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Calculating Discharge Carrying Capacity of River Tapi

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***Abstract*: Massive flood of river Tapi had caused greater damage to personal and property in year 2006. It is observed that discharge carrying capacity of various sections is one of the main reasons for this. The paper describes the methodology for calculating discharge carrying capacity of 309 cross sections measured by irrigation department across lower Tapi basin.**

Key Words: Discharge, River Sections, Tapi, 2006

I. Introduction

Surat city, situated at latitude 21o 06' to 21 o 15' N and longitude 72 o 45' to 72 o 54' E on the bank of river Tapi having coastline of Arabian Sea is on its West. Surat had experienced so many flood events before and after construction of Ukai dam. Flood occurred in August, 2006 is described as worst flood in history of lower Tapi basin. Centre Water Commission(CWC) along with department of irrigation, local Municipal Corporation and other state government agencies have invested large amount of resources for protecting the fastest growing city of the India [1] by making structural and non-structural measures. The variation of erosion and deposition in the channel causes the corresponding regulation of longitudinal section certainly. The variation of longitudinal section is reflected on the slope variation [2]. For the channel controlled gauging station, the level of deepest point opposite the gauge may give a reasonable indication of datum [3] .Sedimentation, siltation, settlements and encroachments are some reasons for the occurrences of flood in this basin. Tapi basin is divided in three zones, Upper Tapi Basin (UTB), Middle Tapi Basin (MTB), and Lower Tapi Basin (LTB).The portion between Ukai Dam to Arabian Sea is known as LTB, includes Surat city and surrounded industrial and rural area. The Tapi river basin in Gujarat, encompassing an area of about 65.95 lakh hectares [4] covers parts of Surat district. The topography in LTB comprises narrow valley and gently sloping ground [5]. The LTB receive an average annual rainfall of 1376 mm, and these heavy downpours are one of the main reasons for occurrence of flood and water loggings downstream. Ukai dam, Kakrapar weir, Mandvi, Ghala, Singanpur Weir, and Hope (Nehru) Bridge are the six stations where the river is gauged. Ukai Dam and Kakrapar Weir are the hydraulic structures constructed across the river in LTB. Live storage capacity of Ukai multipurpose reservoir is 7369 Mm3at its full reservoir level of 105.15 m. This storage spread over 600 square kilometer and length about 112 km. The reservoir is expected to attain Maximum Water Level (MWL) of 107 m (351ft) while passing the Probable Maximum Flood (PMF) of 59747 m3/s. Reservoir is operated according to guide line of Centre Water Commission, New Delhi, in monsoon. Surat city situated on a bend of the river Tapi, where its course swerves suddenly from the south-east to south-west. From the right bank of the river, the ground rises slightly towards the north, with the height above mean sea level 13 m. Water level difference in open wells before and after monsoon has been found around 1.8 m in last thirty five years. Average annual rainfall in this region is recorded 1330 mm with minimum 460 mm to maximum 4660 mm. In this worst flood event of 2006 more than 400 people died and approximately property lost was 4.5 billion US$. Flood occurs typically during monsoon mainly due to heavy rain and less carrying capacity of the river sections.12% land of the total geographical area is flood prone in India. It is very much required to find out the flood and carrying discharge for the river for manage and control the flood. In this paper attempt is made using continuity equation for finding out river carrying capacity in which Manning's formula is used to find out velocity of flow. The process is carried out for 309 river cross-sections which were measured by Surat Municipal Corporation just after flood of 2006 at an interval of about 150m to 200m.

II. Materials and Methodology

Measurements of river discharge are required for flood hazard management, water resource planning, climate and ecology studies, and compliance with trans boundary water agreements. Knowledge of river propagation speed, the time for flows to pass downstream, is critical for flood forecasting, reservoir operations, and watershed modeling. [6] The traditional and simple way to gather information on current discharge is then to measure the water level with gauges and to use the stage-discharge relationship to estimate the flow discharge. It is well known, in fact, that direct measurements of discharge in open channels is costly, time consuming, and sometimes impractical during floods. [7] Even where good monitoring networks exist, hydrologic conditions between stations must be interpolated or modelled, often over long distances. In the developing world, stream- flow data are seldom available for economic, political, and proprietary reasons. [8] The lateral distribution s of averaged depth velocity at the clearly show that the maximum flow velocity occurs in the central of main channel region, which decreases towards the side banks direction, and increases with the increase of flow depth [9]. Cross section of river Tapi showing bed levels and bank levels measured at various points from centre line of the river and measured at an average interval of 150 m to 200 m along length of river from Ukai Dam to Arabian Sea just after the flood of 2006 collected from Surat Municipal Corporation in Auto-CAD format. Typical cross section is shown in Fig.1. Hourly and daily discharge data and corresponding water level were collected from six stations.

