# ENVIRONMENTAL FLOW ESTIMATION OF BURIGANGA RIVER CONSIDERING WATER QUALITY

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## ABSTRACT

This study has been conducted to estimate the Environmental Flow (E-flow) requirements for the Buriganga River using various hydrological, hydraulic, habitat simulation, and holistic approaches, including the Tennant method, the Flow Duration Curve (FDC) method, the Wetted Perimeter Technique (WPT) method, the Habitat Simulation method, and the Building Block Methodology (BBM). The water quality of the river has been taken into consideration while estimating the e-flow which is a unique feature of this research.

Environmental flow refers to the amount, timing, and quality of water flow required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems. In order to keep the natural resources of a stream at the desired level, e-flow is crucial. Understanding the e-flow requirement helps with project planning, project evaluation, and a proper understanding of concerns linked to the stream's natural environment.

According to the analysis, the minimum e-flow demand, using the Tennant method, is 37 m3/s which indicates poor to fair habitat quality (10% of the mean annual flow). The minimum e-flow requirement is found to be 48 m3/s according to the FDC procedure while the recommended e-flow becomes 128 $m^3/s$ using the wetted perimeter method. Golda needs a minimum discharge of 54 $m^3/s$ to survive, whereas carp and tilapia need flows of 15 $m^3/s$ at the very least to survive. However, 113 m3/s of e-flow is the minimal requirement using the Building Block Method and this method provides the most precise results.

Analysis shows that the e-flow is not available in the Buriganga River. Moreover, the river's water quality has declined so drastically that it is worthless to use. That's why the water quality is assessed i.e. DO of the river water is analyzed. The dissolved oxygen level reaches nearly zero in the dry period. In this study, the required flow to dilute the polluted water is estimated and the amount is approximately 260 $m^3/s$ which will help to raise the DO content to the standard level in the low flow season. This amount of fresh water can be provided from the Jamuna River connecting the rivers of Dhaka with the Jamuna by dredging 180 km of waterways of the new Dhaleshwari, Pungli, Bongshi, Turag, and Buriganga Rivers.

***Keywords:*** *Building Block Method (BBM), Wetted Perimeter Technique (WPT), Flow Duration Curve Analysis (FDCA), Dissolved Oxygen (DO), Flow Augmentation*

## 1. INTRODUCTION

Environmental flow refers to the minimal quantity of water that must remain in a river or other freshwater ecosystem to maintain the ecological health and integrity of that system. E-flow indicates that the river water is managed with the intent that downstream consumers and ecosystems get adequate water for their present and future generations. Here the term "water quality" is also a matter of concern in the concept of e-flow because it is necessary to make the water usable besides determining the adequate quantity of water.

The Buriganga is significant to Dhaka city in an economic aspect. The mainstream flow of the Buriganga comes from the Turag and it converges with the Dhaleshwari at Munshigang (Salman, 2018). This river connects Dhaka with the other parts of the country by launches and country boats. But rapid industrialization, unplanned urbanization population pressure, and human activities lead to the pollution of this river, and it has reached its peak in recent years. It is increasingly polluted because of the dumping of industrial wastes and sewage lines causing massive toxicity in the river water. So, it is necessary to assess the e-flow for the restoration and sustenance of Buriganga. By measuring the river's e-flow, it is possible to preserve the ecology of the watercourse as well as the channel diversity and flood-carrying capacity, as well as fisheries support, navigation, saline intrusion prevention, dilution of wastes, etc. (Hossain, 2010).

Work on environmental flow:
Sedighakia Mahdi (2023) undertook a study of an integrated simulation optimization framework for assessing environmental flow in rivers, according to the case study's findings, the ANFIS-based model is reliable for simulating important variables including water quality and the population of macroinvertebrates. The outcomes show how the suggested approach to balancing environmental needs and water availability is reliable and strong. In the years of drought, the optimization model significantly increased the percentage of environmental flow.

Chandi Priya researched Environmental flow of tungabhandra river using global environmental flow to calculation. In the research environmental flows (EFs) are the means through which river flow is kept in a healthy or ecological state. Estimating environmental flows (EFs) requires considering the river's hydrologic (river mapping), hydraulic (cross-section, water depth, and velocity), and environmental (riparian flora and fauna) variables. Understanding the environmental factors that affect the habitat structure, flow regime, water quality, and biological conditions of the river is made easier by the study of river flow health.

Sarvanan Ravindran conducts research on environmental flow using traditional approach, "Traditional ecological knowledge" refers to the accumulated and in-depth information about the ecological systems that exist today and, in the past, (TEK). In order to support TEK in the water sector, environmental flow sufficiency must be ensured. The lowest flow needed for fish species to reproduce and for the related environmental conditions is known as the environmental flow in terms of fish habitat. The maintenance of environmental flow has been suggested to lessen the damage. The amount of the environmental flow that must be preserved is still up for debate.

Saha (2007) performed research on the Gorai River to determine the necessary instream flow based on salinity intrusion and fish habitat considerations. Assessing the flow needed for irrigation water quality with salinity in mind was the goal. Sources for the Sundari tree in the mangrove, as well as for drinking water and domestic use.

Rahman (1998) investigated the Ganges River, one of Bangladesh's great rivers, to ascertain its instream flow requirements. The author used three hydrological approach methodologies in this investigation. The investigation concluded that the Ganges has undergone significant morphological and environmental deterioration since the minimum flow is lower than the necessary flow for instream protection. Since the method used in the study can only provide a preliminary estimate of the instream flow requirement, it was advised to conduct studies to apply methods involving correlation of various parameters to habitat condition before engaging in any extensive, costly, and time-consuming analysis and study.

