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Evaluation of the Scour Reduction at the Downstream of Weirs Using MATLAB-Simulink

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ABSTRACT

Weir, as a hydraulic structure with an upstream and downstream flow pattern, has been of key importance to many researchers in the field of civil engineering. Energy dissipation is considered a challenge that forces researchers to make it high priority. The aim of this study was to examine the impact of the use of different shapes as obstacles at the downstream of a weir on the scour hole depth downstream of its structure. The speculated results were then compared with actual measurements to present the efficiency of CFD techniques to current actual hydraulic-structure problems. The flow 3-D package was considered as the simulation tool in this study. In order to achieve the highest energy dissipation, thus, the minimum scour depth at the downstream, nine various models of different shapes of weirs were numerically and experimentally analyzed. The shapes of the weir models were optimized by numerical simulations then they were physically tested in laboratory experiments. The models have a width of 0.8 m and a height of 0.59 m, while their lengths range from 0.72 to 1.12 m. The bottom of the channel was covered by a sand layer of 0.2 m thickness with a grain gradient rate of 0.002 m. Three different discharge values of 0.015, 0.02 and 0.025 $m^3 \cdot s^{-1}$ were utilized in the experiments. The experimental and numerical simulation results showed similarities with the maximum depths of scour for all analyses were noted to be between 0.003 m and 0.012 m. Six models have been explored, the SU3 model was found to demonstrate the minimum scour depth ranging from 0.003 to 0.005 m under all flow conditions, In this model, the scour has settled during the first (15) minutes of experiment for the first and second discharges (0.015, 0.020 $m^3 \cdot s^{-1}$) to be (0.018, 0.02 m) (Table 2) while the scour has settled for the third discharge (0.025 $m^3 \cdot s^{-1}$) after four hours to reach (0.03 m), therefore, presenting the best performance in terms of energy dissipation.

Keywords: weir, energy dissipation, scour, simulink models.

INTRODUCTION

Weirs are defined as barriers across a river intended to change its flow attributes. Often, weirs appear as obstructions of a smaller size than ordinary dams since water can be pooled behind them while also being able to flow in a steady way above them. Thus, a common use of the weirs is the change of the river flow in order to avoid flooding, determine discharge and assist in making rivers more traversable and clear for crossing. Also, weirs are used in the study and research of returning salmonids.

Weirs are commonly used to raise water level of a river; they are also used by hydraulic engineers to measure the flow discharge in the streams. When water flows over the top of the weir, it appears in the form of jets and develops a hydraulic jump. In addition, dissipating energy in channels, dam spillways, and similar structures so that the excess kinetic energy does not damage them, is one of the most significant applications of the hydraulic jump. Another function the hydraulic jump inflow Froude number performs would also be the rate of energy dissipation or head loss across a hydraulic jump; therefore, when designing a weir, one must consider partially dissipating the energy to prevent scouring that might occur in the downstream ends of the weir.

Nowadays, the investigation of the flow and the sedimentation behavior around a body has been simplified by the CFD techniques which have been the focus of many researchers. The studies by Guodong et al. (2013) investigated the flow and local scour around a non-submerged spur dike based on the Navier-Stokes equations, in order to perform 3-D simulation analyses. They pointed out that the formation of the scoured surface is mainly influenced by a submerged flow and a horseshoe vortex. Few researchers studied scour downstream combined flow. Scour has been given attention by researchers in hydraulic and river engineering sciences because, due to its particular condition as well as complexities and lack of relationship to meet all the conditions, it has been in the history of the field of hydraulics for a long time. While hydraulic structures are obstacles to flow, they also result in changing the flow pattern nearby and causing local scour to happen in the area. The importance of looking into and investigating scour lies in the possibility of the scouring depth becoming so significant that the depth reaches the river foundation structure and puts its stability at stake or even ruins it. On that account, the applications of empirical relationships or physical models constitute the most usual method used to determine the scour depth.

Many studies were conducted in this field in order to reduce the scouring at the downstream of the dams and weirs using different methods. Noori and Hayawi (2011) researched experimentally the stability of rockfill weirs safeguarded by gabions and subjected to overflowing rates in a laboratory study aiming to protect the downstream slope of these rockfill weirs using stepped gabions, the combination of the results of their study and those of other researchers proved that rockfill weirs protected by gabions are subjected to a greater chance of failure of the discharge unit than the earth weirs protected by gabions. In addition, Khalaf et al. (2014) also studied the flow hydraulic characteristics, the flow energy dissipation over stepped spillways, the profile of water surfaces, the piezometric head distribution and energy dissipation (E/E0)% with regards to a semi-circular crest's stepped spillway to prevent scouring downstream the weir.

The aim of this study was to examine the impact of the use of different shapes as obstacles at the downstream of a weir on the scour hole depth downstream of its structure. The speculated results were then compared with actual measurements to present the efficiency of CFD techniques to current actual hydraulic-structure problems. The flow 3-D package was considered as the simulation tool in this study.

Ahmed (2015), demonstrated that the practical use of a physical model with holes in the downstream (double lines water jets) reduces the scour and by comparing the results of his findings using a CFD program, he obtained the same results as the ones obtained via a laboratory model through CFD techniques. In addition, Helal (2014) used single-line floor water jets to examine the diminished scour downstream of a hydraulic structure and concluded that they reduce it by 40% to 85%. Similarly, Ghazali et al. (2012), managed to decrease the scour hole depth and length by placing concrete semi-circular baffle blocks on local scour holes in four lines in the downstream.

Al Talib (2017), also studied the effect of the weir slope, the radius of the crest weir and the type of gradient in the weir body on the scour in the downstream of the weir by using a semi-crest weir with three different gradations. According to Ahmed's calculations (2015) after using three different height obstacle models, the most effective obstacle height was 24 centimeters, because as he concluded, it allowed less scouring in the downstream of the weir. He also added that the gradation and shape of an obstacle had a great effect on the coefficient runoff and the energy dissipation percentage (E%). Finally, when comparing the efficient results of the CFD techniques (Flow 3D program) to the laboratory experiments, the Flow 3D program is admittedly far superior, as it outperforms any other program owing to its capability to measure the flow as it actually is in real life.

Shehab (2024), comparing how energy flow dissipates over submerged dams, utilizing both MATLAB-Simulink simulation and physical experiments with a model-submerged dam supported by an inclined ramp at downstream with angles of 16° and 24.5°. The study analyzed and compared the results from both methods to gauge the simulations accuracy and reliability. Moreover, simulation can be repeated for optimization and analysis of various design scenarios.

In this study, modeling and simulating were developed by using MATLAB-Simulink to evaluate the longitudinal section of water surface to obtain the best results at a record time and to compare the results obtained using the MATLAB-Simulink model with the results obtained using equations and traditional methods. In previous studies, researchers used the MATLAB Simulink model method. In this study, a block diagram model was created using MATLAB Simulink that simulates the equations for evaluating the longitudinal section of the water surface. Comparing the current study, it was found that the circuit obtained using a new technology in the field of MATLAB Simulink gave more accurate models at a speed that does not exceed seconds, as long mathematical equations that take a long time to solve have been eliminated.

