FLOW AUGMENTATION OF DHALESWARI RIVER USING AN UNSTEADY FLOW MODEL HEC-RAS

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ABSTRACT

This study work has been conducted to assess the existing hydrodynamic condition of the Dhaleswari River and apply mathematical modeling for the hydrodynamic analyses for various dredging options. Dhaleswari River, one of the main distributaries of the Jamuna River, is the feeding River to the Buriganga-Turag-Balu-Shitalakshya river systems around Dhaka Metropolitan area. But the flow carrying capacity of the river has been reduced significantly over the past few decades. Because of gradual sedimentation, the conveyance capacities have been decreased causing no flow conditions during the dry season. Consequently, the navigational drafts have been reduced. In this situation, it will be impossible to recover the river water from its dying stage without augmenting the flow. Planed dredging works can be inevitable options to increase the carrying capacity of the river. Mathematical modeling analysis of the river can play an important role in the selection of suitable dredging options. The present study is based on the assessment of hydrodynamic analysis of Dhaleswari River by using a mathematical model namely HEC-RAS of version 5.0.7. The full length of the river is approximately 292 km. However, the present study covers a reach of 80 km starting from off-take Dhaleswari at Porabari to Savar. River cross-sections (RMD1 to RMD12), time series discharge data at the Tilli (SW 68), Water level data at Porabari (SW 50) and Jagir (SW 68.5) are collected from Bangladesh Water Development Board (BWDB) and Water Resources Planning Organizations (WARPO). The setup model has been successfully calibrated and validated against the data for the years 2016 and 2017 respectively. Computed water surface profile shows the least available water depth at different river stations range from 1.0 m to 1.1 m during the lean flow period. Therefore, navigation though the river at this period is a major challenge. To mitigate this issue, the hydrodynamic parameters of the river have been investigated based on dredging with the help of the channel modification module incorporated in HEC-RAS 5.0.7. Simulations have been performed with three different dredging sections that varied in base width, depth, and side slope. The simulated parameters are then compared before and after dredging to assess the functionality of each dredged bathymetry. The dredged section having a base width of 100 m, side slope of 1:5 and 1 m of average dredging depth shows the best hydrodynamic performance, specifically, the maximum flow augmentation. The first dredging strategy can be defined as the most efficient section with a velocity range of 0.41- 1.1 m/s. This study assessed only the hydrodynamic performance. However, morphological response to dredging is needed to investigate the overall stability of the river.

Keywords: *Flow augmentation, Dhaleswari river, Hydrodynamic, Mathematical model, Navigation, Dredging.*

1. INTRODUCTION

Bangladesh, the largest delta in the world, has been formed with sediment deposited by the three mighty rivers namely the Ganges, the Jamuna and the Meghna (GBM). These alluvial rivers are commonly featured with a lot of tributaries and distributaries (FAP24, 1996). The Dhaleshwari River (Figure 1) is one of the distributaries of the Jamuna River in central Bangladesh. It originates from the Jamuna River at the northwestern tip of Tangail District. Afterward, it split into two branches. The north branch retains the same name Dhaleshwari and merges with the Kaliganga River, the opposite branch at the southern a part of Manikganj District. This unified flow meets the Shitalakshya close to Narayanganj District and finally goes southward to merge into the Meghna River. The full length of the river is 292 km (BWDB, 2011). However, the length of the study reach is 80 km beginning from off-take Dhaleswari at Porabari to Savar (Figure 1). The flow rate of the river is very significant as the conveyance capacity of the Buriganga-Turag-Balu-Shitalakshya river systems is mainly depends on it (Khan, 2004). Therefore, the river route is expected to carry the necessary discharge through year-round (IWM, 2004). But the massive sediment coming from Jamuna River is eventually being deposited at the Dhaleswari offtake area as well as at the channel bed causing no flow conditions during the dry season. Consequently, navigational drafts have been reduced (Haque, 2018).

