TABLE OF CONTENTS - SECTION VII

SECTION VII - STORM DRAIN INLETS

7.1 GENERAL

The primary purpose of storm drain inlets is to intercept excess surface runoff and deposit it in a drainage system, thereby reducing the possibility of surface flooding.

The most common location for inlets is in streets which collect and channelize surface flow making it convenient to intercept. Because the primary purpose of streets is to carry vehicular traffic, inlets must be designed so as not to conflict with that purpose.

The following guidelines shall be used in the design of inlets to be located in streets:

1. Minimum transition for depressed inlets shall be 10 feet.
2. When recessed inlets are used, they shall not interfere with the intended use of the sidewalk.
3. The capacity of a recessed inlet on grade shall be calculated the same as the capacity of a similar unrecessed inlet.
4. Design and location of inlets shall take into consideration pedestrian and bicycle traffic.
5. Inlet design and location must be compatible with the criteria established in Section III of this manual.
6. Inlet lengths shall be in 4' increments.
7. Curb inlets with vertical openings larger than 8" will require a grate to block the openings.
8. Grate inlets adjacent to a curb must be a combination inlet.

7.2 CLASSIFICATION

Inlets are classified into three major groups, mainly: Inlets in sumps (Type A), inlets on grade without gutter depression (Type B), and inlets on grade with gutter depression (Type C). Each of the three major classes include several varieties. The following are presented herein and are likely to find reasonable wide use. (See Figures 7.1 - 7.7)

Inlets in Sumps

1.	Curb opening	Type A-1
2.	Grate	Type A-2
3.	Combination (Grate & Curb Opening)	Type A-3
4.	Drop	Type A-4
5.	Drop (Grate Covering)	Type A-5

Inlets on Grade Without Gutter Depression

1.	Curb Opening	Type B-1
2.	Grate	Type B-2
3.	Combination (Grate & Curb Opening)	Type B-3

Inlets on Grade With Gutter Depression

1.	Curb Opening	Type C-1
2.	Grate	Type C-2
3.	Combination (Grate & Curb Opening)	Type C-3

Recessed inlets are identified by the suffix (R), (i.e.: A-1 (R)).

<u>Engineering Department</u> review of the proposed Drainage Plan shall include examination of the supporting calculations. **Computations must be submitted either as a part of the Plans or on separate tabulations sheets convenient for review and use as a permanent record in order to speed review.**

7.3 INLETS IN SUMPS

Inlets in sumps are inlets placed in low points of surface drainage areas to relieve ponding. The capacity of inlets in sumps must be known in order to determine the depth and width of ponding for a given discharge. The charts in this section may be used in the design of any inlet in a sump, regardless of its depth of depression.

7.3.1 CURB OPENING INLETS AND DROP INLETS (TYPE A-1 and A-4)

Unsubmerged curb opening inlets (Type A-1) and drop inlets (Type A-4) in a sump at low points are considered to function as rectangular weirs with

a coefficient of discharge of 3.0. Their capacity shall be based on the following equation:

$$Q = 3.0\, Y^{3/2} L$$

$Q =$ capacity in CFS of curb opening inlet or capacity in CFS of drop inlet

$Y =$ head at the inlet in feet when Y is less than the height of the opening

$L =$ length of opening through which water enters the inlet in feet

Figure 7.8 provides for direct solution of the above equation.

7.3.2 GRATE INLETS (TYPE A-2 and A-5)

A grate inlet, Type A-2 or A-5 in a sump can be considered an orifice with the coefficient of discharge of 0.67. The capacity shall be based on the following:

$$Q = 5.37\, A_g\, Y^{1/2}$$

$Q =$ Capacity in CFS

$A_g =$ area of clear opening in square feet

$Y =$ depth at inlet or head at sump in feet when Y is less than height of opening

The curve shown in Figure 7.9 provides for direct solution of the above equation.

Grate inlets in sumps have a tendency to clog when flows carry debris such as leaves and papers. Clogging shall be taken into consideration when calculating grate inlet capacity.

7.3.3 COMBINATION INLETS (TYPE A-3)

The capacity of a combined inlet type A-3 consisting of a grate and curb opening inlet in a sump shall be considered to be the sum of the capacities obtained from Figures 7.8 and 7.9. When the capacity of the gutter is not exceeded, the grate inlet accepts the major portion of the flow. Under severe flooding conditions, however, the curb inlet will accept most of the flow since its capacity varies with $y^{1.5}$ whereas the capacity of the grate varies as $y^{0.5}$.

7.4 INLETS ON GRADE WITHOUT GUTTER DEPRESSION

7.4.1 CURB OPENING INLETS (UNDEPRESSED: TYPE B-1)

The capacity of the curb inlet, like any weir depends upon the head and length of the overfall. In the case of an undepressed curb opening inlet, the head at the upstream end of the opening is the depth of flow in the gutter. In streets where grades are greater than one percent (1%), the velocities are high and the depths of flow are usually small, as there is little time to develop cross flow into the curb openings. Therefore, undepressed inlets are inefficient when used in streets of appreciable slope, but may be used satisfactorily where the grade is low and the crown slope high or the gutter channelized. Undepressed inlets do not interfere with traffic and usually are not susceptible to clogging. Inlets on grade should be designed and spaced so that 20 to 40 percent of gutter flow reaching each inlet will carry over to the next inlet downstream, provided the water carry-over does not inconvenience pedestrian or vehicular traffic.

The capacity of an undepressed inlet shall be determined by use of Figures 7.10 and 7.11. An example of the use of Figures 7.10 and 7.11 is included at the end of this section.

7.4.2 GRATE INLETS ON GRADE (UNDEPRESSED: TYPE B-2)

Undepressed grate inlets on grade have a greater hydraulic capacity than curb inlets of the same length so long as they remain unclogged. Undepressed inlets on grade are inefficient in comparison to grate inlets in sumps. For flow capacity through grade inlets, the Engineer should refer to Federal Highway publication H.E.C. 12 or refer to appropriate vendor catalog. Grate inlets should be designed and spaced so that 20 to 40 percent of the gutter flow reaching each inlet will carry over to the next downstream inlet, provided the carry-over does not inconvenience pedestrian or vehicular traffic.

Grates shall be certified by the manufacturer as bicycle-safe. For flows on streets with grades less than one percent (1%), little or no splashing occurs regardless of the direction of the bars.

Vane grate inlets are the recommended grates for best hydraulic capacity and should be the first grate type considered on any project. Clogging shall be taken into consideration when calculating grate inlet capacity.

7.4.3 COMBINATION INLETS ON GRADE (UNDEPRESSED: TYPE B-3)

The interception capacity of a combination inlet consisting of a curb opening and grate placed side-by-side, is not appreciably greater than that of the grate alone. Capacity is computed by neglecting the curb opening. A combination inlet is sometimes used with the curb opening or a part of the curb opening placed upstream of the grate. The curb opening in such an installation intercepts debris which might otherwise clog the grate and has been termed a "sweeper" by some. A combination inlet with a curb opening upstream of the grate has an interception capacity equal to the sum of the two inlets, except that the frontal flow and thus the interception capacity of the grate is reduced by interception by the curb opening.

The capacity of a Type B-3 inlet without extensions shall be considered the same as the capacity of a Type B-2 inlet. (considering reduction due to clogging).

7.5 INLETS ON GRADE WITH GUTTER DEPRESSION

7.5.1 CURB OPENING INLETS ON GRADE (DEPRESSED: TYPE C-1)

The depression of the gutter at a curb opening inlet below the normal level of the gutter increases the cross-flow toward the opening, thereby increasing the inlet capacity. Also, the downstream transition out of the depression causes backwater which further increases the amount of water captured. Depressed inlets should be used on continuous grades that exceed one percent (1%) except that their use in traffic lanes shall conform with the requirements of Section VI of this manual.

The depression depth, width, length, and shape all have significant effects on the capacity of an inlet. Reference to Section VI of this manual must be made for permissible gutter depressions.

The capacity of a depressed curb inlet will be determined by the use of Figures 7.10 and 7.11.

7.5.2 GRATE INLETS ON GRADE (DEPRESSED: TYPE C-2)

The depression of the gutter at a grate inlet decreases the flow past the outside of a grate. The effect is the same as that when a curb inlet is depressed, mainly the cross slope of the street directs the outer portion of flow towards the grate.

The bar arrangements for depressed grate inlets on streets with grades greater than one percent (1%) greatly affect the efficiency of the inlet. Grates with longitudinal bars eliminate splash which causes the water to jump and ride over the cross bar grates, and it is recommended that grates have a minimum of transverse cross bars for strength and spacing only.

