Effect of Upstream Accumulated Sediments on Fayoum Type Weir Efficiency.

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تأثير الرسوبيات المتراكمة علي كفاءة الهدار من النوع الفيومي

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الخلاصة

نتيجة التغيرات التي تحدث في معدلات التصرفات المارة في الأنهار والقنوات المائية ، تحدث تراكمات متتالية للرسوبيات أمام الهدارات وبمعدلات متغيرة مع الزمن. في هذا البحث تم عمل دراسة معملية لتحديد نسبة تأثير تلك الرسوبيات المتراكمة علي كفاءة الهدارات من النوع الفيومي (ذو العرض الضيق). استخدمت أربع قيم مختلفة من التصرفات المارة وهي 8 لتر/ثانية، 10 لتر/ثانية، 13 لتر/ثانية و 15 لتر/ثانية كما استخدم أيضا عدد أربعة نماذج خشبية مختلفة المقاسات لتمثل الرسوبيات المتراكمة. أجريت هذه الدراسة علي قناة معملية ذات أبعاد 12 متر (طول) × 40 سم (عرض) × 40 سم (عمق). من أهم النتائج التي تم التوصل إليها من هذه الدراسة أنه مع زيادة حجم الرسوبيات المتراكمة أمام الهدار يقل الضاغط (H) (إرتفاع المياه فوق قمة الهدار) بحوالي 16% تقريبا ويزداد قيمة معامل التصرف (Cd) بحوالي 38% تقريبا. كما ينتج أيضا تناقص تدريجي لمنحني المياه الخلفي أمام الهدار ويقل أكبر ارتفاع لذلك المنحني بحوالي 5,3 %. توصي هذه الدراسة بإزالة الرسوبيات المتراكمة أمام الهدارات وذلك لتحسين كفائتها ورفع مناسيب المياة أمامها.

Abstract

Under various conditions of flows in open channels with time, sediments are accumulated gradually upstream weirs. Accumulated sediments upstream weirs cause the back water curve and discharge coefficient (Cd) of weirs to change. For this reason, the effect of four different models of accumulated sediments on the discharge coefficient and the maximum height of backwater curve (Z) of Fayoum type weir (narrow crested weir) had been experimentally investigated. In this research, four values of discharges equal to 8 lit. /sec., 10 lit. /sec., 13 lit. /sec. and 15 lit. /sec. were used. From the analysis of results, compared with the case of no sediments, it was observed that with the increasing of accumulated sediments, the head over weir crest (H) decreased by about 16 % and consequently, the discharge coefficient of weir increased by about 38 %. The maximum height of back drawdown water curve upstream weir (Z) decreased gradually with the increasing of accumulated sediments by about 5.3%. For the aforementioned analysis, it is recommended to eliminate all of accumulated sediments upstream Fayoum type weirs for improving the performance.

Key words

Sediments, Fayoum weirs, Open channels, Experimental work.

1. Introduction

A weir is considered to be a barrier across any channel or river. It used to alter its flow properties. Usually, weirs used as obstructions and could be considered small compared with dams. They used for pooling water behind them and also, allowing it to flow over their tops. Weirs also are used to change the flow of natural rivers or canals for preventing them from flooding, measuring discharge, and help render rivers to be navigable.

Weirs may be used for reducing the hydraulic slope in channels and also, the head on regulators. With the increase of water demands, the capacity of the used weirs built on canals and the embankment of the canals themselves upstream of the weirs becoming insufficient to pass this

increase of high water demands. So, the proposed solutions are modifying the old structures or replacing them by new ones.

According to the first solution, this requires a modification of the hydraulic characteristics of the weirs while the second is costly prohibitive. The modifications may be concluded in lowering weir crest or operating the existing pipes used at the bottom for emptying the canals to pass extra flow rates to downstream (Gonzalez and Chanson, 2007).

Narrow crested weirs (Fayoum type weirs) may be considered as common engineering structures used in irrigation system in Egypt, especially in Fayoum.

The name "Fayoum type weir" became known (Abdel Halim et al., 1991). Weirs, gates and pipes are usually used individually. Aggradation and degradation processes with time through rivers or canals cause sediments to accumulate upstream weirs or any other structures. Then, a combination of weirs, gates and pipes may be used to eliminate the upstream accumulated sediments.

