

## Detention and Release in Stepped Gabion Weir: Case of Four Steps

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### ABSTRACT

The problem of water scarcity can be noticed clearly in the lined canals which provide the irrigation networks. Using porous structures like gabion weirs contributes as a part solution to this problem. In the current study, a laboratory flume was used to calculate the water depths upstream and downstream of the stepped gabion weir that is to be put inside it at a certain distance, and this flume comes with dimensions of 10 m long by 0.30 m wide and 0.50 m height. While the tested hydraulic model of the weir was built with dimensions of 0.30 m width by 0.40 m maximum height, and five lengths with different total distance of 0.88, 0.96, 1.08, 1.12, and 1.20 m respectively. The used gravel samples to fill the gabions were of monosize query gravel with diameters ranging between 0.0095-0.0140, 0.0140-0.0190, 0.0190-0.0250, 0.0250-0.0375, and 0.0375-0.0500 m in a respective way. While the values of discharge, measured during the experiments were in the range of 0.0007-0.0150 m<sup>3</sup>/s, and a total of 175 trial tests. This study achieved that the detention depth value decreases by increasing the diameter of the gravel sample used, but there is no effect of the gravel sample on the value of release depth, the different illustrated formulas for the detention and release depths maybe can be used usefully for design and scheduling actions in the field where it gave a reasonable matching between the measured and the calculated values of the studied depths, and finally, the errors percentage in an average value for both detention and release tested values were 5.278% and -0.265% respectively

**KEYWORDS:** Open channel projects; Weirs; Gabion weirs; Detention depths; Release depths; Scarcity season

### 1 INTRODUCTION

In most cases, the hydraulic characteristics of flow using the structures located inside the waterways, (solid weirs or humps, gabion mattresses, gates, etc.), for different flow conditions are to be studied by the researchers to test different applications like, calculate the dissipated energy of flow between its two sides [1 - 3], and the hydraulic jump distance formulated beyond these structures [4 - 7] as an effective criteria of energy dissipation to find out a proper way to reduce the water damage on the sides and bed of the waterway, illustrates new formulas between characters that serve to solve multi-issues in hydraulic engineering [11 - 14]. Besides good indicators contribute to making the proper

decisions related to improving the dimensions of the waterway, or the distribution of the whole irrigation system [8 - 10]. Due to the prevalence of climate change phenomenon in the whole globe, and its effect on the policy of water distribution between the shared countries, the need to study new and different solutions is necessary to keep save and control the reduced amount of pure water in the world, to ensure the justified distribution of water for multi-purpose uses. So, this study comes as a part solution to overcome this issue, and consider a continuous case to [15] but with the use of the different shapes of the gabion weir.

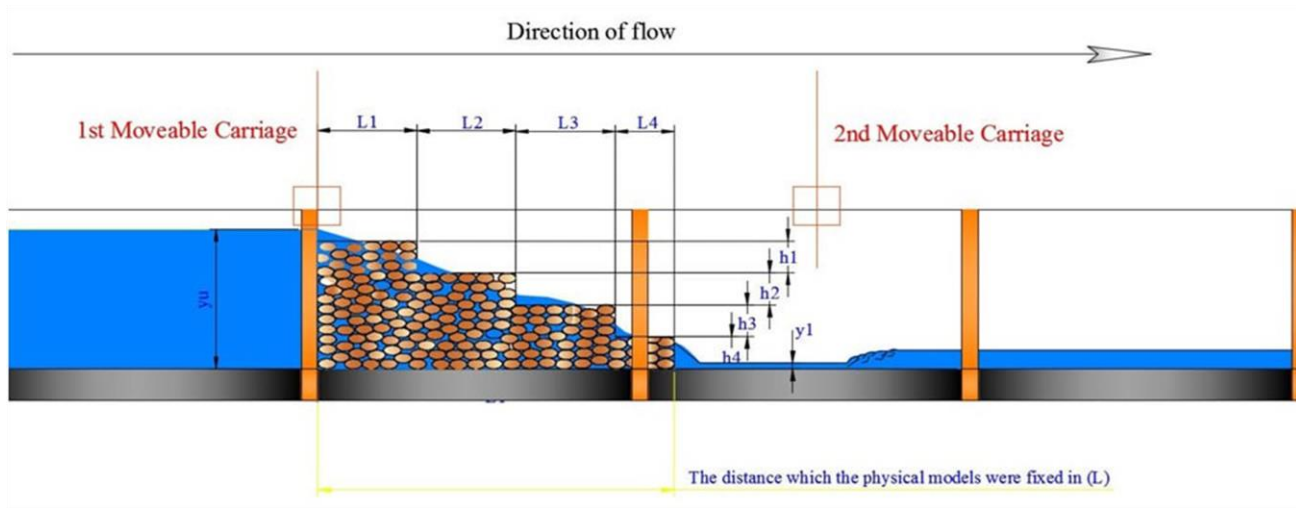
## 2 LABORATORY WORK

The laboratory of fluid mechanics of the College of Engineering at the University of Babylon / Republic of Iraq was used to conduct the test runs. This lab has an ARMFIELD flume of 10.000 m long with 0.300 m wide and 0.500 m in height. The dimensions of the used hydraulic models of the gabion weir and the gravel samples diameters are listed in Table 1, whereas the total number of tested runs were 175 test run. Figure 1 shows the detailed shape of the used hydraulic models of the gabion weir, while Figures 2, 3, 4, 5, and 6 show the actual hydraulic models of the gravel weir.

