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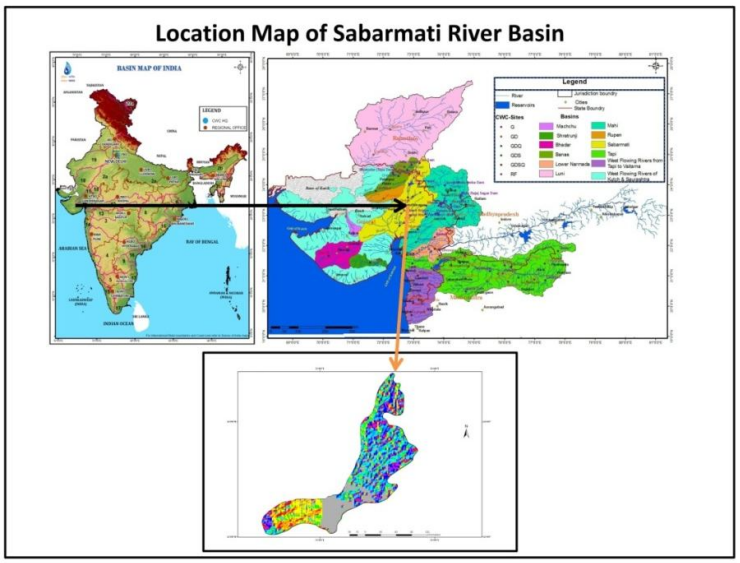
FLUVIAL FLOOD REGIME CHARACTERISTICS OF THE SABARMATI RIVER

Dr. Snehal Nivrutti Kasar
Kr. V.N. Naik Art's Com. & Sci. College, Nasik, Maharashtra, India.

1.1 INTRODUCTION

The flow of regime of the Sabarmati River is strongly controlled by the spatial- temporal distribution of the monsoon rainfall as the basin lies in the very heart of classic monsoonal region. As the other monsoon dominated river the Sabarmati also shows changes in the discharge characteristic from season to season as well as from year to year. A distinct average annual pattern of variation in discharge is observed for every river which can be well portrayed by annual hydrographs.



1.2 FLOOD REGIME CHARACTERISTICS

It is apparent from the above discussion that the monsoon regime plays an important role in determining the river regime conditions of the Sabarmati River. Further, data shows considerable year to year variation in the annual runoff. However, the usefulness of discharge regime characteristics and annual runoff conditions is limited for environmental and geomorphological purposes because it is based on monthly or ten-daily means, and water that leaves the drainage basin as stream flow or river discharge in a particular year. Most of the geomorphic work in seasonal tropics is accomplished by individual events, which are not adequately represented by monthly or ten-daily means or annual runoff. Studies on some large Indian rivers indicate that the channel forms and processes are related to very large, but relatively infrequent flood events (Goswami, 1985; Kale et al., 1994; Gupta, 1995a; Gupta

et al., 1999; Kale, 2003; Kale and Hire, 2004; Kale, 2007). Therefore, in the following section an attempt has been made to understand the magnitude, variability and frequency characteristics of individual high flow events or floods on the Sabarmati River, on the basis of available annual peak discharge data.

1.3 INTER ANNUAL VARIABILITY IN ANNUAL PEAK DISCHARGE

The Inter annual variability in annual peak discharges at five sites on the Sabarmati River illustrated in Fig. 1.1 to 1.5. All the graphs exhibit high inter annual variability in the annual peak discharges. The figures also show the occurrence of one or two extreme events during the gauge period at all the sites.

Wolman and Miller (1960) and several other workers have noted that as stream flow becomes more variable, an increasing proportion of the sediment load is carried by high discharges. In the Sabarmati Basin, since the variability is high, it appears that a large proportion of geomorphic work is accomplished by higher flows.