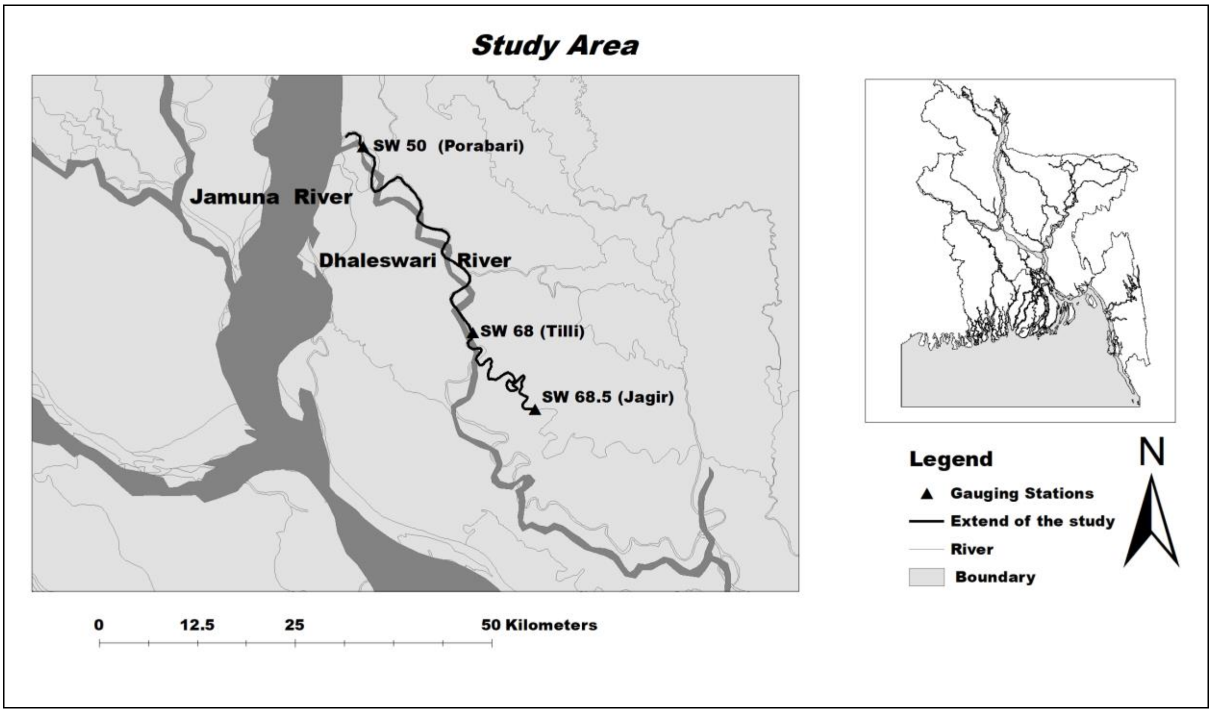

Figure 1: Map of the study area

Planed dredging works that involve the removal of bed materials can be inevitable options to increase the conveyance capacity and hence augmenting the river during the dry period (Paarlberg et al., 2015). Several studies have been made in this regard. Model studies are available indicating flow diversion at the Jamuna-Dhaleswari offtake. IWM (2004) had investigated the strategy for rehabilitating the Buriganga-Turag-Shitalakhya river system for flow augmentation. Still, further study is required to perform for a detailed understanding. The present study of the mathematical modeling aims to supplements the rehabilitation of the river system. In this regard, a one-dimensional numerical model (HEC-RAS 5.0.7) has been applied to perform one-dimensional unsteady flow calculations. HEC-RAS unsteady state simulation computes water surface from one cross-section to the next by solving the standard step iterative procedure to solve the St. Venant's equations of mass and momentum conservation (HEC RAS, 2010).

The present study is directed towards detail hydrodynamic analyses of the river using mathematical modeling with the recently collected flow, water level, and bathymetric data. Three different channel modifications have been made as a part of a solution of flow augmentation. Finally, hydrodynamic parameters including velocity and water level were compared before and after dredging and portrayed in the graphs and charts.

