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APPLICATION OF DELFT3D MATHEMATICAL MODEL IN THE JAMUNA RIVER FOR TWO-DIMENSIONAL SIMULATION

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ABSTRACT

The Jamuna River, one of the most important rivers in Bangladesh which has been playing a vital role in our social economic structure, experiences severe erosion almost every year. Severe erosion poses a constant threat to the people and have long-term negative impact on socio-economic status. Apart from this natural hazards, some man-made interventions i.e. construction of the Bangabandhu Bridge, groynes etc. interrupt the natural flow of the river and therefore changes the hydraulic environment. In order to study the possible changes in river bed morphology due to manmade interventions application of 2D model in the Jamuna River is unavoidable. This study focus principally the different hydrodynamic characteristics of the selected reach of the river by applying a 2D model Delft 3D. The study reaches covers from 30 ksm upstream of Bangabandhu Bridge to 20 kms downstream of this bridge. Boundary conditions for upstream and downstream are defined by discharge and water level data respectively. The model has been developed with the bathymetry data collected from Bangladesh Water Development Board (BWDB). The model has been calibrated with the available observed data for the period of April to July 2010 and validated onto the period of April to August, 2011. The hydrodynamics of the selected area have been simulated by solving two-dimensional depth integrated momentum and continuity equations numerically with finite difference method. The knowledge developed herein may be useful in providing an opportunity in assessing improvement in future prediction and also to suggest the effect of possible development work to be implemented on this river.

Keywords: *Jamuna River, Calibration, Validation.*

1. INTRODUCTION

The Jamuna River usually faces high dynamics and is usually surrounded by network of interlacing channels with numerous sandbars or chars (Marra, Kleinhans & Addink, 2014). These chars are formed as the sediment-carrying capacity of the flow exceeds the incoming sediment load, which is also known as aggradation of the channel (Baki & Gan, 2012). The Jamuna River also experiences severe erosion, operates in several spatial and temporal scales and strongly related to the magnitude of monsoonal peak discharge, leads bank retreat from hundreds of meters annually and causes possible damage to public infrastructure living along its course and on chars (Mount, Tate, Sarker & Thorne, 2013), (Mosselman, 2006). Therefore, understanding of the river’s dynamic behaviour is required to control erosion as well as reduce the damage to public infrastructure.

On the other side, the construction of Bangabandhu Bridge has a significant impact on the dynamics of bar morphology and channel shifting. River training structures along with the bridge creates a water slope between the upstream and downstream level near the bridge section which results in bank erosion (Bhuiyan, Rakib, Takashi, Rahman & Suzuki, 2010). Construction of the bridge has provided the first road and rail link between the northwest and eastern part of the country (Bayes, 2007). Apart from movement of cargo and passenger streams, it promotes conveyance of electricity and natural gas, and telecommunication links to the western region. Thus contributing economic development and eliminating the disparities between the eastern and western districts. Hence, hydraulic conditions in the vicinity of the bridge as well as hydro-morphological forecasts of the river at the critical locations within the bridge area are essential to know and predict the navigability and erosion patterns. Previously extensive studies have been conducted at different duration to assess the behavior of Jamuna River (Jagers, 2003), (Uddin, Rahman, 2012). This study gives an idea of the hydrodynamic characteristics of Jamuna River which will further support the future application of 2D mathematical model under several scenarios. The Study area covers about 50 km reaches of Jamuna River between Kazipur at the upstream end and Chauhali at the downstream end, covers Balkuchi, Sirajganj on the right bank and Gopalpur, Bhuapur on the left bank which are important places to be considered along the study reach. The location of the study area is shown in Figure 1.

