8.5. As seen in DEM West zone is low lying area and its topography varies from

4 m to 13 m. Major parts of Adajan are in submergence. The results of analysis have shown Table No.8.6 in form of high, moderate and low flood risk level.

- The model prepared has been validated by comparing the actual flood depth flood of August 2006 at various point of study area with model result. According to analysis most of the Tapi river flood occurred in the month of August.
- Comparison of model result show that the model is giving the variation in flood depths less than 10% as compared to the actual depths.
- The outputs are a digital floodplain map that shows both extent and depth of inundation
- The difference may be due to error of data or measurement of depths or in accuracy of river cross section and assumptions made in the modeling.
- In order to protect the Surat city, surrounding urban developments and the Hazira industrial are from possible flooding there is need to take up some immediate and long term measures. The construction of flood embankment should be the last alternative as it will increase the flood levels appreciably. The immediate measures will be
- Review of Ukai reservoir operation policy
- Raising of present MWL and utilizing volume between FRL and MWL for flood moderation
- Development of a mathematical model of Tapi river channel network upstream of Ukai

8.11 Recommendations

8.11.1 ARIMA Mathematical Model

8.11.1.1 Immediate Measures

- Development of a Mathematical Model of entire Tapi River channel Network u/s of Ukai.
- Studies for Possible Rise Flood Levels in the Reach Upstream of Ukai.
- Hydrological Data network up gradation / Expansion.
- Availability of Tapi Basin Network Model, Reservoir Operation Model and Information on Hydrological Parameters at Control Room.
- Study of Rainfall and Gauge Discharge Data of Previous Storms.
- Completion of the Ongoing Flood Protection Works between Surat to Kathor.
- Checking of Existing bank Levels.
- Dredging of Kawas, Limla and Tena nalas and increasing Waterways of Bridges on these Nalas.
- Installation of water level gauges in the reach between Magdalla Bridge and ESSAR Plant.

- Assessment of Siltation in Ukai Reservoir.

8.11.1.2 Suggested Long Term Measures to be taken

- Diverting Part of Tapi Flood to Adjoining Creeks on North.
- Provision of Flood Embankment form Nehru Bridge to Magdalla Bridge on Both Banks.
- Diverting part of Tapi discharge (2 to 3 lac cfs) to the Kim. Sena creek on north if reservoir operation policy suggests release of discharges higher than 9910 m^3/s (4 lac cfs) during high floods.
- Provision of flood embankment between Nehru Bridge to Magdalla Bridge if diversion of part of Tapi flood to kim/sena creeks is not feasible.
- Hydrographic survey of river reaches from Kathor to river mouth at a regular Interval of at least five years.
- While designing the strom water drainage system for Hazira Industries (ONGC, KRIBHCO, NTPC, and L & T), the possible HFLs of 6.0 m at the outfall of Limla and about 6.7 m at the outfall of Kawas nalas must be considered. This HFL could continue for a period for 24 hours or more depending upon the Ukai reservoir operation with maximum release of 24069 m^3/s (8.5 lac cfs).
- The flood levels predicted are for the maximum release of discharge of 28315 m^3/s (10 lac cfs) from Ukai. If the discharge higher than are released from Ukai reservoir, then the prevailing flood levels all along the river reach downstream will be higher.

Based on the analysis of results of these studies it was concluded that the flood levels with 28315 m^3/s (10 lac cfs) flood discharge are likely to be of the order of 10.6 m near Bhata and industrial area around ONGC i.e nearly about 2.0 m above 1998 flood levels. These flood levels will further rise to a level of 11.3 after provision of flood embankments. The provision of flood embankment along right bank from Nehru Bridge to Magdalla Bridge and further downstream of KRIBHCO jetty was recommended for protection of Hazira Industrial Area. However, provision of such flood embankments will further increase flood levels all along the river as already mentioned above. Also studies to review the Ukai reservoir operation policy in view of 1998 flooding as well as PMF of 72490 m^3/s (25.6 lac cfs) at Ukai have been considered essential. The need for evolving emergency operation policy during flood was emphasized. Improvement of Ukai reservoir operation has been recommended as immediate measure for flood control. In order to asses possibly of improving reservoir operation during flooding situation by using reservoir volume between FRL (345 ft. i.e. 105.16 m) and MWL (351 ft. i.e. 106.98) preliminary studies for Ukai during September 1998 flood (with peak flow of 10 lac cfs) was considered with different combinations of controlled outflows from

