CHAPTER 4. STREETS AND INLETS

4.1 Design Criteria

The design criteria for streets and inlets includes minimum standards for design storms, streets with curb and gutter, gutter inlet on continuous grade, combination inlet on sag or sump, maximum street spread and streets with side ditch swales.

4.1.1 Design Storms

For street and inlet design the design storm is the 5-year rainfall (see Section 5.1.1 for storm sewer pipe design requirements). After initially designing the streets and inlets for the design storm, a check shall be made to ensure that the 10- and 100-year rainfalls do not exceed the maximum depth of flow (Article 4.1.2).

Final design shall indicate water surface elevations for the design storm. In addition, the 100-year water surface elevation for all streets and inlets shall be shown.

4.1.2 Streets with Curb and Gutter

The design roughness coefficient "n" value shall be 0.015 for paved streets. The minimum gutter slope shall be 0.50 percent. All street resurfacing shall be done to maintain a recommended minimum flow depth of 5 3/4 inches at the face of the curb.

Depth of flow shall not exceed the top of curb for the 5-year design storm. In addition, the 100-year water surface elevations shall not exceed 10-inch depth above the curb for local and collector streets and shall not exceed 6-inch depth at crown for arterial streets. In order for the depth of flow not to exceed the specified limit, especially for the 100-year rainfall, an open channel or storm sewer system may be required to convey some of the flow to a major channel. Where a drainageway is located outside a street right-of-way, easements shall be provided. In determining the required capacity of surface channels and storm sewer system, the street storm inlets and conduit provided shall be assumed to be carrying not more than one-half their design capacity.

4.1.3 Gutter Inlets: Continuous Grade

Gutter inlets shall have a local depression of 3/4 inch below the normal gutter flow line.

Gutter inlets shall be located at all points where the maximum pavement spread or maximum flow depth is reached. No flow is permitted to cross street intersections for the initial design storm. Maximum inlet spacing on a continuous grade shall be 300 feet. Gutter inlets shall not be closer than 3 feet to the point of the drop curb to a driveway or handicap ramp.

4.1.4 Combination Inlets: Sag or Sump

Combination inlets shall be provided at all sag or sump locations. If the length of grade coming into a sag or sump inlet exceeds 600 feet, two combination inlets shall be provided at the sag or sump location. When combination inlets are used, the grate capacity alone shall be considered the capacity of the inlet. The curb opening serves as a relief in the event the grate is clogged.

Combination inlets with grate and curb opening shall have a local depression of 3/4 inches below the gutter flow line.

Combination inlets shall not be closer than 3 feet to the point of the drop curb to a driveway or handicap ramp.

4.1.5 Maximum Street Spread

The following are maximum spread of the 5-year rainfall design storm onto the pavement.

> For two-lane streets, maximum spread is 6 feet from the face of the curb.
>
> For four-lane streets, maximum spread is 8 feet from the face of the curb.

The more restrictive condition for either maximum street spread or depth of flow (Article 4.1.2) shall control.

4.1.6 Streets with Side Ditch Swales

Side ditch swales shall be designed in accordance with the general procedures stated in Chapter 3, "Open Channels" of this manual. The minimum channel bottom slope shall be 1.00 percent for grass or sod lined channels and 0.50 percent for paved or lined channels.

4.2 General Design Procedures

A generalized design approach to inlet spacing is as follows:

Step 1. Locate the first inlet at the point where the maximum gutter capacity is reached based on the 5-year design storm.

Step 2. Determine the inlet capacity Q and percent carryover (gutter flow) to the next inlet (Exhibit IV-1, page 4-8). As a general rule, the carryover flow should be no greater than 15 percent and the picked up flow no less than 85 percent.

Step 3. Locate the next inlet downstream at that point where the gutter capacity is again reached including the gutter flow (carryover) from the upstream inlet. Note that inlets so placed may or may not be located directly across from each other on each side of the street. The individual inlet spacing depends on the configuration of the tributary drainage area and the percent of carryover from the upstream inlet.

Step 4. Continue locating inlets at maximum gutter capacity points on continuous grades until a street intersection or a low point (sag) in the street profile is reached.

Step 5. At street intersections, inlet locations vary, depending on the respective street grades and pedestrian convenience.