**Table 1.** The dimensions of the used hydraulic models of gabion weir, the gravel samples, and test runs.

Gabion		Gabion Dimensions				Discharge Range (m³/s)
Number	Length (m)		Height (m)		Width (m)	
G1	L <sub>1</sub>	0.40	h <sub>1</sub>	0.15	0.30	0.0007 – 0.0150
	L <sub>2</sub>	0.20	h <sub>2</sub>	0.05		
	L <sub>3</sub>	0.20	h <sub>3</sub>	0.10		
	L <sub>4</sub>	0.08	h <sub>4</sub>	0.10		
	Total	0.88	0.40			
G2	L <sub>1</sub>	0.40	h <sub>1</sub>	0.15	0.30	
	L <sub>2</sub>	0.20	h <sub>2</sub>	0.05		
	L <sub>3</sub>	0.20	h <sub>3</sub>	0.10		
	L <sub>4</sub>	0.16	h <sub>4</sub>	0.10		
	Total	0.96	0.40			
G3	L <sub>1</sub>	0.40	h <sub>1</sub>	0.15	0.30	
	L <sub>2</sub>	0.20	h <sub>2</sub>	0.05		
	L <sub>3</sub>	0.20	h <sub>3</sub>	0.10		
	L <sub>4</sub>	0.24	h <sub>4</sub>	0.10		
	Total	1.04	0.40			
G4	L <sub>1</sub>	0.40	h <sub>1</sub>	0.15	0.30	
	L <sub>2</sub>	0.20	h <sub>2</sub>	0.05		
	L <sub>3</sub>	0.20	h <sub>3</sub>	0.10		
	L <sub>4</sub>	0.32	h <sub>4</sub>	0.10		
	Total	1.12	0.40			
G5	L <sub>1</sub>	0.40	h <sub>1</sub>	0.15	0.30	
	L <sub>2</sub>	0.20	h <sub>2</sub>	0.05		
	L <sub>3</sub>	0.20	h <sub>3</sub>	0.10		
	L <sub>4</sub>	0.40	h <sub>4</sub>	0.10		
	Total	1.20	0.40			
Gravel Samples						
Number	GRS.01	GRS.02	GRS.03	GRS.04	GRS.05	

Diameter (m)	0.0095- 0.0140	0.0140- 0.0190	0.0190- 0.0250	0.0250- 0.0375	0.0375- 0.0500	
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**Figure 1.** A The detailed shape of the used hydraulic models of gabion weir.



**Figure 2.** A photo of G1 with GRS.02.



**Figure 3.** A photo of G2 with GRS.02.

### 3 DIMENSIONAL ANALYSIS

Using of the dimensional analysis technique comes to bond all the variables of the studied case in one formula, whereas the resulting dimensionless formula helps both of engineers and researchers to understand the behaviour of variables with other ones [1 - 9, and 11 - 15], for ensuring the equitable and effective management of surface water in irrigation schemes that cater to various field conditions.

For the detention process of water, the upstream water depth,  $y_{us}$ , before the gabion weir refers to the detention depth. The variables affect it were listed as [15] :-

$$y_{us} = F_1 \{q, d, L_T, L_4, \rho, g\} \quad (1)$$

Where,  $q$  is the discharge/unit width ( $m^3/s/m$ ),  $d$  is the middle diameter of the used gravel sample (m),  $L_T$  is the total length of gabion weir (m),  $L_4$  is the length of the 4th step in the gabion weir (m),  $g$  is the gravitational acceleration ( $m/s^2$ ), and  $\rho$  is the mass density ( $kg/m^3$ ), [15].



**Figure 4.** A photo of G3 with GRS.01.



**Figure 5.** A photo of G4 with GRS.01.



**Figure 6.** A photo of G5 with GRS.05.

For the release process of water, the downstream water depth,  $y_{ds}$ , after the gabion weir refers to the release depth. The variables affect it were listed as [15]:-

$$y_{ds} = F_2 \{ q, d, L_T, L_4, \rho, g \} \quad (2)$$

Using the Pi-Theorem, a public expression can be formulated to understand the bonds that connecting the dependent and independent variables of the current study :

$$\frac{y_{us}}{L_T} = F_3 \left\{ \frac{q}{g^{0.5} L_T^{1.5}}, \frac{d}{L_T}, \frac{L_4}{L_T} \right\} \quad (3)$$

Whereas the term  $\left(\frac{y_{us}}{L_T}\right)$  is the detention dimensionless variable, the term  $\left(\frac{q}{g^{0.5} L_T^{1.5}}\right)$  is the unit discharge dimensionless variable, the term  $\left(\frac{d}{L_T}\right)$  is the gravel diameter dimensionless variable, and the term  $\left(\frac{L_4}{L_T}\right)$  is the gabion length ratio.

For release depth, the equation will be as (3) :-

$$\frac{y_{ds}}{L_T} = F_4 \left\{ \frac{q}{g^{0.5} L_T^{1.5}}, \frac{d}{L_T}, \frac{L_4}{L_T} \right\} \quad (4)$$

Whereas the term  $(\frac{y_{ds}}{L_T})$  is the release dimensionless variable.

For practical considerations related to use of the first tested model of the weir in the irrigation networks canals and flumes during the scarcity season, because of its easiness in setup, removing, and relocation along the targeted canal, the term  $(\frac{L_4}{L_T})$  will not be discussed in this study. So, the equations (3) and (4) will be :-

$$\frac{y_{us}}{L_T} = F_5 \left\{ \frac{q}{g^{0.5} L_T^{1.5}}, \frac{d}{L_T} \right\} \quad (5)$$

$$\frac{y_{ds}}{L_T} = F_6 \left\{ \frac{q}{g^{0.5} L_T^{1.5}}, \frac{d}{L_T} \right\} \quad (6)$$

## 4 RESULTS AND DISCUSSION

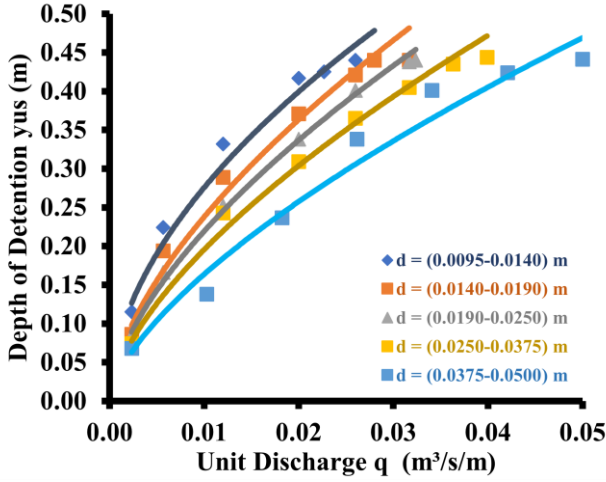
### 1. Effect of discharge on the detention depth