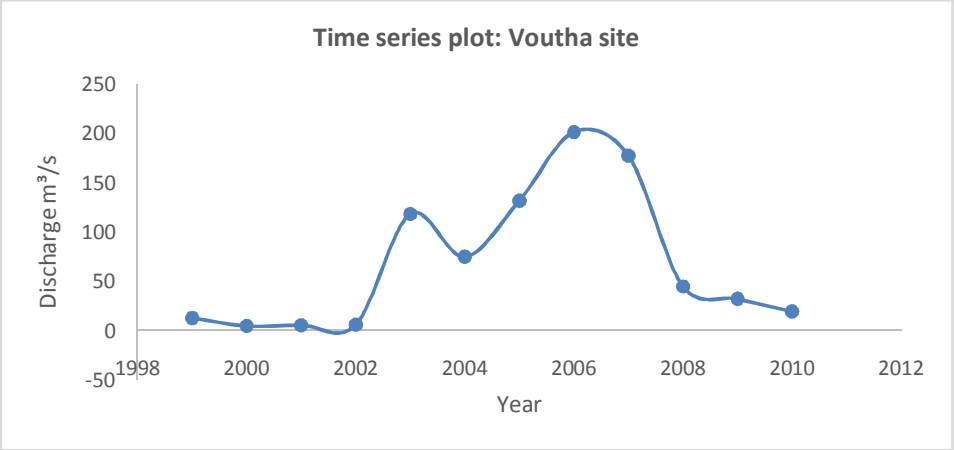


Fig. 1.1

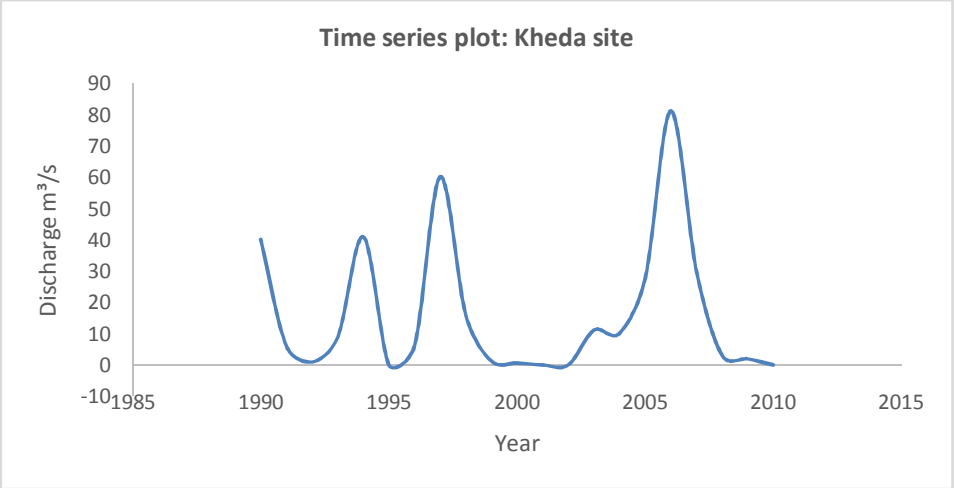


Fig. 1.2

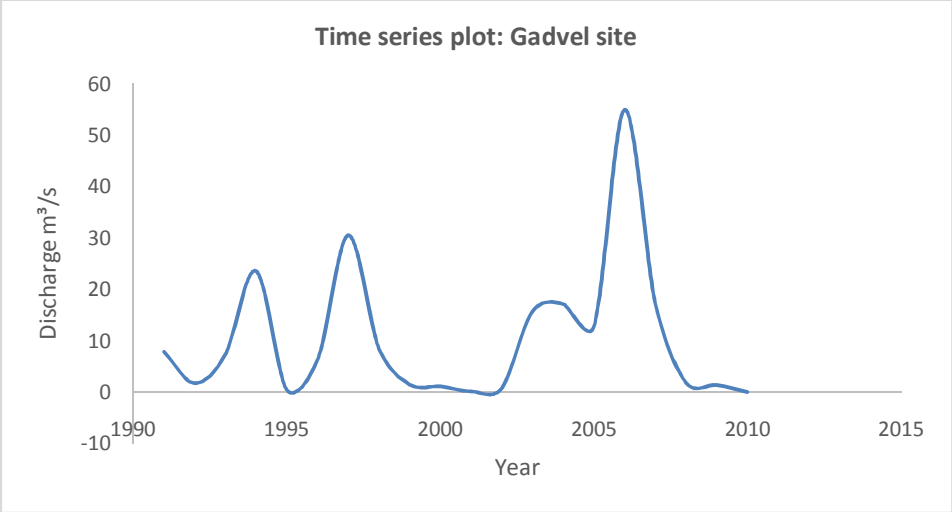


Fig. 1.3

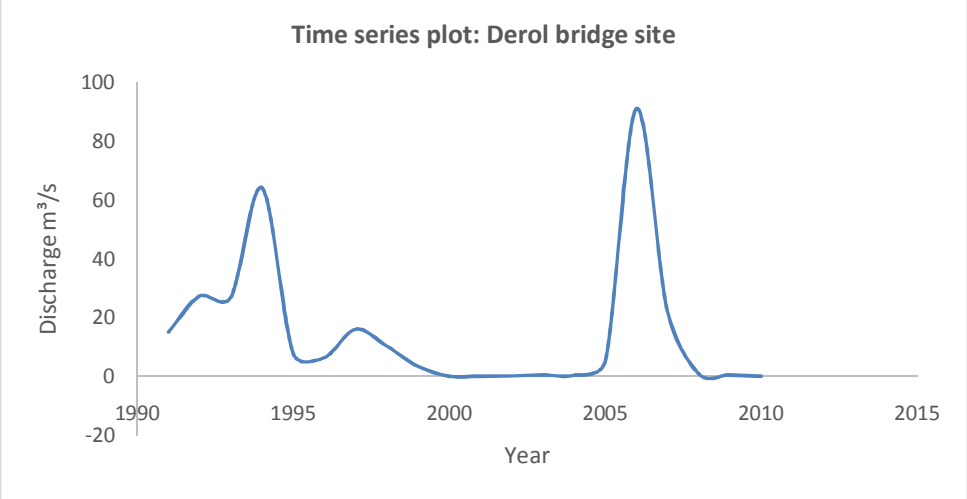


Fig. 1.4

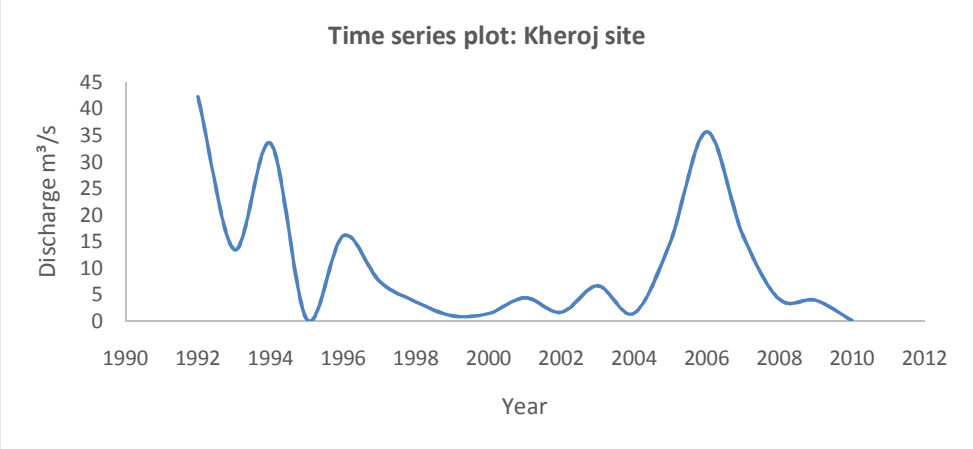


Fig. 1.5

1.4 AVERAGE MAGNITUDE AND VARIABILITY

The mean (Q_m) and range of annual peak discharges are given in the Table 2.1. By and large, the at-a-station range is high. An examination of the table also reveals that, contrary to the expectations, the Q_m value Ghala site is lower than the Q_m discharges at other upstream gauging stations.