For low flows or for streets with grades less than one percent (1%), little or no splashing occurs regardless of the direction of the bars. However, as the flow or street grade increases, the grate with longitudinal bars becomes progressively superior to the cross bar grate. A few small rounded cross bars, installed at the bottom of the longitudinal bars as stiffeners or a safety stop for bicycle wheels do not materially affect the hydraulic capacity of the longitudinal bar grates. A bicycle safe grate must be used.

The capacity of a Type C-2 inlet on grades less than one percent (1%) shall be the capacity determined from Figure 7.9. The capacity of C-2 inlets on grades greater than one percent (1%) shall be **90 percent** of the capacity as determined from Figure 7.9.

Grate inlets and depressions have a tendency to clog when gutter flow carries debris such as leaves and papers. Clogging shall be taken into consideration when calculating grate inlet capacity.

7.5.3 COMBINATION INLETS ON GRADE (DEPRESSED: TYPE C-3)

The interception capacity of a combination inlet consisting of a curb opening and grate placed side-by-side, is not appreciably greater than that of the grate alone. Capacity is computed by neglecting the curb opening. A combination inlet is sometimes used with the curb opening or a part of the curb opening placed upstream of the grate. The curb opening in such an installation intercepts debris which might otherwise clog the grate and has been termed a "sweeper" by some. A combination inlet with a curb opening upstream of the grate has an interception capacity equal to the sum of the two inlets, except that the frontal flow and thus the interception capacity of the grate is reduced by interception by the curb opening.

The capacity of a Type C-3 inlet without extensions shall be considered the same as the capacity of a Type C-2 inlet. (considering reduction due to clogging).

7.6 USE OF FIGURES 7.10 AND 7.11

Example 1

Given:
$S_x = 0.03$
$S = 0.035$

$Q = 5$ ft.^{3}/S
$n = 0.016$

Find:
(1) Q_i for a 10-ft. curb-opening inlet
(2) Q_i for a depressed 10-ft. curb opening inlet
$a = 2$ in.
$W = 2$ ft.

Solution:

(1) $T = 8$ ft. (Figure 6.3)
$L_T = 41$ ft. (Figure 7.10
$L/^{L}T = 10/41 = 0.24$
$E = 0.39$ (Figure 7.11)
$Q_i = EQ = 0.39 \times 5 = 2.0$ ft^3/S

(2) $T = 7.0$ ft. (Figure 6.3)
$W/T = 2/7 = 0.29$
$E_o = 0.72$ (Figure 6.5)
$S_e = S_x + S_w E_o = 0.03 + 0.083(0.72)$
$= 0.09$

$L_T = 23$ ft. (Figure 7.10)
$L/LT = 10/23 = 0.43$
$E = 0.64$ (Figure 7.11)
$Q_i = 0.64 \times 5 = 3.2$ ft.^{3}/S

7.7 INLET FLOW CALCULATION TABLE

Runoff and inlet computations for Inlet Flow Calculation Table (Figure 7.12) Computer generated computations and output are accepted and subject to review by City Engineer.

Column 1: Inlet number. All inlets are classified with a designated number.

Column 2: Inlet location. Location or station of inlet.

Column 3: A - Drainage area in acres contributing runoff to the inlet.

Column 4: C - Average or composite runoff coefficient of the area, A, contributing runoff to the inlet.

Column 5: Tc - Time of concentration for the drainage area in minutes. See section II.

Column 6: i - Rainfall intensity in inches per hour for the design storm. Based on the time of concentration. See Figure 2.5.

Column 7: CA for the drainage area. Equal to Column 3 multiplied by Column 4.

Column 8: Carry over, CA, from preceding inlet (Column 27).

Column 9: Q_t - Total flow at the inlet. Equal to the sum of the values in Column 7 and Column 8 multiplied by the value in Column 6 or $Q_t = i * SCA$

Column 10: n - Manning's roughness coefficient for the gutter section.

Column 11: S - The slope of the gutter profile in feet per foot.

Column 12: S_x - Cross slope of the roadway section at the inlet in feet per foot. Not applicable for parabolic street sections.

Column 13: T - Ponded width of flow in the street/gutter in feet. Obtained from Figure 6.3.

Column 14: d - Depth of flow in the gutter section of the inlet in feet. Obtained from Figure 6.2 or $d = T * S_x$

Column 15: V - Velocity of flow in gutter in feet per second. Equal to Column 8 divided by one half of Column 12 multiplied by Column 13 or V = Q/A

Column 16: L - Length of the inlet in feet.

Column 17: a - Depth of the gutter depression at the inlet in inches.

Column 18: W - Width of the gutter depression at inlet in feet.

Column 19: E_o - Ratio of frontal flow to total flow. Obtained from Figure 6.5 or $E_o = Q_w/Q - 1 - (1 - W/T)^{2.67}$

Column 20: S_e - Equivalent cross slope of the pavement at the inlet in feet per foot:

$$S_e = S_x + (a/12w) * \frac{E_o}{E}$$

Column 21: Lt - Required length of inlet in feet for total flow interception. Obtained from Figure 7.10.

Column 22: E - Efficiency of the inlet of length L. Obtained from Figure 7.11.

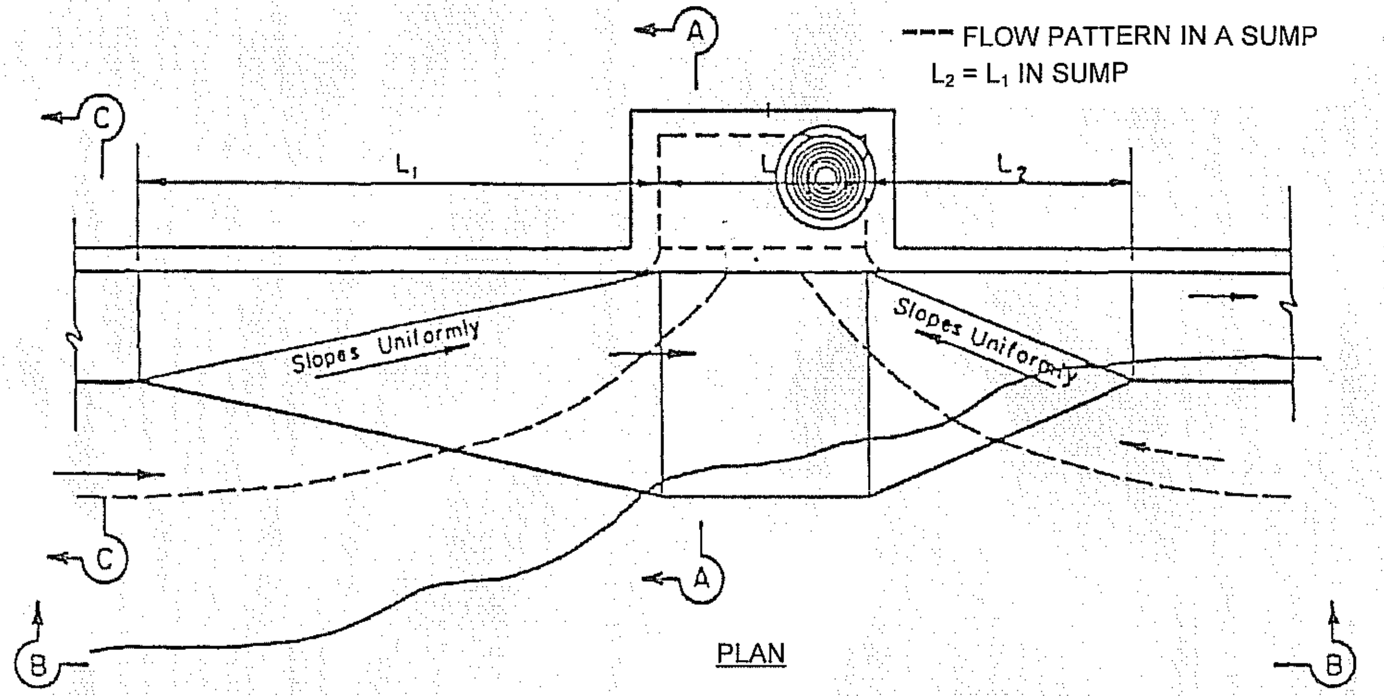
Column 23: Q_i - Flow intercepted by the inlet of length L in CFS. Equal to Column 22 multiplied by Column 9 or $Q_i = Q_t * E$

Column 24: RF - Clogging reduction factor for the inlet.