Works concerning the flow over weirs have been mentioned by Boss et al. (1986), Hager and Schwalt (1994), Mohamed (2005), Göğüş et al. (2006), Sargison and Percy (2009), and many others. A combination of a weir and a gate has been studied recently by many engineers and investigators. Among of them are Alhamid et al. (1997), Negm et al. (1997), Alhamid (1999), Ferro (2000), Ansar (2001) and Negm et al. (2002).

Depending on the pipe conditions and the water elevation on either side of the weir, flow is classified into three different categories; free orifice where the pipe is free pipe, submerged orifice with free overfall weir and submerged pipe and submerged weir (Samani and Mazaheri, 2009).

To find out the relationship between sediments and weirs, the CCHE2D model was used to simulate the sediment transport and the bed morphological changes in the upstream and downstream reach of Chi-Chi Weir in Choshui River, Taiwan (Yeh et al., 2010). The model has been modified to handle the bedrock erosion which was feasible and applicable to the field engineering problem. The main conclusions are; the CCHE2D model is capable of simulating sediment transport and morphological changes within the study reach with unsteady boundary conditions for the flow and sediment; the wetting and drying treatment technique of the model makes simulations with complex morphology very efficient; and the uncertainty of the data such as channel bed topography, sediment load, its composition and bed material composition may affect the prediction accuracy of the numerical model. In this research, the effect of accumulative sediments on the characteristics of Fayoum type weir would be experimentally investigated.

2. Experimental work

The present experiments were conducted in a rectangular flume with a mild slope of 0.40 m wide, 0.40 m deep, and 12.0 m long, with 2.0 m long Perspex sides, **Fig. (1.a) and Fig. (1.b),** in irrigation and hydraulics laboratory of the faculty of engineering, El-Mansoura University.
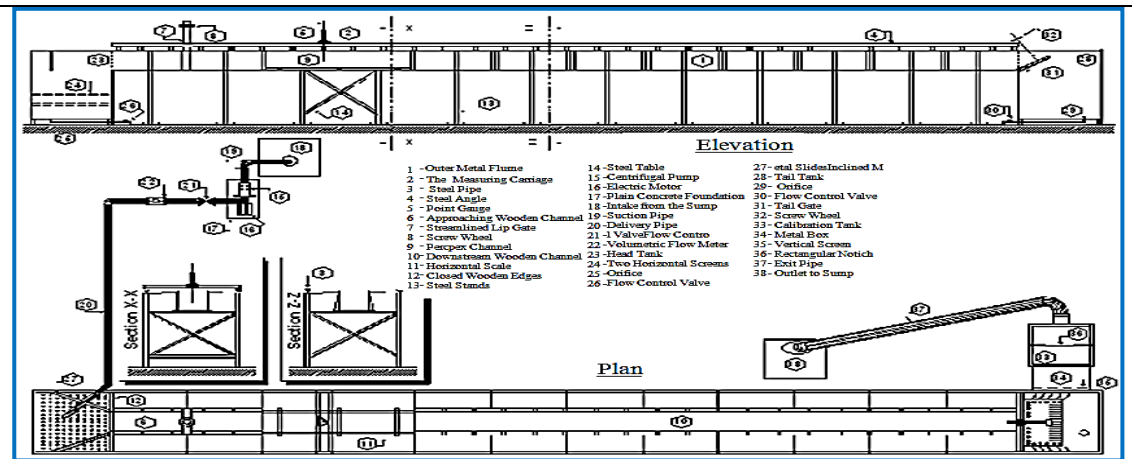
Fig. (1.a): Experimental apparatus and circulating system.

Fig. (1.b): The apparatus and its 'side view'.

