

### **3. STORM DRAINAGE FACILITIES**

#### **3.1 Introduction:**

Drainage facilities shall be designed and constructed at such locations and of such size and dimensions to adequately serve the development and the contributing drainage area above the development, as well as the affected areas downstream. The developer shall provide all the necessary easements and rights-of way required for drainage structures including storm drains and open channels, lined or unlined. Easement widths for storm drain pipelines shall not be less than fifteen (15) feet, and easement widths for open channels shall be at least fifteen (15) feet wider than the top width of the channel. In all cases, easements shall be of an adequate size to allow proper maintenance.

The design flows for the drainage system shall be calculated by the Rational Method in accordance with the requirements set forth in this document. Curbs, inlets, manholes, etc. shall be designed and constructed in accordance to the Standard Details. Materials and construction procedures shall conform with the requirements of the Standard Specifications for Construction.

The developer shall provide plans and specifications and design calculations for all drainage structures. All open channels that are not concrete lined shall be designed to prevent erosion by designing channel velocities less than 6-fps and installing permanent channel bank stabilization features such turf reinforcement mattresses, pilot channels and grouted rock rip-rap at changes in direction of the channel alignment . The City shall review the proposed type of erosion control measures proposed. Prior to City acceptance of a non-lined open channel, a complete coverage of grass shall be established.

The design, size, type and location of all storm drainage facilities shall be subject to the review of the City's Engineer and acceptance by the City. The requirements set forth herein are considered minimum requirements. The developer and the developer's engineer shall bear the total responsibility for the adequacy of design. The acceptance of the facilities by the City or the City's Engineer in no way relieves the developer of this responsibility.

The developer shall be responsible for the necessary facilities to provide drainage patterns and drainage controls such that properties within the drainage area, whether upstream or downstream of the development, are not adversely affected by storm drainage from facilities on the development. These are outlined in the Storm Drainage Management Plan Section 3.4.

The storm drainage management plan provided as part of the final engineering drawings shall address how storm water on the proposed development and affected adjoining properties will be controlled during phased development and completed development. Off-site improvements must be considered and may be required to carry the additional flows caused by the proposed development.

Storm drainage released from the site will be discharged to a natural water course or storm sewer system of an adequate size to convey the 100-year storm runoff expected after development.

The enclosed forms shall be submitted to the City as part of the plan.

### 3.2 Storm Drainage Design Criteria:

- A. General: For all drainage areas less than 600 acres, the rational method of computing runoff will be used. For contributing drainage areas greater than 600 acres, appropriate engineering methods, such as the unit hydrograph method, shall be used to determine the peak storm discharge quantities. The rational method is expressed by the following equation:

$Q = CIA$ , where

$Q$  = The storm flow rate at a given point in cubic feet per second (c.f.s.)

$C$  = A coefficient of runoff (the ratio of rainfall to peak runoff) as delineated in Table 3.1

$I$  = The average intensity of rainfall in inches per hour, for a period equal to the time of flow from the farthest point of the drainage area to the point of design and is obtained from Figure 3.1.

$A$  = The area in acres that is tributary to the point of design.

- B. Time of Concentration: The time of concentration is defined as the longest time, without unreasonable delay, that will be required for water to flow from the upper limit of a drainage area to the point of concentration. The time of concentration to any point in a storm drainage system is a combination of the "inlet time" and the time of flow in the storm drain. The inlet time is the period of time required for water to flow over the, surface of the ground to the storm drain inlet. The minimum time of concentration shall not exceed ten (10) minutes.

Under average conditions the minimum time of concentration from the upstream end of a drainage system will coincide with Table 3.2.

Under circumstances which will produce times of concentration in excess of those shown in Table 3.2, the time of concentration shall be determined through the use of Figure 3.2, "Nomograph for Time of Concentration". The nomograph, however, should be used in a judicious manner; otherwise unrealistic times of concentration may result. Some cautions to be exercised in the use of this nomograph area as follows:

1. The path along which the time of concentration is determined should be representative of the drainage area as a whole. On some irregularly shaped drainage areas, it is possible to find 'the time of concentration along a particular path which is representative of only a small portion of the drainage

area, and this time of concentration which is more representative of the drainage area as a whole.

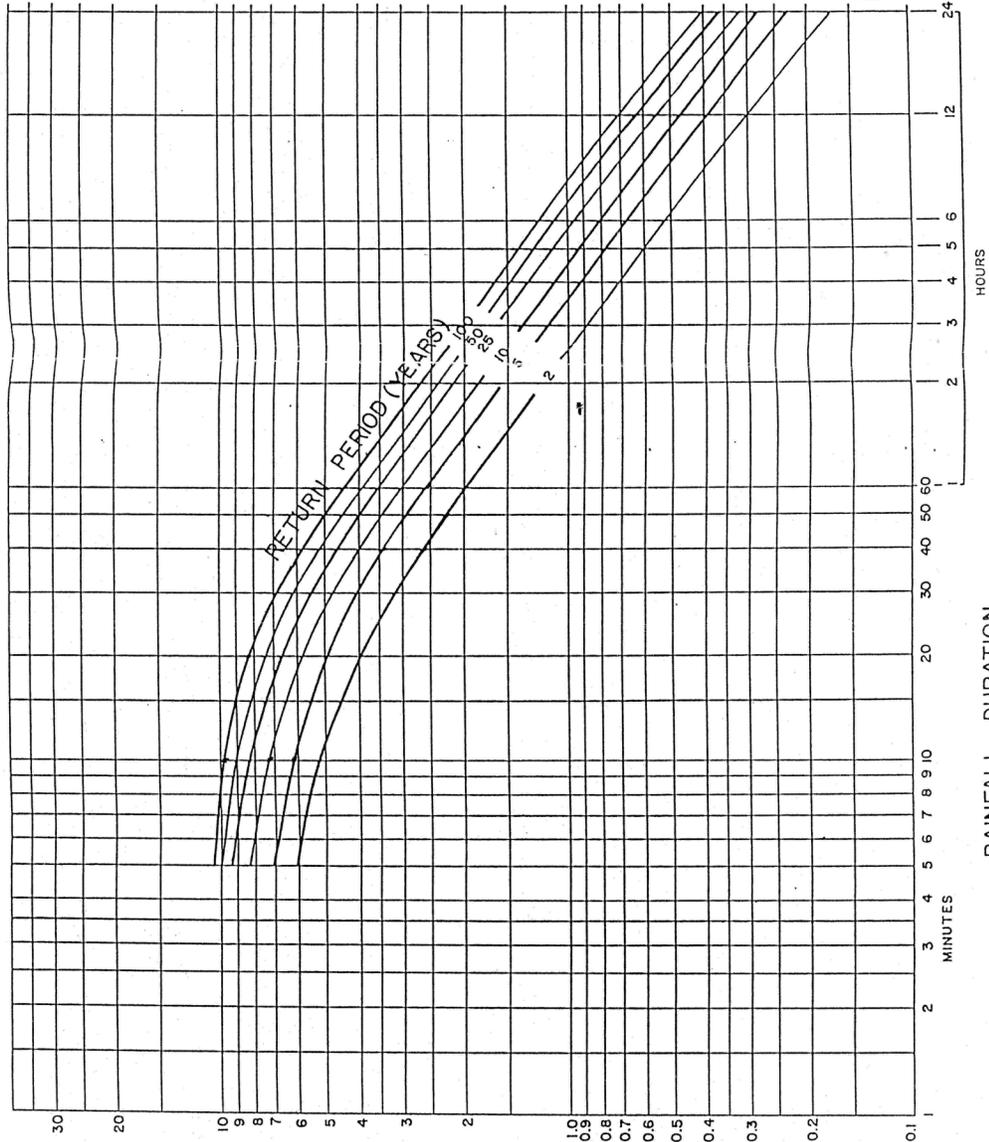
2. Overland flow shall be considered channelized at such time as the distance traveled exceeds two hundred (200) feet.

**TABLE 3.1**

**RUNOFF COEFFICIENT FOR TYPES OF LAND USE**

<b>Type Of Area Or Land Use</b>	<b>Adopted Runoff Coefficient</b>
Parks or Open Areas	0.35
Single Family Residential or Duplex	0.50
School	0.70
Apartments	0.75
Townhouse .	0.80
Churches	0.80
Industrial	0.90
Commercial Business	0.90
Mercantile District	0.90
Retail	0.90
Major and Minor Arterials - R.O.W.	0.90

RAINFALL INTENSITY - INCHES PER HOUR



REFERENCE: U.S. DEPT. OF COMMERCE  
 WEATHER BUREAU  
 TECHNICAL PAPER NO. 40  
 WASHINGTON, D.C.  
 MAY 1961  
 REPRINTED: JAN. 1963

RAINFALL  
 INTENSITY - DURATION - FREQUENCY  
 FOR  
 THE CITY OF ROCKWALL, TEXAS

FIGURE 3.1

RAINFALL DURATION

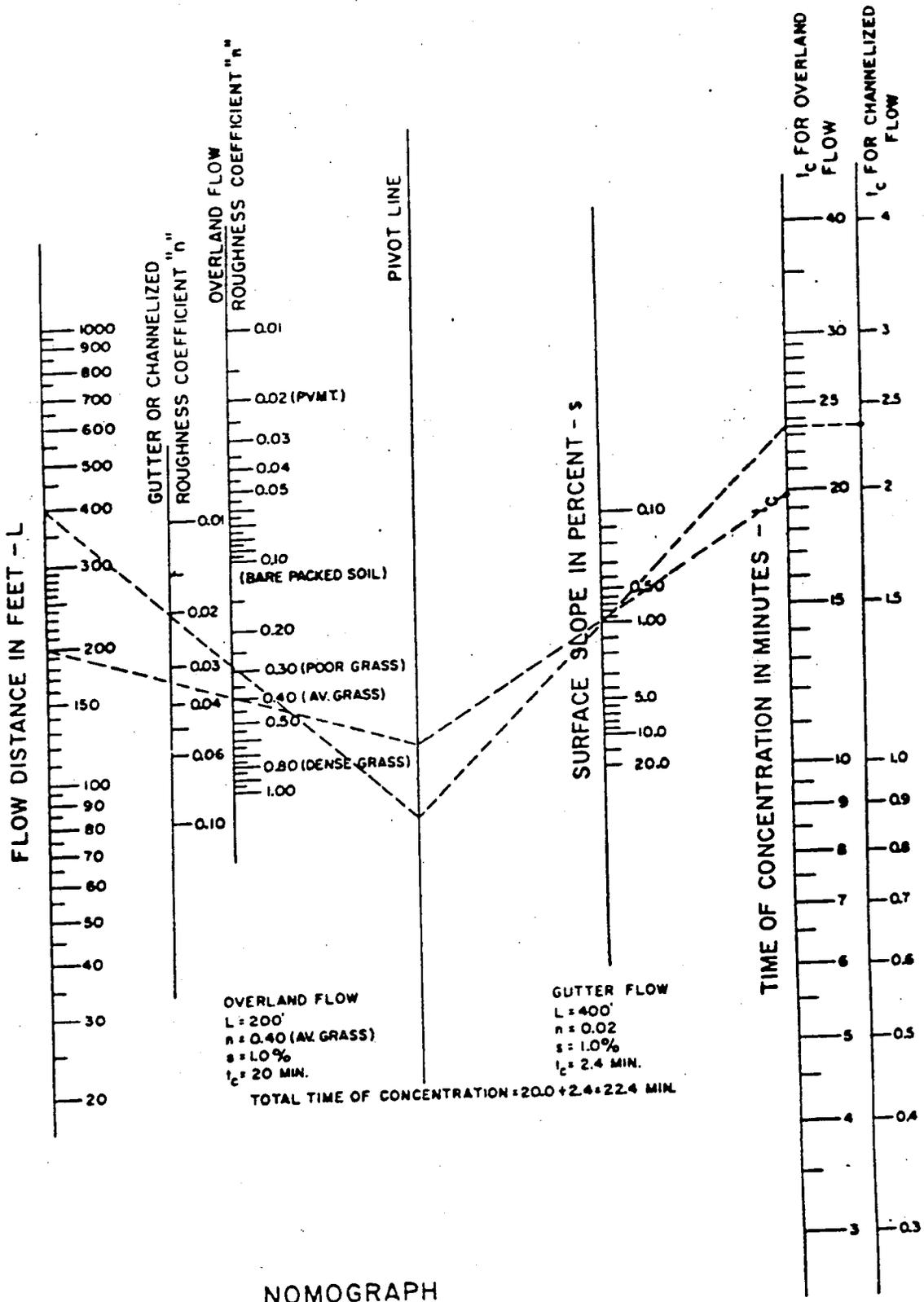
HOURS

MINUTES

**TABLE 3.2**

**MINIMUM INLET TIME OF CONCENTRATION**

<b>Type of Area</b>	<b>Minimum Inlet Time</b>
Parks and Open Areas	20 minutes
Residential	10 minutes
School	10 minutes
Church	10 minutes
Industrial	10 minutes
Business	10 minutes
Mercantile District	10 minutes
Retail	10 minutes
Major and Minor Arterials	10 minutes



**NOMOGRAPH  
 FOR TIME OF CONCENTRATION**

**FIGURE 3.2**

Since urbanization is anticipated on all drainage areas, all improvements shall be designed for the case of full watershed development. It is 'generally not practical to design improvements to gravity drainage a system in stages to match development, except in the case of unlined ditches, and then, it is essential that ultimate rights-of-way be obtained at the outset.

When the watershed in question is basically undeveloped, the developer shall attempt to anticipate future fully developed conditions and storm discharge locations when determining the time of concentration.

- C. Design Storm Frequencies: The design storm frequencies shall be in accordance with Table 3.3.

The relationship between rainfall intensity, duration and frequency is set forth in Figure 3.1. These curves have been developed using Technical Paper No. 40, "Rainfall Frequency Atlas of the United States" by the U.S. Weather Bureau. These curves shall be used in the design of all storm drainage facilities.

- D. Drainage Calculations Summary: The calculations of the 'storm water discharge shall be provided to the City. As a minimum, the engineering plans shall include a storm drainage summary table similar to Form 3.1.

- E. Permissible Spread of Water in Residential Streets, Collectors and Arterials:

1. General: Spread of water refers to the amount of water that may be allowed to collect in streets during a storm of specific design frequency. In order that excess storm water will not collect in streets or arterials during a storm of the design frequency, the following spread of water values shall be used for the various types of streets. Engineer shall verify that one lane of traffic is open during the 50-year storm event.
2. Major and Minor Arterials (Divided): Based on transverse slope of  $\frac{1}{4}$ " per foot on the pavement, the 100-year Design Frequency flow shall not exceed the elevation of the lowest top of curb. A maximum of 45-cfs (22.5 cfs per gutter) will be allowed in the street.

Inlets shall be located at street intersections, at low points of grade or where the gutter flow exceeds the permissible spread of water criteria. Inlets shall be located, when possible, on lesser traveled streets or alleys when grades permit. Inlets located on arterials and where street grade is 6% or greater shall be recessed in order to minimize interference of the gutter depression with travel lanes. A gutter depression six (6) inches, as shown in the Standard Details shall be used. In super-elevated sections, inlets placed against the center medians shall have no gutter depression and shall intercept gutter flow at the point of vertical curvatures to prevent flow from crossing the arterial. Unless expressly approved by the City's Engineer, storm waters will not be allowed to cross arterials on the surface in valley, gutters or otherwise.

**TABLE 3.3**

**DESIGN STORM FREQUENCIES FOR STORM DRAINAGE FACILITIES**

<b><u>Facility</u></b>	<b><u>Storm Design Frequency</u></b>
Enclosed pipe system and streets and right-of-way .....	100 year
Channels and Creeks* .....	100 year
Culverts and Small Bridges .....	100 year
Large Bridges** .....	100 year
Floodways between Building Lines .....	100 year

\*Channels and creeks shall have at least one (1) foot of freeboard.

\*\*Large bridges are those with a total span greater than fifty (50) feet



3. Collector, Streets: Based on parkway slopes of  $\frac{1}{4}$ " per foot behind the curb, the 100-year Design Frequency flows shall not exceed a depth of 1-1/2 inches over the top of curb. A maximum flow of 45-cfs (22.5 cfs per gutter) will be allowed in the street.

Inlets shall be located, at street intersections, low points of grade or where the gutter flow exceeds the permissible spread of water criteria. Inlets shall be located, when at all possible, on lesser traveled streets or alleys where grade permits. Inlets with a gutter depression of four (4) inches shall be used. At locations where depressed inlets are expected to interfere with pedestrian activity, usually at crosswalks or interior spans of the block used for parking, a depression of less than four (4) inches may be required. Their locations may require additional inlet width to compensate for the reduced depression. The City will consider all variances from a standard four (4) inch gutter on an individual basis. Recessed inlets shall be used where street grade is 6% or greater.

4. Residential Streets: Based on parkway slopes of 1/4 inch per foot behind the curb, the 100-year Design Frequency flows shall not exceed a depth of 1- inch over the top of curb. A maximum flow of 45-cfs (22.5 cfs per gutter) will be allowed, in the street.

Inlets shall be located at street intersections, low points of grade or where the gutter flow exceeds the permissible spread of water criteria. A gutter depression of six (6) inches shall be used on inlets located on residential streets. At locations where depressed inlets are expected to interfere with pedestrian activity, usually at crosswalks or interior spans of the block used for parking; a depression of less than six (6) inches may be required. These locations may require additional inlet width to compensate for the reduced depression. All variances from a standard six- (6) inch gutter will be considered on an individual basis. Recessed inlets shall be used where street grade is 6% or greater.

5. Alleys: The 100-year Design Frequency shall not exceed the capacity of the alley pavement.

F. Curb Inlet Design:

General: A depressed curb inlet is more efficient than a non-depressed inlet because a depressed inlet induces a greater cross-flow toward the inlet allowing less water to flow past it. Also, the transition out of the depression causes a backwater effect, which further increases the capacity of the storm drain. Determination of the required size of the storm drain 'inlet will be based on the calculations described in the instructions for FORM 3.2: Inlet Design Calculations. Inlets shall be sized in multiplier of five (5) feet (5, 10, 15 and 20).' Construction of inlets shall be in accordance with the Standard Details. Recessed inlets will be required to be installed at all inlet locations where the street grade is to be 6% or greater.



## **INSTRUCTIONS FOR FORM 3.2**

### **INLET DESIGN CALCULATIONS**

- Column 1 Inlet Number or designation. The first inlet shown is the most upstream.
- Column 2 Construction plan station of the inlet.
- Column 3 Design Storm Frequency and is same as the Design Storm Frequency of the storm wastewater.
- Column 4 Time of concentration of each inlet is taken from TABLE 3.2, or FIGURE 3.2.
- Column 5 Using the time of concentration and the Design Storm Frequency, rainfall intensity is taken from FIGURE 3.1.
- Column 6 Runoff Coefficient is taken from TABLE 3.1 according to the zoning of the drainage area.
- Column 7 Area drained by the specific inlet. Care should be taken to keep the drainage area flow separated into the appropriate street gutters.
- Column 8 Product of Column 5 multiplied by Columns 6 and 7.
- Column 9 If there is any flow which was not fully intercepted by an upstream inlet, it should be entered here.
- Column 10 Sum of Columns 8 and 9.
- Column 11 Capacity of the street gutter, in which the inlet is located, from either FIGURES 3.3 or 3.4. If the total gutter flow shown in Column 10 is in excess of the value in Column 11, an investigation should be made to see if the inlet could be moved downstream.
- Column 12 Street gutter slope to be used in selecting the proper size inlet.
- Column 13 Crown type of the street on which the inlet is located.
- Column 14 Selected size of the inlet taken from FIGURES 3.5 through 3.16.
- Column 15 Inlet type taken from TABLE 3.4.
- Column 16 If the selected inlet does not intercept all of the gutter flow, the difference between the two values should be entered here and in Column 9 of the inlet which will intercept the flow.

