CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled '**ANALYSIS OF SIDE WEIRS AND SLUICE GATES** ' in fulfillment of the requirement for the award of the Degree of Doctor of Philosophy and submitted in the Department of Civil Engineering of the University is an authentic record of my own work carried out during a period from July 1989 to January 1994 under the supervision of Dr. P. K. Swamee and Dr. S. K. Pathak.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other University.

(MASOUD SABZEH ALI)

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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ABSTRACT

Side weirs and side sluice gates are diversion structures widely used in irrigation engineering. A side weir is an overflow weir framed in the side of a channel over which lateral outflow takes place when the water surface in the channel rises above the weir crest. A side sluice gate is an opening in the side of a channel through which lateral outflow takes place.

For computation of sharp crested side weir discharge De Marchi equation is widely used with a constant value of discharge coefficient. Various investigators have proposed different equations relating the weir discharge coefficient to the main channel upstream Froude number F_0 only. The predicted side weir discharge based on these equations will be markedly different for the same values of F_0. This is evidently so due to the fact that other variables like weir height, channel slope, channel roughness, channel bed width *etc.*, which affect the weir discharge have not been considered by these investigators. Further, inspite of their great practical importance, little attention has been given to the study of flow over broad crested side weirs and through side sluice gates.

In the present study, the concept of a discharge coefficient for an elementary strip along the length of side weir or side sluice gate is introduced. Equations of the *elementary discharge coefficient* for various shapes of side weir and rectangular side sluice gate have been obtained. A common methodology involving the solution of the proposed *Elementary discharge coefficient* equation and the spatially varied flow equation has been evolved for the prediction of discharge and flow profile along the diversion structure.

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(M. S. Ali)

LIST OF SYMBOLS

The following symbols are used in this dissertation:

A = flow area;

a = sluice gate opening;

B = channel width;

b = sluice gate length;

C_d = discharge coefficient;

C_e = elementary discharge coefficient;

C_M = discharge coefficient (De Marchi);

c = sluice gate crest width;

E = specific energy;

ER = average percentage errors;

F = Froude number;

g = gravitational acceleration;

H = total energy;

$k_a - k_f$ = constants;

$k_1 - k_{37}$ = constants;

k_s = submergence factor;

L = width of side weir;

m_s = side slope of trapezoidal side weir;

N = number of experimental data;

n = Manning's roughness coefficient;

Q = main channel discharge;

Q_s = lateral outflow;

R = hydraulic radius;

S_f = friction slope;

S_0 = bed slope;

T = flow width;

w = weir height;

x = distance;

y = flow depth;

y_m = flow depth at $x = b/2$;

y_t = tail water depth;

z = channel bed elevation;

ε = percentage error;

η_L = weir head - weir width ratio;

η_W = weir head - weir height ratio;

θ = apex angle;

ν = kinematic viscosity;

ρ = mass density;

σ = surface tension;

ϕ = De Marchi varied flow function;

<u>Subscripts</u>

b = downstream section;

broad = broad crested;

c = computed value;

i = data index;

o = observed value;

0 = upstream section; and

sharp = sharp crested.

CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 SIDE WEIR

Side weirs and side sluice gates are take off and metering diversion devices which are widely used in irrigation, land drainage, urban sewage system and sanitary engineering. A side weir, as the name indicates, is an overflow weir set into the side of a channel with the purpose of allowing part of the liquid to spill over the side if the surface of the flow in the channel rises above the weir crest. It is also called as side spillway or lateral spillway.

Some of the situations in hydraulic engineering where side weirs are in use are:

1) In sanitary engineering the side weirs are used extensively as storm flow outlets in the combined sewer system, for passing a chosen proportion of the storm water to some convenient river, stream or estuary, at the earliest possible moment so as to reduce the cost of the sewer system.

2) In an irrigation canal system the surface runoff may sometimes be let into a canal and excess flow may be disposed off at some convenient location downstream, to some other canal, river, stream or estuary. This can be done with the help of side weir.

3) The side weirs have been used to protect flood plain embankments from overtopping at the time of floods.

4) In the hilly regions the intake of the diversion canals may be situated in a deep and narrow valley. Circumstances may require provision of a side weir in the head works. Such was the situation in the case of head works of the Ouse-Great lake canal taking off from Ouse river in U.S.A. (Nimmo, 1928).

5) Water from gutters of residential streets is sometimes diverted to subsurface drains by means of kerb-opening inlets. When the slot inlet is partially submerged, the structure should be recognized as a free overflow side weir set into the side of a triangular channel.

6) The side weirs have been used in the thermal power installations.

After cooling the power plants, sometimes the warm water is carried in a channel to be spread over a large length of the pond with the use of a side weir.

7) Side weirs with broad crest are used as head regulators of distributaries and escapes in irrigation engineering.

1.2 SIDE SLUICE GATE

A rectangular side sluice gate is a rectangular opening created by a vertical sliding gate, in the side of a channel through which lateral outflow into a side channel takes place. Side sluice gates are flow diversion devices which are widely used as head regulators for canals, branches and distributaries, for silt flushing in a power canal forebay *etc.* Adjustment of the gate opening provides an opportunity to vary the outlet discharge. There is no such opportunity in a side weir. Thus a side weir is a passive device whereas a side sluice gate is an active device for flow diversion.

1.3 STATE OF KNOWLEDGE

For computation of side weir discharge De Marchi equation is widely used which has the inherent weakness of neglecting the effects of channel bed slope and channel resistance. As various investigators have related the side weir discharge coefficient to upstream main channel Froude number only, the other variables like weir height, channel slope, channel roughness, channel bed width *etc.*, which influence the weir discharge have not been considered. Furthermore, the effect of variation of depth of flow along the side weir length has not been taken into consideration by almost all of the investigators.

On the other hand little attention has been given to the study of flow through side sluice gates, inspite of their great practical importance. In these investigations also, several dominant variables like channel bed slope, channel roughness, and sluice gate length have not been considered.

1.4 OBJECTIVE

The present investigation was undertaken with the objective to develop a common methodology for prediction of discharge and flow profile for:

a) sharp and broad crested side weirs of rectangular, triangular and trapezoidal shapes; and

b) sharp and broad crested rectangular side sluice gates.

CHAPTER

TWO

BASIC THEORY

2.1 GENERAL

The side weirs and side sluice gates are flow diversion structures whereas normal weirs and normal sluice gates are flow regulation structures. The flow regulation structures are placed normal to the flow whereas the diversion structures are placed parallel to the flow. The discharge per unit length of a flow regulating structure is essentially constant, if the weir crest or sluice gate opening is at the same elevation throughout its length, whereas the discharge per unit length of a flow diversion structure is not constant since depth of flow changes along the structure. The discharge of a flow diversion structure is strongly influenced by the presence of the side walls in the side channel, since the streamline pattern is then different from that over the flow regulation structure discharging freely into the atmosphere.

Figs. 2.1 and 2.2 show the stramlines over side weir and through side sluice gate with unrestricted outflow (when there is no walls in the side channel and the jet of water is free to flow in any direction) and restricted outflow (with side walls in the side channel and when the flow has the constraints of side walls) respectively.

2.2 SPATIALLY VARIED FLOW EQUATION

The flow along a diversion structure is a typical case of spatially varied flow with decreasing discharge. The energy equation is commonly used for deriving the governing equation under the following assumptions:

1) the flow is steady;

2) the pressure distribution is hydrostatic;

3) the channel is prismatic and is of small slope;

4) the friction losses are adequately represented by Manning's equation; and

5) the one-dimensional method of analysis is applicable.

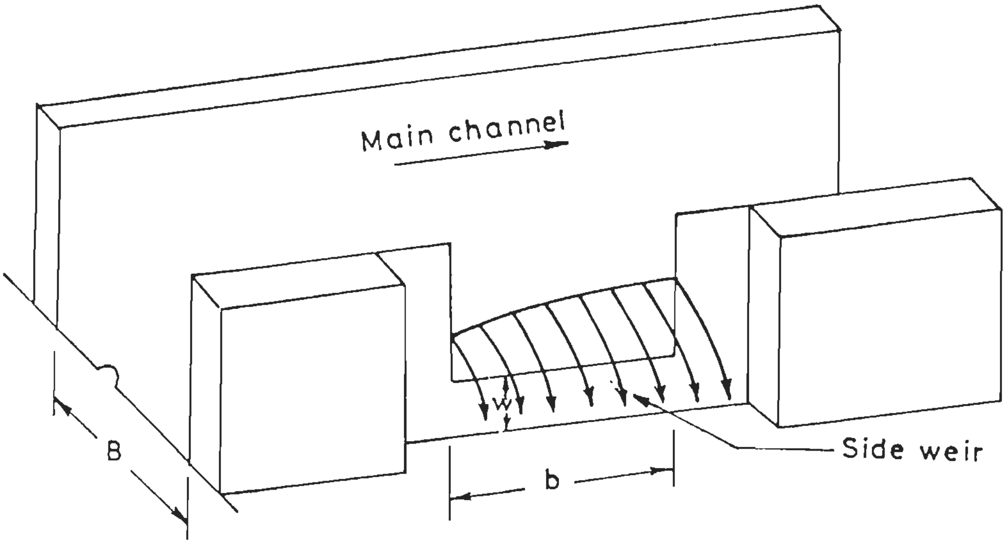
For a side weir or side sluice gate in a rectangular channel (see Fig. 2.3) the total energy H at a section is given by:

$$H = z + y + \frac{Q^2}{2gA^2} \; ; \qquad (2.1)$$

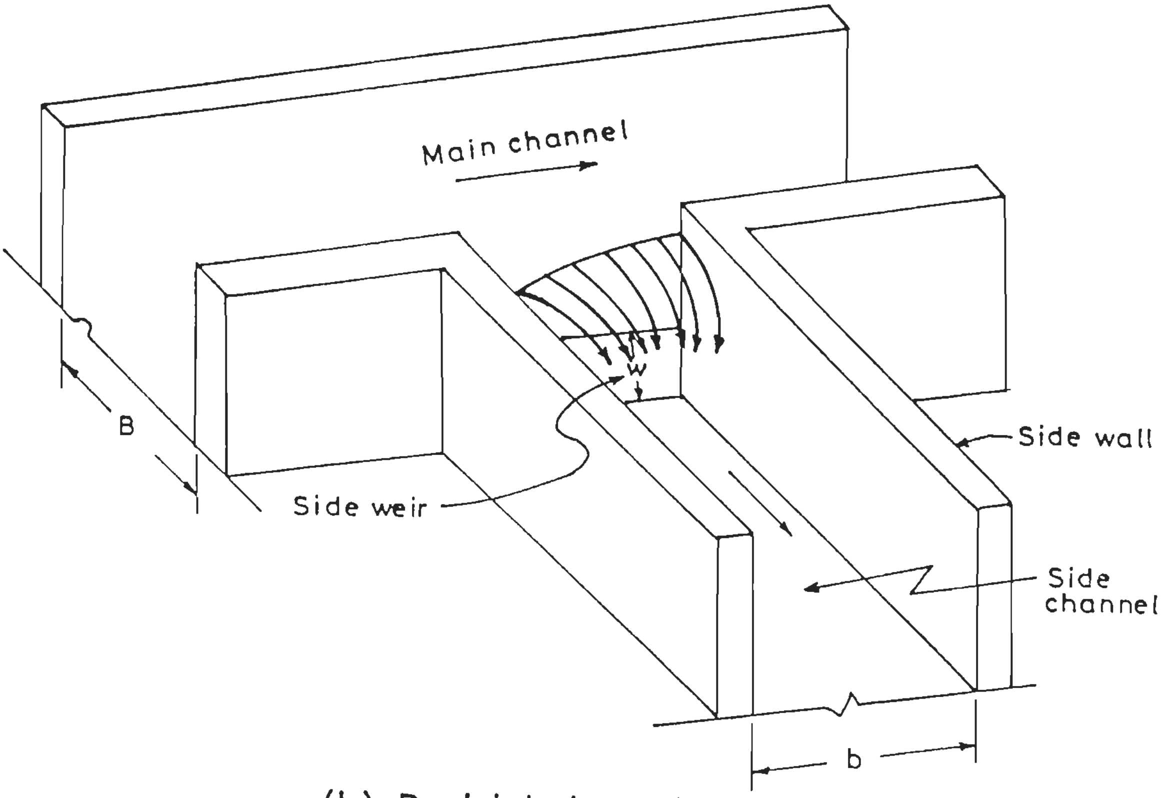
in which z = the channel bed elevation; y = depth of flow; Q = main channel discharge; g = gravitational acceleration; and A = the flow area. Differentiating (2.1) with respect to x, one gets:

$$\frac{dH}{dx} = \frac{dz}{dx} + \frac{dy}{dx} + \frac{Q}{gA^2}\frac{dQ}{dx} - \frac{Q^2}{gA^3}\frac{dA}{dy}\frac{dy}{dx} \; ; \qquad (2.2)$$

herein $dH/dx = -S_f$; $dz/dx = -S_0$; and $dA/dy = T$. Hence (2.2) can be

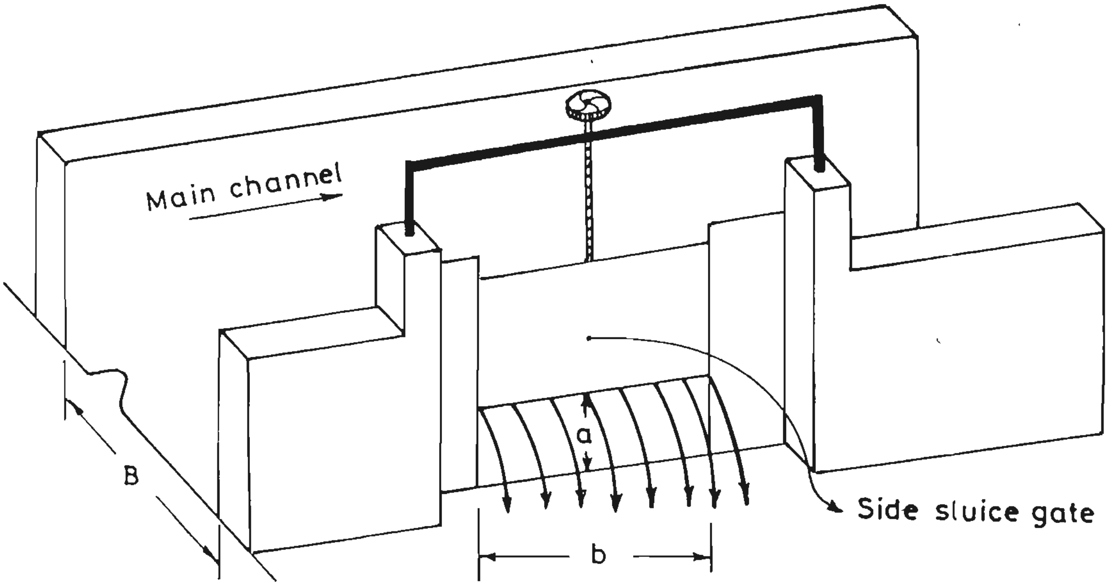


(a) Unrestricted outflow

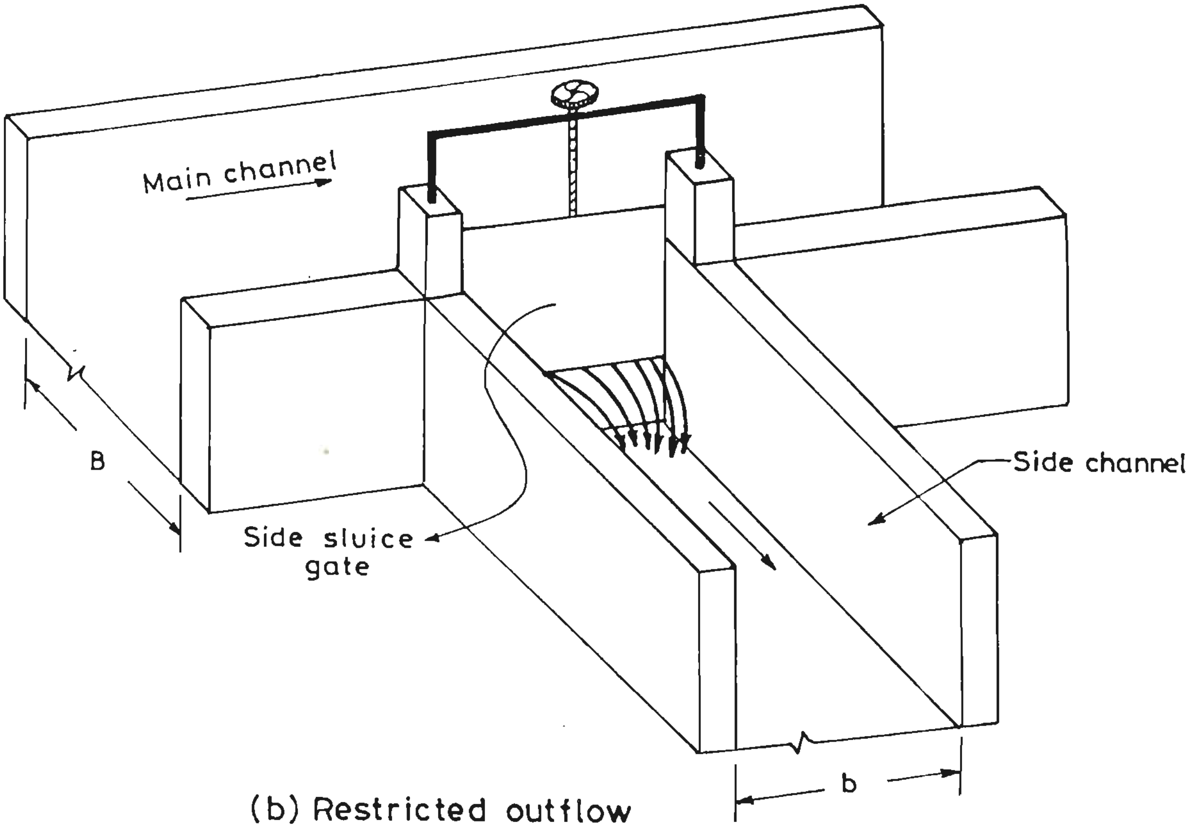


(b) Restricted outflow

Fig. 2.1 Stream lines over Side weir

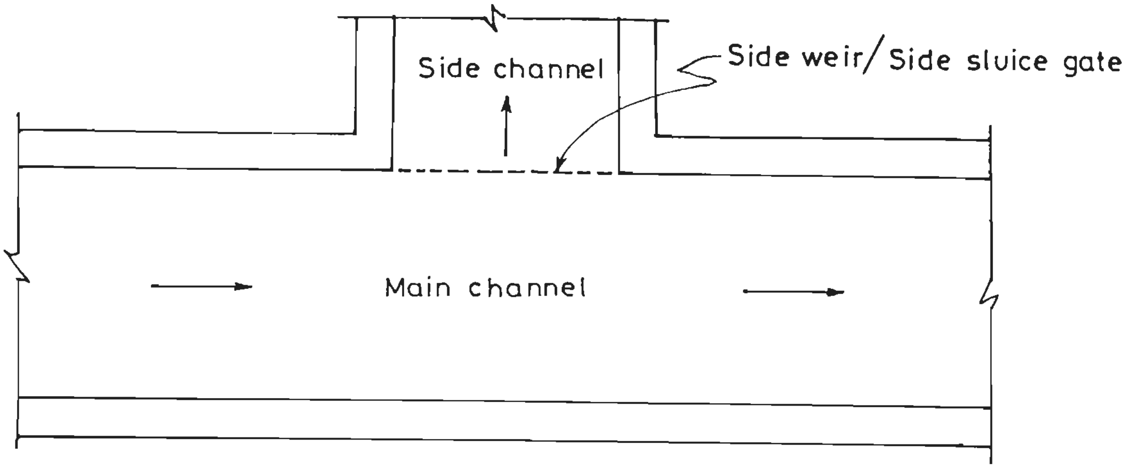


(a) Unrestricted outflow

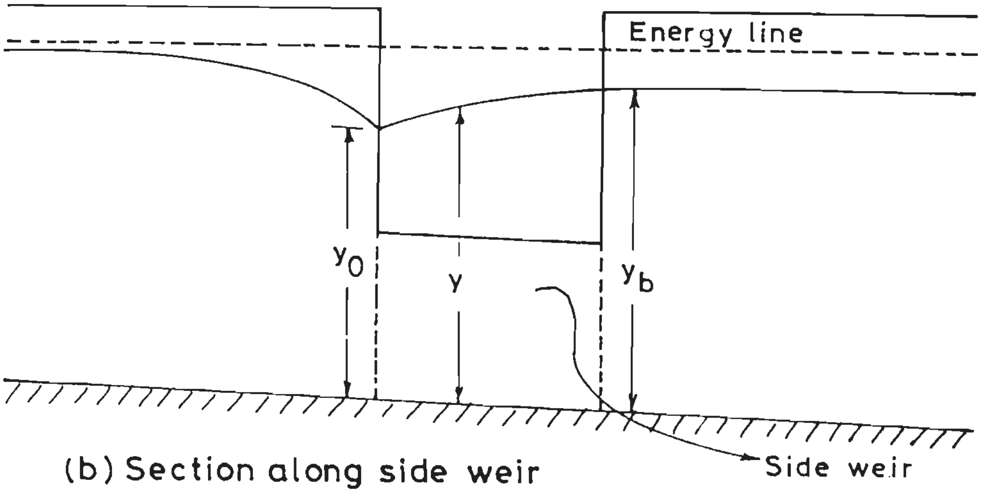


(b) Restricted outflow

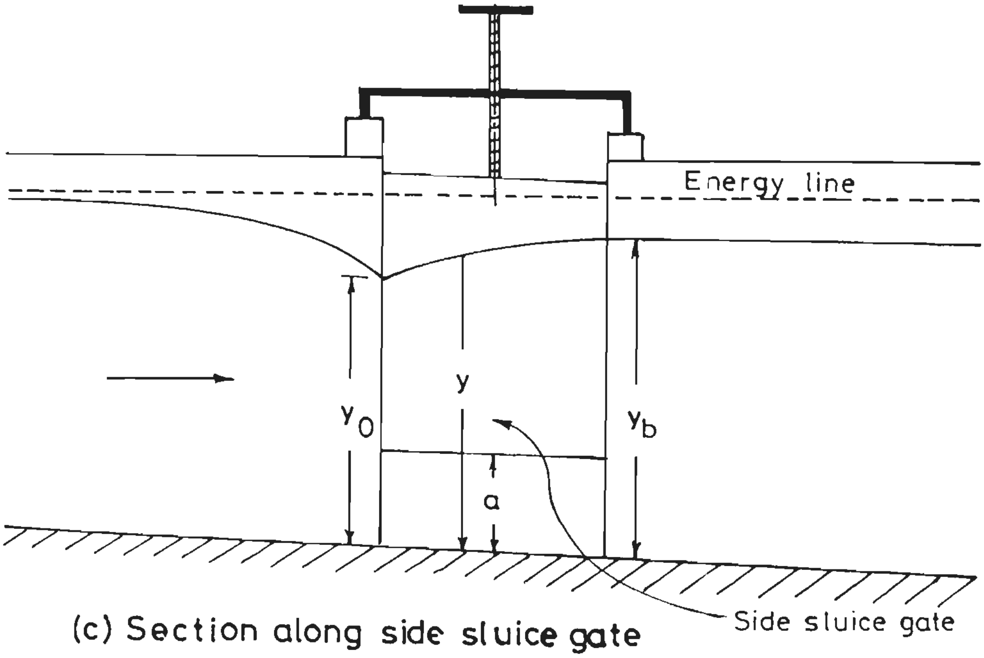
Fig. 2.2 Stream lines through Side sluice gate



(a) Plan



(b) Section along side weir



(c) Section along side sluice gate

Fig. 2.3 Definition sketch

written as:

$$\frac{dy}{dx} = \frac{S_0 - S_f - \frac{Q}{gA^2}\frac{dQ}{dx}}{1 - \frac{Q^2 T}{gA^3}}; \tag{2.3}$$

in which S_0 = the channel bed slope; S_f = the friction slope; and T = the top width of flow. Eq. (2.3) is the basic differential equation governing the motion of spatially varied flow with decreasing discharge.

2.3 CHARACTERISTICS OF FLOW OVER SIDE WEIRS AND THROUGH SIDE SLUICE GATES

Eq. (2.3) indicates that the flow profile along the diversion structure is generally a rising curve for subcritical flow whereas for a supercritical flow it is a falling curve.

2.4 DE MARCHI EQUATION

The spatially varied flow equation for a rectangular side weir was solved by De Marchi (Henderson, 1966) with the assumptions of: (a) flow is steady; (b) the side weir of short length situated in a prismatic channel; (c) the sill of weir is parallel to the channel bed; (d) flow is uniform at a certain distances upstream and downstream of the weir; (e) specific energy along the side weir remains constant; and (f) the discharge per unit length of the side weir can be calculated by the conventional Poleni normal weir equation, namely:

$$\frac{dQ}{dx} = -\frac{2}{3} C_M \sqrt{2g}\,(y-w)^{1.5}; \tag{2.4}$$

in which C_M = De Marchi coefficient of discharge; and w = weir height.

For a side weir in a horizontal frictionless rectangular channel (2.3) becomes:

$$\frac{dy}{dx} = -\frac{AQ}{BQ^2-gA^3}\frac{dQ}{dx}; \tag{2.5}$$

in which B = channel width. Combination of (2.4 and 2.5) yields:

$$\frac{dy}{dx} = \frac{4}{3}\frac{C_M}{B}\frac{\sqrt{(E-y)(y-w)^3}}{3y-2E}; \tag{2.6}$$

in which E = the specific energy given by:

$$E = y + \frac{Q^2}{2A^2g}. \tag{2.7}$$

Integrating between the limits x = 0 and x = b, and designating the beginning and end of the side weir of length b by suffixes 0 and b respectively, one gets:

$$C_M = \frac{3}{2}\frac{B}{b}(\phi_b-\phi_0); \tag{2.8}$$

in which ϕ is De Marchi varied flow function given by:

$$\phi = \frac{2E-3w}{E-w}\sqrt{\frac{E-y}{y-w}} - 3\sin^{-1}\sqrt{\frac{E-y}{y-w}}. \tag{2.9}$$

The curves of varied flow function ϕ against the values of y/E for various values of the parameter w/E are given in Fig. 2.4 (Collinge,

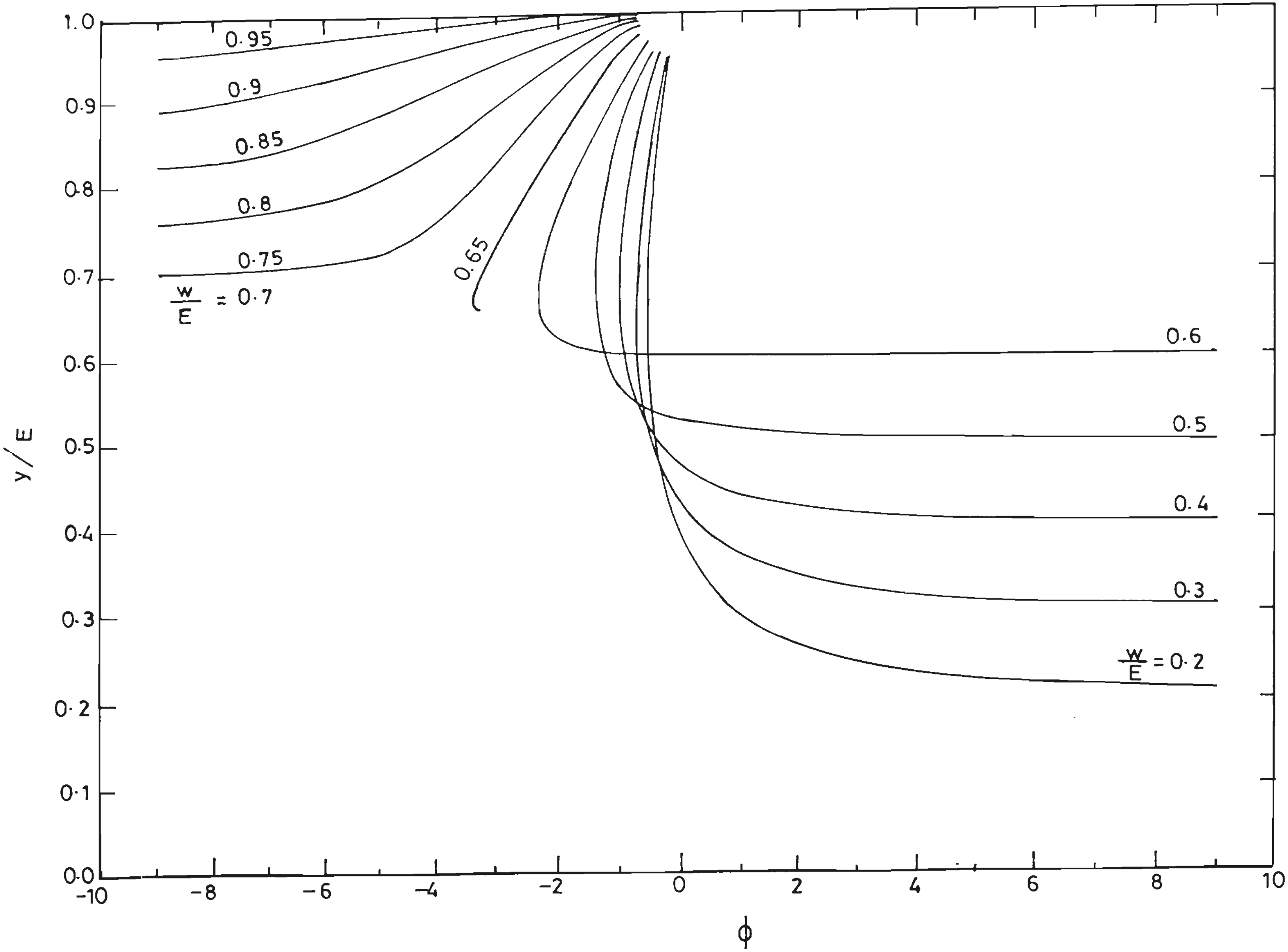


Fig. 2·4 De Marchi varied flow function

1957). Eqs. (2.8 and 2.9) can be combined in the following form:

$$\frac{2bC_M}{3B} = \frac{2E-3w}{E-w}\Bigg[\Bigg[\left(\frac{E-y_b}{y_b-w}\right)^{0.5}-\left(\frac{E-y_0}{y_0-w}\right)^{0.5}\Bigg]-$$

$$3\left[\sin^{-1}\left(\frac{E-y_b}{y_b-w}\right)^{0.5}-\sin^{-1}\left(\frac{E-y_0}{y_0-w}\right)^{0.5}\right]; \qquad (2.10)$$

in which y_0 and y_b are depths of flow at the upstream and downstream sections respectively. Eq. (2.10) can be used to found out discharge over the side weir. Knowing upstream conditions and C_M, Eqs. (2.7 and 2.10) can be solved for downstream discharge Q_b by trial-and-error method. The total discharge Q_s over the side weir will be:

$$Q_s = Q_0 - Q_b; \qquad (2.11)$$

in which Q_0 is the upstream discharge .

CHAPTER THREE

REVIEW OF LITERATURE

3.1 GENERAL

Sharp crested rectangular side weirs have drawn much attention and emphasis of many investigators since the beginning of this century. However, there is not much information available regarding discharge characteristics of broad crested side weirs and side sluice gates. The early studies on the flow characteristics of side weir were empirical in nature and were supported by experiments conducted over a limited range of many variables involved.

3.2 SIDE WEIR

In this section the literature on side weir in a rectangular channel is reviewed.

3.2.1 Rectangular Side Weir

Early studies on the hydraulic behaviour of rectangular side weir installed along a rectangular main channel involved empirical equations based on the limited number of experiments. A good review of literature prior to the work of Nimmo (1928) was given by Hager (1992). Kosinsky (1968) gave a historical review of some of the discharge equations which may be summarized as presented in Table 3.1.

Collinge (1957) carried out experiments to study the hydraulic behaviour of rectangular side weir in a rectangular channel and showed that De Marchi equation is not applicable for critical flow.

The discharge coefficient C_M for a sharp crested rectangular side weir was given by Frazer (Cheong, 1991) as:

$$C_M = 0.55 - 0.115F_0^2 - \frac{0.017E}{b}; \qquad (3.1)$$

in which F_0 = upstream Froude number.

Pattabiramiah and Rajaratnam (1960) proposed a graphical solution for discharge computation of restricted rectangular side weir of zero height.

Krishnappa and Seetharamaiah (Awasthy, 1970) used De Marchi equation for predicting the discharge of a restricted rectangular side weir with subcritical flow in the main channel and supercritical flow in the side channel. However, in applying this equation the head measured

Table 3.1 Historical Review of Empirical Equations for Rectangular Side weir (kosinsky, 1968)

S. No.	Investigator(year)	Equation	Remarks
1	Engles (1917)	$Q_s = 3.32b^{0.83}(y_b - w)^{1.67}$	Large scale model
2	Coleman and Smith (1923)	$Q_s = 0.671b^{0.72}\ E^{1.645}$	sharp crested
3	Forchneimer (1924)	$Q_s = \frac{2}{3} C_d \sqrt{2g}\ b\left[\frac{y_b - y_0}{2}\right]^{1.5}$	Sharp crested
4	Gonzalez and Balmaceda (1930)	$Q_s = 1.53bh^{1.5} + 0.0034\left[\frac{b}{y_0 - w}\right]^{0.5}$	Sharp crested
		$Q_s = 1.43bh_0^{1.5} + 0.0017\left[\frac{b}{y_0 - w}\right]^{0.5}$	Broad crested
5	Dominguez (1954)	$Q_s = \frac{2}{5} C_d\ b\sqrt{2g}\ \frac{(y_0 - w)^{2.5} - (y_b - w)^{2.5}}{y_0 - y_b}$	$F_0 < 1.$
		$Q_s = \frac{2}{5} C_d\ b\sqrt{2g}\ \frac{(y_b - w)^{2.5} - (y_0 - w)^{2.5}}{y_b - y_0}$	$F_0 > 1.$
6	Marthin Smith (1954)	$Q_s = \frac{2}{3} bC_d\sqrt{2g}\ \left[\frac{y_0 - y_b - 2w}{2}\right]^{1.5}$	Sharp crested
7	Marone (1964)	$Q_s = \frac{b^2}{B\ E} \sqrt{2g}\ (E - w)^{2.5}$	Sharp crested
8	Laquerbe (1964)	$Q_s = 1.115\ C_d\sqrt{2g}(y_0 - w)^{1.5}$	Sharp crested
9	Kosinsky (1968)	$Q_s = 0.1414\sqrt{2g}b(y_0 + y_b - 2w)^{1.5}$	Sharp crested

Note: y_0 and y_b = upstream and downstream flow depths adjucent to side weir directly above the weir crest was used. The coefficient of discharge C_M was expressed as a function of F_0 and b/B.

Subramanya and Awasthy (1972) conducted experiments in a rectangular, prismatic, horizontal and frictionless channel. De Marchi coefficient of discharge C_M for a sharp crested rectangular side weir was given by:

$$C_M = 0.864\left[\frac{1 - F_0^2}{2 + F_0^2}\right]^{0.5} \qquad \text{for } F_0 < 0.8 \text{ ; and} \qquad (3.2)$$

$$C_M = 0.36 - 0.08F_0 \qquad \text{for } F_0 > 2.0 \text{ ;} \qquad (3.3)$$

Yu-Tek (1972) proposed the following relationship of C_M:

$$C_M = 0.622 - 0.222F_0. \qquad (3.4)$$

Nadesamoorthy and Thomson (1972) presented the following equation for C_M:

$$C_M = 0.432\left[\frac{2 + F_0^2}{1 + 2F_0^2}\right]^{0.5}. \qquad 0 \leq w \leq 0.6\,m \qquad (3.5)$$

Smith (1973) and El-Khashab and Smith (1976) wrote computer programs for calculating discharge and flow profile along a rectangular side weir in a non-prismatic trapezoidal and rectangular main channel by using energy and momentum approaches respectively. The discharge coefficient was taken as 0.55 which in fact is not constant as it depends upon weir and flow parameters. El-khashab and Smith (1976) showed that the longitudinal component of velocity of spill flow are dependent upon the ratio of the total side weir discharge Q_s to the upstream main channel discharge Q_0 and Froude number F_0.

Prasad (1976) obtained the following equation for C_M for a restricted rectangular sharp crested side weir:

$$C_M = 0.611 - 0.45F_0. \tag{3.6}$$

Whereas for a restricted broad crested rectangular side weir of width L (see Fig. 3.1) the following equation for C_M was given by Prasad (1976):

$$C_M = (0.611 - 0.45F_0)\left[1.258 - 0.135\left(\frac{y_0 - w}{L}\right)\right]. \tag{3.7}$$

Ranga Raju *et al.* (1979) proposed the following modification in De Marchi equation to take into account the separation at vertical upstream corner of the side channel:

$$C_M = \frac{2}{3}\,\frac{B}{b-0.05}(\phi_b-\phi_0); \qquad \text{in SI system of units} \tag{3.8}$$

Ranga Raju *et al.* (1979) obtained the following equation for C_M for a restricted rectangular sharp crested side weir:

$$C_M = 0.81 - 0.6F_0; \tag{3.9}$$

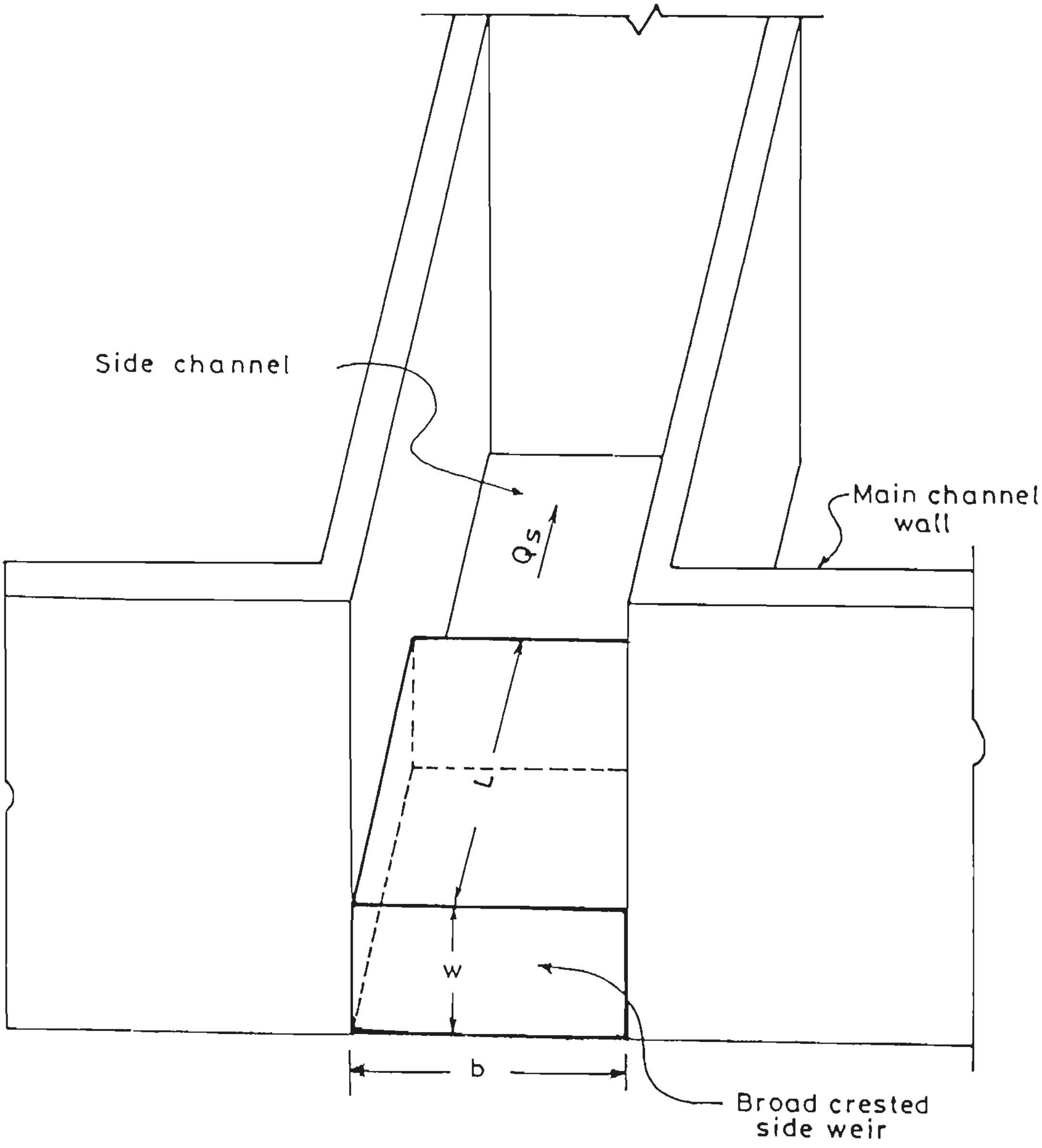


Fig. 3.1 Rectangular broad crested side weir at upstream end of side channel

and for a restricted broad crested side weir the following expression was proposed:

$$C_M = 0.648 - 0.48F_0 + 0.06(1.35 - F_0)\frac{y_0 - w}{L}; \tag{3.10}$$

Ramamurthy and Carballada (1980) recommended the following equation for side weir discharge Q_s with subcritical approach flows:

$$\frac{Q_s}{Q_0} = 0.317\left\{\left[F_0^2 + 2\left(\frac{y_0 - w}{y_0}\right)\right]^{1.5} - F_0^3\right\}\left\{0.203 - \left(0.043 + 0.163\frac{b}{B}\right)\left[1 + \frac{2(y_0 - w)}{F_0^2\, y_0}\right]^{-1.5} + \frac{\left(0.058 + 0.234\frac{b}{B}\right)\left[1 + \frac{2(y_0 - w)}{F_0^2\, y_0}\right]^{-0.5} - 0.54 + 0.25\frac{b}{B}}{1 + \left[1 + \frac{2(y_0 - w)}{F_0^2\, y_0}\right]^{1.5}}\right\}.$$

$$\text{for } \frac{b}{B} \le 1 \tag{3.11}$$

Fig. 3.2 shows the comparison of observed discharge Q_{so} and the computed discharge Q_{sc} using (3.11) for the data of Awasthy (1970). It is evident from Fig. 3.2 that (3.11) does not have a general applicability. Further, the effects of parameters like bed slope, channel roughness, and the varying head along the side weir have not been considered.

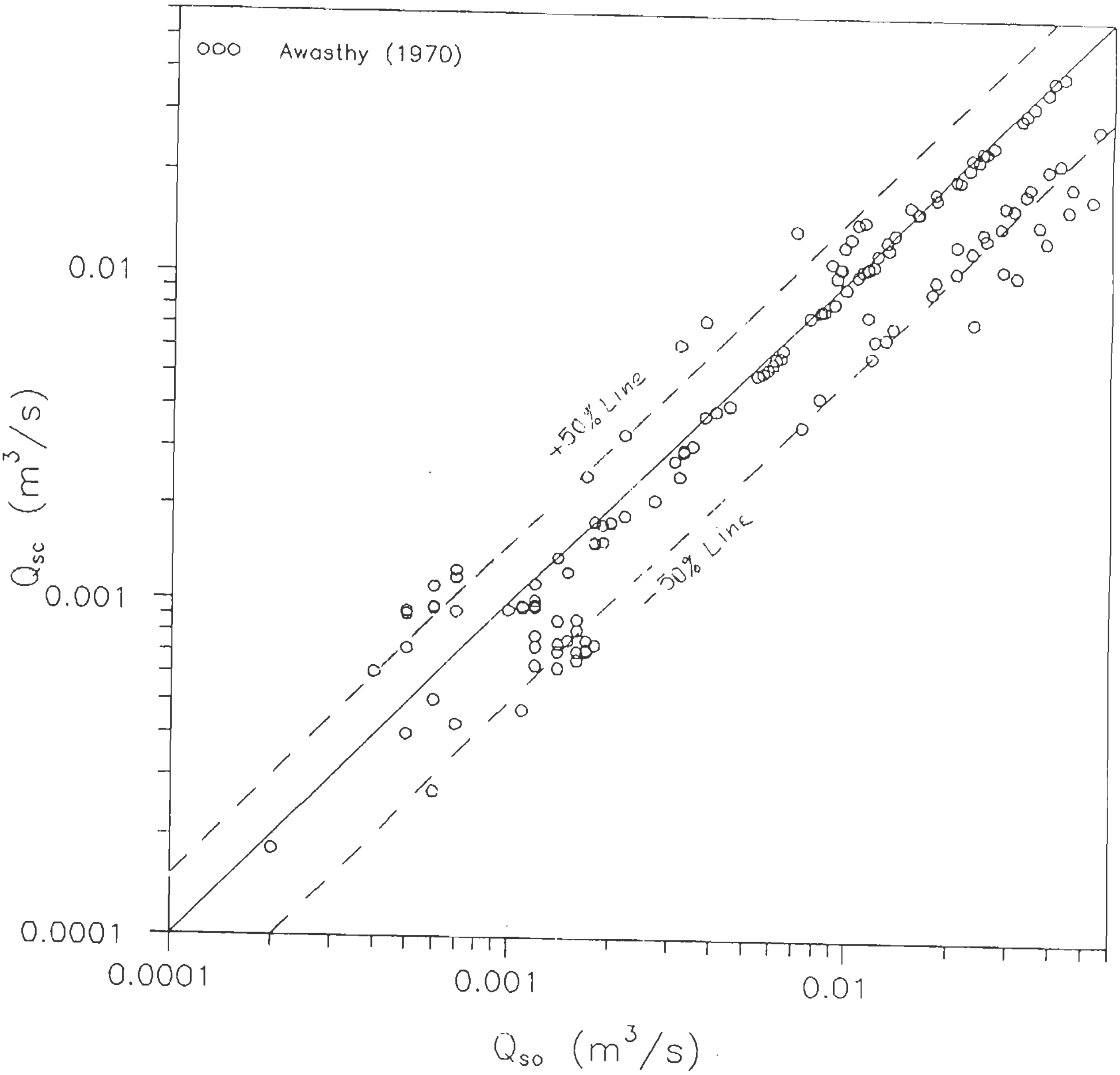


Fig. 3.2 Comparison of observed and computed discharges for sharp crested rectangular side weir using (3.11)

Hager (1983) presented the following relationship for outflow intensity over a rectangular side weir:

$$\frac{dQ}{dx} = -\frac{3}{5}\sqrt{g}\,(y-w)^{1.5}\left[\frac{E-w}{3E-2y-w}\right]^{0.5}. \qquad (3.12)$$

Yadav (1986) proposed the following equations for C_M for a restricted sharp crested rectangular side weir in a horizontal channel:

Free flow: $C_M = 0.753 - 0.145F_0$; and (3.13)

Submerged flow: $C_M = (0.753 - 0.145F_0)k_s$; (3.14)

in which k_s is the submergence factor given by:

$$k_s = 1.377 - 2.489\frac{y_t-w}{y_0-w} + 4.299\left(\frac{y_t-w}{y_0-w}\right)^2 - 3.014\left(\frac{y_t-w}{y_0-w}\right)^3; \qquad (3.15)$$

here y_t = tail water depth in the side channel.

Hager and Volkart (1986) and Hager (1987) recommended the following relationship for outflow rate of a rectangular side weir in non-prismatic channels:

$$\frac{dQ}{dx} = -\frac{3}{5}\sqrt{g}(y-w)^{1.5}\left[\frac{E-w}{3E-2y-w}\right]^{0.5}\left\{1-(S_0+\frac{dB}{dx})\left[\frac{3(E-y)}{y-w}\right]^{0.5}\right\}. \qquad (3.16)$$

The flow profile along a rectangular side weir was derived by Hager and Volkart (1986) as:

$$\frac{dy}{dx} = \frac{S_0 - \frac{S_{f0}+S_{fb}}{2} - \frac{2Q_s V_0^2}{5gbQ_0}\left[\frac{2Q_s}{Q_0} - 1\right] - \frac{Q}{gA^2}\frac{dQ}{dx} + \frac{Q^2}{gA^3}\frac{\partial A}{\partial x}}{1 - \frac{Q^2\,T}{gA^3}}; \qquad (3.17)$$

in which S_{f0} and S_{fb} are friction slopes at the upstream and downstream sections respectively. Eq. (3.17) was solved by an explicit numerical integration scheme.

Hager (1987) proposed the following equation for the local discharge coefficient C_e for a rectangular side weir with $w = 0$:

$$C_e = 0.7275\left[\frac{2gB^2y^3 + Q^2}{2gB^2y^3 + 3Q^2}\right]^{0.5}. = 0.7275\left(\frac{2+F^2}{2+3F^2}\right)^{0.5} \qquad (3.18)$$

Ramamurthy and Satish (1988) obtained the following equation for lateral outflow Q_s with $w = 0$ for subcritical approach flow:

$$\frac{Q_s}{Q_0} = \frac{bC_c}{BF_0}\left[\frac{2 + F_0^2}{3}\right]^{1.5}; \qquad \text{for } \frac{b}{B} \le 1 \qquad (3.19)$$

in which C_c was shown as a function of b/B and F_0. Further Q_s/Q_0 was related to F_b.

