Calibration of flow equations through regulators using computational fluid dynamics CFD modelling

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Keywords

CFD, flow of water, regulator, flow 3D

Abstract

This study examined a simulation performed using the Flow 3D program and compared the outcomes with general and positional equations for calculating the discharge through water facilities that had been established in earlier studies. and investigated the traits of the flow passing through irrigation regulators and the variables influencing them for the two situations of flow at the total opening and partial opening of the regulator gate. Based on the findings of laboratory measurements, the coefficients and other components in the equations for estimating discharge were calculated, and links between these coefficients and the non-dimensional components impacting the flow calculated in the laboratory were drawn.

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Introduction

The CFD (FLOW 3D) simulation program was utilized in this study's results, together with laboratory measurements to install the parameters and elements required in the program's calculations, which may be used to calculate the regulators' discharge based on straightforward field observations. Weirs, regulators, or other water measuring equipment are used to control the water flow in irrigation canals. In areas with little slope, regulators are utilized. showed that CFD can be a good alternative for problem analysis and solution as opposed to generating a final result, mostly because of the large number of assumptions made in the numerical methods employed in CFD. When the flow is three-dimensional (3D), the modeling method is more difficult. (Ghare et al., 2008). The procedure of managing the flow includes regulating the water level, its quantity, or estimating this quantity, or combining the three cases. And there is Gates, which come in a variety of designs like as the sliding gate, radial gate, and cylindrical gate, control the flow in regulators. The regulator's front and back water levels, as well as the size of the gate opening, both influence the drain. By altering the gate opening, the drain traveling through the regulator can be managed. Of course, when the gate is completely opened, the regulator experiences the largest discharge. It is demonstrated that there is a fair amount of agreement for both pressures and discharges between the physical and numerical models. The accessibility and effectiveness of current numerical techniques give engineers another instrument for the construction and study of models.(Savage & Johnson, 2001).in 2020 (Carrillo et al., 2020) conducted a numerical analysis to demonstrate how the coefficient of discharge over labyrinth weirs is affected by submerged and free flows. Additionally, they examined the free surface flow profile at the labyrinth weir's upstream and downstream reaches. The results showed that for a large sidewall angle, CFD models can fairly accurately forecast the coefficient of discharge on submerged and free flow across labyrinth weirs. In 2022 (Pourshahbaz et al., 2022) they utilized the CFD tool FLOW-3D software. They looked at the hydro-morphology and numerical modeling of a set of parallel groynes that were positioned vertically. The critical velocity ratio (Vavg/Vcr) and approach Froude number had an effect on the correctness of the simulation of the FLOW-3D model,

Channel for laboratory

The used laboratory channel is rectangular in shape, has a metal bottom, and has glass on both sides. It is 20 meters in length, 0.9 meters in width, and 0.6 meters in height. It is mounted on the laboratory floor and fastened to an iron frame with movable screws so that the channel's transverse inclination can be changed. The center of the truss is supported by two cylindrical bearings that are fastened to the lab floor. . Additionally, it has a pair of screw jacks at each end, which are fixed on the laboratory floor and allow the jacks to alter the longitudinal slope of the channel. utilizing an electric motor that can be managed using the control panel's keypad. The bracket at the back of the channel is secured with a ruler with millimeter divisions. This ruler, which is just loosely attached to the truss, is calibrated to read zero when the channel is horizontal. The sliding cart that transports the measuring devices is made easy to move by an aluminum track that has been put above the canal walls. Spirals connecting the rails to the channel walls allow for level adjustment. The outlet basin, which connects to the front of the channel, is 2 meters long, 1.6 meters broad, and 1 meter high. A tube with a diameter of 0.3 meters supplies it with water. The tube's positioning inside the basin is intended to diffuse the water's energy and provide a tranquil flow. To further assure that the water was calm, a floating board was positioned and attached to the basin. In each experiment, when the level of the overflow hole could be adjusted, the outflow basin was fitted with a drain to dispose of any extra water.