The discharge-water depth relationship is dependent in most cases as a general relationship to coherent the role of water over solid structures and through previous ones. In addition, some researchers consider this relationship necessary for weir design testing all flow conditions and types. For the current study, the control of the detention depth at the upstream side of the weir is important to ensure a justified supply of raw water for multiple uses during the dry season [8 - 11, and 13 - 15]. The discharge-other variable relationship was drawn using the linear formula as in [12, 14, and 15], and Figures 7, 8, 9, 10, and 11 show this relationship. While both [1 - 6, and 11] were used the power formula to represent this relationship, and both of [3 - 6] used the exponential form for such relationship. From Figures 7, 8, 9, 10, and 11 the detention depth of water increases as the value of discharge increases for all gravel samples used and for all gabion weir models. This direct proportion behaviour was found in the results of both [1 - 6, 11, 12, 14, and 15]. Whereas the power form was the representation equation of this relationship for this study.

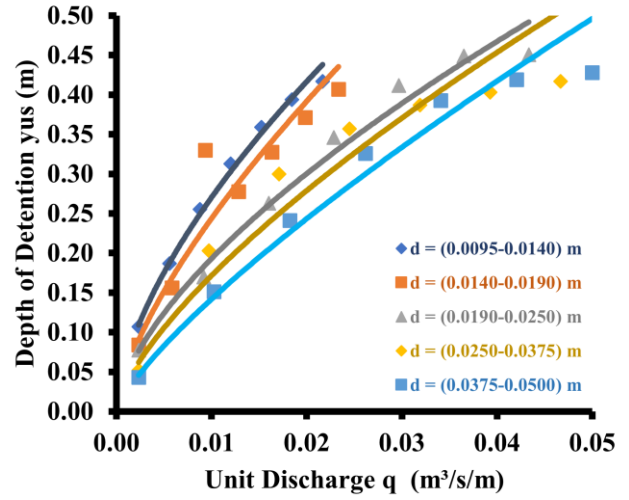
$$y_{us} = a(us) * ((q)^{b(us)}) \quad (7)$$

Where,  $a(us)$  and  $b(us)$  are constants, and Table 2 views the values of these constants.

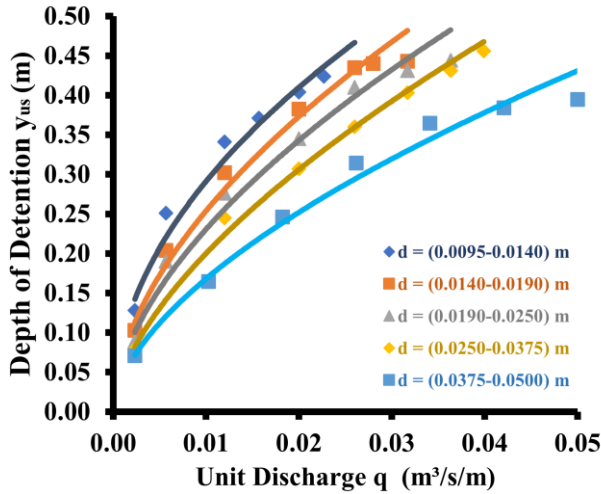




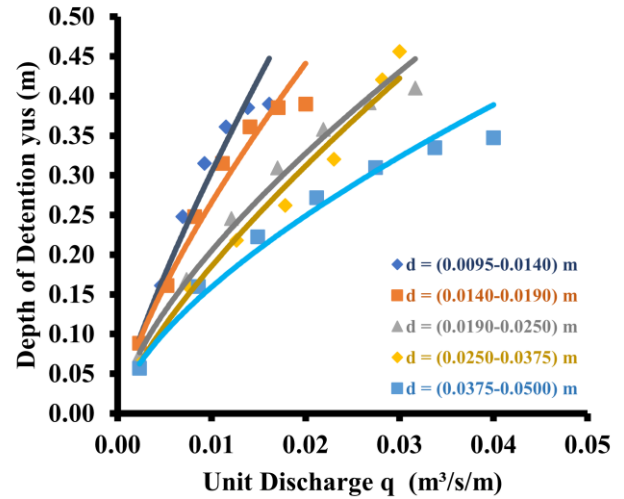
**Figure 7.** The discharge-detention depth relationship for G1-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.



**Figure 8.** The discharge-detention depth relationship for G2-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.



**Figure 9.** The discharge-detention depth relationship for G3-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.



**Figure 10.** The discharge-detention depth relationship for G4-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.

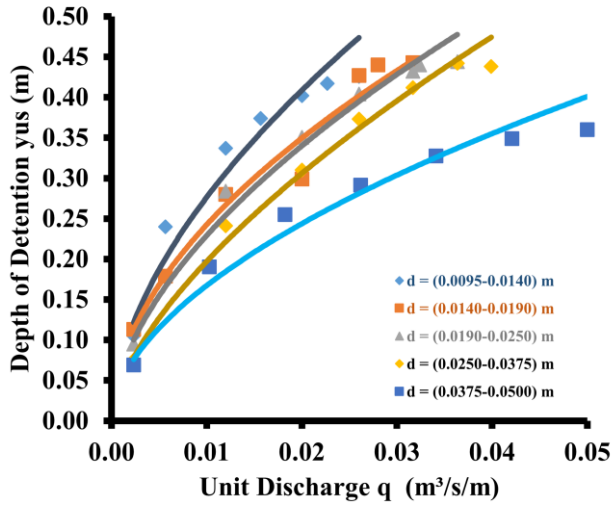
## 2. Effect of gravel samples on the detention depth

Figures 7, 8, 9, 10, and 11 show that the detention depth decreases as the diameter of the used gravel sample increases for all models. This finding align well with observation presented in [15]. The relationship between the detection depth dimensionless variable and the unit discharge dimensionless variable used in all physical models is represented by (8).