Step 6. Inlets located at the sags of vertical curves are designed for a capacity adequate to intercept 100 percent gutter flow.

The following design procedures are included to outline a uniform approach to the determination of gutter carrying capacity, and capacity of inlets.

4.2.1 Gutter Capacity

Step 1. Draw the street cross section and determine the maximum depth of flow and the permissible pavement spread.

Step 2. Determine the gutter slope in feet per foot, and "z," the reciprocal of the cross slope.

Step 3. Calculate the theoretical gutter (triangular channel) carrying capacity by using the modified Manning's formula:

$$Q = (0.56\ Z\ S^{1/2} d^{8/3})/n$$

where Z is the reciprocal of the cross slope (T/d), n is Manning's coefficient of roughness, S is the longitudinal slope of the gutter in feet per foot, d is the depth of flow in the gutter at the deepest point in feet, and T is the top width of water surface in the gutter in feet. A nomograph for the solution of this formula is shown on Exhibit IV-2 (page 4-9). The nomograph may be used for all gutter configurations.

4.2.2 Capacity of a Grate Inlet or Combination Inlet on Continuous Grade

Step 1. Determine the gutter flow at the inlet location (Qa).

Step 2. Determine the gutter flow depth at the curb (d) and the spread of water on the roadway.

Step 3. Calculate the width, depth (d') and amount (Qa') of flow outside of the grate.

Step 4. Determine the flow over the end of the grate as QE = Qa - Qa'.

Step 5. Calculate flow over the side of the grate using the following steps:

a. Using the depth (d') and the depression (a) of the grate, enter Chart A of Exhibit IV-1 (page 4-8) and read Qa'/La.

b. Compute the 100 percent pickup length, La = Qa'/(Qa'/La)

c. Compute the ratio L/La where L is the distance along the outside edge of the grate. If this ratio is greater than or equal to 1.0, 100 percent of the flow is being intercepted, flow over the side of the grate is Qa' and continue with step 6 below. If the ratio is less than 1.0, only a portion of the flow is being intercepted over the side of the grate. The amount intercepted is calculated beginning with step d.

d. Determine the ratio a/d'.

e. Using L/La and a/d' enter Chart B of Exhibit IV-1 (page 4-8) and read Q'/Qa', the ratio of intercepted flow to total flow outside of grate.

f. Calculate the total flow intercepted over the outside edge of the grate, Q' = Qa' x (Q'/Qa').

Step 6. Determine the total flow intercepted Q = (Qa - Qa') + Q'.

Step 7. Calculate the carryover flow to the next inlet, Qa - Q.

Step 8. Calculate the percent of intercepted flow (% pickup), (Q/Qa) x 100.

Step 9. If the intercepted flow is less than 85 percent, try a different inlet location or type of gutter inlet.

4.2.3 Example - Capacity of a Grate Inlet on Continuous Grade

Find the discharge intercepted by the single gutter grate inlet. The inlet has the following characteristics: (1) local depression of 3/4 inch; (2) width of grate of 1.4 feet; (3) length of grate of 2.5 feet; (4) perimeter of grate of 4.6 feet; and (5) total clear opening area of grate of 1.6 square feet. The inlet is located on a four-lane street on a continuous longitudinal slope of 3 percent. The pavement cross slope is 2.5 percent and has a roughness coefficient value of 0.015. The gutter flow at the inlet location is 1.5 cfs.

Step 1. Gutter flow at the inlet location is 1.5 cfs.

Step 2. Use Exhibit IV-2 (page 4-9) with Z/n = (1/0.025)/0.015 = 2667, S = 0.03 ft/ft and Qa = 1.5 cfs read d = 0.15 ft.

Calculate spread of water = d/cross slope = 0.15/0.025 = 6 ft.

Check maximum street spread 6 ft < 8 ft.

Step 3. Calculate width, depth (d'), and flow (Qa') outside of the grate width = spread - width of grate = 6 - 1.4 = 4.6 ft. Depth (d') = width x cross slope = 4.6 x 0.025 = 0.115 ft. Use Exhibit IV-2 (page 4-9) with S = 0.03 ft/ft d' = 0.115 feet and Z/n = 2667. Read Qa' = 0.8 cfs.