Ukai. These studies have shown that by allowing Ukai reservoir level at FRL or about 1.0 m above FRL the maximum outflow from Ukai could be restricted to 8495 m^3/s (3 lac cfs) which could be passed without flooding in Surat and Hazira during incoming 28315 m3/s (10 lac cfs) at Ukai (similar to 1998). These preliminary studies have also shown that the floods similar to 1968 keeping appropriate initial reservoir levels and by raising of MWL by about 1.5 m. Based on the studies carried out some immediate and long-term measures have been suggested for protection of urban and industrial areas along Tapi river from Hazira to Surat. The important immediate measures are completion of ongoing flood protection works. effective operation of Ukai reservoir, review of Ukai reservoir operation policy and detailed studies on reservoir operation, development of a mathematical model for entire Tapi basin river channel network, up gradation / expansion of hydrological data acquisition networks and improvement of local drainage. The long-term measures are diversion of part of Tapi flood to Kim / Sena creeks on north (upstream of Singanpur weir), flood embankments on both banks between Nehru Bridge to Magdalla Bridge. The feasibility of long-term measure such as diversion of Tapi floods into Sena and Kim creek on north needs to be examined, if Ukai reservoir operation policy cannot be modified. The flood embankments have been recommended as the last alternative measure. The maximum routed outflow from Ukai cannot be brought to 14158 m^3/s to 16990 m^3/s (5 to 6 lac cfs) from present design value of 24069 m^3/s (8.5 lac cfs) and also the proposal of diversion of Tapi flood to the creeks on north is not found feasible. The partial flood embankment form Nehru Bridge to Magdalla Bridge only has been recommended if other suggested measures cannot be adopted.

8.11.1.3 Remedial Measure

The effective waterway of river Tapi has been reduced over years due to silting. The dredging of river in certain reaches and other suitable measures can be implemented to increase the carrying capacity of the river. The graph of water level at 25775 m^3/s (9.1 Lac Cusecs), river bed level and left hand side bank to level. There are several sections like LD60 to LD78 near Mugdalla jetty, LD21 to LD36 near Nehru Bridge, Swami Vivekananda Bridge and Sardar is having height of 4.93 m from ground level (and 8.34 m from bed level) and water level at 25775 m^3/s (9.1 Lac Cusecs) was 11.757 m during flood of 2006. So, top level of bank should be raised further by 3.417 m from the existing to increase the carrying capacity of the river.

The partial flood embankment form Nehru Bridge to Magdalla Bridge only has been recommended if other suggested measures cannot be adopted

- Mathematical model (ARIMA) study helpful for Tapi river flood and water levels prediction in future years w.r.t. maximum restricted flood outflow for revised reservoir operation in different flood scenario.
- Construction for widening of canal to divert 2 lacs cusec flood should be considered as first priority.
- At meandering of Tapi River, diverting of Tapi River in to nearby Kim and Seem creek consider for most of flood diversion to save Surat city and nearby areas. Desk study required for diversion of Tapi river flood water to the north side Tena, Sena, Kim and Mindhola creek.
- All floods can be moderated up to 8.40 lac cusecs. Not to provide any embankment in d/s of Nehru Bridge on right side of Tapi river because (it increases afflux) this area is flood plain area of Tapi river.
- Flood Protection works along right bank of Tapi may be taken up from Nehru Bridge to Magdalla Bridge on top priority, and then in the reach from Nehru Bridge to Kathor Bridge may be completed at the earliest. Propose embankments and retaining walls Suggested for Surat City shown below Fig. 8.1. Fig.8.2 shows phase wise suggested flood protection works for short term and long term basis, Fig.8.3 shows suggested strengthening of Bharimata bank protection work near kotar no.7 and 9.