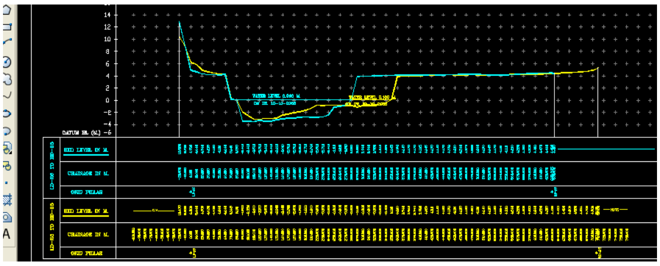

Fig.1 Tapi River Cross-Section

Rivers are natural channels and flow of the rivers can be defined as open channel flow having free surface. Velocity area method is one of the several methods to estimate the discharge. Hence the continuity equation is used to determine discharge of various sections.

$$Q = A \times V \qquad (1)$$

In order to estimate discharge well known and used for several river in USA [10] Manning's formula is applied which gives river flow velocity

$$V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \qquad (2)$$

Where V = flow velocity (m/s), n = river bed roughness, R = hydraulic radius = A / P (m) and S = the river slope(m/m).

In order to find out discharge carrying capacity of each river cross-section manually, above method is used but the work becomes time consuming. As an alternate programme in Microsoft Excel in aid of visual basic has been prepared to determine discharge of various sections.

- Chainage number of the section and ground level is feed in the box as shown in the Fig.2.

CROSS SECTION OF RIVER TAPI AT PROPOSED SITE

WATER LEVEL :- 12.653

G.L.	Chainage	Dist.	Depth	Area	Peri.
10.47	-20.00	0.00	2.18	0.00	0.00
8.84	-10.00	10.00	3.82	30.00	10.13
6.20	0.00	10.00	6.45	51.35	10.34
5.85	10.00	10.00	6.81	66.30	10.01
4.90	20.00	10.00	7.75	72.80	10.04
4.64	30.00	10.00	8.02	78.85	10.00
4.44	40.00	10.00	8.22	81.18	10.00
4.24	50.00	10.00	8.41	83.15	10.00
4.25	60.00	10.00	8.41	84.10	10.00
0.15	70.00	10.00	12.50	104.56	10.81
0.10	80.00	10.00	12.55	125.29	10.00
-1.90	90.00	10.00	14.55	135.53	10.20
-2.55	100.00	10.00	15.20	148.78	10.02
-3.10	110.00	10.00	15.75	154.78	10.02
-3.10	120.00	10.00	15.75	157.53	10.00
-3.00	130.00	10.00	15.65	157.03	10.00
-3.00	140.00	10.00	15.65	156.53	10.00
-2.90	150.00	10.00	15.55	156.03	10.00
-2.40	160.00	10.00	15.05	153.03	10.01
-2.30	170.00	10.00	14.95	150.03	10.00
-2.00	180.00	10.00	14.65	148.03	10.00
-1.90	190.00	10.00	14.55	146.03	10.00
-1.60	200.00	10.00	14.25	144.03	10.00
-1.30	210.00	10.00	13.95	141.03	10.00
-0.80	220.00	10.00	13.45	137.03	10.01

Fig.2 Print Screen showing Chainage and Ground Level

- The degree of roughness depends on several factors, the most important of which in open-channel flow are surface roughness of the bed material, cross-section geometry, channel variations, obstruction to flow, type and density of vegetation, and degree of channel meandering [11]. In general, all factors that tend to cause turbulence and retardance of flow, and hence energy losses, increase the roughness coefficient; those that cause smoother flow conditions tend to decrease the roughness coefficient. Rugosity coefficient is constant ,put it in the box of N, as shown in Fig.3

:DISCHARGE CARRING CAPACITY AT DIFFERENT R.L.IN Mt.:

N value: 0.0400
S value: 0.000893 (1 IN 1120.00)
Design Q : 25768.09 cumec(910000ft³/s)
% Q : 25768 cumecs 100

Max GL of section: 10.470 m.
Min GL of section: -3.10 m.