According to Kochel (1988) floods that are likely to cause significant geomorphic change are those that produce discharges many times above the mean flows experienced by a river. This can be simply established by estimating the Q_{mx}/Q_m ratio. Table 1.1 shows that for most sites the Q_{mx}/Q_m ratio varies between 2 and 3. This indicates that maximum annual peak discharges (Q_{mx}) are 2 to 3 times higher than average peaks (Q_m). Since more variable the flow is, more important the higher discharges become (Wolman and Miller, 1960) and the effect of such extreme flows on geomorphic and environmental activity in channel is likely to be significant

Table 1.1 Flood flow characteristics of the Sabarmati River

Sr. No	River	Site	A km²	Record length	Qmin m³/s	Qmax m³/s	Qm m³/s	Flood range	Qmax / Qm
1	Sabarmati	Voutha	19636	12	4.87	201.59	69.19	196.72	2.91
2	Sabarmati	Kheda	7550	21	0.00	81.27	16.50	81.27	4.92
3	Sabarmati	Gadvel	-	20	0.00	54.84	10.52	54.84	5.21
4	Sabarmati	Derol bridge	6724	20	0.00	90.83	14.81	90.83	6.13
5	Sabarmati	Kheroj	3650	19	0.00	42.2	10.88	42.2	3.88

Data source: CWC; Qmin = Minimum annual peak discharge; Qmax = Maximum annual peak discharge; Qm = Mean annual peak discharge; A = Catchment area; See Fig. 1.1 for location of sites.

Table 1.2 Discharge characteristics of the Sabarmati River

Sr. `No.	River	Site	Record length	Qmax m³/s	Qm m³/s	σ	*Cv*	*Cs*	*Cs/Cv*
1	Sabarmati	Voutha	12	201.59	69.19	71.00	1.03	0.86	0.83
2	Sabarmati	Kheda	21	81.27	16.50	22.51	1.36	1.69	1.24
3	Sabarmati	Gadvel	20	54.84	10.52	13.59	1.29	2.09	1.62
4	Sabarmati	Derol bridge	20	90.83	14.81	23.63	1.59	2.36	1.48
5	Sabarmati	Kheroj	19	42.2	10.88	12.9	1.19	1.45	1.22

Data source: CWC; Qmax = Maximum annual peak discharge; Qm = Mean annual peak discharge; σ= Standard deviation; Cv= Coefficient of variation; Cs = Coefficient of skewness; See Fig. 1.1 for location of sites.

In addition to the Qmax/Qm ratio, the coefficient of variation (Cv) is another useful parameter of variability in the annual peak discharges. The Cv, which is the ratio between standard deviation and the mean, range between 1.35 and 1.91 (or 50 to 110%) (Table1.3). However, a comparison with other large Indian Rivers indicate that the variability in annual peak discharges in the Sabarmati Basin is in fact higher than elsewhere (Hire, 2000).

Several workers have used the Beard's flash flood magnitude index (FFMI) to evaluate the variability of flood frequency measured as an index of flood flashiness (Baker, 1977). The FFMI values are calculated from the standard deviation of logarithms of AMS as given below:

$$FFMI = \sqrt{\frac{\sum X^2}{N-1}} \quad .... \quad eqn\ 2.1,$$

Where $X = X_m - Q_m$, X_m = annual maximum event, Q_m = mean annual peak discharge, N = number of years of record (X, X_m, and Q_m expressed as logarithms to the base of 10).

The FFMI values of the Sabarmati River range between 1.35 and 1.91 (Table 1.3). The highest FFMI value in the Sabarmati Basin is 0.43, which is observed in Voutha and Kheda site. The mean FFMI value of the Sabarmati Basin is 0.32. This value is higher than the mean FFMI value of the world, which is 0.28 (Erskine and Livingstone, 1999). The relatively higher mean FFMI value of Sabarmati Basin indicates slightly flashy and variable nature of floods of the Sabarmati River than the average world rivers. The index further indicates that the possibility of the river experiencing significant geomorphic work and environmental impacts during large floods is higher.

Table 1.3 Flash flood magnitude indices of the Sabarmati River.