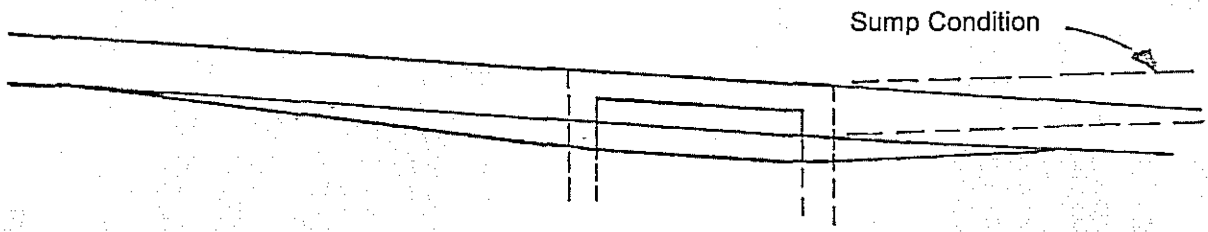
Column 25: Q_a - Actual flow intercepted by the inlet in CFS. Equal to Column 23 multiplied by Column 24 or $Q_a = Q_i * RF$

Column 26: Q_p - Bypass flow in CFS. Equal to Column 25 subtracted from Column 9 or $Q_p = Q_t - Q_a$

Column 27: Carry over, CA, for the next downstream inlet. Equal to Column 26 divided by Column 6 or Carry over = Q_p/i

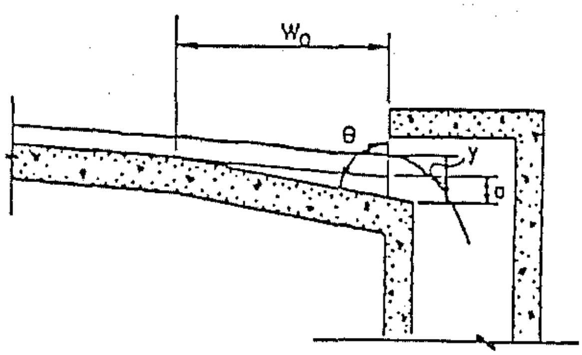


PLAN

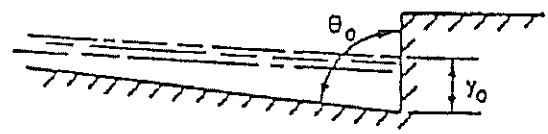


SECTION B - B

$$E = y_o + \frac{v_o^2}{2g} + a$$



SECTION A - A



SECTION C - C

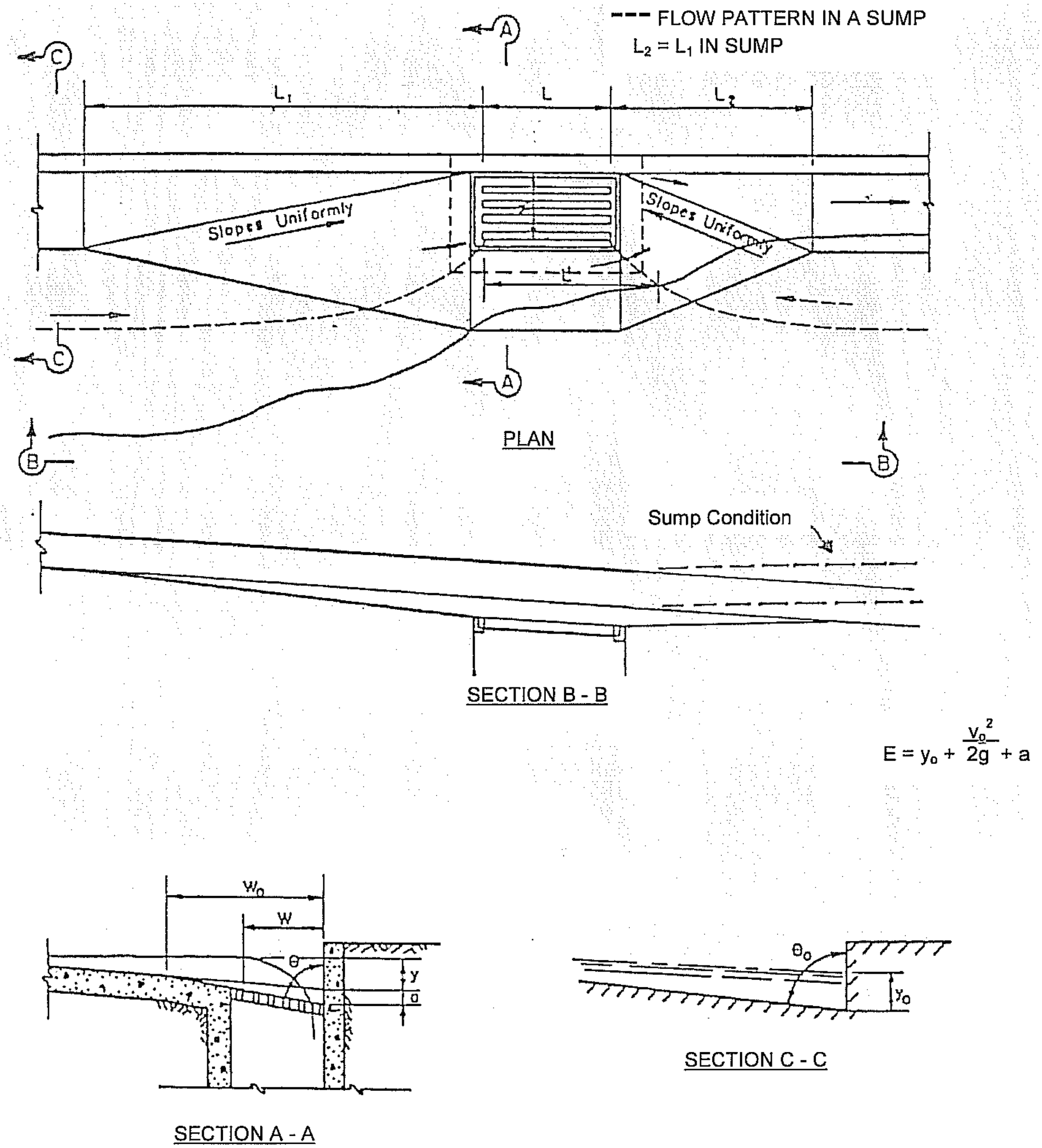
* Detail for Information and Calculation Purposes. Not for Construction

THE CITY OF B BENTONVILLE

DEPRESSED CURB-OPENING INLET
TYPE A-1 & C-1

SOURCE: City of Austin, TX

Figure 7.1



$$E = y_o + \frac{V_o^2}{2g} + a$$

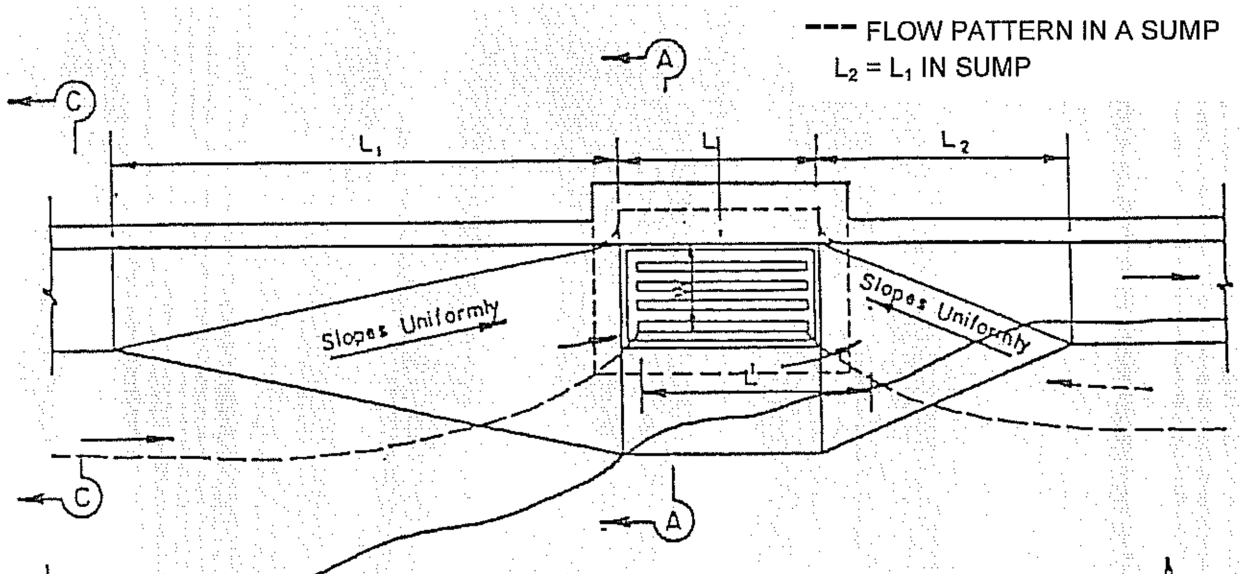
* Detail for Information And Calculation Purposes. Not For Construction

