CHAPTER ONE

INTRODUCTION

Both weirs and gates are used frequently for discharge measurements in open channels. Weirs and gates may be combined together in one device yielding a simultaneous flow over the weir and below the gate. The flow through combined devices may be free when both the flows over weir and below the gate are free and it is termed submerged when the flow below the gate is submerged (and the flow over the weir may or may not be submerged). The simultaneous discharge can be obtained by adding the overflow discharge to the underflow discharge and making use of an interaction factor (Negm, 1996 and Negm et al., 2000).

Discharge-measuring structures such as weirs have been studied by many researchers. Discharge equations derived from energy considerations are calibrated by experimental data for typical weir geometrics. In all measuring structures definition of a discharge coefficient is unavoidable to represent influences of parameters that are not directly included in the derivation of the discharge equation. Restrictions and limitations on the use of discharge equations are also reported in the literature (Bos,1989). Discharge coefficient is usually dependent on dimensionless parameters such as Reynolds and Weber numbers associated with dynamic conditions of flow over the structure, and ratios of weir dimensions which reflect variations in the geometrical design of the measuring structures. .

It was found that a triangular above a rectangular opening is more efficient than reversed.

The use of combined weirs in open channels flow measurement is not extensively studies in literature.

The contribution herein presents a novel approach to calibrate a large 90º V-notch weir using a volume per time approach.

Hayawi HA,yahia AA,hayawi GA(2008) published a paper under the title (free flow over combined triangular weir and under a rectangular gate) with the main objective of investigation the characteristics of free flow through the combined triangular weir and rectangular gate.

1.2 Main Objective:-

This study is carried out with the main objective of estimating the stability of coefficients of discharge for locally designed gate and weir operated separately and the coefficient of discharge for both openings operated simultaneously. The specific objectives can be specified as follows:

1- To study of the coefficient of discharge for the gate under different gate widths and different heads.

2- To study of stability of coefficient of discharge for the V-notch (90^0) weir under different heads.

3- To study of the variation of combined weir coefficient of discharge (gate + V-notch weir) at different gate width and different heads.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction:

Gates and weirs have been used extensively for flow control and discharge measurement in open channel flow. Discharge measuring structures such as weirs have been studied by many researchers. Discharge equations derived from energy considerations are calibrated by experimental data for typical weir geometries. In all measuring structures definition of a discharge coefficient is unavoidable to represent influences of parameters that are not directly included in the derivation of the discharge equation. Restrictions and limitations on the use of discharge equations are also reported in the literature (Bos, 1989). Discharge coefficient is usually dependent on dimensionless parameters such as Reynolds and Weber numbers associated with dynamic conditions of flow over the structure, and ratios of weir dimensions which reflect variations in the geometrical design of the measuring structures.

2.2 Irrigation Structures:

There are many types of irrigation structures used in open canals to master and control discharge (Ashour et al. 2008)

1- Movable Weirs (Type I & Type II)
2- Roller Sluice Gate (RSG)
3- Night Storage Weirs (NSW)
4- Culverts (Pipe Culvert & Box Culvert)
5- Drop Structures
6- Well Head Regulators (WHR)

7- Canals(Main, Major, Minor)

8- Siphons

9- Bridges(Foot Bridge & Vehicle Bridge)

10-Pump Stations (Pump House, Suction Basin, & Delivery Basin)

1 11- Pipe Regulators (PR) (Ashour et al. 2008)

2.3 Functions of Irrigation Structures:

Irrigation structures are used to serve the following function:

1. Maintain water levels in canals at Full Supply Level (FSL), Distribute water to different smaller canals in specific quantities

2 Use NSW to store water in Minor Canals at Night

3 Use Culverts to pass water underneath railway or road

4 Use Siphons to pass canal water underneath stream or drainage water course

5 Use Super passage to pass canal water underneath stream or drainage water course

6 Use canals to convey water from one site to another.

7 Use Bridges as crossing structures for people or vehicles.

8 Employ pump station to lift water from certain level to another high level.

9 Employ drop structures to lower upstream water level (U/S FSL) to downstream water level(D/S FSL) without causing erosion (U/S FSL – D/S FSL !.0 m (Ashour et al. 2008)

2.4 Types of Flow:

2.4.1 Free flow:

• Also called "modular" flow, is a condition in which the napped discharges into the air

• This exists when the downstream water surface is lower than the lowest point of the weir crest elevation

• Aeration is automatic in a contracted weir

• In a suppressed weir the sides of the structure may prevent air from circulating under the napped, so the underside of the nappe should be vented (if used for flow measurement)

• If not vented, the air beneath the nappe may be exhausted, causing a reduction of pressure beneath the napped, with a corresponding increase in discharge for a given head (Chan-son and Wang 2012).

2.4.2 Submerged flow:

Also referred to as "non-modular" flow, is a condition in which the discharge is partially under water, where changes in the downstream depth will affect the flow to upstream.

A condition which indicates the change from free-flow to submerged-flow is called transition submergence, where submergence is defined as the ratio of downstream to upstream specific energy (E_d/E_u)

For practical application of weirs as flow measurement devices, it is preferable that they operate under free-flow conditions so that only the upstream depth need be measured to arrive at a discharge value.

The calibration of free-flow weirs is more accurate that the calibration of submerged-flow weirs (Chan-son and Wang 2012).

2.5 Flow measurement structures:-

2.5.1 Weirs:

A weir is an irrigation measurements structure placed across a channel which raises the upstream water level and may be used to measure the flow rate. A range of measuring weirs were developed

Weirs are overflow structures built across open channels to measure the volumetric rate of water flow

The crest of a measurement weir is usually perpendicular to the direction of flow
If this is not the case, special calibrations must be made to develop a stage discharge relationship
Oblique and "duckbill" weirs are sometimes used to provide nearly constant upstream water depth, but they can be calibrated as measurement devices. Weirs are typically installed in open channels such as streams to determine discharge (flow rate).The basic principle is that discharge is directly related to the water depth above the weir crest. (Darcy and Bazin 1865, Bos 1976, Ackers et al. 1978).

2.5.2 Types of Weirs:

There are many different types of weirs that can be constructed and used to determine the flow rate in a ditch or stream. The three most common weirs types are (Water watch, 2002).:
(1) V-Notch or Triangular
(2) Rectangular
(3) Cipolletti.
The weir is sturdy enough to hold up against the flow of the water. Figure 2.1 shows an example of the three different types. The top two are rectangular weirs (Water watch,

2002). The first is a rectangular contracted weir and is one of the most commonly used. The second is another rectangular weir but since the sides of the weir are actually the sides of the ditch, it is called a suppressed rectangular weir. The third type shown in is the Cipolletti weir (Fig. 2.1.c). This type of weir has a trapezoidal shaped notch. The last type shown is a triangular or V-notched type (Fig. 2.1.b). With proper installation, all of these weirs can be accurate. (Water watch, 2002).

