Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), 7~9 February 2020, KUET, Khulna, Bangladesh (ISBN-978-984-34-8764-3)

ASSESSMENT OF ENVIRONMENTAL FLOW REQUIREMENT OF TEESTA RIVER BY HYDROLOGICAL METHODS

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ABSTRACT

Teesta River is one of the many transboundary rivers shared between India and Bangladesh. It is an important river for both India and Bangladesh. However, the river has also been an issue of debate between the two nations. Due to construction of a number of dam and barrages, the natural flow of the river has been highly utilized, diverted and controlled. But as the river is a transboundary river, it has never been easy to come to a satisfactory conclusion as to how much flow must be maintained in the river. Therefore assessment of environmental flow for Teesta River is of great importance not only for better negotiation but also to maintain the riverine ecosystem properly.The study assesses environmental flow of Teesta River by three hydrological methods- Tennant method, Flow Duration Curve method and Constant Yield method. The environmental flow is measured at Dalia station and Kaunia station which are upstream and downstream of Teesta barrage respectively. Therefore, the study aims at recommending a flow that has to be maintained upstream of the barrage and also to set recommendation of how much water must be maintained in the river downstream of the barrage. It should also be mentioned that in the study low flow period was considered from November to April and high flow period was considered from May to October. At Dalia, according to Tennant method environmental flow requirement was found to be 151 cumec (for good habitat quality) for the months of low flow. On the other hand, for high flow months environmental flow was found to be 302 cumec (good habitat quality) at Dalia. At Kaunia, EFR is 162 cumec (good habitat quality) and 324 cumec (outstanding habitat quality) for the low flow month. Again for high flow months at Kaunia EFR for good is 324 cumec. In flow duration curve method, the requirement range changed to 5 to 160 cumec for low flow and 422 to 1912 cumec for high flow at Dalia. For Kaunia it was found to be 10 to 314 cumec for low flow and 462 to 2111 cumec for high flow months. For constant yield method the requirement was found to be 41 to 284 cumec (low flow period)and 369 to 1844 cumec (high flow period) for Dalia. 81 to 307 cumec (low flow period) and 408 to 1940 cumec (high flow period) for Kaunia. In the study it was found that the prevailing flow is sufficient in high flow season (May to October) to meet the requirement derived by tenant and constant yield method. However in low flow season (November to April) the prevailing flow is found to be insufficient according to Tennant method.

As Tennant method is the common and accepted method for EFR assessment and low flow period is the main concern, the requirement found from the study can be stated as 151 cumec at Dalia and 162 cumec at Kaunia.

Keywords: *EFR, Hydrological method, Tennant method, Flow duration curve, Constant yield method.*

1. INTRODUCTION

1.1 Background:

Bangladesh is a riverine country. A network consisting of around 800 rivers flow through this land. Bangladesh Water Development Board (BWDB) has numbered 405 rivers, among which 57 are transboundary rivers. Bangladesh shares 54 transboundary rivers with India and 3 with Myanmar.

Teesta is one of the 57 transboundary rivers of Bangladesh. It originates in India and then crosses the India-Bangladesh border to meet Brahmaputra River at Kurigram district in Bangladesh. It is numbered as 52 number north-western river by Bangladesh Water Development Board.

Total length of the Teesta is about 315 km of which about 113 km falls inside Bangladesh (http://en.banglapedia.org/index.php?title=Tista_River). The river Teesta is one of the main Himalayan rivers and originates from the glaciers of Sikkim in North at an elevation of about 5,280 m (CISMHE, 2006). The glacial lake is located at the tip of the Teesta Khangse glacier, which descends from Pauhunri peak. The river rises in mountainous terrain in extreme north as Chhombo Chhu, which flows eastward and then southward to be joined by Zemu Chhu, upstream of Lachen village near Zema. The river takes a gentle turn in southeast direction and meets Lachung Chhu at Chungthang where it takes the form of a mighty Himalayan river. After the confluence of Teesta River and Lachung Chhu at Chungthang, the river gradually widens and takes a strong westward turn upstream of Tong and after flowing down to Singhik, the river drops from 1,550 m to 750 m (CISMHE, 2006).. The map of catchment area is shown in the Figure 1.1