THE CITY OF B BENTONVILLE

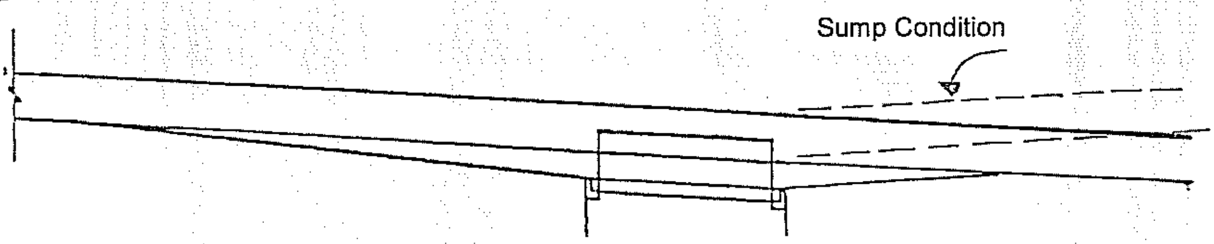
DEPRESSED GRATED INLET
TYPE A-2 & C-2

SOURCE: City of Austin, TX

Figure 7.2

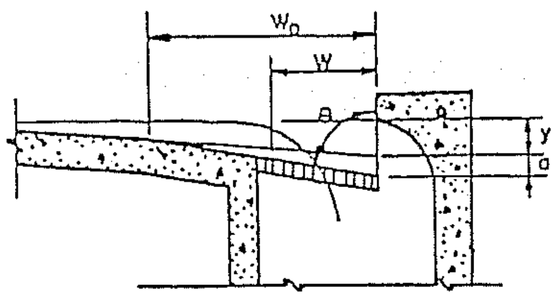


PLAN

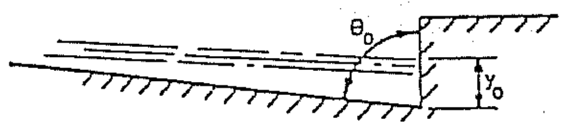


SECTION B - B

$$E = y_o + \frac{V_o^2}{2g} + a$$



SECTION A - A



SECTION C - C

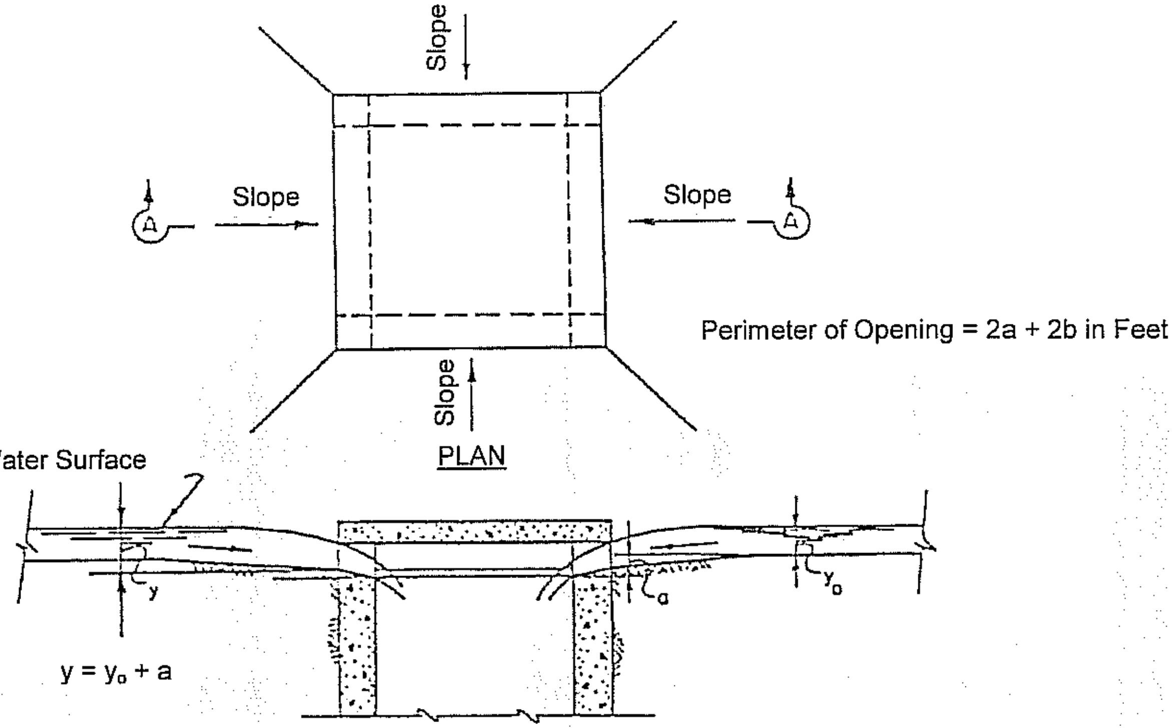
* Detail for Information and Calculation Purposes. Not for Construction

THE CITY OF BENTONVILLE

DEPRESSED COMBINATION INLET
TYPE A-3 & C-3

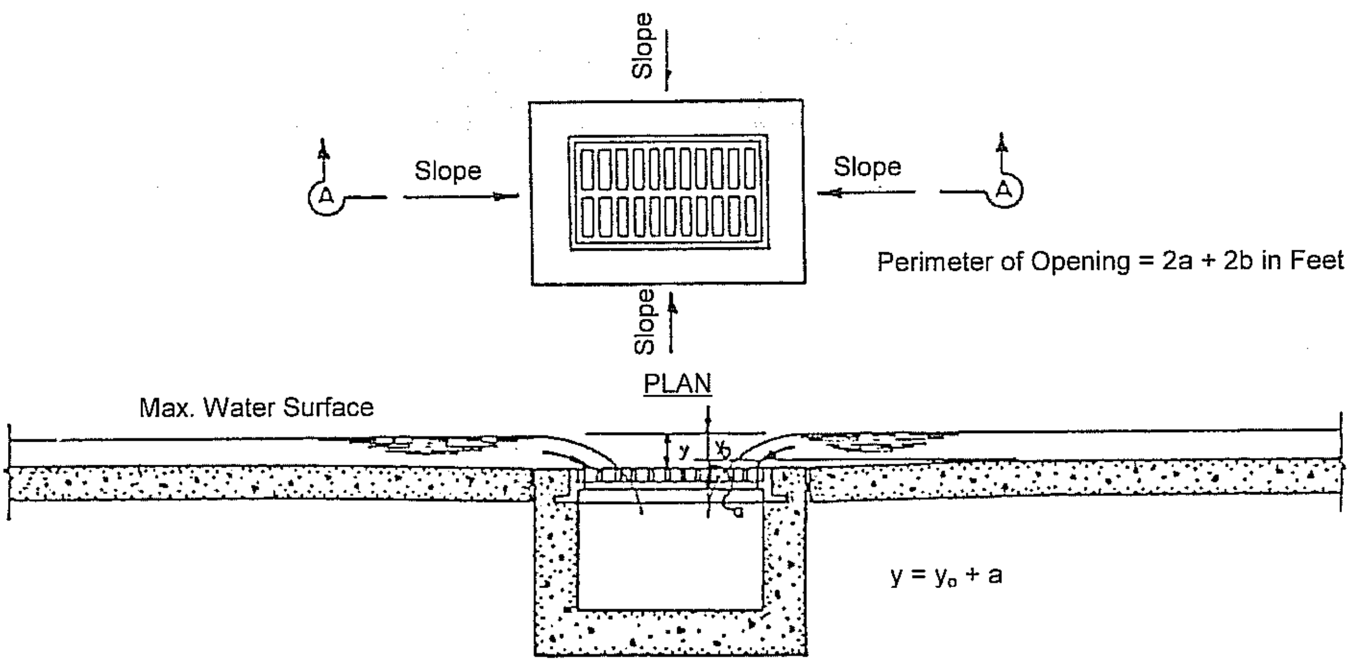
SOURCE: City of Austin, TX

Figure 7.3



SECTION A – A

DROP INLET
TYPE A-4



SECTION A – A
DROP INLET
(Grate Covering)

