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Bed Configurations of Downstream Sharp Crested Weir with Orifices

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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Original Research Article

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ABSTRACT

Weirs are utilized for measuring of discharge, diminishing the water slope in canals and dissemination of water between canals for irrigation, etc. Classical sharp crested weir is associated with increases in turbulence and bed problems in downstream resulting in scouring activity that is considered one of unfavorable processes which dangers the general steadiness of the weir. Sharp crested weir with orifices along these lines introduces the same functions of the classical type but with has the capacity for minimizing changes in downstream bed configurations. An experimental study was conducted to predict and evaluate the geometry of bed configurations downstream of a sharp crested weir equipped with rounded orifices. Ninety nine (99) experimental runs were conducted. 11 weir models, 3 discharges, and 3 tail water depths. The utilized models referred to 11 scenarios for orifices schedules presented in terms of numbers and locations. 9 symmetrical orifices, 3 cm distance across each were made in the utilized weir to pass on much water in the downstream heading. The orifices were orchestrated in 3 equals spaced rows and 3 equal spaced columns. The study reach secured 4m length downstream the weir. Results were analyzed and graphically displayed. The geometry of bed configurations due to flow over the weir with orifices were contrasted with those of the classical sharp crested weir. Quantitative volumes assessments of local scour and silting utilizing the 11 scenarios were likewise introduced. Large contrasts between tested cases were reported.

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Keywords: Weir; narrow crest; orifice; experiments; bed configurations; flume.

NOTATIONS

H	= water head above the weir crest	[m]
y	= water depth at the tail gate	[m]
Q	= water discharge through the flume	[m^3/s]
g	= gravity acceleration	[m/s^2]
B	= flume width	[m]
V	= the mean velocity at the downstream cross section of flume	[m/s]
d	= orifice diameter	[m]
d_{50}	= mean particle diameter	[m]
d_s	= maximum scour depth	[m]
L_{ap}	= length of apron	[m]
P	= weir height	[m]
h	= distance from bed level to the horizontal axis of orifices	[m]
a	= open orifices area	[m^2]
S_o	= bed slope of the flume	
R	= Reynolds number	
n	= number of opened orifices	
C_u	= Uniformity coefficient	
F_r	= Froude number	

GREEK SYMBOLS

ρ	= Fluid density	[kg/m^3]
ρ_s	= soil particle density	[kg/m^3]
μ	= Dynamic viscosity of fluid	[kg/m.s]
υ	= Kinematic viscosity of fluid	[m^2/s]

1. INTRODUCTION

Weirs are structures (including a dam, lock, regulator, barrage or causeway) across a defined watercourse that restrict flow or hinder the movement of fish along natural flow paths, in normal flow conditions. Weirs are normally provided for any one or more of the following fundamental functions:

- Water Level Management,
- Flow Measurement,
- Environmental enhancement and
- Channel Stabilization.

Classified under the term ‘sharp-crested’ or ‘thin-plate’ weirs are those overflowing structures that are the top thickness of the crest and side plates between 1 and 2 mm, [1]. The weir plate should be smooth and plane, especially on the upstream face, while the crest surface and the sides of the notch should have plane surfaces which make sharp 90-degree intersections with the upstream weir face [2]. Flow over spillways or underneath gates has a tremendous amount of potential energy, which is converted into kinetic energy downstream control structures. This energy should be dissipated to prevent the possibility of excessive scouring of the downstream waterway bed, minimize erosion and undermining of structures, which endanger the structure safety.

For mobile bed rivers, the bed is constantly subjected to special and temporal changes which modify the habitat characteristics. The scouring action at downstream of the hydraulic structures is an important problem and was studied by many hydraulic engineers in order to identify the variables governing this phenomena and also to find the solutions for it. The extent of scour downstream a hydraulic structure like weir depends on characteristics of flow, bed material composition and geometry of structure [3].

Scour in bed material downstream weirs was considered the most unfavorable process that threats the overall stability of the weir. Several attempts were done to study in detail the flow over different shapes of normal conventional weirs including those with sharp crest, side weirs, and oblique weirs, mainly based on experimental work. There were many formulae for scour following hydraulic jump in a stilling basin such as developed by [4-17]. Many studies were done to investigate the discharge coefficient and the flow characteristics downstream weirs [2,18-21].

Focusing on scour investigations downstream weirs, Cheng et al. analyzed results from a series of studies concerning scouring downstream of weirs on soft rock [22]. The study indicated that the shape of a scour hole on soft rock differs markedly from that of a scour hole on hard rock. Pagliara et al. [23] studied the scour of clear water rock w-weirs in straight rivers and concluded that the maximum scour depth decreases and its location shifts downstream with respect to classical W-weirs. Fahmy carried out experimental and statistical study of local scour downstream of a sharp crested weir with a horizontal apron with and without baffle blocks [24]. He concluded that the installation of baffle blocks had a significant influence on the scour hole. Guan et al. [25] studied the flow patterns and turbulence structures in a scour hole downstream of a submerged weir. The study presented the distributions of flow patterns, bed shear stresses, and turbulence structures in the approach flow and the scour hole downstream of a submerged weir.

Rare studies have been done on weirs with orifice. Abdel Halim, et al. carried out an experimental study to calibrate the combined structure (weir and large diameter orifice). A mean value for the coefficient of discharge for the combined structure was found to be 0.623 which was very close to the theoretical values for each separate structure [26]. Sobeih et al. [27] investigated experimentally the influence of using orifices in weirs on scour hole depth downstream the weir. The study concluded that, the maximum scour depth for all considered opening arrangements was directly proportional to velocity. The study developed an equation based on their measurements.

$$d_s/y= -2.54*10^{-2}(1/Fr^2) - 0.481(d/P) + 0107(h/P) -1.687*10^{-2}(n) + 2.218(a/P) + 0.723 \quad (1)$$

Where: d_s= maximum scour depth, y= tail gate water depth, F_r= Froude No., d= orifice diameter, P = weir height, h= distance from bed level to the horizontal axis of openings, n= no of orifice, a= open orifices area.

Hassan et al. studied experimentally the flow over clear over fall weir with bottom circular opening [28]. The study demonstrated that there is a large difference between the flow over weir with a circular opening and those of the weir without an opening having the same dimensions. Also, the study demonstrated that the hydraulic jump behind the weir with an opening occurs nearer to the weir than that at weir without the opening. This may affect the scour characteristics downstream the weir. Ibrahim carried out experimental study to investigate the hydraulics of sharp crested weir with orifice including the discharge coefficient, and the hydraulic jump [29]. He concluded that, in the case of weir with orifice, the discharge coefficient was higher than the classical weir under the same conditions. However, the jump length was reduced. Esam and El-Azab studied experimentally the effect of single line of floor water jets on the scour hole parameters downstream of a control structure. (Fayoum type weir) with different jet discharges, locations, and tail water depths [30]. The study indicated that the system of suggested floor water jets gave from 50% to 90% reduction in maximum scour depth and from 42% to 85% reduction in scour hole length compared to the case of the floor without water jets. Zhang et al. [31] used experimental data for eight sharp-crested rectangular weirs of different sizes, to define a new method for calculating discharge at the low head and clinging flow regime.

