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# Laboratory Experiments and Numerical Model of Scour at Upstream of a Slit Weir

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ABSTRACT

This study presents an experimental measurements and three-dimensional simulation of time-varying scour, along with the variables affecting the resulted scour hole dimensions and evolution at center and side weirs. Slit weir location, crest level, flow rate and sediment size were tested within 34 steady and unsteady flow conditions under various flow rates 125, 95, 62, 50 and 34 L/s to study the scour behavior. All tests were carried out with non-uniform sediments of median sizes 0.24 mm and 0.55 mm. Steel slit weirs of 0.25 m width, 0.004 m thickness, and 0.07, 0.12 and 0.17 m crest level with respect to the mobile bed surface, which was constructed in a laboratory flume made up of brick and concrete within dimensions of (8 m, 1.25 m, and 1 m) long, wide and deep respectively. The present research demonstrates that maximum values of scour volume and scour depth obtained when the weir locate at center of the flume with flat crest for both steady and unsteady flow. Besides, the results indicated a low discrepancy between the experimental measures and the sediment scour model FLOW 3D software, both are showed a good agreement in presenting the scour development accurately as well as the model had excellent ability in predicting the velocity magnitudes at the slit location and the values of shear stress which was hard to measure directly.

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## 1. Introduction

Reservoir sedimentation defined as a natural process of settling soil particles from the flowing stream and accumulated as layers in water bodies [1, 2]. This process is affected by watershed slope, the inlet streams, upstream vegetation cover, watershed hydrology, sediment inflow, particle size, reservoir's size, and shape [3, 4]. Hydropower sedimentation is frequently removed by dredging and various techniques; most of these techniques are costly and disrupt dam power generation; therefore, adopting sustainable and economic techniques was essential. Releasing sediment with water from the dam gate by generating a local scour at the upstream side consider an economical and environmental solution. Thus, three-dimensional flow occurs due to the high shear stress, which causes water and sediment releases from the slit opening due to the creation of rotating vortices upstream of the dam gate that prevents the dam from clogging as well as manages the dam's operational process. In previous years many researchers studied sediment releases issues and local scour development at different water hydraulic constructions numerically and experimentally. Numerous modeling in sedimentation conveyance approved less efficient and less accurate in predicting time -varying scour development than the advanced turbulent models, which based on the Reynold Naiver Stock formula, incorporate the models of eddy and large eddy simulations (DES, LES) [5]. Predicted the bed scour generated and the flow characteristic around spur dike and cylindrical piers by 3D software simulations includes Reynolds average and Navier- Stockes formulas as well as based on a non-linear K-turbulent model under unsteady flow condition [6]. The Euler- Lagrange model suggested in corporate with detached eddy simulation DES approach to demonstrate sedimentation conveyance under clear water scour condition numerically within saltation along with sliding condition at a pier structure of a cylindrical shape [7]. The Temporal evolution of sedimentation scours hole investigated at the upstream side of dam release gate via adopting nonlinear (ODE) which depend on a continuity equations and bed load entrainment volume incorporate with CFD software's for a uniform sediment of median grain sizes of (22, 77, 1) $\times 10^{-2}$ mm under steady and unsteady inflow discharges. The study presents a particular relation between scour depth and scour volume [8]. Proposed a transition process from bed to suspension load for the non-equilibrium sediment releases through a stream flow and predicted the topographical change around weir hydraulic structures by adopting the 3D lagrangian model- Eulerian approach. Furthermore, for scour prediction k-ω SST model had been selected as an adequate option, which caused scour holes around hydraulic structures. The study showed an appropriate agreement between the numerical and experimental work in scour shape only, as opposed to the maximum scour depth, was not get a sufficient result [9]. Present the flow characteristic and the scour development downstream of the broad crested weir by numerical model FLOW 3D which, can act as the mechanism of generating the scour hole under steady flow conditions and particle grain size of 1.8mm [10]. FLOW 3D (CFD) software was adopted to numerically investigate the sediment transportation and scour process throughout the box culvert structure based on experimental data. An empirical equation for scour depth prediction was obtained. [11] This research adopted FLOW 3D software to numerically examine and predict the scour hole creation around a bridge pier structure. The resulting scour depth was comparable to an experimental study [12]. FLOW 3D software was adopted to numerically simulate the flow patterns, erosion, and sedimentations creation at parallel, non-submerge, and impermeable groynes incorporated with Van-Rijn sediment transport formula and conservation of mass and momentum equations [13]. Scour depth development around different hydraulic structures like bridges, piles, pipelines, and grade control are reviewed, compared, and summarized according to their soft computing algorithms, which depended on field and experimental data collections. The reviewed studies were evaluated and assessed in this research [14]. Computational fluid dynamics CFD software incorporate with MATLAB application for both models selected for simulating the study boundary conditions, and a generated scour around submerge weir within different geometry configurations. The results come up with empirical equations of scour depth, scour length and flow condition [15]. Scour development in a sediment accumulation for the best conveyance mechanism examined within a one-dimensional hydrodynamic model incorporated with HEC-RAS software under quasi-unsteady flow conditions, various manning coefficients and empirical equations [16]. Maximum sediment depth and production of Wadi al- Najaf watershed was investigated using the Soil Water Assessment tool (SWAT) incorporate with Digital Elevation Model (DEM) to delineate the watershed boundary area. Nevertheless, many studies focused on the topographical changes due to experimentally developing scour around the hydraulic structures [17]. The study included a small and large scale of physical models experimentally and numerically to figure out an empirical equation of maximum scour depth prediction at longitudinal wall structure within non-uniform sedimentations of median sizes $d_{50}$= 0.5, 3.5, 5.5 and 7.6 mm [18]. Conducted an experimental and numerical work within a physical model to study the impact of different flow intensity ranged from 0.4 to0.8 L/s and weir geometry with uniform sedimentations under steady flow condition on generated scour hole depth and area downstream sharp-crested weir for more sediment releases [19]. Series of experimental runs within a physical model carried out to estimate the discharge rating curve in a meander river by adopting conveyance estimation system (CES) model [20]. Finite element tool identified within GEOSTUDIO 2012 software to investigate and analyze the stability and seepage risk of Haditha dam [21]. Presented physical and laboratory study on scour downstream of the triangular labyrinth weir to study the structure geometry influence as apex angles ($90^{O}$, $75^{O}$, $60^{O}$ and $45^{O}$) within various flow rates of 3, 4, 5, 6, 7, 8, 9 and 10 L/s. The study come up with scour prediction statistical formulas which showed a good agreement with different other studies formulas of scour downstream hydraulic structures [22]. Scour development at a broad weir within various geometry tested with non-uniformity about $1.8 \times 10^{-3}$ m sediment experimentally under different flow intensities 15, 20 and 25 L/s. The scour hole dimensions obtained according to various weir crest angles [23]. Prediction of maximum scour depth carried out with 10 tests of experiments at downstream side of an open channel within low value of Froud number and sediment median sizes of 0.6 and 1.2 mm [24]. The geometry of local scour hole downstream gated hydraulic structure within a different roughness coefficient investigated by adopting a physical model, the study come up with an empirical scour hole formula prediction based on Straube formula [25]. Physical model under eighteen different flow rates and three various geometries of a Piano Key Weir implemented experimentally to study the head -discharge relationship and the governing parameters on sediment self-cleaning process [26]. Sediment transportation in an open channel analyzed and discussed by physical laboratory tests with a sharp crested weir which had a various geometry configuration under a flow rate ranged between 100-300 L/min [27]. An experimental work carried out to study the effecting parameters on the shape and dimensions of the generated scour hole throughout flushing process from dam, the study presented equations for predict scour quantitate values of the cone shape hole [28]. Scour depth experimentally investigated and the impact of flow condition and the soil characteristics within a $15 \times 10^{-2}$mm uniform sediment on generated scour-hole at upstream and downstream of a group of circular bridge piers with a variable spacing tested under clear water scour conditions [29]. The research conducted a circular orifice experimentally to study the flow condition and sediment releases upstream an orifice structure within fixed and mobile bed for different sediment sizes and heads [30]. Sediment releases throughout dam gate tested experimentally as well as simulated numerically within three-dimensional software [31]. Ota and Sato (2015) research represented within a numerical model which considered the sediment in bed and suspension modes for efficient sedimentation removal from the dam gate [32]. Two sizes of non-uniform sand 0.3 and 0.7mm and four flow rates adopted in a laboratory study within a rectangular flume to predict scour-hole development close to sharp rectangular weir [33]. Laboratory research and flume experiments embraced in order to study different properties of the soil effect on a pile hydraulic structure [34]. New formula of sediment transport rate presented in the study and compared with Van Rijn and Karim-Kennedy equations. The study conducted a 25 series of field data collection of non-uniform selected sand ranged of $9\text{-}15 \times 10^{-2}$ mm and flow rate of 271-835 $m^3/s$ [35]. An experimental study carried out to improved Hummer's Method by adopting different additives such as graphite powder, Hydrogen peroxide, Ltd. Sulfuric acid and Distilled water. Ultra-sonication and filtration were implemented with optimal parameters 50 kHz frequency. The results recommended that to used GO synthesis in a laboratory work [36]. The study investigated the importance and main sources and impact of biodiesel. Series of experiments conducted by using response surface method. Main study variables were discussed and analyzed which showed a good agreement in a coefficient of determinations [37]. Enhancing the soil quality of Bahr al-Najaf region to be proper for oil drilling was the target of this research. Experimental work carried out in order to select suitable additives and eliminate some of materials from the sand texture. The related published researches of a scour and sedimentation issues predictions at different flow and control constructions can be categorized laboratory-experiments, software simulations, furthermore a statistical study. A proposed models and statistical simulations were validated using experimental data. Almost all the related studies were investigated the scour at downstream side of a weir structure under various hydraulic geometries as well as the discharge properties. However, the published studied on scour prediction at upstream side of a slit weir were limited and most of them employed a numerical model to estimate the scour volume resulted at upstream side of a slit weir. Ota & Sato (2015) highlighted that the numerical models underestimated the experimental scour volume by up to 30%. The above findings highlighted the need for more experimental studies on scouring upstream of slit weir in order to design an optimal dam get dimensions for efficient sediment releases. The experimental and numerical investigations on the impact of steady and unsteady flow conditions for relatively fine and coarse sediments on scour volume and scour depth is the main contribution of the present study.