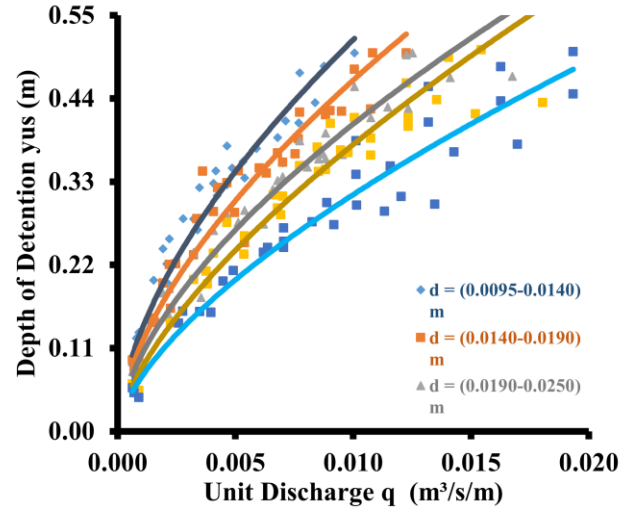
$$\frac{y_{us}}{L} = f_3 \left\{ \frac{q}{g^{0.5} L_T^{1.5}} \right\}$$

8)

Figure 12 views the relationship of these variables. This image demonstrates that the mean diameter of the gravel sample utilized in all physical models decreases as the detention depth increases. These results give a vision that changing the gabion filling material should be synchronized with the increases in the degree of scarcity, whereas it changes from coarser to finer when the scarcity degree increases to keep a safe elevation of water depth that serve this process.



**Figure 11.** The discharge-detention depth relationship for G5-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.



**Figure 12.** The discharge-detention depth relationship all for gabion weir and gravel samples used.

**Table 2.** Values of constants a(us) and b(us).

Gabion Number	Gravel Sample Number	q (m³/s/m)		y <sub>us</sub> (m)		a(us)	b(us)	R²
		from	to	from	to			
G1	GRS.01	0.00233	0.02800	0.115	0.441	03.2422	0.5352	0.9760
	GRS.02	0.00233	0.03168	0.086	0.440	03.9801	0.6117	0.9759
	GRS.03	0.00233	0.03237	0.084	0.440	03.7962	0.6191	0.9951
	GRS.04	0.00233	0.03990	0.074	0.444	03.6479	0.6352	0.9929
	GRS.05	0.00233	0.05000	0.068	0.442	03.3274	0.6540	0.9787
G2	GRS.01	0.00233	0.02167	0.107	0.417	04.7856	0.6239	0.9965
	GRS.02	0.00233	0.02333	0.084	0.407	05.6896	0.6839	0.9270
	GRS.03	0.00233	0.04333	0.078	0.451	03.6357	0.6373	0.9918
	GRS.04	0.00233	0.04667	0.052	0.417	03.6479	0.6352	0.9929
	GRS.05	0.00233	0.05000	0.042	0.428	03.3274	0.6540	0.9787
G3	GRS.01	0.00233	0.02600	0.128	0.435	02.8195	0.4929	0.9660
	GRS.02	0.00233	0.03168	0.103	0.443	03.2772	0.5554	0.9823
	GRS.03	0.00233	0.03633	0.089	0.444	03.2093	0.5716	0.9775
	GRS.04	0.00233	0.03990	0.079	0.456	03.6479	0.06352	0.9929
	GRS.05	0.00233	0.05000	0.071	0.395	03.3274	0.6540	0.9787
G4	GRS.01	0.00233	0.01613	0.123	0.423	12.4900	0.8050	0.9758

	GRS.02	0.00233	0.02000	0.098	0.390	07.6279	0.7287	0.9813
	GRS.03	0.00233	0.03167	0.074	0.410	04.6019	0.6755	0.9929
	GRS.04	0.00233	0.03000	0.062	0.456	03.4679	0.06352	0.9929
	GRS.05	0.00233	0.04000	0.057	0.348	03.3274	0.6540	0.9787
G5	GRS.01	0.00233	0.02600	0.105	0.426	03.7032	0.5634	0.9482
	GRS.02	0.00233	0.03168	0.113	0.443	02.7596	0.5281	0.9794
	GRS.03	0.00233	0.03633	0.095	0.444	03.1521	0.5692	0.9878
	GRS.04	0.00233	0.03990	0.075	0.438	03.6479	0.6352	0.9929
	GRS.05	0.00233	0.05000	0.069	0.360	03.3274	0.6540	0.9787

From figure 12, it's obvious that power form is the reasonable formula for the variables of equation (8).

$$\frac{y_{us}}{L} = A * \left( \left( \frac{q}{g^{0.5} L_T^{1.5}} \right)^B \right) \quad (9)$$

Where, A and B are constants, and Table 3 presents the values of these constants.