2.5.3 Advantages of weirs:

1. Capable of accurately measuring a wide range of flows
2. Tend to provide more accurate discharge ratings than flumes and orifices
3. Easy to construct
4. Can be used in combination with turnout and division structures
5. Can be both portable and adjustable
6. Most floating debris tend to pass over the structure

2.5.4 Disadvantages of weirs:

1. Relatively higher heads are required, particularly for free flow conditions. This precludes the practical use of weirs for flow measurement in flat areas.
2. The upstream pool must be maintained clean of sediment and kept free of Weeds and trashes, otherwise the calibration will shift and the measurement accuracy will be compromised

2.6 Classification of weirs according to edge shape:

Weirs are identified by the edge of the opening which can be either sharp- or broad-crested

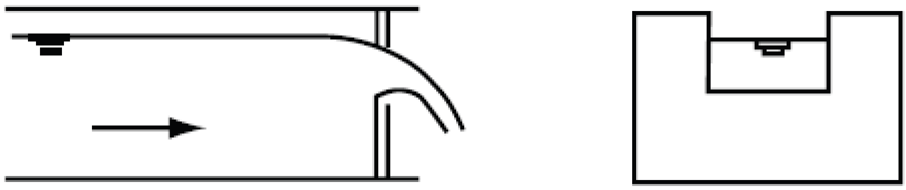
2.6.1 Sharp-crested weirs:

• A weir with a sharp upstream corner, or edge, such that the water springs clear of the crest

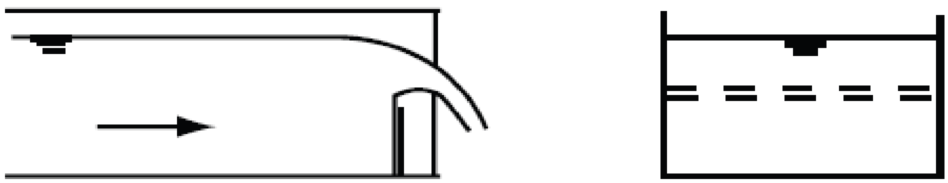
• Those most frequently used are sharp-crested rectangular, trapezoidal, and triangular or 90 ° V-notch weirs

• According to the USBR, the weir plate thickness at the crest edges should be from 0.03 to 0.08 inches

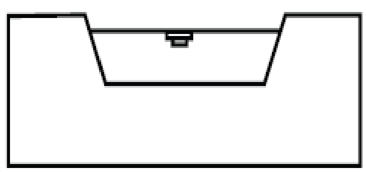
• The weir plate may be beveled at the crest edges to achieve the necessary thickness



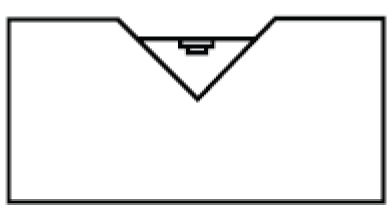
(2.1.a) Contracted Rectangular



(2.1.b) Suppressed rectangular



(2.1.c) Cipoletti Contracted



(2.1.d) Contracted Triangular or V-Notch

Figure 2.1(a.b.c.d) Different types of weirs used to measure flow rate in an open ditch. (USDI-BOR, 1997).

2.6.2 Broad-crested weir:

• A weir that has a horizontal or nearly horizontal crest sufficiently long in the direction of flow so that the nappy will be supported and hydrostatic pressures will be fully developed for at least a short distance.

• Some weirs are not sharp- nor broad-crested, but they can be calibrated for flow measurement. (USDI-BOR, 1997).

2.7 classification of weirs according to opening width

Weirs may also be designed as suppressed or contracted:

2.7.1 Suppressed weir

• A rectangular weir whose notch (opening) sides are coincident with the sides of the approach channel, also rectangular, which extend unchanged downstream from the weir

• It is the lateral flow contraction that is "suppressed"

2.7.2 Contracted weir

• The sides and crest of a weir are far away from the sides and bottom of the approach channel

• The nappe will fully contract laterally at the ends and vertically at the crest of the weir

• Also called an "unsuppressed" weir

• Calibration is slightly more complex than for a suppressed weir(USDI-BOR, 1997).

2.8 Discharge measurement equation of the V -notch weir:

The V-notch thin-plate weir, also called triangular weir, has an overflow edge in the form of an isosceles triangle. The Australian Standards (1991) expresses the discharge calibration of the V-notch weir in the form (USDI-BOR, 1997).:

$$Q = C_d \ *8/15 \ *\tan \alpha \sqrt{2gh^5} \qquad (2.1)$$

Where:

Q = water discharge

C_d = dimensionless discharge coefficient

α= notch opening angle

g = gravity acceleration

h = upstream water depth above the notch (Fig 2.1.c)

2.9 Discharge measurement equation of the sluice gates:

Discharge can conveniently be measured by hydraulic structures for controlling discharge and water depth, as they create a one-to-one relationship between depth and discharge. Their applications include irrigation and drainage canals and overflow spill ways. Notably, other discharge measuring device are costly, e.g. Laser Doppler Anemometer. Attention to the understanding of the performance of weir-type flow control structure, e.g. over-flow and sharp-crested weirs is relatively better than that of standard gates. The basic knowledge of the hydraulic performances of gated structures is even poorer than of the vibration of these gates.

2.9.1 Discharge Formulation

Using the Bernoulli's and continuity equations in sluice gate hydraulic jump flow; it is possible to derive the following widely known expression to calculate the gate discharge for a rectangular cross section:

$$q = \mathrm{Cd} \times b\sqrt{2\mathrm{gy}1} \qquad (2.2)$$

Where:

q = discharge per unit width of channel

g = gravity acceleration

b = gate opening

y1 = upstream depth

C_d = discharge coefficient.

C_d depends on different parameters such as upstream and tail water depths, gate opening, contraction coefficient of gate and the flow condition.

2.10 Discharge measurement equation of the combined gate under weir structure:

Weirs and gates may be combined together in one device yielding a simultaneous flow over the weir and below the gate. The flow through combined devices may be free, when both the flow over weir and below the gate is free. It is known as submerged when the flow below the gate is submerged (and the flow over the weir may or may not be submerged). Problems concerning sedimentation and depositions are minimized by combined weirs and gates as outlined by(Alhamid,Negm and Al-Brahim (1997)), (Fadil 1997) developed a metre for the combined flow through contracted sluice gate and weir, also combined-submerged flow through weirs and below gates were analyzed and discussed by (Negm et al.1999),(Negm 2000) .The characteristics of the combined flow over weirs and below gates of equal contraction are discussed by Abdel-Azim et al.(2002), different geometrical combination are used, the discharge characteristics of a combined weirs and gate structure are discussed, they found that the flow parameter (D/H) (the ratio between the upstream water depth and the height of the gate opening) and the geometrical parameter (D/y) (the ratio of the vertical distance between the lower edge of the weir and the upper edge of the gate opening and the height of the gate opening) have major effects on the discharge.

