**International Journal of Research in Environmental Science (IJRES)**
*Volume 10, Issue 3, 2024, PP 1-11*
*ISSN No. (Online) 2454-9444*
*DOI: http://dx.doi.org/10.20431/2454-9444.1003001*
*www.arcjournals.org*

# Study on Environmental Flow Assessment of the Kushiyara River

**Md. Khairul Amin[1*] and K.M. Ahtesham Hossain Raju[2]**

[1]*Dept. of Civil Engineering, Military Institute of Science and Technology, Dhaka-1216, Bangladesh*

[2]*Dept. of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*

***Corresponding Authors:** ***Md. Khairul Amin,*** *Dept. of Civil Engineering, Military Institute of Science and Technology, Dhaka-1216, Bangladesh*

**Abstract:** *The Kushiyara River stands as one of the paramount waterways in Bangladesh, renowned for its extensive natural flow dynamics. Being a river shared between India and Bangladesh, the Kushiyara's transboundary nature presents a significant challenge in establishing a mutually agreed minimum flow. Recognizing the river's substantial impact on the environment is crucial not only for facilitating negotiations but also for the preservation of its ecological integrity. The alterations in the Barak River's course during the Pre-Monsoon season, diverting a considerable amount of water into the Kushiyara, and the reduction in tributary flow during dry seasons, significantly impacting Boro Rice and winter vegetable cultivation, underscore the necessity to gauge the river's environmental flow. The primary objective of this study is to precisely quantify the environmental flow of the Kushiyara River, leveraging multiple methodological approaches. Through the rigorous application of the Tennant, Flow Duration Curve, and Constant Yield methods, a comprehensive assessment of the river's environmental flow has been conducted. Additionally, the study aims to propose a consistent flow rate at the Sheola station, a pivotal point for water flow measurement. The investigation has specifically identified sufficient flow during the low flow seasons, which occur from March to May and November. The analysis highlights the need for a flow rate of 112-155 m³/s during the low flow season from November to April, and a flow rate of 942-1570 m³/s during the high flow period from May to October at Sheola. Although the Tennant method detects an adequate flow during periods of high flow, other methods identified a lack of flow during the low flow season. The findings can be used for future reference in management of flows in Kushiyara river.*

## 1. Introduction

Since the middle of the 20th century, environmental flow has become an important part of river growth in many parts of the world. The term "environmental flow requirement" is often used to mean "minimum flow" (usually 10 percent of the average annual runoff) in a river, "managed flood," or "river flow objective" (Acreman et al., 2000). Natural flow is an important part of river health, economic growth, and reducing poverty (Dyson et al., 2003). There have been several attempts to describe the integrity, health, sustainability, and resilience of river ecosystems (Norris and Thoms, 1999). At the Earth Summit in Rio de Janeiro in 1992, the river environment was categorized by "water allocation to species and ecosystems other than human needs" (Acreman and Dunbar, 2004).

Resource managers have had trouble making sure that all of the species in a river environment have the best possible conditions at the same time. To solve this problem, the focus has moved away from a minimum flow method and towards one that starts with the "natural" flow of the river. Environmental flow assessment (EFA) is the study of how a river should run so that it doesn't harm the environment. Several EFA methods have been developed, but only 11 percent of poor countries use them (Jowett, 1998; Tharme, 2003). This is different from developed countries, where most of the methods are used.

Because of where Bangladesh is, the rivers run very fast during the monsoon and very slowly during the dry season. Considering how river water is managed now, Bangladesh needs to examine the original flow characteristics based on historical flow data and estimate the environmental water requirements (EWR) for the rivers (Mullick et al., 2010). But in Bangladesh, the idea of natural flow is still pretty new. By giving environmental flow more importance, the Government of Bangladesh (GoB) came up with one of the seven ways to figure out how much environmental flow is needed. This is done after ranking twelve key issues or problems as the main causes of coastal and marine pollution (DoE, 2007).

One river in Bangladesh that flows across international borders is the Kushiyara River. The Indian Barak people come from the northern hills of Assam. At Amalshid, on the northeast border of Zakiganj upazila in the Sylhet district, the Barak splits into two streams. The Surma is the arm in the northwest, and the Kushiyara is the arm in the southwest. Over the last 100 years, the flow of the Barak River has changed so that most of the water goes to Kushiyara and the rest goes to Surma. At Amalshid, a big part of the Surma's bed has dried up, so about 85 percent of the Barak's flow goes through the Kushiyara (Ahmed, 2022). To protect the habitat, it is important to understand the processes and factors of the river flow regime that are needed to keep the river ecosystem functioning at a certain level. So, the goal of this study is to figure out what the environmental flow needs of the Kushiyara River are and make ideas for how to meet the best environmental flow needs.

More and more, impoundments like dams and weirs, abstractions for farmland and urban water supply, drainage return flows, maintaining flows for navigation, and structures for flood control are changing the flow of the world's rivers (Korsgaard, 2007). Both the amount of water that rivers need and the quality of the water in the rivers are at risk (Postel and Richter, 2012). So, it's important to find the best flow that needs to be kept in a river to keep the riverine environment alive and to get the most benefits from a river. The concept of environmental flow sources is to not only find out how healthy a river is and change how it flows but also to get the most out of free-flowing water (Dissanayake et al., 2010).