Distinctive techniques to reduce local scour have been employed in previous studies by making use of splitter plates or collars or conveying the discharge to the downstream through a pipe. In the same context, baffle blocks installed on stilling basins have been also utilized to stabilize the formation of the jump and increase the turbulence, thereby assisting in the dissipation of energy. All the past arrangements demonstrated a decent execution in minimizing scour, yet from a money related contemplation utilizing orifices was discovered a legitimate arrangement with less cost; as no more materials were needed.

After thoroughly investigations for the previous works included in mulling over the weir with orifices, it was noticed that most of them were simulating only one orifice, e.g. [26] or one row e.g. [27], and none of them were a comparative study. Hence, in this exploration a correlation from the perspective of local scour and silting between the classical sharp crested weir and weir equipped with identical rounded orifices masterminded in 3 equal spaced rows and 3 equal spaced columns under the same flow conditions were displayed to characterize viability of orifices numbers and areas in minimizing the unfavorable activity of the traditional sharp crested weir.

This research was thus initiated keeping in mind the end goal to examine the influence of discharge, tail water depth, location and number of orifices on the bed configurations downstream a sharp crested weir with orifices and to compare results with the classical weir type.

2. DIMENSIONAL ANALYSIS

The local scour downstream of a sharp crested weir with orifices and a horizontal floor relies on upon countless and dregs variables of flow and sediment as follows:

$$\phi\left(B, P, H, Y, L_{ap}, V, d, d_{50}, g, Q, \rho_s, \rho, \mu, \mathrm{S_o}, \mathrm{n}, \mathrm{h}, \mathrm{a}, \mathrm{A}\right) = 0 \quad (2)$$

where: H= the water head above the weir crest, y= tail gate water depth, Q = water discharge through the flume, V= the mean velocity at the downstream cross section of flume, g= gravitational acceleration, ρ= water density of the flow, μ = dynamic viscosity of the water, d_{50} = mean particle diameter, ρ_s= soil particle density, L_{ap}= length of apron, P = weir height, S_o= flume bed slope, B= flume width, n= no of orifice, h= distance from bed level to the horizontal axis of orifices, d= orifice diameter, d_s= maximum scour depth, a= open orifices area, A= weir area.

Where in this study P, B, S_o, d, d_{50}, ρ_s, L_{ap} were kept constant. Then, the Eq. (2) might be written in the following form:

Using π-theorem and applying the properties of dimensional analysis, it yields;

$$\frac{\mathrm{d_s}}{\mathrm{y}} = \phi\left(\frac{H}{y}, \frac{h}{y}, \frac{V}{\sqrt{gy}}, \frac{\rho Q}{d\mu}, \frac{a}{A}, \mathrm{n}\right) \quad (3)$$

In which $\frac{V}{\sqrt{gy}}$ = Froude number, and $\frac{\rho Q}{d\mu}$ = Reynolds number. The Reynolds number effect identified with the flow through orifices may be neglected as the effect of viscosity is accepted of optional significance in assessing the scour parameters as the flow is essentially gravitational. Additionally, the velocity was exhibited in the term of the Froude number. Eq. (3) may take the following form:

$$\frac{\mathrm{d_s}}{\mathrm{y}} = \phi\left(\frac{H}{y}, \frac{h}{y}, F_r, \frac{a}{A}, \mathrm{n}\right) \quad (4)$$

3. METHODS AND MATERIALS

The experimental work of this study was conducted in a flume of the Hydraulics Research Institute (HRI) of the National Water Research Center, Egypt. The flume channel was 21 m long, 0.6 m wide, 0.5 m deep, and equipped with a steel wooden gate with an orifice with a rectangular shape, also has movable downstream gate situated toward the end of the flume. Centrifugal pump driven by induction motor to re-circulate the flow from an underground reservoir to the flume. The model was a sharp crested type weir made of steel was utilized as a heading-up structure. The weir has 0.02 m thick 0.3 m height and 0.6 m width. 9 indistinguishable orifices 3 cm diameter each, were organized symmetrically, (Fig. 1). The tested discharges were 10, 20, and 30l/s while the tested tail gate water depths were 10, 15, and 20 cm. The tested discharges and tail gate water depths were chosen by accessible pump and flume limit. The benefits of embracing more than one worth discharge and tail gate water depth was to simulate a genuine condition for a canal in terms of maximum, average, and minimum flow conditions.

The research investigates the influence of the above variables ona 20 cm layer bed material of (bulk density= 1.92 gm/cm^3, d_{50}= 3.11 mm, d_{10} = 1.92 mm, d_{16} = 2.54 mm, d_{60} = 3.75 mm, d_{84} = 4.52 mm, and uniformity coefficient C_u = d_{60}/d_{10} = 1.95). The given material was utilized to reproduce live bed conditions. Then again, more than bed material could be utilized as a part of further studies to assess the impact of d_{50} on the local scour associated to sharp crested weir with orifices.

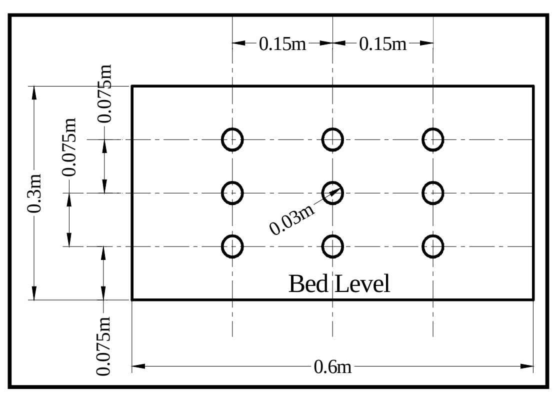

Fig. 1. Weir model with 9 orifices

3.1 Justifications of Parameters Assumptions

The present study has some parameter assumptions as an essential examination concentrated on weir dimensions, orifice diameter, discharge, and the tail water depth.

The weir width was chosen of 0.60 m to concur with the flume width. The thickness was 2 mm to reproduce a sharp crested weir, Martínez et al. [1].

After several trial experimental works, parameters assumptions were:

- The weir height was 0.30 m to permit an adequate free board to prevent flow from spilling out in case of classical sharp crested weir (without orifices) was fitted to the most extreme tried discharge (30l/s). The free reported board for this situation was 5 cm.
- The orifice diameter of 3cm was deliberately chosen to ensure a compelling measure of flow passes the weir by virtue of 9 orifices. As it were, the orifices don't expend the entire flow if more than 3 cm orifice diameter was utilized. In the event that orifices of diameter under 3 cm were utilized, the best measure of flow passed over the weir, thus the orifices presence get to be ineffectual.
- The discharges less than 10l/s didn't show any significant influence on bed topography on account of weir with 9 orifices. However, the discharges higher than 30l/s may prompt to flow spilling outside the flume. The discharge of 20l/s was selected as an average value to simulate the average conditions in a given canal.
- At long last, the tail water depths, it was noticed the bed material was completely uprooted if the tail water depth was less than 10 cm on account of maximum discharge passes a classical sharp crested weir. Then again, no extraordinarily warnings were accounted for tail water depth higher than 20 cm in the case of minimum discharge passes a weir with 9 orifices.

