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Research Article

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Evaluation of Using Baffle Column Approach as a Sedimentation Mitigation Measure

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Abstract There are a lot of sedimentation problems in front of Nile River intakes. In this research, the baffle column approach was investigated to reduce the amount of sediment entering the intake structures without any adverse impacts on the operation process. The objectives of this study are: Identification and prediction of the morphological changes along the Nile River, Investigate in details the morphological changes in the area surrounding the intake of the water cooling system which is considered as a near field region, Study the impact of sedimentation problem in the intake structures and Study the mitigation measures of sedimentation problem in front of the intake structure. The physical model is used to simulate different flow conditions. The results will be shown with and without using the baffle columns. The model shows that baffle columns are effective in reducing the amount of sediment entering the intake.

Keywords Baffle Columns, Intake Structure, Nile River, Physical Model and Sedimentation

1. Introduction

Rivers are dynamic in the sense that they have continuous morphological changes. Morphological changes are primarily manifested in the form of changes in bed-level, width and slope resulting from scour and deposition processes. The stability of the bed of alluvial channel depends on the definition of the threshold of sediment movement [1]. There are three fundamental control sediment moving through a river channel: competence, capacity and sediment supply [2]. Intake structures are constructed to withdraw water from rivers, canals, lakes, seas and other bodies of water for communities and industries [3]. Today, the worldwide annually loss of storage capacity because of sedimentation is already greater than the increase of capacity by the building of new reservoirs [4]. The model study proved to be a useful means of evaluating the hydraulic performance of the intake structure and of improving the initial designs [5]. Scale models are significant due to the increasing understanding of physical phenomena and the possibility of solving very complex physical problems. On the other hand, the scale models are covering relatively small areas and give much more detailed information [6]. Mathematical modeling is only possible when the equations can be transformed suitably to a useful solution form. The equations for turbulent flow are very complicated & they can be solved only by help of computers. The accuracy of mathematical modeling is limited by the accuracy of the functional mathematical relationships [7].

Sedimentation in front of intake structures can be controlled by a lot of methods such as modifications to the area in front of the intake and the upstream riverbank, Introducing groins in the area of sediment accumulation, producing a quiescent or lentic water pool into which inflowing solids are deposited, using submerged vanes which mounted vertically on the river bed at an angle to the prevailing flow direction and using baffle column in front of intake structures [8-14]. Several studies [10, 15-16] tried to solve Sedimentation problems in front of intake structures using different mitigation measure. A new approach was investigated to reduce or even eliminate the vortex activities in the vicinity of the intake structure without hampering the regular dredging process of the sedimentation basin & also without any adverse impacts on the operation and maintenance of the intake structure. This approach depends on installing baffle posts on the top of the upstream side and the offshore long side of the sedimentation basin of the intake structure and to perform a full investigation to design these baffles to be used effectively to act as anti-vortex devices [15]. The arrangement of baffle columns at the upstream and the offshore sides of the intake structure as a mitigation measure for flow non-uniformity at the intake was also studied [17]. Finally the baffle column technique is highly recommended for enhancing the intake withdrawal-efficiency, through eliminating undesired nonuniform flow conditions approaching the intake.

2. Materials and Methods

2.1. Field Measurements and Data Collection

To study the effect of baffle column in reducing the amount of sediment entering the intake and for modelling purposes, field measurements are necessary. Field survey was carried out covering about 5 km from Nile River. The field measurements included topographic and bathymetric survey and hydrometric measurements. The survey was carried out by HRI during December 2015 and April 2017. Figure 1 shows the detailed contour map results and measured profile.

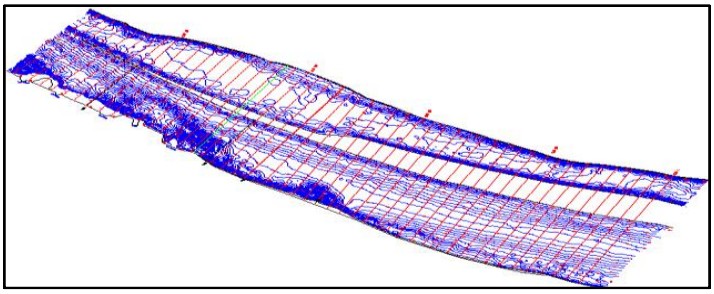

Figure 1: Detailed Contour map for modeled reach

2.2. Methodology

To release the objectives, the following methodology will be used:

1. Literature review and data collection of mitigation measures of sediment problem.
2. Develop an undistorted movable bed model with scale of 1:50 to simulate the flow pattern and morphological changes processes in the vicinity of the intake structure
3. Model scenarios will be proposed to be simulated under different flow conditions.
4. The Power Plant will be simulated in the models before and after adding the baffle column structure.
5. Analysis of the results for different model scenarios.

