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A Study on Sediment Control in Alluvial River Systems

Melody Debbarma[1] and Dibakar Chakrabarty[2]

[1]*M.Tech Student, Department of Civil Engineering National Institute of Technology Silchar, Assam*
[2]*Department of Civil Engineering National Institute of Technology Silchar Assam*
E-mail: [1]melodydebbarma29@gmail.com, [2]dibachakra@gmail.com

Abstract—*Sedimentation in alluvial rivers is a natural phenomenon causing great concern to researchers and field engineers from time immemorial. Estimating sedimentation, i.e. both aggradation and degradation, in alluvial river system is complex as the physical processes involved are characterized by various uncertainties. Different methodologies have been reported in literature for studying this complex phenomenon under various simplistic assumptions. In this paper effect of upstream weirs on sedimentation in the downstream river reach of an alluvial river system has been studied. The illustrative alluvial river system considered in this study is simple and consists of a tributary meeting a main river. The sedimentation in the lower reach has been estimated under three different scenarios. In the first scenario (scenario 1), sedimentation in the lower reach of the river system has been estimated without considering any weir in the system. The second scenario (scenario 2) considers presence of a weir of specified height in the upstream of the junction in the main river. In the third scenario (scenario 3), the lower reach sedimentation has been estimated considering a larger height weir on the main river. In all the cases, quasi-unsteady flow conditions have been assumed and one dimensional flow has been considered. The simulations have been performed using HEC-RAS; the river system analysis software developed by US Army Corps Engineers. The results obtained show that the sedimentation in the lower reach gets affected both by the presence of an upstream weir as well as its height. Results also show that the methodology studied has the potential to control sedimentation in the lower reach of the river system by constructing weirs at suitable locations and adjusting their heights.*

Keywords: *Alluvial river system, weir-river system, Sedimentation, Sediment control, Quasi-unsteady flow, HEC-RAS.*

1. INTRODUCTION

Rivers are affected by both natural and human factors, leading to erosion on their bed and banks. Sometimes, the erosion is severe resulting in sedimentation in the form of aggradation, degradation etc. Excessive aggradation and degradation of bed and banks, particularly for alluvial river system, ultimately lead to geomorphologic changes in the river system. One of the key areas in river engineering is to investigate flow hydraulics, river morphology that describes the river geometry, bed shape longitudinal profile, cross-sections and changes of river shape. In alluvial rivers bed aggradation evolves primarily from the passage of flood events. This rise of the bed profile consequently reduces the conveyance capacity of the river. Bed degradation, which may simultaneously occur in the same river, threatens safety of both inline structures and bank structures. Quite often, it becomes necessary to control sedimentation at some portion of an alluvial river system for a variety of technical reasons. In this study, our concern is to estimate sedimentation on the downstream river reach of an alluvial river system under different scenarios. The main purpose of the present study is to investigate effects of weirs of different heights on sedimentation on the downstream reach of a simple alluvial river system consisting of one main river and a tributary. Construction of inline structures, like weirs or embankments, across a river generally alters the flow in the river system, thereby changing the sedimentation pattern in the vicinity of the constructed structures. Sedimentation in the downstream river reaches is controlled by the flow from the upstream river reaches. Once the flow pattern in the upstream river reaches are altered the sedimentation in the lower downstream reaches changes according to the cause and effect principle. Estimating sedimentation in alluvial river system is complex as the physical processes involved are characterized by various uncertainties. Subject to availability of adequate data, HEC-RAS is one of the freely available software, which finds application in the analysis of the sedimentation in river systems.

2. HEC-RAS

The Hydrologic Engineering Center's River Analysis System (HEC-RAS) was originally designed in 1964. The United States Army Corps of Engineers (Hydrologic Engineering Center) was formed to advance the experience that the post-World War II engineers had gained in hydraulics and hydrology engineering. HEC-RAS is being developed as part of the "Next Generation" project. Being a one dimensional flow mathematical model, HEC-RAS can be used to simulate the flow in order to obtain the water surface elevation, flow velocity, and sediment transport capacity along a river reach under a set of steady flow conditions. The HEC-RAS software

(Version 4.1.0) is used in this study to perform the necessary simulations.