4. TEST PROCEDURE

4.1 Run Duration

Toward the start of the experimental works, a few tests were led utilizing distinctive weir models and discharges. To characterize the run length of time; Figs. 2 and 3 were plotted for settled discharge and tail water depth of 20l/s and 15cm, separately .Classical sharp crested weir model and weir with 9 orifices were utilized; as they present the normal greatest and least measurements of local scour hole. The overall time was taken as 6 hours. The depth and length of scour hole were recorded every 15 minutes in the first hour, then at regular intervals of 30 minutes in the rest 5 hours. It was noticed following 30 minutes from beginning, the depth and length scour hole were stretched around 75-85% their most extreme qualities settled following 3 hours from beginning. Subsequently, the run length of time of any test was equivalent to 4 hours to underline the quasi-equilibrium state were occurred as there are no considerable changes in the geometry of the local scour hole.

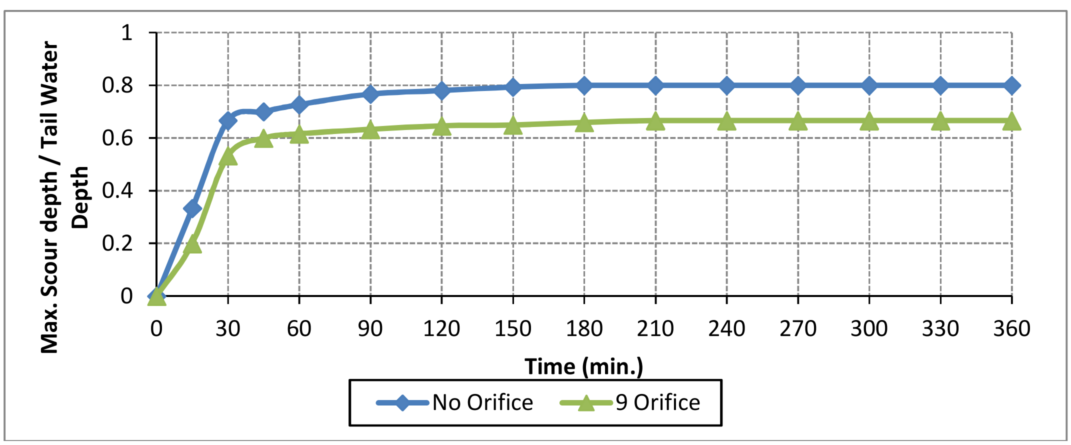

Fig. 2. Relation between time and maximum scour depth for classical and 9 orifice sharp crested weirs

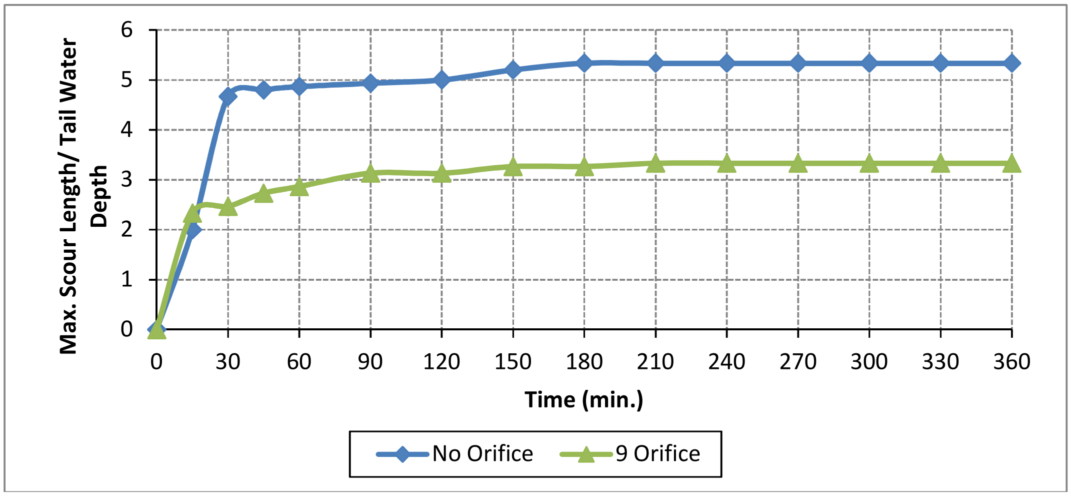

Fig. 3. Relation between time and maximum scour length for classical and 9 orifice sharp crested weirs

4.2 Run Procedure

After the flume was loaded with 20 cm depth bed material and precisely leveled (the leveling exactness was checked by means of a point gauge with an accuracy of ± 0.1 mm and leveling device). The following steps were done for each run:1- The selected weir model was installed painstakingly in the flume in its place, 2- The tail gate was completely closed, back water feeding was begun first until its depth reached higher than the craved downstream water depth, 3- The control valve at the feeding opening was gradually opened till keep up the obliged discharge, 4- The exact water discharge was measured utilizing an ultrasonic flow-meter with an accuracy of ±1%,5- The tail gate was screwed gradually until the required downstream water depth is reached at utilizing the point gauge, 6- The running time of the test is started, 7- After 4 hours (where there is no appreciable change in bed profile), the pump was switched off, 8- The flume was purged from water by tail gate very slowly in order to do not aggravate the bed configurations, 9- After the model was drained, the bed levels were recorded utilizing point gauge and ordinary scale through settled framework. Steps 1 to 9 were completely rehashed for each run.

5. DIFFICULTIES, CHALLENGES AND PROPOSED SOLUTIONS

The current experimental work has found some difficulties and challenges beginning from test setup and finished by estimations. Following there are some of these difficulties and proposed solutions:

5.1 Flume selection

The used flume was deliberately chosen from the perspective of dimensions, pump capacity, and feeding systems to cover the proposed scenarios.

5.2 Uniform Flow

To create a uniform flow, a screen stone box filled with large gravel was implemented at the flume entrance to pass the water through to scatter the vitality at the bay and smother any exorbitant turbulence. Likewise, 3m downstream the screen stone box, a screen wooden box of 0.6m width, 0.3m length, and 0.4m height was fitted to guarantee the creation of the uniform flow, Fig. 4.

5.3 Flow Measurements

To assure the measurements precision of the utilized ultrasonic flow-meter, extra way was utilized. A solid sharp crested weir of predetermined discharge coefficient (0.64) was utilized to measure the discharge. A correlation between the both estimations was displayed to ensure the precision, Fig. 5.

5.4 The weir Material

The weir was an iron sheet to prevent the volumetric changes due to water (like wood for example).

5.5 The Orifices

The 9 rounded orifices were performed in the solid weir using an electronic cutting machine furnished with scale to guarantee the orifices are indistinguishable of 3 cm distance across definite.

5.6 Fitting the Weir

The weir model was fitted in its place through 2 groves in the flume side walls of 3 mm thickness each. The weir was carefully placed and assured using a leveling device. A silicon layer was utilized to fill the little spaces between the weir and the groves additionally the weir and the flume bottom to underscore that no water leakage from these locations.

