# LINEAR PROPORTIONAL WEIRS

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A Dissertation
in
The Faculty
7
of
Engineering

Presented in Partial Fulfillment of the Requirement
for the degree of Master of Engineering at
Concordia University
Montréal, Québec, Canada

September, 1975

## ABSTRACT

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LINEAR PROPORTIONAL WEIRS

Existing profile computations for constructing linear proportional weirs involve complex mathematical expressions. For ease of construction, a practical quadrant edge weir, composed of two quadrants of a circular profile, was recently developed by some investigators.

The concept of the quadrant edge weir was extended in the present study to linear proportional weir assemblies composed of two or more quadrants of a circle. A computer program was developed to determine the head-discharge relationship for quadrant edge weirs. Numerical integration of the relevant equations was done. An extensive experimental program on nine different test weir assemblies was carried out to verify the linearity of the head-discharge relationship.

Preliminary development work on lateral weirs by plain contouring of the channel bed was also carried out. Field application of proportional weir assemblies include lateral weirs forming uniformly discharging irrigation outlets.

## ACKNOWLEDGEMENTS

The Author wishes to thank Dr. A.S. Ramamurthy for suggesting this thesis topic, and Dr. K. Subramanya for his guidance during the early stages of the experimental work.

The assistance of Mr. L.S. Stankevicius and Mr. D. Roy of the Water Resources Laboratory is highly appreciated. Also, the cooperation of Mr. L. Carballada in formulating the computer program and assisting in the lateral weir development study is thankfully acknowledged.

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## NOTATIONS

| | |
|---|---|
| $A$ | depth of rectangular portion of proportional weir |
| $B$ | top width of opening of proportional weir |
| $C_d$ | coefficient of discharge |
| $F_1$ | Froude number in inlet channel at start of lateral weir |
| $g$ | acceleration due to gravity |
| $H$ | head over weir sill of proportional weir |
| $\Delta H$ | increment of head over weir sill of proportional weir |
| $H_{max}$ | maximum head over weir sill of proportional weir |
| $H'$ | head over rectangular portion of proportional weir |
| $\Delta H'$ | increment of head over rectangular portion of proportional weir |
| $K$ | number of openings in proportional weir assembly |
| $L$ | length of lateral weir |
| $Q$ | flow in channel at any point between start and end of lateral weir |
| $Q_a$ | actual discharge through proportional weir assembly |
| $Q_H$ | theoretical discharge through proportional weir assembly at head H |
| $Q_{H'}$ | theoretical discharge through proportional weir assembly at head H' |
| $Q_R$ | theoretical discharge through proportional weir assembly at head R |
| $Q_t$ | theoretical discharge through proportional weir assembly |
| $Q_1$ | flow in inlet channel at start of lateral weir |
| $Q^*$ | outflow discharge through lateral weir of length L |
| $R$ | radius of segments of proportional weir assembly |
| $S_b$ | height of weir sill above bottom of proportional weir channel |
| $V$ | mean velocity in channel at any point between start and end of lateral weir |
| $V_1$ | mean velocity in inlet channel at start of lateral weir |
| $V_2$ | mean velocity in outlet channel after end of lateral weir |

## NOTATIONS (Cont'd)

| | |
|---|---|
| $x$ | length of element from origin measured along X-axis of proportional weir |
| $y$ | distance of centre line of element from origin measured along Y-axis of proportional weir |
| $y'$ | distance of centre line of element measured along Y-axis over rectangular portion of proportional weir |
| $Y$ | normal depth in channel at any point between start and end of lateral weir |
| $Y_1$ | normal depth in inlet channel at start of lateral weir |
| $Y_2$ | normal depth in outlet channel after end of lateral weir |
| $Z$ | hump height at any point between start and end of lateral weir where normal depth is Y |
| $Z_1$ | hump height at end of lateral weir |
| $\eta$ | ratio of depth y to radius R of proportional weir assembly |
| $\eta'$ | ratio of depth y' to radius R of proportional weir assembly |
| $\eta_A$ | ratio of depth of rectangular portion A to radius R of proportional weir assembly |
| $\eta_B$ | ratio of top width of opening B to radius R of proportional weir assembly |
| $\eta_H$ | ratio of head over weir sill H to radius R of proportional weir assembly |
| $\eta'_H$ | ratio of head over rectangular portion H' to radius R of proportional weir assembly |

# LINEAR PROPORTIONAL WEIRS

## INTRODUCTION

Proportional weirs and their discharge characteristics have been under investigation ever since the concept of such weirs was first proposed by Stout (14). These weirs have a profile which ensures a certain relationship between the head on the weir and the discharge. Linear proportional weirs are used as flow measuring devices, and as outlets for settling basins, grit chambers and dosing syphons. There are various types of linear proportional weirs depending on the shape of the base profile, which may be parabolic, triangular, trapezoidal or rectangular.

The "Sutro-Weir" is the most common of the linear proportional weirs with rectangular bottom sections. The Sutro profile is asymptotic at the bottom (Fig.1) leading to an infinitely wide base. To overcome this, Sutro assumed a known base in the form of a rectangular weir of depth A, above which the weir profile is fitted (9). Recently, Keshava Murthy and Seshagiri (2) presented a generalized mathematical theory of proportional weirs, and supported their theory with experimental verification. Theoretical calculations were subsequently made by Lakshmana Rao et al (5 to 8) and Sreenivasulu and Raghavendran (13) together with experimental studies.

From the point of view of constructing the linear weir profile, the profile computations suggested by earlier investigators involve complex mathematical expressions. In engineering field applications, it is necessary to seek a solution which ensures ease of construction of the weir and provides the required accuracy in the linear head-discharge relationship. This was the motivation for Venkataraman and Subramanya (16) to propose the practical quadrant edge plate weir. Preliminary study made by them on quadrant plate notches (Fig.3) indicated that they were just as effective as the theoretical profiles when the accuracy sought in the head-discharge relationship was not excessively high (Table 1).

In the present study, the concept of the quadrant edge weir has been extended based on :

(1) A theoretical basis to justify the assumption of linearity of the quadrant edge weir with A/R and B/R as the principal variables.

(2) Adaptability of proportional weirs as weir assemblies to enhance their field applications.

(3) An extensive experimental program to verify the characteristics of the proportional weirs and weir assemblies.

## THEORETICAL CONSIDERATIONS

For obtaining the theoretical head-discharge relationship, flow is assumed through a single quadrant edge weir (Fig.3).

Special Case A = 0, B = 0

Considering one half of the weir profile in Fig. 4, the expression for the weir discharge, based on elementary considerations, can be stated as follows:

Assuming coefficient of discharge, $C_d$, as constant

$$\frac{Qa}{2} = \int_0^H C_d \sqrt{2g} \sqrt{H-y} \{R - \sqrt{2yR-y^2}\} dy$$

i.e.

$$\frac{Qa}{2 C_d \sqrt{2g}} = \int_0^H R \sqrt{H-y}\, dy - \int_0^H \sqrt{(H-y)\ (2yR-y^2)}dy \quad \ldots\ldots\ldots\ldots \quad (1)$$

Equation (1) can be reduced to the following form

$$\frac{Qa}{2 C_d \sqrt{2g}R^{5/2}} = \frac{2}{3}\frac{H^{3/2}}{R^{3/2}} - \frac{1}{R^{5/2}} \int_0^{H/R} R^{5/2} \sqrt{\frac{y^3}{R^3} - \frac{y^2}{R^2}\left(\frac{H}{R} + 2\right) + 2\left(\frac{y}{R}\right)\left(\frac{H}{R}\right)} \frac{dy}{R} \quad \ldots(2)$$

Set $\eta_H = \frac{H}{R}$ and $\eta = \frac{y}{R}$ to get

$$\frac{Qa}{2 C_d \sqrt{2g}R^{5/2}} = \frac{2}{3} \eta_H^{3/2} - \int_0^{\eta_H} \sqrt{\eta^3 - \eta^2 (\eta_H + 2) + 2\eta\eta_H}\, d\eta$$

$$Q_t = \frac{Qa}{2 C_d \sqrt{2g}R^{5/2}}$$

Therefore, $Q_t = \frac{2}{3} \eta_H^{3/2} - \int_0^{\eta_H} f(\eta)\, d\eta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$

Where $f(\eta) = \sqrt{\eta^3 - \eta^2 (\eta_H + 2) + 2\eta\eta_H}$

A computer program (Table 5) was developed to determine the head-discharge relationship based on Equation (3). In this program, the following increments were used:

$\eta_H = 0, 0.02, 0.04, 0.06, 0.08, 0.10 \ldots 1.0$

For each value of $\eta_H$, values of $Q_t = f\ (\eta_H)$ were obtained.

The computer output information for a few radii is shown in Table 6.

General Case A>0, B>0

Fig. 5 illustrates the general case applicable to single quadrant edge weirs. In this case, one half of the total area of actual flow is equal to area of rectangular portion P plus area of curved portion Q.

If $Q_t$ represents the theoretical flow and $Q_a$ is the actual flow,

$$\frac{Q_a}{2} = \int_P C_d \sqrt{2g} \sqrt{H-y}\ dx dy + \int_Q C_d \sqrt{2g} \sqrt{H-y}\ dx dy \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Equation (4) can be simplified to

$$\frac{Q_a}{2\ C_d \sqrt{2g} R^{5/2}} = \frac{2}{3} \{1+\tfrac{1}{2}\ (\tfrac{B}{R})\}\ (\tfrac{H}{R})^{3/2}$$

$$- \int_A^H \sqrt{\frac{y^3}{R^3} + \frac{y^2}{R^3} \{-2(R+A)-H\} + \frac{y}{R^3} \{A^2+2AR+2HR+2AH\} - \frac{A^2 H}{R^3} - \frac{2AH}{R^2}}\ \frac{dy}{R} \quad \ldots\ldots\ldots (5)$$

Set $\eta_A = \frac{A}{R}$, $\eta_B = \frac{B}{R}$, $\eta_H = \frac{H}{R}$; $y = R\eta$ or $\frac{dy}{R} = d\eta$

To get $\dfrac{Q_a}{2\ C_d \sqrt{2g} R^{5/2}} = \dfrac{2}{3} \{1+\tfrac{1}{2}\eta_B\} \eta_H^{3/2} -$

$$\int_{\eta_A}^{\eta_H} \sqrt{\eta^3+\eta^2\{-2(1+\eta_A)-\eta_H\}+\eta\{\eta_A^2+2\eta_A+2\eta_H+2\eta_A\eta_H\}-\eta_A^2\eta_H-2\eta_A\eta_H}\ d\eta \quad \ldots\ldots (6)$$

Also setting $\eta = \eta' + \eta_A$ and $\eta'_H = \eta_H - \eta_A$,

Equation (6) reduces after simplifying to

$$Q_t = \frac{Q_a}{2\ C_d\ \sqrt{2g}R^{5/2}}$$

$$Q_t = \frac{1}{3}\ \{2+\eta_B\}\eta_H^{3/2} - \int_0^{\eta'_H} \sqrt{\eta'^3 - \eta'^2(+2+\eta'_H) + 2\eta'\eta'_H}\ d\eta \quad \text{.......................(7)}$$

Based on equation (7), a computer ptogram (Table 5) was developed to determine the head-discharge relationship. As in the special case, the following increments were used:

$\eta'_H$ = 0, 0.02, 0.04, 0.06, 0.08, 0.10.....1.0

For each value of $\eta'_H$, values of $Q_t$ were obtained from equation (7).

Tables 9 and 10 list the computer output information for $\frac{A}{R} = 0.1$, $\frac{B}{R} = 0.4$ and $\frac{A}{R} = 0.1$, $\frac{B}{R} = 0.5$ for a few radii.

## General Remarks

Table 3 and Fig. 2 show a comparison of theoretical and practical weir profiles of a typical proportional weir assembly. The relative error of the two profiles appears to have the same value as the standard deviation of discharge versus head as indicated in Table 2.

In Fig. 2, the almost rectangular shape EFGH can be ignored due to non-linearity. From G to J, the two profiles are almost identical; a deviation starts beyond point J.

## LINEAR PROPORTIONAL WEIR ASSEMBLIES

The principal parameters that influence the discharge coefficient for weir assemblies (Fig. 6(a) to 6(i) ) can be grouped as follows:

$$C_d = C_d \left[ \frac{A}{R} , \frac{B}{R} , K , m \right]$$

where $\frac{A}{R}$ = ratio of depth of rectangular weir to radius of quadrant edge plate weir

$\frac{B}{R}$ = ratio of top of quadrant edge plate weir to its radius

$K$ = number of openings of proportional weir assemblies

$m$ = blockage ratio, which is the ratio of the effective weir area through which flow occurs and the area of the approach channel

# EXPERIMENTAL SET-UP

The objective of the present experimental investigation was to verify the linear proportionality of practical proportional weir assemblies composed of pairs of quadrants of a circle, besides the single quadrant edge weir, for a range of A/R and B/R values.

Nine plexiglass weir plate assemblies were constructed. The definition sketch of the proportional weir assembly is shown in Fig. 3. Figures 6(a) to 6(i) illustrate the weir plate assemblies used for the experimental verification. All the edges of the weir through which flow occurs have an upstream sharp edge with a 45° bevel. The weir plates were fixed at the end of a horizontal rectangular flume 48 inches wide and 10 inches deep, as shown in Fig. 7. Table 4 gives the range of variables studied.

The depth of flow in the rectangular flume was measured by a precision point gauge. The discharge was collected in a measuring channel of known dimensions. A stop watch was used to determine the rate of flow into the measuring channel. Excess flow was directed into an adjacent floor channel, separated by a dividing steel plate. Diversion of excess flow was attained by means of a trolley mounted on wheels; the trolley was manipulated along the top of the measuring channel such that the flow through a proportional weir assembly was discharged into the channel for a specified time.

## RESULTS AND DISCUSSION

### Simple Numerical Models

Figures 18, 19 and 21 and Tables 13 to 20 and 22 to 25 indicate numerical models of linear head-discharge relationship of three typical single quadrant edge weirs with A/R = 0, 0.1 and 0.2 and B/R = 0, 0.2, 0.4, 0.5 and 0.8. In the computer program, the value of the discharge coefficient, $C_d$, was chosen to be 1.0. On the basis of the computer values of theoretical discharge in Tables 6 to 10 and 12, depth ratios H/R and flow discharge ratios $Q_H/ Q_R$ were calculated and plotted. The principal variables A/R and B/R of the test weirs, in particular A/R = 0.1 and B/R = 0.4 as also A/R = 0.1 and B/R = 0.5, were selected from these numerical models for experimental study.

Columns (6) and (8) of Tables 13 to 20 and 22 to 25 provide a measure of the linearity of the head-discharge relationship. The performance of the quadrant edge weir improves significantly when the value of A/R is held constant and B/R is varied (Tables 17 and 18). It is also interesting to note that the information in Tables 18 and 19 can be recast in a slightly different manner. For instance, choosing the datum at the top of the rectangular portion of the weir in Figure 5 provides an almost exact linear relationship between the new coordinates H'/R and $Q_{H'}/ Q_R$ (Tables 26 and 27).

To show that a quadrant edge weir of suitable A/R and B/R can be fitted for a given theoretical profile, a graphical trial and error solution was sought. Accordingly, a value of A/R = 0.18 and B/R = 1.0 fits the specific theoretical profile (Fig. 2) for which the coordinates are readily available (Table 3). The characteristics of the head-discharge curve for this particular quadrant edge weir is shown in Fig. 20 and tabulated in Table 21 based on computer output in Table 11.

## Experimental Data

The experimental results of variation of actual discharge $Q_a$ through the proportional weir assemblies with head H over the weir sill are given in Figures 8 to 11. Figures 12 to 15 also indicate the variation of the coefficient of discharge, $C_d$, with head H. Photographs of flow profiles through typical proportional weir assemblies are shown in Fig.22.

An excellent linear relationship between $Q_a$ and H existed for the case of the practical proportional weir for all values of A (Table 1). This linear relationship holds good for proportional weir assemblies (Table 4) formed of two or more pairs of quadrants of circles ( i.e. K = 1,2,3,4). For A = 0, the line of $Q_a$ against H passed through the origin. For all other proportional weir assemblies ( i.e. A >0), the line indicating the variation of $Q_a$ with H did not pass through the origin. This may be due to non-linearity of flow through the rectangular portion of the weir profile.

Lakshmana Rao and Abdul Bhukari (8) carried-out an experimental study on a linear proportional weir with a trapezoidal bottom, which showed that the coefficient of discharge, $C_d$ , decreases with head H. Further, for the Sutro-weir, it was observed by Doebler and Rayfield that the coefficient of discharge, $C_d$ , exhibited a tendency to decrease at low heads, reaching a minimum value, and then increasing. Such phenomenon was also observed in the present investigation. The definite increase in coefficient of discharge was not obtained in all the cases. This may be due to the effect of blockage, which is defined at the bottom of this page.

Table 29 indicates the variation of average $C_d$ with differing values of A, B, K and R. For the same value of K, A and R, the increase in the value of B resulted in an insignificant increase in the value of average $C_d$. Similarly, for the same values of A, B and R, but with differing values of K, the increase in value of average $C_d$ is also insignificant.

Before these results are generalized, it is necessary that additional experimental studies be carried out with ranges of $H_{max}$ and $Q_a$ higher than those obtained in the present investigation. Also, in practice, the variation of $C_d$ with head H must be established experimentally for proportional weir assemblies after the variables A/R and B/R and the number of openings K are identified for the range of $Q_a$ maximum to be dealt with.

## Blockage

Blockage may be defined as the ratio of the effective weir area through which flow occurs and the area of the approach channel.

Blockage tests were carried out on two typical weir assemblies to determine the effect on the value of $C_d$ of raising the height of the weir sill, $S_b$, from the bottom of the flume. The results are indicated in Figures 16 and 17. It was noted that the coefficient of discharge, $C_d$, decreases with increase in the value of $S_b$ initially; thereafter, there was little or no effect.

# CONCLUSIONS

(1) The variables A/R and B/R of the quadrant edge weir can be varied to provide a close approximation to the theoretical profiles of proportional weirs generated by complex mathematical expressions. Graphically, it is possible to provide a matching quadrant edge weir for some proportional weirs derived from intricate mathematical equations.

(2) For the class of quadrant edge weirs tested with A/R = 0 & B/R = 0, A/R = 0.1 & B/R = 0.4 and A/R = 0.1 & B/R = 0.5, it was experimentally found that the standard deviation of discharge versus head was under 2%. Consequently, this class of weirs can find field applications.

(3) Linear proportional weir assemblies, composed of pairs of quadrants of circles are easy to construct, without resorting to complex mathematical expressions to obtain their profile. Field application of linear proportional weirs is enhanced. Computation of flow discharge for any given head over weir sill, knowing the coefficient of discharge, $C_d$ , for a particular weir assembly beforehand, becomes simpler. Calibration of such weir assemblies becomes possible, thereby making flow measurements easier.

(4) Proportional weir assemblies are suitable for adoption in industry, treatment plants, irrigation channels, etc. particularly where a constant mean velocity is required irrespective of variations in head. Such weir assemblies may also be used as lateral weirs for side overflow discharges by contouring of the weir sill in conjunction with contouring of the channel bed. Preliminary study of channel bed contouring by means of a 1" hump was carried out and the development work is given in Appendix 4.

# RECOMMENDATIONS FOR FURTHER STUDIES

Limitations on the size of the receiving tank and the measuring channel placed a restraint on the total volume of flow collected for all the tests on proportional weir assemblies. From an engineering point of view, it would be interesting to conduct further experimental studies to the full height $H_{max}$ and to establish the true linearity of practical proportional weirs with multiple pairs of quadrants of a circle. The tendency of the coefficient of discharge, $C_d$, to decrease, reaching a minimum value and then increasing (as observed by Doebler and Rayfield) with an increase in head could then be verified for the full height of the weir assembly.