3. METHODOLOGY

In order to calculate the sedimentation using HEC-RAS, the following steps are followed:

3.1. Step 1: Geometric data

Geometric data in HEC-RAS consists of linking the river cross sections along the whole reach to create the schematic river system. A two-river system (Main River and a tributary) is developed by connecting them by a junction as shown in Fig. 1. This simple configuration results in three hydraulic reaches, viz. upstream main river reach, tributary reach and the downstream river reach beyond the junction. The upstream main river reach, having a length of 1.100 km, is divided into four sections while the tributary river reach, having a length of 1.080 km is also divided into four sections for computation purposes. The downstream river reach, where the sedimentation under the three scenarios has been investigated, is divided into ten sections within its total length of 1.800 km. A weir of two different heights (4.5 m and 7.5 m respectively) is considered in the upstream main river reach. The data required for simulations mainly include stations and their elevations for each cross section for all the proposed river reaches. The input data required to create geometric data file include Manning's coefficients for left over banks, channel reaches and right over banks. Apart from these values, expansion and contraction values are also required as input data. In the present study, the Manning's values for bed, left bank, and the right bank are considered as 0.035, 0.06, and 0.05 respectively.

3.2. Step 2: Quasi-Unsteady Flow Data

For estimation of sedimentation in alluvial river system, HEC-RAS considers the flow to be quasi-unsteady. Flow data in HEC-RAS consists of discharge and reach boundary conditions. Flow stage along with the corresponding flow data is required as one of the inputs to compute rating curve and carry out quasi-unsteady flow analysis.

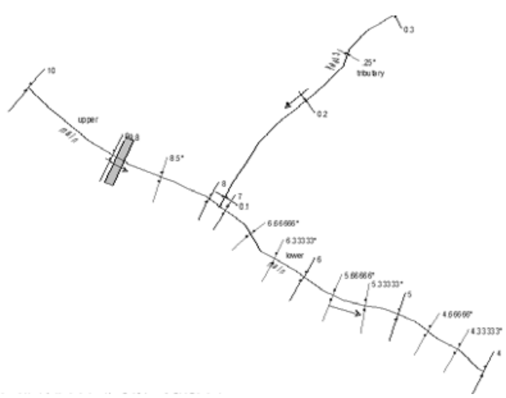

Fig. 1: Schematic river system

3.3. Step 3: Sediment Data

In this study, Ackers white function has been used as the transport function. The general transport equation for the Ackers- white function for a single grain size is represented by

$$X = \frac{G_{gr}\, sDs}{D\left(\frac{U_*}{V}\right)^n} \qquad (1)$$

$$G_{gr} = C\left(\frac{F_{gr}}{A} - 1\right) \qquad (2)$$

Where,

X = sediment concentration, in parts per part

G_{gr} = sediment transport parameter

D_s = mean particle diameter, in mm

F_{gr} = sediment mobility parameter

U_* = shear velocity, in meter per sec

s = specific gravity of sediment

n = transition coefficient, depending upon sediment size

C = coefficient

D = effective depth in meter

V = average channel velocity, in meter per second

3.4. Step 4: Sediment Continuity

The HEC- RAS routing routine solves the sediment continuity equation. In this study, the Exner Equation, as given below, is used as the continuity equation:

$$(1 - \lambda p)B\frac{\partial n}{\partial t} = -\frac{\partial Q_s}{dx} \qquad (3)$$