5.7 Weir Models

To minimize the expenses of weir materials; a weir of 9 identical orifice was firstly implemented, then on account of less number of orifices a wooden blocks of inverted cone shapes are fitted in the orifices to be bolted. A layer of silicon was embedded around the orifice and the wood to anticipate water leakage.

5.8 Flume Feeding

The flume was outfitted with a pump of 200l/s maximum capacity. Accordingly, to anticipate motor damage on account of small discharges of 10 and 20l/s; a smaller pump of 25l/s maximum capacity was connected.

5.9 Flume Filling

To avoid bed development before the run span begins because of upstream water sustaining, back water feeding was initially starts up to the desired downstream water depth, then the upstream water nourishing begins.

5.10 Bed Profile

The bed profile measurements were helped out through 105 points, Fig.4 to assure that all bed configurations were correctly exhibited. For more accuracy, the measurements were taken twice times utilizing 2 diverse point gauges, and the mean values were accounted for.

5.11 Bed Leveling

Before beginning another run, the bed material was re-levelled using a sharp long stick and checked by means of leveling devices.

6. MODEL RUNS

The test program consists of 99 experimental runs utilizing, 3 discharges, 3 tail water depths and 11 scenarios for orifices schedules presented in terms of numbers and locations throughout 11 diverse weir models. The scenarios were selected to define the optimum number and orifices schedules under diverse flow conditions to minimize the local scour downstream the weir. A designed mesh consists of 105 measuring points arranged in 5 rows, 10 cm spacing and 21 column started at weir location and ended after 4 m with 0.2 m interim were utilized to characterize the bed profile with high precision, Fig. 6. It should be signified that to reenact sharp crested weirs installed in small channels; no apron or stilling basin were utilized as a part of the examinations. Henceforth, the viability of orifices in minimizing the downstream local scour was highlighted. Consequently, the bed material was located just downstream the weir model, Fig. 7.

Table 1. Range of variables used in the experiments

Parameter	Symbol	Value	Range		Units
			From	To	
Discharge	Q	10,20,30	10	30	l/s
Tail gate water depth	y	10,15,20	10	20	cm
Head over weir	H	Varied	0.95	7.9	cm
Distance from bed level to the horizontal axis of orifices	h	7.5, 15, 22.5	7.5	22.5	cm
Number of orifices	n	3, 6, 9	3	9	------
Area of orifices	a	0.21, 0.42, 0.64	0.21	0.64	cm^2

Fig. 4. Screen stone and wooden boxes

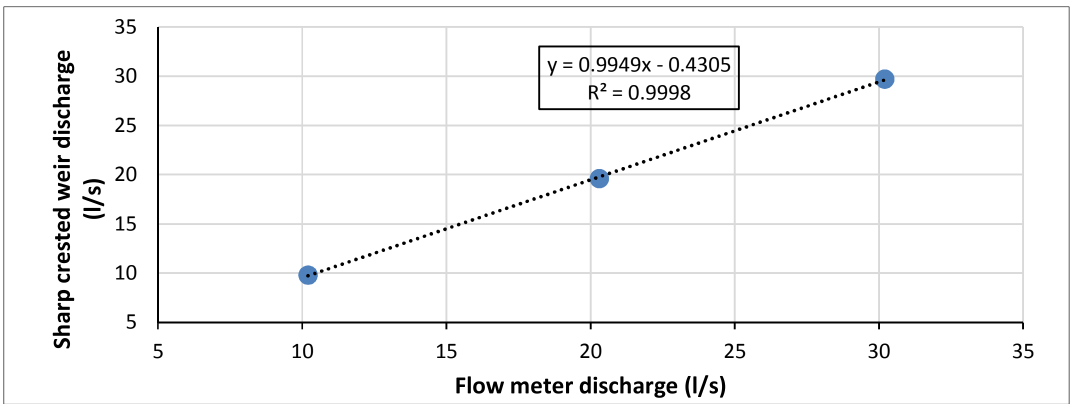

Fig. 5. Comparison between the discharges measured from flowmeter and sharp crested weir

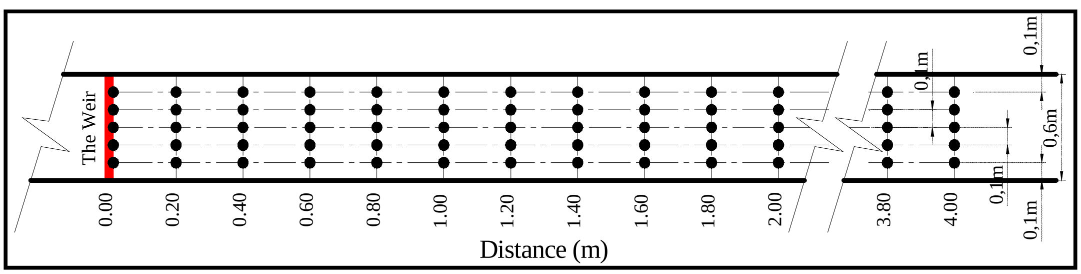

Fig. 6. Locations of bed profile measuring points

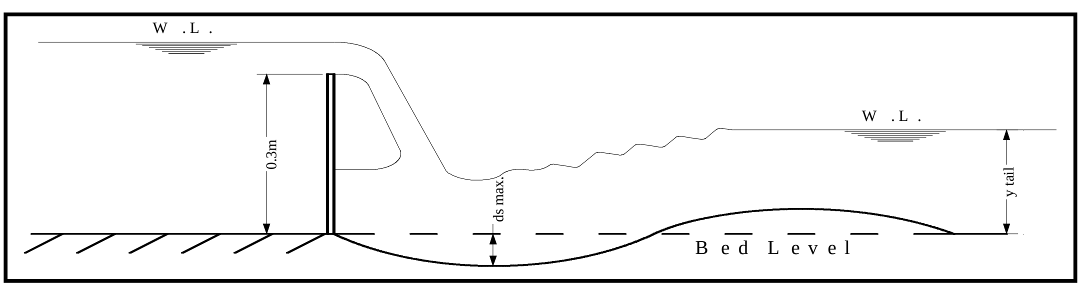

Fig. 7. Schematic diagram showing the geometry of the scour and silting

7. RESULTS AND DISCUSSION

Figs. 8 and 9 were plotted under settled 20l/s discharge and 15 cm tail water depth using the readings of the 105 measuring points introduced in Fig. 6 to examine the bed levels on account of classical sharp crested weir and weir with 9 orifices. Studying results from Figs 8 and 9 it was noticed that the bed configurations in terms of local scour and silting were higher in the case of using the classical weir contrasted with weir with 9 orifices.

To delineate the explanations for that, Fig. 10 was plotted for the Froude No. along the tested length for the both types of weirs. It should be specified that the velocity measurements were started after the initial 1 m just downstream the weir where the velocity readings were seriously off base influenced by the activity of the hydraulic jump, [29]. Exploring Fig. 10 notable differences were found in the Froude no. for the both type of weirs particularly in the initial 1.5 m just downstream. The orifices presence lessens the water turbulences downstream the weir, then the velocity was diminished, and so consequently the Froude no. That explains the discoveries in Figs 8 and 9 where the geometry of local scour and silting for the classical sharp crested weir was particularly seen contrasted with the weir with 9 orifices.