Step 4. Calculate the flow over the end of the grate QE = Qa - Qa' = 1.5 - 0.8 = 0.7 cfs (flow at inlet location - flow outside of grate).

Step 5a. Use Exhibit IV-1 (page 4-8) Chart A with d' = 0.115 ft and a = 0.0625 ft and read Qa'/La = 0.047.

Step 5b. Calculate 100 percent pickup length (La). La = Qa'/(Qa'/La) = 0.8/0.047 = 17.02 ft.

Step 5c. Calculate ratio of length of grate L/La = 2.5/17.02 = 0.15 < 1.0 only portion of flow is intercepted.

Step 5d. Calculate ratio of local depression a/d' = 0.0625/0.115 = 0.54

Step 5e. Use Exhibit IV-1 (page 4-8) Chart B with L/La = 0.15 and a/d' = 0.54 and read Q'/Qa' = 0.27.

Step 5f. Calculate flow over the side of the grate Q' = (Qa')(Q'/Qa') = (0.8)(0.27) = 0.22 cfs.

Step 6. Calculate total flow intercepted Q = (Qa - Qa') + Q' = (1.5 - 0.8) + 0.22 cfs = 0.92 cfs.

Step 7. Calculate carryover flow = Qa - Q = 1.5 - 0.92 = 0.58

Step 8. Calculate percent of intercepted flow = (Q/Qa) x 100 = (0.92/1.5) x 100 = 61

Step 9. Check that intercept flow picks up 85 percent of flow in gutter. (1.5)(0.85) = 1.28 cfs > 0.92 cfs. Therefore, change location of inlet or try a double gutter inlet.

4.2.4 Capacity of Grate Inlet or Combination Inlet in Sag or Sump (Water Ponded on Grate)

The following general procedures are stated for a combination grate inlet. The same procedures would apply to a grate only inlet; however, in consideration of possible clogging of the grate it is recommended the design perimeter and the design area of the grate be one-half of the effective perimeter (P) and effective area (A) determined below.

Step 1. Calculate the total inflow (Q) to the inlet.

Step 2. Determine the effective perimeter of the grate opening (P) in feet ignoring the bars and omitting any side of the grate over which water does not enter; e.g., side against face of curb.

Step 3. Calculate the discharge per foot of perimeter (Q/P). Q is the total gutter discharge from each side of the grate.

Step 4. Determine the total clear opening area (A), excluding the area of the bars.

Step 5. Calculate the discharge per square foot of effective area (Q/A).

Step 6. Enter Exhibit IV-3 (page 4-10) with the values of Q/P and Q/A and read the required head (H) in feet using the appropriate weir or orifice curve.

Step 7. Compare the two head values from Curve A and Curve B to determine the type of flow; i.e., weir flow or orifice flow.

Step 8. If the required head (H) is between 0.4 and 1.4 feet, the actual head may be anywhere in this head range. Use the value that gives the more conservative result (highest H).

Step 9. Compare the value of H determined in the preceding steps to the maximum allowable gutter depth (d) including local depression (a).

a. $H > (d + a)$ indicates that the allowable ponding limits are exceeded and that additional inlets are required.

b. $H < (d + a)$ indicates the inlet has ample grate capacity and the maximum allowable ponding limits will not be exceeded.

4.2.5 Capacity of Combination Inlet on Continuous Grade

Step 1. Determine the length (L) of the inlet opening and the depth of local flow line depression (a) at the inlet.

Step 2. Calculate the design gutter discharge (Q_a) for the initial design storm as stated in the preceding Article 4.3.1, including carryover from previous inlets.

Step 3. Determine the gutter flow depth (d) at design Q_a for the particular street section using Exhibit IV-2 (page 4-9).

Step 4. Enter Chart A of Exhibit IV-1 (page 4-8) with depth of flow in gutter (d) and local depression (a) and determine the interception per foot of inlet opening (Q_a/L_a).

Step 5. Calculate the length, $L_a = Q_a(Q_a/L_a)$. If length L_a is less than actual inlet length L, 100 percent of the flow is being intercepted. If L_a is greater than L, determine the percentage intercepted following Steps 6 through 10.

Step 6. Calculate the ratio of actual inlet length (L) in feet to length of inlet required to intercept 100 percent of gutter flow (L_a). The ratio is expressed as (L/L_a). Also, calculate the ratio a/d.