Study of Buriganga River in Bangladesh:
Pasha (2023) carried out a study to determine the primary factor contributing to Buriganga river pollution as well as the community's overall health. Also, the study also identified every prevalent disease that residents in the Burganga river region experience. The study then correlated the results with those from other southeast Asian nations to establish a connection and make it simpler to comprehend the current effects of water pollution on public health in the East Asian and Southeast Asian regions.

Sabbir (2022) undertook research to examine the hydro-morphological features of the Buriganga River and the variations in water quality indices. Water levels did not vary significantly, although during the dry season, they were very low, which might make navigation more difficult. The main issue, however, was water pollution because no action was made to stop further pollution.

Hasan (2022) conducted a study with the goal of identifying various Buriganga River water quality indicators close to Dhaka City. The study found that while Dissolved Oxygen is higher in the wet season than the dry season, BOD, TDS, EC, Turbidity, Suspended Solids, and Alkalinity are higher in the dry season than in the wet season.

Pasha (2022) examined at the physicochemical characteristics of the water in the Buriganga River and the amount of vegetation in the vicinity. The study examined the state of 10 physicochemical characteristics and discovered that most of them exceeded the strict standards established by the world health organization and department of the environment.

**The precise objectives are noted here**:

- To estimate the e-flow for the Buriganga river using the appropriate methodology.
- To understand the impact of water quality on e-flow and how to augment the flow during dry season considering the water quality.

**Possible outcomes are noted here:**

- Monthly mean discharge requirement for fisheries, channel maintenance, morphological equilibrium, and ecosystem of the river.
- The amount of flow required to be delivered to improve the water quality so that it can be used for a variety of purposes.

## 2. METHODOLOGY

Environmental flow assessment indicates to the quantification of water desirable to improve the natural ecological balance and maintain the biodiversity of aquatic habitats. Users of a river must agree to certain assumptions and modifications of the natural habitat. (Akter, 2010). For the estimation of E-flow, various methods are accessible. There are more than 200 approaches have been used for the measurement of E-flow worldwide. Some of the most popular methods have been used in this research for e-flow assessment. Tharme (1996, 2003) has classified all these approaches into four major distinct methods.
These are as follows:

a. Hydrological Method
b. Hydraulic Rating Method

c. Habitat Simulation Method
d. Holistic Method

Every technique requires different types of data, procedures, and ecological conditions.

## 2.1 Hydrological Method

The easiest of all four methods for assessing E-flow is the Hydrological method, which mainly depends on the use of hydrologic data. Usually, these are long periodic, continuous monthly, or daily discharge data utilized for E-flow assessment. These approaches require minimum data to determine the E-flow. That's why results found from these methods are usually uncertain. These methods get less weightage when there is sufficient data available. The most popular techniques include (Bari et al. 2006):

- Tennant or Montana method
- Flow Duration Curve analysis
- Aquatic Base Flow Method
- Range of variability Method

These methods are quite advantageous as they are simple to use and require only historical discharge data. Moreover, it does not need to carry out any costly fieldwork. These methods indicate the minimum flow required for the river. Ecological parameters are not taken into consideration in these methods. Usually, hydrological methods are not used in sensitive projects and studies having a vast scope.

### 2.1.1 Tennant Method

The most popular hydrological method is the Tennant method. It is often referred to as the Montana technique or the Mean Annual Flow. In North America, it is still regarded as the second most common approach (Reiser et al. 1989). The Tennant technique is predicated on the idea that specific percentages of mean annual flow represent various aspects of river habitat quality. The least amount of data is required for this type of e-flow assessment. For this strategy to work, long-term historical flow data are needed.

Table 1: Percentages of mean annual flow for Tennant Method

| Habitat quality | % of 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 |

Source: Bari et al (2006)

Tennant method serves some advantages as well as disadvantages. The most favorable fact of this method is that it is easy to use. Only flow data are needed to estimate the percentages of flow for different habitat quality. Moreover, it does not demand any intensive fieldwork. This method never recommends zero flow for any stream. This method is limited to specific regions and not applicable to semi-arid regions (Akter. 2010).

### 2.1.2 Flow Duration Curve Analysis

Flow Duration Curve (FDC) method is a very familiar and popular method around the world for determining E-flow. FDC shows us the relation between discharge and the percentage of time of exceedance. Historic flow records are needed to establish a flow duration curve (Akter, 2010). The flow duration curve shows us the recommended flow for each month. E-flow has been set $50^{th}$ (for high flow season), and $90^{th}$ (for low flow season) percentile flow of the monthly flow duration curve (Bari et al., 2006; Rahman, 1998). That's the reason the flow duration curve constructs each month's flow. The $90^{th}$ flow is that which exceeds 90% of the year. This flow is very low for the high flow season that's why this flow is considered for only low flow season. Each month's daily discharge is required to construct a flow duration curve. Then discharge is plotted in a graph with cumulative probabilities of exceedance. This method is more accurate than Tennant because we considered a lot of data to determine Environmental flow.

## 2.2 Hydraulic Method

Hydraulic approach for assessment of E-flow refers to the use of hydraulic models to determine the amount of water needed to maintain ecological health and well-being in a river or stream. The hydraulic approach is based on the concept that water flow is critical to the functioning of the river ecosystem, and that any alteration in water flow can have negative effects on the ecosystem. The hydraulic approach involves the use of complex mathematical models to simulate the hydrological and hydraulic processes in the river, and to determine the flow regime that is required to support the ecological integrity of the river. This approach is particularly important in areas where water resources are scarce or where water is being used for multiple purposes, such as agriculture, industry, and urban development.
Few instances of hydraulic approaches are (Rahman, 1998);
(a) Habitat-Discharge Method,
(b) Wetted Perimeter Method
(c) R-2 Cross Method,
(d) WSP Hydraulic Simulation Method.