# APPENDIX 1

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# APPENDIX 2

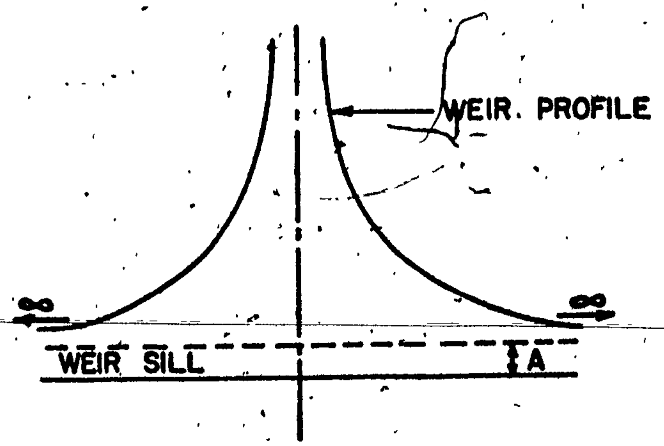
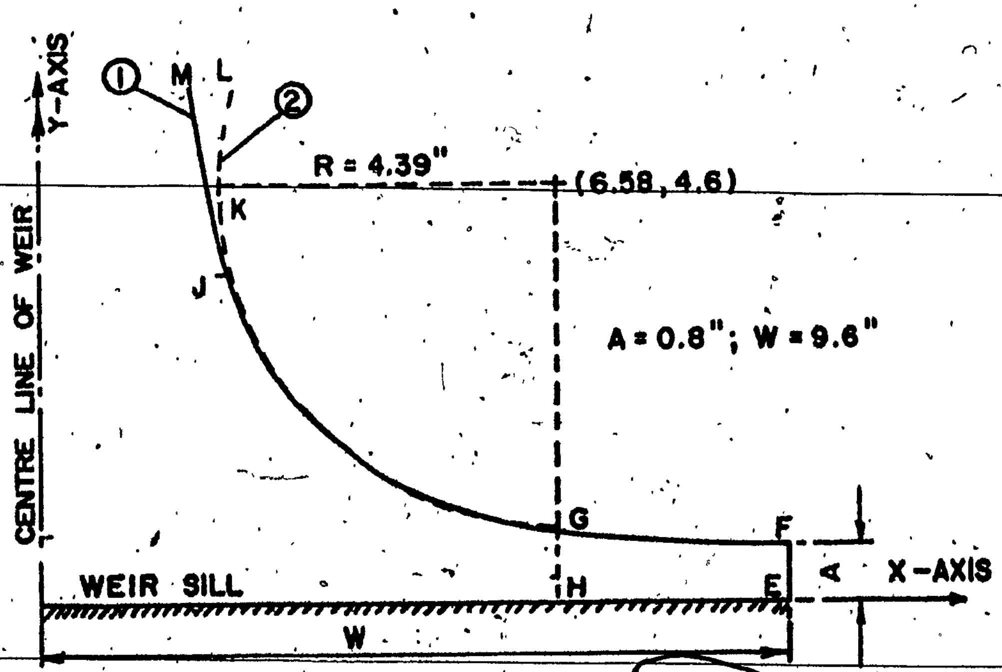


FIG. I SUTRO-WEIR

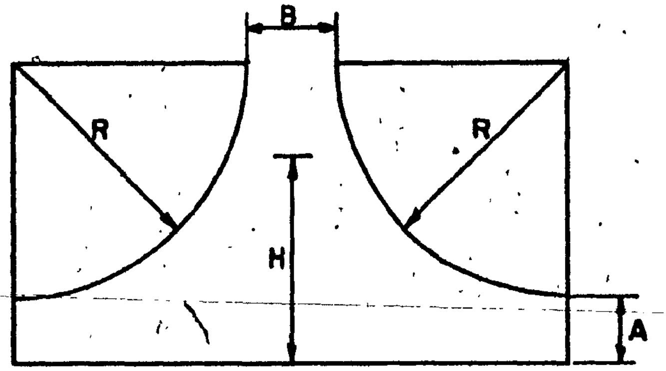


① THEORETICAL WEIR PROFILE $X = 9.6\left[\sqrt{1+\frac{Y}{0.8}} - \sqrt{\frac{Y}{0.8}}\right]$

② PRACTICAL WEIR PROFILE $(X-6.58)^2 + (Y-4.6)^2 = 4.39^2$

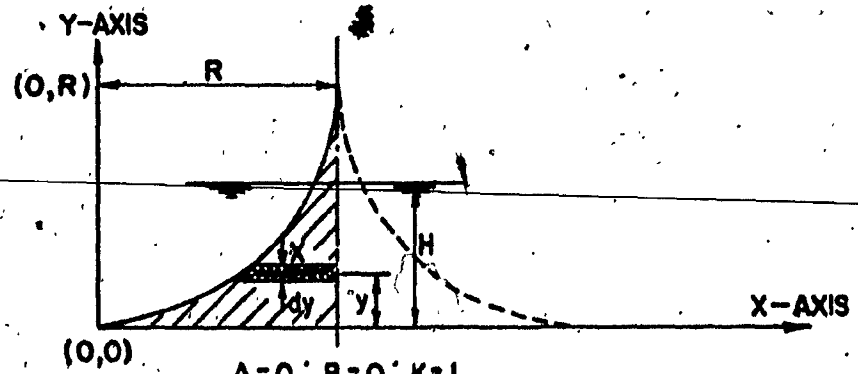
NOTE: SEE TABLE 3 FOR CO-ORDINATES

FIG. 2 COMPARISON OF WEIR PROFILES



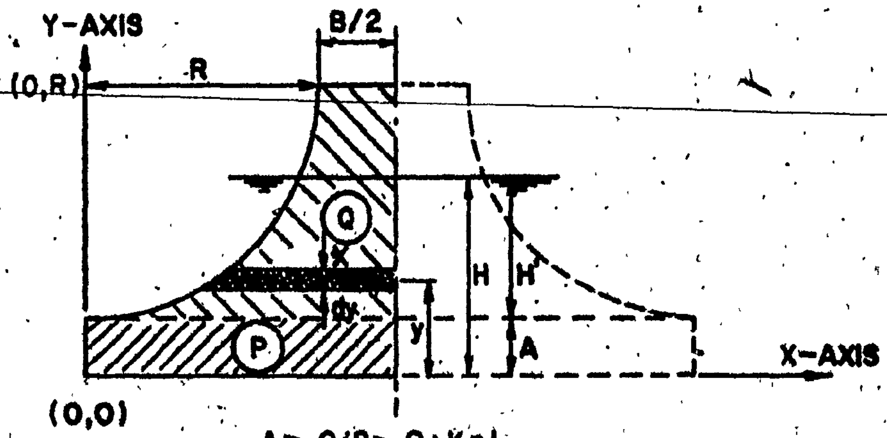
K = NO. OF OPENINGS WITH
TWO QUADRANTS OF CIRCLES

FIG. 3 DEFINITION SKETCH OF WEIR PLATE ASSEMBLIES



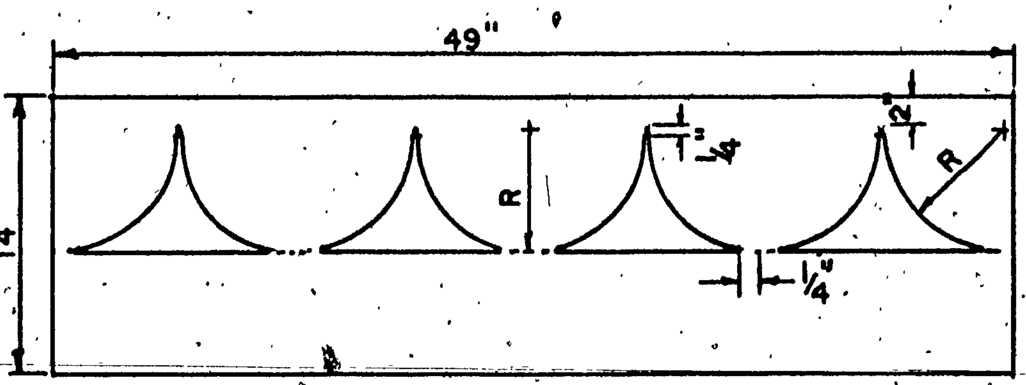
A=0 ; B=0 ; K=1

FIG.4 WEIR PLATE ASSEMBLY – SPECIAL CASE



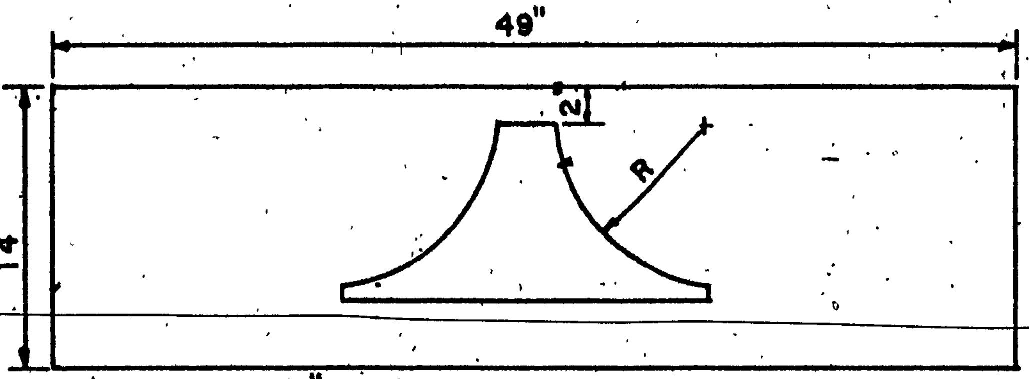
A>0 ; B>0 ; K=1

FIG.5 WEIR PLATE ASSEMBLY – GENERAL CASE



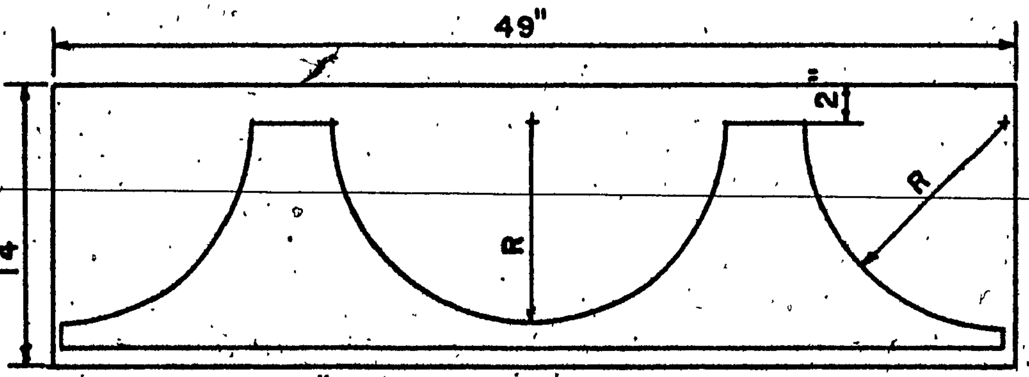
R = 6" K = 4
A = 0" B = 0"

FIG. 6 (a)



R = 6" K = 1
A = 0.6" B = 2.4"

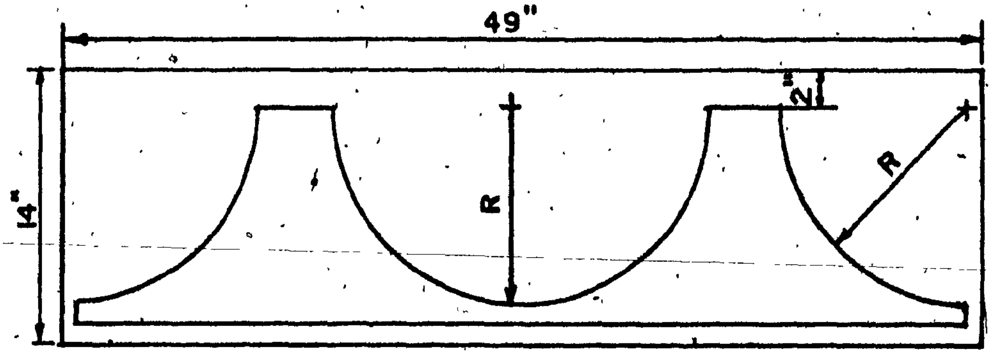
FIG. 6 (b)



R = 10" K = 2
A = 1.0" B = 4.0"

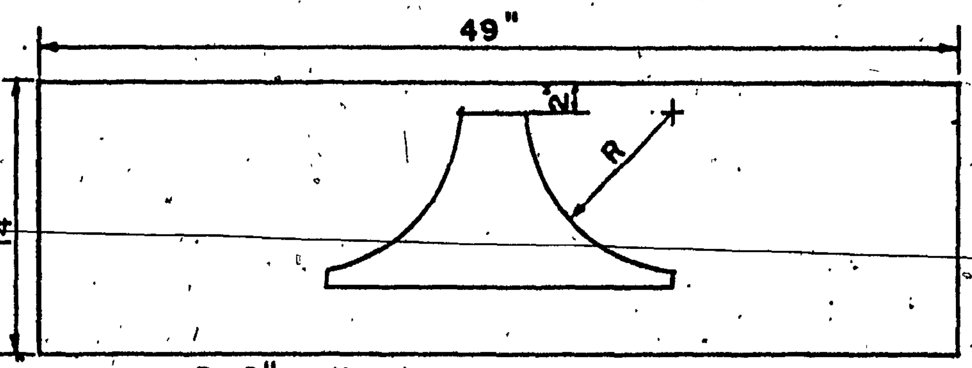
FIG. 6 (c)

FIG. 6 (a) TO (c) WEIR PLATE ASSEMBLIES



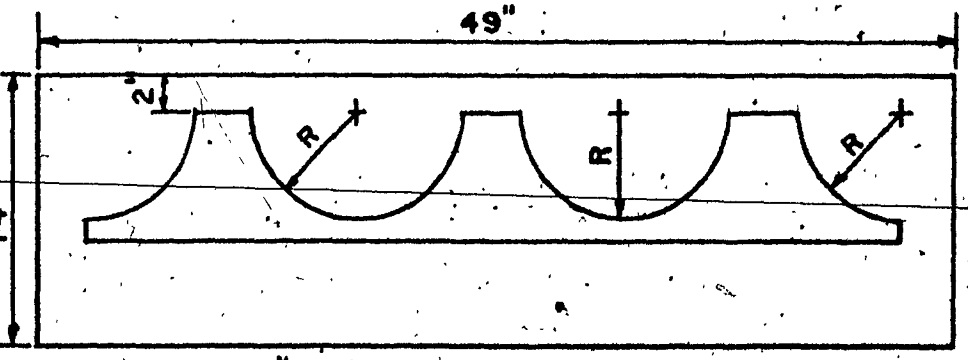
R = 8" K = 2
A = 0.8" B = 4.0"

FIG. 6 (d)



R = 8" K = 1
A = 0.8" B = 3.2"

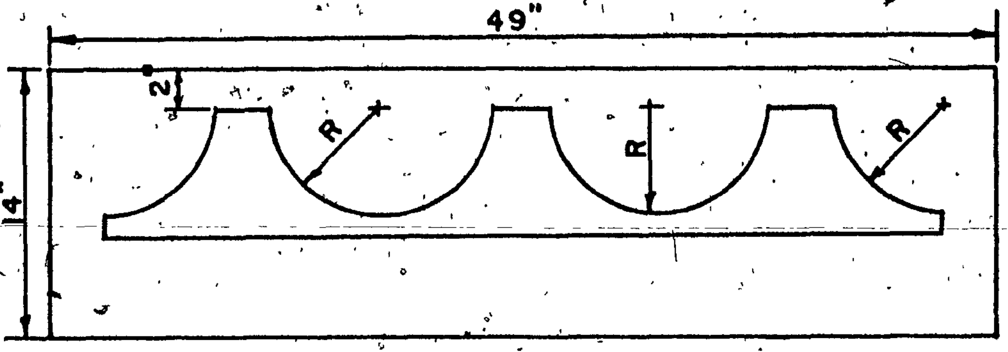
FIG. 6 (e)



R = 6" K = 3
A = 0.6" B = 3.0"

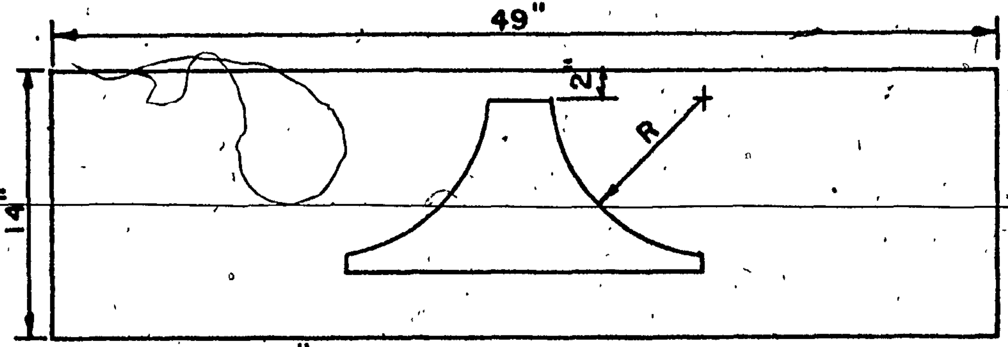
FIG. 6 (f)

FIG. 6 (d) TO (f) WEIR PLATE ASSEMBLIES (cont'd)



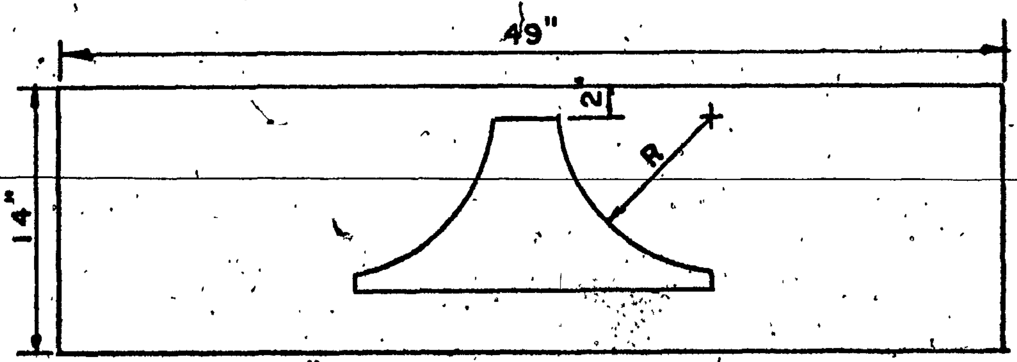
R= 6" K = 3
A = 0.6" B = 2.4"

FIG. 6 (g)



R= 10" K = 1
A = 1.0" B = 4.0"

FIG. 6 (h)



R= 10" K = 1
A = 1.0" B = 5.0"

FIG. 6 (I)

FIG. 6 (g) TO (I) WEIR PLATE ASSEMBLIES (cont'd)

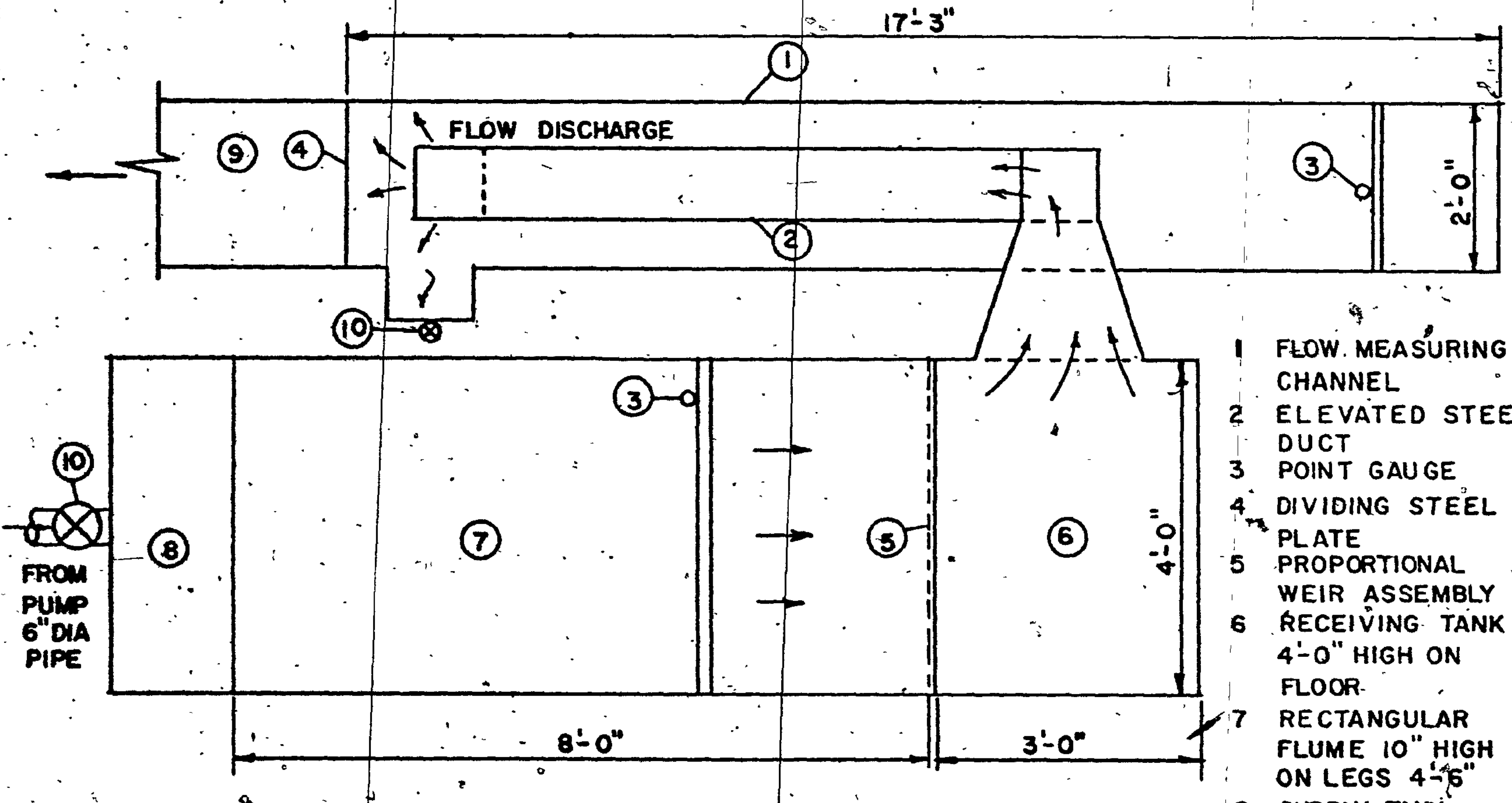


FIG.7 EXPERIMENTAL SET-UP FOR PROPORTIONAL WEIR ASSEMBLIES

1 FLOW MEASURING CHANNEL
2 ELEVATED STEEL DUCT
3 POINT GAUGE
4 DIVIDING STEEL PLATE
5 PROPORTIONAL WEIR ASSEMBLY
6 RECEIVING TANK 4'-0" HIGH ON FLOOR
7 RECTANGULAR FLUME 10" HIGH ON LEGS 4'-6"
8 SUPPLY TANK
9 EXCESS FLOW CHANNEL TO PUMP SUMP
10 FLOW CONTROL VALVE TO SUMP