2. METHODOLOGY

The methodology of the study covers data collection, setting up a model of 80 km river reach of the upper Dhaleswari. Cross-section data (RMD1 – RMD12), time series discharge data at the Tilli (SW 68), Water level data at Porabari (SW 50) and Jagir (SW 68.5) are collected from Bangladesh Water Development Board (BWDB) and Water Resources planning organizations (WARPO) for the model setup. The types of data, location, and duration are shown in detail (Table 2).

Table 1: Model performance analysis

Types of Data	Location	Duration/ Time
Bathymetry Data	RMD1 to RMD12	2013, 2016
Discharge Data	SW 68.5	2013-2017
Water Level Data	SW 50; SW 68	2013-2017

2.1 1-D Model Setup, Calibration and Validation

The model setup is required bathymetry of the river network and two boundary conditions. Time series of discharge i.e. flow hydrograph had used as the upstream boundary condition and time series of water level i.e. stage hydrograph had specified as the downstream boundary condition. The distance between river stations was measured from BWDB maps and Google earth using ArcMap 10.2.2. The initial flow value for model computation had specified using opening discharge value in the respective flow hydrograph. The setup model had run for the period from 1st January 2016 to 31st December 2016. Computed water surface elevations had compared with the observed water surface elevations at an intermediate gauging station Tilli (SW-68). Roughness is the only parameter (calibration parameter) that can be changed to obtain an adequate match with the observed field conditions. Such fine-tuning for making a match of model output with real field observation is nothing but the calibration of the numerical model (Figure 2). Manning's roughness coefficient had adjusted after several trials of the model during calibration to an average value of n = 0.018.

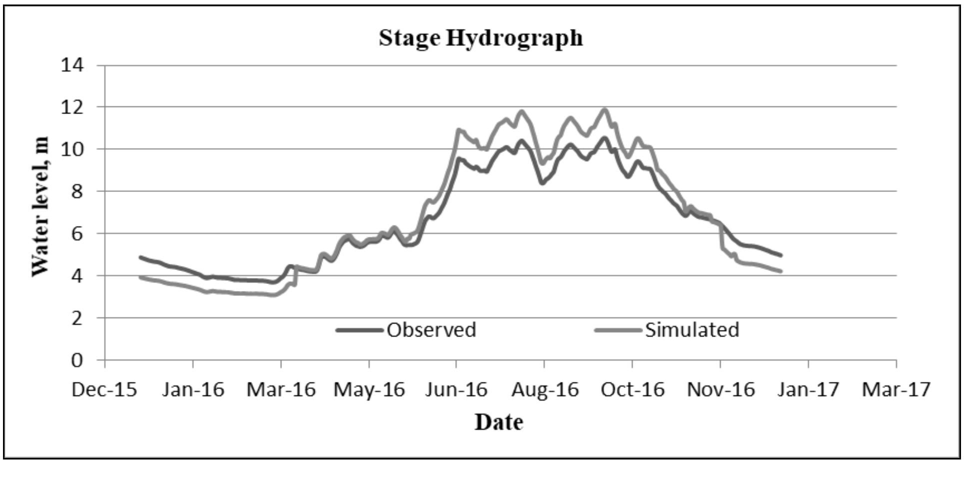

Figure 2: Calibration of water level at Tilli of Dhaleswari River

After estimating the model parameter (n =0.018), the model had been checked to assure that they adequately perform the functions satisfactorily. This verification of a calibrated model is known as validation (Figure 3). The model had been validated at the gauging station Tilli (SW 68) for the period 1st of January 2017 to 31st of December 2017.