To compute the discharge through a combined weir (V-notch with sharp crested rectangular gate) the following equation may be obtained by adding the discharge over the weir and gate as:

$$Q_{theo} = Q_g + Q_w \qquad (2.3)$$

Where:

Q_{theo}: Total theoretical discharge. (L^3T^{-1})

Q_g: discharge through the gate. (L^3T^{-1})

Q_w: discharge through the triangular weir. (L^3T^{-1})

$$Qg = \sqrt{2gH} \times BD \qquad (2.4)$$

Where:

Q_g: discharge through the gate. (L^3T^{-1})

g: acceleration due to gravity . (LT^{-2})

Head; h: head of water through weir. (Length)

B: the gate width. (Length)

D: the gate height. (Length)

$$Q_w = \frac{8}{15}\sqrt{2g} \times tan\frac{\boldsymbol{\theta}}{\mathbf{2}} h^{2.5} \qquad (2.5)$$

Where:

Q_w: discharge through the triangular weir. (L^3T^{-1})

g: acceleration due to gravity . (LT^{-2})

h: head of water through weir. (Length)

$$Q_{act} = Cd\sqrt{2g}\left[\frac{8}{15}\sqrt{2g} \times tan\frac{\boldsymbol{\theta}}{\mathbf{2}} h^{2.5}\right] \qquad (2.6)$$

Where:

Q_{act}: Total actual discharge. (L^3T^{-1})

C_d: coefficient of discharge.

g: acceleration due to gravity . (LT^{-2})

h: head of water through weir. (Length) (Abdel-Azim et al. 2002)

2.11 Orifices as flow measurement structures:

An orifice meter is a conduit and a restriction to create a pressure drop. An hour glass is a form of orifice.A nozzle, venture or thin sharp edged orifice can be used as the flow restriction. In order to use any of these devices for measurement it is necessary to empirically calibrate them. That is, pass a known volume through the meter and note the reading in order to provide a standard for measuring other quantities. Due to the ease of duplicating and the simple construction, the thin sharp edged orifice has been adopted as a standard and extensive calibration work has been done so that it is widely accepted as a standard means of measuring fluids. Provided the standard mechanics of construction are followed no further calibration is required (Fadil ,H.A.,1997).

2.11.1 Discharge measurement equation of the orifices:

The flow of water through an orifice is illustrated in Figure (2.3) Water approaches the orifice with a relatively low velocity, passes through a zone of accelerated flow, and issues from the orifice as a contracted jet. If the orifice discharges free into the air, there is modular flow and the orifice is said to have free discharge; if the orifice discharges under water it is known as a submerged orifice. If the orifice is not too close to the bottom, sides, or water surface of the approach channel, the water particles approach the orifice along uniformly converging streamlines from all directions.

If we assume that the free discharging orifice shown in Figure 2.3 discharges under the average head HI (if H, >> w) and that the pressure in the jet is atmospheric, we may apply Bernoulli's theorem.

$$HI = (h, + vI2/2g) = v2/2g \qquad (2.7)$$

Hence

$$V = \sqrt{2gH} \qquad (2.8)$$

This relationship between v and $\sqrt{H}$ was first established experimentally in 1643 by Torricelli.

If we introduce a C,-value to correct for the velocity head and a C,-value to correct for the assumptions made above, we may write

$$V = c_a \, c_f \sqrt{2gh} \qquad (2.9)$$

According to Equation 2.9 the discharge through the orifice equals the product of the velocity and the area at the vena contract. This area is less than 'the orifice area, the ratio between the two being called the contraction coefficient, 6. Therefore

$$Q = C_d \, C_v \, 6 \, A\sqrt{2gh} \qquad (2\text{-}10)$$

The product of cd, C, and 6 is called the effective discharge coefficient Ce. Equation (2-11) may therefore be written as

$$Q = C \, A \sqrt{2gh} \qquad (2.11)$$

Proximity of abounding surface of the approach channel on one side of the orifice prevents the free approach of water and the contraction is partially suppressed on that side.

If the orifice edge is flush with the sides or bottom of the approach channel, the contraction along this edge is fully suppressed. The contraction coefficient, however, does not vary greatly with the length of orifice perimeter that has suppressed contraction. If there is suppression of contraction on one or more edges of the orifice and full contraction on at least one remaining edge, more water will approach the' orifice with a flow parallel to the face of the orifice plate on the remaining edge(s) and cause an increased contraction, which will compensate for the effect of partially or fully suppressed contraction.