Where,

η = channel elevation, meter

B = channel width, in meter

Q_S = transported sediment load

λ_P = active layer porosity

t = time, hour

x = distance , meter

3.5. Step 5: Fall Velocity Method

The analytical relation developed by Rubey involving fluid, sediment properties and the fall velocity based on the combination of Stokes law and an impact formula is used in this study. This equation has been shown to be adequate for silt, sand and gravel grains. The analytical relationship is given below:

$$\omega = F_1\sqrt{(s-1)}\, gd \qquad (4)$$

Where,

$$F_1 = \sqrt{\frac{2}{3} + \frac{36v^2}{gd^3\,(s-1)}} - \sqrt{\frac{36v^2}{gd^3(s-1)}} \quad (5)$$

4. RESULT AND ANALYSIS

All the simulations are performed using HEC-RAS under three different scenarios as mentioned earlier. The scenario 1 estimates sedimentation on the downstream river reach without presence of any weir in the system. The scenario 2 considers a weir of height 4.5 m on the main river as shown in Fig. 1 while in scenario 3, the height of the weir is taken as 7.5 m, located at the same position as that in scenario 2. The simulations have been carried out for 120 hours, with 12 hours flow duration. The results of sediment mass change along the downstream river reach are given in Tables 1, 2, and 3 respectively for the considered scenarios and the corresponding sediment spatial plots are shown in Figs. 2, 3, and 4 respectively. The bed changes under different scenarios are also given in Tables 1, 2, and 3, as already detailed above.

4.1. Scenario 1

The scenario 1 considers sedimentation in the downstream reach without any weir in the system. The results are given in Table 1.

Table 1

Time (hr)	**Inflow to the down-stream (m3/s)**	**Mass bed Change (tons)**		
		Aggradation	**Degradation**	**Change**
1	1000	0	0	0
2	1600	16622.95	16607.95	-15.00332
3	2100	1900.703	1900.703	0
4	2500	2745.414	2745.703	0
5	3800	56116.4	56117.9	1.5
6	2000	81229.66	812336.9	4.03
7	3000	2652.214	2652.214	0
8	2400	5050.485	5050.485	0
9	1900	3504.587	3504.587	0
10	1600	2410.377	2410.377	0
cumulative				

4.2. Scenario 2

The scenario 2 considers a weir of height 4.5 m at the location shown in Fig. 1. The results are assembled in Table 2**.**

Table 2

Time (hr)	Inflow to the downstream (m3/s)	Mass Bed change (tons)		
		Aggradation	degradation	Change
1	1000	0	0	0
2	1600	16484.71	16469.71	-15.00339
3	2100	1903.363	1903.363	0
4	2500	2764.119	2764.119	0
5	3800	56505.28	56506.7	1.41
6	2000	81578.71	81582.77	4.06
7	3000	2654.161	2654.161	0
8	2400	5060.532	5060.532	0
9	1900	3508.121	3508.121	0
10	1600	2419.806	2419.806	0
cumulative				

4.3. Scenario 3

The scenario 3 is the same as that considered under scenario 2 except that the height of the weir is considered as 7.5 m. The results are tabulated in Table 3.

Table 3

Time (hr)	**Inflow to the down-stream (m3/s)**	**Mass bed change (tons)**		
		Aggradation	**degradation**	**Change**
1	1000	0	0	0
2	1600	11728.05	11720.09	-7.97
3	2100	14729.23	14729.23	0
4	2500	2508.974	2508.974	0
5	3800	56857.44	56860.62	3.18
6	2000	81113.93	81115.13	1.20
7	3000	2425.06	2425.06	0
8	2400	5046.872	5046.872	0
9	1900	3444.50	3444.50	0
10	1600	2061.04	2061.04	0

5. SEDIMENT MASS BED CHANGE

The sediment spatial plots for mass bed changes are given in Figs. 2, 3, and 4 respectively for the corresponding scenarios**.**