Sr. No.	R. L. in m	Area in m² A	Perimeter in m P	R= A/P	2/3 R	Velocity in m/s V=1/NxRxS	Discharge in m³/sec Q = A x V	Disch. in %	
1	1.502	842.71	287.81	2.93	2.05	1.53	1288.40	5	%
2	3.047	1292.11	296.23	4.36	2.67	1.99	2576.81	10	%
3	4.100	1612.43	359.76	4.48	2.72	2.03	3274.33	15	%
4	5.830	2651.40	631.71	4.20	2.60	1.94	5153.62	20	%
5	6.460	3052.60	642.89	4.75	2.83	2.11	6442.02	25	%
6	7.017	3410.11	645.08	5.29	3.03	2.27	7730.43	30	%
7	7.537	3745.29	647.12	5.79	3.22	2.41	9018.83	35	%
8	8.028	4062.53	649.05	6.26	3.40	2.54	10307.23	40	%
9	8.495	4364.94	650.88	6.71	3.56	2.66	11595.64	45	%
10	8.942	4655.49	652.88	7.13	3.70	2.77	12884.04	50	%
11	9.375	4937.57	655.56	7.53	3.84	2.87	14172.45	55	%
12	9.792	5210.38	658.14	7.92	3.97	2.97	15460.85	60	%
13	10.194	5475.00	660.64	8.29	4.10	3.06	16749.26	65	%
14	10.581	5729.85	662.34	8.65	4.21	3.15	18037.66	70	%
15	10.948	5972.02	662.34	9.02	4.33	3.24	19326.07	75	%

Fig.3 – Print Screen showing key for n, S and Q

- Bed slope (S) is worked out for each section manually and its values for different sections are already put in the programme by Key menu. The box of 'n' 'S' and 'Q'is shown in Fig.3.

- For finding out discharge carrying capacity of any section, calculated discharge value is selected for respective section.
- For case study a river section near Nehru Bridge is taken and different value of assumed discharge is put. For a value 25768.09 m3/s (9.1 Lakh Cusecs) is used to see water level at this section. The water level at this section is shown by blue line, which shows water level at 12.65 m .See Fig.4

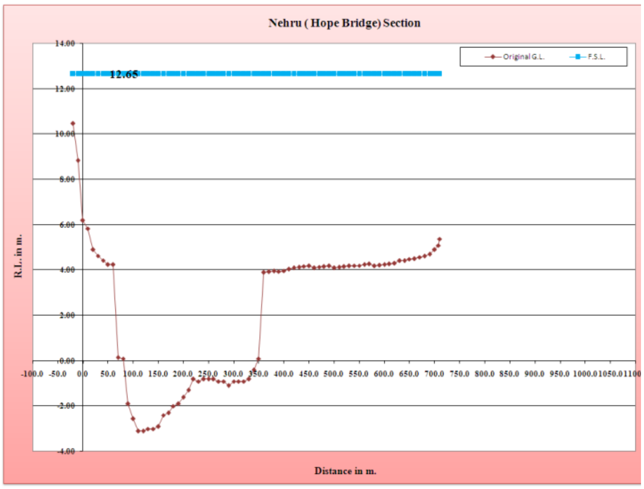

Fig.4 Print Screen Showing Cross-Section of River Tapi near Nehru (Hope) Bridge as Q 25768.09 m3/s (9.1 Lakh Cusecs)