Sr. No.	River	Site	Record length	FFMI
1	Sabarmati	Voutha	12	1.35
2	Sabarmati	Kheda	21	1.91
3	Sabarmati	Gadvel	20	1.73
4	Sabarmati	Derol bridge	20	1.73
5	Sabarmati	Kheroj	19	1.62

Data source: CWC; FFMI = Flash flood magnitude index;

1.5 SKEWNESS

Skewness is one of the most commonly used moments in the flood hydrology and geomorphology. Since most of the AMS data are not normally distributed, it is important to find the skewness of the data. Therefore, the coefficient of skewness (CSk) of the AMS data has been calculated (Table 2.2). There are positive values of coefficient of skewness for rivers ranging from 0.86 to 2.36. The positive CSk values suggest the occurrence of one or two (or a few) very large magnitude flows during the gauge period. However, the characteristics of skewness are doubtful value when it is estimated from less than 50 year data (Viessman et al., 2008). Therefore, the ratio between skewness and coefficient of variation has also been used by some hydrologist to further to verify the degree of skewness (Shaligram and Lele, 1978). Most of the values of this ratio for different discharge gauging site in the study area do range from 0.83 to 1.62 (Table 2.2). For most large Indian rivers the ratio values are more than 2.0 (Shaligram and Lele, 1978). Therefore this suggests that distribution of peak discharges is not highly skewed in case of Sabarmati River.

1.6 UNIT DISCHARGES

Unit discharge is another useful measure of the potential of large floods on a river (Gupta, 1988). It is the ratio between maximum annual peak discharge (Qmax) and the upstream catchment area (A). It gives discharge (or water yield) per unit drainage area ($m^3/s/km^2$). The values of unit discharges calculated for each site in Gupta, A., 1988, large floods as geomorphic events in the humid tropics in V.R. Baker, R.C. Kochel and P.C.Patton (Eds), "Flood Geomorphology", Wiley, New York, pp. 301-315. The unit discharge for the river is ranging from 0.37 $m^3/s/km^2$ to 0.60 $m^3/s/km^2$ (Table 2.4). Table 2.4 reveals that most of the values of the unit discharges are below 1.0. The unit discharge of the Sabarmati Basin (0.60 $m^3/s/km^2$) which is higher than other Indian Rivers with comparable drainage areas (Hire, 2000). For instance, the unit discharges for the Pennar River (A = 55213 km^2) and Kaveri River (A = 81155 km^2) are 0.24 $m^3/s/km^2$ and 0.16 $m^3/s/km^2$ respectively.

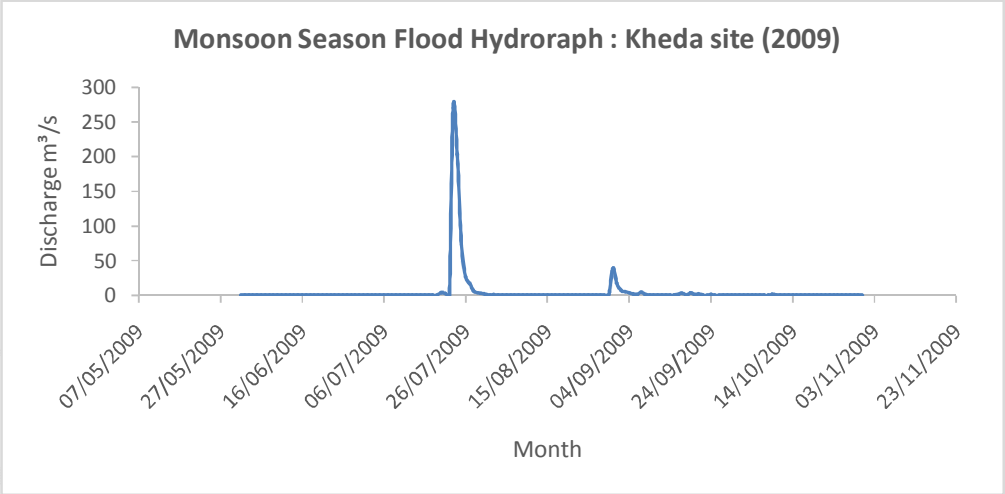
Table 1.4 Unit discharges of the Sabarmati River.

