Application of Different Concepts to Estimate Dominant Discharge in the Gumti River of Bangladesh

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Abstract— Various methods have been proposed by different investigators for the choice of representative discharge which is very important in studying the river characteristics. This representative discharge is also referred to as dominant discharge in the literature and may be defined as that hypothetical discharge which would produce the same result in terms of average channel dimensions as the actual varying discharge. Moreover, dominant discharge produces maximum morphological activities for a regime channel. Estimation of the frequency of dominant discharge in the rivers is necessary for flood plain management. The determination of the dominant discharge is also very important for flood mitigation and estimation of flood damage. As a case study, different concepts (flow duration concept, bankfull discharge concept, bed generative discharge concept, meander wavelength concept) are adopted here for the computation of dominant discharge of the Gumti river of Bangladesh. In this study the frequency of dominant discharge of the Gumti River at Comilla was investigated and the dominant discharge was also determined. The flood discharge at particular station (Station ID-110) for 30 years had been analysed by collecting the data from BWDB (Bangladesh Water Development Board). The flood frequency analysis was used to find the return period of the dominant discharge in the Gumti River. It was found that the dominant discharge in the Gumti River at the above station has return period of around 1.005 years on partial series analysis. Finally, the dominant discharge for the Gumti River was found around 7000 cusec.

Index Terms— Bankfull stage, Dominant discharge, Gumti River, Meander wavelength, Rating curve, River morphology, Sediment load transport.

1 Introduction

The dominant discharge is the flow doing most geomorphic work and it is, therefore, the channel forming discharge. Determining the dominant discharge is very important for sedimentation problem in the river and it is also very useful for the riverine stabilization and fish habitats. Despite the importance of the dominant discharge, it is not yet completely determined for the existing rivers. Inglis (1949) defined that the dominant discharge in a natural stream is a discharge, representative of a whole range of discharges that pass through the channel and that forms the channel morphology. The dominant discharge is usually defined as; i) the most effective discharge for sediment transport. Benson and Thomas (1966) defined that the dominant discharge is the discharge which transports the most sediment transport in suspended load. Pickup and Warner (1976) defined the dominant discharge as the discharge that transports the sediment particles as the bed load. Andrew (1980) defined the dominant discharge as the discharge which transports the most sediment particles as total load. ii) The natural bankfull discharge or the discharge in a river which just fills the main channel and not overbanking the flood plains. iii) The dominant discharge is also defined as the discharge or a flood of fixed frequency such as 1-2 years flood and iv) it is defined as the discharge which exhibits the best statistical correlation with various channel morphological characteristics.

Dominant discharge was also studied by many researchers; for instance, Williams (1978) found that the dominant discharge is a bankfull discharge of approximately 1.5 years. Keshavarzi and Erskine (1995) and Erskine and Keshavarzy (1996) investigated that the dominant discharge on South Creek in New South Wales, in Australia has an average recurrence interval (ARI) of 1.89 to 2.40 years on the partial series. Valentine et al. (2001) studied regime theory and the stability of straight channels with bankfull.

For the rivers of Bangladesh, Hossain (1992) computed dominant discharge of the Ganges and Jamuna by bed generative discharge concept using the observed sediment discharge at Hardinge Bridge and Bahadurabad.

In this study, total sediment load transport was primarily used to estimate the dominant discharge. Here the frequency of dominant discharge of the Gumti River in Comilla was determined using 30 years of recorded flood discharge. The stage discharge curve and meander wavelength method were also used to find the dominant discharge.

2 Methodology

As a case study, different concepts (flow duration concept, bankfull discharge concept, bed generative discharge concept, meander wavelength concept) were adopted here for the computation of dominant discharge of the Gumti River. This river originates from Dumur in the North-eastern hilly region of Tripura state of India. From its source it flows about 150 km along a meandering course through the hills, turns west and enters Bangladesh near Katak Bazar (Comilla Sadar), shown in Fig. 1. Then it takes a meandering course again and passes

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through the northern side of Comilla town. The Gumti is about 135 km long within Bangladesh. It is a hilly river having a strong current in which flow varies from 100 to 20,000 cusec at Comilla. Flash floods are common phenomena of this river and it occurs at regular intervals.

