RESEARCH PAPER | Engineering | Volume : 4 | Issue : 1 | Jan 2014 | ISSN - 2249-555X

Peak Flood Probability Analysis for Tapi River

KEYWORDS: Peak Flood, Probability analysis, Flood forecasting, Flood preparedness

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ABSTRACT *Floods are recurrent phenomena in India from time immemorial. Every year some or the other parts of the country are affected by floods of varying magnitude. Different regions of the country have different climates and rainfall patterns. Out of the total rainfall of India, about 75% of it is received during the four moths (June to September) due to the South-West monsoon which is non-uniformly distributed in space as well. India is traversed by a large number of river systems. The rivers of North and Central India are prone to frequent floods during the South-West monsoon season. Surat is one of the major important cities of Gujarat. It is a locus of trade and economical activities along with varieties of industries starting from Cotton industry, Diamond industry, Sugar industry to Petrochemical industries located in or around nearby area. Any natural calamity which causes loss of lives to property & infrastructure along with effects on industrial processes going on has serious impact on economy of the state. So, it becomes highly necessary that past flood events must be studied and analyzed properly in order to propose adequate flood control & protection measures in time to come. In this research paper, effort towards peak flood frequency probability analysis is carried out and diversion of Tapi river flood study listed and discussed.*

INTRODUCTION

Floods are recurrent phenomena in India from time immemorial. Every year some or the other parts of the country are affected by floods of varying magnitude. Different regions of the country have different climates and rainfall patterns and as such it is also experienced that when part of the country is experiencing devastating floods, there is another part of the country at the same time which is in grips of severe drought. Out of the total rainfall of India, about 75% is received during the four moths (June to September) due to the South-West monsoon which is non-uniformly distributed in space as well. India is traversed by a large number of river systems. The rivers of North and Central India are prone to frequent floods during the South-West monsoon season, particularly in the month of July, August and September. In the Brahmaputra river basin, floods have often been experienced as early as in late May while in southern rivers floods continue till November. However, the heavy and intense rainfall is not the only factor contributing to floods. The other causes of flood are inadequate capacity within riverbanks to contain high flows and silting of riverbeds, landslides leading to obstruction of flow and change in the river course, retardation of flow due to tidal and backwater effects, poor natural drainage, cyclones, snowmelt and glacial outbursts, and dam break flow.

River Tapi is the 2nd largest west flowing river of Gujarat State, Central India. It originates from Mulati of Betul District of Madhya Pradesh; which is located 323 Km. from Maharashtra and 189 Km. from Gujarat. Tapi is known for occurrence of large floods due to influence of depressions originating from bay of Bengal traveling East to West causing rainfall, first in the upper catchment and then in lower catchment resulting of flood along its course.

Ukai Dam (Tapi River valley 2nd Stage) is the largest multipurpose project, next to Narmada Project. It was completed in 1973. The Dam is located at village Ukai, Taluka Songadh of District Surat at distance of about 90 Km. from Surat city. It caters multiple purposes like Irrigation, Power generation, Water supply to industries and households, fisheries etc. It is major flood control point coming on Surat city.

Surat city popularly known as Diamond city is an industrial hub where significant portion of Gujarat's total economic activities, is centered. Presently spread over 334.23 Km^2 areas, Surat had a population of 58, 77,241 as per Census 2010. Surat has been blessed with flow of river Tapi which fulfills most of its water requirements. It flows through city and meets Arabian Sea at about 16 Km. from Surat. Big water resources projects like Ukai Dam, Kakrapar weir are near the Surat. Five main and several minor creeks pass through the Surat and meet river Mindhola in south of it. As mentioned earlier Surat has been blessed by the flow of Tapi however, it has also suffered a lot because of floods in Tapi since historic time. In present study the probability analysis for Tapi River has been carried out.

FLOOD SITUATION IN SURAT CITY AND HAZIRA TWIN CITY.