Different four wooden models of accumulated sediments are used as shown in **Fig. (2)** and **Table (1).** A narrow wooden crested weir with crest width of 4 cm and 15 cm in height with a base width of 11.5 cm is chosen for experimental tests. The general layout of these models is illustrated in **Fig. (3).**
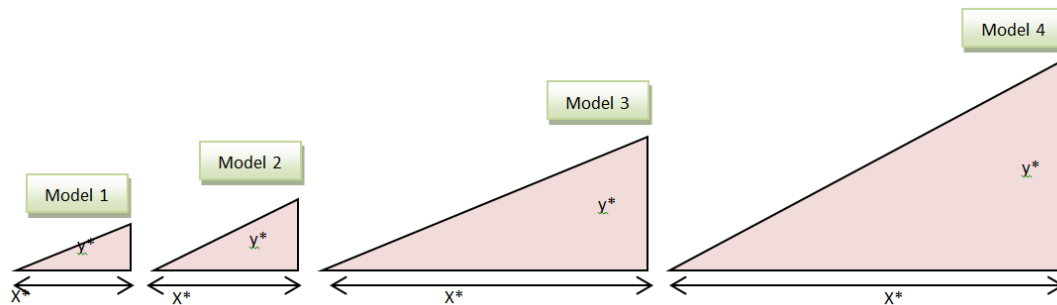

Fig. (2): Sketch of selected wooden models.

Table (1): Dimensions of selected models.

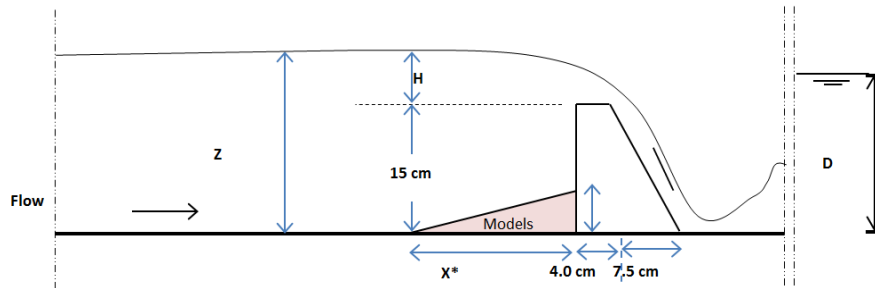| Model No.	X* (cm)	y* (cm)
1	5	2
2	7	3
3	14	7
4	17	10

Fig (3): Layout of models

where:

D = downstream normal water depth;

H = head of water above weir crest; and

Z = maximum height of back water curve.

After adjustment of the models, different four discharges of 8 lit. /sec., 10 lit. /sec., 13 lit. /sec. and 15 lit. /sec. are used. The downstream normal water depth (D) and the corresponding normal water velocity are measured, **Table (2).**

Table (2): Used discharges and the corresponding measured D.S. depths and velocities.

Discharge Q lit. /sec.	D.S. normal water depth (D) cm	corresponding water velocity (V) m/sec.
8.0	20.00	0.10
10.0	20.80	0.12
13.0	21.70	0.15
15.0	22.80	0.16

For each discharge, the maximum height of back water curve (Z) and the head over weir crest (H) are measured, then, the discharge coefficient (Cd) is calculated from the following equation:

$$Q = \frac{2}{3} \, Cd \, B \, \sqrt{2g} \, H^{\frac{3}{2}} \quad \text{................... (1)}$$

where;

Q = discharge;

Cd= discharge coefficient;

B = weir width (equals 40 cm = channel width for all runs);

g = gravitational acceleration; and

H = head over weir crest.

The experimental runs are repeated again with each of accumulated sediments models with the different four discharges.

3. Results and analysis

The first part of analysis concerns with the effect of selected different used models of accumulated sediments on the head of water over weir crest (H) and the corresponding discharge coefficient (Cd). The second one of analysis exhibits the effect of the used models on the maximum height of back water curve. These analyses are important to determine the situation of removing sediments.