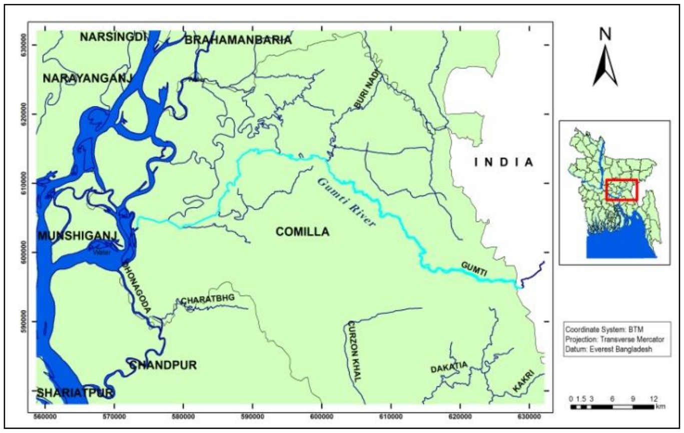

Fig 1: The Gumti River in Bangladesh

To estimate the dominant discharge, firstly a graphical relationship was established between discharge and the frequency of discharge. Then another graphical relationship was developed between flow discharge and sediment load discharge at the same station. Finally the two relationships were used to develop a third histogram which relates discharge and product of sediment load and frequency. The dominant discharge corresponds to largest volume of sediment discharge which can be read directly from the histogram.

The computed dominant discharge was compared to the discharge at bankfull stage using rating curve of that station. The Dury's method (1965) of dominant discharge using meander wavelength was also used. Meander wavelengths were measured from the satellite images by ArcGIS-10 software. To check the return period of dominant discharge, flood frequency analysis was applied to the 30 flood data at Comilla station. Water level and discharge data (1965-1994) and sediment data (1986-1993) of the above station were collected for this study from Bangladesh Water Development Board (BWDB).

