# RW02
# Flow characteristics and environmental flow requirements for the Teesta River, Bangladesh

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*Abstract*—**Managing river health is a daunting challenge in much of the world. Increasing concerns over environmental sustainability and maintaining integrity of the riverine ecosystem demand environmental flow (EF) provisions in rivers. Estimation of EF first requires in depth analysis of the flow regimes of the river concern. This paper analyzes the flow characteristic of the Teesta River in Bangladesh based on 40 years historic flow data and further estimates the environmental flow requirements for the river following different hydrological methods. The results will particularly be useful for water management for the Teesta as well as in water sharing negotiation with the upstream country.**

## INTRODUCTION

Increasing concerns over environmental sustainability and maintaining ecosystem integrity in rivers persuade the water managers to recognize the need of allowing certain amount of flow with an acceptable level of quality in the rivers which is often regarded as environmental flow (EF) [1]. Such flow is now recommended for all the regulated rivers to maintain the river health at least to a specified level. Through mimicking the natural flow regime, EF ensures provisions of ecosystem goods and services that rivers provide on which humanity rely in myriad ways.

Owing to its geographic location, rivers in Bangladesh have very high flow in monsoon and low flow in dry season. Historically, water resources and the rivers in Bangladesh have been managed from a supply perspective, particularly putting emphasis on flood management and irrigation development. In contrary, less attention was paid on low flow and environmental flow management. However, with increasing awareness and approbation for maintaining environmental sustainability, focus in water management is being turned into a year round water management [2].

A number of rivers in Bangladesh are shared with India at the upstream and those are being affected considerably by the water demand and utilization in the upper riparian country. In the recent past, the flow regimes of rivers in Bangladesh have significantly been changed due to human intervention and injudicious appropriation of river water for out of stream uses. Large scale activities such as National River Linking Project and several small projects under implementation or in the pipeline by India will alter the entire annual hydrograph of the major rivers of this region in the near future. Considering the current state of river water management, analyses of the original flow characteristics based on historic flow data and estimating environmental water requirements for the rivers are critically important.

However, researches along this line in Bangladesh show tremendous inadequacy even though the National Water Policy (1999) and National water management plan (2001) explicitly recognizes the water requirement for nature. Reference [2] is the pioneer among very few works related to EF for the rivers in Bangladesh. Aiming to contribute to the research gap, this paper analyzes the flow characteristics of the Teesta River from North-west part of Bangladesh and estimates the environmental flow requirements for the river.

## STUDY SITE

Teesta, the forth main river in terms of discharge in Bangladesh originates from the glaciers in Sikkim, India and enters into Bangladesh at Chatnai, Nilphamari district and finally meets with the Jamuna in Bangladesh. Figure I shows the location map of the Teesta. It is a sandy braided river with steep slope, exhibiting high seasonal flow variability and cause inundation of floodplains in monsoon and low flow conditions in dry season [2].

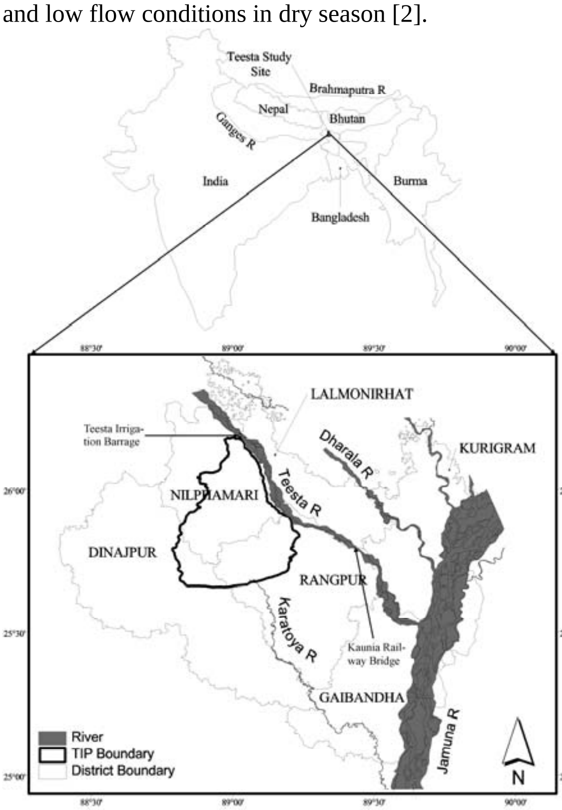


Figure I Teesta River and Teesta Irrigation Project in Bangladesh

Teesta is the main source of water in northwest drought-prone region of Bangladesh yet with significant agricultural potential. River flow has been regulated since 1987 when India constructed an irrigation barrage at Gazaldoba. Afterwards another barrage with same purpose was established at Dalia-Doani point in Lalmonirhat district of Bangladesh in 1990 to supply water to Teesta

Irrigation Project (TIP) (Fig. I).