Ramamurthy *et al.* (1990) proposed the following equation for side weir discharge with $w = 0$:

$$\frac{Q_s}{Q_0} = 1 - \left\{ \left[F_0^2 \left(\frac{5-0.15F_0^2}{3} \right)^2 - \frac{8y_b}{y_0} \left[\left(\frac{y_b}{y_0} \right)^2 - \frac{F_0^2(1+0.15F_0^2)}{3} - 1 \right] \right]^{0.5} + \right.$$

$$\left. \frac{5 - 0.15F_0^2}{3} \right\} \frac{y_b}{4y_0}; \qquad \text{for } 0 < F_0 < 0.75 \qquad (3.20)$$

The discharge coefficient for a lateral opening has been given by Cheong (1991) as:

$$C_M = 0.45 - 0.22F_0^2. \qquad (3.21)$$

3.2.2 Triangular Side Weir

Kumar and Pathak (1987) studied the hydraulic behaviour of sharp and broad crested triangular side weirs. The following discharge equations were proposed for $\pi/3 < \theta < 2\pi/3$; θ being the the apex angle (see Fig. 3.3):

Sharp crested:

$$Q_s = 0.5908C_M\sqrt{2g}\ \tan\frac{\theta}{2}\left[0.5(y_0 + y_b) - w\right]^{2.5}; \quad \text{and} \qquad (3.22)$$

Broad crested:

$$Q_s = \left(0.4453 - 0.055\frac{0.5(y_0+y_b)-w}{L}\right)C_M\sqrt{2g}\ \tan\frac{\theta}{2}\left(\frac{y_0 + y_b}{2}\right)^{2.5}; \qquad (3.23)$$

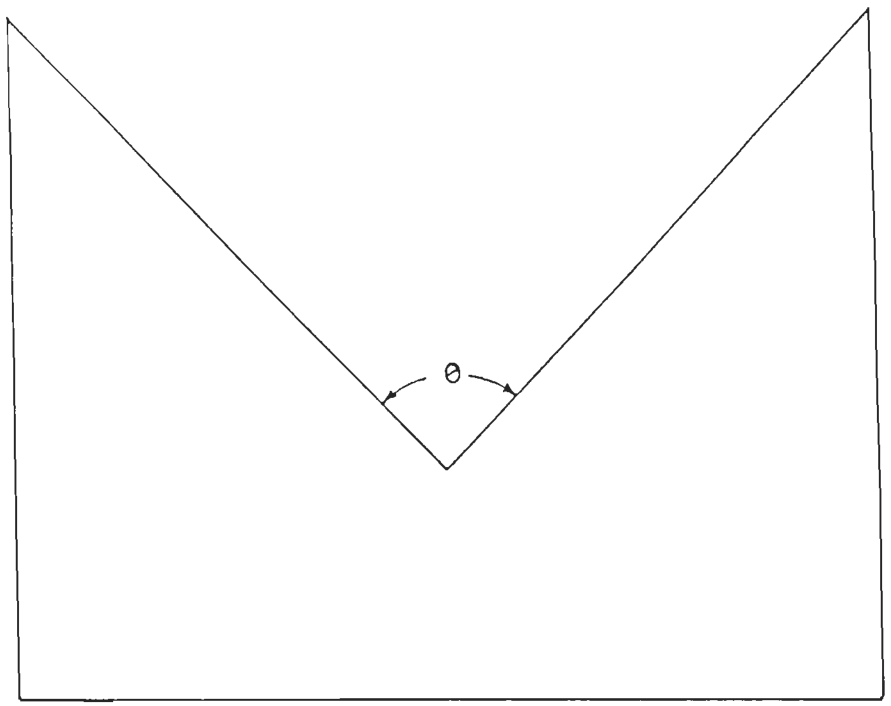


Fig. 3.3 Triangular side weir

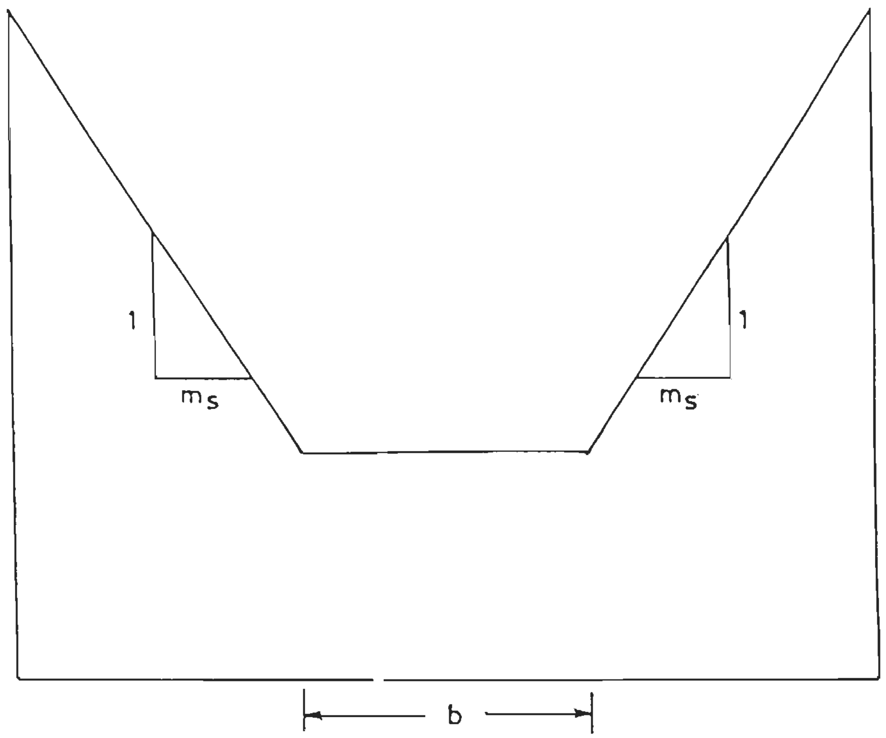


Fig. 3.4 Trapezoidal side weir

in which:

$$C_M = 0.811 - 0.321 \tan\frac{\theta}{2} + 0.129 \tan^2\frac{\theta}{2} -$$

$$\left[0.695-0.638 \tan\frac{\theta}{2} + 0.15 \tan^2\frac{\theta}{2}\right]F_0. \qquad (3.24)$$

Yadav (1986) obtained the following equations for C_M for a sharp crested triangular side weir in a horizontal channel:

Free flow : $C_M = 0.645 - 0.112F_0$; for $\theta = \pi/2$; and (3.25)

Submerged flow : $C_M = (0.645 - 0.112F_0)k_s$; (3.26)

in which:

$$k_s = 1.115-1.215\frac{y_t-w}{y_0-w} + 3.004\left[\frac{y_t-w}{y_0-w}\right]^2 -2.656\left[\frac{y_t-w}{y_0-w}\right]^3. \qquad (3.27)$$

3.2.3 Trapezoidal Side Weir

Pandey (1985) studied the flow characteristics of sharp crested trapezoidal side weir and presented the following equation for C_M:

$$C_M = 0.2546 + 1.3194m_s - 1.054m_s^2 + \left[-0.5418 + 1.209m_s - 0.8345m_s^2\right]F_0;$$

(3.28)

for $0.268 \le m_s \le 1$; m_s being side slope of the side weir. See Fig. 3.4.

Yadav (1986) presented the following equation for C_M for a sharp crested trapezoidal side weir in a horizontal channel:

$$C_M = (k_a - K_b F_0) k_s; \tag{3.29}$$

in which:

$$k_s = k_c - k_d \frac{y_t - w}{y_0 - w} + k_e \left(\frac{y_t - w}{y_0 - w} \right)^2 - k_f \left(\frac{y_t - w}{y_0 - w} \right)^3 ; \tag{3.30}$$

the values of constants k_a to k_f were obtained for different values of m_s as given in Table 3.2.

Table 3.2 Values of Constants in (3.29) and (3.30)

m_s	k_a	k_b	k_c	k_d	k_e	k_f
0.268	0.562	0.056	2.01	5.03	8.834	5.65
0.577	0.641	0.206	1.071	0.696	1.745	1.878
1	0.622	0.136	1.388	2.036	3.851	2.965
1.428	0.629	0.068	0.983	0.277	0.914	1.284

Further Yadav (1986) proposed the following relationship for C_M:

$$C_M = 0.366 + 1.019m_s + 1.179m_s^2 + 0.416m_s^3 -$$

$$\left[-0.341 + 2.073m_s - 2.433m_s^2 + 0.836m_s^3\right]F_0;$$

$$\text{for } 0.268 \le m_s \le 1.428 \tag{3.31}$$

As indicated earlier, the majority of the studies on side weirs are based on De marchi equation which assumes a constant discharge coefficient C_M. Figs. 3.5 and 3.6 show the comparison of equations for C_M as proposed by various investigators for unrestricted and restricted sharp crested rectangular side weirs respectively. Using the data of Awasthy (1970) and Prasad (1976) values of C_M were computed by (2.7) and (2.10). These are also included in Figs. 3.5 and 3.6. A perusal of Figs. 3.5 and 3.6 reveals that there is little agreement among the proposed equations. Moreover experimental data show high departure from the proposed equations. Thus, the predicted side weir discharge based upon these equations will be markedly different for the same values of F_0. This departure is on account of non-inclusion of the most dominant variable, namely, head weir height ratio. Further, the effect of varying head along the weir length, length of the side weir and local Froude number have not been taken into consideration by almost all the investigators. On the other hand some investigators have given various explicit equations for Q_s. These equations have been related to different parameters and do not agree with each other and therefore, results in different values of side weir discharge for the same conditions.

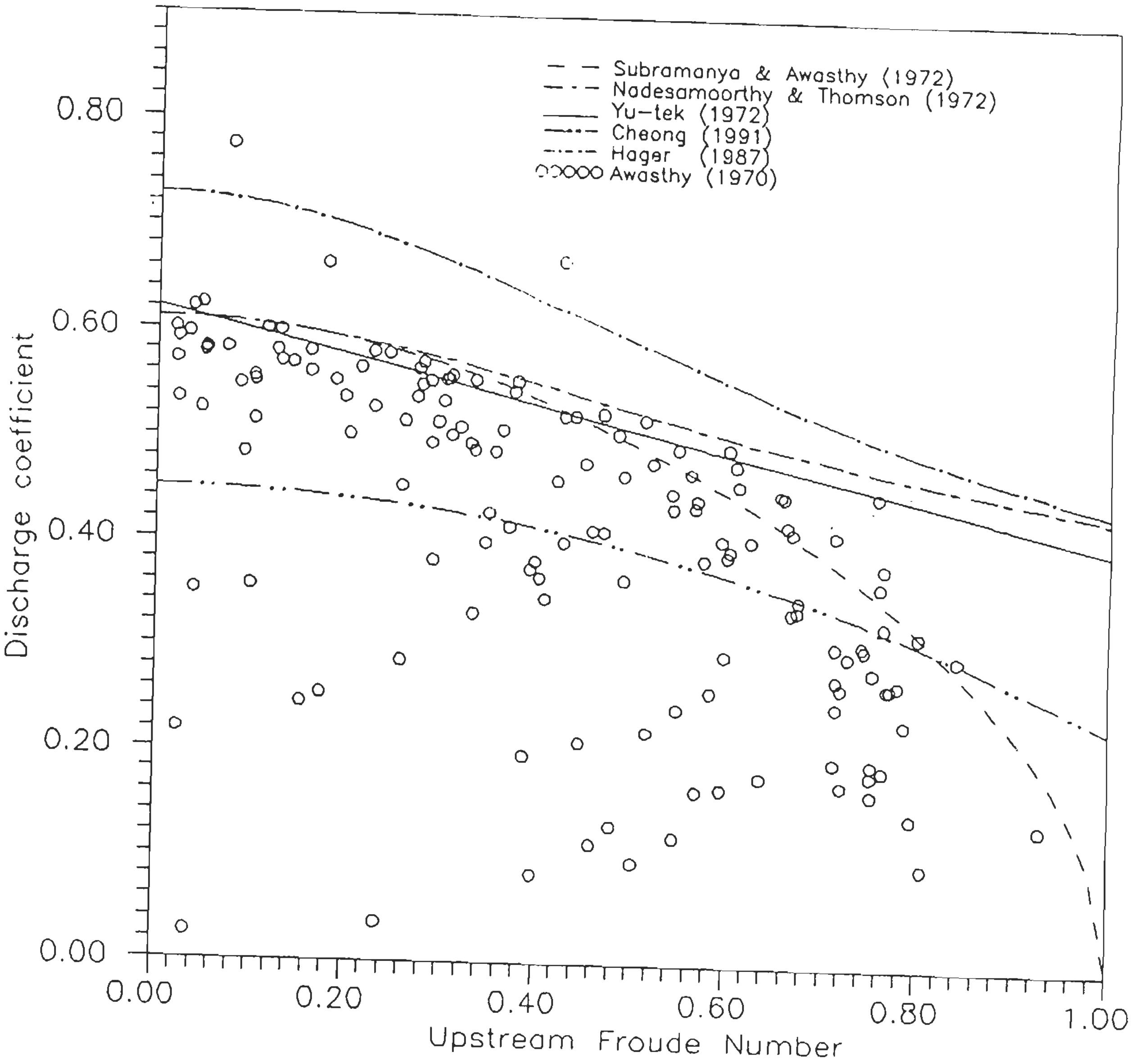


Fig. 3.5 Comparison of discharge coefficient equations for unrestricted sharp crested rectangular side weir

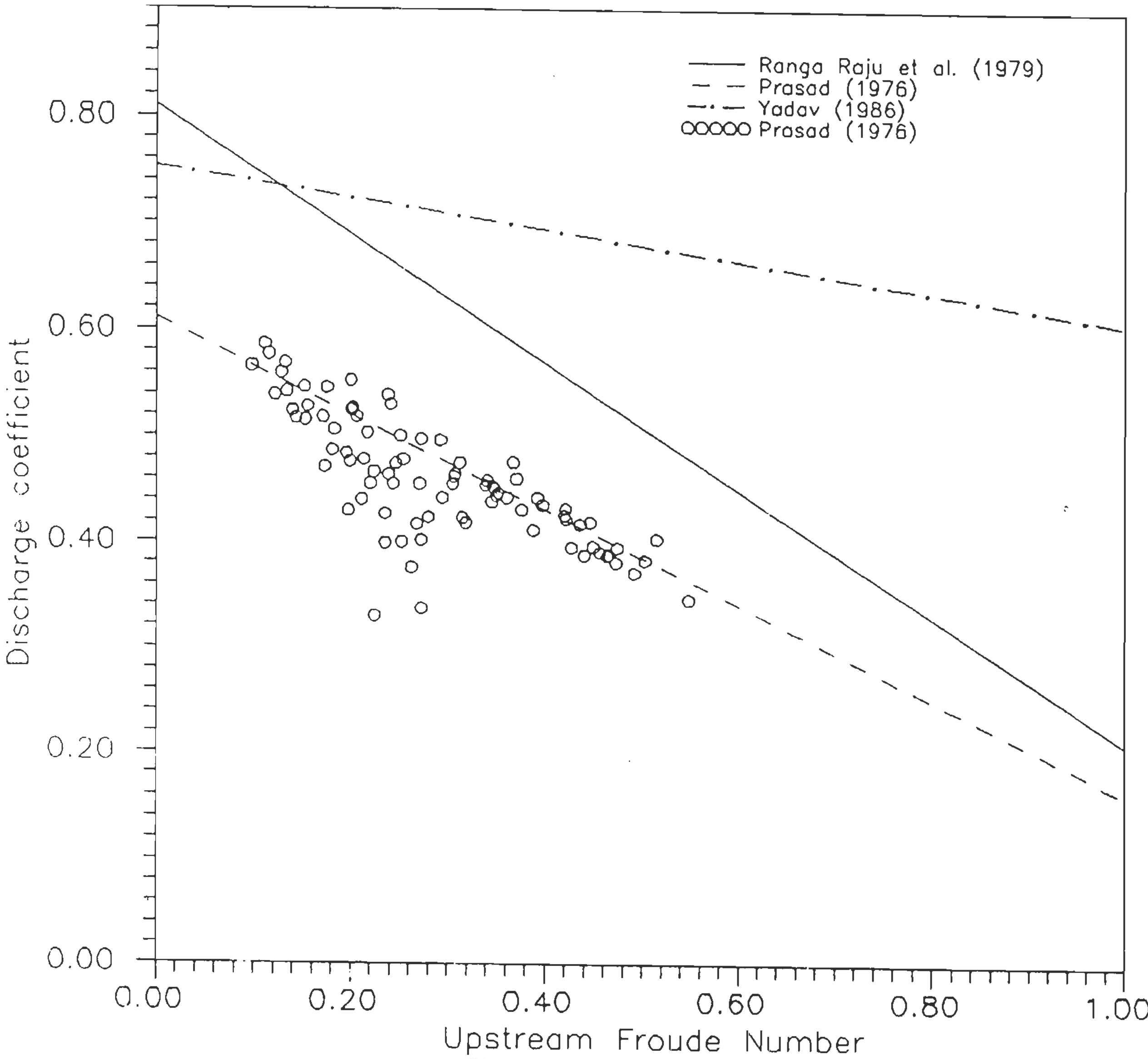


Fig. 3.6 Copmarison of discharge coefficient equations for restricted sharp crested rectangular side weir

It is evident that none of the existing approaches are adequately capable of predicting the side weir discharge accurately. Hence an accurate approach for computing the side weir discharge and the flow profile is required.

3.3 SIDE SLUICE GATE

Review of literature indicated that little attention has been given to the study of flow through side sluice gate. Panda (1981) studied the nature of velocity distribution and water surface profile in the main as well as side channels under free flow condition. The side sluice discharge equation was given as:

$$Q_s = C_d a b \sqrt{g(y_0 + y_b)}. \tag{3.32}$$

Panda (1981) stated that the coefficient of discharge C_d is not strongly dependent on the upstream Froude number F_0 and reported that the C_d of the side sluice gate is higher than that of the normal sluice gate, the difference being 10% to 15% for larger values of $0.5(y_0 + y_b)$. Further the effects of b/B on C_d was reported to be marginal.

Tanwar (1984) studied the flow characteristics of side sluice gate under free and submerged flow conditions and showed that the coefficient of discharge is a function of the ratio of flow depth at the intersection of the channels y_m (*i.e* at $x = b/2$) to the side sluice gate opening a for free flow and to an additional parameter: ratio of tail water depth y_t to side sluice gate opening a for submerged flow conditions (see Fig. 3.7).

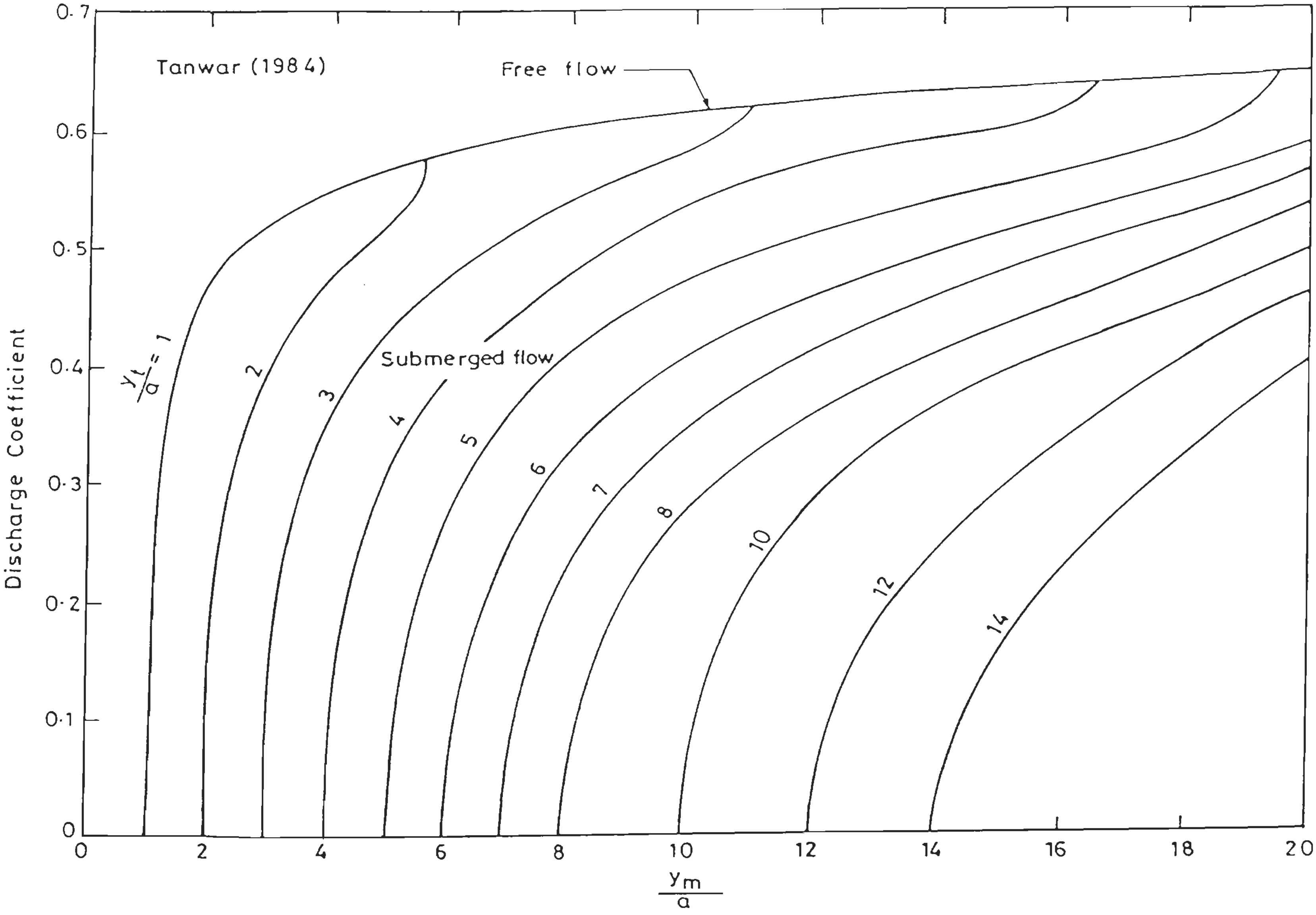


Fig. 3.7 Variation of discharge coefficient with y_m/a and y_t/a for sharp crested Side sluice gate.

Hager (1983) and Hager and Volkart (1986) proposed the following equation for discharge variation along the rectangular side sluice gate in a prismatic rectangular channel of small slope:

$$\frac{dQ}{dx} = \frac{a}{E}\left[\frac{2gE^4}{3E(4E-3y)}\right]^{0.5} \qquad (3.33)$$

Since there is not much information available regarding the flow characteristics of side sluice gate, an accurate approach for discharge and flow profile computation of side sluice gate is needed.

CHAPTER FOUR

THEORETICAL CONSIDERATION

4.1 FLOW OVER SIDE WEIR

The flow over a side weir is a typical case of spatially varied flow with decreasing discharge. The governing differential equation for such a flow as derived in Chapter 2 is given by:

$$\frac{dy}{dx} = \frac{S_0 - S_f - \dfrac{Q}{gA^2}\dfrac{dQ}{dx}}{1 - \dfrac{Q^2 T}{gA^3}}; \qquad (2.3)$$

with the assumption of insignificant energy loss on account of flow diversion.

The friction slope S_f in (2.3) is given by Manning's equation as:

$$S_f = \frac{Q^2 n^2}{A^2 R^{4/3}}; \qquad (4.1)$$

in which n = the Manning's roughness coefficient; and R = the hydraulic radius.

Considering a discharge dQ flowing out through an elementary strip of length dx along the side weir (see Fig. 4.1), the discharge per unit length of the side weir is given by:

$$\frac{dQ}{dx} = -\frac{2}{3} C_e \sqrt{2g}\,(y-w)^{1.5}; \tag{4.2}$$

in which C_e = the discharge coefficient. It is a discharge coefficient of a vertical elementary strip along the side weir. This discharge coefficient is different than C_M discussed in Chapter 2 and it can be called *Elementary Discharge Coefficient.*

For a rectangular channel section of bed width B, combining (2.3, 4.1 and 4.2) yields:

$$\frac{dy}{dx} = \frac{S_0 - \dfrac{Q^2 n^2}{B^2 y^{10/3}}\left[1+\dfrac{2y}{B}\right]^{4/3} + \dfrac{2\sqrt{2}}{3}\,\dfrac{QC_e}{B^2 y^2 \sqrt{g}}\,(y-w)^{1.5}}{1 - \dfrac{Q^2}{gB^2 y^3}}. \tag{4.3}$$

Eqs. (4.2 and 4.3) can be solved as an initial value problem using a fourth order Runge-Kutta method with the following initial conditions:

$$\text{At } x = 0: \quad y = y_0; \text{ and } \quad Q = Q_0. \tag{4.4}$$

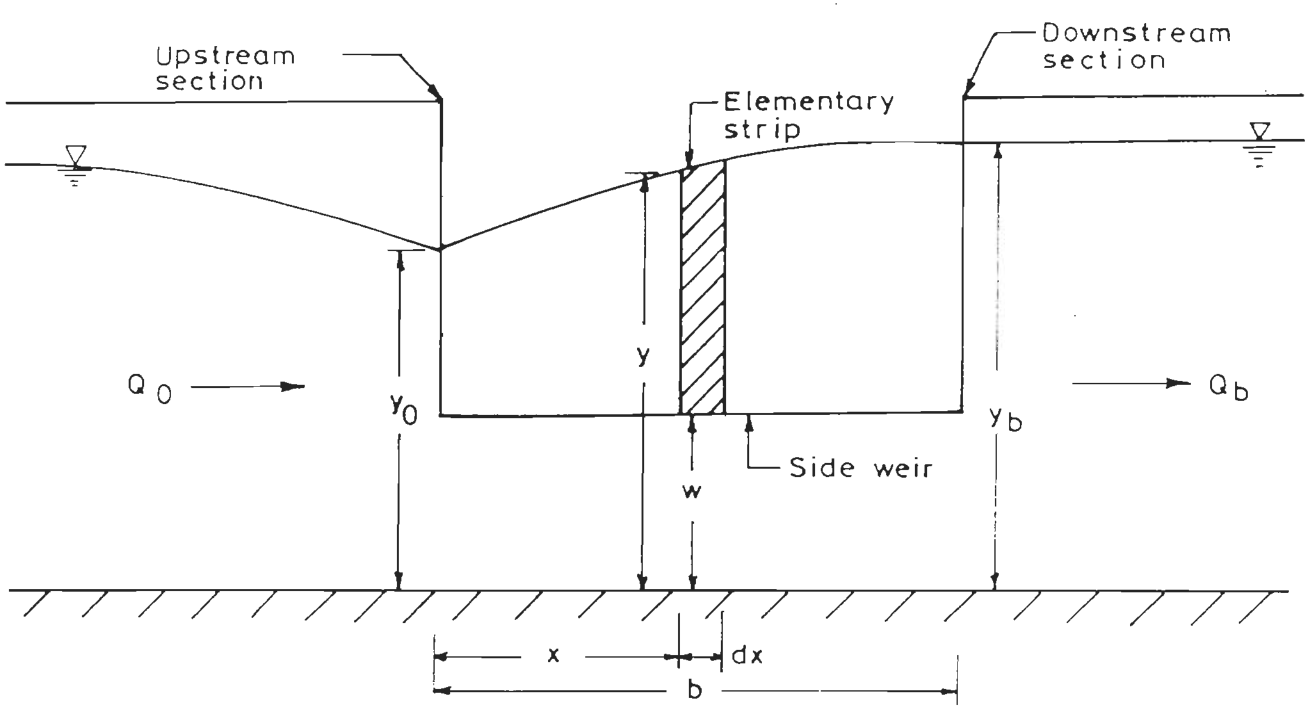


Fig. 4.1 Flow along side weir

Since in the subcritical flow the control section is at the downstream section, therefore, the computations are usually carried out from this section. However, there is no mathematical restriction as regard to the direction of the computations. Since the upstream conditions at section $x = 0$ (*ie.* y_0 and Q_0) are known, the computations were started from this section.

For the solution of (4.2 and 4.3), one requires a functional relationship for C_e. Since (4.3) involves S_0, n, channel geometry and local Froude number, C_e for a sharp crested side weir is assumed to be a function of the weir head to the weir height ratio, and for a broad crested side weir it is assumed to be a function of the weir head to the weir width ratio.

The discharge coefficient is strongly affected by the presence of the side walls in the side channel. Ranga Raju *et al.* (1979) showed that the side walls in the side channel increases C_M.

4.2 FLOW THROUGH SIDE SLUICE GATE

Like side weir, the flow through a side sluice gate is also a typical case of spatially varied flow with decreasing discharge with the governing differential equation being (2.3).

Considering the discharge dQ passing through an elementary strip of length dx along the side sluice gate (see Fig. 4.2), the discharge per

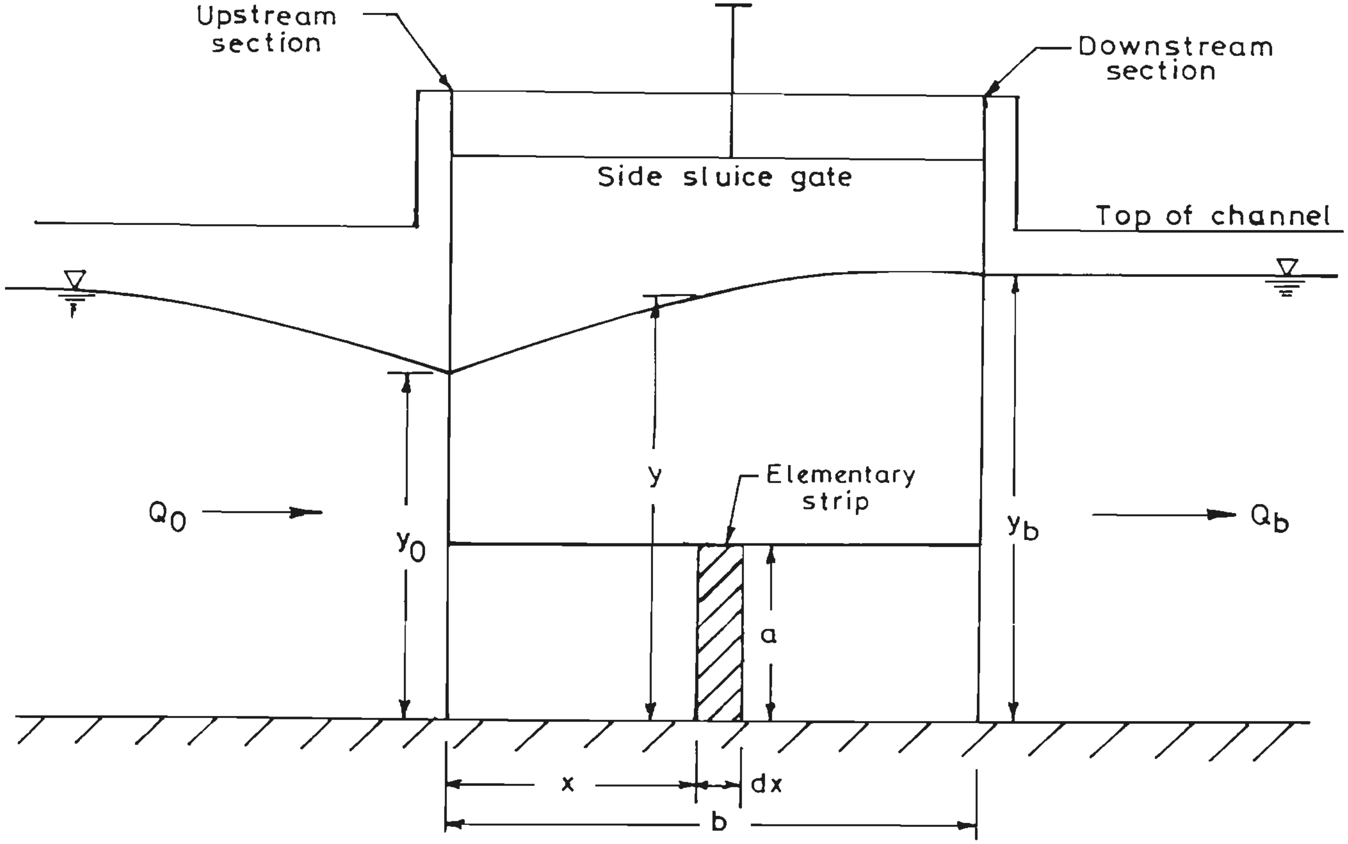


Fig. 4.2 Flow along side sluice gate

unit length of the side sluice gate is given by:

$$\frac{dQ}{dx} = - C_e a \sqrt{2gy} \; ; \tag{4.5}$$

in which a = the gate opening (see Fig. 4.2).

For a rectangular channel section, combining (2.3, 4.1 and 4.5) yields:

$$\frac{dy}{dx} = \frac{S_0 - \dfrac{Q^2 n^2}{B^2 y^{10/3}} \left[1 + \dfrac{2y}{B}\right]^{4/3} \dfrac{QaC_e}{B^2 y} \sqrt{\dfrac{2}{gy}}}{1 - \dfrac{Q^2}{gB^2 y^3}} \; . \tag{4.6}$$

Eqs. (4.5 and 4.6) can be solved as an initial value problem with the initial conditions (4.4). For the solution of (4.5 and 4.6) a functional relationship for C_e is required. Since (4.6) incorporates the effects of S_0, n, channel geometry and local Froude number; for free flow through a sharp crested side sluice gate, C_e may be assumed to be a function of the flow depth to the gate opening ratio y/a. For submerged flow in addition to y/a, C_e will depend on the tail water depth to the gate opening ratio y_t/a. For a broad crested side sluice gate C_e will be a function of an additional parameter, namely, ratio of the gate thickness c to the gate opening a.

CHAPTER FIVE

EXPERIMENTAL PROGRAM

5.1 EXPERIMENTAL SET-UP

Experiments on unrestricted side weirs were conducted using a prismatic, horizontal main channel (9.0m long, 0.5m width and 0.5m deep), the schematic view of which is given in Fig. 5.1. The side weir was located 4.m from the upstream end. At the downstream end of the main channel a steel tail gate was provided for maintaining the desired flow depths in the main channel. The side channel was constructed parallel to the main channel, thereby, allowing the streamlines to have unrestricted direction after passing over side weir. The upstream main channel discharge was measured using a sharp crested weir installed at the end of the common drain. The side channel was provided with a sharp crested weir at its end for measuring the lateral discharge. Ventilation holes

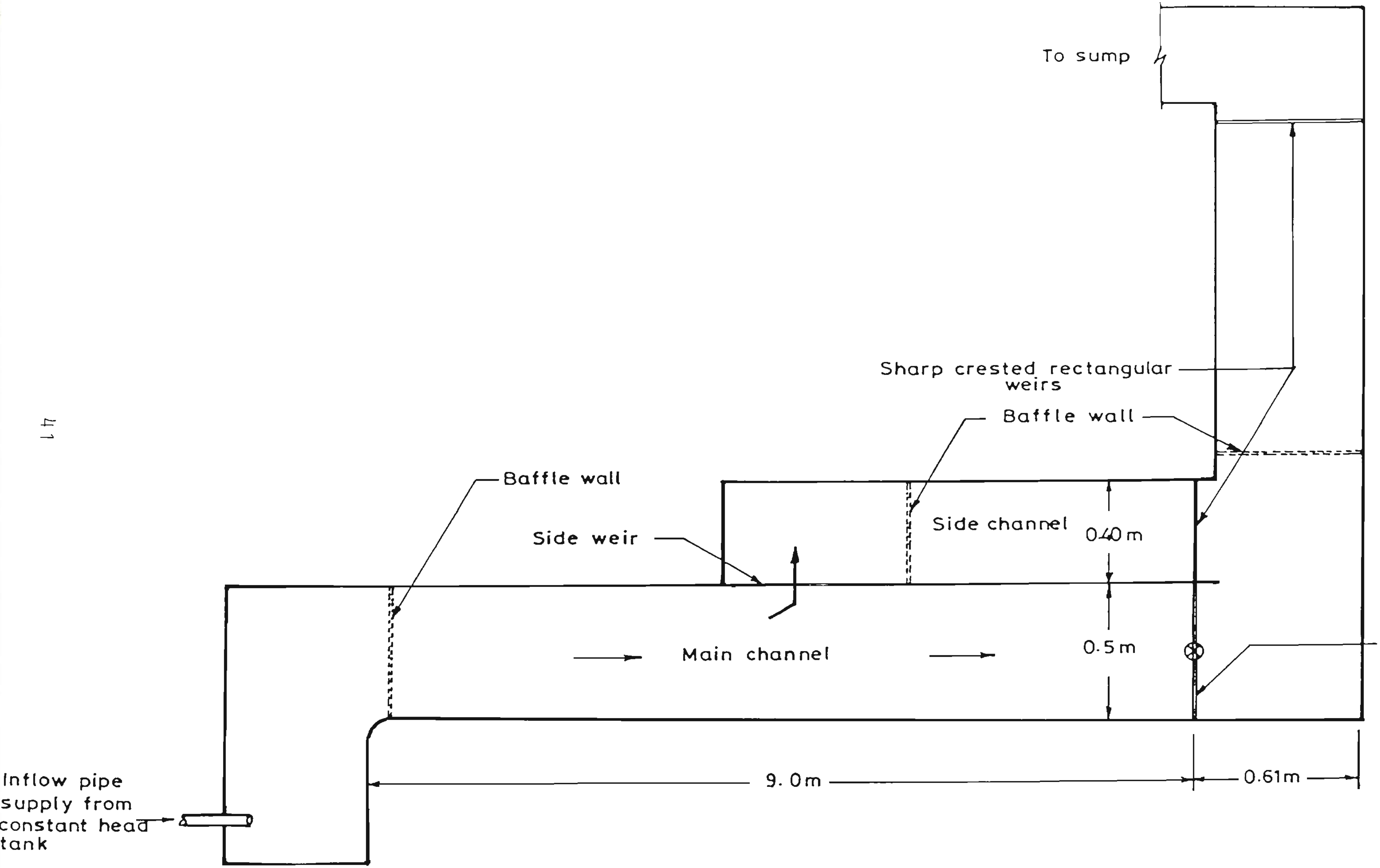


Fig. 5.1 Schematic view of experimental set-up (unrestricted outflow)

were provided in all the weirs tested, thereby, giving an aerated nape.

For investigating the effect of lateral constraint due to walls of the side channel, the set-up was modified as shown in Fig. 5.2. In this case the side channel was constructed at 90° to the main channel. At the end of the side channel a wooden tail gate was provided to ensure various degree of submergence in the side channel for experiments on side sluice gates. Side channel was connected to a side channel extension at the end of which a sharp crested side weir was installed for measuring the lateral discharge.

Main channel and side channel were made of brick masonry and plastered with cement. The sharp crested side weirs of rectangular and triangular shapes, and rectangular sharp crested side sluice gate (see Figs. 5.3 - 5.5) were made of mild steel plates, which were suitably beveled to get sharp crests. The side weir or side sluice gate was installed at the upstream end of the side channel flush with the main channel wall. The broad crested side weirs were built of cement plastered brick masonry and were provided with sharp upstream corner. The upstream and downstream faces of the broad crested side weir were maintained vertical. Marine plywood of different thicknesses were bolted to the downstream face of the side sluice gate to get broad crested side sluice gates of various lip thicknesses [see Fig. 5.5(b)]. To ensure a smooth and disturbance free flow baffle walls were provided at the upstream end of channels. Further, in all the experiments wooden floats at the upstream end of the channels were used to reduce the surface waves and surface irregularities especially at high values of Froude number.

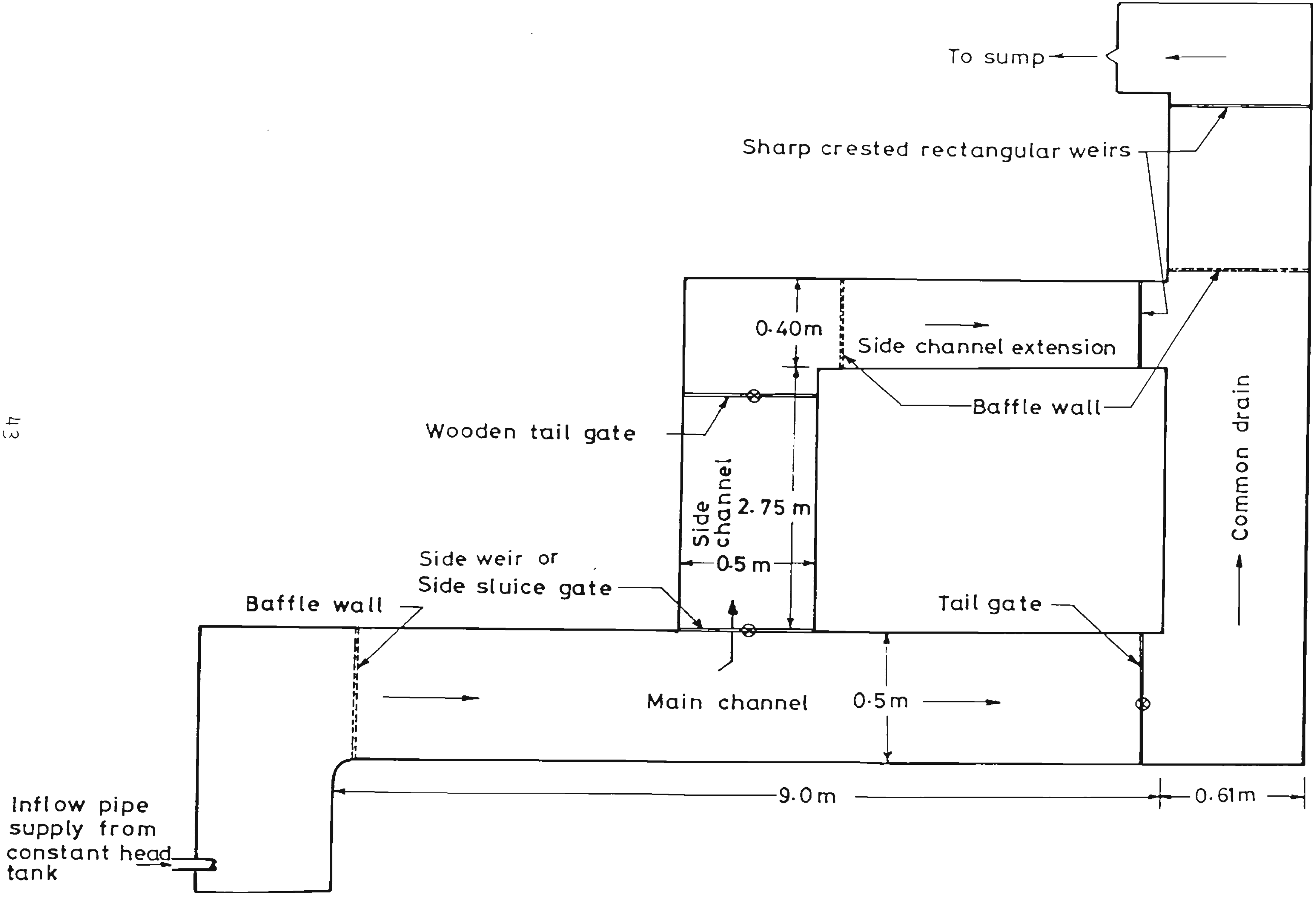
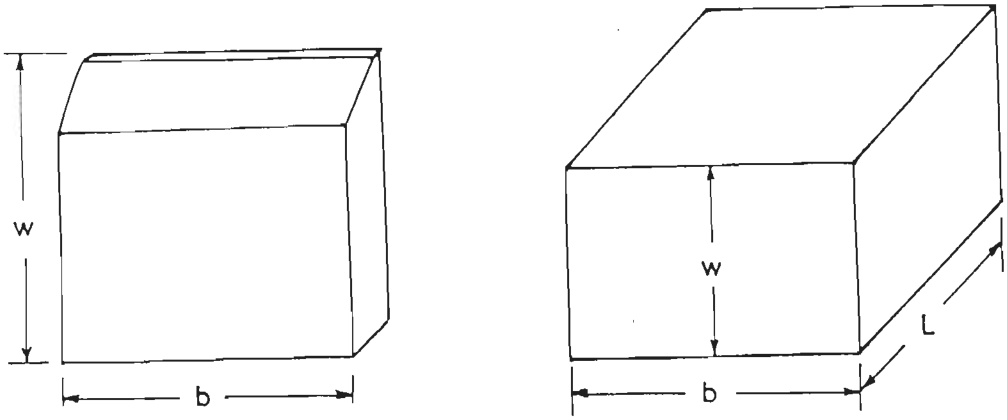
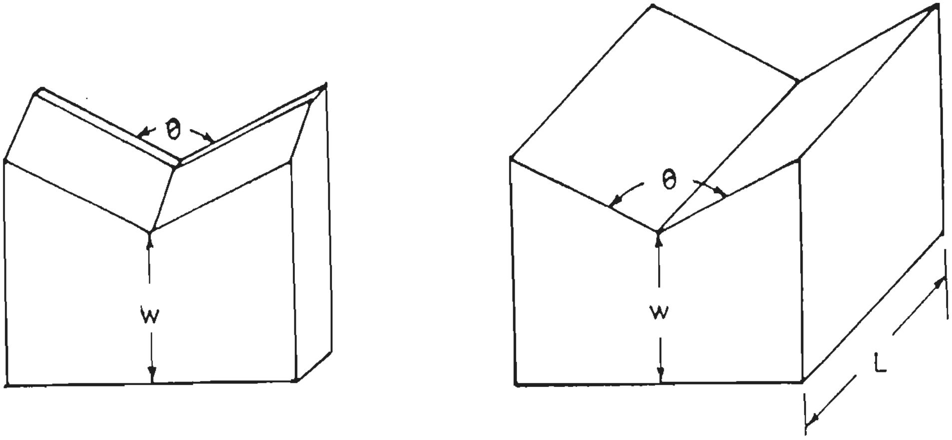


Fig. 5. 2 Schematic view of experimental set-up (restricted outflow)



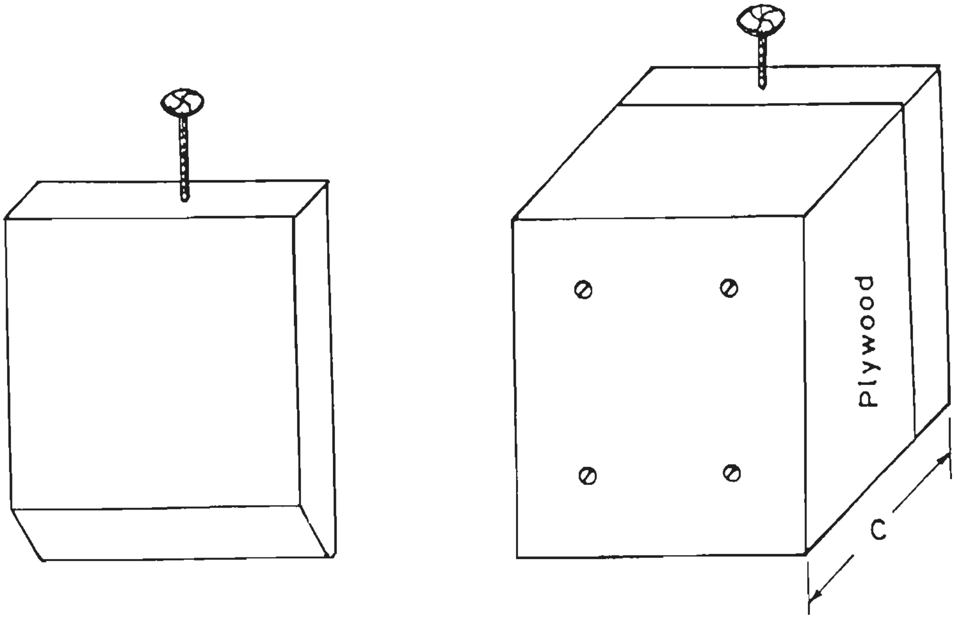
(a) Sharp crested (b) Broad crested

Fig. 5.3 Rectangular side weir



(a) Sharp crested (b) Broad crested

Fig. 5.4 Triangular side weir



(a) Sharp crested (b) Broad crested

Fig. 5.5 Side sluice gate

5.1.1 The Water Supply

Water was supplied to the main channel through a supply pipe from an overhead tank provided with an overflow arrangement to maintain constant head. The water inflow was controlled by a valve. The water after flowing through the experimental set-up collected in an underground sump, from which it was pumped back to the overhead tank.

5.1.2 Measurements

Flow depths y_0 and y_b (see Fig. 5.6) at the upstream and downstream sections ($x = 0$ and $x = b$) were measured at the center line of the main channel with a point gauge having an accuracy of ±0.1mm. The water surface profiles along the side weir and side sluice gate at the center line of the main channel were also recorded for some of the runs. The head over the sharp crested normal weirs in the main and the side channel extensions were measured in order to compute discharge in the main and the side channels. The temperature of water was also noted in order to apply discharge corrections for viscosity and surface tension (Kindsvater and Carter, 1957).