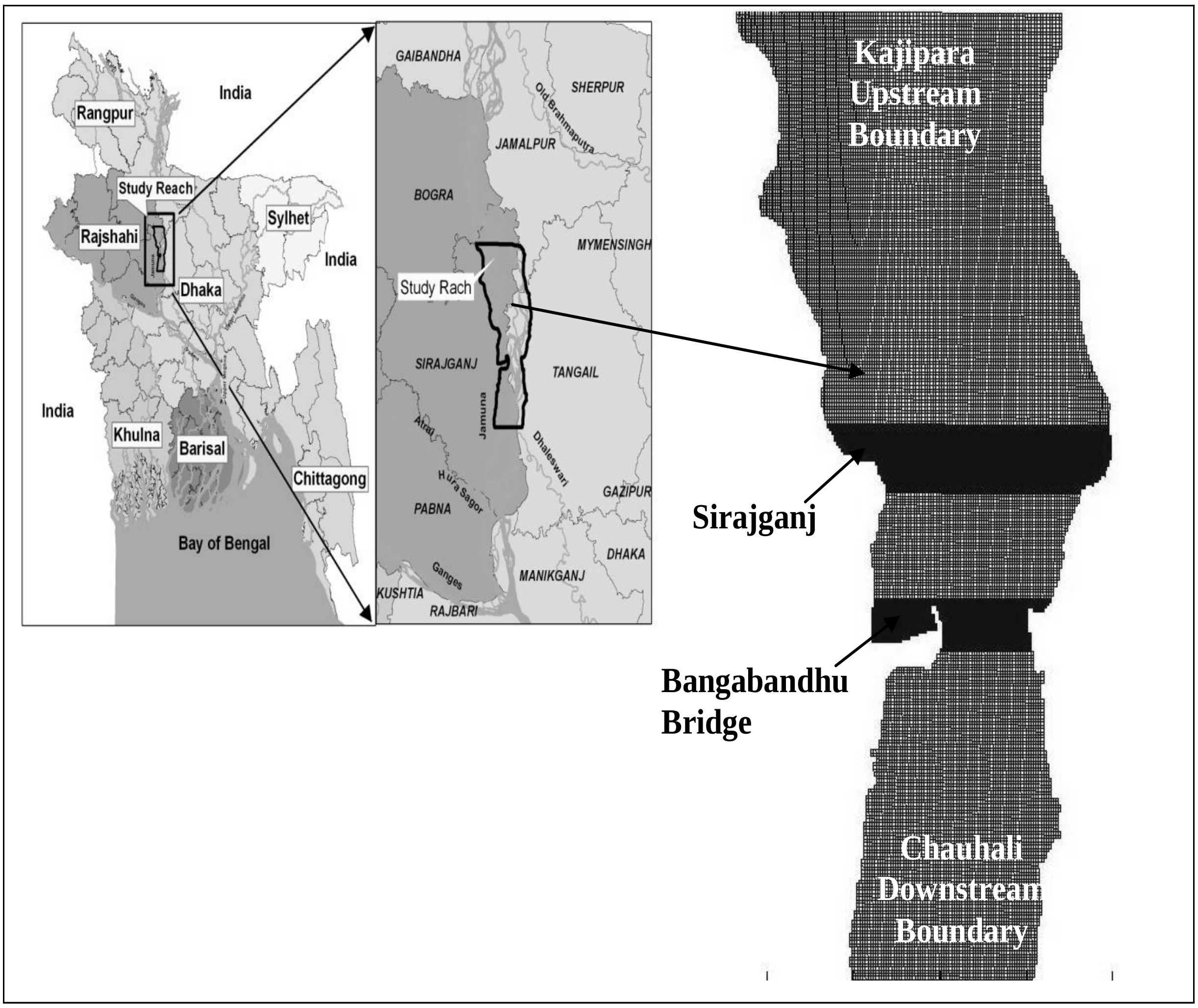


Figure 1: Study Area on the Jamuna River

2. METHODOLOGY

In order to simulate the hydrodynamics of Jamuna River, a 2D hydrodynamics model Delft3D has been applied. Flow, MOR, Wave, WAQ are different modules of Delft3D. Delft3D-FLOW module has been implemented in this study, which is a multidimensional (2D or 3D) hydrodynamic and transport simulation program. The non steady flow and transport phenomenon is being calculated by this module, resulting from tidal and meteorological forcing on a rectilinear or a curvilinear boundary fitted grid.

3. GRID GENERATION AND BATHYMETRY

In order to carry out continuous simulation curvilinear grid was used, which was generated, modified and visualized by Delft3D-RGFGRID module. This module generates grid in Cartesian coordinate system. The grid was extended over the upstream near Kazipur to downstream close to Chowhali.