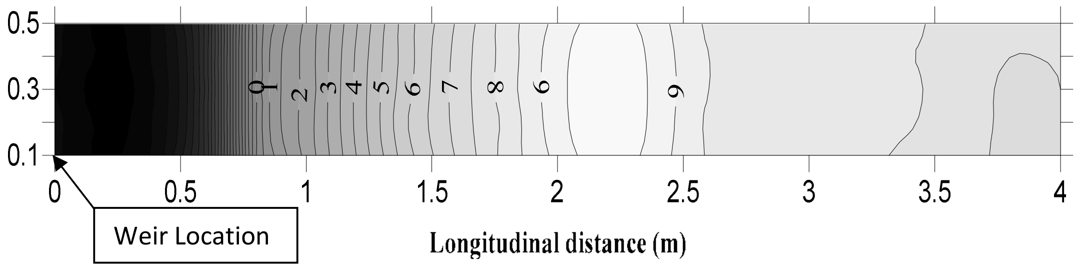

Fig. 8. Bed contours in the case of classical weir

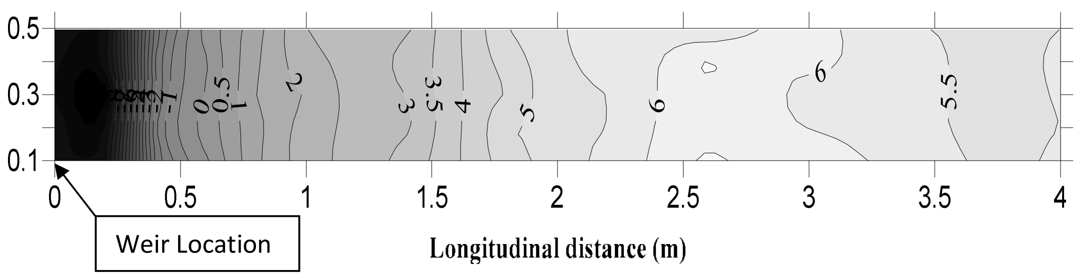

Fig. 9. Bed contours in the case of weir with 9 orifices

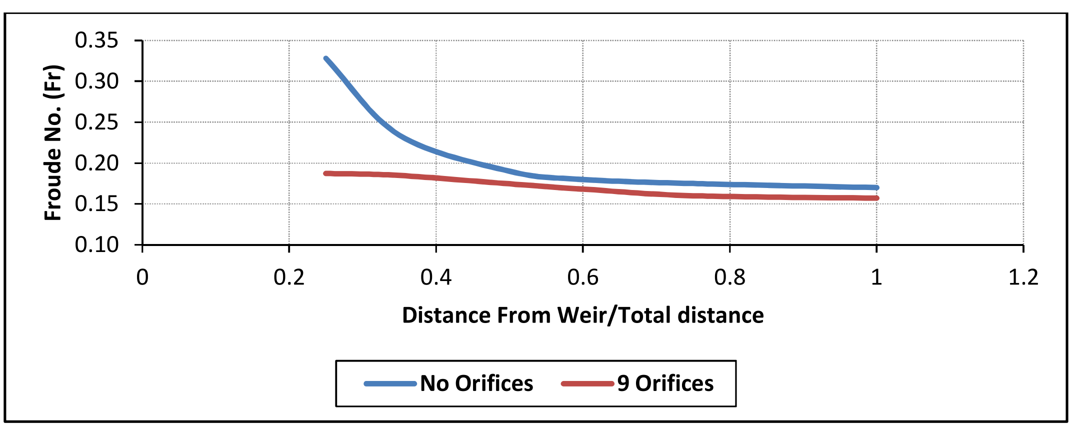

Fig. 10. Froude No. in case of classical and 9 orifices weirs

Figs. 11-17 were plotted to investigate the bed configurations exhibited in terms of the geometry of scour and silting downstream a classical sharp crested weir and combined weir with orifices in the mid channel (at 30 cm from right or left wall, Fig. 6), as the measurements of the 2 rows (10 and 50 cm from right wall) were affected by the flume side walls. However, the measurements of the 2 rows (20, and 40 cm from right wall) gave the same pattern with no qualities contrasts.

7.1 Influence of Discharge

Figs. 11 and 12 illustrate the influence of discharge on the bed configurations downstream classical sharp crested weir and weir equipped with 9 orifices, individually under settled tail water depth of 15 cm. Comparable bed pattern was found with contrasts in qualities. The figures demonstrated the maximum and minimum bed configurations introduced as far as scour and silting were found at discharges of 30 and 10l/s, separately for the both tested weir types. However, the weir equipped with orifices gave little qualities. Discussing these remarks, under settled cross sectional area, the velocity was higher than if there would have been an occurrence of 30l/s discharge contrasted with 10l/s discharge. Consequently, and because of the way that the scour is a practical parameter in velocity, the geometry of scour hole was expanded in case of 30l/s discharge. In the same direction, the increment in scour depth should prompt augmentation in silting height.

To investigate the effectiveness of orifices in minimizing the unfavorable activity due to local scour at downstream, a comparison between geometry of local scour resulted in installing both types of weirs under the same flow condition was required. Under 30 l/s fixed discharge, concentrating on the scour region, the maximum local scour depth and length for the classical sharp crested weir were -17 cm and 1.6 m respectively (Fig. 11). Then again, the relating estimations were -13.5 cm and 1 m, individually for weir equipped with 9 orifices exhibited in Fig. 12. In this way, the weir equipped with orifices prompted lessening in scour depth and length by 21% and 38% respectively. These outcomes were noticed due to a part of the tested discharge that went through the orifices, subsequently the head over weir and the downstream velocity were diminished. Likewise, shorter hydraulic jump was created, [29]. Therefore the orifices demonstrated a superior in diminishing the downstream local scour.

7.2 Influence of Tail Water Depth

Figs. 13 and 14 discussed the influence of tail water depth on the bed configurations downstream in the classical sharp crested weir and weir equipped with 9 orifices respectively under fixed discharge of 20 l/s. The upstream water level (U.S.W.L.) for a 20 l/s discharge was discovered 36 cm delivered from flume bed on account of classical sharp crested weir. Comparable bends pattern was found for the examined cases. On account of classical sharp crested weir, Fig. 13 demonstrated that for 10 cm tail water level, the bed configurations were amplified (local scour depth and length were -15 cm, and 1 m, respectively) in contrast with 20 cm tail water level (local scour depth and length were -11 cm, and 0.8 m, respectively). That can be interpreted as minimizing the tail water depth; the velocity increments therefore the geometry of scour and silting owing to minimizing the flow cross section under settled discharge.