The goal of this study is to find out how much natural flow a river needs to keep its ecosystem alive. Environmental flows are a set of discharges of a certain size, frequency, and timing that are needed to get a certain range of benefits from a river. These benefits are needed to keep parts of the natural aquatic ecosystem alive, such as fish, flood protection, and wild animals. This is becoming an important trend in managing water resources (Dissanayake et al., 2010).

During the rainy season, the Kushiyara River is well known for its flash floods. This makes a mess. During the dry flow season, the river's flow slows down a lot. Since the water level has dropped a lot in the last few decades, the canals of the Kushiyara River are dry during the dry season. This makes it hard to grow Boro rice and winter veggies. Because of this, the river's natural environment is changing, which is bad for farming, fishing, boating, and other things. But because the river flows through more than one country, it has never been easy to agree on how much flow must be kept in the river.

So, figuring out the natural flow of the Kushiyara River is very important, both for better negotiations and for keeping the river's ecosystem in good shape.

Therefore, the main aims and objectives of this study are:

• To assess the hydrological characteristics of the Kushiyara River.

• To assess the environmental flow of the Kushiyara River.

## 2. MATERIAL AND METHODS

### 2.1 Study Area and the characteristics of Kushiyara River

One of Bangladesh's transboundary rivers is the Kushiyara River. The Barak of India starts in the northern hills of the Indian state of Assam. As it runs farther, it forms the border between the states of Nagaland and Manipur. The river flows west from Milchar in India's Kachar district and into Bangladesh at 24º53' north latitude and 92º32' east longitude. At Amalshid, on the northeast border of Zakiganj upazila in the Sylhet district, the Barak splits into two streams. The Surma is the arm in the northwest, and the Kushiyara is the arm in the south-west. At Markuli in Ajmiriganj upazila, the Kushiyara meets up with the Surma. It then runs south to Bhairab Bazar, where it gets the name Kalni. The Kalni joins the Dhanu, which is a branch of the Surma that has been renamed the. Part of the Kushiyara's path upstream from Markuli is called the Bibiyana.

At Amalshid, a big part of the Surma's bed has dried up, so about 85 percent of the Barak's flow goes through the Kushiyara. The Kushiyara is about 161 km long as a whole. The river is 268 metres wide on average, 347 metres wide at its widest point, and 196 metres wide at its narrowest point. During the rainy season, the river is 10 metres deep on average. The river carries a lot of water and sediment from Karimganj in Assam and the hilly parts of Hill Tripura until it reaches the Kushiyara reach. At the downstream station (SW 175.5) in Sherpur, the highest and lowest flows were recorded to be 3,700 cumecs and 33 cumecs, respectively.

Three places are used by the Bangladesh Water Development Board to measure the daily flow of the Kushiyara River. Sheola and Fenchuganj Station are two of them. The other is Sherpur Station, which is near where the Surma River and the Kushiyara River meet. The chosen stretch of road from Sheola to Sherpur is about 130 km long.

Kushiyara is a snow-fed river that flows year-round. Its flow changes, being high during the summer and low during the dry season. Some of the water in rivers comes from melting, especially in May and June. So, Monsoon weather becomes the most important factor. On the other hand, during the dry season, most of the water in the rivers comes from groundwater that was fed by the rain from the previous season.

