

CHAPTER 3

STORM DRAINAGE SYSTEMS

3.5 Curb Inlet Design

3.5.1 Curb Inlets On Grade

Following is a discussion of the procedures for the design of curb inlets on grade. Curb-opening inlets are effective in the drainage of highway pavements where flow depth at the curb is sufficient for the inlet to perform efficiently. Curb opening are relatively free of clogging tendencies and offer little interference to traffic operation. They are a viable alternative to grates in many locations where grates would be in traffic lanes or would be hazardous for pedestrians or bicyclists.

The length of curb-opening inlet required for total interception of gutter flow on a pavement section with a straight cross slope, is determined using Figure 3.5.1-1. The efficiency of curb-opening inlets shorter than the length required for total interception, is determined using Figure 3.5.1-2.

The length of inlet required for total interception by depressed curb-opening inlets or curb-openings in depressed gutter sections can be found by the use of an equivalent cross slope, S_e , in the following equation.

$$S_e = S_x + S'_w E_o \quad \text{(Eq 3.5.1-1)}$$

Where: E_o = ratio of flow in the depressed section to total gutter flow

S'_w = cross slope of the gutter measured from the cross slope of the pavement, S_x

S'_w = $(a/12W)$ (a-in, W – ft)

a = gutter depression (in)

It is apparent from examination of Figure 3.5.1-1 that the length of curb opening required for total interception can be significantly reduced by increasing the cross slope or the equivalent cross slope. The equivalent cross slope can be increased by use of a continuously depressed gutter section or a locally depressed gutter section.

Design Steps

Steps for using figures 3.5.1-1 and 3.5.1-2 in the design of curb inlets on grade are given below.