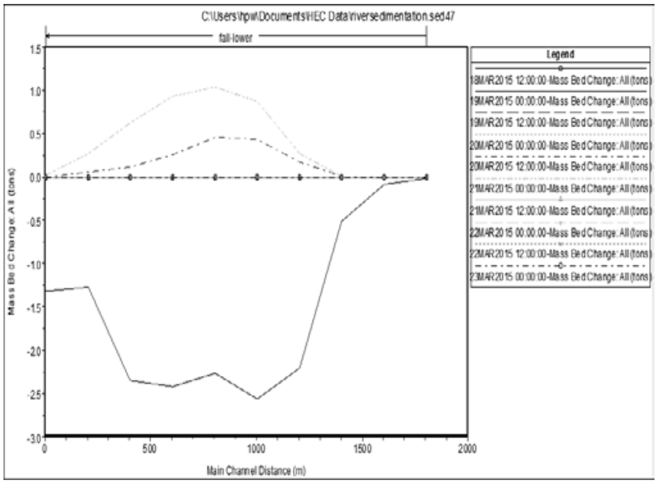

Fig. 2: Sediment spatial plot for scenario 1

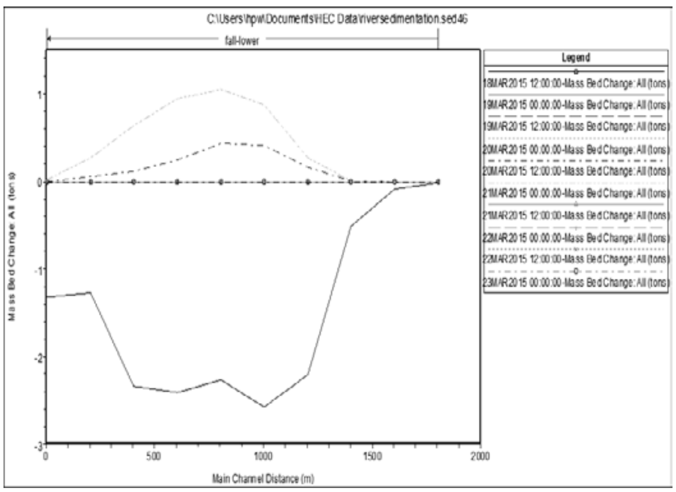

Fig. 3: Sediment spatial plot for scenario 2

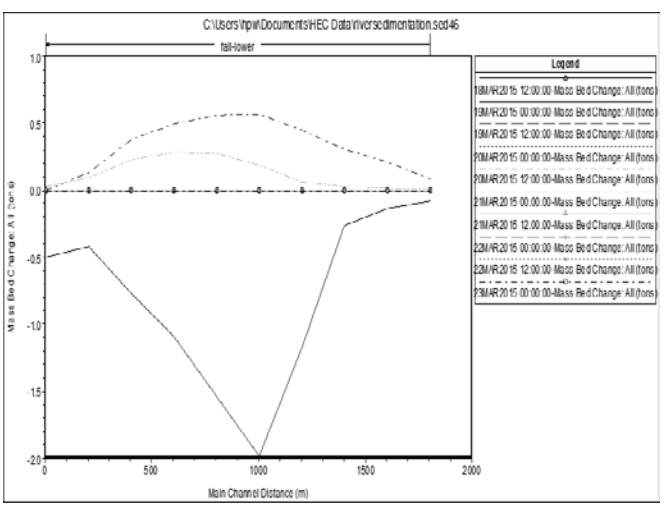

Fig. 4: Sediment spatial plot for scenario 3

The results obtained from the simulations performed under different scenarios for 120 hours in each case show different sediment bed changes and estimated aggradation and degradation at selected locations. When scenario 1 is compared with scenario 2, slightly aggradation and degradation are observed in scenario 1. In scenario 3, substantial decrease in aggradation and increase in degradation can be seen when compared with scenario 1. The comparison of bed changes are given in Fig. 5 for all the three scenarios. In the figure, scenario 1 is not so visible due to very less difference with scenario 2.