The model consists of a total of 299 and 146 cells in M-N directions respectively with dimensions of (124×171) m^2. Surveyed bathymetric data was collected from IWM and interpolated into mesh nodes using the Delft3D-QUICKIN module. Bathymetry file was generated for Delft3D after a series of processes such as grid cell averaging, triangular interpolation and internal diffusion. The hydrodynamic simulation time has been set to 122 days with time step of 1 minute.

4. BOUNDARY CONDITIONS

Time series discharge data was used at the upstream inflow boundary near Kazipur and water level data in the downstream direction near Chowhali collected from Shirajganj station.

In the year 2010, the water level rises abruptly during April to July as well as the discharge also increased abruptly. Again in 2011, it can be observed from the hydrograph that the water level raised abruptly during April to June, fluctuated slightly during the next three months then slightly falls from the end of August almost to the mid of September then again slightly raises in the end of September. In case of discharge similarly abruptly discharge raised from April to July then slightly fluctuated downward for the next three months, and falls rapidly during the end of August to September.

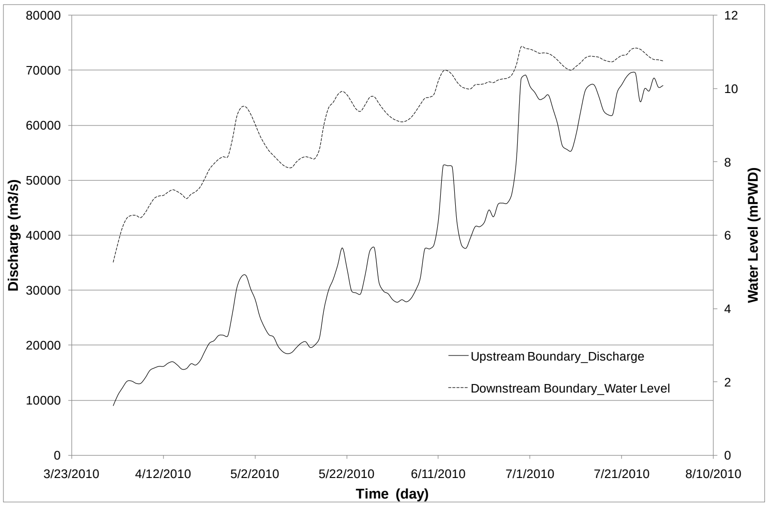


Figure 2: Time series hydrographs from April to July 2010 used in the model as Boundary Conditions for Calibration Period

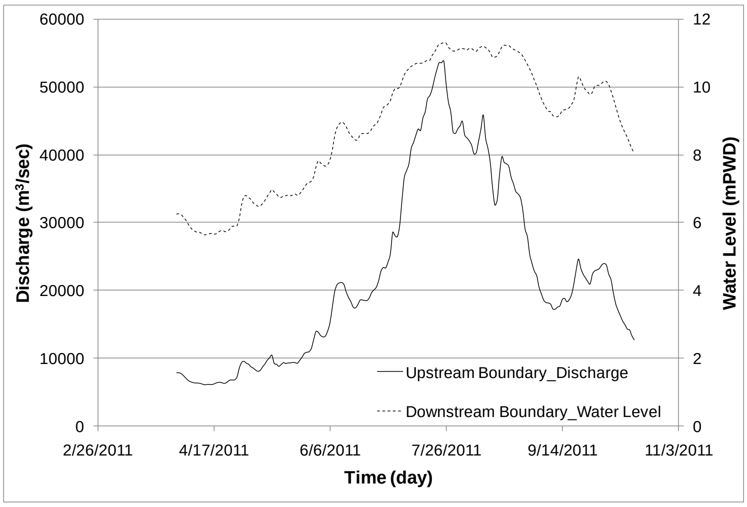


Figure 3: Time series hydrographs from April to October 2011 used in the model as Boundary Conditions for Validation Period

5. CALIBRATION AND VALIDATION

Initially the sensitivity of the model has been analysed to concentrate on the influential parameters that impact the calibration in order to determine the models performance.