Figure 3.5.1-1

Curb-Opening And Slotted Drain Inlet Length For Total Interception

Source: HEC-12

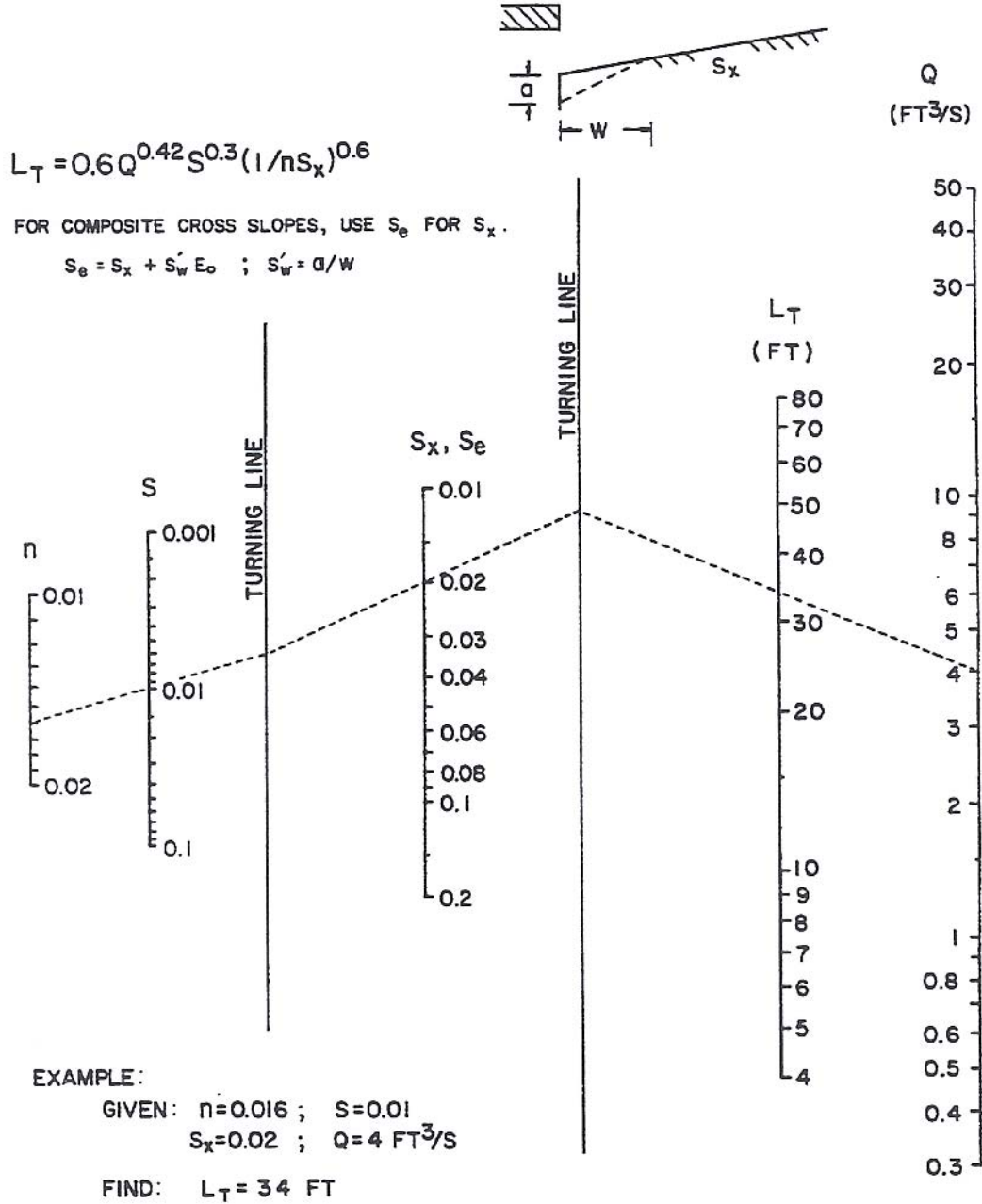
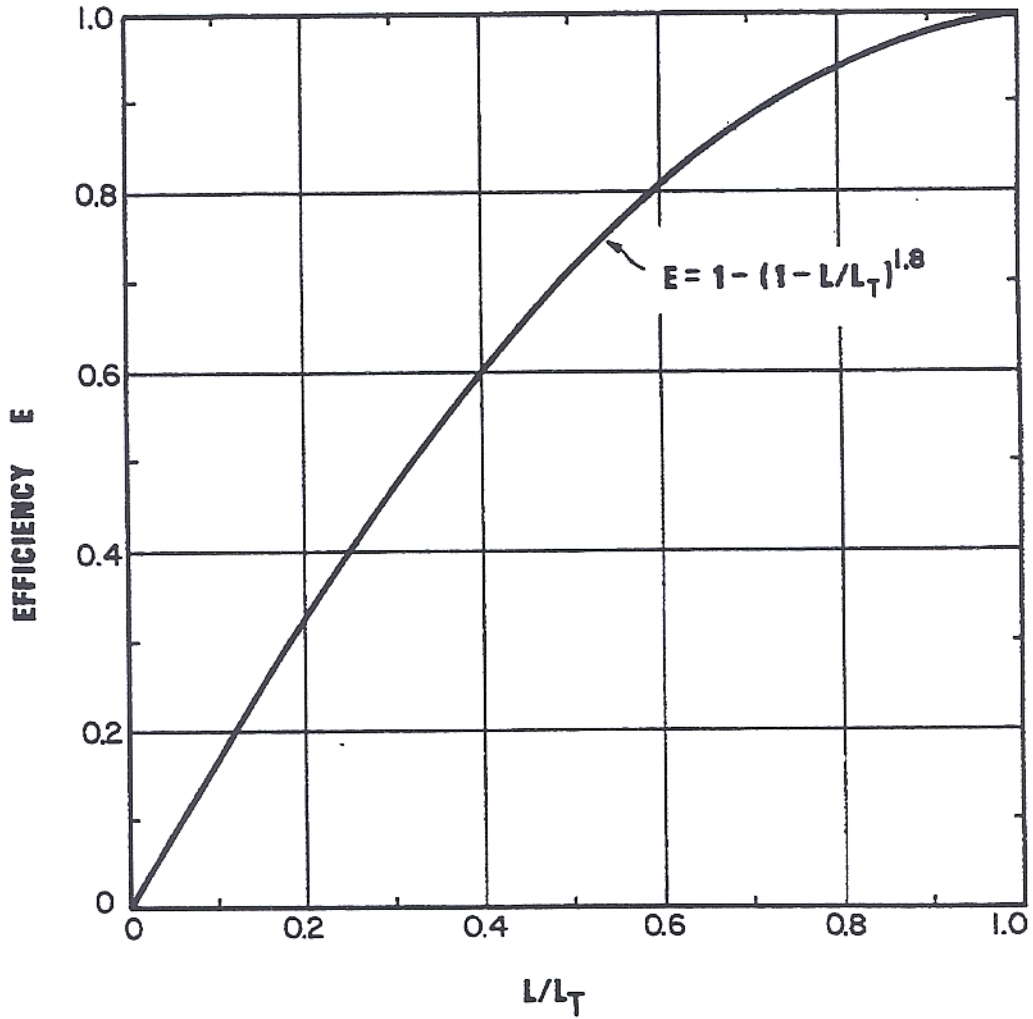