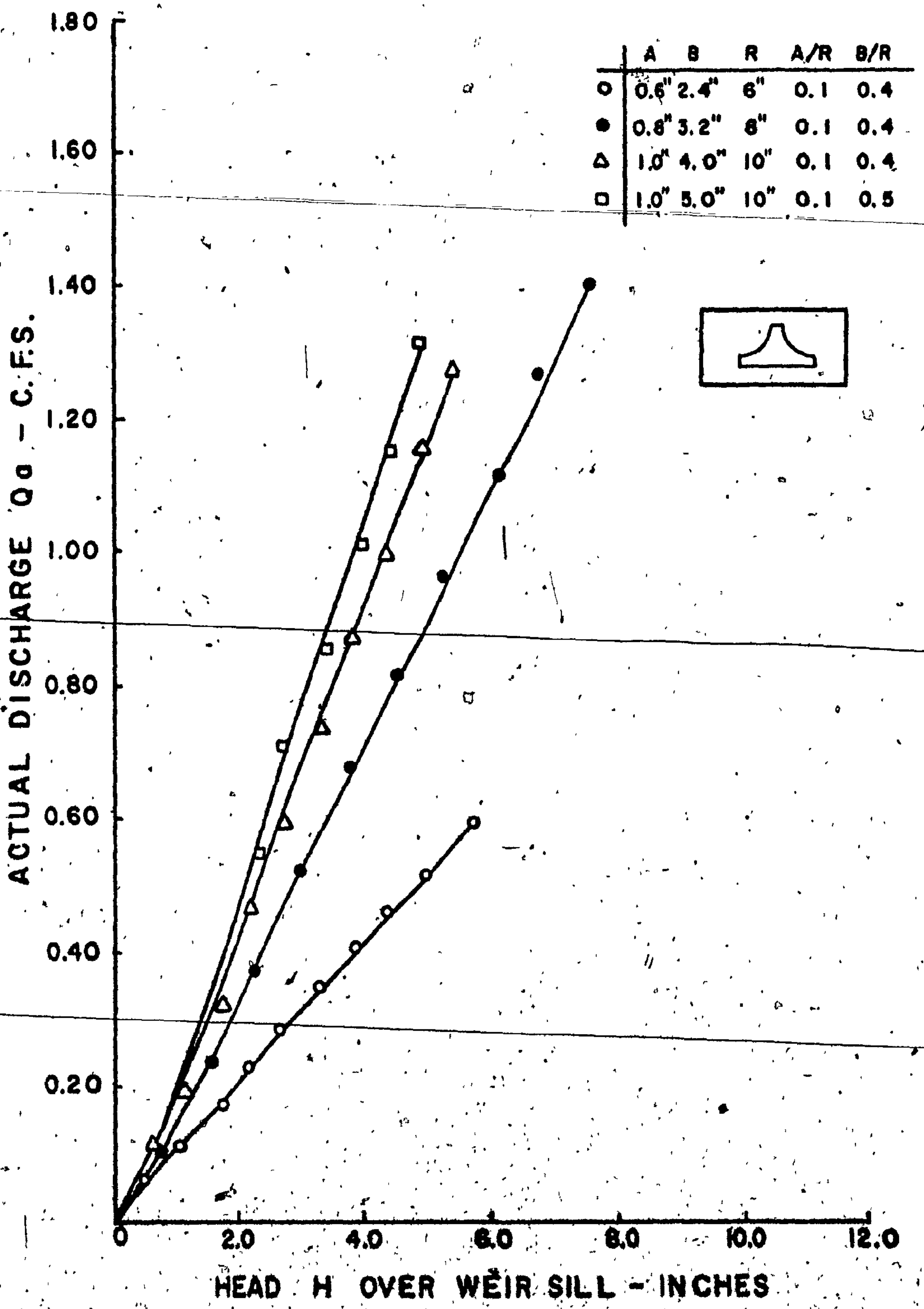


FIG. 8 VARIATION OF Qa WITH H (K=1)

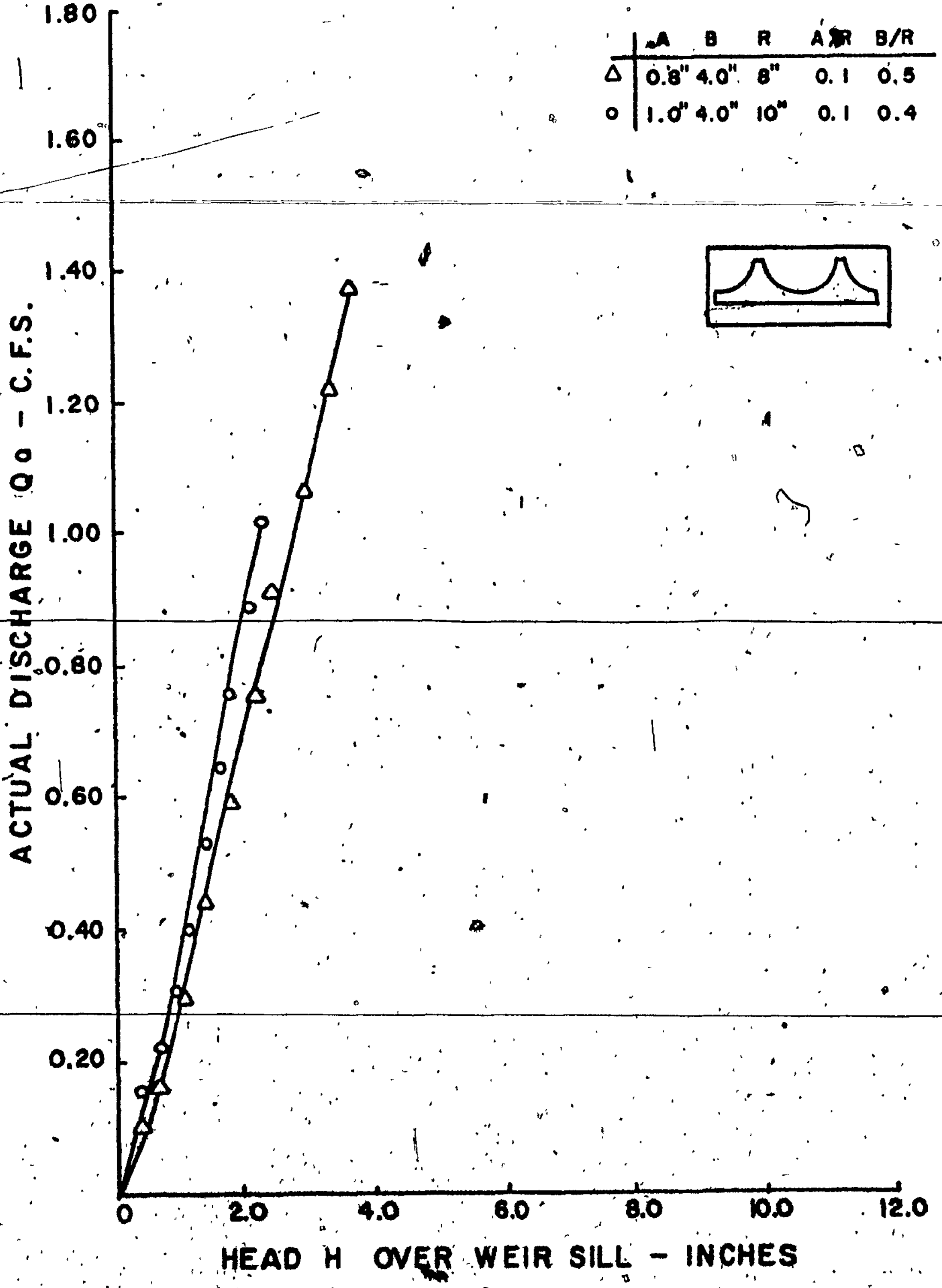


FIG. 9 VARIATION OF Qa WITH H (K=2)

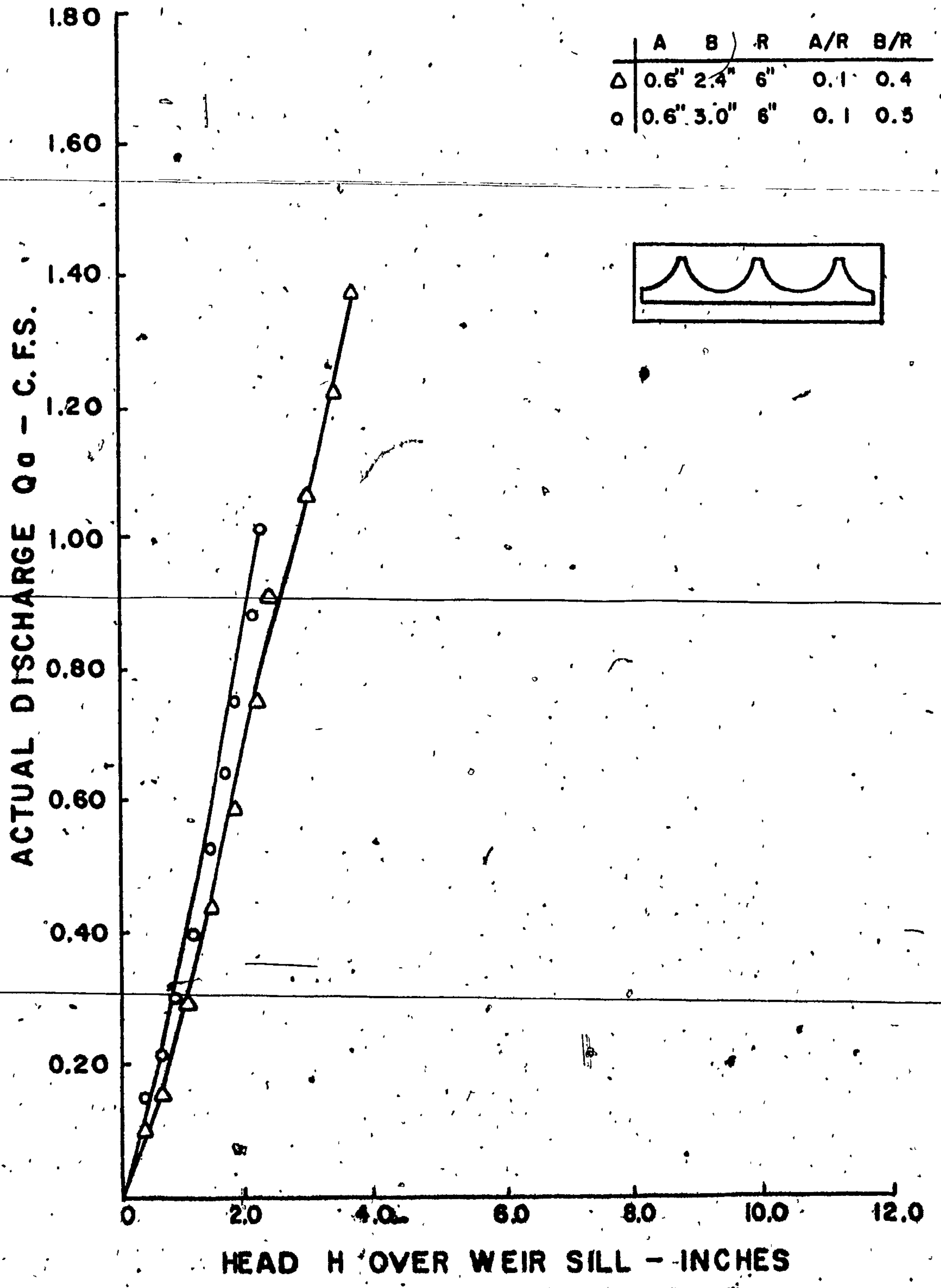


FIG. 10 VARIATION OF Qa WITH H (K=3)

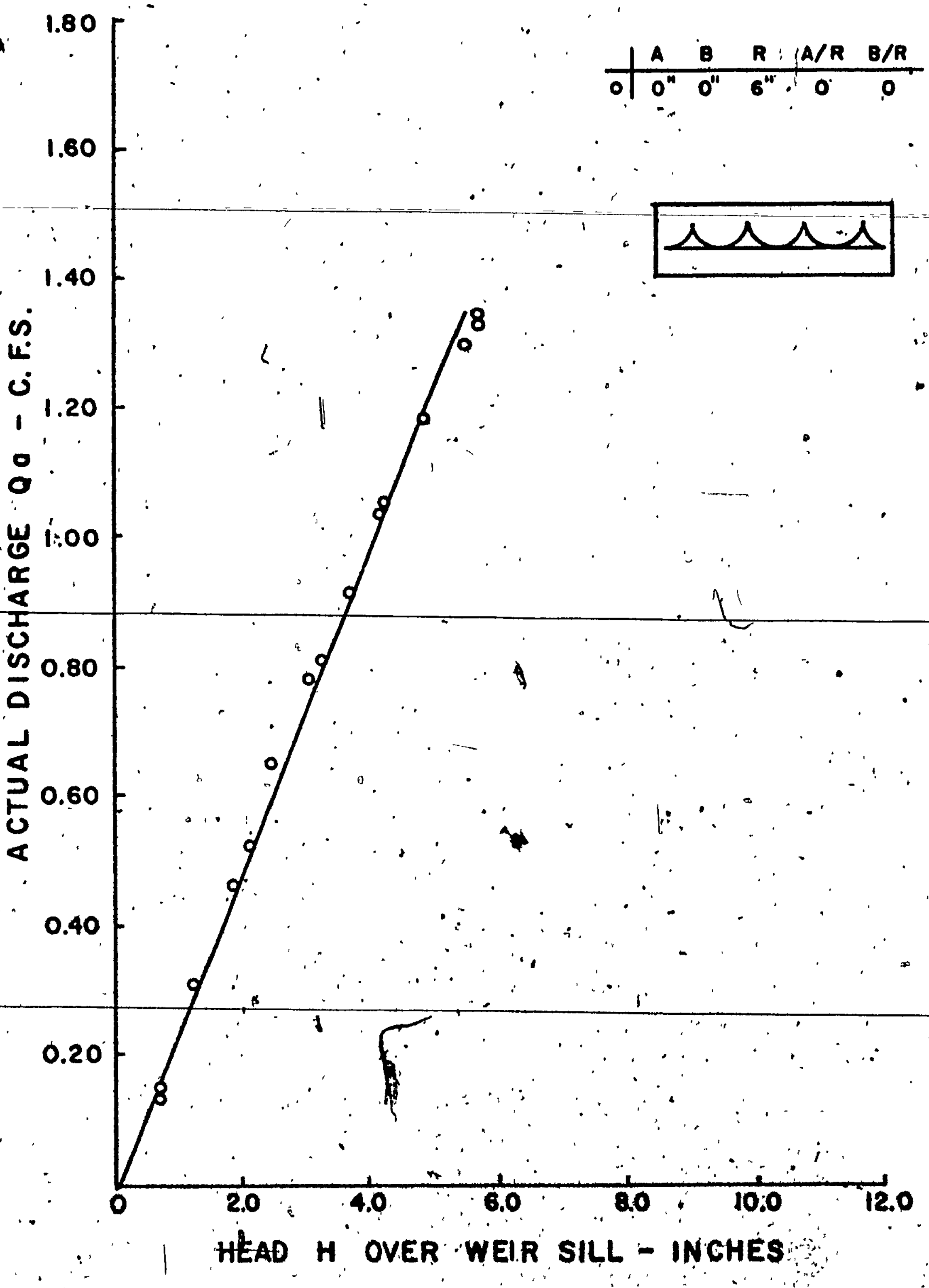


FIG. 11 VARIATION OF Qa WITH H (K=4)

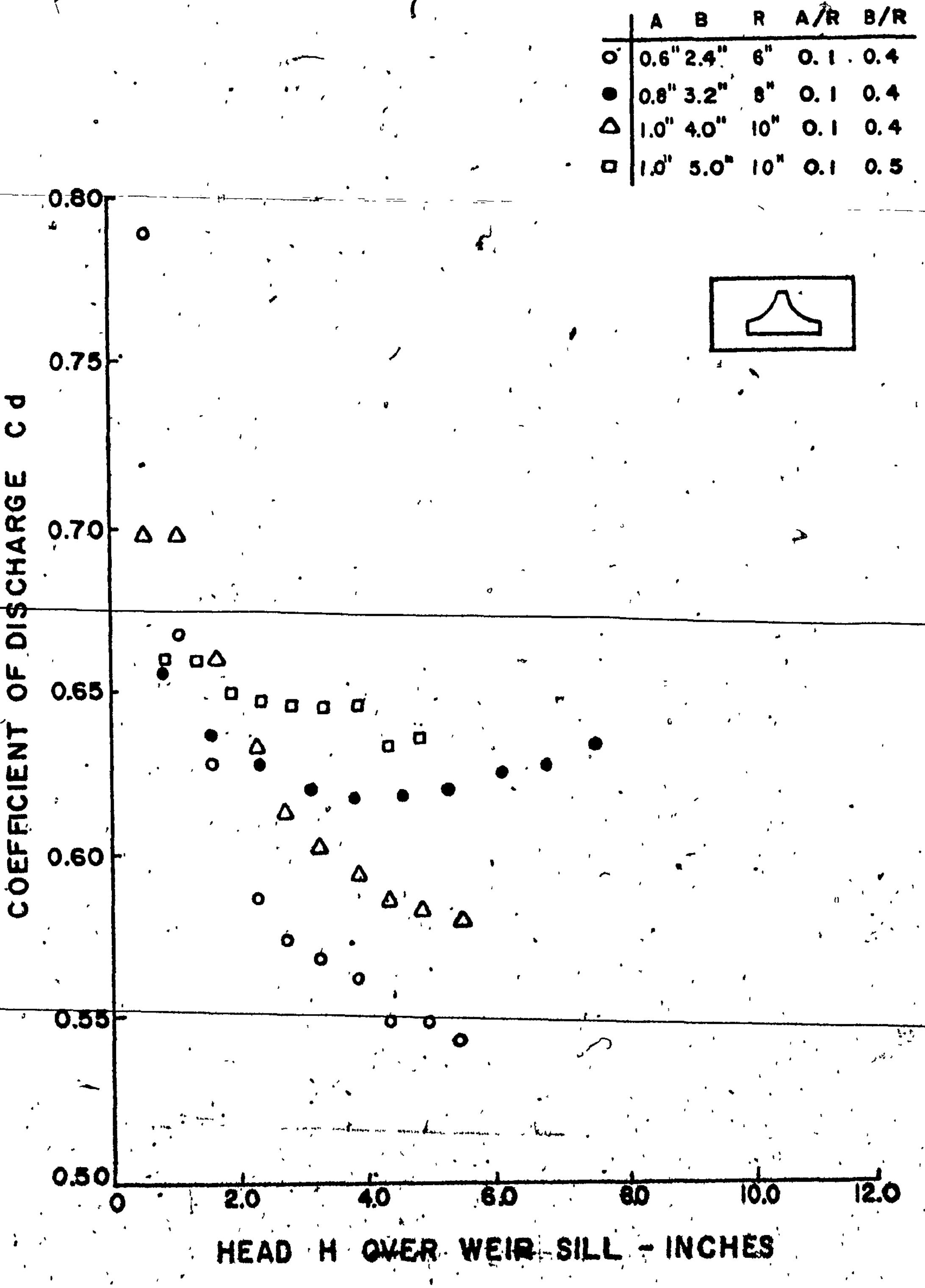


FIG.12 VARIATION OF C d WITH H (K=1)

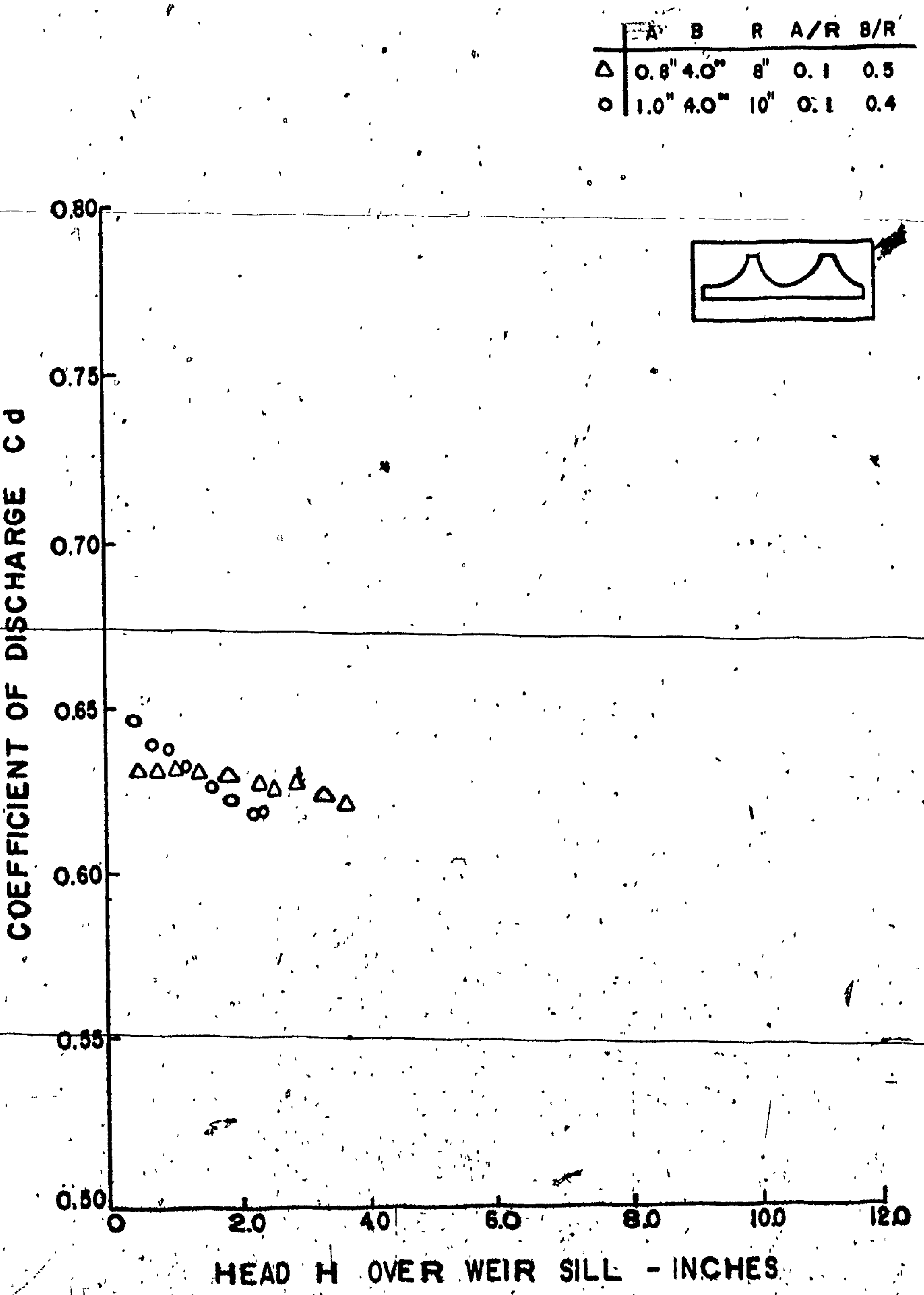


FIG.13 VARIATION OF Cd WITH H (K=2)