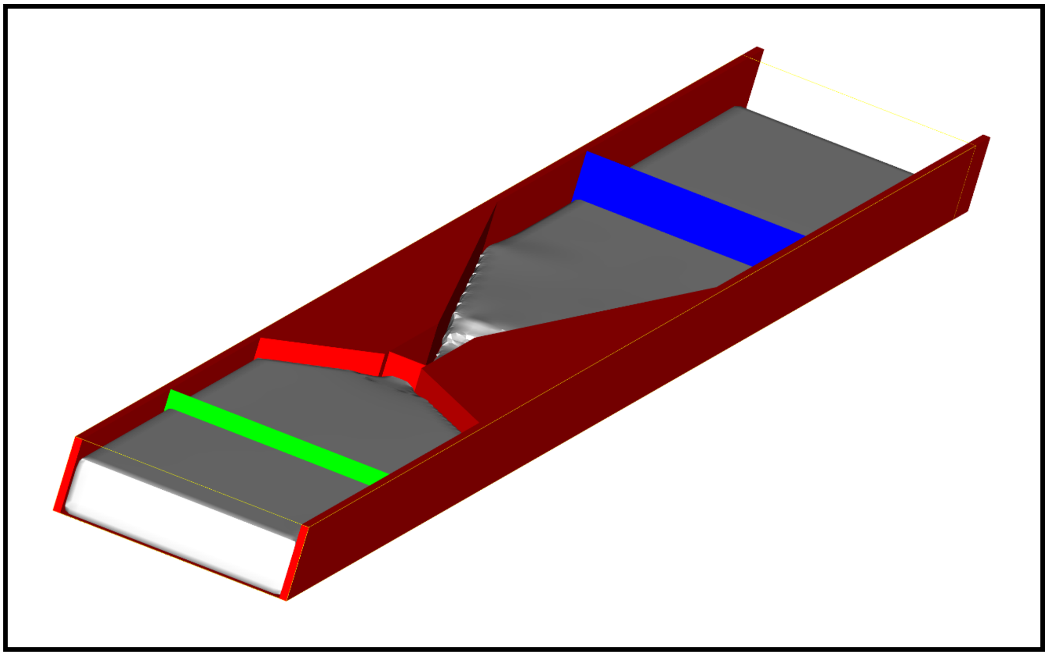

Figure 1. Regulator Channel

Experimental work

The goal of conducting experiments is to obtain measurements that are readily available in the field in order to determine the equation of flow. These measurements include the water level in the front and its level in the back, or the natural depth of flow and the opening of the gate, and after performing the calibration, they are used to calculate the flow passing through the regulator opening. The same holds true for laboratory tests. The depth of the foreground flow was measured at a distance of 2 m from the model, and the depth of the natural flow was calculated using the natural flow equation at the backside and at a distance of 2 m from the model, assuming a suitable slope for the lands of Iraq, which is 0.002, and a roughness coefficient of 0.018. The relationship between the discharge and the depth of the water at the backside is depicted in Figure 1. The triangular submersible dam also measured drainage. Along with these readings, the distribution of the water's velocity charge in the front and the depth of the water flowing through the regulator were also noted After calibrating the model, measurements are taken of the discharge, height and width of the gate and the water level in the inlet and outlet to be compared later with the results extracted from the program.

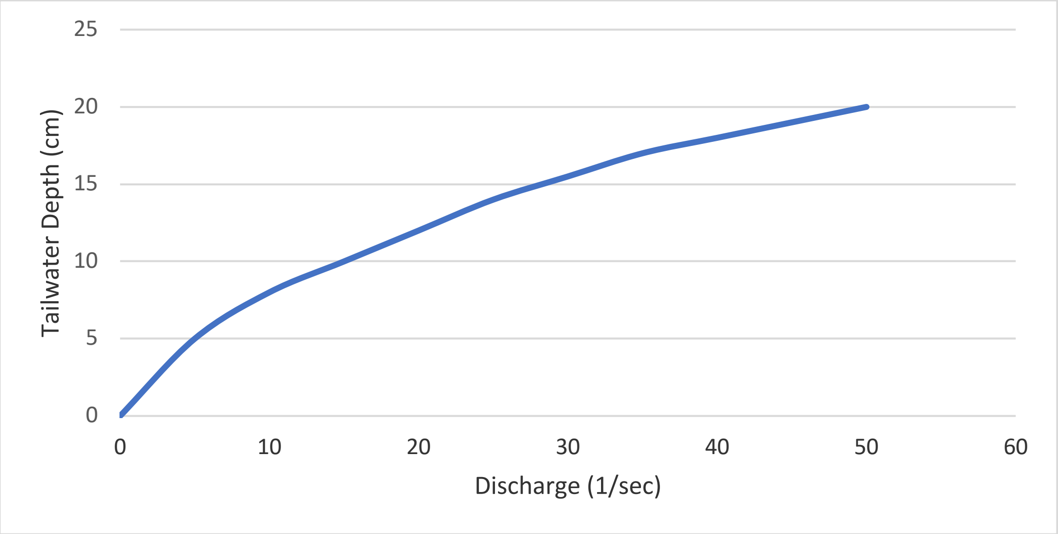

Figure 2. Relationship Between Drainage And Normal Depth At The Outlet

Dimensional analyiıs

Engineers must use translation and base their choices on observations, experience, and experimental data. The method that formulates the problems more effectively is dimensional analysis. The principles of dimensional analysis are used in a theoretical study to connect the relationships between the numerous parameters that affect flow and are affected by changes in the regulator shape, Froude number, change in height of gate, and width of gate in the model. **Table.1** illustrates how the categories of mass (M), length (L), and time (T) can be written.