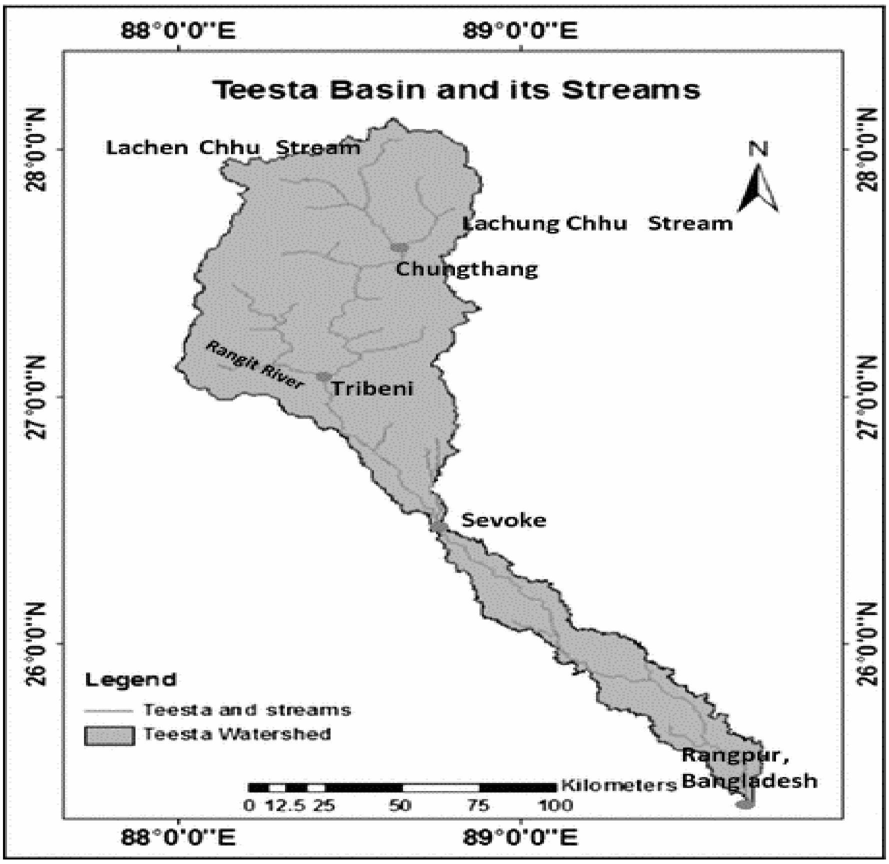


Figure 1.1: Map of catchment area of Teesta River

Teesta is an important river for both India and Bangladesh. Both the governments have created numerous structures and have proposed several projects throughout the years to utilize the water for irrigation and power generation. The large scale construction of dams in this area has been controversial.

One of the major two projects undertaken are Teesta Barrage at Gozaldoba, Jolpaiguri in West Bengal, India and Teesta barrage at Dalia situated in Lalmonirhat district, Bangladesh.

The water in Teesta has been regulated in India through the construction of irrigation barrage at Gozaldoba in 1987. Afterwards another irrigation barrage was established by Bangladesh at Dalia-Doani point in Lalmonirhat district in 1990 to supply water to Teesta Irrigation Project (TIP).