## 2. Experimental and Laboratory Procedures

The experimental tests included the sediment preparations, sieve analysis as shown in Fig. 1. The tests carried out in a rectangular flume of (8×1.25×1) m long, wide and deep respectively, made of a brick and concrete at the hydraulic Lab of Ministry of water resources, Iraq, presented in Fig. 2a, b and c.

**Figure 1:** Sediment preparations.

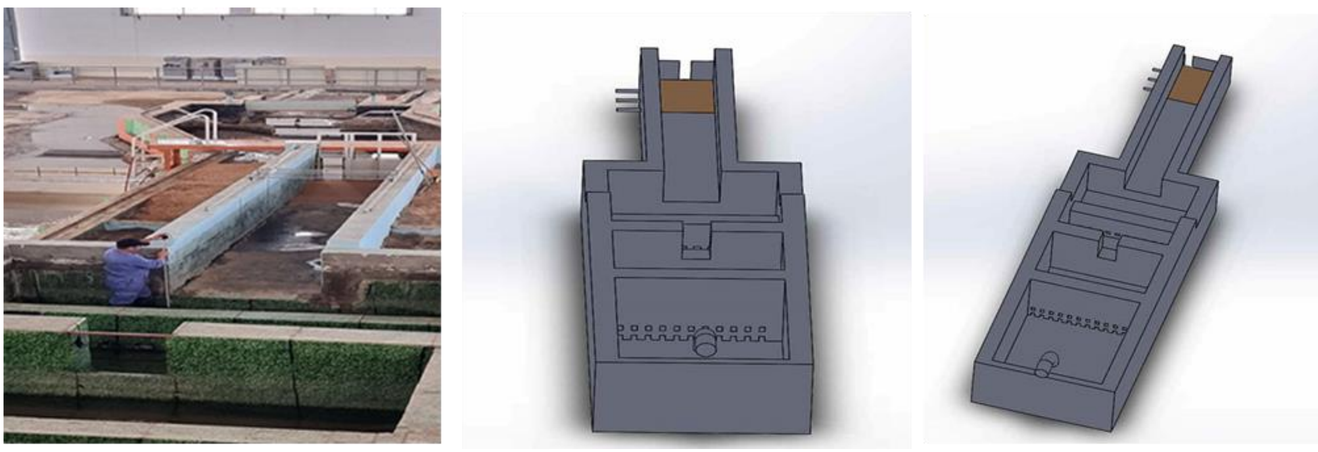


**Figure 2:** (a) the study conduit, (b) schematic diagram with center weir location; (c) schematic diagram with side weir location.