The dam is located across the river Tapi about 29 km upstream of the Kakrapar weir. A barrier is constructed across Tapi River in form of an Ukai dam, water gets stored on upstream side of the dam, forming a pool of water called as Ukai dam reservoir. Tapi River covers approximately 515041 cm (79%) of Maharashtra state, 9804 km (15%) of Madhya Pradesh and 3837 km (5%) of Gujarat State, The basin finds its outlet in the Arabian Sea and is bounded on three sides by ranges of hills. The Tapi River and its tributaries flow over the plains of Vidharbha, Khandesh and later to Gujarat, and can be divided in to three Zones, Viz.Upper Tapi basin (UTB), Middle Tapi Basin (MTB) and Lower Tapi Basin (LTB). The portion in between Ukai Dam to the Arabian Sea is considered as Lower Tapi Basin (LTB), mainly occupying the Surat and Hazira twin cities along with tens of small towns and village by the river. The Surat and Hazira twin cities are almost 90 km downstream of Ukai dam and are affected by the recurrence of floods at regular intervals. Five main and several minor creeks pass through the city and meet river Mindhola in south of Surat.

Surat has experienced considerable growth in industrial activities (especially textiles) along with trading activities. Concentration of those activities combined with residential developments has resulted in considerable expansion of the city limits.

Tapi river is known for occurrence of large floods due to influence of depressions originating from Bay of Bengal and

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travelling from East to West along the river course causing rains first in upper catchments and then in the lower catchments resulting in aggravation in magnitude of flood along its course. The city of Surat has developed on both banks of the river Tapi. It is located barely 20 km upstream of the confluence of Tapi with the Arabian Sea. The river flows through a large meander just upstream of Surat. The city of Surat is located at the downstream end of a large meander in the river and on concave side of the river course. Tapi river floods in yr. 1998 and 2006 have created havoc on Surat city lives and properly recently in the memory of people.

STUDY AREA

River Tapi flows through the city and meets the Arabian Sea at about 16 km from Surat. Surat is 90 km in downstream of Ukai Dam over river Tapi. Five main and several minor creeks pass through the city and meet river Mindhola in south of Surat. Schematic diagram of Tapi creek channel network as shown in Plate.1.

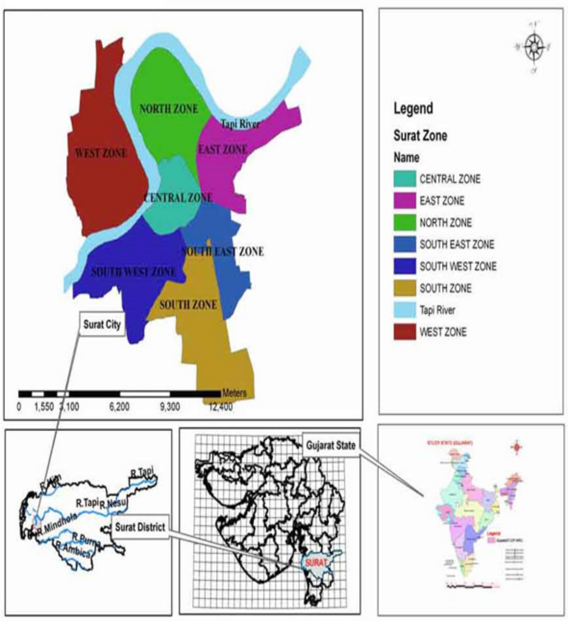
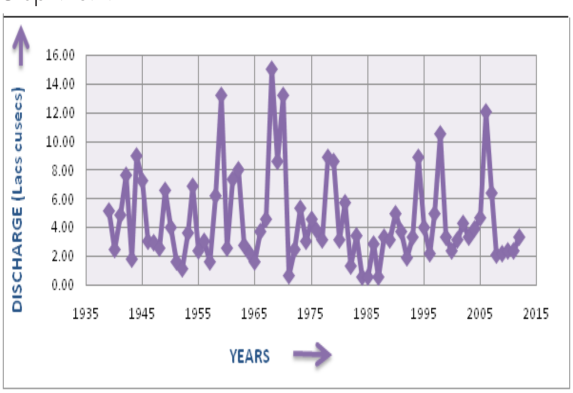


Plate.1. Location Map of Study Area.