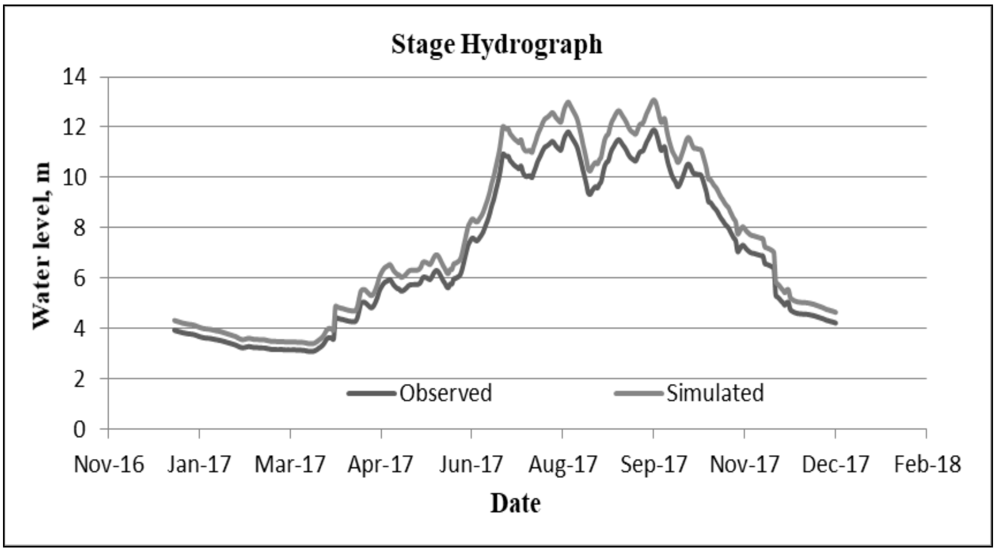

Figure 3: Validation of water level at Tilli of Dhaleswari River

From the calibration and validation curve of the hydrodynamic model, it figured that there are slight differences between observed and predicted water levels. RMSE-observations standard deviation ratio (RSR), Nash-Sutcliffe efficiency (NSE) used for determining the fitness of the calibration and validation curve. The values (Table 2) are indicating a good performance of the model.

Table 2: Model performance analysis

	RSR	**NSE**
Calibration	0.335	0.854
Validation	0.401	0.815

2.2 Selection of Dredging Section

The existing channel geometry is rigorously analyzed before selecting the design channel sections. It includes the comparative analysis through the plotting of all the cross-sections in a single figure (Figure 4). From the analysis, the average width of these cross-sections varies from 80 m to 200 m while the side slope varies from 1: 5 to 1: 35. Based on the existing geometry of the river three different dredge sections (Figure 5) have been introduced for channel modifications.

Strategy-1: Base width of around 100m with side slopes of 1:5
Strategy-2: Base width of around 150m with side slopes of 1:10
Strategy-3: Base width of around 200m with side slopes of 1:15