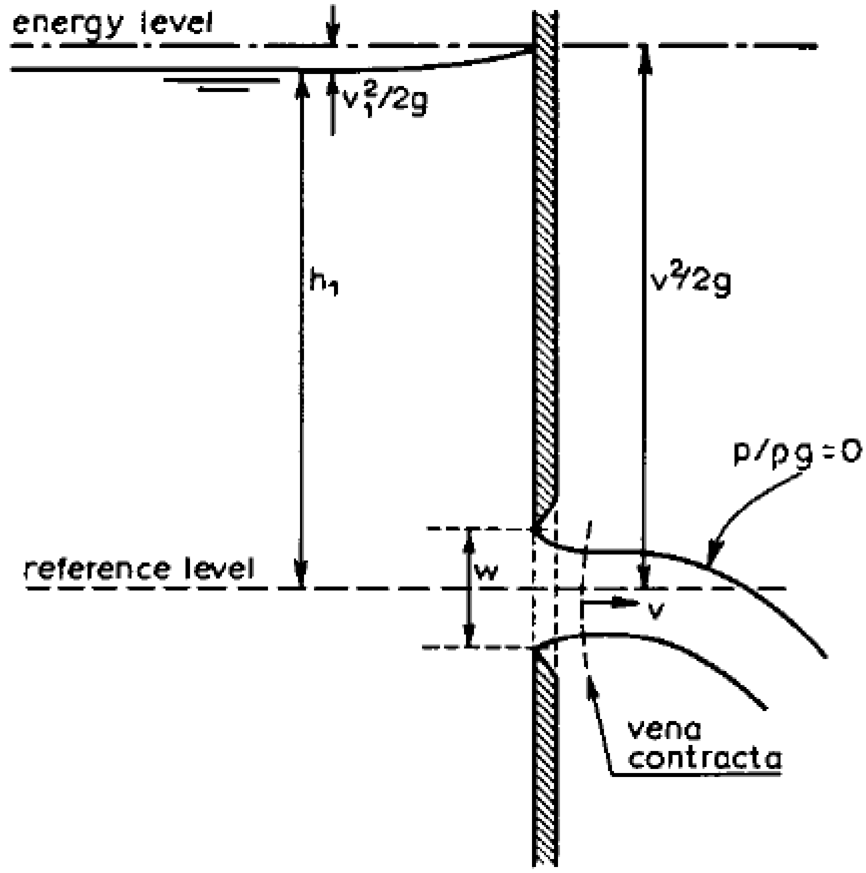


Fig (2.3) free discharge

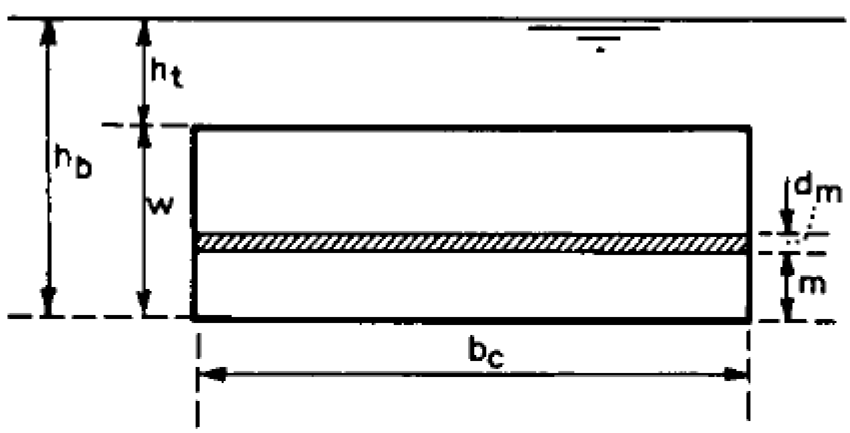


Fig (2.4) rectangular orifice

2.12 Volume and discharge meters:

Flow meters are devices that measure the amount of liquid, gas or vapor that passes through them. Some flow meters measure flow as the amount of fluid passing through the flow meter during a time period (such as 100 liters per minute). Other flow meters measure the totalized amount of fluid that has passed through the flow meter (such as 100 liters). Flow measurement can be described by:

$$Q = A \cdot V \qquad (2.12)$$

Which means that the volume of fluid passing through a flow meter is equal to the cross-sectional area of the pipe (A) times the average velocity of the fluid (v)

2.12.1 Types of flow meter:

There are many types of flow meter such as:

1- Volumetric flow meters directly measure the volume of fluid (Q) passing through the flow meter. The only flow meter technology that measures volume directly is the positive displacement flow meter.

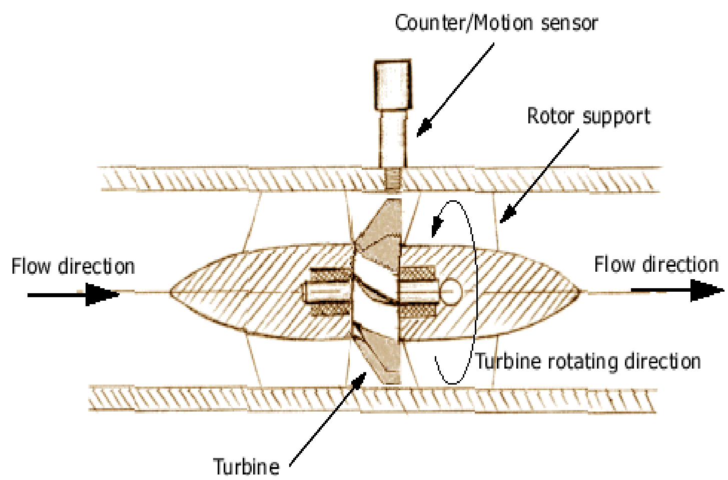
2- Velocity flow meters utilize techniques that measure the velocity (v) of the flowing stream to determine the volumetric flow. Examples of flow meter technologies that measure velocity include **magnetic**, **turbine**, **ultrasonic**, and vortex shedding and fluidic flow meters plat (2.1.a) (2.1.b).

3- Mass flow meters utilize techniques that measure the mass flow (W) of the flowing stream. Examples of flow meter technologies that measure mass flow include Carioles mass and thermal flow meters.

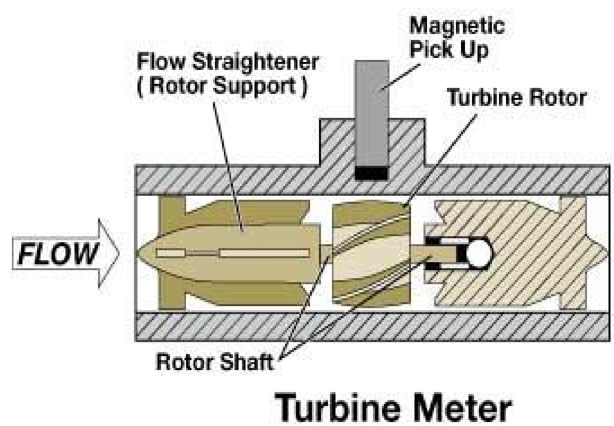
4- Inferential flow meters do not measure volume, velocity or mass, but rather measure flow by inferring its value from other measured parameters. Examples of flow meter technologies that measure inferentially include **differential pressure**, **target** and **variable area** flow meters.

5- **Flow computers** are often used to compensate flow measurements for actual process conditions, such as pressure, temperature, **viscosity**, and composition. Additional flow meter technologies include flow meters that measure liquid flowing in an **open channel**, and **insertion** flow meters that measure flow at one location in a pipe and use this measurement to infer the flow in the entire pipe. Insertion flow measurement systems often use a **flow computer** to compensate for hydraulic effects.

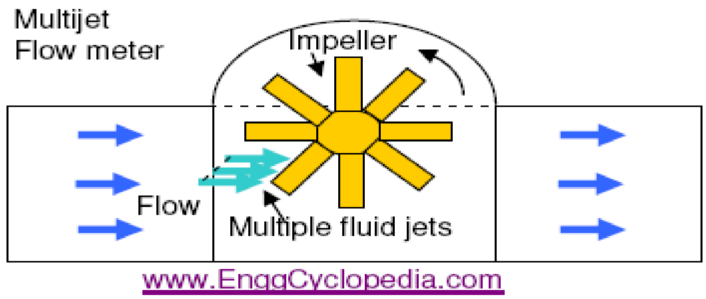
6- Mechanism similar to turbine flow meters Use a mechanism similar to turbine flow meters and consist of a simple impeller wheel with radial vanes, impinged upon by a single jet. For paddle wheel flow meters the wheel blades are smaller in width compared to single jet flow meter and are only partially projected in the path of the flow. plate (2.2).



Plate(2.1.a):Turbine flow meters



Plate(2.1.b):Turbine flow meters



Plate(2.2):Turbine and paddle wheel flow meters

CHAPTER THREE

MATERIALS AND METHODS

3.1 The study site:-

The study was conducted during period (January 2013- May 2014) in the College of Agricultural Studies, Department of Agricultural Engineering. (Shambat) Khartoum city. The experiments were carried out in the department of irrigation demonstration field. The gate was designed and constructed at the department workshop.