Data collected for Peak flood in Tapi River-Year 1939 to 2012 listed here in Table.no.1. and peak flood pattern shown in Graph.no.1.



Graph.1. Peak Flood in Ukai Reservoir Year (1939-2012).

Table.1 Peak Flood in Ukai Reservoir Year (1939-2012).

Sr.no	YEARS	PEAK FLOOD IN lacs cusecs	Sr.no	YEARS	PEAK FLOOD IN lacs cusecs	Sr.no	YEARS	PEAK FLOOD IN lacs cusecs
1	1939	5.15	31	1969	8.56	61	1999	3.3
2	1940	2.43	32	1970	13.14	62	2000	2.38
3	1941	4.81	33	1971	0.66	63	2001	3.09
4	1942	7.58	34	1972	2.47	64	2002	4.32
5	1943	1.79	35	1973	5.29	65	2003	3.32
6	1944	9	36	1974	3.06	66	2004	3.89
7	1945	7.22	37	1975	4.56	67	2005	4.68
8	1946	3	38	1976	3.81	68	2006	12.05
9	1947	2.91	39	1977	3.09	69	2007	6.37
10	1948	2.55	40	1978	8.88	70	2008	2.08
11	1949	6.62	41	1979	8.58	71	2009	2.15
12	1950	3.98	42	1980	3.17	72	2010	2.32
13	1951	1.62	43	1981	5.73	73	2011	2.31
14	1952	1.12	44	1982	1.33	74	2012	3.35
16	1954	6.89	46	1984	0.5			
17	1955	2.36	47	1985	0.5			
18	1956	3.06	48	1986	2.86			
19	1957	1.58	49	1987	0.5			
20	1958	6.2	50	1988	3.3			
21	1959	13.16	51	1989	3.1			
22	1960	2.55	52	1990	4.9			
23	1961	7.36	53	1991	3.68			
24	1962	7.99	54	1992	1.84			
25	1963	2.7	55	1993	3.35			
26	1964	2.15	56	1994	8.87			
27	1965	1.55	57	1995	4.01			
28	1966	3.66	58	1996	2.12			
29	1967	4.55	59	1997	4.94			
30	1968	15	60	1998	10.53			
30	1968	15	60	1998	10.53			

Source: Ukai Flood Control Cell

DETERMINATION OF PEAK FLOOD FREQUENCY PROBABILITY BY CALIFORNIA METHOD

Probability analysis for occurrence of peak flood calculated by three methods viz; Hazen's statically method, Well Weibulls method and California method. Probability analysis for occurrence of peak flood calculated by Hazen's statically method and plotted on log scale. The peak flood data used 73 years (from 1939-2012) for this research study. Peak flood will occur after nineteen years according to this method. Respective equations used in each method for statistical analysis shown in Table. No.2. the result of analysis shown in Graph no.2.

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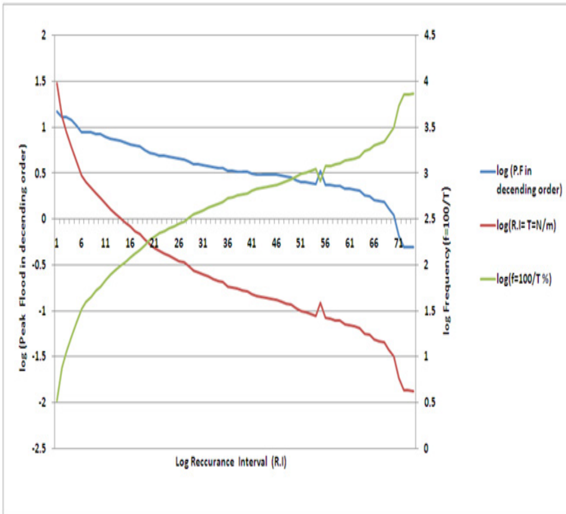
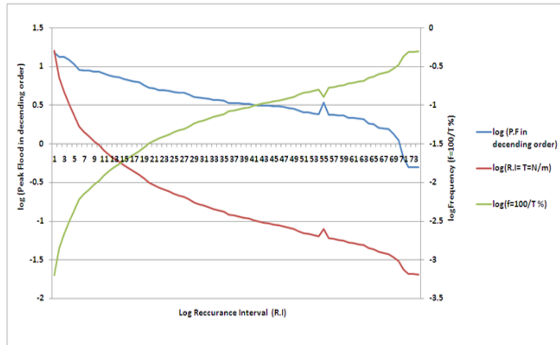
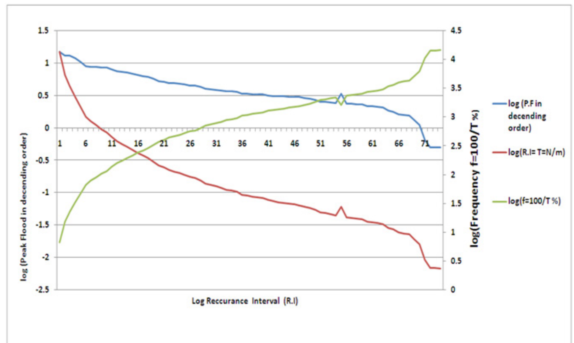