Table 1. The Affect Parameters on Flow of Water

1-Parameters characterizing the fluid flow		Unit	Dimensions
ρ	Density of the fluid	kg/ m^3	ML^{-3}
Q	The discharge	M^3/l	L^3T^{-1}
g	Gravitational acceleration	m/s^2	LT^{-2}
μ	dynamic viscosity of the fluid N.s/m2	N.s/m^2	$ML^{-1}T^{-1}$
Y_1	Depths of the water in upstream flow	m	L
V_1	Velocity of the water in upstream flow	m/s	LT^{-1}

2-Parameters characterizing the model		Unit	Dimensions
S	model bed slop	-	-
L	Length of model	m	L
W	width of model	m	L
N	Number of gates	-	-
B	width of the gate	m	L
H	Height of the open gate	m	L
3-Time		Unit	Dimensions
T	Duration of RUN	Min	T

After using the dimensional analysis using Buckingham's Π theory method and neglecting the non-influential values, and simplifying the equations, discharge's functional relationship can be expressed as follows:

$$\mathbf{Q = g^{0.5} . Y^{2.5} F4(Fr,N,B/Y,H/Y)} \quad \text{..........} \quad \mathbf{1}$$

SPSS Program

The statistics package for social sciences (SPSS) version 26 program and an artificial neural network were used to generate the ANN models in the current study (ANN). The discharge (q) was chosen as the output parameter, while the level of water in the inlet (Y), the width of the gate (B), and the height of the gate (H) functioned as the input parameters. The dataset utilized in this study was split into three groups with a random member in each: holdout, testing (validation), and training. The standardized rescaling method was used for covariates. In this rescaling process, the mean is subtracted from the data and the final result is divided by the standard deviation. The rescaling methods normalized, adjusted normalized, and none are also available. These ANN models used the standard methodology. The network was trained using a batch training method in conjunction with the gradient descent methodology. On that, the default SPSS software settings were utilized. When properly trained, an artificial neural network can forecast how a process will behave. After being properly trained, neural networks can deliver accurate results even in situations that they have never experienced due to their exceptional capacity to generalize.(Al-saadi, 2022)

In **Table.2**, the number of layers and the number of neurons in each layer are shown. There are three independent variables in the input layer. Height, width, and intake water level of the gate. The standardized rescaling technique was applied to covariates. The output layer featured a single node for the dependent variable course result, whereas the hidden layer was assigned to a single layer with three nodes via automatic architecture selection. The activation function for the hidden layer was the hyperbolic tangent, which has the form f(x) = tanh (x) within the hidden layer. The output layer's identity function, which has the form i.e. f (x)= x, was used.

Table 2. Network Information

Network Information			
Input Layer	Covariates	1	Height of the gate (H)
		2	Water level in inlet (Y)
		3	Width of the gate (B)
	Number of Units [a]		3
	Rescaling Method for Covariates		Standardized
Hidden Layer(s)	Number of Hidden Layers		1
	Number of Units in Hidden Layer 1[a]		3
	Activation Function		Hyperbolic tangent
Output Layer	Dependent Variables	1	Discharge
	Number of Units		1
	Rescaling Method for Scale Dependents		Standardized
	Activation Function		Identity
	Error Function		Sum of Squares

a. Excluding the bias unit

It can be argued that this model demonstrates very good agreement with the actual observation because its coefficient of determination (R2) is (0.897), as shown in Figure.3.