- Blue line indicating water level touches any of the lowest bank height of the cross- section, the assumed value of discharge indicate maximum carrying capacity of the given section. By taking discharge 25768.09 m3/s (9.1 Lakh Cusecs) the water level does not touch to the bank height but it is above from lowest bank height.
- By taking less value than the discharge taken earlier, run the programme and see position of blue line, until it touches to the lowest point of the either bank height.
- When water level i.e. blue line touches lowest bank height read the value of area A, perimeter P, and hydraulic radius R from the column D, E, and F respectively.
- The value of velocity is obtained from column 'H ', Manning's equation is used for it.
- The maximum discharge of the given section is obtained by using continuity equation and in the programme it is seen in column 'I'.
- Column 'J' gives the percentage discharge that the section can carry at different water level. According to water level i.e. blue line indicates possible discharge the section can carry in the percentage.
- For the section near Hope Bridge the maximum discharge is found out by running the programme making number of trials. The maximum carrying capacity is found 4530.65 m3/s (1.6 Lakh Cusecs) and river level 5.51 m., see Fig.5 and Fig.6

CROSS SECTION OF RIVER TAPI AT PROPOSED SITE

WATER LEVEL :- 5.508

G.L.	Chainage	Dist.	Depth	Area	Peri.
10.47	-20.00	0.00	0.00	0.00	0.00
8.84	-10.00	0.00	0.00	0.00	0.00
6.20	0.00	0.00	0.00	0.00	0.00
5.85	10.00	0.00	0.00	0.00	0.00
4.90	20.00	6.43	0.61	1.95	6.46
4.64	30.00	10.00	0.87	7.40	10.00
4.44	40.00	10.00	1.07	9.73	10.00
4.24	50.00	10.00	1.27	11.70	10.00
4.25	60.00	10.00	1.26	12.65	10.00
0.15	70.00	10.00	5.36	33.11	10.81
0.10	80.00	10.00	5.41	53.84	10.00
-1.90	90.00	10.00	7.41	64.08	10.20
-2.55	100.00	10.00	8.06	77.33	10.02
-3.10	110.00	10.00	8.61	83.33	10.02
-3.10	120.00	10.00	8.61	86.08	10.00
-3.00	130.00	10.00	8.51	85.58	10.00
-3.00	140.00	10.00	8.51	85.08	10.00
-2.90	150.00	10.00	8.41	84.58	10.00
-2.40	160.00	10.00	7.91	81.58	10.01
-2.30	170.00	10.00	7.81	78.58	10.00
-2.00	180.00	10.00	7.51	76.58	10.00
-1.90	190.00	10.00	7.41	74.58	10.00
-1.60	200.00	10.00	7.11	72.58	10.00
-1.30	210.00	10.00	6.81	69.58	10.00
-0.80	220.00	10.00	6.31	65.58	10.01

Fig.5 Print Screen water level @ 4530.65 m3/s (1.6 Lakh Cusecs)

:DISCHARGE CARRING CAPACITY AT DIFFERENT R.L.IN Mt.:

N value: 0.0400 — Max GL of section: 10.470 m.
S value: 0.000893 (1 IN 1120.00)
Design Q : 4530.65 cumec(160000ft³/s) — Min GL of section: -3.10 m.
% Q : 4531 cumecs 100

Sr. No.	R. L. in m	Area in m² A	Perimeter in m P	R= A/P	2/3 R	Velocity in m/s V=1/NxRxS	Discharge in m³/sec Q = A x V	Disch. in %	
1	-0.522	282.53	254.08	1.11	1.07	0.80	226.53	5	%
2	0.074	438.55	269.65	1.63	1.38	1.03	453.06	10	%
3	0.544	569.92	282.59	2.02	1.60	1.19	679.60	15	%
4	0.930	679.31	284.70	2.39	1.79	1.33	906.13	20	%
5	1.279	778.70	286.59	2.72	1.95	1.45	1132.66	25	%
6	1.600	870.83	288.35	3.02	2.09	1.56	1359.20	30	%
7	1.900	957.38	289.98	3.30	2.22	1.66	1585.73	35	%
8	2.184	1039.45	291.52	3.57	2.33	1.74	1812.26	40	%
9	2.453	1117.81	292.99	3.82	2.44	1.82	2038.79	45	%
10	2.710	1193.02	294.39	4.05	2.54	1.90	2265.33	50	%
11	2.957	1265.54	295.73	4.28	2.64	1.97	2491.86	55	%
12	3.195	1335.70	297.03	4.50	2.72	2.04	2718.39	60	%
13	4.569	1867.06	608.53	3.07	2.11	1.58	2944.92	65	%
14	4.722	1960.36	615.10	3.19	2.17	1.62	3171.46	70	%
15	4.868	2050.54	620.63	3.30	2.22	1.66	3397.99	75	%
16	5.004	2134.65	622.93	3.43	2.27	1.70	3624.52	80	%
17	5.134	2215.69	624.31	3.55	2.33	1.74	3851.05	85	%
18	5.262	2294.98	625.66	3.67	2.38	1.78	4077.59	90	%
19	5.386	2372.66	626.99	3.78	2.43	1.81	4304.12	95	%
20	5.508	2448.83	628.28	3.90	2.48	1.85	4530.65	100	%