**Table 3.4**  
**STORM DRAIN INLETS**

<u>INLET TYPE</u>	<u>INLET DESCRIPTION</u>	<u>AVAILABLE INLET SIZES</u>	<u>WHERE USED</u>	<u>DESIGN CURVES</u>
I	Standard Curb Opening Inlet on Grade	5' 10' 15' 20'	28' Residential Street 40' Minor Collector Street, Alley	Figure 3.5a-d, 3.6
IA	Standard Curb Opening Inlet at Low Point	5' 10' 15' 20'	28' Residential Street 40' Minor Collector Street, Alley	Figure 3.7
II	Recessed Curb Opening Inlet on Grade	5' 10' 15' 20'	44' Major Collector Street 2-24' Minor Arterial 2-36' Principal Arterial Street Grade 6% or Greater	Figure 3.5a-d
II-A	Recessed Curb Opening Inlet at Low Point	5' 10' 15' 20'	44' Major Collector Street 2-24' Minor Arterial 2-36' Principal Arterial	Figure 3.7
III	Combination Inlet on Grade	4' 6' 8'	Combination Inlets to be Used Where Space Behind Curb Prohibits Other Inlet Types	Figures 3.8 through 3.10
III-A	Combination Inlet at Low Grade	4' 6' 8'	Combination Inlets to be Used Where Space Behind Curb Prohibits Other Inlet Types	Figure 3.15
IV	Grate Inlets	2 Grate 3 Grate 4 Grate 6 Grate	Grate Inlets to be Used Where Space Restrictions Prohibit Other Inlet Types or at Locations With No Curb	Figures 3.10 through 3.14
V	Drop Inlet	2'x2' 3'x3' 4'x4' 5'x5'	Open Channels	Figure 3.16

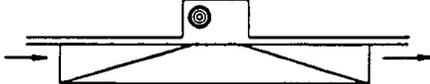
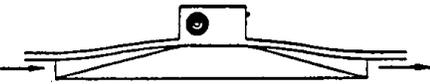
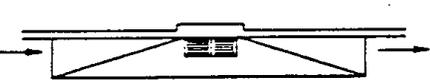
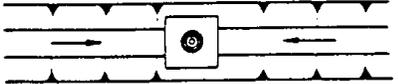
STORM DRAIN INLETS		
INLET TYPE	INLET DESCRIPTION	AVAIL. INLET SIZES
I	 <p>STANDARD CURB OPENING INLET ON GRADE</p>	5' 1/2" 10' 15' 20'
IA	 <p>STANDARD CURB OPENING INLET AT LOW POINT</p>	5' 10' 15' 20'
II	 <p>RECESSED CURB OPENING INLET ON GRADE</p>	5' 10' 15' 20'
IIA	 <p>RECESSED CURB OPENING INLET AT LOW POINT</p>	5' 10' 15' 20'
III	 <p>COMBINATION INLET ON GRADE</p>	4' 6' 8'
IIIA	 <p>COMBINATION INLET AT LOW POINT</p>	4' 6' 8'
IV	 <p>GRATE INLETS</p>	2 GRATE 3 GRATE 4 GRATE 6 GRATE
V	 <p>DROP INLET</p>	2 x 2' 3 x 3' 4 x 4' 5 x 5'

TABLE 3.4 Cont'd

**EXAMPLE**

**Known:**

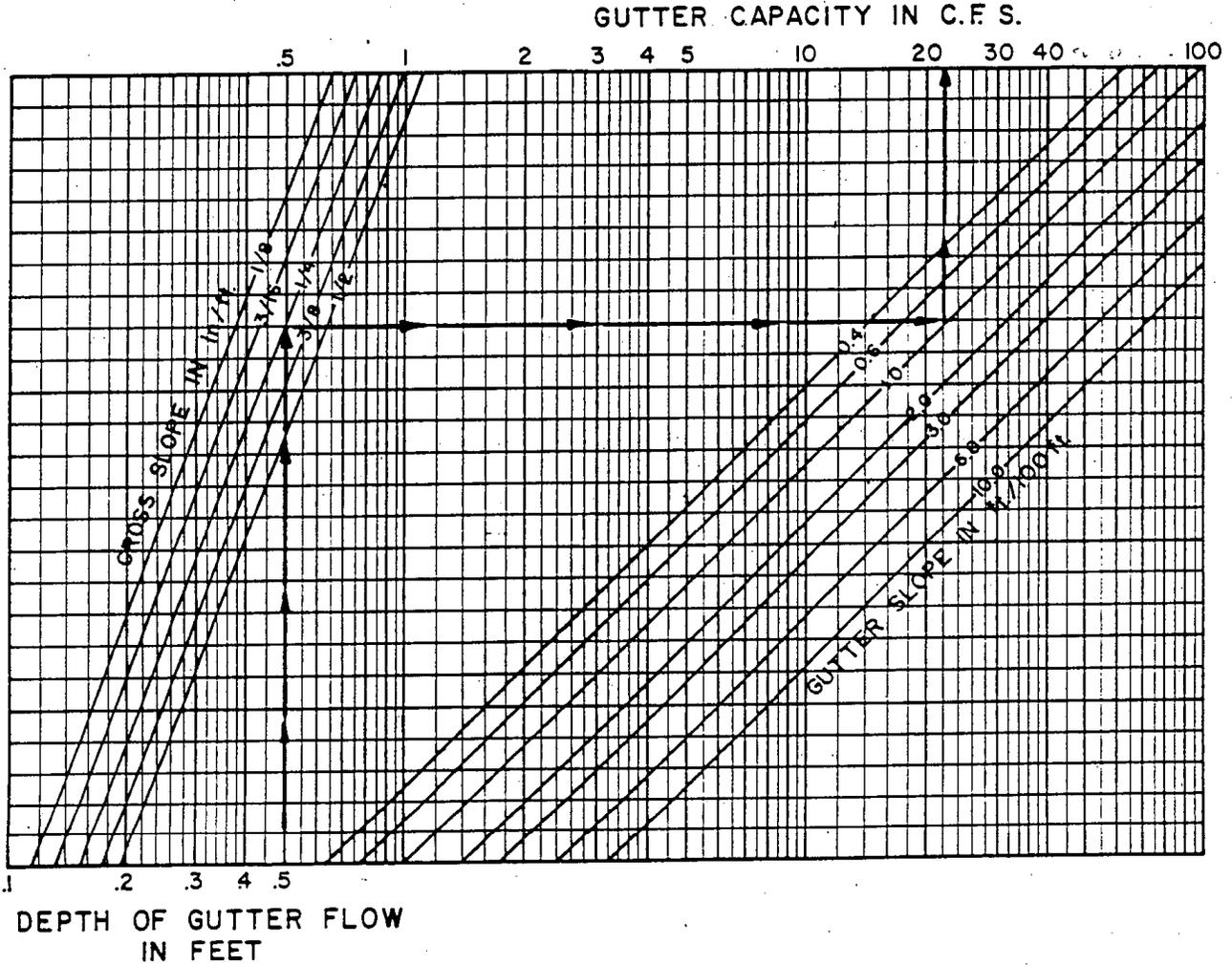
- Major Thoroughfare, Type C
- Pavement Width = 33'
- Gutter Slope = 1.0%
- Pavement Cross Slope = 1/4"/1'
- Depth of Gutter Flow = .5'

**Solution:**

- Enter Graph at .5'
- Intersect Cross Slope = 1/4"/1'
- Intersect Gutter Slope = 1.0%
- Read Gutter Capacity = 22 c.f.s.

**Find:**

Gutter Capacity



**CAPACITY OF TRIANGULAR GUTTERS**

(Roughness Coefficient  $n = .0175$ )

**FIGURE 3.3**

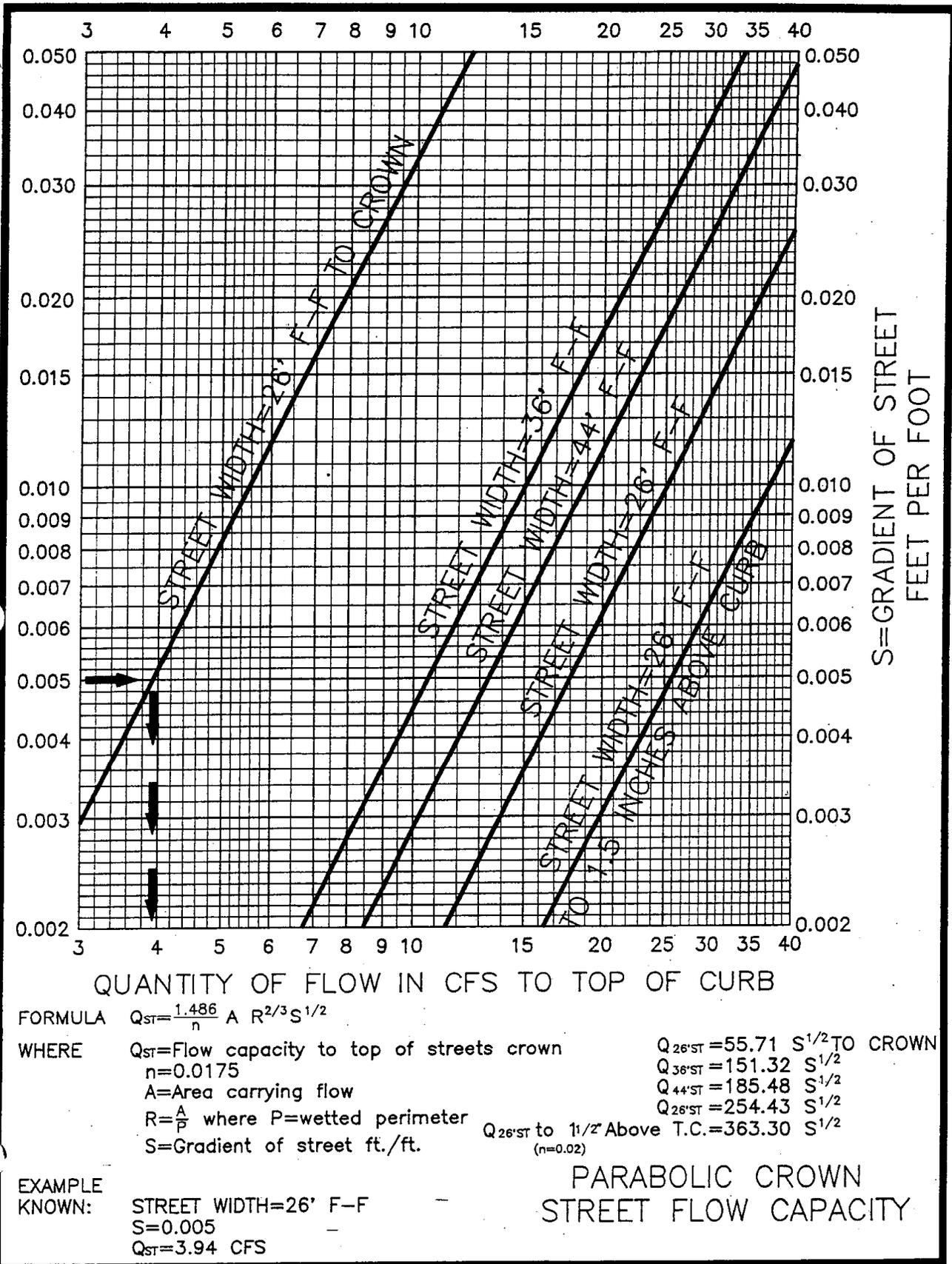
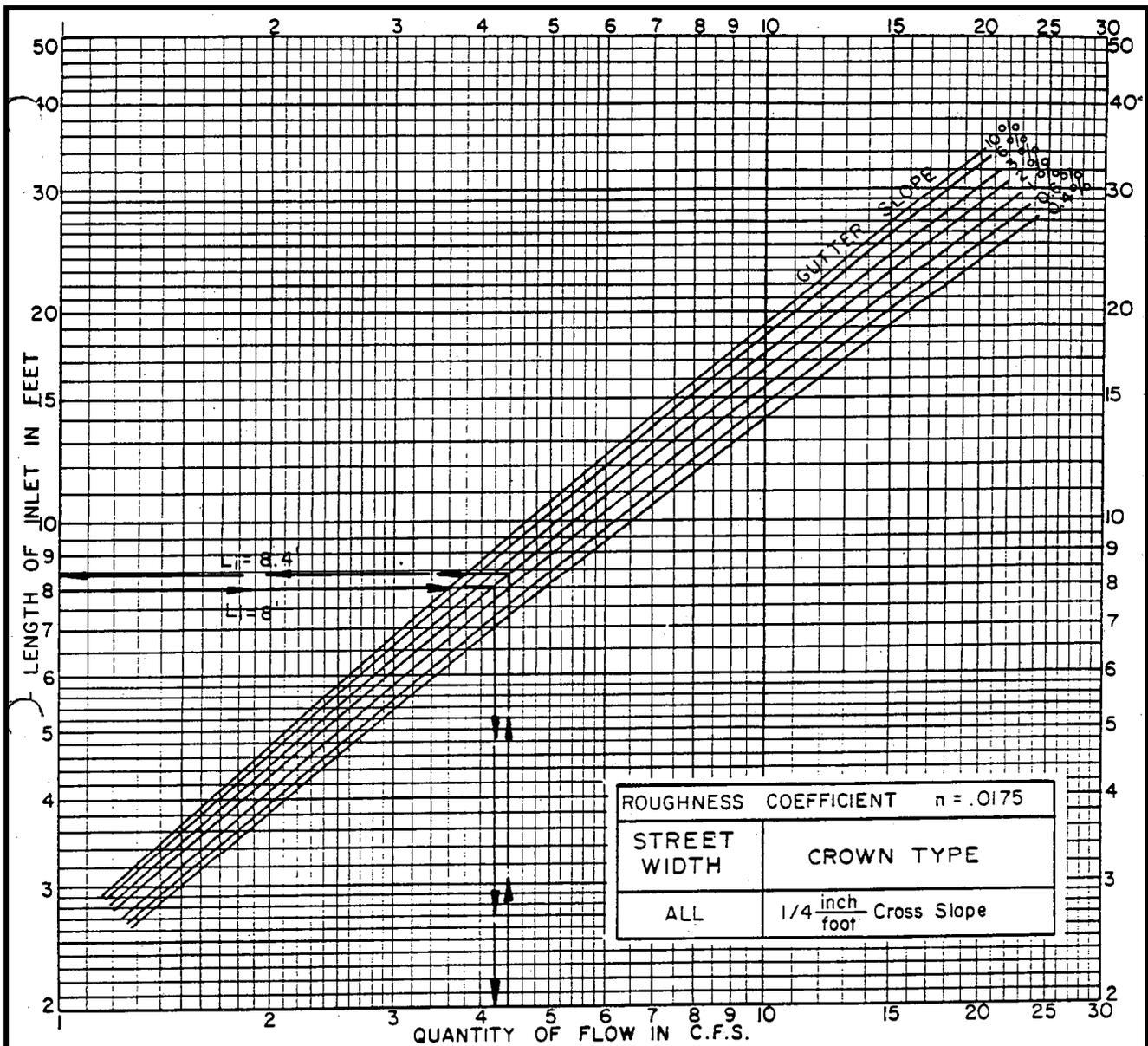


FIGURE 3.4



**EXAMPLE**

**Known:**

Pavement Width = 24'  
 Gutter Slope = 2.0 %  
 Pavement Cross Slope = 1/4" / 1'  
 Gutter Flow = 4.4 cfs

**Find:**

Length of Inlet Required ( $L_i$ )

**Solution:**

Enter Graph at 4.4 cfs  
 Intersect Slope = 2.0 %  
 Read  $L_i = 8.4'$

**Decision:**

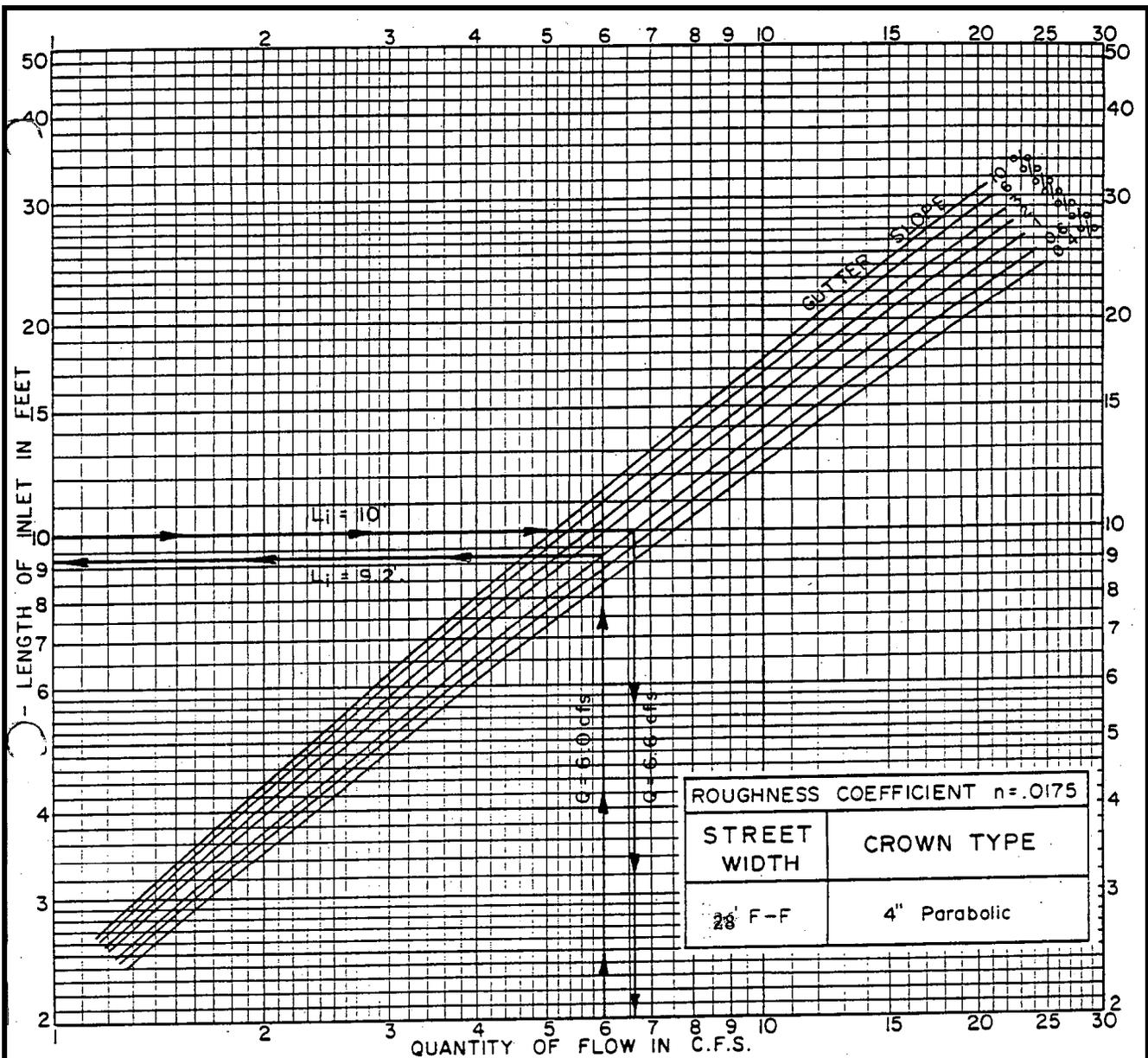
1. Use 10' Inlet  
No Flow Remains in Gutter
2. Use 8' Inlet  
Intercept Only Part of Flow