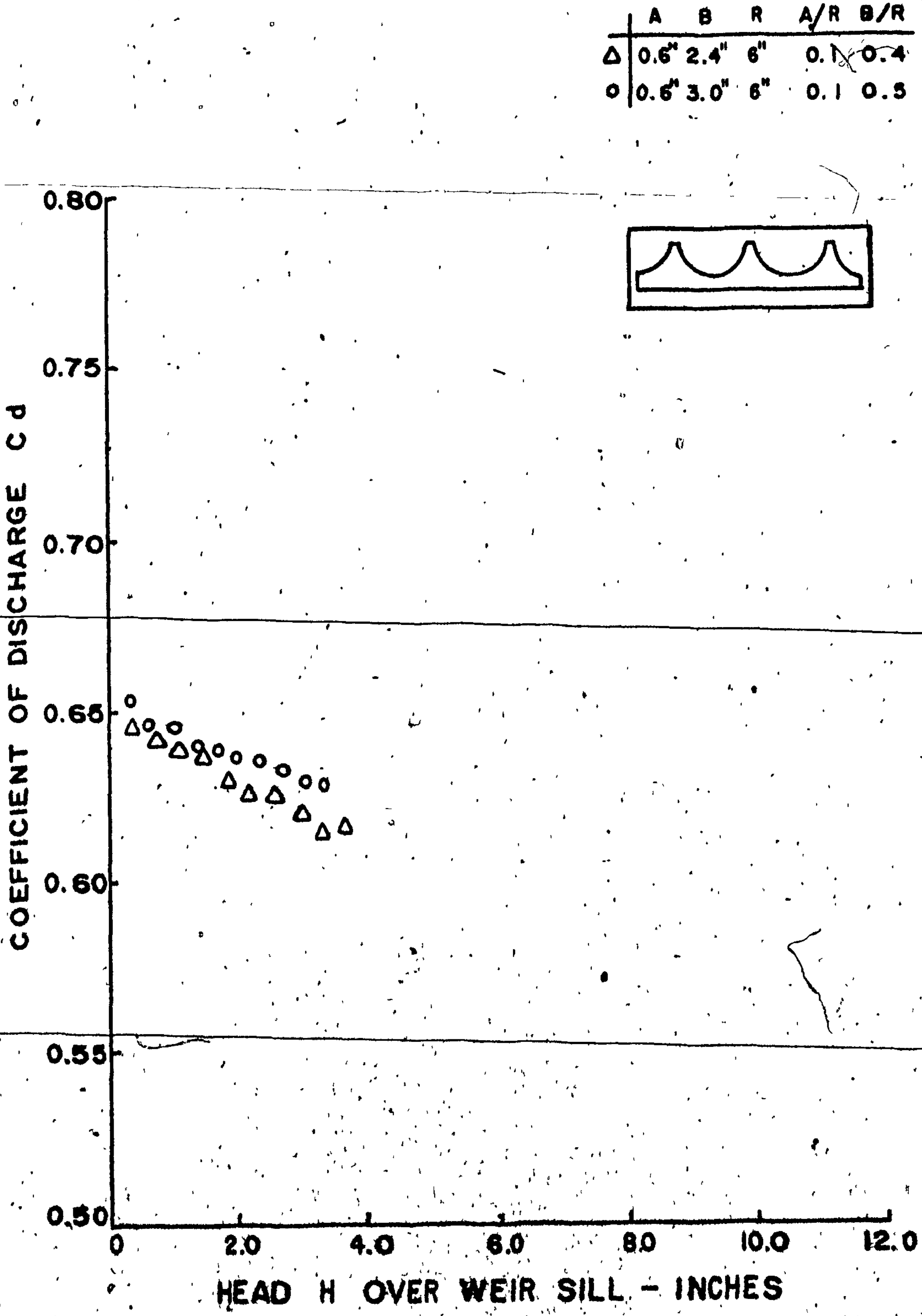


FIG.14 VARIATION OF Cd WITH H (K=3).

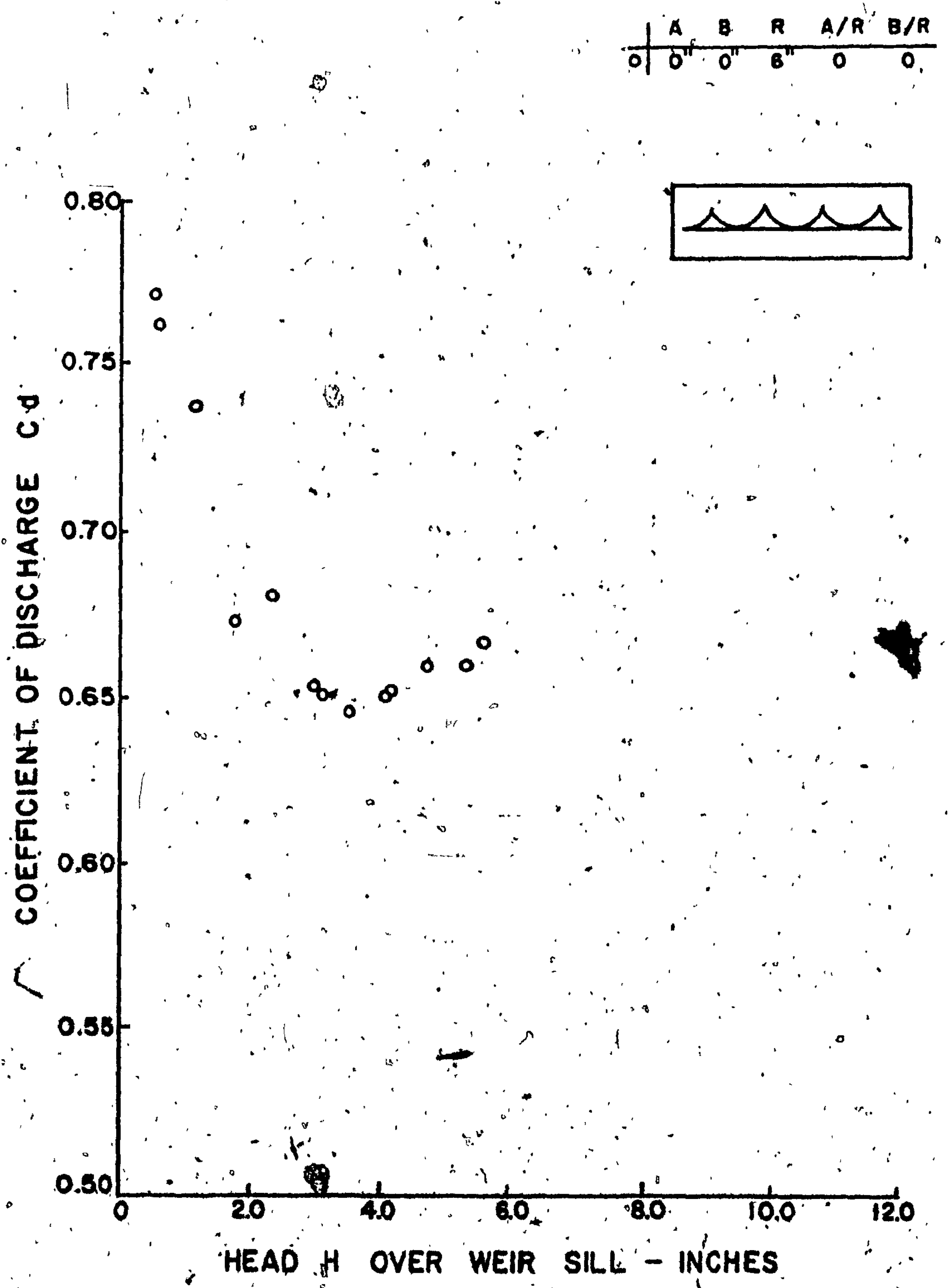
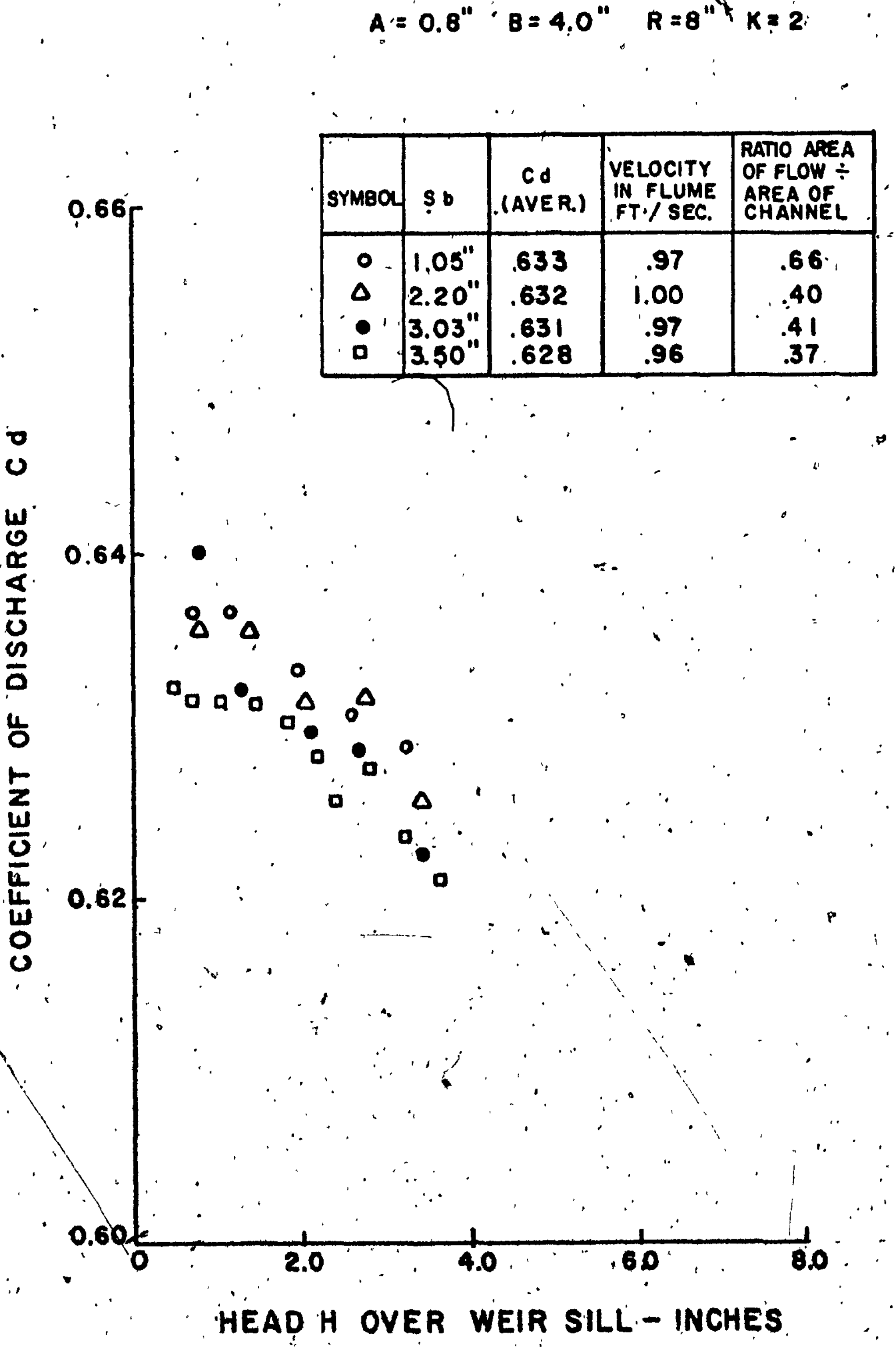


FIG.15 VARIATION OF Cd WITH H (K=4)



| SYMBOL | S b | C d (AVER.) | VELOCITY IN FLUME FT./SEC. | RATIO AREA OF FLOW ÷ AREA OF CHANNEL |
|---|---|---|---|---|
| ○ | 1.05" | .633 | .97 | .66 |
| △ | 2.20" | .632 | 1.00 | .40 |
| ● | 3.03" | .631 | .97 | .41 |
| □ | 3.50" | .628 | .96 | .37 |

FIG.16 VARIATION OF C d WITH H AND S b (R = 8")

A = 1.0"   B = 4.0"   R = 10"   K = 2

| SYMBOL | S b | C d (AVER.) | VELOCITY IN FLUME FT / SEC. | RATIO AREA OF FLOW ÷ AREA OF CHANNEL |
|---|---|---|---|---|
| ○ | 0.20" | .844 | 1.37 | .84 |
| □ | 0.69" | .637 | 1.13 | .67 |
| △ | 1.07" | .637 | 1.15 | .58 |

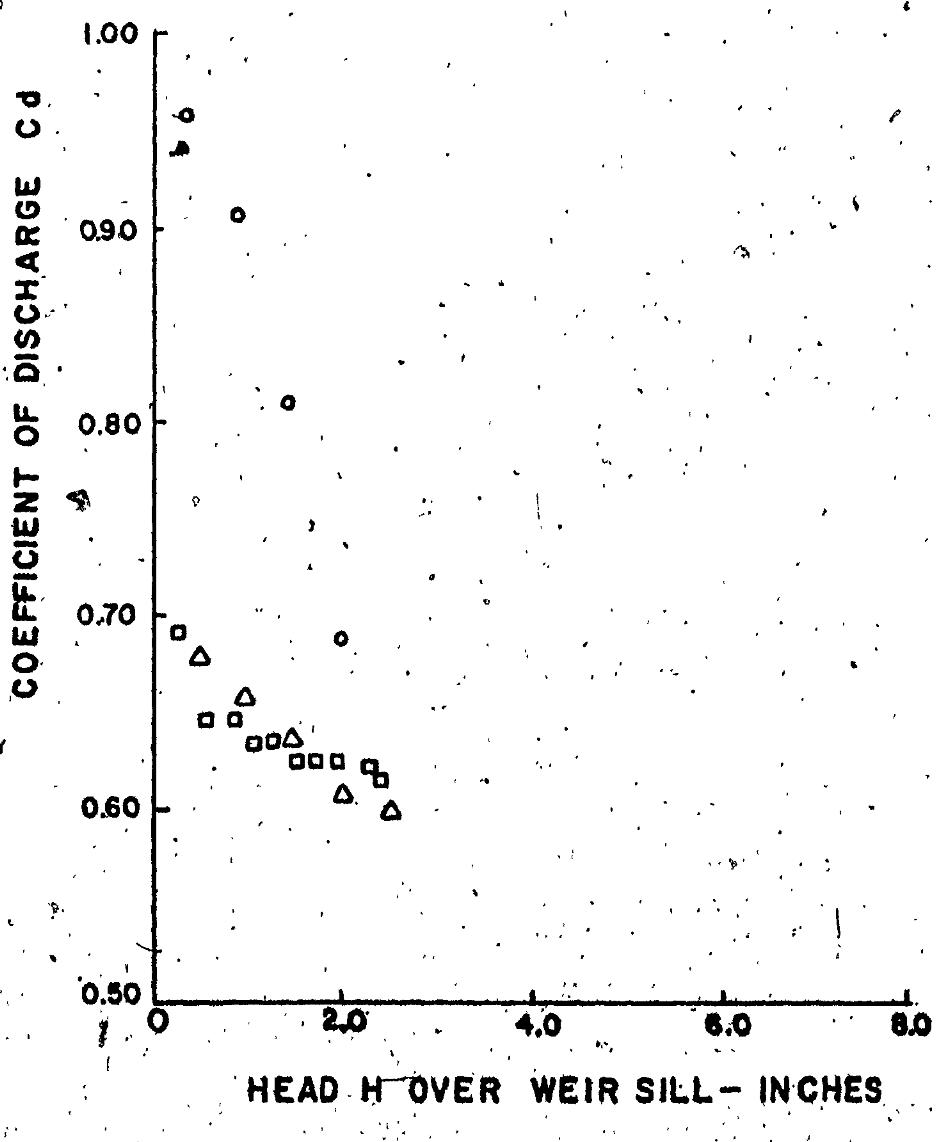
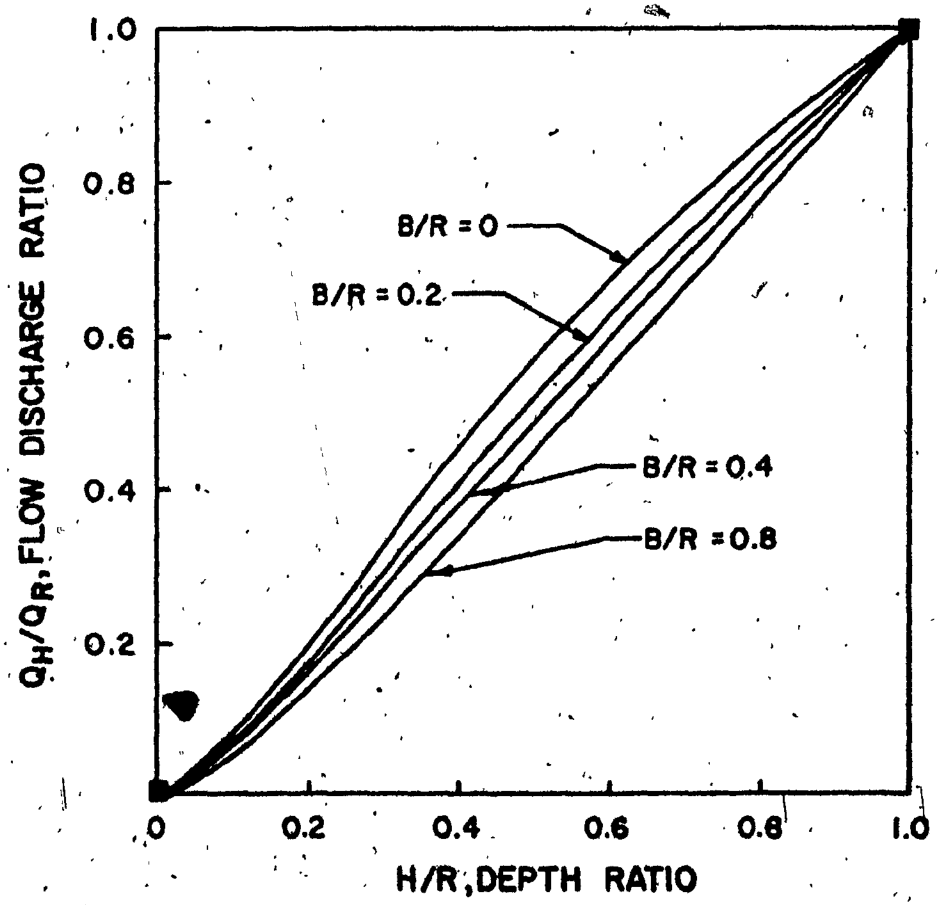
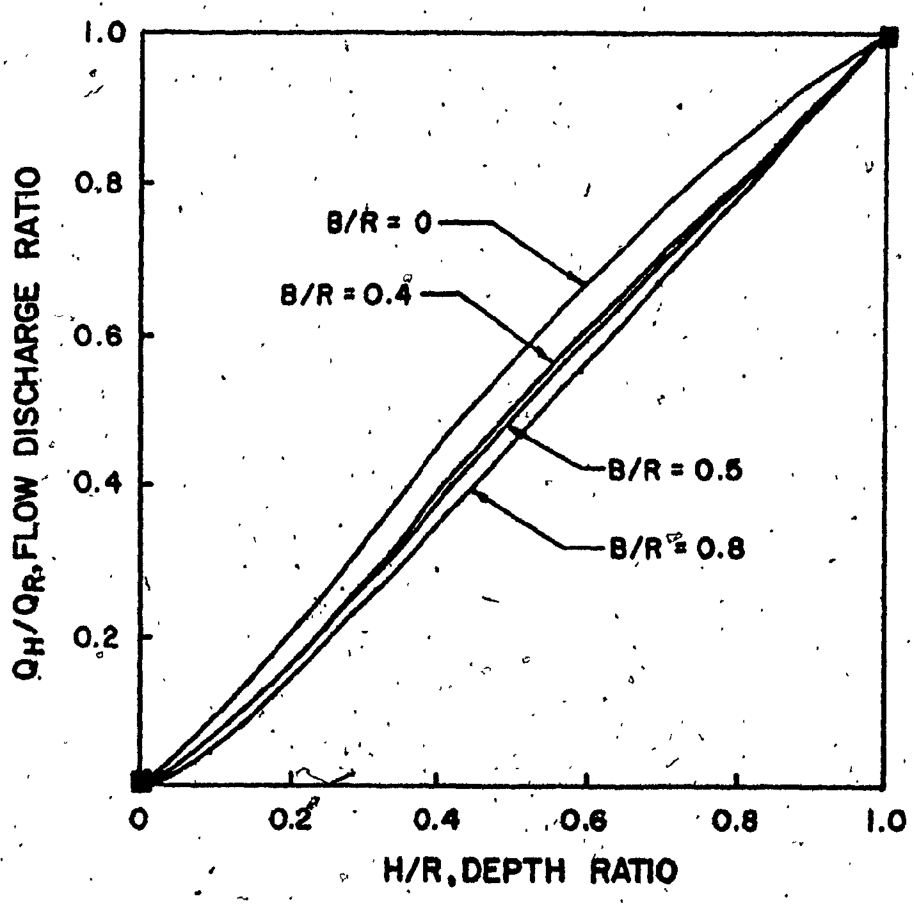