- ***Head over Weir Crest (H) and Discharge Coefficient (Cd)***

The effect of accumulated sediments upstream weir on the head over weir crest (H) and the discharge coefficient (Cd) using the selected four discharges of 8 lit. /sec.,

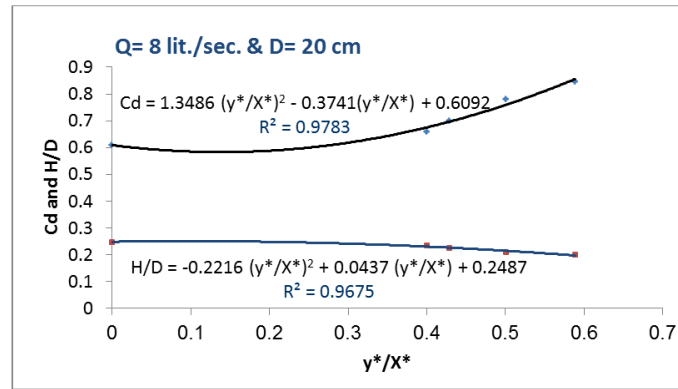10 lit. /sec., 13 lit. /sec. and 15 lit. /sec. respectively is illustrated in **Figs. (4)** Through **(7).**

Fig. (4): Effect of accumulated sediment size ratio on Cd and (H/D) for Q = 8.0 lit. /sec.
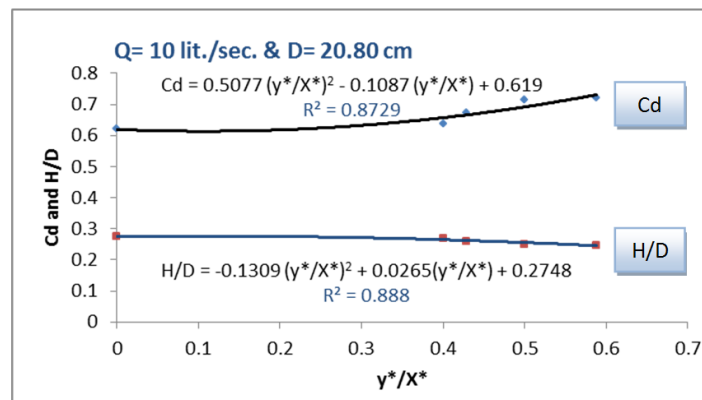

Fig. (5): Effect of accumulated sediment size ratio on Cd and (H/D) for Q = 10 lit. /sec.
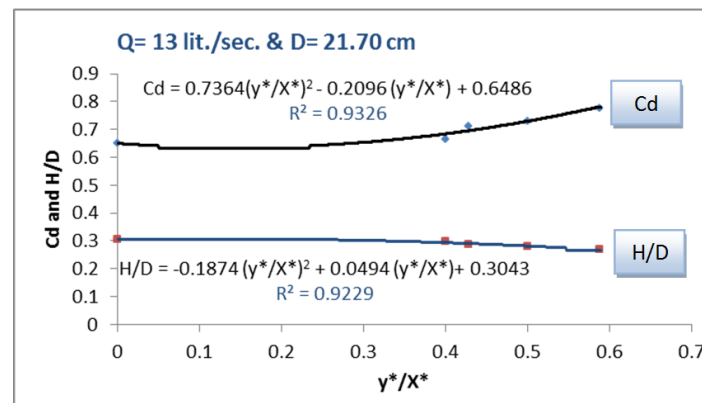

Fig. (6): Effect of accumulated sediment size ratio on Cd and (H/D) for Q =13 lit. /sec.
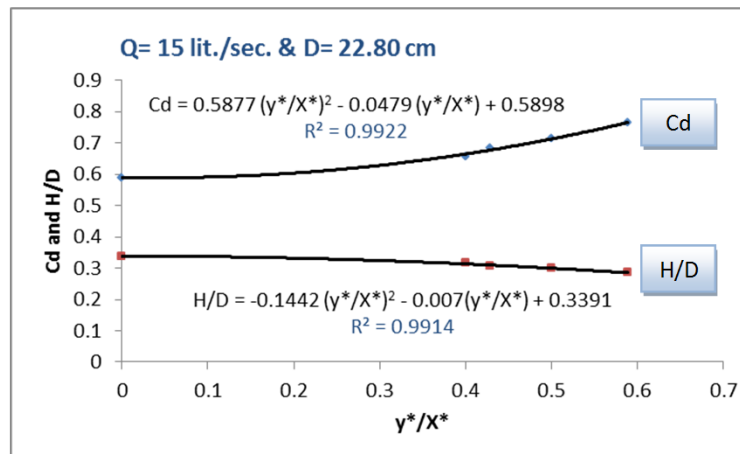
Fig. (7): Effect of accumulated sediment size ratio on Cd and (H/D) for Q =15 lit. /sec.