**Use 8' Inlet**

Enter Graph at  $L_i = 8'$   
 Intersect Slope = 2.0 %  
 Read  $Q = 4.2$  cfs  
 Remaining Gutter Flow =  
 4.4 cfs - 4.2 cfs = 0.2 cfs

**RECESSED AND STANDARD  
 CURB OPENING INLET  
 CAPACITY CURVES  
 ON GRADE**

FIGURE 3.5a



**EXAMPLE**

**Known:**

Pavement Width = 28'  
 Gutter Slope = 1%  
 4" Parabolic Crown  
 Gutter Flow = 6.0 cfs

**Find:**

Length of Inlet Required ( $L_i$ )

**Solution:**

Enter Graph at 6.0 cfs  
 Intersect Slope = 1%  
 Read  $L_i = 9.2'$

**Decision:**

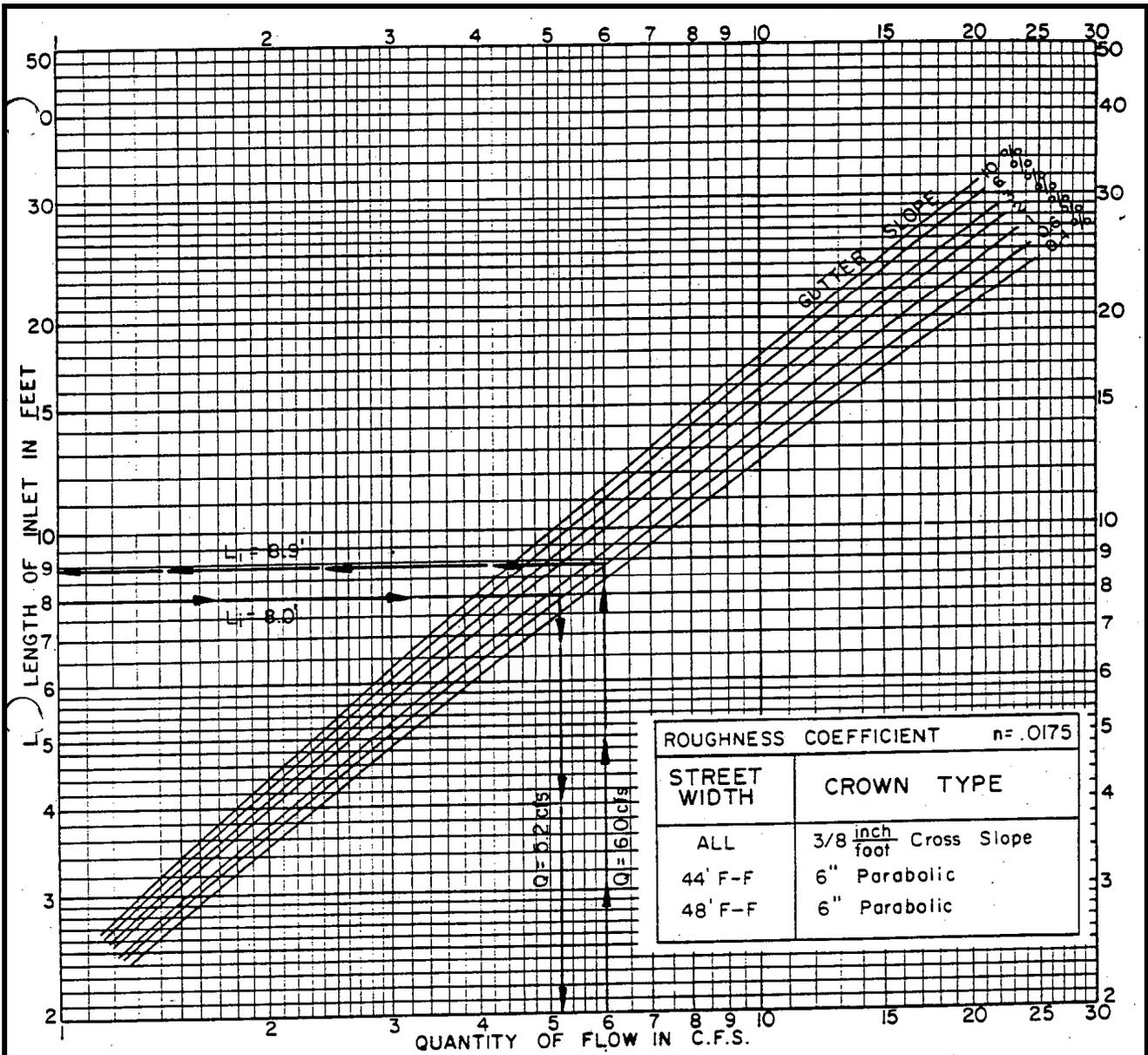
1. Use 10' Inlet  
 No Flow Remains in Gutter
2. Use 8' Inlet  
 Intercept Only Part of Flow

**Use 10' Inlet**

Enter Graph at  $L_i = 10'$   
 Intersect Slope = 1%  
 Read  $Q = 6.6$  cfs  
 No Flow Remains in Gutter

**RECESSED AND STANDARD  
 CURB OPENING INLET  
 CAPACITY CURVES  
 ON GRADE**

FIGURE 3.5b



**EXAMPLE**

**Known:**

Pavement Width = 44'  
 Gutter Slope = 0.6 %  
 6" Parabolic Crown  
 Gutter Flow = 6.0 cfs

**Find:**

Length of Inlet Required ( $L_j$ )

**Solution:**

Enter Graph at 6.0 cfs  
 Intersect Slope = 0.6 %  
 Read  $L_j = 8.9'$

**Decision:**

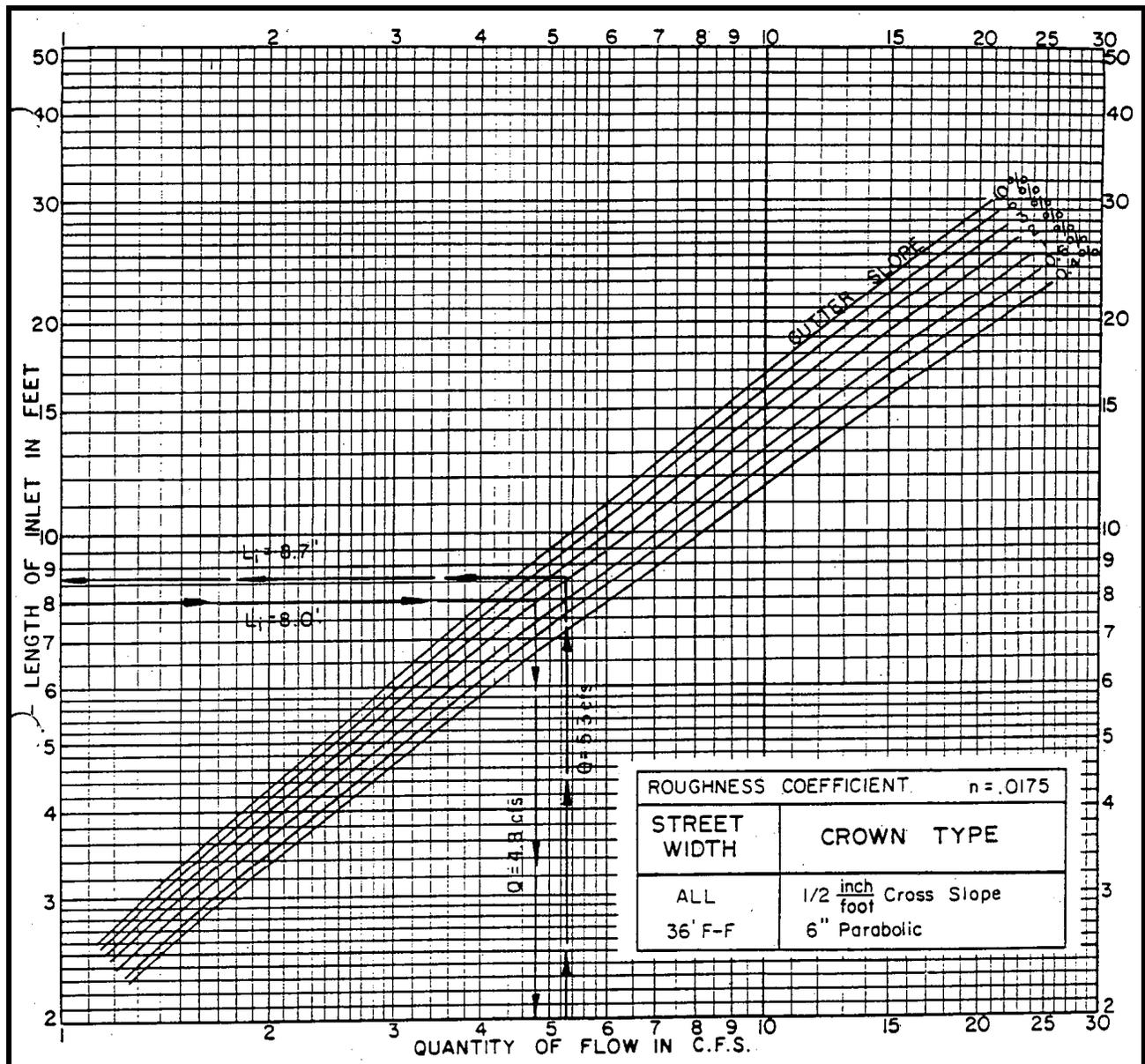
1. Use 10' Inlet  
No Flow Remains in Gutter
2. Use 8' Inlet  
Intercept Only Part of Flow

**Use 8' Inlet**

Enter Graph at  $L_j = 8'$   
 Intersect Slope = 0.6 %  
 Read  $Q = 5.2$  cfs  
 Remaining Gutter Flow =  
 $6.0$  cfs -  $5.2$  cfs =  $0.8$  cfs

**RECESSED AND STANDARD  
 CURB OPENING INLET  
 CAPACITY CURVES  
 ON GRADE**

FIGURE 3.5c



**EXAMPLE**

Known:  
 Pavement Width = 36'  
 Gutter Slope = 2%  
 6" Parabolic Crown  
 Gutter Flow = 5.3 cfs

Find:  
 Length of Inlet Required ( $L_i$ )

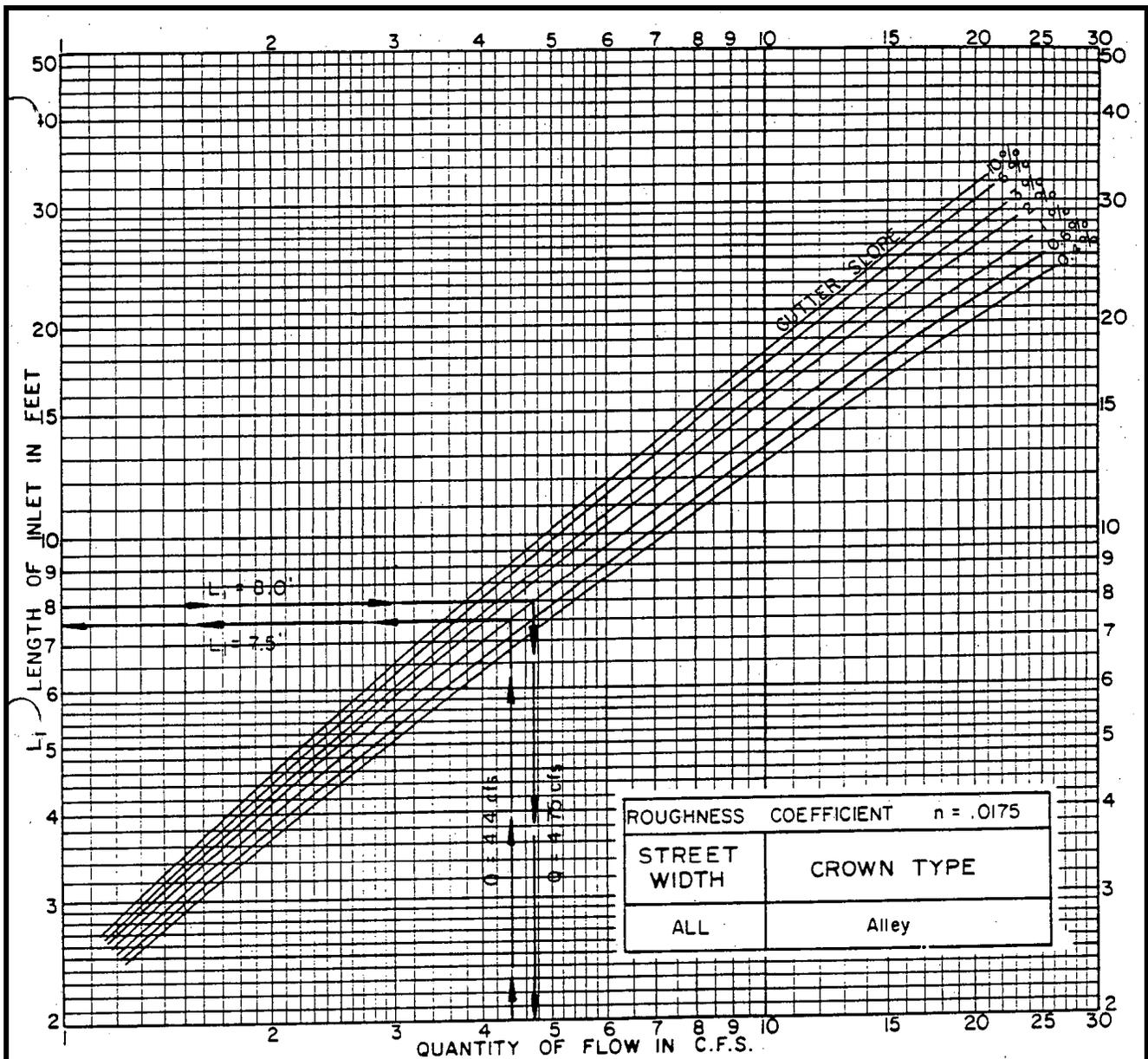
Solution:  
 Enter Graph at 5.3 cfs  
 Intersect Slope = 2%  
 Read  $L_i = 8.7'$

Decision:  
 1. Use 10' Inlet  
 No Flow Remains in Gutter  
 2. Use 8' Inlet  
 Intercept Only Part of Flow  
 Use 8' Inlet

Enter Graph at  $L_i = 8'$   
 Intersect Slope = 2%  
 Read  $Q = 4.8$  cfs  
 Remaining Gutter Flow =  
 $5.3$  cfs -  $4.8$  cfs =  $0.5$  cfs

**RECESSED AND STANDARD  
 CURB OPENING INLET  
 CAPACITY CURVES  
 ON GRADE**

FIGURE 3.5d



**EXAMPLE**

Known:

- Pavement Width = 16'
- Gutter Slope = 1%
- Pavement Cross Slope = 1/4"/1'
- Gutter Flow = 4.4 cfs

Find:

Length of Inlet Required ( $L_i$ )

Solution:

- Enter Graph at 4.4 cfs
- Intersect Slope = 1%
- Read  $L_i = 7.5'$

Decision:

1. Use 8' Inlet  
No Flow Remains in Gutter
2. Use 6' Inlet  
Intercept Only Part of Flow

Use 8' Inlet

Enter Graph at  $L_i = 8'$

Intersect Slope = 1%

Read  $Q = 4.75$  cfs

No Flow Remains in Gutter

**RECESSED AND STANDARD  
CURB OPENING INLET  
CAPACITY CURVES  
ON GRADE**

FIGURE 3.6

**EXAMPLE**

**Known:**

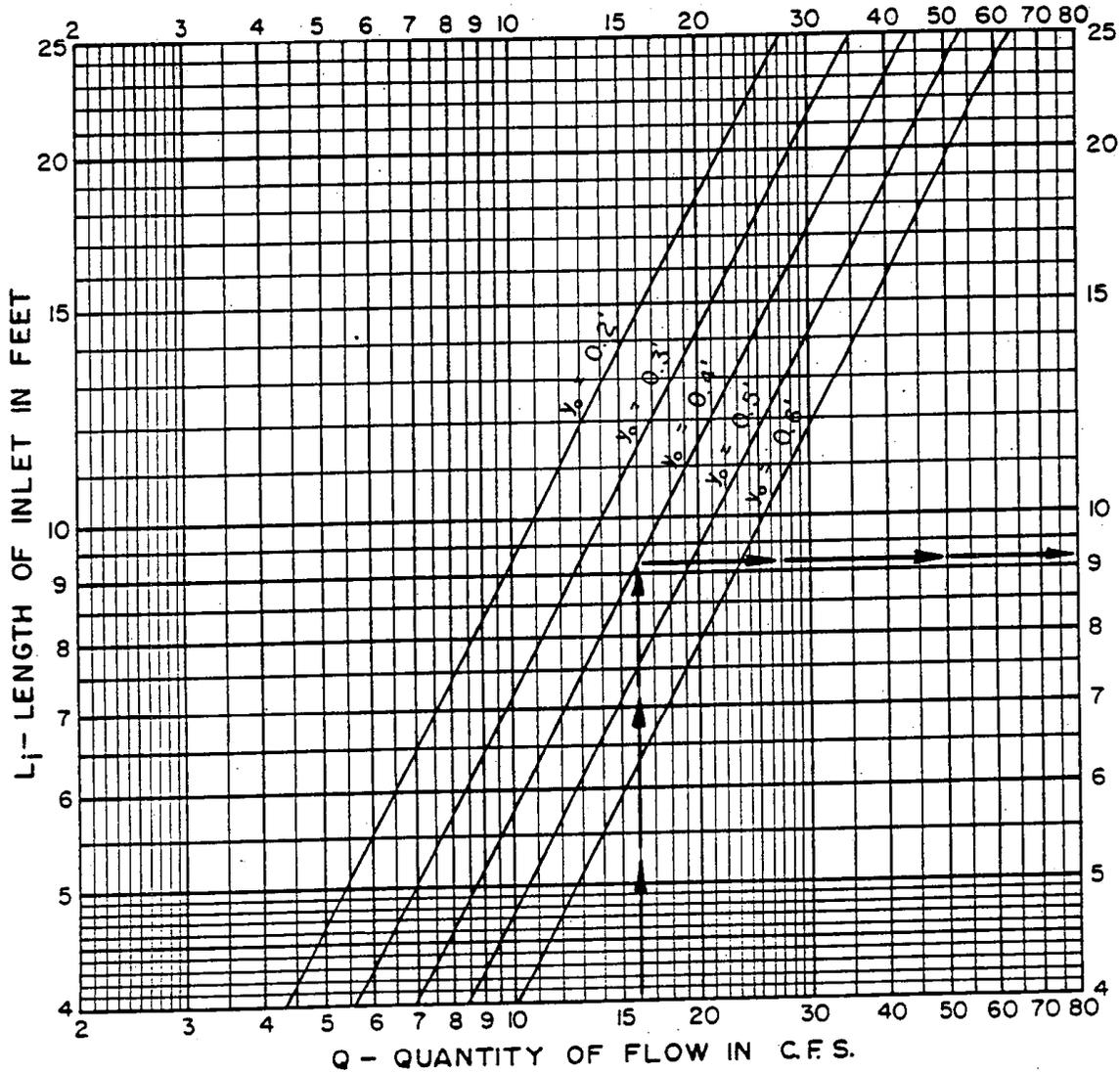
Quantity of Flow = 16.0 c.f.s.  
 Maximum Depth of Flow Desired  
 in Gutter At Low Point ( $y_0$ ) = 0.4'