FIG.17 VARIATION OF C d WITH H AND Sb (R=10")



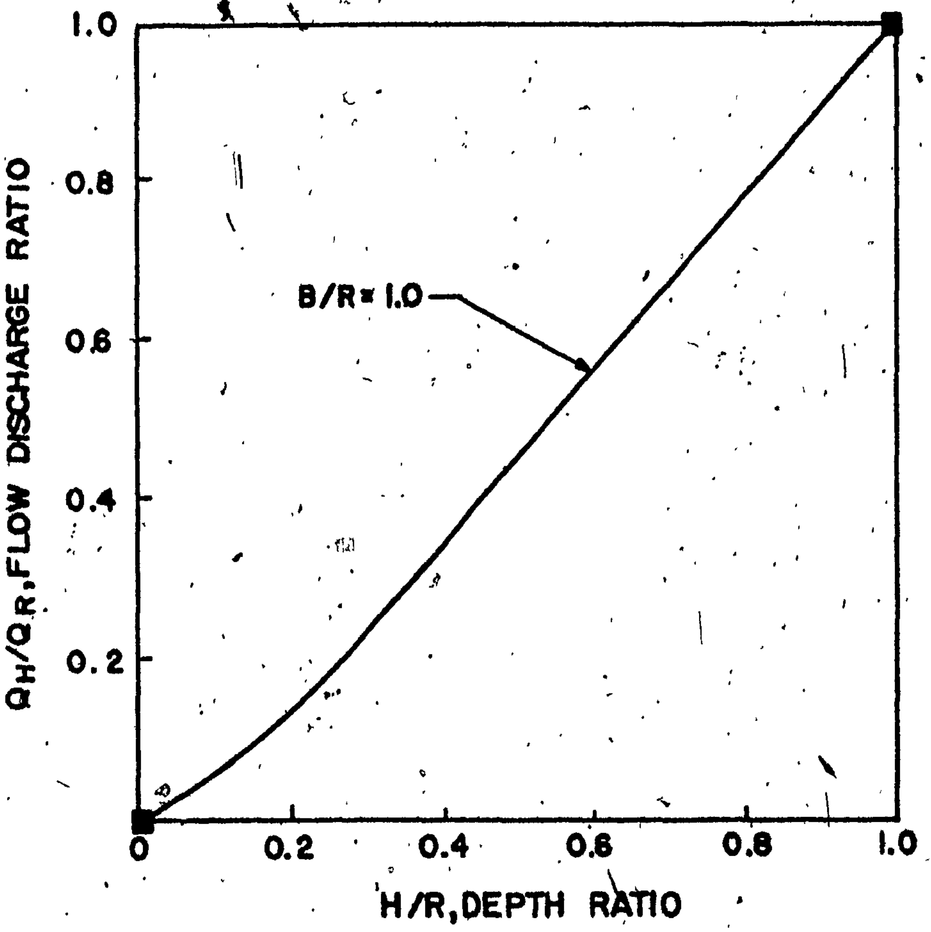
NOTE : SEE TABLES 6, 7 AND 13 TO 16

FIG. 18 NUMERICAL MODEL A / R = 0



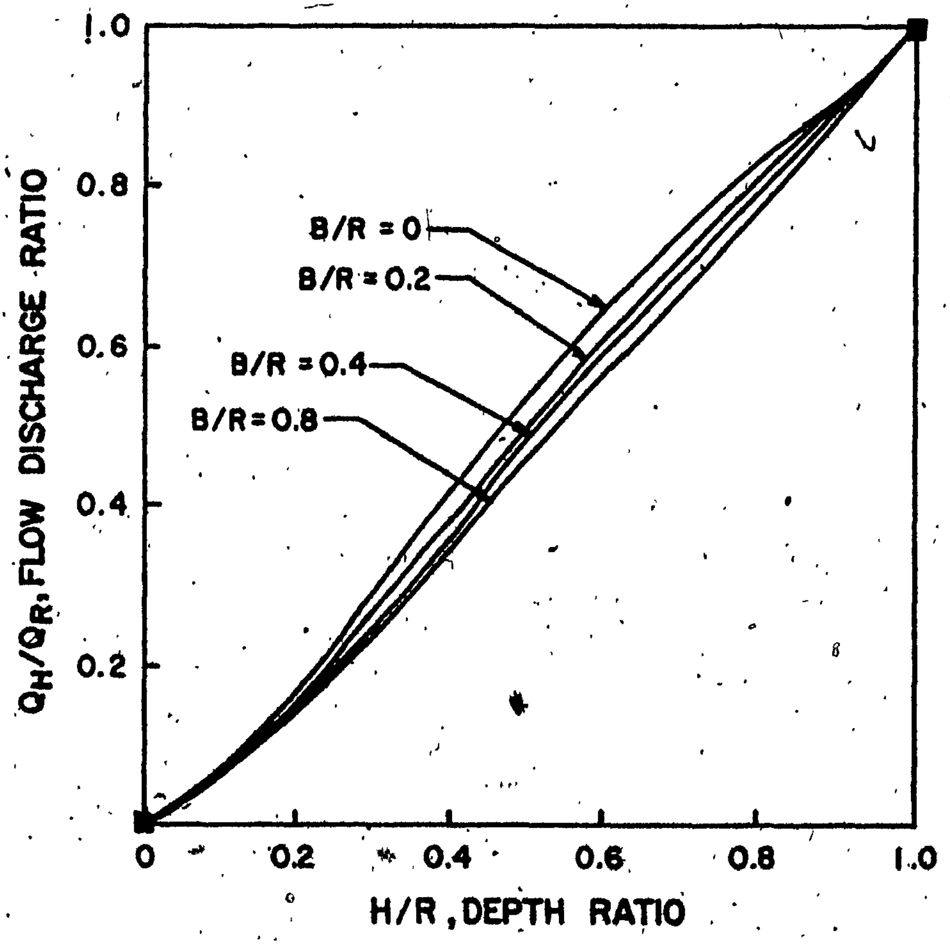
NOTE : SEE TABLES 8 TO 10 AND 17 TO 20

FIG. 19 NUMERICAL MODEL A/R = 0.1



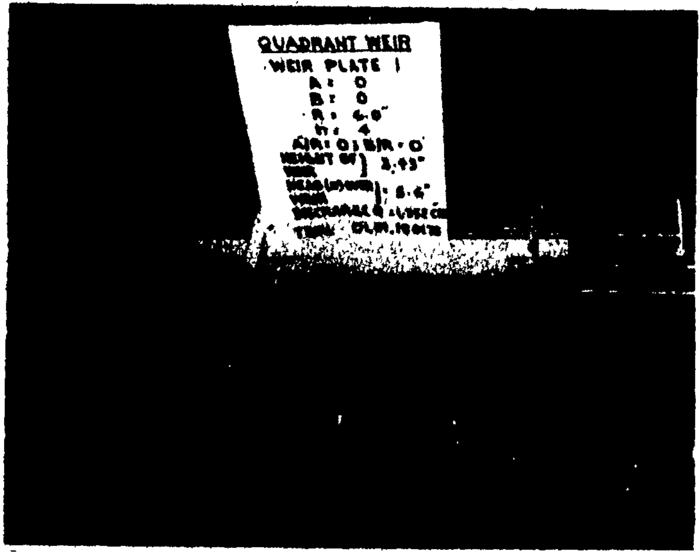
NOTE: SEE TABLES 3, 11, 21, 28 AND FIG. 2

FIG. 20 NUMERICAL MODEL A/R = 0.18

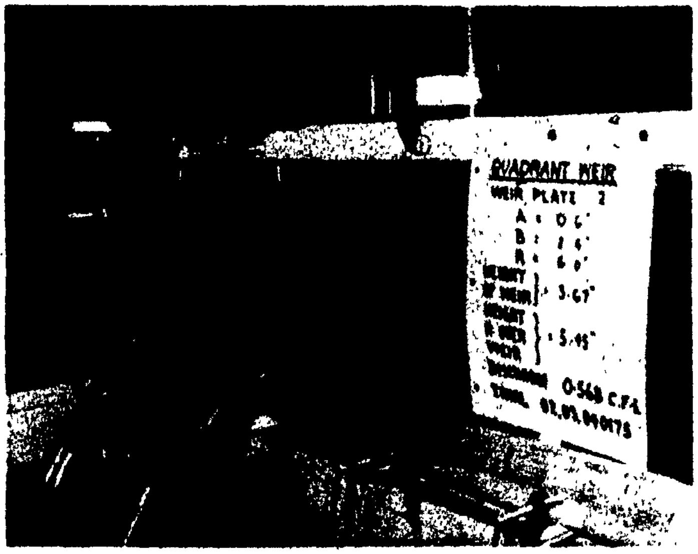


NOTE: SEE TABLES 12 AND 22 TO 25

FIG. 21 NUMERICAL MODEL A/R = 0.2



(a) A = 0"; B = 0"
R = 6"; K = 4



(b) A = 0.6"; B = 2.4"
R = 6"; K = 1

(c) A = 0.6"; B = 2.4"
R = 6"; K = 1

FIG. 22 PHOTOGRAPHS OF FLOW PROFILES

(d) A = 0"; B = 0"
R = 6"; K = 4

(e) A = 0.6"; B = 2.4"
R = 6"; K = 3

FIG. 22 PHOTOGRAPHS OF FLOW PROFILES (CONT'D)

# APPENDIX 3

## TABLE 1

## STANDARD DEVIATION OF PRACTICAL PROPORTIONAL WEIR BY VENKATARAMAN (16)

| A | Standard Deviation Discharge vs Head | Remarks |
|---|---|---|
| 0 cm. | + 3.22 | Reference: Fig. 2 (16) |
| 1 cm. | + 3.20 | B = 45 cm. |
| 2 cm. | - 3.23 | R = 17.5 cm. |
| 3 cm. | - 2.18 | |
| 4 cm. | - 2.26 | |

## TABLE 2

## STANDARD DEVIATION OF PROPORTIONAL WEIR ASSEMBLIES OF PRESENT STUDY

| No. of Openings K | Radius of Quadrant R (ins.) | A (ins.) | B (ins.) | $\frac{A}{R}$ | $\frac{B}{R}$ | Standard Deviation Discharge vs Head | Remarks |
|---|---|---|---|---|---|---|---|
| 4 | 6 | 0 | 0 | 0 | 0 | + 0.40 | |
| 1 | 6 | 0.6 | 2.4 | 0.1 | 0.4 | + 0.15 | |
| 2 | 10 | 1.0 | 4.0 | 0.1 | 0.4 | - 0.24 | |
| 2 | 8 | 0.8 | 4.0 | 0.1 | 0.5 | - 0.35 | |
| 1 | 8 | 0.8 | 3.2 | 0.1 | 0.4 | - 0.38 | |
| 3 | 6 | 0.6 | 3.0 | 0.1 | 0.5 | - 0.35 | |
| 3 | 6 | 0.6 | 2.4 | 0.1 | 0.4 | - 0.36 | |
| 1 | 10 | 1.0 | 4.0 | 0.1 | 0.4 | - 0.35 | |
| 1 | 10 | 1.0 | 5.0 | 0.1 | 0.5 | + 0.38 | |

## TABLE 3

## COMPARISON OF WEIR PROFILES OF TYPICAL PROPORTIONAL WEIR ASSEMBLY (Fig. 2)

| | Theoretical* Profile | Practical** Profile | Relative Error | |
|---|---|---|---|---|
| Y (ins.) | X (ins.) | X (ins.) | ΔX (ins.) | Remarks |
| 0.25 | 5.93 | 5.99 | +0.06 | Assumed A = 0.8"; W = 9.6" |
| 0.30 | 5.69 | 5.70 | +0.01 | |
| 0.35 | 5.47 | 5.48 | +0.01 | * Based on Table 2 (13) |
| 0.40 | 5.28 | 5.30 | +0.02 | Note: A is same as a |
| 0.45 | 5.11 | 5.15 | +0.04 | assumed by Sreenivasulu. |
| 0.50 | 4.97 | 5.01 | +0.04 | |
| 0.75 | 4.36 | 4.47 | +0.11 | ** Equation |
| 1.00 | 3.98 | 4.07 | +0.09 | $(X-6.58)^2 + (Y-4.6)^2 = 4.39^2$, |
| 1.50 | 3.42 | 3.47 | +0.05 | where radius R = 4.39", |
| 2.00 | 3.05 | 3.04 | -0.01 | centre (6.58, 4.6). |
| 2.50 | 2.78 | 2.73 | -0.05 | |
| 3.00 | 2.57 | 2.49 | -0.08 | Relative error of |
| 3.50 | 2.40 | 2.33 | -0.07 | practical profile from |
| 4.00 | 2.28 | 2.23 | -0.05 | theoretical profile = + 0.35%. |
| 4.50 | 2.15 | 2.19 | +0.04 | See Fig.20 and Tables 11, 21 |
| | | | | and 28. |

## TABLE 4

## RANGES OF VARIABLES STUDIED IN LINEAR PROPORTIONAL WEIR ASSEMBLIES

| No. of Openings K | Radius of Quadrant R (ins.) | A (ins.) | B (ins.) | $\frac{A}{R}$ | $\frac{B}{R}$ | Range of H (ins.) | Range of $Q_a$ (CFS) |
|---|---|---|---|---|---|---|---|
| 4 | 6 | 0 | 0 | 0 | 0 | 0 - 5.60 | 0 - 1.35 |
| 1 | 6 | 0.6 | 2.4 | 0.1 | 0.4 | 0 - 5.45 | 0 - 0.57 |
| 2 | 10 | 1.0 | 4.0 | 0.1 | 0.4 | 0 - 2.36 | 0 - 1.03 |
| 2 | 8 | 0.8 | 4.0 | 0.1 | 0.5 | 0 - 3.69 | 0 - 1.38 |
| 1 | 8 | 0.8 | 3.2 | 0.1 | 0.4 | 0 - 7.53 | 0 - 1.41 |
| 3 | 6 | 0.6 | 3.0 | 0.1 | 0.5 | 0 - 3.54 | 0 - 1.35 |
| 3 | 6 | 0.6 | 2.4 | 0.1 | 0.4 | 0 - 3.63 | 0 - 1.28 |
| 1 | 10 | 1.0 | 4.0 | 0.1 | 0.4 | 0 - 5.44 | 0 - 1.29 |
| 1 | 10 | 1.0 | 5.0 | 0.1 | 0.5 | 0 - 5.12 | 0 - 1.36 |

## TABLE 5 - COMPUTER PROGRAM FOR THEORETICAL DISCHARGE

```
PROGRAM LUIS  73/73  OPT= 1 FTN 4.2+P380  75/08/22.  15.30.17.

      PROGRAM LUIS (INPUT,OUTPUT,TAPE5=INPUT,TAPE 6=OUTPUT,TAPE 10)
      DIMENSION XR(12)
      DIMENSION EPH(101)
      DIMENSION MX(12)
      DIMENSION Q(101)
      DIMENSION MK(12)
      DIMENSION B(101,2),BI(202)
      DIMENSION QS(30),M1 (40), M2(40), M3 (40),M4(40)
      DIMENSION ETAA(6),ETAB(6),EPJ(101),AUX(4000)
      COMMON A,XU
      EXTERNAL FCT
      DATA  (XR (I),I =1,3)/.5,.6666,.833/
      DATA(ETAA (I),I =1,6)/0.,0.1,0.2,0.3,0.4,0.5/
      DATA  (ETAB(I),I=1,6)/0.0,0.1,0.2,0.3,0.4,0.5/
      MK(1) =10HA/R =
      MK(2) =10HB/R =
      MX(1) =10H0.1
      MX(2) =10H0.2
      MX(3) =10H0.3
      MX(4) =10H0.4
      MX(5) =10H0.5
      MX(6) =10H0.6
      MX(7) =10H0.7
      MX(8) =10H0.8
      MX(9) =10H0.9
      MX(10)=10H1.
      M1(1) =10HQ DISCHARG
      M1(2) =10HE
      M2(1) =10HH-WATER  H
      M2(2) =10HEIGHT
      DO 101 I=1,6
      A=ETAA(I)
      DO 102 K=1,6
      R =ETAB(K)
      DO   100  II=1,3
      DO   103   J=1,51
      EPH(J) =(1./50.)*FLOAT(J-1)
      EH=EPH(J) +A
      W1=(1./3.)*(2.+R)*EH*SQRT(EH)
      XL=0.
      XU=EPH(J)
      EPS=0.0001
      NDIM=4000
      CALL  QATR(XL,XU, EPS,NDIM,FCT,Y,IER,AUX)
```

### TABLE 5 - COMPUTER PROGRAM FOR THEORETICAL DISCHARGE (Cont'd)

```
103 Q(J)=(W1-Y)*16.05*(XR(II)**2.5)
    WRITE (6,109)  IER
109 FORMAT      (2X,//,*IER=*,I2,//)
205 FORMAT      (2X,*A/R=*,F5.3,6X,*B/R=*,F5.3,//)
    WRITE (6,205)  A,R
    WRITE (6,306)
    DO  999  M=1,51
    WRITE (6,456) EPH (M),Q(M)
999 CONTINUE
100 CONTINUE
306 FORMAT (/,1(4X,* ETAH*,4X,*   Q    *),/)
456 FORMAT (E10.3,4X,E10.3)
307 FORMAT  (10(4X,F5.3),/)
102 CONTINUE
101 CONTINUE
    STOP
    END

    FUNCTION   FCT(XX)
    COMMON A,XU
    FCT=SQRT   (XX*XX*XX-(2.+XU)*XX*XX+2.*XX*XU)
    RETURN
    END
```

## TABLE 6 - COMPUTER VALUES OF THEORETICAL DISCHARGE

A/R = 0; B/R = 0; $C_d$ = 1.0 (assumed)

| $\eta'_H = \left(\frac{H}{R} - \frac{A}{R}\right)$ | | $Q_t$ K = 1 | | REMARKS |
|---|---|---|---|---|
| | R = 6" | R = 8" | R = 10" | |
| 0. | 0. | 0. | 0. | For K > 1,<br>multiply $Q_t$<br>by value<br>of K.<br>$Q_t = Q_H$<br>(limit 0 to<br>$Q_R$) |
| .200E-01 | .472E-02 | .970E-02 | .169E-01 | |
| .400E-01 | .126E-01 | .259E-01 | .453E-01 | |
| .600E-01 | .222E-01 | .456E-01 | .795E-01 | |
| .800E-01 | .329E-01 | .675E-01 | .118E+00 | |
| .100E+00 | .443E-01 | .910E-01 | .159E+00 | |
| .120E+00 | .564E-01 | .116E+00 | .202E+00 | |
| .140E+00 | .688E-01 | .141E+00 | .246E+00 | |
| .160E+00 | .816E-01 | .167E+00 | .292E+00 | |
| .180E+00 | .947E-01 | .194E+00 | .339E+00 | |
| .200E+00 | .108E+00 | .221E+00 | .386E+00 | |
| .220E+00 | .121E+00 | .249E+00 | .434E+00 | |
| .240E+00 | .134E+00 | .276E+00 | .482E+00 | |
| .260E+00 | .148E+00 | .303E+00 | .530E+00 | |
| .280E+00 | .161E+00 | .331E+00 | .578E+00 | |
| .300E+00 | .175E+00 | .358E+00 | .625E+00 | |
| .320E+00 | .188E+00 | .385E+00 | .673E+00 | |
| .340E+00 | .201E+00 | .412E+00 | .720E+00 | |
| .360E+00 | .214E+00 | .439E+00 | .766E+00 | |
| .380E+00 | .227E+00 | .466E+00 | .813E+00 | |
| .400E+00 | .239E+00 | .492E+00 | .858E+00 | |
| .420E+00 | .252E+00 | .517E+00 | .903E+00 | |
| .440E+00 | .264E+00 | .543E+00 | .947E+00 | |
| .460E+00 | .277E+00 | .568E+00 | .991E+00 | |
| .480E+00 | .289E+00 | .593E+00 | .103E+01 | |
| .500E+00 | .301E+00 | .617E+00 | .108E+01 | |
| .520E+00 | .312E+00 | .641E+00 | .112E+01 | |
| .540E+00 | .324E+00 | .664E+00 | .116E+01 | |
| .560E+00 | .335E+00 | .687E+00 | .120E+01 | |
| .580E+00 | .346E+00 | .710E+00 | .124E+01 | |
| .600E+00 | .357E+00 | .732E+00 | .128E+01 | |
| .620E+00 | .367E+00 | .754E+00 | .132E+01 | |
| .640E+00 | .378E+00 | .775E+00 | .135E+01 | |
| .660E+00 | .388E+00 | .796E+00 | .139E+01 | |
| .680E+00 | .398E+00 | .816E+00 | .143E+01 | |
| .700E+00 | .408E+00 | .836E+00 | .146E+01 | |
| .720E+00 | .417E+00 | .856E+00 | .149E+01 | |
| .740E+00 | .426E+00 | .875E+00 | .153E+01 | |
| .760E+00 | .436E+00 | .894E+00 | .156E+01 | |
| .780E+00 | .445E+00 | .912E+00 | .159E+01 | |
| .800E+00 | .453E+00 | .930E+00 | .162E+01 | |
| .820E+00 | .462E+00 | .948E+00 | .165E+01 | |
| .840E+00 | .470E+00 | .965E+00 | .168E+01 | |
| .860E+00 | .479E+00 | .982E+00 | .171E+01 | |
| .880E+00 | .487E+00 | .999E+00 | .174E+01 | |
| .900E+00 | .494E+00 | .101E+01 | .177E+01 | |
| .920E+00 | .502E+00 | .103E+01 | .180E+01 | |
| .940E+00 | .510E+00 | .105E+01 | .183E+01 | |
| .960E+00 | .517E+00 | .106E+01 | .185E+01 | |
| .980E+00 | .525E+00 | .108E+01 | .188E+01 | |
| .100E+01 | .532E+00 | .109E+01 | .191E+01 | |