1.2 Study Area

The study focuses on determining the environmental flow for Teesta River which lies in Bangladesh portion (Figure 1.2). The river enters into Bangladesh at Dahagram village in Lalmonirhat and joins Brahmaputra (Jamuna) River near Chilmari Upazilla of Kurigram district (extending from 88055’40” E, 26018’N to 89038’59” E,2501’10” N)

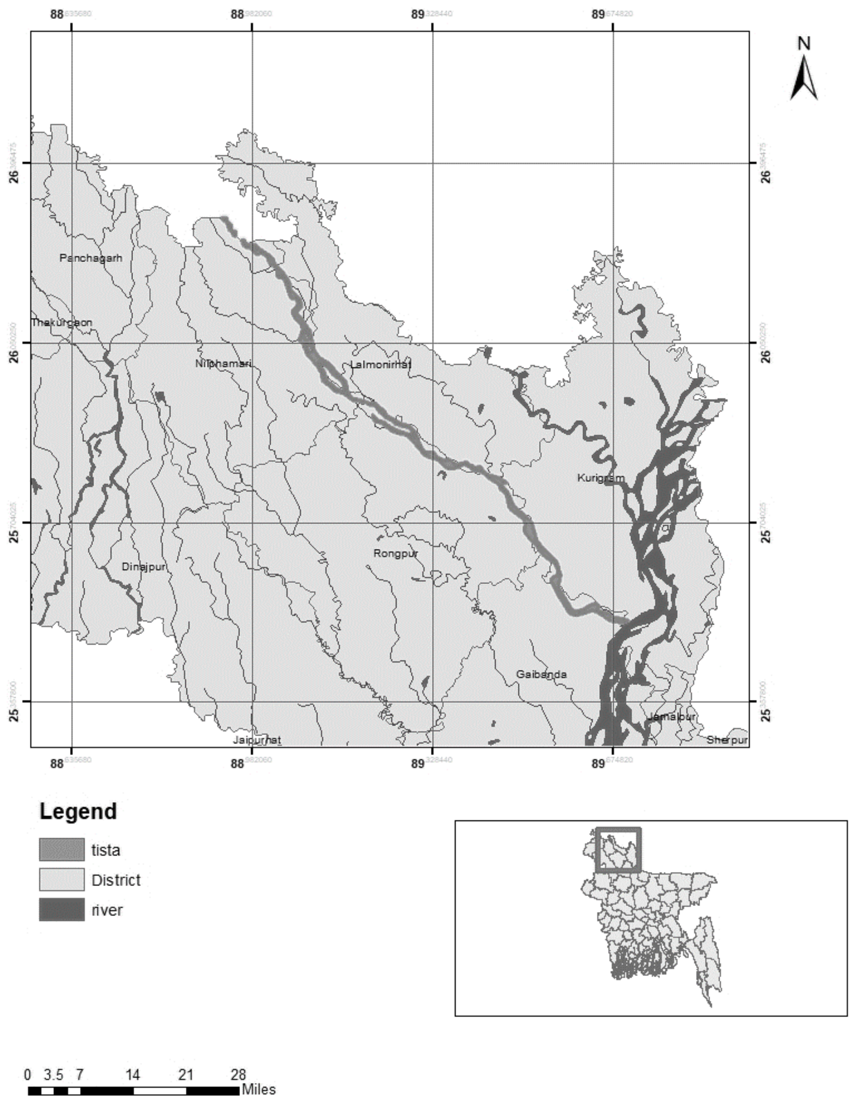


Figure 1.2: Location map of Teesta River in Bangladesh

Teesta River is the life line of the drought prone area of northern Bangladesh. It has always been at the centre point of the riverine ecosystem of the northern side of the country. However, subsequent construction of upstream structures, specially Gozaldoba and Dalia barrage, has drastically reduced its flow during dry period. Therefore, assessment of Teesta River environmental flow has been an important issue.