## 2.3 Wetted Perimeter Technique

The wetted perimeter technique makes the assumption that a healthy ecosystem requires a wetted perimeter with sufficient flow at a minimum. We must build a wetted perimeter and discharge relationship in order to calculate the minimum E-flow. The wetted perimeter versus discharge is exhibited on a non-dimensional graph. The discharge and wetted perimeter data, which are given as a percentage of their maximum value, were plotted. The graph provided the inflection point for the curve. At this inflection point, slight flow reductions cause the wetted perimeter to decrease by increasing amounts. There may be more than one breakpoint and an uneven relationship between the wetted perimeter and discharge in compound cross-sections with several benches. In these circumstances, determining the minimum flow is typically most important to the lowest breakpoint.
WPT has the advantages of requiring fewer data and being simpler to use than other methods. However, this method constructs a stage-discharge curve for the given cross-section and requires documented watercourse cross-sections at suitable places. Therefore, this approach is site-specific and only suggests a minimal environmental base flow.

## 2.4 Habitat Simulation Method

The Habitat simulation method is the most expensive, complex, and data-required method but provide more accurate, comprehensive, and modeled results. A combination of hydrological, hydraulic, and biological data is required in these methods to estimate the e-flow. They show the variation of habitats with the flow for environmental utilization. Variations of physical habitats related to the stream flow are modeled and collected at various cross-sections within a given river reach.

These methods provide habitat-discharge curves that are used for optimum e-flow recommendation.

### 2.5 Holistic Method

Holistic methods have been established considering this concept that initially originated in South Africa, Australia, and nowadays in the UK. Among these methodologies, the most commonly used method is the Building Block Methodology (BBM).
Few instances of holistic approaches are (Arthington et al., 2004; Bari et al. 2006);
a) Building Block Method,
b) DRIFT,
c) Ecotope method

### 2.6 Building Block Method

The BBM was established in South Africa by the Department of Water Affairs and Forestry and some other academic organizations (Hughes and Munster, 1999). This method consists of four building blocks elements:

- Low flows
- Habitat maintenance floods
- Flushing floods / Channel maintenance
- Spawning migration flows

The method has the upper hand over other methods because it considers all the possible parameters for the maintenance and sustenance of the river ecosystems. Moreover, it considers the variation of monthly discharges for low flows as well as high flows. From the low flow building block component, the preliminary e-flow demands can be determined.

### 2.7 Comparison of the E-Flow Methodologies

All the above-mentioned methodologies of e-flow assessment have distinctions concerning their data demands, assumptions, procedures, and impact on the river dynamics.
Hydrological methodologies require the least data and are used for preliminary e-flow assessment. Whereas the hydraulic methods aim to maintain water in the river channel. The ecological focus is to maintain the wetted perimeter and the area of the river. The applicability of these methods is limited, and the point of inflection determines the value of the e-flow requirement. The impact on depth and velocity depends on the morphology in these methodologies.
Holistic methodologies require a large amount of data for different river parameters, morphology, and flooding patterns. It provides the most accurate and reasonable results as it considers all aspects of the river ecosystem while it is a costly and lengthy method. On the other hand, habitat simulation methods provide more complex decisions, and it is difficult to use. These methods show the habitat variations with the stream flow. These methodologies are usually used for the sustenance of the fish species and to establish a close relationship between the habitat and ecology of the river. History, experience, and the objective of the different approaches available can play a vital role in the decision-making about the choice of the most suitable method for the e-flow assessment.

### 2.8 Choice of Suitable Methodologies

Environmental flow choices involve negotiating river water sharing agreements with riparian nations, approving a water withdrawal permit, setting up a project's operating schedule for water storage, or implementing a component of a country's national water managing strategy (Bari and Marchand, 2006). The Tennant method, the Flow Duration Curve method, the Wetted Perimeter technique, the Habitat Simulation method, and the Building Block Methodology have all been used to evaluate the Buriganga River's e-flow demand in this study.

## 3. ILLUSTRATIONS

### 3.1 Analysis of the Required E-Flow

Analysis has been conducted for the estimation of the e-flow requirement for the Buriganga River using the Tennant method, Flow Duration Curve (FDC) method, Wetted Perimeter method, Habitat Simulation method, and Building Block Methodology (BBM). The results obtained from the analysis applying these methods are shown in the upcoming sections.

### 3.2 Tennant Method

Usually June to October, these five months are recognized as the high-flow season and the rest of the seven months are recognized as the low-flow season. The mean monthly flow and the corresponding habitat quality for the year 2012 are presented in Table 2. The most recent discharge data we have is from the year 2016, although it seems to be faulty data for the month of March. That's why the analysis of 2012 is used for the estimation of the minimum e-flow requirement according to the Tennant method.