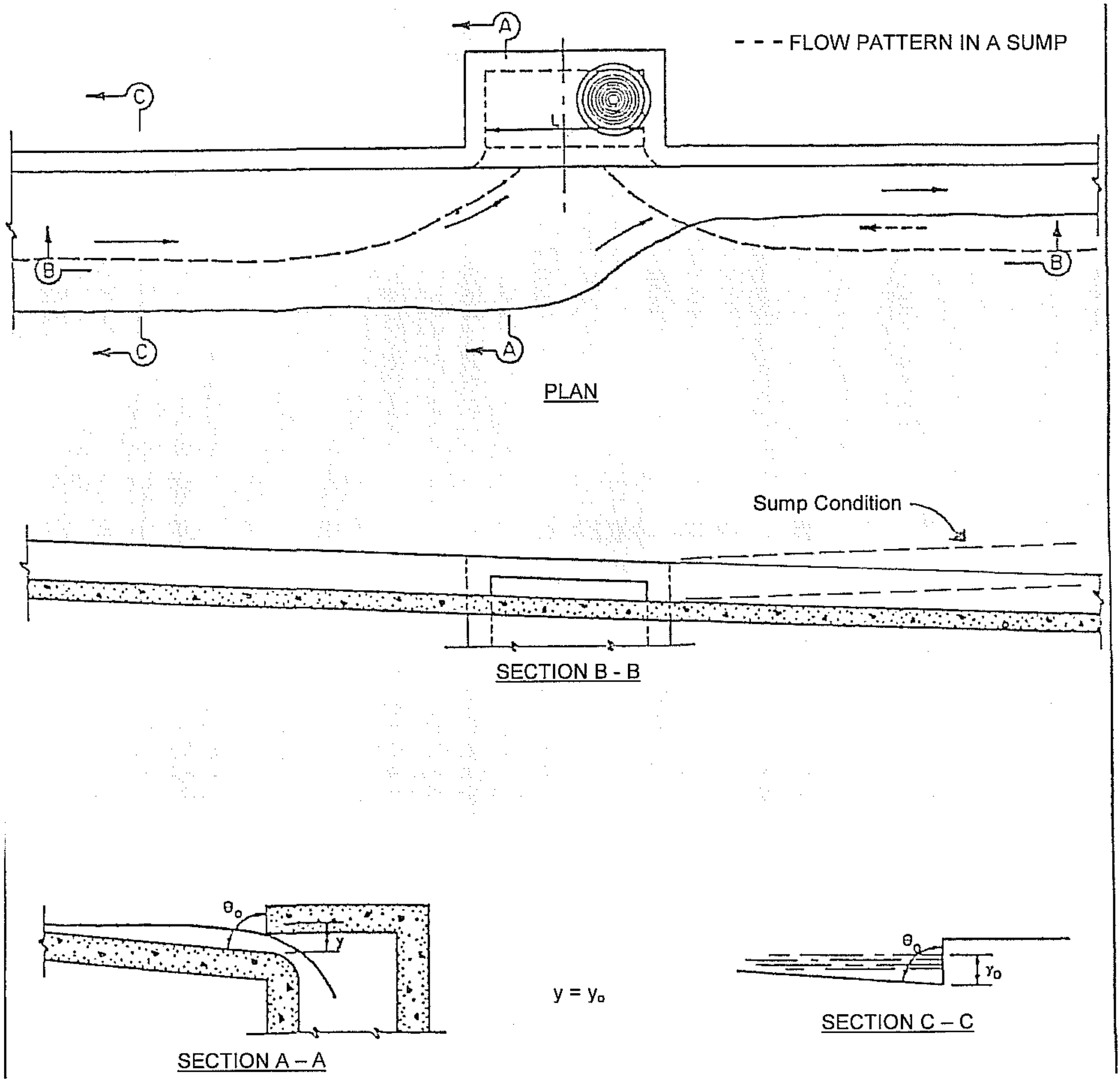
* Detail for Information and Calculation Purposes. Not for Construction

THE CITY OF BENTONVILLE

DROP INLET (Grate Covering)
TYPE A-4 & TYPE A-5

SOURCE: City of Austin, TX

Figure 7.4



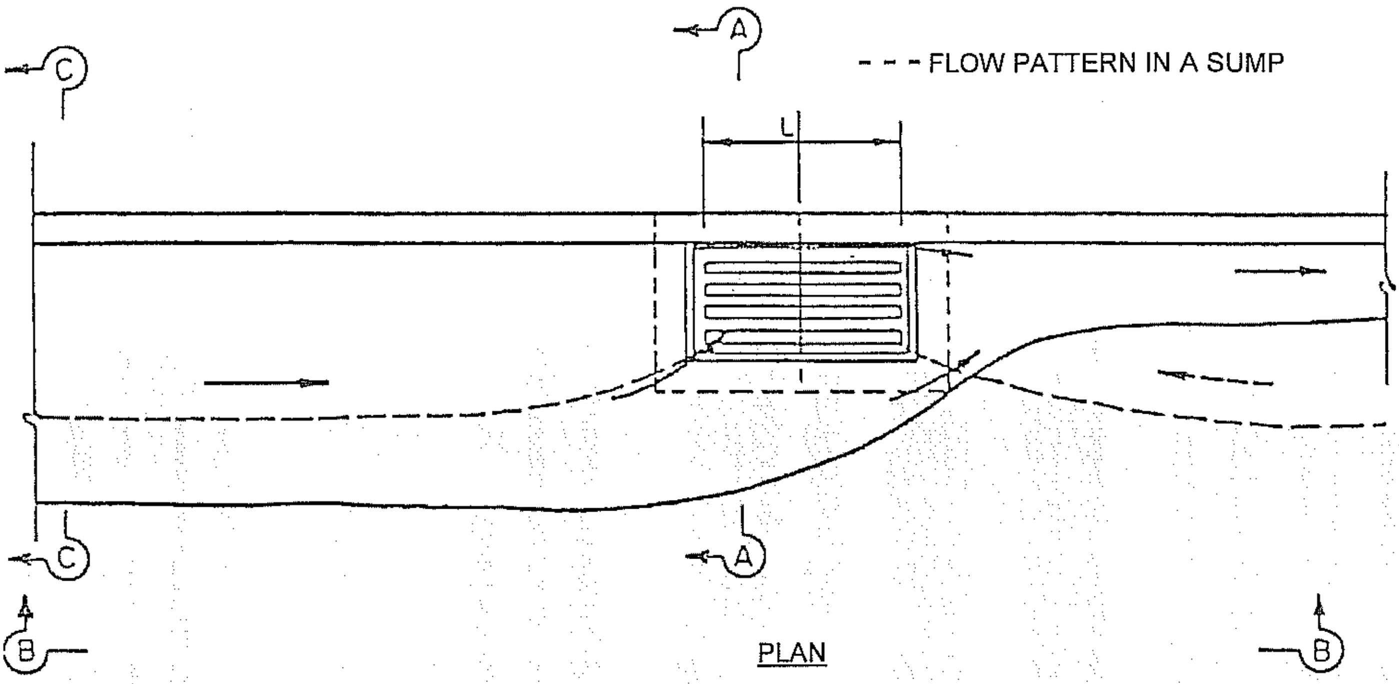
* Detail for Information and Calculation Purposes. Not for Construction

THE CITY OF B BENTONVILLE

UNDEPRESSED CURB-OPENING
INLET TYPE A-1 & B-1 (RECESSED)