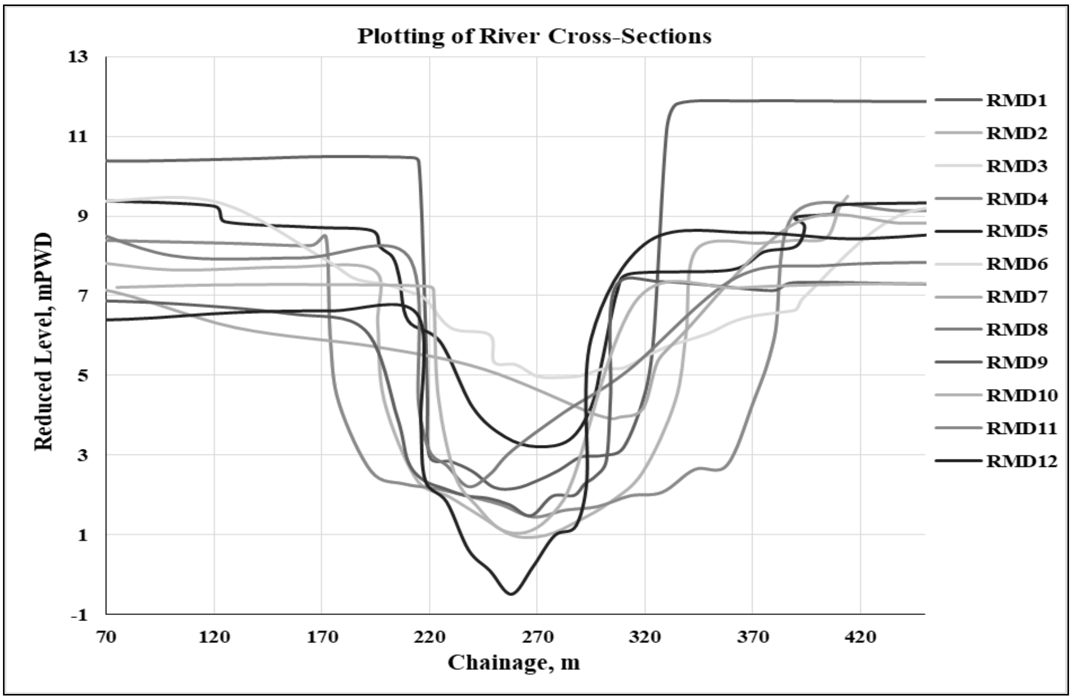

Figure 4: Plotting of original bathymetry

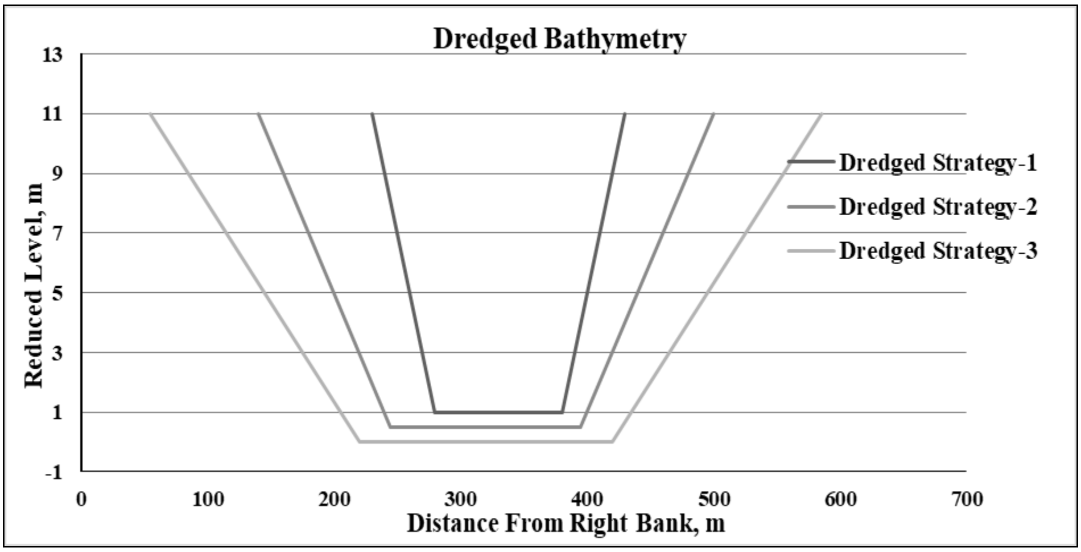

Figure 5: Channel section at three different dredging strategies

3. RESULTS AND ANALYSIS

3.1 Rating Curve Using Conveyance Analysis

A dredging strategy alters the bathymetry remarkably. This change in geometry triggers the conveyance capacity of the river. The rating curve has been developed (Figure 6) for the upstream cross-section using conveyance analysis. Maximum and minimum discharge calculated as 900 m^3/s and 200 m^3/s respectively. Manning's roughness and channel slope values were considered being 0.018 and 0.000025.