MATERIAL AND METHODS

The experiments are conducted in the hydraulic laboratory of Gaziantep University, Civil Engineering department, Turkey. The flume used in the experiments was of zero-slope, 12 m in length, 0.9 m in deep and 0.8 m in width as shown in (Figure 1). The channel was designed with a recirculating system of water. The channel is provided with a flow meter for flow measurements. The water diverged from the flow meter is puring in a sump tank, which is combined to the channel inlet and includes in the middle a perforated metal plate for breaking down the velocity of water entered to the channel. The outlet was provided with a traping basket for collecting the diverged bed materials used in the experiments such as sand. The filtered water passes through underground penstocks to the storage tank. The channel walls are made of glass and the bed is aluminium. The channel was provided with a sliding point gauge for measuring water and bed levels. In addition, a digital point gauge and laser meter were provided to investigate water level and scour depth, respectively At the inlet, a thin layer of punched fiber glass was placed, which calmed the entering water. The channel intake was combined to magnetic flow meter where the latter was connected to a pump, which transfer water from an underground tank to the channel as maximum capacity as 150 l·s.

The models were investigated and evaluated in terms of a minimum scour depth under three different flow conditions, 0.015 $m^3 \cdot s^{-1}$, 0.02 $m^3 \cdot s^{-1}$ and 0.025 $m^3 \cdot s^{-1}$. Each side of channel domain, which is a rectangular shape, is given a condition constraining its behavior during the simulation progress. The channel inlet is given a volume flowrate condition, the outlet is considered as an outflow while the top of channel is given an atmospheric pressure. All other sides are taken as walls besides the weir body (Figure 2). In order to do a simulation process, the program should be given an initial water level. Currently, water level is suggested as 0.61 m for the minimum discharge and 0.64 m for the peak flow. It is planned to perform experimental work after the theoretical one, so a sieve analysis was conducted to obtain the grain size that will be used in both of the numerical and experimental studies. Different three models were designed. The models were made of steel as separate parts and then combined with each other by welding process. The flow boundary is shown in Figure 3.

The experimental program of this study included three cases termed as SU models (SU_1 – SU_3) (Figure 4). The models differ from each other by the design and performance. The SU model has a single part, “L” shape. The weir is rounded with crest radius (R = 0.1 m) and (R = 0.09 m) at tail end. The inner surface is rounded with a radius of 0.28 m. The width of the model is 0.8 m and weir hight at the upstream is 0.59 m. The models are designed with nine different shapes depending upon the profile of the weir. The designed weirs are based on the variation of downstream energy dissipation. Due to the structural disparities in all the given cases, specific symbols were given in order to describe,

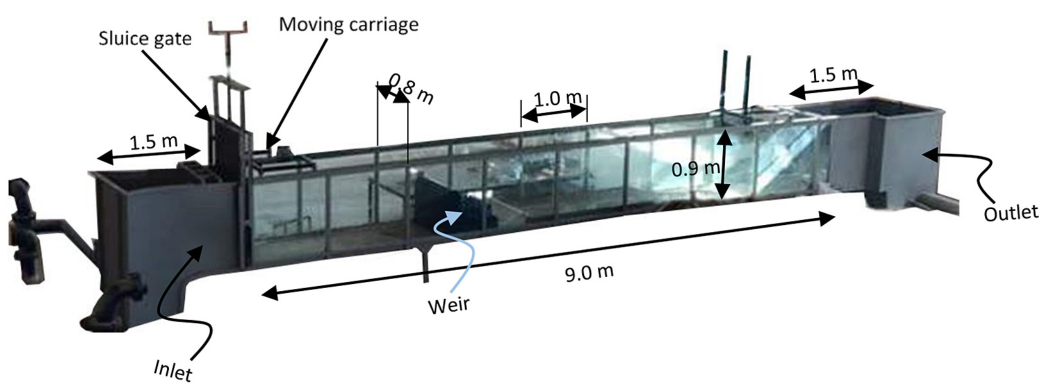

Figure 1. Experimental channel

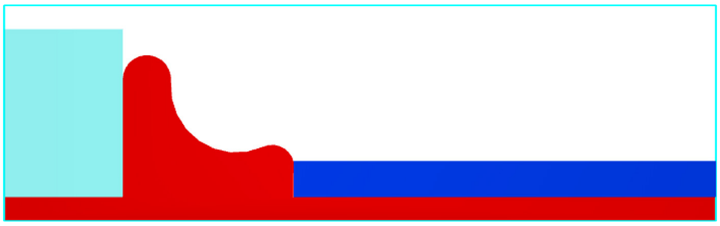

Figure 2. Channel domain

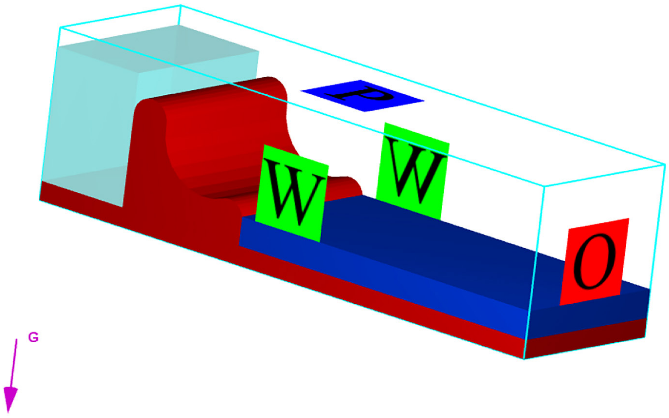

Figure 3. Flow boundary

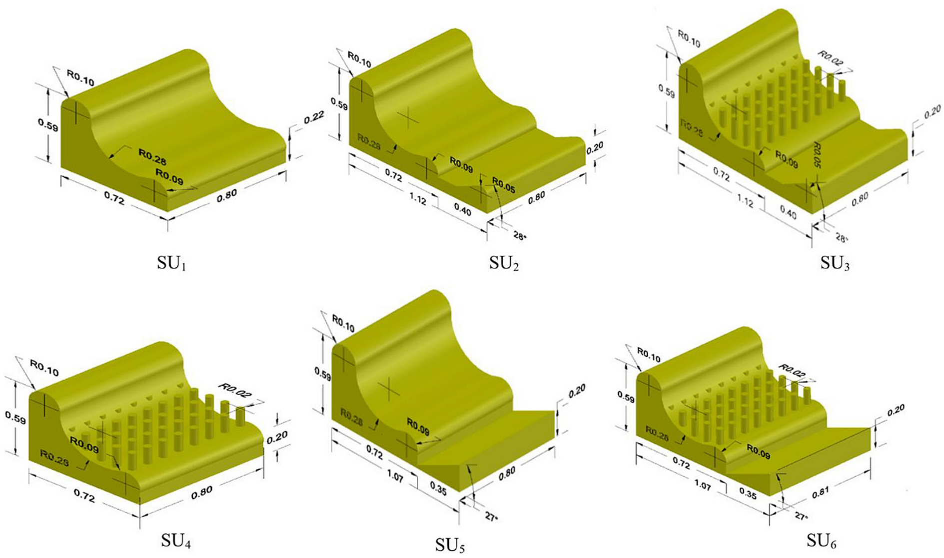

Figure 4. The experimental models

separately, the dimensions of each model as shown below (Figure 5). In order to distinguish the difference in dimensions among the models, a summary of the geometrical properties is illustrated in Table 1.