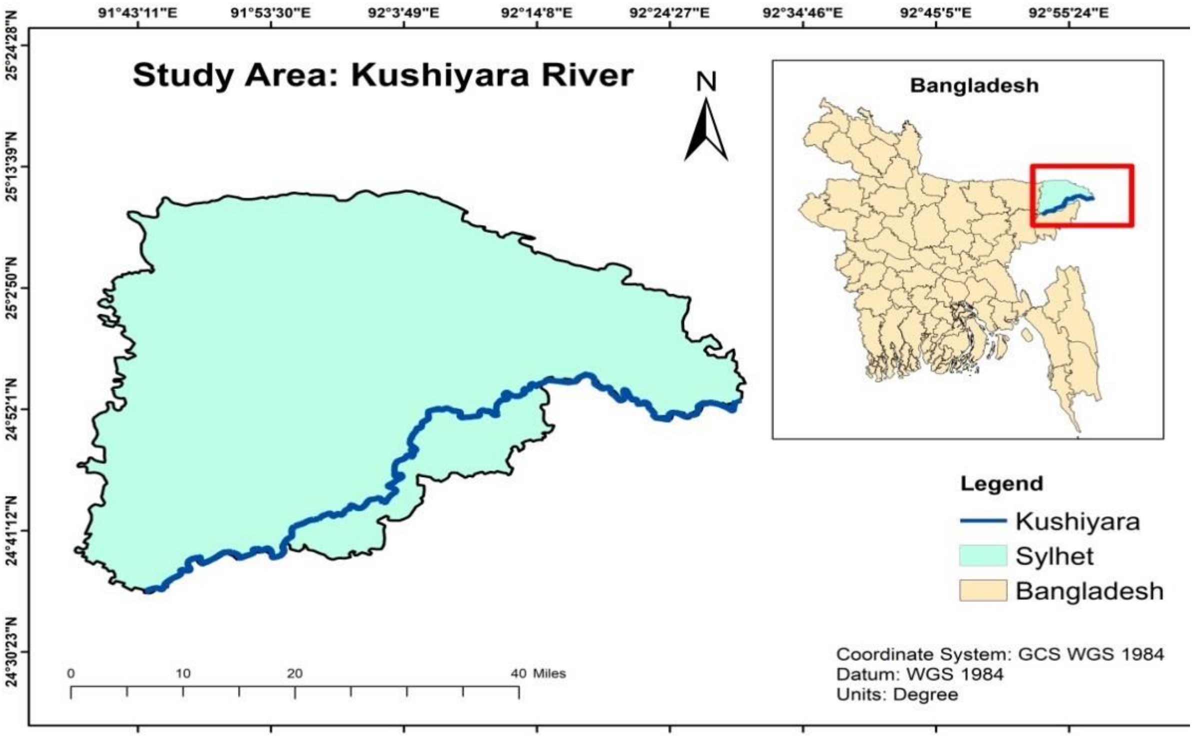


**Figure1.** *Location of the Kushiyara River, Bangladesh.*

## 2.2 Data and Methods

Data has been collected from Bangladesh Water Development Board (BWDB) for the station Sheola and Sherpur. Location of the two stations is shown in Figure 1. As stated before, there are several methods used in determining environments flow, in this study three hydrological methods have been used. They are:

- Tennant Method
- Flow duration Curve Method
- Constant Yield Method

### *2.2.1 Tennant Method*

The Tennant method says that the needed flow is a percentage of the river’s mean annual flow. For different habitat conditions, like "flushing," "excellent," "good," etc., the needed flow ranges from 10 percent to 200 percent of the mean annual flow. Tennant method also uses different percentages of mean yearly flow for low flow and high flow periods. The Tennant method is based on the idea that the mean annual flow is the flow that has kept the river’s ecosystem for plants, animals, and people going for a long time. Different percentages of the mean annual flow can be used to figure out the environmental flow requirement. Tennant’s suggestion for natural flow to support different types of fish habitat. In this table, "habitat quality" is the level of habitat quality that the authority wants to reach, and "percentage of mean annual flow" is the percentage of Mean Annual Flow (MAF) that is needed to reach that level of habitat quality. Seven of these categories, from "optimum" to "severe degradation," describe the quality of the habitat for fish and other aquatic wildlife, and the eighth, "flushing or maximum," describes the amount of water moving through the habitat. The MAF method says that the required amounts of MAF for habitat quality range from 10 percent (severe degradation) to 60-100 percent (optimum range), with 200 percent of MAF needed for flushing. For the Tennant method to work, MAF must be able to be determined from either an old flow or a new flow.

*2.2.2 Flow Duration Curve Method*

Another way to study water is to use the flow time curve method. In this method, the environmental flow requirement is found by looking at the discharge and how often it is surpassed. In this low exceedance rate, each month from 1996 to 2022 is considered. For months when there is a lot of water flowing, the flow should be greater than or equal to the 50th percentile flow. For lows during low season, the 90th percentile flow is the suggestion. Here, "50$^{th}$ percentile flow" means the flow that is higher than average 50 percent of the time. In other words, it is the value of discharge that is expected to happen or be exceeded 50 percent of the time. In the same way, the 90th percentile flow is the flow that has a 90 percent chance of happening or exceeding.

In this study, the average monthly flow rate from Sheola and Sherpur station from 1996 to 2022 was used to make a flow duration graph for each month. For high flow months, like May, June, July, August, September, and October, the 50th percentile flow is set as the suggested discharge. The 90th percentile flow is set as the suggested discharge for low-flow months like November, December, January, February, March, and April.

*2.2.3 Constant Yield Method*

In the constant yield method, the suggested flow is set to be 100 percent of each month’s median flow. For this reason, the median flow for each month from 1996 to 2022 has been worked out for each year. So, the average flow for each month was found and set as the needed flow for the environment. Environmental flow assessment necessitates mean daily water level and mean daily discharge data that were collected at Sheola and Sherpur stations of Bangladesh Water Development Board. The selected reach from Sheola to Sherpur has a length of approximately 130 km. The environmental flow of the Kushiyara River is assessed using Tenant method, Flow Duration Curve method, and Constant Yield method.

The Tenant method determines a river's required flow as a proportion of its annual mean flow. Flushing, exceptional, good, and other habitat conditions require 10% to 200% of the mean annual flow. The constant yield technique prescribes 100% of the monthly median flow. The required environmental flow was the monthly median flow (Bari and Marchand, 2006). The flow duration curve determines the flow exceedance percentage (50 for high and 90 for low flow season) for each month as suggested in a study.

## 3. RESULTS AND DISCUSSION

### 3.1 Hydrological Characteristics of the Kushiyara River

Hydrological characteristics for Kushiyara River have been analyzed from the years 1996 to 2022 based on data collected from Sheola and Sherpur Station. Maximum, Minimum and Average Discharge and Water Level variation has been analyzed from the collected data. In the following figures the variations have been shown graphically.