Step 7. Enter Chart B of Exhibit IV-1 (page 4-8) with the ratios calculated in Step 6 and determine Q/Q_a (the ratio of total flow intercepted by the inlet to gutter flow).

Step 8. Calculate the total intercepted flow, $Q = Q/Q_a \times Q_a$.

Step 9. The carryover flow to the next inlet is $Q_a - Q$.

Step 10. Calculate the percent of intercepted flow (percent pickup) = $Q/Q_a \times 100$.

Step 11. If the intercepted flow is less than 85 percent, try a different inlet location.

4.2.6 Capacity of Gutter Inlet or Combination Inlet at Street Intersections

Inlets are usually placed immediately upstream from pedestrian crosswalks and street intersections and should intercept 100 percent of the gutter flow. The ponded water depth at such low points of street intersections is determined in terms of curb opening height (Exhibit IV-4, page 4-11) as follows:

Step 1. Calculate the inflow (Q) to the inlet.

Step 2. Determine the vertical height of curb opening (h) at the curb face, including local depression (a).

Step 3. Calculate the required capacity of the inlet per foot of length of opening, Q/L in cfs/foot.

Step 4. Determine the ratio of ponded water depth (H) to vertical curb opening height (h), H/h, using Exhibit IV-4 (page 4-11).

Step 5. Calculate the ponded water depth, $H = H/h \times h$ (in feet).

Step 6. The ponded water depth (H) is compared to the maximum allowable depth of flow in the gutter including local depression (a).

a. If H is less than (d + a) using the same units of depth, the curb opening inlet is intercepting 100 percent of the initial design storm discharge.

b. If H is greater than (d + a), the physical design criteria are exceeded and adjustments in the design are necessary.