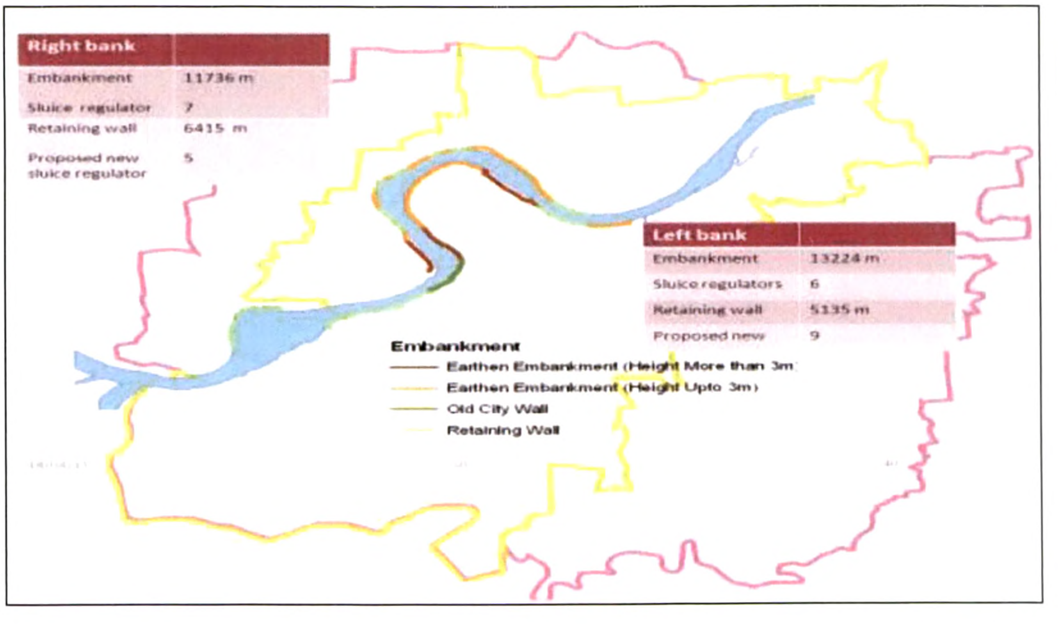


Fig.8.1 Embankments and Retaining Walls

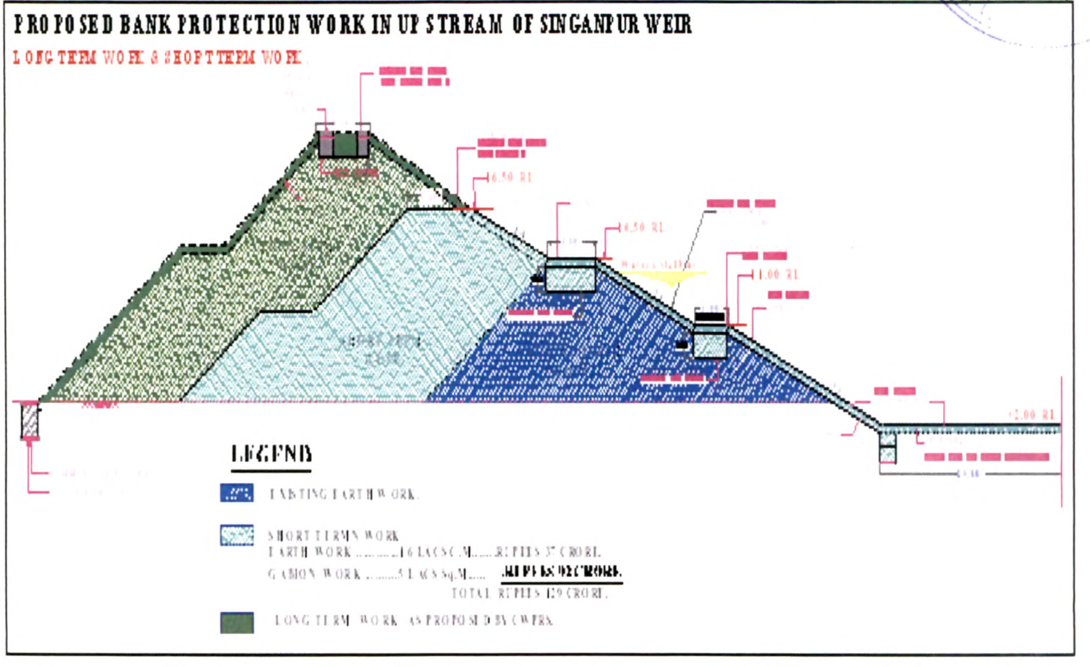


Fig.8.2 Phase wise Suggested Flood Protection Works for Short Term and Long Term Basis