*3.1.1 Water Level Analysis*

The variation of Maximum, Minimum and Average Water Level from the years 1996 to 2022 have been shown in figure 2 for both location Sheola and Sherpur. The Water level has slightly decreased over the years. From the figure it is clear that water level at Sheola is greater than Sherpur in general. Water level at Sheola varied from approximately 2 to 15 mPWD whereas in Sherpur water level was between the range 1 to 10 mPWD. At Sheola, Maximum water level dropped 2.19 percent, Average dropped 3.93 percent and Minimum dropped 4.64 percent over the past 27 years.

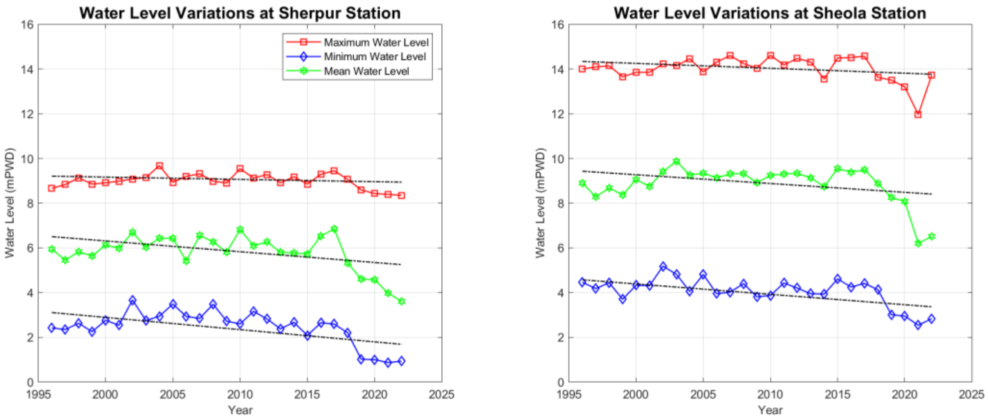


**Figure2.** *Water Level Variations at Sherpur and Sheola Stations.*

**Table2.** *Mann–Kendall test and Sen's slope statistics of Sheola Station*

| Variable | P value | Sen’s slope (mm) | Significant | Trend |
|---|---|---|---|---|
| Mean Water Level | 0.008 | -54.141 | Yes | Downward |
| Maximum Water Level | 0.350 | -65.726 | No | Downward |
| Minimum Water Level | 0.276 | -64.479 | No | Downward |

At Sherpur, Maximum water level dropped 1.03 percent, Average dropped 4.82 percent and Minimum dropped 5.47 percent over the past 27 years.

**Table3.** *Mann–Kendall test and Sen’s slope statistics of Sherpur Station*

| Variable | P value | Sen’s slope (mm) | Significant | Trend |
|---|---|---|---|---|
| Mean Water Level | 0.169 | -28.475 | No | Downward |
| Maximum Water Level | 0.196 | -28.272 | No | Downward |
| Minimum Water Level | 0.169 | -28.636 | No | Downward |

**Table4.** *Mann–Kendall test and Sen’s slope statistics of Sheola and Sherpur Stations*

| Variable | Mann-Kendall test | | Sen’s slope | Significant | Trend |
|---|---|---|---|---|---|
| | Test statistics Z | P value | | | |
| Mean Discharge at Sheola | -1.96 | 0.050 | -8.179 ($m^3$/s) | Yes | Downward |
| Mean Water Level at Sheola | -2.67 | 0.008 | -54.141 (mm) | Yes | Downward |
| Mean Water Level at Sherpur | -1.38 | 0.169 | -28.475 (mm) | No | Downward |

*3.1.2 Discharge Analysis*

The discharge at Sheola station has also been analyzed as Maximum, Minimum and Average over the years 1996 to 2022. It is observed that Maximum flow has been gradually decreasing since 2002 and Minimum flow has been static from 1996 to 2022.

Highest value of Maximum flow at Sheola is found to be 2580 cumec and lowest value of Minimum flow is 28 cumec. The analysis has been shown in the figure 3. The variation of Mean Daily Discharge over the period 1996 to 2022 has been shown for Sheola Station Upstream. Mean Daily Discharge at Sheola is 699 cumec.

*3.1.3 Seasonal Variability*

The Kushiyara River flows continuously throughout the year. However, the year can be divided into two seasons, low flow season and high flow season. Based on the availability of flows, Low season lasts from November to April, whereas high flow season lasts from May to October. In figure 3, the mean monthly flow is illustrated using available data from 1996 to 2022. It is seen that the lowest mean monthly flow is February and highest in the month of August.