SOURCE: City of Austin, TX

Figure 7.5



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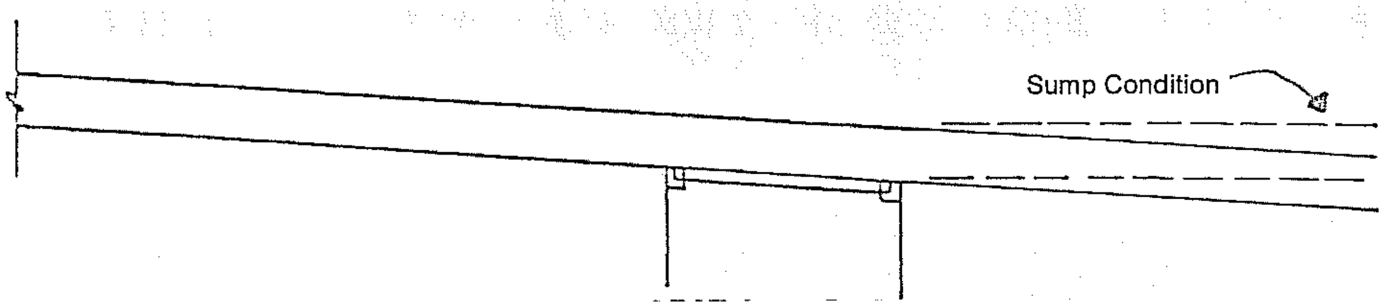
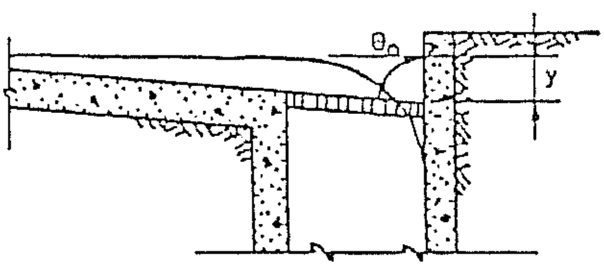


SECTION B - B



SECTION A – A

SECTION C – C

$y = y_0$

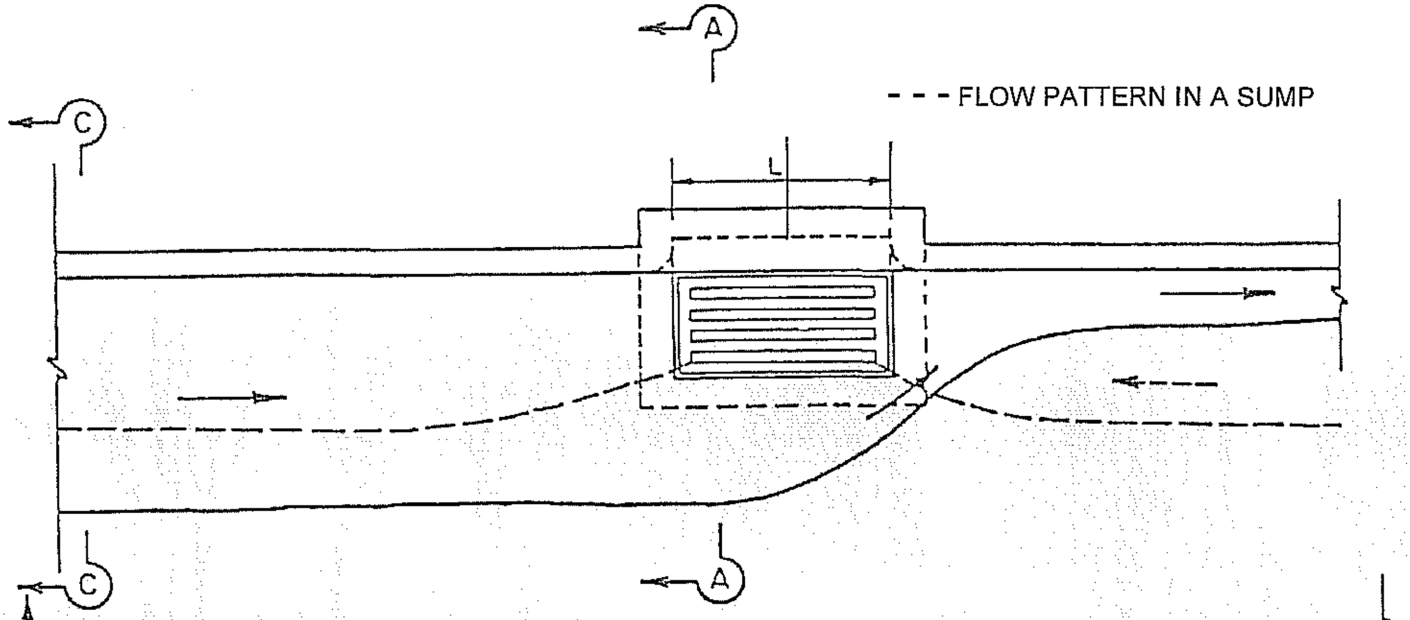
* Detail for Information and Calculation Purposes. Not for Construction

THE CITY OF BENTONVILLE

UNDEPRESSED GRATE INLET
TYPE A-2 & B-2

SOURCE: City of Austin, TX

Figure 7.6



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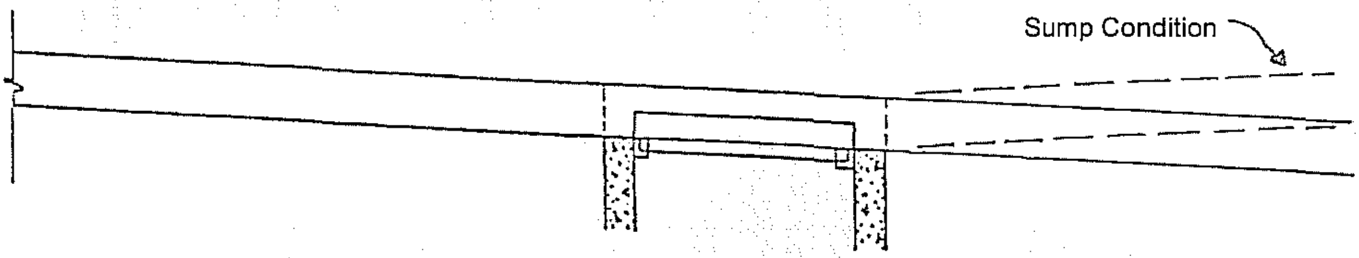
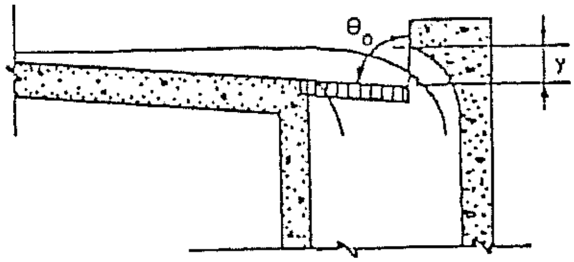
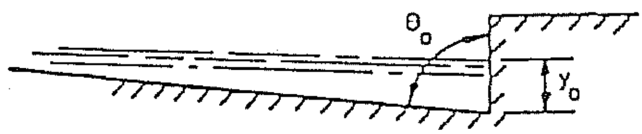