SIMULATION CONSTRAINTS

Many features are available in the Flow-3D program help in the insertion of the real parameters expected to be included in the experiments. In the present study, the flow mode is considered as an incompressible flow with free surface (open channel flow mode). Clear water is used as the single fluid in all the simulation work. The fluid density is considered as 1000 kg·m^{-3}, the viscosity is 0.001 N·s·m^{-2} at 20 °C. The gravity is activated in the physical properties, which is 9.81 m·s^{-2}. In the numerical model setup, the renormalized group (RNG) viscous model is used with no-slip wall shear boundary condition.

Table 1. Geometrical characteristics of all models under study

Model	W (m)	L (m)	H (m)	R_c (m)	R_i (m)	R_{T1} (m)	Additional parts				
							L_{hs}	L_R	R_{T2}	θ	Piers
SU_1	0.8	0.72	0.59	0.1	0.28	0.09	–	–	–	–	No
SU_2	0.8	1.12	0.59	0.1	0.28	0.09	0.15	0.22	0.05	28	No
SU_3	0.8	1.12	0.59	0.1	0.28	0.09	0.15	0.22	0.05	28	Yes

Note: W – width of weir (m); L – length of weir (m); H – height of weir (m); R_c – crest radius (m); R_i – radius of inner surface (m); R_{T1} – tail radius (m); R_{T2} – tail radius of the added part (m); L_{hs} – distance from the end point of the main body to the lower edge of the ramp (m); L_R – length of ramp (m); θ: inclination angle of ramp (degrees).

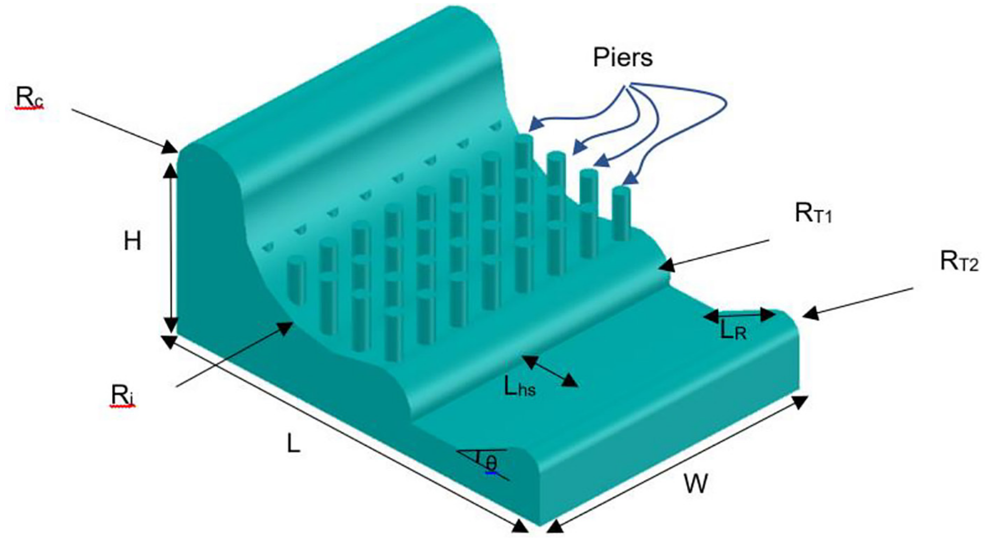

Figure 5. Symbols used in defining the dimensions

Sandy layer is placed in the channel with a diameter of 0.0018 m and a density of 2650 kg·m^{-3}. Three different flow types are used, 0.015 m^3·s^{-1}, 0.02 m^3·s^{-1}, 0.025 m^3·s^{-1}. The initial value of upstream flow depth at the inlet is taken 0.8 m. The water level at the outlet is determined automatically by the program during the simulation progress. Other sides of the channel are considered as walls except the upper one where it is subjected to the atmospheric pressure. Figure 4.8 clarifies the symbols used to describe each model. Each weir is distinguished by a single case reviewed as follows: R_c, R_i, R_{T1}, R_{T2} are the radii of crest, main body, the weir end and the end of the additional part, respectively; H is the weir height; L is the total length of weir; W is the width of weir; L_{hs} is the length of the chamber created downstream the main body of the weir; L_R is the length of the inclined side of ramp.

Case No. 1

The energy dissipater, which is a water calming structure, Figure 6 did not consider in the first model to represent the base case. A simple shape of sturucture without adding additional parts was used to evaluate the water energy and the downstream scour depth. Accordingly, an appropriate sutable solutions to eliminate the scour were studed.

Case No. 2

An additional part was added in the SU_2 model to make a reduction in water energy and scour depth. The new additional part contained a horizontal body with 0.15 m thikness above the channel bed. Followed by a ramp of 28°, and ended by a rounded surface of 0.1 m diameter (Figure 7).

Case No. 3

The fifth case SU_3, an additional part were added to the water calming structre as shown in (Figure 8). A combination between the main body that was formed as horizontal surface 0.15 m above the channel bed and the a ramp with 28°. This ramp was ended by a rounded surface of 0.1 m diameter. Moreover, forty piers were added to solve the problem of scour with the same dimensions as in the case No. 4.