## TABLE 7 - COMPUTER VALUES OF THEORETICAL DISCHARGE

$A/R = 0; \quad B/R = 0.2, 0.4, 0.8; \quad R = 6''$

| $\eta'_H = \left(\frac{H}{R} - \frac{A}{R}\right)$ | $Q_t$ B/R = 0.2 | $Q_t$ B/R = 0.4 | $Q_t$ B/R = 0.8 | REMARKS |
|---|---|---|---|---|
| 0. | 0. | 0. | 0. | $C_d = 1.0$ (assumed) and K = 1. For K > 1, multiply $Q_t$ by value of K.<br>$Q_t = Q_H$ (limit 0 to $Q_R$) |
| .200E-01 | .526E-02 | .579E-02 | .686E-02 | |
| .400E-01 | .142E-01 | .157E-01 | .187E-01 | |
| .600E-01 | .250E-01 | .278E-01 | .333E-01 | |
| .800E-01 | .372E-01 | .414E-01 | .500E-01 | |
| .100E+00 | .503E-01 | .563E-01 | .683E-01 | |
| .120E+00 | .643E-01 | .721E-01 | .879E-01 | |
| .140E+00 | .787E-01 | .886E-01 | .108E+00 | |
| .160E+00 | .937E-01 | .106E+00 | .130E+00 | |
| .180E+00 | .109E+00 | .124E+00 | .152E+00 | |
| .200E+00 | .125E+00 | .142E+00 | .176E+00 | |
| .220E+00 | .141E+00 | .160E+00 | .199E+00 | |
| .240E+00 | .157E+00 | .179E+00 | .223E+00 | |
| .260E+00 | .173E+00 | .198E+00 | .248E+00 | |
| .280E+00 | .189E+00 | .217E+00 | .273E+00 | |
| .300E+00 | .206E+00 | .237E+00 | .299E+00 | |
| .320E+00 | .222E+00 | .256E+00 | .325E+00 | |
| .340E+00 | .238E+00 | .276E+00 | .351E+00 | |
| .360E+00 | .255E+00 | .296E+00 | .377E+00 | |
| .380E+00 | .271E+00 | .315E+00 | .404E+00 | |
| .400E+00 | .287E+00 | .335E+00 | .431E+00 | |
| .420E+00 | .304E+00 | .355E+00 | .458E+00 | |
| .440E+00 | .320E+00 | .375E+00 | .485E+00 | |
| .460E+00 | .336E+00 | .395E+00 | .513E+00 | |
| .480E+00 | .352E+00 | .415E+00 | .540E+00 | |
| .500E+00 | .367E+00 | .434E+00 | .568E+00 | |
| .520E+00 | .383E+00 | .454E+00 | .596E+00 | |
| .540E+00 | .399E+00 | .474E+00 | .624E+00 | |
| .560E+00 | .414E+00 | .493E+00 | .652E+00 | |
| .580E+00 | .429E+00 | .513E+00 | .680E+00 | |
| .600E+00 | .445E+00 | .533E+00 | .708E+00 | |
| .620E+00 | .460E+00 | .552E+00 | .737E+00 | |
| .640E+00 | .475E+00 | .571E+00 | .765E+00 | |
| .660E+00 | .489E+00 | .591E+00 | .794E+00 | |
| .680E+00 | .504E+00 | .610E+00 | .822E+00 | |
| .700E+00 | .518E+00 | .629E+00 | .851E+00 | |
| .720E+00 | .533E+00 | .648E+00 | .879E+00 | |
| .740E+00 | .547E+00 | .667E+00 | .908E+00 | |
| .760E+00 | .561E+00 | .686E+00 | .937E+00 | |
| .780E+00 | .575E+00 | .705E+00 | .966E+00 | |
| .800E+00 | .589E+00 | .724E+00 | .995E+00 | |
| .820E+00 | .602E+00 | .743E+00 | .102E+01 | |
| .840E+00 | .616E+00 | .762E+00 | .105E+01 | |
| .860E+00 | .629E+00 | .780E+00 | .108E+01 | |
| .880E+00 | .643E+00 | .799E+00 | .111E+01 | |
| .900E+00 | .656E+00 | .817E+00 | .114E+01 | |
| .920E+00 | .669E+00 | .836E+00 | .117E+01 | |
| .940E+00 | .682E+00 | .855E+00 | .120E+01 | |
| .960E+00 | .695E+00 | .873E+00 | .123E+01 | |
| .980E+00 | .708E+00 | .892E+00 | .126E+01 | |
| .100E+01 | .721E+00 | .910E+00 | .129E+01 | |

## TABLE 8 - COMPUTER VALUES OF THEORETICAL DISCHARGE

A/R = 0.1; B/R = 0, 0.2, 0.8; R = 6"

| $\eta'_H$ | $Q_t$ | | | |
|---|---|---|---|---|
| $=\left(\frac{H}{R} - \frac{A}{R}\right)$ | B/R = 0 | B/R = 0.2 | B/R = 0.8 | REMARKS |
| 0. | .598E-01 | .658E-01 | .837E-01 | $Q_d$ = 1.0 (assumed) and K = 1. For K > 1, multiply $Q_t$ by value of K. $Q_t = Q_H$ (limit 0 to $Q_R$) |
| .200E-01 | .780E-01 | .859E-01 | .109E+00 | |
| .400E-01 | .966E-01 | .106E+00 | .136E+00 | |
| .600E-01 | .115E+00 | .128E+00 | .164E+00 | |
| .800E-01 | .135E+00 | .149E+00 | .192E+00 | |
| .100E+00 | .154E+00 | .171E+00 | .221E+00 | |
| .120E+00 | .173E+00 | .192E+00 | .251E+00 | |
| .140E+00 | .192E+00 | .214E+00 | .281E+00 | |
| .160E+00 | .211E+00 | .236E+00 | .312E+00 | |
| .180E+00 | .230E+00 | .258E+00 | .343E+00 | |
| .200E+00 | .249E+00 | .281E+00 | .374E+00 | |
| .220E+00 | .268E+00 | .303E+00 | .405E+00 | |
| .240E+00 | .287E+00 | .325E+00 | .437E+00 | |
| .260E+00 | .306E+00 | .347E+00 | .469E+00 | |
| .280E+00 | .324E+00 | .368E+00 | .501E+00 | |
| .300E+00 | .342E+00 | .390E+00 | .534E+00 | |
| .320E+00 | .360E+00 | .412E+00 | .566E+00 | |
| .340E+00 | .378E+00 | .433E+00 | .599E+00 | |
| .360E+00 | .396E+00 | .455E+00 | .632E+00 | |
| .380E+00 | .413E+00 | .476E+00 | .664E+00 | |
| .400E+00 | .430E+00 | .497E+00 | .697E+00 | |
| .420E+00 | .446E+00 | .517E+00 | .730E+00 | |
| .440E+00 | .463E+00 | .538E+00 | .763E+00 | |
| .460E+00 | .479E+00 | .559E+00 | .796E+00 | |
| .480E+00 | .495E+00 | .579E+00 | .829E+00 | |
| .500E+00 | .511E+00 | .599E+00 | .863E+00 | |
| .520E+00 | .526E+00 | .619E+00 | .896E+00 | |
| .540E+00 | .542E+00 | .638E+00 | .929E+00 | |
| .560E+00 | .556E+00 | .658E+00 | .962E+00 | |
| .580E+00 | .571E+00 | .677E+00 | .995E+00 | |
| .600E+00 | .585E+00 | .696E+00 | .103E+01 | |
| .620E+00 | .600E+00 | .715E+00 | .106E+01 | |
| .640E+00 | .613E+00 | .734E+00 | .110E+01 | |
| .660E+00 | .627E+00 | .752E+00 | .113E+01 | |
| .680E+00 | .640E+00 | .770E+00 | .116E+01 | |
| .700E+00 | .653E+00 | .789E+00 | .119E+01 | |
| .720E+00 | .666E+00 | .806E+00 | .123E+01 | |
| .740E+00 | .679E+00 | .824E+00 | .126E+01 | |
| .760E+00 | .691E+00 | .842E+00 | .129E+01 | |
| .780E+00 | .703E+00 | .859E+00 | .133E+01 | |
| .800E+00 | .715E+00 | .876E+00 | .136E+01 | |
| .820E+00 | .727E+00 | .893E+00 | .139E+01 | |
| .840E+00 | .738E+00 | .910E+00 | .143E+01 | |
| .860E+00 | .749E+00 | .927E+00 | .146E+01 | |
| .880E+00 | .760E+00 | .944E+00 | .149E+01 | |
| .900E+00 | .771E+00 | .960E+00 | .153E+01 | |
| .920E+00 | .782E+00 | .977E+00 | .156E+01 | |
| .940E+00 | .792E+00 | .993E+00 | .159E+01 | |
| .960E+00 | .802E+00 | .101E+01 | .163E+01 | |
| .980E+00 | .813E+00 | .102E+01 | .166E+01 | |
| .100E+01 | .823E+00 | .104E+01 | .170E+01 | |

## TABLE 9 - COMPUTER VALUES OF THEORETICAL DISCHARGE

A/R = 0.1; B/R = 0.4; $C_d$ = 1.0 (assumed)

| $\eta'_H$ |  | $Q_t$<br>K = 1 |  |  |
|---|---|---|---|---|
| $= \left(\frac{H}{R} - \frac{A}{R}\right)$ | R = 6" | R = 8" | R = 10" | REMARKS |
| 0. | .718E-01 | .147E+00 | .257E+00 | For K > 1, |
| .200E-01 | .937E-01 | .192E+00 | .336E+00 | multiply $Q_t$ |
| .400E-01 | .116E+00 | .239E+00 | .417E+00 | by value |
| .600E-01 | .140E+00 | .287E+00 | .500E+00 | of K. |
| .800E-01 | .163E+00 | .335E+00 | .585E+00 | $Q_t = Q_H$ |
| .100E+00 | .188E+00 | .385E+00 | .672E+00 | (limit 0 to |
| .120E+00 | .212E+00 | .435E+00 | .759E+00 | $Q_R$) |
| .140E+00 | .237E+00 | .486E+00 | .848E+00 |  |
| .160E+00 | .261E+00 | .537E+00 | .937E+00 |  |
| .180E+00 | .287E+00 | .588E+00 | .103E+01 |  |
| .200E+00 | .312E+00 | .640E+00 | .112E+01 |  |
| .220E+00 | .337E+00 | .691E+00 | .121E+01 |  |
| .240E+00 | .362E+00 | .743E+00 | .130E+01 |  |
| .260E+00 | .387E+00 | .795E+00 | .139E+01 |  |
| .280E+00 | .413E+00 | .847E+00 | .148E+01 |  |
| .300E+00 | .438E+00 | .899E+00 | .157E+01 |  |
| .320E+00 | .463E+00 | .951E+00 | .166E+01 |  |
| .340E+00 | .488E+00 | .100E+01 | .175E+01 |  |
| .360E+00 | .514E+00 | .105E+01 | .184E+01 |  |
| .380E+00 | .539E+00 | .111E+01 | .193E+01 |  |
| .400E+00 | .563E+00 | .116E+01 | .202E+01 |  |
| .420E+00 | .588E+00 | .121E+01 | .211E+01 |  |
| .440E+00 | .613E+00 | .126E+01 | .220E+01 |  |
| .460E+00 | .638E+00 | .131E+01 | .228E+01 |  |
| .480E+00 | .662E+00 | .136E+01 | .237E+01 |  |
| .500E+00 | .687E+00 | .141E+01 | .246E+01 |  |
| .520E+00 | .711E+00 | .146E+01 | .255E+01 |  |
| .540E+00 | .735E+00 | .151E+01 | .263E+01 |  |
| .560E+00 | .759E+00 | .156E+01 | .272E+01 |  |
| .580E+00 | .783E+00 | .161E+01 | .281E+01 |  |
| .600E+00 | .807E+00 | .166E+01 | .289E+01 |  |
| .620E+00 | .831E+00 | .170E+01 | .298E+01 |  |
| .640E+00 | .854E+00 | .175E+01 | .306E+01 |  |
| .660E+00 | .878E+00 | .180E+01 | .314E+01 |  |
| .680E+00 | .901E+00 | .185E+01 | .323E+01 |  |
| .700E+00 | .924E+00 | .190E+01 | .331E+01 |  |
| .720E+00 | .947E+00 | .194E+01 | .339E+01 |  |
| .740E+00 | .970E+00 | .199E+01 | .347E+01 |  |
| .760E+00 | .993E+00 | .204E+01 | .356E+01 |  |
| .780E+00 | .102E+01 | .208E+01 | .364E+01 |  |
| .800E+00 | .104E+01 | .213E+01 | .372E+01 |  |
| .820E+00 | .106E+01 | .218E+01 | .380E+01 |  |
| .840E+00 | .108E+01 | .222E+01 | .388E+01 |  |
| .860E+00 | .110E+01 | .227E+01 | .396E+01 |  |
| .880E+00 | .113E+01 | .231E+01 | .404E+01 |  |
| .900E+00 | .115E+01 | .236E+01 | .412E+01 |  |
| .920E+00 | .117E+01 | .240E+01 | .420E+01 |  |
| .940E+00 | .119E+01 | .245E+01 | .428E+01 |  |
| .960E+00 | .122E+01 | .249E+01 | .435E+01 |  |
| .980E+00 | .124E+01 | .254E+01 | .443E+01 |  |
| .100E+01 | .126E+01 | .258E+01 | .451E+01 |  |

## TABLE 10 - COMPUTER VALUES OF THEORETICAL DISCHARGE

$A/R = 0.1$; $B/R = 0.5$; $C_d = 1.0$ (assumed)

|  |  | $Q_t$<br>$K = 1$ |  |  |
|---|---|---|---|---|
| $\eta'_H = \left(\frac{H}{R} - \frac{A}{R}\right)$ | R = 6" | R = 8" | R = 10" | REMARKS |
| 0. | .748E-01 | .153E+00 | .268E+00 | For $K > 1$, multiply $Q_t$ by value of K. $Q_t = Q_H$ (limit 0 to $Q_R$) |
| .200E-01 | .977E-01 | .200E+00 | .350E+00 |  |
| .400E-01 | .121E+00 | .249E+00 | .435E+00 |  |
| .600E-01 | .146E+00 | .299E+00 | .522E+00 |  |
| .800E-01 | .171E+00 | .350E+00 | .611E+00 |  |
| .100E+00 | .196E+00 | .402E+00 | .702E+00 |  |
| .120E+00 | .222E+00 | .455E+00 | .794E+00 |  |
| .140E+00 | .248E+00 | .508E+00 | .887E+00 |  |
| .160E+00 | .274E+00 | .562E+00 | .982E+00 |  |
| .180E+00 | .301E+00 | .617E+00 | .108E+01 |  |
| .200E+00 | .327E+00 | .672E+00 | .117E+01 |  |
| .220E+00 | .354E+00 | .727E+00 | .127E+01 |  |
| .240E+00 | .381E+00 | .782E+00 | .136E+01 |  |
| .260E+00 | .408E+00 | .837E+00 | .146E+01 |  |
| .280E+00 | .435E+00 | .892E+00 | .156E+01 |  |
| .300E+00 | .462E+00 | .948E+00 | .165E+01 |  |
| .320E+00 | .489E+00 | .100E+01 | .175E+01 |  |
| .340E+00 | .516E+00 | .106E+01 | .185E+01 |  |
| .360E+00 | .543E+00 | .111E+01 | .195E+01 |  |
| .380E+00 | .570E+00 | .117E+01 | .204E+01 |  |
| .400E+00 | .597E+00 | .123E+01 | .214E+01 |  |
| .420E+00 | .624E+00 | .128E+01 | .223E+01 |  |
| .440E+00 | .651E+00 | .134E+01 | .233E+01 |  |
| .460E+00 | .677E+00 | .139E+01 | .243E+01 |  |
| .480E+00 | .704E+00 | .145E+01 | .252E+01 |  |
| .500E+00 | .731E+00 | .150E+01 | .262E+01 |  |
| .520E+00 | .757E+00 | .155E+01 | .271E+01 |  |
| .540E+00 | .784E+00 | .161E+01 | .281E+01 |  |
| .560E+00 | .810E+00 | .166E+01 | .290E+01 |  |
| .580E+00 | .836E+00 | .172E+01 | .300E+01 |  |
| .600E+00 | .862E+00 | .177E+01 | .309E+01 |  |
| .620E+00 | .888E+00 | .182E+01 | .318E+01 |  |
| .640E+00 | .914E+00 | .188E+01 | .328E+01 |  |
| .660E+00 | .940E+00 | .193E+01 | .337E+01 |  |
| .680E+00 | .966E+00 | .198E+01 | .346E+01 |  |
| .700E+00 | .992E+00 | .204E+01 | .355E+01 |  |
| .720E+00 | .102E+01 | .209E+01 | .364E+01 |  |
| .740E+00 | .104E+01 | .214E+01 | .374E+01 |  |
| .760E+00 | .107E+01 | .219E+01 | .383E+01 |  |
| .780E+00 | .109E+01 | .224E+01 | .392E+01 |  |
| .800E+00 | .112E+01 | .230E+01 | .401E+01 |  |
| .820E+00 | .114E+01 | .235E+01 | .410E+01 |  |
| .840E+00 | .117E+01 | .240E+01 | .419E+01 |  |
| .860E+00 | .119E+01 | .245E+01 | .428E+01 |  |
| .880E+00 | .122E+01 | .250E+01 | .437E+01 |  |
| .900E+00 | .124E+01 | .255E+01 | .446E+01 |  |
| .920E+00 | .127E+01 | .260E+01 | .455E+01 |  |
| .940E+00 | .129E+01 | .265E+01 | .463E+01 |  |
| .960E+00 | .132E+01 | .271E+01 | .472E+01 |  |
| .980E+00 | .134E+01 | .276E+01 | .481E+01 |  |
| .100E+01 | .137E+01 | .281E+01 | .490E+01 |  |

