STUDY ON CHANNEL CHANGES AND BED DEFORMATION IN CONFLUENCE REGION OF GANGES AND JAMUNA RIVERS UNDER DIFFERENT INFLOW CONDITIONS

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ABSTRACT

The present study discusses channel morphological changes in the Padma reach with the confluence region of two great rivers, Ganges and Jamuna Rivers, using a numerical model based on the depth averaged two-dimensional governing equations for water flow and sediment transportation. To investigate influences of hydrographs and their differences at the confluence of the two reaches, patterns of the hydrographs are classified into three; the peak flow discharge is comparable for the both river (case 1), it is dominant in Jamuna reach (case 2), and dominant in Ganges reach (case 3). The numerical simulation results show that the right bank of the Padma reach is eroded in case 2. For case 3 left bank of the river Padma faces erosion. In case 1, channel pattern demonstrate more braided shape. In addition, computed results on sediment transport rate show that, erosion take place in the overall Padma reach only in case 2, and other cases deposition occurs.

Keywords: River morphology, Bed form, Channel change, Flow pattern, Confluence.

INTRODUCTION

Ganges and Jamuna rivers have different catchment characteristics, and hydrological and morphological characteristics to each other. Multiple discharge peaks can be found in a flood year ranging from April to October. Besides, several patterns of hydrographs with different peak discharges are observed at inflow points of Padma River. It is recognized that the morphology and its change are influenced by hydrographs and their combinations. Figure 1 illustrates the morphological changes identified during the floods in 1986, 1988 and 2001 in order to show the influences of two inflow hydrographs at the confluence. In Figure 2, hydrographs observed in 1986, 1988 and 2001 are illustrated. 2001 flood has a same peak discharge at two inflow points from Ganges and Jamuna. The peak inflow discharge from Jamuna is significantly larger than Ganges in 1988 flood. Whereas in 1986 flood, the peak discharge from Ganges is larger than Jamuna. It is very important to understand such influences of hydrographs on morphological changes for river channel management. This study aims to investigate channel changes numerically in three different combinations of inflow discharges at the confluence.

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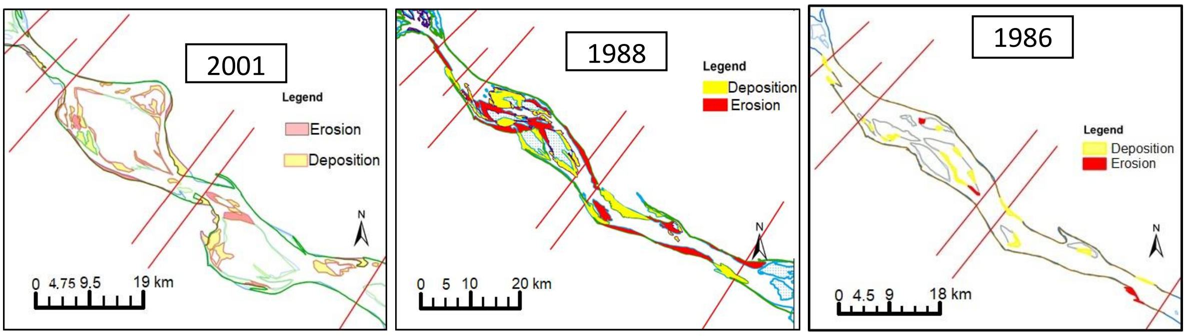

Figure 1 Erosion and deposition during year 1986, 1988 and 2001 in Padma River.