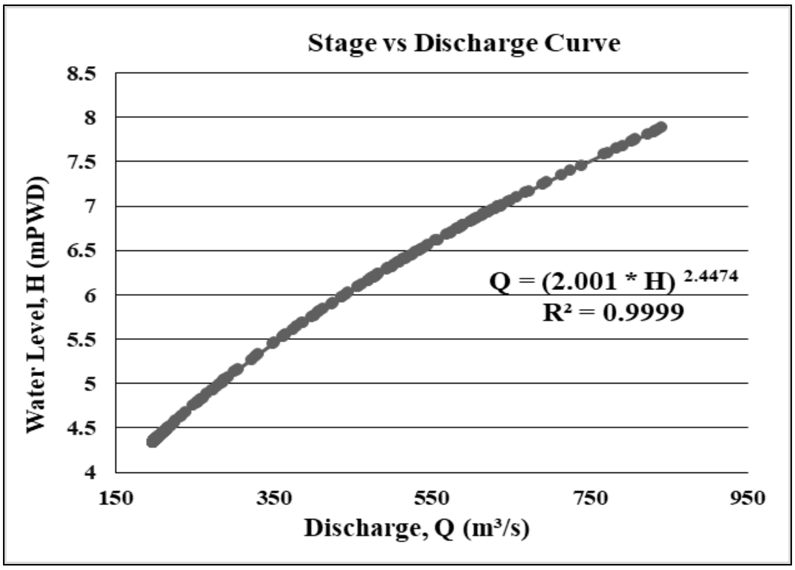

Figure 6: Rating curve using conveyance analysis

3.2 Response Due to Dredging

Dredging allows more water to flow through the main channel, thus conveyance capacity of the channel increased while water surface elevation may drop as dredging creates smooth passage of water flow. Water surface elevation of the study reach during dry and wet seasons had compared before and after dredging. Minimum available navigation depth at the different month of the year are shown in table (Table 3). During the lean flow period, minimum available depth is about 1.0-1.1 m for existing bathymetry, 2.85-2.87 m for the dredging option-1. Thus there is a significant increase in water depth compared to the original depth profile at this period. During the wet season there is lower water depth in the main channel of dredged bathymetry comparing with the original depth profile. Similar observations show for the second and third available dredging options.

Table 3: Response to different dredging strategies

	Minimum Available Water Depth (m)			
Month	**Existing bathy**	**Dredged strategy-1**	**Dredged strategy-2**	**Dredged strategy-3**
January	1.49	2.87	2.85	2.84
February	1.15	2.87	2.85	2.84
March	1.02	2.86	2.84	2.83
April	1.09	2.86	2.84	2.83
May	2.92	2.87	2.84	2.83
June	5.09	5.19	4.83	4.32
July	7.25	6.53	5.62	5.12
August	6.91	5.95	5.18	4.76
September	6.8	5.04	4.66	4.18
October	4.42	3.02	2.93	2.89
November	2.54	2.85	2.83	2.82
December	1.92	2.84	2.83	2.82

3.3 Comparison of Velocity Profiles

Dredging strategy changes the flow parameters by altering the bathymetry. A smoother passage for the flow occurred as dredging increases the bed slopes. Figure 7 shows a comparison of velocity at pre and post dredging conditions. During both the wet and dry season for the year 2017, there is a higher velocity of flow in the main channels and flood plains in case of dredged bathymetry. During the wet season flow velocity varies from 0.42 m/s-1.1 m/s in dredged bathymetry while the velocity falls within the range of 0.37 m/s-0.41 m/s during the lean period flow. As the flow velocity increases due to dredging, it induces an increase in discharge along the study reach that augments both the dry and wet season flow.

