Detention and Release in Rectangular Gabion Weir

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Abstract. The present paper aims to study the mechanization of detention and release processes when a rectangular gabion weir is used in lined irrigation canals as the preliminary solution to treat the problem of lowering water levels generally during the summer season. At this study a laboratory flume canal with dimensions of 10.0 m long by 0.3 m wide and 0.5 m high was used to carry out the weir experiments. The used hydraulic model constructed with dimensions of 0.3 m width by 0.4 m height, and five different lengths of 0.4, 0.6, 0.8, 1.0, and 1.2 m respectively. Whereas the used gravel samples, as filling material, were of monosized gravel with diameters ranged between 9.5-14.0, 14.0-19.0, 19.0-25.0, 25.0-37.5, and 37.5-50 mm respectively. While the measured discharge values during the experiments were in the range of 0.0007-0.015.0 m³/s, they reached a total of 194 test runs. The results showed that the upstream water depth, as Detention depth, is directly proportional to both of the discharge and the length of the weir, and inversely proportional to the diameter of the used gravel sample, the downstream water depth, as Release depth, is directly proportional with discharge, simultaneously there is no clear effect for both the length weirs length and the used gravel sample on it's value. Finally, both values of detention and release depths are directly proportional to each other. A series of empirical formulas were made for designers to manage detention and release processes for this type of weirs.

1. Introduction
The control of water amount during scarcity seasons considers as a serious problem for engineers and specialists in the field of water resources to ensure equity in water distributions. Using weirs may give a proper distribution of water in canal for irrigation purposes, reduce the hydraulic slope in the canals, and reduce the acting head of water on regulators [1]. Also storing water upstream of dams and weirs in rivers and open channels is necessary for human, irrigation, industrial, and other uses [2]. The submerged weirs consider as the commonly used solid hydraulic structures for detention and uplifting the head of water, measuring the discharge, and controlling the steep gradients in rivers and canals as drop structures [3], an alternative structure made of loose stones such as gabion weir is preferred, since the latter can better meet natural and ecological requirements [1 & 4]. The water is flowing with it in two parts, the base flow through the body of the weir and the flow over the weir [5], which makes it a useful hydraulic structure even for protection of the bed and sides of the natural and artificial channel from scouring process [6]. The increasing need for stores water requires intensive efforts from hydraulic engineers to develop rapid methods for weir design and construction [7]. The objective of this study is to investigate the effect of using the rectangular shape gabion weir on the detention and release processes that formulate inside the lined irrigation canals.
2. Laboratory Work
The tests were carried out in the hydraulic laboratory/College of Engineering/University of Babylon in Iraq. The laboratory has a tilting flume of 10.0 m long with 0.3 m wide and 0.5 m high. The physical models that are used, have lengths 0.4, 0.6, 0.8, 1.0, and 1.2 m, and named as GWNo.I, Gabion Weir Number I, GWNo.II, GWNo.III, GWNo.IV, and GWNo.V respectively. All models have constant cross-section, width 0.3 m and height 0.4 m. in contrast, the gravel samples that used as filling material for the physical models were five monosized gravel samples with diameters ranged between 9.5-14.0 mm, 14.0-19.0 mm, 19.0-25.0 mm, 25.0-37.5 mm, and 37.5-50.0 mm, and numbered as GSNo.I, Gravel Sample Number I, GSNo.II, GSNo.III, GSNo.IV, and GSNo.V respectively. The body of the weir was made of thin steel plates, covered by metal mesh. A photo of GWNo.III with GSNo.III is provided in figure 1. A hydraulic pump with capacity of 0.04 m3/s was used to lift the water to the flume. A total of ten days of the experimental work, and 194 operation tests were carried out and varied between minimum and maximum values of discharges recorded from 0.0007 to 0.15 m3/s, respectively.