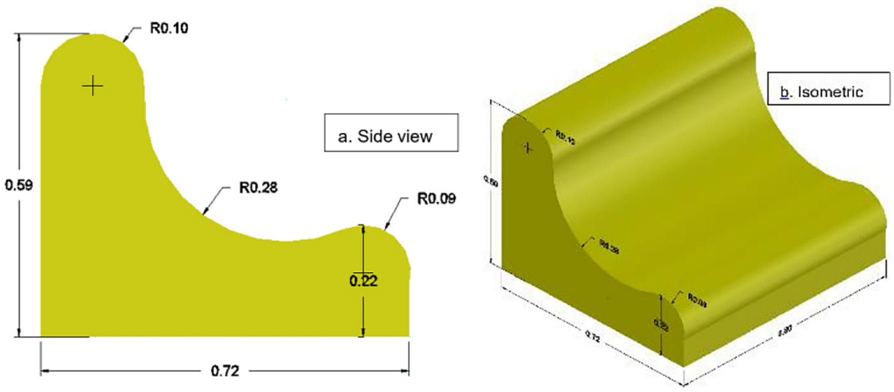

Figure 6. Geometrical shape of SU1: (a) side view, (b) isometric

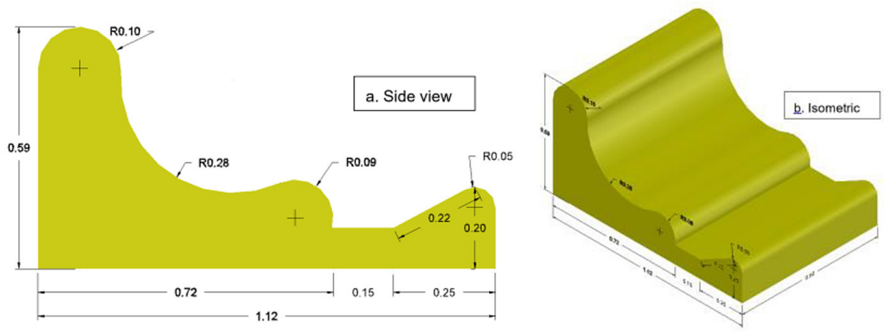

Figure 7. Geometrical shape of SU2: (a) side view, (b) isometric

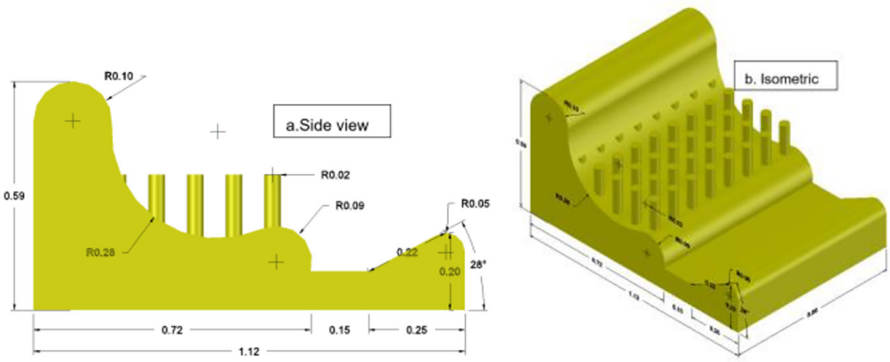

Figure 8. Geometrical shape of SU3: (a) side view, (b) isometric

SCOUR DEPTH ANALYSIS

The best method used to figure the scour values in a simple visualization is the contour map. The contour map consists of several lines; each line defines a single value of scour depth. The contour lines are formed by several points of x, y and z dimensions. The x and y dimensions represent the lateral and longitudinal distances, respectively, while the scour depth is defined by z value. Unlike the scour values, which are measured by a digital point gauge moves horizontally and vertically, the other dimensions are measured by rulers fixed to the channel sides. The 3D points obtained after each run are inserted into SURFER software (version 13) in a way to be accepted by the program.

Model SU_1

Contour maps of scour depth (Figures 9–11) are used as a measure of the weir efficiency in term of scour hole reduction. The experimental results shown in Figure 6.1 indicate that when a continuous inflow of 0.015 $m^3 \cdot s^{-1}$ is applied, a scour region is created behind the weir and extended to the channel sides, see Figure 9. Applying a discharge of 0.02 $m^3 \cdot s^{-1}$, maximum scour was noticed in the middle of the channel downstream the weir at a distance of about 0.2 m from the downstream edge of weir where the scour depth was 0.115 m in average. A similar behavior was noticed when a discharge of 0.025 $m^3 \cdot s^{-1}$ is used.[1]

Model SU$_2$

The additional part added to the main body of weir is designed to trap the vortices over there and stop their progressing towards the sand layer.

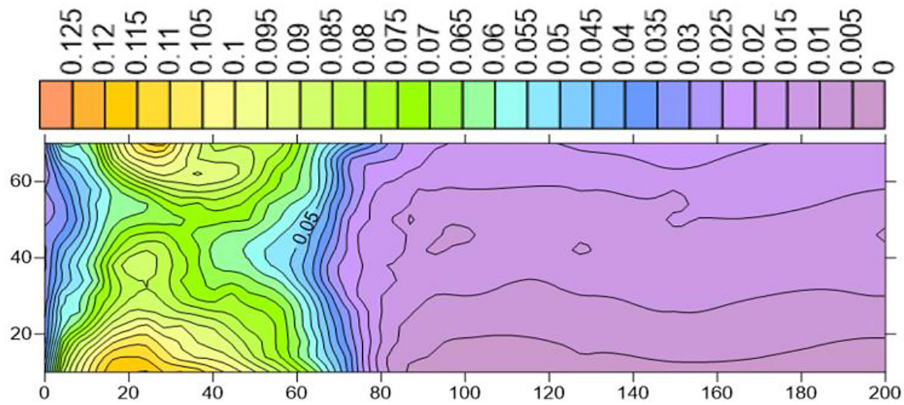

Figure 9. Scour contour lines downstream the SU1 weir, $Q = 0.015\ m^3 \cdot sec^{-1}$

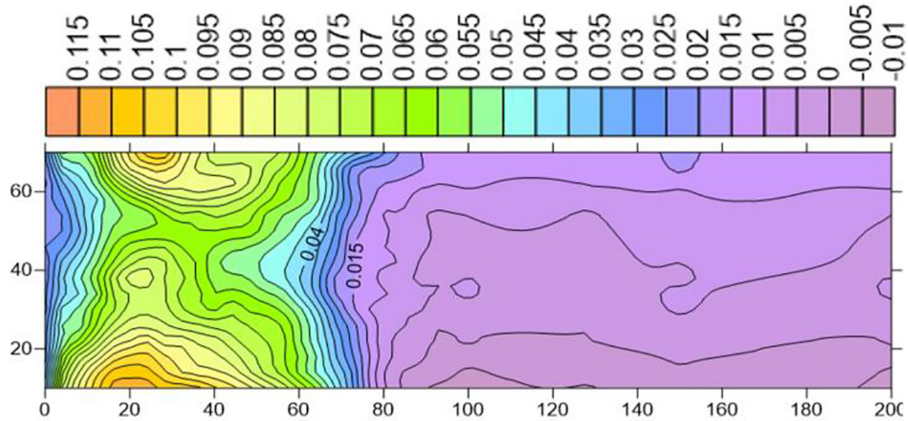

Figure 10. Scour contour lines downstream the SU1 weir, $Q = 0.02\ m^3 \cdot sec^{-}$

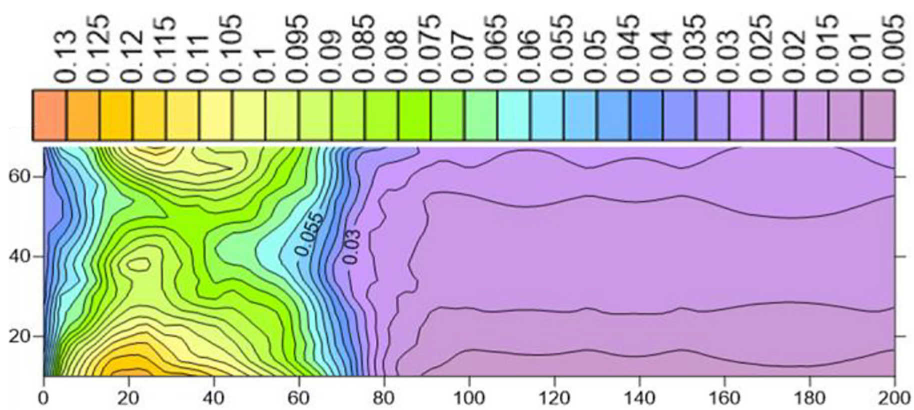

Figure 11. Scour contour lines downstream the SU1 weir, $Q = 0.025\ m^3 \cdot sec^{-1}$

The experimental results show that the severity of scour is concentrated in the middle of the cross-wise direction downstream the weir and decreased significantly in the stream-wise direction. It was noticed that the scour region formed (Figure 12) is almost followed the same behavior at the three given discharges (Figures 13–15). The distance of maximum scour was pointed at 0.08 m from the downstream edge. Regarding the depth of scour, it was slightly changed from 0.045 m to 0.065 m. Moreover, the vortex intensity is limited just over the additional part and extended a little bit towards the sand layer (Figure 12).