Figure 3.5.1-2

Curb-Opening And Slotted Drain Inlet Interception Efficiency

Source: HEC-12



Step 1 Determine the following input parameters:

Cross slope = S_x (ft/ft) Longitudinal slope = S (ft/ft)

Gutter flow rate = Q (cfs) Manning's $n = n$

Spread of water on pavement = T (ft) from Figure 3.3.3-1

Step 2 Enter figure 3.5.1-1 using the two vertical lines on the left side labeled n and S . Locate the value for Manning's n and longitudinal slope and draw a line connecting these points and extend this line to the first turning line.

Step 3 Locate the value for the cross slope (or equivalent cross slope) and draw a line from the point on the first turning line through the cross slope value and extend this line to the second turning line.

Step 4 The far right vertical line labeled Q locate the gutter flow rate. Draw a line from this value to the point on the second turning line. Read the length required from the vertical line labeled L_T .

Step 5 If the curb-opening inlet is shorter than the value obtained in step 4, Figure 3.5.1-2 can be used to calculate the efficiency. Enter the x-axis with the L/L_T ratio and draw a vertical line upward to the E curve. From the point of intersection, draw a line horizontally to the intersection with the y-axis and read the efficiency value.

Example

Given: $S_x = 0.03$ ft/ft

$n = 0.016$

$S = 0.035$ ft/ft

$S'_w = .083$ ($a = 2$ in, $W = 2$ ft)

$Q = 5$ cfs

Find:

Q_i for a 10-ft curb-opening inlet

Q_i for a depressed 10-ft curb-opening inlet with

$a = 2$ in,

$W = 2$ ft

$T = 8$ ft (Figure 3.3.3-1)

Solution:

From Figure 3-7

$L_T = 41$ ft

$L/L_T = 10/41 = 0.24$

From Figure 3-8

$$E = 0.39$$

$$Q_i = EQ = 0.39 \times 5 = 2 \text{ cfs}$$

$$Q_n = 5.0 \times 0.016 = 0.08 \text{ cfs}$$

$$S_w/S_x = (0.03 + 0.083)/0.03 = 3.77$$

From Figure 3.3.5-1

$$T/W = 3.5$$

$$T = 3.5 \times 2 = 7 \text{ ft}$$

$$W/T = 2/7 = 0.29 \text{ ft}$$

From Figure 3.3.3-2

$$E_o = 0.72$$

$$\text{Therefore, } S_e = S_x + S'_w E_o = 0.03 + 0.083(0.72) = 0.09$$

From Figure 3.5.1-1

$$L_T = 23 \text{ ft}$$

$$L/L_T = 10/23 = 0.43$$

From Figure 3.5.1-2

$$E = 0.64$$

$$Q_i = 0.64 \times 5 = 3.2 \text{ cfs}$$

The depressed curb-opening inlet will intercept 1.6 times the flow intercepted by the undepressed curb opening and over 60 percent of the total flow.