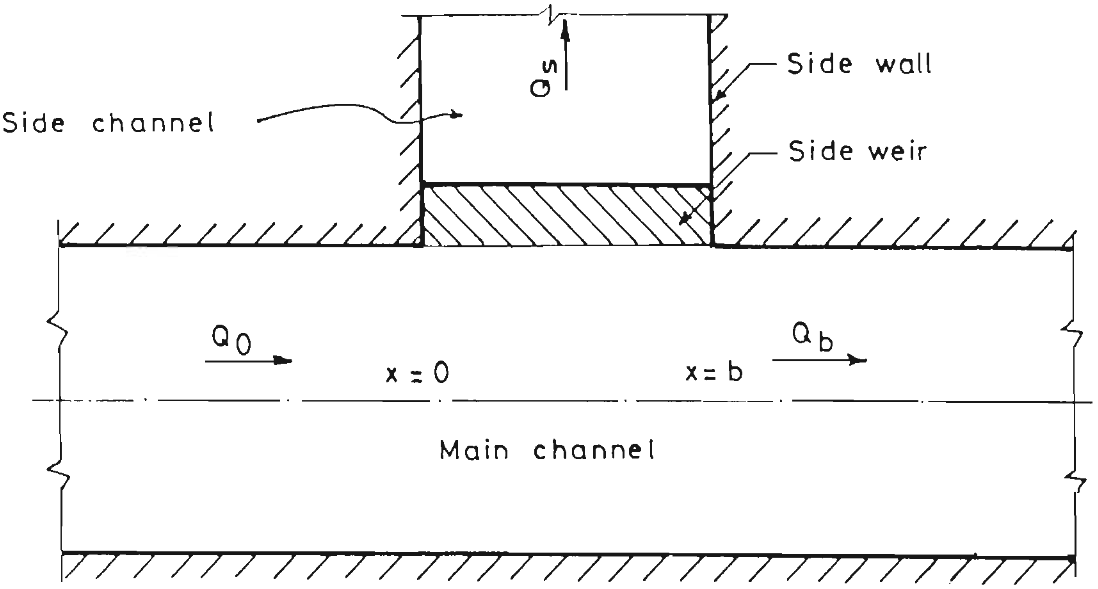
5.2 EXPERIMENTAL PROCEDURE

Experiments were conducted for subcritical approach flows in the main channel. Side weirs were studied under free flow while side sluice gates were studied under free and submerged flow conditions in the side channel.

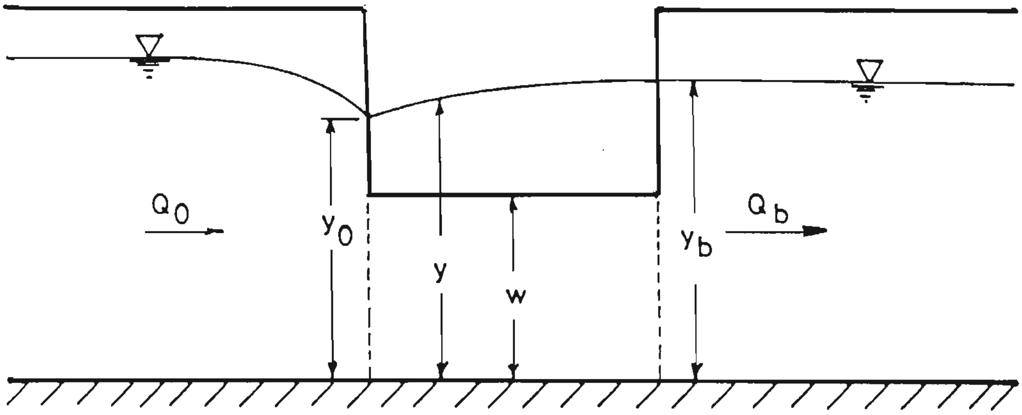
5.2.1 Experimental Procedure for Side Weirs

The procedure of experiment and observations is described bellow:

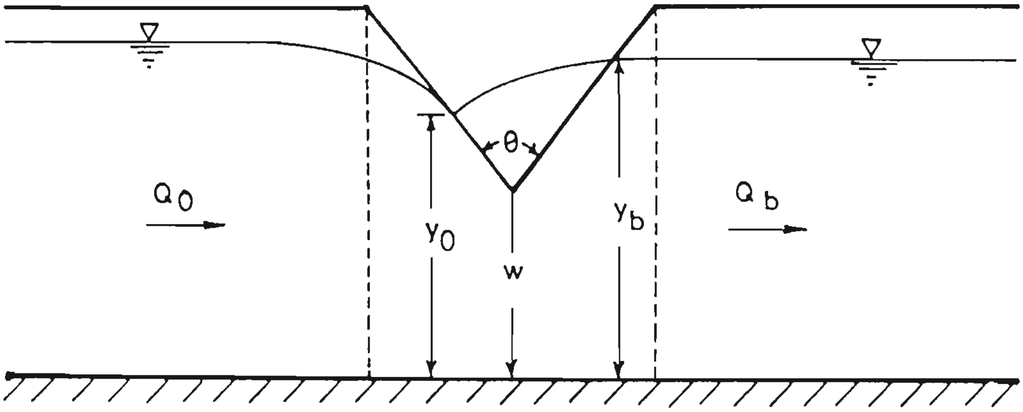
1) Install a side weir of desired shape and height at the upstream head of the side channel.



(a) Plan



(b) Rectangular Side weir



(c) Triangular Side weir

Fig. 5.6 Side weir on horizontal floor

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2) Allow a certain discharge into the main channel with the help of supply valve and operate the tail gate to obtain a required flow depth in the main channel. Keep the tail gate of the side channel open to maintain a free flow in the side channel.

3) Measure the depths of flow y_0 and y_b at the center line of the main channel.

4) Record the heads over the normal sharp crested weirs for computation of upstream main channel discharge Q_0 and side channel discharge Q_s.

5) Note the water temperature for applying viscosity and surface tension corrections.

6) Measure flow profile along the side weir at the center line of the main channel for some of the runs.

7) For the same discharge allowed in the main channel, change the depth of flow in the main channel with the help of main channel tail gate. Maintain five or six depths of flow for each upstream discharge and record observations for each case as explained above.

8) Change the discharge in the main channel by means of the supply valve and repeat the entire procedure from steps 3 to 7. Take a number of discharges to cover a large range of variables involved.

9) Change the height of the side weir and repeat the procedure from steps 2 to 8.

The range of various parameters covered in the present experiments on side weirs are given in Tables 5.1 and 5.2. Appendices II through VI give the details of the experimental data for rectangular and triangular side weirs.

Table 5.1 - Range of Variables for Rectangular Side Weir Data

Type of weir	Weir height	Upstream depth of flow	Length of weir	Upstream discharge	Side weir discharge	Upstream Froude number	Width of weir	Number of data
	w (m)	y_0 (m)	b (m)	Q_0 (m^3/s)	Q_s (m^3/s)	F_0	L (m)	N
(I) Unrestricted outflow								
Sharp crested	0.0 to 0.1	0.07 to 0.32	0.2 to 0.5	0.02 to 0.10	0.001 to 0.071	0.1 to 0.93	0.002	272
Broad crested	0.1	0.13 to 0.25	0.5	0.02 to 0.086	0.004 to 0.05	0.1 to 0.92	0.1	20
(II) Restricted outflow								
Sharp crested	0.0 to 0.10	0.07 to 0.29	0.5	0.025 to 0.087	0.002 to 0.085	0.1 to 0.9	0.002	101
Broad crested	0.1	0.12 to 0.32	0.5	0.02 to 0.083	0.003 to 0.081	0.1 to 0.70	0.1	18

Table 5.2 - Range of Variables for Triangular Sharp Crested Side Weir Data

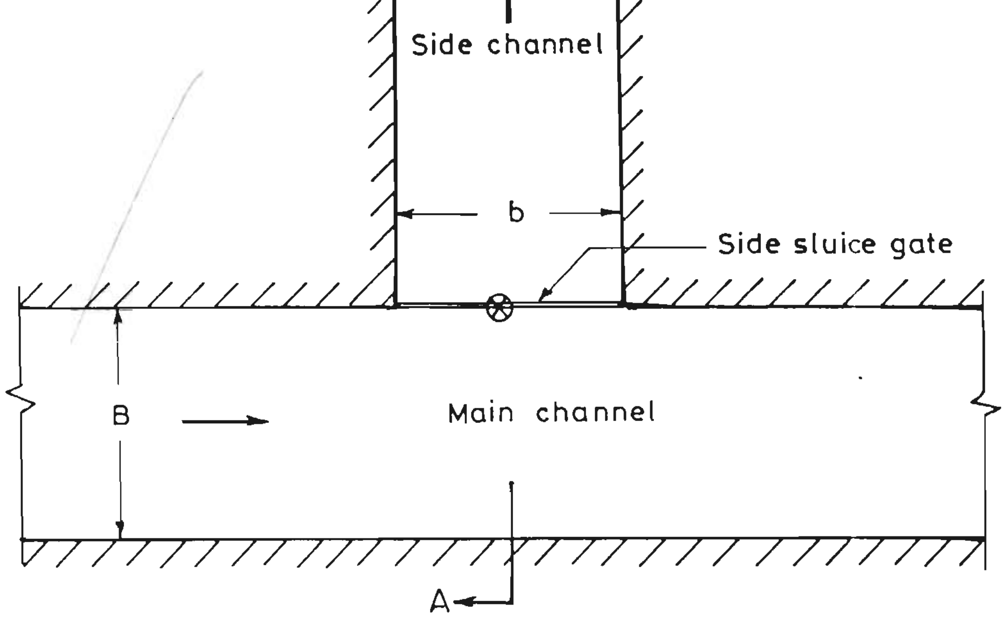
Apex angle	Side weir height	Upstream depth of flow	Upstream discharge	Side weir discharge	Upstream Froude number	No. of data
θ (rad)	w (m)	y_0 (m)	Q_0 (m^3/s)	Q_s (m^3/s)	F_0	N
$\pi/6$	0.0 - 0.05	0.07 - 0.37	0.0001-0.032	0.0006-0.030	0.02-0.13	63
$\pi/3$	0.0 - 0.15	0.11 - 0.39	0.0006-0.045	0.0005-0 042	0.03-0.97	112
$\pi/2$	0.0 - 0.24	0.05 - 0.47	0.001 -0.046	0.0007-0.045	0.04-0.8	131
$2\pi/3$	0.0 - 0.15	0.06 - 0.28	0.0008-0.025	0.0008-0.021	0.06-0.9	100

5.2.2 Experimental Procedure for Side Sluice Gates

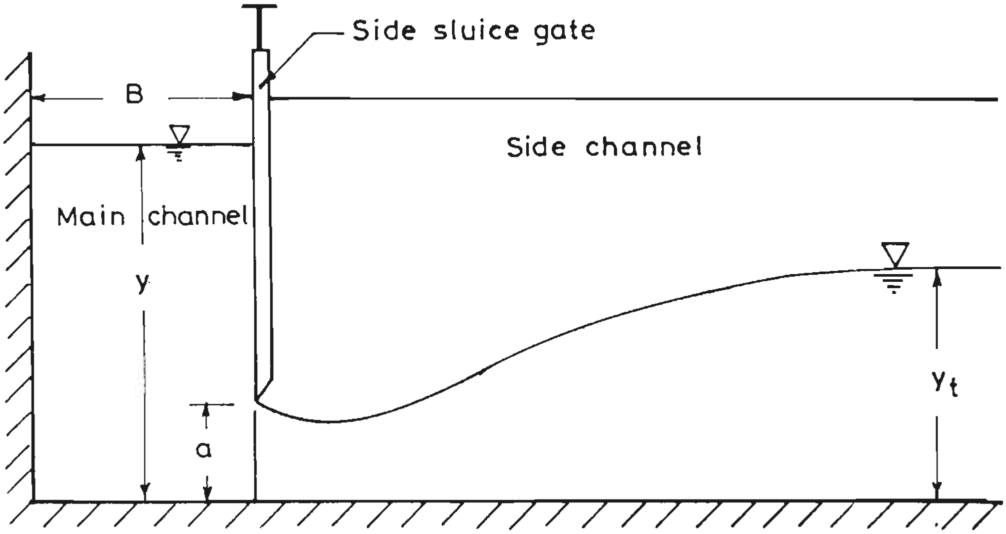
Experiments on sharp and broad crested side sluice gate have been conducted for both the free as well as submerged flow conditions within the side channel. See Fig. 5.7.

The procedure of experiment and observations is described bellow:

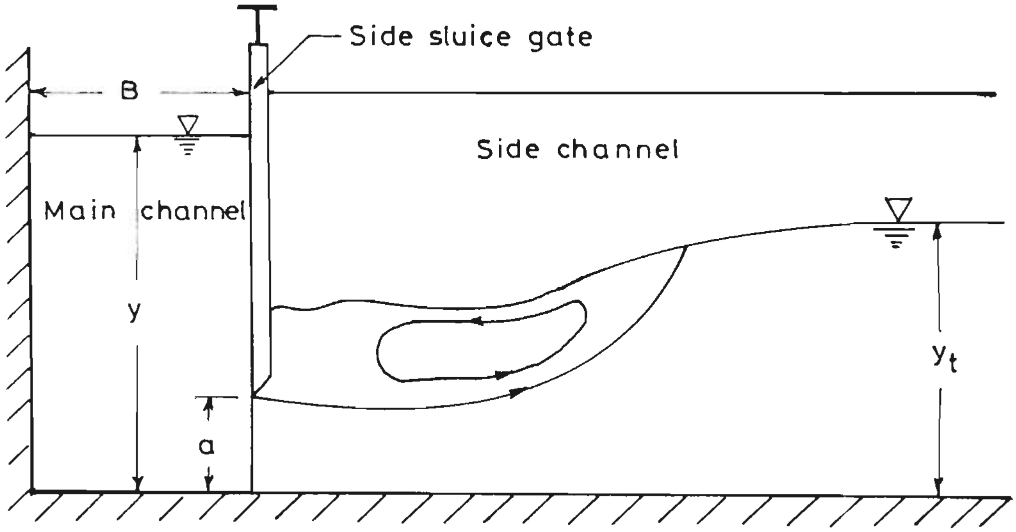
1) Set the side sluice gate opening to a desired value and allow a certain discharge in the main channel by means of the supply valve. Operate the tail gate of the main channel to adjust a required depth of flow.
2) Keep the tail gate of the side channel fully open so as to maintain a free flow in the side channel.
3) Measure the depths of flow y_0 and y_b at the center line of the main channel.
4) Record the heads over the normal sharp crested weirs to obtain discharges Q_0 and Q_s.
5) Note the temperature of water for applying viscosity and surface tension corrections.
6) Measure flow profile along the side weir at the center line of the main channel for some of the runs.
7) Operate tail gate of the side channel to obtain different submergence ratio y_t/a in the downstream of the side sluice gate. Measure the tail water depth y_t in the side channel. Repeat Steps 3 - 6 for each submergence ratio.
8) For the same discharge allowed in the main channel, change the depth of flow with the help of main channel tail gate. Maintain five or six



(a) Plan



(b) Section at A-A : Free flow



(c) Section at A-A : Submerged flow

Fig. 5.7 Definition sketch

depths of flow for each constant discharge and record observations for each case as explained above.

9) Change the discharge in the main channel by means of the supply valve and repeat the entire procedure from steps 2 to 8.

10) Change the opening of the side sluice gate and repeat the procedure from steps 2 to 9.

Table 5.3 gives the range of various parameters covered in the present experiments on side sluice gates. The details of the experimental data for both sharp crested and broad crested side sluice gate under free and submerged flow conditions have been given in Appendices VII to X.

Table 5.3 - Range of Variables for Side Sluice Gate Data

Variable	Sharp crested		Broad crested	
	Free flow	Submerged flow	Free flow	Submerged flow
Upstream discharge Q_0 (m^3/s)	0.014-0.097	0.007-0.097	0.010-0.087	0.07-0.09
Sluice gate discharge Q_s (m^3/s)	0.005-0.08	0.003-0.050	0.003-0.055	0.0015-0.06
Upstream flow depth y_0 (m)	0.06- 0.78	0.07-0.40	0.07-0.39	0.075-0.40
Tail water depth y_t (m)	-	0.05-0.40	-	0.06-0.40
Gate opening a (m)	0.01-0.10	0.01-0.10	0.01-0.10	0.01-0.10
Gate thickness c (m)	0.002	0.002	0.05-0.15	0.05-0.15
Upstream Froude number F_0	0.02-0.8	0.025-0.89	0.03-0.8	0.04-0.8
$\frac{c}{a}$	0.02-0.2	0.02-0.2	0.5-15	0.5-15
$\frac{y_0}{a}$	1.5 - 33.0	1.25-35.0	1.60-34.0	1.40-36.0
$\frac{y_t}{a}$	-	0.31-29.0	-	0.50-30.0
No. of data N	77	188	142	396

CHAPTER
SIX

ANALYSIS OF DATA

6.1 SIDE WEIR ANALYSIS

6.1.1 Elementary Discharge Coefficient Functions

Equation (4.3) incorporates the effects of S_0, n, local Froude number and channel geometry, The *elementary discharge coefficient* equations will be a function of head/weir height ratio $\eta_w = (y - w)/w$ for a sharp crested side weir and head/weir width ratio $\eta_L = (y - w)/L$ for a broad crested side weir. However, dependency of *elementary discharge coefficient* on Froude number for the present experimental data was also studied and it was found that C_e remains invariant with respect to Froude number (see Appendix XI). Swamee (1988) has given equations for discharge coefficient for normal rectangular sharp and broad crested weirs. Employing the same functional form, the following expressions for C_e for sharp crested and broad crested side weirs were adopted:

Sharp crested side weir:

$$C_e = k_0\left\{\left[\frac{k_1}{k_2+\eta_w}\right]^{k_3} + \left[\frac{\eta_w}{\eta_w+1}\right]^{k_4}\right\}^{-k_5}; \text{ and} \qquad (6.1)$$

Broad crested side weir:

$$C_e = k_6 + k_7 \left[\frac{\eta_L^{k_8} + K_9 \eta_L^{k_{10}}}{1 + K_{11} \eta_L^{k_{12}}} \right]^{k_{13}} ; \qquad (6.2)$$

in which k_0 through k_{13} are unknown positive constants to be determined from the experimental data.

6.1.2 Determination of Constants

For an ith data, (4.2 and 4.3) are solved by a fourth order Runge-Kutta method subjected to the initial condition given by (4.4) at the upstream section, $x = 0$. This requires trial values of constants in the *elementary discharge coefficient* equations. The solution gives the computed values of flow depth and discharge at the various x-values along the side weir and ultimately yields the computed values of water depth y_{bi} and discharge Q_{bi} at the downstream section $x = b$. Hence the computed discharge over the side weir is:

$$Q_{sci} = Q_{0i} - Q_{bi}. \qquad (6.3)$$

The computed side weir discharge Q_{sci} is then compared with the observed side weir discharge Q_{soi} to yield the percentage error ϵ_i as:

$$\epsilon_i = 100 \frac{Q_{sci} - Q_{soi}}{Q_{soi}} \qquad (6.4)$$

Using (6.4) the average percentage error ER in the entire set of N data is expressed as:

$$ER = \frac{100}{N}\sum_{i=1}^{N} \left| \frac{Q_{sci} - Q_{soi}}{Q_{soi}} \right| . \tag{6.5}$$

The average percentage error ER is a function of the constants in the *elementary discharge coefficient* equations and at its minimum value the computed side weir discharge will have maximum agreement with the observed side weir discharge. The average percentage error ER can be minimized by using any of the standard optimization techniques. However, in the present study, grid search (Fox, 1971) method was used to obtain the optimal values of the constants.

6.1.3 Sharp Crested Rectangular Side Weirs

The procedure described in Section 6.1.2 yielded the following best fit equation of C_e for the unrestricted rectangular sharp crested side weir:

$$C_e = 0.447\left\{\left(\frac{44.7}{50+\eta_w}\right)^{6.67} + \left(\frac{\eta_w}{\eta_w+1}\right)^{6.67}\right\}^{-0.15} . \tag{6.6}$$

Similarly for a restricted rectangular sharp crested side weir C_e was obtained as:

$$C_e = 0.465\left\{\left(\frac{46.5}{41.1+\eta_w}\right)^{10} + \left(\frac{\eta_w}{\eta_w+1}\right)^{10}\right\}^{-0.1} ; \tag{6.7}$$

Eqs. (6.6 and 6.7) are applicable for the entire range of head to weir height ratios. The average error ER of the entire experimental data of the present study leading to (6.6 and 6.7) are 6.63% and 6.3% respectively. Figs. 6.1 and 6.2 show the comparison of observed and computed side weir discharges using (4.2, 4.3, 4.4) and (6.6) for unrestricted, and (6.7) for restricted sharp crested rectangular side weirs respectively. A perusal of Figs. 6.1 and 6.2 shows that majority of the data points lie in the error width of ±15%. Figs. 6.1 and 6.2 fully justify the use of (6.6 and 6.7) for computation of discharge over unrestricted and restricted sharp crested rectangular side weirs respectively.

6.1.3.1 Validation of the Equations for Sharp Crested Side Weirs

Fig. 6.3 shows the comparison of observed side weir discharge and the computed discharge using the data of Awasthy (1970) (see Table 6.1) for an unrestricted sharp crested rectangular side weir. A perusal of Fig. 6.3 shows that majority of the data points fall in the error width of ±10%. A comparison of Figs. 6.3 and 3.2 shows the superiority of the present approach.

Fig. 6.4 shows the comparison of observed side weir discharge and the computed discharge using the data of Prasad (1976) (see Table 6.1) for a restricted sharp crested rectangular side weir. It can be seen from Fig. 6.4 that in this case also, majority of the data points fall in the error width of ±10%.

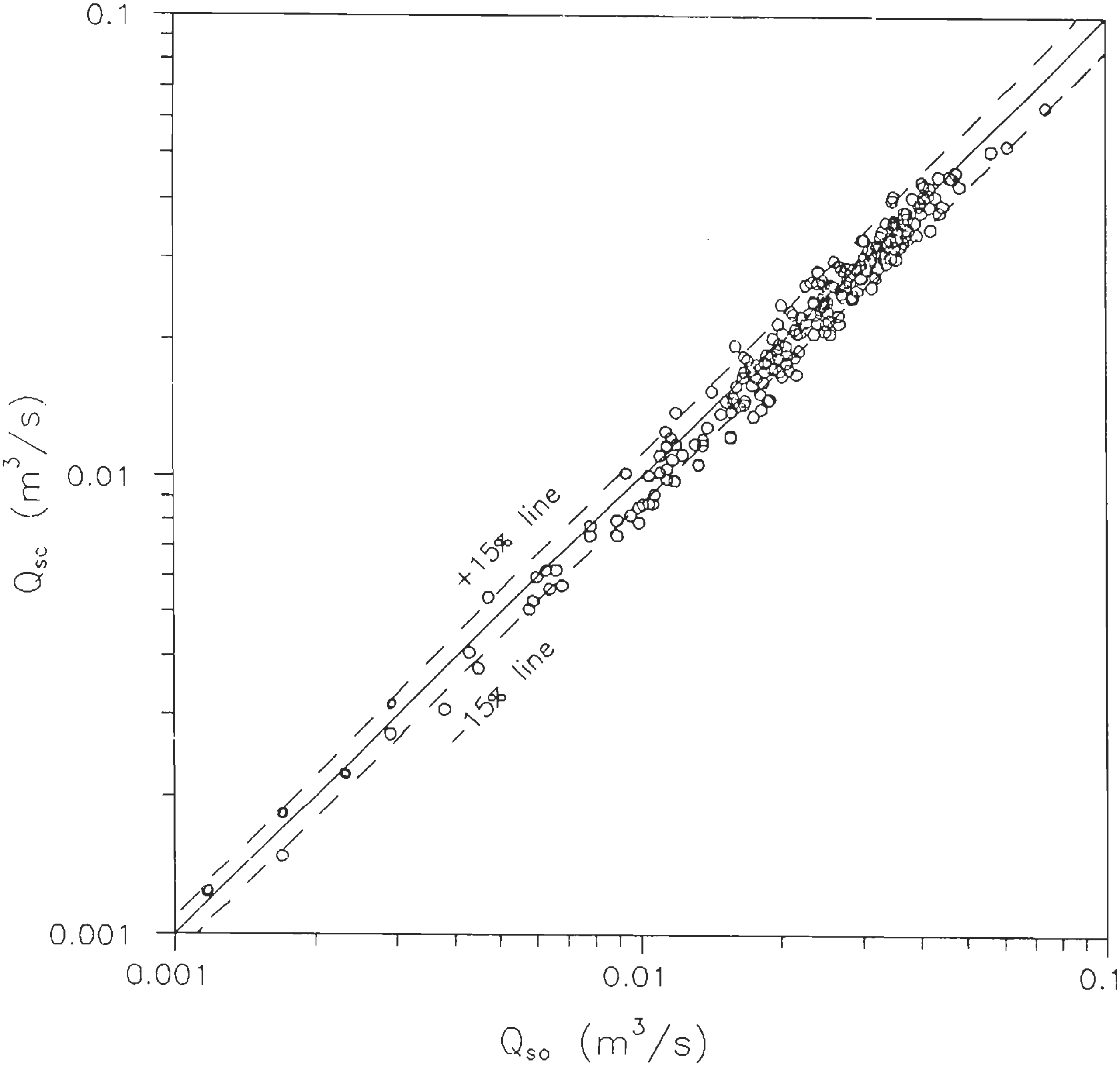


Fig. 6.1 Comparison of observed and computed discharges for unrestricted sharp crested rectangular side weir

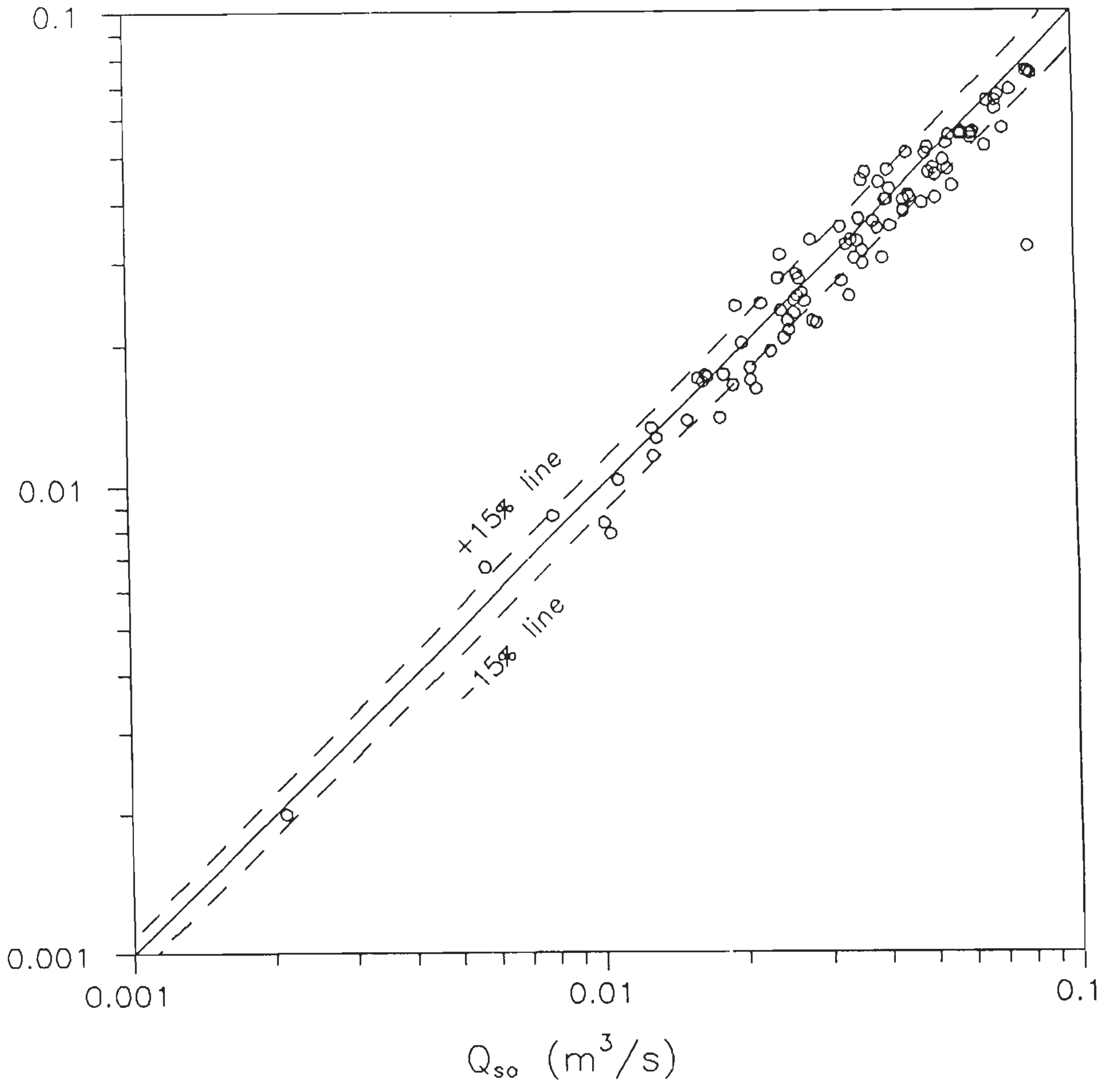


Fig. 6.2 Comparison of observed and computed discharges for restricted sharp crested rectangular side weir

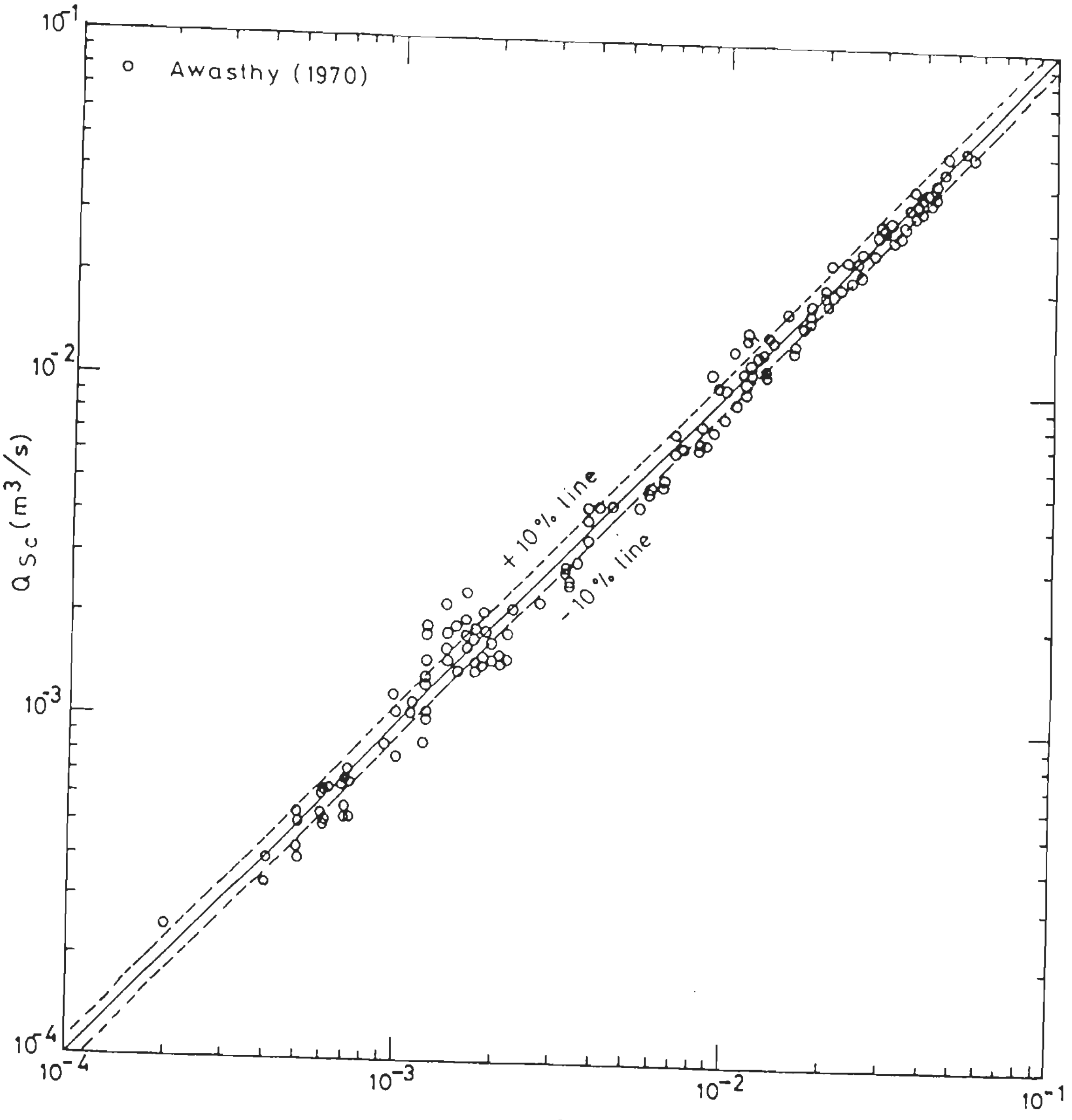


Fig. 6.3 Validation diagram for unrestricted sharp crested rectangular Side weir

Table 6.1- Range of Parameters for Rectangular Side Weir Data (used for verification)

Investigator (year)	weir height	Upstream depth of flow	weir length	Upstream discharge	Side weir discharge	Upstream Froude number	No. of data
	w (m)	y_0 (m)	b (m)	Q_0 (m^3/s)	Q_s (m^3/s)	F_0	N
(I) Sharp crested unrestricted outflow: b/B = 0.2 - 1.0							
Awasthy (1970)	0.0-0.6	0.019-0.66	0.1-0.62	0.0007-0.1	0.0002-0.055	0.02-0.85	158
(II) Broad crested restricted outflow: b/B = 0.33 - 0.5							
Prasad (1976)	0.05-0.2	0.12-0.43	0.10-0.5	0.01-0.08	0.0028-0.022	0.06-0.56	179
(III) Sharp crested restricted outflow: b/B = 0.33 - 0.5							
Prasad (1976)	0.05-0.2	0.13-0.36	0.20	0.023-0.07	0.00044-0.02	0.09-0.55	87

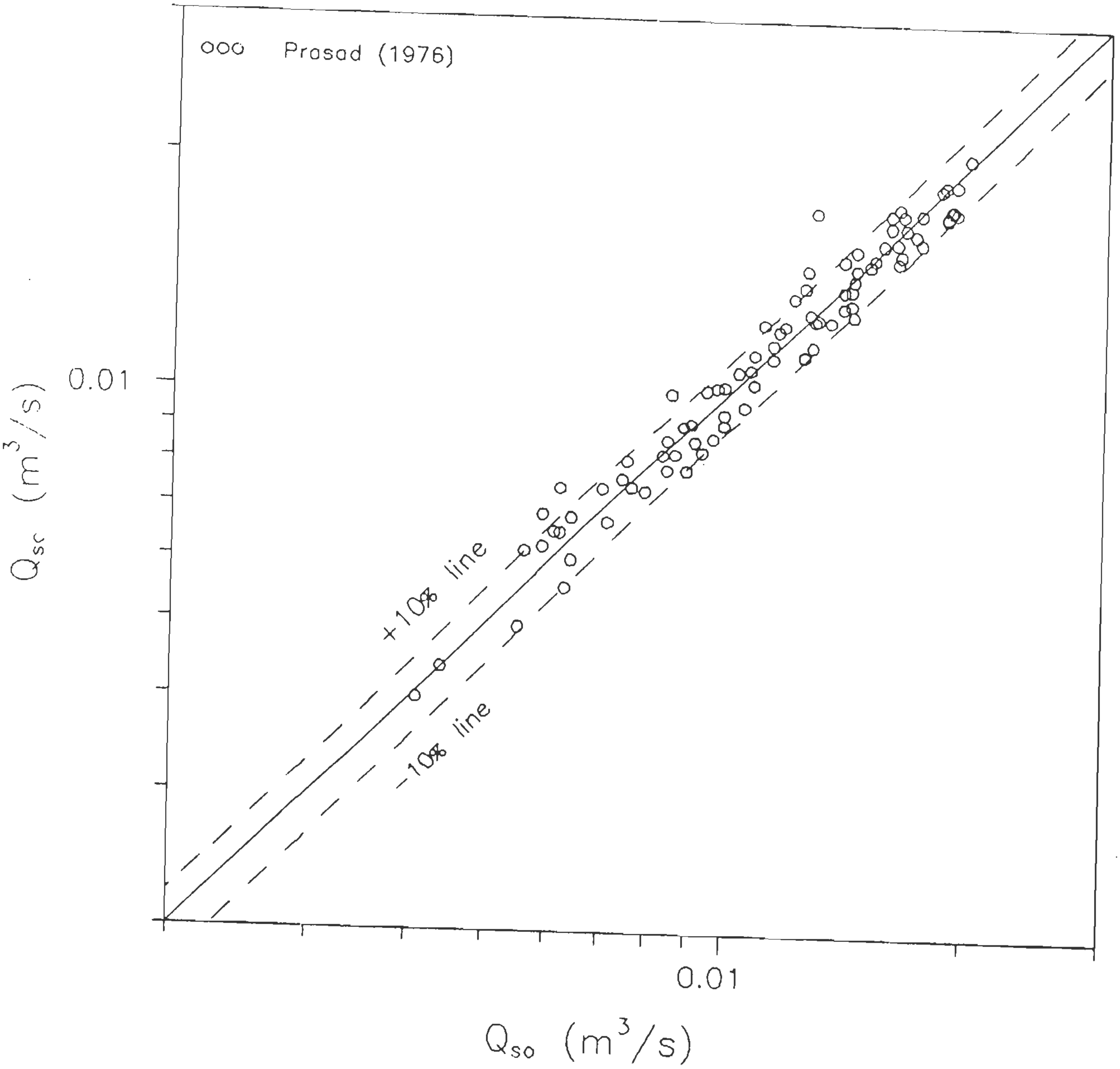


Fig. 6.4 Validation diagram for restricted sharp crested rectangular side weir

6.1.4 Broad Crested Rectangular Side Weirs

The following best fit results of (6.2) for unrestricted and restricted broad crested side weirs were obtained:

Unrestricted:

$$C_e = 0.425 + 0.1\left[\frac{\eta_L^{3.3} + 0.025\eta_L^{7}}{1 + 5.5\,\eta_L^{0.02}}\right]; \text{and} \qquad (6.8)$$

Restricted:

$$C_e = 0.447 + 0.1\left[\frac{\eta_L^{1.79} + 0.05\eta_L^{1.69}}{1 + 2.9\,\eta_L^{0.02}}\right]. \qquad (6.9)$$

The average error involved in (6.8 and 6.9) are 5.2% and 4.5% respectively. Figs. 6.5 and 6.6 show the comparison of the observed side weir discharge and the computed discharge for unrestricted and restricted broad crested rectangular side weirs. A perusal of Figs. 6.5 and 6.6 shows that majority of the data points lie in the error width of ±10%.

6.1.4.1 Validation of The Equations for Broad Crested Side Weirs

Fig. 6.7 shows the comparison of observed side weir discharge and the computed discharge for the data of Prasad (1976) for a restricted broad crested rectangular side weir (see Table 6.1). It can be seen that majority of the data points fall in the error width of ±10%.

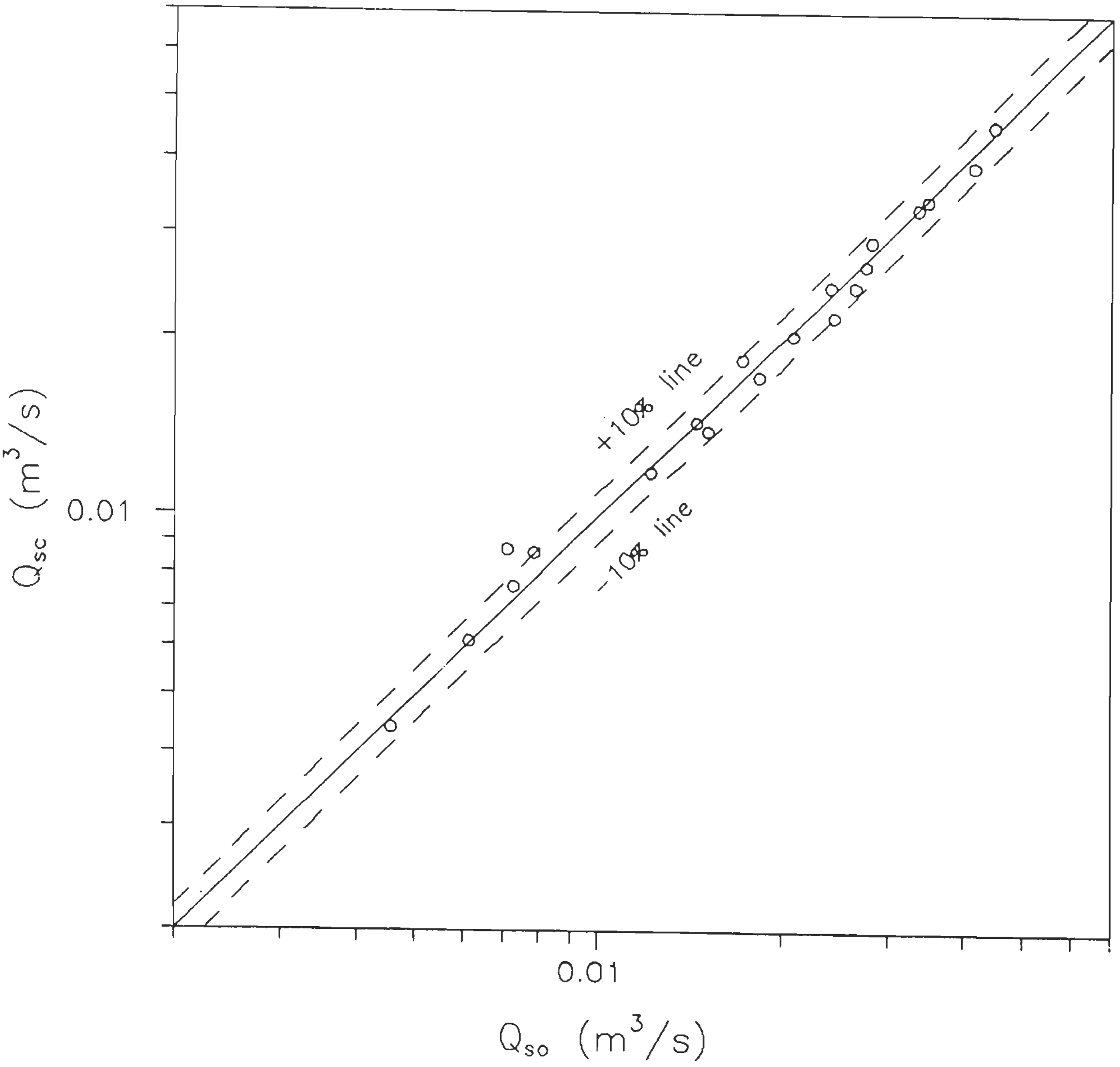


Fig. 6.5 Comparison of observed and computed discharges for unrestricted broad crested rectangular side weir

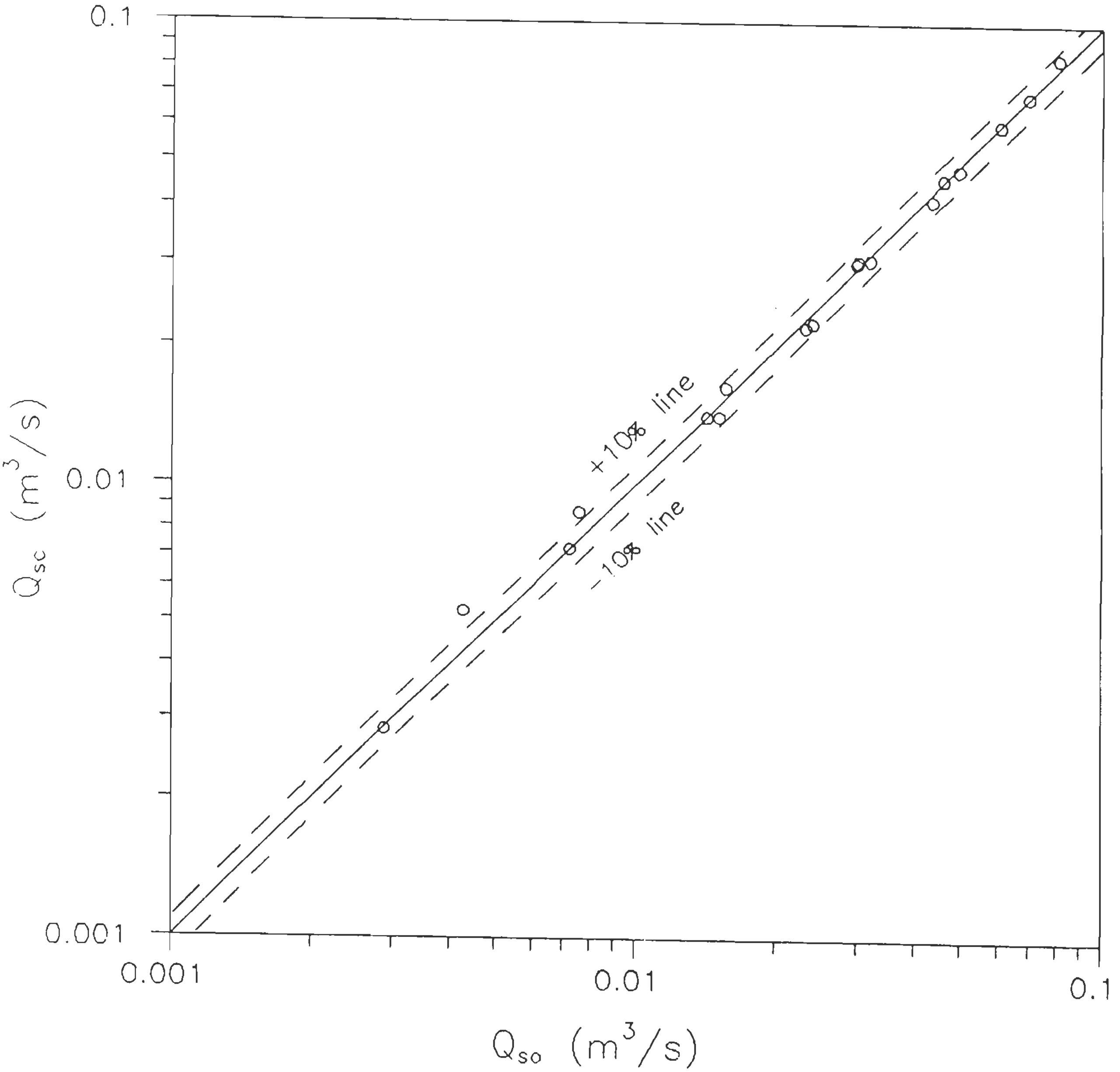


Fig. 6.6 Comparison of observed and computed discharges for restricted broad crested rectangular side weir

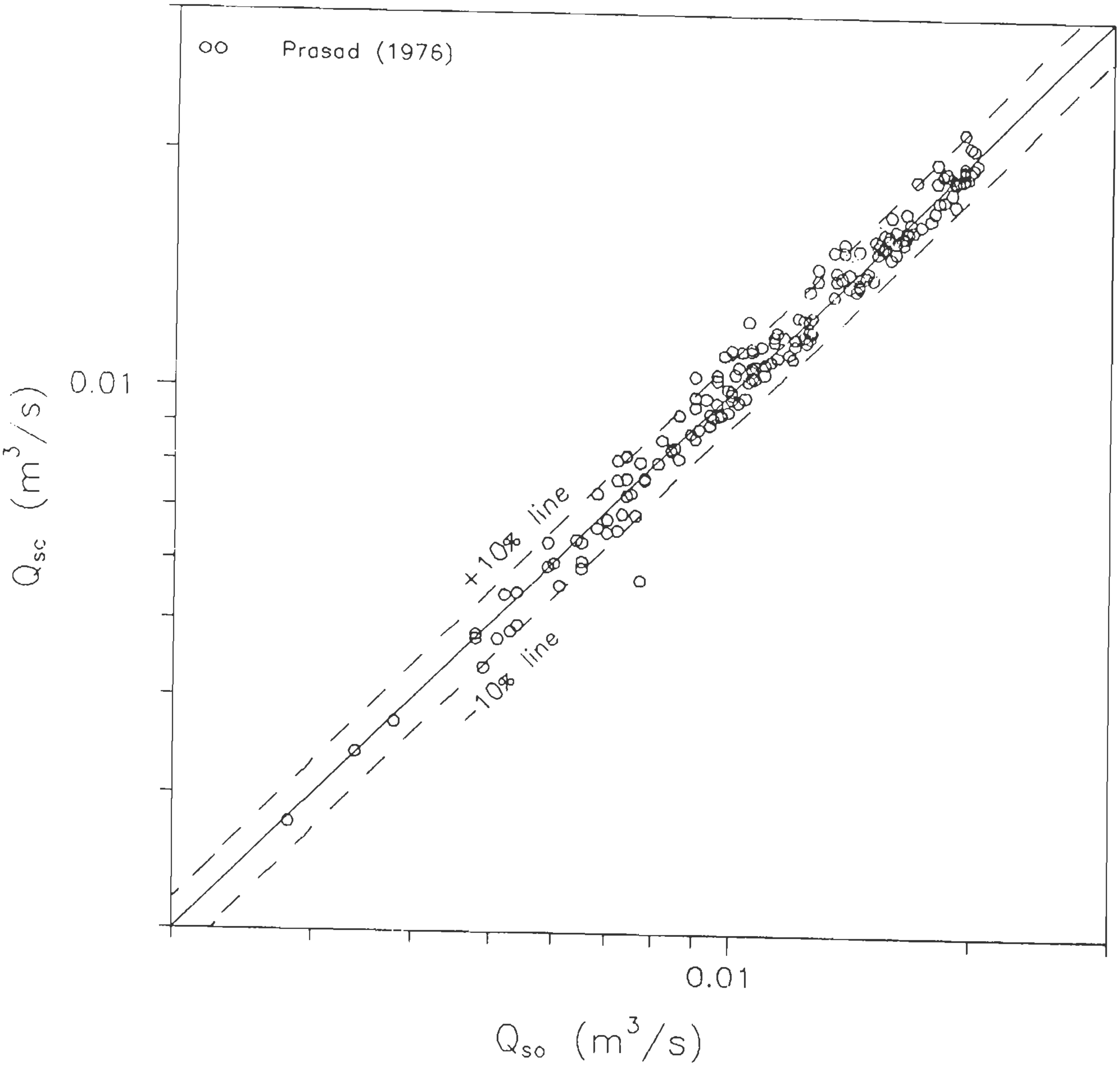


Fig. 6.7 Validation diagram for restricted broad crested rectangular side weir

6.1.5 Generalized Equations for Rectangular Side Weirs

Considering the nature of variation of C_e for sharp and broad crested side weirs; (6.6 and 6.8), for unrestricted, and (6.7 and 6.9), for restricted rectangular side weirs can be combined as:

$$C_e = \left\{ \left[1+\left(\frac{k_{14}}{\eta_L}\right)^{k_{15}}\right]^{-1} C_{esharp}^{\frac{-1}{k_5}} + \left[1+\left(\frac{\eta_L}{k_{16}}\right)^{k_{17}}\right]^{-1} C_{ebroad}^{\frac{-1}{k_5}} \right\}^{-k_5} ; \qquad (6.10)$$

in which k_{14} through k_{17} are unknown positive constants; C_{esharp} and C_{ebroad} are the *elementary discharge coefficients* for sharp and broad crested rectangular side weirs respectively.