Model SU_3

The experimental results obtained from this model clarified that the scour depth is reduced

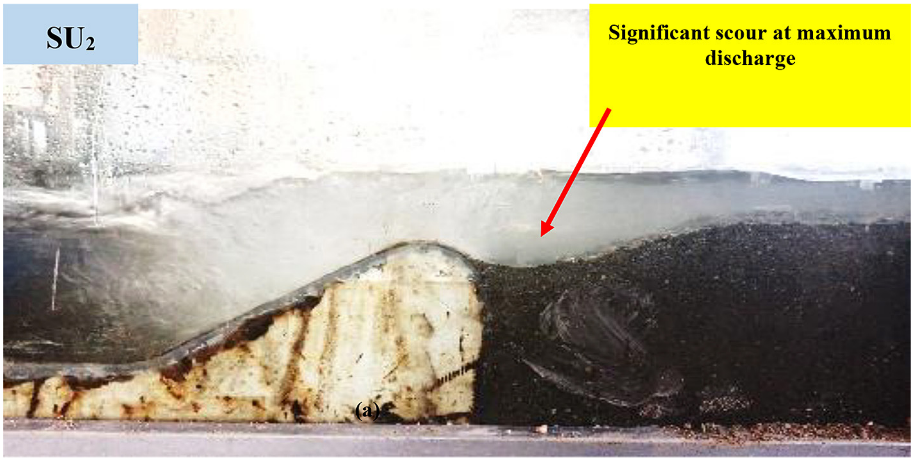

Figure 12. Scour region downstream the SU2 weir

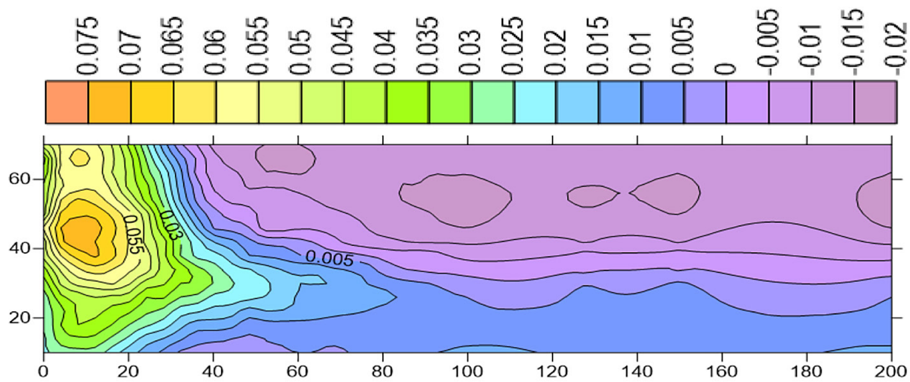

Figure 13. Scour contour lines downstream the SU2 weir, $Q = 0.015\ m^3 \cdot s^{-1}$

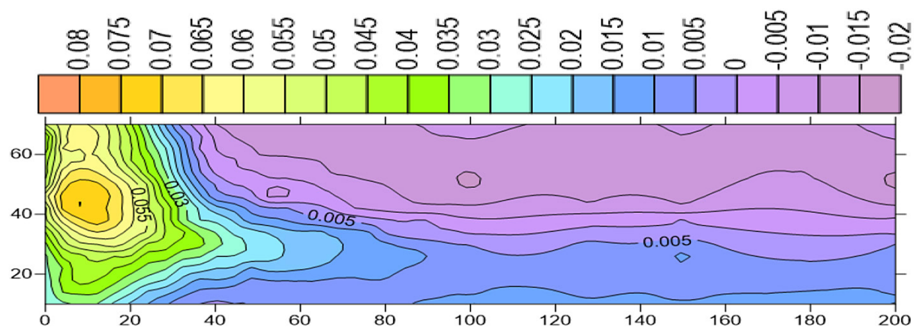

Figure 14. Scour contour lines downstream the weir SU2 weir, $Q = 0.02\ m^3 \cdot s^{-1}$

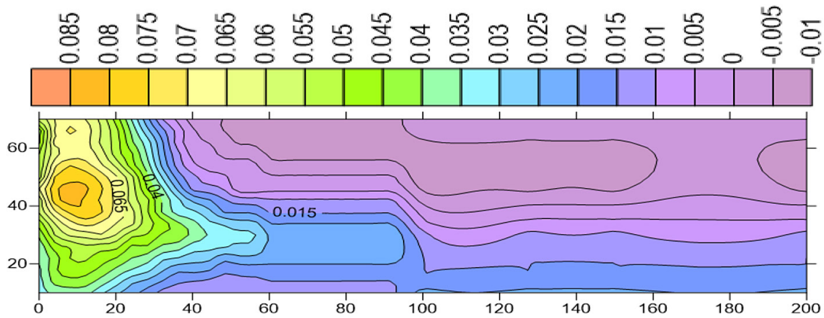

Figure 15. Scour contour lines downstream the weir SU2 weir, $Q = 0.025\ m^3 \cdot s^{-1}$

significantly. The additional part helped in dissipating much water energy of the outcoming flow throuout the piers (Figure 16). The scour region is reduced much more than the model SU_2 where the maximum depth of scour was oscillating between 0.018 m to 0.031 m just after the weir (Figures 17–19).

PERCENTAGE OF SCOUR REDUCTION

Among all the proposed designs used to reduce scour behind the weirs, it was found that the third model, SU_3, is the best structures compared to the first model SU_1, where they were able to reduce the scour proportion by about 82% (Table 2). the second SU_2 demonstrated about 54% reduction in scour. Regarding the third model, SU_3, the scour was decreased about 30% in comparison to the first model.

DIMENSION ANALYSES

The depth and length of scour located at downstream the weir W_c, is considered as function

Figure 16. Scour region downstream the SU3 weir

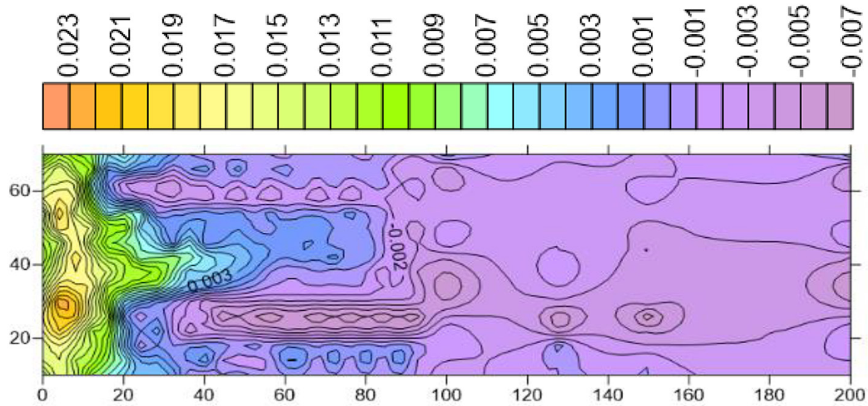

Figure 17. Scour contour lines downstream the SU3 weir, $Q = 0.015\ m^3 \cdot s^{-1}$