3. Physical Model

3.1. Model Description

This work was performed in the Hydraulic Laboratory of the Hydraulics Research Institute, (HRI), Delta Barrage, Egypt to investigate the effect of using the baffle column on the intake structure. The length of the reach simulated in the physical model is about 2.7 Km of the Nile River. The model occupies an area of about 1008 m^2 (56 m x 18 m) in the experimental hall of the HRI. The model was chosen to be of undistorted type, with a constant scale ratio in all dimensions such as length, width, and depth. According to the simulated river reach and in order to achieve a full description of the phenomena and the available space in the experimental hall, a geometric scale ratio of 1:50 was chosen. The model is constructed according to the Froude similarity, then the velocity, discharge and time scale ratios are derived from the following equations:

$$n_v = n_l^{0.5} \quad (1)$$

$$n_q = n_l^{2.5} \tag{2}$$

$$n_t = n_l^{0.5} \tag{3}$$

Where:
nl: Length scale ratio
nv: Velocity scale ratio
nq: Discharge scale ratio
nt: Time scale ratio

The similarity criteria, for morphological parameters governing mobile bed models, are quite complex, because both water movement and sediment movement have to be observed. Light material is used to simulate the sediment in the model and is placed to cover the cooling system vicinity (intake vicinity). The selection of bed material is more dependent on the experience of HRI. Such material should not present any secondary phenomena of electrostatic nature. In addition, it should be chemically inert so that it does not react with eventual actions present in the water. The selected material is PVC with average diameter (D50) of 1.6mm.

3.2. Model Construction

The model consists of three parts (the entrance, the modelled reach and exist). Figure 2 shows the physical model layout. There are pipelines and pump system to discharge water to the model through the openings of the first pipeline.