**Find:**

Length of Inlet Required ( $L_i$ )

**Solution:**

Enter Graph at 16.0 c.f.s.  
 Intersect  $y_0 = 0.4'$   
 Read  $L_i = 9.2'$   
 Use 10' Inlet



ROUGHNESS COEFFICIENT $n = .0175$	
STREET WIDTH	CROWN TYPE
ALL	Straight and Parabolic

RECESSED AND STANDARD  
 CURB OPENING INLET  
 CAPACITY CURVES  
 AT LOW POINT

FIGURE 3.7

### EXAMPLE

#### Known:

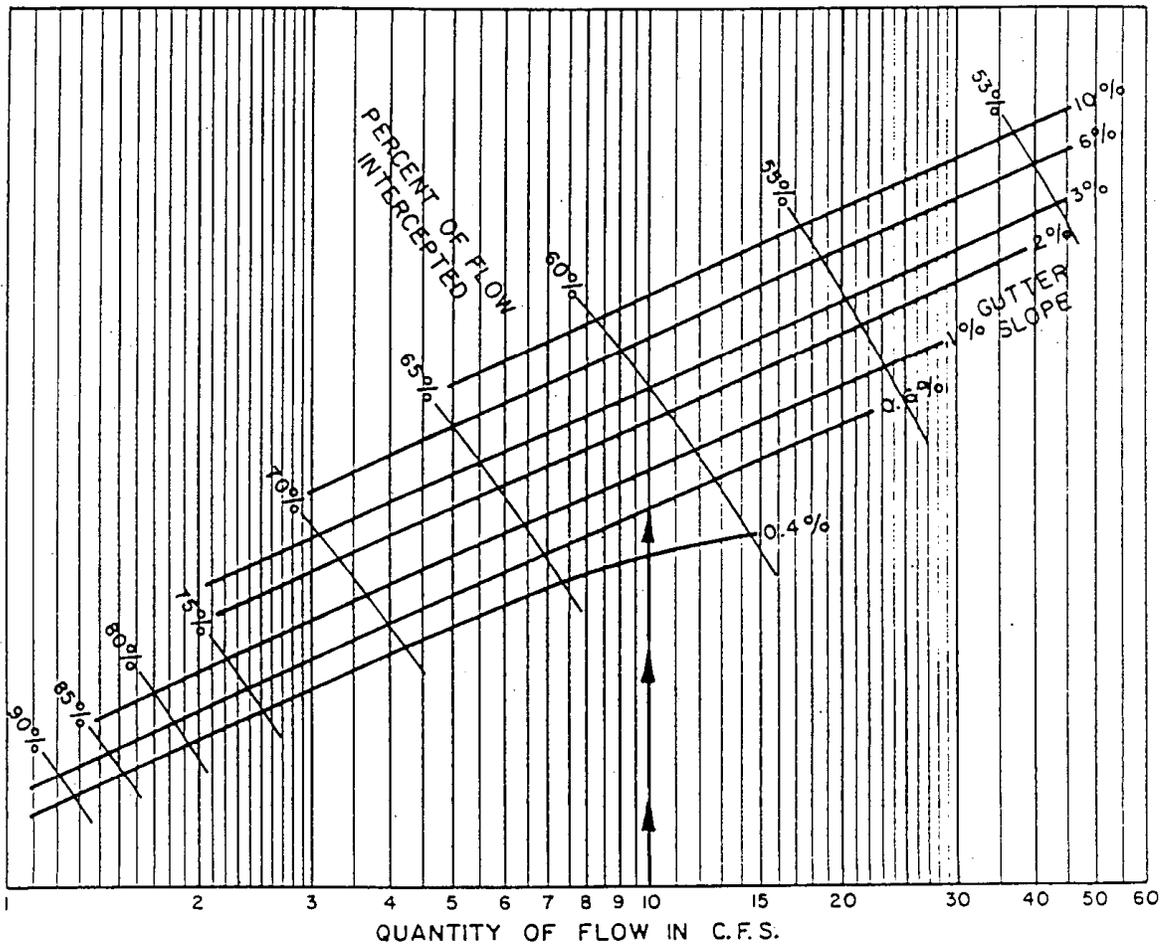
Quantity of Flow = 10.0 c.f.s.  
Gutter Slope = 0.6 %

#### Find:

Capacity of Two Grate Combination  
Inlet

#### Solution:

Enter Graph at 10.0 c.f.s.  
Intersect Slope = 0.6 %  
Read Percent of Flow  
Intercepted = 62 %  
62 % of 10.0 c.f.s. = 6.2 c.f.s.  
as Capacity of Two Grate  
Combination Inlet  
Remaining Gutter Flow =  
10.0 c.f.s - 6.2 c.f.s. = 3.8 c.f.s.



TWO GRATE COMBINATION INLET  
CAPACITY CURVES  
ON GRADE

FIGURE 3.8

**EXAMPLE**

**Known:**

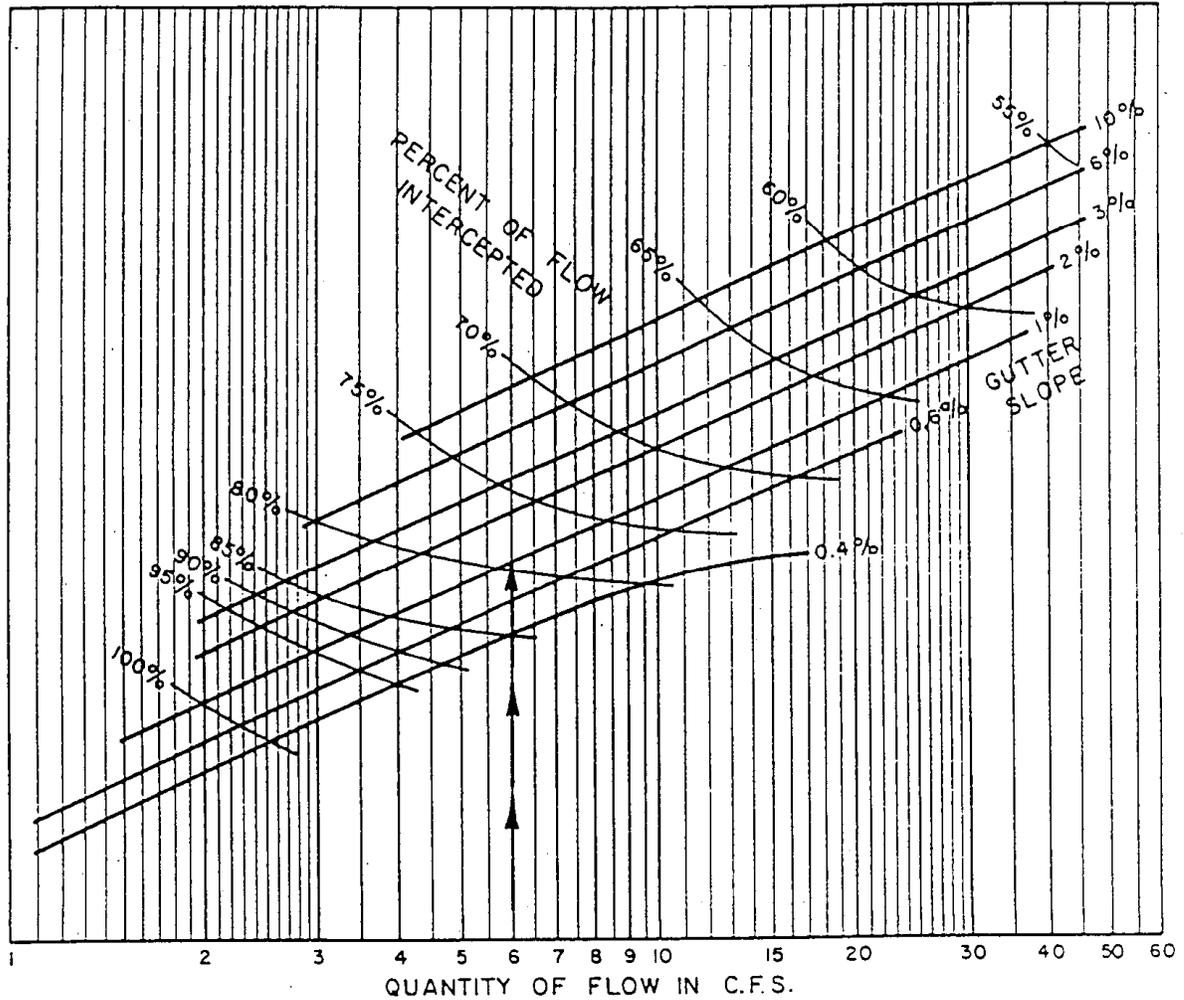
Quantity of Flow = 6.0 c.f.s.  
Gutter Slope = 1.0 %

**Find:**

Capacity of Four Grate Combination  
Inlet

**Solution:**

Enter Graph at 6.0 c.f.s.  
Intersect Slope = 1.0 %  
Read Percent of Flow  
Intercepted = 79 %  
79 % of 6.0 c.f.s. = 4.7 c.f.s.  
as Capacity of Four Grate  
Combination Inlet  
Remaining Gutter Flow =  
6.0 c.f.s. - 4.7 c.f.s. = 1.3 c.f.s.



FOUR GRATE COMBINATION INLET  
CAPACITY CURVES  
ON GRADE

FIGURE 3.9

**EXAMPLE**

**Known:**

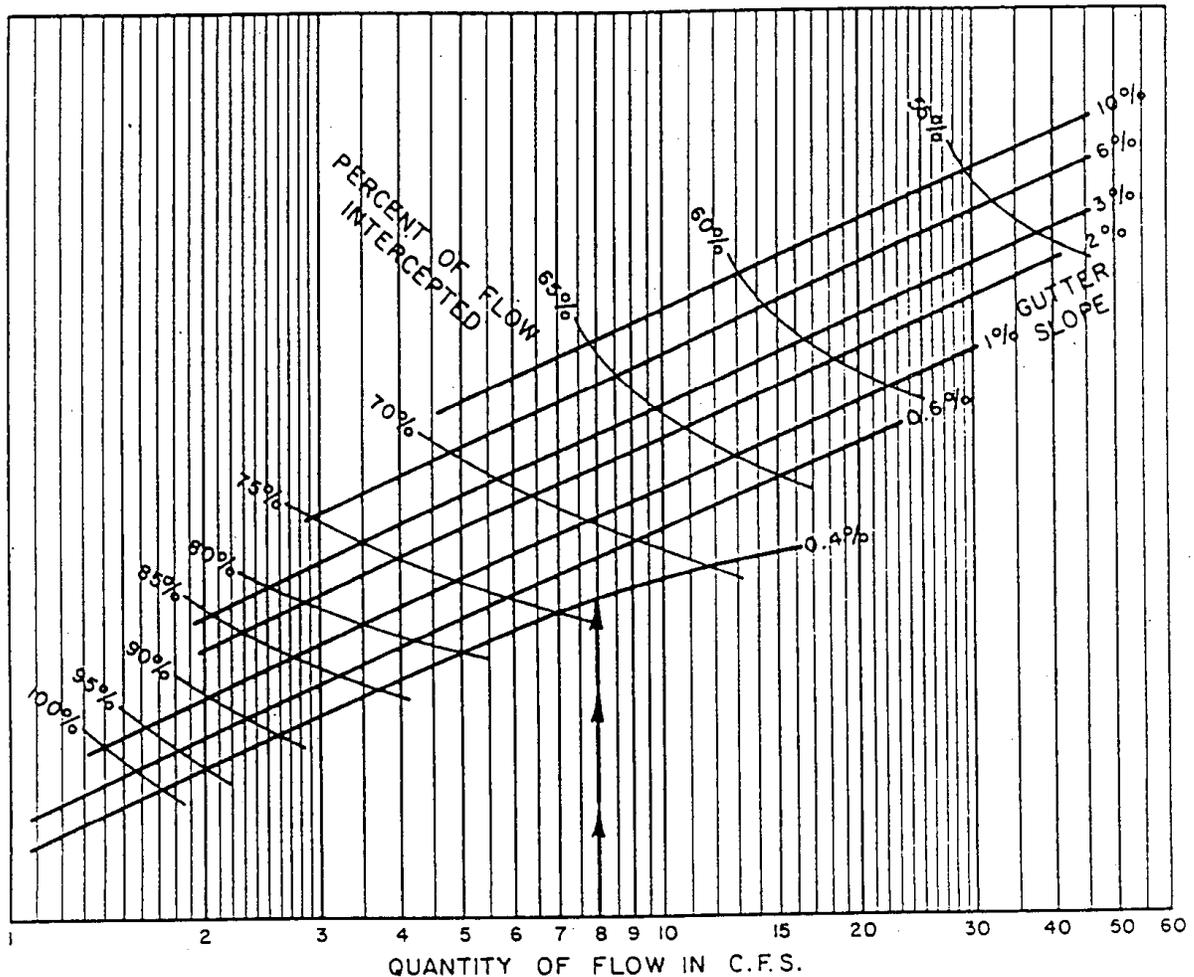
Quantity of Flow = 8.0 c.f.s.  
 Gutter Slope = 0.4%

**Find:**

Capacity of Three Grate Inlet

**Solution:**

Enter Graph at 8.0 c.f.s.  
 Intersect Slope = 0.4%  
 Read Percent of Flow Intercepted = 74%  
 74% of 8.0 c.f.s. = 5.9 c.f.s.  
 as Capacity of Three Grate Inlet  
 Remaining Gutter Flow =  
 8.0 c.f.s. - 5.9 c.f.s. = 2.1 c.f.s.



**THREE GRATE INLET AND  
 THREE GRATE COMBINATION INLET  
 CAPACITY CURVES  
 ON GRADE**

**FIGURE 3.10**

### EXAMPLE

Known:

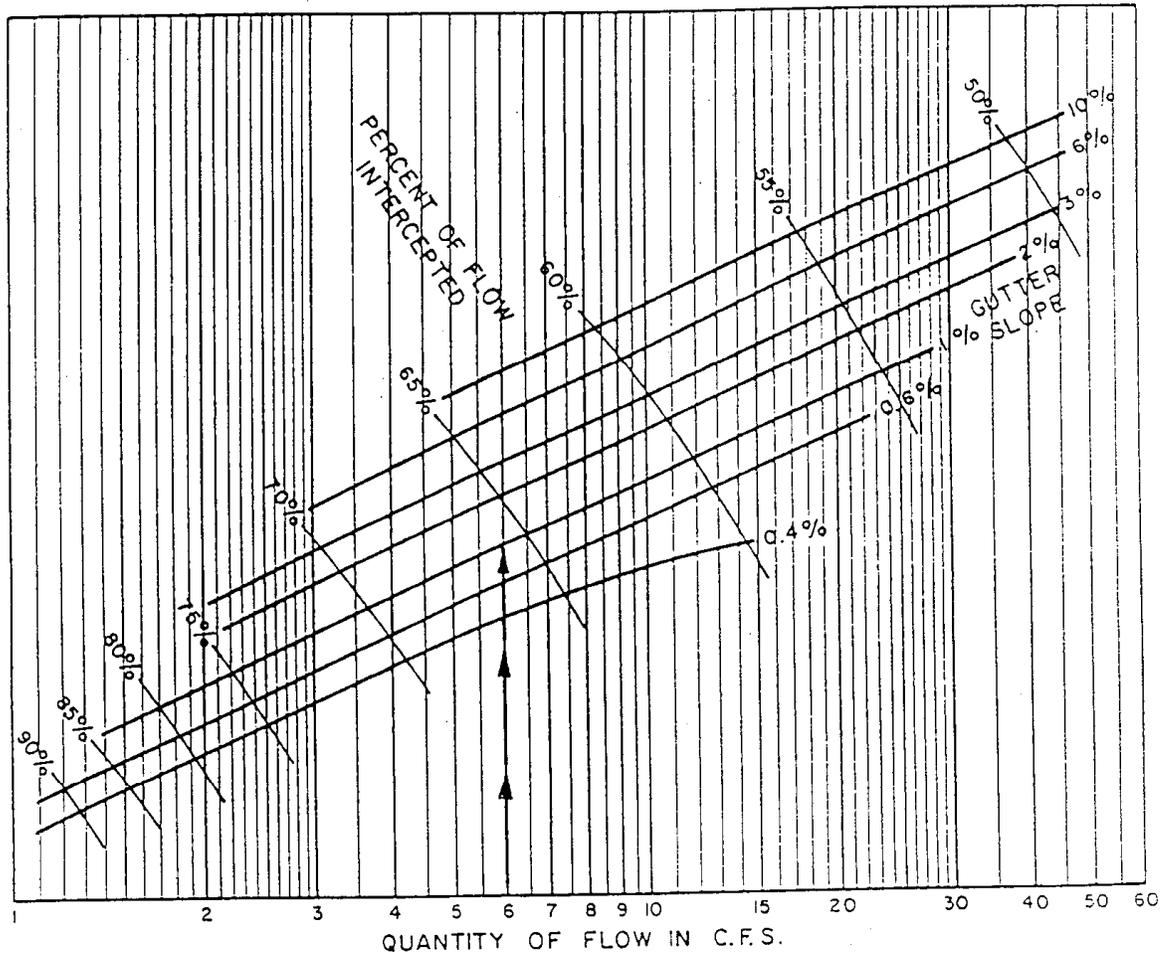
Quantity of Flow = 6.0 c.f.s.  
Gutter Slope = 1.0%

Find:

Capacity of Two Gate Inlet

Solution:

Enter Graph at 6.0 c.f.s.  
Intersect Slope = 1.0%  
Read Percent of Flow Intercepted = 66%  
66% of 6.0 c.f.s. = 4.0 c.f.s.  
as Capacity of Two Gate Inlet  
Remaining Gutter Flow =  
6.0 c.f.s. - 4.0 c.f.s. = 2.0 c.f.s.