3. Dimensional analysis
Simplifying formulas that are used for calculations and design are the aim of the researchers, field engineers, and also farmers to satisfy the fair and successful management of surface irrigation projects by investment of the available water to be delivered with minimizing or prevent head losses to ensure acceptable irrigation efficiency up to the farthest outlets [8]. Generally, the relationships between different parameters can be represented dimensionally in many ways such as standard formulas [4 & 9], empirical equations [6, 8, and 10], direct relationships [5, 7, 11, 12, and 13], or in dimensionless groups [1, 2, 3, 14, 15, 16, and 17].

In detention process, the upstream water depth, \( y_u \), in front of the weir represents the detention depth, and the parameters affect it can be expressed as:

\[
y_u = f_1 \{ q, d, L, \rho, g \}
\]  

Figure 1. A photo of Gabion Weir No.III with Gravel Sample No.III.
Where, \( q \) is the discharge per unit width (m\(^3\)/s), \( d \) is the mean diameter of the used gravel sample (mm), \( L \) is the length of weir (m), \( g \) is the gravitational acceleration (m/s\(^2\)), and \( \rho \) is the Mass density (kg/m\(^3\)).

In release process, the downstream water depth, \( y_d \), at the weir toe represents the release depth, and the parameters that affect it may expressed as :

\[
y_d = f_2 \{q, d, L, \rho, g\}
\] (2)

4. Results and Discussion

4.1. Effect of discharge on the detention depth
The relationship between the discharge and the upstream water depth has been depended in many studies as an essential relationship to understand the behaviour of water over solid structures, and through pervious structures. Besides, [4] consider this relationship is necessary for a weir design. In this study controlling the detention depth upstream the weir is very important to ensure a safe supply of raw water for domestic uses in the first place, and irrigation outlets in the second place for lined canals during the scarcity season. To represent the relationship between the discharge and the detention depth, the linear formula was used as in [11], and figures 2, 3, 4, 5, and 6 show this relationship. While both [10, 14, and 18] were used the power formula to represent this relationship. From the figures 2, 3, 4, 5, and 6, it's clear that the detention depth increases with increasing the value of discharge for all gravel samples used and for all physical models. This direct proportion was achieved as a result by both [1, 3, 7, 12, 13, and 16]. While both of [15, 19, and 20] were just referred to this relationship graphically without a writing the results. Equation (3) shows the Discharge-Detention depth relationship for this study

\[
y_u = a_1(q) + b_1
\] (3)

Where, \( a_1 \) and \( b_1 \) are constants, and Table 1 presents the values of these constants.

4.2. Effect of gravel sample on the detention depth
From the figures 2, 3, 4, 5, and 6. It's obvious that the detention depth decreases with increasing the mean value of diameter of gravel sample used and for all physical models. This result is clearly consonant with that achieved by [11]. By using of Buckingham Pi-Theorem, a general equation can be made to correlate and understand the relationship between the detection depth and the gravel sample used in all physical models,

\[
\frac{y_u}{L} = f_3 \left\{ \frac{q}{g^{0.5}L^{1.5}} \right\} 
\] (4)

Figure 7 shows the relationship between the parameter of equation (4) where each single trend line represents the data of a gravel sample used in all physical models. This figure confirms the fact that the detention depth increases by decreasing the mean diameter of gravel sample used in all physical models. These results lead to another fact that the filling material of the body of the hydraulic structure should be changed to a finer diameter with increasing of the degree of scarcity which is estimated for a chosen study region to ensure a safe level of water inside the irrigation canal. In addition, it is noticed that the values of detention depth are so close to each other at the low discharge values for all gravel samples and physical models used, and that is because of the velocity of water which has a smooth and laminar flow through voids among gravel particles without any effective obstruction and friction, but
with increase of discharge value, the flow obstruction and its friction with the rough surface of gravel particles become obvious which leads to increase the detention depth. The linear formula was used to give a mathematical expression for the parameters of equation (4).

\[
\frac{y_u}{L} = a_2 \left( \frac{q}{g^{0.5} L^{1.5}} \right) + b_2
\]  

(5)

Where, \(a_2\) and \(b_2\) are constants, and Table 2 presents the values of these constants.

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**Figure 2.** The discharge-detention depth relationship for all gravel samples used in Gabion Weir No. I.