Comparing (6.10) with (6.6 and 6.8) for the entire range of η_L and η_W and minimizing the average error yields: $k_{14} = 1.8$, $k_{15} = 18.0$, $k_{16} = 2.0$ and $k_{17} = 18$. Thus for unrestricted rectangular side weir (6.10) reduces to:

$$C_e = 0.447\left\{ \left[\left(\frac{44.7}{50+\eta_W}\right)^{6.67} + \left(\frac{\eta_W}{\eta_W+1}\right)^{6.67}\right] \left[1+\left(\frac{1.8}{\eta_L}\right)^{18}\right]^{-1} + \right.$$

$$\left. 1.4\left[\frac{1+5.5\eta_L^{0.02}}{1+5.5\eta_L^{0.02}+0.235\eta_L^{3.3}+0.00588\eta_L^{7}}\right]^{6.67} \left[1+\left(\frac{\eta_L}{2}\right)^{18}\right]^{-1} \right\}^{-0.15} .$$

(6.11)

Similarly, the combined equation for restricted rectangular side weir is obtained as:

$$C_e = 0.465\left\{\left[\left(\frac{46.5}{41.1+\eta_w}\right)^{10} + \left(\frac{\eta_w}{\eta_w+1}\right)^{10}\right]\left[1+\left(\frac{1.8}{\eta_L}\right)^{18}\right]^{-1} + 1.484\left[\frac{1+2.9\eta_L^{0.02}}{1+2.9\eta_L^{0.02}+0.224\eta_L^{1.79}+0.0112\eta_L^{1.69}}\right]^{10}\left[1+\left(\frac{\eta_L}{2}\right)^{18}\right]^{-1}\right\}^{-0.1}. \tag{6.12}$$

Eqs. (6.11 and 6.12) are depicted in Figs. 6.8 and 6.9 respectively. It can be seen that for both restricted and unrestricted side weirs, for $\eta_L \leq 1$ the side weir is broad crested and for $\eta_L \geq 3$ it is sharp crested; and the transition occurs in the range $1 < \eta_L < 3$. Thus (6.11 and 6.12) are applicable to all types of rectangular side weirs irrespective of variation of η_w or η_L.

6.1.6 Flow Profile Comparison

Figs. 6.10 and 6.11 show the comparison of typical observed and computed flow profiles along an unrestricted and restricted sharp crested rectangular side weir respectively. It is evident that there is a good agreement between the computed flow profiles and the observed data points. For broad crested side weirs also good agreement between observed and computed profiles were observed.

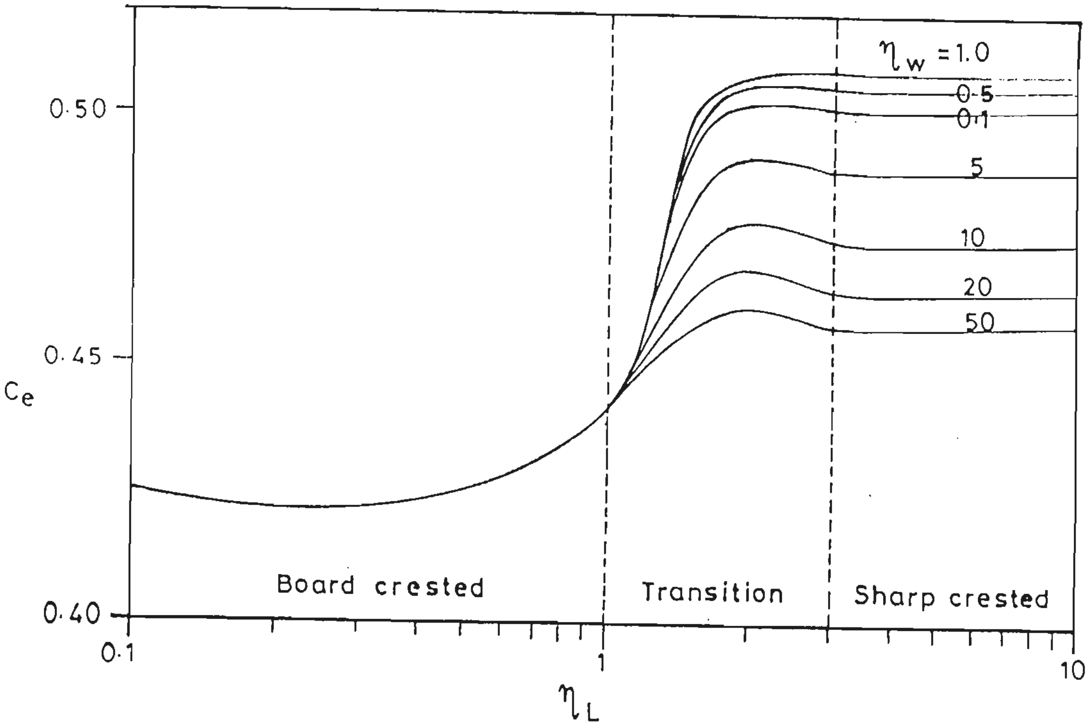


Fig. 6.8 Variation of C_e with η_L and η_w for unrestricted rectangular side weir

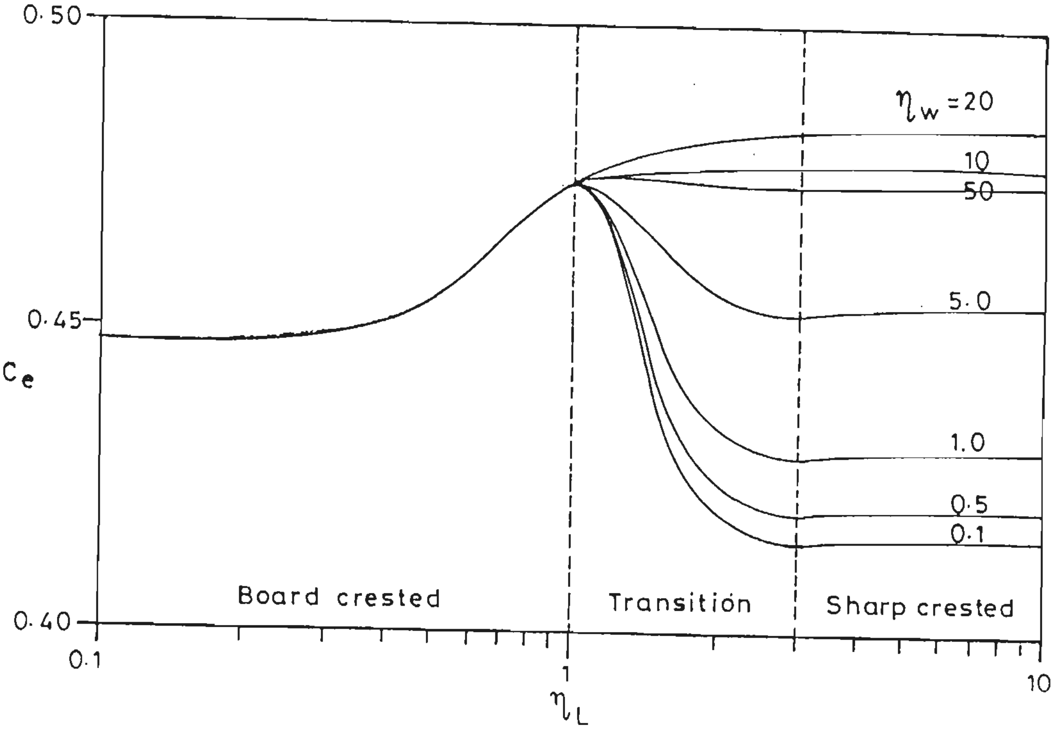


Fig. 6.9 Variation of C_e with η_L and η_w for restricted rectangular side weir

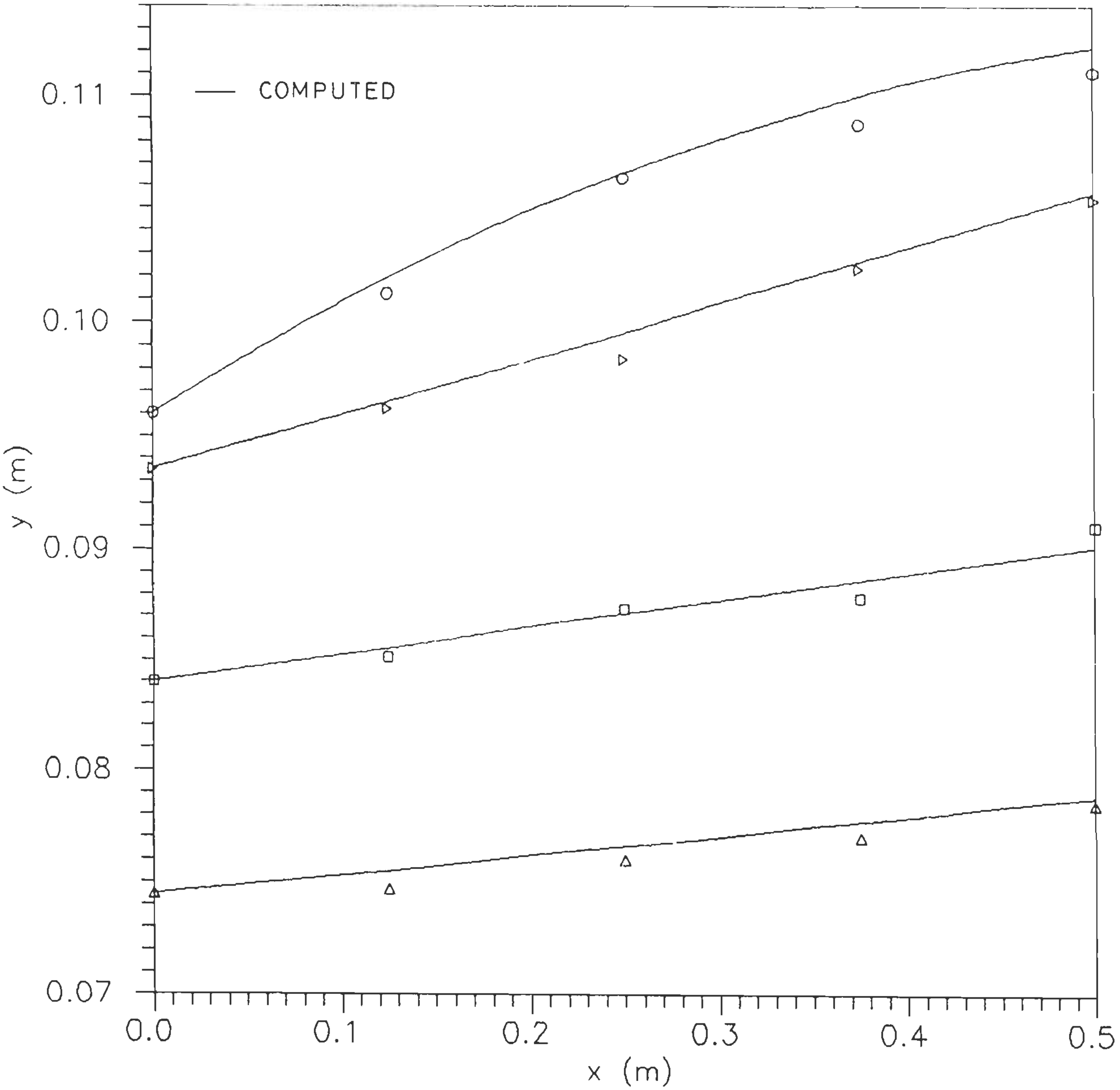


Fig. 6.10 Comparison of observed and computed flow profiles along an unrestricted rectangular sharp crested side weir

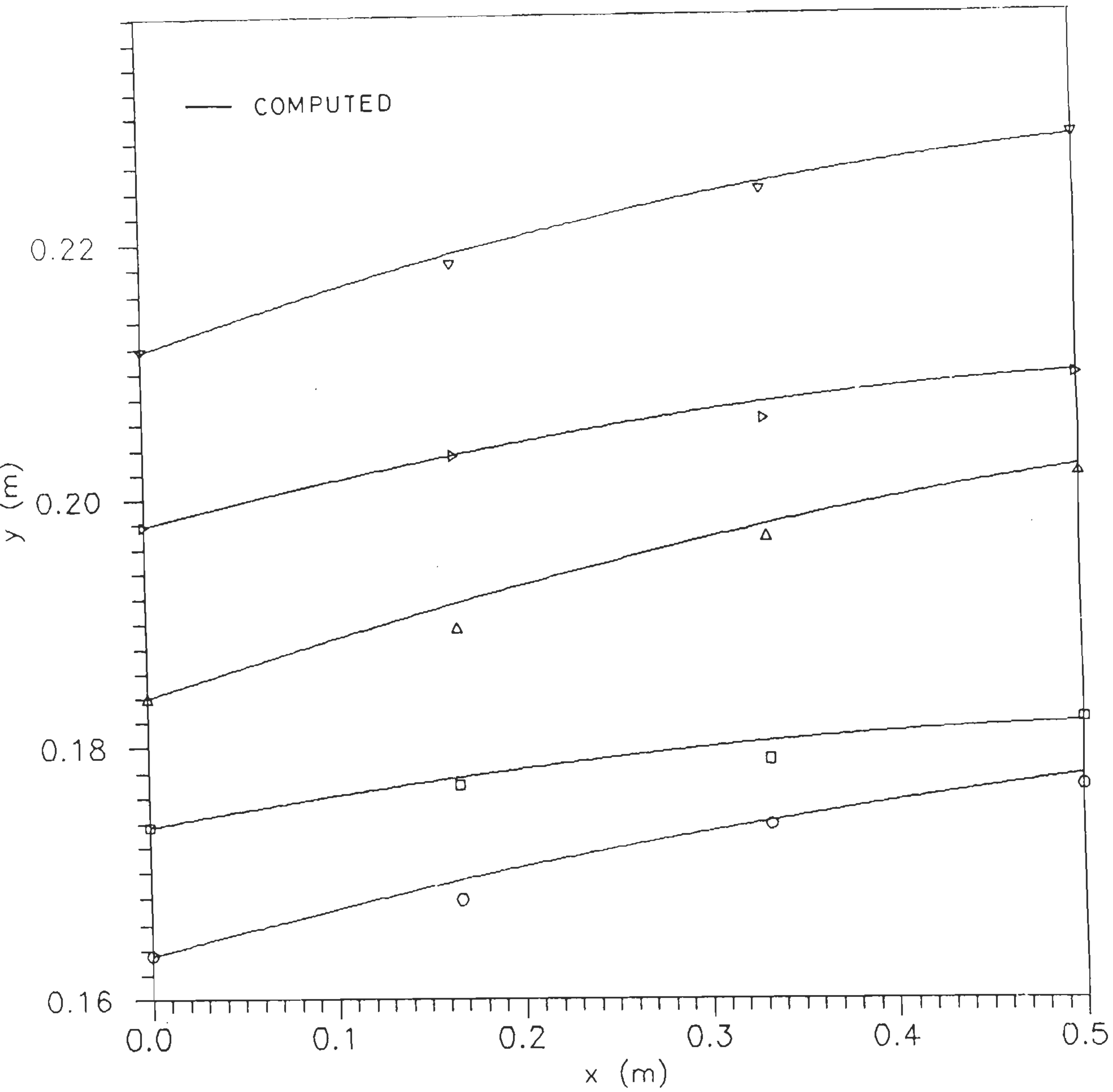


Fig. 6.11 Comparison of observed and computed flow profiles along a restricted rectangular sharp crested side weir

Ranga Raju *et al.* (1979) have reported a measured flow profile along a restricted broad crested rectangular side weir. For these data the flow profile was computed and a good agreement was observed. (see Fig. 6.12).

6.1.7 Triangular Side Weirs

6.1.7.1 Sharp Crested Triangular Side Weirs

The collected data on unrestricted sharp crested triangular side weir for different apex angles were used for obtaining equations for C_e. For a sharp crested triangular side weir C_e may be assumed to be a function of η_w and apex angle θ. The following functional forms of C_e for a sharp crested triangular side weir were assumed:

For $\eta_w \leq 5$:

$$C_e = k_{18} e^{-k_{19}(\theta - \pi/2)^2} + k_{20}\eta_w; \quad \text{and} \tag{6.13}$$

For $\eta_w \geq 15$:

$$C_e = \left[k_{21} + k_{22}(\pi - \theta)^{k_{23}}\right]\left[\frac{\eta_w + 1}{\eta_w}\right]^{k_{24}}; \tag{6.14}$$

in which k_{18} through k_{24} are positive constants to be determined from the experimental data. Using the procedure described in Section 6.1.2 the following equations for C_e for sharp crested triangular side weirs were obtained:

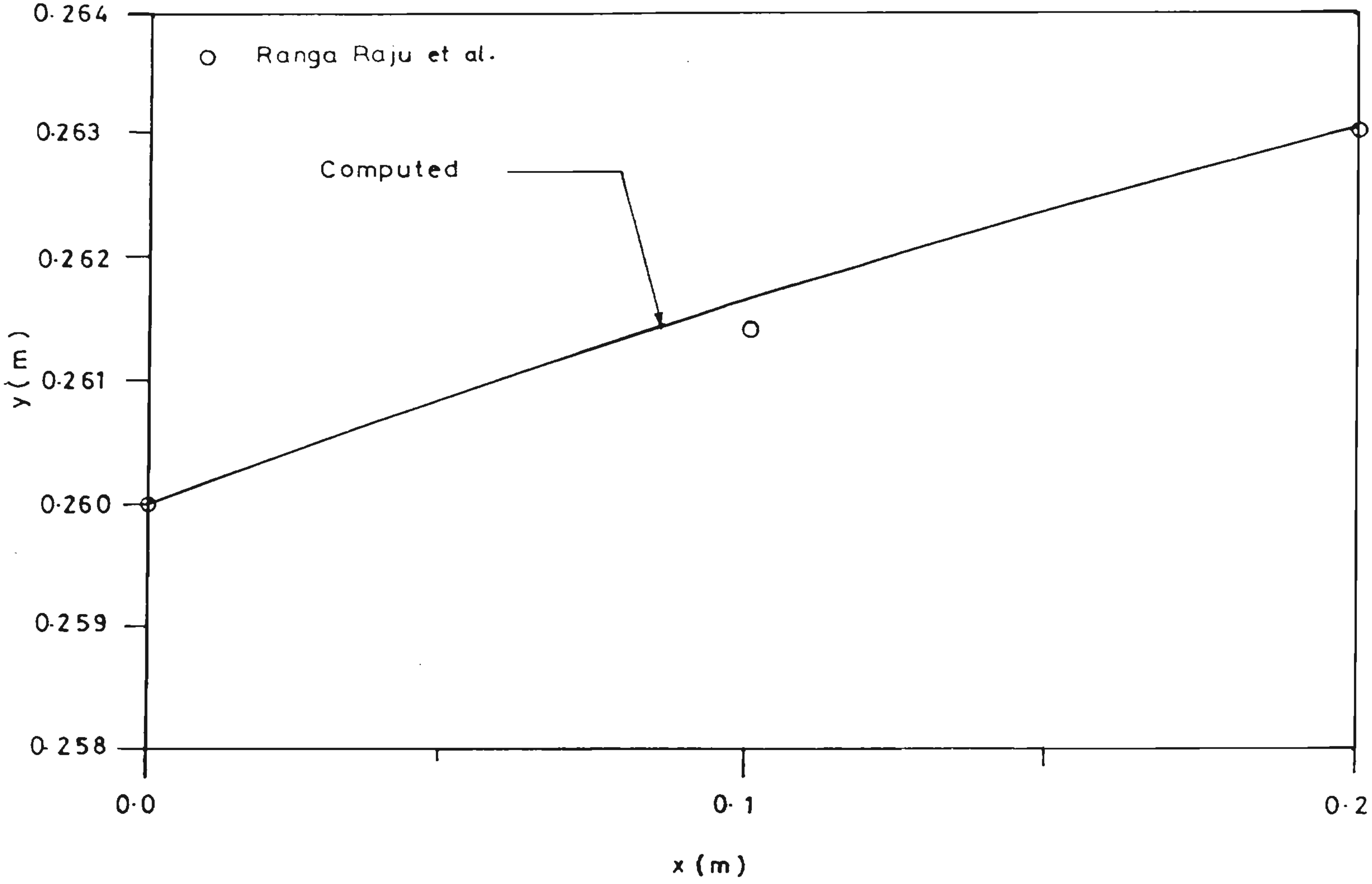


Fig. 6.12 Validation diagram for flow profile along a restricted broad crested rectangular side weir

For $\eta_w \leq 5$:

$$C_e = 0.55e^{-0.0386(\theta - \pi/2)^2} + 0.01\eta_w; \qquad \text{and} \tag{6.15}$$

For $\eta_w \geq 15$:

$$C_e = \left[0.447 + 0.0224(\pi - \theta)^{1.773}\right] \frac{\eta_w+1}{\eta_w}. \tag{6.16}$$

Eqs. (6.15 and 6.16) are valid for θ ranging from $\pi/6$ to π. Combining (6.15 and 6.16) and fitting the experimental data the following full range equation was obtained:

$$C_e = 0.447\left\{\left[\frac{44.7}{55e^{-0.0386(\theta-\pi/2)^2} + \eta_w}\right]^p + \left[\frac{\eta_w}{[1+0.05(\pi-\theta)^{1.773}](\eta_w+1)}\right]^p\right\}^{-\frac{1}{p}}; \tag{6.17}$$

in which:

$$p = 2.167\left[\frac{\theta^{2.5} + 1.342(\pi - \theta)^{2.5}}{\theta^{0.045} + (\pi - \theta)^{0.045}}\right]^{0.4}. \tag{6.18}$$

Eq. (6.17) is valid for all values of η_w and $\theta \geq \pi/6$. For $\theta = \pi$, (6.17) reduces to (6.6) for unrestricted sharp crested rectangular side weir. Fig. 6.13 shows the comparison of observed side weir discharge and the computed discharge for triangular sharp crested side weir with different values of θ. It is evident from Fig. 6.13 that majority of the data points fall in the error width of ±10%.

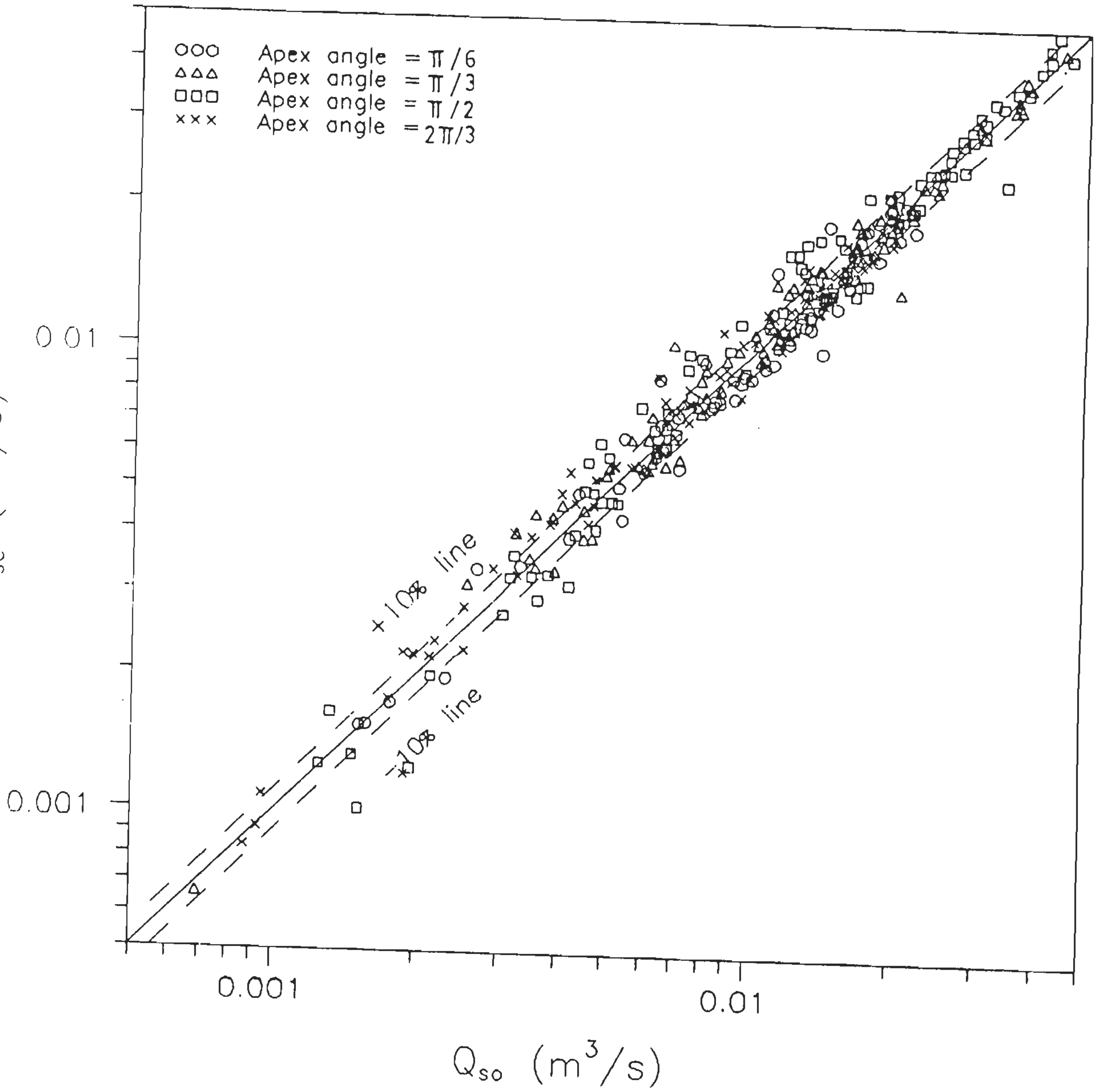


Fig. 6.13 Comparison of observed and computed discharges for sharp crested triangular side weir

6.1.7.1.1 Verification of The Equation for Triangular Sharp Crested Side Weirs

Fig. 6.14 shows the comparison of observed side weir discharge and the computed discharge using kumar's (1985) data for sharp crested triangular side weirs with different apex angle. See Table 6.2 for description of the data. From a perusal of Fig. 6.14 it is evident that majority of the data points fall in the error width of ±10%.

6.1.7.2 Broad Crested Triangular Side Weir

For obtaining the equation of C_e for a broad crested triangular side weir, Kumar's (1985) data were used (see Table 6.2). Adopting the functional form of (6.2) and minimizing the average percentage error, the following equation for a broad crested triangular side weir for $\theta = \pi/2$ was obtained:

$$C_e = 0.46 + 0.1\left[\frac{\eta_L^{1.2} + 0.025\eta_L^{1.7}}{1 + 3.7\eta_L^{0.02}}\right]. \qquad (6.19)$$

The average error involved in (6.19) is 3.88%. Fig. 6.15 shows the comparison of observed and the computed side weir discharges for broad crested triangular side weir with $\theta = \pi/2$. It can be seen that majority of the data points fall in the error width of ±10%. Since for obtaining (6.19) the data pertaining to $\theta = \pi/2$ were used, hence further checking of (6.19) by the experimental data with different apex angles is required.

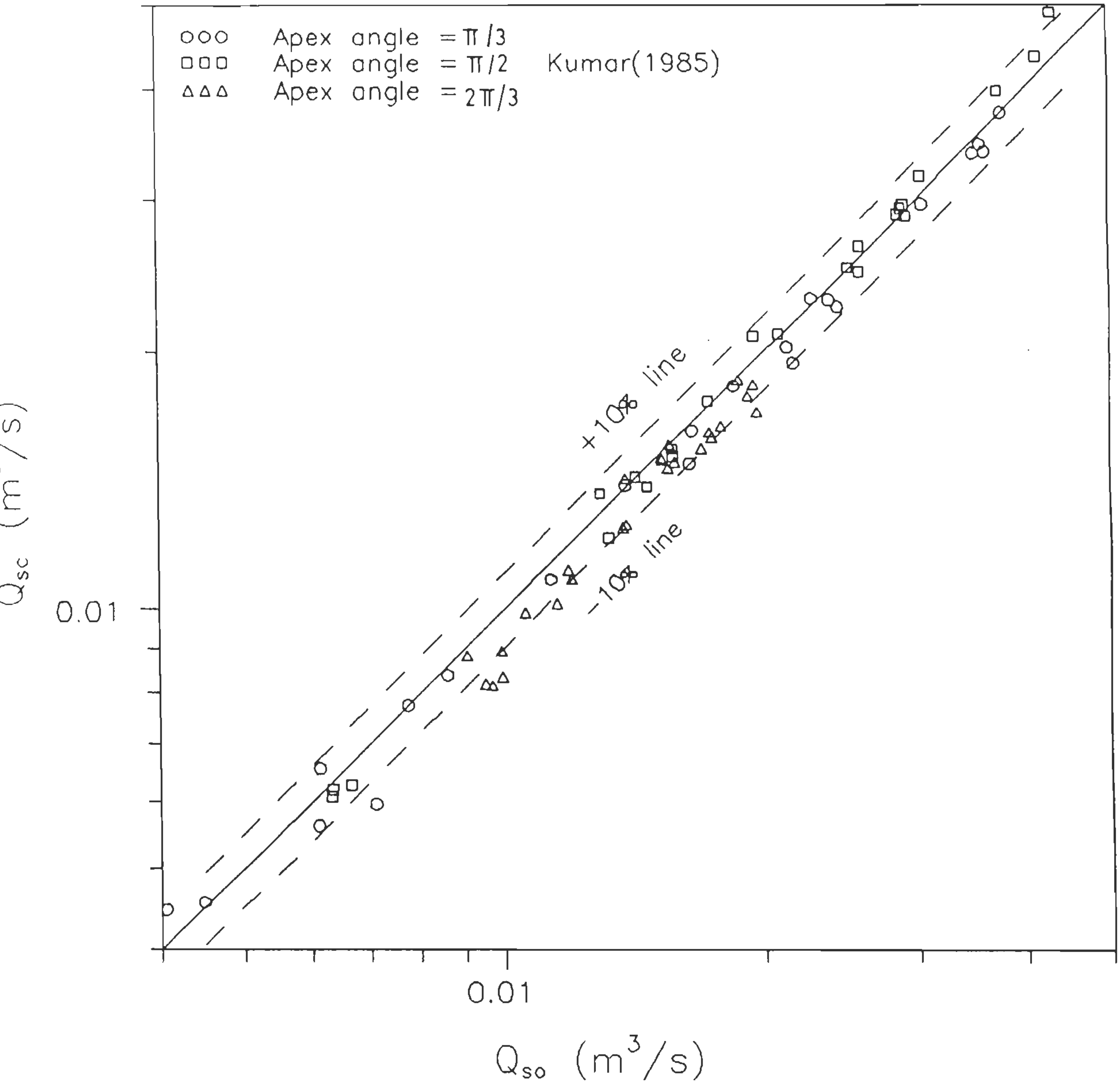


Fig. 6.14 Validation diagram for sharp crested triangular side weirs

Table 6.2- Range of Paameters for Triangular Side Weir data (Kumar, 1985)

B = 0.5m

Type of weir	Apex angle	Weir height	Weir width	Upstream depth of flow	Upstream discharge	Side weir discharge	Upstream Froude number	No. of data
	θ (rad)	w (m)	L (m)	y_0 (m)	Q_0 (m^3/s)	Q_s (m^3/s)	F_0	N
Sharp crested	$\pi/3$	0.068	-	0.20-0.41	0.023-0.09	0.004-0.038	0.09-0.61	23
	$\pi/2$	0.068 and 0.242	-	0.20-0.46	0.035-0.12	0.006-0.044	0.09-0.64	23
	$2\pi/3$	0.068 and 0.122	-	0.16-0.27	0.019-0.08	0.009-0.02	0.14-0.7	25
Broad crested	$\pi/2$	0.068	.075-.3	0.18-0.32	0.035-0.12	0.006-0.04	0.15-0.65	42

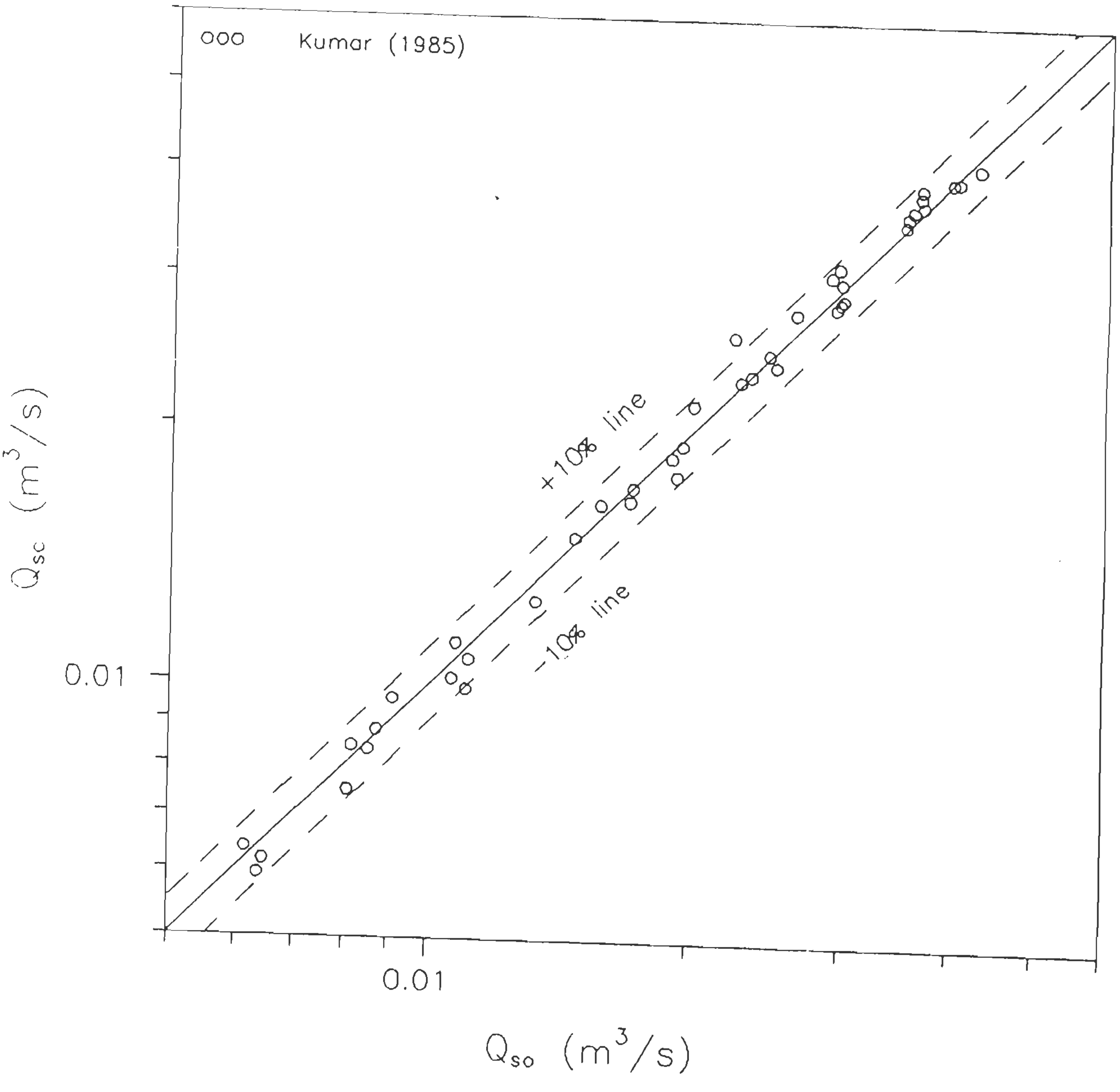


Fig. 6.15 Comparison of observed and computed discharges for broad crested triangular side weir ($\theta = \pi/2$)

6.1.8 Generalized Equation for Triangular Side Weirs

Considering the nature of variation of C_e for sharp and broad crested triangular side weirs, (6.17 and 6.19) can be combined as:

$$C_e = \left\{ \left[1 + \left(\frac{k_{25}}{\eta_L} \right)^{k_{26}} \right]^{-1} C_{esharp}^{-k_{29}} + \left[1 + \left(\frac{\eta_L}{k_{27}} \right)^{k_{28}} \right]^{-1} C_{ebroad}^{-k_{29}} \right\}^{\frac{-1}{k_{29}}} ; \qquad (6.20)$$

in which k_{25} through k_{29} are unknown positive constants; C_{esharp} and C_{ebroad} are the *elementary discharge coefficients* for sharp and broad crested triangular side weirs given by (6.17 and 6.19) respectively. Comparing (6.20) with (6.17 and 6.19) for the entire range of η_L and η_w, and minimizing the average error yields: $k_{25} = 1.8$, $k_{26} = 18.0$, $k_{27} = 2.0$; $k_{28} = 18$ and $k_{29} = 10.0$. With these values (6.20) reads:

$$C_e = 0.447 \left\{ \left[\left(\frac{44.7}{55 + \eta_w} \right)^p + \left(\frac{0.9\eta_w}{\eta_w + 1} \right)^p \right]^{\frac{10}{p}} \left[1 + \left(\frac{1.8}{\eta_L} \right)^{18} \right]^{-1} + \right.$$

$$\left. 0.75 \left[\frac{1 + 3.7\eta_L^{0.02}}{1 + 3.7\eta_L^{0.02} + 0.217\eta_L^{1.2} + 0.00543\eta_L^{1.7}} \right]^{10} \left[1 + \left(\frac{\eta_L}{2} \right)^{18} \right]^{-1} \right\}^{-0.1} .$$

(6.21)

Eq. (6.21) is depicted in Fig. 6.16 for $\theta \doteq \pi/2$. It can be seen that

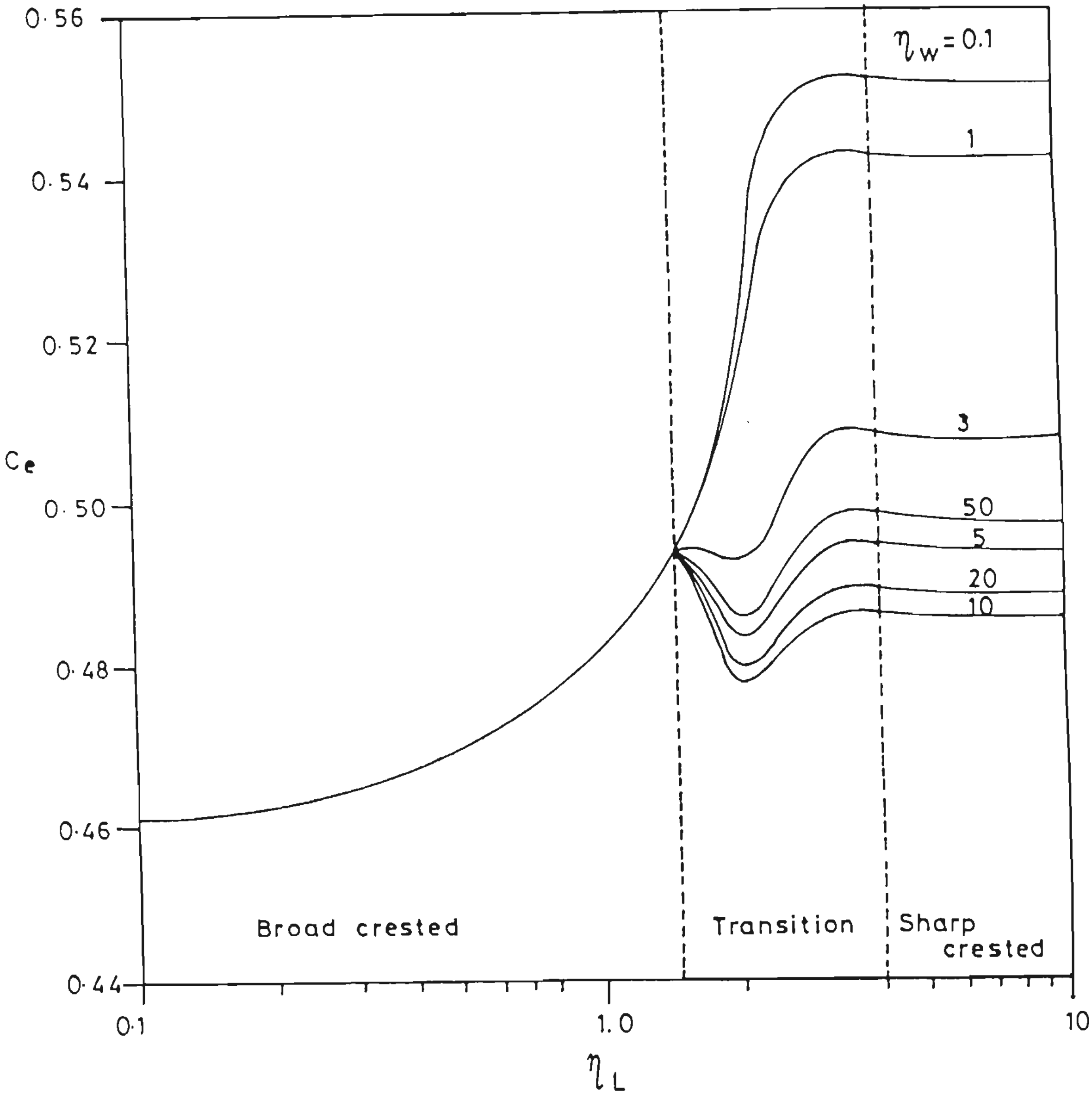


Fig. 6.16 Variation of C_e with η_L and η_w for triangular side weir ($\theta = \pi/2$)

(6.21) holds good for all values of η_L which are less than 1.5. As η_L increases beyond this value the weir gradually behaves as a sharp crested weir and for $\eta_L > 3$, it is finally converted to sharp crested side weir. In this transition both η_L and η_w govern the *elementary discharge coefficient* equation. Thus (6.21) is applicable to all types of sharp crested triangular side weirs with $\theta \geq \pi/6$ and broad crested triangular side weir with $\theta = \pi/2$ irrespective of variation of η_w or η_L.

6.1.9 Trapezoidal Side Weir Analysis

The available data on sharp crested trapezoidal side weir were those of Yadav (1986) which were used for obtaining the *elementary discharge coefficient* equation. The description of the data is given in Table 6.3. The following optimal shape of C_e for an unrestricted sharp crested trapezoidal side weir was obtained:

$$C_e = 0.5\left[\left(1+2.6m_s\right)^{-5} + 0.832m_s^2\right]^{0.2} + 0.01\eta_w \quad \text{for } \eta_w \leq 5. \qquad (6.22)$$

Fig. 6.17 shows the comparison of observed side weir discharge and the computed discharge for different values of m_s using Yadav's (1986) data. Since the data which were used for obtaining (6.22) are pertaining to the range of $\eta_w \leq 5$, and further bottom width of side weirs for all the data was 0.1m, hence extensive experimental data are required for obtaining a generalized equation for *elementary discharge coefficient* of a trapezoidal side weir.

Table 6.3 - Range of Data on Trapezoidal Side Weir (Yadav, 1986)

$B = 0.5\text{m}$

Side slope	weir height	Upstream depth of flow	Upstream discharge	Side weir discharge	Upstream Froude number	Bottom width of weir	Number of data
m_s	w (m)	y_0 (m)	Q_0 (m^3/s)	Q_s (m^3/s)	F_0	b (m)	N
0.268	0.0336	0.15-0.46	0.014-0.11	0.007-0.085	0.15-0.56	0.1	28
0.577	0.051	0.17-0.31	0.027-0.09	0.012-0.047	0.15-0.61	0.1	29
1	0.055	0.16-0.23	0.034-0.068	0.01-0.03	0.19-0.5	0.1	16
1.428	0.063	0.16-0.20	0.017-0.070	0.011-0.027	0.15-0.62	0.1	23

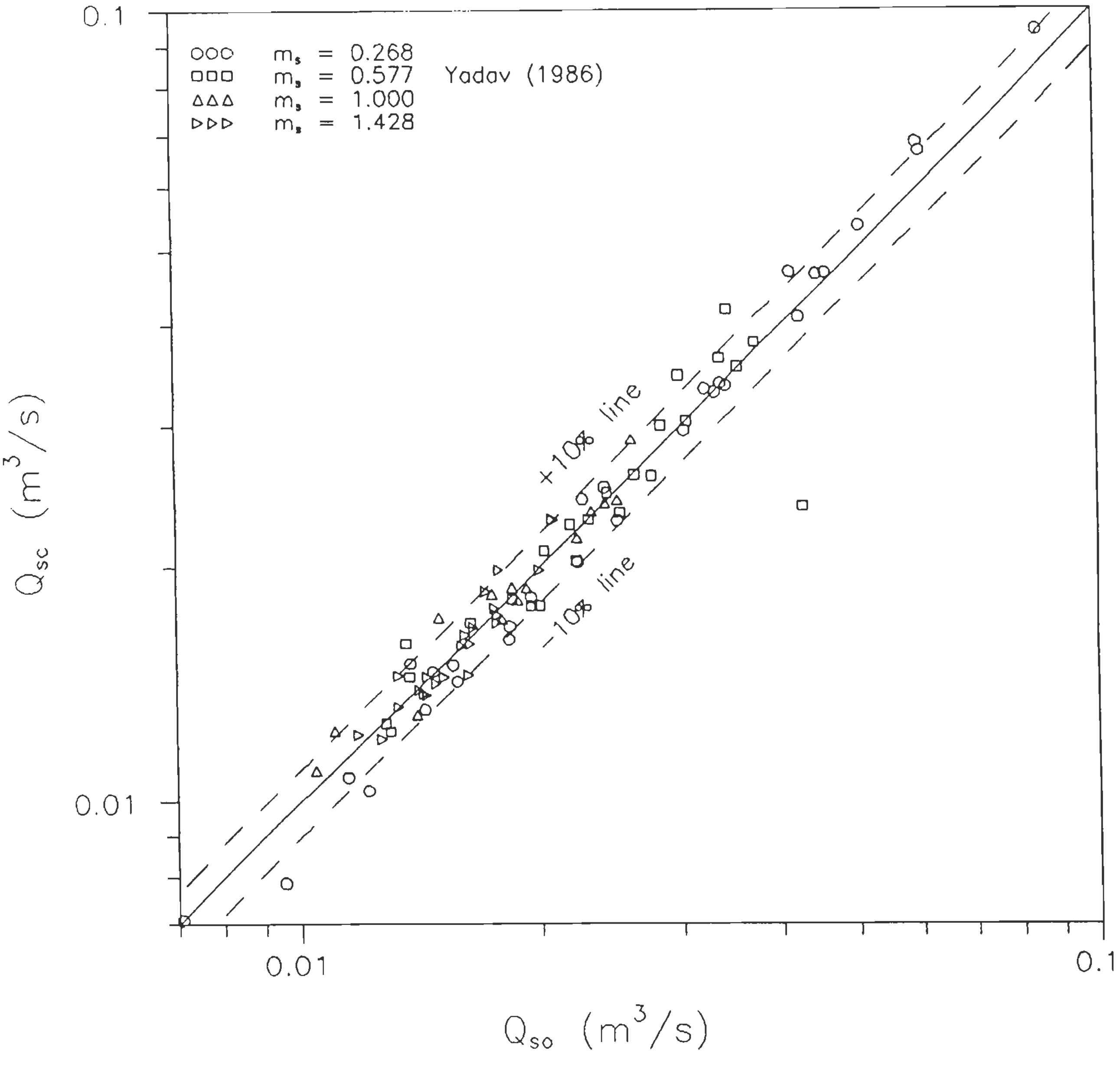


Fig. 6.17 Comparison of observed and computed discharges for sharp crested trapezoidal side weirs

6.2 SIDE SLUICE GATE ANALYSIS

6.2.1 Equations for Sharp Crested Side Sluice Gate

The *elementary discharge coefficient* for a sharp crested side sluice gate will be a function of flow depth y along the length of the sluice gate and the sluice gate opening a for free flow condition. For a submerged flow condition, tail water depth y_t in the side channel is an additional parameter having a considerable influence on C_e. Swamee (1992) has given equations for free and submerged flow conditions, for a normal sluice gate. Adopting the same expressions for discharge coefficient the following functional form for free flow through a sharp crested side sluice gate may be assumed:

$$C_e = k_{30}\left(\frac{y - a}{y+k_{31}a}\right)^{k_{32}}; \tag{6.23}$$

whereas for submerged flow condition occurring with a sharp crested side sluice gate the functional form assumed is:

$$C_e = k_{30}\left(\frac{y - a}{y+k_{31}a}\right)^{k_{32}}\left\{k_{33}\left[\frac{k_{34}y_t\left(\frac{y_t}{a}\right)^{k_{35}} - y}{y - y_t}\right]^{k_{36}} + 1\right\}^{-k_{37}}; \tag{6.24}$$

in which k_{30} through K_{37} are unknown positive constants to be determined from the experimental data.