TWO GATE INLET  
CAPACITY CURVES  
ON GRADE

FIGURE 3.11

**EXAMPLE**

**Known:**

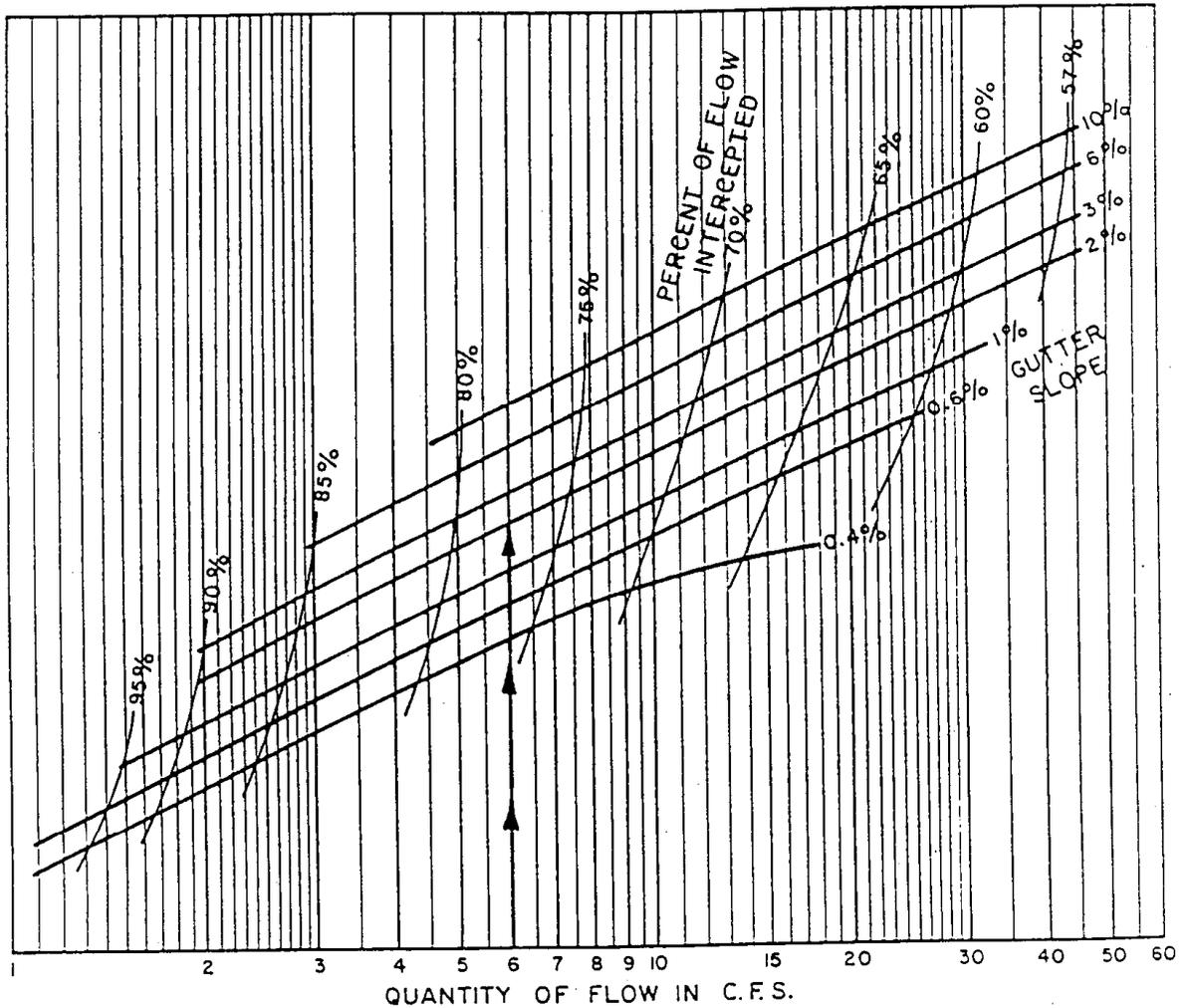
Quantity of Flow = 6.0 c.f.s.  
 Gutter Slope = 1.0%

**Find:**

Capacity of Four Grate Inlet

**Solution:**

Enter Graph at 6.0 c.f.s.  
 Intersect Slope = 1.0%  
 Read Percent of Flow Intercepted = 77%  
 77% of 6.0 c.f.s. = 4.6 c.f.s.  
 as Capacity of Four Grate Inlet  
 Remaining Gutter Flow =  
 6.0 c.f.s. - 4.6 c.f.s. = 1.4 c.f.s.



**FOUR GRATE INLET  
 CAPACITY CURVES  
 ON GRADE**

**FIGURE 3.12**

### EXAMPLE

#### Known:

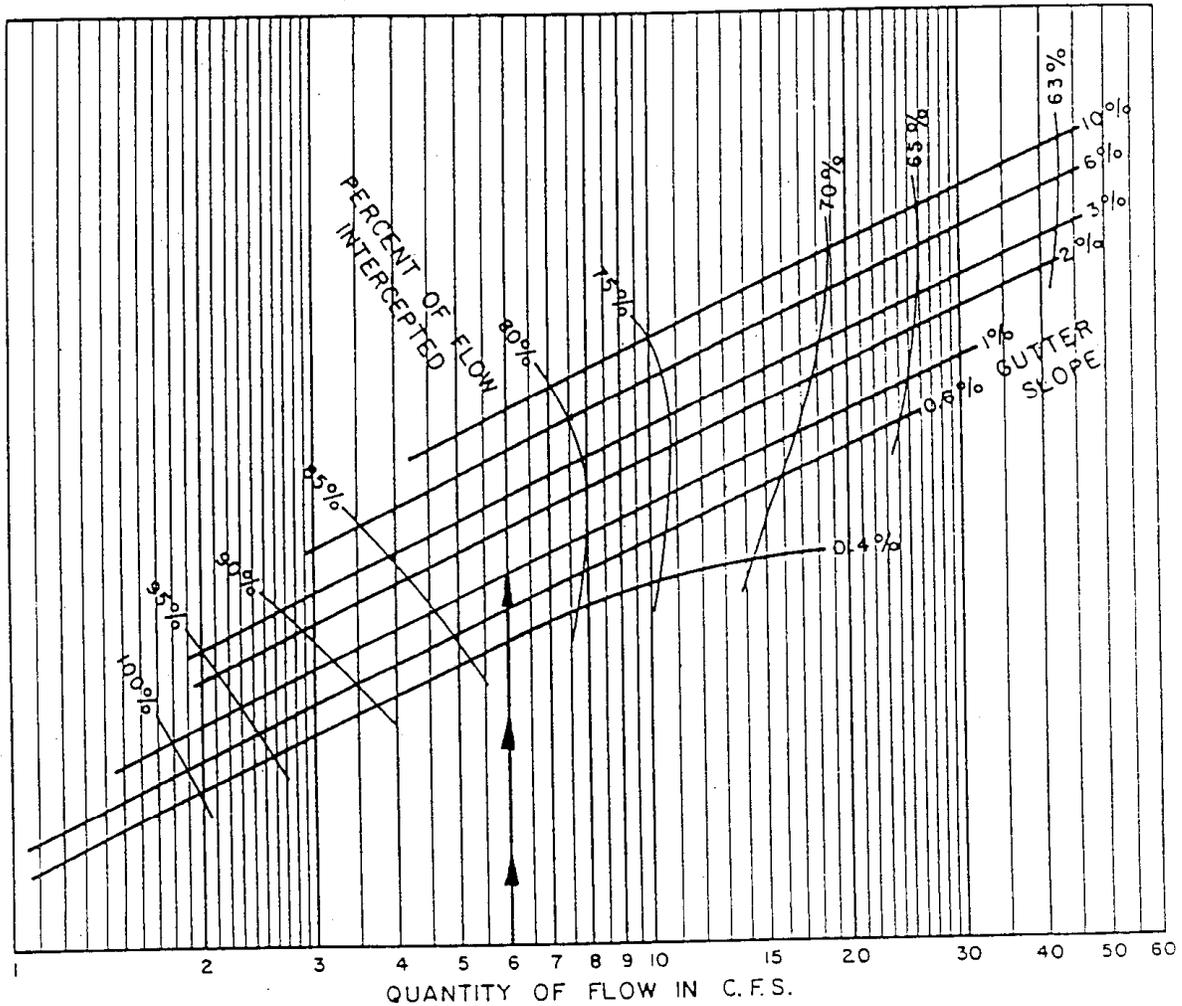
Quantity of Flow = 6.0 c.f.s.  
Gutter Slope = 1.0%

#### Find:

Capacity of Six Grate Inlet

#### Solution:

Enter Graph at 6.0 c.f.s.  
Intersect Slope = 1.0%  
Read Percent of Flow Intercepted = 82%  
82% of 6.0 c.f.s. = 4.9 c.f.s.  
as Capacity of Six Grate Inlet  
Remaining Gutter Flow =  
6.0 c.f.s. - 4.9 c.f.s. = 1.1 c.f.s.



SIX GRATE INLET  
CAPACITY CURVES  
ON GRADE

FIGURE 3.13

**EXAMPLE**

**Known:**

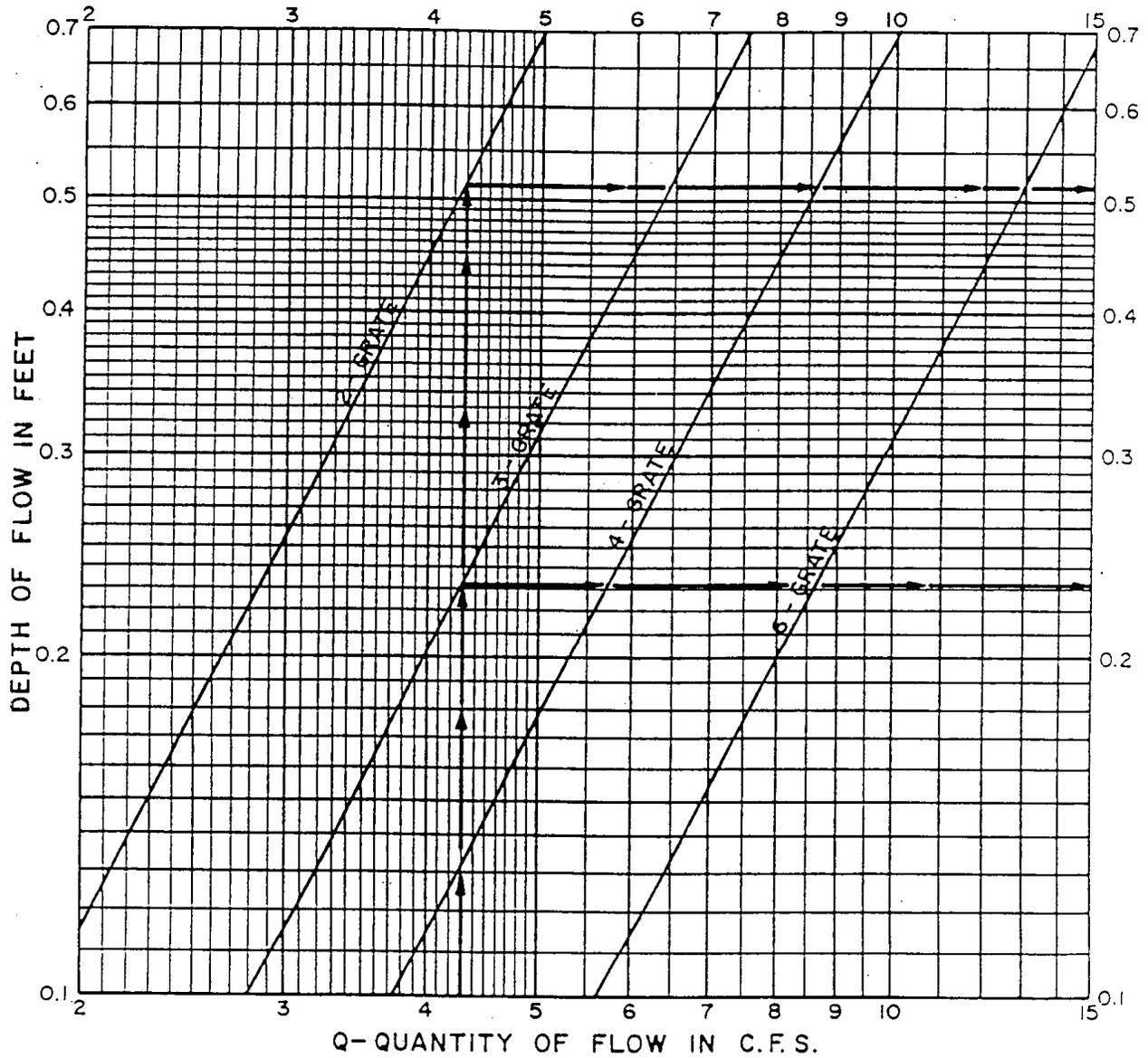
Quantity of Flow = 4.3 c.f.s.  
 Maximum Depth of Flow Desired  
 at Low Point = 0.3'

**Find:**

Inlet Required

**Solution:**

Enter Graph at 4.3 c.f.s.  
 Intersect 3-Grate at 0.23'  
 Intersect 2-Grate at 0.51'  
 Use 3-Grate



GRATE INLET  
 CAPACITY CURVES  
 AT LOW POINT

FIGURE 3.14

**EXAMPLE**

**Known:**

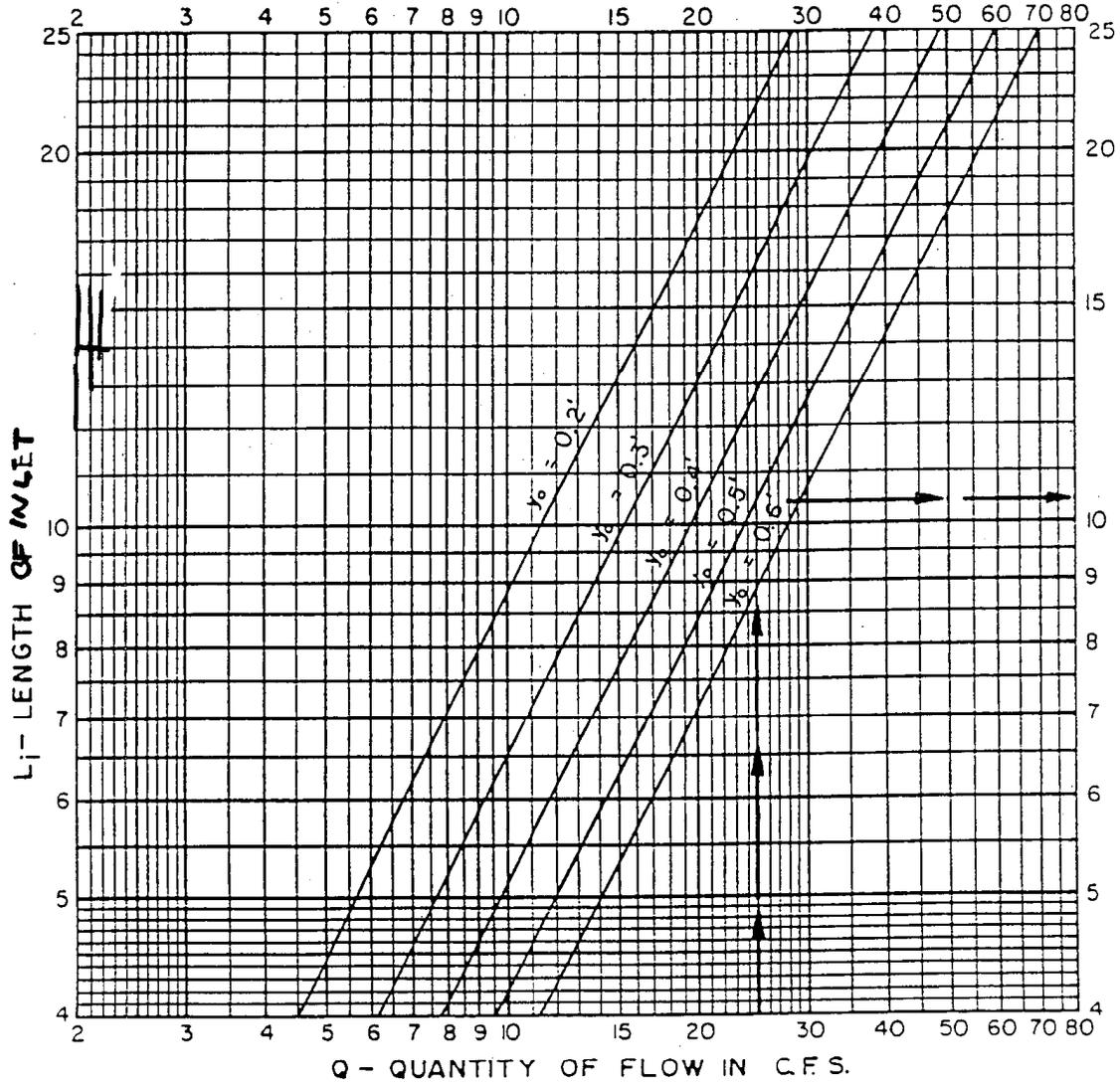
Quantity of Flow = 25.0 c.f.s.  
 Maximum Depth of Flow Desired  
 At Low Point ( $y_0$ ) = 0.5'

**Find:**

Length of Inlet Required ( $L_i$ )

**Solution:**

Enter Graph at 25.0 c.f.s.  
 Intersect  $y_0 = 0.5'$   
 Read  $L_i = 10.4'$   
 Use 12' Inlet



ROUGHNESS COEFFICIENT $n = .0175$	
STREET WIDTH	CROWN TYPE
ALL	Straight and Parabolic