**Figure 3.** The discharge-detention depth relationship for all gravel samples used in Gabion Weir No. II.

**Figure 4.** The discharge-detention depth relationship for all gravel samples used in Gabion Weir No. III.

**Figure 5.** The discharge-detention depth relationship for all gravel samples used in Gabion Weir No. IV.
4.3. Effect of gabion length on the detention depth

To obtain the effect of gabion length on the detention depth, two values of discharge, minimum 0.0007 and 0.0036 m$^3$/s, were chosen for comparison purposes.

| GWN. | GSN. | $q$ (m$^3$/s/m) from | to | $y_u$ (m) from | to | $a_1$ | $b_1$ | $R^2$ |
|------|------|----------------------|----|----------------|----|-------|-------|-------|
| I    | I    | 0.00233              | 0.02600 | 0.232        | 0.446 | 08.370 | 0.282 | 0.690 |
|      | II   | 0.00233              | 0.03168 | 0.084        | 0.436 | 12.790 | 0.072 | 0.975 |
|      | III  | 0.00233              | 0.03633 | 0.065        | 0.425 | 10.830 | 0.055 | 0.989 |
|      | IV   | 0.00233              | 0.03767 | 0.060        | 0.412 | 09.945 | 0.048 | 0.996 |
|      | V    | 0.00233              | 0.04675 | 0.062        | 0.425 | 08.104 | 0.061 | 0.994 |
| I    | I    | 0.00233              | 0.02000 | 0.111        | 0.423 | 16.550 | 0.110 | 0.961 |
|      | II   | 0.00233              | 0.02600 | 0.084        | 0.442 | 15.650 | 0.063 | 0.973 |
|      | III  | 0.00233              | 0.03633 | 0.074        | 0.442 | 11.400 | 0.055 | 0.966 |
|      | IV   | 0.00233              | 0.03633 | 0.068        | 0.439 | 11.020 | 0.055 | 0.994 |
|      | V    | 0.00233              | 0.03633 | 0.057        | 0.400 | 10.120 | 0.040 | 0.998 |
| I    | I    | 0.00233              | 0.02000 | 0.100        | 0.430 | 17.730 | 0.086 | 0.982 |
|      | II   | 0.00233              | 0.02000 | 0.075        | 0.401 | 17.610 | 0.055 | 0.989 |
|      | III  | 0.00233              | 0.03168 | 0.073        | 0.425 | 11.920 | 0.062 | 0.991 |
|      | V    | 0.00233              | 0.03633 | 0.067        | 0.423 | 10.380 | 0.058 | 0.994 |
| I    | I    | 0.00233              | 0.02000 | 0.123        | 0.423 | 15.410 | 0.152 | 0.872 |
|      | II   | 0.00233              | 0.02000 | 0.098        | 0.435 | 18.080 | 0.085 | 0.981 |
|      | III  | 0.00233              | 0.03168 | 0.080        | 0.450 | 11.890 | 0.089 | 0.975 |
Table 2. Values of constants $a_2$ and $b_2$.

| GSNo. | $q \text{ (m}^3\text{/s/m)}$ from | $q \text{ (m}^3\text{/s/m)}$ to | $L \text{ (m)}$ from | $L \text{ (m)}$ to | $y_u \text{ (m)}$ from | $y_u \text{ (m)}$ to | $a_2$ | $b_2$ | $R^2$ |
|-------|--------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----|-----|------|
| I     | 0.00233                        | 0.02600         | 0.4             | 1.2             | 0.099           | 0.446           | 38.170 | 0.241 | 0.702 |
| II    | 0.00233                        | 0.03168         | 0.4             | 1.2             | 0.075           | 0.442           | 27.340 | 0.167 | 0.940 |
| III   | 0.00233                        | 0.03633         | 0.4             | 1.2             | 0.055           | 0.450           | 22.100 | 0.161 | 0.940 |
| IV    | 0.00233                        | 0.03767         | 0.4             | 1.2             | 0.055           | 0.445           | 19.790 | 0.156 | 0.941 |
| V     | 0.00233                        | 0.04675         | 0.4             | 1.2             | 0.029           | 0.455           | 16.820 | 0.155 | 0.948 |

Table 3 shows the values of detention depth of all gravel samples and physical models tested in this study at the comparison discharge values. From this table it's clear that the detention depth increases with increasing the length of the gabion weir, and confirm the inverse proportion of detention depth with the mean diameter of the used gravel sample.