Nonuniform sediment mobile bed of 0.24, 0.55 mm filled the working section with a layer of 300 mm thick of a 990 kg and 1140 kg for fine and coarse sand respectively, the working section was located at upstream side of the weir. The mobile bed at the working section had the same level of the flume bottom surface, which leveled and checked by a Mechanical point gauge within a precision of (±1 mm) as well as used to measure the topographical changes in a scour hole and the flowing water level. Five different discharges 0.125, 0.095, 0.062, 0.050 and 0.034 m3/s, were passing through the slit opening regulated and controlled by the rectangular weir constructed at the upstream side. 2-dimensional velocity measures were recorded at each 50 cm distance for the whole flume length starting from the upstream water iterance towards the slit weir by digital 2D current meter.

## 3. Experimental Condition

Laboratory tests conducted under a conditions of clear water scour. Thus, the aim of the present study is to investigate the time varying scour at the mobile bed due to the flowing water throughout an obstacle of the slit weir. However, the flow properties within the selected flow rates such as the measured water depth was 380, 290, 250, 230, 180 mm respectively and Fr number was 0.136, 0.148, 0.126, 0.114, 0.112. Within an average velocity magnitude of 0.26, 0.2, 0.17 and 0.15 m/s. The flow properties had no change with time within the selected test through the scour progression.

## 4. Experimental Procedures

Before the experiments commencement the slit weir was closed with a plate has a same size of the slit and the flume flooded for one-hour duration then open the slit weir and start the experiment which continued until reach an equilibrium scour condition (when there is no more scour development) which was attended at 10 hours from each test establishing time, the topographical changes just at slit location measured and recorded every 1 hour. First the slit locates at center of the flume with flat crest and the runs carried out under the all-flow rates for both sand sizes; as well as the whole-previous procedures repeated with side weir location. The above scenarios carried out again for both center and side slit weir under a discharge of 0.125 $m^3/s$ with various crest heights of 530, 480 and 430 mm (Fig. 3), respectively for each median sizes of 0.24, 0.55 mm. The all mentioned experiments conducted under steady flow condition with an overall 32 test and additional 2 tests of unsteady flow condition at a center slit weir.

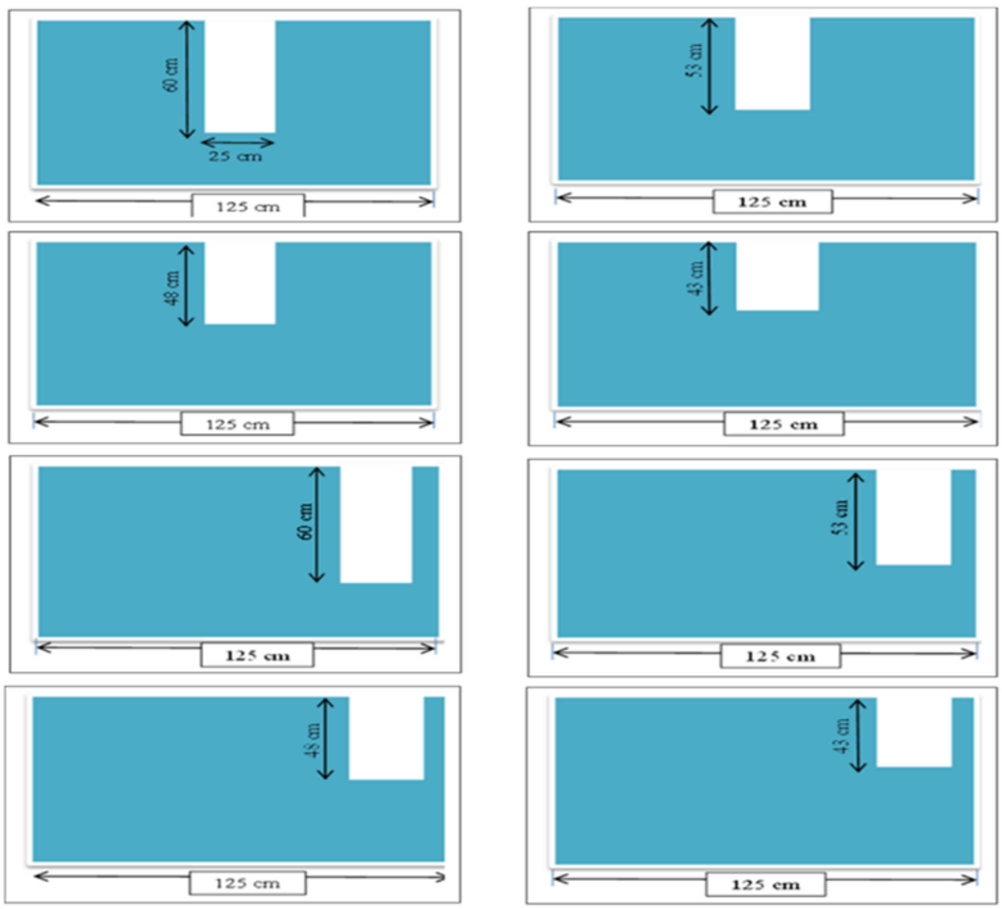
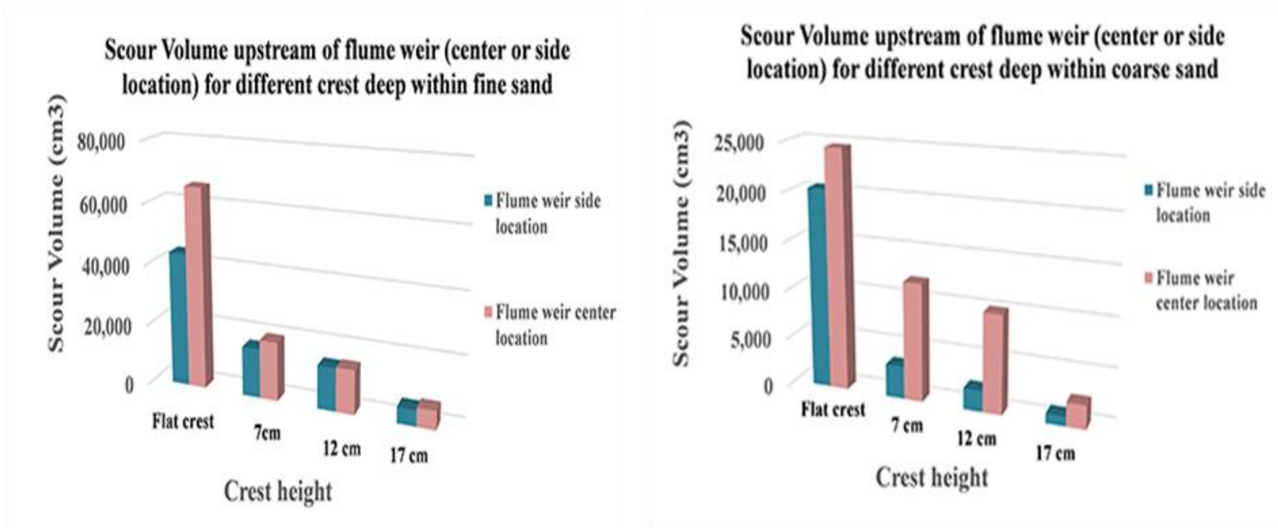