3. 2 Combined weir design:-

The combined rectangular gate under triangular weir was constructed so that the v-notch weir works over the rectangular gate. Three different gate widths with maximum gate height of ten centimeters. The V-notch weir angle is ninety degrees (Fig. 3-1). The combined weir was installed on an open cement-lined-trapezoidal channel (plate3.1).

3.2.1 Gate design; -

1 – The combined weir gate frame dimensions are 75 x 35 Cm.
2 – The gate opening dimensions :-

- The gate width 10 – 8.5 – 7.5 cm.
- The gate height is variable with the maximum 10 cm.
- Fixed metal sheet dimension 35x13 cm (Fig. 3-2)

3.2.2 V- notch weir design:-

1 – Weir metal sheet dimensions 35 x 29 Cm.
2 – V-notch angle 90^o.
3 – Maximum height of v-notch 10 cm. (Fig. 3-3).

4- Vertical distance between the lower edge of the weir and the upper edge of the gate opening (y = 10 cm).

5- The combined weir operating mechanism:

- The screw length is 44 cm
- The screw diameter is 16 mm.

- The screw up lift range is 9cm.

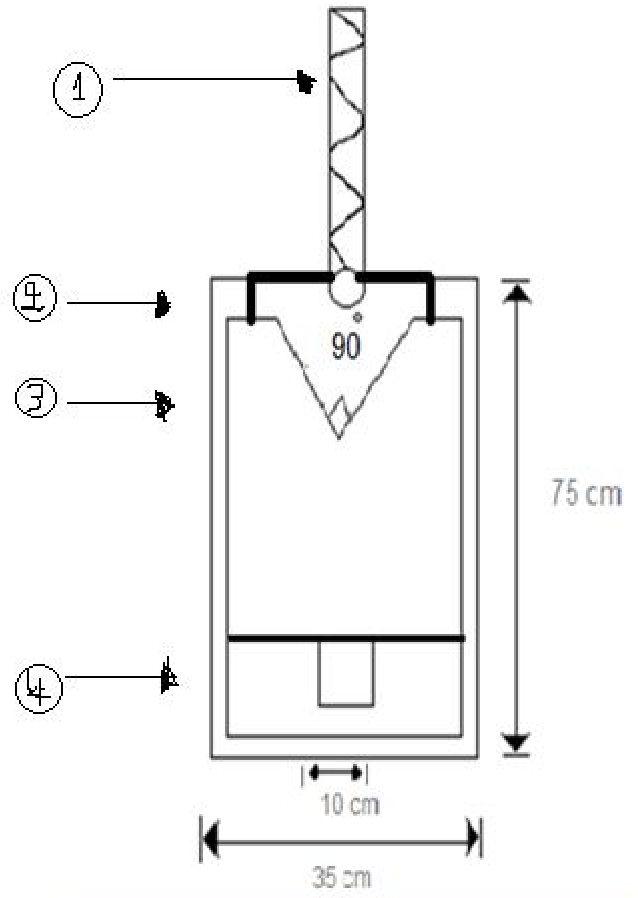


Fig (3.1): Schematic sketch for combined gate under V-notch (90^0) weir

Key:

1. Screw
2. Frame
3. Weir plate
4. gate plate

3.3 Materials used in the construction of the combined weir: -

1 - Sheet metal of 1.5 mm thinness.
2 –Angle iron 38 mm.
3_ Threaded 16 mm rod (square screw thread) .
4 – Metal ball joint.
5 – One mm thin zinc coated sheet metal.

6- Arc – welding rods

7- Paint.

3.3.1 Building Materials for installation: -

1 –Masonry bricks.
2 - Sand.
3 - Cement.
4 - Gypsum.
5 - Gravel.

3.3.2 Equipment used in construction: -

1 – Welding machine.
2 –Workshop hand tools.

3.3.3 Water supply equipment and connecters: -

1 - Piston pump installed in a shallow well (plate 3.2).
2 – A 12.01261m^3 size water tank on a four wheeled tractor trailed cart (plate 3.3).
3- Seventy six mm internal diameter polyethylene pipe (plate 3.5).
4 – Flange connector 76 mm. (plate3.4)
5 – Seventy six mm (3inch) ball valve. (Plate 3.6)
6 - Ring Clips.
7 - Nuts and Bolts.
8 – Mechanics tool box.

(Plate 3.2) Piston pump

(Plate 3.1): combine weir design

(Plate 3.3): water tank

(plate 3.4): flange

(Plate 3.5): three inch plastic pipe

(plate 3.6): three inch ball valve

(plate3.7): Flow meter connected to pump and tank (3inch)

3.4 Measuring tools and equipment: -

1 –Flow meter 76 mm. (3inch) (plate 3.7)

2 – Measuring tape and rulers .

3- Stop watch.

4- Sprit level.

3.5 The experiment equipments:-

3.5.1 Water sources:

Shallow well and storage

Two water sources were connected to the flow meter. Flow meter is connected to the delivery basin. The delivery is equipped with sluice gate, which directs water to a cement lined trapezoidal cannel on which the combined weir is installed at about 3.15 m from basin gate.

3.5.2 Determination of the gate discharge:-

Discharge through the gate is calculated using equation (3-1).

$$Q_g = AV \qquad (3\text{-}1)$$

$$Q_g = C_f \, BD \sqrt{2g} \, H^{0.5} \qquad (3\text{-}2)$$

Where:

B = gate width one (10, 8.5, 7.5cm Fig3.2.b_1)

D = gate depth one (3.5, 4.5, 5.5cm)

H = the water height from center of gate.

The gate discharge equation coefficient is determined as from the following experiment.

3.5.3 Volume of water passing through the flow meter:-

The volume of water passing through the flow meter during the gate operation time is taken directly from the flow meter readings.

3.5.4 Determination of the gate coefficient:-

The coefficient of gate can be determined by the ratio of volume of water passing through the gate and volume recorded by the flow meter as given by equation (3-3).

$$C_f = Q_g T_0 / V_{fm} \qquad (3\text{-}3)$$

T_0 = operating time

V_{fm} = flow meter reading in volume

3.6 Determination of the V- notch weir discharge:-

Discharge through the (90^0) V- notch weir is calculated from equation(3-4).

$$Q_w = C_f h^{2.5}\sqrt{2g} \qquad (3\text{-}4)$$

Where h is the head above weir notch (Fig.3.2.a).

3.6.1 Volume of water passing through the flow meter:-

The volume of water passing through the flow meter during the weir operation time is taken directly from the flow meter readings.

Each of these size readings are replicated three times and related to the flow meter discharges.

3.6.2 Determination of the V- notch weir coefficient:-

The coefficient of V-notch weir can be determined by the ratio of volume of water passing throw the v- notch weir and reading of flow meter as given by equation (3-5)

$$C_f = Q_w T_0 \backslash V_{fm} \qquad (3\text{-}5)$$

Where:

Q_w = flow meter discharge

V_{fm} = volume of water passing through flow meter

Each of these experiments was replicated three times and corresponding flow meter readings taken.