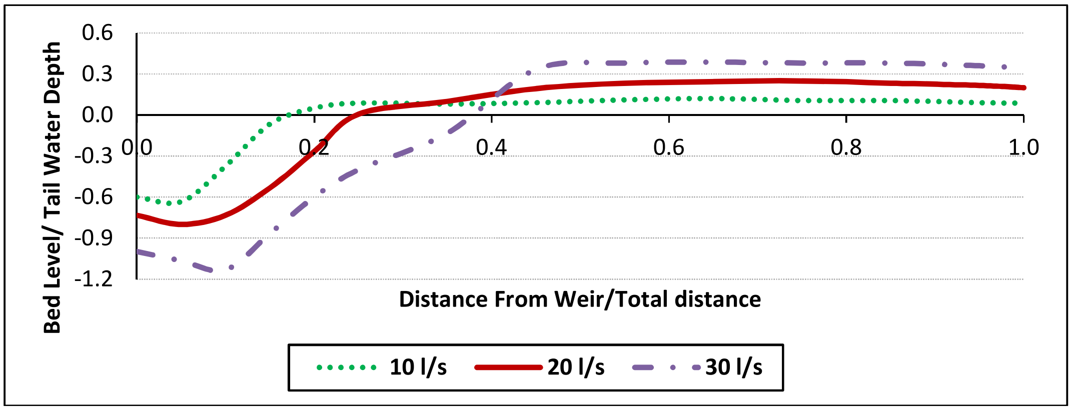

Fig. 11. Bed configurations downstream classical weir at different discharges

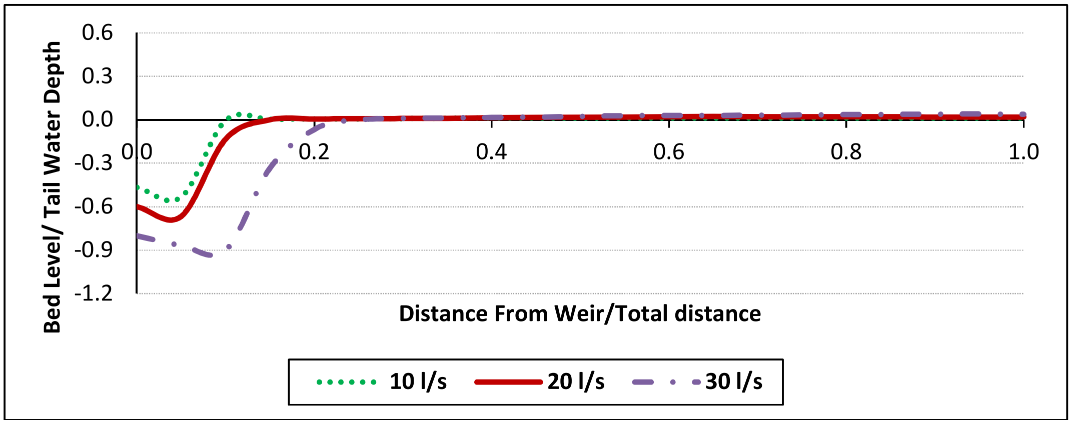

Fig. 12. Bed configurations downstream weir with 9 orifices at different discharges

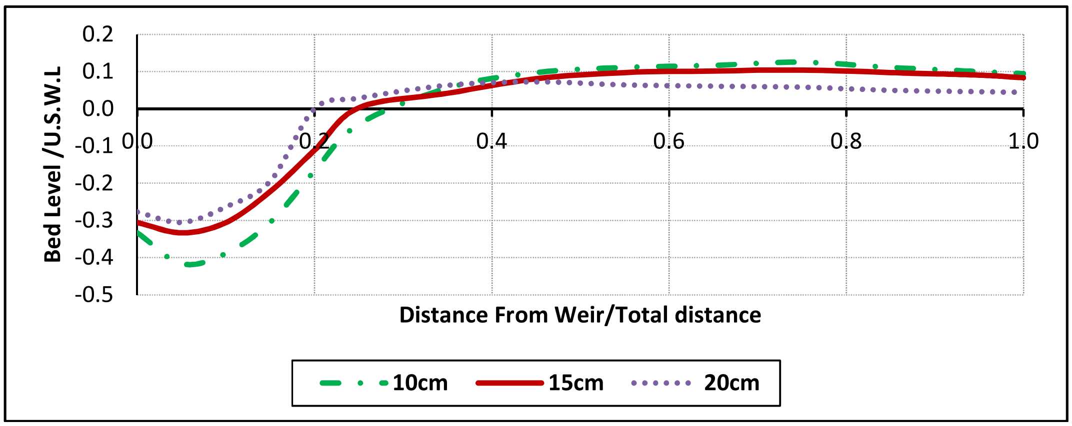

Fig. 13. Bed configurations downstream classical weir at different tail water depths

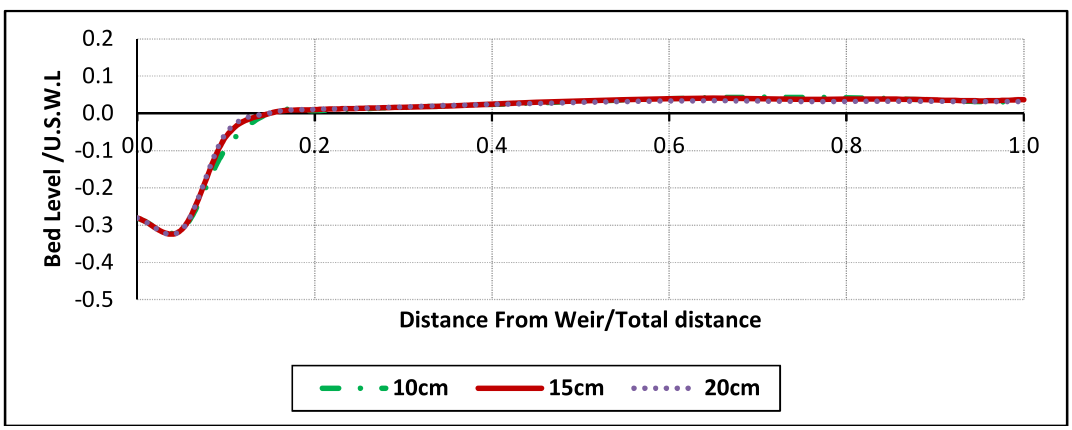

Fig. 14. Bed configurations downstream weir with 9 orifices at different tail water depths

For the weir equipped with 9 orifices, no critical impact for tail water depth was noticed; no distinct qualities for bed levels were measured. Owing to orifices presence, the scour depth and length were lessened by 33% and 47% contrasted with the classical sharp crested weir for 10 cm settled tail water depth. Consequently, the orifices demonstrated high proficiency in enhancing the downstream local scour.

7.3 Influence of Orifices Locations and Numbers

Figs. 15-18, and Table 2 were presented to characterize the influence of orifices locations and numbers on local scour and silting downstream weir with orifices, utilizing distinctive scenarios contrasting the classical sharp crested weir. The measurements were accounted for settled discharge and tail water depth of 20 l/s and 15 cm, respectively.

Fig. 15 was plotted to define the influence of flow over weir with 3 orifices arranged in single row at different heights measured from bed level (i.e. top, middle, and bottom row were at heights equal to 0.225, 0.15, and 0.075 m measured from bed level respectively, Fig. 1).