**Figure 3:** Center and side slit weirs dimensions.

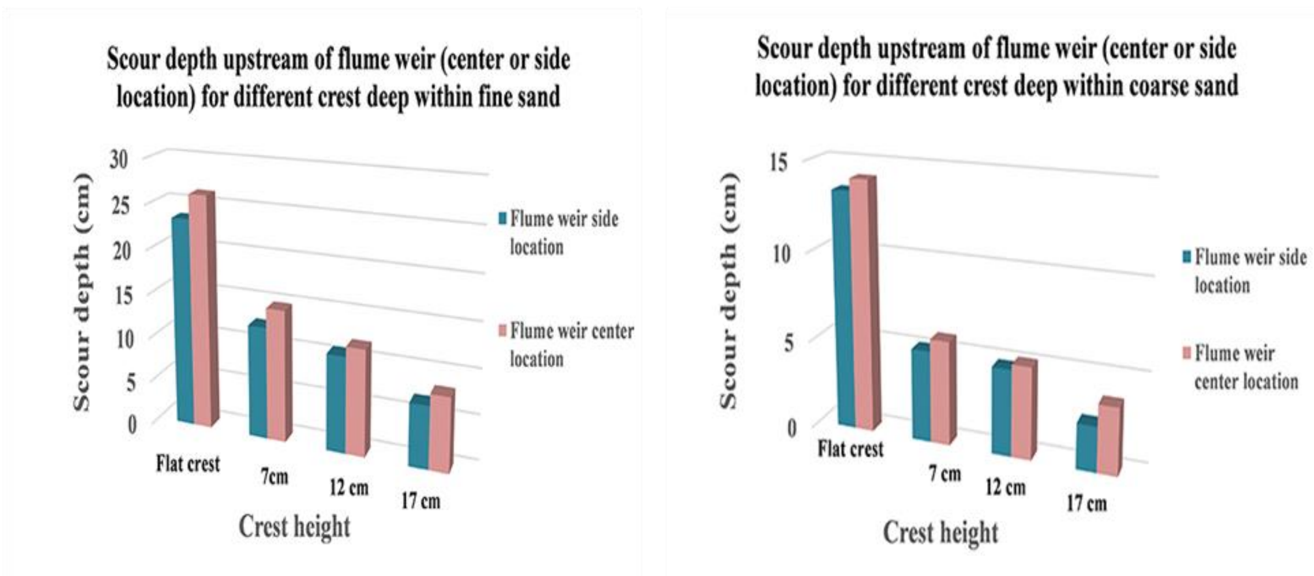
## 5. Results and Discussion

To demonstrate the impact of the study variables on resulted scour volume and depth, the slit weirs (center and side locations) geometry and dimensions examined under maximum discharge value for both fine and coarse sand as presented in Fig. 4 and 5. The results clarified that maximum values of scour depth and scour volume recorded for a case of a flat crest i.e., weir dimensions (60×25) cm and when the weir positioned at center of the flume either the sand fine or coarse classified. Nevertheless, the results showed a certain reduction in resulted scour depth and volume with the increase of the crest height. In a present study, when consider the maximum scour volume and maximum scour depth magnitudes obtained with flat crest scenario, as a reference case. Therefore, the reduction percentage in results according to the weir location, weir geometry and sand size presented in Tables 1 and 2 below:




(a) (b)

**Figure 4:** The value of scour hole volume in cm3 (a) fine mobile bed; (b) coarser mobile bed.




(a) (b)

**Figure 5:** Scour depth values in cm (a) fine mobile bed; (b) coarser mobile bed.

**Table 1:** Reduction percent % in scour volume and scour depth within different slit weir height for median size 0.24 mm.

| No. | Crest height cm | Side slit weir Fine sand | | Center slit weir Fine sand | |
|---|---|---|---|---|---|
| | | $V_s$ reduction, % | $d_s$ reduction, % | $V_s$ reduction, % | $d_s$ reduction, % |
| 1 | Flat crest Q=0.125 $m^3/s$ | - | - | - | - |
| 2 | Crest height 7 cm Q=0.125 | 64 | 47 | 71 | 44 |
| 3 | Crest height 12 cm Q=0.125 | 68 | 54 | 78 | 55 |
| 4 | Crest height 17 cm Q=0.125 | 88 | 71 | 91 | 69 |

**Table 2:** Reduction percent % in scour volume and scour depth within different slit weir height for median size 0.55 mm.

| No. | Crest height cm | Side slit weir | | Center slit weir | |
|---|---|---|---|---|---|
| | | $V_s$ reduction, % | $d_s$ reduction, % | $V_s$ reduction, % | $d_s$ reduction, % |
| 1 | Flat crest Q=0.125 $m^3/s$ | - | - | - | - |
| 2 | Crest height 7 cm Q=0.125 | 83 | 62 | 51 | 60 |
| 3 | Crest height 12 cm Q=0.125 | 89 | 64 | 59 | 64 |
| 4 | Crest height 17 cm Q=0.125 | 95 | 81 | 90 | 74 |

From Tables 1 and 2. It was obvious that when the slit weir crest changed from flat crest referencing to the mobile bed surface into (7, 12 and 17 cm) height that had a certain impact on resulted values of scour hole depth and volume for all the selected mobile bed and with similar flow regime, initial and boundary conditions. However, the highest value of scour hole depth in this study observed (26.2 cm at center and 23.4 cm at side) for sediment size 0.24 mm and (14.1cm at center and 13.4 cm at side) for sediment size 0.55 mm with a flat crest but these values were changed as listed in Table 1 and 2 due to the change in slit crest height which causes a reduction in a value of the released sedimentation at upstream of the slit weir. From the above results, it was remarked that a necessity to examine and compare the scour depth for unsteady flow with the maximum values obtained from the condition of steady flow. Fig. 6 display the hole scour depth values for the all-sediment sizes and within both flow types.