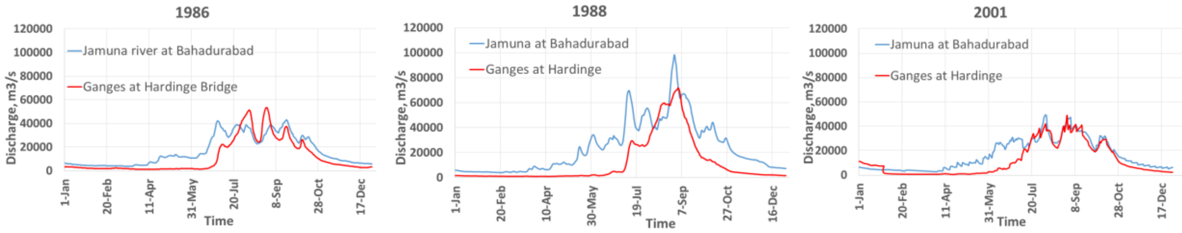

Figure 2 Discharge combinations from Ganges and Jamuna.

THEORY AND METHODOLOGY

Governing equations of depth averaged two-dimensional forms are employed for numerical simulation in this study. These are composed mass and momentum conservation equations for water flow and mass conservation equations for suspended sediment and bed sediment. The mass conservation equation for water flow in Cartesian coordinate system is described as:

$$\frac{\partial h}{\partial t}+\frac{\partial}{\partial x}(uh)+\frac{\partial}{\partial y}(vh)=0 \qquad (1)$$

Where, h is the flow depth, t is the time, u and v are x and y components of depth averaged flow velocity respectively. x and y components of momentum conservation equations for water flow in Cartesian coordinate system are described as:

$$x: \frac{\partial uh}{\partial t}+\frac{\partial uuh}{\partial x}+\frac{\partial uvh}{\partial y}=-gh\frac{\partial}{\partial x}(h+z_b)-\frac{\tau_x}{\rho}+\frac{1}{\rho}\left\{\left(\frac{\partial}{\partial x}(h\sigma_{xx})+\frac{\partial}{\partial y}(h\tau_{yx}\right)\right\} \qquad (2)$$

$$y: \frac{\partial vh}{\partial t}+\frac{\partial vuh}{\partial x}+\frac{\partial vvh}{\partial y}=-gh\frac{\partial}{\partial y}(h+z_b)-\frac{\tau_y}{\rho}+\frac{1}{\rho}\left\{\left(\frac{\partial}{\partial y}(h\sigma_{yy})+\frac{\partial}{\partial x}(h\tau_{xy}\right)\right\} \qquad (3)$$

Where, g is the acceleration due to gravity, z_b is the bed elevation, ρ is the mass density of water, σ_{xx}, σ_{yy}, τ_{xy} and τ_{yx} are depth-averaged Reynold's stresses, τ_x and τ_y are the x and y components of bed shear stress. Mass conservation equation for suspended sediment for flow body is described as:

$$\frac{\partial h}{\partial t}+\frac{\partial r_1\bar{c}uh}{\partial x}+\frac{\partial r_1\bar{c}vh}{\partial y}=\frac{\partial}{\partial x}\left(h\varepsilon_x\frac{\partial\bar{c}}{\partial x}\right)+\frac{\partial}{\partial y}\left(h\varepsilon_y\frac{\partial\bar{c}}{\partial y}\right)+E_i-D_i \qquad (4)$$

Where, $\bar{c}$ is the depth averaged sediment concentration, r_1 is the correction factor, ε_x and ε_y are the x and y components of dispersion coefficient respectively, E_i is the erosion rate and D_i is the deposition rate of suspended sediment in each grid. Mass conservation equation for bed sediment is described as:

$$\frac{\partial Z_b}{\partial t}+\frac{1}{1-\lambda}\sum_i\left(\frac{\partial q_{bix}}{\partial x}+\frac{\partial q_{biy}}{\partial y}+E_i-D_i\right)=0 \qquad (5)$$

Where, q_{bix} is the bed load transport rate in x-direction for grain size di, q_{biy} is the bed load transport rate in y- direction for grain size d_i and λ is the porosity of bed sediment (Takebayashi, 2014). To calculate governing equations, formulas for bed load transport rate, erosion-deposition rates of suspended sediment are required. In this study Ashida and Michiue's formula is employed.