Table 2: The Mean Monthly Flow and The Corresponding Habitat Quality According to Tennant Method for the year 2012

| Month | Mean Discharge ($m^3/s$) | % of MAF | Remarks |
|---|---|---|---|
| Jan | 16.6 | 5 | **SEVERE DEGRADATION** |
| Feb | 54.38 | 15 | FAIR |
| Mar | 54.08 | 15 | FAIR |
| Apr | 118.06 | 32 | EXCELLENT |
| May | 120.36 | 33 | EXCELLENT |
| Jun | 381.77 | 104 | OPTIMUM |
| Jul | 631.95 | 173 | OPTIMUM |
| Aug | 647.48 | 177 | OPTIMUM |
| Sep | 594.55 | 162 | OPTIMUM |
| Oct | 708.65 | 194 | OPTIMUM |
| Nov | 147.98 | 40 | OUTSTANDING |
| Dec | 44.68 | 12 | FAIR |
| | **MAF = 366** | | |

It is observed that severely degraded habitat condition (less than 10% of MAF) occurs in the month of January. So, it can be said that e-flow is maintained in all the months except January and that's why the flow of January in the Buriganga River is highly hazardous for its ecosystem. The flows of the month of February, March and December are fair enough which is lower than 20% of the MAF. The flows in the months of June, July, August, September, and October maintain the optimum habitat quality having flows lower than 200% of the MAF of the river while the flushing flow is not occurred for any month. The minimum e-flow requirement using The Tennant method is considered to be 37 $m^3/s$ which is 10% of the mean annual flow.

### 3.3 Flow Duration Curve Method

E-flow requirement is estimated for various months of the year. But in this research, the yearly e-flow requirement is assessed using the FDC method due to the unavailability of the daily stream flow data of the Buriganga River. The flow duration curve is shown for the year 2012 in Figure 1.
The $90^{th}$ percentile flow is found to be 48 $m^3/s$ for 2012 from the flow duration curve shown in Figure 1.

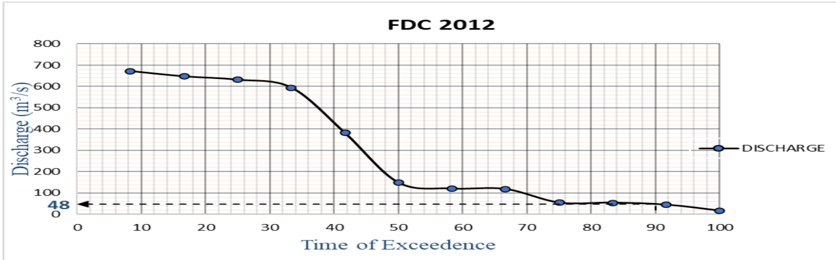


Figure 1: FDC for the estimation of the e-flow

## 3.4 Wetted Perimeter Technique

The analysis has been conducted for three different stations i.e. stations 1, 4, and 8 of the Buriganga River as it is observed that the values of e-flow requirement are close enough for all the stations. The relationship between Q/Qmax and P/Pmax for station 1 in the year 2012 is shown in Figure 2 because the data from 2016 appears to be inappropriate.

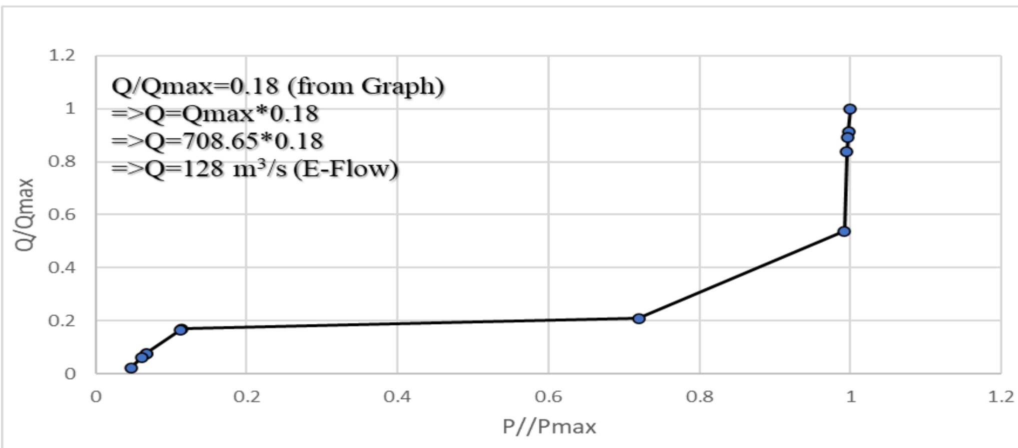


Figure 2: Relation between wetted perimeter and discharge for station 1, 2012

The value of $Q/Q_{max}$ at the point of inflection is found to be 0.18 from the above graph which provides the required e-flow and the value is 128 $m^3/s$ for station 1. The required e-flow is estimated to be 128 $m^3/s$ for station 1 and the value is almost similar for stations 4 and 8. So, the recommended e-flow becomes 128 $m^3/s$ using the wetted perimeter method.

## 3.5 Habitat Simulation Method

The habitat simulation method provides the e-flow recommendation taking account into the required discharge and water depth of some target fish species that is adequate to sustain the river ecosystem. In this study, three types of fish species i.e. Carp, Golda, and Tilapia are considered. The latest data we have for assessing e-flow is from the year 2016. However, it seems that the March 2016 discharge data is faulty. So the data from 2012 is used instead of 2016 for this method.

The monthly required discharge for the sustenance of these species is estimated using the cross-sectional data (computed from Hec-ras) of station 2 which is shown in Table 3 as it has provided more logical results than station 1. The cross-sectional areas are too large for the remaining stations, which may be located at or near Sadarghat. These types of sections are not considerable and do not produce logical results. The e-flow requirement according to the habitat simulation method is the maximum value of the range of minimum flow requirements of the fish species.