From analysis of the abovementioned figures, it is illustrated that with the increasing of the accumulated sediments the head above weir crest (H) decreases gradually and the corresponding values of discharge coefficient (Cd) increase by polynomial equations of the second degree for all discharges.

To associate all affecting parameters with each other's, dimension analysis is carried out. Equations (2) through (9) presents the relation between sediment size ratio (y*/X*) and both of the ratio of head over weir crest with D.S. normal water depth (H/D) and the corresponding discharge coefficient (Cd).

at Q=8.0 lit. /sec.

$$\frac{H}{D} = -0.2216 \left(\frac{y*}{X*}\right)^2 + 0.0437 \left(\frac{y*}{X*}\right) + 0.2487 \quad (R^2 = 0.9675) \dots\dots\dots\dots \dots\dots\dots (2)$$

$$Cd = +1.3486 \left(\frac{y*}{X*}\right)^2 - 0.3741 \left(\frac{y*}{X*}\right) + 0.6092 \quad (R^2 = 0.9783) \quad \dots\dots\dots \dots\dots\dots (3)$$

▪ at Q=10.0 lit. /sec.

$$\frac{H}{D} = -0.1309 \left(\frac{y*}{X*}\right)^2 + 0.0265 \left(\frac{y*}{X*}\right) + 0.2748 \quad (R^2 = 0.8880) \dots\dots\dots\dots\dots\dots\dots (4)$$

$$Cd = +0.5077 \left(\frac{y*}{X*}\right)^2 - 0.1087 \left(\frac{y*}{X*}\right) + 0.6190 \quad (R^2 = 0.8729) \dots\dots\dots\dots\dots\dots (5)$$

▪ at Q=13.0 lit. /sec.

$$\frac{H}{D} = -0.1874 \left(\frac{y*}{X*}\right)^2 + 0.0494 \left(\frac{y*}{X*}\right) + 0.3043 \quad (R^2 = 0.9229) \dots\dots\dots\dots \dots\dots\dots (6)$$

$$Cd = +0.7364 \left(\frac{y*}{X*}\right)^2 - 0.2096 \left(\frac{y*}{X*}\right) + 0.6480 \quad (R^2 = 0.9326) \dots\dots\dots\dots\dots \dots\dots (7)$$

- **at Q=15.0 lit. /sec.**

$$\frac{H}{D} = -\,0.1442\left(\frac{y*}{X*}\right)^2 + 0.0070\left(\frac{y*}{X*}\right) + 0.3391 \quad (R^2 = 0.9914) \dots\dots\dots\dots\dots\dots \ (8)$$

$$Cd = +0.5877\left(\frac{y*}{X*}\right)^2 - 0.0479\left(\frac{y*}{X*}\right) + 0.589 \quad (R^2 = 0.9922) \dots\dots\dots\dots\dots\dots \ (9)$$

From the analysis of results, compared with the case of no sediments, it is observed that with the increasing of the accumulated sediments, the head over weir crest (H) decreases by about 16 % and consequently, the discharge coefficient (Cd) of weir increases by about 38 % as average percentage for all discharges. So, it is recommend removing the accumulated sediments upstream weirs to raise the heading up and water level.

- ### *Maximum rise of Back Water Curve*

The effect of accumulated sediments upstream weir is obviously appeared on the head over crest for all discharges as mentioned before, and consequently, it is important to determine exactly this effect on the maximum water height upstream weir of the back water curve (Z) for all used selected models.