Graph.2. Flood Probability by Hazen's Method

Probability analysis for occurrence of peak flood calculated by Well Weibulls statically method and graph plotted on log scale. Peak flood will occur after fourteen years according to this method. The result of analysis shown in Graph no.3 and Table. 2. Probability analysis for occurrence of peak flood calculated by California statically method and log graph plotted for Tapi river-Surat. Peak flood will occur after every eight years according to this method best suitable for Indian climate condition. The result of analysis shown in Graph no.4 and Table. No. 2.



Graph.3. Flood Probability by Well Weibulls Method



Graph.4. Flood Probability by California Method

Table.2 Probability Analysis by California Method, Hazen's Method and Well Weibulls Method

Sr. No.	P.F in descending order	Rank (m)	P.F in descending order	California Method		P.F in descending order	Hazen's Method		P.F in descending order	Well Weibulls Method	
				R.I= T=N/m	f=100/T %		T=n/(m*0.5)	f=1/t*100		T=(N+1)/m	f=1/T*100
1	15	1	15	15	6.666666667	15	30	3.333333333	15	16	0.000625
2	13.16	2	13.16	6.58	15.19756839	13.16	13.16	7.598784195	13.16	7.08	0.001412429
3	13.14	3	13.14	4.38	22.83105023	13.14	8.76	11.41552511	13.14	4.713333333	0.002121641
4	12.05	4	12.05	3.0125	33.19502075	12.05	6.025	16.59751037	12.05	3.2625	0.003065134
5	10.53	5	10.53	2.106	47.48338082	10.53	4.212	23.74169041	10.53	2.306	0.004336513
6	9	6	9	1.5	66.66666667	9	3	33.33333333	9	1.666666667	0.006
7	8.88	7	8.88	1.268571429	78.82882883	8.88	2.537142857	39.41441441	8.88	1.411428571	0.00708502
8	8.87	8	8.87	1.10875	90.19165727	8.87	2.2175	45.09582864	8.87	1.23375	0.00810537
9	8.58	9	8.58	0.953333333	104.8951049	8.58	1.906666667	52.44755245	8.58	1.064444444	0.009394572
10	8.56	10	8.56	0.856	116.8224299	8.56	1.712	58.41121495	8.56	0.956	0.010460251
11	7.99	11	7.99	0.726363636	137.6720901	7.99	1.452727273	68.83604506	7.99	0.817272727	0.012235818
12	7.58	12	7.58	0.631666667	158.3113456	7.58	1.263333333	79.15567282	7.58	0.715	0.013986014
13	7.36	13	7.36	0.566153846	176.6304348	7.36	1.132307692	88.31521739	7.36	0.643076923	0.015550239
14	7.22	14	7.22	0.515714286	193.9058172	7.22	1.031428571	96.95290859	7.22	0.587142857	0.01703163
15	6.89	15	6.89	0.459333333	217.7068215	6.89	0.918666667	108.8534107	6.89	0.526	0.019011407
16	6.62	16	6.62	0.41375	241.6918429	6.62	0.8275	120.8459215	6.62	0.47625	0.020997375
17	6.37	17	6.37	0.374705882	266.8759812	6.37	0.749411765	133.4379906	6.37	0.433529412	0.023066486
18	6.2	18	6.2	0.344444444	290.3225806	6.2	0.688888889	145.1612903	6.2	0.4	0.025
19	5.73	19	5.73	0.301578947	331.5881326	5.73	0.603157895	165.7940663	5.73	0.354210526	0.028231798
20	5.29	20	5.29	0.2645	378.0718336	5.29	0.529	189.0359168	5.29	0.3145	0.031796502