Table 3: Mean Monthly discharge of the river and the monthly required discharge of the species for the year 2012 at station 2

| Month | Discharge | Area | Golda | | Carp | | Tilapia | |
|---|---|---|---|---|---|---|---|---|
| | | | Velocity | Required Discharge | Velocity | Required Discharge | Velocity | Required Discharge |
| Jan | 16.6 | 147.63 | 0.6 | 88.578 | 0.1 | 14.763 | 0.1 | 14.763 |
| Feb | 54.38 | 211.82 | 0.6 | 127.092 | 0.1 | 21.182 | 0.1 | 21.182 |
| Mar | 54.08 | 211.44 | 0.6 | 126.864 | 0.2 | 42.288 | 0.1 | 21.144 |
| Apr | 118.06 | 268.98 | 0.6 | 161.388 | 0.3 | 80.694 | 0.2 | 53.796 |
| May | 120.36 | 270.6 | 0.2 | 54.12 | 0.6 | 162.36 | 0.35 | 94.71 |
| Jun | 381.768 | 295.3 | 0.2 | 59.06 | 0.6 | 177.18 | 0.35 | 103.355 |
| Jul | 631.949 | 313.46 | 0.2 | 62.692 | 0.6 | 188.076 | 0.35 | 109.711 |
| Aug | 647.48 | 314.34 | 0.2 | 62.868 | 0.6 | 188.604 | 0.35 | 110.019 |
| Sep | 594.55 | 311.22 | 0.2 | 62.244 | 0.6 | 186.732 | 0.35 | 108.927 |
| Oct | 708.65 | 317.63 | 0.6 | 190.578 | 0.6 | 190.578 | 0.35 | 111.1705 |
| Nov | 147.98 | 267.9 | 0.6 | 160.74 | 0.3 | 80.37 | 0.2 | 53.58 |
| Dec | 44.68 | 198.54 | 0.6 | 119.124 | 0.1 | 19.854 | 0.1 | 19.854 |
| **Min Value** | **16.6** | | | **54.12** | | **14.763** | | **14.763** |

From Table 3, it is seen that the minimum discharge of the river station is 17 $m^3/s$ while the minimum discharge requirement for Golda, Carp, and Tilapia is 54 $m^3/s$, 15 $m^3/s$, and 15 $m^3/s$ respectively. So, 54 m3/s of e-flow is needed for the selected fisheries to survive in the Buriganga River using the habitat modeling method.

### 3.6 Building Block Method (BBM)

The Building Block Method is by far the most well-liked holistic approach. Golda, carp, tilapia, flushing, and morphology are the chosen indicators for this analysis. The following sections go into detail about each indicator's requirements.

#### 3.6.1 Demand For Fisheries

Figure 3 and equation 1 show the link between the water level and the cross-sections of the Buriganga. Following the resulting equation, cross sections for that particular water level are determined.

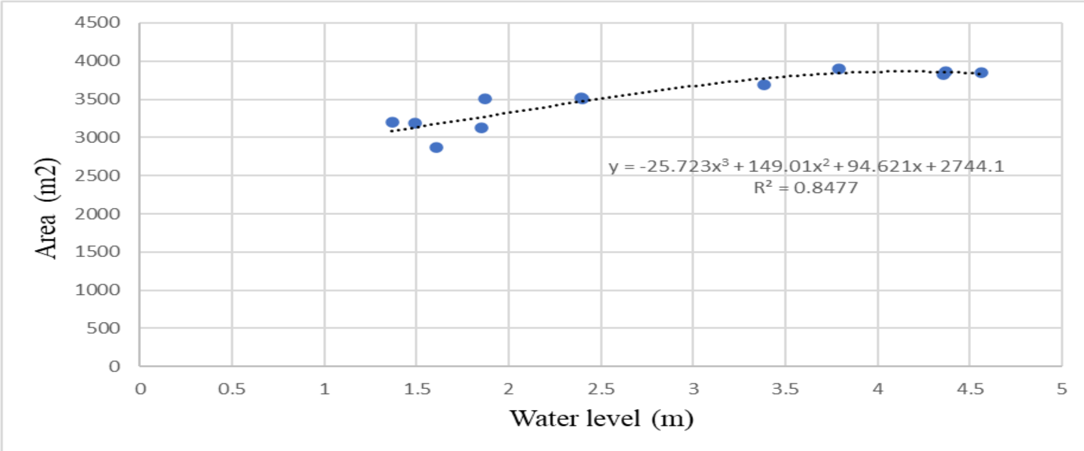


Figure 3: Correlation between water level and area

Correlation between water level and cross-sectional area for Buriganga River:

$$y = -25.723x^3 + 149.01x^2 + 94.621x + 2744.1 \quad (1)$$

Where, Y= cross sectional area and x= water level.

The relation generated in equation 1 is used to get the necessary cross-section. There is also a needed velocity for this species. The required discharge is calculated by multiplying the controlling velocity by the computed cross sections, as in Q=AV, where Q stands for discharge, A for cross-sectional area, and V for velocity.