COMBINATION INLET  
 CAPACITY CURVES  
 AT LOW POINT

**FIGURE 3.15**

**Known:**

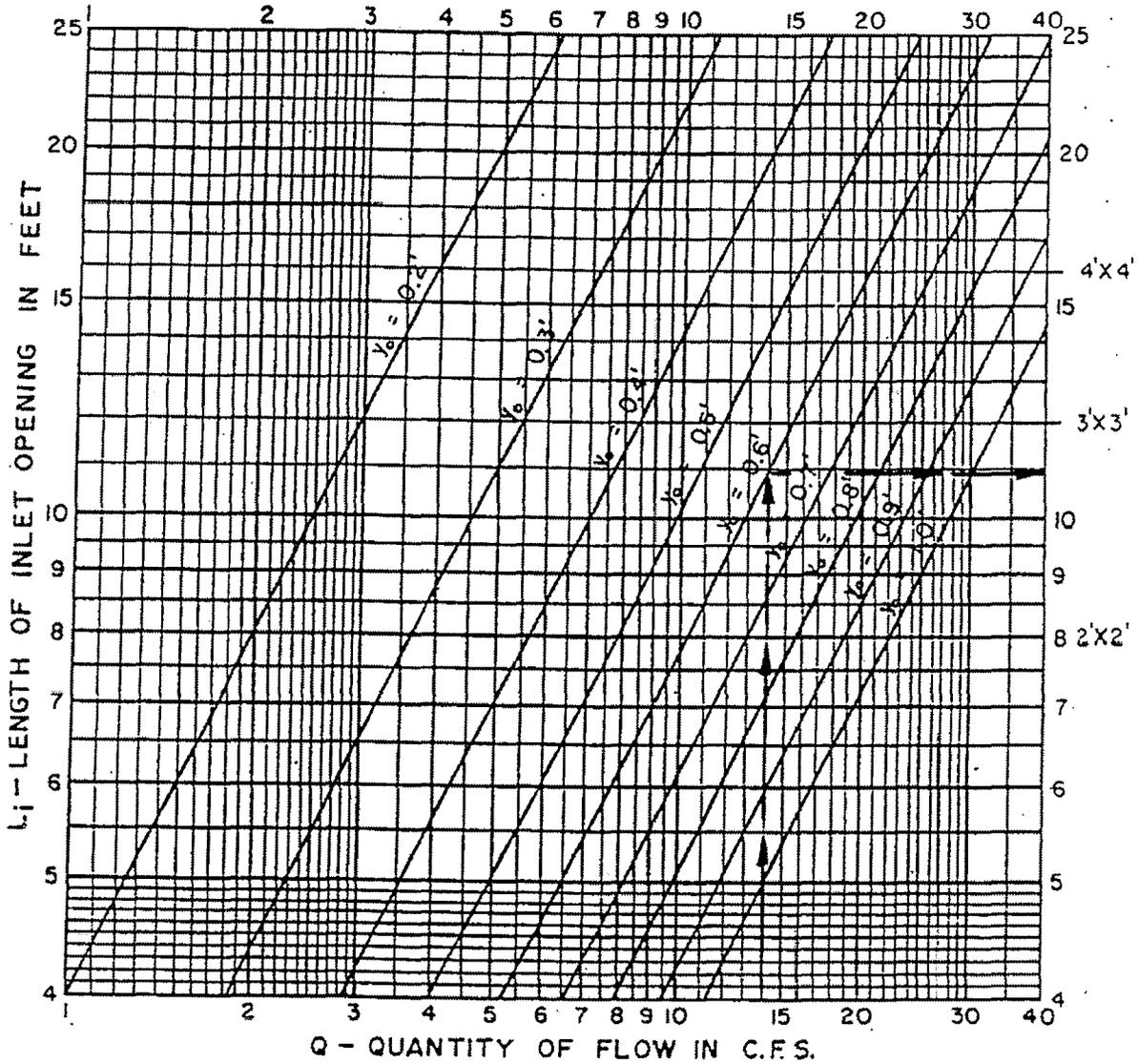
Quantity of Flow = 14.0 c.f.s.  
Maximum Depth of Flow Desired  
( $y_0$ ) = 0.6'

**Find:**

Length of Inlet Opening Required ( $L_i$ )

**Solution:**

Enter Graph at 14.0 c.f.s.  
Intersect  $y_0 = 0.6'$   
Read  $L_i = 10.9'$   
Use 12' of Inlet; 3' x 3'



Standard Drop Inlet Sizes:  
2' x 2';  $L_i = 8'$   
3' x 3';  $L_i = 12'$   
4' x 4';  $L_i = 16'$   
5' x 5';  $L_i = 25'$

**DROP INLET  
CAPACITY CURVES  
AT LOW POINT**

**FIGURE 3.16**

## G. Flow in Storm Drain Conduits and Their Appurtenances

### 1. Hydraulic Gradient of Conduits:

A storm drainage conduit must have sufficient capacity to discharge a design storm with a minimum of interruption and inconvenience to the public using streets and thoroughfares. The size of the conduit is determined by accumulating runoff from contributing inlets and calculating the slope of a hydraulic gradient 'from Manning's Equation:

$$S = \frac{Qn^2}{1.486 AR^{2/3}}$$

Beginning at the upper most inlet on the system, a tentative hydraulic gradient for the selected conduit size is plotted approximately 1.5 feet below the gutter between each contributing inlet to insure that the selected conduit will carry the design flow at an elevation below the gutter profile. As the conduit size is selected and the tentative hydraulic gradient is plotted between each inlet pickup point, a head loss due to a change in velocity and pipe size must be incorporated in the gradient profile.

The equation for head loss at an obstruction is:

$$H_j = K_j \frac{V^2}{2g}$$

$K_j$  = Velocity Head Coefficient for closed conduits (see TABLE 3.5). See TABLE 3.6 and 3.7 for examples of Minor Head losses due to turbulence at structures.

Also, at each point where an inlet lateral enters the main conduit the gradient must be sufficiently low to allow the hydraulic gradient in the inlet to be below the gutter grade.

At the discharge end of the conduit (generally a creek or stream) the hydraulic gradient of the creek for the design storms must coincide with the gradient of the storm drainage conduit. and an adjustment is usually required in the tentative conduit gradient and, necessarily, the initial pipe selection could also change.

Reinforced Concrete Pipe (RCP) conduit shall be used to carry the storm water, and flow chart, FIGURE 3.17, based on Manning's Equation may be used to determine the various hydraulic elements including the pipe size, the hydraulic gradient and the velocity. Special hydraulic calculators are also available for solution of Manning's Equation.

Corrugated pipe is not acceptable.

The roughness coefficients for each of these conduit types are shown in TABLE 3.8.

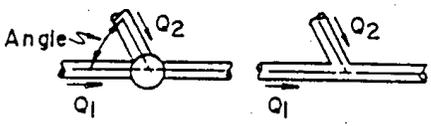
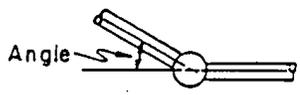
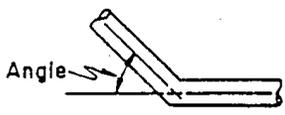
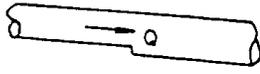
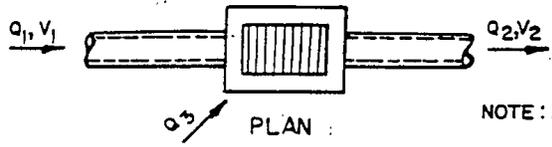
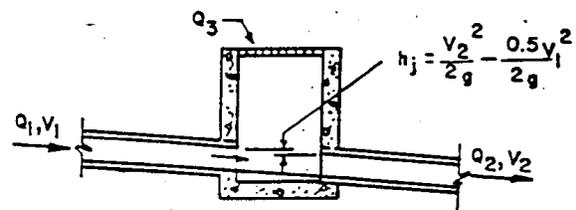
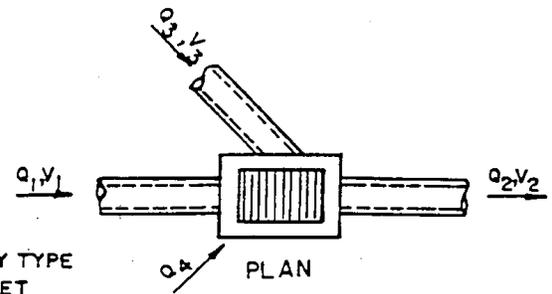
VELOCITY HEAD LOSS COEFFICIENTS FOR CLOSED CONDUITS			
MANHOLE ON MAIN LINE WITH BRANCH LATERAL OR WYE CONNECTION			
DESCRIPTION	ANGLE	RATIO OF $Q_2/Q_1$	HEAD LOSS COEFFICIENT $K_j$
	60°	< .20	0.40
		.20 to .60	0.50
		> .60	0.60
	45°	< .20	0.20
		.20 to .60	0.30
		> .60	0.40
MANHOLE AT CHANGE IN PIPE DIRECTION			
DESCRIPTION	ANGLE	HEAD LOSS COEFFICIENT $K_j$	
	90°	1.00	
	60°	0.80	
	45°	0.65	
	30°	0.50	
BENDS IN PIPES			
DESCRIPTION	ANGLE	HEAD LOSS COEFFICIENT $K_j$	
	90°	0.80	
	60°	0.60	
	45°	0.50	
	30°	0.45	
ENLARGEMENTS IN PIPE SIZES WITH CONSTANT FLOW			
DESCRIPTION	RATIO OF UPSTREAM DIAMETER TO DOWNSTREAM DIAMETER		HEAD LOSS COEFFICIENT $K_j$
	0.81		1.00
	0.82		0.90
	0.84		0.80
	0.85		0.70
	0.86		0.60
	0.88		0.50
	0.90		0.40
	0.92		0.30

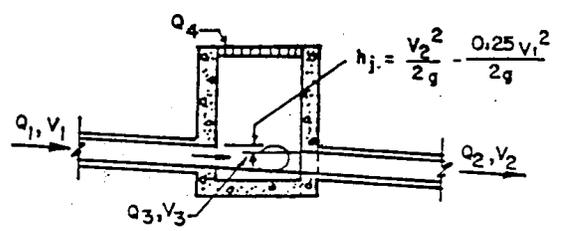
TABLE 3.5



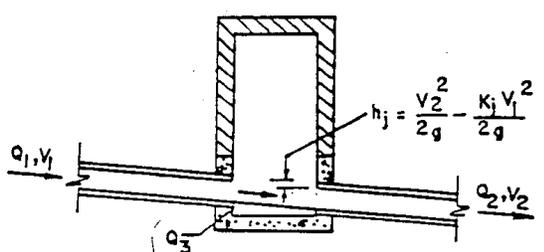
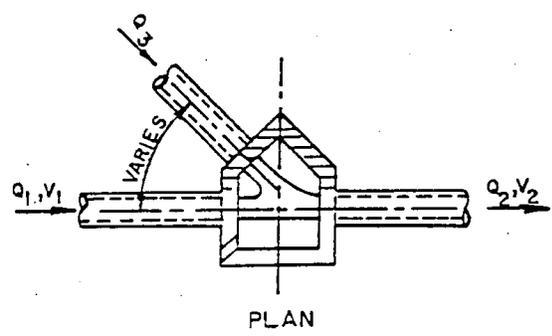
NOTE: FOR ANY TYPE OF INLET



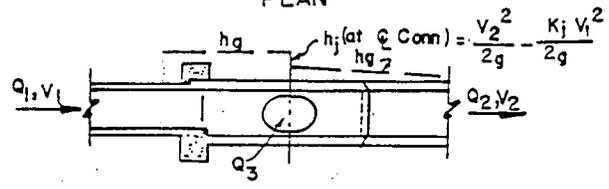
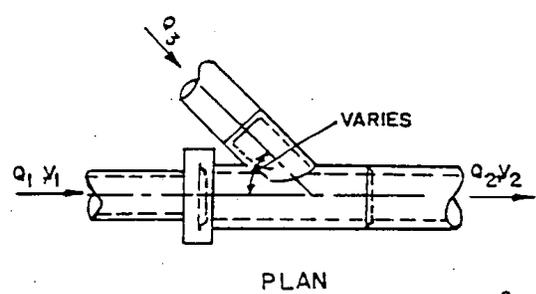
SECTION CASE I  
INLET ON MAIN LINE



SECTION CASE II  
INLET ON MAIN LINE WITH BRANCH LATERAL



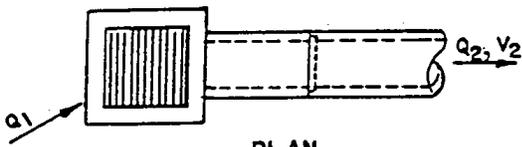
SECTION CASE III  
MANHOLE ON MAIN LINE WITH BRANCH LATERAL



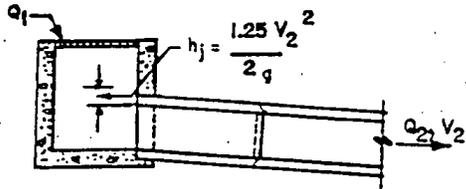
SECTION CASE IV  
WYE CONNECTION OR CUT IN

MINOR HEAD LOSSES DUE TO TURBULENCE AT STRUCTURES

TABLE 3.6

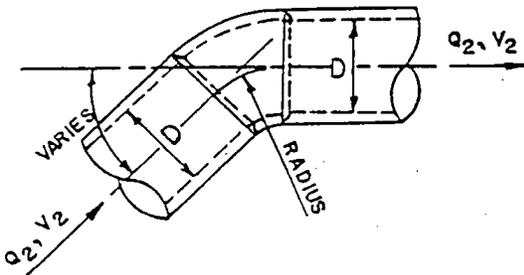


PLAN



SECTION

**CASE V**  
**INLET OR MANHOLE AT**  
**BEGINNING OF LINE**

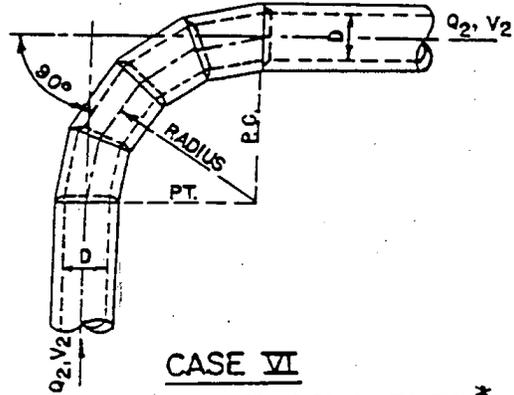


**CASE VII**  
**BENDS WHERE RADIUS IS**  
**EQUAL TO DIAMETER OF PIPE**

NOTE : HEAD LOSS APPLIED AT BEGINNING OF BEND. BENDS TO BE USED ONLY WITH THE PERMISSION OF THE DRAINAGE DESIGN ENGINEER.

90° BEND  $h_j = 0.50 \frac{V_2^2}{2g}$     60° BEND  $h_j = 0.43 \frac{V_2^2}{2g}$   
 45° BEND  $h_j = 0.35 \frac{V_2^2}{2g}$     22.5° BEND  $h_j = 0.20 \frac{V_2^2}{2g}$

**MINOR HEAD LOSSES DUE TO**  
**TURBULENCE AT STRUCTURES**



**CASE VI**  
**CONDUIT ON 90° CURVES\***

NOTE : HEAD LOSS APPLIED AT P.C. FOR LENGTH OF CURVE

RADIUS = (2-8) x DIA. OF PIPE  $h_j = 0.40 \frac{V_2^2}{2g}$

RADIUS = (8-20) x DIA. OF PIPE  $h_j = 0.25 \frac{V_2^2}{2g}$

RADIUS = GREATER THAN 20 x DIA. OF PIPE  $h_j = 0$

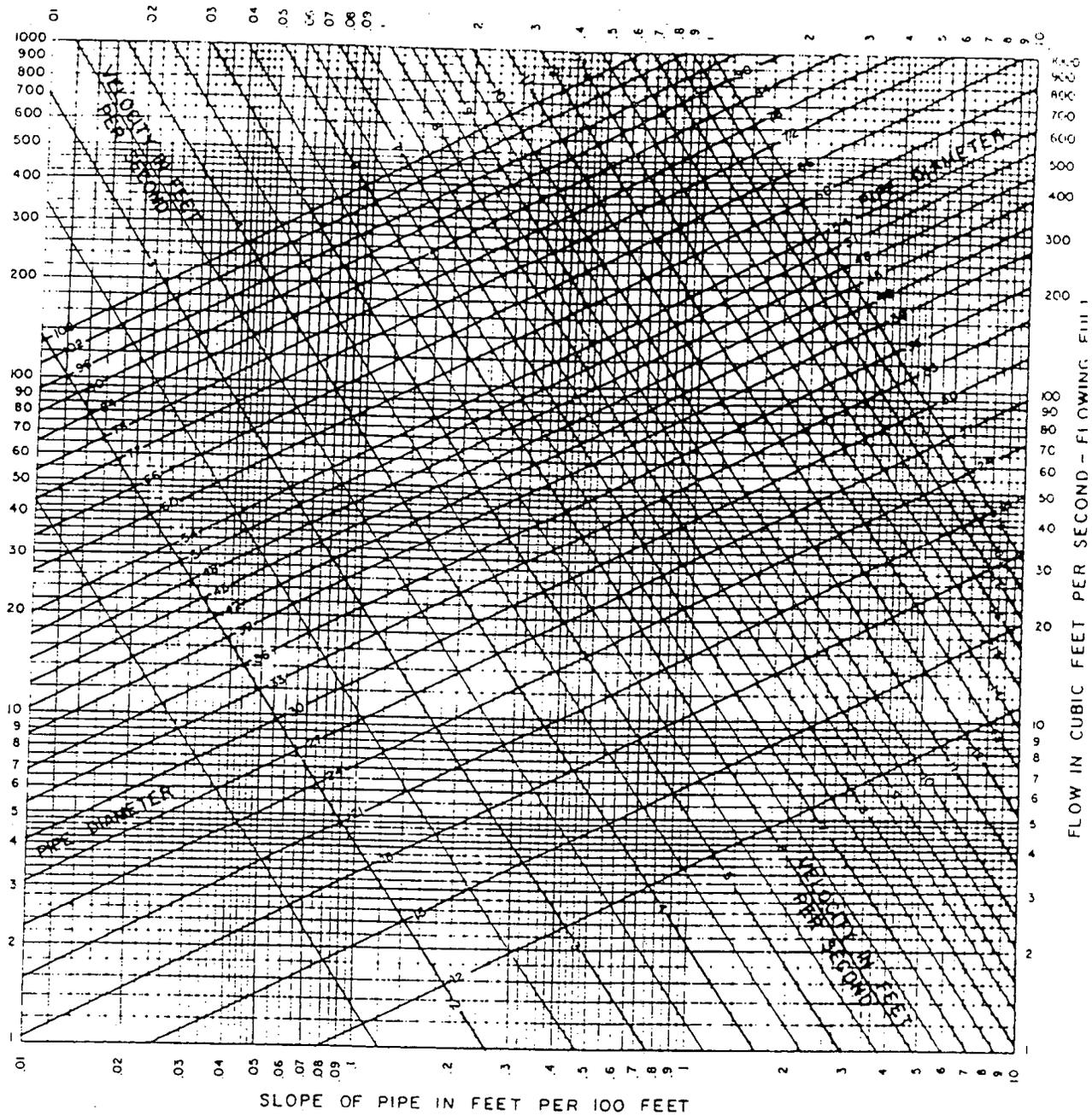
\* WHEN CURVES OTHER THAN 90° ARE USED, APPLY THE FOLLOWING FACTORS TO 90° CURVES

60° CURVE 85%

45° CURVE 70%

22 1/2° CURVE 40%

TABLE 3.7



CAPACITY OF CIRCULAR  
PIPES FLOWING FULL

A GRAPHICAL SOLUTION  
OF  
MANNING'S EQUATION

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

n = 0.013

FIGURE 3.17

**TABLE 3.8**

**ROUGHNESS COEFFICIENTS FOR CLOSED CONDUITS**

<b><u>Materials of Construction</u></b>	<b><u>Recommended Roughness Coefficient “n”</u></b>
New Monolithic Concrete Conduit .....	.015
Concrete Pipe Storm Sewer — New Construction .....	.013
Existing Concrete Storm Sewer — Good Alignment, Smooth Joints .....	.013
Existing Concrete Storm Sewer— Fair Alignment, Ordinary Joints .....	.015
Existing Concrete Storm Sewer — Poor Alignment, Poor Joints .....	.017
Concrete Pipe Culverts .....	.012
Monolithic Concrete Culverts .....	.012

With the hydraulic gradient established, considerable latitude is available for establishment of the conduit flow line. The inside top of the conduit must be at or below the hydraulic gradient thus allowing the conduit to be lowered where necessary. The hydraulic gradient should be plotted directly on the construction plan profile worksheet and adjusted as necessary.

There will be hydraulic conditions, which cause the conduits to flow partially full, and where this occurs, the hydraulic gradient should be shown at the inside crown (soffit) of the conduit. This procedure will provide a means for conservatively selecting a conduit size, Which will carry the flood discharge.