**Table 3.** Values of constants A and B.

Gravel Sample Number	q (m <sup>3</sup> /s/m)		L <sub>T</sub> (m)		y <sub>us</sub> (m)		A	B	R <sup>2</sup>
	from	to	from	to	from	to			
I	0.00233	0.02800	0.88	1.20	0.115	0.441	7.9121	0.5921	0.9456
II	0.00233	0.03168	0.88	1.20	0.086	0.443	7.5764	0.6064	0.9527
III	0.00233	0.04333	0.88	1.20	0.084	0.451	6.7062	0.6089	0.9703
IV	0.00233	0.04667	0.88	1.20	0.074	0.456	8.0683	0.6640	0.9704
V	0.00233	0.05000	0.88	1.20	0.068	0.442	6.0718	0.6439	0.9646

The final form of equation (5) after applying the regression process is :-

$$\frac{y_{us}}{L_T} = 0.214842 + 27.86011 \left( \frac{q}{g^{0.5} L_T^{1.5}} \right) - 4.221891 \left( \frac{d}{L_T} \right) \quad R^2 = 0.847 \quad (10)$$

### 3. Effect of discharge on the release depth

The power form was used to draw the relationship between the discharge and the release depth of water in Figures 13, 14, 15, 16, and 17. From these figures, the same results and relation of the discharge/detention depth were illustrated for the release water depth. Equation (11) shows this relation

$$y_{ds} = a(ds) * ((q)^b(ds)) \quad (11)$$

Where, a(ds) and b(ds) are constants, and Table 4 views the values of these constants.

### 4. Effect of gravel samples on the release depth

Figures 13, 14, 15, 16, and 17 show a zero effect in increase the diameter of the gravel material on the water release depth, for all gabion models tested. This result gives an indication that a change in the diameter of the filling material of the gabion weir affects the detention depth more than the release depth, and that is a variable that plays an important role in the scheduling process for the irrigation canal during the scarcity seasons. The relationship between the release depth dimensionless variable and the unit discharge dimensionless variable used in all physical models is represented by (12).

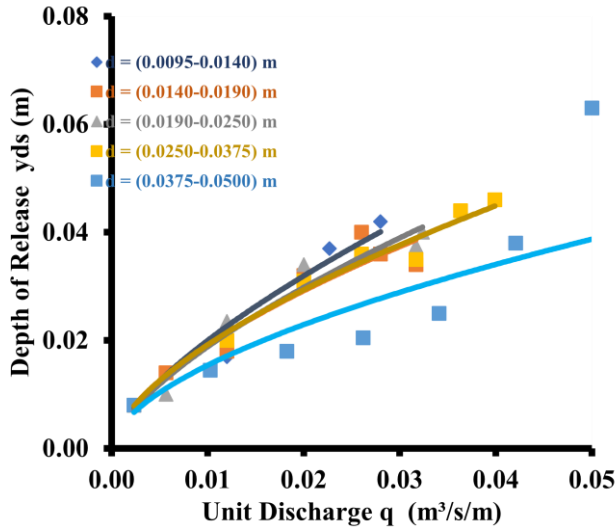
$$\frac{y_{ds}}{L} = f_4 \left\{ \frac{q}{g^{0.5} L_T^{1.5}} \right\} \quad (12)$$

For Figure 18, also that power form is a good and precise mathematical representation of the variables of equation (12) :-

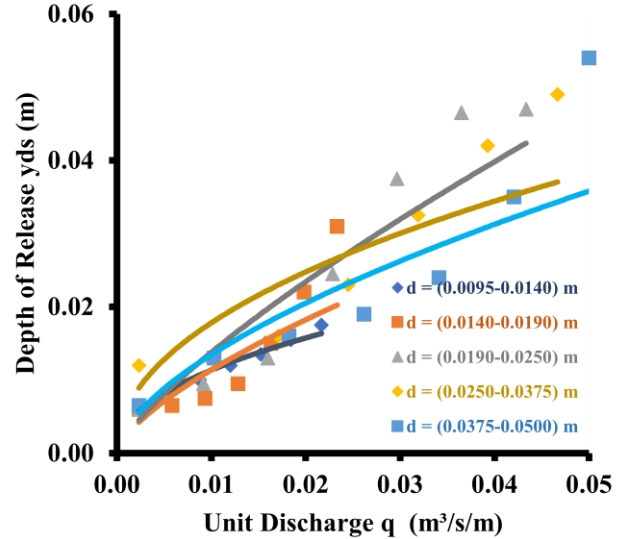


$$\frac{y_{ds}}{L} = A1 * \left( \frac{q}{g^{0.5} L_T^{1.5}} \right)^{B1} \quad (13)$$

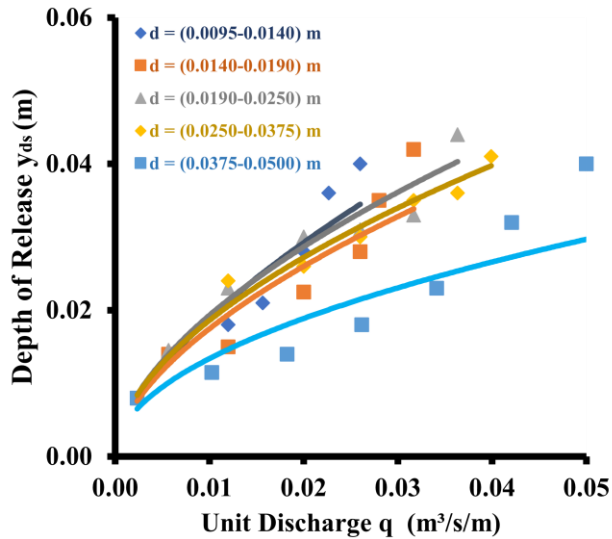
Where A1 and B1 are constants, and their variables are listed in table 5.



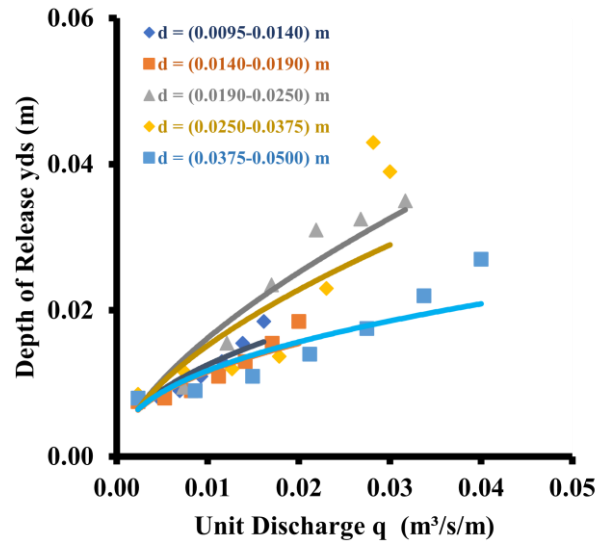
**Figure 13.** The discharge-release depth relationship for G1-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.