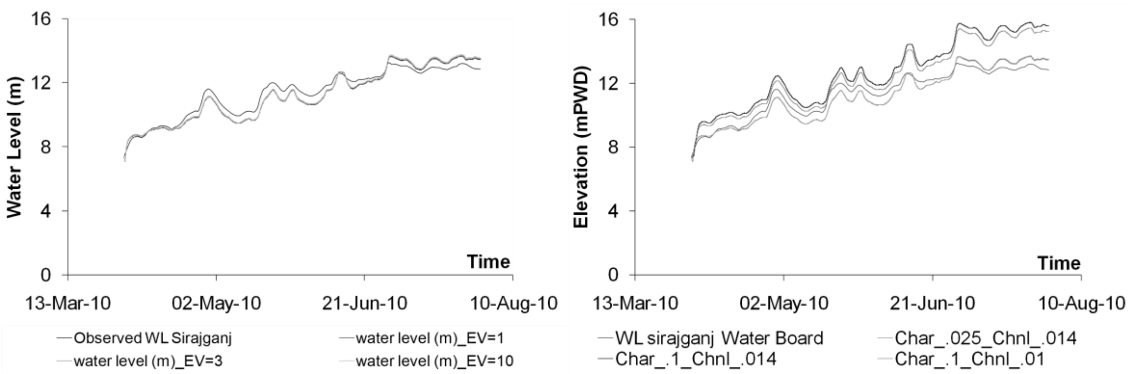


Figure 4: Influence of Manning parameter and Eddy viscosity on amplitudes of water level

The developed Delft3D model was calibrated using water level as the parameter for calibration. Data has been collected from IWM. The model was calibrated by using the observed water level elevation data at Shirajganj station. The calibrated model, performed fairly well with the measured water level.

In order to examine the range of validity of the calibrated model, the simulated results have been compared with the observed data without adjusting the values of calibration parameters. The simulated and observed water level showed quite good agreement with slight variation.

Roughness and eddy viscosity were the parameters that have been used as a trial to obtain suitable match with the observed field condition. Manning's roughness co-efficient was adjusted with the varying water depth i.e. n=.014, when water depth was lower than 6m and n=.025, when water depth was higher than 6m. The value of eddy viscosity was considered 1.

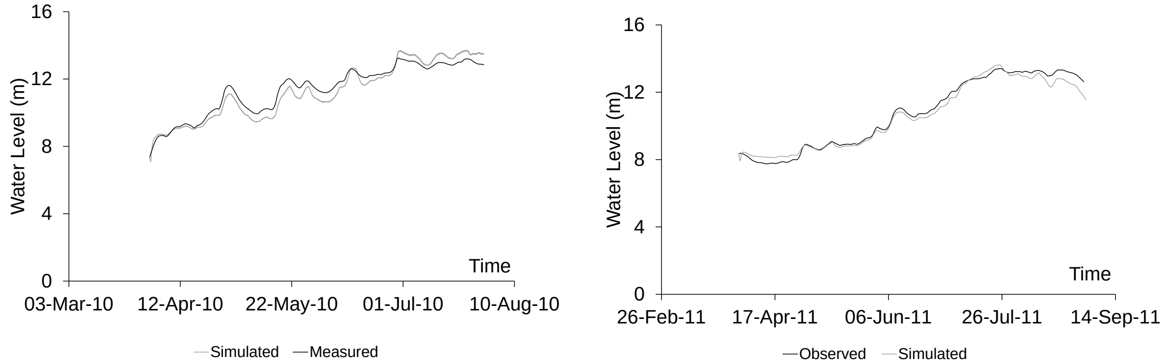


Figure 5: Simulated and measured water levels of Jamuna River for calibration and validation at Shirajganj

6. RESULTS AND DISCUSSIONS

The next step involved was running the model successfully for the whole year and to compare it with observed bed level data of December 2010. Bathymetry of April 2010 has been taken as base for simulation.