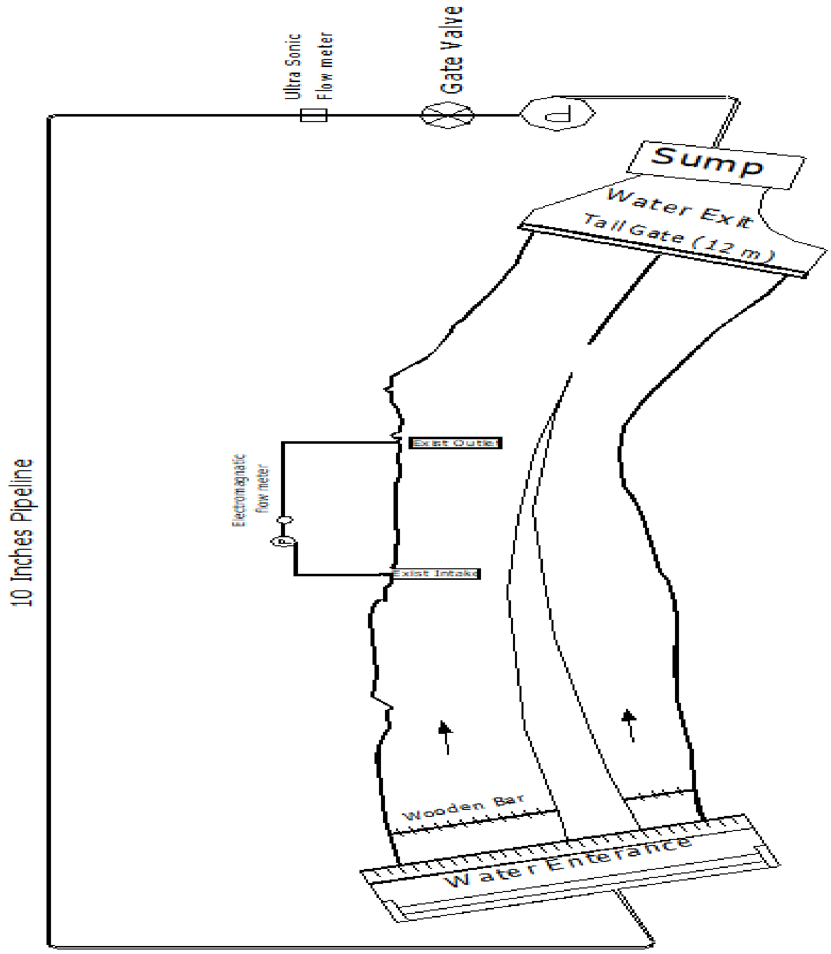

Figure 2: Physical model layout

Intake structure

Outfall structure

Photo 1: the model intake & outfall

At the beginning of the model there are pieces of wood to uniformly distribute the inflow to the model. The model has a bed constructed of clayey soil covered by smooth thin layer of cement mortar. According to the hydrographic and topographic surveys, which were carried out, the global coordinates of different simulated cross sections are known. These cross sections are then scaled down to the model dimensions and placed at their proper coordinates in the model. Guide wooden frames are used to form the cross sections and then the river bed is formed. The water level and the surface water slope are adjusted and measured using two point gauges. The surface water slope is controlled in the model using a flab gate, which is located at the end of the model. The power plant consists of one unit with once through cooling system with surface discharge structure. The capacity of power plant is 650 MW with a total cooling water discharge of 50 m^3/s. The intake structure of the plant is on the left bank of the River in front of a small sand bar, while the outfall structure is located further downstream of the intake structure on the left bank of the Nile River as shown in Photo 1. The used measuring devices are the flowmeter for measuring the flow discharge, the current meter for measuring the flow velocity, the point gauge for adjusting the water level at the model.

3.3. Model Scenarios

In this section a detailed description for scenarios will be shown. The total number of the tests is 6 tests. As known the discharge of the Nile River is seasonally varied so the tests were conducted under three hydraulic conditions as showed in table 1. Each discharge will be tested with and without using the baffle column.

Table 1: The Hydraulic Conditions for the Executed runs

	Q_1	Q_2	Q_3
Q(m^3/s)	1883	1471.5	662
W.L(m)	16.69	16.69	16.5

4. Results & Discussion

Figure 3 shows the location of measured sections. Section-1 located inside the intake (at the intake opening), section-2 located the intake entrance and section-3 located at a distance of 25m in front of the intake in the direction with flow direction. Section-4, 5 & 6 located in the vicinity of the intake in the direction perpendicular to the flow direction.

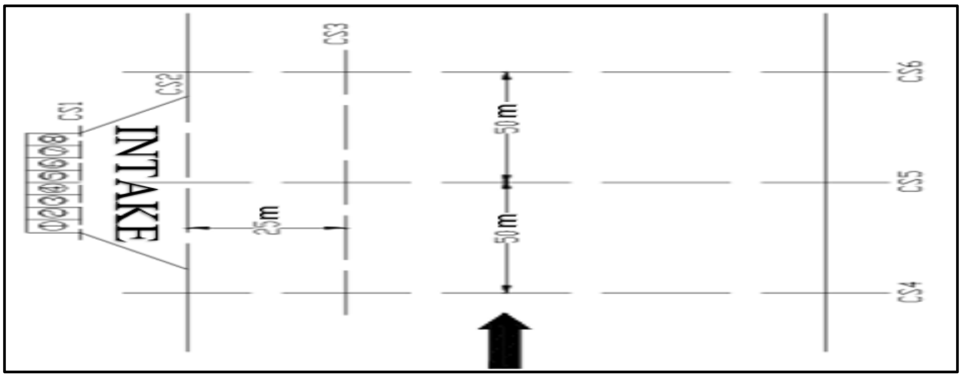

Figure 3: The measured cross sections

4.1. Flow Pattern

Flow velocity approaching the intake vents after using the baffle columns were compared with the flow velocity without baffle columns as shown below in figure 4 and also figure 5 shows the velocity values at the intake entrance with and without using the baffle column. From the figures it is clear that using the baffle columns made the flow more uniformly distributed under different flow conditions. The flow pattern before and after using the baffle columns is shown in photo 6.3. From the photo it is clear that the flow become more uniformly distributed in front of the intake and also inside the intake opening after using the baffle columns.