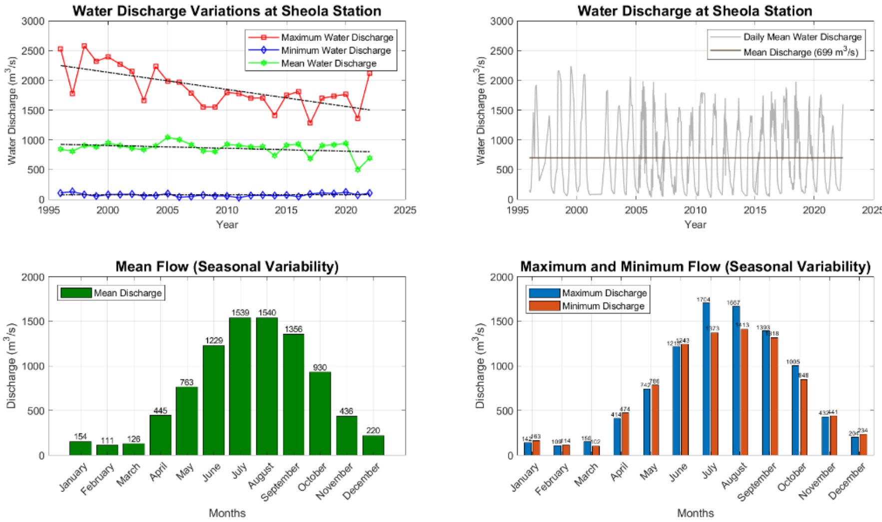


**Figure3.** *Discharge Variations and Seasonal Variability at Sheola Station.*

## 3.2 Assessment of Environmental Flow

Environmental flow requirement has been assessed by Tennant method, Flow Duration Curve method and Constant Yield method. In the following section the flow requirement derived from these methods are discussed.

### *3.2.1 Tennant Method*

As discussed before, in tenant method different percentage of mean annual flow is set as required environmental flow for different habitat quality. The percentage varies from 10 percent to 200 percent percentage of mean annual flow depending on habitat quality. Annual flow for years 1996 to 2022 has been computed for Sheola Station. From that Mean Annual Flow for Sheola station has been computed. For Kushiyara River, Mean Annual Flow at Sheola station for Low Flow Season was found to be 306 cumec which is shown in Table 5. For Kushiyara River, Mean Annual Flow at Sheola station for High Flow Season was found to be 1138 cumec which is shown in Table 5. These values have been used to determine environmental flow requirement using Tennant Method.

**Table5.** *Environmental Flow Requirement (cumec) according to Tennant method at Sheola Station*

| 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 |
| Tenant Method (Habitat Quality) | Good | 31 | 22 | 25 | 89 | 305 | 492 | 615 | 616 | 542 | 372 | 87 | 44 |
| | Out-standing | 62 | 44 | 51 | 178 | 458 | 737 | 923 | 924 | 813 | 558 | 174 | 88 |

### *3.2.2 Flow Duration Curve Method*

In this method 90th percentile flow is set as environmental flow for low flow season and 50th percentile flow is set for high flow season. November to April is considered as low flow season and May to October is considered as high flow season in this study for Teesta River. Based on available data from 1996 to 2022, flow duration curve is produced for each month at Sheola station.

**Table6.** *Environmental Flow Requirement (cumec) according to Flow Duration Curve method at Sheola Station*

| 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 |
| 50th Percentile Flow (cumec) | 150 | 102 | 91 | 398 | 731 | 1294 | 1549 | 1570 | 1395 | 942 | 427 | 211 |
| 90th Percentile Flow (cumec) | 106 | 73 | 63 | 130 | 368 | 717 | 1146 | 1135 | 893 | 548 | 228 | 136 |
| EFR | 106 | 73 | 63 | 130 | 731 | 1294 | 1549 | 1570 | 1395 | 942 | 228 | 136 |

Table 6 shows the required environmental flow using flow duration curve method. It is seen that flow requirement for low flow season varies from 63 cumec to 228 cumec and for high flow season it ranges from 731 cumec to 1570 cumec.

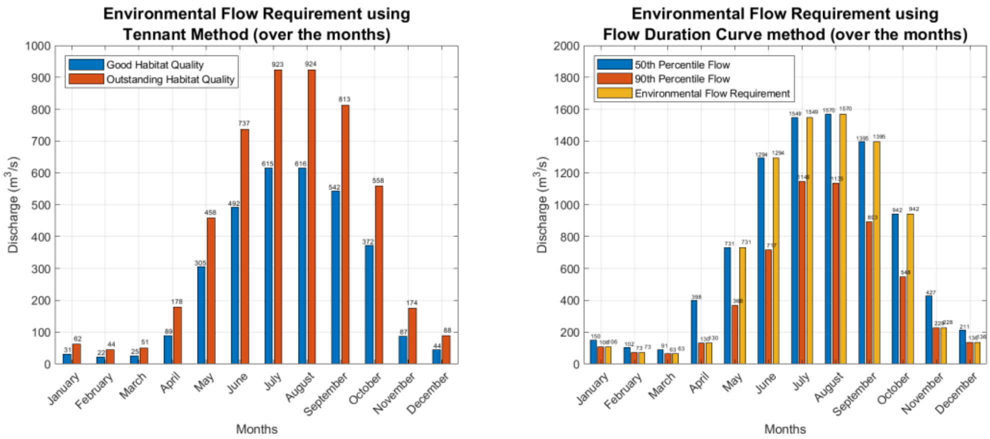


**Figure4.** *Environmental Flow Requirement (cumec) according to Tennant method and Flow Duration Curve method*

### *3.2.3 Constant Yield Method*

Constant yield method sets 100 percent median monthly flow as the required environmental flow. For this method median monthly flow has been computed for each month in two ways. In first method, median monthly flow is computed by determining the median of all the available flow data for a particular month. In second method, median flow for a month is determined for each year from 1996 to 2022. Later the median of the determined median monthly flow for all the years has been selected as median monthly flow for that month. Finally, by comparing the median monthly flow obtained from first and second option, the greater value of median monthly flow was taken as the environmental flow requirement for a particular month.