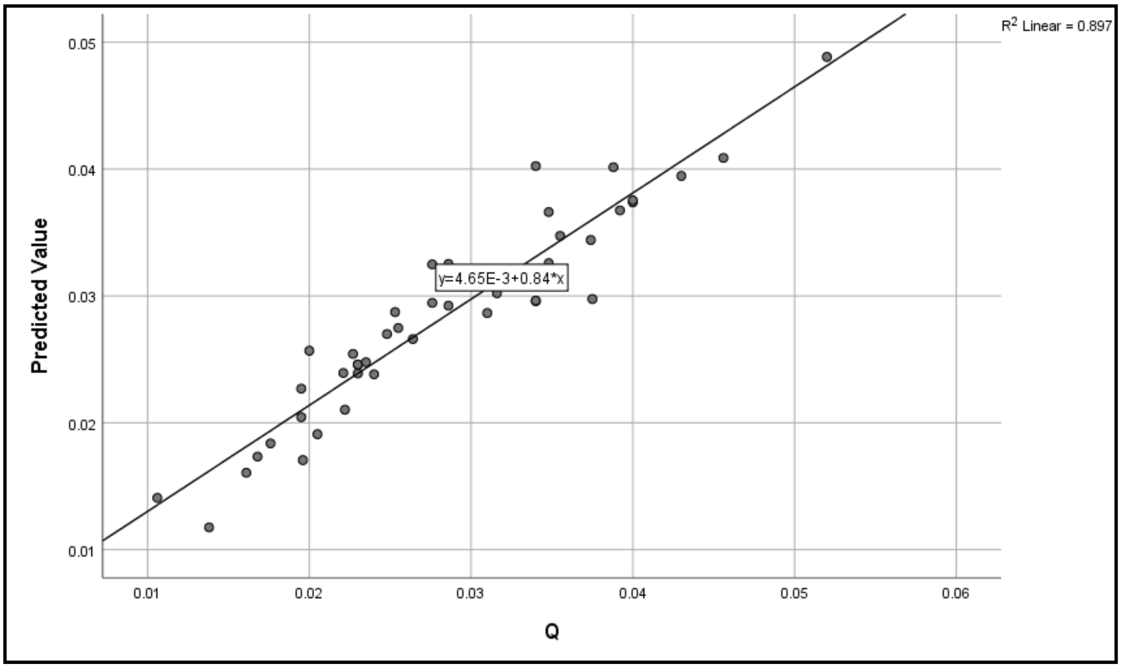

Figure 3. Predicted Value

Analysis and Discussions

Adjusting the discharge rate (Q) and measuring the water level (Y1) downstream of the weir were used to gather data. Measurements weren't performed until a sufficient period of time had passed, which was at least 4 min as advised by (Crookston 2010), in order to ensure the flow is under steady-state conditions. After analyzing and making calculations in the SPSS program, it appeared to us that water level in the intake had the biggest impact on discharge with an importance ratio of about 51.9%, followed by distance with a significance ratio of about 28.7% and height of the gate with a significance ratio of about 19.4%. As shown in the **figure.3**.

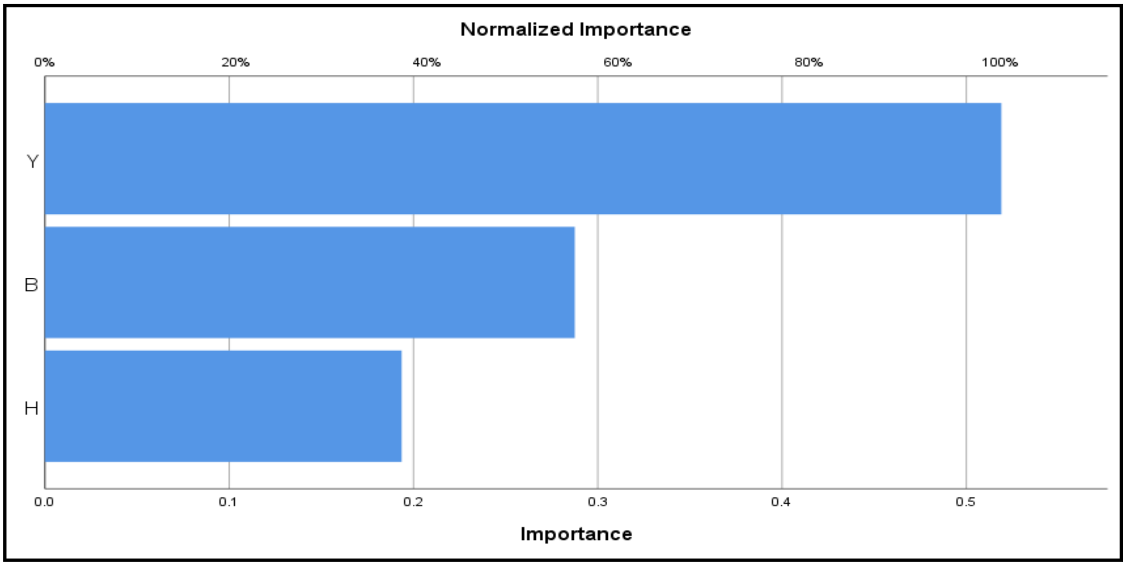

Figure 4. The Effect of Independent Variables on The Prediction of The Discharge Rate

Conflict of Interest

Author declare that there is no conflict of interest.

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