The parameters affect the detention depth in equation (1) can be expressed dimensionally as:

$$
\frac{y_u}{L} = 0.164836455 + 2.647269117 \left(\frac{q}{g^{0.5}L^{1.5}}\right)^{0.5} - 12.929313770 \left(\frac{d}{L}\right)^2 \quad R^2 = 0.831441 \quad (6)
$$

Table 3. Values of detention depth at minimum 0.7 and 3.6 l/s comparison discharges.

| GWNo. | $q \text{ (m}^3\text{/s/m)}$ | I    | II   | III  | IV   | V    |
|-------|-----------------|------|------|------|------|------|
| I     | 23.15           | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  |
| II    | 11.10           | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  |
| III   | 10.00           | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  |
| IV    | 12.25           | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  |
| V     | 09.90           | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  | 0.7  | 3.6  |

4.4. Effect of discharge on the release depth

The relationship between the discharge and the release depth can be represented also by using of the linear formula and the figures 8, 9, 10, 11, and 12 show this relationship. These figures show that the release depth increases with increasing the value of discharge for all gravel sample used and for all physical models, but this increment happens slighter than the detention depth which give a fact that there is always a water depth at the weir toe even in low discharge value, also the values of release depth are so close to each other at the low discharge values for all gravel samples and physical models used. Equation (7) shows the Discharge-Release depth relationship for this study.
\[ y_d = a_3(q) + b_3 \] (7)

Where, \(a_3\) and \(b_3\) are constants, and Table 4 presents the values of these constants.

4.5. Effect of gravel sample on the release depth

From the figures 8, 9, 10, 11, and 12. It's obvious that increasing the mean value of diameter of the gravel samples used has no clear indication the release depth for all physical models, and also show a random arrangement for the trend lines which represent the gravel sample in each figure. This result gives a wide range of choice for site engineers and field operators of regulators in emergency cases to use any available gravel sample within the depended design of the hydraulic structure.

The general equation to correlate and understand the relationship between the release depth and the gravel sample used in all physical models can be expressed as:

\[ \frac{y_d}{L} = f_4 \left\{ \frac{q}{g^{0.5}L^{1.5}} \right\} \] (8)

Figure 13 shows the relationship between the parameter of equation (8) where each single trend line represents the data of a gravel sample used in all physical models. This figure confirms the fact that the mean diameter of gravel sample used in all physical models has no clear indication on release depth. These results lead to another fact that the downstream water depth resulted by this hydraulic structure meets the least requirement of water multiple uses without any cut out during the scarcity season whatever filling material used within the design of this structure.

The linear formula was used to give a mathematical expression for the parameters of equation (8).

\[ \frac{y_d}{L} = a_4 \left( \frac{q}{g^{0.5}L^{1.5}} \right) + b_4 \] (9)

Where, \(a_4\) and \(b_4\) are constants, and Table 5 presents the values of these constants.

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**Figure 8.** The discharge-release depth relationship for all gravel samples used in Gabion Weir No. I.

**Figure 9.** The discharge-release depth relationship for all gravel samples used in Gabion Weir No. II.
4.6. Effect of gabion length on the release depth

Table 6 shows the values of release depth for all gravel samples and physical models at the comparison discharge values. From this table it’s obvious that there is no effect of increasing the weir length on the release depth where its value is about 0.6 cm for most readings at the 0.0007 m³/s discharge value. Also, this value takes an undular form at the 0.0036 m³/s discharge value. The parameters affect the release depth in equation (2) can be expressed dimensionally as:

$$\frac{y_d}{L} = 0.058129746 + 1.243568061 \left( \frac{q}{g^{0.5} L^{1.5}} \right)^{0.5} - 0.980445023 \left( \frac{d}{L} \right)^2$$

$$R^2 = 0.9498$$  \hspace{1cm} (10)

Figure 10. The discharge-release depth relationship for all gravel samples used in Gabion Weir No. III.