2. METHODOLOGY

2.1 Study Approach

Study approach is shown in figure 2.1

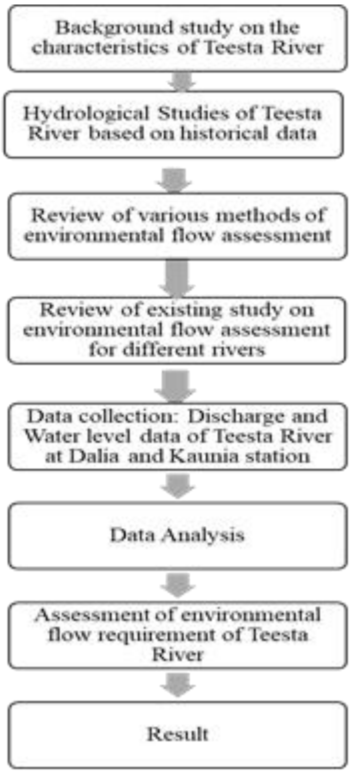


Figure 2.1: Study approach

The study approach is simple and sequential. To assess the environmental flow background study of the Teesta River characteristic (including physical and hydrological) is carried out. There are numerous ways of assessing environmental flow of a river. So to decide an appropriate method of environmental flow assessment for Teesta river, a literature review of various studies is performed. Finally through data analysis, environmental flow requirement is assessed according to the selected methods.

2.2 Data collection

Data has been collected from Bangladesh Water Development Board (BWDB) for the station Dalia and Kaunia. Dalia station is located upstream of Teesta barrage in Lalmonirhat district and Kaunia station is located downstream of the barrage in Rangpur. The distance between the two stations is about 70 km

2.3 Methods of Environmental Flow Assessment

As stated before, there are several methods used in determining environmental flow. In this study three hydrological methods have been used. They are:

1. Tennant Method
2. Flow duration Curve Method
3. Constant Yield Method

Tennant Method

According to Tennant method, required flow is a percentage of the mean annual flow of a river. For different habitat conditions (i.e. Flushing, excellent, good, etc.), the required flow varies from 10% to 200% of mean annual flow. Tennant method also uses different percentage of mean annual flow for low flow period and high flow. Tennant method is based on the reasoning that mean annual flow represents flow which has sustained the habitat of the flora, fauna and human activities of the river for several years and hence various percentage of the mean annual flow can be used to determine environmental flow requirement. Table 2 shows Tennant's recommendation for environmental flow to support varying qualities of fish habitat.

Table 2: Percentage of MAF for various habitat quality (Source: Bari and Marchand, 2006)

Habitat Quality	**Percent of Mean Annual Flow (MAF)**	
	Low Flow Season	**High Flow Season**
Flushing or maximum	200	200
Optimum	60-100	60-100
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair	10	30
Poor	10	10
Severe degradation	<10	<10

Flow Duration Curve Method

Flow duration curve method is another hydrological method. In this method environmental flow requirement is determined by observing the discharge and the percentage of time it is exceeded. In this method flow exceedance percentage is computed for each moth from the period 1985 to 2016. For months of high flow season, flow greater or equal to 50th percentile flow is recommended. For low flow season the recommendation is set at 90th percentile flow. Here 50th percentile flow refers to the flow which is exceeded 50% of the time. In other words, it is the value of discharge which is likely to occur or exceeded 50% of the time. Similarly, 90th percentile flow refers to flow which has 90% probability of occurring or exceeding.

In this study, flow duration curve for each month has been obtained using mean monthly discharge data from the years 1985 to 2016 of Dalia and Kaunia station. From there the 90th percentile flow is recommended for low flow season extending from the months of November, December, January, February, March, April. For high flow months (which includes May, June, July, August, September, October) 50th percentile flow is set as recommended discharge.