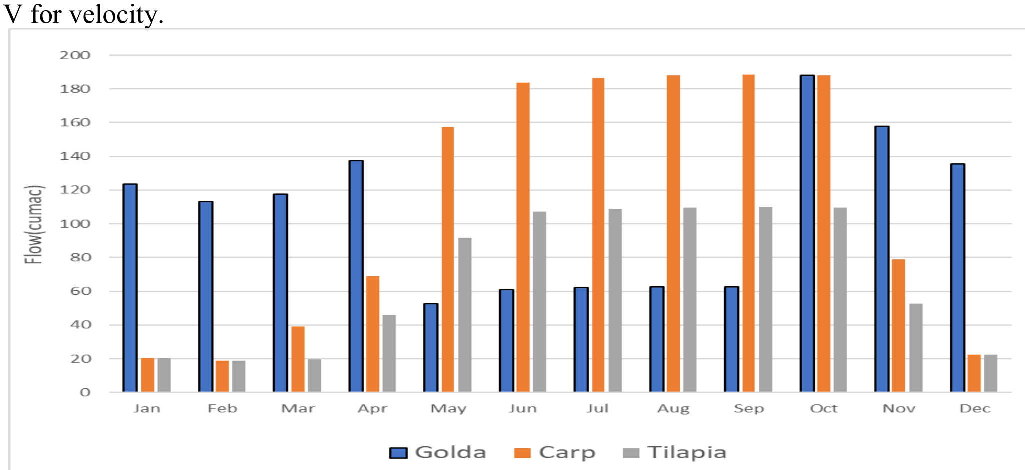


Figure 4: Flow Requirement For Golda, Carp & Tilapia

The summary table of fish species requirements demonstrates that the highest flow is 188 $m^3/s$ which occurs in August, September, and October while the lowest flow is 19 $m^3/s$ occurring in February. The peak value of the flow requirements of Golda is found to be 188 $m^3/s$ and the least value is found to be 53 $m^3/s$. The three species selected have a dominant flow requirement from May to September for carp fish while the flow requirement for Golda dominates from November to April. In October, both Carp and Golda species requirements are dominant. The bare minimum flow is needed each month for tilapia fish.

### 3.6.2 Flushing Flow

A flushing flow is typically thought of as a huge additional flow discharge meant to create a specific environmental response. It is noticed that optimum habitat quality is maintained in the wet season according to Tennant and the existing wet season flows are lesser than the required flow for river flushing. So, the flushing flow (200% of the MAF) is not available in Buriganga. That's why flushing flow has not been considered for BBM.

### 3.6.3 Morphological Equilibrium

The discharge in a natural river fluctuates annually and seasonally in accordance with the flow regime. Semicontinuous changes in the morphology of alluvial reaches are driven by variations in mean discharge, flood discharge, or the yearly variability of discharge. (Klaassen, 1995; Knighton, 1998; Bridge, 2003). A step change or impulse in the flow regime, on the other hand, may result from, for example, a big flood or a change in the catchment's land use, respectively, and cause the channel to lose its equilibrium condition and become unstable. (Jakia, 2010). The flow required for morphological balance has been computed using the Gamble distribution, taking into account the 80% reliable flow during the dry period (November to May). The flows in Table 4 represent the e-flow requirement for the Buriganga River to be in morphological equilibrium.

Table 4: E-flow for Morphological Equilibrium

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E-Flow | 132.3 | 80.97 | 86.2 | 128.96 | 318.8 | - | - | - | - | - | 310.27 | 104.15 |

### 3.6.4 Summary of E-Flow Requirement by BBM

To determine the entire requirement, the flow requirements for the indicators—fisheries, flushing and morphology — are compiled. Each month's flow demand has been determined using the highest value of these variables. Figure 5 and Table 5 provide an overview of the total demand for a selection of indicators. In this study, morphological flow requirements for the wet season have not been computed as the minimum e-flow requirement is estimated. That's why flow requirements for morphological equilibrium is required only for the dry season months in this study. From Figure 5 it can be concluded that flow requirements for morphology govern throughout the year (it is obvious that morphological flow requirements for the wet period are higher than for the dry period) except December, February, March, and April. Flow requirements for Golda govern for those months. The analysis presented in this study indicates that the Buriganga River does not flush, hence the flushing flow is considered zero for the building block methodology.

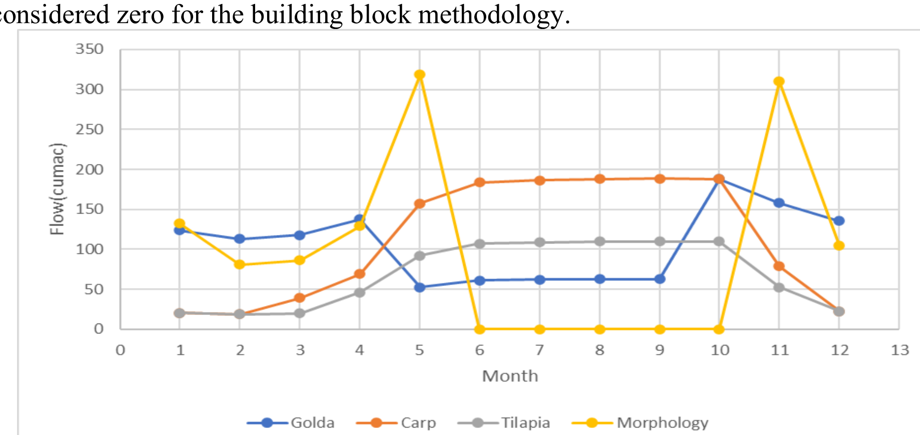


Figure 5: Summary of all demand for selected indicators

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Table 5: E-Flow Requirement For Buriganga River ($m^3/s$)

| Indicator/month | Jan | Feb | Mar | Apr | May | Jun | Jul | aug | sep | oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Carp | 20.57 | 18.86 | 39.2 | 69 | 157 | 183 | 186 | 188 | 188 | 188 | 79 | 22.55 |
| Tilapia | 20.57 | 18.86 | 19.6 | 46 | 91.8 | 107 | 109 | 110 | 110 | 110 | 53 | 22.55 |
| Golda | 123.4 | 113.2 | 118 | 138 | 52.5 | 61 | 62 | 63 | 62.8 | 188 | 158 | 135.3 |
| Flushing flow | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Morphology | 132.4 | 80.97 | 86.2 | 129 | 319 | - | - | - | - | - | 310 | 104.2 |
| Required E-flow | 132 | 113 | 118 | 138 | 319 | - | - | - | - | - | 310 | 135 |

## 3.7 Summary of Computed Minimum E-flow Requirements

An overview of the required environmental flow for the Buriganga River is estimated by the Tennant method, FDC method, WPT method, Habitat Simulation method, and BBM is presented in Figure-6. It is observed that the minimum e-flow requirement governs using the Wetted Perimeter technique. But the minimum e-flow for Buriganga River using the Building Block Methodology has been taken into account in this study because fisheries, flushing or channel maintenance, ecosystem, and morphological equilibrium all types of indicators are considered in BBM. Therefore, the minimum e-flow requirement for Buriganga River is 113 $m^3/s$.