3.5.2 Curb Inlets In Sump

For the design of a curb-opening inlet in a sump location, the inlet operates as a weir to depths equal to the curb opening height and as an orifice at depths greater than 1.4 times the opening height. At depths between 1.0 and 1.4 times the opening height, flow is in a transition stage.

Figure 3.5.2-1

Depressed Curb-Opening Inlet Capacity In Sump Locations

Source: HEC-12

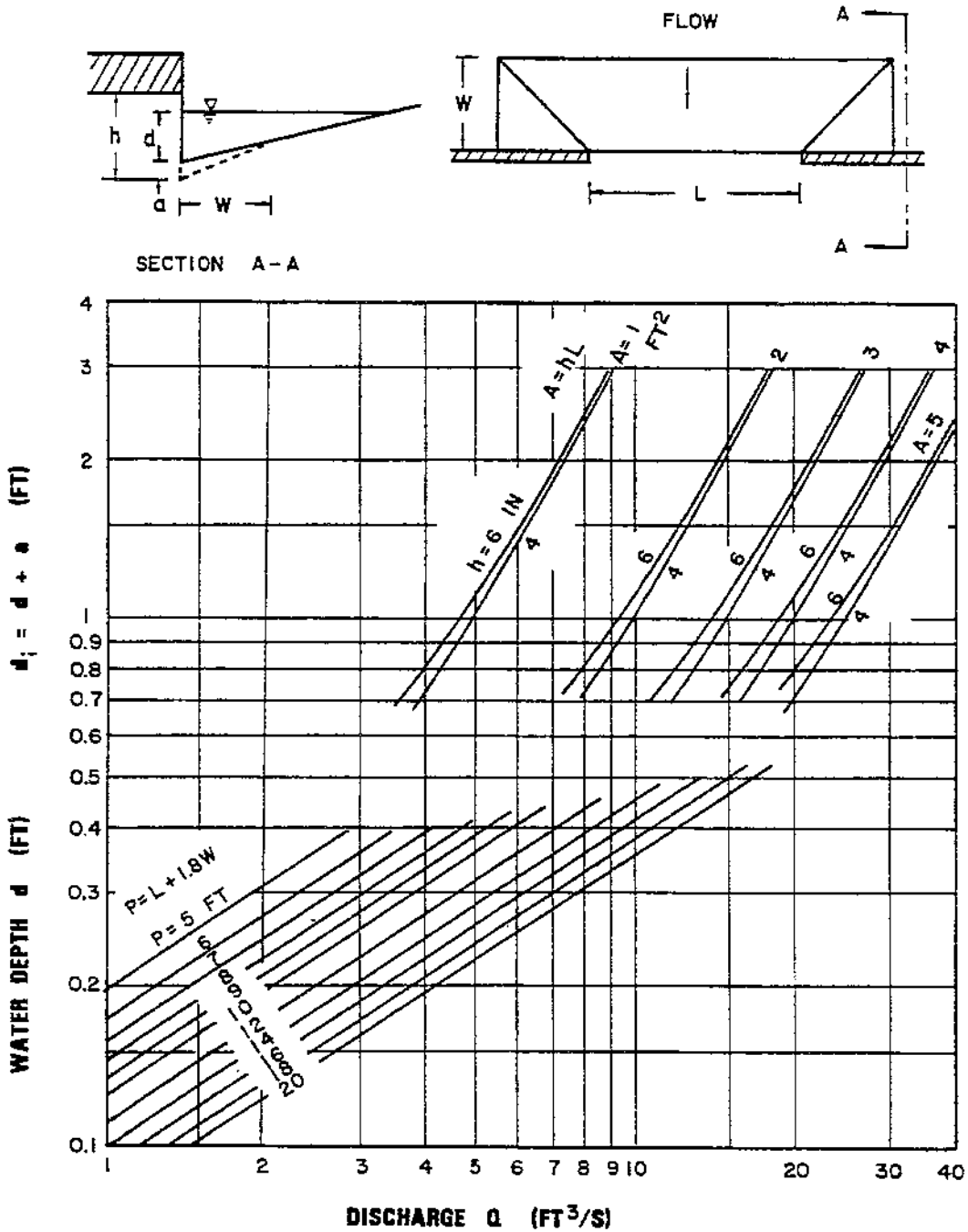


Figure 3.5.2-2

Curb-Opening Inlet Capacity In Sump Locations

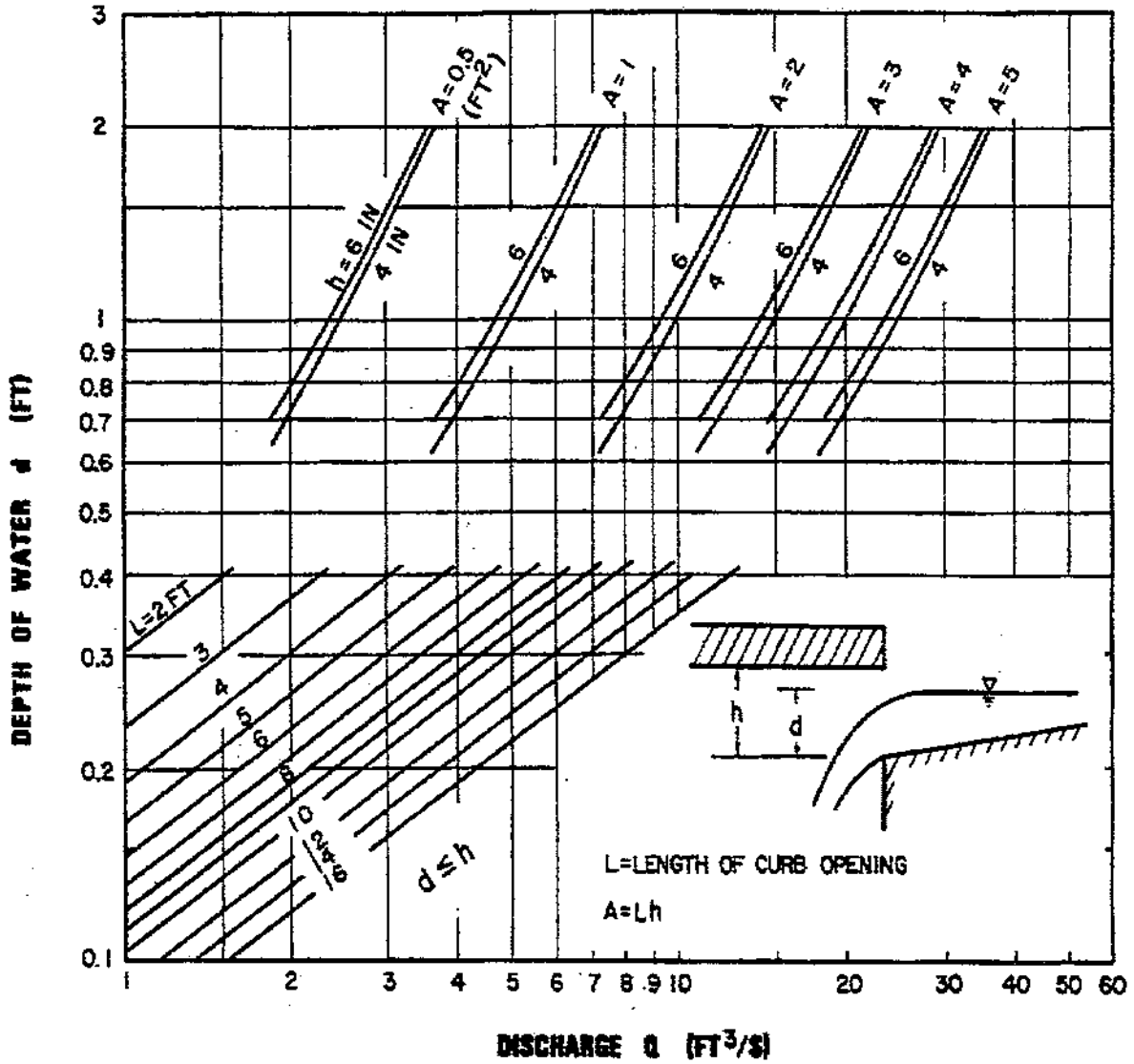
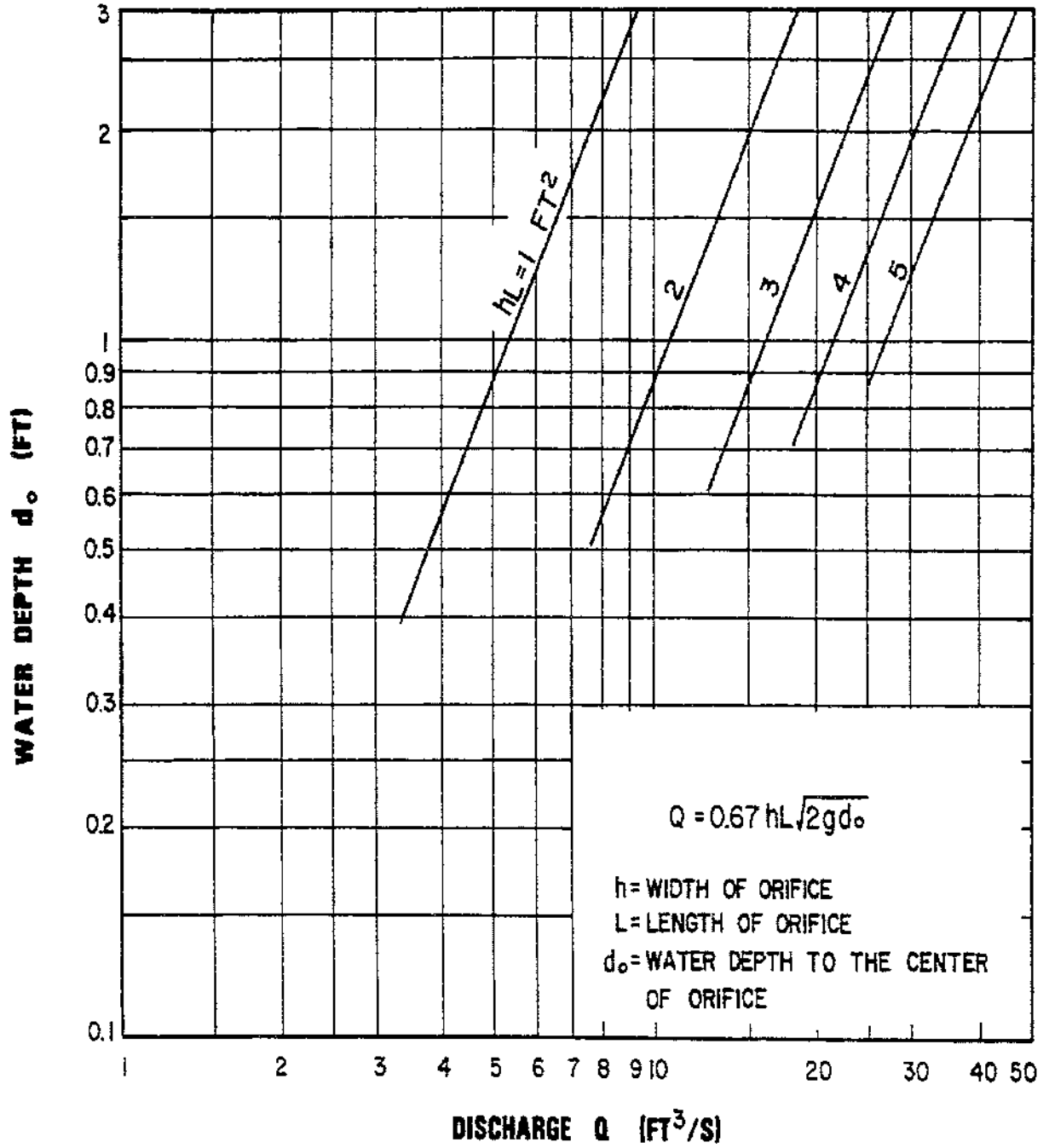