6.2.2 Determination of Constants

Using the experimental data of sharp crested side sluice gate the average percentage error ER was minimized to yield the following best fit results of (6.23 and 6.24) respectively.

Free flow:

$$C_e = 0.611\left[\frac{y - a}{y + a}\right]^{0.216} \quad ; \text{ and} \tag{6.25}$$

Submerged flow:

$$C_e = 0.611\left[\frac{y - a}{y + a}\right]^{0.216} \left\{1+0.24\left[\frac{2.5y_t\left[\dfrac{y_t}{a}\right]^{0.2} - y}{y - y_t}\right]^{0.67}\right\}^{-1.0}. \tag{6.26}$$

The average error of the entire experimental data of the present study leading to (6.25 and 6.26) are 5.56% and 5.5% respectively. Fig. 6.18 depicts plot of (6.25 and 6.26). Figs. 6.19 and 6.20 show the comparison of observed and the computed sharp crested side sluice gate discharges with free and submerged flows respectively. It is evident that majority of the data points fall in the error width of ±10% for both free and submerged flow conditions.

6.2.3 Validation of The Equation for Sharp Crested Side Sluice Gate

Fig. 6.21 shows the comparison of observed and the computed sharp crested side sluice gate discharges for the data of Panda (1981) (see Table 6.4). A perusal of Fig. 6.21 shows that majority of the data points lie in the error with of ±10%.

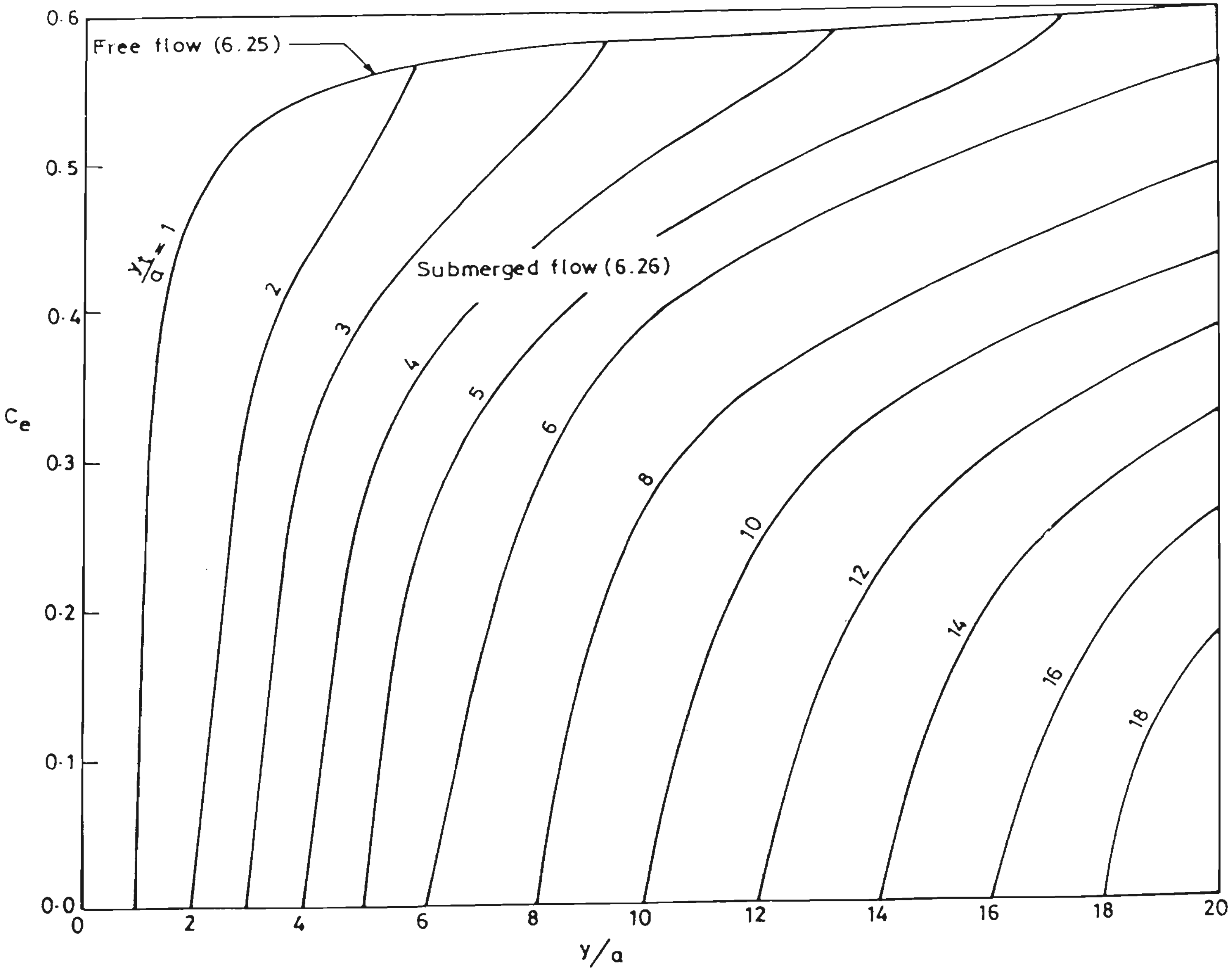


Fig. 6.18 Variation of C_e with y/a and y_t/a for sharp crested side sluice gate

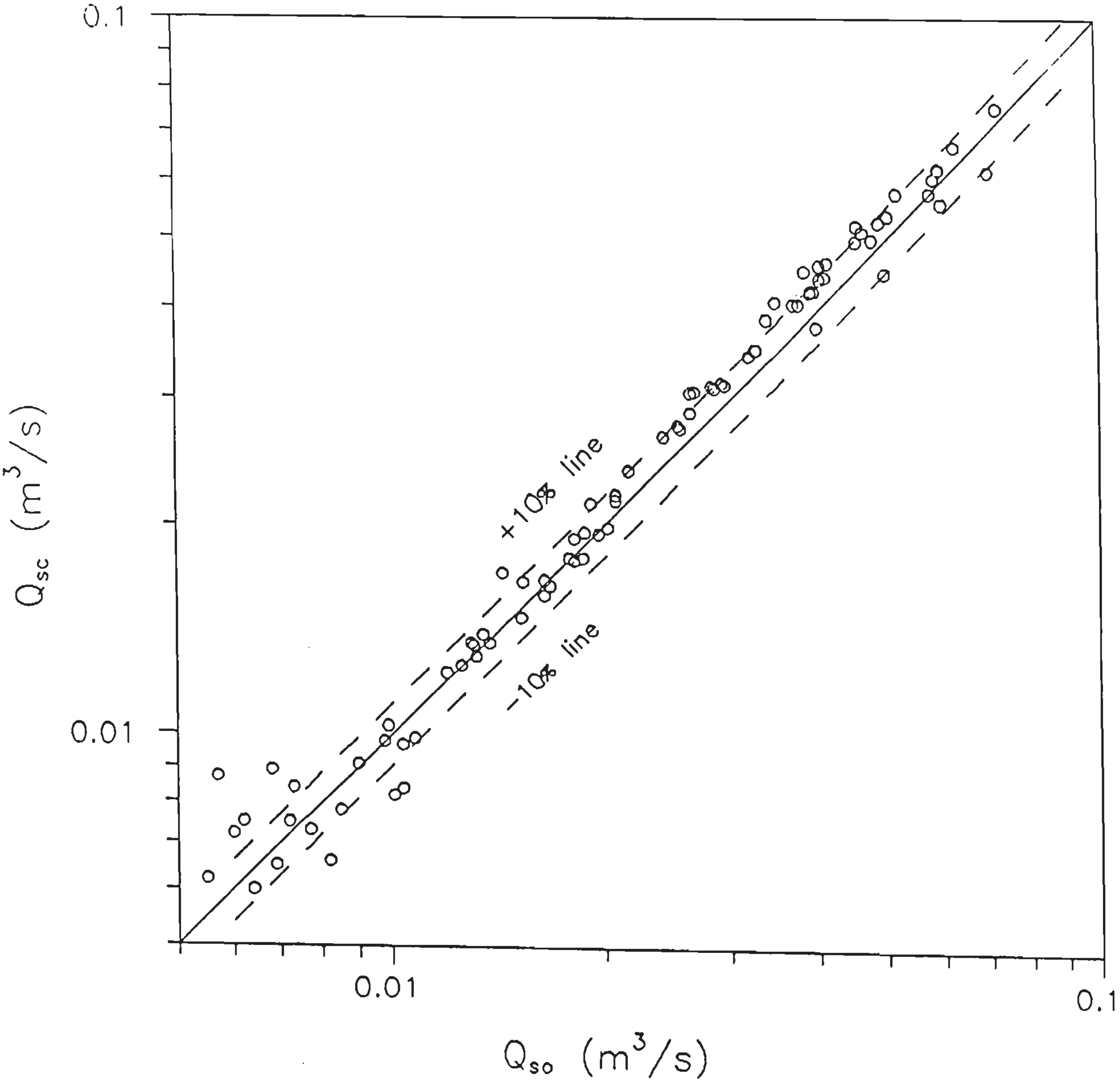


Fig. 6.19 Comparison of observed and computed discharges fo
sharp crested side sluice gate (free flow)

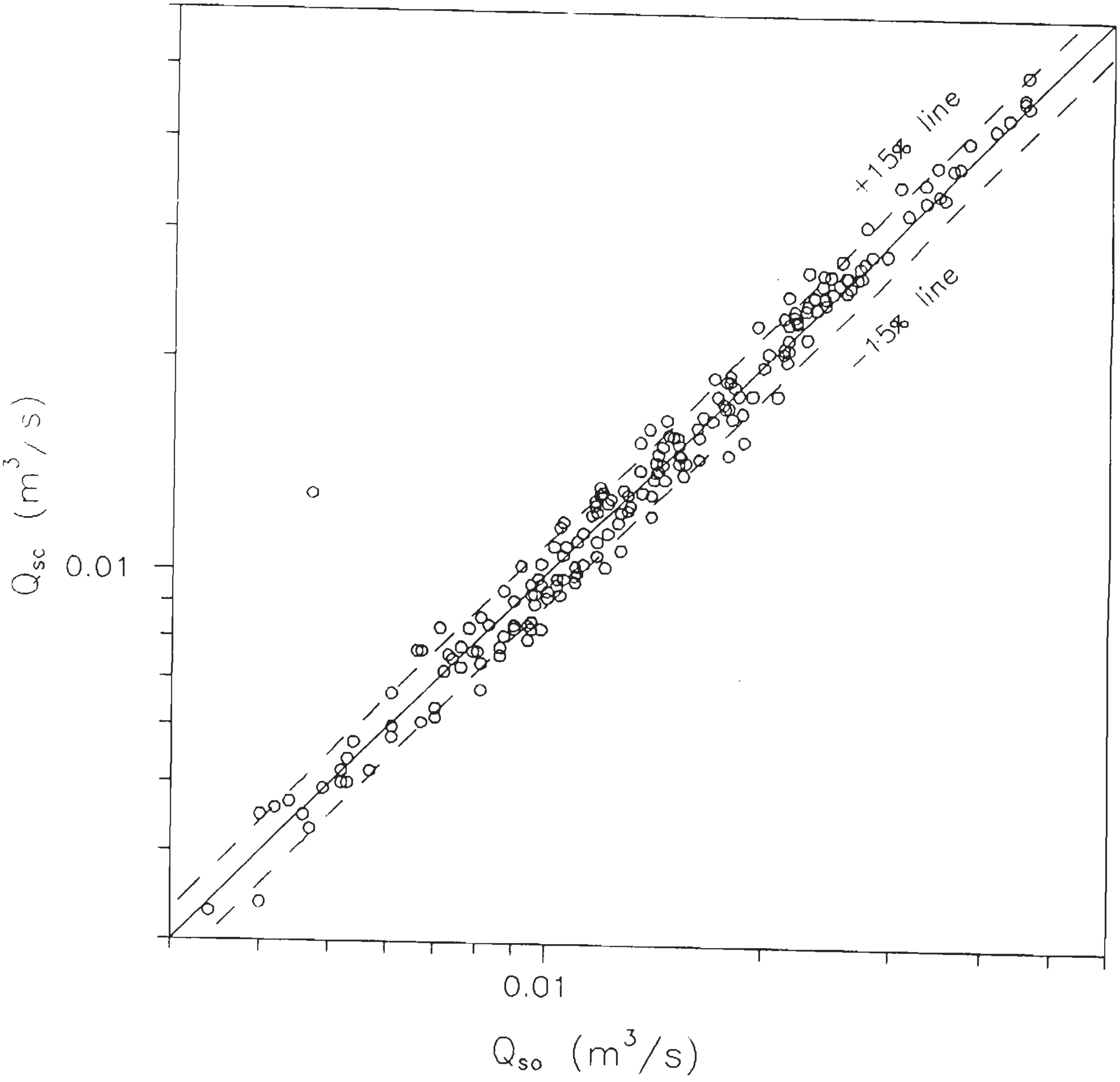


Fig. 6.20 Comparison of observed and computed discharges for sharp crested side sluice gate (submerged flow)

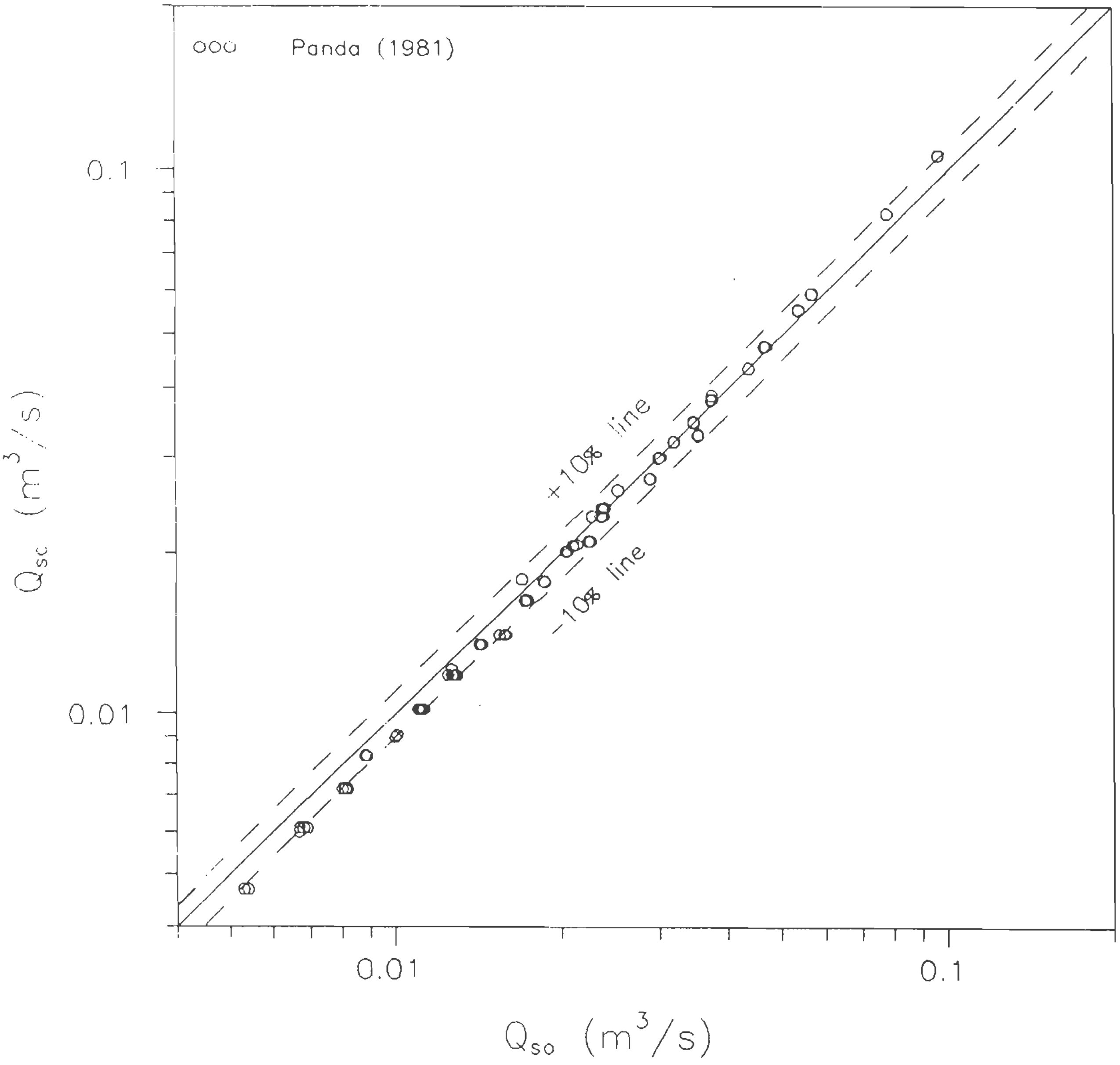


Fig. 6.21 Validation diagram for sharp crested side sluice gate (free flow)

Table 6.4 - Range of Parameters on Sharp Crested side Sluice gate data (Panda, 1981)

S. No.	Parameters		Ranges of variable
1	Upstream discharge:	$Q_0 (m^3/s)$	0.016 - 0.13
2	Side sluice gate discharge:	$Q_s (m^3/s)$	0.005 - 0.097
3	Upstream depth of flow:	y_0 (m)	0.29 - 0.7
4	Gate opening:	a (m)	0.01 - 0.08
5	Flow depth/opening:	y_0/a	3.60 - 66.00
6	Channel width ratio:	B/b	1.2 - 1.6
7	Upstream Froude number:	F_0	0.05 - 0.40
8	Number of data		105

6.2.4 Equations for Broad Crested Side Sluice Gate

For broad crested side sluice gate the ratio of the gate thickness c to the gate opening a is an additional important parameter influencing the C_e. For broad crested side sluice gate the coefficient k_{30}, k_{33} and k_{34} in (6.23 and 6.24) were found to be functions of ratio of gate thickness c to the gate opening a as:

$$k_{30} = 0.611\left[1 + 0.0112\,\frac{c}{a}\right]; \tag{6.27}$$

$$k_{33} = \frac{0.24}{1+0.05\frac{c}{a}}; \text{ and} \tag{6.28}$$

$$k_{34} = 2.5\left[1 + 0.0188\,\frac{c}{a}\right]; \tag{6.29}$$

whereas coefficients k_{31}, k_{32}, k_{35}, k_{36} and k_{37} remained the same as that of sharp crested side sluice gate. Incorporating (6.27) in (6.23), the equation for C_e for a broad crested side sluice gate under free flow condition becomes:

$$C_e = 0.611\left[\,1 + 0.0112\,\frac{c}{a}\,\right]\left[\frac{y - a}{y + a}\right]^{0.216}. \tag{6.30}$$

Similarly incorporating (6.27, 6.28 and 6.29) in (6.24) the equation for C_e for a broad crested side sluice gate under submerged flow condition takes the form of:

$$C_e=0.611\left[1+0.0112\ \frac{c}{a}\right]\left[\frac{y-a}{y+a}\right]^{0.216}\left\{1+\frac{0.24}{1+0.05\frac{c}{a}}\left[\frac{2.5\left[1+0.0188\frac{c}{a}\right]y_t\left(\frac{y_t}{a}\right)^{0.2}-y}{y-y_t}\right]^{0.67}\right\}^{-1}. \qquad (6.31)$$

Eq. (6.31) is valid for both sharp and broad crested side sluice gate under free and submerged flow conditions. When c → 0, which corresponds to sharp crested side sluice gate, (6.30 and 6.31) gradually reduce to (6.25 and 6.26) respectively. A comparison of (6.25 and 6.30) indicates that in the case of free flow condition, for the sluice gate thickness $c \leq 2.25a$, the increase in C_e above its corresponding value for the sharp crested side sluice gate is less than 2.5%. Similarly, from (6.26 and 6.31), the increase in C_e above the corresponding value for the submerged sharp crested side sluice gate is less than 2.5% for $c \leq 0.78a$.

Figs. 6.22 and 6.23 show the comparison of observed and the computed discharges for broad crested side sluice gate under free and submerged flow conditions respectively. A perusal of Figs. 6.22 and 6.23 shows that majority of the data points lie in the error width of ±10%.

6.2.5 Submergence Criteria

It can be seen from (6.31) that $C_e = 0$ for $y = y_t$. An increase in y above y_t causes a rapid increase in C_e, until it becomes equal to the value of C_e predicted by (6.30) for free flow condition. Thus y attains

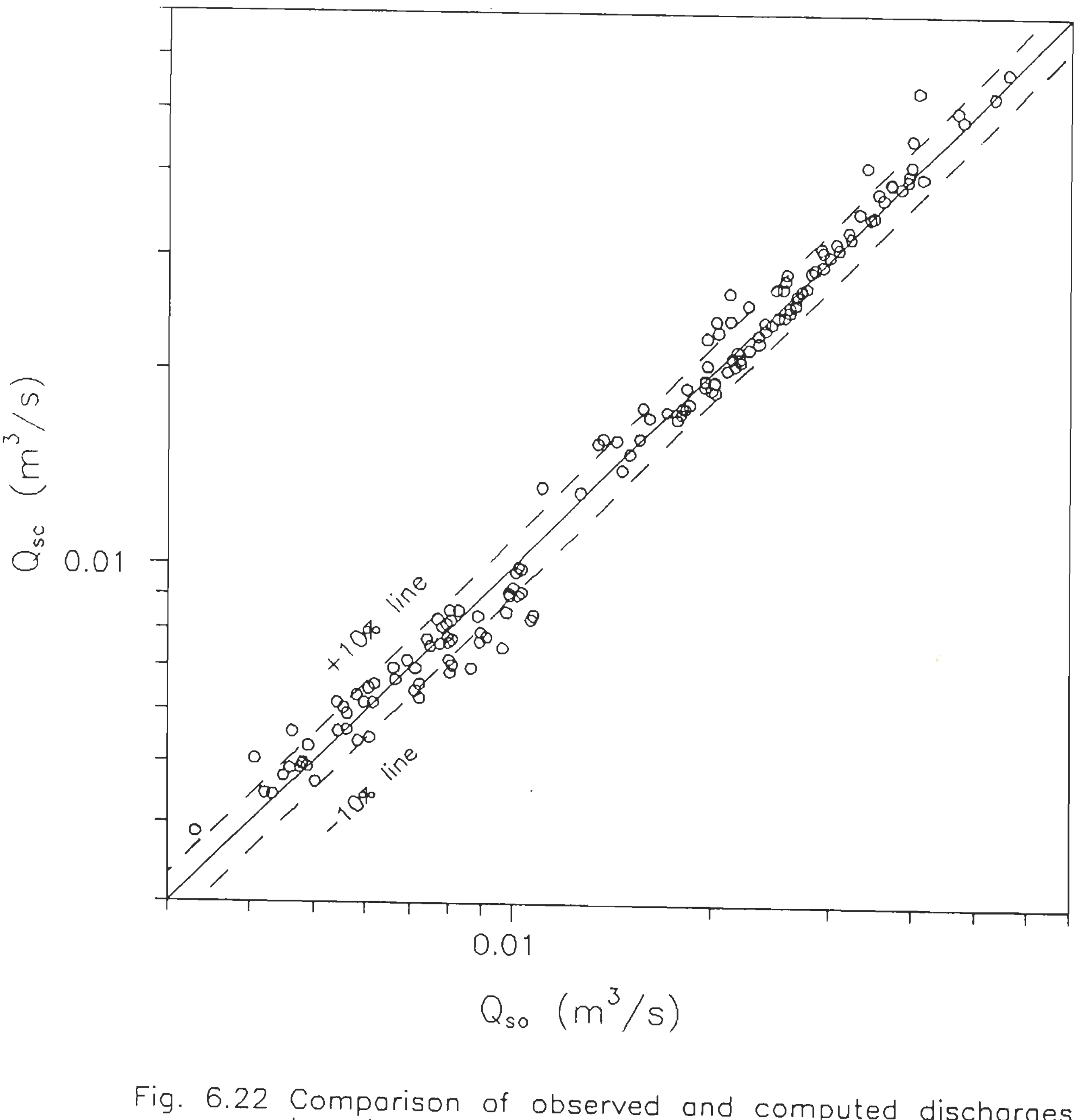


Fig. 6.22 Comparison of observed and computed discharges for broad crested side sluice gste (free flow)

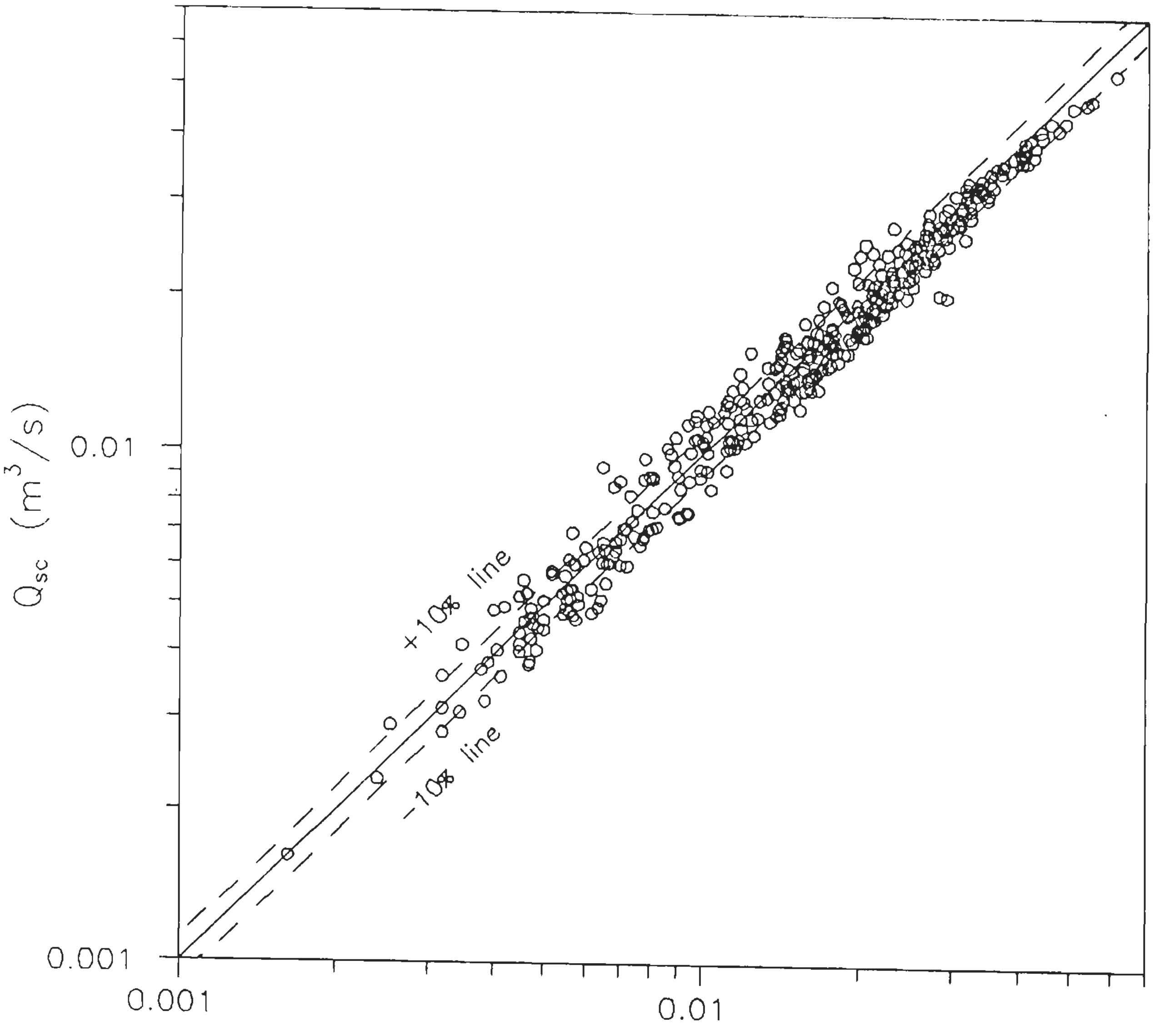


Fig. 6.23 Comparison of observed and computed discharges for broad crested side sluice gate (submerged flow)

a maximum value y_{max} given by:

$$y_{max} = 2.5\left[1+0.0188\ \frac{c}{a} \right] y_t \left[\frac{y_t}{a} \right]^{0.2} . \qquad (6.32)$$

At $y = y_{max}$ the submerged flow condition has just ended and the flow is free. Thus the condition for existence of submerged flow is given by:

$$y_t < y < 2.5 \left[1+0.0188\ \frac{c}{a}\right] y_t \left[\frac{y_t}{a}\right]^{0.2} . \qquad (6.33)$$

Eq. (6.33) is the applicability criteria for (6.31). Similarly the condition for existence of free flow is:

$$y \geq 2.5\left[1+0.0188\ \frac{c}{a}\right] y_t \left[\frac{y_t}{a}\right]^{0.2} . \qquad (6.34)$$

6.2.6 Flow Profile Comparison

Panda (1981) has reported a measured flow profile along a sharp crested side sluice gate with free flow condition. For these data the flow profile was computed as shown in Fig. 6.24. It is evident that there is a good agreement between computed flow profile and the observed data points.

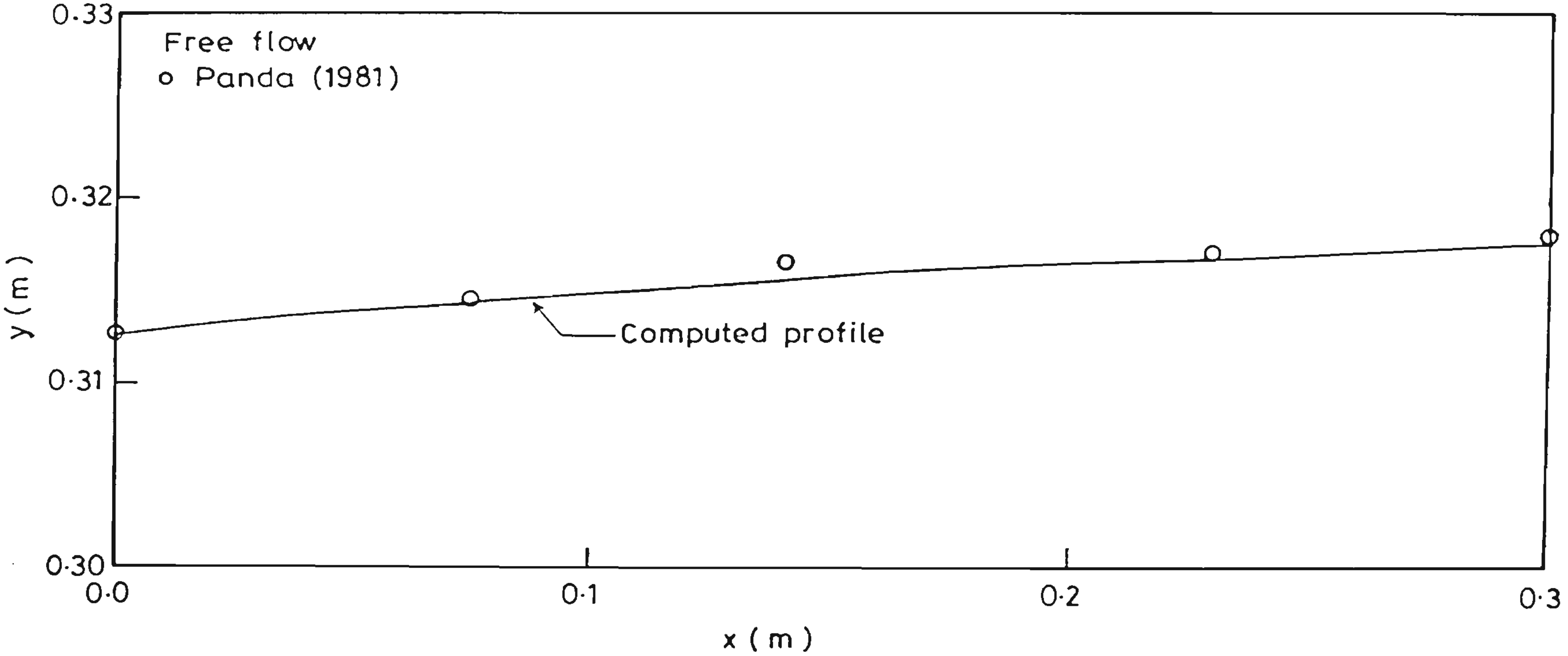


Fig. 6.24 Validation diagram for flow profile along a sharp crested Side sluice gate

6.3 SUMMARY OF EQUATIONS

It has been possible to obtain equations for *elementary discharge coefficient* for various practical diversion structures. The equations are summarized as shown in Table 6.5.

The application of proposed methodology and equations of *elementary discharge coefficient* are illustrated through examples as given in Appendix I.

Table 6.5- Resume of Elementary Discharge Coefficient Equations

S. No.	Diversion structure	Eq. No.	Remarks
	(I) Sharp crested		
1	**WEIRS**		
	a) Rectangular (unrestricted)	6.6	all ranges of η_w
	b) Rectangular (restricted)	6.7	all ranges of η_w
	c) Triangular	6.13	$\eta_w \le 5$ and $\theta \ge \pi/6$
		6.14	$\eta_w \ge 15$ and $\theta \ge \pi/6$
	d) Trapezoidal	6.22	$\eta_w \ge 5$; $0.268 \le m_s \le 1.428$
2	**SLUICE GATE**		
	e) Rectangular side sluice gate	6.25	free flow
	f) Rectangular side sluice gate	6.26	submerged flow
	(II) Broad crested		
3	**WEIRS**		
	g) Rectangular (unrestricted)	6.8	$\eta_L < 1$
	h) Rectangular (restricted)	6.9	$\eta_L < 1$
	i) Triangular	6.19	$\eta_L < 1.5$
4	**SLUICE GATE**		
	j) Rectangular side sluice gate	6.30	free flow
	(III) Generalized equations		
5	**WEIRS**		
	k) Rectangular (unrestricted)	6.11	
	l) Rectangular (restricted)	6.12	
	m) Triangular	6.21	
6	**SLUICE GATE**		
	n) Rectangular side sluice gate	6.31	

CHAPTER SEVEN

CONCLUSION

From the foregoing Chapters the following conclusions can be drawn:

1. The concept of the *elementary discharge coefficient* equation for an elementary vertical strip along the diversion structure has been introduced.

2. A methodology for computation of the discharge of a diversion structure and flow profile in the main channel have been developed.

3. Equations for the *elementary discharge coefficient* for both sharp and broad crested rectangular and triangular side weirs have been obtained.

4. Equations for the *elementary discharge coefficient* for both sharp and broad crested rectangular side sluice gates under free and submerged flow conditions have been obtained.

5. Criterion for existence of free or submerged flow through a side sluice gate has been proposed.

6. Experimental data show high accuracy of the expressions for C_e and the proposed methodology.

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APPENDIX I

PRACTICAL EXAMPLES

In order to express the utility of the methodology developed in the foregoing chapters, the following examples are considered:

Example 1

Find the discharge of an unrestricted rectangular side weir for the following data:

<u>Main channel</u>

Bed width: $B = 2.0\text{m}$

Bed slope: $S_0 = 0.001$

Manning's roughness coefficient: $n = 0.012$

Upstream discharge: $Q_0 = 0.9\ \text{m}^3/\text{s}$

Upstream flow depth: $y_0 = 0.3\text{m}$

<u>Side weir</u>

Weir length: $b = 2.5\text{m}$

Weir width: $L = 0.1\text{m}$

Weir height: $w = 0.15\text{m}$

Solution: Substituting the data in (4.2) and (6.11) one gets:

$$\frac{dQ}{dx} = -1.318(y-0.15)^{1.5}\left\{\left[\left(\frac{6.71}{7.35+y}\right)^{6.67}+\left(\frac{y-0.15}{y}\right)^{6.67}\right]\left[\left(\frac{0.18}{y-0.15}\right)^{18}+1\right]^{-1}+\right.$$

$$1.4\left[\frac{1+5.76(y-0.15)^{0.02}}{1+5.76(y-0.15)^{0.02}+468.9(y-0.15)^{3.3}+58800(y-0.15)^{7}}\right]^{6.67},$$

$$\left.\left[1+(5y-0.75)^{18}\right]^{-1}\right\}^{-0.15}. \qquad \text{(I-1)}$$

Similarly on substitution of the data (2.3 and 4.1) reduce to:

$$\frac{dy}{dx} = \left[0.001-0.000036Q^{2}y^{-10/3}(1+y)^{4/3}-0.0256Qy^{-2}\frac{dQ}{dx}\right]\left[1-0.0256Q^{2}y^{-3}\right]^{-1}. \qquad \text{(I-2)}$$

Eqs. (I-1 and I-2) have the following initial conditions:

$$\text{at } x = 0.0\text{m as: } Q = 0.9 \text{ m}^3/\text{s; and } y=0.3\text{m}. \qquad \text{(I-3)}$$

Solving (I-1 and I-2) by a fourth order Runge-Kutta method for initial conditions (I-3), one finds: $Q_b = 0.281$ m^3/s; and $y_b = 0.35$m. Using (6.3) the side weir discharge is: $Q_s = 0.619$m^3/s.

Example 2

Find the discharge through a sharp crested side sluice gate, under free flow condition, for the following data:

<u>Main channel</u>

Bed width: $B = 2.5m$

Bed slope: $S_0 = 0.001$

Manning's roughness coefficient: $n = 0.012$

Upstream discharge: $Q_0 = 0.9\ m^3/s$

Upstream flow depth: $y_0 = 0.3m$

<u>Side sluice gate</u>

Sluice gate length: $b = 2.0m$

Sluice gate opening: $a = 0.2m$

Solution: Substituting the above data into (4.5 and 6.25) one gets:

$$\frac{dQ}{dx} = -0.541\sqrt{y}\left[\frac{y-0.2}{y+0.2}\right]^{0.216} . \qquad (I-4)$$

Similarly on substitution of data (2.3 and 4.1) reduce to:

$$\frac{dy}{dx} = \left[0.001-0.0000171Q^2y^{-10/3}(1.25+y)^{4/3}-0.01636Qy^{-2}\frac{dQ}{dx}\right]\left[1-0.01636Q^2y^{-3}\right]^{-1} . \qquad (I-5)$$

Eqs. (I-4 and I-5) have the following initial conditions:

$$\text{at } x = 0.0: \quad y = 0.3m; \text{ and } Q_0 = 0.9\ m^3/s. \qquad (I-6)$$

Solving (I-4 and I-5) by a forth order Range-Kutta method for the initial condition (I-6) one finds: $Q_b = 0.459\ m^3/s$ and $y_b = 0.35m$. Using (6.3), the side sluice gate discharge is $Q_s = 0.441\ m^3/s$.

APPENDIX II

EXPERIMENTAL DATA ON UNRESTRICTED SHARP CRESTED RECTANGULAR SIDE WEIR

$B = 0.5m$

S. No.	Length of weir	Height of weir	Upstream depth of flow	Downstream depth of flow	Upstream discharge	Side weir discharge	Temp. of water
	b (m)	w (m)	y_0 (m)	y_b (m)	Q_0 (m^3/s)	Q_s (m^3/s)	(^oc)
1	2	3	4	5	6	7	8
1	0.500	0.150	0.2528	0.2606	0.06080	0.03150	14
2	0.500	0.150	0.2261	0.2346	0.05930	0.02020	14
3	0.500	0.150	0.2942	0.3000	0.06380	0.04840	14
4	0.500	0.150	0.2747	0.2826	0.06530	0.04210	14
5	0.500	0.150	0.2562	0.2650	0.06320	0.03220	14
6	0.500	0.150	0.2486	0.2462	0.06260	0.02470	14
7	0.500	0.150	0.2105	0.2242	0.06230	0.01660	14
8	0.500	0.150	0.2301	0.2348	0.02500	0.02090	14
9	0.500	0.150	0.2132	0.2145	0.02320	0.01360	14
10	0.500	0.150	0.2007	0.2038	0.02380	0.01060	14
11	0.500	0.150	0.1877	0.1914	0.03000	0.00640	14
12	0.500	0.150	0.2585	0.2648	0.03720	0.03210	14
13	0.500	0.150	0.2068	0.2141	0.03450	0.01140	14
14	0.500	0.150	0.1789	0.1831	0.03500	0.00450	15
15	0.500	0.150	0.1656	0.1667	0.03510	0.00170	15
16	0.500	0.150	0.2645	0.2728	0.04930	0.03550	15
17	0.500	0.150	0.2497	0.2554	0.04850	0.02850	15
18	0.500	0.150	0.2306	0.2303	0.04760	0.02070	15
19	0.500	0.150	0.2041	0.2104	0.04680	0.01140	15
20	0.500	0.150	0.2681	0.2768	0.06040	0.03640	15

1	2	3	4	5	6	7	8
21	0.500	0.150	0.2497	0.2588	0.05980	0.02840	15
22	0.500	0.150	0.2295	0.2398	0.05880	0.02060	15
23	0.500	0.150	0.2085	0.2153	0.05790	0.01230	15
24	0.500	0.150	0.1855	0.1925	0.05710	0.00590	15
25	0.500	0.150	0.2675	0.2765	0.06630	0.03640	15
26	0.500	0.150	0.2497	0.2597	0.06510	0.02870	15
27	0.500	0.150	0.2270	0.2365	0.06510	0.01990	15
28	0.500	0.150	0.2102	0.2197	0.06310	0.01360	15
29	0.500	0.150	0.1845	0.1912	0.06230	0.00580	15
30	0.500	0.150	0.2665	0.2779	0.08000	0.03520	15
31	0.500	0.150	0.2453	0.2574	0.07850	0.02490	15
32	0.500	0.150	0.2265	0.2384	0.07760	0.01730	15
33	0.500	0.150	0.1985	0.2145	0.07710	0.01010	15
34	0.500	0.100	0.1931	0.1982	0.03040	0.02550	16
35	0.500	0.100	0.1705	0.1738	0.02980	0.01680	16
36	0.500	0.100	0.1469	0.1513	0.02800	0.00890	16
37	0.500	0.100	0.1249	0.1283	0.02740	0.00380	16
38	0.500	0.100	0.2141	0.2209	0.04130	0.03360	16
39	0.500	0.100	0.1905	0.1963	0.04340	0.02680	16
40	0.500	0.100	0.1690	0.1757	0.03920	0.01580	16
41	0.500	0.100	0.1389	0.1447	0.03890	0.00660	16
42	0.500	0.100	0.1988	0.2089	0.04730	0.02730	16
43	0.500	0.100	0.1727	0.1821	0.04620	0.01740	16
44	0.500	0.100	0.1448	0.1508	0.04510	0.00780	16
45	0.500	0.100	0.2376	0.2469	0.05940	0.04300	16
46	0.500	0.100	0.2127	0.2243	0.05880	0.03270	16
47	0.500	0.100	0.1852	0.1977	0.06140	0.02560	16
48	0.500	0.100	0.1586	0.1733	0.05690	0.01310	16
49	0.500	0.100	0.1458	0.1616	0.05670	0.00950	16
50	0.500	0.100	0.2100	0.2247	0.06880	0.03190	16
51	0.500	0.100	0.1972	0.2143	0.06850	0.02720	16
52	0.500	0.100	0.1747	0.1954	0.06760	0.01920	16
53	0.500	0.100	0.1660	0.1864	0.06800	0.01670	16
54	0.500	0.100	0.2323	0.2472	0.07770	0.04000	16
55	0.500	0.100	0.2152	0.2332	0.07910	0.03460	16
56	0.500	0.100	0.1930	0.2162	0.07710	0.02520	16
57	0.500	0.050	0.1640	0.1697	0.03650	0.03220	18

1	2	3	4	5	6	7	8
58	0.500	0.050	0.1418	0.1519	0.03430	0.02390	18
59	0.500	0.050	0.1168	0.1304	0.03430	0.01530	18
60	0.500	0.050	0.1653	0.1774	0.04730	0.03400	18
61	0.500	0.050	0.1430	0.1602	0.04620	0.02490	18
62	0.500	0.050	0.1209	0.1429	0.04470	0.01660	18
63	0.500	0.050	0.1863	0.2011	0.05790	0.04160	18
64	0.500	0.050	0.1645	0.1852	0.05850	0.03370	18
65	0.500	0.050	0.1470	0.1729	0.05790	0.02710	18
66	0.500	0.050	0.1816	0.2006	0.06750	0.04060	18
67	0.500	0.050	0.1574	0.1863	0.06710	0.03150	18
68	0.500	0.050	0.1911	0.2158	0.07720	0.04370	18
69	0.500	0.050	0.1730	0.2026	0.07790	0.03690	18
70	0.500	0.050	0.1847	0.2187	0.08500	0.04070	18
71	0.400	0.050	0.1575	0.1616	0.02550	0.02410	20
72	0.400	0.050	0.1241	0.1307	0.02430	0.01390	20
73	0.400	0.050	0.1937	0.1991	0.04190	0.03720	20
74	0.400	0.050	0.1697	0.1774	0.04070	0.02780	20
75	0.400	0.050	0.1432	0.1539	0.04020	0.01910	20
76	0.400	0.050	0.1172	0.1313	0.03930	0.01140	20
77	0.400	0.050	0.1891	0.2002	0.05320	0.03580	20
78	0.400	0.050	0.1612	0.1771	0.05310	0.02520	20
79	0.400	0.050	0.1372	0.1581	0.05160	0.01730	20
80	0.400	0.050	0.1937	0.2082	0.06040	0.03730	20
81	0.400	0.050	0.1734	0.1893	0.05990	0.02920	20
82	0.400	0.050	0.1520	0.1731	0.05960	0.02290	20
83	0.400	0.050	0.1945	0.2119	0.07180	0.03680	20
84	0.400	0.050	0.1800	0.2016	0.07130	0.03090	20
85	0.400	0.050	0.1653	0.1886	0.07050	0.02410	20
86	0.400	0.050	0.1909	0.2154	0.08120	0.03510	20
87	0.400	0.050	0.1713	0.1981	0.08060	0.02690	20
88	0.400	0.100	0.1962	0.1984	0.02700	0.02150	22
89	0.400	0.100	0.1629	0.1850	0.02600	0.01180	22
90	0.400	0.100	0.1333	0.1348	0.02550	0.00480	22
91	0.400	0.100	0.2333	0.2361	0.04030	0.03460	22
92	0.400	0.100	0.1971	0.2012	0.03930	0.02200	22
93	0.400	0.100	0.1574	0.1842	0.03780	0.01040	22
94	0.400	0.100	0.1247	0.1274	0.03740	0.00320	22

1	2	3	4	5	6	7	8
95	0.400	0.100	0.2393	0.2449	0.05220	0.03680	22
96	0.400	0.100	0.2052	0.2156	0.05100	0.02510	22
97	0.400	0.100	0.1772	0.1854	0.04970	0.01490	22
98	0.400	0.100	0.1427	0.1525	0.04960	0.00680	22
99	0.400	0.100	0.2327	0.2412	0.06320	0.03300	22
100	0.400	0.100	0.1964	0.2073	0.06250	0.02060	22
101	0.400	0.100	0.1617	0.1749	0.06150	0.01040	22
102	0.400	0.100	0.2387	0.2476	0.06740	0.03570	22
103	0.400	0.100	0.2091	0.2204	0.06640	0.02440	22
104	0.400	0.100	0.1802	0.1934	0.06510	0.01580	22
105	0.400	0.100	0.2378	0.2516	0.07830	0.03550	22
106	0.400	0.100	0.2102	0.2262	0.07580	0.02370	22
107	0.400	0.150	0.2556	0.2586	0.03210	0.02500	25
108	0.400	0.150	0.2051	0.2070	0.03110	0.00990	25
109	0.400	0.150	0.2670	0.2700	0.04550	0.02870	25
110	0.400	0.150	0.2380	0.2416	0.04580	0.01840	25
111	0.400	0.150	0.2023	0.2073	0.04390	0.00890	25
112	0.400	0.150	0.2766	0.2771	0.04170	0.03170	25
113	0.400	0.150	0.2602	0.2645	0.04940	0.02670	25
114	0.400	0.150	0.2344	0.2390	0.04860	0.01810	25
115	0.400	0.150	0.2100	0.2145	0.04750	0.01070	25
116	0.400	0.150	0.1882	0.1919	0.04740	0.00590	25
117	0.400	0.150	0.2788	0.2840	0.05830	0.03250	25
118	0.400	0.150	0.2530	0.2587	0.05760	0.02360	25
119	0.400	0.150	0.2305	0.2367	0.05720	0.01630	25
120	0.400	0.150	0.2071	0.2126	0.05620	0.00990	25
121	0.400	0.150	0.2934	0.2997	0.06750	0.03920	25
122	0.400	0.150	0.2684	0.2756	0.06630	0.02930	25
123	0.400	0.150	0.2415	0.2485	0.06450	0.01950	25
124	0.300	0.150	0.2532	0.2535	0.02280	0.01780	28
125	0.300	0.150	0.2104	0.2095	0.02200	0.00780	28
126	0.300	0.150	0.3034	0.3026	0.03480	0.03120	28
127	0.300	0.150	0.2695	0.2700	0.03360	0.02170	28
128	0.300	0.150	0.2245	0.2243	0.03310	0.01100	28
129	0.300	0.150	0.1810	0.1800	0.03040	0.00290	28
130	0.300	0.150	0.2920	0.2923	0.04150	0.02780	28
131	0.300	0.150	0.2577	0.2590	0.04030	0.01850	28