Figs. (8) through **(13)** show the change of maximum height of back water curve divided on D.S. normal water depth (Z/D) with the variation of accumulated sediments size ratio (y*/X*) for all discharges respectively.
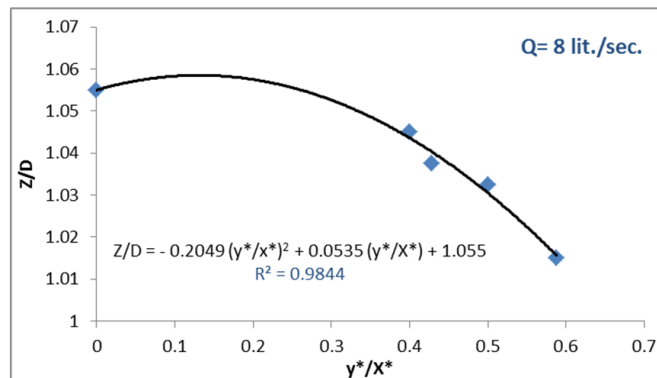

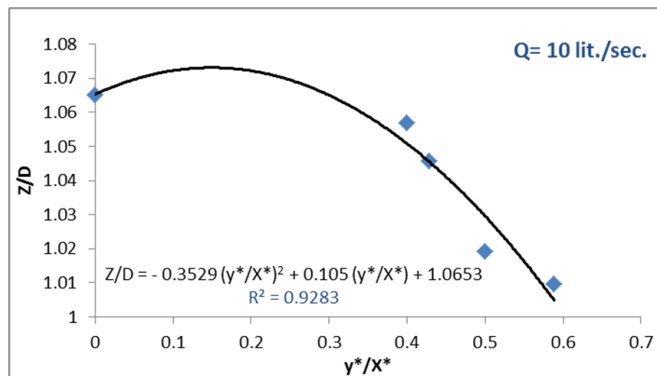*Fig. (8): Effect of accumulated sediments size ratio on (Z/D) for Q =8 lit. /sec.*

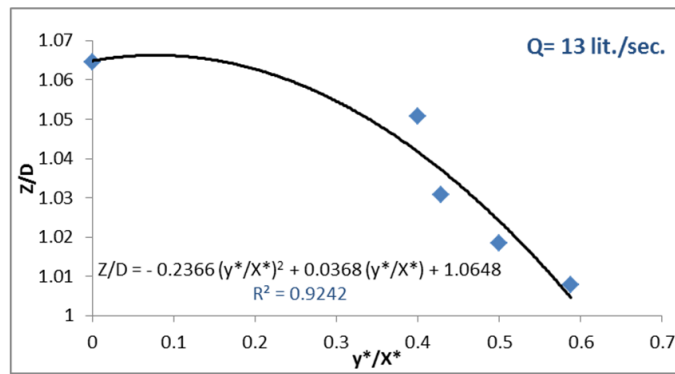*Fig. (9): Effect of accumulated sediments size ratio on (Z/D) for Q =10 lit. / sec.*

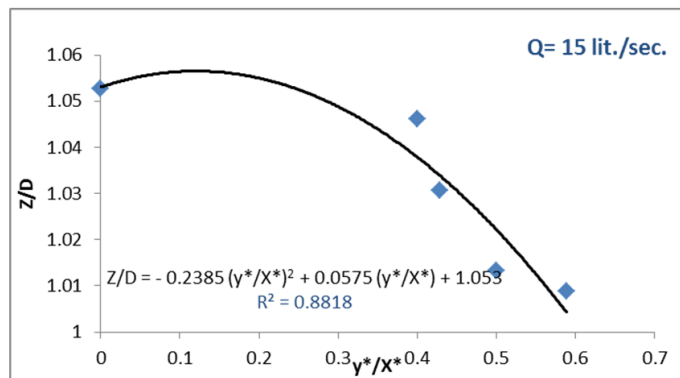*Fig. (10): Effect of accumulated sediments size ratio on (Z/D) for Q =13 lit. / sec.*

Fig. (11): Effect of accumulated sediments size ratio on (Z/D) for Q =15 lit. / sec.

The effect of accumulated sediments size ratio (y*/X*) on the ratio between maximum back water height and D.S. normal depth ratio (Z/D) for all discharges, could be appeared in Equations (10) through (13).