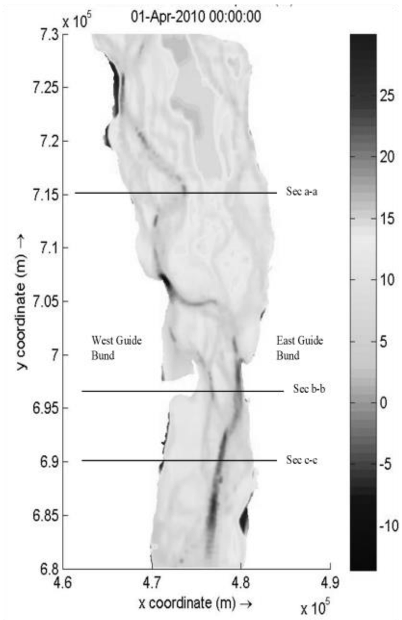
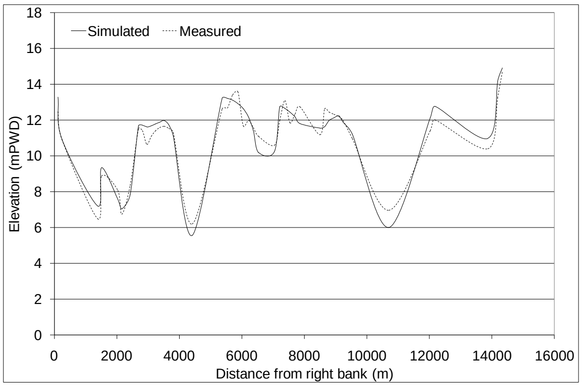
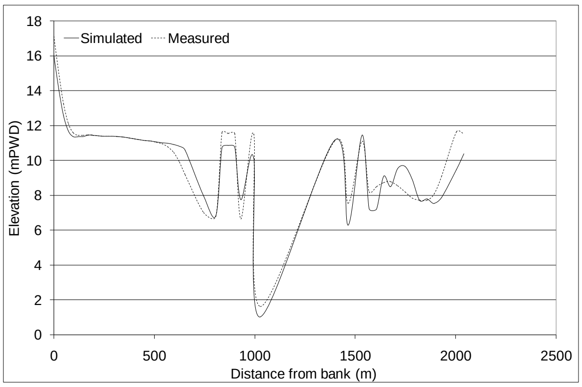


Figure 6: Cross Sections shown in Bathymetry of selected reach of the Jamuna River for comparison

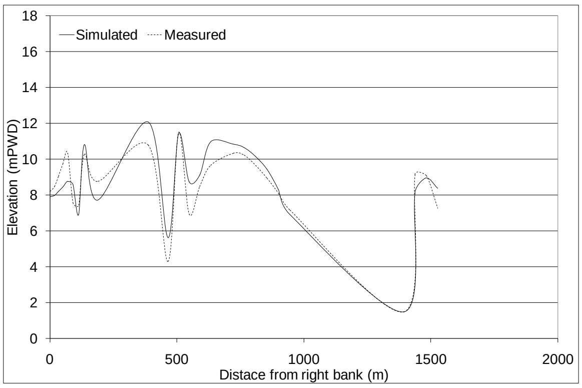
The simulated bed level data presented in this study have not been quantitatively verified due to the scarcity of observed data. However, the ranges of simulated results seem to be reasonable and consistent with the observed one. Comparisons of the simulated bed level against the observed one at various sections of December 2010 are shown in Figure 7.



(a) Sec a-a



(b) Sec b-b



(c) Sec c-c

Figure 7: Comparison of Cross-Sections

Overall, this study was mainly focused on the calibration and validation processes, which showed quite satisfactory results and the morphological assessment has been done successfully. Thus, this model can be applied for further development and/or future interventions in the Jamuna River.

7. CONCLUSIONS

Two-dimensional (2D) depth averaged model has been developed for the Jamuna River. Calibration and validation of the model shows significant compliance with the observed data against water surface elevations at Sirajganj. Only the high flow data has been considered as most of the morphological activities occur during this period. Model results are generated for bed level and water level at various locations. Further use of this model is to assess the morphological changes such as erosion or sedimentation of the river, relation between the sediment transport and depth average velocity as well as shifting process of river course. Through the application of this model, the change in river behaviour under different scenarios can also be assessed for proper planning of any development project on Jamuna River.

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