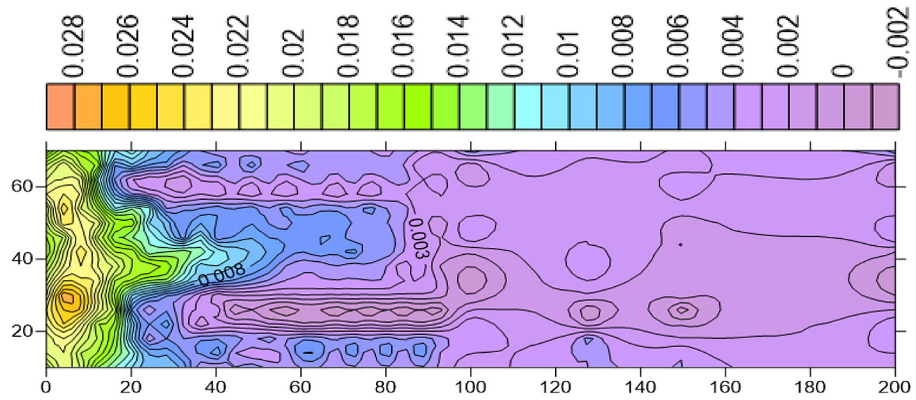

Figure 18. Scour contour lines downstream the SU3 weir, Q = 0.02 $m^3 \cdot s^{-1}$

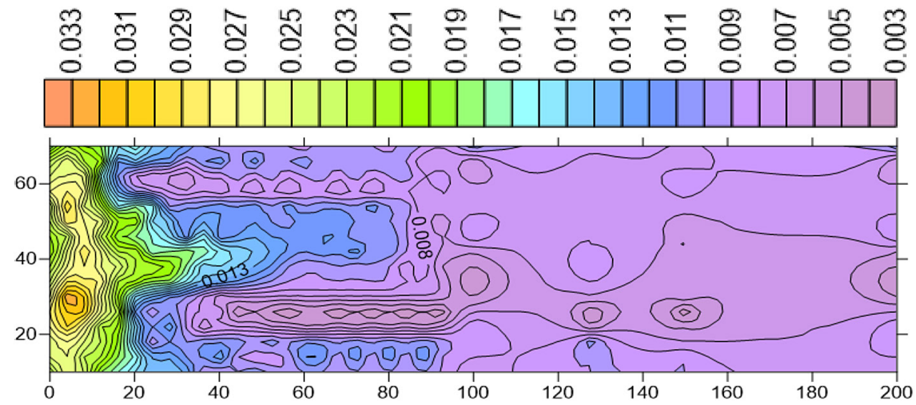

Figure 19. Scour contour lines downstream the SU3 weir, Q = 0.025 $m^3 \cdot s^{-1}$

Table 2. Experimental data of all models

Model	Q $m^3 \cdot s^{-1}$	d_s (m)	Ls (m)	Y_u (m)	Y_d (m)	Y_t (m)	P_1 (m)	P_2 (m)	Scour reduction percentage
SU_1	0.015	0.110	0.16	0.64	0.24	0.235	0.59	0.2	0%
	0.02	0.116	0.17	0.65	0.245	0.24	0.59	0.2	0%
	0.025	0.121	0.17	0.66	0.245	0.24	0.59	0.2	0%
SU_2	0.015	0.045	0.08	0.64	0.24	0.23	0.59	0.2	59%
	0.02	0.055	0.088	0.647	0.25	0.245	0.59	0.2	52.2%
	0.025	0.065	0.09	0.66	0.27	0.245	0.59	0.2	45.8%
SU_3	0.015	0.018	0.04	0.66	0.265	0.24	0.59	0.2	83.6%
	0.02	0.020	0.044	0.65	0.25	0.235	0.59	0.2	82.6%
	0.025	0.028	0.05	0.66	0.265	0.242	0.59	0.2	74.1%

of the discharge, length of ramp, height of ramp, channel width, tail water depth, number of pier, and flow characteristics.

The Buckingham Pi-theorem is used to generate a non-dimensional relationship between the depth and length of scour individually and the independent variables in this study. The functional relationship among the dependent and the independent variables is:

$$D_s = f\ (Q, L_r, W_c, T_w, P_2, B_p, \rho, g, \theta) \quad (1)$$

And

$$L_s = f\ (Q, L_r, W_c, T_w, P_2, B_p, \rho, g, \theta) \quad (2)$$

where: D_s – depth of scour, L_s – depth of scour, dependent variable (L), Q – discharge (L^3T^{-1}), L_r – length of ramp (L), W_c – width of the channel (L), Tw – tail water depth (L), P_2 – length of the ramp (L), P_B – number of piers multiply by circumference of pier (L), ρ – density of water ($M \cdot L^{-3}$), g – gravity ($L \cdot T^{-2}$), θ – the ramp angle in additional part.

The non-dimensional forms of the above Equations are:

$$\frac{D_s}{W_c} = f\left(\frac{g\,W_c^5}{Q^2}, \frac{L_r}{W_c}, \frac{T_w}{W_c}, \frac{P_2}{W_c}, \frac{B_p}{W_c}, \theta\right) \quad (3)$$

And

$$\frac{L_s}{W_c} = f\left(\frac{g\,W_c^5}{Q^2}, \frac{L_r}{W_c}, \frac{T_w}{W_c}, \frac{P_2}{W_c}, \frac{B_p}{W_c}, \theta\right) \quad (4)$$

Multiple regression analysis of the depth of scour and length of scour previous cases for dependent variable in Equation 4, $\frac{D_s}{W_c}$, and $\frac{L_s}{W_c}$ versus independent variables in the same equation leaded to the following forms of Equations, all the data for dependent and independent variables is used to analyse in this case.

$$\frac{D_s}{W_c} = 0.269\,\frac{Y_t}{W_c} + 9.358 * \frac{QW_c^5}{g} - 0.0847 * \frac{L_r}{W_c} - 0.00122 * \frac{N_p}{W_c} + 0.25 * \frac{P_2}{W_c} - 0.00112\,\theta \quad (5)$$

The analysis gives R^2 of 0.95, which tells us the percent of the variation in explained by the regression. In this case, 95% of the variation in independent variable is explained by dependent variables and 5% is unexplained. The standard error in this case is 0.01717, which is the measure of how far the actual points are from the regression line. In addition, the significant F is 2.34E-12 which is less than 0.05. Therefore, the overall regression model is significant. Linear relationship between $\frac{D_s}{W_c}$ that measured from experiment and predicted from the Equation 5 is drawn as shown in Figure 20. The Equation of the length of scour by channel width in this case is;

$$\frac{L_s}{W_c} = 0.426\,\frac{Y_t}{W_c} + 6 * \frac{QW_c^5}{g} - 0.051 * \frac{L_r}{W_c} - 0.0011 * \frac{N_p}{W_c} + 0.25 * \frac{P_2}{W_c} - 0.002\,\theta \quad (6)$$

The analysis gives R^2 of 0.87, which tells us the percent of the variation in explained by the regression. In this case 87% of the variation in independent variable is explained by dependent variables and 13% is unexplained. The standard error in case of length of scour is 0.045. In addition, the significant F is 4.82E-08, which is less than 0.05. Therefore, the overall regression model is significant. Linear relationship between $\frac{L_s}{W_c}$ measured from experiment and predicted from the Equation 6 is drawn as shown in Figure 21.