Constant Yield Method

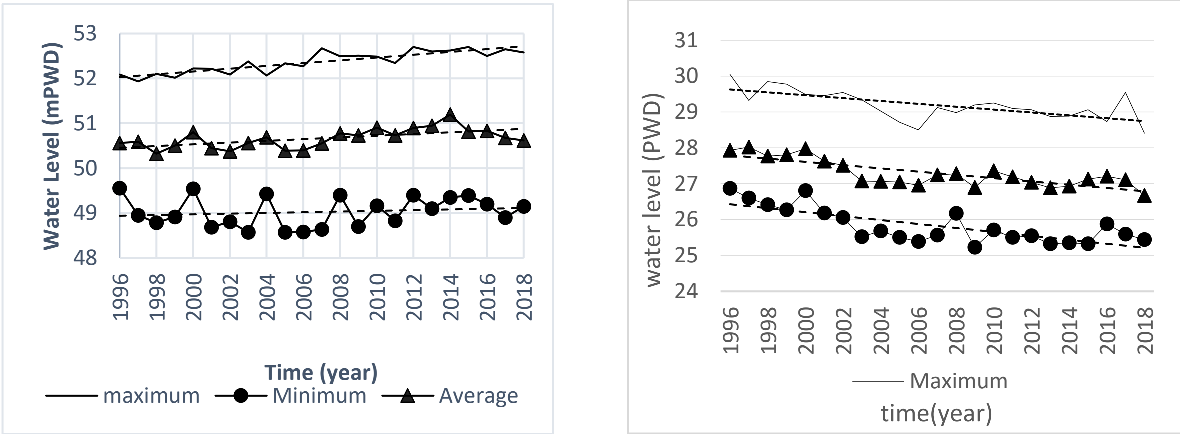
In constant yield method, recommended flow is set at 100% of median flow of each month. For this purpose, the median flow for each month has been computed for each year from 1985 to 2016. Hence median monthly flow of each month was obtained and set as required environmental flow.

3. DATA ANALYSIS AND RESULTS

3.1 Flow characteristics of Teesta

Hydrological characteristics for Teesta River has been analysed from the years 1985 to 2016 based on data collected from Dalia and Kaunia station. Maximum, minimum and average discharge and water level variation has been analyzed from the collected data. In the following figures the variation has been shown graphically.

Water level: The variation of maximum, minimum and average water level from the years 1996 to 2018 have been shown in figure 3.1(a) and 3.1(b) for both the location Dalia and kaunia. The water level has not significantly decreased or increased over the years. From the figure it is clear that water level at Dalia is greater than Kaunia in general. Water level in Dalia varied from approximately 48 to 53 mPWD whereas in Kaunia water level was between the range 25 to 30 mPWD. Another observation is that at upstream of Teesta barrage, water level is rising. The trend lines shown in Figure 4.1 (a) all have a positive slope and denote an overall increasing tendency of water level. However, the opposite scenario seems to be present at Kaunia. The water level here seems to have a declining trend, as shown in figure 4.1(b).

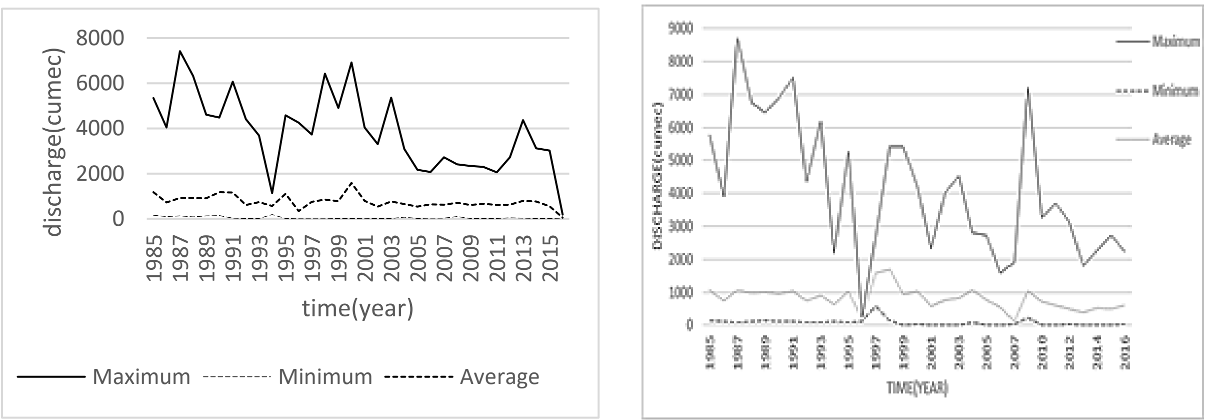


(a) (b)

Figure 3.1: Maximum, minimum and average water level at (a) Dalia station upstream of Teesta Barrage and (b) Kaunia station downstream of Teesta Barrage