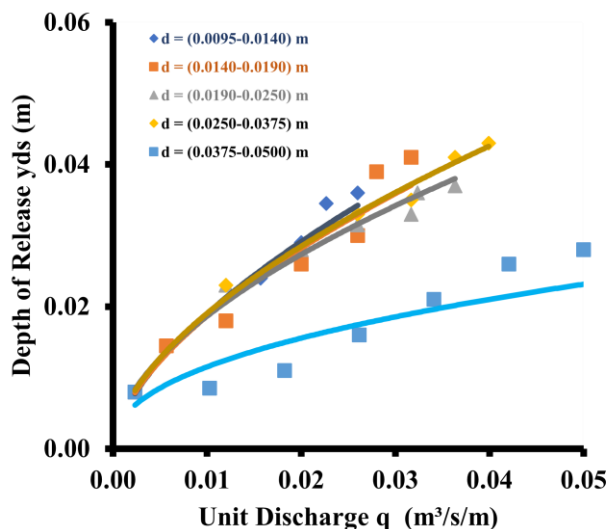
**Figure 14.** The discharge-release depth relationship for G2-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.



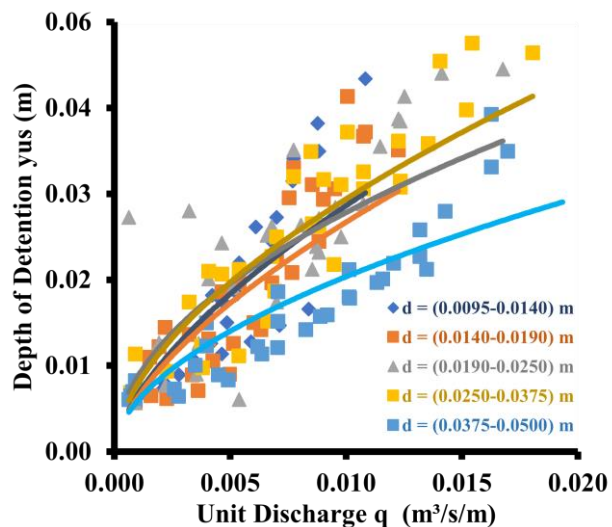
**Figure 15.** The discharge-release depth relationship for G3-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.



**Figure 16.** The discharge-release depth relationship for G4-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.



**Figure 17.** The discharge-release depth relationship for G5-GRS.01, GRS.02, GRS.03, GRS.04, and GRS.05.



**Figure 18.** The discharge-release depth relationship all for gabion weir and gravel samples used.

**Table 4.** Values of constants  $a(ds)$  and  $b(ds)$ .

Gabion Number	Gravel Sample Number	$q \text{ (m}^3\text{/s/m)}$		$y_{ds} \text{ (m)}$		$a(ds)$	$b(ds)$	$R^2$
		from	to	from	to			
G1	GRS.01	0.00233	0.02800	0.008	0.042	0.4498	0.6761	0.9611
	GRS.02	0.00233	0.03168	0.008	0.034	0.3160	0.6089	0.9635
	GRS.03	0.00233	0.03237	0.008	0.040	0.3971	0.6620	0.9588
	GRS.04	0.00233	0.03990	0.008	0.046	0.3238	0.6136	0.9896
	GRS.05	0.00233	0.05000	0.008	0.063	0.2156	0.5731	0.8370
G2	GRS.01	0.00233	0.02167	0.006	0.018	0.0992	0.4705	0.9836
	GRS.02	0.00233	0.02333	0.006	0.031	0.2604	0.6798	0.7374
	GRS.03	0.00233	0.04333	0.006	0.047	0.4680	0.7655	0.8915
	GRS.04	0.00233	0.04667	0.012	0.049	0.1592	0.4757	0.7602
	GRS.05	0.00233	0.05000	0.007	0.054	0.2210	0.6077	0.8852
G3	GRS.01	0.00233	0.02600	0.008	0.040	0.3409	0.6278	0.9449
	GRS.02	0.00233	0.03168	0.008	0.042	0.2449	0.5734	0.9194
	GRS.03	0.00233	0.03633	0.008	0.044	0.2674	0.5716	0.9810
	GRS.04	0.00233	0.03990	0.008	0.041	0.2326	0.5485	0.9816
	GRS.05	0.00233	0.05000	0.008	0.040	0.1309	0.4951	0.8540
G4	GRS.01	0.00233	0.01613	0.008	0.019	0.1067	0.4645	0.8546
	GRS.02	0.00233	0.02000	0.008	0.019	0.0783	0.4144	0.8348
	GRS.03	0.00233	0.03167	0.008	0.035	0.3030	0.6356	0.9011
	GRS.04	0.00233	0.03000	0.009	0.039	0.2271	0.5873	0.7086
	GRS.05	0.00233	0.04000	0.008	0.027	0.0794	0.4147	0.8056
G5	GRS.01	0.00233	0.02600	0.008	0.036	0.3243	0.6159	0.9755
	GRS.02	0.00233	0.03168	0.008	0.041	0.2880	0.5939	0.9665
	GRS.03	0.00233	0.03633	0.008	0.037	0.2361	0.5510	0.9888
	GRS.04	0.00233	0.03990	0.008	0.043	0.2754	0.5798	0.9941
	GRS.05	0.00233	0.05000	0.008	0.028	0.8479	0.4330	0.7845