3 Results and Discussions

3.1 Total Load Transport

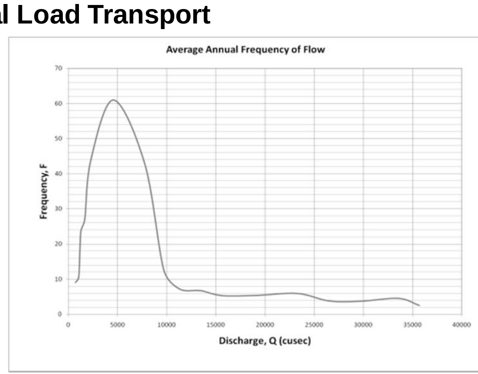

Fig 2: Discharge-Frequency relation of the Gumti at Comilla

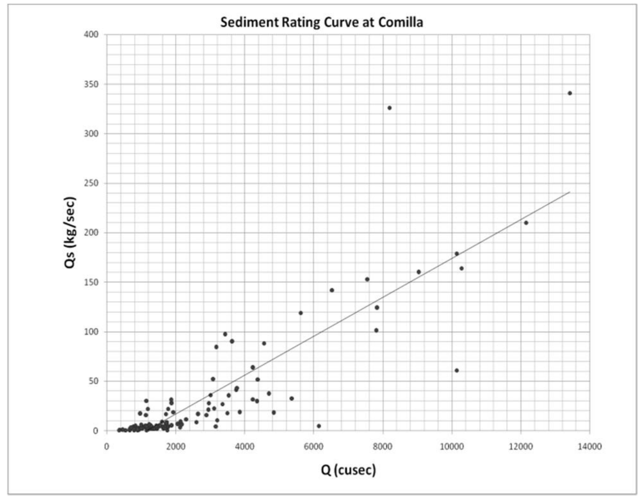

Fig 3: Relationship between discharge and total sediment load

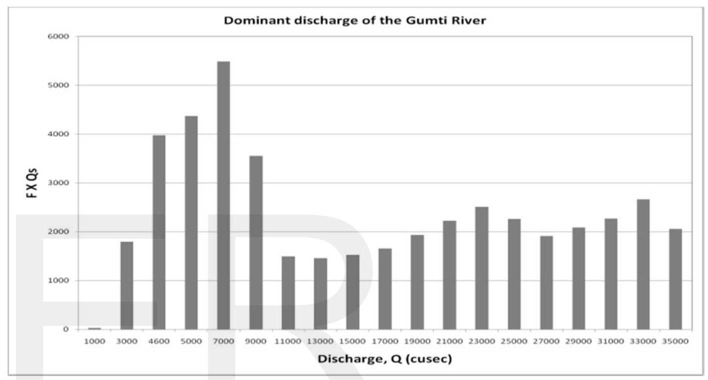

Fig 4: Dominant Discharge of the Gumti River at Comilla

Figure 2 to 4 show the steps involved in the estimation of dominant discharge as described earlier. From the histogram of Figure 4, the mode was identified which corresponds to the dominant discharge. According this concept, the bed generative discharge was found to be around 7000 cusec.

3.2 Stage-Dischage Curve

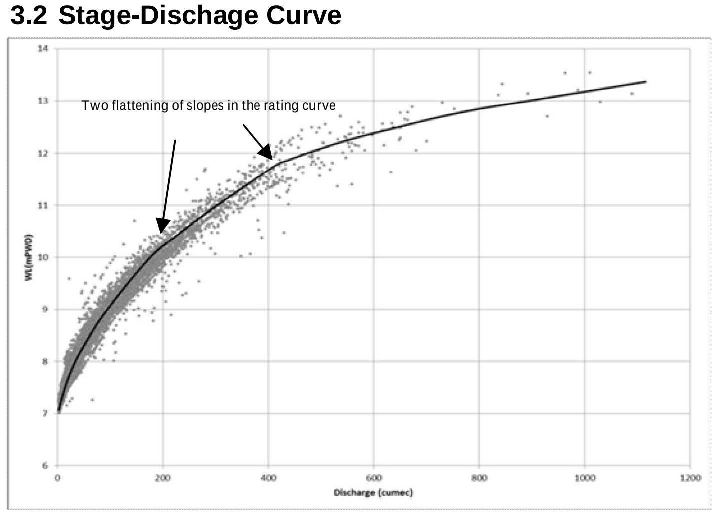

Fig 5: Rating curve for the Gumti River at Comilla

As mentioned previously, a definition of dominant discharge

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was equal to the bankfull discharge and in the stage discharge curve it is the point at which the rating curve exhibits an abrupt flattening in slope. When discharge increases beyond the effective flow, water begins to spill over the bank tops at more and more locations. The effective discharge should be compared to the bankfull discharge. This can be accomplished as well by identifying the bankfull stage during stream reconnaissance of the project reach and calculating the corresponding discharge.

It is to be mentioned that, the left bank of the river section at Comilla is around 2 m higher than that of right bank. Because of this reason, stage-discharge relation at this station represents a 3-stage rating curve. However, for the consideration of dominant discharge, discharge corresponds to the lower bank level was taken here rather than the discharge corresponds to average bank level. From the rating curve of Gumti River at Comilla station, the flow for bankfull level was found to be around 200 m^3/s or 7000 cusec, shown in Figure 5.

3.3 Meander Wavelength

Meander wavelength varies with the square root of bankfull discharge and any empirical relationship between wavelength (L) and bankfull discharge (Q_{bf}) may be statistical rather than causal (Dury, 1965). Wolman and Leopold (1957) concluded that bed width is determined directly by discharge, whereas wavelength depends directly on width and thus only indirectly on discharge. Then;

$L = K.q^b$ (1)

Where L is meander wavelength, q is dominant discharge, K is coefficient and b is the exponent. The above parameters are in FPS unit.