SECTION B - B



SECTION A – A



SECTION C – C

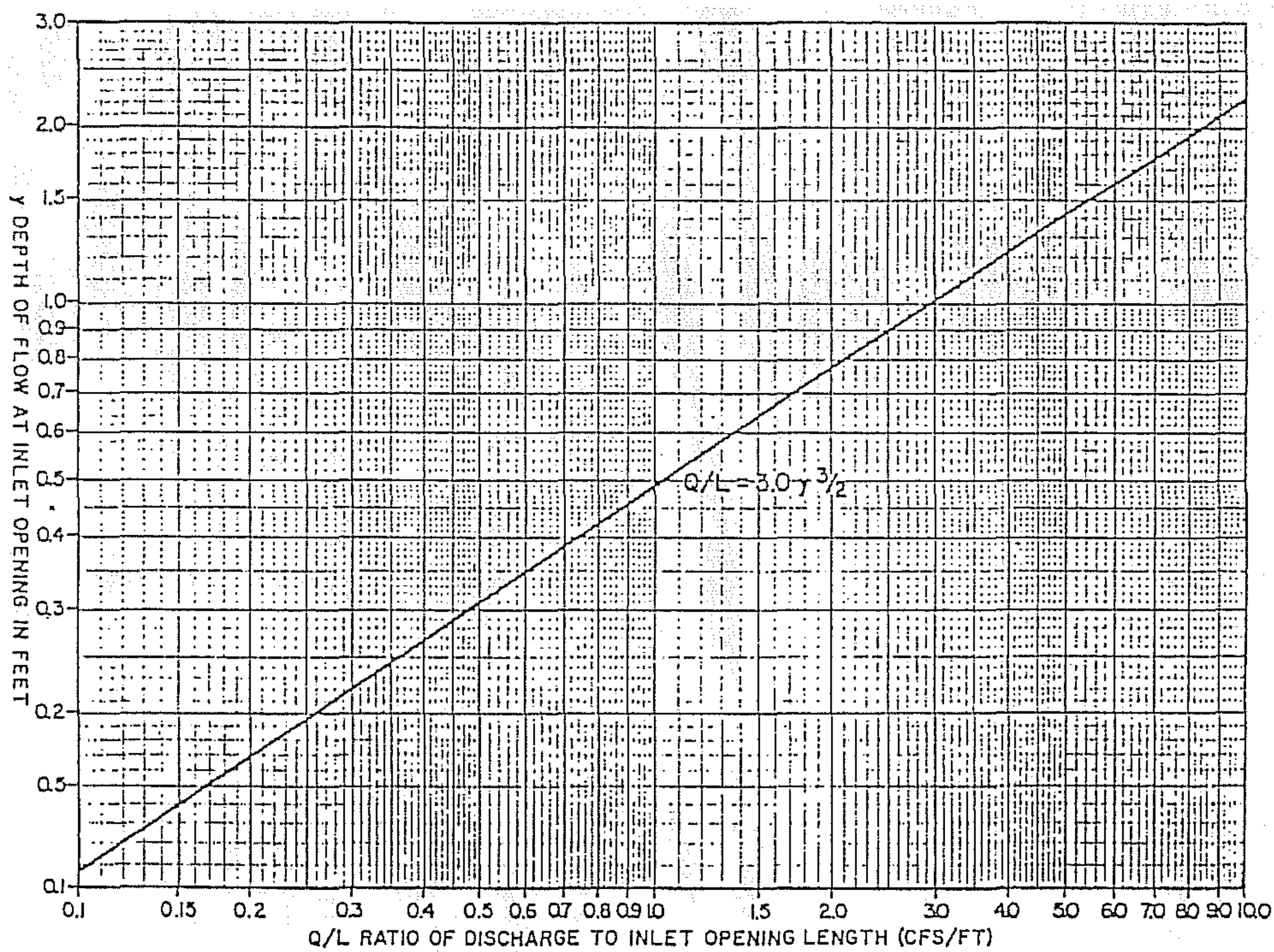
$y = y_o$

* Detail for Information and Calculation Purposes. Not for Construction

UNDEPRESSED COMBINATION INLET
TYPE A-3 & B-3 (RECESSED)

SOURCE: City of Austin, TX

Figure 7.7

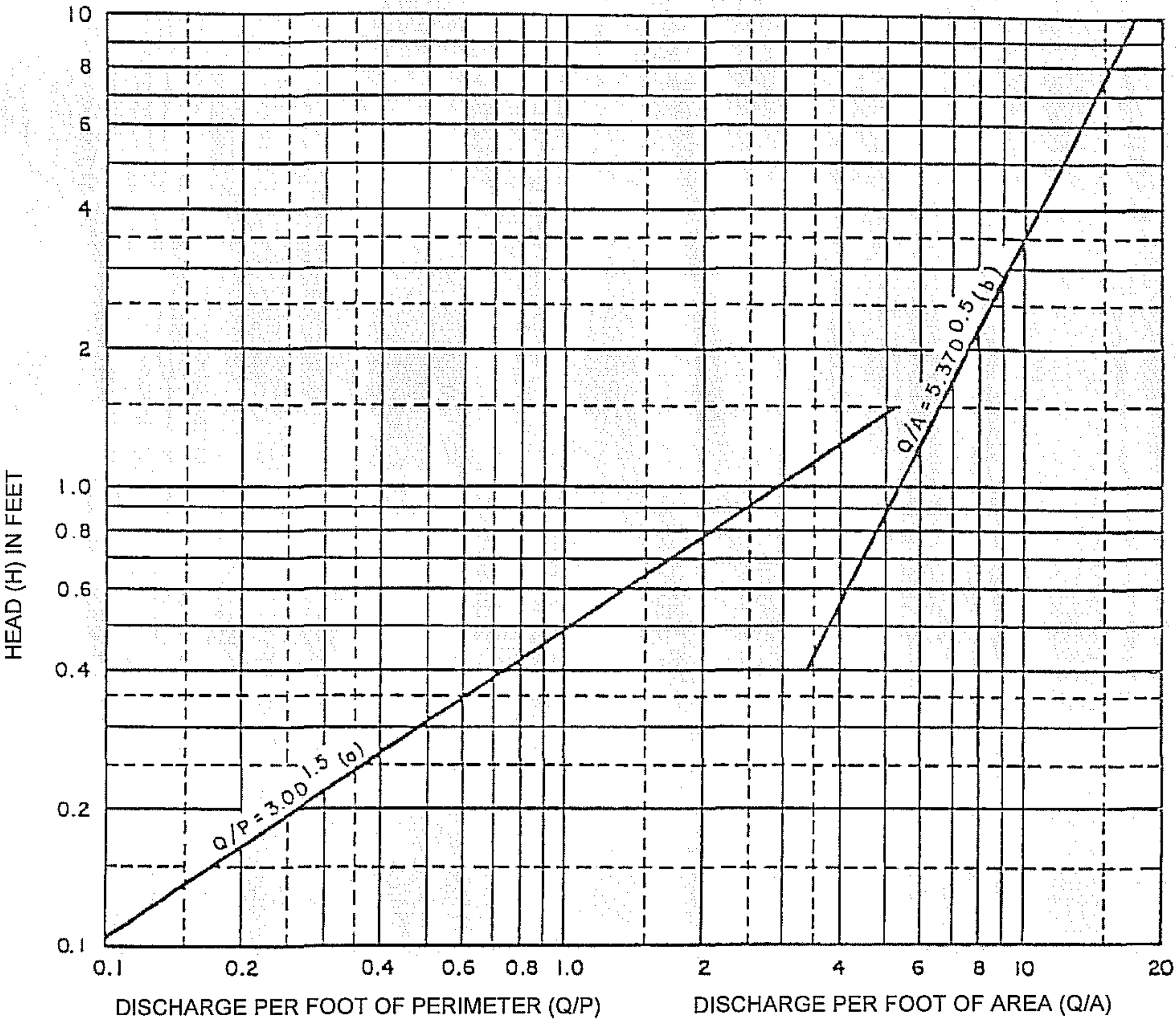


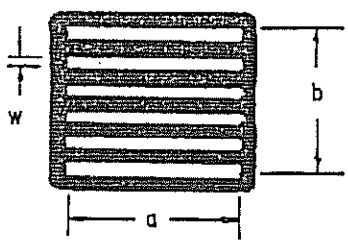
THE CITY OF BENTONVILLE

INLET CAPACITY
TYPE A-1 & A-4

SOURCE: City of Little Rock, AR

Figure 7.8





P = 2 (a + b)
A = 6 aw

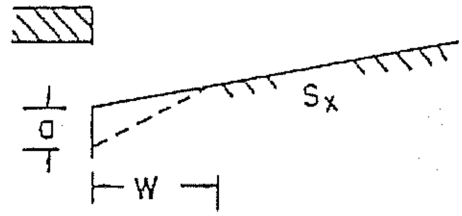
HEADS UP TO 0.4, CURVE (a) APPLIES
HEADS ABOVE 1.4, CURVE (b) APPLIES
HEADS BETWEEN 0.4 & 1.4, TRANSITION
SECTOR, USE LESSOR VALUE OF DISCHARGE