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21	5.15	21	5.15	0.245238095	407.7669903	5.15	0.49047619	203.8834951	5.15	0.292857143	0.034146341
22	4.94	22	4.94	0.224545455	445.3441296	4.94	0.449090909	222.6720648	4.94	0.27	0.037037037
23	4.9	23	4.9	0.213043478	469.3877551	4.9	0.426086957	234.6938776	4.9	0.256521739	0.038983051
24	4.81	24	4.81	0.200416667	498.960499	4.81	0.400833333	249.4802495	4.81	0.242083333	0.04130809
25	4.68	25	4.68	0.1872	534.1880342	4.68	0.3744	267.0940171	4.68	0.2272	0.044014085
26	4.56	26	4.56	0.175384615	570.1754386	4.56	0.350769231	285.0877193	4.56	0.213846154	0.04676259
27	4.55	27	4.55	0.168518519	593.4065934	4.55	0.337037037	296.7032967	4.55	0.205555556	0.048648649
28	4.32	28	4.32	0.154285714	648.1481481	4.32	0.308571429	324.0740741	4.32	0.19	0.052631579
29	4.01	29	4.01	0.138275862	723.19202	4.01	0.276551724	361.59601	4.01	0.172758621	0.057884232
30	3.98	30	3.98	0.132666667	753.7688442	3.98	0.265333333	376.8844221	3.98	0.166	0.060240964
31	3.89	31	3.89	0.125483871	796.9151671	3.89	0.250967742	398.4575835	3.89	0.157741935	0.063394683
32	3.81	32	3.81	0.1190625	839.8950131	3.81	0.238125	419.9475066	3.81	0.1503125	0.066528067
33	3.68	33	3.68	0.111515152	896.7391304	3.68	0.223030303	448.3695652	3.68	0.141818182	0.070512821
34	3.66	34	3.66	0.107647059	928.9617486	3.66	0.215294118	464.4808743	3.66	0.137058824	0.072961373
35	3.6	35	3.6	0.102857143	972.2222222	3.6	0.205714286	486.1111111	3.6	0.131428571	0.076086957
36	3.35	36	3.35	0.093055556	1074.626866	3.35	0.186111111	537.3134328	3.35	0.120833333	0.082758621
37	3.35	37	3.35	0.090540541	1104.477612	3.35	0.181081081	552.238806	3.35	0.117567568	0.085057471
38	3.32	38	3.32	0.087368421	1144.578313	3.32	0.174736842	572.2891566	3.32	0.113684211	0.087962963
39	3.3	39	3.3	0.084615385	1181.818182	3.3	0.169230769	590.9090909	3.3	0.11025641	0.090697674

Table.2 Probability Analysis by California Method, Hazen's Method and Well Weibulls Method – Continue