2. Minor Head Losses: The values of  $K_j$  to be used are tabulated for various conditions in TABLE 3.5. In designing storm sewer systems, the head losses that occur at points of turbulence shall be computed and reflected in the profile of the hydraulic gradient.
3. Minimum Grades: Storm drains should operate with flow velocities sufficient to prevent excessive deposits of solid materials; otherwise objectionable clogging may result. The controlling velocity with regard to sediment deposition is near the bottom of the conduit and considerably less than the mean velocity of the storm water. Storm drains shall be designed to have a minimum mean velocity flowing full of 2.5 feet per second (f.p.s.). TABLE 3.9 indicates the minimum grades for concrete pipe with "Manning's  $n$ " = 0.013
4. Maximum Velocities: The slope of a storm sewer should also be such that excessive velocities will not damage the pipeline or drainage structures. TABLE 3.10 delineates the maximum desirable velocities for storm sewer.
5. Discharge of Storm Drain Pipe: Where storm drain pipes discharge into water courses, the invert of the pipe shall be at the same grade as the low point of the water course. Adequate concrete or grouted riprap or other erosion protection shall be provided, to prevent downstream erosion. Storm sewers shall discharge into open channels at a maximum velocity of eight (8) feet per second.
6. Manholes: Storm drain manholes shall be located at intervals not to exceed five hundred (500) feet for twenty four (24) inches in diameter or smaller pipes. Storm drain manholes for pipes greater than twenty-four. (24) inches in diameter shall be located at points where design indicates entrances into the pipe are desirable. Inlet and manhole lids shall be at least twenty-two (22) inches with locking lids.

**TABLE 3.9**  
**MINIMUM GRADES FOR STORM DRAIN PIPELINES**  
**SLOPE IN FOOT/FOOT**

<b>Pipe Size (Inches)</b>	<b>Concrete Pipe</b>
Minimum	
18	0.0018
21	0.0015
24	0.0013
27	0.0011
30	0.0009
33	0.0008
36	0.0007
39	0.0006
42	0.0006
45	0.0005
48	0.0005
54	0.0005
60	0.0004
66	0.0004
72	0.0003
78	0.0003
84	0.0003
90	0.0002
96	0.0002
102	0.0002

Note: Corrugated pipes are not allowed

**TABLE 3.10**  
**MAXIMUM VELOCITIES\* IN CLOSED CONDUITS**

<b><u>Type of Conduit</u></b>	<b><u>Maximum Velocity</u></b>
Culverts	15 f.p.s.
Inlet Laterals	15 f.p.s.
Storm Sewer	12.5 f.p.s.
Pipe	

**\*The maximum velocities shall be the actual velocity — full flow or partial.**

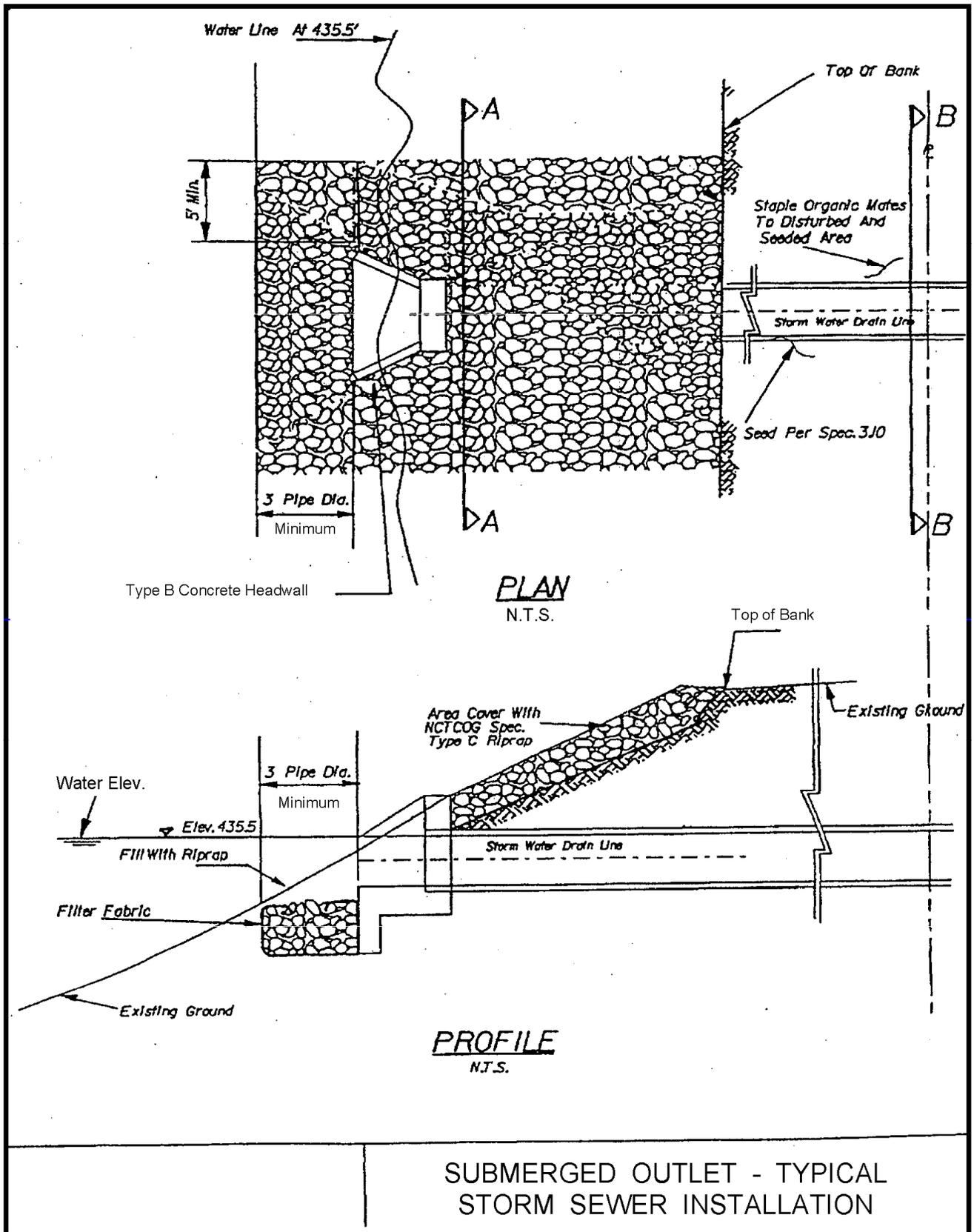


EXHIBIT 3A

7. Lateral Lines: The minimum size storm sewer line from the inlet box to the collector lines shall be eighteen (18) inches in diameter for a discharge of less than 10 cfs. Where discharge exceeds 10 cfs, lateral lines shall be a minimum of twenty-one (21) inches in diameter.
8. Drainage Channels: All channels shall have a minimum bottom width of six (6) feet and based on a maximum flow. Side slopes of channels shall not be steeper than one (1) foot rise to three (3) feet horizontal distance. Where slopes are greater than 3 to 1, the slopes shall be concrete lined for slope protection. In unlined open channels, the side slopes and channel slopes shall be such that erosion is controlled and the channel is stable. All channels shall be designed for a minimum of one (1) foot of freeboard at maximum design flow. Channels discharging into water courses shall have the same invert level as the water course. Open channel designs shall include open channel calculations, channel profiles and sufficient cross-sections showing the 100-year water surface for each proposed channel vertical grade change or change in cross-section.
9. 100-Year Flood Zones: Where the Federal Emergency Administration (FEMA) has defined a flood hazard area with regard to a drainage course, the flood hazard zone and the floodplain and floodway, if available, shall be shown on the plat and drainage area map.
10. Local 100-Year Flood Zones: 100-year flood zones shall be determined for non-FEMA creeks or streams (flowing or not) within a subdivision.

#### H. Storm Sewer Design — Closed Conduit

1. General: The instructions for FORM 3.3: STORM SEWER CALCULATIONS, have been included in this section to facilitate the hydraulic design of a storm sewer.

#### I. Storm Sewer Design — Open Channels

1. General: The instructions for FORM 3.4: OPEN DRAINAGE CHANNEL CALCULATIONS, have been included in this section to facilitate the hydraulic design of an open channel.

#### J. Culvert Design

1. General: The design of culverts shall be adequate for the maximum storm discharge expected. The hydraulic calculations shall be entered into FORM 3.5, which is further described herein.
2. Information in the upper right of form:
  - Culvert Location — This is a word description of the physical location.
  - Length — The actual length of the culvert.
  - Total Discharge, Q — This is the flow computed on FORM 3.1.

### **INSTRUCTIONS FOR FORM 3.3** **STORM SEWER CALCULATIONS**

- Column 1 Upstream station of the section of conduit being designed. Normally, this would be the point of a change in quantity of flow, such as an inlet, or a, change in grade.
- Column 2 Downstream station of the section of conduit being designed.
- Column 3 Distance, in feet between the upstream and downstream stations.
- Column 4 Drainage sub-area designation from which flow enters, the conduit at the upstream station.
- Column 5 Area in acres of the drainage sub-area entering the conduit.
- Column 6 Runoff coefficient, obtained from TABLE 3.1, based on the characteristics of the sub-drainage area.
- Column 7 Column 5 multiplied by Column 6.
- Column 8 Obtained by adding the value shown in Column 7 to the value shown immediately above in Column 8.
- Column 9 This time in minutes is transposed from Column 20 on the previous line of calculations. The original time shall be equal to the time of concentration as shown on TABLE 3.2 or FIGURE 3.2, whichever value has been used.
- Column 10 Design Storm Frequency.
- Column 11 Using the time at the upstream station shown in Column 9 and the Design 'Storm Frequency shown in Column 10, this value is taken from FIGURE 3.1.
- Column 12 Column 8 multiplied by Column 11.
- Column 13 This slope should be computed from the profile of the ground surface. Normally, the hydraulic gradient will have a slope approximately the same as the proposed conduit and will be located above the inside crown of the conduit.
- Column 14 Utilizing the values in Columns, 12 and 13, a conduit size should be selected. In the case of concrete pipe, FIGURE 3.17 may be used.
- Column 15 Velocity in the selected conduit based on the values in Columns 12, 13 and 14 taken from FIGURE 3.17 for concrete pipe.
- Column 16 Coefficient is taken from TABLE 3.5 based on the physical conditions, which will exist at the upstream station.
- Column 17 Calculation is made utilizing the values of Columns 15 and 16.
- Column 18 Calculation is based on the values of Columns 3 and 15.
- Column 19 Sum of Columns 9 and 18.
- Column 20 Special design comments may be entered here.



**INSTRUCTIONS FOR FORM 3.4:**  
**OPEN DRAINAGE CHANNEL CALCULATIONS**

- Column 1     Downstream limit of the section of channel under consideration.
- Column 2     Upstream limit of the section of channel under consideration.
- Column 3     Type of channel as shown shall be either Type I natural unimproved channel, Type II unlined with maintenance section, (concrete pilot channel) or Type III, concrete lined channel.
- Column 4     Flow in the section of channel under consideration.
- Column 5     Roughness coefficient of the channel cross-section taken from TABLE 3.11.
- Column 6     Slope of the channel which is most often parallel to slope of the hydraulic gradient.
- Column 7     Square root of Column 6.
- Column 8     Calculation is made using the values in Columns 4, 5 and 7.
- Column 9     Assumed width of the bottom width of the channel.
- Column 10    Assumed depth of flow.
- Column 11    Assumed slope of the sides of the channel.
- Column 12    Area of flow which is calculated based on Columns 9, 10 and 11.
- Column 13    Wetted perimeter calculated from Columns 9, 10 and 11.
- Column 14    Value is calculated from Columns 12 and 13.
- Column 15    Column 14 raised to 2/3 power.
- Column 16    Product of Column 13 times Column 15.
- When the value of Column 16 equals the value of Column 8 the channel has been adequately sized. When the value of Column 16 exceeds the value of Column 8 by more than five percent, the channel width or depth should be decreased and another trial section analyzed.
- Column 17    Calculation is based on the values of Columns 4 and 12
- Column 18    Calculation is based on Column 17
- Column 19    Remarks concerning the channel section analyzed may be entered.



**TABLE 3.11****ROUGHNESS COEFFICIENTS FOR OPEN CHANNELS**

Channel Description	Roughness Coefficient			Maximum Velocity
	Minimum	Normal	Maximum	
<u>Minor Natural Streams - Type I Channel</u>				
Moderately Well Defined Channel				
Grass and Weeds, Little Brush	0.025	0.030	0.033	8
Dense Weeds, Little Brush	0.030	0.035	0.040	8
Weeds, Light Brush on Banks	0.030	0.035	0.040	8
Weeds, Heavy Brush on Banks	0.035	0.050	0.060	8
Weeds, Dense Willows on Banks	0.040	0.060	0.080	8
Irregular Channel with Pools and Meanders				
Grass and Weeds, Little Brush	0.030	0.036	0.042	8
Dense Weeds, Little Brush	0.036	0.042	0.048	8
Weeds, Light Brush on Banks	0.036	0.042	0.048	8
Weeds, Heavy Brush on Banks	0.042	0.060	0.072	8
Weeds, Dense Willows on Banks	0.048	0.072	0.096	8
Flood Plain, Pasture				
Short Grass, No Brush	0.025	0.030	0.035	8
Tall Grass, No Brush	0.030	0.035	0.050	8
Flood Plain, Cultivated				
No Crops	0.025	0.030	0.035	8
Mature Crops	0.030	0.040	0.050	8
Flood Plain, Uncleared				
Heavy Weeds, Light Brush	0.035	0.050	0.070	8
Medium to Dense Brush	0.070	0.100	0.160	8
Trees with Flood State below Branches	0.080	0.100	0.120	8
<u>Major Natural Streams - Type I Channel</u>				
The roughness coefficient is less than that for minor streams of similar description because banks offer less effective resistance.				
Moderately Well Defined Channel	0.025	--	0.060	8
Irregular Channel	0.035	--	0.100	8
<u>Unlined Vegetated Channels - Type II Channel</u>				
Mowed Grass, Clay Soil	0.025	0.030	0.035	8
Mowed Grass, Sandy Soil	0.025	0.030	0.035	6
<u>Unlined Non-Vegetated Channels - Type II Channel</u>				
Clean Gravel Section	0.022	0.025	0.030	8
Shale	0.025	0.030	0.035	10
Smooth Rock	0.025	0.030	0.035	15
<u>Lined Channels - Type II</u>				
Smooth Finished Concrete	0.013	0.015	0.020	15
Riprap (Rubble)	0.030	0.040	0.050	12

Design Storm Frequency — Obtained from TABLE 3.3 and used on FORM 3.1.

Roughness Coefficient,  $n$  — Obtained from TABLE 3.8.

Maximum Discharge Velocity — Obtained from TABLE 3.12.

Tailwater — This is the design depth of water in the downstream channel and is obtained in connection with the channel design performed on FORM 3.4.

D.S. Channel Width — This is the bottom width of the downstream channel. The culvert should be sized to approximate this width.

Entrance Description — This is a listing of the actual condition as shown in the “Culvert Entrance Data” shown on the calculation sheet:

Roadway Elevation — The elevation of the top of curb at the upstream end of culvert.

U.S. Culvert F.L. — The flow line of the culvert at the upstream end.

Difference — The difference in elevations of the roadway and the upstream flow line.

Required Freeboard — The vertical distance required for safety between the upstream design water surface and the roadway elevation or such other requirements, which may occur because of particular physical conditions.

Allowable Headwater — This is obtained by subtracting the freeboard from the difference shown immediately above.

D.S. Culvert F.L. — The flow line elevation of the downstream end of the culvert.

Culvert Slope,  $S$  — This is the physical slope of the structure calculated as indicated.

3. The instructions for FORM 3.5: CULVERT DESIGN CALCULATIONS have been included in this section to facilitate the hydraulic design of a culvert.

**TABLE 3.12**

**CULVERT DISCHARGE VELOCITIES\***

<b><u>Culvert Discharges On</u></b>	<b><u>Maximum Allowable Velocity (f.p.s.)</u></b>
Earth (Sandy)	6
Earth (Clay)	8
Sodded Earth	8
Concrete	15
Shale	10
Rock	15

**\*Velocities are based on actual velocity —. partial or full flow**

**INSTRUCTIONS FOR FORM 3.5:**  
**CULVERT DESIGN CALCULATIONS**

Columns 1 through 10 deal with selection of trial culvert size and are explained as follows:

- Column 1 Total design discharge,  $Q$ , passing through the culvert divided by the allowable maximum velocity gives trial total area of culvert opening.
- Column 2 Culvert width should be reasonably close to the channel bottom width,  $W$ , downstream of the culvert.
- Column 3 Lower range for choosing culvert depth is trial area of culvert opening, Column 1 divided by channel width, Column 2.
- Column 4 Allowable headwater obtained from upper right of sheet.
- Column 5 Trial depth,  $D$ , of culvert corresponding to available standard sized and between the numerical values of Columns 3 and 4.

Columns 6, 7 and 8 are solved simultaneously based on providing a total area equivalent to the trial area of opening in Column 1.

- Column 6 Number of culvert openings.
- Column 7 Inside width of one opening.
- Column 8 Inside depth of one opening if culvert is box structure or diameter if culvert is pipe.
- Column 9 Column 6 multiplied by Column 7 and Column 8.
- Column 10 Total discharge divided by number of openings shown in Column 6.

Columns 11 through 15 (Inlet Control) and 16 through 27 (Outlet Control) deal with headwater calculations which verify hydraulics of trial culvert selected and are explained as follows.

- Column 11 Obtained from upper right of sheet.
- Column 12 When the allowable headwater is equal to or less than the value in Column 8, enter Case I. When the allowable headwater is more than the value in Column 8, enter Case II.
- Column 13 Column 10 divided by Column 7.
- Column 14 Obtained from FIGURE 3.18 for box culverts or FIGURE 3.19 for pipe culverts.
- Column 15 Column 14 multiplied by Column 8.

- Column 16 Obtained from upper part of sheet.
- Column 17 Obtained from FIGURE 3.20 for box culverts and FIGURE 3.21 for pipe culverts.
- Column 18 Tailwater depth from upper right of sheet.
- Column 19 Culvert slope, S, multiplied by culvert length, both obtained from upper right of sheet.
- Column 20 Sum of Columns 17 and 18, minus Column 19.
- Column 21 Obtained from FIGURE 3.20 for box culverts and FIGURE 3.21 for pipe culverts.
- Column 22 Critical depth obtained from FIGURE 3.22 for box culverts and FIGURE 3.23 for pipe culverts.
- Column 23 Sum of Columns 22 and 8 divided by 2.
- Column 24 Tail water depth from upper right of sheet.
- Column 25 Enter the larger of the two values shown in Column 23 or Column 24.
- Column 26 Previously calculated in Column 19 and may be transposed.
- Column 27 The sum of Columns 21 and 25 minus Column 26.
- Column 28 Enter the larger of the values from either Column 15, Column 20.or Column 27. This determines the controlling hydraulic conditions of the particular size culvert investigated.
- Column 29 When the Engineer is satisfied with the hydraulic investigations of various culverts and has determined which would be the most economical selection; the description should be entered.