CHART A

DISCHARGE PER FOOT OF LENGTH OF CURB OPENING INLETS WHEN INTERCEPTING 100% OF GUTTER FLOW

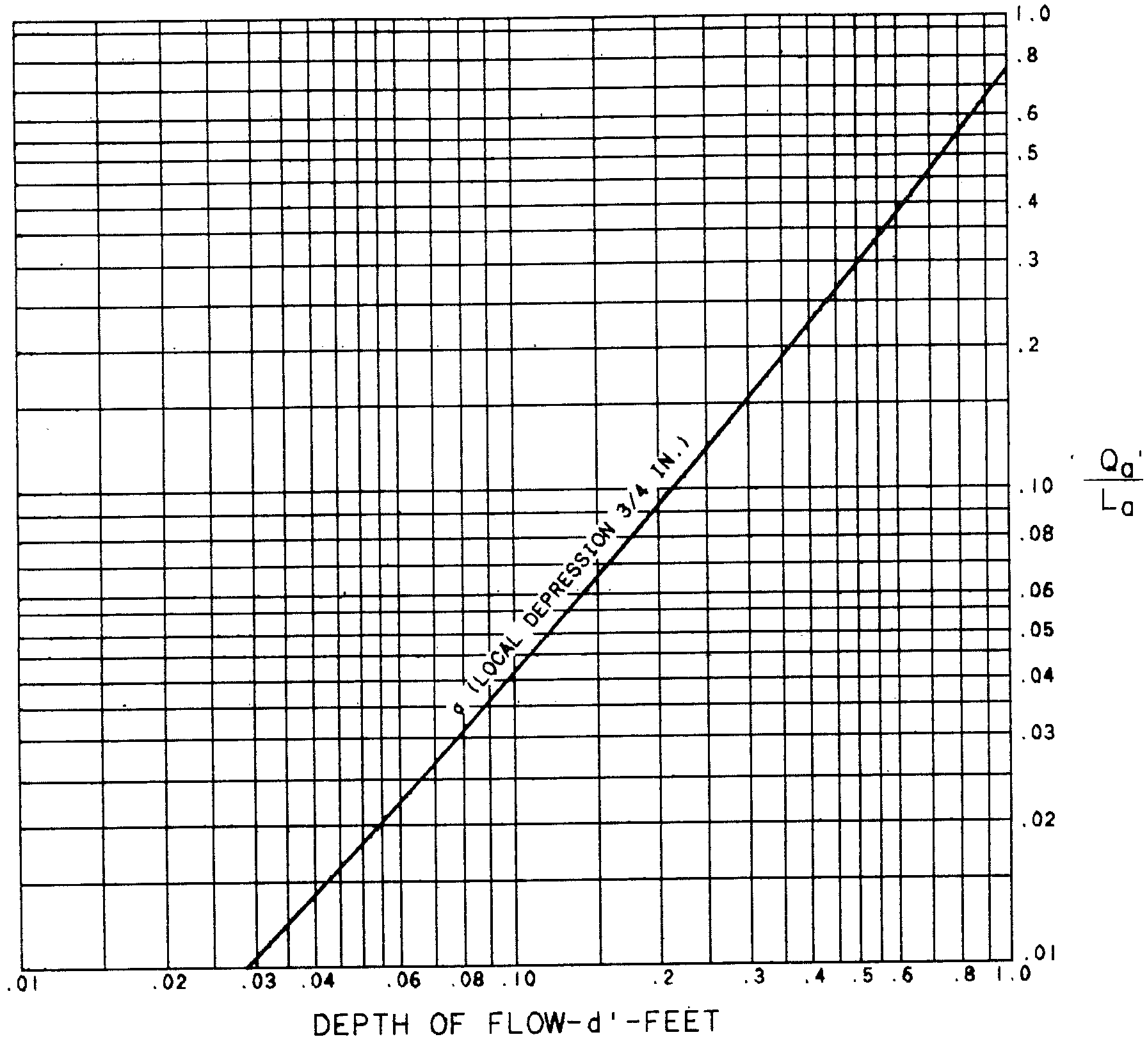
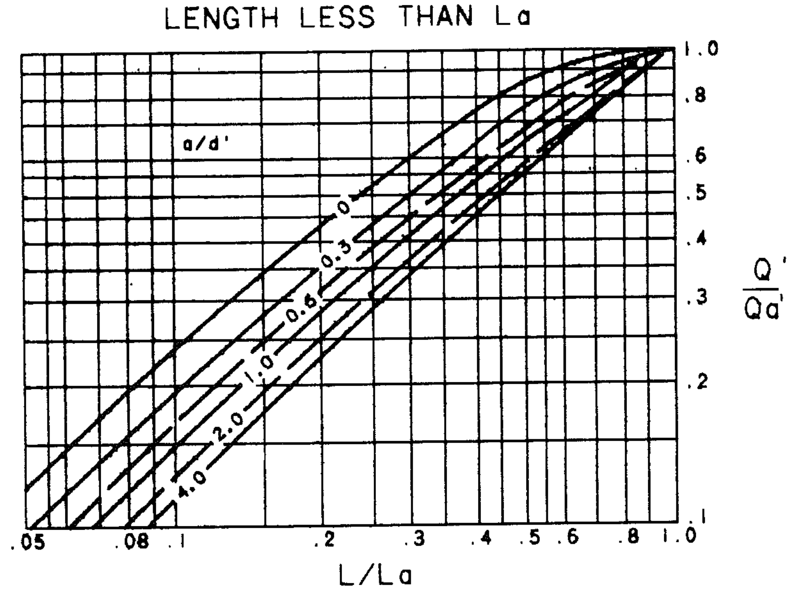
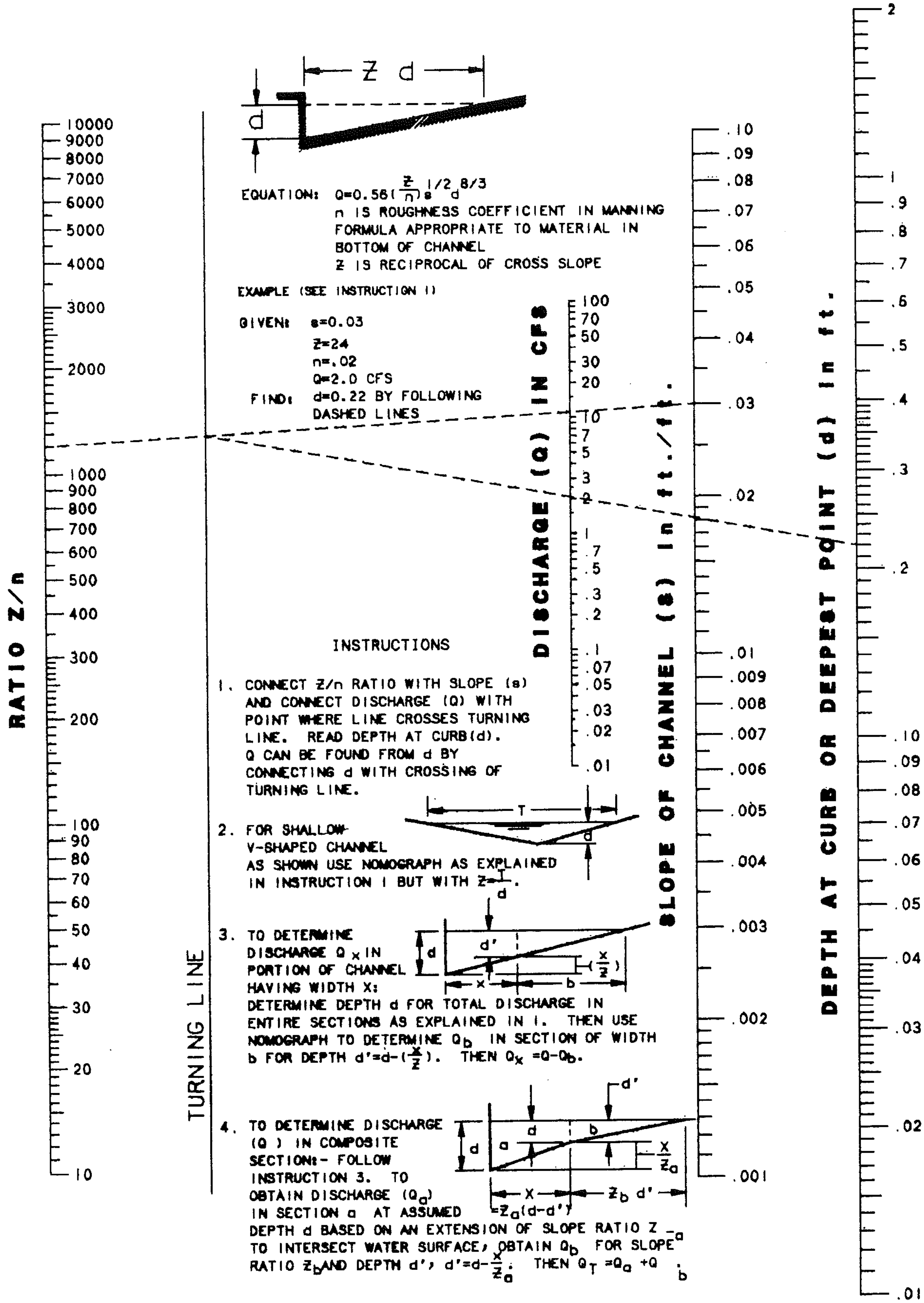