The discharge at Dalia and Kaunia station has also been analyzed as maximum, minimum and average over the years 1985 to 2016. For Dalia, it is observed that the maximum value has been gradually decreasing since 2003 and the minimum value has also decreased drastically from1996 to 2003. After that the minimum flow values have increased. But overall the minimum flow is on the decreasing trend Maximum flow occurs during high flow season and minimum flow for any year occurs during low flow season. Therefore, it is observed that irrespective of whether the season is of high flow or low flow, flow is on the decreasing trend. Highest value of maximum discharge at Dalia is found to be 7420 cumec and lowest value of minimum flow is .20 cumec.

For Kaunia it is also seen that maximum, minimum and average flow for any year is also on the decreasing tendency. Similar to Dalia, it is also seen that minimum value of flow was drasctically decresed from 1999 to 2003. Highest value of maximum discharge at Dalia is found to be 8710 cumec and lowest value of minimum flow is 4.49 cumec. Hence it can be said that discharge at Kaunia seems to be higher than discharge at Dalia although water level at Kaunia is comparatively lower. The analysis has been shown in the figure 3.2 (a) to figure 3.2 (b).



(a) (b)

Figure 3.2: Maximum, minimum and average discharge over the years 1985 to 2016 at (a) Dalia upstream of Teesta Barrage and (b) Kaunia station downstream of Teesta barrage.

3.2 Environmental Flow Requirement (EFR) of Teesta River

Environmental flow requirement has been assessed at Dalia (upstream of Teesta Barrage) and Kaunia (Downstream of Teesta Barrage). The requirement was estimated using hydrological methods which include – Tennant method, flow duration curve method and constant yield method. The acquired environmental flow requirements using these three methods have been tabulated in the following sections.

Tennant Method: Using different percentage of mean annual flow for different habitat quality, environmental flow requirement has been computed at Dalia and Kaunia. In the study, good and outstanding habitat quality is taken under consideration. For good and outstanding habitat quality the results from this method is given in Table 3.1

Table 3.1: Environmental flow requirement at Dalia and Kaunia station using Tennant method

Station: Dalia		
Environmental Flow requirement (cumec)		
Habitat Quality	Low flow Season	High Flow season
Good	151	302
Outstanding	302	454
Station: Kaunia		
Environmental Flow requirement (cumec)		
Habitat Quality	Low flow Season	High Flow season
Good	162	324
Outstanding	324	486

Flow Duration Curve Method: Environmental Flow requirement from flow duration curve has been tabulated in the following Table 3.2

Table 3.2: Environmental flow requirement at Dalia and Kaunia station using flow duration curve method

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Flow season	Low	Low	Low	Low	High	High	High	High	High	High	Low	Low
Station: Dalia												
EFR (cumec)	6	5	6	41	422	1231	1912	1761	1452	671	160	23
Station: Kaunia												
EFR (cumec)	33	15	10	50	462	1133	2111	1925	1436	785	314	211

Constant Yield Method: Environmental Flow requirement from flow duration curve has been tabulated in the following Table 3.3

Table 3.3: Environmental flow requirement at Dalia and Kaunia station using constant yield method

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Flow season	**Low**	**Low**	**Low**	**Low**	**High**	**High**	**High**	**High**	**High**	**High**	**Low**	**Low**
Station: Dalia												
EFR	95	41	53	162	369	1149	1844	1777	1386	670	284	170
Station: Kaunia												
EFR	141	81	106	192	408	1140	1940	1867	1411	712	307	208

3.3 Comparison between environmental flow requirement (EFR) and flow availability

Environmental flow requirement has been assessed for Dalia station and Kaunia Station as stated earlier. In this section of the study, the determined environmental flow is compared with flow that is currently present in the river. For this purpose, the determined environmental flow requirement from various methods has been compared against the mean monthly flow of each month for both stations.