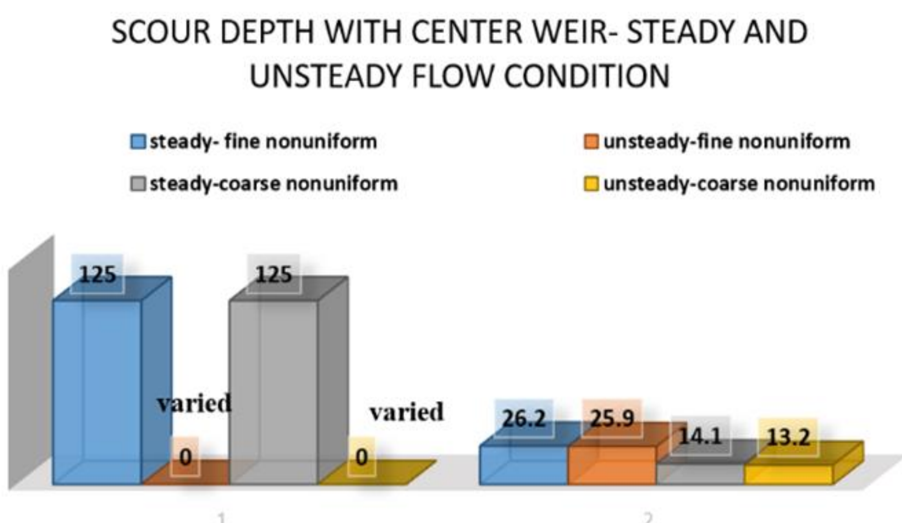



**Figure 6:** Scour depth values under steady and unsteady flow at flume-center location.

Fig. 6 clarified the difference between the resulted sour depth predicted under unsteady flow, which was lowered by 1.14% and 6.4% for fine and coarse sand respectively than the values measured under steady flow; in spite of the equilibrium condition achieved in unsteady flow condition within shorter duration than it observed with steady flow.

## 6. Numerical Analysis

The scour hole topographical changes measurements obtained in an experimental section simulated within 3D numerical software in order to validate the scour depth results as well as investigate the flow hydrodynamics which could not predicted with the laboratory part (velocity at the slit position and the shear stress).

### 6.1 Analytical Methods

The numerical simulations carried out within FLOW 3D v. 11.2.0. The software developed by Flow Science Institute which included an empirical equation within a high ability in simulating the scour and sediment transport criteria in an economical way. The fundamental and basic equations that the model based on are continuity and momentum equations (Eq. (1), (2), (3), and (4)) as follows:

$$\frac{\partial \rho}{\partial t}+\frac{\partial u_i}{\partial x_i}=0 \quad (1)$$

$$\frac{\partial u_i}{\partial t}+u_j\frac{\partial u_i}{\partial x_i}=-\frac{1}{\rho}\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_i}\left(2vS_{ij}-\overline{u_i'u_j'}\right) \quad (2)$$

Where

$$S_{ij}=\frac{1}{2}\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right) \quad (3)$$

$$\overline{u_i'u_j'}=v_t\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)-\frac{2}{3}k\delta_{ij} \quad (4)$$

Thus, ui: the water velocity magnitude, ρ: water density, t: time, υ: kinetic viscosity, P: pressure, k: kinetic energy of the turbulence, $v_t$: turbulence viscosity, ($\overline{u_i'u_j'}$): Reynold tensor and $\delta_{ij}$: Kronecker delta ranged (0-1). The solver used finite difference in solving Navier-Stokes equations and discretize the mesh geometry as well as Volume of Fluid (VOF) to capture the free surface. The solver included turbulence model which based on normalized group RNG $k-\varepsilon$ model within slandered wall method to comprises the regions closed to the weir opening. In addition, Mastbergen, Van Den Berg and Soulsby-Whitehouse, 1997 equations used in sediment scour model to estimate the sediment transport dynamics, the model tested with maximum packing factor of 0.64 and one species of non- cohesive mobile bed.

### 6.2 Boundary Condition and Gird Generation

The simulations conducted under clear water scour flow and the selected fluid was water of 20$^{O}$C in an incompressible state with a density of 1000 kg/m$^3$ and 0.001 kg/ms viscosity. However, in order to generate an optimal and accurate mesh FAVOR option adopted. 150,000 cubic cell of 0.02 m generated in an orthogonal mesh incorporate with Fractional Area volume FAVRTM to present the slit weir geometry. The geometry mesh domain and boundary conditions shown in Fig. 7 and 8, where, Q is the discharge, O: out flow, S: sedimentation and P: the pressure.