MODELING AND SIMULATIONS

MATLAB Simulink is a powerful tool for modeling and simulating hydraulic structures MATLAB Simulink is a valuable tool for researchers in the field of hydraulic structures who want to model and simulate the behavior of these complex systems (Shehab, 2024). The Simulink model can be used for a wide range of hydraulic irrigation structures. The Simulink model was tested by entering the laboratory data acquired from the laboratory examination. Its ability to handle complex equations and simulate real-world scenarios makes it an essential tool for engineers and researchers alike (Ayoob and Hamad, 2022). It is used for modeling the hydraulic behavior of different types of structures, such as gates, valves, and

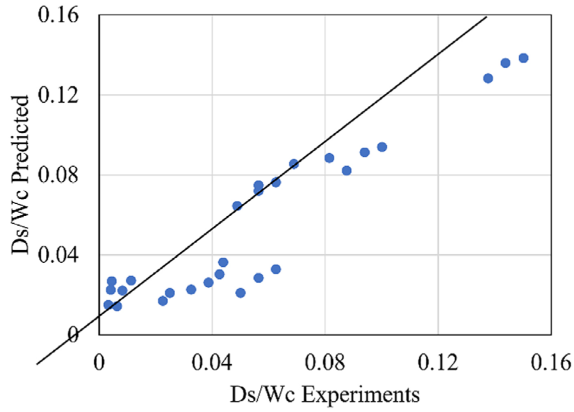

Figure 20. Linear relationship between predicted and measured $\frac{D_s}{W_c}$

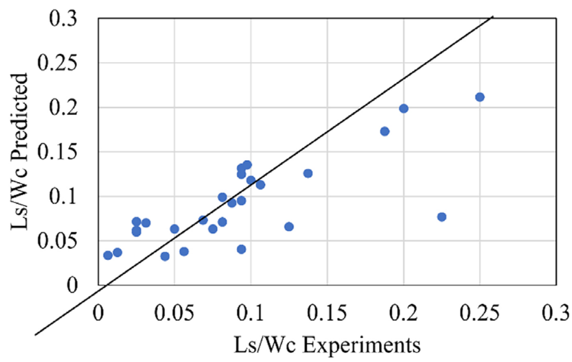

Figure 21. Linear relationship between predicted and measured $\frac{L_s}{W_c}$

pumps, as well as simulating the flow of water through different types of structures, such as channels, pipes, and culverts (Naghavi et al., 2011). A simulation model circuit was built by the MATLAB program for the purpose of evaluating the depth of scour and length of scour downstream the weirs so that the dimensions of the weir, flow discharge, depth of water over the weir are show the input values while Ds and Ls are representing the output results in the circuit Figure (22–23). The Simulink model can be utilized in a variety of research projects in this sector, because it reduces the time spent solving Equations 5, 6.

RESULTS

In this study, modeling and simulating were developed by using MATLAB-Simulink to evaluate the percentage of scour reduction in the channel in front of the three models of the weirs so as to obtain the best results. In the first SU_1 model, the depth and length of scouring in the channel in front of the weir were measured for the three discharges (0.015, 0.02, 0.025) $m^3 \cdot s^{-1}$ and it reached (0.12, 0.21), respectively, at Q = 0.025 while the values reached in model SU_2 that developed by adding the inclined ramp (Ds, Ls) (0.065, 0.08) at Q = 0.025 and the scour reduction percentage