Inglis (1949) found following relationship:

$L = $ □$36q^{0.5}$ (2)

Dury (1965) used a very large data set and found that

$L = 30q^{0.5}$ (3)

The above relationship was applied to the meander wavelength in the Gumti River. The numbers of selected bends were 28 and the average meander wavelength (L) was 2590.614 ft (Table 1). Therefore, bankfull discharge calculated by the Dury's method (equation 3) was found to be 7456.98 cusec. This discharge agrees closely with the discharge which was determined from stage discharge curve.

TABLE1
BEND NUMBER ALONG WITH THEIR MEANDER WAVELENGTH

Bend No.	Wavelength(ft)	Bend No.	Wavelength(ft)
1	5638.32	15	2689.6
2	3365.28	16	2574.8
3	3030.72	17	2079.52
4	2236.96	18	1813.84
5	2076.24	19	1853.2
6	2017.2	20	1764.64
7	2486.24	21	2948.72
8	1918.8	22	4569.04
9	1354.64	23	4496.88
10	2643.68	24	2407.52
Bend No.	Wavelength(ft)	Bend No.	Wavelength(ft)
11	1403.84	25	2030.32
12	1256.24	26	3972.08
13	1623.6	27	3873.68
14	2168.08	28	2243.52

3.4 Flood Frequency Analysis

Wolman and Leopold recommended that bankfull discharge has an Average Recurrence Interval (ARI) of 1-2 years ($Q_{bf} = Q_{1\text{-}2years}$) on the annual series. Dury (1965) suggested that bankfull discharge is a discharge with ARI of 1.58 years or $Q_{bf} = 0.97Q_{1.58}$.

30 largest floods were selected for the flood frequency analysis in this study. Here the following probability distributions were used to determine the best probability frequency of the data.

1. Gumbel distribution function
2. Log-Normal distribution function
3. Log-Pearson distribution function

With the comparison of the Chi-square value, it was found that the best fitted frequency distribution to the data was Log-Pearson as it gives lowest value in Chi-square test. Therefore, the annual exceedence probability (AEP) of dominant discharge in Gumti River was found using Log-Pearson distribution.

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TABLE 2
RESULTS OF FLOOD FREQUENCY ANALYSIS

Type of Distribution	Chi-square Value
Gumbel distribution function	3.1852
Log-Normal distribution unction	3.1852
Log-Pearson distribution function	2.8148

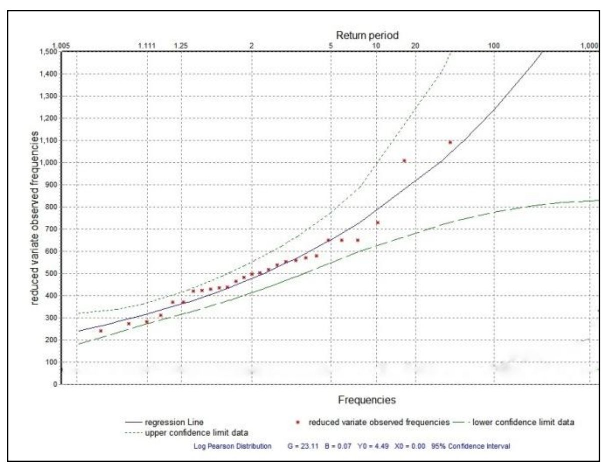

Fig 6: Flood frequency analysis

From the previous analysis, the value of bankfull discharge was found to be around 7000 cusec or 200 m^3/s. This agrees closely with the bankfull discharge and characteristic discharge which is determined from meander wavelength. Therefore the ARI of dominant discharge for the Gumti River was

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found from the Log-Pearson distribution and it was 1.005 years.

4 Conclusion

To predict the morphological changes of the alluvial river, the computation of the changes due to widely varying discharge is difficult. Although the use of a single discharge for the computation of the changes in the entire river regime may be questionable, but still, dominant discharge offers the advantage to correlate the average channel characteristics and help designing channel protection works. In this work, the bed generative discharge along with rating curve methods were used to determine dominant and bankfull discharge in the Gumti River. It was found that the average value of dominant discharge for the Gumti River at Comilla station may be taken to be 7000 cusec which has an ARI of 1.005 year.

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