**Table7.** *Environmental Flow Requirement (cumec) according to Constant Yield method at Sheola Station*

| | Monthly Median Flow ($m^3$/s) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1st Method | 146 | 101 | 91 | 394 | 708 | 1207 | 1530 | 1551 | 1372 | 920 | 409 | 200 |
| 2nd Method | 155 | 112 | 122 | 441 | 754 | 1235 | 1556 | 1535 | 1357 | 932 | 431 | 220 |
| EFR | 155 | 112 | 122 | 441 | 754 | 1235 | 1556 | 1551 | 1372 | 932 | 431 | 220 |

Table 7 shows environmental flow requirement using Constant Yield Method. According to constant yield method, environmental flow ranges from 122 cumec to 1556 cumec.

### *3.2.4 Comparison between Environmental Flow Requirement and Flow Availability*

As previously stated, the Environmental Flow Requirement for Sheola Station has been evaluated. The determined Environmental Flow and the flow that is currently occurring in the river are contrasted in this phase of the study. For this reason, Sheola Station's mean monthly flow for each month has been compared to the environmental flow requirement established using a variety of approaches.

Comparisons between the available flow and the computed EFR using various approaches are provided in Table and Figure. According to the Constant Yield Method, it can be observed that the available flow is less than the necessary environmental flow in the low flow season, but that it is sufficient in the high flow season. According to the Tennant Method, the available flow is also sufficient to meet the requirements for good and outstanding habitat quality during high flow seasons, but it is insufficient during low flow seasons for either of the habitat qualities. In contrast, the available flow fails to meet EFR in High Flow Season but is adequate in Low Flow Season, according to the Flow Duration Curve Method. All of the Environmental Flow Requirements are met by the available flow from March to May and November to December. The Constant Yield Method is not met in January and February. Flow Duration Curve and Constant Yield Method are not met from June to October.

The purpose of the study was to assess the Environmental Flow Requirement (EFR) of the Kushiyara River and evaluate the change in flow characteristics over time. The analysis of hydrological data from 1996 to 2022 revealed significant insights into the flow characteristics and environmental water requirements of the Kushiyara River. The water level variations demonstrated a decreasing trend over the past 27 years, with Sheola station generally experiencing higher water levels than Sherpur station. The maximum, average, and minimum water levels exhibited declines of varying magnitudes, highlighting the river's diminishing flow regime. The study's findings align with previous research on other rivers in Bangladesh, such as the Gorai and Padma Rivers, highlighting the significant seasonal and temporal variations in river flows (Rahman and Rahaman, 2018; Hasan, 2019; Ali and Hasan, 2022; Sayed and Akter, 2022; Chowdhury et al., 2024; Rajib et al., 2024)

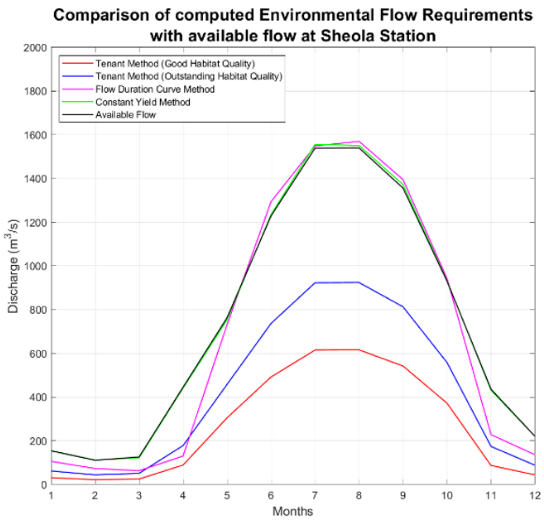


**Figure5.** *Comparison of computed Environmental Flow Requirements with available flow at Sheola Station*

**Table8.** *Comparison of computed Environmental Flow Requirements by different methods with available flow (Sheola Station)*

| Month | Flow Season | Environmental Flow Requirement ($m^3/s$) | | | | Available Flow ($m^3/s$) | Proposed E-Flow ($m^3/s$) |
|---|---|---|---|---|---|---|---|
| | | Tenant Method | | Flow Duration Curve Method | Constant Yield Method | | |
| | | Good Habitat Quality | Outstanding Habitat Quality | | | | |
| January | Low | 31 | 62 | 106 | 155 | 154 | 155 |
| February | Low | 22 | 44 | 73 | 112 | 111 | 112 |
| March | Low | 25 | 51 | 63 | 122 | 126 | |
| April | Low | 89 | 178 | 130 | 441 | 445 | |
| May | High | 305 | 458 | 731 | 754 | 763 | |
| June | High | 492 | 737 | 1294 | 1235 | 1229 | 1294 |
| July | High | 615 | 923 | 1549 | 1556 | 1539 | 1556 |
| August | High | 616 | 924 | 1570 | 1551 | 1540 | 1570 |
| September | High | 542 | 813 | 1395 | 1372 | 1356 | 1395 |
| October | High | 372 | 558 | 942 | 932 | 930 | 942 |
| November | Low | 87 | 174 | 228 | 431 | 436 | |
| December | Low | 44 | 88 | 136 | 220 | 220 | |