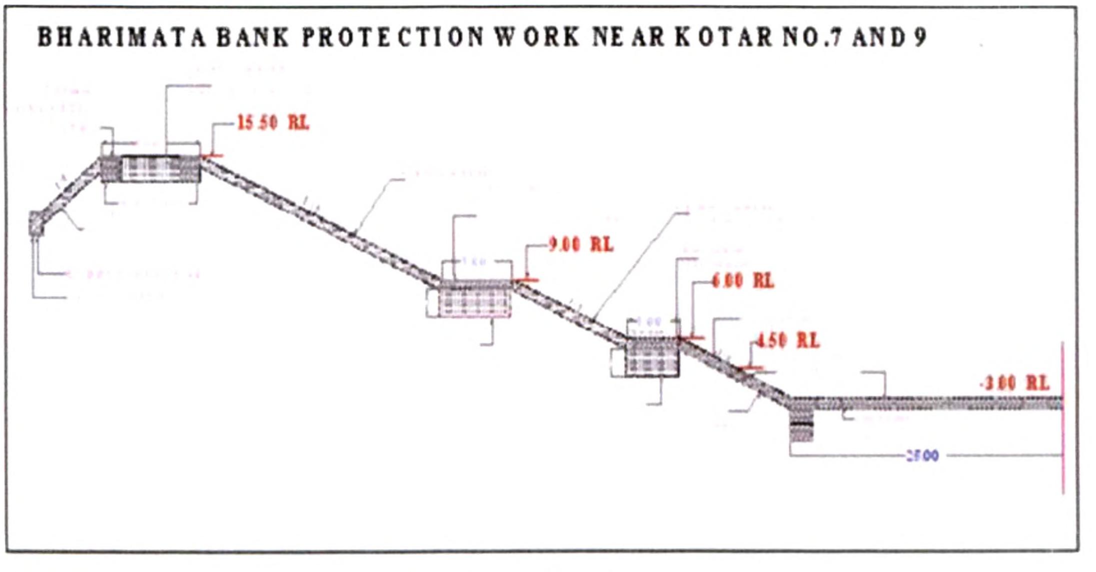


Fig.8.3 Suggested Strengthening of Bharimata Bank Protection Work near Kotar No.7 and 9

8.11.2 Recommendation from Graphical Techniques

Improve the quality of forecasts and warnings (with sufficient lead time) Gidhade to Ukai to enable areas likely to be affected and to make adequate advance preparations. The catchment area, in sq.km, up to Gidhade, Sarangkheda and Ukai are 54750, 58400 and 62225 respectively. At Gidhade real time houly gauge, daily discharge and 3 hourly rainfall/daily rainfalls are available, further at Ukai also hourly gauge and daily rainfall are available.

The proposed stations are:

(a) Sagbara (Existing Raingauge of Indian Meteorological Department) – For transmitting rainfall data,

(b) Navapur (River Rangawali) – For transmitting Rainfall/Gauge/Discharge data.

8.11.2.1 Tapi River Carrying Capacity

To avoid such repetitive conditions these sections are necessary to raise as early as possible to increase safe carrying capacity of the river.

8.11.2.2 Peak Flood Probability

Behavioral training and actions against this type of flood disaster at every eight year should be considered for Surat city people and surrounding nearby industrialists.

8.11.3 Revised Reservoir Operation

It is recommended that Ukai Dam reservoir operation must be operated according to suggested rule level and gate operation (Table No.8.1 and 8.2). According to result gate operation for different quantum of flood absorbed and can be stage wise released.

Ukai reservoir created silting at an average annual rate of 5% actual rate of sedimentation > designed rate of sedimentation. Therefore, the reservoir capacities for moderating floods are decreasing rather fast. Even the live storage of several dams has been encroached by the reservoir sedimentation. Cleaning of siltation (16 lacs m^3 quantity) from such river, removal of unauthorized slums/residential buildings/commercial buildings and cleaning of drains should be first priority.

8.11.4 Flood Risk Map and Flood Hazard Map

By using GIS and RS on NRSC Surat city image, flood risk and flood hazard map prepared which is helpful to indicate risk level of submergence areas at Surat city under different flood events.