Q1 Q2 Q3

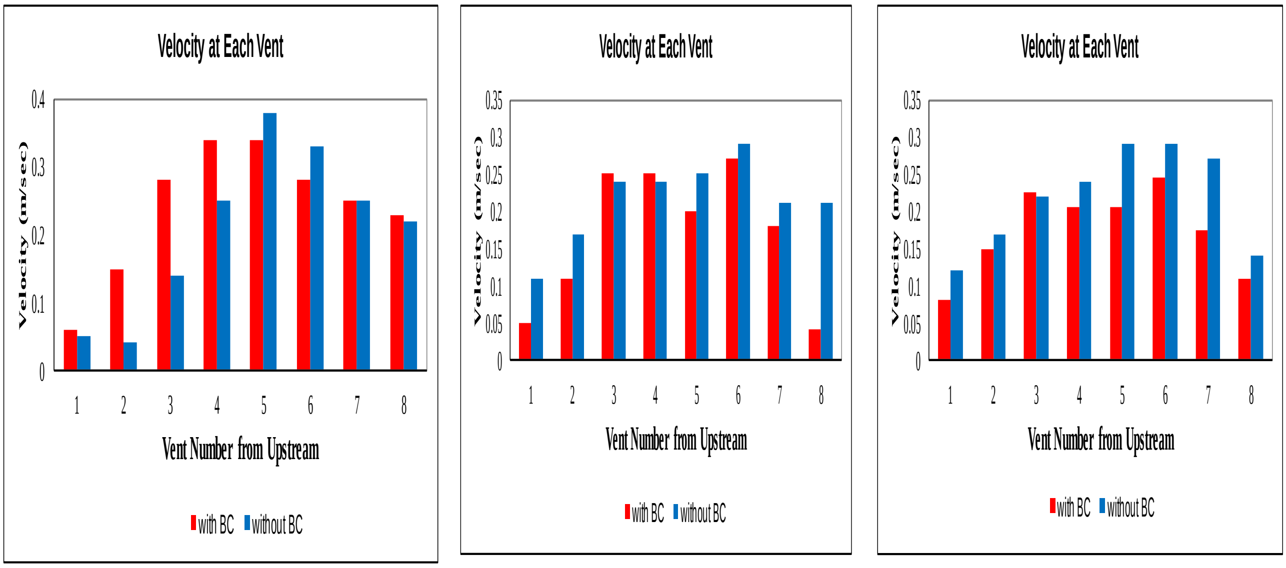

Figure 4: Velocity values approaching the intake vents under different flow conditions with& without the baffle column

Q1 Q2 Q3

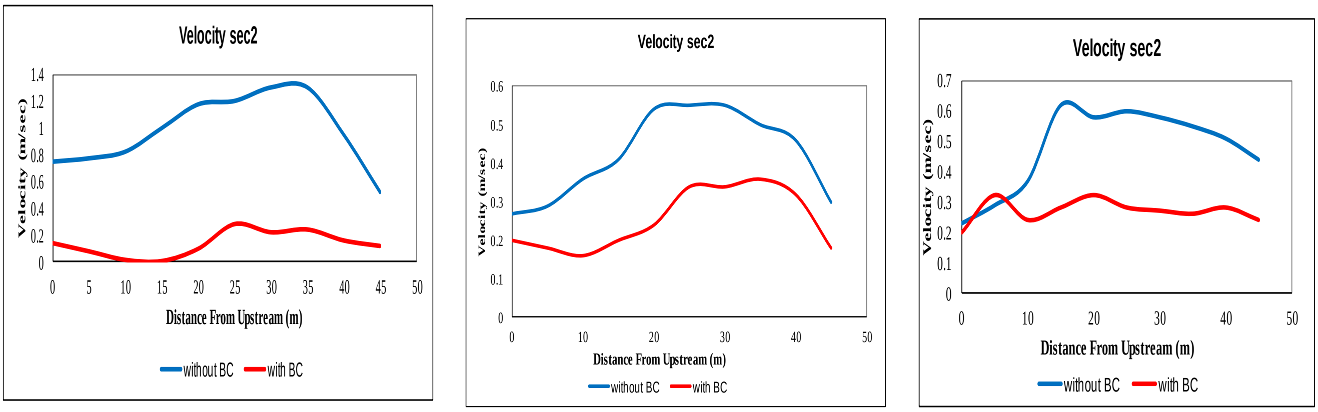

Figure 5: Velocity values at the intake entrance under different flow conditions with & without the baffle column