**Table 5.** Values of constants A1 and B1.

Gravel Sample Number	$q \text{ (m}^3\text{/s/m)}$		$L_T \text{ (m)}$		$y_{ds} \text{ (m)}$		A1	B1	$R^2$
	from	to	from	to	from	to			
GRS.01	0.00233	0.02800	0.88	1.20	0.115	0.441	0.6039	0.6414	0.7758
GRS.02	0.00233	0.03168	0.88	1.20	0.086	0.443	0.5319	0.6289	0.7550
GRS.03	0.00233	0.04333	0.88	1.20	0.084	0.451	0.3146	0.5059	0.5686
GRS.04	0.00233	0.04667	0.88	1.20	0.074	0.456	0.4619	0.5774	0.8517
GRS.05	0.00233	0.05000	0.88	1.20	0.068	0.442	0.2671	0.5382	0.7689

The final form of equation (6) after applying the regression process is :-

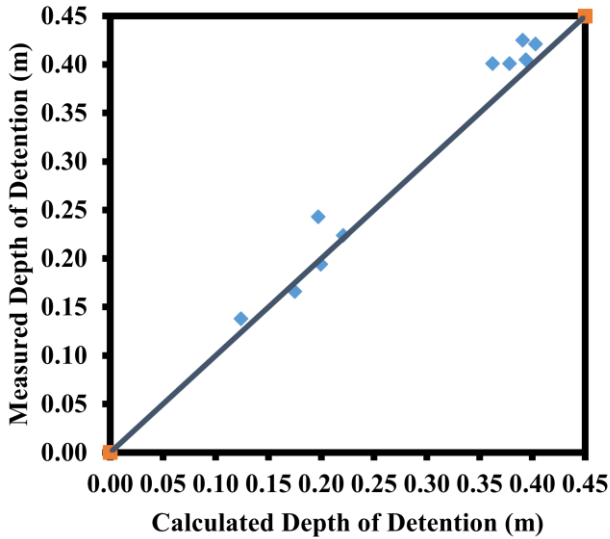
$$\frac{y_{ds}}{L_T} = 0.000674 + 2.502605 \left( \frac{q}{g^{0.5} L_T^{1.5}} \right) - 0.032891 \left( \frac{d}{L_T} \right) \quad R^2 = 0.738 \quad (14)$$

Which is not might be not good for designing purposes. For that another technique was used between the calculated and the measured information.

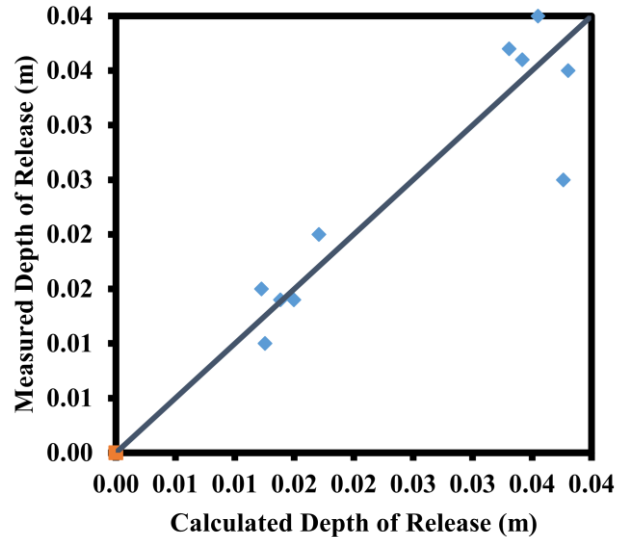
The calculated values of detention and release depths of water, and the measured ones were drawn as in figures 19 and 20 [15]. The data of the first gabion weir model was used to draw this relationship for practical considerations by make an elimination for the data of the second and fifth test runs of each used gravel sample.

$$\frac{y_{us}}{L_T} = 0.246053 + 29.37438 \left( \frac{q}{g^{0.5} L_T^{1.5}} \right) - 4.462720 \left( \frac{d}{L_T} \right) \quad R^2 = 0.915 \quad (15)$$

$$\frac{y_{ds}}{L_T} = 0.013333 + 3.128334 \left( \frac{q}{g^{0.5} L_T^{1.5}} \right) - 0.238162 \left( \frac{d}{L_T} \right) \quad R^2 = 0.903 \quad (16)$$



**Figure 19.** The measured-calculated relationship of the detention depth of water in the first length of gabion weir.



**Figure 20.** The measured-calculated relationship of the release depth of water in the first length of gabion weir.

$$y_{us \text{ measured}} = 1.0657 * y_{us \text{ calculated}} - 0.0013 \quad R^2 = 0.9795 \quad (17)$$

$$y_{ds \text{ measured}} = 0.7692 * (y_{ds \text{ calculated}})^{0.9343} \quad R^2 = 0.8628 \quad (18)$$

To know errors percentage in the readings for both depths, equations (19) and (20) for the first length of the weir model, and tables 6 and 7 present these values.

$$y_{us} \% = \left[ \frac{(y_{us})_{\text{Measured}} - (y_{us})_{\text{Calculated}}}{(y_{us})_{\text{Measured}}} \right] * 100 \quad (19)$$

$$y_{ds} \% = \left[ \frac{(y_{ds})_{\text{Calculated}} - (y_{ds})_{\text{Measured}}}{(y_{ds})_{\text{Calculated}}} \right] * 100 \quad (20)$$

**Table 6.** Errors percentage for detention depth in the first weir length.

Sample Number	Gravel	$y_{us}$ measured (m)		$y_{us}$ calculated (m)		Error %	
		2 <sup>nd</sup> q	5 <sup>th</sup> q	2 <sup>nd</sup> q	5 <sup>th</sup> q	2 <sup>nd</sup> q	5 <sup>th</sup> q
GRS.01	4	0.22	0.42	0.22	0.39	0.01	0.080
GRS.02	4	0.19	0.42	0.20	0.40	0.02	0.043
GRS.03	6	0.16	0.40	0.17	0.37	0.05	0.056
GRS.04	3	0.24	0.40	0.19	0.39	0.18	0.027
GRS.05	8	0.13	0.40	0.12	0.36	0.10	0.096