Sr. No.	P.F in de-scending order	Rank (m)	P.F in de-scending order	California Method		P.F in de-scending order	Hazen's Method		P.F in de-scending order	Well Weibulls Method	
				R.I= T=N/m	f=100/T %		T=n/(m*0.5)	f=1/t*100		T=(N+1)/m	f=1/T*100
40	3.3	40	3.3	0.0825	1212.121212	3.3	0.165	606.0606061	3.3	0.1075	0.093023256
41	3.17	41	3.17	0.077317073	1293.375394	3.17	0.154634146	646.6876972	3.17	0.101707317	0.098321343
42	3.1	42	3.1	0.073809524	1354.83871	3.1	0.147619048	677.4193548	3.1	0.097619048	0.102439024
43	3.09	43	3.09	0.071860465	1391.585761	3.09	0.14372093	695.7928803	3.09	0.095116279	0.105134474
44	3.09	44	3.09	0.070227273	1423.94822	3.09	0.140454545	711.97411	3.09	0.092954545	0.107579462
45	3.06	45	3.06	0.068	1470.588235	3.06	0.136	735.2941176	3.06	0.090222222	0.110837438
46	3.06	46	3.06	0.066521739	1503.267974	3.06	0.133043478	751.6339869	3.06	0.08826087	0.113300493
47	3	47	3	0.063829787	1566.666667	3	0.127659574	783.3333333	3	0.085106383	0.1175
48	2.91	48	2.91	0.060625	1649.484536	2.91	0.12125	824.742268	2.91	0.081458333	0.122762148
49	2.86	49	2.86	0.058367347	1713.286713	2.86	0.116734694	856.6433566	2.86	0.07877551	0.126943005
50	2.7	50	2.7	0.054	1851.851852	2.7	0.108	925.9259259	2.7	0.074	0.135135135
51	2.55	51	2.55	0.05	2000	2.55	0.1	1000	2.55	0.069607843	0.143661972
52	2.55	52	2.55	0.049038462	2039.215686	2.55	0.098076923	1019.607843	2.55	0.068269231	0.146478873
53	2.47	53	2.47	0.046603774	2145.748988	2.47	0.093207547	1072.874494	2.47	0.065471698	0.152737752
54	2.43	54	2.43	0.045	2222.222222	2.43	0.09	1111.111111	2.43	0.063518519	0.157434402
55	3.38	55	3.38	0.061454545	1627.218935	3.38	0.122909091	813.6094675	3.38	0.079636364	0.125570776
56	2.36	56	2.36	0.042142857	2372.881356	2.36	0.084285714	1186.440678	2.36	0.06	0.166666667
57	2.35	57	2.35	0.04122807	2425.531915	2.35	0.08245614	1212.765957	2.35	0.05877193	0.170149254
58	2.32	58	2.32	0.04	2500	2.32	0.08	1250	2.32	0.057241379	0.174698795
59	2.31	59	2.31	0.039152542	2554.112554	2.31	0.078305085	1277.056277	2.31	0.056101695	0.178247734