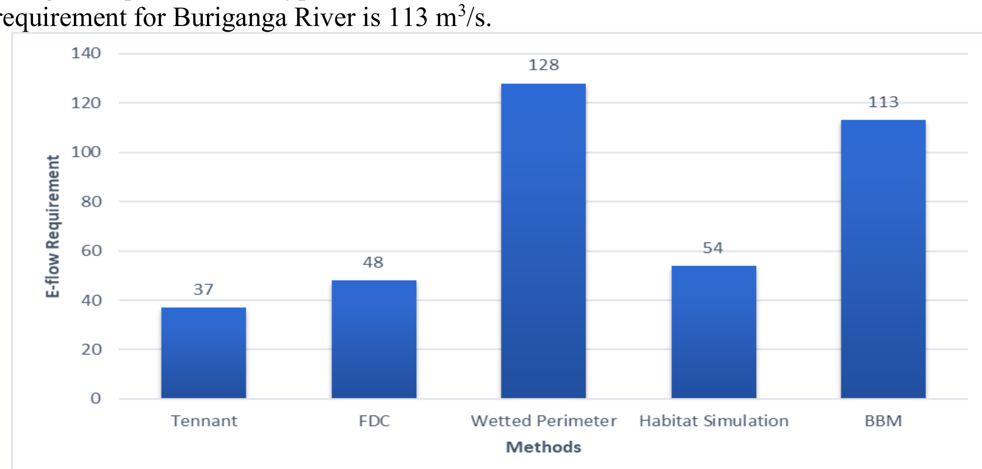


Figure 6: E-flow Requirement of Buriganga River according to different Methods

## 3.8 Impact of Water Quality on E-Flow

With the exception of a few dry months, the Buriganga River usually always maintains the minimal environmental flow demand. Due to extensive water pollution, the Buriganga River's water continues to be worthless. As a result, this study concentrates on ways to improve the river's water quality. We have data availability for the water quality parameters i.e. Dissolved Oxygen (DO), Total Dissolved Solid (TDS), salinity, Electric Conductivity (EC), Chloride, Fe. Among them the DO concentrations are the most vulnerable in the dry season.

### 3.8.1 Variation of DO Concentration

Figure 7 represents the variation of the monthly DO concentration for different years. It can be said that the concentration of DO is much higher in the wet season (June, July, August, September, and October) than in the dry season. The concentration of DO has increased from 2006 to 2012 on average while the trend is in the decline after 2012. This is because industrial activities reduced after 2006 near the bank of Buriganga but further increased after 2012. Domestic waste disposal, waste dumping of the dyeing industry, tanneries, and fertilizer industry are the main reasons for the reduction of the DO level in Buriganga.

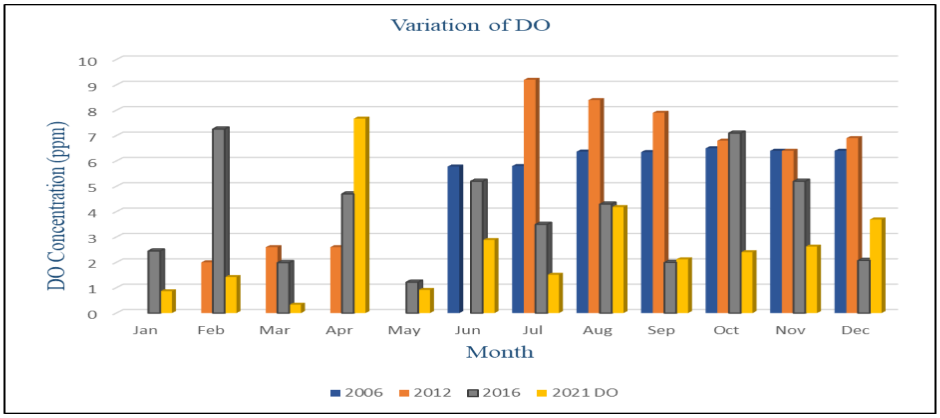


Figure 7: Variation of DO Concentration For Different Years

### 3.8.2 Relationship of Discharge and DO Concentration

The DO levels do not meet the standard value for irrigation and fisheries in the dry period in Buriganga. The discharge of the dry period has to be increased to raise the DO level to meet the standard value. As a result, a relationship between stream discharge and DO concentration is established and it is considered to be linear (best-fit curve) in this study which is presented in Figure 8 for the year 2012. This is because the DO concentration data from 2016 seems to be faulty while the data from 2006 and 2010 is not properly available.