Sr. No.	River	Site	*A* km²	Qmax m³/s	Unit discharge m³/s/km²
1	Sabarmati	Voutha	19636	7201.6	0.37
2	Sabarmati	Kheda	7550	4507.51	0.60
3	Sabarmati	Gadvel	-	3732.15	-
4	Sabarmati	Derol bridge	6724	3079	0.46
5	Sabarmati	Kheroj	3650	1402	0.38

Data source: CWC; A = Catchment area; Qmax = Maximum annual peak discharge;

1.7 MONSOON SEASON HYDROGRAPH ANALYSIS

Mean annual hydrographs give an average picture, but the diurnal variations in discharge are insufficiently expressed by such graphs. Therefore, to get some idea about the nature of changes in the daily discharges during a year, annual hydrographs are prepared. However, data are not available for drawing annual hydrograph. But data on diurnal discharges for the monsoon season of the water year (2009) are available for Kheda site (Fig. 1.6) on the Sabarmati River. The monsoon season hydrograph (Fig. 1.7) clearly indicates that the period is characterized by multiple, short and sharp peaks. It is also interesting to note that the river flow is comparatively higher in the later part of the monsoon season. It is attributed to the contribution of base flow to the river channel. Such high peaks in the early monsoon season are geomorphologically important in terms of sediment transport. The concentrations of suspended sediment are usually high during the early monsoon season and fall as the wet season progresses (Hire, 2000, Kale and Hire, 2004). The graph reveals only one major peak flood of about 280 m³/s. Such floods have important implications in terms of hydrological impacts.



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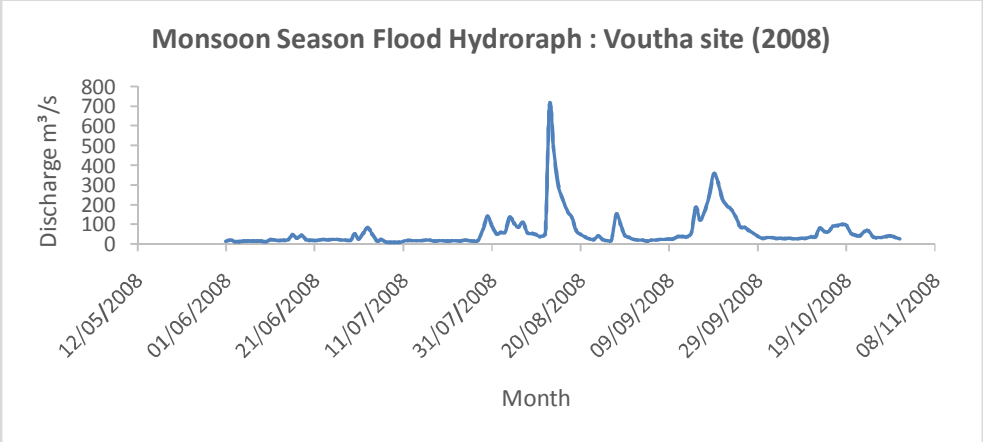

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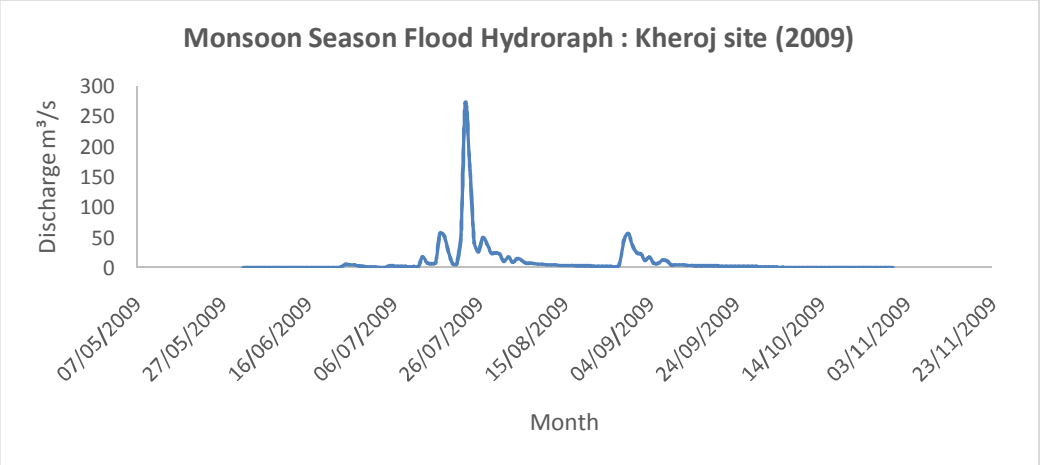