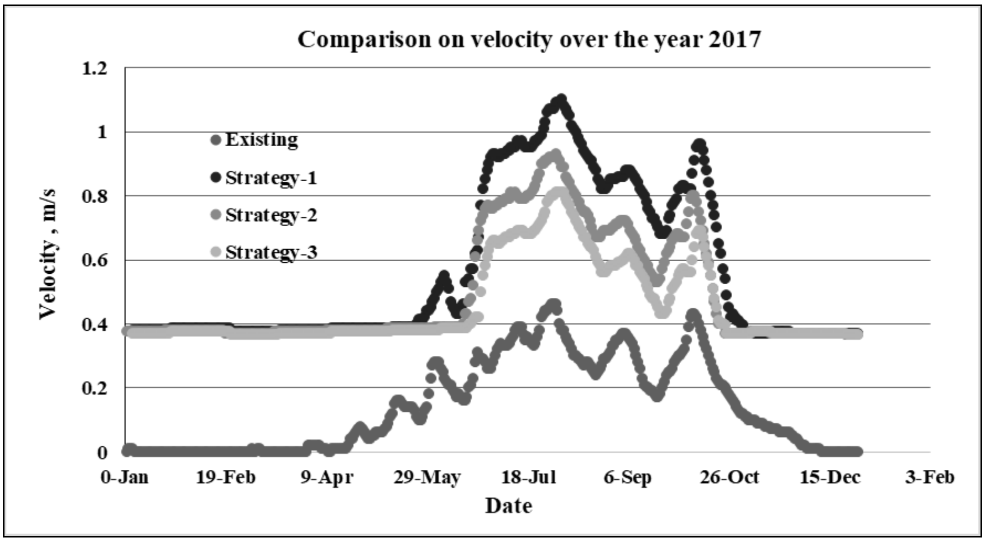

Figure 7: Velocity profile before and after dredging

3.4 Efficiency of Dredging Strategies

A comparative analysis has been performed to identify the most efficient dredging strategy among the proposed three. Minimum available water depth during the dry and wet season has been shown in figure (Figure 8a). During dry season all of these three options show approximately the same depth. Among these three strategies, option-1 gives the maximum available depth of 5.19 m. The variation in velocity is shown in figure 8(b). Maximum velocity exist in the option-1, varies from 0.41-1.1 m/s showing the fact that increase in velocity of flow is maximum in case of the dredging strategy-1 helps to divert more flow through the channel at the same time instant comparing with the other two.

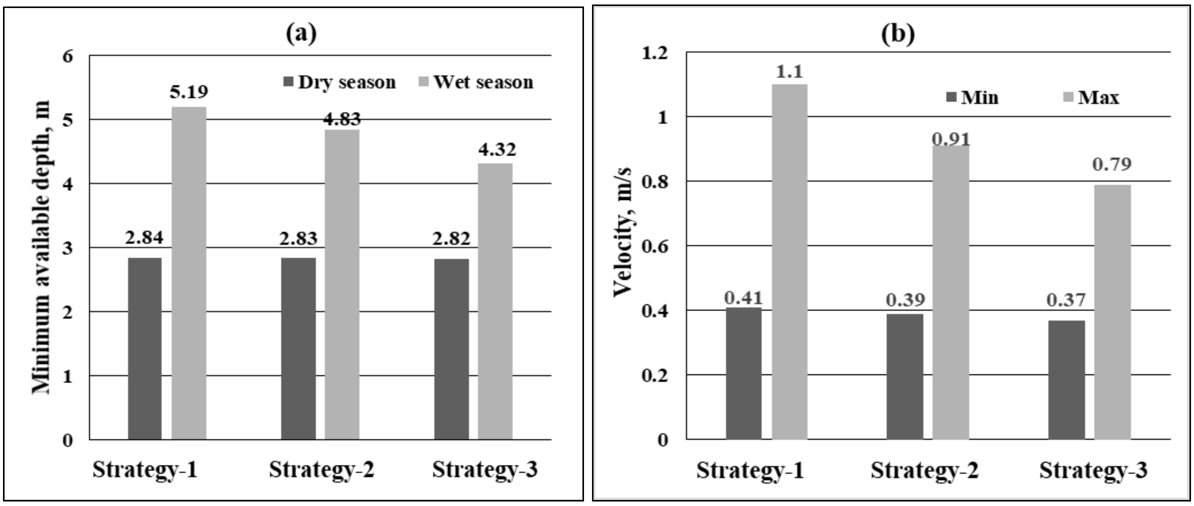

Figure 8(a): Minimum available navigation depth (b) Maximum and minimum velocity for the three proposed dredging strategies

Dredging works involves huge earth work (cutting and filling). Comparative cutting and filling volumes are shown in figure 8(c). Strategy-1 requires lees cutting volume compare to strategy-3.