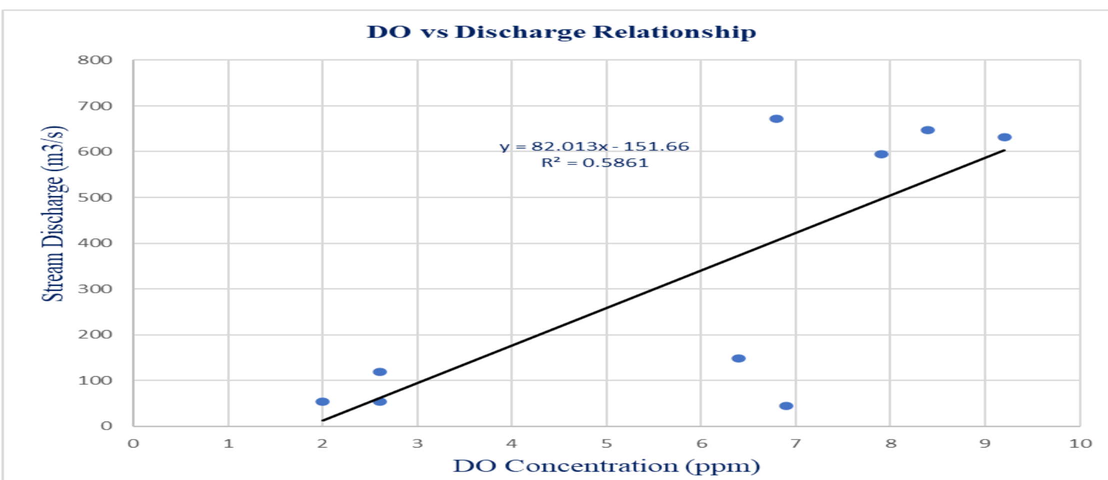


Figure 8: Relationship between the DO concentration and the stream discharge in 2012

### 3.8.3 Flow Augmentation to Improve Water Quality

From Figure 10, the discharge required to raise the DO concentration to 5 ppm which is the standard value for fisheries and irrigation is found to be 260 $m^3/s$. As 90% flow of the Buriganga River is found to be 48 $m^3/s$, additional approximately 220 $m^3/s$ of freshwater flow is required in the dry season to improve the quality of the Buriganga River water. This amount of flow can be diverted from the Jamuna River as there is sufficient pollution-free flow available in the dry season (Kibria, 2015).

# 4. CONCLUSIONS

## 4.1 Conclusion

A comparison of the findings is established and the monthly flow need has been determined as the highest flow requirement for any chosen indication. From the analysis, it is possible to deduce the following decisions:

- The Tennant method states that the minimum e-flow requirement for the Buriganga River at Mill Barrack is 37 $m^3/s$ indicating poor to fair habitat quality. It is the 10% flow of the MAF of the river which is not maintained in January. Flushing flow (200 % of the MAF) is not available in Buriganga River.

- The FDC methodology suggests that the required minimal e-flow is 48 $m^3/s$. The optimum e-flow requirement is 128 $m^3/s$ according to the Wetted Perimeter Technique as well. According to the habitat simulation approach, the e-flow need is close to 54 $m^3/s$ for a viable riverine ecosystem taking the indicator fish species into account.

- E-flow requirement is found to be 113 $m^3/s$ according to the Building Block Methodology. This method provides the most accurate result as it considers all types of indicators i.e. fisheries, channel maintenance or flushing, morphological equilibrium, ecosystem. As a result, BBM is considered for the estimation e-flow requirement. Therefore, the minimum environmental flow needed for Buriganga River is 113 $m^3/s$ to maintain a healthy riverine ecosystem.

- The DO concentration falls below the recommended level for irrigation and fisheries during the dry season, and in certain situations, it even becomes nearly zero.

- The required e-flow is roughly maintained in the Buriganga River. But the flow is not usable due to severe pollution. That's why the flow of the Buriganga River must be increased by approximately 260 $m^3/s$ to improve the water quality.

The study's final finding is that no single approach can satisfy every need, and the minimum flow measurement can be revised in response to shifting requirements for various indicators. E-flow estimation is a challenging procedure that requires both technical evaluation and consultation. The results of this study can provide water management with useful information to make decisions. The effect of upstream withdrawal exhibits a typical hydraulic shift, which may pose a concern to aquatic species. The decision-making process will be significantly influenced by past environmental risk management experiences.

## 4.2 Recommendation

Utilizing the Tennant, FDC, Habitat Simulation, and BBM methods, the current study assessed the e-flow requirements for the Buriganga River. These techniques were created in regions with very dissimilar aquatic flora and fauna, such as South Africa, Australia, the United States, and Europe, compared to Bangladesh. The various standards employed by the aforementioned approaches to figure out the e-flow need may be appropriate for the circumstances in which they were created. It's possible that Bangladesh's conditions will necessitate a modification to the EFR standards, which may not be exact.

As a result, it would be desirable to conduct a number of in-depth studies, focusing on the application of the approaches and the different percentages used in computing EFR, in at least five rivers in each of Bangladesh's hydrologic zones. The riverine environment and IFR techniques would both benefit from a deeper knowledge of these concepts.

In this study, the relationship between stream discharge and DO concentration is considered linear. But actually, it's not perfectly linear. As a result, some modifications may be required.

The e-flow requirement is 113 $m^3/s$ and an additional approximately 220 $m^3/s$ flow is required to divert from the Jamuna to the Buriganga River to dilute the pollutants and improve the water quality in the dry season. This amount of flow may be provided by dredging 180 km of the new Dhaleshwari, Pungli, Bongshi, Turag, and Buriganga rivers' waterways would link the rivers of Dhaka with the Jamuna River. But the feasibility is not assessed in this study due to lack of sufficient data and time. However, Government has taken this project and is already going through the approval procedure. If this project is successful, it will not only enhance the water quality of Dhaka's periphery rivers but also boost water supply, and irrigation for agriculture, fishing, and navigation. This is an excellent illustration of integrated water resources management.

Data on daily discharge, cross-sections, and water quality were not readily accessible for the Buriganga and were also expensive to purchase. Because of this, we purchased monthly discharge data from the BWDB for the years 2006, 2010, 2012, and 2016 and used the data to carry out the study. The analysis may produce more precise results if there is access to data from more years in further studies.

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