Fig.6 Print Screen showing Discharge 4530.65 m3/s (1.6 Lakh Cusecs)

- By taking different values of discharges when discharge of 4530.65 m3/s is taken the water level i.e. blue line touches to lowest point of left side bank height that means this river section does not carry more discharge than this. The river section with water level is shown in Fig. 7

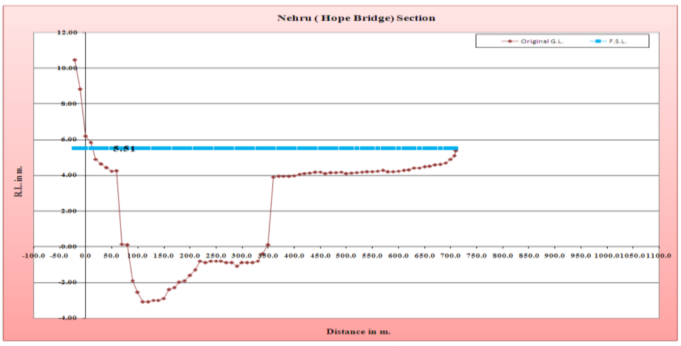

Fig.7 Print Screen Showing Cross-Section of River Tapi near Nehru Bridge as Q 4530.65 m3/s (1.6 Lakh Cusecs)

III. RESULT ANALYSIS

The maximum discharge for each section is calculated as discussed above and the graph of various sections versus discharge is plotted as shown in Fig.8. Discharge carrying capacity of river at various sections is maximum up to 70 x 103 m3/s (24 Lakh Cusecs) following the other large sections having range from 40 x 103 m3/s (14 Lakh Cusecs) to 70 x 103 m3/s (24 Lakh Cusecs). The graph shows that it varies between 4531 m3/s (1.6 Lakh Cusecs) to 70 x 103 m3/s (24 Lakh Cusecs). From graph we can also read that most of the sections which are having less carrying capacity are near Nehru (Hope) bridge in West Zone.

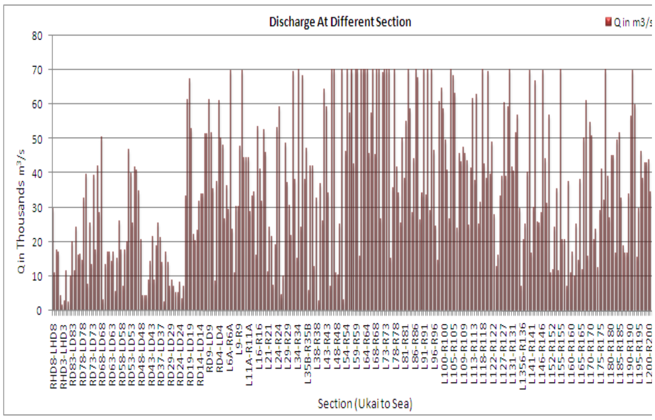

Fig. 8 - Discharge Carrying Capacity at Various Cross Sections of river Tapi.

IV. CONCLUSION

Software developed in Microsoft Excel for finding out maximum carrying capacity of the river gives very reliable results. The river hydraulic data are very useful for analysis, narrowing of the Tapi river is revealing one. 40 years back it could carry 28310 m3/s (10 Lakh Cusec) of water. It has been reduced to 9910 m3/s (3.5 Lakh Cusecs). Analysis shows that after the flood of 2006 safe carrying capacity of river near Surat is reduced to 4531 m3/s to 5660 m3/s (1.60 to 2.0 Lakh Cusecs). Right side embankment of the river Tapi from section RD20 to RD83 is very low in height; West Zone is developed in this reachand affected severely in recent flood events.

V. ACKNOWLEDGEMENT

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