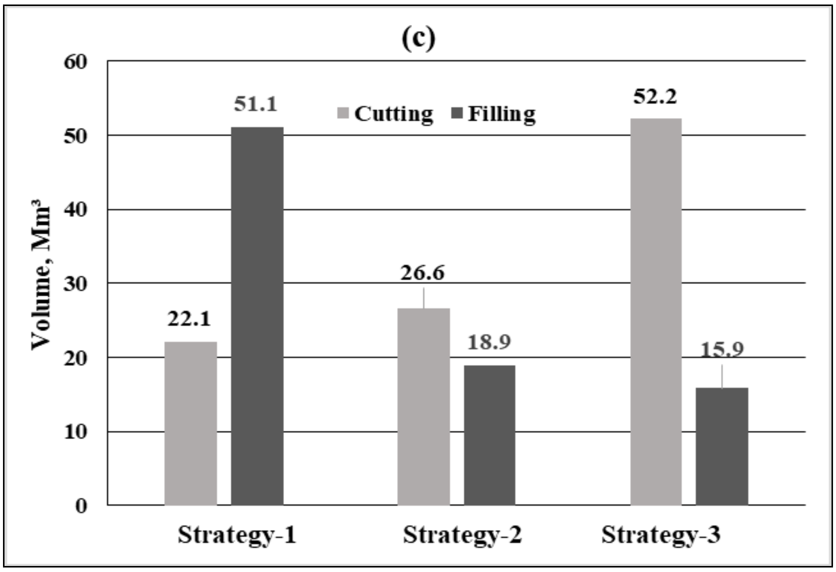

Figure 8(c): Cutting and filling volume for the three proposed dredging strategies

4. CONCLUSIONS AND RECOMMENDATIONS

The analysis has been done to assess the hydrodynamic response of the selected options for improving the dry season flow condition. It is found that for the dredging section having 100 m base width, side slope is approximately 1:5 and average dredging depth of 1.0 m hydrodynamic performance, specifically, flow augmentation is maximum. It has been found that Option-1 has the best functionality among others. Each dredged section has applied individually. But the geometry specifically the cross-sections are not constant in shape. Therefore, further study should perform considering different dredged sections in a single model setup for better realistic understanding.

REFERENCES

BWDB. (2011). *Bangladesh er nod-nodi*. Bangladesh Water Development Board (BWDB), Dhaka, Bangladesh.

FAP24. (1994). *Study report No. 3: Morphological studies phase 1, Available data and characteristics*. FAP24, Dhaka, Bangladesh.

HEC-RAS Applications Guide (2010). Hydrologic Engineering Center US Army Corps.

Haque, A., Z., M., S. (2018). Hydrodynamic and morphological analyses of new Dhaleswari River offtake using mathematical model (M. Sc. Thesis, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh). Retrieved from http://lib.buet.ac.bd:8080/xmlui/handle/123456789/126

IWM (2004). Feasibility & Mathematical Model Study of Approaching and Investigating Strategy for Rehabilitating the Buriganga-Turag-Shitalakhya River System and Augmentation of Dry Season Flow in the Buriganga River. Dhaka, Bangladesh

IWM. (2011). Mathematical modelling for offtake management of the new Dhaleswari River and hydraulic monitoring of new Dhaleswari-Pungli-BangshiTurag-Buriganga system: Prepared for Bangladesh Water Development Board, Dhaka, Bangladesh.

Khan, A., S. (2004). Augmentation of dry season flows in the peripheral rivers of Dhaka for improvement of water quality and round the year navigation. Institut für Wasserbau und THM der TU Dresden, pp. 237-247

Mushfequzzaman, M., Matin, M., A., & Noor, F. (2016). Response in the selected reach of Jamuna River due to dredging. Tech. Journal of River Research Institute, Vol.13, No.1, pp. 102-110.

Paarlberg, A., J., Guerrero, M., Huthoff, F., & Re, M. (2015). Optimizing dredge-and-dump activities for river navigability using a hydro-morphodynamic model. Water, 7(7), 3943-3962. https://doi.org/10.3390/w7073943