Dalia Station: In Table 3.4 and Figure 3.3 (a) comparison between computed EFR using various methods and available flow has been shown. It is seen that available flow is higher than the required environmental flow according to Constant yield method. Available flow is also sufficient enough to meet the requirement for good and outstanding habitat quality in high flow season according to Tennant Method, however it is not sufficient in low flow season for either of the habitat qualities. On the other hand, according to flow duration curve method, the available flow fails to exceed EFR in high Flow season but is sufficient in low flow season.

Table 3.4: Comparison of computed environmental flow requirements by different methods with available flow (Dalia Station)

Month	Flow season	Environmental Flow requirement (cumec)				Available flow (cumec)
		Tenant Method		Flow Duration Curve Method	Constant Yield Method	
		Good Habitat Quality	Outstanding Habitat Quality			
January	Low	151	302	6	95	107
February	Low	151	302	5	41	78
March	Low	151	302	6	53	106
April	Low	151	302	41	162	239
May	High	302	454	422	369	443
June	High	302	454	1231	1149	1317
July	High	302	454	1912	1844	1988
August	High	302	454	1761	1777	1897
September	High	302	454	1452	1386	1488
October	High	302	454	671	670	772
November	Low	151	302	160	284	311
December	Low	151	302	23	170	181

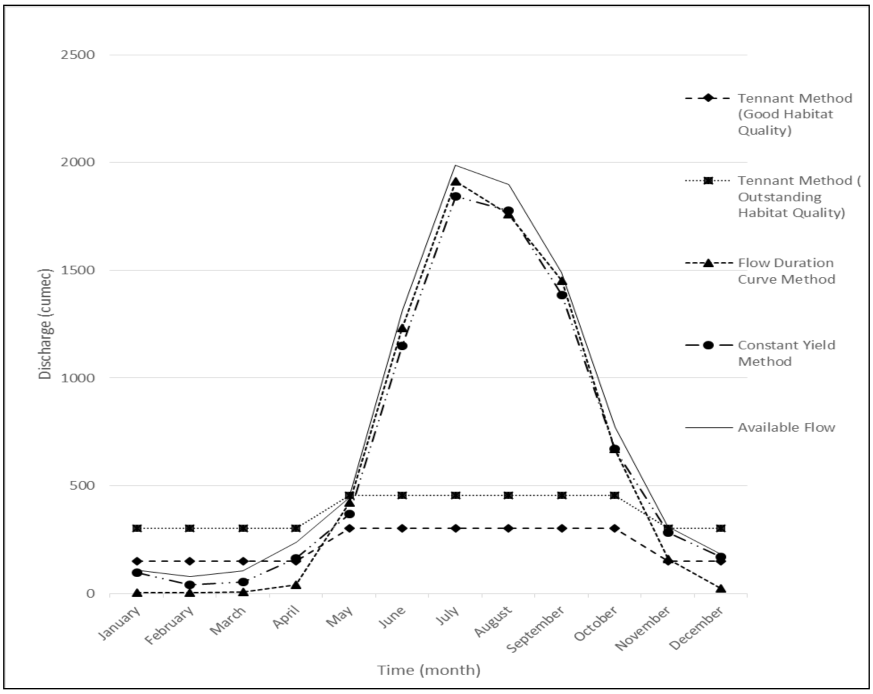


Figure 3.3 (a): Comparison of computed environmental flow requirements with available flow at Dalia Station

Kaunia Station: In Table 3.5 and Figure 3.3(b) comparison between computed EFR using various methods and available flow has been shown for Kaunia Station. In Table 4.8 and Figure 4.7 comparison between computed EFR using various methods and available flow has been shown. It is seen that available flow is higher than the required environmental flow according to Constant yield method and Flow Duration Curve method. Available flow is also sufficient enough to meet the requirement for good and outstanding habitat quality in high flow season according to Tennant Method, however it is not sufficient in low flow season for either of the habitat qualities which similar to the observation made in Dalia station.