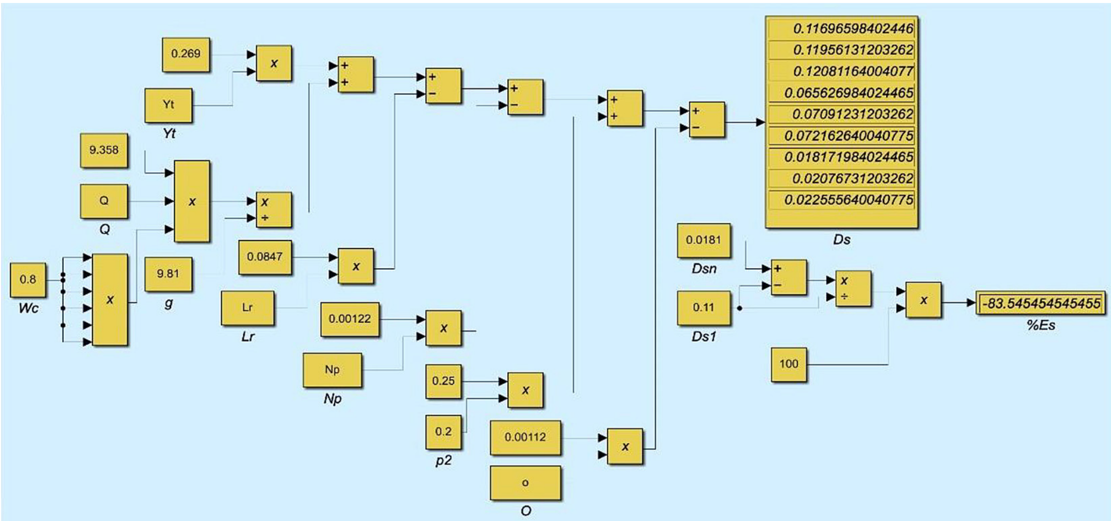

Figure 22. Block diagram of MATLAB Simulink to evaluating Ds

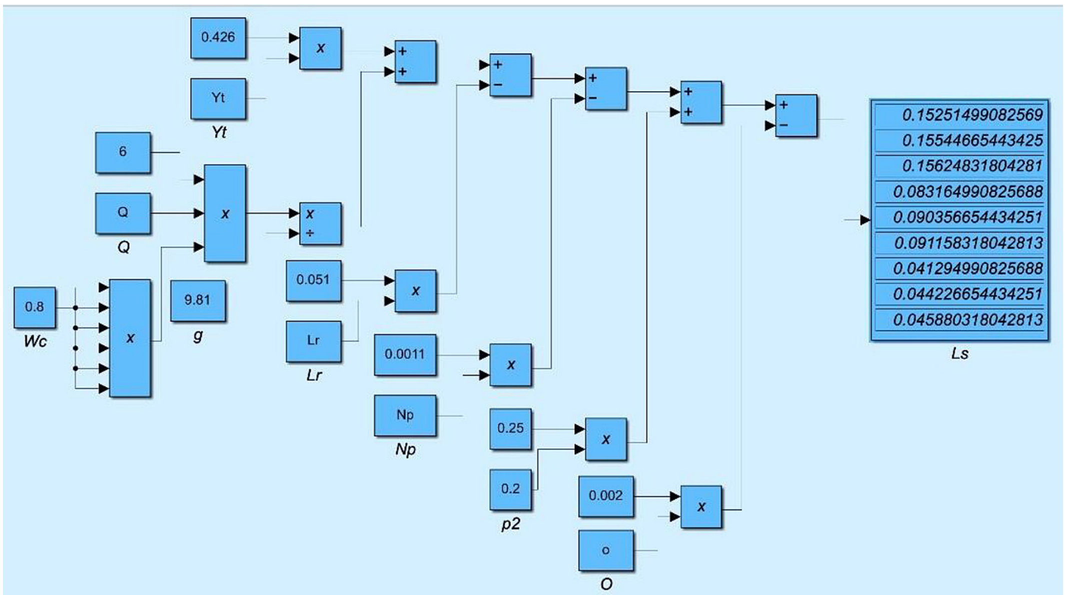

Figure 23. Block diagram of MATLAB Simulink to evaluating Ls

was 45%. Forty piles comprised of five rows and eight columns were placed at the bottom of the weir in model SU_3 to increase the dissipation of energy and decreasing the scouring in the channel by 83%. Then, by using dimension analyses theory it was found that Ds and Ls as a function of discharge, length of ramp, height of ramp, channel width, tail water depth number of piers and flow characteristics. A modeling and simulating were developed by using MATLAB-Simulink to evaluate the depth and length of scour in order to obtain the best results as in Table 2 which represents the value of Ds, Ls and scour reduction percentage for the three models. The comparison between the experimental results and those that were obtained from MATLAB-Simulink shows the good agreement, with a percentage error rate of 1.5%.

DISCUSSION

Scour has been given attention by researchers in hydraulic and river engineering sciences because, due to its particular condition and at the same time complexities and lack of relationship to meet all the conditions, it has been in the history of the field of hydraulics for a long time. While hydraulic structures are obstacles to flow, they also result in changing the flow pattern nearby and causing local scour to happen in the area. The importance of looking into and investigating scour lies in the possibility of the scouring depth becoming so significant that the depth reaches the river foundation structure and puts its stability at stake or even ruins it. On that account, the applications of empirical relationships or physical models constitute the most common method used to determine the scour depth. Notwithstanding the extensive studies on estimating local scour around various hydraulic structures, a generic and holistic correlation of calculating the local scour depth around river structures arose. In addition, despite the occasional difference between the theoretical and experimental differences of a variety of different. All in all, Joolaeian and Nohani (2015) define scour as the 'eddy currents' formed by 'the erosion of channel bed and edge due to water flow or bed erosion at the downstream of hydraulic structures' caused by 'high water flow or turbulent flows'.

In the study Shehab, (2024), scientists used the MATLAB Simulink model, and the accuracy of their forecast was at the level good. At the same time, the model developed in the current study showed the best result in forecasting the scour reduction percentage. This was achieved by using a new technology that included a block diagram of the MATLAB simulation model. Scientists used the MATLAB Simulink model method to build the block diagram to show that the proposed simulation greatly reduces the computational time compared the other numerical schemes. The scour is affected by time in addition to other influences mentioned previously, such as the shape of weir and flow characteristics. In this study, experiments were conducted in the laboratory for a period of six hours to give enough time for observing the variables, as it is noticed that the scour stabilizes in some models for the first two hours, and the other settles in four hours. The first SU1 model did not give satisfactory results until the loom part was added to increase the calming of the water, dissipate its energy and reduce erosion behind the weir. The results were somewhat satisfactory, as the value of erosion in the SU2 model, was 0.0317 m, while the lengths of the erosion was 0.085 m. This means that the percentage of erosion reduction increased from (0% to 63%). The results prompted the pursuit of developing improved models.

Forty piles comprised of five rows and eight columns were placed at the bottom of the weir to increase the dissipation of energy. A significant change was observed in the flow pattern, as the energy of the water descending from the top of the weir was dispersed by the columns placed at the bottom of the weir. This significantly prevented the occurrence of high eddies at the bottom of the weir thus further reducing the percentage of erosion. The significant level of erosion reduction reached percentages which have not previously been achieved in other studies. The SU5 model, achieved a 60%, reduction of erosion. The dimensional analysis showed that the depth and length of the erosion pit divided by the width of the channel (L_s/W_c, D_s/W_c) depends on the length of the added part, the number of columns placed at the bottom of the weir, and the angle of the ramps at the back of the part added to the weir.

The Flow 3D program showed high efficiency in representing the flow in reality. The program was tested on previous laboratory results, and the program data was similar to the laboratory data in terms of flow speed, water flow shape, and the depth of the erosion pit, in addition to its length. There is a significant convergence between program results and laboratory results. Six models were tested in this study, showing impressive results in reducing the depth and length of the erosion pit below the weir, then a MATLAB Simulink model was built to compute the reducing in the scouring depth. The model was tested for several cases and realistic practical models, and the method proved efficient and accurate, with an error rate of less than 1.5%. Comparing the current study, it was found that the circuit obtained using a new technology in the field Matlab Simulink gave more accurate models at a very short time not exceed seconds, as other mathematical equations.

CONCLUSIONS

Previous studies reviewed were progressing slowly in finding solutions to reduce the depth and length of the erosion pit. The current study found a different approach from the previous ones by designing six new models of sheds that may have an influential role in preventing erosion behind hydraulic installations. The new method that using the new models can raise the water level at the weir top, dispersing the energy of the runoff and ultimately decreasing the erosion at the weir bottom. The results obtained were consistent with or without the presence of struts at the bottom of the weir or not, and despite the shape and angle of the added part. Among all the proposed designs used to reduce scour behind the weirs, it was found that the third SU3 model constitute the best structures, compared to the first SU1 model, where it was able to reduce the scour proportion about 80%, (Table 2). While the fourth SU4 model showed similar scour reduction percentage (60%). Nevertheless, the second SU2 model demonstrated about 50% reduction in scour. Regarding the third model, SU5, the scour is decreased about 30% in comparison to the first model. Contour maps were used to show the depth of erosion as a measure of the efficiency of the weir. The experimental results indicate that when the three discharges are applied continuously for a period of six hours, erosion areas arise behind the weirs, extend to both sides of the canal, and their shapes differ according to the model utilized. The deepest erosion pit was formed behind the first model (SU1). It reached 0.12 m and a length of 0.21 m. using the highest drainage of the three used discharges 0.015 m^3·sec., 0.020 m^3·sec., and 0.025 m^3·sec. The lowest pit was 0.0035 m and the shortest length 0.04 m for the highest drainage used in the ninth model (SU3). MATLAB-Simulink can be used to evaluate the depth and length of scour at the bottom of the weir. For this purpose, the equation obtained from the dimension analyses was used and incorporated into a Simulink model. MATLAB Simulink is a versatile tool that can be used for a wide range of applications in hydraulic structure research. From modeling and simulation, the behavior of hydraulic structures to evaluating the depth and length of scour, Simulink provides researchers with powerful tools for analyzing and optimizing these complex systems and it gives more accurate results in a very short time. When comparing the current study, it was found that the circuit obtained using a new technology in the field Matlab Simulink gave more accurate models at a very short time not exceed seconds, compared to other mathematical Equations.

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