Figure 11. The discharge-release depth relationship for all gravel samples used in Gabion Weir No. IV.

Figure 12. The discharge-release depth relationship for all gravel samples used in Gabion Weir No. V.

Figure 13. The relationship between the parameters of equation 8.
### Table 4. Values of constants $a_3$ and $b_3$.

| GWNo. | GSNo. | $q\ (m^3/s/m)$ | $y_d\ (m)$ | $a_3$ | $b_3$ | $R^2$ |
|-------|-------|----------------|------------|-------|-------|-------|
|       | I     | 0.00233        | 0.02600    | 0.007 | 0.035 | 0.006 | 0.966 |
|       | II    | 0.00233        | 0.03168    | 0.006 | 0.033 | 0.003 | 0.990 |
|       | III   | 0.00233        | 0.03633    | 0.006 | 0.038 | 0.004 | 0.998 |
|       | IV    | 0.00233        | 0.03767    | 0.008 | 0.048 | 0.010 | 0.966 |
|       | V     | 0.00233        | 0.04675    | 0.006 | 0.043 | 0.007 | 0.971 |
|       | I     | 0.00233        | 0.02000    | 0.006 | 0.023 | 0.006 | 0.956 |
|       | II    | 0.00233        | 0.02600    | 0.006 | 0.030 | 0.005 | 0.973 |
|       | III   | 0.00233        | 0.03633    | 0.007 | 0.048 | 0.003 | 0.935 |
|       | IV    | 0.00233        | 0.03633    | 0.008 | 0.043 | 0.007 | 0.984 |
|       | V     | 0.00233        | 0.03633    | 0.006 | 0.040 | 0.007 | 0.971 |
|       | I     | 0.00233        | 0.02000    | 0.006 | 0.021 | 0.005 | 0.976 |
|       | II    | 0.00233        | 0.02000    | 0.007 | 0.022 | 0.007 | 0.948 |
|       | III   | 0.00233        | 0.02600    | 0.004 | 0.026 | 0.005 | 0.928 |
|       | IV    | 0.00233        | 0.03168    | 0.007 | 0.036 | 0.004 | 0.992 |
|       | V     | 0.00233        | 0.03633    | 0.008 | 0.043 | 0.006 | 0.903 |
|       | I     | 0.00233        | 0.02000    | 0.006 | 0.022 | 0.005 | 0.963 |
|       | II    | 0.00233        | 0.02000    | 0.006 | 0.025 | 0.005 | 0.980 |
|       | III   | 0.00233        | 0.03168    | 0.006 | 0.036 | 0.005 | 0.985 |
|       | IV    | 0.00233        | 0.03168    | 0.006 | 0.036 | 0.006 | 0.971 |
|       | V     | 0.00233        | 0.03633    | 0.006 | 0.038 | 0.007 | 0.965 |
|       | I     | 0.00233        | 0.02333    | 0.005 | 0.032 | -0.001 | 0.971 |
|       | II    | 0.00233        | 0.02667    | 0.007 | 0.034 | 0.005 | 0.994 |
|       | III   | 0.00233        | 0.03000    | 0.006 | 0.044 | 0.003 | 0.988 |
|       | IV    | 0.00233        | 0.03333    | 0.006 | 0.027 | 0.008 | 0.917 |
|       | V     | 0.00233        | 0.03667    | 0.006 | 0.034 | 0.009 | 0.856 |