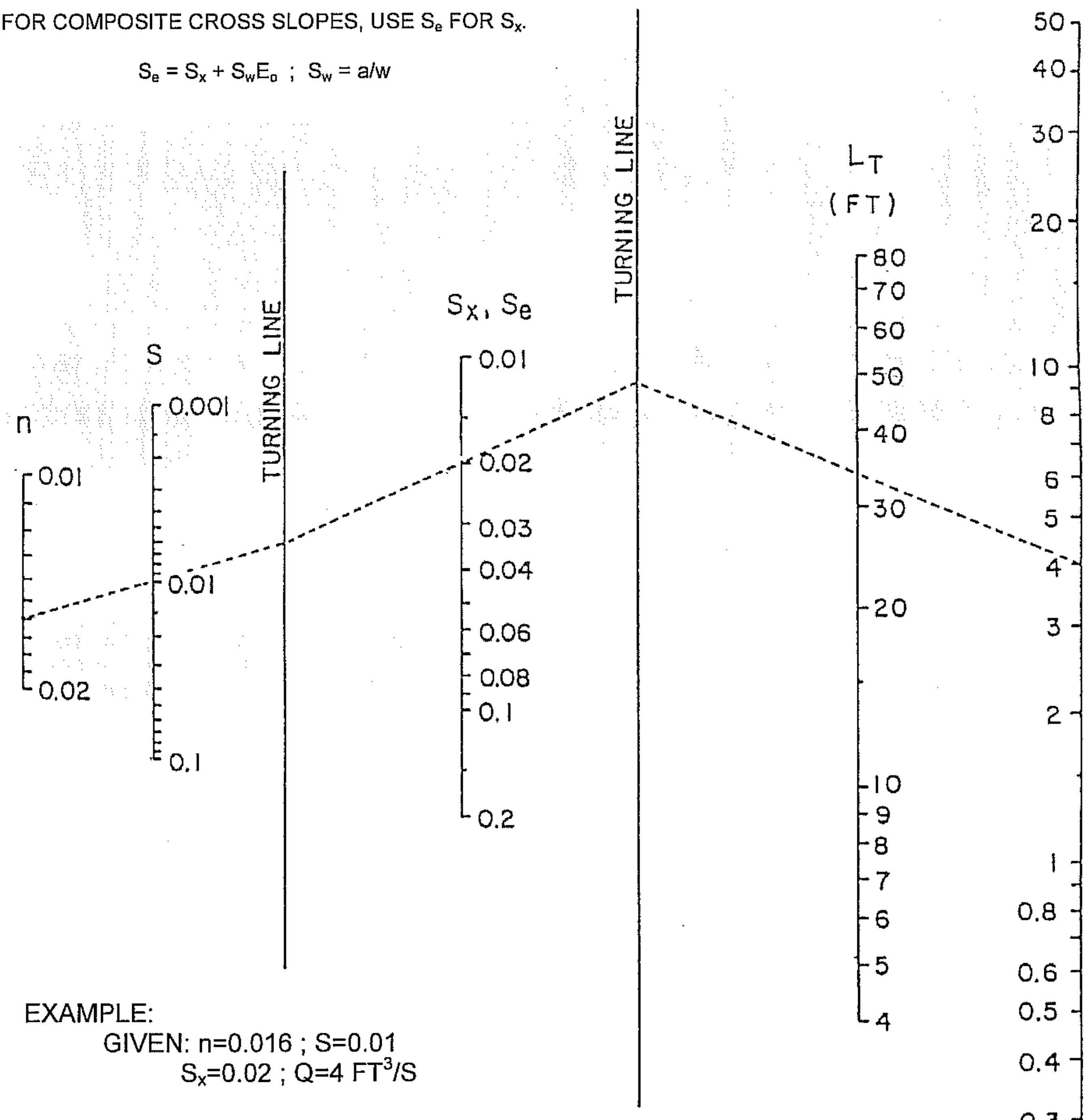
CAPACITY OF GRATE INLET IN SAG

$$L_T = 0.6Q^{0.42}S^{0.3}(1/nS_x)^{0.6}$$

FOR COMPOSITE CROSS SLOPES, USE S_e FOR S_x.

$S_e = S_x + S_wE_o$; $S_w = a/w$





EXAMPLE:

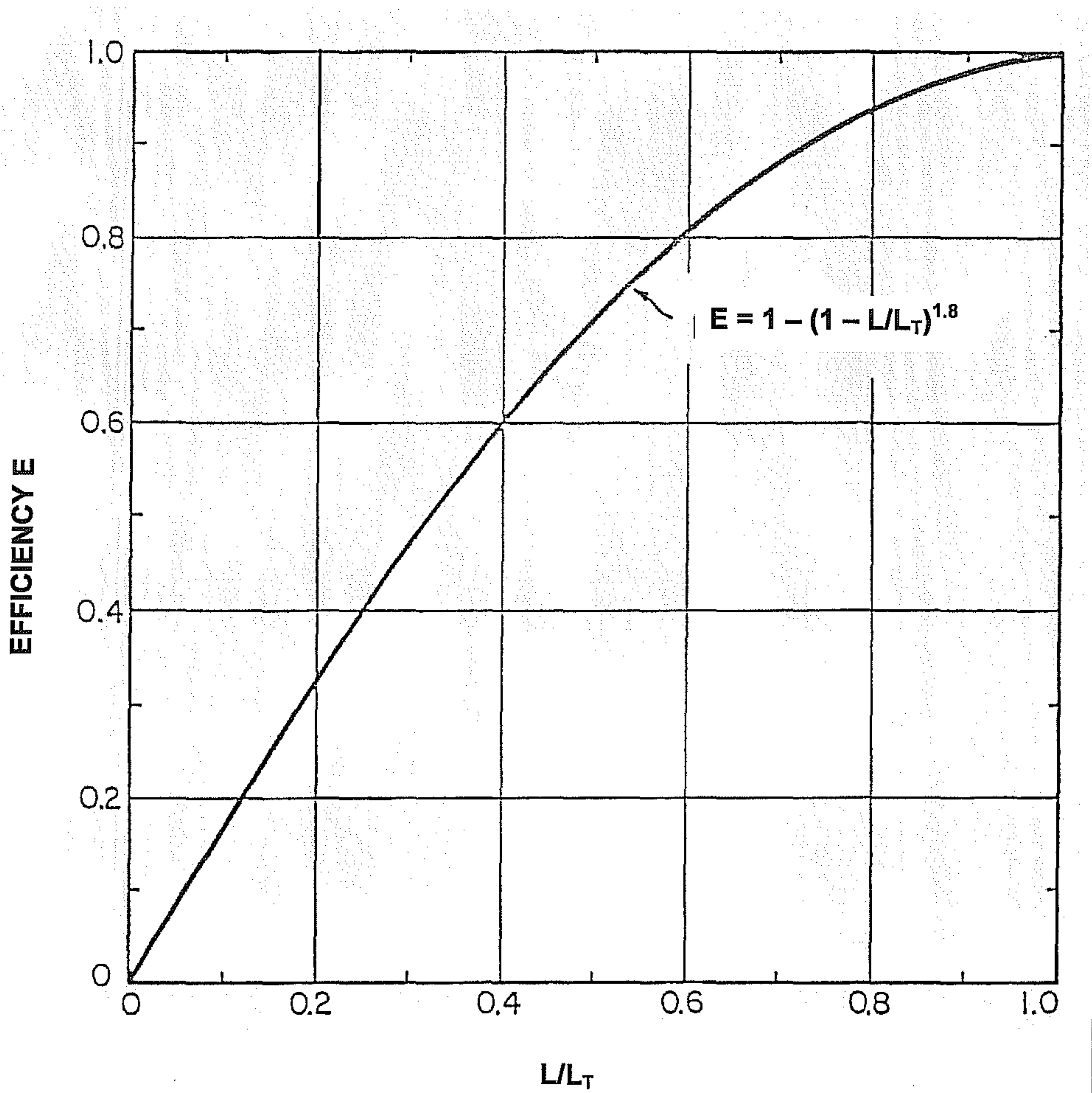
GIVEN: n=0.016 ; S=0.01
S_x=0.02 ; Q=4 FT^3/S

FIND: L_T = 34 FT

CURB-OPENING AND SLOTTED DRAIN INLET LENGTH FOR TOTAL INTERCEPTION

SOURCE: Federal Highway Administration – Circular 12

Figure 7.10

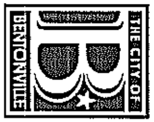


THE CITY OF BENTONVILLE

CURB-OPENING AND SLOTTED DRAIN INLET INTERCEPTION EFFICIENCY

SOURCE: Federal Highway Administration – Circular 12

Figure 7.11



CITY OF BENTONVILLE, ARKANSAS
INLET FLOW CALCULATION TABLE

PROJECT ____________________

PLAN SHT. NO. ____________ DATE ____________

COMPUTED BY ____________ CKD. ____________

1 No	2 Location	3 Area (AC)	4 C	5 Tc (Min)	6 I (IN/HR)	7 Runoff At Inlet (CA)	8 Carry Over (CA)	9 Total Flow Qt (CFS)	10 n	11 RDWY Slope S	12 Cross Slope Sx	13 Ponded Width T (FT)	14 Depth At Curb d (FT)	15 VEL V (FPS)	16 L (FT)	17 a (IN)	18 W (FT)	19 Eo	20 Se	21 Lt (FT)	22 E	23 Qi (CFS)	24 RF	25 Qa (CFS)	26 Bypass Qp (CFS)	27 Carry Over (CA)

INLET FLOW CALCULATION TABLE

Figure 7.12