Focusing on the local scour produced from flow over weir with single orifice it was seen that the weir with bottom orifices introduced the most extreme local scour hole which was much closer for the estimations reported for classical weir. That can be represented as a subpart of flow went through the bottom orifices with high velocity going about a submerged jet due to the water head. Hence, enacting the local scouring activity as the bottom orifices were shut to the flume bed (7.5 cm higher).

In the same setting and despite what might be expected it was the instance of top orifices where the minimum local scour was found. As flow from top orifices slammed the flow over weir prompted minimize the effect of hydraulic jump, hence the turbulence in bed levels. Subsequently, it was reasoned that the geometries of local scour and furthermore the silting were conversely relative to the orifices row height measured from the bed level.

Fig. 16 was plotted to recreate the flow over weir with simultaneous 6 orifices arranged in dual-rows. Comparative bends pattern were found with more or less indistinguishable qualities for the tested cases. The measurements of local scour were closer to the weir with 9 orifices. Along these lines, it was presumed that the flow over weir with 6 orifices arranged in any dual-rows gave comparable impact on downstream local scour and silting. Consequently, the effect of rows height was vanished in the event of dual-rows opened.

Fig. 17 was plotted to investigate the influence of flow over weir with single or simultaneous dual-columns orifices. Underscoring the local scour, it was outlined that the instance of 3 orifices arranged in single edge column created local scour higher than the instance of 3 orifices arranged in the middle column due to the flow uniformity and consistency. Be that as it may, the instance of 6 orifices arranged in dual edge columns demonstrated local scour smaller than the instance of single column regardless to its location edge or middle.

As increasing the number of orifices diminishes the head over weir; along these lines decreases the effect of the hydraulic jump; hence the local scour. Concentrating on the silting region, it was noticed the columns of orifices regardless to their locations and numbers reduces the silting height compared to the classical weir.

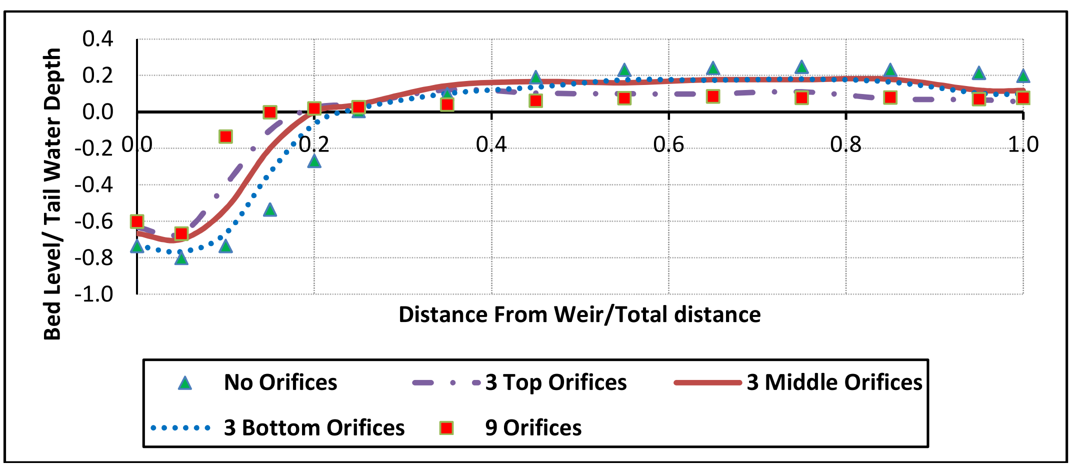

Fig. 15. Bed configurations downstream weir with single row orifices

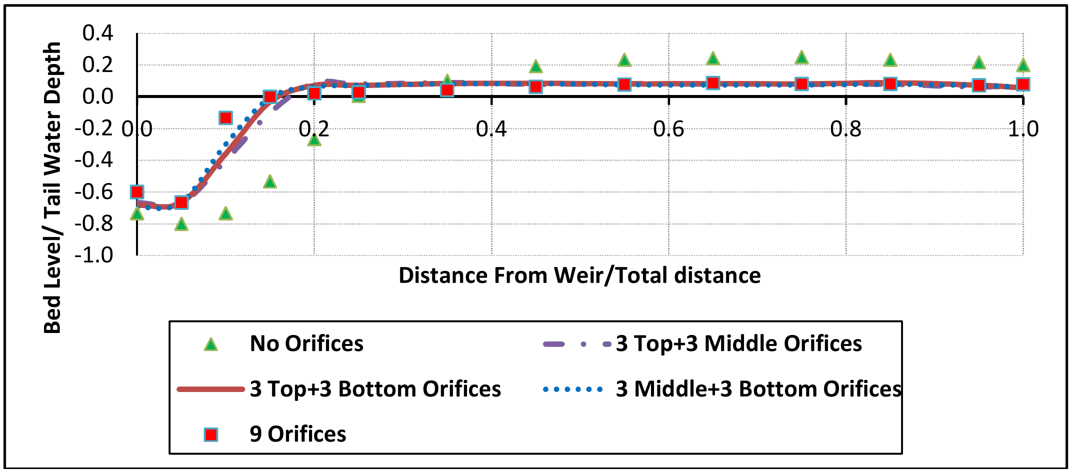

Fig. 16. Bed configurations downstream weir with simultaneous dual-Rows orifices

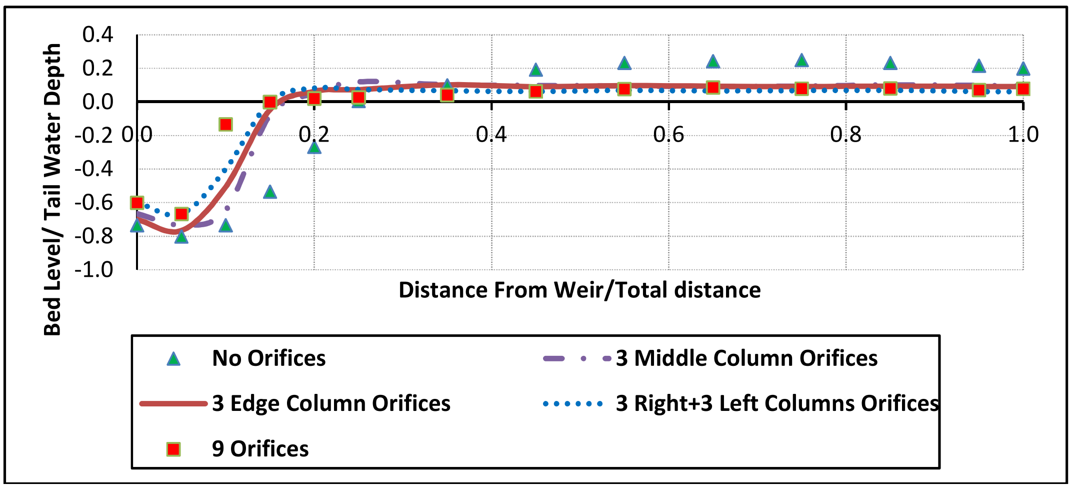

Fig. 17. Bed configurations downstream weir with single and simultaneous dual-columns orifices