## TABLE 11 - COMPUTER VALUES OF THEORETICAL DISCHARGE

A/R = 0.18; B/R = 1.0; $C_d$ = 1.0 (assumed)

| $\eta' = \left(\frac{H}{R} - \frac{H_A}{R}\right)$ | $Q_t$<br>K = 1 | | | |
|---|---|---|---|---|
| | R = 4.39" | R = 6" | R = 8" | REMARKS |
| Q. | .993E-01 | .217E+00 | .445E+00 | For K > 1, multiply $Q_t$ by value of K.<br>$Q_t = Q_H$ (limit 0 to $Q_R$) |
| .200E-01 | .116E+00 | .253E+00 | .520E+00 | |
| .400E-01 | .133E+00 | .290E+00 | .596E+00 | |
| .600E-01 | .150E+00 | .328E+00 | .673E+00 | |
| .800E-01 | .168E+00 | .366E+00 | .752E+00 | |
| .100E+00 | .186E+00 | .405E+00 | .831E+00 | |
| .120E+00 | .204E+00 | .444E+00 | .911E+00 | |
| .140E+00 | .222E+00 | .483E+00 | .992E+00 | |
| .160E+00 | .240E+00 | .523E+00 | .107E+01 | |
| .180E+00 | .258E+00 | .563E+00 | .116E+01 | |
| .200E+00 | .277E+00 | .603E+00 | .124E+01 | |
| .220E+00 | .295E+00 | .644E+00 | .132E+01 | |
| .240E+00 | .314E+00 | .684E+00 | .140E+01 | |
| .260E+00 | .332E+00 | .725E+00 | .149E+01 | |
| .280E+00 | .351E+00 | .766E+00 | .157E+01 | |
| .300E+00 | .370E+00 | .807E+00 | .166E+01 | |
| .320E+00 | .389E+00 | .849E+00 | .174E+01 | |
| .340E+00 | .408E+00 | .890E+00 | .183E+01 | |
| .360E+00 | .427E+00 | .931E+00 | .191E+01 | |
| .380E+00 | .446E+00 | .973E+00 | .200E+01 | |
| .400E+00 | .465E+00 | .101E+01 | .208E+01 | |
| .420E+00 | .484E+00 | .106E+01 | .217E+01 | |
| .440E+00 | .503E+00 | .110E+01 | .225E+01 | |
| .460E+00 | .522E+00 | .114E+01 | .234E+01 | |
| .480E+00 | .541E+00 | .118E+01 | .242E+01 | |
| .500E+00 | .561E+00 | .122E+01 | .251E+01 | |
| .520E+00 | .580E+00 | .126E+01 | .260E+01 | |
| .540E+00 | .599E+00 | .131E+01 | .268E+01 | |
| .560E+00 | .618E+00 | .135E+01 | .277E+01 | |
| .580E+00 | .637E+00 | .139E+01 | .285E+01 | |
| .600E+00 | .657E+00 | .143E+01 | .294E+01 | |
| .620E+00 | .676E+00 | .147E+01 | .303E+01 | |
| .640E+00 | .695E+00 | .152E+01 | .311E+01 | |
| .660E+00 | .714E+00 | .156E+01 | .320E+01 | |
| .680E+00 | .733E+00 | .160E+01 | .328E+01 | |
| .700E+00 | .753E+00 | .164E+01 | .337E+01 | |
| .720E+00 | .772E+00 | .168E+01 | .346E+01 | |
| .740E+00 | .791E+00 | .173E+01 | .354E+01 | |
| .760E+00 | .811E+00 | .177E+01 | .363E+01 | |
| .780E+00 | .830E+00 | .181E+01 | .372E+01 | |
| .800E+00 | .849E+00 | .185E+01 | .380E+01 | |
| .820E+00 | .869E+00 | .189E+01 | .389E+01 | |
| .840E+00 | .888E+00 | .194E+01 | .398E+01 | |
| .860E+00 | .907E+00 | .198E+01 | .406E+01 | |
| .880E+00 | .927E+00 | .202E+01 | .415E+01 | |
| .900E+00 | .946E+00 | .206E+01 | .424E+01 | |
| .920E+00 | .966E+00 | .211E+01 | .432E+01 | |
| .940E+00 | .985E+00 | .215E+01 | .441E+01 | |
| .960E+00 | .100E+01 | .219E+01 | .450E+01 | |
| .980E+00 | .102E+01 | .22[illegible]E+01 | .459E+01 | |
| .100E+01 | .104E+01 | .228E+01 | .467E+01 | |

## TABLE 12 - COMPUTER VALUES OF THEORETICAL DISCHARGE

A/R = 0.2; B/R = 0.2, 0.4, 0.8; R = 6"

| $\eta_H = (\frac{H}{R} - \frac{A}{R})$ | $Q_t$ B/R = 0.2 | $Q_t$ B/R = 0.4 | $Q_t$ B/R = 0.8 | REMARKS |
|---|---|---|---|---|
| 0. | .186E+00 | .203E+00 | .237E+00 | $C_d$ = 1.0 (assumed) and K = 1. For K > 1, multiply $Q_t$ by value of K. $Q_t = Q_H$ (limit 0 to $Q_R$) |
| .200E-01 | .214E+00 | .234E+00 | .273E+00 | |
| .400E-01 | .242E+00 | .264E+00 | .309E+00 | |
| .600E-01 | .270E+00 | .295E+00 | .345E+00 | |
| .800E-01 | .298E+00 | .326E+00 | .382E+00 | |
| .100E+00 | .326E+00 | .357E+00 | .420E+00 | |
| .120E+00 | .354E+00 | .389E+00 | .457E+00 | |
| .140E+00 | .382E+00 | .420E+00 | .495E+00 | |
| .160E+00 | .410E+00 | .451E+00 | .533E+00 | |
| .180E+00 | .438E+00 | .482E+00 | .571E+00 | |
| .200E+00 | .465E+00 | .513E+00 | .609E+00 | |
| .220E+00 | .492E+00 | .544E+00 | .647E+00 | |
| .240E+00 | .519E+00 | .575E+00 | .685E+00 | |
| .260E+00 | .546E+00 | .605E+00 | .723E+00 | |
| .280E+00 | .573E+00 | .636E+00 | .762E+00 | |
| .300E+00 | .599E+00 | .666E+00 | .800E+00 | |
| .320E+00 | .626E+00 | .697E+00 | .838E+00 | |
| .340E+00 | .652E+00 | .727E+00 | .877E+00 | |
| .360E+00 | .677E+00 | .757E+00 | .915E+00 | |
| .380E+00 | .703E+00 | .786E+00 | .953E+00 | |
| .400E+00 | .728E+00 | .816E+00 | .992E+00 | |
| .420E+00 | .753E+00 | .845E+00 | .103E+01 | |
| .440E+00 | .778E+00 | .875E+00 | .107E+01 | |
| .460E+00 | .802E+00 | .904E+00 | .111E+01 | |
| .480E+00 | .826E+00 | .932E+00 | .114E+01 | |
| .500E+00 | .850E+00 | .961E+00 | .118E+01 | |
| .520E+00 | .874E+00 | .990E+00 | .122E+01 | |
| .540E+00 | .898E+00 | .102E+01 | .126E+01 | |
| .560E+00 | .921E+00 | .105E+01 | .130E+01 | |
| .580E+00 | .944E+00 | .107E+01 | .133E+01 | |
| .600E+00 | .966E+00 | .110E+01 | .137E+01 | |
| .620E+00 | .989E+00 | .113E+01 | .141E+01 | |
| .640E+00 | .101E+01 | .116E+01 | .145E+01 | |
| .660E+00 | .103E+01 | .118E+01 | .149E+01 | |
| .680E+00 | .105E+01 | .121E+01 | .152E+01 | |
| .700E+00 | .108E+01 | .124E+01 | .156E+01 | |
| .720E+00 | .110E+01 | .126E+01 | .160E+01 | |
| .740E+00 | .112E+01 | .129E+01 | .164E+01 | |
| .760E+00 | .114E+01 | .132E+01 | .167E+01 | |
| .780E+00 | .116E+01 | .134E+01 | .171E+01 | |
| .800E+00 | .118E+01 | .137E+01 | .175E+01 | |
| .820E+00 | .120E+01 | .140E+01 | .179E+01 | |
| .840E+00 | .122E+01 | .142E+01 | .182E+01 | |
| .860E+00 | .124E+01 | .145E+01 | .186E+01 | |
| .880E+00 | .126E+01 | .147E+01 | .190E+01 | |
| .900E+00 | .128E+01 | .150E+01 | .193E+01 | |
| .920E+00 | .130E+01 | .152E+01 | .197E+01 | |
| .940E+00 | .132E+01 | .155E+01 | .201E+01 | |
| .960E+00 | .134E+01 | .157E+01 | .205E+01 | |
| .980E+00 | .136E+01 | .160E+01 | .208E+01 | |
| .100E+01 | .138E+01 | .162E+01 | .212E+01 | |

## TABLE 13

### NUMERICAL MODEL A/R = 0; B/R = 0

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ ÷H/R (6) | $\Delta Q_H/Q_R$ ÷ΔH/R (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 4 & 18 and Table 6 (R = 6"). Test Weir. $\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | .1 | .1 | .08 | .08 | .80 | .80 | -.20 | |
| .2 | .2 | .1 | .20 | .12 | 1.00 | 1.20 | NIL | |
| .3 | .3 | .1 | .33 | .13 | 1.10 | 1.30 | +.10 | |
| .4 | .4 | .1 | .45 | .12 | 1.12 | 1.20 | +.12 | |
| .5 | .5 | .1 | .57 | .12 | 1.14 | 1.20 | +.14 | |
| .6 | .6 | .1 | .67 | .10 | 1.12 | 1.00 | +.12 | |
| .7 | .7 | .1 | .77 | .10 | 1.10 | 1.00 | +.10 | |
| .8 | .8 | .1 | .85 | .08 | 1.06 | .80 | +.06 | |
| .9 | .9 | .1 | .93 | .08 | 1.03 | .80 | +.03 | |
| 1.0 | 1.0 | .1 | 1.00 | .07 | 1.00 | .70 | NIL | |

## TABLE 14

### NUMERICAL MODEL A/R = 0; B/R = 0.2

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ ÷H/R (6) | $\Delta Q_H/Q_R$ ÷ΔH/R (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 4 & 18 and Table 7. $\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | .1 | .1 | .07 | .07 | .70 | .70 | -.30 | |
| .2 | .2 | .1 | .17 | .10 | .85 | 1.00 | -.15 | |
| .3 | .3 | .1 | .29 | .12 | .97 | 1.20 | -.03 | |
| .4 | .4 | .1 | .40 | .11 | 1.00 | 1.10 | NIL | |
| .5 | .5 | .1 | .51 | .11 | 1.02 | 1.10 | +.02 | |
| .6 | .6 | .1 | .62 | .11 | 1.03 | 1.10 | +.03 | |
| .7 | .7 | .1 | .72 | .10 | 1.03 | 1.00 | +.03 | |
| .8 | .8 | .1 | .82 | .10 | 1.02 | 1.00 | +.02 | |
| .9 | .9 | .1 | .91 | .09 | 1.01 | .90 | +.01 | |
| 1.0 | 1.0 | .1 | 1.00 | .09 | 1.00 | .90 | NIL | |

## TABLE 15

## NUMERICAL MODEL A/R = 0; B/R = 0.4

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ ÷H/R (6) | $\Delta Q_H/Q_R$ ÷ΔH/R (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 4 & 18 and Table 7.<br>$\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | .1 | .1 | .06 | .06 | .60 | .60 | -.40 | |
| .2 | .2 | .1 | .16 | .10 | .80 | 1.00 | -.20 | |
| .3 | .3 | .1 | .26 | .10 | .87 | 1.00 | -.13 | |
| .4 | .4 | .1 | .37 | .11 | .93 | 1.10 | -.07 | |
| .5 | .5 | .1 | .48 | .11 | .96 | 1.10 | -.04 | |
| .6 | .6 | .1 | .59 | .11 | .98 | 1.10 | -.02 | |
| .7 | .7 | .1 | .69 | .10 | .99 | 1.00 | -.01 | |
| .8 | .8 | .1 | .80 | .11 | 1.00 | 1.10 | NIL | |
| .9 | .9 | .1 | .90 | .10 | 1.00 | 1.00 | NIL | |
| 1.0 | 1.0 | .1 | 1.00 | .10 | 1.00 | 1.00 | NIL | |

## TABLE 16

## NUMERICAL MODEL A/R = 0; B/R = 0.8

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ ÷H/R (6) | $\Delta Q_H/Q_R$ ÷ΔH/R (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 4 & 18 and Table 7.<br>$\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | .1 | .1 | .05 | .05 | .50 | .50 | -.50 | |
| .2 | .2 | .1 | .14 | .09 | .70 | .90 | -.30 | |
| .3 | .3 | .1 | .23 | .09 | .77 | .90 | -.23 | |
| .4 | .4 | .1 | .33 | .10 | .83 | 1.00 | -.17 | |
| .5 | .5 | .1 | .44 | .11 | .88 | 1.10 | -.12 | |
| .6 | .6 | .1 | .55 | .11 | .92 | 1.10 | -.08 | |
| .7 | .7 | .1 | .66 | .11 | .94 | 1.10 | -.06 | |
| .8 | .8 | .1 | .77 | .11 | .96 | 1.10 | -.04 | |
| .9 | .9 | .1 | .88 | .11 | .98 | 1.10 | -.02 | |
| 1.0 | 1.0 | .1 | 1.00 | .12 | 1.00 | 1.20 | NIL | |

## TABLE 17

### NUMERICAL MODEL A/R = 0.1; B/R = 0

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ ÷H/R (6) | $\Delta Q_H/Q_R$ ÷ΔH/R (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 5 & 19 and Table 8.<br>$\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | .1 | .08 | .08 | .80 | .80 | -.20 | |
| .2 | .1 | .1 | .20 | .12 | 1.00 | 1.20 | NIL | |
| .3 | .2 | .1 | .32 | .12 | 1.07 | 1.20 | +.07 | |
| .4 | .3 | .1 | .44 | .12 | 1.10 | 1.20 | +.10 | |
| .5 | .4 | .1 | .56 | .12 | 1.12 | 1.20 | +.12 | |
| .6 | .5 | .1 | .66 | .10 | 1.10 | 1.00 | +.10 | |
| .7 | .6 | .1 | .76 | .10 | 1.09 | 1.00 | +.09 | |
| .8 | .7 | .1 | .85 | .09 | 1.06 | .90 | +.06 | |
| .9 | .8 | .1 | .93 | .08 | 1.03 | .80 | +.03 | |
| 1.0 | .9 | .1 | 1.00 | .07 | 1.00 | .70 | NIL | |

## TABLE 18

### NUMERICAL MODEL A/R = 0.1; B/R = 0.4

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ ÷H/R (6) | $\Delta Q_H/Q_R$ ÷ΔH/R (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | |
| .1 | 0. | .1 | .06 | .06 | .60 | .60 | -.40 | See Figrs. 5 & 19 and Table 9 (R = 6"). Test Weir. Refer Table 26 for modified model with datum shifted.<br>$\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .2 | .1 | .1 | .16 | .10 | .80 | 1.00 | -.20 | |
| .3 | .2 | .1 | .27 | .11 | .90 | 1.10 | -.10 | |
| .4 | .3 | .1 | .38 | .11 | .95 | 1.10 | -.05 | |
| .5 | .4 | .1 | .49 | .11 | .98 | 1.10 | -.02 | |
| .6 | .5 | .1 | .60 | .11 | 1.00 | 1.10 | NIL | |
| .7 | .6 | .1 | .70 | .10 | 1.00 | 1.00 | NIL | |
| .8 | .7 | .1 | .80 | .10 | 1.00 | 1.00 | NIL | |
| .9 | .8 | .1 | .90 | .10 | 1.00 | 1.00 | NIL | |
| 1.0 | .9 | .1 | 1.00 | .10 | 1.00 | 1.00 | NIL | |

## TABLE 19

## NUMERICAL MODEL A/R = 0.1; B/R = 0.5

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ ÷H/R (6) | $\Delta Q_H/Q_R$ ÷ΔH/R (7) | DEVIATION COL.(6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 5 & 19 and Table 10 (R = 6"). Test Weir. Refer Table 27 for modified model with datum shifted. $\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | .1 | .06 | .06 | .60 | .60 | -.40 | |
| .2 | .1 | .1 | .16 | .10 | .80 | 1.00 | -.20 | |
| .3 | .2 | .1 | .26 | .10 | .87 | 1.00 | -.13 | |
| .4 | .3 | .1 | .37 | .11 | .93 | 1.10 | -.07 | |
| .5 | .4 | .1 | .48 | .11 | .96 | 1.10 | -.04 | |
| .6 | .5 | .1 | .59 | .11 | .98 | 1.10 | -.02 | |
| .7 | .6 | .1 | .70 | .11 | 1.00 | 1.10 | NIL | |
| .8 | .7 | .1 | .80 | .10 | 1.00 | 1.00 | NIL | |
| .9 | .8 | .1 | .90 | .10 | 1.00 | 1.00 | NIL | |
| 1.0 | .9 | .1 | 1.00 | .10 | 1.00 | 1.00 | NIL | |

## TABLE 20

## NUMERICAL MODEL A/R = 0.1; B/R = 0.8

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ ÷H/R (6) | $\Delta Q_H/Q_R$ ÷ΔH/R (7) | DEVIATION COL.(6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 5 & 19 and Table 8. $\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | .1 | .05 | .05 | .50 | .50 | -.50 | |
| .2 | .1 | .1 | .14 | .09 | .70 | .90 | -.30 | |
| .3 | .2 | .1 | .24 | .10 | .80 | 1.00 | -.20 | |
| .4 | .3 | .1 | .35 | .11 | .88 | 1.10 | -.12 | |
| .5 | .4 | .1 | .46 | .11 | .92 | 1.10 | -.08 | |
| .6 | .5 | .1 | .56 | .10 | .93 | 1.00 | -.07 | |
| .7 | .6 | .1 | .67 | .11 | .96 | 1.10 | -.04 | |
| .8 | .7 | .1 | .78 | .11 | .98 | 1.10 | -.02 | |
| .9 | .8 | .1 | .89 | .11 | .99 | 1.10 | -.01 | |
| 1.0 | .9 | .1 | 1.00 | .11 | 1.00 | 1.10 | NIL | |

## TABLE 21

### NUMERICAL MODEL A/R = 0.18; B/R = 1.0

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ $\div H/R$ (6) | $\Delta Q_H/Q_R$ $\div \Delta H/R$ (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 5 & 20 and Table 11. (R = 4.39"). Refer Table 28 for modified model with datum shifted. $\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | .1 | .06 | .06 | .60 | .60 | -.40 | |
| .2 | .02 | .1 | .13 | .07 | .65 | .65 | -.35 | |
| .3 | .12 | .1 | .23 | .10 | .77 | 1.00 | -.23 | |
| .4 | .22 | .1 | .34 | .11 | .85 | 1.10 | -.15 | |
| .5 | .32 | .1 | .45 | .11 | .90 | 1.10 | -.10 | |
| .6 | .42 | .1 | .56 | .11 | .93 | 1.10 | -.07 | |
| .7 | .52 | .1 | .67 | .11 | .96 | 1.10 | -.04 | |
| .8 | .62 | .1 | .78 | .11 | .98 | 1.10 | -.02 | |
| .9 | .72 | .1 | .89 | .11 | .99 | 1.10 | -.01 | |
| 1.0 | .82 | .1 | 1.00 | .11 | 1.00 | 1.10 | NIL | |

## TABLE 22

### NUMERICAL MODEL A/R = 0.2; B/R = 0

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ $\div H/R$ (6) | $\Delta Q_H/Q_R$ $\div \Delta H/R$ (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 5 & 21. R = 6". $\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | .1 | .08 | .08 | .80 | .80 | -.20 | |
| .2 | 0. | .1 | .17 | .09 | .85 | .90 | -.15 | |
| .3 | .1 | .1 | .30 | .13 | 1.00 | 1.30 | NIL | |
| .4 | .2 | .1 | .42 | .12 | 1.05 | 1.20 | +.05 | |
| .5 | .3 | .1 | .54 | .12 | 1.08 | 1.20 | +.08 | |
| .6 | .4 | .1 | .65 | .11 | 1.08 | 1.10 | +.08 | |
| .7 | .5 | .1 | .75 | .10 | 1.07 | 1.00 | +.07 | |
| .8 | .6 | .1 | .84 | .09 | 1.05 | .90 | +.05 | |
| .9 | .7 | .1 | .92 | .08 | 1.02 | .80 | +.02 | |
| 1.0 | .8 | .1 | 1.00 | .08 | 1.00 | .80 | NIL | |

## TABLE 23

### NUMERICAL MODEL A/R = 0.2; B/R = 0.2

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R \div H/R$ (6) | $\Delta Q_H/Q_R \div \Delta H/R$ (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 5 & 21 and Table 12. $\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | .1 | .08 | .08 | .80 | .80 | -.20 | |
| .2 | 0. | .1 | .16 | .08 | .80 | .80 | -.20 | |
| .3 | .1 | .1 | .28 | .12 | .93 | 1.20 | -.07 | |
| .4 | .2 | .1 | .39 | .11 | .98 | 1.10 | -.02 | |
| .5 | .3 | .1 | .51 | .12 | 1.02 | 1.20 | +.02 | |
| .6 | .4 | .1 | .62 | .11 | 1.03 | 1.10 | +.03 | |
| .7 | .5 | .1 | .72 | .10 | 1.03 | 1.00 | +.03 | |
| .8 | .6 | .1 | .82 | .10 | 1.03 | 1.00 | +.03 | |
| .9 | .7 | .1 | .92 | .10 | 1.02 | 1.00 | +.02 | |
| 1.0 | .8 | .1 | 1.00 | .08 | 1.00 | .80 | NIL | |

## TABLE 24

### NUMERICAL MODEL A/R = 0.2; B/R = 0.4

| H/R (1) | H'/R (2) | Δ H/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R \div H/R$ (6) | $\Delta Q_H/Q_R \div \Delta H/R$ (7) | DEVIATION COL. (6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 5 & 21 and Table 12. $\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | .1 | .07 | .07 | .70 | .70 | -.30 | |
| .2 | 0. | .1 | .15 | .08 | .75 | .80 | -.25 | |
| .3 | .1 | .1 | .26 | .11 | .87 | 1.10 | -.13 | |
| .4 | .2 | .1 | .37 | .11 | .93 | 1.10 | -.07 | |
| .5 | .3 | .1 | .49 | .12 | .98 | 1.20 | -.02 | |
| .6 | .4 | .1 | .60 | .11 | 1.00 | 1.10 | NIL | |
| .7 | .5 | .1 | .70 | .10 | 1.00 | 1.00 | NIL | |
| .8 | .6 | .1 | .80 | .10 | 1.00 | 1.00 | NIL | |
| .9 | .7 | .1 | .91 | .11 | 1.01 | 1.10 | +.01 | |
| 1.0 | .8 | .1 | 1.00 | .09 | 1.00 | .90 | NIL | |