- Up gradation / modernization of hydrological data acquisition network.
- Immediate completion ongoing works of flood embankment and sluice gates around Surat city.
- Dredging of Kawas Limla and Tena nalas and properly disposing the dredged material for improving the existing drainage.
- Appropriate increase in waterways of Bridges on these nalas including providing some additional openings in railway embankments on the backside of NTPC and KRIBCHO colony.
- Installation of water level gauges between Hazira to Magdalla.
- Improve communication links for the transmission of basic data and providing related warning information about natural hazards. The development and use of radar/GPS/GIS etc. for forecasting and measuring rainfall events gives better results. The increased number of telemetric rainfall stations for the rapid collection and processing of precipitation data and thus the forecasting of floods. Finalizing river boundary and bank levels. Providing vegetative fencing of hub, shrub and trees at 500 feet interval to the constructed river flood embankments.
- Based upon topographic survey, submergence area for Surat city must be published for different flood discharges. Development policy shall be fixed by considering HFL of Tapi River.
- Tapi River requires upstream catchments treatment, Ukai reservoir revise gate operation and downstream channel improvements.

Research Contribution:

In the present study detail analysis of impact of flood on Surat city has been discussed. The vigorous data analysis is carried out. Interpretation of data analysis is done. The result analysis carried out in detail. Outcome of result analysis listed in conclusion in form of recommendation from the present research. The researcher has discussed following points in detail.

- Prediction of water surface profile using ARIMA 1-D mathematical model.
- Validation of predicted water surface with observed levels at fixed locations along the river reach with special reference to Surat city.
- Detailed analysis of model results and comparing with observed results. Critical and detailed analysis of impact of flood in the various downstream area of Ukai dam.
- Recommendation for detailed, logical short and long term measures to mitigate losses due to flood.
- Various early warning measures on river Tapi. Identification of area contributing to high flow. Analysis of sufficiency of flood warning system in the basin. Recommendations to improve early warning system.
- Flood routing studies to understand routing of flood. Analysis is carried out using different flood inflows and initial level. Impact of releases on downstream areas. Recommended operation policy from routing of floods of different magnitude.
- Assessing carrying capacity of river. Analysis for status of existing right and left bank river conditions to different discharges in the Tapi River.
- Probability analysis by three methods about recurrence interval of peak flood.
- Reservoir optimization studies.
- Computation of release from the Ukai dam reservoir gate operation on real time basis.
- Study flooding in the different areas of Surat city in past and preparing flood inundation map.

Usefulness of Research:

Ukai Dam reservoir can be operated as per revised calculated and suggested rule levels month wise and Forecast Based Reservoir Operation (FBRO) condition vise. According to result gate operation for different quantum of flood absorbed and can be stage wise released such that released outflow not increased more than 4 lacs cusecs at single time. Improve communication links for the transmission of basic data and providing related warning information about natural hazards. The development and use of radar/GPS/GIS etc. for forecasting and measuring rainfall events gives better results. The increased number of telemetric rainfall stations for the rapid collection and processing of precipitation data and thus the forecasting of floods according to this research study.

According to ARIMA 1-D Mathematical model help to forecast Tapi River water surface profile for different flood scenario at various locations at Surat city. Authority must finalize Tapi river boundary and bank levels. Providing vegetative fencing of hub, shrub & trees at 500 feet interval to the constructed river flood embankments. Flood corp require for flood plain management.

According to this study, construction for widening of canal to divert 2 lacs cusec flood should consider first priority. All floods can be moderated up to 23809.52 cumecs (8.40 lac cusecs). Not to provide any embankment in downstream of Nehru bridge on right side of Tapi river because (it increases afflux) this area is flood plain area of Tapi river. Flood Protection works along right bank of Tapi may be taken up from Nehru bridge to Magdalla bridge on top priority, and then in the reach from Nehru bridge to Kathor bridge may be completed at the earliest. Based upon topographic survey, submergence area for Surat city published for different flood discharges. Development policy shall be fixed by considering HFL of Tapi River. Tapi River requires upstream catchments treatment, Ukai reservoir revise gate operation and downstream channel improvements to minimize Tapi River flood impact – Surat City. This research study is also helpful to Surat Municipal Corporation for any development along Tapi river flood plain by keeping research points in mind.

Scope of Further Study:

- Revised Rule level for Ukai Dam reservoir gate operation study can be computed more accurately in the year 2074 as Researcher will get 100 years (1973-2073) data for research study.
- ARIMA-1 D mathematical model can be developed for full length of Tapi river i.e.by keeping boundary condition from origin to Arabian Sea.