The discharge analysis at Sheola station corroborated these findings, with maximum flows gradually decreasing since 2002 and minimum flows remaining relatively static. The highest recorded maximum flow was 2580 cumec, while the lowest minimum flow was 28 cumec, underscoring the river's substantial flow variability. The mean daily discharge of 699 cumec at Sheola station further emphasized the need for careful management of the river's water resources. The average EFR determined by various methods for the Kushiyara River shows similar trends to those observed in the Gorai River study. The low flow requirements are higher when expressed as a percentage of mean seasonal flow but lower when expressed as a percentage of MAF (Hasan, 2019; Ali and Hasan, 2022).

The seasonal variability analysis revealed a distinct pattern, with low flow seasons lasting from November to April and high flow seasons spanning May to October. The mean monthly flow illustrated a clear peak in August and a trough in February, reflecting the river's responsiveness to seasonal precipitation patterns. This seasonality has profound implications for various water users and ecosystem functions dependent on the Kushiyara River. The declining trend in water levels and discharges, particularly in the dry season, reflects broader regional hydrological changes, possibly linked to climate change, upstream water management practices, and anthropogenic activities (Mullick et al., 2012; Tajmunnaher and Chowdhury, 2017; Uddin et al., 2017; Rahman et al., 2019). These changes have significant implications for riverine ecosystems, agriculture, fisheries, and local communities dependent on the river.

To determine the environmental flow requirements, three widely accepted methods were employed: Tennant method, Flow Duration Curve method, and Constant Yield method. The Tennant method, which bases flow requirements on percentages of mean annual flow, indicated that the available flow meets the criteria for good and outstanding habitat quality during high flow seasons but falls short during low flow seasons. Conversely, the Flow Duration Curve method suggested that available flow fails to meet EFR during the high flow season but is adequate during the low flow season. The study underscores the need for integrated water resource management strategies that consider both environmental and human water demands (Mullick et al., 2012). The environmental flow assessments can inform policy and decision-making to ensure sustainable water use and conservation of aquatic habitats. Future research should incorporate larger datasets and more advanced modeling techniques to refine EFR estimates and better understand the impacts of hydrological changes on riverine ecosystems. Additionally, incorporating sediment load data and using dynamic models like HEC-RAS 2-D or DELFT-3D can enhance the accuracy of hydrological and morphological assessments (Khan and Das, 2018; Mohib et al., 2020).

## 4. CONCLUSIONS

This study conducted a comprehensive environmental flow assessment of the Kushiyara River using long-term hydrological data from 1996 to 2022. The analysis revealed declining trends in water levels and discharges, particularly maximum flows, which have implications for sustainable water resource management. The seasonal variability, with distinct low and high flow periods, necessitates careful consideration of environmental flow requirements across different times of the year. Multiple methodologies, including Tennant, Flow Duration Curve, and Constant Yield methods, were employed to quantify the environmental flow needs. The analysis determined that the available flow is sufficient during the low flow seasons (March to May and November) using the method of Tennant and Flow Duration Curve. However, the Constant Yield approach demonstrates that flow is insufficient during the high and low flow months of January to February and June to October, respectively. While some methods indicated sufficient flows during certain seasons, deficiencies were identified during other key periods, highlighting the need for integrated strategies that balance environmental and human water demands. The findings underscore the importance of continuous monitoring, adaptive management, and incorporation of environmental flows into water policies and national legislation to ensure the long-term health and resilience of the Kushiyara River and its associated ecosystems. Future research should explore advanced modeling techniques, larger datasets, and sediment load considerations to refine the environmental flow estimates and support sustainable decision-making for this vital water resource.

## 5. ACKNOWLEDGEMENTS

The study acknowledges the Bangladesh University of Engineering and Technology (BUET) for supporting the project.

## REFERENCES

Acreman, M., Farquharson, F.A.K., McCartney, M.P., Sullivan, C., Campbell, K., Hodgson, N., Morton, J., Smith, D., Birley, M., Knott, D. and Lazenby, J., 2000. Managed flood releases from reservoirs: issues and guidance. Report to DFID and the World Commission on Dams. Centre for Ecology and Hydrology, Wallingford, UK. p86.

Acreman, M.C. and Dunbar, M.J., 2004. Defining environmental river flow requirements–a review. *Hydrology and Earth System Sciences*. 8 (5), 861-876.