## TABLE 25

### NUMERICAL MODEL A/R = 0.2; B/R = 0.8

| H/R (1) | H'/R (2) | ΔH/R (3) | $Q_H/Q_R$ (4) | $\Delta Q_H/Q_R$ (5) | $Q_H/Q_R$ ÷H/R (6) | $\Delta Q_H/Q_R$ ÷ΔH/R (7) | DEVIATION COL.(6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | 0. | - | 0. | - | - | - | - | See Figrs. 5 & 21 and Table 12.<br>$\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | .1 | .07 | .07 | .70 | .70 | -.30 | |
| .2 | 0. | .1 | .14 | .07 | .70 | .70 | -.30 | |
| .3 | .1 | .1 | .24 | .10 | .80 | 1.00 | -.20 | |
| .4 | .2 | .1 | .35 | .11 | .88 | 1.10 | -.12 | |
| .5 | .3 | .1 | .46 | .11 | .92 | 1.10 | -.08 | |
| .6 | .4 | .1 | .57 | .11 | .95 | 1.10 | -.05 | |
| .7 | .5 | .1 | .67 | .10 | .96 | 1.00 | -.04 | |
| .8 | .6 | .1 | .78 | .11 | .98 | 1.10 | -.02 | |
| .9 | .7 | .1 | .89 | .11 | .99 | 1.10 | -.01 | |
| 1.0 | .8 | .1 | 1.00 | .11 | 1.00 | 1.10 | NIL | |

## TABLE 26

### MODIFIED NUMERICAL MODEL A/R = 0.1; B/R = 0.4

NOTE: DATUM SHIFTED TO TOP OF RECTANGULAR WEIR (FIG.5)

| H/R (1) | H'/R (2) | ΔH'/R (3) | $Q_{H'}/Q_R$ (4) | $\Delta Q_{H'}/Q_R$ (5) | $Q_{H'}/Q_R$ ÷H'/R (6) | $\Delta Q_{H'}/Q_R$ ÷ΔH'/R (7) | DEVIATION COL.(6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | - | - | - | - | - | - | - | See Fig.5 and Table 18.<br>$\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | - | - | - | - | - | - | |
| .2 | .1 | .1 | .10 | .10 | 1.00 | 1.00 | NIL | |
| .3 | .2 | .1 | .20 | .10 | 1.00 | 1.00 | NIL | |
| .4 | .3 | .1 | .31 | .11 | 1.03 | 1.10 | +.03 | |
| .5 | .4 | .1 | .41 | .10 | 1.03 | 1.00 | +.03 | |
| .6 | .5 | .1 | .52 | .11 | 1.04 | 1.10 | +.04 | |
| .7 | .6 | .1 | .62 | .10 | 1.03 | 1.00 | +.03 | |
| .8 | .7 | .1 | .72 | .10 | 1.03 | 1.00 | +.03 | |
| .9 | .8 | .1 | .81 | .09 | 1.01 | .90 | +.01 | |
| 1.0 | .9 | .1 | .91 | .10 | 1.01 | 1.00 | +.01 | |
| 1.1 | 1.0 | .1 | 1.00 | .09 | 1.00 | .90 | NIL | |

## TABLE 27

### MODIFIED NUMERICAL MODEL A/R = 0.1; B/R = 0.5

NOTE: DATUM SHIFTED TO TOP OF RECTANGULAR WEIR (FIG.5)

| H/R (1) | H'/R (2) | $\Delta H'/R$ (3) | $Q_{H'}/Q_R$ (4) | $\Delta Q_{H'}/Q_R$ (5) | $Q_{H'}/Q_R \div H'/R$ (6) | $\Delta Q_{H'}/Q_R \div \Delta H'/R$ (7) | DEVIATION COL.(6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | - | - | - | - | - | - | - | See Fig.5 and Table 19.<br>$\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .1 | 0. | - | - | - | - | - | - | |
| .2 | .1 | .1 | .09 | .09 | .90 | .90 | -.10 | |
| .3 | .2 | .1 | .19 | .10 | .95 | 1.00 | -.05 | |
| .4 | .3 | .1 | .30 | .11 | 1.00 | 1.10 | NIL | |
| .5 | .4 | .1 | .40 | .10 | 1.00 | 1.00 | NIL | |
| .6 | .5 | .1 | .51 | .11 | 1.02 | 1.10 | +.02 | |
| .7 | .6 | .1 | .61 | .10 | 1.02 | 1.00 | +.02 | |
| .8 | .7 | .1 | .71 | .10 | 1.01 | 1.00 | +.01 | |
| .9 | .8 | .1 | .81 | .10 | 1.01 | 1.00 | +.01 | |
| 1.0 | .9 | .1 | .90 | .09 | 1.00 | .90 | NIL | |
| 1.1 | 1.0 | .1 | 1.00 | .10 | 1.00 | 1.00 | NIL | |

## TABLE 28

### MODIFIED NUMERICAL MODEL A/R = 0.18; B/R = 1.0

NOTE: DATUM SHIFTED TO TOP OF RECTANGULAR WEIR (FIG.5)

| H/R (1) | H'/R (2) | $\Delta H'/R$ (3) | $Q_{H'}/Q_R$ (4) | $\Delta Q_{H'}/Q_R$ (5) | $Q_{H'}/Q_R \div H'/R$ (6) | $\Delta Q_{H'}/Q_R \div \Delta H'/R$ (7) | DEVIATION COL.(6) (8) | REMARKS (9) |
|---|---|---|---|---|---|---|---|---|
| 0. | - | - | - | - | - | - | - | See Fig.5 and Tables 11 (R = 4.39") and 21.<br>$\frac{H'}{R} = \frac{H}{R} - \frac{A}{R}$ |
| .18 | 0. | - | - | - | - | - | - | |
| .28 | .1 | .1 | .09 | .09 | .90 | .90 | -.10 | |
| .38 | .2 | .1 | .19 | .10 | .95 | 1.00 | -.05 | |
| .48 | .3 | .1 | .29 | .10 | .97 | 1.00 | -.03 | |
| .58 | .4 | .1 | .39 | .10 | .98 | 1.00 | -.02 | |
| .68 | .5 | .1 | .49 | .10 | .98 | 1.00 | -.02 | |
| .78 | .6 | .1 | .59 | .10 | .98 | 1.00 | -.02 | |
| .88 | .7 | .1 | .69 | .10 | .99 | 1.00 | -.01 | |
| .98 | .8 | .1 | .80 | .11 | 1.00 | 1.10 | NIL | |
| 1.08 | .9 | .1 | .90 | .10 | 1.00 | 1.00 | NIL | |
| 1.18 | 1.0 | .1 | 1.00 | .10 | 1.00 | 1.00 | NIL | |

## TABLE 29

## COEFFICIENT OF DISCHARGE OF TEST LINEAR PROPORTIONAL WEIR ASSEMBLIES

| No.of Openings K | Radius of Quadrant R (ins.) | A (ins.) | B (ins.) | Depth of flow in flume (ins.) | Head over weir $H_{max}$ (ins.) | $C_d$(average) * Trial 1 | $C_d$(average) * Trial 2 |
|---|---|---|---|---|---|---|---|
| 4 | 6 | 0 | 0 | 9.03 | 5.60 | .677 | .679 |
| 1 | 6 | 0.6 | 2.4 | 9.12 | 5.45 | .603 | .605 |
| 2 | 10 | 1.0 | 4.0 | 3.05 | 2.36 | .631 | .637 |
| 2 | 8 | 0.8 | 4.0 | 7.19 | 3.69 | .628 | .630 |
| 1 | 8 | 0.8 | 3.2 | 8.80 | 7.53 | .629 | .633 |
| 3 | 6 | 0.6 | 3.0 | 7.14 | 3.54 | .638 | .637 |
| 3 | 6 | 0.6 | 2.4 | 7.30 | 3.63 | .627 | .629 |
| 1 | 10 | 1.0 | 4.0 | 6.81 | 5.44 | .625 | .629 |
| 1 | 10 | 1.0 | 5.0 | 6.73 | 5.12 | .648 | .647 |

# APPENDIX 4

## DEVELOPMENT WORK ON LATERAL WEIRS

Considerable work has been done in the design of lateral weirs to meet specific needs, some of which serve to separate a certain quantity or excess flow from open channels. Such weirs are commonly set into the side of a channel in irrigation, sanitary engineering and flood control systems. These are known as lateral or side-spillway weirs or simply side-weirs.

In spatially varied flow through this type of weirs, the pattern of flow with decreasing discharge has been treated as a flow diversion where the diverted water does not affect the energy head. Theoretically, De Marchi proved that the energy head along the spillway crest is essentially constant and that the flow profile is curved, rising in sub-critical flow and dropping in supercritical flow in the reach containing the lateral weirs. This is true when the channel bed slope and the friction slope are very small. This theoretical investigation was further verified experimentally by Gentilini.

Recently studies made on spatially varied flow over weirs by Subramanya and Awasthy (15) dealt with continuously increasing (sub-critical flow) and continuously decreasing (supercritical flow) water surface profiles of lateral weirs.

Ramamurthy et al (10) have indicated methods of obtaining uniform discharge distribution along the length of the lateral weir by altering the geometric parameters of the weir system. The following methods of plain contouring which they suggested are simple and easy to construct, even in existing channels:

1) plain contouring of the channel bed
2) plain contouring of the channel side
3) plain contouring of the weir sill

Channel bed contouring involves raising the bed of a rectangular channel locally to a height $Z_1$ in the vicinity of the lateral weir of length L. The total rise in the channel bed hump, $Z_1$, required to keep the water surface elevation horizontal for a given velocity, $V_1$, entry channel flow depth, $Y_1$, entry channel flow, $Q_1$, and weir outflow discharge, $Q^*$, was given by

$$\frac{Q^*}{Q_1} = \frac{Z_1}{Y_1}$$

A preliminary experimental study of plain contouring of the channel bed using a hump 1" in height and a rectangular lateral weir 18" long was carried out. The objective of the study was to verify the uniformity of discharge along the length of the lateral weir; the results are given on page 66.

A linear proportional weir assembly may be used as a lateral weir in field applications in combination with plain contouring of the channel bed. The advantage of this combination is linear head-discharge relationship of the proportional weir assembly and a uniform water surface profile due to the presence of the hump. However, more detailed experimental study is required.

## PRELIMINARY RESULTS OF 1 INCH HUMP

Tests were conducted in a rectangular steel plate flume 18" wide and 15" deep (Fig. 23a), in which a sharp edged lateral weir 18" long made of plexiglass was placed at 3.86" above the bottom of the channel. Sufficient entry and exit lengths were provided to reduce turbulence effects in the vicinity of the weir.

A plexiglass sheet hump 18" long, 17½" wide and 1" high was constructed and set in the weir section as shown in Fig. 23b. Tests were made with and without the hump in position. Depth measurements were made along the centre line of the channel at both ends of the weir and at three other points in between.

Figures 24 and 25 show centre line flow profiles with or without the hump. When the ratio $Q^*/Q_1$ approaches the value of $Z_1/Y_1$, the experimental results indicate a nearly horizontal water surface profile with a 1" hump. With the hump in position and $\frac{Q^*}{Q_1} = \frac{Z_1}{Y_1}$ considered as ideal design conditions, surface profiles were further examined for off-design conditions by varying $Q_1$ (and consequently $Y_1$) but keeping Froude number $F_1$ constant throughout. The results are indicated in Fig. 25. In such off-design cases where $Z_1/Y_1$ is either greater or less than $Q^*/Q_1$, the velocity either increases or decreases in the flume as it flows over the hump, causing a falling ($Y_1 > Y + Z_1$) or a rising ($Y_1 < Y + Z_1$) water surface profile respectively. This is indicative of a non-uniform flow pattern.

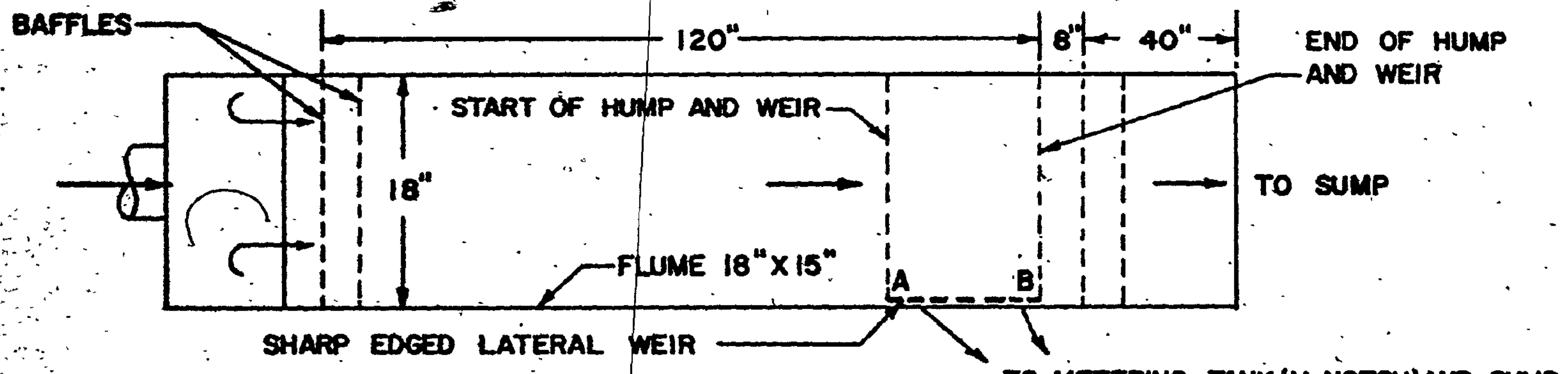


FIG.23 (a) PLAN VIEW

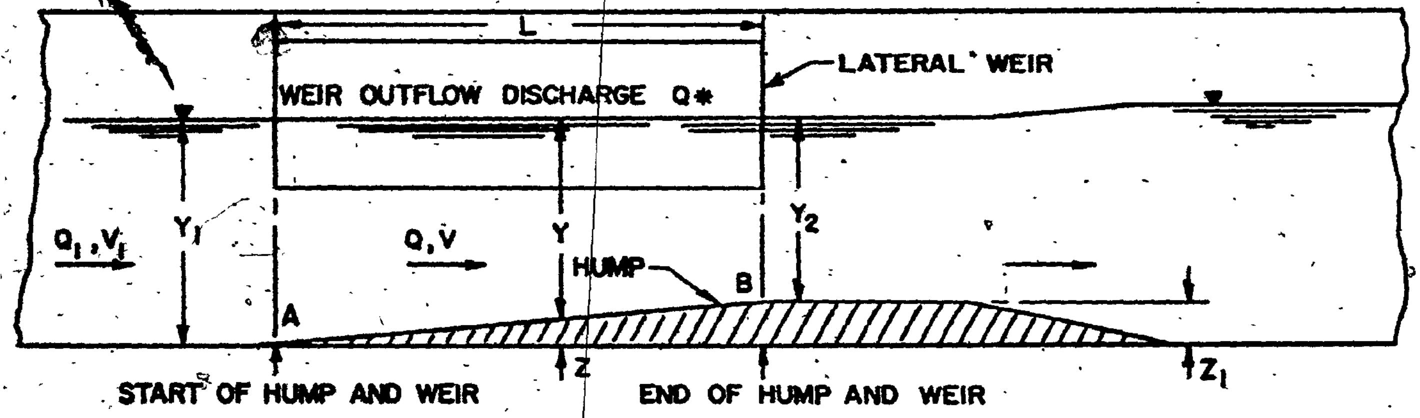


FIG.23 (b) DETAILS — HUMP LOCATION (SECTION)

FIG.23 LATERAL WEIR FLUME

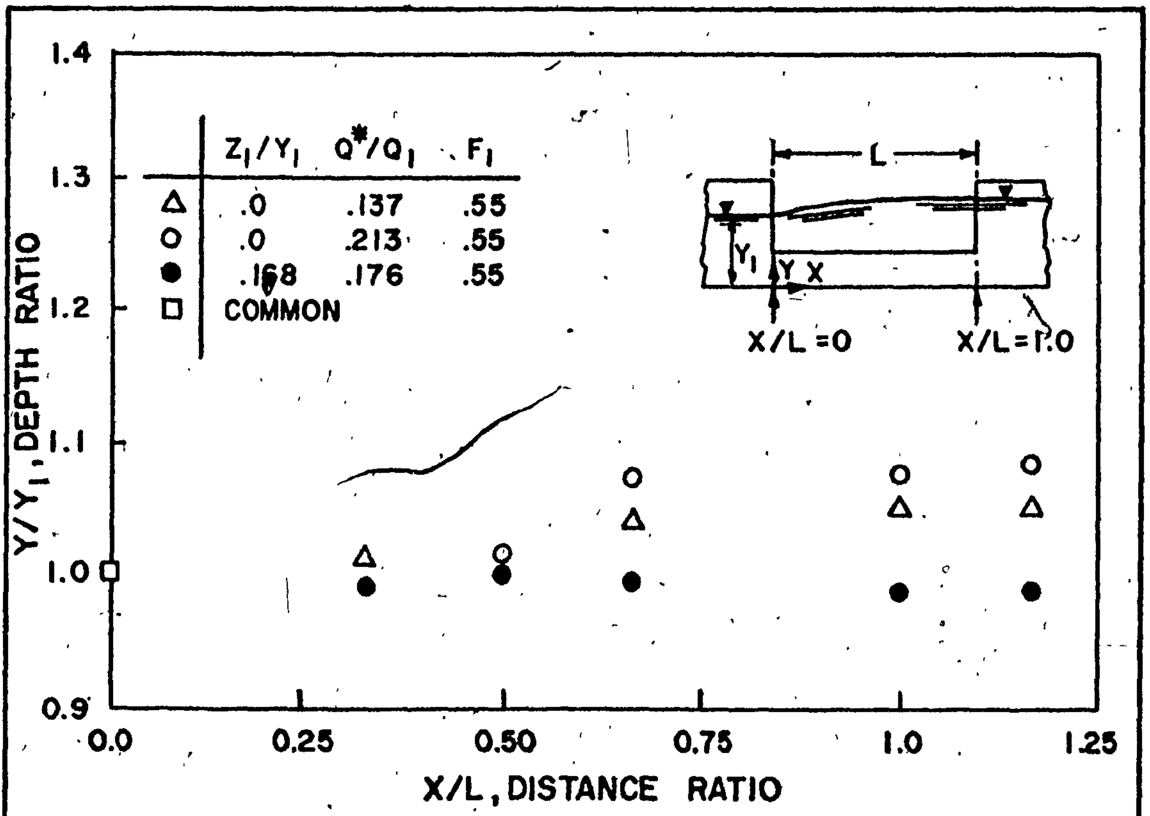


FIG. 24 CENTRE LINE FLOW PROFILES OF LATERAL WEIR FLUME ( $Z_1 = 0, Z_1 = 1''$ )

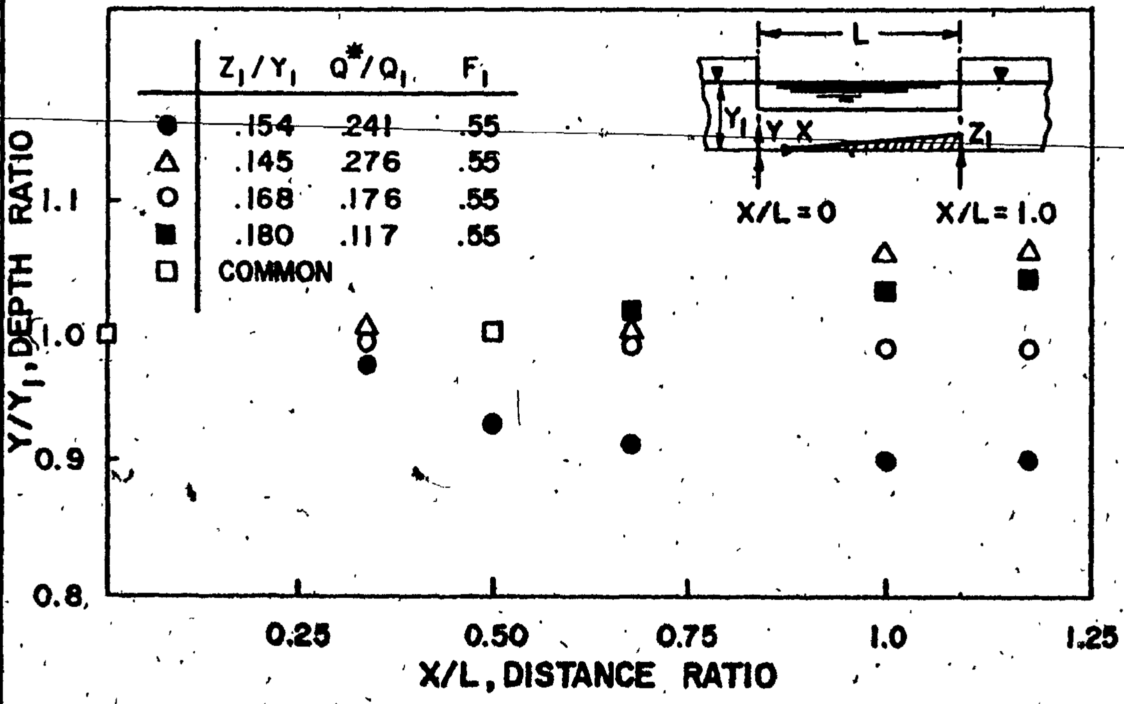


FIG. 25 CENTRE LINE FLOW PROFILES OF LATERAL WEIR FLUME ( $Z_1 = 1''$ )