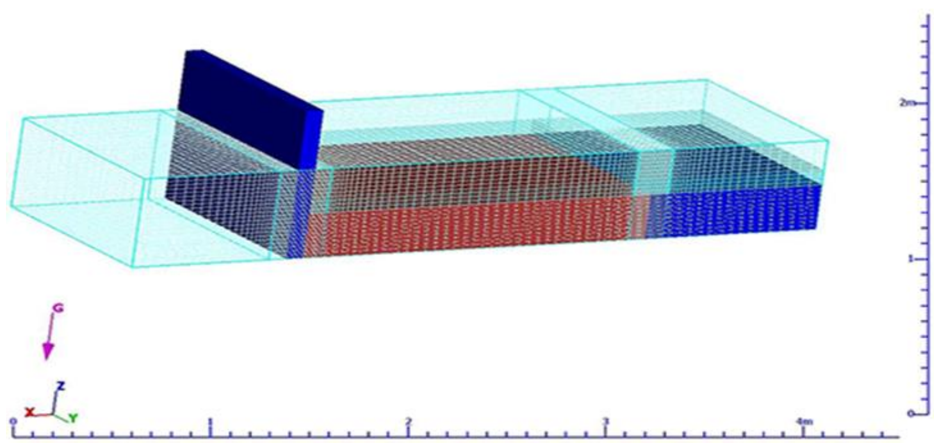


**Figure 7:** Geometry and mesh domain.

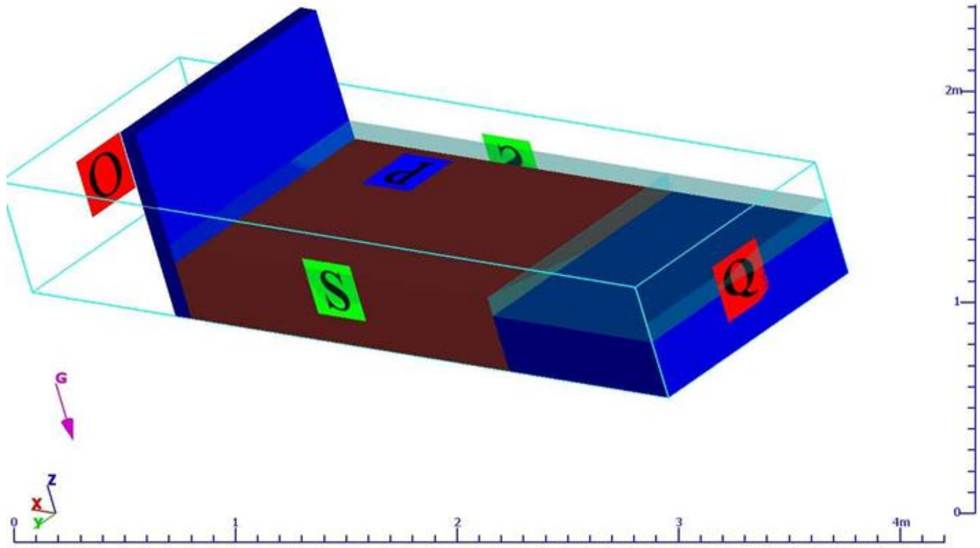


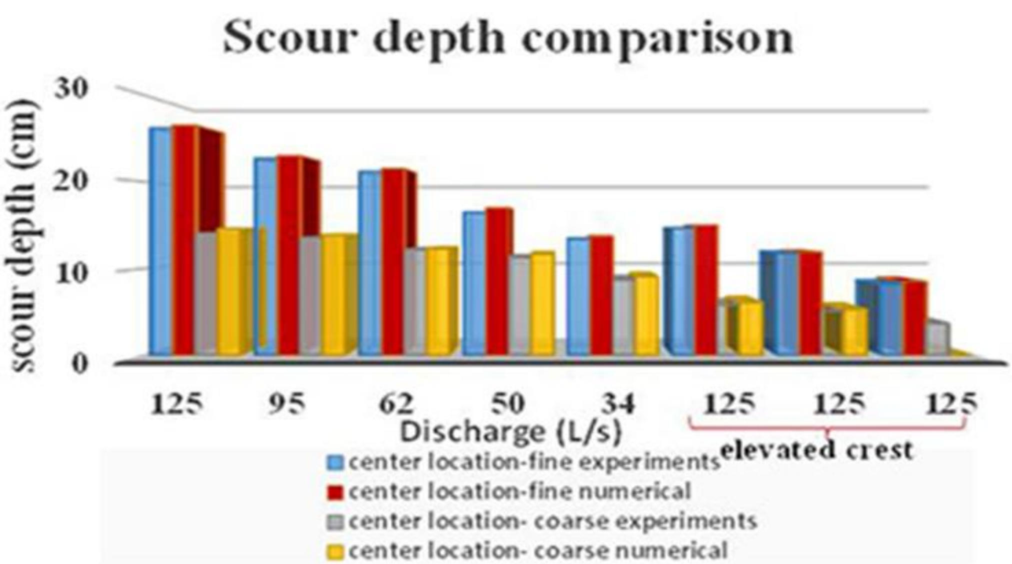

**Figure 8:** Model boundary conditions.

### 6.3 Model Calibration

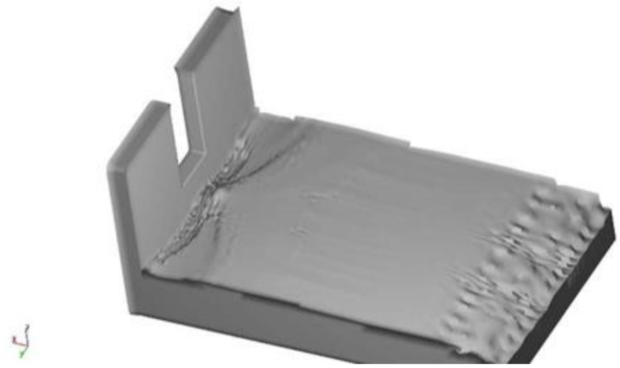
The calibration holds up for different values of the (bed roughness/ $d_{50}$) ratio and the test duration which is tested in two stages in order to match the model parameters and coefficients with the real experimental conditions.

### 6.4 Scour Depth Validation at Flume Center and Flume Side Locations

Sediment scour model included three bed load transport equation, in the present study Meyer-Peter and Müller, 1948 used, because it has ability in predicting the volumetric flow of sediment per unit width over the surface of the packed bed as well as it's behaved adequately in sensitivity analysis within 0.938 and 5% for Nash Sutcliffe and MAPE respectively. Fig. 9 a. and 10a presents the resulted scour depth obtained from the experiments for fine and coarse sands and the values resulted from the numeric simulations for different weir geometry, flow rates and sediment size. Maximum discrepancy between the measured data and the simulated values was 5.1% and 4% for flume-center and flume side locations which showed a good agreement with the measured data. Fig. 9 b. and 10b manifest the scour development close to the weir throughout the simulation.

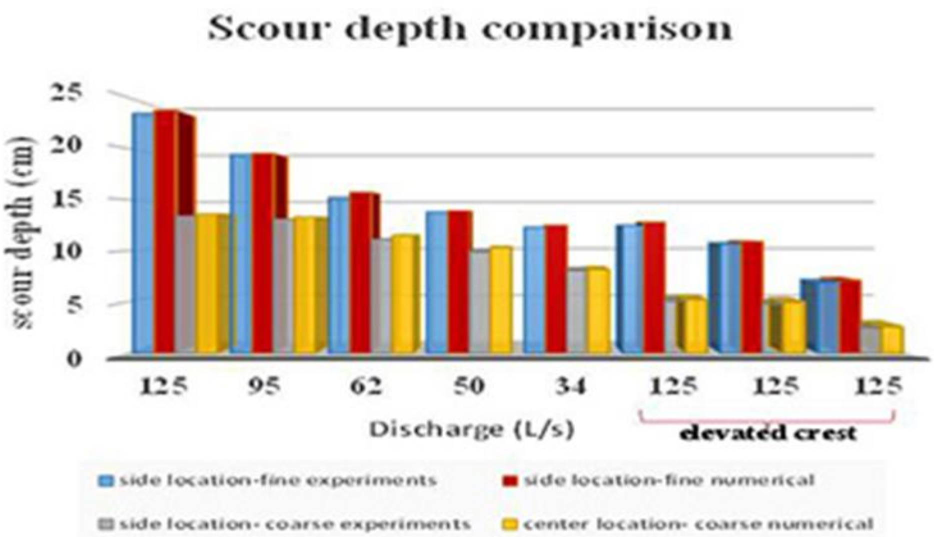



(a)