### Table 5. Values of constants $a_4$ and $b_4$.

| GSNo. | $q\ (m^3/s/m)$ | $L\ (m)$ | $y_d\ (m)$ | $a_4$ | $b_4$ | $R^2$ |
|-------|----------------|----------|------------|-------|-------|-------|
|       | from to | from to | from to |       |       |       |
| I     | 0.00233 | 0.02600 | 0.4 | 1.2 | 0.007 | 0.021 | 0.2811 | 0.007 | 0.948 |
| II    | 0.00233 | 0.03168 | 0.4 | 1.2 | 0.007 | 0.022 | 0.1846 | 0.010 | 0.964 |
| III   | 0.00233 | 0.03633 | 0.4 | 1.2 | 0.007 | 0.026 | 0.2367 | 0.011 | 0.902 |
| IV    | 0.00233 | 0.03767 | 0.4 | 1.2 | 0.008 | 0.027 | 0.2287 | 0.010 | 0.966 |
| V     | 0.00233 | 0.04675 | 0.4 | 1.2 | 0.008 | 0.034 | 0.0995 | 0.021 | 0.437 |
Table 6. Values of release depth at minimum 0.7 and 3.6 l/s comparison discharges.

| GSNo. | I  | II | III | IV  | V  | I  | II |
|-------|----|----|-----|-----|----|----|----|
| GWNo. | q  | 0.7 | 3.6 | 0.7 | 3.6 | 0.7 | 3.6 | 0.7 | 3.6 | 0.7 | 3.6 |
| I     | 0.007 | 0.023 | 0.006 | 0.013 | 0.006 | 0.016 | 0.008 | 0.017 | 0.006 | 0.019 |
| II    | 0.006 | 0.018 | 0.006 | 0.015 | 0.007 | 0.015 | 0.008 | 0.021 | 0.006 | 0.017 |
| III   | 0.006 | 0.015 | 0.007 | 0.017 | 0.004 | 0.018 | 0.007 | 0.016 | 0.008 | 0.019 |
| IV    | 0.006 | 0.016 | 0.006 | 0.017 | 0.006 | 0.018 | 0.006 | 0.020 | 0.006 | 0.021 |
| V     | 0.005 | 0.015 | 0.007 | 0.016 | 0.006 | 0.016 | 0.006 | 0.017 | 0.006 | 0.020 |

4.7. The detention – release depths relationship

For design and operation purposes, the relationship between both the detention and release depths should be made to correlate and control the two processes during the release of water from the main canals. Figures 14, 15, 16, 17, and 18 show this relationship. From these figures, it's clear that they have a direct proportion for all gravel samples and all physical models. The linear form was used to obtain equation of detention – release depths.

\[ y_u = a_5 (y_d) + b_5 \]  

Where, \( a_5 \) and \( b_5 \) are constants, and Table 7 presents the values of these constants. The relation between the calculated and measured values of detention and release depths can be represented and plotted as followed by [2, 3, 11, and 14] and so many researchers as in figures 19a, 19b, 20a, and 20b. 60% of data was used for regression process by using of Micro-Soft Excel computer Program, (data collected for test runs of the 1st, 3rd, and 5th lengths of the gabion weir), and 40% of data was used for verification of the resulted formula, (data collected for test runs of 2nd and 4th lengths of the gabion weir). According to these figures, a good agreement has been achieved between these values. Equations (12), (13), (14), and (15) present the relationship between the calculated and measured values of detention and release depths plotted in figures 19a, 19b, 20a, and 20b respectively.

Figure 14. The release-detection depth relationship for all gravel samples used in Gabion Weir No. I.