Figure 3.5.2-3

Curb-Opening Inlet Orifice Capacity For Inclined

And Vertical Orifice Throats



The capacity of curb-opening inlets in a sump location can be determined from Figure 3.5.2-1 which accounts for the operation of the inlet as a weir and as an orifice at depths greater than $1.4h$. This figure is applicable to depressed curb-opening inlets and the depth at the inlet includes any gutter depression. The height (h) in the figure assumes a vertical orifice opening (see sketch on Figure 3.5.2-1). The weir portion of Figure 3.5.2-1 is valid for a depressed curb-opening inlet when $d \leq (h + a/12)$.

The capacity of curb-opening inlets in a sump location with a vertical orifice opening but without any depression can be determined from figure 3.5.2-2. The capacity of curb-opening inlets in a sump location with other than vertical orifice openings can be determined by using Figure 3.5.2-3.

Design Steps

Steps for using Figures 3.5.2-1, 3.5.2-2, and 3.5.2-3 in the design of curb-opening inlets in sump locations are given below.

Step 1 Determine the following input parameters:

Cross slope = S_x (ft/ft)

Spread of water on pavement = T (ft) from Figure 3.3.3-1

Gutter flow rate = Q (cfs) or dimensions of curb-opening inlet [L (ft) and H (in)]

Dimensions of depression if any [a (in) and W (ft)]

Step 2 To determine discharge given the other input parameters, select the appropriate Figure (3.5.2-1, 3.5.2-2, or 3.5.2-3 depending whether the inlet is in a depression and if the orifice opening is vertical).

Step 3 To determine the discharge (Q), given the water depth (d) locate the water depth value on the y-axis and draw a horizontal line to the appropriate perimeter (p), height (h), length (L), or width x length (hL) line. At this intersection draw a vertical line down to the x-axis and read the discharge value.

Step 4 To determine the water depth given the discharge, use the procedure described in step except you enter the figure at the value for the discharge on the x-axis.

Example

Given: Curb-opening inlet in a sump location

$$L = 5 \text{ ft} \qquad h = 5 \text{ in}$$

Undepressed curb opening

$$S_X = 0.05 \text{ ft/ft} \qquad T = 8 \text{ ft}$$

Depressed curb opening

$$S_X = 0.05 \text{ ft/ft}$$

$$a = 2 \text{ in}$$

$$W = 2 \text{ ft}$$

$$T = 8 \text{ ft}$$

Find: Discharge Q_i

Solution: $d = TS_X = 8 \times 0.05 = 0.4 \text{ ft}$

$$d < h$$

From Figure 3.5.2-2

$$Q_i = 3.8 \text{ cfs}$$

$$d = 0.4 \text{ ft}$$

$$h + a/12 = (5 + 1/12)/12 = 0.43 \text{ ft}$$

since $d < 0.43$ the weir portion of Figure 3.5.2-1 is applicable (lower portion of the Figure).

$$P = L + 1.8W = 5 + 3.6 + 8.6 \text{ ft}$$

From Figure 3-9, $Q_i = 5 \text{ cfs}$

At $d = 0.4 \text{ ft}$, the depressed curb-opening inlet has about 30 percent more capacity than an inlet without depression.

END OF SECTION 3.5