1	2	3	4	5	6	7	8
132	0.300	0.150	0.2234	0.2240	0.03980	0.01040	28
133	0.300	0.150	0.1903	0.1900	0.03910	0.00430	28
134	0.300	0.150	0.3080	0.3100	0.05060	0.03260	28
135	0.300	0.150	0.2702	0.2706	0.04950	0.02160	28
136	0.300	0.150	0.2314	0.2325	0.04860	0.01190	28
137	0.300	0.150	0.2028	0.2041	0.04800	0.00630	28
138	0.300	0.150	0.3128	0.3146	0.05830	0.03430	28
139	0.300	0.150	0.2603	0.2619	0.05120	0.01870	28
140	0.300	0.150	0.2283	0.2287	0.05020	0.01100	28
141	0.300	0.150	0.2015	0.2028	0.05020	0.00600	28
142	0.300	0.150	0.3240	0.3250	0.06050	0.03750	28
143	0.300	0.150	0.2878	0.2896	0.05970	0.02630	28
144	0.300	0.150	0.2536	0.2562	0.05860	0.01670	28
145	0.300	0.050	0.1672	0.1687	0.02170	0.01930	30
146	0.300	0.050	0.1226	0.1265	0.02250	0.00930	30
147	0.300	0.050	0.1893	0.1928	0.03350	0.02600	30
148	0.300	0.050	0.1677	0.1727	0.03300	0.02020	30
149	0.300	0.050	0.1454	0.1511	0.03230	0.01420	30
150	0.300	0.050	0.2027	0.2071	0.04270	0.03030	30
151	0.300	0.050	0.1804	0.1875	0.04200	0.02360	30
152	0.300	0.050	0.1570	0.1647	0.04100	0.01670	30
153	0.300	0.050	0.1373	0.1476	0.04100	0.01190	30
154	0.300	0.050	0.2149	0.2246	0.05980	0.03300	30
155	0.300	0.050	0.1865	0.1996	0.05900	0.02420	30
156	0.300	0.050	0.2190	0.2300	0.06790	0.03380	30
157	0.300	0.050	0.1846	0.2004	0.06630	0.02270	30
158	0.200	0.050	0.2559	0.2576	0.03210	0.02980	30
159	0.200	0.050	0.2015	0.2046	0.03140	0.01790	30
160	0.200	0.050	0.2473	0.2501	0.04190	0.02760	30
161	0.200	0.050	0.2120	0.2163	0.04140	0.01990	30
162	0.200	0.050	0.2340	0.2383	0.05030	0.02450	30
163	0.200	0.050	0.2639	0.2659	0.04810	0.02970	30
164	0.200	0.050	0.2297	0.2344	0.04880	0.02320	30
165	0.200	0.050	0.2725	0.2775	0.05840	0.03300	30
166	0.200	0.050	0.2397	0.2441	0.05700	0.02480	30
167	0.100	0.059	0.1640	0.1650	0.02440	0.00760	18
168	0.100	0.059	0.2000	0.2010	0.02460	0.01150	18

1	2	3	4	5	6	7	8
169	0.100	0.059	0.2310	0.2320	0.02500	0.01480	18
170	0.100	0.059	0.1850	0.1855	0.03570	0.00930	18
171	0.100	0.059	0.2110	0.2120	0.03600	0.01250	18
172	0.100	0.059	0.1675	0.1690	0.04310	0.00760	18
173	0.100	0.059	0.1965	0.1970	0.04130	0.01140	18
174	0.100	0.059	0.2735	0.2745	0.04230	0.02060	18
175	0.100	0.059	0.1710	0.1720	0.04220	0.00790	18
176	0.100	0.059	0.1900	0.1920	0.04240	0.00990	18
177	0.100	0.059	0.2155	0.2165	0.04210	0.01270	18
178	0.100	0.059	0.1705	0.1730	0.05530	0.00820	18
179	0.100	0.059	0.1850	0.1865	0.05450	0.00900	18
180	0.100	0.059	0.1985	0.2000	0.05440	0.01040	18
181	0.100	0.059	0.2180	0.2194	0.05500	0.01310	18
182	0.200	0.050	0.2273	0.2530	0.09650	0.03050	22
183	0.200	0.050	0.1891	0.2000	0.08200	0.02150	22
184	0.200	0.050	0.1783	0.2100	0.08130	0.01880	22
185	0.200	0.050	0.1528	0.1700	0.07160	0.01330	22
186	0.200	0.050	0.1633	0.1840	0.07130	0.01560	22
187	0.200	0.050	0.1753	0.1980	0.07120	0.01820	22
188	0.200	0.050	0.1923	0.2200	0.07110	0.02170	22
189	0.200	0.050	0.1802	0.2150	0.06840	0.01900	22
190	0.200	0.050	0.1723	0.1980	0.06810	0.01750	22
191	0.200	0.050	0.1643	0.1760	0.06780	0.01560	22
192	0.200	0.050	0.1283	0.1490	0.05540	0.00940	22
193	0.200	0.050	0.1453	0.1580	0.05560	0.01250	22
194	0.200	0.050	0.1593	0.1790	0.05510	0.01490	22
195	0.500	0.030	0.1680	0.1942	0.07540	0.04030	22
196	0.500	0.030	0.1680	0.1942	0.07540	0.04030	22
197	0.500	0.030	0.1780	0.1878	0.04940	0.04670	22
198	0.500	0.030	0.1599	0.1713	0.04940	0.03740	22
199	0.500	0.030	0.1470	0.1600	0.04940	0.03000	22
200	0.500	0.030	0.1288	0.1485	0.04940	0.02340	22
201	0.500	0.030	0.1063	0.1359	0.04940	0.01600	22
202	0.500	0.030	0.1799	0.1922	0.05550	0.04740	22
203	0.500	0.030	0.1656	0.1770	0.05550	0.03850	22
204	0.500	0.030	0.1454	0.1645	0.05550	0.03030	22
205	0.500	0.030	0.1313	0.1529	0.05550	0.02410	22

1	2	3	4	5	6	7	8
206	0.500	0.020	0.1526	0.1766	0.06960	0.03500	22
207	0.500	0.020	0.1305	0.1562	0.06960	0.02310	22
208	0.500	0.020	0.1710	0.1802	0.05180	0.04750	22
209	0.500	0.020	0.1582	0.1711	0.05180	0.04080	22
210	0.500	0.020	0.1457	0.1191	0.05180	0.03510	22
211	0.500	0.020	0.1267	0.1481	0.05180	0.02610	22
212	0.500	0.020	0.1467	0.1542	0.03910	0.03470	22
213	0.500	0.020	0.1271	0.1368	0.03910	0.02700	22
214	0.500	0.010	0.1436	0.1668	0.06280	0.03480	22
215	0.500	0.010	0.1509	0.1684	0.06280	0.04180	22
216	0.500	0.010	0.1330	0.1577	0.06280	0.02910	22
217	0.500	0.010	0.1202	0.1444	0.06280	0.02150	22
218	0.500	0.010	0.1476	0.1564	0.04380	0.03980	22
219	0.500	0.010	0.1383	0.1479	0.04380	0.03500	22
220	0.500	0.010	0.1262	0.1380	0.04380	0.03110	22
221	0.500	0.010	0.1160	0.1322	0.04380	0.02420	22
222	0.500	0.010	0.1010	0.1332	0.04380	0.01680	22
223	0.500	0.010	0.1306	0.1406	0.03580	0.03230	22
224	0.500	0.010	0.1205	0.1304	0.03580	0.02890	22
225	0.500	0.010	0.1124	0.1234	0.03580	0.02540	22
226	0.500	0.010	0.0978	0.1132	0.03580	0.01980	22
227	0.500	0.005	0.1327	0.1507	0.05060	0.03490	22
228	0.500	0.005	0.1256	0.1420	0.05060	0.03280	22
229	0.500	0.005	0.1256	0.1340	0.03950	0.03280	22
230	0.500	0.005	0.1159	0.1265	0.04030	0.02990	22
231	0.500	0.005	0.1085	0.1177	0.03760	0.02580	22
232	0.500	0.005	0.1000	0.1159	0.03760	0.02010	22
233	0.500	0.005	0.0925	0.1176	0.03760	0.01690	22
234	0.500	0.005	0.1053	0.1122	0.02790	0.02470	22
235	0.500	0.005	0.0994	0.1057	0.02790	0.02210	22
236	0.500	0.005	0.0843	0.0955	0.02790	0.01700	22
237	0.500	0.005	0.0871	0.0922	0.02040	0.01850	22
238	0.500	0.005	0.1328	0.1400	0.03910	0.03580	22
239	0.500	0.005	0.1252	0.1340	0.03910	0.03170	22
240	0.500	0.005	0.1152	0.1258	0.03910	0.02790	22
241	0.500	0.005	0.1079	0.1213	0.03910	0.02490	22
242	0.500	0.005	0.0907	0.0956	0.02140	0.01970	22

1	2	3	4	5	6	7	8
243	0.500	0.000	0.0960	0.1072	0.03160	0.02140	20
244	0.500	0.000	0.1323	0.1432	0.04440	0.03880	20
245	0.500	0.000	0.1093	0.1392	0.04300	0.02750	20
246	0.500	0.000	0.1332	0.1550	0.05590	0.04010	20
247	0.500	0.000	0.1469	0.1754	0.07310	0.04590	20
248	0.400	0.000	0.1020	0.1082	0.02370	0.02070	20
249	0.400	0.000	0.1082	0.1204	0.03470	0.02150	20
250	0.400	0.000	0.1355	0.1527	0.04710	0.03380	20
251	0.400	0.000	0.1204	0.1427	0.04630	0.02700	20
252	0.400	0.000	0.1502	0.1692	0.05910	0.03770	20
253	0.400	0.000	0.1322	0.1582	0.05820	0.03130	20
254	0.500	0.000	0.1090	0.1172	0.03240	0.02830	20
255	0.300	0.000	0.1043	0.1129	0.02630	0.01610	20
256	0.300	0.000	0.1295	0.1385	0.03550	0.02270	20
257	0.300	0.000	0.1298	0.1459	0.04510	0.02240	20
258	0.300	0.000	0.1305	0.1482	0.05270	0.02110	20
259	0.300	0.000	0.1685	0.1869	0.06180	0.03460	20
260	0.300	0.000	0.1451	0.1677	0.06070	0.02470	20
261	0.200	0.000	0.1156	0.1236	0.03100	0.01170	20
262	0.200	0.000	0.1194	0.1300	0.04040	0.01140	20
263	0.200	0.000	0.1224	0.1390	0.04770	0.01160	20
264	0.200	0.000	0.1547	0.1702	0.05520	0.01850	20
265	0.200	0.000	0.1584	0.1730	0.06300	0.01860	20
266	0.200	0.000	0.1584	0.1730	0.06300	0.01860	20
267	0.500	0.000	0.0960	0.1072	0.03160	0.02140	20
268	0.500	0.050	0.0840	0.0878	0.02689	0.00473	18
269	0.500	0.050	0.0745	0.0845	0.02699	0.00252	18
270	0.500	0.050	0.0935	0.0793	0.04443	0.00460	18
271	0.500	0.050	0.1095	0.0923	0.06067	0.00771	18
272	0.500	0.050	0.1421	0.1060	0.08046	0.01197	18

APPENDIX III

EXPERIMENTAL DATA ON RESTRICTED SHARP CRESTED RECTANGULAR SIDE WEIR

B = 0.5m and b = 0.5m.

S. No.	Upstream depyh of flow	Downstream depth of flow	Height of weir	Upstream discharge	Side weir discharge	Temp. of water
	y_0 (m)	y_b (m)	w (m)	Q_0 (m^3/s)	Q_b (m^3/s)	(^oc)
1	2	3	4	5	6	7
1	0.1214	0.1235	0.100	0.034800	0.002120	29.0
2	0.1528	0.1572	0.100	0.034800	0.010462	29.0
3	0.1534	0.1627	0.100	0.056951	0.010136	29.0
4	0.1758	0.1859	0.100	0.056951	0.017900	29.0
5	0.1844	0.2009	0.100	0.073740	0.020828	29.0
6	0.1855	0.1891	0.100	0.034800	0.021383	29.0
7	0.2021	0.2173	0.100	0.073740	0.028169	29.0
8	0.2034	0.2123	0.100	0.056951	0.028701	29.0
9	0.2153	0.2176	0.100	0.034800	0.033562	29.0
10	0.2263	0.2396	0.100	0.073740	0.039532	29.0
11	0.1164	0.1448	0.050	0.052642	0.013130	30.0
12	0.0734	0.0881	0.030	0.026413	0.005661	21.5
13	0.2542	0.2628	0.100	0.071476	0.051334	29.0
14	0.1295	0.1630	0.050	0.067565	0.016920	30.0
15	0.2622	0.2668	0.100	0.056951	0.055755	29.0
16	0.1347	0.1540	0.050	0.052642	0.020786	30.0
17	0.2822	0.2887	0.100	0.071476	0.065414	29.0
18	0.1423	0.1492	0.050	0.037376	0.022964	30.0
19	0.2926	0.2991	0.100	0.075954	0.071102	29.0

CONT. ...

1	2	3	4	5	6	7
20	0.0886	0.0972	0.030	0.026413	0.010880	21.5
21	0.1530	0.1786	0.050	0.067565	0.027127	30.0
22	0.1636	0.1759	0.050	0.052642	0.032416	30.0
23	0.1022	0.1093	0.030	0.026413	0.015298	21.5
24	0.0682	0.0466	0.020	0.025815	0.004403	22.0
25	0.1737	0.1772	0.050	0.037376	0.035902	30.0
26	0.0696	0.0862	0.020	0.025815	0.007894	22.0
27	0.1098	0.1277	0.030	0.044250	0.016752	21.5
28	0.1840	0.2017	0.050	0.067565	0.041207	30.0
29	0.1978	0.2057	0.050	0.052642	0.048146	30.0
30	0.0814	0.0919	0.020	0.025815	0.012906	22.0
31	0.1278	0.1516	0.030	0.026413	0.025153	21.5
32	0.2117	0.2240	0.050	0.067565	0.054608	30.0
33	0.1304	0.1596	0.030	0.061836	0.026197	21.5
34	0.1361	0.1166	0.030	0.044250	0.026762	21.5
35	0.0943	0.1219	0.020	0.044419	0.016524	22.0
36	0.0991	0.1047	0.020	0.025815	0.019112	22.0
37	0.1530	0.1606	0.030	0.044250	0.035902	21.5
38	0.1534	0.1824	0.030	0.083092	0.032329	21.5
39	0.1583	0.1759	0.030	0.061836	0.038587	21.5
40	0.1127	0.1177	0.020	0.025815	0.024522	22.0
41	0.1701	0.1756	0.030	0.044250	0.043899	21.5
42	0.1712	0.1966	0.030	0.083092	0.041063	21.5
43	0.1157	0.1327	0.020	0.044419	0.024156	22.0
44	0.1219	0.1533	0.020	0.062348	0.026342	22.0
45	0.1840	0.1953	0.030	0.061836	0.051281	21.5
46	0.1957	0.2123	0.030	0.083092	0.054173	21.5
47	0.1359	0.1465	0.020	0.044419	0.034499	22.0
48	0.2067	0.2150	0.030	0.061836	0.060843	21.5
49	0.1463	0.1648	0.020	0.062348	0.037932	22.0
50	0.0736	0.0861	0.010	0.025570	0.012818	22.0
51	0.2264	0.2366	0.030	0.083092	0.069404	21.5
52	0.1573	0.1661	0.020	0.044419	0.043998	22.0
53	0.1585	0.1856	0.020	0.083920	0.039011	22.0

Cont. ...

1	2	3	4	5	6	7
54	0.2436	0.2528	0.030	0.083092	0.080889	21.5
55	0.1686	0.1811	0.020	0.062348	0.051387	22.0
56	0.0875	0.0964	0.010	0.025570	0.018246	22.0
57	0.1865	0.2059	0.020	0.083920	0.058303	22.0
58	0.1892	0.1998	0.020	0.062348	0.060956	22.0
59	0.1023	0.1236	0.010	0.044241	0.021934	22.0
60	0.1038	0.1094	0.010	0.025570	0.025000	22.0
61	0.2147	0.2253	0.020	0.083920	0.073682	22.0
62	0.1107	0.2334	0.010	0.083505	0.079796	22.0
63	0.2283	0.2377	0.020	0.083920	0.079668	22.0
64	0.1179	0.1454	0.010	0.054502	0.024120	22.0
65	0.1263	0.1583	0.010	0.044241	0.033163	22.0
66	0.1343	0.1572	0.010	0.054502	0.035356	22.0
67	0.0706	0.0879	0.005	0.027083	0.010695	19.5
68	0.1432	0.1801	0.010	0.083505	0.035856	22.0
69	0.1472	0.1573	0.010	0.044241	0.043998	22.0
70	0.1578	0.1727	0.010	0.054502	0.049755	22.0
71	0.1620	0.1926	0.010	0.083505	0.049338	22.0
72	0.0888	0.0974	0.005	0.027083	0.019979	19.5
73	0.1802	0.1913	0.010	0.054502	0.058470	22.0
74	0.0937	0.1244	0.005	0.045122	0.019402	19.5
75	0.1937	0.2109	0.010	0.083505	0.065885	22.0
76	0.1038	0.1106	0.005	0.027083	0.025769	19.5
77	0.1067	0.1263	0.005	0.045122	0.026069	19.5
78	0.1153	0.1684	0.005	0.062128	0.028006	19.5
79	0.1214	0.1369	0.005	0.045122	0.035084	19.5
80	0.1354	0.1596	0.005	0.062128	0.040199	19.5
81	0.1419	0.1759	0.005	0.084668	0.036542	19.5
82	0.1445	0.1556	0.005	0.045122	0.044995	19.5
83	0.1537	0.1784	0.005	0.084668	0.044645	19.5
84	0.1576	0.1726	0.005	0.062128	0.053363	19.5
85	0.1652	0.1938	0.005	0.084668	0.054934	19.5
86	0.1754	0.1867	0.005	0.062128	0.061642	19.5
87	0.1893	0.2107	0.005	0.084668	0.068622	19.5

Cont. ...

1	2	3	4	5	6	7
88	0.2109	0.2241	0.005	0.084668	0.081730	19.5
89	0.0967	0.1055	0.000	0.026287	0.025769	19.5
90	0.0750	0.0877	0.000	0.026287	0.016128	19.5
91	0.1409	0.1501	0.000	0.045662	0.045296	19.5
92	0.1194	0.1327	0.000	0.045662	0.033962	19.5
93	0.1019	0.1207	0.000	0.045662	0.023854	19.5
94	0.1714	0.1853	0.000	0.062495	0.061071	19.5
95	0.1503	0.1693	0.000	0.062495	0.050858	19.5
96	0.1330	0.1581	0.000	0.062495	0.040726	19.5
97	0.2076	0.2196	0.000	0.085002	0.081860	19.5
98	0.1811	0.2042	0.000	0.085002	0.068502	19.5
99	0.1632	0.1910	0.000	0.085002	0.057745	19.5
100	0.1510	0.1832	0.000	0.085002	0.048974	19.5
101	0.1408	0.1775	0.000	0.085002	0.040774	19.5

APPENDIX IV

EXPERIMENTAL DATA ON UNRESTRICTED BROAD CRESTED RECTANGULAR SIDE WEIR

B = 0.5m and b = 0.5m

S. No.	Upstream flow depth	Downstream flow depth	Height of weir	Width of weir	Upstream discharge	Side weir discharge
	y_0 (m)	y_b (m)	w (m)	L (m)	Q_0 (m^3/s)	Q_s (m^3/s)
1	0.2021	0.2046	0.10	0.10	0.026645	0.024402
2	0.1765	0.1789	0.10	0.10	0.027645	0.015133
3	0.1443	0.1467	0.10	0.10	0.027645	0.006136
4	0.2073	0.2149	0.10	0.10	0.046438	0.026444
5	0.1859	0.1926	0.10	0.10	0.046438	0.018371
6	0.1671	0.1736	0.10	0.10	0.046438	0.012202
7	0.1499	0.1557	0.10	0.10	0.046438	0.007274
8	0.2108	0.2228	0.10	0.10	0.062936	0.027582
9	0.1934	0.2053	0.10	0.10	0.062936	0.020912
10	0.1751	0.1847	0.10	0.10	0.062936	0.014488
11	0.1534	0.1666	0.10	0.10	0.062936	0.007866
12	0.2141	0.2304	0.10	0.10	0.085838	0.028119
13	0.2029	0.2125	0.10	0.10	0.085838	0.024074
14	0.1858	0.2075	0.10	0.10	0.085838	0.017225
15	0.2393	0.2436	0.10	0.10	0.046438	0.041449
16	0.2478	0.2554	0.10	0.10	0.062936	0.044695
17	0.2277	0.2363	0.10	0.10	0.062936	0.034814
18	0.2226	0.2424	0.10	0.10	0.085838	0.033562
19	0.1343	0.1328	0.10	0.10	0.062936	0.004571
20	0.1526	0.1375	0.10	0.10	0.085838	0.007104

APPENDIX V

EXPERIMENTAL DATA ON RESTRICTED BROAD CRESTED RECTANGULAR SIDE WEIR

B = 0.5m and b = 0.5m.

S. No.	Upstream flow depth	Downstream flow depth	Heigth of weir	Width of weir	Upstream discharge	Side weir discharge
	y_0	y_b	w	L	Q_0	Q_s
	(m)	(m)	(m)	(m)	(m^3/s)	(m^3/s)
1	0.1992	0.1997	0.10	0.10	0.02536	0.024009
2	0.1736	0.1746	0.10	0.10	0.02536	0.015131
3	0.1473	0.1491	0.10	0.10	0.02536	0.007239
4	0.1255	0.1248	0.10	0.10	0.02536	0.002880
5	0.2427	0.2452	0.10	0.10	0.04383	0.043400
6	0.2188	0.2231	0.10	0.10	0.04383	0.031980
7	0.1957	0.2015	0.10	0.10	0.04383	0.023250
8	0.1718	0.1765	0.10	0.10	0.04383	0.014240
9	0.1375	0.1388	0.10	0.10	0.04383	0.004265
10	0.2760	0.2791	0.10	0.10	0.06082	0.060670
11	0.2541	0.2587	0.10	0.10	0.06082	0.049550
12	0.2161	0.2253	0.10	0.10	0.06082	0.030090
13	0.1774	0.1853	0.10	0.10	0.06082	0.015630
14	0.1511	0.1617	0.10	0.10	0.06082	0.007582
15	0.3107	0.3171	0.10	0.10	0.08063	0.080374
16	0.2882	0.2963	0.10	0.10	0.08063	0.069580
17	0.2466	0.2565	0.10	0.10	0.08063	0.045900
18	0.2126	0.2298	0.10	0.10	0.08063	0.029930

APPENDIX VI(a)

EXPERIMENTAL DATA ON SHARP CRESTED TRIANGULAR SIDE WEIR

$B = 0.5m;$ and $\theta = \pi/6$

S. No.	Height of weir w (m)	Upstream depth of flow y_0 (m)	Downstream depth of flow y_b (m)	Upstream discharge Q_0 (m^3/s)	Side weir discharge Q_s (m^3/s)	Temp. of water (°c)
1	2	3	4	5	6	7
1	0.05	0.3429	0.3439	0.05226	0.01843	15.0
2	0.05	0.3286	0.3305	0.03773	0.01631	15.0
3	0.05	0.1651	0.1636	0.02633	0.00152	15.0
4	0.05	0.2677	0.2672	0.04584	0.00827	15.0
5	0.05	0.2162	0.2179	0.02633	0.00418	15.0
6	0.05	0.2710	0.2700	0.02633	0.00839	15.0
7	0.05	0.3611	0.3615	0.02633	0.01240	15.0
8	0.05	0.3030	0.3069	0.05226	0.01295	15.0
9	0.05	0.2082	0.2071	0.04860	0.00331	15.0
10	0.05	0.3282	0.3301	0.05171	0.01599	15.0
11	0.05	0.2317	0.2828	0.04584	0.00530	15.0
12	0.05	0.3061	0.3068	0.03827	0.01331	15.0
13	0.03	0.3396	0.3415	0.04832	0.02198	16.0
14	0.03	0.2658	0.2672	0.04832	0.01070	16.0
15	0.03	0.2688	0.2688	0.01283	0.01114	16.0
16	0.03	0.2040	0.2042	0.01864	0.00540	16.0
17	0.03	0.2744	0.2755	0.02920	0.01410	16.0
18	0.03	0.1500	0.1580	0.03247	0.00177	16.0
19	0.03	0.2777	0.2797	0.04832	0.00630	16.0
20	0.03	0.2232	0.2232	0.02920	0.00709	16.0
21	0.03	0.2779	0.2761	0.05917	0.01204	16.0

Cont. ...

1	2	3	4	5	6	7
22	0.03	0.2515	0.2515	0.03234	0.00923	16.0
23	0.03	0.2966	0.2989	0.04832	0.01507	16.0
24	0.03	0.0716	0.0718	0.05917	0.00011	16.0
25	0.03	0.3096	0.3100	0.01864	0.01682	16.0
26	0.03	0.1452	0.1452	0.01864	0.00157	16.0
27	0.03	0.1563	0.1563	0.03247	0.00231	16.0
28	0.03	0.2571	0.2584	0.01864	0.01001	16.0
29	0.03	0.2494	0.2506	0.05917	0.00861	16.0
30	0.03	0.2042	0.2057	0.05694	0.03132	16.0
31	0.03	0.3352	0.3361	0.02920	0.02036	16.0
32	0.02	0.3316	0.3314	0.02974	0.01446	18.5
33	0.02	0.3263	0.3274	0.02260	0.01928	18.5
34	0.02	0.3413	0.3424	0.02911	0.02154	18.5
35	0.02	0.2467	0.2561	0.02918	0.00644	18.5
36	0.02	0.3047	0.3052	0.02156	0.01126	18.5
37	0.02	0.2561	0.2563	0.02320	0.00652	18.5
38	0.02	0.3242	0.3257	0.02116	0.01154	18.5
39	0.02	0.2149	0.2139	0.02918	0.02409	18.5
40	0.01	0.3110	0.3112	0.04783	0.01684	22.0
41	0.01	0.2707	0.2719	0.07112	0.01108	22.0
42	0.01	0.1912	0.1913	0.04783	0.00437	22.0
43	0.01	0.1638	0.1669	0.04783	0.00268	22.0
44	0.01	0.2189	0.2200	0.04109	0.00648	22.0
45	0.01	0.3171	0.3200	0.07112	0.01734	22.0
46	0.01	0.2457	0.2484	0.07112	0.00800	22.0
47	0.01	0.3246	0.3253	0.02251	0.01831	22.0
48	0.01	0.2123	0.2123	0.07112	0.00544	22.0
49	0.01	0.2650	0.2642	0.04109	0.01087	22.0
50	0.01	0.2280	0.2290	0.01111	0.00750	22.0
51	0.01	0.3289	0.3318	0.04059	0.01952	22.0
52	0.00	0.2825	0.2838	0.05651	0.01576	19.0
53	0.00	0.1900	0.1900	0.02905	0.00597	19.0
54	0.00	0.2567	0.2580	0.05651	0.01265	19.0
55	0.00	0.2301	0.2303	0.04069	0.00963	19.0
56	0.00	0.3156	0.3068	0.02037	0.01937	19.0

Cont. ...

1	2	3	4	5	6	7
57	0.00	0.1995	0.2000	0.04069	0.00665	19.0
58	0.00	0.2933	0.2948	0.04069	0.01753	19.0
59	0.00	0.2606	0.2623	0.04069	0.01324	19.0
60	0.00	0.2705	0.2716	0.02905	0.01439	19.0
61	0.00	0.2274	0.2256	0.02905	0.00952	19.0
62	0.00	0.1546	0.1504	0.02794	0.01773	19.0
63	0.00	0.3116	0.3128	0.05651	0.02000	19.0

APPENDIX VI(b)

EXPERIMENTAL DATA ON SHARP CRESTED TRIANGULAR SIDE WEIR

B = 0.5m; and $\theta = \pi/3$

S. No.	Height of weir	Upstream depth of flow	Downstream depth of flow	Upstream discharge	Side weir discharge	Temp. of water
	w (m)	y_0 (m)	y_b (m)	Q_0 (m^3/s)	Q_s (m^3/s)	(^oc)
1	2	3	4	5	6	7
1	0.15	0.3842	0.3856	0.02498	0.02142	21.0
2	0.15	0.3872	0.3887	0.04387	0.02134	21.0
3	0.15	0.2958	0.2959	0.06378	0.00644	21.0
4	0.15	0.3237	0.3241	0.01118	0.01066	21.0
5	0.15	0.3651	0.3679	0.06378	0.01661	21.0
6	0.15	0.3370	0.3373	0.02498	0.01218	21.0
7	0.15	0.2925	0.2928	0.04387	0.00623	21.0
8	0.15	0.3594	0.3611	0.43870	0.01646	21.0
9	0.15	0.3993	0.4020	0.06378	0.02478	21.0
10	0.15	0.3247	0.3278	0.06378	0.00940	21.0
11	0.15	0.3245	0.3249	0.04387	0.01045	21.0
12	0.15	0.3062	0.3081	0.02498	0.00788	21.0
13	0.10	0.2620	0.2618	0.04479	0.00802	25.0
14	0.10	0.2893	0.2906	0.50120	0.01215	25.0
15	0.10	0.2559	0.2586	0.05012	0.00778	25.0
16	0.10	0.2948	0.2959	0.44790	0.01329	25.0
17	0.10	0.2411	0.2431	0.06017	0.00580	25.0
18	0.10	0.2164	0.2174	0.02131	0.00345	25.0
19	0.10	0.2217	0.2231	0.05012	0.00449	25.0
20	0.10	0.3091	0.3016	0.06017	0.01551	25.0

Cont. ...

1	2	3	4	5	6	7
21	0.10	0.2794	0.2803	0.02131	0.01035	25.0
22	0.10	0.3314	0.3340	0.06017	0.02018	25.0
23	0.10	0.3169	0.3197	0.05012	0.01724	25.0
24	0.10	0.3271	0.3271	0.02051	0.01957	25.0
25	0.10	0.2765	0.2798	0.06017	0.01058	25.0
26	0.10	0.2220	0.2230	0.04479	0.00468	25.0
27	0.10	0.2816	0.2823	0.02051	0.01123	25.0
28	0.10	0.3168	0.3181	0.04022	0.01791	25.0
29	0.06	0.1870	0.1907	0.07295	0.00405	30.0
30	0.06	0.3325	0.3372	0.07268	0.03058	30.0
31	0.06	0.1883	0.1907	0.05713	0.00449	30.0
32	0.06	0.2604	0.2655	0.08961	0.01389	30.0
33	0.06	0.2943	0.2976	0.05779	0.02133	30.0
34	0.06	0.2670	0.2693	0.04306	0.01646	30.0
35	0.06	0.2037	0.2048	0.03089	0.00711	30.0
36	0.06	0.2732	0.2763	0.07342	0.01657	30.0
37	0.06	0.2182	0.2204	0.07346	0.00775	30.0
38	0.06	0.3595	0.3669	0.08860	0.03766	30.0
39	0.06	0.3484	0.3516	0.05581	0.03502	30.0
40	0.06	0.3058	0.3119	0.08883	0.02277	30.0
41	0.06	0.2418	0.2432	0.05786	0.01136	30.0
42	0.06	0.2838	0.2890	0.07913	0.01853	30.0
43	0.06	0.2001	0.2011	0.04250	0.00611	30.0
44	0.06	0.3057	0.3082	0.04125	0.02439	30.0
45	0.06	0.2232	0.2262	0.07958	0.00862	30.0
46	0.06	0.3041	0.3074	0.02674	0.02385	30.0
47	0.06	0.3498	0.3520	0.03903	0.03612	30.0
48	0.06	0.3481	0.3559	0.07856	0.03566	30.0
49	0.06	0.2077	0.2117	0.08872	0.00613	30.0
50	0.06	0.2918	0.2935	0.02381	0.02169	30.0
51	0.05	0.2702	0.2801	0.02246	0.01881	30.0
52	0.05	0.2344	0.2352	0.02285	0.01141	30.0
53	0.05	0.1961	0.1965	0.02285	0.00634	30.0
54	0.05	0.2736	0.2756	0.03734	0.01990	30.0
55	0.05	0.2547	0.2586	0.05164	0.01553	30.0

Cont. ...

1	2	3	4	5	6	7
56	0.05	0.2096	0.2120	0.05164	0.00719	30.0
57	0.05	0.2363	0.2392	0.05164	0.01163	30.0
58	0.05	0.1639	0.1637	0.02285	0.00839	30.0
59	0.05	0.2474	0.2476	0.03734	0.01300	30.0
60	0.05	0.1906	0.1934	0.05164	0.00599	30.0
61	0.03	0.1742	0.1752	0.03044	0.00625	30.0
62	0.03	0.2160	0.1826	0.01978	0.00622	30.0
63	0.03	0.1704	0.1754	0.04817	0.00663	30.0
64	0.03	0.2200	0.2212	0.03044	0.01080	30.0
65	0.03	0.2585	0.2674	0.01978	0.01049	30.0
66	0.03	0.1450	0.1497	0.01942	0.00355	30.0
67	0.03	0.0893	0.0903	0.01978	0.00069	30.0
68	0.03	0.2335	0.2375	0.04817	0.01299	30.0
69	0.03	0.2012	0.2044	0.04817	0.00805	30.0
70	0.03	0.2498	0.2509	0.03044	0.01635	30.0
71	0.03	0.1445	0.1445	0.03044	0.00391	30.0
72	0.03	0.1693	0.1645	0.01978	0.00501	30.0
73	0.03	0.1817	0.1452	0.01978	0.00689	30.0
74	0.03	0.2627	0.2646	0.04817	0.01849	30.0
75	0.02	0.2521	0.2527	0.02555	0.00687	31.0
76	0.02	0.2219	0.2231	0.03270	0.01325	31.0
77	0.02	0.1743	0.1768	0.03270	0.00669	31.0
78	0.02	0.1468	0.1500	0.04904	0.00387	31.0
79	0.02	0.1687	0.1713	0.04904	0.00562	31.0
80	0.02	0.2538	0.2577	0.04904	0.01938	31.0
81	0.02	0.2212	0.2239	0.04904	0.02049	31.0
82	0.02	0.1947	0.1964	0.04904	0.00889	31.0
83	0.02	0.1746	0.1765	0.02555	0.00673	31.0
84	0.02	0.2586	0.2599	0.03212	0.02055	31.0
85	0.01	0.2793	0.2832	0.05438	0.02756	22.0
86	0.01	0.2653	0.2673	0.03918	0.02411	22.0
87	0.01	0.1641	0.1695	0.05438	0.00623	22.0
88	0.01	0.1331	0.1358	0.03918	0.00324	22.0
89	0.01	0.1941	0.1992	0.05438	0.01018	22.0
90	0.01	0.2886	0.2945	0.06541	0.02976	22.0

Cont. ...

1	2	3	4	5	6	7
91	0.01	0.2209	0.2237	0.03918	0.01551	22.0
92	0.01	0.3058	0.3081	0.03857	0.03559	22.0
93	0.01	0.2474	0.2560	0.06541	0.01933	22.0
94	0.01	0.3158	0.3117	0.05438	0.03698	22.0
95	0.01	0.2080	0.2151	0.06541	0.01188	22.0
96	0.01	0.1812	0.1818	0.03918	0.00803	22.0
97	0.01	0.2350	0.2409	0.05438	0.01727	22.0
98	0.01	0.3326	0.3369	0.06541	0.04442	22.0
99	0.00	0.1681	0.1706	0.02790	0.00787	31.5
100	0.00	0.2106	0.2126	0.02790	0.01378	31.5
101	0.00	0.2112	0.2113	0.01478	0.01398	31.5
102	0.00	0.1570	0.1583	0.01492	0.00673	31.5
103	0.00	0.2017	0.2086	0.06971	0.01123	31.5
104	0.00	0.2264	0.2299	0.05027	0.01677	31.5
105	0.00	0.1588	0.1587	0.05027	0.03157	31.5
106	0.00	0.1279	0.1293	0.02790	0.00356	31.5
107	0.00	0.1803	0.1838	0.05027	0.03928	31.5
108	0.00	0.1779	0.1823	0.06971	0.00687	31.5
109	0.00	0.1120	0.1128	0.01465	0.00255	31.5
110	0.00	0.1379	0.1378	0.07735	0.00505	31.5
111	0.00	0.2271	0.2357	0.06971	0.01655	31.5
112	0.00	0.1399	0.1393	0.06971	0.00271	31.5

APPENDIX VI(c)

EXPERIMENTAL DATA ON SHARP CRESTED TRIANGULAR SIDE WEIR

B = 0.5m; and $\theta = \pi/2$

S. No.	Height of weir	Upstream depth of flow	Downstream depth of flow	Upstream discharge	Side weir discharge	Temp. of water
	w (m)	y_0 (m)	y_b (m)	Q_0 (m^3/s)	Q_s (m^3/s)	($^o c$)
1	2	3	4	5	6	7
1	0.20	0.3340	0.3344	0.05016	0.00915	16.0
2	0.20	0.3499	0.3519	0.03315	0.01197	16.0
3	0.20	0.2625	0.2630	0.03513	0.00147	16.0
4	0.20	0.3220	0.3209	0.03315	0.00664	16.0
5	0.20	0.2608	0.2612	0.06209	0.00125	16.0
6	0.20	0.2557	0.2564	0.05067	0.00152	16.0
7	0.20	0.2605	0.2617	0.07789	0.00195	16.0
8	0.20	0.2855	0.2869	0.07789	0.00361	16.0
9	0.20	0.4565	0.4577	0.08279	0.02908	16.0
10	0.20	0.3170	0.3204	0.07789	0.00640	16.0
11	0.20	0.4552	0.4537	0.05537	0.02863	16.0
12	0.20	0.2977	0.2999	0.05067	0.00475	16.0
13	0.20	0.3147	0.3151	0.05016	0.00505	16.0
14	0.20	0.3477	0.3481	0.05016	0.01175	16.0
15	0.20	0.4547	0.4562	0.06069	0.02928	16.0
16	0.14	0.3000	0.3000	0.01659	0.01463	18.0
17	0.14	0.3238	0.3246	0.05788	0.02020	18.0
18	0.14	0.3279	0.3299	0.03922	0.02180	18.0
19	0.14	0.2240	0.2240	0.01726	0.00305	18.0
20	0.14	0.3300	0.3302	0.02872	0.02227	18.0
21	0.14	0.2885	0.2890	0.02872	0.01227	18.0

Cont. ....

1	2	3	4	5	6	7
22	0.14	0.2380	0.2380	0.03922	0.00431	18.0
23	0.14	0.2993	0.3010	0.03922	0.01451	18.0
24	0.14	0.2305	0.2309	0.02872	0.00350	18.0
25	0.14	0.2920	0.2938	0.57880	0.01285	18.0
26	0.14	0.2677	0.2678	0.01659	0.00835	18.0
27	0.10	0.2576	0.2616	0.06307	0.01409	19.0
28	0.10	0.2803	0.2857	0.06307	0.02008	19.0
29	0.10	0.1910	0.1912	0.01481	0.00379	19.0
30	0.10	0.2451	0.2475	0.03118	0.01190	19.0
31	0.10	0.1733	0.1742	0.03186	0.00215	19.0
32	0.10	0.2594	0.2600	0.03922	0.00700	19.0
33	0.10	0.2047	0.2053	0.03118	0.00514	19.0
34	0.10	0.2782	0.2797	0.03118	0.01944	19.0
35	0.10	0.2047	0.2050	0.01481	0.00529	19.0
36	0.10	0.2589	0.2589	0.04775	0.01650	19.0
37	0.10	0.2493	0.2500	0.01481	0.01260	19.0
38	0.10	0.2417	0.2487	0.06307	0.01136	19.0
39	0.10	0.2187	0.2227	0.06307	0.00697	19.0
40	0.06	0.3008	0.3140	0.01173	0.03736	19.5
41	0.06	0.3119	0.3202	0.08767	0.04138	19.5
42	0.06	0.2435	0.2589	0.11793	0.01953	19.5
43	0.06	0.2158	0.2265	0.09576	0.01298	19.5
44	0.06	0.2465	0.2560	0.09922	0.02086	19.5
45	0.06	0.2124	0.2129	0.03537	0.01327	19.5
46	0.06	0.2725	0.2857	0.11813	0.02885	19.5
47	0.06	0.3222	0.3317	0.11440	0.04308	19.5
48	0.06	0.2657	0.2745	0.09402	0.02585	19.5
49	0.06	0.2194	0.2303	0.09898	0.01427	19.5
50	0.06	0.2607	0.2720	0.09938	0.02509	19.5
51	0.06	0.2327	0.2445	0.00992	0.01730	19.5
52	0.06	0.2640	0.2662	0.03588	0.02586	19.5
53	0.05	0.2522	0.2596	0.06334	0.02463	19.5
54	0.05	0.2546	0.2608	0.02867	0.02767	19.5
55	0.05	0.1186	0.1186	0.01739	0.00132	19.5
56	0.05	0.1539	0.1609	0.06658	0.00470	19.5
57	0.05	0.2091	0.2134	0.04672	0.01424	19.5
58	0.05	0.2004	0.2072	0.06334	0.01154	19.5

Cont. ...

1	2	3	4	5	6	7
59	0.05	0.2056	0.2066	0.02825	0.01374	19.5
60	0.05	0.2004	0.2049	0.05252	0.03162	19.5
61	0.05	0.1871	0.1879	0.01719	0.00971	19.5
62	0.05	0.2697	0.2734	0.04672	0.03052	19.5
63	0.05	0.1548	0.1564	0.02867	0.00488	19.5
64	0.05	0.1440	0.1456	0.02825	0.00321	19.5
65	0.05	0.1715	0.1731	0.02825	0.00628	19.5
66	0.05	0.2165	0.2174	0.01719	0.01549	19.5
67	0.05	0.2216	0.2269	0.05252	0.01629	19.5
68	0.05	0.1379	0.1335	0.06334	0.00419	19.5
69	0.05	0.1561	0.1583	0.05252	0.00451	19.5
70	0.05	0.3049	0.3087	0.06334	0.04485	19.5
71	0.05	0.2143	0.2169	0.02867	0.01550	19.5
72	0.05	0.1736	0.1779	0.05252	0.00705	19.5
73	0.05	0.2357	0.2371	0.02825	0.02060	19.5
74	0.05	0.3067	0.3099	0.04672	0.04580	19.5
75	0.03	0.1811	0.1846	0.01313	0.00740	19.0
76	0.03	0.1788	0.1791	0.01155	0.00710	19.0
77	0.03	0.1937	0.2070	0.06658	0.00938	19.0
78	0.03	0.1539	0.1609	0.06658	0.00670	19.0
79	0.03	0.2023	0.2082	0.03131	0.01144	19.0
80	0.03	0.1484	0.1499	0.02391	0.00665	19.0
81	0.03	0.2111	0.2145	0.02391	0.01274	19.0
82	0.03	0.1478	0.1478	0.01155	0.00657	19.0
83	0.03	0.1845	0.1858	0.02391	0.01274	19.0
84	0.03	0.1816	0.1898	0.06658	0.00656	19.0
85	0.03	0.2101	0.2235	0.06658	0.01227	19.0
86	0.03	0.1476	0.1493	0.03131	0.00635	19.0
87	0.02	0.1617	0.1866	0.07402	0.00585	20.0
88	0.02	0.1595	0.1643	0.03320	0.00787	20.0
89	0.02	0.1564	0.1587	0.01699	0.00738	20.0
90	0.02	0.1933	0.1950	0.03320	0.01193	20.0
91	0.02	0.1491	0.1582	0.05228	0.00553	20.0
92	0.02	0.2007	0.2084	0.05228	0.01332	20.0
93	0.02	0.1462	0.1502	0.03320	0.00590	20.0
94	0.02	0.2040	0.2180	0.07402	0.01324	20.0
95	0.02	0.1898	0.2038	0.07402	0.00985	20.0

Cont. ...

1	2	3	4	5	6	7
96	0.02	0.1950	0.1953	0.01692	0.01243	20.0
97	0.02	0.1876	0.1939	0.05228	0.01017	20.0
98	0.02	0.1603	0.1796	0.05228	0.00741	20.0
99	0.02	0.1339	0.1363	0.01699	0.00457	20.0
100	0.01	0.2028	0.2129	0.06333	0.01936	22.0
101	0.01	0.1824	0.1953	0.07354	0.01297	22.0
102	0.01	0.1996	0.2125	0.07354	0.01751	22.0
103	0.01	0.1771	0.1868	0.06333	0.01261	22.0
104	0.01	0.2113	0.2150	0.03840	0.02236	22.0
105	0.01	0.1727	0.1770	0.03840	0.01597	22.0
106	0.01	0.2240	0.2296	0.04928	0.02602	22.0
107	0.01	0.1601	0.1661	0.04928	0.00946	22.0
108	0.01	0.2422	0.2523	0.07354	0.03179	22.0
109	0.01	0.1261	0.1313	0.03840	0.00484	22.0
110	0.01	0.1853	0.1935	0.04928	0.01519	22.0
111	0.01	0.1136	0.1140	0.04928	0.00239	22.0
112	0.01	0.2308	0.2407	0.06333	0.02864	22.0
113	0.01	0.2140	0.2270	0.07354	0.01839	22.0
114	0.01	0.2512	0.2540	0.03840	0.03542	22.0
115	0.01	0.1017	0.1017	0.03840	0.00179	22.0
116	0.00	0.1748	0.1809	0.03584	0.01559	22.0
117	0.00	0.2180	0.2259	0.05334	0.02732	22.0
118	0.00	0.0597	0.0615	0.01290	0.00074	22.0
119	0.00	0.1618	0.1784	0.05334	0.01742	22.0
120	0.00	0.1744	0.1901	0.06912	0.01383	22.0
121	0.00	0.2502	0.2566	0.05334	0.03944	22.0
122	0.00	0.2345	0.2376	0.03584	0.03311	22.0
123	0.00	0.2050	0.2077	0.03584	0.02350	22.0
124	0.00	0.1514	0.1517	0.01298	0.01151	22.0
125	0.00	0.2624	0.2672	0.04928	0.04132	22.0
126	0.00	0.0917	0.0923	0.01290	0.00315	22.0
127	0.00	0.1187	0.1232	0.03643	0.00433	22.0
128	0.00	0.1977	0.2099	0.06912	0.03405	22.0
129	0.00	0.1420	0.1479	0.03643	0.00901	22.0
130	0.00	0.1930	0.2034	0.05334	0.02015	22.0
131	0.00	0.2260	0.2360	0.06912	0.02969	22.0

APPENDIX VI(d)

EXPERIMENTAL DATA ON SHARP CRESTED TRIANGULAR SIDE WEIR

$B = 0.5m$; and $\theta = 2\pi/3$

S. No.	Height of weir	Upstream depth of flow	Downstream depth of flow	Upstream discharge	Side weir discharge	Temp. of water
	w (m)	y_0 (m)	y_b (m)	Q_0 (m^3/s)	Q_s (m^3/s)	(^oc)
1	2	3	4	5	6	7
1	0.15	0.2307	0.2308	0.02978	0.00459	31.5
2	0.15	0.2326	0.2348	0.05661	0.00471	31.5
3	0.15	0.1934	0.1963	0.05661	0.00093	31.5
4	0.15	0.2757	0.2767	0.02978	0.01412	31.5
5	0.15	0.2129	0.2130	0.01402	0.00252	31.5
6	0.15	0.2452	0.2464	0.01402	0.00694	31.5
7	0.15	0.2765	0.2761	0.01402	0.01398	31.5
8	0.15	0.2487	0.2498	0.05661	0.00742	31.5
9	0.15	0.2112	0.2123	0.05661	0.00214	31.5
10	0.15	0.2680	0.2724	0.05661	0.01083	31.5
11	0.15	0.1925	0.1904	0.02978	0.00087	31.5
12	0.15	0.2515	0.2515	0.02978	0.00801	31.5
13	0.10	0.1677	0.1691	0.03001	0.00252	32.0
14	0.10	0.2022	0.2030	0.03001	0.00747	32.0
15	0.10	0.1724	0.1734	0.01692	0.00326	32.0
16	0.10	0.2088	0.2089	0.01692	0.00858	32.0
17	0.10	0.1799	0.1814	0.04310	0.00381	32.0
18	0.10	0.1468	0.1457	0.01692	0.00095	32.0
19	0.10	0.1479	0.1490	0.04310	0.00190	32.0
20	0.10	0.2297	0.2322	0.04310	0.01387	32.0

Cont. ...