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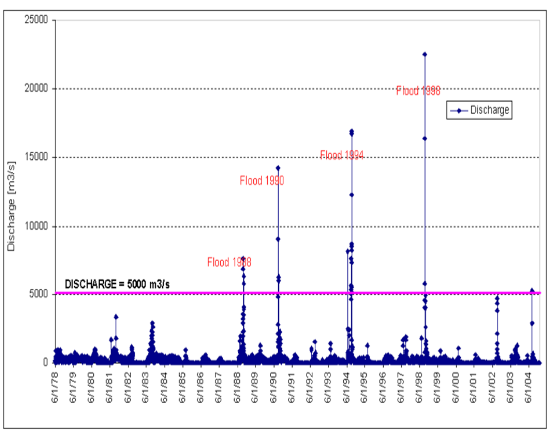
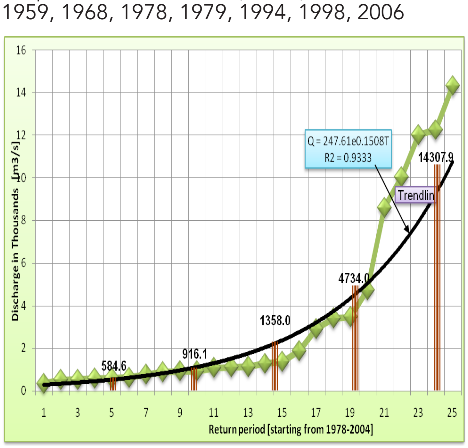
60	2.15	60	2.15	0.035833333	2790.697674	2.15	0.071666667	1395.348837	2.15	0.0525	0.19047619
61	2.15	61	2.15	0.035245902	2837.209302	2.15	0.070491803	1418.604651	2.15	0.051639344	0.193650794
62	2.12	62	2.12	0.034193548	2924.528302	2.12	0.068387097	1462.264151	2.12	0.050322581	0.198717949
63	2.08	63	2.08	0.033015873	3028.846154	2.08	0.066031746	1514.423077	2.08	0.048888889	0.204545455
64	1.84	64	1.84	0.02875	3478.26087	1.84	0.0575	1739.130435	1.84	0.044375	0.225352113
65	1.79	65	1.79	0.027538462	3631.284916	1.79	0.055076923	1815.642458	1.79	0.042923077	0.23297491
66	1.62	66	1.62	0.024545455	4074.074074	1.62	0.049090909	2037.037037	1.62	0.03969697	0.251908397
67	1.58	67	1.58	0.02358209	4240.506329	1.58	0.047164179	2120.253165	1.58	0.038507463	0.259689922
68	1.55	68	1.55	0.022794118	4387.096774	1.55	0.045588235	2193.548387	1.55	0.0375	0.266666667
69	1.33	69	1.33	0.019275362	5187.969925	1.33	0.038550725	2593.984962	1.33	0.033768116	0.296137339
70	1.12	70	1.12	0.016	6250	1.12	0.032	3125	1.12	0.030285714	0.330188679
71	0.66	71	0.66	0.009295775	10757.57576	0.66	0.018591549	5378.787879	0.66	0.023380282	0.427710843
72	0.5	72	0.5	0.006944444	14400	0.5	0.013888889	7200	0.5	0.020833333	0.48
73	0.5	73	0.5	0.006849315	14600	0.5	0.01369863	7300	0.5	0.020547945	0.486666667
74	0.5	74	0.5	0.006756757	14800	0.5	0.013513514	7400	0.5	0.02027027	0.493333333

Below Graph.5 Shows Flood Probability Analysis at Ghala Station No Lower Tapi Basin: Issues Experienced floods during 1959, 1968, 1978, 1979, 1994, 1998, 2006 i.e.1 in 8 years, Graph.6 shows Flood frequency analysis at Ghala gauge station: 27-years measured data shows good trend fit, R2 = 0.93 but, extreme values are not yet well captured. Thematic map based on Google-earth and IRS-1D prepared and same shown in Plate.2.



Graph.5 Flood Probability Analysis at Ghala - Floods during 1959, 1968, 1978, 1979, 1994, 1998, 2006



Graph.6 Flood frequency analysis at Ghala Gauge station

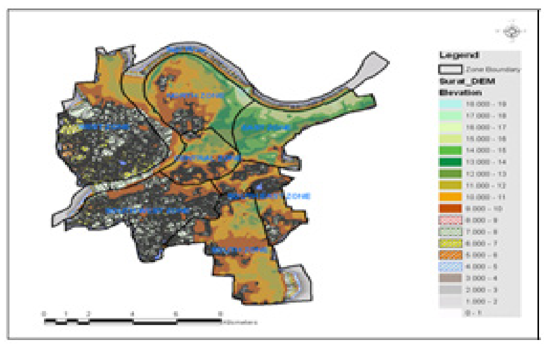


Plate.2 Thematic Map Based On Google-Earth and

IRS-1D Data

RESULTS & CONCLUSIONS

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 Weibulls method. Peak flood will occur after every eight years according to California method.

FLOOD FREQUENCY AT SELECTED STATIONS

The flood frequency analysis of the water level and discharge data analysis 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. Graph.5 shows the 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 1.0 Lac cusecs at every 17 years, 2.0 Lac cusecs at every 21 years and 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. 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. California method gives good agreement with observed peak flood years.

ACKNOWLEDGEMENT

I would like to express my specially thank to Dr. **A.S. Patel (Ph.D. GUIDE)** who is the main inspiration for me for this entire research work. It would not have been successfully completed without his unending support and encouragement.

Volume : 4 | Issue : 1 | Jan 2014 | ISSN - 2249-555X

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