Figure 15. The release-detection depth relationship for all gravel samples used in Gabion Weir No. II.
| GWNo. | GSNo. | $y_d(m)$ | $y_d(m)$ | $a_5$ | $b_5$ | $R^2$ |
|-------|-------|----------|----------|-------|-------|-------|
|       |       | from     | to       |       |       |       |
| I     | I     | 0.232    | 0.446    | 0.007 | 0.035 | 08.370| 0.282 | 0.690 |
|       | II    | 0.084    | 0.436    | 0.006 | 0.033 | 12.760| 0.072 | 0.975 |
|       | III   | 0.065    | 0.425    | 0.006 | 0.038 | 10.830| 0.055 | 0.989 |
|       | IV    | 0.060    | 0.412    | 0.008 | 0.048 | 09.945| 0.048 | 0.996 |
|       | V     | 0.062    | 0.425    | 0.006 | 0.043 | 08.104| 0.061 | 0.994 |
| II    | I     | 0.111    | 0.423    | 0.006 | 0.023 | 18.750| -0.009| 0.998 |
|       | II    | 0.084    | 0.442    | 0.006 | 0.030 | 16.540| -0.005| 0.832 |
|       | III   | 0.074    | 0.442    | 0.007 | 0.048 | 09.837| 0.042 | 0.876 |
|       | IV    | 0.068    | 0.439    | 0.008 | 0.043 | 11.020| 0.055 | 0.994 |
|       | V     | 0.057    | 0.400    | 0.006 | 0.040 | 10.120| 0.040 | 0.998 |
| III   | I     | 0.100    | 0.430    | 0.006 | 0.021 | 22.250| -0.036| 0.997 |
|       | II    | 0.075    | 0.401    | 0.007 | 0.022 | 21.270| -0.092| 0.980 |
|       | III   | 0.086    | 0.419    | 0.004 | 0.026 | 14.510| 0.004 | 0.962 |
|       | IV    | 0.073    | 0.425    | 0.007 | 0.036 | 11.920| 0.062 | 0.991 |
|       | V     | 0.067    | 0.423    | 0.008 | 0.043 | 10.380| 0.058 | 0.994 |
| IV    | I     | 0.123    | 0.423    | 0.006 | 0.022 | 18.470| 0.049 | 0.946 |
|       | II    | 0.098    | 0.435    | 0.006 | 0.025 | 17.950| -0.003| 0.995 |
|       | III   | 0.080    | 0.450    | 0.006 | 0.036 | 11.990| 0.021 | 0.992 |
|       | IV    | 0.071    | 0.440    | 0.006 | 0.036 | 11.850| 0.066 | 0.988 |
|       | V     | 0.069    | 0.424    | 0.006 | 0.038 | 10.610| 0.060 | 0.990 |
| V     | I     | 0.099    | 0.440    | 0.005 | 0.032 | 17.200| 0.089 | 0.917 |
|       | II    | 0.109    | 0.425    | 0.007 | 0.034 | 12.750| 0.126 | 0.915 |
|       | III   | 0.055    | 0.445    | 0.006 | 0.044 | 14.080| 0.072 | 0.925 |
|       | IV    | 0.060    | 0.460    | 0.006 | 0.027 | 13.510| 0.077 | 0.883 |
|       | V     | 0.029    | 0.429    | 0.006 | 0.034 | 11.800| 0.048 | 0.939 |
Figure 16. The release-detention depth relationship for all gravel samples used in Gabion Weir No. III.

Figure 17. The release-detention depth relationship for all gravel samples used in Gabion Weir No. IV.

Figure 18. The release-detention depth relationship for all gravel samples used in Gabion Weir No. V.
Figure 19a. The measured-calculated relationship of the detention depth in the 2nd length of the gabion Weir.

Figure 19b. The measured-calculated relationship of the detention depth in the 4th length of the gabion Weir.

Figure 20a. The measured-calculated relationship of the release depth in the 2nd length of the gabion Weir.

Figure 20b. The measured-calculated relationship of the release depth in the 4th length of the gabion Weir.

\[ y_u \text{ measured} = 0.455 \ y_u \text{ calculated} + 0.118 \quad R^2 = 0.920 \quad (12) \]

\[ y_u \text{ measured} = -12.70 \ (y_u \text{ calculated})^3 + 11.42 \ (y_u \text{ calculated})^2 - 2.63 \ (y_u \text{ calculated}) + 0.417 \quad R^2 = 0.928 \quad (13) \]
The percentage of errors for both values of detention and release, measured and calculated, was obtained by equations (16) and (17) for the 2nd and 4th lengths of gabion weir respectively, and tables 8, 9, 10, and 11 present these values.

\[ y_u \% = \frac{(y_u)_{\text{Calculated}} - (y_u)_{\text{Measured}}}{(y_u)_{\text{Calculated}}} \]  
\[ (16) \]

\[ y_d \% = \frac{(y_d)_{\text{Calculated}} - (y_d)_{\text{Measured}}}{(y_d)_{\text{Calculated}}} \]  
\[ (17) \]