3.7 Determination of volume passing through the combined weir:-

Determination of combined weir volume passing through the combined is determent through summing up of the gate and V- notch weir volumes.

$$V_{cw} = (Q_g T_0) +(Q_w T_0) \qquad (3\text{-}6)$$

Where:

Q_g : discharge through the gate .

Q_w : discharge through the weir .

T_0 : operation time

V_{cw} : total volume of combined weir

3.8 Determination of water volume passing through the flow meter:-

The volume of water passing through the flow meter during the combined weir operation time is taken directly from the flow meter readings.

3.9 Determination of discharge coefficient of combined weir:-

The coefficient of combined weir can be determined by the ratio of combined weir volume and flow meter volume as given in equation (3-7)

$$C_f = V_{cw}/ V_{fm} \qquad (3\text{-}7)$$

3.10 Statistical analysis:-

The experiment data was analyzed by the descriptive statistics data analysis tool in excel program to compute Mean, Standard Error, Median, Standard Deviation, Sample Variance, Skewers, Range, Minimum, Maximum, Sum, Count and CV.

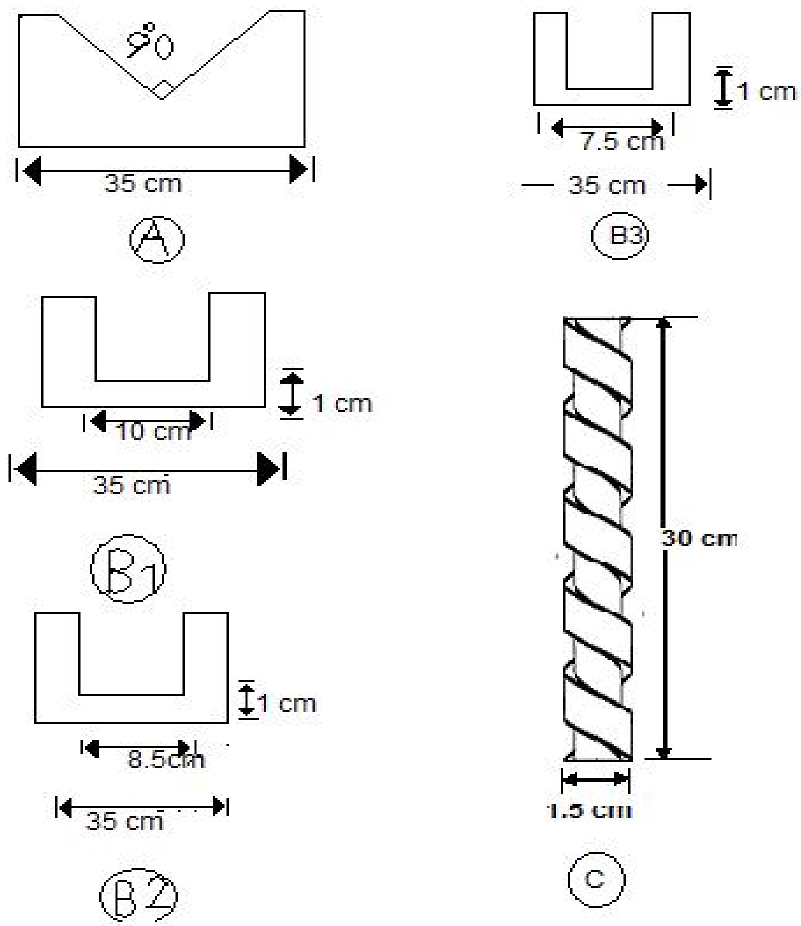


Fig. (3.2): The v- notch weir and gate plate dimensions and lifting screw dimensions.

CHAPTER FOUR

RESULTS AND DISCUSSION

The use of combined weirs in open channels flow measurement is not extensively studied in literature.
Discharge equations are calibrated by experimental data for typical weir geometrics.
Discharge coefficient for sluice gate, v-notch weirs and combined gate weir coefficient are reported in literature. In this study a combined gate under weir structure was designed to compare discharge coefficient for gate and weir operated separately and coefficient of discharge for gate and weir operated simultaneously.

4.1 Coefficient of discharge for sluice gate:

Table (4.1) shows the average operational coefficient of discharge under three different gate widths and three different upstream heads

Table (4.1): overall average gate operational coefficient for three widths and three heads

	Head3.5cm	Head4.5cm	Head5.5cm	av. Cf.	overall av. Cf.
av. Cf. (width 10cm)	0.619125	0.6082388	0.538	0.588	
av. Cf. (width 8.5cm)	0.6289183	0.6324651	0.618	0.626	0.61136957
av. Cf. (width 7.5cm)	0.6535908	0.6053676	0.599	0.619	

Analysis of variance table (4.2) shows that there is no significant difference in gate coefficient with variation in gate width and upstream head, at 0.05 significance level.

Table (4.2): analysis of variance for sluice gate operation coefficient for three widths and three upstream heads

Tests of Between-Subjects Effects

Dependent Variable:
response_mean

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.003[a]	4	.001	3.870	.109
Intercept	3.284	1	3.284	1.779E4	.000
depth	.000	2	.000	.990	.447
width	.002	2	.001	6.749	.052
Error	.001	4	.000		
Total	3.288	9			
Corrected Total	.004	8			

4.2 coefficient of discharge for v-notch weir:

Table (4.3) shows the average operational discharge coefficient of weir under three different heads

Table (4.3): Overall average of V-notch weir coefficient in three different heads

	Coefficient. Of discharge	Overall avg.
avg.cf.rep1	0.55572977	
avg.cf.rep2	0.53980736	0.554113819
avg.cf.rep3	0.566804326	

Table (4.4) shows that there is no significant difference in weir coefficient with variation in upstream head, at 0.05 level of significance

Table (4.4): Analysis of variance for weir operation coefficient for three different heads

ANOVA					
re					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	2	.000	.029	.972
Within Groups	.039	5	.008		
Total	.040	7			

4.3 Coefficient of discharge for combined weir:

Table (4.5) shows the average operational coefficient of discharge under three different gate width and three different upstream heads

Table (4-5): Overall average coefficient of discharge for combined weir at three different widths and three upstream heads

	Head 1cm	Head 2cm	Head 3cm	av. Cf.	overall av. Cf.
av. Cf. (width 10cm)	0.5981	0.4653	0.4646	0.5094	
av. Cf. (width 8.5cm)	0.5617	0.5296	0.4809	0.5241	0.5022
av. Cf. (width 7.5cm)	0.4757	0.4962	0.4472	0.4731	

Table (4.6): Analysis of variance for combined weir discharge coefficient under three different widths and three upstream heads

Tests of Between-Subjects Effects

Dependent Variable:response_mean

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.003[a]	4	.001	1.844	.284
Intercept	2.077	1	2.077	4.404E3	.000
depth	.001	2	.001	1.267	.375
width	.002	2	.001	2.421	.205
Error	.002	4	.000		
Total	2.082	9			
Corrected Total	.005	8			

Tests of Between-Subjects Effects

Dependent Variable:response_mean

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.003[a]	4	.001	1.844	.284
Intercept	2.077	1	2.077	4.404E3	.000
depth	.001	2	.001	1.267	.375
width	.002	2	.001	2.421	.205
Error	.002	4	.000		
Total	2.082	9			

Analysis of variance table (4.6) shows that there is no significant difference in combined weir coefficient with variation in upstream head, at 0.05 significance level.