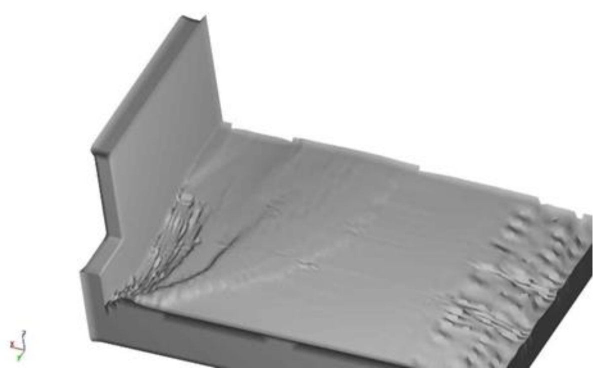


(b)

**Figure 9:** Center -flume location a. Experimental and numerical values of scour depth, b. Scour hole progress.




(a)

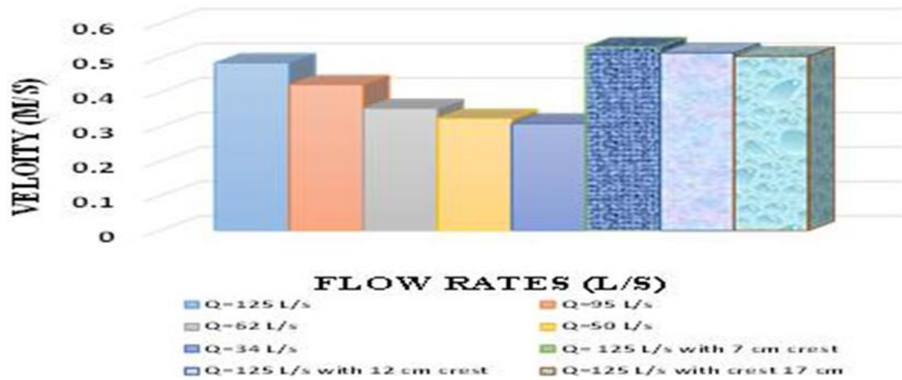


(b)

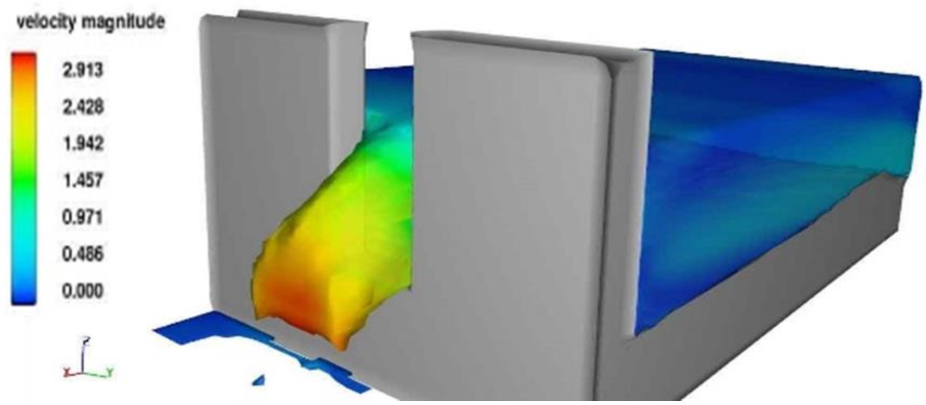
**Figure 10:** Side -flume location a. Experimental and numerical values of scour depth, b. Scour hole progress.

**6.5 Study-Hydrodynamics (Velocity and Shear Stress at the Slit Location)**

Uniform flow condition existed during all the experimental tests at upstream side of the weir and the velocity magnitudes recorded. Whereas, the velocity at the opening was hard to measure accurately in the Lab due to the high kinetic energy and the generation of tornedo-eddies caused by the contraction of the water path through the slit construction, therefore the velocity values at slit position predicted by FLOW 3D software as presented in Fig. 11 a and b.



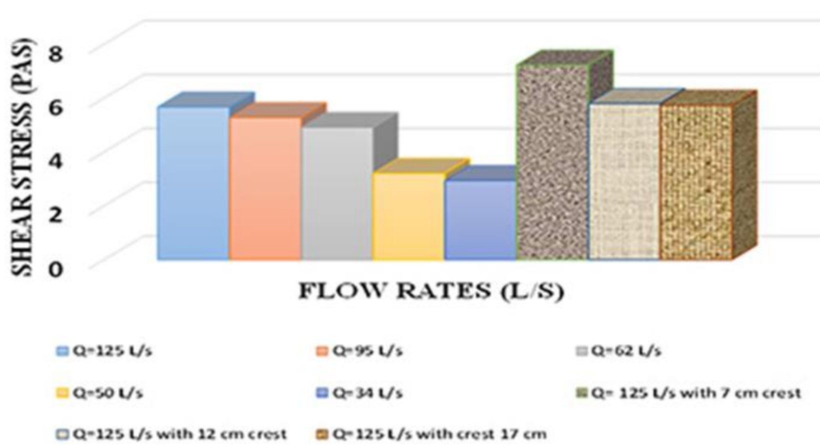

(a)