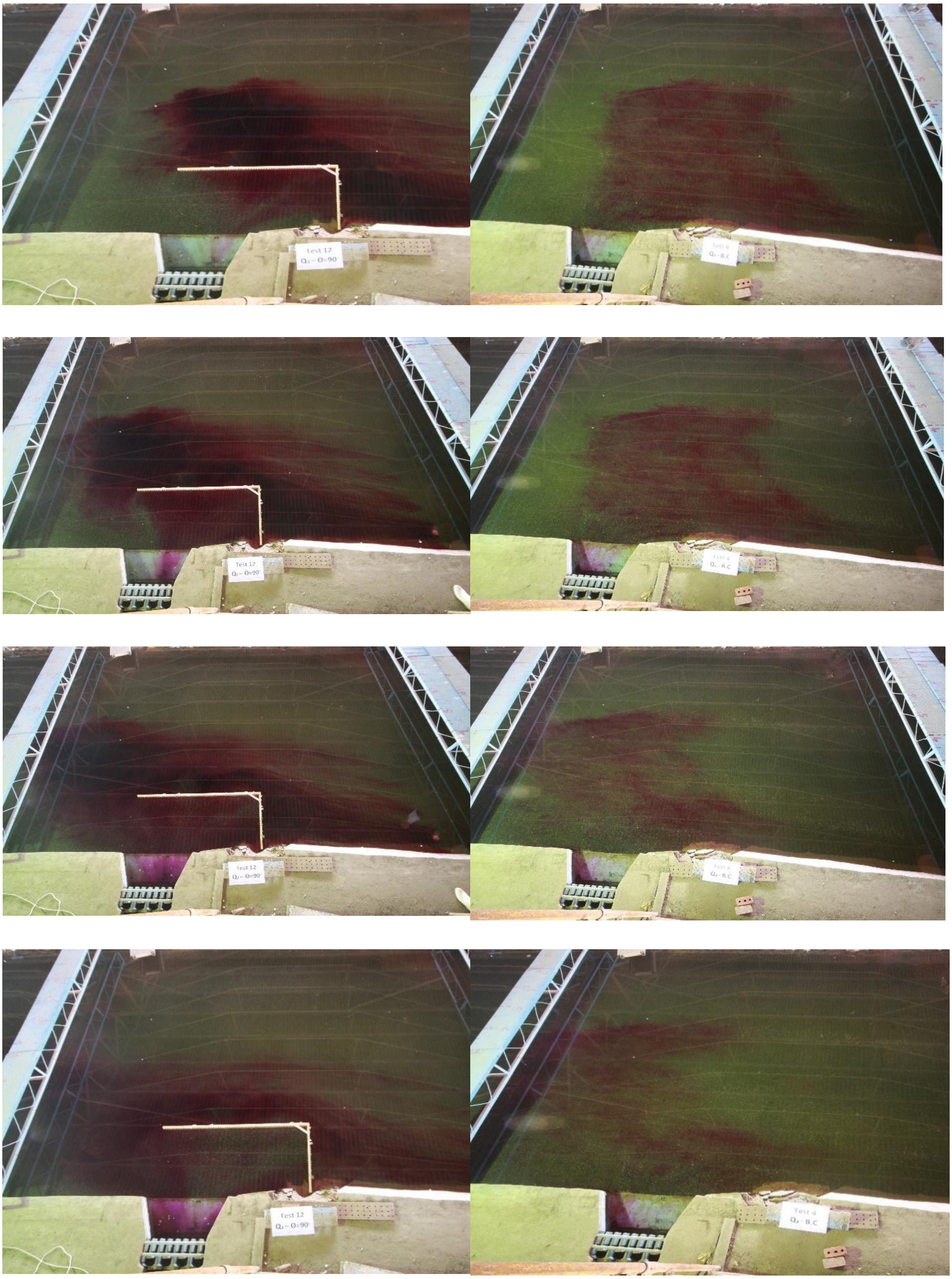

Photo 2: Flow pattern across the intake with and without the baffle column

4.2. Sedimentation inside Intake

The volume of sedimentation which entering the intake in each case was calculated and shown in table 2. The table shows that using baffle columns has a significant effect in reducing the amount of sediment enter the intake as it reduces the volume of sediment which enter the intake for all river conditions.

Table 2: Volume of Sedimentation Entering the Intake with and without the baffle column

Scenario	Volume of sediment (m^3) With baffle column	Volume of sediment (m^3) Without baffle column
Q1	3720	250
Q2	660	187
Q3	262	125

4.3. Morphological Changes

Figure 6 shows the bed level before and after using the baffle column compared with the initial bed level at the intake entrance. From the figure it is clear that using the baffle column reduce the sedimentation which occurred at the intake entrance and the bed levels almost turned back to the initial levels under all flow conditions. Figure 7 shows the bed level before and after using the baffle column compared with the initial bed level at sec 3. From the figure it can be seen that the amount of sediment in the vicinity of the intake is reduced especially in maximum flow.