The study results showed that the coefficient of discharge for gate and weir operated separately (0.61136957, 0.554113819) respectively are quite stable in the study results and quite comparable to those reported in literature (0.61, 0.53) respectively.
The combined gate under weir coefficient of discharge value (C_d) is (0.5022) for v-notch weir $\theta = 90^0$ which is quiet comparable to the values reported in previous works(0.533).
In literature the coefficient of discharge (C_d) for combined flow condition were calculated and discussed for a case when the angle (θ) of the weir increase (C_d) decrease i.e. For (θ = 30o , 45o and 60o) the average value of (C_d = 0.694, 0.691and 0.665) ,respectively
In this study ($\theta = 90^0$) which is greater than (θ = 30o , 45o and 60o) reported in the above mentioned the study so the value of C_d (0.5022) found in this study is quite reasonable

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATION

1- Coefficient of discharge for sluice gate designed and constructed locally (C_d = 0.61) can be used safely in discharge measurement equations.

2- Coefficient of discharge for v-notch weir ($\theta = 90^0$) designed and constructed locally (C_d = 0.53) can also be used at a high degree of confidences for discharge calculation.

3- Combined gate v-notch 90^0 weir coefficient of discharge (C_d = 0.5011) can also be used for discharge measurement in combined gate under weir structures at high reliability.

4- The study results confirmed the stability of the sluice gate coefficient of discharge with different gate widths and upstream heads.

5- From the above result it could be concluded that a gate under v-notch weir 90^0 can be designed and constructed locally to measure discharge in open channels with high reliability and accompanied with all combined weir merits

6- Further studies on the effect of locally constructed gate under v-notch weir structures on silt sediment removal in open channels are recommended.

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APPENDICES

Gate discharge :

Table (1-a1) : calculation of the 10cm gate discharge at different heads in cm3/min.

Depth	width	Head	discharge
3.5	10	21.25	714.66
4.5	10	17.75	839.77
5.5	10	16.25	982.06

Table (1-a2): flow meter discharge in m^3/min

Time (sec)	V meter
60	0.072
60	0.077
60	0.097

Table (1-a3): calculation of the 10cm width gate operational coefficient (replication 1)

Vg(m3)	V meter	Cf.	av. Cf.
0.042879	0.072	0.595547	
0.050386	0.077	0.654367	0.619125
0.058924	0.097	0.607461	

Table (1-b1): calculation of the 10cm gate discharge at different heads(rep2)

D	B	Y	h	H	Qg
3.5	10	10	23	21.25	714.66
4.5	10	10	24	21.75	929.59
5.5	10	10	19	16.25	982.06

Table (1-b2): flow meter discharge as m^3/min

Time(sec)	V meter(m3)
60	0.078
60	0.091
60	0.089

Table (1-b3): calculation of the 10cm width gate operational coefficient (replication2)

Vg(m^3)	V meter	Cf.	av. Cf.
0.042879	0.078	0.549735	
0.055775	0.091	0.612917	0.608239
0.058924	0.089	0.662064	

Table (1-c1): calculation of the 10cm gate discharge at different heads in cm3/min (rep3)

D	B	Y	H	H	Qg
3.5	10	10	23	21.25	714.66
4.5	10	10	24	21.75	929.59
5.5	10	10	24	21.25	1123

Table (1-c2): flow meter discharge in m3/min

Time(sec)	V meter
60	0.084
60	0.105
60	0.118

Table (1-c3): calculation of the 10cm width gate operational coefficient (replication3)

Vg(m3)	V meter	Cf.	av. Cf.
0.042879	0.084	0.510469	
0.055775	0.105	0.531195	0.537565
0.067382	0.118	0.571033	

Table (2-a1): calculation of the 8.5cm gate discharge at different heads in cm3/min (rep 1)

D	B	Y	H	H	Qg
3.5	8.5	10	20	18.25	562.95
4.5	8.5	10	24	21.75	790.15
5.5	8.5	10	24	21.25	954.58

Table (2-a2): flow meter discharge in m3/min

Time(sec)	V meter
60	0.052
60	0.078
60	0.091

Table (2-a3) : calculation of the 10cm width gate operational coefficient (replication1)

Vg(m3)	V meter	Cf.	av. Cf.
0.033777	0.052	0.649555	
0.047409	0.078	0.607809	0.628918
0.057275	0.091	0.629391	

Table (2-b1): calculation of the 8.5cm gate width discharge at different head in cm3/min

D	B	Y	h	H	Qg
3.5	8.5	10	20	18.25	562.95
4.5	8.5	10	20	17.75	713.81
5.5	8.5	10	23	20.25	931.84

Table (2-b2): flow meter discharge in m3/min

Time(sec)	V meter
60	0.051
60	0.069
60	0.091

Table (2-b3): calculation of the 8.5cm width gate operational coefficient (replication 2)

Vg(m3)	V meter	Cf.	av. Cf.
0.033777	0.051	0.662291	
0.042828	0.069	0.620701	0.632465
0.055911	0.091	0.614403	

Table (2-c1): calculation of the 8.5cm gate discharge at different heads in cm3/min (rep3)

D	B	Y	h	H	Qg
3.5	8.5	10	23	21.25	607.46
4.5	8.5	10	23	20.75	771.77
5.5	8.5	10	21	18.25	884.63

Table (2-c2): flow meter discharge in m3/min

Time(sec)	V meter
60	0.059
60	0.074
60	0.087

Table (2-c3): calculation of the 8.5cm width gate operational coefficient (replication3)

Vg(m3)	V meter	Cf.	av. Cf.
0.036447	0.059	0.617753	
0.046306	0.074	0.625762	0.617869
0.053078	0.087	0.610091	

Table (3-a1) : calculation of the 7.5cm gate discharge at different heads in cm3/min

D	B	Y	h	Hu	Qg
3.5	7.5	10	19	17.25	482.92
4.5	7.5	10	23	20.75	680.98
5.5	7.5	10	23	20.25	822.22

Table (3-a2): flow meter discharge in m3/min

Time(sec)	V meter
60	0.042
60	0.064
60	0.078

Table (3-a3): calculation of the 7.5cm width gate operational coefficient (replication1)

Vg(m3)	V meter	Cf.	av. Cf.
0.028975	0.042	0.689883	
0.040859	0.064	0.638416	0.653591
0.049333	0.078	0.632474	