## METHODS AND DATA

*Analysis of flow characteristics*

Last 40 years (1967 – 2006) daily mean discharge at *Kaunia Railway Station* point was collected from the Bangladesh Water Development Board database and then analyzed. The flow characteristics are analyzed by calculating the mean monthly maximum, mean monthly minimum and mean monthly flow. All these three flow parameters are presented in seasonal form breaking into three time periods, Pre-barrage period from 1967-1990, Post-barrage-1 from 1991-2000 (low impact) and Post-barrage-2 from 2001-2006 (severe impact). The flow in the Teesta distinctly varies in between the seasons. The seasons are categorized as high flow season for the months of June to September, intermediate flow season for October, November, April and May and low flow season for the months of December to March.

*Estimation of environmental flow*

Since 1960s and '70s an assortment of methods to assess the EF requirement has been developed. The methods differ in scope of application and data requirements. However, the initial attention of 'minimum flow' targeting to preserve some specific species in a river reach has been shifted to a 'range of flow' with the broad view of restoring and protecting the riverine ecosystem [3]. Reference [1] noted 207 methods from 44 countries that had been used to assess EF requirements.

Following the classification schemes proposed by [1] and [4], the different methods of EF assessment used all over the world can be grouped into four main categories: hydrological, hydraulic rating, habitat simulation and holistic methods. Hydrological methods correspond to standard setting problems mainly related to fisheries [5], is the easiest to use and require data on the historic flow records of the stream concern. Considering the initial stage of research at the Teesta, hydrological methods are applied to assess the EF requirements in this river. Flow data for last 24 years of the pre-barrage period (1967- 1990) at *Kaunia* are used in this case. Under the category of hydrological methods, three different methods viz. Tennant method [6], Flow Duration Curve (FDC) method and Range of Variability Approach (RVA) [7] are applied.

Tennant method prescribes the EF as a certain percentage of mean annual flow (MAF) which is different for high and low flow season. Table II 1st column shows the flow requirement for different status and for different seasons. Flow duration curve method is based on monthly FDC. In this study 50 percentile flow for high and intermediate flow season and 90 percentile flows for the low flow season is considered as EF. The RVA method provides a flow target that resembles the natural flow regime with the primary objective of protecting natural ecosystem. RVA analysis is performed using IHA (Indicator of Hydrological Alteration) software released by Nature conservancy, USA.

## RESULTS

*Flow characteristics of the Teesta*

Analyses on the historic flow data show a drastic flow reduction in recent years that results an alarming situation to the agriculture as well as to the in-stream users downstream to the barrage in Bangladesh part. Table I presented the calculated long term flow characteristics of the Teesta at *Kaunia*, the only flow gauge station downstream to the barrage and before the river's confluence with the Jamuna.

TABLE I LONG TERM FLOW CHARACTERISTIC OF THE TEESTA (ALL FLOWS ARE MEASURED AT *KAUNIA* IN $m^3s^{-1}$)

| Seasons | Period | MMX | MMF | MMN |
|---|---|---|---|---|
| HFS | 1967-1990* | 3674 | 1970 | 1031 |
| | 1991-2000[1] | 3647 | 2140 | 1271 |
| | 2001-2006[2] | 2259 | 1548 | 966 |
| IFS | 1967-1990 | 1159 | 519 | 310 |
| | 1991-2000 | 926 | 500 | 275 |
| | 2001-2006 | 770 | 408 | 174 |
| LFS | 1967-1990 | 228 | 169 | 139 |
| | 1991-2000 | 226 | 152 | 110 |
| | 2001-2006 | 114 | 80 | 50 |

Note – MMX = Mean monthly maximum flow; MMF = Mean monthly flow; MMN = Mean monthly minimum flow; HFS = High flow season; IFS = Intermediate flow season; LFS = Low flow season; * Pre-barrage period; [1] = Post-barrage-1; [2] = Post-barrage-2

It is evident from Table I that the variation of flow within the year for the Teesta River is disproportionate; however, the flow is decreasing with time for all the seasons. The MAF is also decreasing and the value of MAF for pre-barrage, post-barrage 1 & 2 are respectively 886, 931 and 679 $m^3s^{-1}$.