■ **at Q=8.0 lit. /sec.**

$$\frac{Z}{D} = -\ 0.2049 \left(\frac{y*}{X*}\right)^2 + 0.0535 \left(\frac{y*}{X*}\right) + 1.055 \quad (R^2 = 0.9844) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

■ **at Q=10.0 lit. /sec.**

$$\frac{Z}{D} = -\ 0.3529 \left(\frac{y*}{X*}\right)^2 + 0.105 \left(\frac{y*}{X*}\right) + 1.0653 \quad (R^2 = 0.9283) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

■ **at Q=13.0 lit. /sec.**

$$\frac{Z}{D} = -\ 0.2366 \left(\frac{y*}{X*}\right)^2 + 0.0368 \left(\frac{y*}{X*}\right) + 1.0648 \quad (R^2 = 0.9242) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

- **at Q=15.0 lit. /sec.**

$$\frac{Z}{D} = -0.2385 \left(\frac{y*}{X*}\right)^2 + 0.0575 \left(\frac{y*}{X*}\right) + 1.055 \quad (R^2 = 0.8818) \dots\dots\dots\dots\dots\dots\dots (13)$$

The maximum height of back water curve upstream weir (Z) decreases gradually with the increasing of accumulated sediments by about 5.3% as average percentage for all range of used discharges. For this reasons and analysis it is recommended to eliminate all of accumulated sediments upstream Fayoum type weirs.

Figs. (12) through **Fig. (15)** illustrate the variation in back water curve at discharges of 8 lit. /sec., 10 lit. /sec., 13 lit. /sec. and 15 lit. /sec. for all ranges of (y*/X*).
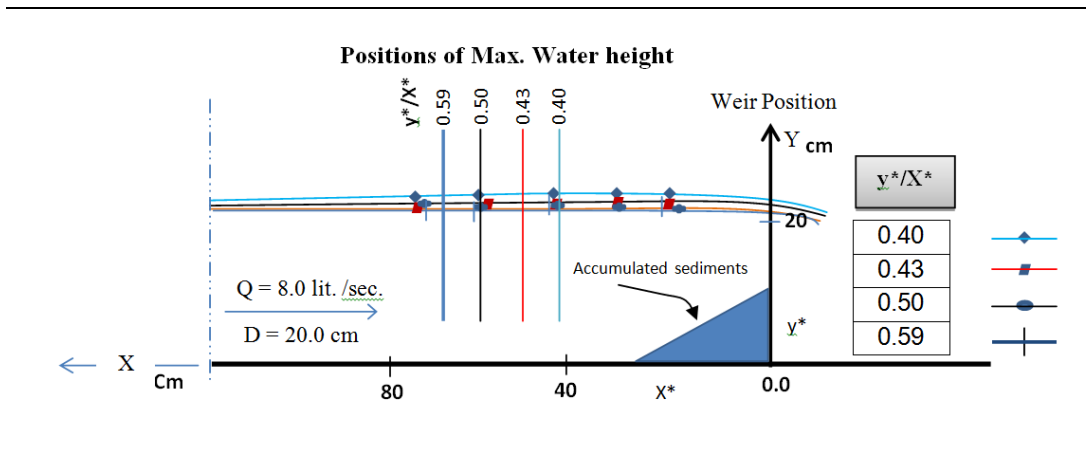

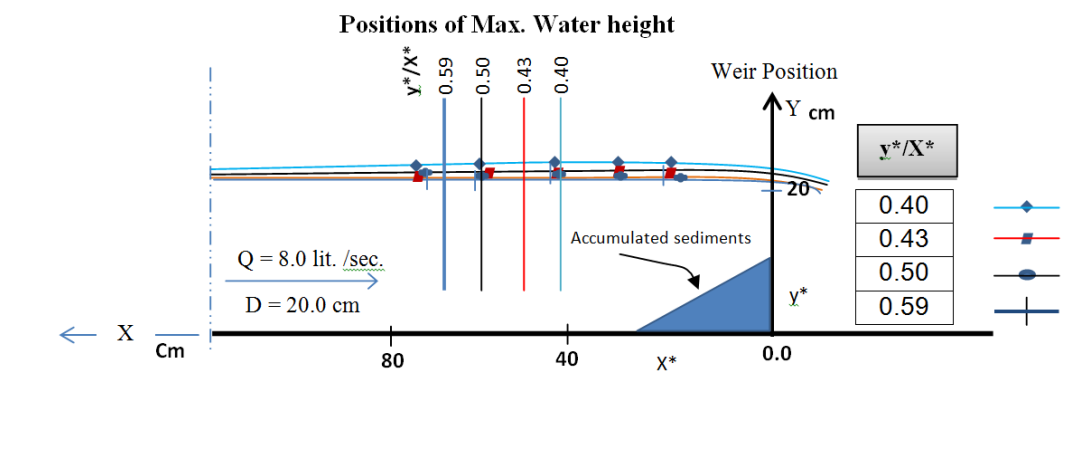*Fig. (12): Back water curve profiles for all accumulated sediment models at Q =8 lit. /sec.*