Table (3-b1): calculation of the 7.5cm gate discharge at different heads in cm3/min

D	B	Y	h	H	Qg
3.5	7.5	10	20	18.25	496.72
4.5	7.5	10	24	21.75	697.19
5.5	7.5	10	23	20.25	822.22

Table (3-b2): flow meter discharge in m3/min

Time(sec)	V meter
60	0.049
60	0.069
60	0.082

Table (3-b3): calculation of the 7.5cm width gate operational coefficient (replication2)

Vg(m3)	V meter	Cf.	av. Cf.
0.029803	0.049	0.608227	
0.041832	0.069	0.606255	0.605368
0.049333	0.082	0.601622	

Table (3-c1): calculation of the 7.5cm gate discharge at different head

D	B	Y	h	H	Qg
3.5	7.5	10	20	18.25	496.72
4.5	7.5	10	24	21.75	697.19
5.5	7.5	10	24	21.25	842.27

Table (3-c2): flow meter discharge in m3/min

Time(sec)	V meter
60	0.049
60	0.073
60	0.082

Table (3-c3): calculation of the 7.5cm width gate operational coefficient (replication3)

Vg(m3)	V meter	Cf.	av. Cf.
0.029803	0.049	0.608227	
0.041832	0.073	0.573035	0.599186
0.050536	0.082	0.616297	

Table (4):overall average of gate operational coefficient for all widths

	rep (1)	rep(2)	rep(3)	av. cf	overall av. Cf.
av. Cf (width 10cm)	0.619125	0.6082388	0.538	0.588	
av. Cf (width 8.5cm)	0.6289183	0.6324651	0.618	0.626	0.61136957
av. Cf (width 7.5cm)	0.6535908	0.6053676	0.599	0.619	

Weir discharge:

Table (4) a: V- notch weir coefficient (replication 1)

h	T	Qw	Vm3	V meter	Tan 90/2	Cf.	avg. cf.
7	60	574.2	0.034	0.019	1	0.55145	
7.5	60	682.3	0.041	0.021	1	0.51294	0.55572977
8	60	801.8	0.048	0.029	1	0.6028	

Table(4) b : V- notch weir coefficient (replication 2)

h	T	Qw	Vm3	V meter	Tan 90/2	Cf.	avg. cof.
7.5	60	682.3	0.041	0.023	1	0.56179	
9	60	1076	0.065	0.035	1	0.54195	0.53980736
11	60	1778	0.107	0.055	1	0.51568	

Table(4) c : V- notch weir coefficient (replication 3)

h	T	Qw	Vm3	V meter	Tan 90/2	Cf.	avg. cof.
6	60	390.6	0.023	0.016	1	0.68272	
11.5	60	1987	0.119	0.051	1	0.42788	0.56680433
10.5	60	1582	0.095	0.056	1	0.58981	

Table 5: V-notch weir coefficient

	Overall avg.
avg.cf.rep1	0.55572977
avg.cf.rep2	0.53980736
avg.cf.rep3	0.566804326
avg.cf.	0.554113819

Combined weir discharge:

Table (6- a1) : combined 10 cm width gate and V- notch weir discharge measurement in cm3/min for different heads

D	B	Y	h	H	T sec	Qg
1	10	10	17	16.5	60	134.94374
2	10	10	16	15	60	257.32761
3	10	10	15	13.5	60	366.18361

D	B	Y	h	H	T sec	Qw
1	10	10	17	16.5	60	5278.0294
2	10	10	16	15	60	4535.7536
3	10	10	15	13.5	60	3859.9142

Table (6-a2): the total combined weir discharge in cm3/min

Qg	Qw	Qg+w
134.9	5278	5413
257.3	4536	4793
366.2	3860	4226

Table (6-a3): the total volume in m3/min

Vg(m3)	Vw(m3)	Vg+w(m3)
0.008	0.317	0.325
0.015	0.272	0.288
0.022	0.232	0.254

Table (6-a4): flow meter discharge in m3/min

Time(sec)	V meter
60	0.543
60	0.512
60	0.533

Table (6-a5) : comparison between combined weir flow and flow meter in m3/min

Vg+w(m3)	V meter	cf.
0.325	0.543	0.598
0.288	0.512	0.562
0.254	0.533	0.476

Table (7- b1) : combined 8.5 cm width gate and V- notch weir discharge measurement in cm3/min for different heads

D	B	Y	h	H	T sec	Qg
1	8.5	10	17	16.5	60	134.94374
2	8.5	10	16	15	60	257.32761
3	8.5	10	15	13.5	60	366.18361

D	B	Y	h	H	Qw
1	8.5	17	16.5	60	5278.0294
2	8.5	16	15	60	4535.7536
3	8.5	15	13.5	60	3859.9142

Table (7-b2) : the total combined weir discharge in cm3/min

Qg	Qw	Qg+w
134.9	5278	5413
257.3	4536	4793
366.2	3860	4226

Table (7-b3): the total combined weir volume in m3/min

Vg(m3)	Vw(m3)	Vg+w(m3)
0.008	0.317	0.325
0.015	0.272	0.288
0.022	0.232	0.254

Table (7-b4): flow- meter discharge in m3/min

Time(sec)	V meter
60	0.698
60	0.543
60	0.511

table (7-b5) : comparison between combined weir flow and flow meter in m3/min

Vg+w(m3)	V meter	cf.
0.325	0.698	0.465
0.288	0.543	0.53
0.254	0.511	0.496

Table (8- c1): combined 7.5 cm width gate and V- notch weir discharge measurement in cm3/min for different heads

D	B	Y	h	H	T(sec)	Qg
1	7.5	10	17	16.5	60	134.94374
2	7.5	10	16	15	60	257.32761
3	7.5	10	15	13.5	60	366.18361

D	B	Y	h	H	T(sec)	Qw
1	7.5	10	17	16.5	60	5278.0294
2	7.5	10	16	15	60	4535.7536
3	7.5	10	15	13.5	60	3859.9142

Table (8-c2) : the total combined weir discharge in cm3/min

Qg	Qw	Qg+w
134.9	5278	5413
257.3	4536	4793
366.2	3860	4226

Table (8-c3): the total volume in m3/min

Vg(m3)	V w(m3)	V g+w(m3)
0.008	0.317	0.325
0.015	0.272	0.288
0.022	0.232	0.254

Table (8-c4): flow meter discharge in m3/min

Time(sec)	V meter
60	0.699
60	0.598
60	0.567

table (8-c5) : comparison between combined weir flow and flow meter in m3/min

V_{g+w}(m3)	V meter	cf.
0.325	0.699	0.464633
0.288	0.598	0.480911
0.254	0.567	0.447206

Table (9): Average of gate widths coefficient discharge in the combined weir

D(cm)	Qt(rep1)	Qt(rep2)	Qt(rep3)	Avg.
1	5413	5413	5413	5413
2	4793	4793	4793	4793
3	4226	4226	4226	4226