CHART B

PARTIAL INTERCEPTION RATIO FOR INLETS OF LENGTH LESS THAN La

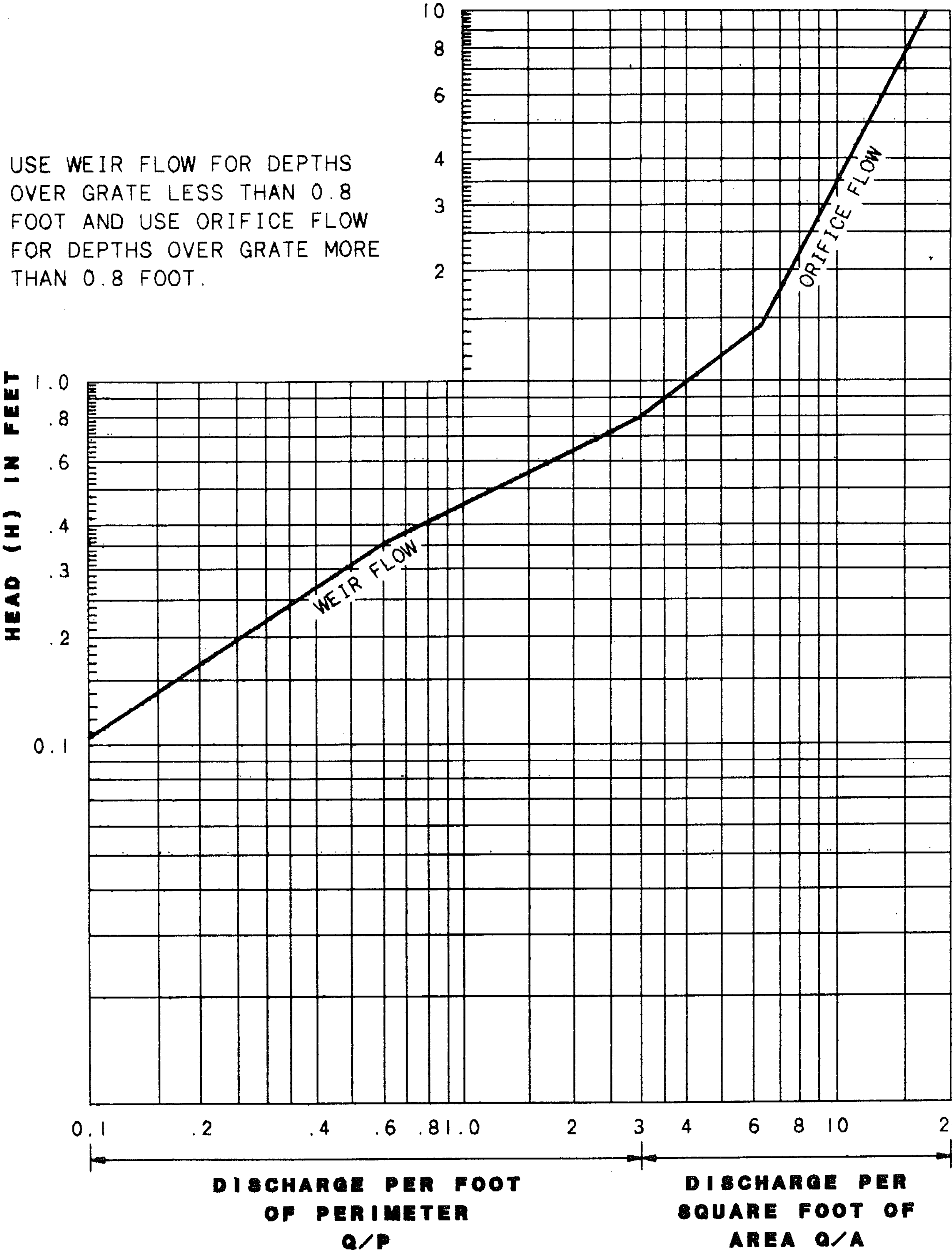


CAPACITY OF CURB OPENING INLETS ON CONTINUOUS GRADE

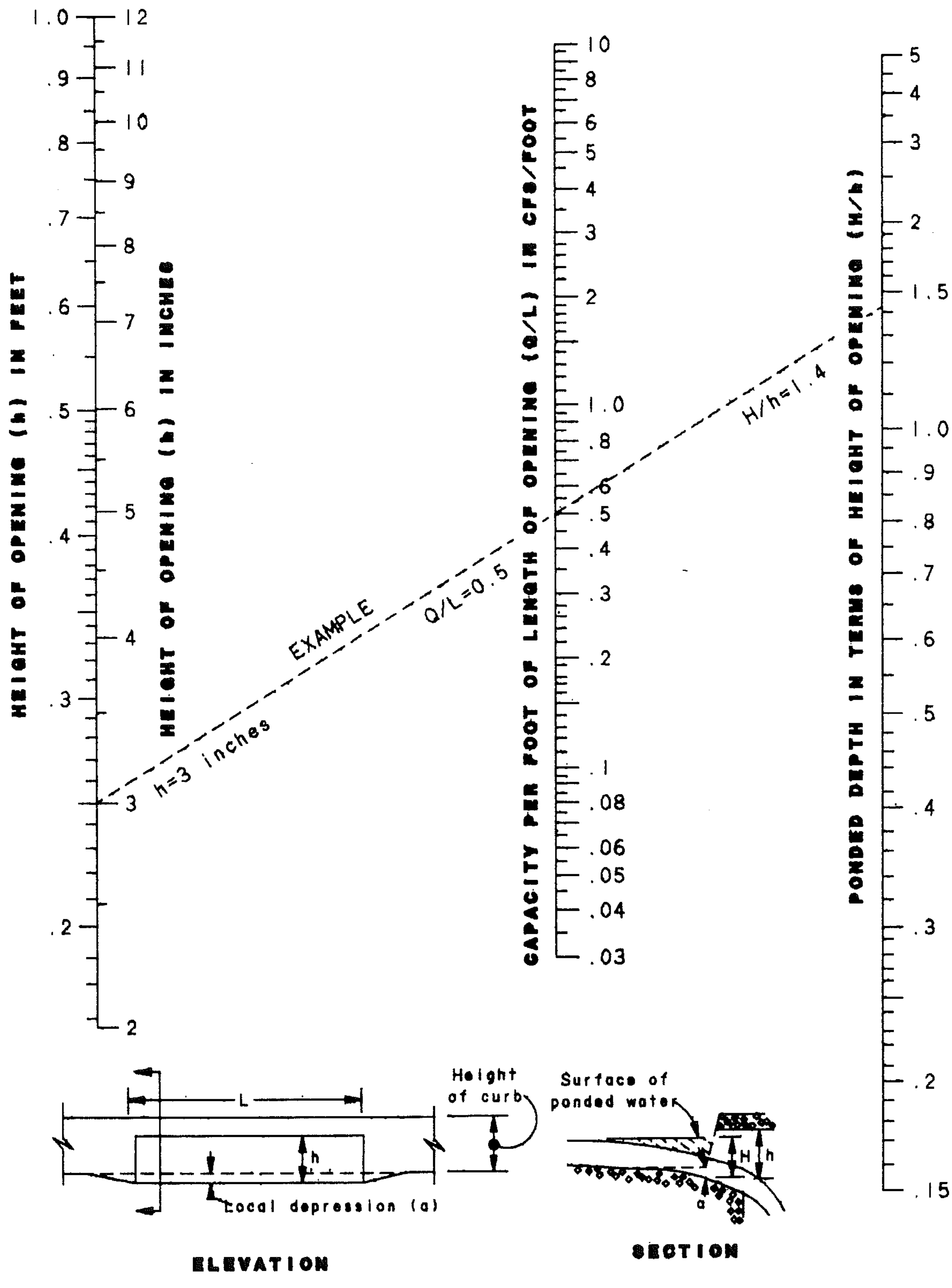


NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

USE WEIR FLOW FOR DEPTHS OVER GRATE LESS THAN 0.8 FOOT AND USE ORIFICE FLOW FOR DEPTHS OVER GRATE MORE THAN 0.8 FOOT.



CAPACITY OF GRATE INLET IN SUMP
(WATER PONDED ON GRATE)



CAPACITY OF CURB OPENING INLET AT LOW POINT IN GRADE (STREET INTERSECTION)

PAVEMENT DRAINAGE COMPUTATIONS

PROJECT ______________________ DESIGNER ______________________ DATE __________

DISCHARGE										GUTTER FLOW				GRATE OPENINGS INLETS					CURB OPENING INLETS									CHECK
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
INLET STATION	UPSTREAM STATION	LENGTH	WIDTH	A	C	CA	TIME	YEAR FREQUENCY I	Qo	GUTTER SLOPE (S)	CROSS SLOPE (Z)	DEPTH AT CURB (d)	SPREAD	TYPE OF INLET	WIDTH OF FLOW OUTSIDE OF GRATE	DEPTH OUTSIDE EDGE OF GRATE (d')	FLOW OUTSIDE OF GRATE (Q'o)	FLOW AT END OF GRATE (Qo-Q'o)	Qo/Lo CURB OPENING Q'o/Lo GRATE OPENING	100% PICKUP LENGTH (Lo)	L/Lo	o/d CURB OPENING o/d' GRATE OPENING	Q/Qo CURB OPENING Q'/Q'o GRATE OPENING	FLOW OVER SIDE OF GRATE (Q')	TOTAL FLOW INTERCEPTED (Q)	CARRY OVER FLOW	% PICKUP	INLET OK
		FT	FT	ACRES		ACRES	MIN	IN/HR	CFS	FT/FT	FT/FT	FT	FT		FT	FT	CFS	CFS		FT				CFS	CFS	CFS		