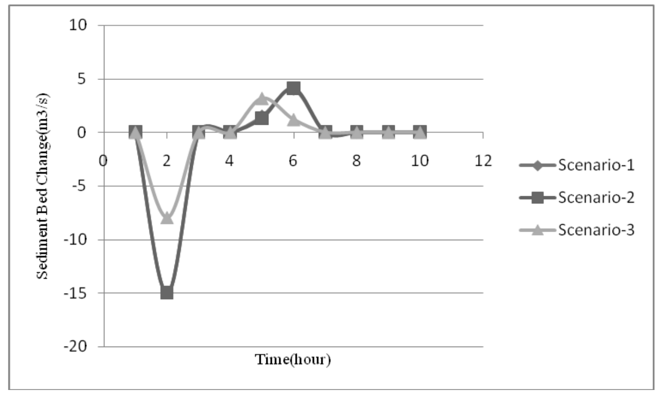

Fig. 5: Comparisons of sediment bed changes under different scenarios.

6. CONCLUSION

Based on the simulations performed, the major conclusions are briefly summarized below**:**

- HEC-RAS is useful in simulating sediment transport at a remarkably short computation time
- The output gives a complete table showing the aggradation and degradation for each simulation time.
- Acker-white Sediment transport function serves as the best option to compute the bed changes along the river reach. The fall velocity used to compute sediment bed change in Acker-white function seems to be adequate.
- Weir constructed at upstream reach at a suitable location can regulate the sedimentation in the downstream reach.
- This study performed can be further extended in predicting the sedimentation in the downstream reach for future periods as may be required in real world scenarios.
- It is possible to estimate sedimentation in the downstream reach by increasing the simulation time for any required duration.

The results obtained also show that a suitable combination of a weir location and its height can dictate regulation of sedimentation in the downstream reach as well as the gross bed changes there. Nonetheless, the study reveals that the desired sedimentation in the downstream reach along with the desired bed changes there may be obtained by linking an optimization routine to the proposed methodology.

REFERENCES

[1] Carriage, C. C., and Mays, L. W. (1992). "Model For Determining Optimal Reservoir Releases To Control Downstream Sedimentation Under uncertainties Of Sediment Transport Parameters." *Proc.. Water Forum* 1992, ASCE, New York, N.Y.
[2] Carriage, C.C., and May, L. W. (1995), ASCE “Optimal Control Approach For Sedimentation Control In Alluvial” *Rivers J. Water Resour. Plann. Manage.* 1995.121:408-417.
[3] Carriage, C.C., and May , L. W. (1995). ASCE "Optimization modelling for sedimentation in alluvial river." *J. Water Resour. Plann. Manage.* 1995.121:251-259.
[4] Engelund, F., and Hansen, E. (1967)." *A monograph on sediment transport in alluvial streams."* Tecnisk Vorlag, Copenhagen, Denmark.Gershwin, H., and Jacobson, D. H. (1970). "A discrete-time differential dynamic programming algorithm with application to optimal orbit transfer." *AIAA* 1., Vol. 8, 1616-1626.
[5] HEC RAS v4.1 User manual , Hydraulic Reference manual and application guide.
[6] Jiang Zhu1, Qingcun Zeng,2 Dongjian Guo,3 and Zhuo Liu4. "Optimal Control Of Sedimentation In Navigation Channels." *J. Hydraul. Eng.* 1999.125:750-759.
[7] Kamal El Kadi Abderrezzak1 and André Paquier2, ASCE "Applicability of Sediment Transport Capacity Formulas to Dam-Break Flows over Movable Beds." *J. Hydraul. Eng. 2011.137:209-221.*
[8] Robert C. MacArthur, Charles R. Neill, Brad R. Hall, Vic J. Galay,and Andrey B. Shvidchenko "Overview of Sedimentation Engineering."
[9] Yager, E. M., J. W. Kirchner, and W. E. Dietrich (2007), American Geophysical Union "Calculating bed load transport in steep boulder bed channels." *Water Resour. Res.*, 43, W07418, doi:10.1029/2006WR005432.