Ahmed, T., 2022. Sirajul Islam (ed.). "Kushiyara River". Banglapedia: National Encyclopedia of Bangladesh. *Asiatic Society of Bangladesh*. https://en.banglapedia.org/index.php/Kushiyara_River (accessed on March 17, 2022)

Ali, M.S. and Hasan, M.M., 2022. Environmental Flow Assessment of Gorai River in Bangladesh: A comparative analysis of different hydrological methods. *Heliyon*. 8 (7).

Bari, M.F. and Marchand, M., 2006. Introducing Environmental Flow Assessment in Bangladesh: Multidisciplinary Collaborative Approach. *BUET-DUT Linkage Project. Ph-III. Final Technical Report, May*.

Chowdhury, P., Roy, A., Das, N. and Mullick, R.A., 2024. Assessment of Agricultural Water and Environmental Flow Demand for Bangladesh. *In Proceedings of the 7th International Conference on Civil Engineering for Sustainable Development (ICCESD 2024), Bangladesh*.

Dissanayake, P., Weragala, N. and Smakin, V., 2010. Environmental flow assessment: recent examples from Sri Lanka. *In National Conference on Water, Food Security and Climate Change in Sri Lanka*. 2, 23-37.

DoE, 2007. Bangladesh national program of action for protection of the coastal and marine environment from land-based activities. *Department of Environment, Dhaka, Bangladesh*. p60.

Dyson, M., Bergkamp, G. and Scanlon, J., 2003. Flow: the essentials of environmental flows. IUCN, Gland, Switzerland and Cambridge, UK. 20-87.

Hasan, M.M., 2019. Flow Characteristics and Environmental Flow Requirement of Gorai River in Bangladesh, Msc. Engineering Thesis, *Department of Civil Engineering, KUET, Khulna*.

Jowett, I.G., 1998. Hydraulic geometry of New Zealand rivers and its use as a preliminary method of habitat assessment. *Regulated Rivers: Research & Management: An International Journal Devoted to River Research and Management*. 14 (5), 451-466.

Khan, M.S.M. and Das, P., 2018. Assessment of hydro-morphological change of Surma-Kushiyara River system. *Journal of Modern Science and Technology*, 6 (1), 113-123.

Korsgaard, L., 2007. Environmental flows in integrated water resources management: linking flows, services and values. *Institute of Environment and Resources, Technical University of Denmark, Bygningstorvet, Lyngby*. 5-8.

Mohib, K.M., Rozario, P.M., Ahmed, S., Das, P., Sabbir, M. and Khan, M., 2020. Flood Inundation Mapping of Kushiyara River using HEC-RAS 1D/2D Coupled Model. *In Proceedings of the 5th International Conference on Civil Engineering for Sustainable Development (ICCESD 2020), Bangladesh.*

Mullick, R.A., Babel, M.S. and Perret, S.R., 2010. Flow characteristics and environmental flow requirements for the Teesta River, Bangladesh. *In Proceedings of international conference on environmental aspects of Bangladesh (ICEAB10), Japan*. 159-162.

Mullick, R., Khattak, M. H. and Haq, Z., 2012. Considering environmental flow for water resources management in South Asia: current status and challenges. *Journal of Engineering and Applied Science*. 31 (1), 37-44.

Norris, R.H. and Thoms, M.C., 1999. What is river health? *Freshwater biology*, 41 (2), 197-209.

Postel, S. and Richter, B., 2012. Rivers for life: managing water for people and nature. *Island Press, Washington DC, USA.*

Rahman, M.M. and Rahaman, M.M., 2018. Impacts of Farakka barrage on hydrological flow of Ganges River and environment in Bangladesh. *Sustainable Water Resources Management*. 4, 767–780.

Rahman, A., C. Roy, A. Rahman, F. Jamil, and Islam, M. S., 2019. Environmental Flow Assessment for the Main Rivers of the North-West Zone of Bangladesh. *North American Academic Research*. 2 (3), 81-101.

Rajib, M.R.I., Khan, M.R., Rifat, M. and Saleh, A.F.M., 2024. Environmental Flow Estimation of Buriganga River considering Water Quality. *In Proceedings of the 7th International Conference on Civil Engineering for Sustainable Development (ICCESD 2024), Bangladesh*.

Sayed, M.A. and Akter, A., 2022. The low flow assessment of Padma River in Bangladesh. *In Journal of the Civil Engineering Forum.* 8 (1), 11-20.

Tajmunnaher, T. and Chowdhury, M.A.I., 2017. Correlation study for assessment of water quality and its parameters of Kushiyara River, Sylhet, Bangladesh. *International Journal of New Technology and Research.* 3 (12), 2631792

Tharme, R.E., 2003. A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. *River Research and Applications*, 19 **(**5-6), 97-441.

Uddin, M.E., Akter, S.A., Uddin, M.J. and Diganta, M.T.M., 2017. Trend analysis variations and relation between discharge and rainfall: a study on Kushiyara River. *Journal of Environmental Science & Natural Resources*. 10 (2), 121-132.

**Citation:** *Md. Khairul Amin and K.M. Ahtesham Hossain Raju, " Study on Environmental Flow Assessment of the Kushiyara River", International Journal of Research in Environmental Science (IJRES), vol. 10, no. 3, pp. 1-11, 2024. Available: DOI: http://dx.doi.org / 10.20431/2454-9444.1003001*