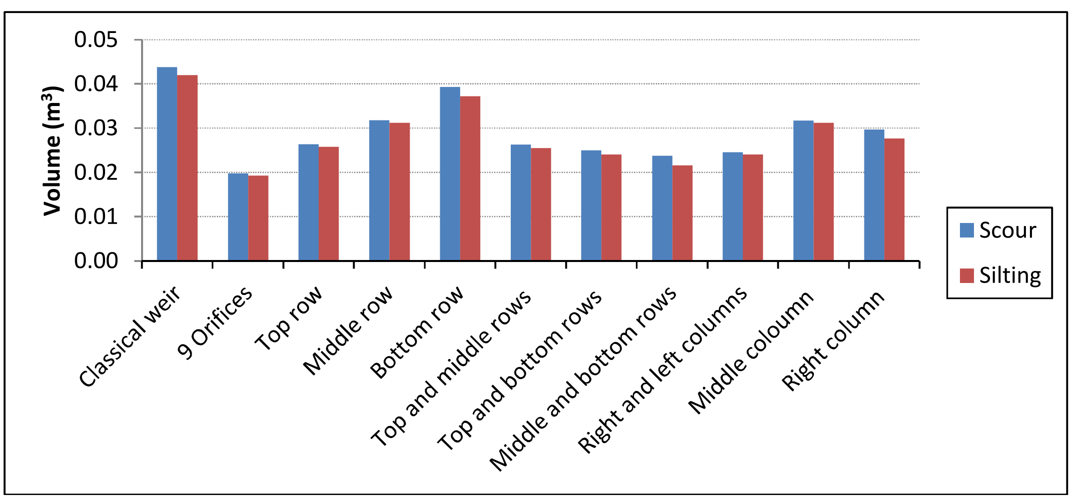

Fig. 18. Volumes of scour and silting

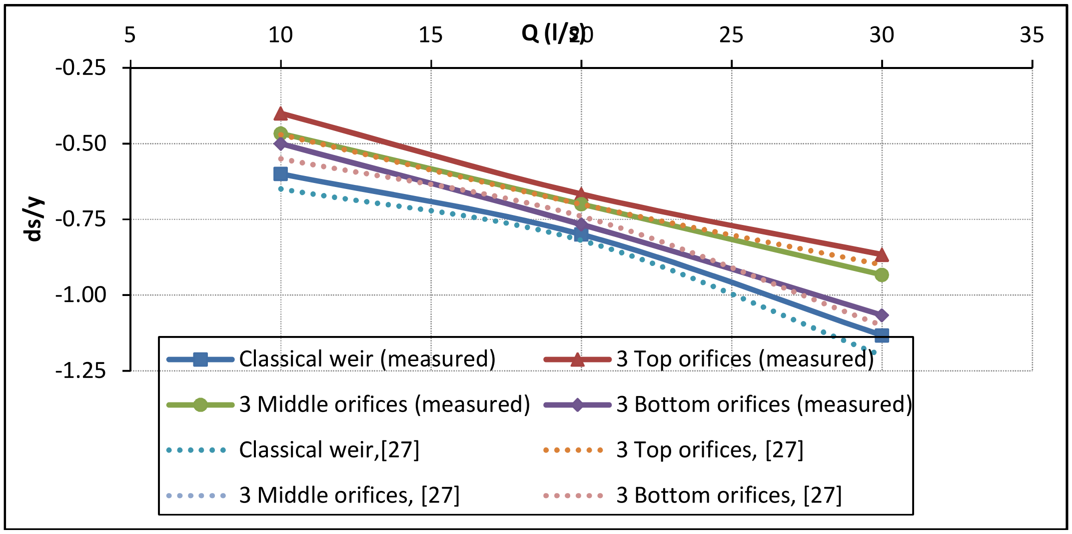

Fig. 19. Comparison between the measured and predicted [27] maximum scour depth/tail water depth

A quantitative assessment including the volumes of scour and silting were introduced in Fig. 18. The figure outlined that for settled weir type, the local scour volumes were practically equivalent to the volumes of silting; the experiments were carried out under clear water flow conditions. Little contrasts were seen as some of soil particles were rolled towards the tail gate and didn't settle in the region under the study. The figure additionally demonstrated that the maximum local scour and silting volumes were situated on account the classical sharp crested weir. Despite what might be expected, the minimum values were found on account of weir equipped with 9 orifices.

Table 2. Percentages of reduction in volumes of scour and silting

Type	% Classical weir	
	Scour	Silting
Classical weir	0	0
9 orifices	-54.733	-54.143
Top row	-39.781	-38.571
Middle row	-27.298	-25.714
Bottom row	-10.151	-11.429
Top and middle rows	-39.918	-39.286
Top and bottom rows	-42.936	-42.857
Middle and bottom rows	-45.679	-48.571
Right and left columns	-43.896	-42.857
Middle column	-27.435	-25.714
Right column	-32.099	-34.286

The adequacy and the superiority of the weir with orifices contrasted with the classical sharp crested weir in minimizing the local scour is shown in Table 2. The rates of decrease in local scour and silting of the tested 11 weir models in contrasted with the classical sharp crested weir were characterized. It was noticed that most extreme rate of volume decrease in local scour was given by weir with 9 orifices. Thus, dismissing number and location of orifices and utilizing a weir with orifices instead of the classical sharp crested weir prompted a decrease in the unfavorable scouring activity.

8. COMPARISON WITH OTHER STUDIES

To emphasize the measurements of the current study, a set of data using 3 different discharges and 4 weir models under fixed 15cm tail water depth were compared to [27], presented in Fig. 19. The comparison showed a good agreement between the current and deduced measurements.

9. CONCLUSIONS

The experimental study to investigate the influence of discharge, tail gate water level, locations and numbers of orifices on the bed configurations downstream 11 weir models including classical sharp crested weir equipped with orifices prompted the accompanying conclusions:

- Weir equipped with orifices regardless to their numbers and arrangement indicated great capacity in diminishing the local scour geometry in contrast with the classical sharp crested weir.

- Weir with 9 orifices exhibited the highest performance from the perspective of minimizing the bed configurations defined in terms of scour and silting compared to any tested weir model.
- The geometry of local scour and silting were straightforwardly relative to the discharge and contrarily corresponding to tail water depth for the tested weir models.
- The influence of the tail water depth on the geometry of local scour was unnoticed and inconsequential for weir with 9 orifices.
- The geometry of local scour and silting were inversely related to the row height measured from the bed level in case of weir equipped with single row orifices.
- In the instance of weir with simultaneous dual-rows orifices, the influence of rows height on the geometry of local scour and silting were negligible.
- The weir with single column orifices did not demonstrate the capacity for improving the geometry of local scour contrasted with simultaneous dual-edge columns orifices.

The author recommend in further studies to use the reported scenarios in the current study under higher flow conditions, utilize more than one bed material to simulate fixed and live bed conditions, utilize other shapes of orifices (e.g. rectangular, square,….etc.), and use other types of weirs equipped with orifices.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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