1	2	3	4	5	6	7
21	0.10	0.2379	0.2380	0.01692	0.01602	32.0
22	0.10	0.2000	0.2023	0.04310	0.00695	32.0
23	0.10	0.1615	0.1634	0.04310	0.00188	32.0
24	0.10	0.2328	0.2357	0.03001	0.01484	32.0
25	0.06	0.2008	0.2141	0.06561	0.01875	28.0
26	0.06	0.1881	0.1988	0.06206	0.01531	28.0
27	0.06	0.1890	0.2056	0.07308	0.01524	28.0
28	0.06	0.1978	0.2005	0.02646	0.01790	28.0
29	0.06	0.1974	0.1982	0.01949	0.01738	28.0
30	0.06	0.1638	0.1766	0.06640	0.00907	28.0
31	0.06	0.1852	0.1976	0.06812	0.01387	28.0
32	0.06	0.2031	0.2094	0.04144	0.01952	28.0
33	0.06	0.1873	0.2118	0.08549	0.01582	28.0
34	0.06	0.1734	0.1766	0.02725	0.01156	28.0
35	0.06	0.1969	0.2059	0.05413	0.01971	28.0
36	0.06	0.1791	0.2000	0.08253	0.01391	28.0
37	0.06	0.1630	0.1672	0.02936	0.00953	28.0
38	0.06	0.1935	0.1987	0.03895	0.01698	28.0
39	0.06	0.1897	0.1964	0.05172	0.01554	28.0
40	0.06	0.1699	0.1786	0.05360	0.01059	28.0
41	0.06	0.1902	0.2011	0.06251	0.01558	28.0
42	0.06	0.1814	0.1878	0.04060	0.01381	28.0
43	0.06	0.1756	0.1805	0.04133	0.01201	28.0
44	0.06	0.1669	0.1713	0.04125	0.00993	28.0
45	0.06	0.1960	0.1997	0.02921	0.01748	28.0
46	0.05	0.1356	0.1426	0.04619	0.00475	28.0
47	0.05	0.1686	0.1709	0.02122	0.01171	28.0
48	0.05	0.1588	0.1588	0.00819	0.00640	28.0
49	0.05	0.1406	0.1417	0.02122	0.00573	28.0
50	0.05	0.1541	0.1551	0.03399	0.00855	28.0
51	0.05	0.1812	0.1901	0.03399	0.01343	28.0
52	0.05	0.1070	0.1062	0.00622	0.00175	28.0
53	0.05	0.1541	0.1573	0.04619	0.00743	28.0
54	0.05	0.1296	0.1327	0.03399	0.00385	28.0
55	0.05	0.1927	0.1932	0.02314	0.01831	28.0

Cont. ...

1	2	3	4	5	6	7
56	0.02	0.1434	0.1502	0.02658	0.01256	28.0
57	0.02	0.1332	0.1446	0.04724	0.00957	28.0
58	0.02	0.0927	0.0970	0.02658	0.00290	28.0
59	0.02	0.1383	0.1396	0.01142	0.01107	28.0
60	0.02	0.1108	0.1137	0.01142	0.00565	28.0
61	0.02	0.1033	0.1102	0.04724	0.00404	28.0
62	0.02	0.1198	0.1245	0.02658	0.00709	28.0
63	0.02	0.0813	0.0828	0.01142	0.00197	28.0
64	0.01	0.0941	0.0964	0.01331	0.00432	28.5
65	0.01	0.1197	0.1248	0.02580	0.00886	28.5
66	0.01	0.1293	0.1348	0.02580	0.01138	28.5
67	0.01	0.1685	0.1730	0.02580	0.01625	28.5
68	0.01	0.1356	0.1370	0.01331	0.01075	28.5
69	0.01	0.1134	0.1156	0.01331	0.00739	28.5
70	0.01	0.1458	0.1482	0.01737	0.01495	28.5
71	0.01	0.0889	0.0911	0.01737	0.00349	28.5
72	0.01	0.1147	0.1176	0.01737	0.00793	28.5
73	0.01	0.1007	0.1044	0.02580	0.00520	28.5
74	0.01	0.0735	0.0786	0.01331	0.00219	28.5
75	0.01	0.1192	0.1220	0.04602	0.01013	18.0
76	0.01	0.1326	0.1387	0.06224	0.01281	18.0
77	0.01	0.0952	0.1001	0.02807	0.00518	18.0
78	0.01	0.1343	0.1398	0.02807	0.01409	18.0
79	0.01	0.1076	0.1120	0.02807	0.00754	18.0
80	0.01	0.1413	0.1415	0.02807	0.01627	18.0
81	0.01	0.1282	0.1295	0.02807	0.01076	18.0
82	0.01	0.1417	0.1460	0.06224	0.01576	18.0
83	0.01	0.1021	0.1112	0.04602	0.00384	18.0
84	0.01	0.1318	0.1390	0.04602	0.01325	18.0
85	0.01	0.0799	0.0810	0.02807	0.00223	18.0
86	0.01	0.1522	0.1561	0.02807	0.02023	18.0
87	0.00	0.1400	0.1257	0.02455	0.01613	28.5
88	0.00	0.0752	0.0806	0.02642	0.00192	28.5
89	0.00	0.1133	0.1151	0.01406	0.01068	28.5
90	0.00	0.0607	0.0620	0.01290	0.00117	28.5

Cont. ...

1	2	3	4	5	6	7
91	0.00	0.1250	0.1275	0.01290	0.01207	28.5
92	0.00	0.0532	0.0562	0.01290	0.00093	28.5
93	0.00	0.1310	0.1420	0.04267	0.01312	28.5
94	0.00	0.0886	0.0948	0.02642	0.00419	28.5
95	0.00	0.1228	0.1280	0.02643	0.01111	28.5
96	0.00	0.1303	0.1317	0.01357	0.01281	28.5
97	0.00	0.1163	0.1298	0.04267	0.00870	28.5
98	0.00	0.1032	0.1089	0.02642	0.00661	28.5
99	0.00	0.0788	0.0815	0.01290	0.00320	28.5
100	0.00	0.1439	0.1520	0.04308	0.01712	28.5

APPENDIX VII

EXPERIMENTAL DATA ON SHARP CRESTED SIDE SLUICE GATE UNDER FREE FLOW

B = 0.5m, b = 0.5m

S. No.	Upstream depth of flow	Downstrem depth of flow	Upstream discharge	Sluice gate discharge	Sluice gate opening	Temp. of water
	y_0 (m)	y_b (m)	Q_0 (m^3/s)	Q_s (m^3/s)	a (m)	(^oc)
1	2	3	4	5	6	7
1	0.2632	0.2726	0.06448	0.00716	0.010	29.5
2	0.3103	0.3116	0.02833	0.00847	0.010	29.5
3	0.1786	0.1789	0.03762	0.00770	0.010	30.0
4	0.1201	0.1234	0.03762	0.00636	0.010	30.0
5	0.3119	0.3123	0.02988	0.01042	0.010	30.0
6	0.1425	0.1446	0.03096	0.00690	0.010	30.0
7	0.2956	0.2970	0.04495	0.01884	0.025	30.0
8	0.2293	0.2304	0.04953	0.01435	0.025	30.0
9	0.2180	0.2237	0.04801	0.01653	0.025	30.0
10	0.1495	0.1579	0.04801	0.01383	0.025	30.0
11	0.1290	0.1427	0.04801	0.01258	0.025	30.0
12	0.2525	0.2534	0.02398	0.01790	0.025	30.0
13	0.1402	0.1426	0.02585	0.01317	0.025	30.0
14	0.0838	0.0992	0.02585	0.00981	0.025	30.0
15	0.2839	0.2866	0.06227	0.01818	0.025	32.5
16	0.2145	0.2223	0.06227	0.01539	0.025	32.5
17	0.1567	0.1693	0.06227	0.01352	0.025	32.5
18	0.1458	0.1631	0.06227	0.01305	0.025	32.5

Cont. . . .

1	2	3	4	5	6	7
19	0.3727	0.3757	0.06227	0.02079	0.025	32.5
20	0.3582	0.3834	0.06227	0.02079	0.025	32.5
21	0.0692	0.0913	0.02703	0.00879	0.025	32.5
22	0.1279	0.1292	0.01418	0.01197	0.025	32.5
23	0.1525	0.1527	0.01522	0.01302	0.025	32.5
24	0.0929	0.0972	0.01888	0.00992	0.025	32.5
25	0.0745	0.0798	0.01682	0.00896	0.025	32.5
26	0.3048	0.3276	0.07445	0.02032	0.025	30.0
27	0.2482	0.2724	0.07445	0.01815	0.025	30.0
28	0.2450	0.2709	0.07445	0.01815	0.025	30.0
29	0.1971	0.2279	0.07445	0.01649	0.025	30.0
30	0.1725	0.3057	0.07812	0.01530	0.025	30.0
31	0.2959	0.3194	0.01975	0.01975	0.025	30.0
32	0.2529	0.2815	0.01865	0.01867	0.025	30.0
33	0.2134	0.2487	0.01679	0.01679	0.025	30.0
34	0.3357	0.3386	0.08433	0.03769	0.050	30.0
35	0.2584	0.3673	0.08433	0.03271	0.050	30.0
36	0.2591	0.2688	0.08433	0.03291	0.050	30.0
37	0.2104	0.2265	0.08433	0.02970	0.050	30.0
38	0.1606	0.1851	0.08433	0.02567	0.050	30.0
39	0.1320	0.1863	0.08433	0.02140	0.050	30.0
40	0.2157	0.2238	0.05995	0.02940	0.050	30.0
41	0.1682	0.1852	0.06067	0.02553	0.050	30.0
42	0.1282	0.1548	0.06067	0.02169	0.050	30.0
43	0.3647	0.3662	0.06067	0.03915	0.050	30.0
44	0.3605	0.3617	0.06067	0.03921	0.050	30.0
45	0.1875	0.1876	0.02795	0.02648	0.050	31.0
46	0.3649	0.3650	0.04368	0.03966	0.050	31.0
47	0.2121	0.2166	0.04368	0.02867	0.050	31.0
48	0.1607	0.1692	0.04368	0.02432	0.050	31.0
49	0.1107	0.1305	0.04368	0.01923	0.050	31.0
50	0.0912	0.1148	0.04368	0.01563	0.050	31.0
51	0.2522	0.2569	0.04727	0.04550	0.075	30.0
52	0.2551	0.2573	0.04727	0.04792	0.075	30.0
53	0.1423	0.1527	0.04727	0.03213	0.075	30.0

Cont. ...

1	2	3	4	5	6	7
54	0.1183	0.1409	0.04814	0.02651	0.075	30.0
55	0.1249	0.1331	0.03267	0.02693	0.075	30.0
56	0.1282	0.1351	0.03267	0.02841	0.075	30.0
57	0.3670	0.3696	0.07382	0.05957	0.075	30.0
58	0.1901	0.2125	0.07611	0.03928	0.075	30.0
59	0.1622	0.1830	0.07611	0.03398	0.075	30.0
60	0.1267	0.1673	0.07611	0.02752	0.075	30.0
61	0.2741	0.2821	0.08235	0.04913	0.075	30.0
62	0.3483	0.3531	0.08235	0.05859	0.075	30.0
63	0.2034	0.2270	0.08235	0.04107	0.075	30.0
64	0.2009	0.2237	0.08466	0.04037	0.075	30.0
65	0.1434	0.1901	0.08659	0.03052	0.075	30.0
66	0.1734	0.2033	0.08659	0.03708	0.075	30.0
67	0.2189	0.2371	0.08659	0.04153	0.075	30.0
68	0.2821	0.2903	0.08659	0.05054	0.075	30.0
69	0.3675	0.3731	0.08659	0.05950	0.075	30.0
70	0.2109	0.2276	0.08309	0.05191	0.100	30.0
71	0.1800	0.2099	0.08309	0.04568	0.100	30.0
72	0.3280	0.3338	0.08309	0.07220	0.100	30.0
73	0.2687	0.2797	0.08309	0.06278	0.100	30.0
74	0.2118	0.2325	0.08309	0.05783	0.100	30.0
75	0.1855	0.1914	0.04729	0.04652	0.100	30.0
76	0.1569	0.1686	0.04729	0.03847	0.100	30.0
77	0.1627	0.1691	0.04157	0.04040	0.100	30.0

APPENDIX VIII

EXPERIMENTAL DATA ON SHARP CRESTED SIDE SLUICE GATE UNDER SUBMERGED FLOW

B = 0.5m, b = 0.5m

S. No.	Upstream depth of flow	Downstrem depth of flow	Tail water depth	Upstream discharge	Sluice gate discharge	Sluice gate opening	Temp. of water
	y_0 (m)	y_b (m)	y_t (m)	Q_0 (m^3/s)	Q_s (m^3/s)	a (m)	(°c)
1	2	3	4	5	6	7	8
1	0.1846	0.1877	0.0924	0.06264	0.0042	0.010	29.5
2	0.2063	0.2100	0.0550	0.07556	0.0067	0.010	29.5
3	0.3238	0.3245	0.0999	0.03093	0.0074	0.010	29.5
4	0.3381	0.3388	0.0965	0.03762	0.0098	0.012	30.0
5	0.3607	0.3691	0.1164	0.03762	0.0095	0.012	30.0
6	0.3786	0.3793	0.1672	0.03762	0.0087	0.012	30.0
7	0.2160	0.2166	0.1279	0.03762	0.0057	0.012	30.0
8	0.1935	0.1949	0.0907	0.03762	0.0061	0.012	30.0
9	0.1848	0.1865	0.0567	0.03762	0.0072	0.012	30.0
10	0.1226	0.1254	0.0530	0.03762	0.0052	0.012	30.0
11	0.1258	0.1273	0.0658	0.03762	0.0046	0.012	30.0
12	0.3530	0.3544	0.1408	0.03762	0.0090	0.012	30.0
13	0.3465	0.3469	0.1553	0.02988	0.0086	0.012	30.0
14	0.3215	0.3221	0.1140	0.02988	0.0094	0.012	30.0
15	0.2247	0.2265	0.1002	0.03096	0.0070	0.012	30.0
16	0.1541	0.1563	0.0685	0.03096	0.0053	0.012	30.0
17	0.1570	0.1589	0.0849	0.03096	0.0049	0.012	30.0
18	0.1577	0.1617	0.1006	0.03096	0.0047	0.012	30.0

Cont. ...

1	2	3	4	5	6	7	8
19	0.3165	0.3180	0.1248	0.04495	0.0178	0.025	30.0
20	0.3262	0.3282	0.1431	0.04495	0.0169	0.025	30.0
21	0.3252	0.3579	0.1898	0.04495	0.0154	0.025	30.0
22	0.3752	0.3765	0.2255	0.04495	0.0144	0.025	30.0
23	0.2584	0.2594	0.1801	0.04495	0.0105	0.025	30.0
24	0.2604	0.2642	0.1480	0.04953	0.0122	0.025	30.0
25	0.2461	0.2485	0.1327	0.04953	0.0129	0.025	30.0
26	0.1639	0.1709	0.0691	0.04801	0.0116	0.025	30.0
27	0.1728	0.1790	0.0963	0.04801	0.0106	0.025	30.0
28	0.1883	0.1924	0.1297	0.04801	0.0100	0.025	30.0
29	0.1644	0.1695	0.1183	0.04801	0.0083	0.025	30.0
30	0.1534	0.1599	0.0788	0.04801	0.0102	0.025	30.0
31	0.2711	0.2732	0.1270	0.02266	0.0162	0.025	30.0
32	0.2858	0.2867	0.1439	0.02235	0.0155	0.025	30.0
33	0.3146	0.3162	0.1819	0.02159	0.0145	0.025	30.0
34	0.1017	0.1080	0.0556	0.02585	0.0081	0.025	30.0
35	0.1111	0.1162	0.0703	0.02585	0.0072	0.025	30.0
36	0.1199	0.1230	0.0915	0.02585	0.0061	0.025	30.0
37	0.0973	0.1009	0.0912	0.02585	0.0034	0.025	30.0
38	0.0902	0.0949	0.0779	0.02585	0.0044	0.025	30.0
39	0.0773	0.0889	0.0584	0.02585	0.0054	0.025	30.0
40	0.3726	0.3722	0.3009	0.06227	0.0097	0.025	32.5
41	0.3739	0.3751	0.3045	0.06227	0.0095	0.025	32.5
42	0.3587	0.3594	0.2683	0.06227	0.0110	0.025	32.5
43	0.3097	0.3128	0.1590	0.06227	0.0152	0.025	32.5
44	0.2491	0.2515	0.1410	0.06227	0.0116	0.025	32.5
45	0.2684	0.2707	0.1947	0.06227	0.0098	0.025	32.5
46	0.2559	0.2585	0.1483	0.06227	0.0121	0.025	32.5
47	0.2855	0.2875	0.2422	0.06227	0.0076	0.025	32.5
48	0.2157	0.2190	0.1969	0.06227	0.0052	0.025	32.5
49	0.1997	0.2050	0.1611	0.06227	0.0073	0.025	32.5
50	0.1921	0.1980	0.1349	0.06227	0.0090	0.025	32.5
51	0.1748	0.1772	0.1263	0.01147	0.0090	0.025	32.5
52	0.2210	0.2228	0.2030	0.00801	0.0053	0.025	32.5
53	0.1959	0.1973	0.1545	0.02213	0.0079	0.025	32.5

Cont. ...

1	2	3	4	5	6	7	8
54	0.1867	0.1875	0.1307	0.01443	0.0096	0.025	32.5
55	0.1781	0.1787	0.1122	0.01443	0.0109	0.025	32.5
56	0.1086	0.1111	0.0702	0.01639	0.0066	0.025	32.5
57	0.1148	0.1172	0.0917	0.01631	0.0061	0.025	32.5
58	0.1375	0.1383	0.1241	0.01515	0.0040	0.025	32.5
59	0.3702	0.3922	0.2142	0.06985	0.0153	0.025	31.0
60	0.3827	0.3739	0.2066	0.07445	0.0149	0.025	31.0
61	0.3388	0.3603	0.1698	0.07445	0.0162	0.025	31.0
62	0.3323	0.3537	0.1282	0.07445	0.0172	0.025	31.0
63	0.2719	0.2978	0.1146	0.07445	0.0151	0.025	31.0
64	0.2796	0.3038	0.1397	0.07445	0.0141	0.025	31.0
65	0.2954	0.3189	0.1905	0.07445	0.0126	0.025	31.0
66	0.3154	0.3385	0.2463	0.07445	0.0103	0.025	31.0
67	0.2545	0.2755	0.2170	0.07445	0.0076	0.025	31.0
68	0.2373	0.2613	0.1715	0.07445	0.0105	0.025	31.0
69	0.2278	0.2538	0.1455	0.07445	0.0117	0.025	31.0
70	0.2192	0.2464	0.1078	0.07445	0.0127	0.025	31.0
71	0.2084	0.2366	0.1336	0.07812	0.0117	0.025	31.0
72	0.2258	0.2502	0.1631	0.07812	0.0103	0.025	31.0
73	0.2369	0.2623	0.1968	0.07812	0.0080	0.025	31.0
74	0.3549	0.3754	0.2790	0.09729	0.0109	0.025	31.0
75	0.3564	0.3781	0.2821	0.09729	0.0110	0.025	31.0
76	0.3348	0.3572	0.1962	0.09729	0.0142	0.025	31.0
77	0.3276	0.3518	0.1664	0.09729	0.0152	0.025	31.0
78	0.3214	0.3429	0.1367	0.09729	0.0164	0.025	31.0
79	0.2882	0.3093	0.1555	0.09729	0.0141	0.025	31.0
80	0.2903	0.3153	0.1849	0.09729	0.0129	0.025	31.0
81	0.3075	0.3297	0.2466	0.09729	0.0100	0.025	31.0
82	0.3107	0.3309	0.2485	0.09729	0.0096	0.025	31.0
83	0.2669	0.2908	0.2257	0.09729	0.0067	0.025	31.0
84	0.2545	0.2797	0.1818	0.09729	0.0112	0.025	31.0
85	0.2503	0.2729	0.1559	0.09729	0.0125	0.025	31.0
86	0.2432	0.2685	0.1305	0.09729	0.0135	0.025	31.0
87	0.3622	0.3638	0.2676	0.08433	0.0219	0.050	30.0
88	0.3325	0.3372	0.2148	0.08433	0.0245	0.050	30.0

Cont. ...

1	2	3	4	5	6	7	8
89	0.3098	0.3135	0.1568	0.08433	0.0274	0.050	30.0
90	0.2571	0.2662	0.1503	0.08433	0.0239	0.050	30.0
91	0.2773	0.2841	0.1941	0.08433	0.0215	0.050	30.0
92	0.3312	0.3350	0.2928	0.08433	0.0144	0.050	30.0
93	0.2804	0.2830	0.2599	0.08433	0.0121	0.050	30.0
94	0.2412	0.2483	0.1934	0.08433	0.0175	0.050	30.0
95	0.2248	0.2348	0.1637	0.08433	0.0199	0.050	30.0
96	0.1961	0.2090	0.1401	0.08433	0.0179	0.050	30.0
97	0.2204	0.2275	0.1876	0.08433	0.0142	0.050	30.0
98	0.2480	0.2518	0.2273	0.08433	0.0105	0.050	30.0
99	0.2153	0.2205	0.2030	0.08433	0.0087	0.050	30.0
100	0.1647	0.1969	0.1381	0.08433	0.0134	0.050	30.0
101	0.3720	0.3720	0.3116	0.05995	0.0179	0.050	30.0
102	0.3227	0.3235	0.2323	0.05995	0.0219	0.050	30.0
103	0.2919	0.2933	0.1745	0.05995	0.0240	0.050	30.0
104	0.2209	0.2274	0.1346	0.06067	0.0212	0.050	30.0
105	0.2564	0.2611	0.2009	0.06067	0.0181	0.050	30.0
106	0.3302	0.3312	0.3082	0.06067	0.0112	0.050	30.0
107	0.2580	0.2594	0.2492	0.06067	0.0081	0.050	30.0
108	0.1998	0.2064	0.1685	0.06067	0.0152	0.050	30.0
109	0.1742	0.1842	0.1473	0.06067	0.0140	0.050	30.0
110	0.2208	0.2246	0.2105	0.06067	0.0070	0.050	30.0
111	0.2444	0.2458	0.1656	0.02795	0.0228	0.050	31.0
112	0.2975	0.2980	0.2248	0.02795	0.0202	0.050	31.0
113	0.3582	0.3585	0.2966	0.02795	0.0177	0.050	31.0
114	0.2481	0.2485	0.2203	0.02795	0.0118	0.050	31.0
115	0.2101	0.2191	0.1671	0.02795	0.0138	0.050	31.0
116	0.2495	0.2500	0.2946	0.04368	0.0078	0.050	31.0
117	0.3689	0.3697	0.1864	0.04727	0.0456	0.075	30.0
118	0.3711	0.3730	0.2882	0.04727	0.0331	0.075	30.0
119	0.3348	0.3358	0.2481	0.04727	0.0345	0.075	30.0
120	0.2968	0.2996	0.2126	0.04727	0.0351	0.075	30.0
121	0.2213	0.2278	0.1661	0.04727	0.0273	0.075	30.0
122	0.2682	0.2720	0.2206	0.04727	0.0252	0.075	30.0
123	0.3382	0.3403	0.3048	0.04727	0.0215	0.075	30.0

Cont. ...

1	2	3	4	5	6	7	8
124	0.3310	0.3313	0.3200	0.04727	0.0115	0.075	30.0
125	0.2427	0.2455	0.2240	0.04727	0.0180	0.075	30.0
126	0.1995	0.2075	0.1699	0.04814	0.0212	0.075	30.0
127	0.3640	0.3640	0.3520	0.04814	0.0139	0.075	30.0
128	0.3725	0.3730	0.3588	0.04814	0.0139	0.075	30.0
129	0.3682	0.3685	0.1288	0.04814	0.0119	0.075	30.0
130	0.2593	0.2606	0.2135	0.03267	0.0247	0.075	30.0
131	0.2152	0.2161	0.1636	0.03267	0.0257	0.075	30.0
132	0.1920	0.1948	0.1752	0.03267	0.0122	0.075	30.0
133	0.1583	0.1673	0.1347	0.03267	0.0147	0.075	30.0
134	0.3690	0.3724	0.3321	0.07382	0.0221	0.075	30.0
135	0.3643	0.3692	0.3206	0.07382	0.0241	0.075	30.0
136	0.3187	0.3234	0.2627	0.07382	0.0279	0.075	30.0
137	0.2741	0.2815	0.2008	0.07382	0.0313	0.075	30.0
138	0.2451	0.2539	0.2008	0.07612	0.0261	0.075	30.0
139	0.2852	0.2892	0.2498	0.07612	0.0221	0.075	30.0
140	0.3506	0.3531	0.3328	0.07612	0.0147	0.075	30.0
141	0.3002	0.3019	0.2884	0.07612	0.0118	0.075	30.0
142	0.2422	0.2489	0.2220	0.07612	0.0192	0.075	30.0
143	0.2251	0.2336	0.1977	0.07612	0.0215	0.075	30.0
144	0.3995	0.3727	0.3326	0.08466	0.0250	0.075	30.0
145	0.3335	0.3367	0.2847	0.08466	0.0270	0.075	30.0
146	0.2887	0.2955	0.2469	0.08466	0.0233	0.075	30.0
147	0.3192	0.3230	0.2846	0.08466	0.0195	0.075	30.0
148	0.3571	0.3595	0.3375	0.08466	0.0146	0.075	30.0
149	0.3210	0.3226	0.3109	0.08466	0.0117	0.075	30.0
150	0.2801	0.2849	0.2591	0.08466	0.0184	0.075	30.0
151	0.2568	0.2646	0.2295	0.08466	0.0212	0.075	30.0
152	0.3701	0.3741	0.3045	0.08136	0.0379	0.100	30.0
153	0.3439	0.3478	0.2726	0.08136	0.0412	0.100	30.0
154	0.3229	0.3276	0.2459	0.08136	0.0430	0.100	30.0
155	0.2877	0.2955	0.2340	0.08309	0.0361	0.100	30.0
156	0.3525	0.3581	0.3047	0.08309	0.0305	0.100	30.0
157	0.3100	0.3136	0.2888	0.08309	0.0242	0.100	30.0
158	0.2885	0.2945	0.2638	0.08309	0.0267	0.100	30.0

Cont. ...

1	2	3	4	5	6	7	8
159	0.3499	0.3511	0.3444	0.08309	0.0096	0.100	30.0
160	0.3554	0.3563	0.3512	0.08309	0.0092	0.100	30.0
161	0.3013	0.3052	0.2887	0.08309	0.0170	0.100	30.0
162	0.2677	0.2734	0.2543	0.08309	0.0214	0.100	30.0
163	0.2489	0.2666	0.2299	0.08309	0.0235	0.100	30.0
164	0.2893	0.2921	0.2848	0.08309	0.0089	0.100	30.0
165	0.2333	0.2425	0.2265	0.08309	0.0134	0.100	30.0
166	0.2017	0.2157	0.1822	0.08309	0.0215	0.100	30.0
167	0.1864	0.2068	0.1628	0.08309	0.0229	0.100	30.0
168	0.3653	0.3666	0.3427	0.04709	0.0227	0.100	30.0
169	0.2905	0.2928	0.2031	0.04729	0.0458	0.100	30.0
170	0.3450	0.3461	0.2565	0.04729	0.0452	0.100	30.0
171	0.3720	0.3722	0.2811	0.04729	0.0452	0.100	30.0
172	0.3701	0.3706	0.3193	0.04729	0.0330	0.100	30.0
173	0.3043	0.3073	0.2468	0.04729	0.0343	0.100	30.0
174	0.2315	0.2346	0.1722	0.04729	0.0368	0.100	30.0
175	0.1804	0.1891	0.1478	0.04729	0.0293	0.100	30.0
176	0.2314	0.2361	0.2072	0.04729	0.0258	0.100	30.0
177	0.3195	0.3274	0.3080	0.04729	0.0186	0.100	30.0
178	0.3126	0.3132	0.3019	0.04753	0.0161	0.100	30.0
179	0.1717	0.1740	0.1470	0.04753	0.0233	0.100	30.0
180	0.2325	0.2349	0.2300	0.04753	0.0071	0.100	30.0
181	0.1323	0.1426	0.1140	0.04877	0.0168	0.100	30.0
182	0.2560	0.2545	0.2516	0.00953	0.0076	0.100	30.0
183	0.1260	0.1565	0.1191	0.01377	0.0104	0.100	30.0
184	0.3670	0.3670	0.3430	0.03509	0.0228	0.100	30.0
185	0.2624	0.2624	0.2311	0.03665	0.0254	0.100	30.0
186	0.2087	0.2101	0.1779	0.03665	0.0269	0.100	30.0
187	0.2330	0.2358	0.2270	0.03665	0.0130	0.100	30.0
188	0.1577	0.1609	0.1464	0.03804	0.0176	0.100	30.0

APPENDIX IX

EXPERIMENTAL DATA ON BROAD CRESTED SIDE SLUICE GATE UNDER FREE FLOW

B = 0.5m, b = 0.5m

S. No.	Upstream depth of flow	Downstrem depth of flow	Upstream discharge	Sluice gate discharge	Sluice gate opening	Sluice gate width	Temp. of water
	y_0 (m)	y_b (m)	Q_0 (m^3/s)	Q_s (m^3/s)	a (m)	c (m)	(^oc)
1	2	3	4	5	6	7	8
1	0.2271	0.2351	0.06227	0.03198	0.05	0.20	31.5
2	0.1771	0.1915	0.06227	0.02640	0.05	0.20	31.5
3	0.1333	0.1625	0.06227	0.02112	0.05	0.20	31.5
4	0.3599	0.3631	0.06227	0.03950	0.05	0.20	31.5
5	0.3522	0.3602	0.08409	0.04153	0.05	0.20	31.5
6	0.2749	0.2850	0.08643	0.03505	0.05	0.20	31.5
7	0.2325	0.2460	0.08643	0.03174	0.05	0.20	31.5
8	0.1827	0.2088	0.08643	0.02658	0.05	0.20	31.5
9	0.1388	0.1695	0.08643	0.02199	0.05	0.20	31.5
10	0.1758	0.1884	0.02928	0.02769	0.05	0.20	31.0
11	0.0799	0.0878	0.02087	0.01411	0.05	0.20	31.0
12	0.1093	0.1142	0.02087	0.02014	0.05	0.20	31.0
13	0.1057	0.1095	0.01990	0.01890	0.05	0.20	31.0
14	0.3692	0.3703	0.05298	0.02759	0.03	0.20	31.0
15	0.2358	0.2401	0.05121	0.02174	0.03	0.20	31.0
16	0.1833	0.1923	0.05121	0.01863	0.03	0.20	31.0
17	0.1468	0.1628	0.05121	0.01601	0.03	0.20	31.0
18	0.3635	0.3652	0.06568	0.02341	0.03	0.20	29.0
19	0.2106	0.2181	0.06382	0.02012	0.03	0.20	29.0

Cont...

1	2	3	4	5	6	7	8
20	0.1765	0.1906	0.06382	0.01764	0.03	0.20	29.0
21	0.1429	0.1635	0.06382	0.01479	0.03	0.20	29.0
22	0.2715	0.2732	0.06382	0.02350	0.03	0.20	29.0
23	0.3617	0.3663	0.08811	0.02752	0.03	0.20	29.0
24	0.2535	0.2632	0.08811	0.02214	0.03	0.20	29.0
25	0.2175	0.2300	0.08811	0.02012	0.03	0.20	29.0
26	0.1662	0.1927	0.08811	0.01658	0.03	0.20	29.0
27	0.2894	0.2958	0.08811	0.02028	0.03	0.20	29.0
28	0.3499	0.3544	0.02947	0.02702	0.03	0.20	28.5
29	0.3619	0.3633	0.03089	0.02702	0.03	0.20	28.5
30	0.1897	0.1932	0.03089	0.01908	0.03	0.20	28.5
31	0.1842	0.1875	0.03089	0.01880	0.03	0.20	28.5
32	0.1355	0.1417	0.03089	0.01548	0.03	0.20	28.5
33	0.1061	0.1157	0.03089	0.01302	0.03	0.20	28.5
34	0.3650	0.3650	0.04781	0.01065	0.01	0.20	28.5
35	0.2508	0.2508	0.04781	0.00820	0.01	0.20	28.5
36	0.2454	0.2491	0.04781	0.00809	0.01	0.20	28.5
37	0.1835	0.1860	0.04631	0.00737	0.01	0.20	28.5
38	0.1447	0.1490	0.04631	0.00616	0.01	0.20	28.5
39	0.1173	0.1254	0.06257	0.00479	0.01	0.20	29.0
40	0.3565	0.3565	0.06082	0.01046	0.01	0.20	29.0
41	0.2289	0.2317	0.06082	0.00823	0.01	0.20	29.0
42	0.1934	0.1978	0.06082	0.00715	0.01	0.20	29.0
43	0.1632	0.1692	0.06082	0.00639	0.01	0.20	29.0
44	0.3217	0.3217	0.01859	0.01033	0.01	0.20	30.0
45	0.2260	0.2275	0.01859	0.00837	0.01	0.20	30.0
46	0.2209	0.2209	0.01859	0.00825	0.01	0.20	30.0
47	0.2192	0.2192	0.01859	0.00803	0.01	0.20	30.0
48	0.1460	0.1473	0.01859	0.00636	0.01	0.20	30.0
49	0.0934	0.0978	0.01859	0.00476	0.01	0.20	30.0
50	0.3697	0.3715	0.08651	0.01052	0.01	0.20	30.0
51	0.3094	0.3105	0.08651	0.01018	0.01	0.20	30.0
52	0.2634	0.2655	0.08651	0.00915	0.01	0.20	30.0
53	0.1425	0.1363	0.08651	0.00560	0.01	0.20	30.0
54	0.2128	0.2187	0.08651	0.00775	0.01	0.20	30.0

Cont...

1	2	3	4	5	6	7	8
55	0.0707	0.0651	0.02830	0.00342	0.01	0.10	30.0
56	0.3763	0.3756	0.02877	0.01064	0.01	0.10	30.0
57	0.1991	0.2001	0.02877	0.00747	0.01	0.10	30.0
58	0.1384	0.1404	0.02743	0.00628	0.01	0.10	30.0
59	0.1018	0.1067	0.02743	0.00519	0.01	0.10	30.0
60	0.3664	0.3664	0.04618	0.01021	0.01	0.10	30.0
61	0.1805	0.1839	0.04618	0.00747	0.01	0.10	30.0
62	0.1339	0.1408	0.04618	0.00603	0.01	0.10	30.0
63	0.0928	0.1000	0.04618	0.00435	0.01	0.10	30.0
64	0.1105	0.1007	0.06162	0.00493	0.01	0.10	31.0
65	0.3679	0.3679	0.06162	0.01051	0.01	0.10	31.0
66	0.2671	0.2695	0.06162	0.00921	0.01	0.10	31.0
67	0.2264	0.2287	0.06162	0.00837	0.01	0.10	31.0
68	0.1893	0.1032	0.06162	0.00736	0.01	0.10	31.0
69	0.1145	0.1067	0.06162	0.00497	0.01	0.10	31.0
70	0.3268	0.3292	0.08417	0.01011	0.01	0.10	31.0
71	0.2843	0.2861	0.08417	0.00924	0.01	0.10	31.0
72	0.2340	0.2367	0.08417	0.00828	0.01	0.10	31.0
73	0.1418	0.1447	0.08417	0.00562	0.01	0.10	31.0
74	0.3438	0.3444	0.02897	0.02537	0.03	0.10	31.0
75	0.1899	0.1921	0.02897	0.01851	0.03	0.10	31.0
76	0.1307	0.1336	0.02897	0.01507	0.03	0.10	31.0
77	0.2750	0.2751	0.02897	0.02271	0.03	0.10	31.0
78	0.3590	0.3592	0.04309	0.02595	0.03	0.10	31.0
79	0.2326	0.2365	0.04309	0.02075	0.03	0.10	31.0
80	0.1956	0.2009	0.04309	0.01620	0.03	0.10	31.0
81	0.1527	0.1597	0.04309	0.01387	0.03	0.10	31.0
82	0.3607	0.3658	0.08079	0.02595	0.03	0.10	31.0
83	0.3022	0.3087	0.08079	0.02426	0.03	0.10	31.0
84	0.2587	0.2663	0.08079	0.02237	0.03	0.10	31.0
85	0.2178	0.2292	0.08079	0.02059	0.03	0.10	31.0
86	0.3609	0.3635	0.05944	0.02649	0.03	0.10	31.0
87	0.2666	0.2710	0.05944	0.02280	0.03	0.10	31.0
88	0.2171	0.2250	0.05944	0.02087	0.03	0.10	31.0
89	0.1794	0.1901	0.05944	0.01828	0.03	0.10	31.0

Cont...

1	2	3	4	5	6	7	8
90	0.3609	0.3661	0.08194	0.03939	0.05	0.10	31.0
91	0.2839	0.2943	0.08351	0.03467	0.05	0.10	31.0
92	0.2231	0.2405	0.08351	0.03101	0.05	0.10	31.0
93	0.1817	0.2064	0.08351	0.02867	0.05	0.10	31.0
94	0.3475	0.3475	0.04431	0.03854	0.05	0.10	30.0
95	0.2547	0.2570	0.04431	0.03335	0.05	0.10	30.0
96	0.1842	0.1896	0.04413	0.02811	0.05	0.10	30.0
97	0.1411	0.1541	0.04413	0.02423	0.05	0.10	30.0
98	0.2124	0.2223	0.05966	0.03029	0.05	0.10	30.0
99	0.1830	0.1961	0.05966	0.02821	0.05	0.10	30.0
100	0.1491	0.1711	0.05966	0.02480	0.05	0.10	30.0
101	0.1127	0.1413	0.05966	0.02031	0.05	0.10	30.0
102	0.1499	0.1590	0.04349	0.03013	0.07	0.10	32.0
103	0.1206	0.1346	0.04349	0.02576	0.07	0.10	32.0
104	0.1019	0.1294	0.04349	0.02095	0.07	0.10	32.0
105	0.1415	0.1693	0.06125	0.03032	0.07	0.10	32.0
106	0.1249	0.1531	0.06125	0.02671	0.07	0.10	32.0
107	0.3561	0.3591	0.06125	0.05329	0.07	0.10	32.0
108	0.3067	0.3133	0.08202	0.04780	0.07	0.10	32.0
109	0.2306	0.2444	0.08202	0.03985	0.07	0.10	32.0
110	0.1943	0.2177	0.08202	0.03559	0.07	0.10	32.0
111	0.1662	0.2075	0.08559	0.04002	0.10	0.10	32.0
112	0.1921	0.2293	0.09570	0.04680	0.10	0.10	32.0
113	0.1952	0.2016	0.04450	0.03619	0.07	0.10	32.0
114	0.1770	0.1924	0.06125	0.03418	0.07	0.10	32.0
115	0.2384	0.2573	0.09570	0.05591	0.10	0.10	32.0
116	0.3423	0.3452	0.06257	0.02483	0.03	0.05	31.0
117	0.1150	0.1150	0.06257	0.01140	0.03	0.05	31.0
118	0.1233	0.1384	0.06227	0.00504	0.01	0.05	31.0
119	0.2251	0.2275	0.06227	0.00688	0.01	0.05	31.0
120	0.3416	0.3416	0.06227	0.00834	0.01	0.05	31.0
121	0.3005	0.3015	0.06227	0.00766	0.01	0.05	31.0
122	0.2441	0.2457	0.06227	0.00683	0.01	0.05	31.0
123	0.1781	0.1801	0.06227	0.00580	0.01	0.05	31.0
124	0.1152	0.1307	0.06227	0.00465	0.01	0.05	31.0

Cont...

1	2	3	4	5	6	7	8
125	0.3661	0.3682	0.06227	0.00857	0.01	0.05	31.0
126	0.2451	0.2458	0.04516	0.00683	0.01	0.05	30.0
127	0.3672	0.3674	0.04516	0.00831	0.01	0.05	30.0
128	0.2131	0.2147	0.04482	0.00626	0.01	0.05	30.0
129	0.1261	0.1327	0.04482	0.00495	0.01	0.05	30.0
130	0.1020	0.1171	0.04482	0.00446	0.01	0.05	30.0
131	0.3465	0.3459	0.01890	0.00794	0.01	0.05	30.0
132	0.2034	0.2036	0.01917	0.00600	0.01	0.05	30.0
133	0.1869	0.1871	0.02692	0.00573	0.01	0.05	30.0
134	0.1435	0.1457	0.02692	0.00507	0.01	0.05	30.0
135	0.3579	0.3614	0.08334	0.03724	0.05	0.05	30.0
136	0.2666	0.2765	0.08334	0.03310	0.05	0.05	30.0
137	0.2099	0.2289	0.08334	0.02948	0.05	0.05	30.0
138	0.3639	0.3665	0.06220	0.03713	0.05	0.05	30.0
139	0.2084	0.2189	0.06220	0.02910	0.05	0.05	30.0
140	0.1348	0.1388	0.02466	0.02254	0.05	0.05	31.0
141	0.2399	0.2447	0.06257	0.02083	0.03	0.05	31.0
142	0.1590	0.1649	0.08575	0.00580	0.01	0.05	31.0

APPENDIX X

EXPERIMENTAL DATA ON BROAD CRESTED SIDE SLUICE GATE UNDER SUBMERGED FLOW

B = 0.5m, b = 0.5m

S. No.	Upstream depth of flow	Downstrem depth of flow	Tail water depth	Upstream discharge	Sluice gate discharge	Sluice gate opening	Sluice gate width	Temp. of water
	y_0 (m)	y_b (m)	y_t (m)	Q_0 (m^3/s)	Q_s (m^3/s)	a (m)	c (m)	(^oc)
1	2	3	4	5	6	7	8	9
1	0.3035	0.3051	0.2306	0.04386	0.04296	0.10	0.20	32.0
2	0.3584	0.3595	0.3130	0.04373	0.03282	0.10	0.20	32.0
3	0.2839	0.2859	0.2325	0.04373	0.03454	0.10	0.20	32.0
4	0.2375	0.2411	0.1803	0.04373	0.03505	0.10	0.20	32.0
5	0.1858	0.1929	0.1490	0.04373	0.02763	0.10	0.20	32.0
6	0.2379	0.2411	0.2093	0.04373	0.02522	0.10	0.20	32.0
7	0.3227	0.3250	0.3030	0.04373	0.02132	0.10	0.20	32.0
8	0.2514	0.2532	0.2400	0.04373	0.01478	0.10	0.20	32.0
9	0.1773	0.1833	0.1628	0.04422	0.02038	0.10	0.20	32.0
10	0.1460	0.1561	0.1395	0.04422	0.01630	0.10	0.20	32.0
11	0.3684	0.3710	0.2900	0.06227	0.02199	0.05	0.20	31.0
12	0.3235	0.3263	0.2170	0.06227	0.02501	0.05	0.20	31.0
13	0.2884	0.2918	0.1550	0.06227	0.02764	0.05	0.20	31.0
14	0.2193	0.2269	0.1238	0.06227	0.02229	0.05	0.20	31.0
15	0.2524	0.2580	0.1864	0.06227	0.01875	0.05	0.20	31.0
16	0.3322	0.3330	0.3085	0.06227	0.01061	0.05	0.20	31.0
17	0.1982	0.2052	0.1570	0.06227	0.01468	0.05	0.20	31.0
18	0.1796	0.1922	0.1245	0.06227	0.01713	0.05	0.20	31.0
19	0.2128	0.2232	0.2391	0.08643	0.01675	0.05	0.20	31.0

Cont. ...

1	2	3	4	5	6	7	8	9
20	0.2634	0.2702	0.1737	0.08643	0.01998	0.05	0.20	31.0
21	0.2371	0.2492	0.1356	0.08643	0.02318	0.05	0.20	31.0
22	0.2988	0.3065	0.1515	0.08643	0.02782	0.05	0.20	31.0
23	0.3650	0.3683	0.2860	0.08643	0.02038	0.05	0.20	31.0
24	0.3715	0.3716	0.1958	0.08643	0.03120	0.05	0.20	31.0
25	0.3578	0.3608	0.1632	0.08643	0.03298	0.05	0.20	31.0
26	0.3096	0.3096	0.1978	0.02928	0.02677	0.05	0.20	31.0
27	0.3442	0.3442	0.2363	0.02928	0.02663	0.05	0.20	31.0
28	0.3367	0.3367	0.3095	0.02928	0.01325	0.05	0.20	31.0
29	0.1504	0.1521	0.1291	0.01985	0.00999	0.05	0.20	31.0
30	0.3372	0.3372	0.2395	0.05298	0.01503	0.03	0.20	31.0
31	0.2893	0.2921	0.1608	0.05121	0.01832	0.03	0.20	31.0
32	0.2214	0.2260	0.1139	0.05121	0.01450	0.03	0.20	31.0
33	0.2448	0.2491	0.1855	0.05121	0.01218	0.03	0.20	31.0
34	0.2826	0.2839	0.2500	0.05121	0.00803	0.03	0.20	31.0
35	0.1951	0.1990	0.1473	0.05121	0.01014	0.03	0.20	31.0
36	0.1833	0.1887	0.1198	0.05121	0.01133	0.03	0.20	31.0
37	0.1507	0.1596	0.1097	0.05121	0.00981	0.03	0.20	31.0
38	0.2596	0.2632	0.1442	0.06382	0.01454	0.03	0.20	29.0
39	0.2161	0.2223	0.1450	0.06382	0.01212	0.03	0.20	29.0
40	0.2273	0.2312	0.1725	0.06382	0.01052	0.03	0.20	29.0
41	0.1919	0.1963	0.1497	0.06382	0.00886	0.03	0.20	29.0
42	0.1746	0.1832	0.1068	0.06382	0.01144	0.03	0.20	29.0
43	0.3167	0.3201	0.1520	0.06382	0.01943	0.03	0.20	29.0
44	0.3524	0.3542	0.2441	0.06382	0.01639	0.03	0.20	29.0
45	0.3564	0.3587	0.2298	0.08811	0.01673	0.03	0.20	29.0
46	0.2968	0.3013	0.1833	0.08811	0.01551	0.03	0.20	29.0
47	0.2875	0.2917	0.1499	0.08811	0.01699	0.03	0.20	29.0
48	0.2433	0.2506	0.1177	0.08811	0.01628	0.03	0.20	29.0
49	0.2565	0.2634	0.1566	0.08811	0.01444	0.03	0.20	29.0
50	0.2856	0.2881	0.2373	0.08811	0.00919	0.03	0.20	29.0
51	0.2200	0.2260	0.1506	0.08811	0.01153	0.03	0.20	29.0
52	0.2041	0.2152	0.1080	0.08811	0.01371	0.03	0.20	29.0
53	0.1939	0.2067	0.1173	0.08811	0.01179	0.03	0.20	29.0
54	0.2653	0.2666	0.1689	0.03089	0.01599	0.03	0.20	28.5

Cont. ...

1	2	3	4	5	6	7	8	9
55	0.3106	0.3106	0.2231	0.03089	0.01476	0.03	0.20	28.5
56	0.3128	0.3135	0.2277	0.03089	0.01458	0.03	0.20	28.5
57	0.2267	0.2274	0.1812	0.03089	0.01040	0.03	0.20	28.5
58	0.1998	0.2015	0.1521	0.03089	0.01160	0.03	0.20	28.5
59	0.1481	0.1522	0.1063	0.03089	0.00898	0.03	0.20	28.5
60	0.1647	0.1668	0.1381	0.03089	0.00753	0.03	0.20	28.5
61	0.2590	0.2607	0.0965	0.04781	0.00740	0.01	0.20	28.5
62	0.2755	0.2764	0.1595	0.04781	0.00578	0.01	0.20	28.5
63	0.2237	0.2247	0.1425	0.04953	0.00481	0.01	0.20	28.5
64	0.2129	0.2147	0.0943	0.04953	0.00616	0.01	0.20	28.5
65	0.1907	0.1927	0.0526	0.04631	0.00628	0.01	0.20	28.5
66	0.1550	0.1591	0.0825	0.04631	0.00433	0.01	0.20	28.5
67	0.1620	0.1644	0.1157	0.04631	0.00359	0.01	0.20	28.5
68	0.2765	0.3776	0.0872	0.06082	0.00831	0.01	0.20	29.0
69	0.2939	0.2953	0.1919	0.06082	0.00536	0.01	0.20	29.0
70	0.2545	0.2555	0.1773	0.06082	0.00463	0.01	0.20	29.0
71	0.2380	0.2400	0.0976	0.06082	0.00670	0.01	0.20	29.0
72	0.1987	0.2033	0.0643	0.06082	0.00621	0.01	0.20	29.0
73	0.2041	0.2066	0.1024	0.06082	0.00536	0.01	0.20	29.0
74	0.1787	0.1821	0.0956	0.06082	0.00477	0.01	0.20	29.0
75	0.1706	0.1754	0.0467	0.06082	0.00583	0.01	0.20	29.0
76	0.2613	0.2623	0.1332	0.01859	0.00657	0.01	0.20	30.0
77	0.2655	0.2657	0.1342	0.01859	0.00675	0.01	0.20	30.0
78	0.1812	0.1812	0.1103	0.01859	0.00488	0.01	0.20	30.0
79	0.1637	0.1647	0.0778	0.01859	0.00560	0.01	0.20	30.0
80	0.3231	0.3241	0.1641	0.08651	0.00731	0.01	0.20	30.0
81	0.3120	0.3188	0.1148	0.08651	0.00877	0.01	0.20	30.0
82	0.3132	0.3139	0.0687	0.08651	0.00948	0.01	0.20	30.0
83	0.2677	0.2704	0.0771	0.08651	0.00778	0.01	0.20	30.0
84	0.2731	0.2744	0.1276	0.08651	0.00723	0.01	0.20	30.0
85	0.2286	0.2331	0.1161	0.08651	0.00593	0.01	0.20	30.0
86	0.2230	0.2258	0.0997	0.08651	0.00699	0.01	0.20	30.0
87	0.1556	0.1734	0.0870	0.08651	0.00413	0.01	0.20	30.0
88	0.2105	0.2118	0.0947	0.02877	0.00636	0.01	0.10	30.0
89	0.2400	0.2476	0.1724	0.02877	0.00462	0.01	0.10	30.0

Cont. ...