$$q_{bk} = 17 p_k {\tau_*}^{1.5} \left(1 - K_c \frac{\tau_{*ck}}{\tau_{*k}}\right)\left(1 - \sqrt{\left(K_c \frac{\tau_{*ck}}{\tau_{*k}}\right)}\right)\sqrt{s_g g {d_k}^3} \quad (6)$$

Where, p_k is the fraction of the size class d_k, τ_* is the non-dimensional bed shear stress, K_c is the correction factor for the local bed-slope. Erosion rate E_i is evaluated by:

$$E_i = C_{ai} w_{0i} \quad (7)$$

In which C_{ai} is reference sediment concentration and w_{0i} is the fall velocity of sediment size class d_i. C_{ai} can be given by Lane-Kalinske's (1941) formula:

$$C_{ai} = 5.55 p_i \left[\frac{1}{2}\frac{u_*}{w_{0i}} \exp\left(-\frac{w_{0i}}{u_*}\right)\right]^{1.61} \quad (8)$$

Here p_i is the fraction of sediment size class in bed load layer.

GRID SYSTEM MODIFICATION AND MODEL SETUP

Topographic data was collected from earth explorer website of USGS. Void filled Shuttle Radar Topography Mission (SRTM) data was used as a topographic data. As hydrological data, this study uses discharge and water level data of Ganges at Hardinge Bridge, Jamuna at Bahadurabad and Padma at Baruria and Mawa. These data was measured and preserved by BWDB. The study uses data ranging from 1985 to 2006. The study used a built in grid creation algorithm from Nays2DH software using Laplace's equation to solve gridlines. Mesh size of the grid was $\Delta x = 100m$ and $\Delta y = 110m$ respectively. But since SRTM cannot give value for under water, the grid was modified. A gentle slope of 0.000045 in Padma river continued up to confluence and while it was 0.00005 towards upstream of Ganges (Sarker et al., 2009). The bed slope for Jamuna was kept as 0.00009 (nhc, 2013). Still, the flat bed with a uniform longitudinal bed slope does not represent natural bed form in a river. Numerical simulation was done for 20 days using the mean daily discharge over the data period of flood season for both rivers taking as upstream boundary condition. For Ganges 27,300 m^3/s and Jamuna 40,800 m^3/s discharge was taken as mean daily discharge in flood season. It was assumed that this will create an average flood situation and create an average natural like topography. After simulation the output topography was close to natural and was used for further computation cases.

Since the river shape obtained from SRTM was taken at a time close to our target year 2001, the discharge of 2001 was considered more relevant for numerical simulation. To determine the discharge input for 2001, the discharge value of 90%-95% of the peak discharge value observed in 2001 was taken to be the representative discharge. Three discharge combinations was taken for numerical simulation. Case 4 is prepared for investigating influence of computational domain on the computational results. In this case upstream boundary is specified as a single cross-section.

Table 1 four combinations of discharges.

Case	Discharge on Jamuna, m^3/s	Discharge on Ganges, m^3/s	Total (Discharge on Padma, m^3/s)
1	45,000	45,000	90,000
2	63,000	27,000	90,000
3	27,000	63,000	90,000
4	-	-	90,000

Maning's roughness coefficient is taken as 0.02 and a uniform sediment size of 0.2 mm was taken for the computations. For all the cases 20 days numerical simulations were done.