*Environmental flow requirements for the Teesta*

Environmental flow requirements for the Teesta are estimated using three different hydrological methods. Table II represents the EF requirements for the Teesta based on Tennant method. Table III reports the EF values calculated by FDC method. Low flow season (December to March) is the main concern and the EF requirements for low flow season is 89 – 177 $m^3s^{-1}$ to maintain good to fair condition based on Tennant method and FDC method prescribes 108 – 151 $m^3s^{-1}$ flow for the same season. There is good agreement between the two methods of calculation.

TABLE II ENVIRONMENTAL FLOW REQUIREMENTS FOR THE TEESTA BASED ON TENNANT METHOD

| Flow requirement (% of MAF) | HFS ($m^3s^{-1}$) | LFS ($m^3s^{-1}$) |
|---|---|---|
| Flushing flow (200%) | 1772 | 1772 |
| Optimum range (60-100%) | 532 – 886 | 532 – 886 |
| Outstanding (60% at HFS, 40% at LFS) | 532 | 354 |
| Excellent (50% at HFS, 30% at LFS) | 443 | 266 |
| Good (40% at HFS, 20% at LFS) | 354 | 177 |
| Fair or degrading (30% at HFS, 10% at LFS) | 266 | 89 |
| Poor (10%) | 89 | 89 |
| Severe degradation (<10%) | <89 | <89 |

Note – MAF = mean annual flow based on the pre-barrage period; HFS = High Flow Season; LFS = Low Flow Season

TABLE III ENVIRONMENTAL FLOW REQUIREMENTS FOR THE TEESTA BASED ON FLOW DURATION CURVE (FDC) METHOD

| Flow Season | Percentile value on FDC | Flow ($m^3s^{-1}$) |
|---|---|---|
| High flow | $50^{th}$ | 1280 – 2180 |
| Intermediate flow | $50^{th}$ | 228 – 803 |
| Low flow | $90^{th}$ | 108 – 151 |

Mean monthly flow for the pre-barrage and post-barrage period with the RVA targets are reported in Table IV. RVA targets are computed setting at +/- 1 standard deviation, in setting such target it is implicitly assumed that values within these limits from the mean are not expected to have significant impact on stream ecology.

TABLE IV RVA TARGETS AND MEAN MONTHLY FLOWS FOR THE TEESTA

| Month | RVA range ($m^3s^{-1}$) | MMF for 1967-1990 | MMF for 1991-2000 | MMF for 2001-2006 |
|---|---|---|---|---|
| Jan | 200 – 118 | 159 | 144 | 40 |
| Feb | 168 – 119 | 143 | 126 | 24 |
| Mar | 190 – 134 | 162 | 138 | 57 |
| Apr | 315 – 199 | 257 | 235 | 146 |
| May | 675 – 413 | 544 | 535 | 335 |
| Jun | 1847 – 1013 | 1430 | 1497 | 1182 |
| Jul | 2875 – 2015 | 2445 | 2596 | 1978 |
| Aug | 2757 – 1583 | 2170 | 2527 | 1669 |
| Sep | 2207 – 1466 | 1836 | 1938 | 1362 |
| Oct | 1278 – 602 | 940 | 898 | 864 |
| Nov | 460 – 250 | 355 | 333 | 289 |
| Dec | 279 – 149 | 214 | 199 | 200 |

Note – MMF = Mean monthly flow in $m^3s^{-1}$

It is evident from table IV that the flows in the post-barrage-2 period (2001 – 2006) became highly impacted. Severe flow alteration occurred in the month of January and February. Fig. II represents the RVA analysis of the Teesta flow at *Kaunia* for the driest month February for the period of 1967 – 2006. The analysis is based on mean monthly flow for the above mentioned time period. The upper and bottom solid line in the Figure indicates the upper and lower RVA boundary of flow for the month of analysis. The dotted horizontal line indicates the mean flow for the above period. The year 1990 when the Teesta irrigation barrage was commissioned is taken as the starting of the hydrologic impact even though the barrage in India was commissioned on 1987.

Hydrologic alteration (HA) values are reported at the left upper corner of the Figure. Hydrologic alteration is calculated as (observed frequency – expected frequency)/ (expected frequency) for the three segments viz. high HA relates to the number of years above the upper RVA boundary, low HA relates to the number of years observed below the lower RVA boundary and middle HA is for the in between RVA boundaries. Results are obtained for all the months using IHA software; however, only the driest month is presented here as representative.