Fig. (13): Back water curve profiles for all accumulated sediment models at Q =10 lit. /sec.

Fig. (14): Back water curve profiles for all accumulated sediment models at Q =13 lit. /sec.

Fig. (15): Back water curve profiles for all accumulated sediment models at Q =15 lit. /sec.
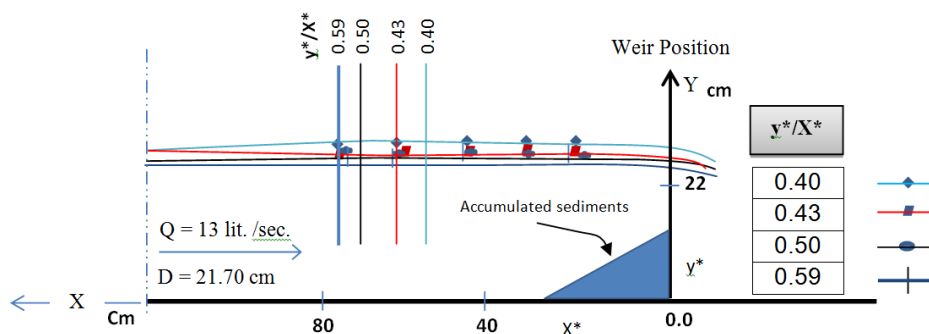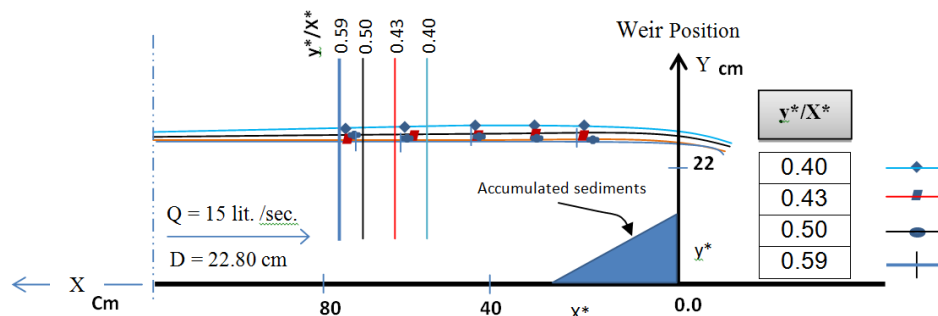
It is illustrated from the above-mentioned figures that the distance of maximum points for the back water curve from weir changes with the variation of accumulated sediments. With the increasing of accumulated sediments, the distance of maximum point of back water curve from the weir increases, the approaching water depths upstream weir decrease and the corresponding velocities increase.

4. Conclusions

In this research, experimental runs were carried out to find out the effect of accumulated sediments on narrow crested weir (Fayoum type) characteristics and also the variation in back water curve upstream it. This experimental work was carried out using four wooden different sizes of accumulated sediments (y* and X*) under various four discharges of 8 lit. /sec., 10 lit. /sec., 13 lit. /sec. and 15 lit. /sec. It is found

from this study that the accumulated sediments upstream weir clearly affects the head over it (H) and the back water profile. It was noticed that with the increasing of accumulated sediments, the head over weir crest (H) decreases by about 16 % and consequently, the discharge coefficient of weir increases by about 38 %. The maximum height of back water curve upstream weir (Z) decreases gradually with the increasing of accumulated sediments by about 5.3%. For this reasons and analysis it is recommended to eliminate all of accumulated sediments upstream Fayoum type weirs.

Acknowledgments

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