RESULTS AND DISCUSSION

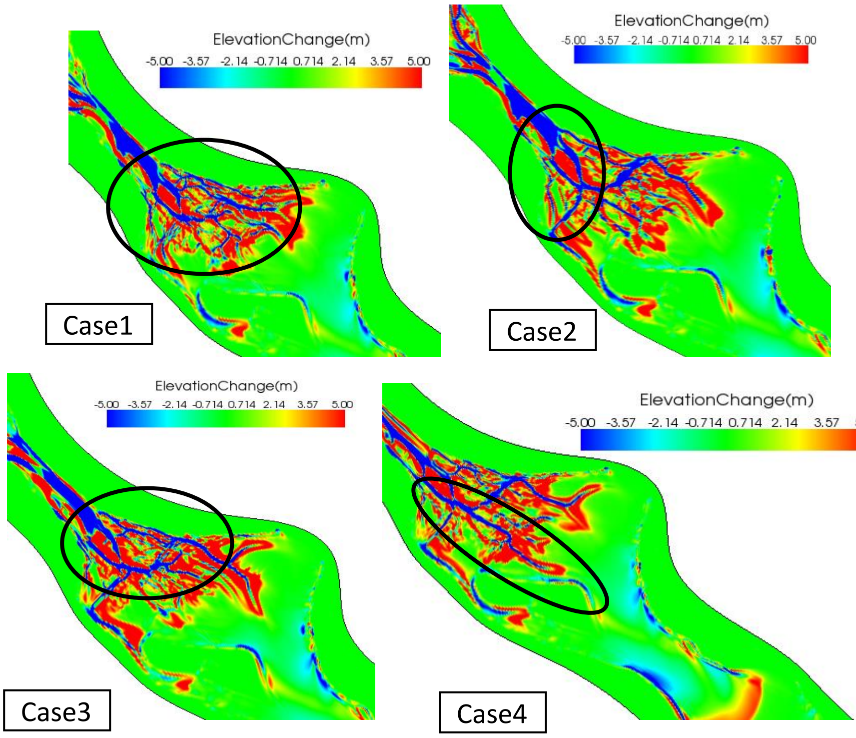

Figure 3 Bed elevation change results after 20 days simulation.

Figure 3 shows formation and propagation of multiple row bars obtained from numerical computations in case 1 to case 4. Channels and bed forms computed in case 1 are created in the Padma River equally across the width. The area marked by black circle clearly shows that the channel formation has happened actively in almost all direction towards the downstream end. And some major deposition happened in the downstream side. The trend is similar to the trend found in 2001 case illustrated in figure 2. Result computed in case 2 shows that the main channels are shifting towards middle to right side of the river in the area marked by black circle. There is a small channel towards the left bank also. But that channel seems to be closing by active deposition. And similar to case 1 downstream part is showing deposition. In result shown in case 3, the main channels show a tendency towards the center to left bank side.

Although there is a small channel pulling towards right bank, it shows that the entrance of the channel is closing with active deposition. That is why we can say that simulation result from case 3 shows the tendency of the main channel towards the left bank. The result obtained from computation in case 4 shows erosion in the center part forming a long center aligned main channel and deposition in the other area. This result also signifies that, results obtained from considering confluence and without considering confluence are totally different.

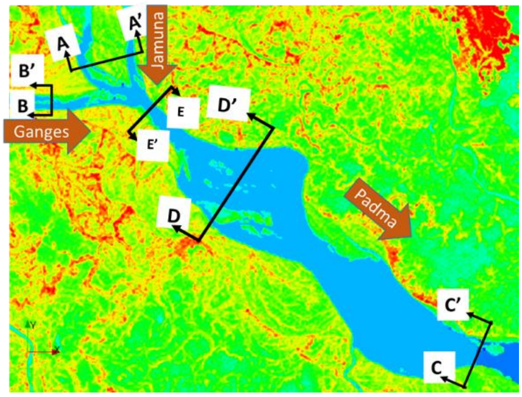

Figure 4 Location of cross section.

Figure 4 shows the locations for analyzing total sediment transport rate at each cross sections of the reach.