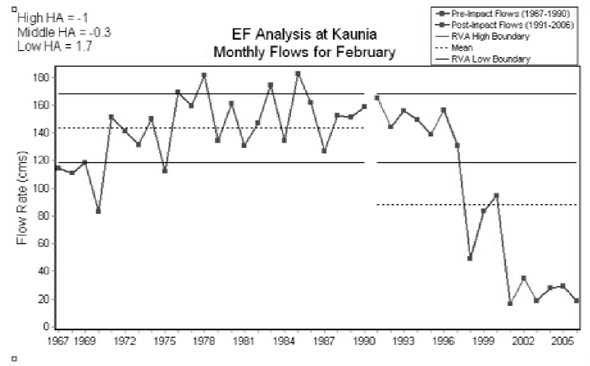


Figure II RVA boundary and hydrologic alteration for the Teesta for month of February

DISCUSSION AND CONCLUSION

The analysis is based on the observed flow data at Kaunia which is about 70km downstream of the TIP barrage at Dalia. The analyses show that considerable amount of flow reduction has taken place especially in the recent past from the year 2001. Environmental flow requirements have been calculated using three methods and the results are consistent between the methods. The results suggest that flow about 90 to 120 $m^3s^{-1}$ for the dry season in particular for January and February is essentially required for the sustenance of the river itself. However, in the period of 2001 – 2006 (post-barrage-2), the dry season (December – March) mean flow is observed only 80 $m^3s^{-1}$ (Table I) whereas mean January, February and March flow is observed only 40, 24 and 57 $m^3s^{-1}$ respectively; all these values are quite below from the EF requirement.

Since both the river-sharing countries have one barrage each, flow analyses for the point above TIP diversion is also necessary to look into. The flow above the barrage in Bangladesh part has been analyzed for the post barrage period of 1990 – 2006. The year 1990 is again taken as the basis of analysis since the Teesta Barrage was commissioned on that year. The dry season flow scenarios are presented in Fig. III which shows considerable flow decrease that occurred before the diversion of water to TIP.

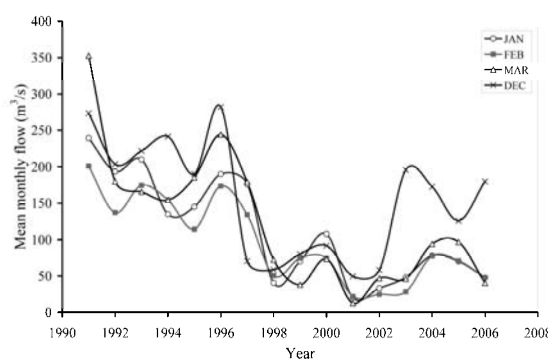


Figure III Dry season flow scenario at Dalia, above Teesta Irrigation Project diversion

Environmental flow is essentially required for the sustenance of the river itself as well as for the whole ecosystem including poor's livelihood which is largely shaped by the river flow especially in a country like Bangladesh. In addition to the proper functioning of the riverine ecosystem, flow in the Teesta is critically important for the instream uses namely capture fishery and small scale navigation mainly by the riparian poor people. In-stream water requirements set forth in different management plans until now are based on some rudimentary judgment only [2]. Result from this study will provide necessary information to the water management authority in managing water in a more sustainable way.

Since the Teesta is a shared river between two countries namely India and Bangladesh, water sharing is a crucial and often bargaining issue in the two countries' Joint River Commission (JRC) meeting. In the last $37^{th}$ JRC meeting held on $18^{th}$ – $19^{th}$ March 2010 in New Delhi the Teesta water sharing issue discussed with an emphasize since the flow coming to Bangladesh has been decreased significantly in the recent past (as shown in Fig. III).

"At present, Bangladesh receives almost all the water as it is not being used by India but after the ongoing construction of a barrage on the river (Teesta) is completed, some water will be utilized by us as well" – said by the Indian Water Resources Secretary U.N. Panjiyar [8]. This statement provides an idea of future further flow reduction that would be observed in Bangladesh. In contrary, in the last JRC meeting Bangladesh proposed to have water sharing on a 50-50 basis at Gazoldoba – the only release point of Teesta river water to Bangladesh – however; India is yet to take a final call on this issue. In conclusion, it is to be said that this study might act to help stopping several bargains through introducing the environmental sustainability and river sustenance issue to the broader community.

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