**Table 8.** Values of percentage of errors for detention depth in the 2nd gabion weir length.

| GSN0. | \( y_u \) measured (m) | \( y_u \) calculated (m) | Error % |
|-------|------------------------|------------------------|---------|
|       | from | to | from | to | from | to |                   |         |
| I     | 0.111 | 0.423 | 0.160 | 0.282 | 0.3042 | -0.4994 |
| II    | 0.084 | 0.442 | 0.157 | 0.305 | 0.4637 | -0.4477 |
| III   | 0.074 | 0.442 | 0.152 | 0.339 | 0.5134 | -0.3022 |
| IV    | 0.068 | 0.439 | 0.141 | 0.329 | 0.5193 | -0.3352 |
| V     | 0.057 | 0.400 | 0.121 | 0.309 | 0.5299 | -0.2962 |

**Table 9.** Values of percentage of errors for detention depth in the 4th gabion weir length.

| GSN0. | \( y_u \) measured (m) | \( y_u \) calculated (m) | Error % |
|-------|------------------------|------------------------|---------|
|       | from | to | from | to | from | to |                   |         |
| I     | 0.123 | 0.423 | 0.235 | 0.375 | 0.4794 | -0.1292 |
| II    | 0.098 | 0.435 | 0.234 | 0.373 | 0.5804 | -0.1667 |
| III   | 0.176 | 0.450 | 0.231 | 0.425 | 0.2397 | -0.0588 |
| IV    | 0.148 | 0.440 | 0.224 | 0.418 | 0.3407 | -0.0526 |
| V     | 0.123 | 0.424 | 0.212 | 0.425 | 0.4208 | 0.0023 |

**Table 10.** Values of percentage of errors for release depth in the 2nd gabion weir length.

| GSN0. | \( y_d \) measured (m) | \( y_d \) calculated (m) | Error % |
|-------|------------------------|------------------------|---------|
|       | from | to | from | to | from | to |                   |         |
| I     | 0.007 | 0.023 | 0.039 | 0.074 | 0.8348 | 0.6872 |
| II    | 0.007 | 0.030 | 0.039 | 0.081 | 0.8342 | 0.6281 |
| III   | 0.008 | 0.048 | 0.039 | 0.091 | 0.8078 | 0.4740 |
| IV    | 0.008 | 0.044 | 0.039 | 0.091 | 0.7925 | 0.5209 |
| V     | 0.006 | 0.040 | 0.038 | 0.090 | 0.4807 | 0.5551 |
Table 11. Values of percentage of errors for release depth in the 4th gabion weir length.

| GSNo. | \(y_d\) measured (m) from | to | \(y_d\) calculated (m) from | to | Error % from | to |
|-------|---------------------------|---|-----------------------------|---|-------------|---|
| I     | 0.006                     | 0.022 | 0.056                      | 0.095 | 0.8934     | 0.7688 |
| II    | 0.006                     | 0.035 | 0.056                      | 0.095 | 0.8933     | 0.7370 |
| III   | 0.006                     | 0.036 | 0.056                      | 0.110 | 0.8928     | 0.6727 |
| IV    | 0.006                     | 0.036 | 0.056                      | 0.110 | 0.8928     | 0.6727 |
| V     | 0.006                     | 0.038 | 0.055                      | 0.115 | 0.8915     | 0.6686 |

5. Conclusions

In the present study, the detention and release in the rectangular type of gabion weir has been investigated by studying the factors affecting these depths by this hydraulic structure. Within the limitations of this study, it has been concluded that:-

1. Both the detention and release depths increase by increasing the discharge.
2. The detention depth decreases by increasing the mean diameter of the used gravel sample, while the latter has no clear indication on the release depth.
3. The detention depth increase by increasing the length of the gabion weir, while the latter has no effect on the release depth.
4. The detention depth has a direct proportion with the release depth.
5. General formulas have been created for detention and release depths, and a good agreement for comparison between measured and calculated values of these depths has been achieved.

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