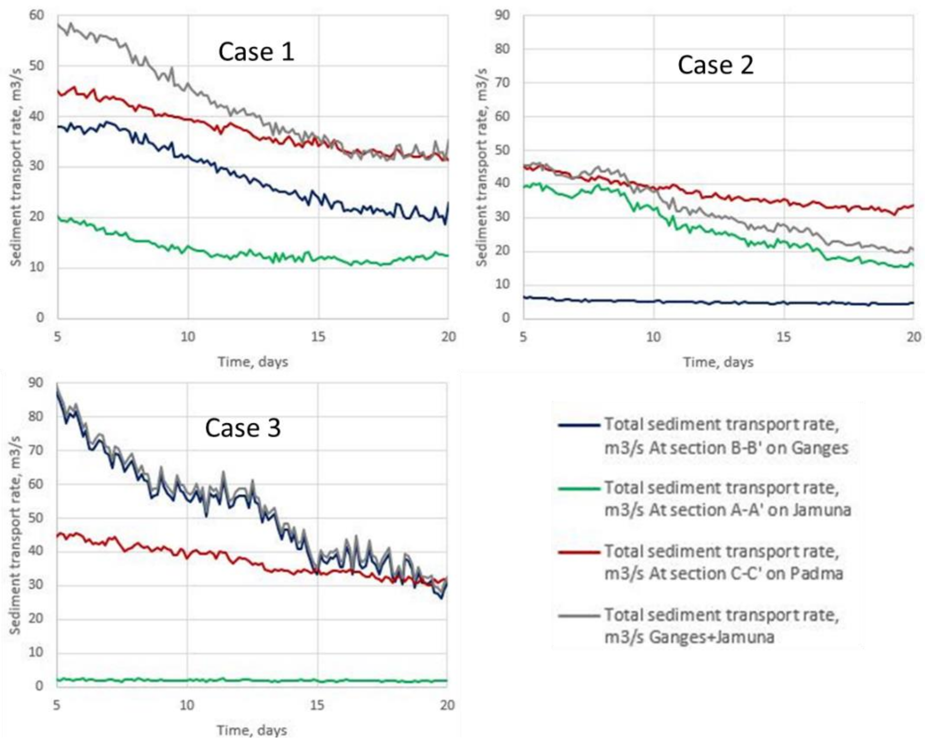

Figure 5 Sediment transport rate results.

Figure 5 shows the results on total sediment transport rate at each cross section. We can identify that in case 1, initially lot of sediment deposition happens in the confluence and inflow and outflow of sediment comes to balance with passing time. Results from Case 2 suggests that, in the Padma region overall erosion tendency is increasing with time. Also, the results show that the computational domain tends to be eroded in case 2 and vice versa in case 3. Such results provides important information of river channel management.

CONCLUSION AND RECOMMENDATION

The present study aims to investigate the influences of flow discharges at two inflow points on morphological changes of Padma River reach by means of numerical simulations. The results obtained from this study are summarized as follows. The result obtained from the numerical simulation with similar discharge at both inflow points suggests that, it is more likely that Padma River to face overall deposition and channel pattern becoming more braided. While inflow discharge from Jamuna is dominant, channels in Padma River indicate a trend of moving towards right bank. Again, while Ganges have dominant discharge, channels in Padma River indicates a trend towards left bank. Results obtained from computation for the channel reach with a single inflow point, shows that a main channel is developing along the channel center, which is different from actual channel changes. Overall erosion trend can be found in Padma River only when Jamuna had dominant discharge. Other cases show overall deposition trend. Besides, numerical results show that it is important to specify two upstream boundary conditions properly in evaluating channel changes in confluence reach. This study will clearly help the policy makers and river managers to get some base idea of channel change tendencies in the Padma River based on discharge combinations of Ganges and Jamuna River. That can help to plan and prepare for emergency structural and non-structural counter measures to mitigate damages inflicted by erosion-deposition in Padma River.

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REFERENCES

Egashira, S. (2015). Mechanics of sediment transportation and channel changes, lecture notes in International Center for Water Hazard and Risk Management (ICHARM), public work research Institute (PWRI).

Yasuki, s., & Takebayashi, H. (2014). iRIC software , changing science, Nays2DH solver manual.

Sarker, 2009. Morphological response of Brahmaputra-Padma-Lower Meghna River System to the Assam earthquake of 1950.

NHC, 2013. ADB technical assistance report for Bangladesh, Dhaka: Main river flood and bank erosion risk management program.