Table 3.5: Comparison of computed environmental flow requirements by different methods with available flow (Kaunia Station)

Month	Flow season	Environmental Flow requirement (cumec)				Available flow (cumec)
		Tennant Method		Flow Duration Curve Method	Constant Yield Method	
		Good Habitat Quality	Outstanding Habitat Quality			
January	Low	162	324	33	141	121
February	Low	162	324	15	81	89
March	Low	162	324	10	106	98
April	Low	162	324	50	192	181
May	High	324	486	462	408	490
June	High	324	486	1133	1140	1268
July	High	324	486	2111	1940	2118
August	High	324	486	1925	1867	2025
September	High	324	486	1436	1411	1616
October	High	324	486	785	712	811
November	Low	162	324	314	307	320
December	Low	162	324	211	208	211

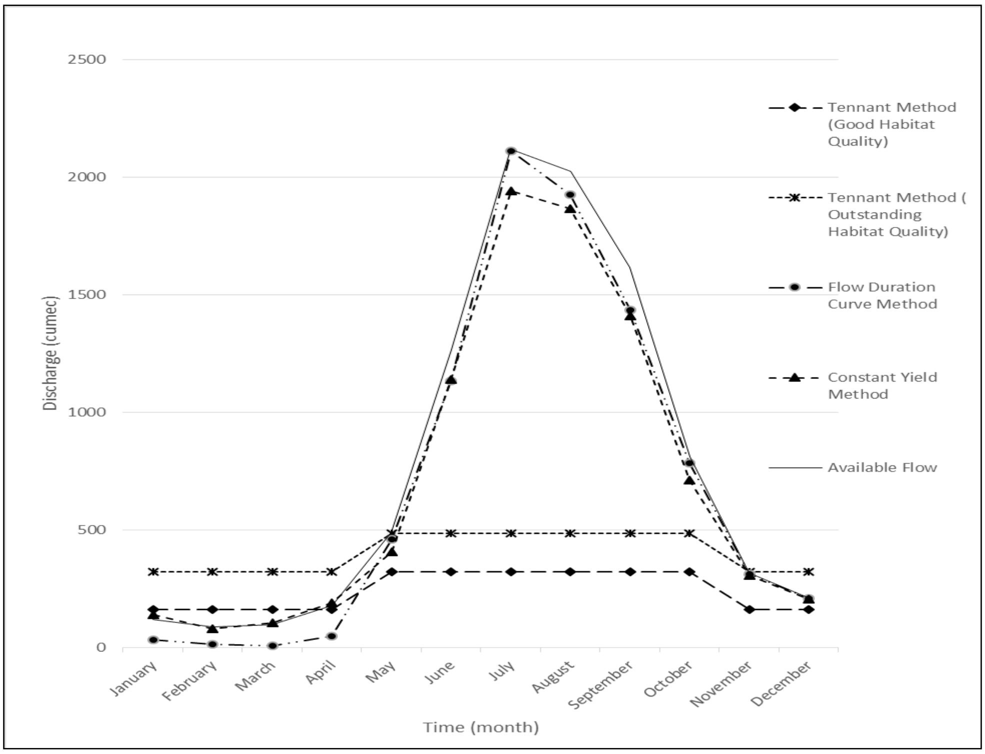


Figure 3.3 (b): Comparison of computed environmental flow requirements with available flow at Kaunia station

4. CONCLUSIONS

Teesta is an important river for both India and Bangladesh. Sharing of water of Teesta River has always been and still is a burning issue for both the nations. Assessment of environmental flow of such river can play a key role in determining rightful share and help in fruitful negotiation.

Environmental flow has been assessed of Teesta River at Dalia and Kaunia station where Dalia station is upstream of Teesta barrage and Kaunia station is at downstream of Teesta barrage. Therefore, the study is an effort to recommend a requirement of flow upstream and downstream of the barrage. The low flow period is the main concern for EFR assessment. As Tennant method is the common and accepted method for EFR assessment and low flow period is the main concern, the requirement was found as 151 cumec at Dalia and 162 cumec at Kaunia. In the study it was found that available flow is sufficient in high flow season to meet the derived requirements. However in low flow season the prevailing flow is found to be insufficient according to Tennant method.

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