Q1 Q2 Q3

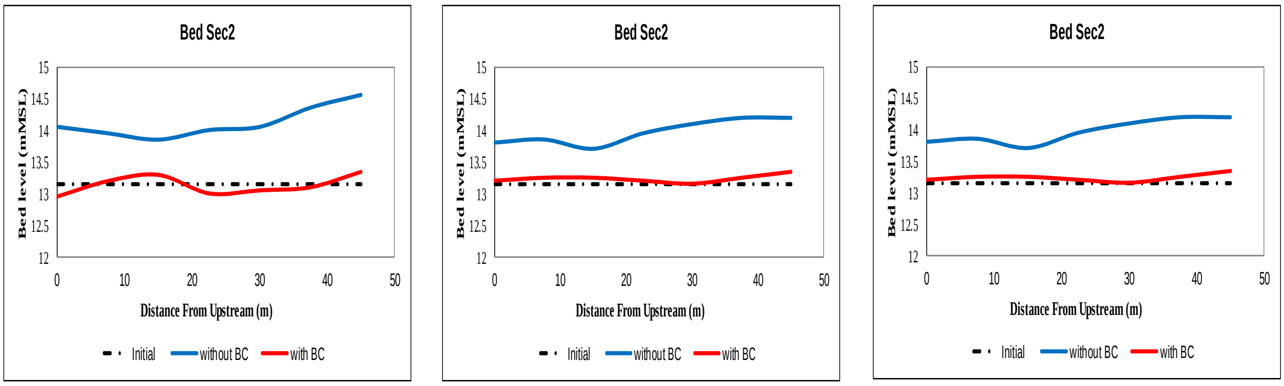

Figure 6: Bed level comparison at intake entrance under different flow conditions with & without the baffle column

Q1 Q2 Q3

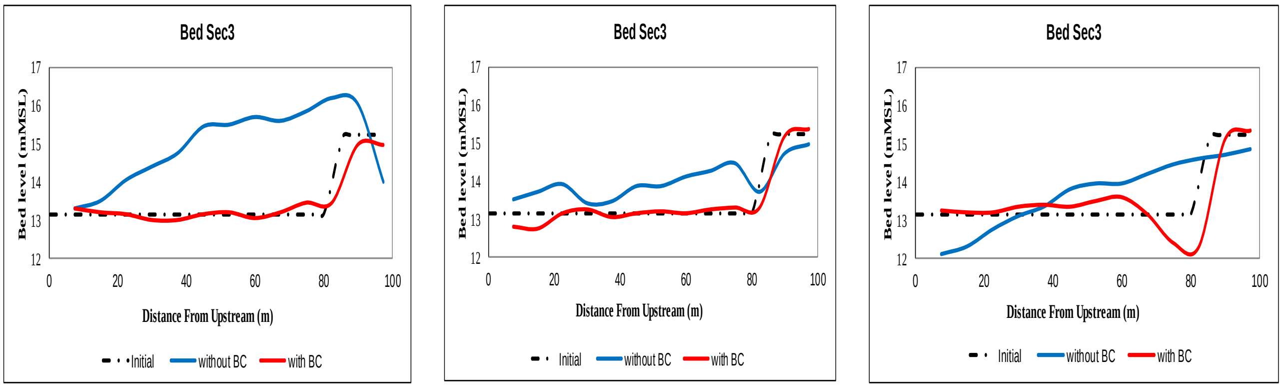

Figure 7: Bed level comparison at sec 3 under different flow conditions with & without the baffle column

5. Conclusion

The present paper studied the effect of using the baffle columns as a sedimentation mitigation measure under different flow conditions. The Physical model is applied to simulate the flow pattern and bed topography under different flow conditions. Based on the results of different scenarios, it can be conclude that the baffle columns can be used as a sedimentation mitigation measure in front of intake structures. Also it is clear that using baffle columns in front of intake structure has significant effect in making the flow pattern uniform distributed inside the intake and in reducing the amount of sedimentation which entering the intake as the volume of sedimentation which entering the intake reduced by 90% to 67% after using the baffle columns. It is clear that the percentage of reduction in volume of sedimentation which entering the intake is directly proportional to the flow discharge as the percentage of reduction in volume of sedimentation which entering the intake decreased with the reduction of flow discharge.

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