1	2	3	4	5	6	7	8	9
90	0.1718	0.1721	0.1359	0.02743	0.00330	0.01	0.10	30.0
91	0.1528	0.1542	0.0745	0.02743	0.00502	0.01	0.10	30.0
92	0.1139	0.1170	0.0619	0.02743	0.00391	0.01	0.10	30.0
93	0.1224	0.1283	0.1050	0.02743	0.00248	0.01	0.10	30.0
94	0.3219	0.3219	0.2130	0.02743	0.00580	0.01	0.10	30.0
95	0.3025	0.3034	0.1534	0.04618	0.00723	0.01	0.10	30.0
96	0.2889	0.2889	0.0887	0.04618	0.00845	0.01	0.10	30.0
97	0.2218	0.2239	0.0778	0.04618	0.00691	0.01	0.10	30.0
98	0.2331	0.2356	0.1372	0.04618	0.00568	0.01	0.10	30.0
99	0.1986	0.1997	0.1153	0.04618	0.00474	0.01	0.10	30.0
100	0.1908	0.1929	0.0768	0.04618	0.00585	0.01	0.10	30.0
101	0.1437	0.1489	0.0585	0.04618	0.00493	0.01	0.10	30.0
102	0.1527	0.1550	0.0978	0.04618	0.00404	0.01	0.10	30.0
103	0.1012	0.1197	0.0721	0.04618	0.00263	0.01	0.10	30.0
104	0.1001	0.1164	0.0524	0.04618	0.00330	0.01	0.10	30.0
105	0.2767	0.2787	0.0837	0.06162	0.00817	0.01	0.10	31.0
106	0.2511	0.2514	0.1756	0.06162	0.00462	0.01	0.10	31.0
107	0.2381	0.2399	0.0914	0.06162	0.00667	0.01	0.10	31.0
108	0.1992	0.2026	0.0866	0.06162	0.00572	0.01	0.10	31.0
109	0.2037	0.2052	0.1187	0.06162	0.00516	0.01	0.10	31.0
110	0.1637	0.1664	0.1018	0.06162	0.00419	0.01	0.10	31.0
111	0.1541	0.1601	0.0558	0.06162	0.00516	0.01	0.10	31.0
112	0.3450	0.3450	0.1555	0.08417	0.00797	0.01	0.10	31.0
113	0.2995	0.3001	0.1487	0.08417	0.00683	0.01	0.10	31.0
114	0.2912	0.2933	0.0838	0.08417	0.00761	0.01	0.10	31.0
115	0.2393	0.2428	0.0698	0.08417	0.00707	0.01	0.10	31.0
116	0.2462	0.2485	0.1303	0.08417	0.00582	0.01	0.10	31.0
117	0.2024	0.2069	0.1165	0.08417	0.00486	0.01	0.10	31.0
118	0.1865	0.1934	0.0620	0.08417	0.00567	0.01	0.10	31.0
119	0.3114	0.3114	0.2370	0.02897	0.01446	0.03	0.10	31.0
120	0.2469	0.2472	0.1526	0.02897	0.01642	0.03	0.10	31.0
121	0.1755	0.1770	0.1121	0.02897	0.01221	0.03	0.10	31.0
122	0.2171	0.2181	0.1796	0.02897	0.00978	0.03	0.10	31.0
123	0.2708	0.2742	0.1531	0.04309	0.01766	0.03	0.10	31.0
124	0.2930	0.2946	0.1869	0.04309	0.01690	0.03	0.10	31.0

Cont. ...

1	2	3	4	5	6	7	8	9
125	0.3766	0.3772	0.3068	0.04309	0.01153	0.03	0.10	31.0
126	0.2952	0.2955	0.2559	0.04309	0.00834	0.03	0.10	31.0
127	0.2395	0.2414	0.1474	0.04309	0.01224	0.03	0.10	31.0
128	0.2165	0.2202	0.1040	0.04309	0.01439	0.03	0.10	31.0
129	0.1765	0.1806	0.1107	0.04309	0.01083	0.03	0.10	31.0
130	0.1716	0.1760	0.1212	0.04309	0.01018	0.03	0.10	31.0
131	0.1821	0.1865	0.1421	0.04309	0.01054	0.03	0.10	31.0
132	0.3281	0.3319	0.1670	0.08079	0.02108	0.03	0.10	31.0
133	0.3584	0.3624	0.2531	0.08079	0.01694	0.03	0.10	31.0
134	0.3139	0.3164	0.2368	0.08079	0.01439	0.03	0.10	31.0
135	0.2954	0.3000	0.1886	0.08079	0.01687	0.03	0.10	31.0
136	0.2784	0.2825	0.1399	0.08079	0.01986	0.03	0.10	31.0
137	0.2407	0.2477	0.1350	0.08079	0.01724	0.03	0.10	31.0
138	0.2590	0.2642	0.1780	0.08079	0.01471	0.03	0.10	31.0
139	0.2743	0.2792	0.2198	0.08079	0.01201	0.03	0.10	31.0
140	0.2297	0.2340	0.1963	0.08079	0.00939	0.03	0.10	31.0
141	0.2091	0.2182	0.1426	0.08079	0.01274	0.03	0.10	31.0
142	0.2889	0.2928	0.1343	0.05944	0.02083	0.03	0.10	31.0
143	0.3489	0.3491	0.2573	0.05944	0.01594	0.03	0.10	31.0
144	0.2908	0.2924	0.2311	0.05944	0.01288	0.03	0.10	31.0
145	0.2602	0.2642	0.1700	0.05944	0.01616	0.03	0.10	31.0
146	0.2419	0.2446	0.1298	0.05944	0.01812	0.03	0.10	31.0
147	0.2014	0.2092	0.1202	0.05944	0.01536	0.03	0.10	31.0
148	0.2220	0.2280	0.1637	0.05944	0.01291	0.03	0.10	31.0
149	0.2409	0.2444	0.1997	0.05944	0.01023	0.03	0.10	31.0
150	0.1915	0.1958	0.1708	0.05944	0.00766	0.03	0.10	31.0
151	0.1727	0.1807	0.1363	0.05944	0.01023	0.03	0.10	31.0
152	0.1630	0.1713	0.1147	0.05944	0.01149	0.03	0.10	31.0
153	0.1870	0.1876	0.1187	0.02412	0.02271	0.05	0.10	31.0
154	0.2448	0.2448	0.1741	0.02412	0.02195	0.05	0.10	31.0
155	0.3604	0.3692	0.2975	0.02412	0.02174	0.05	0.10	31.0
156	0.2784	0.2784	0.2436	0.02412	0.01532	0.05	0.10	31.0
157	0.1777	0.1800	0.1296	0.02412	0.01747	0.05	0.10	31.0
158	0.1183	0.1233	0.0928	0.02412	0.01425	0.05	0.10	31.0
159	0.1374	0.1409	0.1180	0.02412	0.01172	0.05	0.10	31.0

Cont. ...

1	2	3	4	5	6	7	8	9
160	0.1843	0.1861	0.1706	0.02412	0.00930	0.05	0.10	31.0
161	0.1031	0.1079	0.0903	0.02412	0.00831	0.05	0.10	31.0
162	0.3239	0.3305	0.1798	0.08351	0.03178	0.05	0.10	32.5
163	0.3529	0.3576	0.2337	0.08351	0.02888	0.05	0.10	32.5
164	0.3111	0.3178	0.2409	0.08351	0.02291	0.05	0.10	32.5
165	0.2845	0.2913	0.1943	0.08351	0.02589	0.05	0.10	32.5
166	0.2319	0.2439	0.1676	0.08351	0.02223	0.05	0.10	32.5
167	0.2619	0.2693	0.2155	0.08351	0.01804	0.05	0.10	32.5
168	0.2890	0.2948	0.2589	0.08351	0.01407	0.05	0.10	32.5
169	0.2407	0.2453	0.2220	0.08351	0.01051	0.05	0.10	32.5
170	0.2154	0.2244	0.1864	0.08351	0.01477	0.05	0.10	32.5
171	0.1926	0.2083	0.1453	0.08351	0.01784	0.05	0.10	32.5
172	0.3371	0.3385	0.1950	0.04431	0.03073	0.05	0.10	30.0
173	0.3720	0.3728	0.2481	0.04431	0.03025	0.05	0.10	30.0
174	0.3180	0.3192	0.2515	0.04413	0.02188	0.05	0.10	30.0
175	0.2649	0.2679	0.1856	0.04413	0.02423	0.05	0.10	30.0
176	0.2450	0.2474	0.1551	0.04413	0.02551	0.05	0.10	30.0
177	0.1947	0.2014	0.1403	0.04413	0.02031	0.05	0.10	30.0
178	0.2187	0.2233	0.1699	0.04413	0.01821	0.05	0.10	30.0
179	0.2517	0.2539	0.2162	0.04413	0.01639	0.05	0.10	30.0
180	0.3684	0.3685	0.3157	0.05966	0.01959	0.05	0.10	30.0
181	0.3001	0.3020	0.2192	0.05966	0.02432	0.05	0.10	30.0
182	0.2684	0.2716	0.1672	0.05966	0.02609	0.05	0.10	30.0
183	0.2330	0.2398	0.1565	0.05966	0.02345	0.05	0.10	30.0
184	0.2590	0.2636	0.1981	0.05966	0.02133	0.05	0.10	30.0
185	0.2940	0.2954	0.2462	0.05966	0.01844	0.05	0.10	30.0
186	0.2473	0.2509	0.2160	0.05966	0.01511	0.05	0.10	30.0
187	0.2206	0.2263	0.1745	0.05966	0.01825	0.05	0.10	30.0
188	0.1983	0.2070	0.1447	0.05966	0.02059	0.05	0.10	30.0
189	0.1641	0.1761	0.1199	0.05966	0.01699	0.05	0.10	30.0
190	0.1810	0.1902	0.1517	0.05966	0.01489	0.05	0.10	30.0
191	0.2132	0.2177	0.1963	0.05966	0.01163	0.05	0.10	30.0
192	0.1831	0.1880	0.1712	0.05966	0.00820	0.05	0.10	30.0
193	0.1507	0.1633	0.1259	0.05966	0.01235	0.05	0.10	30.0
194	0.2513	0.2545	0.1516	0.04450	0.03483	0.07	0.10	32.0

Cont. ...

1	2	3	4	5	6	7	8	9
195	0.3080	0.3094	0.2054	0.04450	0.03428	0.07	0.10	32.0
196	0.3726	0.3744	0.2830	0.04450	0.03312	0.07	0.10	32.0
197	0.2828	0.2836	0.2308	0.04349	0.02518	0.07	0.10	32.0
198	0.2470	0.2490	0.1941	0.04349	0.02657	0.07	0.10	32.0
199	0.2111	0.2153	0.1532	0.04349	0.02809	0.07	0.10	32.0
200	0.1669	0.1762	0.1281	0.04349	0.02245	0.07	0.10	32.0
201	0.2371	0.2412	0.2128	0.04349	0.01796	0.07	0.10	32.0
202	0.1938	0.1985	0.1801	0.04349	0.01366	0.07	0.10	32.0
203	0.1586	0.1670	0.1355	0.04349	0.01709	0.07	0.10	32.0
204	0.1417	0.1544	0.1144	0.04349	0.01819	0.07	0.10	32.0
205	0.3457	0.3473	0.3104	0.05952	0.02111	0.07	0.10	32.0
206	0.2817	0.2827	0.2307	0.05952	0.02572	0.07	0.10	32.0
207	0.2510	0.2563	0.1816	0.06125	0.02955	0.07	0.10	32.0
208	0.2067	0.2162	0.1578	0.06125	0.02554	0.07	0.10	32.0
209	0.2319	0.2372	0.1925	0.06125	0.02270	0.07	0.10	32.0
210	0.3069	0.3097	0.2819	0.06125	0.01777	0.07	0.10	32.0
211	0.2608	0.2641	0.2447	0.06125	0.01376	0.07	0.10	32.0
212	0.2101	0.2181	0.1806	0.06125	0.01949	0.07	0.10	32.0
213	0.1869	0.1989	0.1510	0.06125	0.02203	0.07	0.10	32.0
214	0.1599	0.1754	0.1270	0.06125	0.01894	0.07	0.10	32.0
215	0.1832	0.1932	0.1613	0.06125	0.01626	0.07	0.10	32.0
216	0.2159	0.2214	0.2038	0.06125	0.01165	0.07	0.10	32.0
217	0.3676	0.3719	0.2182	0.08202	0.04266	0.07	0.10	32.0
218	0.3667	0.3704	0.3084	0.08202	0.02894	0.07	0.10	32.0
219	0.3206	0.3259	0.2386	0.08202	0.03327	0.07	0.10	32.0
220	0.3047	0.3113	0.2076	0.08202	0.03464	0.07	0.10	32.0
221	0.2601	0.2677	0.1899	0.08202	0.03080	0.07	0.10	32.0
222	0.3083	0.3144	0.2502	0.08202	0.02608	0.07	0.10	32.0
223	0.3500	0.3532	0.3119	0.08202	0.02165	0.07	0.10	32.0
224	0.2999	0.3031	0.2742	0.08202	0.01731	0.07	0.10	32.0
225	0.2525	0.2600	0.2088	0.08202	0.02347	0.07	0.10	32.0
226	0.2346	0.2475	0.1908	0.08202	0.02549	0.07	0.10	32.0
227	0.2190	0.2289	0.1940	0.08202	0.01819	0.07	0.10	32.0
228	0.2448	0.2517	0.2277	0.08202	0.01414	0.07	0.10	32.0
229	0.2706	0.2722	0.1994	0.04547	0.04089	0.10	0.10	31.0

Cont. ...

1	2	3	4	5	6	7	8	9
230	0.3124	0.3129	0.2347	0.04547	0.04072	0.10	0.10	31.0
231	0.3678	0.3684	0.2996	0.04547	0.04060	0.10	0.10	31.0
232	0.3536	0.3547	0.3185	0.04547	0.02980	0.10	0.10	31.0
233	0.2761	0.2792	0.2387	0.04547	0.03189	0.10	0.10	31.0
234	0.2245	0.2283	0.1857	0.04450	0.03135	0.10	0.10	31.0
235	0.1748	0.1817	0.1485	0.04450	0.02439	0.10	0.10	31.0
236	0.2166	0.2216	0.1972	0.04450	0.02170	0.10	0.10	31.0
237	0.3143	0.3160	0.3032	0.04450	0.01649	0.10	0.10	31.0
238	0.1663	0.1732	0.1560	0.04450	0.01489	0.10	0.10	31.0
239	0.1371	0.1494	0.1195	0.04450	0.01751	0.10	0.10	31.0
240	0.3083	0.3103	0.1932	0.06031	0.05443	0.10	0.10	31.0
241	0.3579	0.3595	0.2479	0.06031	0.05316	0.10	0.10	31.0
242	0.3681	0.3685	0.3081	0.06031	0.03708	0.10	0.10	31.0
243	0.3075	0.3101	0.2397	0.06031	0.03991	0.10	0.10	31.0
244	0.2866	0.2902	0.2140	0.06031	0.04095	0.10	0.10	31.0
245	0.2208	0.2300	0.1859	0.06031	0.03155	0.10	0.10	31.0
246	0.2495	0.2557	0.2167	0.06031	0.02947	0.10	0.10	31.0
247	0.2714	0.2739	0.2638	0.06031	0.01485	0.10	0.10	31.0
248	0.2164	0.2236	0.2014	0.06031	0.02030	0.10	0.10	31.0
249	0.1816	0.1957	0.1605	0.06031	0.02357	0.10	0.10	31.0
250	0.1441	0.1645	0.1257	0.06031	0.01816	0.10	0.10	31.0
251	0.1634	0.1768	0.1518	0.06031	0.01612	0.10	0.10	31.0
252	0.2298	0.2452	0.1969	0.08559	0.03022	0.10	0.10	32.0
253	0.2607	0.2697	0.2328	0.08559	0.02712	0.10	0.10	32.0
254	0.3320	0.3358	0.3157	0.08559	0.01890	0.10	0.10	32.0
255	0.3354	0.3402	0.3099	0.08559	0.02726	0.10	0.10	32.0
256	0.2879	0.2947	0.2499	0.08559	0.03193	0.10	0.10	32.0
257	0.2474	0.2605	0.1973	0.08559	0.03510	0.10	0.10	32.0
258	0.3121	0.3180	0.2286	0.08559	0.04373	0.10	0.10	32.0
259	0.3494	0.3540	0.2738	0.08559	0.04165	0.10	0.10	32.0
260	0.3506	0.3521	0.2800	0.08301	0.04060	0.10	0.10	32.0
261	0.3585	0.3630	0.2167	0.08301	0.06049	0.10	0.10	32.0
262	0.3673	0.3711	0.2892	0.09570	0.04392	0.10	0.10	32.0
263	0.3281	0.3342	0.2444	0.09570	0.04717	0.10	0.10	32.0
264	0.2909	0.2997	0.1867	0.09570	0.05015	0.10	0.10	32.0

Cont. ...

1	2	3	4	5	6	7	8	9
265	0.2611	0.2743	0.2014	0.09570	0.04101	0.10	0.10	32.0
266	0.2891	0.3015	0.2349	0.09570	0.03691	0.10	0.10	32.0
267	0.3665	0.3726	0.3277	0.09570	0.03018	0.10	0.10	32.0
268	0.3089	0.3154	0.2834	0.09570	0.02425	0.10	0.10	32.0
269	0.2623	0.2745	0.2320	0.09570	0.03032	0.10	0.10	32.0
270	0.2320	0.2528	0.1898	0.09570	0.03378	0.10	0.10	32.0
271	0.1679	0.2210	0.1390	0.09570	0.02378	0.10	0.10	32.0
272	0.2839	0.2863	0.2106	0.04470	0.04066	0.10	0.05	31.0
273	0.3422	0.3429	0.2766	0.04470	0.04037	0.10	0.05	31.0
274	0.3243	0.3259	0.2774	0.04470	0.03263	0.10	0.05	31.0
275	0.2647	0.2677	0.2128	0.04470	0.03258	0.10	0.05	31.0
276	0.2249	0.2289	0.1714	0.04470	0.03455	0.10	0.05	31.0
277	0.1690	0.1765	0.1321	0.04470	0.02867	0.10	0.05	31.0
278	0.2090	0.2155	0.1849	0.04470	0.02722	0.10	0.05	31.0
279	0.2877	0.2911	0.2657	0.04470	0.02383	0.10	0.05	31.0
280	0.1817	0.1892	0.1687	0.04470	0.02030	0.10	0.05	31.0
281	0.1503	0.1619	0.1319	0.04470	0.02250	0.10	0.05	31.0
282	0.3574	0.3607	0.2633	0.06264	0.04856	0.10	0.05	31.0
283	0.3632	0.3649	0.3011	0.06264	0.03708	0.10	0.05	31.0
284	0.3032	0.3085	0.2348	0.06264	0.04019	0.10	0.05	31.0
285	0.2486	0.2545	0.1784	0.06264	0.04236	0.10	0.05	31.0
286	0.2073	0.2195	0.1547	0.06264	0.03554	0.10	0.05	31.0
287	0.2487	0.2548	0.2015	0.06264	0.03409	0.10	0.05	31.0
288	0.3443	0.3460	0.3118	0.06264	0.02890	0.10	0.05	31.0
289	0.2730	0.2775	0.2587	0.06264	0.02191	0.10	0.05	31.0
290	0.2239	0.2380	0.2049	0.06264	0.02590	0.10	0.05	31.0
291	0.1898	0.2057	0.1655	0.06264	0.02838	0.10	0.05	31.0
292	0.1876	0.2008	0.1717	0.06264	0.02195	0.10	0.05	31.0
293	0.2498	0.2541	0.2410	0.06264	0.01422	0.10	0.05	31.0
294	0.3699	0.3736	0.3504	0.08434	0.02258	0.10	0.05	31.0
295	0.2393	0.2530	0.1963	0.08434	0.03473	0.10	0.05	31.0
296	0.2180	0.2359	0.1849	0.08434	0.03184	0.10	0.05	31.0
297	0.2520	0.2638	0.2208	0.08434	0.02834	0.10	0.05	31.0
298	0.3231	0.3292	0.3075	0.08434	0.02034	0.10	0.05	31.0
299	0.2756	0.2803	0.2671	0.08434	0.01601	0.10	0.05	31.0

Cont. ...

1	2	3	4	5	6	7	8	9
300	0.2203	0.2345	0.2061	0.08434	0.02310	0.10	0.05	31.0
301	0.1901	0.2120	0.1677	0.08434	0.02631	0.10	0.05	31.0
302	0.1621	0.1935	0.1385	0.08434	0.02170	0.10	0.05	31.0
303	0.1915	0.2110	0.1788	0.08434	0.01910	0.10	0.05	31.0
304	0.3487	0.3540	0.2579	0.10347	0.04568	0.10	0.05	29.0
305	0.2888	0.2999	0.2321	0.10347	0.03825	0.10	0.05	29.0
306	0.3238	0.3336	0.2754	0.10347	0.03417	0.10	0.05	29.0
307	0.3656	0.3705	0.3321	0.10347	0.02987	0.10	0.05	29.0
308	0.2964	0.3027	0.2769	0.10347	0.02363	0.10	0.05	29.0
309	0.2187	0.2443	0.1854	0.10347	0.03326	0.10	0.05	29.0
310	0.1638	0.2258	0.1399	0.10347	0.02516	0.10	0.05	29.0
311	0.2026	0.2280	0.1850	0.10347	0.02252	0.10	0.05	29.0
312	0.2580	0.2683	0.2482	0.10347	0.01483	0.10	0.05	29.0
313	0.3652	0.3694	0.2277	0.10347	0.03882	0.07	0.05	29.0
314	0.3074	0.3172	0.2070	0.10347	0.03414	0.07	0.05	29.0
315	0.3333	0.3387	0.2500	0.10347	0.03201	0.07	0.05	29.0
316	0.2834	0.2952	0.2304	0.10347	0.02826	0.07	0.05	29.0
317	0.3397	0.3442	0.3060	0.10347	0.02097	0.07	0.05	29.0
318	0.3617	0.3642	0.3382	0.10347	0.01818	0.07	0.05	29.0
319	0.3078	0.3107	0.2922	0.10347	0.01504	0.07	0.05	29.0
320	0.2723	0.2802	0.2457	0.10347	0.02052	0.07	0.05	29.0
321	0.2342	0.2500	0.1927	0.10347	0.02534	0.07	0.05	29.0
322	0.3619	0.3648	0.1985	0.08400	0.04195	0.07	0.05	30.0
323	0.2799	0.2971	0.1796	0.08400	0.03472	0.07	0.05	30.0
324	0.3076	0.3133	0.2200	0.08400	0.03215	0.07	0.05	30.0
325	0.3605	0.3636	0.2938	0.08400	0.02770	0.07	0.05	30.0
326	0.2992	0.3035	0.2642	0.08400	0.02285	0.07	0.05	30.0
327	0.2547	0.2637	0.2030	0.08400	0.02746	0.07	0.05	30.0
328	0.2291	0.2415	0.1639	0.08400	0.02996	0.07	0.05	30.0
329	0.2103	0.2265	0.1762	0.08400	0.02353	0.07	0.05	30.0
330	0.2487	0.2571	0.2276	0.08400	0.01856	0.07	0.05	30.0
331	0.3042	0.3072	0.2940	0.08400	0.01033	0.07	0.05	30.0
332	0.2702	0.2736	0.1711	0.06206	0.03275	0.07	0.05	30.0
333	0.3294	0.3228	0.2464	0.06206	0.02967	0.07	0.05	30.0
334	0.3696	0.3710	0.2992	0.06206	0.02733	0.07	0.05	30.0

Cont. ...

1	2	3	4	5	6	7	8	9
335	0.2486	0.2526	0.2294	0.06206	0.01786	0.07	0.05	30.0
336	0.2080	0.2160	0.1741	0.06206	0.02192	0.07	0.05	30.0
337	0.1844	0.1977	0.1416	0.06206	0.02388	0.07	0.05	30.0
338	0.1343	0.1610	0.1107	0.06206	0.01790	0.07	0.05	30.0
339	0.1624	0.1771	0.1477	0.06206	0.01558	0.07	0.05	30.0
340	0.2006	0.2076	0.1929	0.06206	0.01058	0.07	0.05	30.0
341	0.3223	0.3228	0.1944	0.04683	0.03603	0.07	0.05	30.0
342	0.2348	0.2376	0.1644	0.04683	0.02770	0.07	0.05	30.0
343	0.2744	0.2772	0.2108	0.04683	0.02614	0.07	0.05	30.0
344	0.3766	0.3777	0.3344	0.04683	0.02171	0.07	0.05	30.0
345	0.2419	0.2427	0.2317	0.04683	0.01179	0.07	0.05	30.0
346	0.1811	0.1863	0.1644	0.04521	0.01576	0.07	0.05	30.0
347	0.1523	0.1611	0.1257	0.04521	0.01836	0.07	0.05	30.0
348	0.1042	0.1305	0.0930	0.04521	0.01248	0.07	0.05	30.0
349	0.1394	0.1502	0.1313	0.04521	0.00999	0.07	0.05	30.0
350	0.3077	0.3148	0.1623	0.08334	0.02915	0.05	0.05	30.0
351	0.3355	0.3390	0.2089	0.08334	0.02668	0.05	0.05	30.0
352	0.2850	0.2901	0.2309	0.08334	0.02023	0.05	0.05	30.0
353	0.2591	0.2667	0.1802	0.08334	0.02328	0.05	0.05	30.0
354	0.2405	0.2510	0.1377	0.08334	0.02538	0.05	0.05	30.0
355	0.1969	0.2144	0.1371	0.08334	0.02154	0.05	0.05	30.0
356	0.2151	0.2288	0.1714	0.08334	0.01915	0.05	0.05	30.0
357	0.2600	0.2667	0.2398	0.08334	0.01205	0.05	0.05	30.0
358	0.2549	0.2616	0.1546	0.06220	0.02471	0.05	0.05	30.0
359	0.3118	0.3149	0.2440	0.06220	0.02088	0.05	0.05	30.0
360	0.2751	0.2771	0.2546	0.06220	0.01241	0.05	0.05	30.0
361	0.2250	0.2316	0.1846	0.06220	0.01805	0.05	0.05	30.0
362	0.2012	0.2108	0.1378	0.06220	0.02064	0.05	0.05	30.0
363	0.1555	0.1710	0.1207	0.06220	0.01661	0.05	0.05	30.0
364	0.1720	0.1840	0.1464	0.06220	0.01454	0.05	0.05	30.0
365	0.2124	0.2145	0.1974	0.06220	0.00912	0.05	0.05	30.0
366	0.1743	0.1752	0.1004	0.02466	0.02174	0.05	0.05	31.0
367	0.2166	0.2166	0.1449	0.02466	0.02166	0.05	0.05	31.0
368	0.2928	0.2915	0.2261	0.02466	0.02104	0.05	0.05	31.0
369	0.2282	0.2213	0.1790	0.02717	0.01568	0.05	0.05	31.0

Cont. ...

1	2	3	4	5	6	7	8	9
370	0.1726	0.1757	0.1261	0.02717	0.01702	0.05	0.05	31.0
371	0.1505	0.1536	0.0995	0.02717	0.01801	0.05	0.05	31.0
372	0.1120	0.1193	0.0862	0.02717	0.01311	0.05	0.05	31.0
373	0.1690	0.1713	0.1564	0.02717	0.00939	0.05	0.05	31.0
374	0.1913	0.1924	0.1656	0.02717	0.00828	0.03	0.05	31.0
375	0.3194	0.3197	0.2439	0.02717	0.01383	0.03	0.05	31.0
376	0.2204	0.2220	0.1056	0.02768	0.01743	0.03	0.05	31.0
377	0.2620	0.2671	0.1263	0.06257	0.01843	0.03	0.05	31.0
378	0.2863	0.2885	0.1850	0.06257	0.01598	0.03	0.05	31.0
379	0.3146	0.3162	0.2520	0.06257	0.01308	0.03	0.05	31.0
380	0.2003	0.2039	0.1874	0.06257	0.00572	0.03	0.05	31.0
381	0.1610	0.1700	0.0739	0.08575	0.00516	0.01	0.05	31.0
382	0.1353	0.1452	0.0942	0.06227	0.00357	0.01	0.05	31.0
383	0.2260	0.2270	0.0888	0.06227	0.00677	0.01	0.05	31.0
384	0.2993	0.3005	0.0945	0.06227	0.00800	0.01	0.05	31.0
385	0.3748	0.3751	0.1672	0.04516	0.00786	0.01	0.05	30.0
386	0.2390	0.2402	0.0684	0.04516	0.00707	0.01	0.05	30.0
387	0.2492	0.2508	0.1393	0.04516	0.00578	0.01	0.05	30.0
388	0.2660	0.2671	0.2030	0.04516	0.00426	0.01	0.05	30.0
389	0.2144	0.2158	0.0922	0.04482	0.00600	0.01	0.05	30.0
390	0.2377	0.2390	0.2000	0.04482	0.00330	0.01	0.05	30.0
391	0.1526	0.1526	0.1411	0.04482	0.00167	0.01	0.05	30.0
392	0.1265	0.1331	0.0422	0.04482	0.00490	0.01	0.05	30.0
393	0.2145	0.2145	0.1293	0.01917	0.00488	0.01	0.05	30.0
394	0.2600	0.2600	0.1511	0.02692	0.00563	0.01	0.05	30.0
395	0.2072	0.2077	0.1316	0.02692	0.00462	0.01	0.05	30.0
396	0.1473	0.1492	0.0802	0.02692	0.00437	0.01	0.05	30.0

APPENDIX XI

EFFECTS OF FROUDE NUMBER ON ELEMENTARY DISCHARGE COEFFICIENTS

For a side weir, the *elementary discharge coefficient* may be assumed to be a function of Froude number, η_w and η_L, i.e.

$$C_e = f(\eta_w, \eta_L, F) \tag{XI-1}$$

In order to ascertain the dependency of C_e on **F**, the experimental data of the present study was reanalyzed as explained below:

For an unrestricted sharp crested side weir, the constants k_0 though k_5 in (6.1) were first considered to be a functions of $\mathbf{F}_0$. The experimental data having same or very nearly same $\mathbf{F}_0$ were separated and for each such set the side weir constants were obtained by minimizing the average percentage error between the computed and observed side weir discharges. Fig XI-1 depicts the plot of constants k_i (i = 0, 1, ...,5) versus $\mathbf{F}_0$. It may be noted that these constants do not deviate considerably from the k_i values obtained using the entire data set, that is, when C_e was considered as a function of η_w only (k_0 = 0.447, k_1 = 44.7, k_2 = 50.0, k_3 = 6.67, k_4 = 6.67 and k_5 = 0.15). Further, a perusal of Fig. XI-1 indicated that these deviations in k_i values do not show

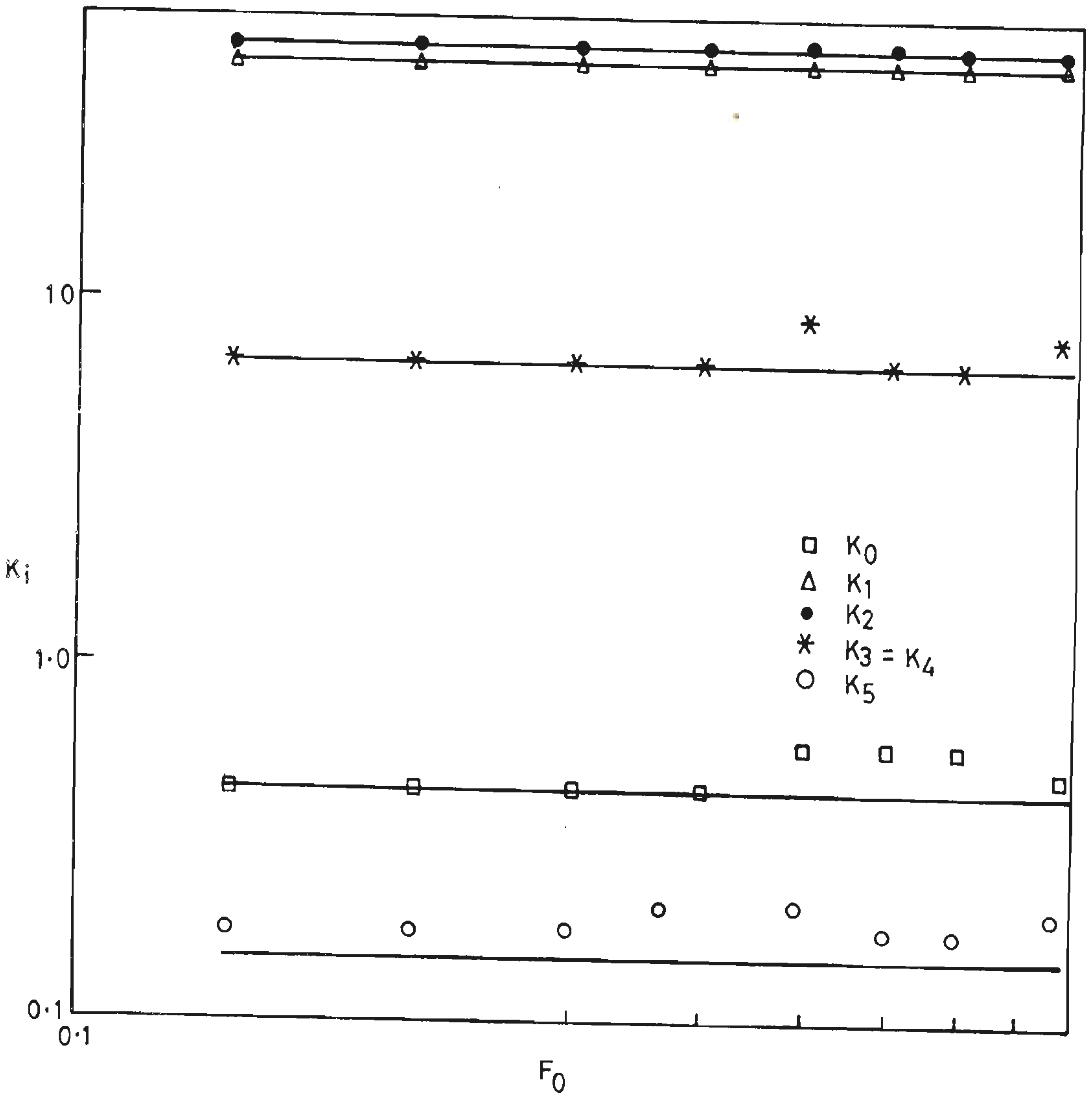

Fig. XI-1 Side Weir Constants

any trend with respect to F_0 and are possibly due to the sensitivity of the optimization process to relatively small population of the data set corresponding to each F_0. Thus, it becomes evident that side weir constants k_i do not depend on F_0.

The constants k_i in (6.1) were next considered to be functions of F_b and the above analysis was repeated. Fig. XI-2 shows the plot of k_i versus F_b. Again, it is evident from Fig. XI-2 that k_i values do not show any dependency on F_b.

Thus, the above analysis indicates that C_e is practically independent of F_0 as well as F_b. Since the local Froude number varies in a continuous manner between F_0 and F_b, the range of dependency of C_e on F would lie somewhere between that on F_0 and F_b. Therefore, it is logical to infer that C_e is also practically independent of F.

Similar results were obtained from the reanalysis of the experimental data of the present study for other types of side weir and side sluice gates.

For the sake of comparison, starting from (3.16) due to Hager and Volkart (1986), the following expression of C_e was obtained for unrestricted sharp crested side weir in a prismatic ($dB/dx = 0$) channel:

$$C_e = 0.6364 \left[\frac{1 + 0.5\left(\dfrac{1+\eta_w}{\eta_w}\right)F^2}{1 + 1.5\left(\dfrac{1+\eta_w}{\eta_w}\right)F^2} \right]^{0.5} \left[1 - 1.2247 \left(\frac{1+\eta_w}{\eta_w}\right)^{0.5} S_0 F \right] \qquad \text{(XI-2)}$$

Equation (XI-2) is shown plotted in Fig. XI-3 for the case of

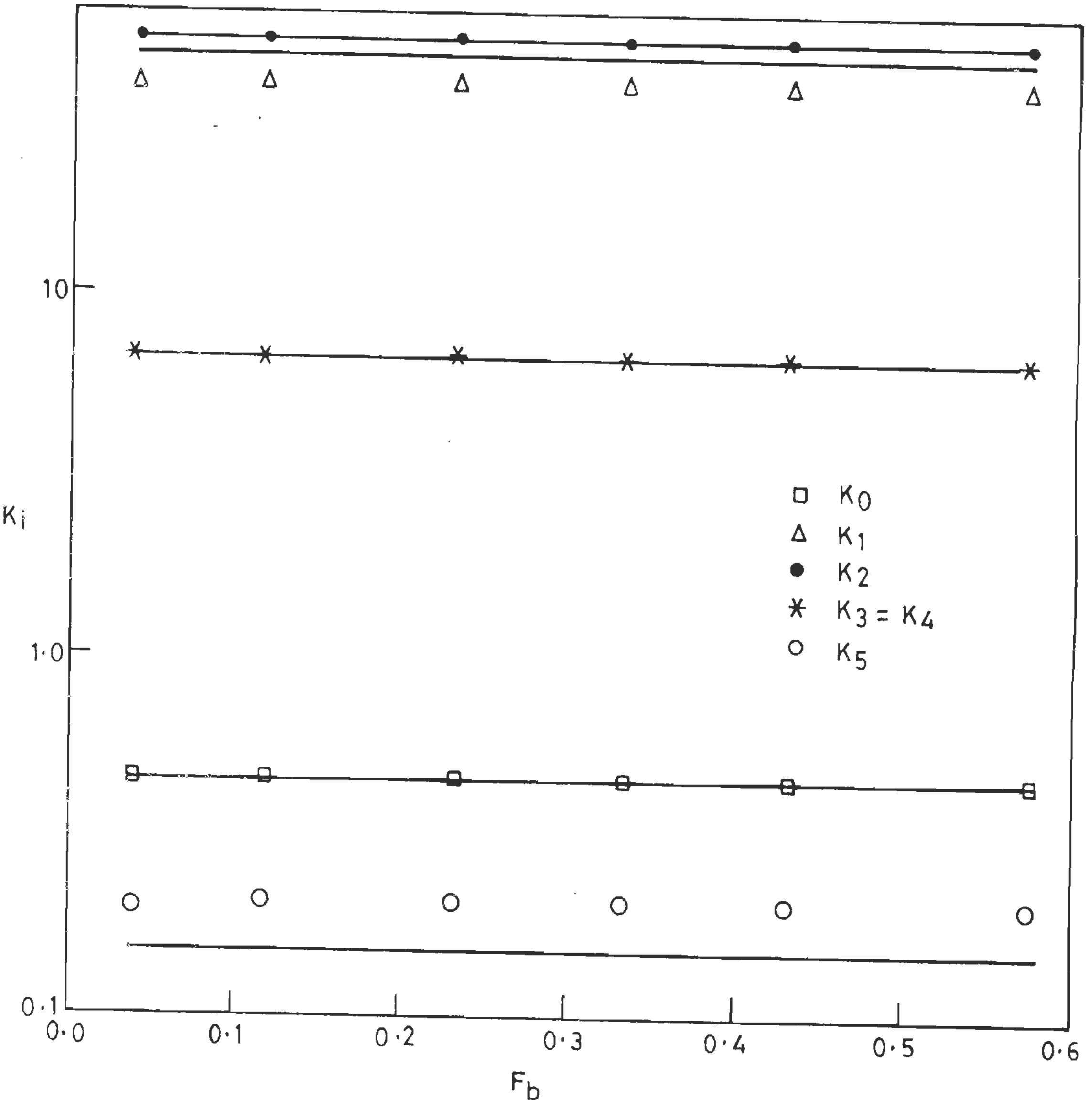

Fig. XI-2 Side Weir Constants

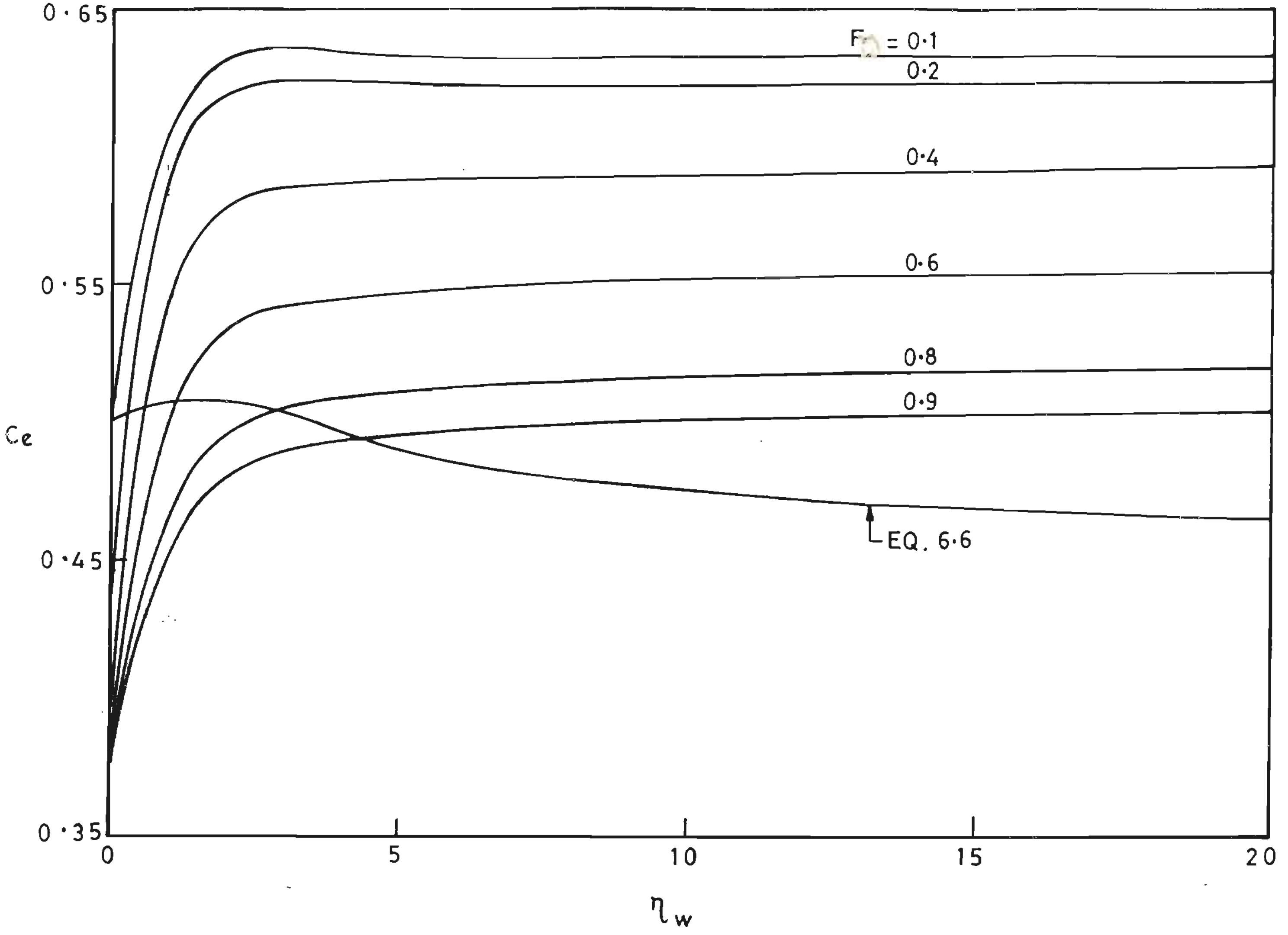

Fig. XI-3 Elementary Discharge Coefficient of Side Weir horizontal channel (S_0 = 0). The large variation in C_e with F as predicted by (XI-2) is not supported by the experimental variation of C_e as obtained from the present study and embodied in (6.6). It may also be pointed out that for $S_0 \neq 0$, (XI-2) gives negative value of C_e for low η_w indicating thereby negative side weir discharge which is not physically possible.

Further, using (XI-2), the side weir discharge was computed and compared with observed discharge in Fig. XI-4. Using (XI-2) yielded the error = 16.64 which is larger than the corresponding average percentage error of 6.63 using (6.6). See Fig. 6.1. A perusal of Fig. XI-4 also indicates ~~that~~ the predicted side weir discharge is consistently higher than the observed side weir discharge.

In view of the above discussion, it is reasonable to adopt a functional form of C_e involving the diversion structure geometry only, as in the case of the discharge coefficient in normal weir (Swamee 1988) and normal sluice gate (Swamee 1992). It may also be pointed out that the effect of flow dynamics is adequately taken into to account by the governing spatially varied flow equation (2.3).

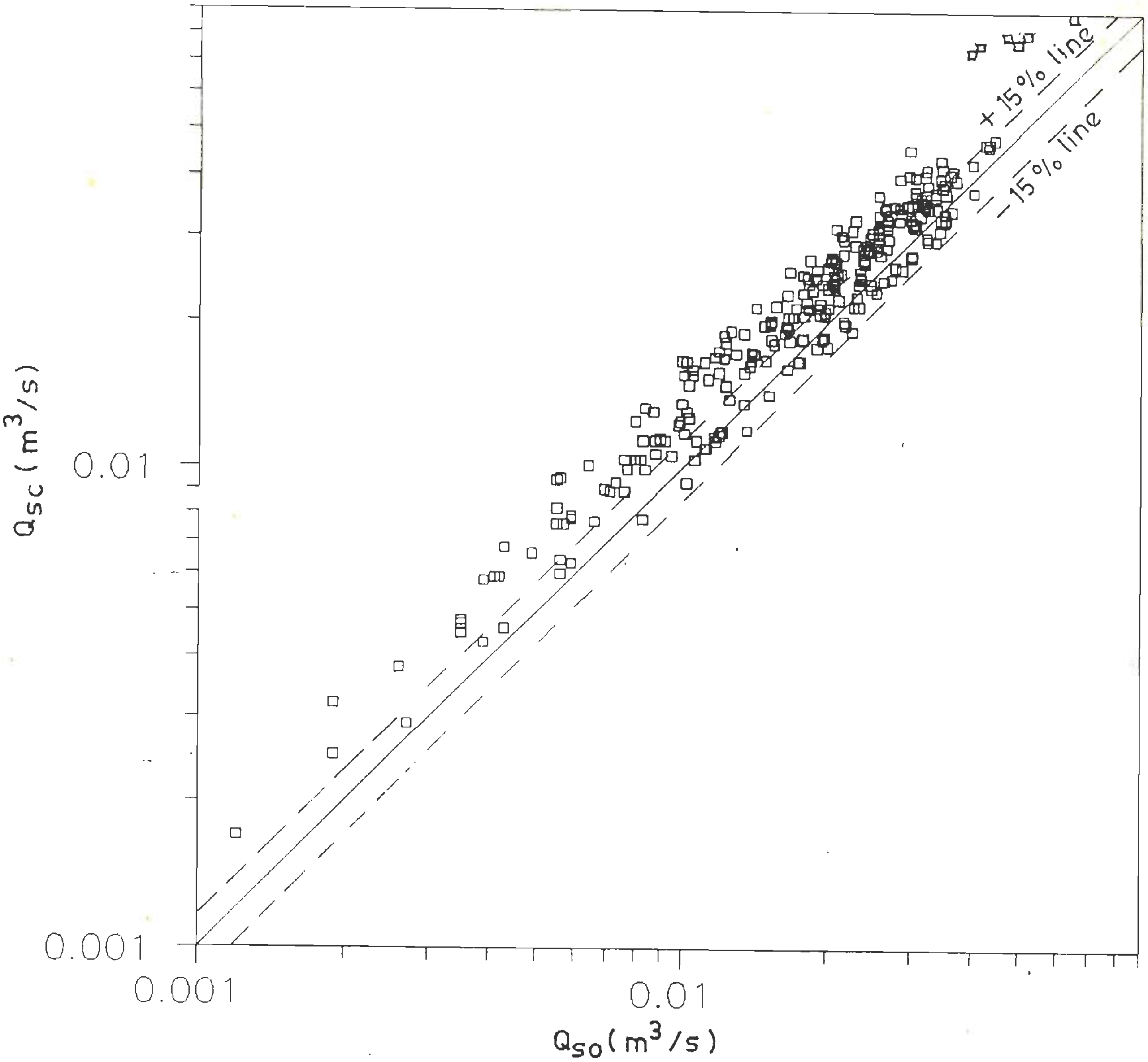

Fig. XI-4 Comparison of Discharge (Hager and Volkart, 1986)

List of Publications Out of This Thesis

1. "Rectangular side sluice gate analysis," *J. Irrig., and Drain. Engrg.*, ASCE, 119(6), Nov - Dec 1993 , 1026 — 1035

2. "Subcritical flow over rectangular side weirs," *J. Irrig. and Drain. Engrg.*, ASCE, 120(1), Jan - Feb 1994, 212-217

3. "Side weir using elementary discharge coefficient", ~~Accepted for Publication in~~ *J. Irrig. and Drain. Engrg.*, ASCE. , Jul - Aug. 1994 120(4), 742-755,