**Table 7.** Errors percentage for release depth in the first weir length.

Sample Number	Gravel	$y_{ds}$ measured (m)		$y_{ds}$ calculated (m)		Error %	
		2 <sup>nd</sup> q	5 <sup>th</sup> q	2 <sup>nd</sup> q	5 <sup>th</sup> q	2 <sup>nd</sup> q	5 <sup>th</sup> q
GRS.01	4	0.01	0.03	0.01	0.03	0.06	0.118
GRS.02	4	0.01	0.04	0.01	0.03	0.01	0.127
GRS.03	0	0.01	0.03	0.01	0.03	0.20	0.053
GRS.04	0	0.02	0.03	0.01	0.03	0.17	0.079
GRS.05	5	0.01	0.02	0.01	0.03	0.22	0.335

The average values of the data listed in tables 6 and 7 were 5.278% and 0.265% respectively.

## 5 CONCLUSION

For the present study, the following points were concluded :-

- 1- The detention depth value lowers by Increasing the used gravel sample diameter, but there is zero effect of the former on the release depth.
- 2- The different illustrated formulas for the detention and release depths are usefully used for design and scheduling actions in field where it gave a reasonable matching between the measured / calculated values of the studied depths.

3-The errors percentage in average value for both detention and release tested values were 5.278% and 0.265% respectively.

## REFERENCES

1. Al-Fawzy, A M, & Al-Mohammed F M 2019, "Dissipation of Energy of Flow by Conventional Type of Gabion Weir", IOP Publishing IOP Conf. Series: Materials Science and Engineering, 584, 012038, doi:10.1088/1757-899X/584/1/012038
2. Al-Fawzy, A M, Al-Mohammed, F M, Al-Fatlawi, Th J, & Al-Zubaidy R Z 2020, "Dissipation energy of Flow by Stepped Type Gabion Weir IOP Publishing", IOP Conf. Series: Materials Science and Engineering, 737, 012158, doi:10.1088/1757-899X/737/1/012158
3. Al-Fawzy, A M, Al-Shukur, A K, Al-Mohammed, F M, & Hommadi, A H 2023, "Using of Stepped Shape Rock filled Weir as Squandering Energy Structure in Rectangular Channels : A Laboratory Study", 4th International Conference on Architectural & Civil Engineering Sciences, pp. 67-72 doi: <http://doi.org/10.24086/ICACE2022/paper.876>
4. Al-Fawzy, A M, Al-Mohammed, F M, & Alwan, H H 2020, "Energy dissipation in gabion weirs", IOP Publishing IOP Conf. Series: Materials Science and Engineering, 671, 012068, doi:10.1088/1757-899X/671/1/012068
5. Al-Fawzy, A M, Al-Merib, F H, Al-Mohammed, F M, Hommadi, A H, & Al-Zubaidy, R Z 2020, "Effect of using stepped gabions on the distance of the hydraulic jump", IOP Publishing IOP Conf. Series: Materials Science and Engineering, 888, 012061, doi:10.1088/1757-899X/888/1/012061
6. Al-Fawzy, A M, Al-Taee, K N, Al-Mohammed, F M, & Hommadi, A H 2020, "The Hydraulic Jump Formed Downstream a Stepped Gabion Weir: An Experimental Study", IOP Publishing IOP Conf. Series: Materials Science and Engineering, 978, 012018, doi:10.1088/1757899X/978/1/012018
7. Djamaa, W, Ghomri, A, & Al-Fawzy, A M 2022, "Experimental Study of The Sequent Depths Ratio of The Hydraulic Jump in a Rectangular Compound Channel with a Rough Minor Bed", Larhyss Journal Legal Deposit, vol. 1266-2002, pp. 197-206
8. Al-Fawzy, A M, Hasan, I A, & Hasan, H K 2021, "Decision of The Hydraulic State of Rivers within Growth Cities using GIS: Al-Hneidiyah River as Example", E3S Web of Conferences, 318, 04003, ICGE 2021 <https://doi.org/10.1051/e3sconf/202131804003>
9. Al-Fawzy, A M, Hasan, I A, Hasan, H K , & Najm, A N 2021, "Re-distributing the field outlets for irrigation networks within the new growth cities: The Central District of Kerbala city as Example", IOP Publishing Journal of Physics: Conference Series, 1973, 012186, doi:10.1088/1742-6596/1973/1/012186

10. Hommadi, A H, Al-Mohammed, F M, Mutasher, A A, Al Obaidy, A I, AL-Rawi, S S, Almasraf, S A, & Al-Fawzy, A M 2021, "Application of SWRT Technique to Reduce Stress and Water Supply", IOP Publishing IOP Conf. Series: Earth and Environmental Science, 722, 012044, doi:10.1088/1755-1315/722/1/012044
11. Irzooki, R H & Yass, M F 2015, "Hydraulic characteristics of flow over triangular broad crested weirs", Engineering and Technology Journal, University of Technology, vol.33 A, 7, pp. 1186-1196
12. Al-Mohammed, F M, & Mohammed, S H 2015, "Flow through and over gravel gabion weirs", Journal of Kerbala University vol.13, 25 Scientific, pp. 193-205
13. Hussein, N J 2015, "Experimental study of height and surface roughness effects of crump weirs on over flow characteristics", Journal of Babylon University/Engineering Sciences, vol.22, 4, pp. 845-859
14. Maatooq, J S 2016, "Hydraulic characteristics and discharge of canal sluice gate : practical approach", Journal of Engineering, Baghdad University, vol.22, 11, pp. 16-35
15. Al-Fawzy, A M 2021, "Detention and Release in Rectangular Gabion Weir", IOP Publishing Journal of Physics: Conference Series, 1973, 012182, doi:10.1088/1742-6596/1973/1/01218