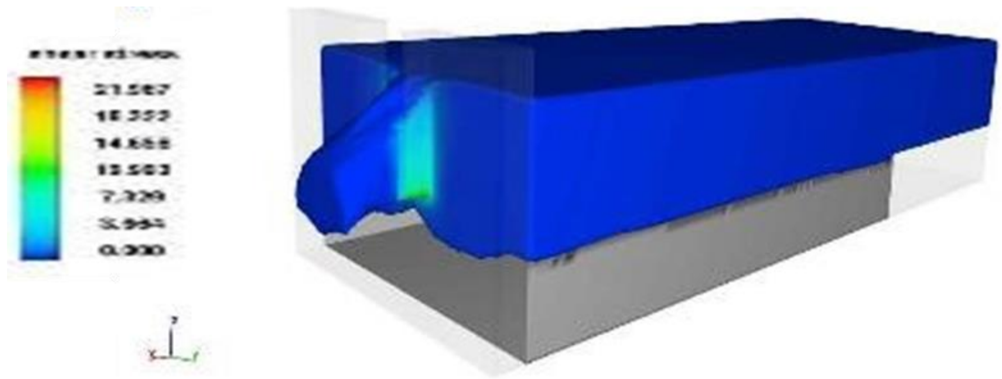

(b)

**Figure 11:** a, b Velocity values at slit weir location.

In addition, the shear stress magnitudes acquired numerically within each weir geometry and discharge value as presented in Fig. 12 a and b. Maximum values of the kinetic energy occur within a maximum discharge value then this value decreed with lowest flow rates. Furthermore, the recorded shear stress was gained a high value with a slit crest of 7 cm under maximum discharge. In consequence, even though the weir crest increased in its level but the shear stress value starts to decrease with crest height (12 and 17) cm due to the over flow condition occurred up of the weir wings. Fig. 13 clarifying the rotating kinetic eddies which was responsible of carrying the sand up of the weir opening at upstream side.




(a)



(b)

**Figure 12:** a, b Shear stress values at slit weir location.

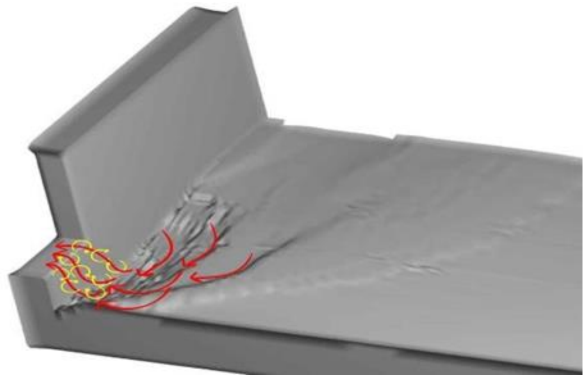


**Figure 13:** Rotating eddies at weir upstream.

### 7. Research Discussion

Even though there were many researches on a scour phenomenon at different hydraulic structures included various experimental techniques and software's modeling. However, most of these structures used either as a protection and control structures against sediment erosion; either the study experimentally or numerically as explained in the literatures. A quantitate comparison holds up with some of the literature studies in order to manifest the gain of slit weir adoption under the selected geometry, sediment size and flow condition in compare with other different hydraulic structures in a function of sediment releases. Therefore, maximum scour depth obtained under different flow patterns and flume configurations presented in Fig. 14.

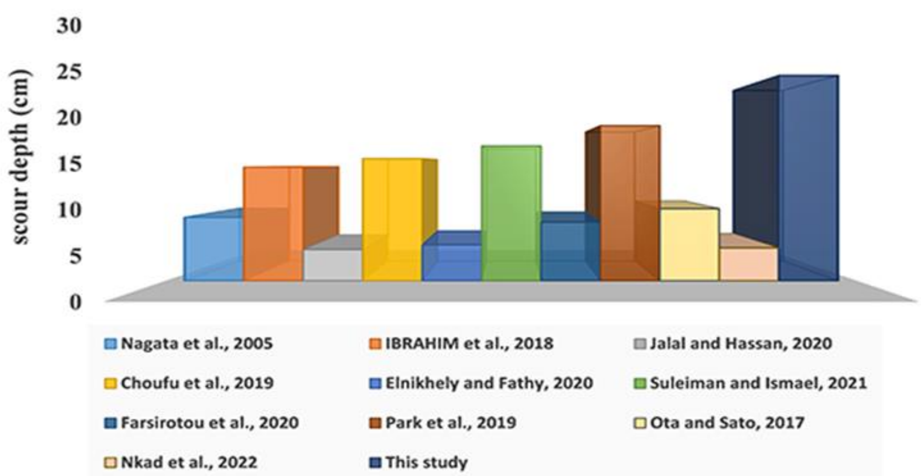



**Figure 14:** Maximum scour depth (cm) for different studies.

Removing sedimentation from dam reservoir within slit weir had not widely experienced. However, (Ota *et al*., 2017 a) and (Nkad *et al*., 2022) studies qualitatively compared within the present study. The results of this study investigated with a maximum discharge value which was 6.25 greater than that used by them. Also, the minimum discharge used was about double the maximum discharge used in their studies. This creates a discrepancy between the results. In addition, scour depth and volume relationship of the present study determined based on the empirical equation derived by (Ota *et al*., 2017 a) were conform a well agreement with a coefficient of determination of 0.93.

## 8. Conclusions

Laboratory work within 34 experiments conducted in this research to study the scouring issues at a flume weir. Scour hole volume and scour depth evolutions obtained under equilibrium hydrodynamic flow and sediment releases within various weir geometry, flow rates and sediment size of a nonuniform sand. Besides, time-varying scour progress simulated numerically within FLOW 3D software, consequently the relationship between the adopted variables and the results debated. The experimental measurements showed negative relation between weir crest-height and the resulted scour volume and scour depth, in contrast the volume and depth of the scour hole changed positively with increasing the discharge. The experiments and numeric simulation well agreed in presenting scour mechanism and scour hole dimensions. In addition, the hydrodynamics parameters at a slit location (shear stress and velocity) predicted numerically which was hard to measure in lab. High values of shear stress occurred due to the existence of the obstacle, however that's play a major role in efficient sediment carrying capacity economically. This study recommended for a civil designer and hydraulic engineering to be implemented which provides a resendable and economic guideline in design the dam gate dimensions for continues and functional sediment releases without power generation interruption.

## Author Contribution

"Conceptualization, R.K; methodology, R.K.; software, R.K.; validation, R.K..; formal analysis, R.K.; investigation, R.K.; resources, R.K.; data curation, R.K.; writing—original draft preparation, R.K.; writing—review and editing, R.K., A.A and T.A; visualization, R.K.; supervision, A.A. and T.A.; project administration, R.K.; funding acquisition, R.K. All authors have read and agreed to the published version of the manuscript.

## Data Availability Statement

All of the data were collected from field measurements and the laboratory work are presented in recent manuscript.

## Conflict of Interest

The authors declare that they have no conflict of interest.

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