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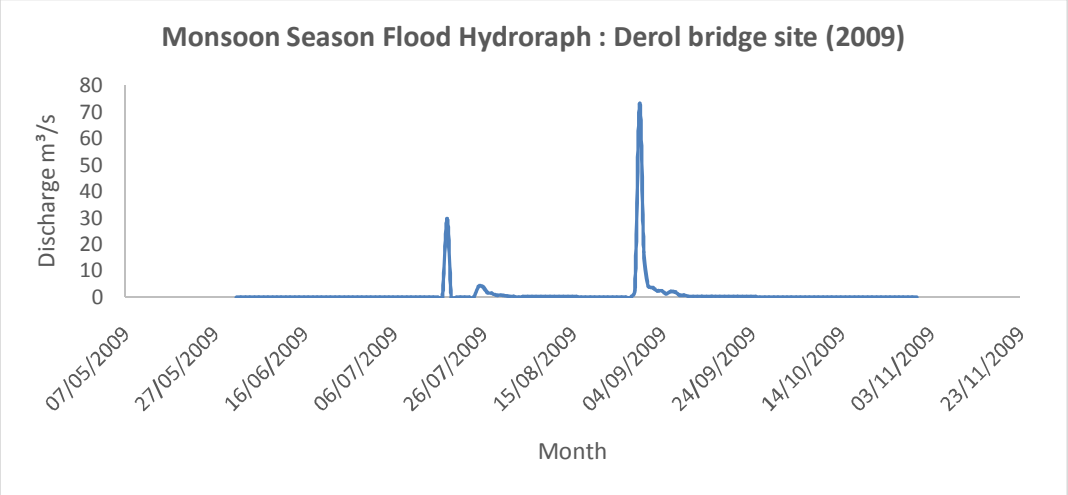

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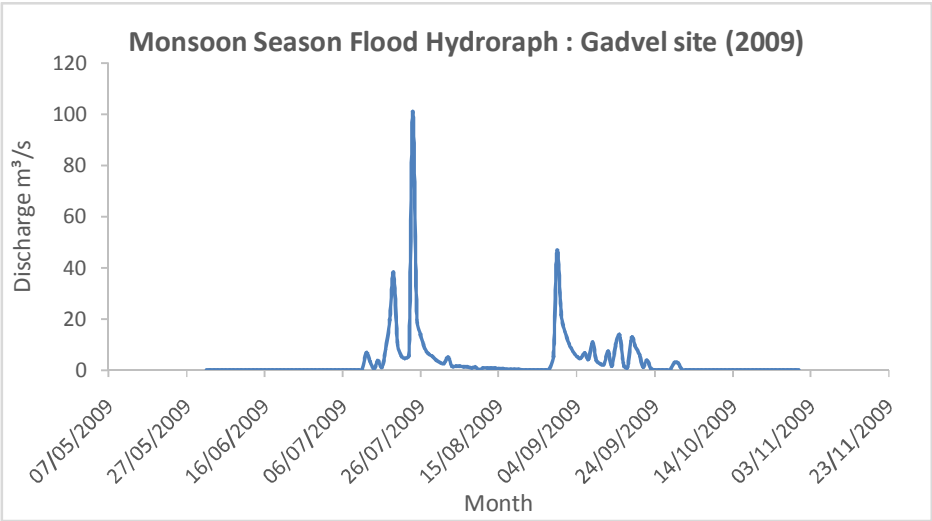

Fig. 1.10

1.8 CONCLUSION

Analyses of the mean annual flow pattern and the flood regime of the Sabarmati River through the analyses of stream flow data concludes following points.

1. The mean annual flow pattern reflects the seasonal rhythm of the monsoon rainfall. The highest peak occurs in early August. The Sabarmati River experiences average high discharge in the month of August and therefore maximum geomorphic work is accomplished in the same month.
2. High unit discharges indicate the high potential of floods in the Sabarmati River.
3. The monsoon season hydrograph clearly indicates that the period is characterized by multiple, short and sharp peaks. It is also interesting to note that the river flow is comparatively higher in the later part of the monsoon season.
4. During the August 2006 flood event, the flood peaks at different sites occur after 2-3 days from the time when discharge starts rising. Because it was same flood at all the sites, the duration of flood was from 5 to 6 days.

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