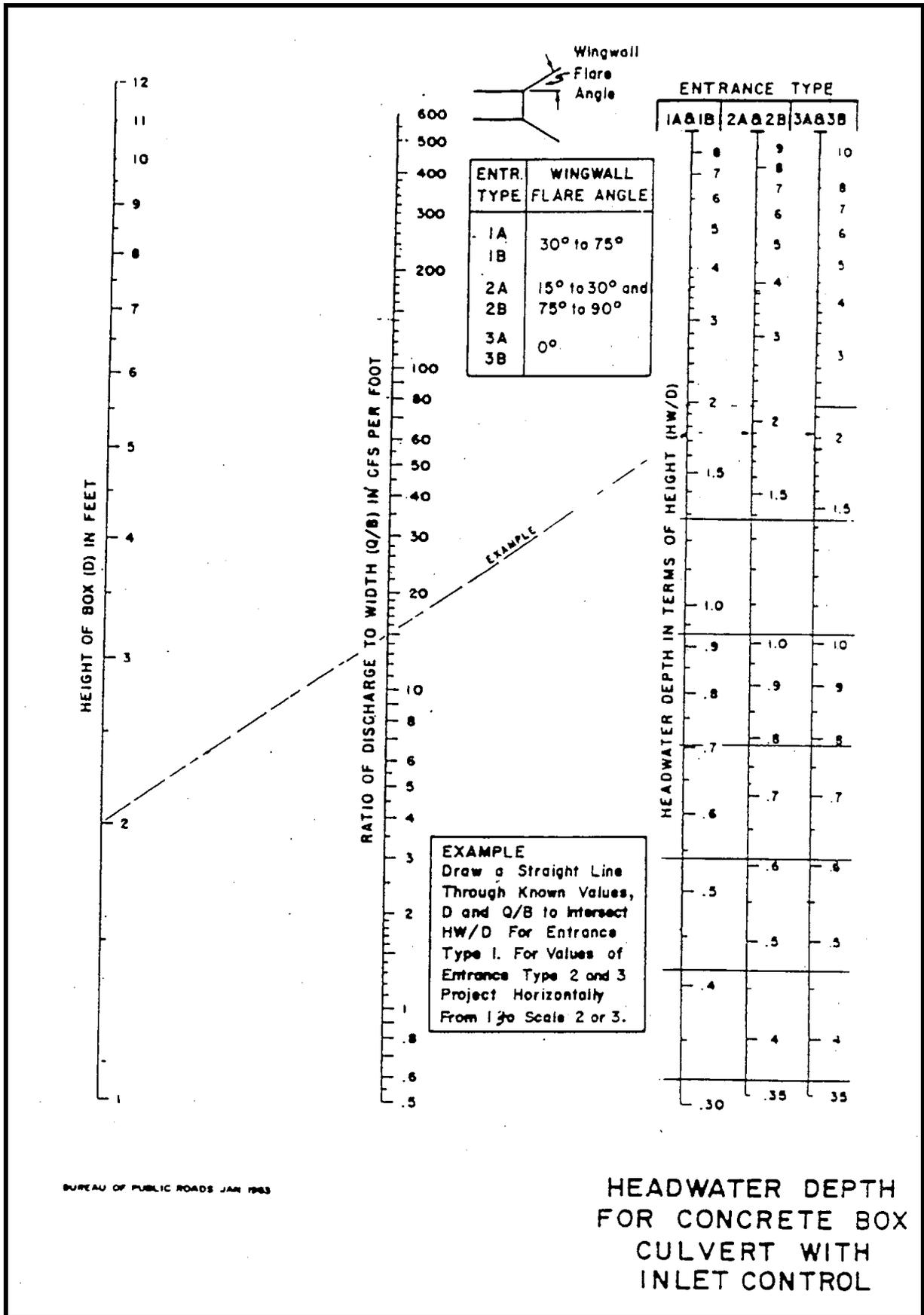


FIGURE 3.18

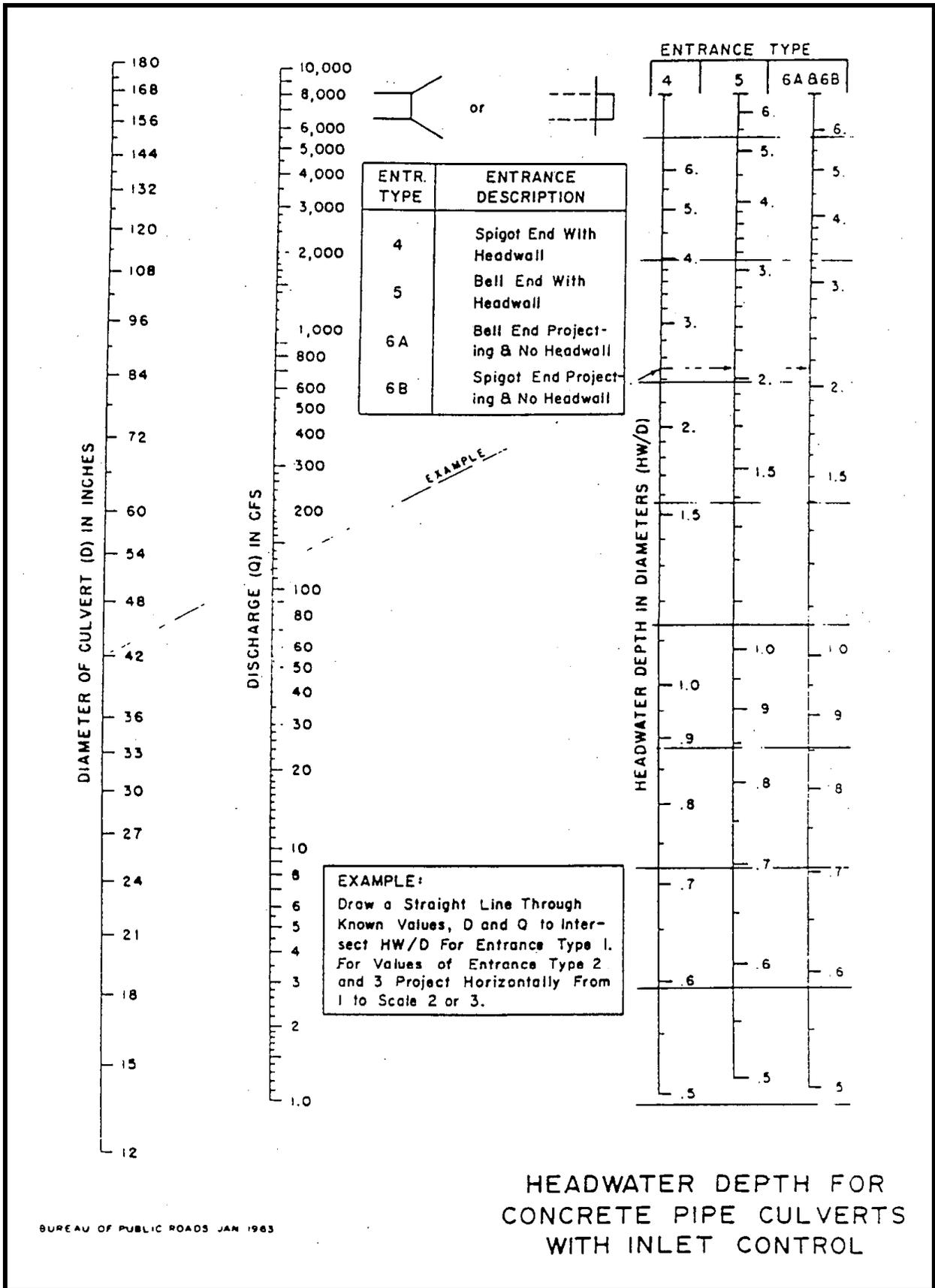
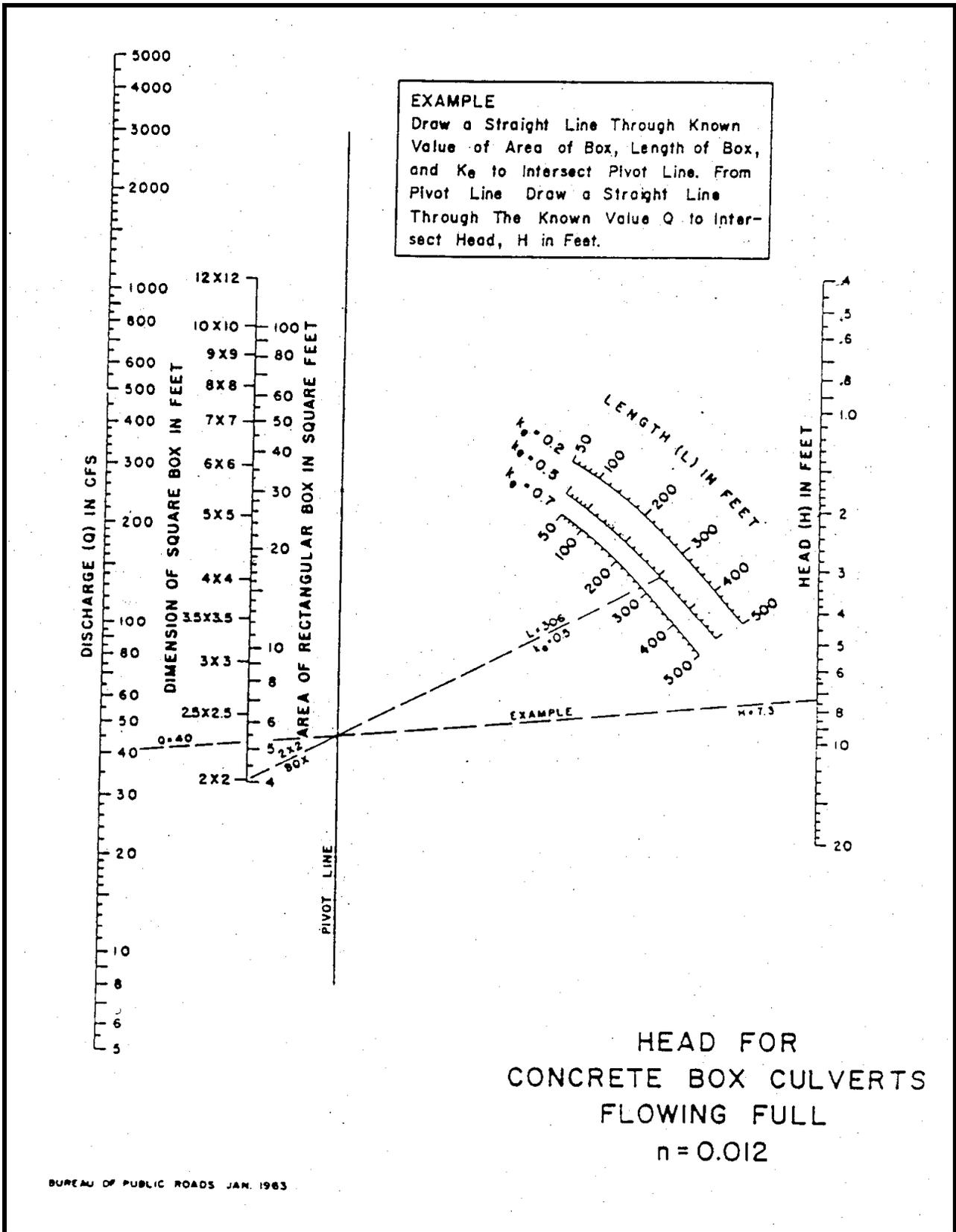


FIGURE 3.19



**FIGURE 3.20**

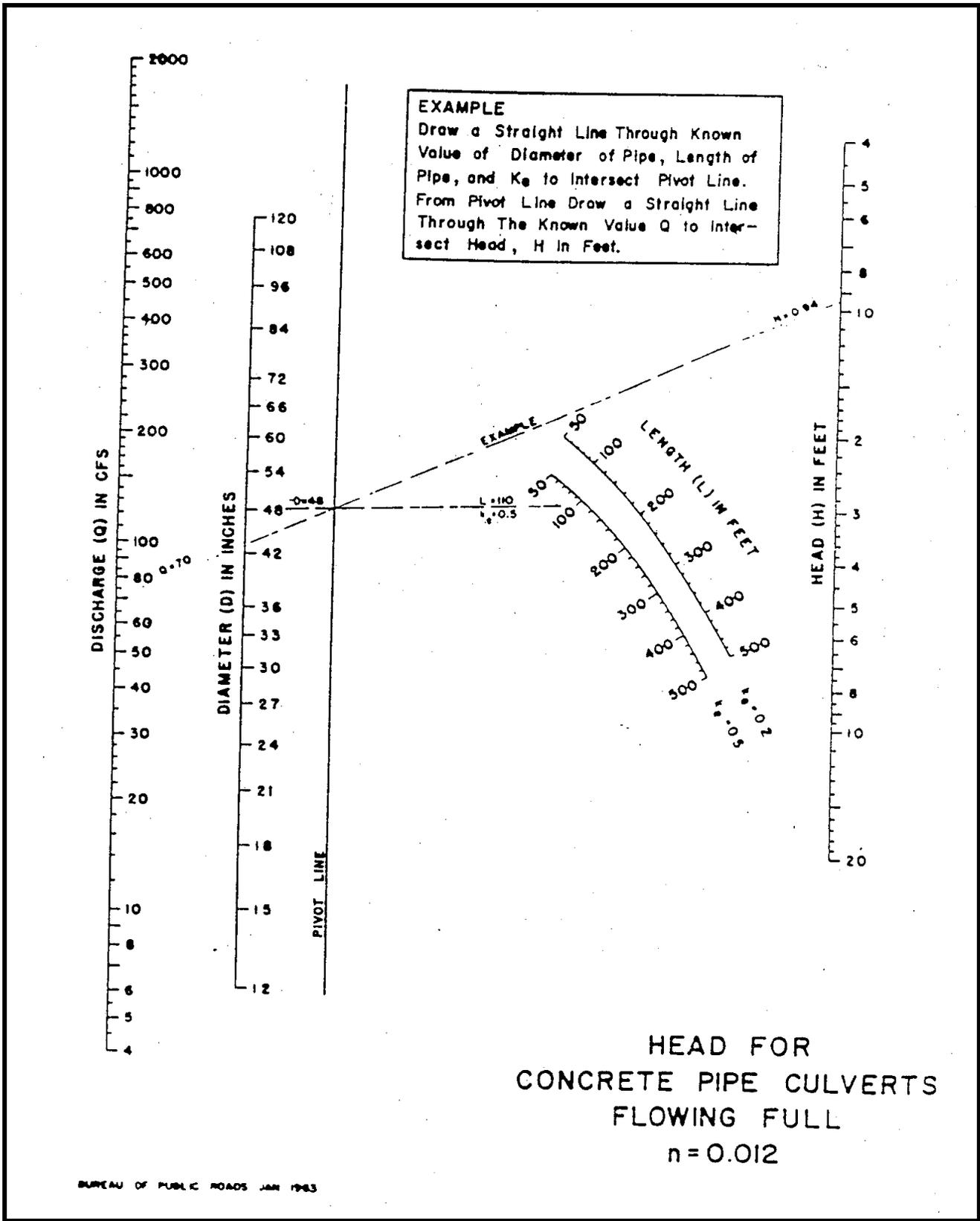


FIGURE 3.21

**EXAMPLE**

**Known:**

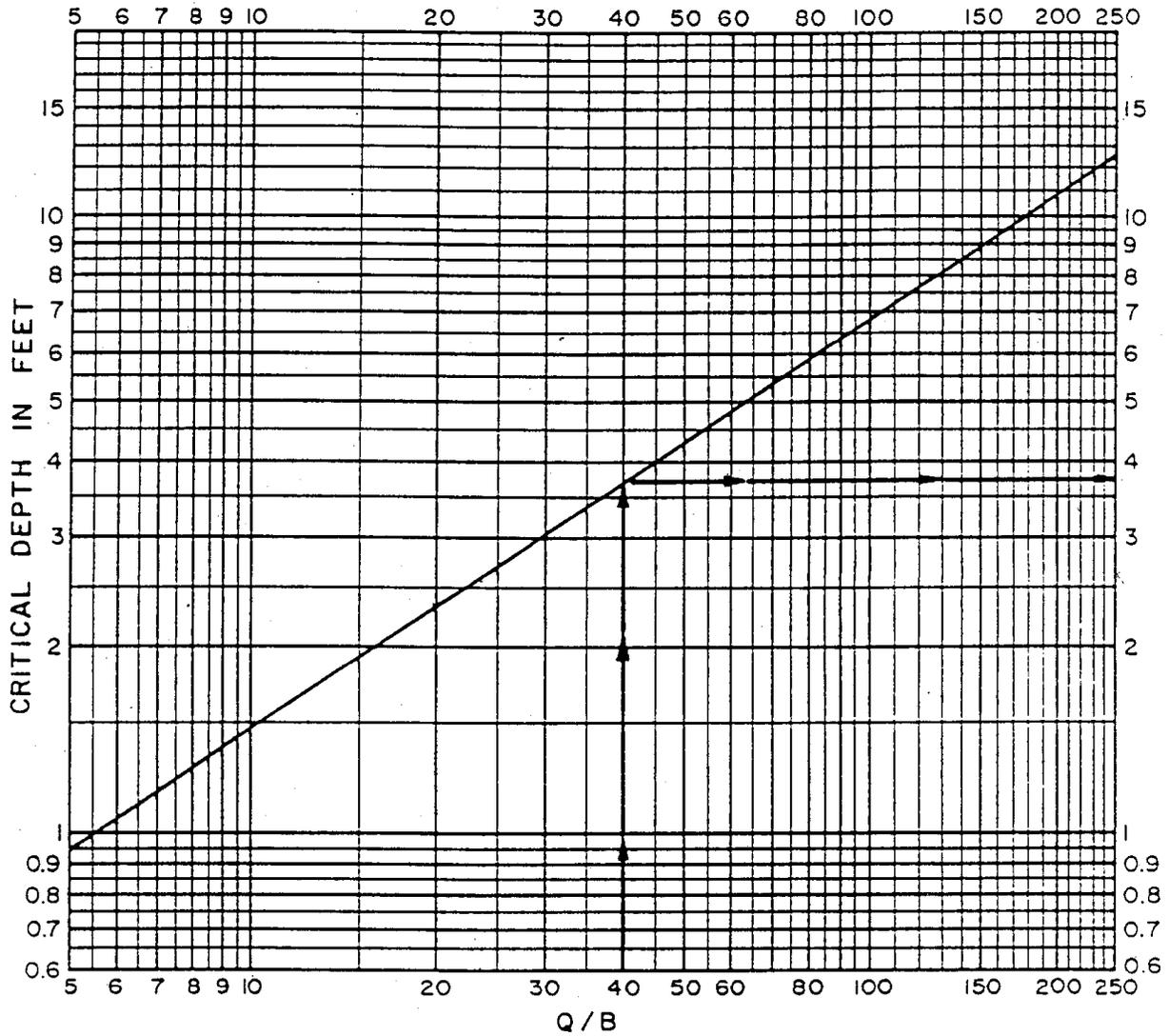
Discharge = 200 c.f.s.  
Width of Conduit = 5'  
 $Q/B = 40$

**Solution:**

Enter Graph at  $Q/B = 40$   
Intersect Critical Depth  
at 3.7

**Find:**

Critical Depth



**CRITICAL DEPTH  
OF FLOW FOR  
RECTANGULAR CONDUITS**

**FIGURE 3.22**

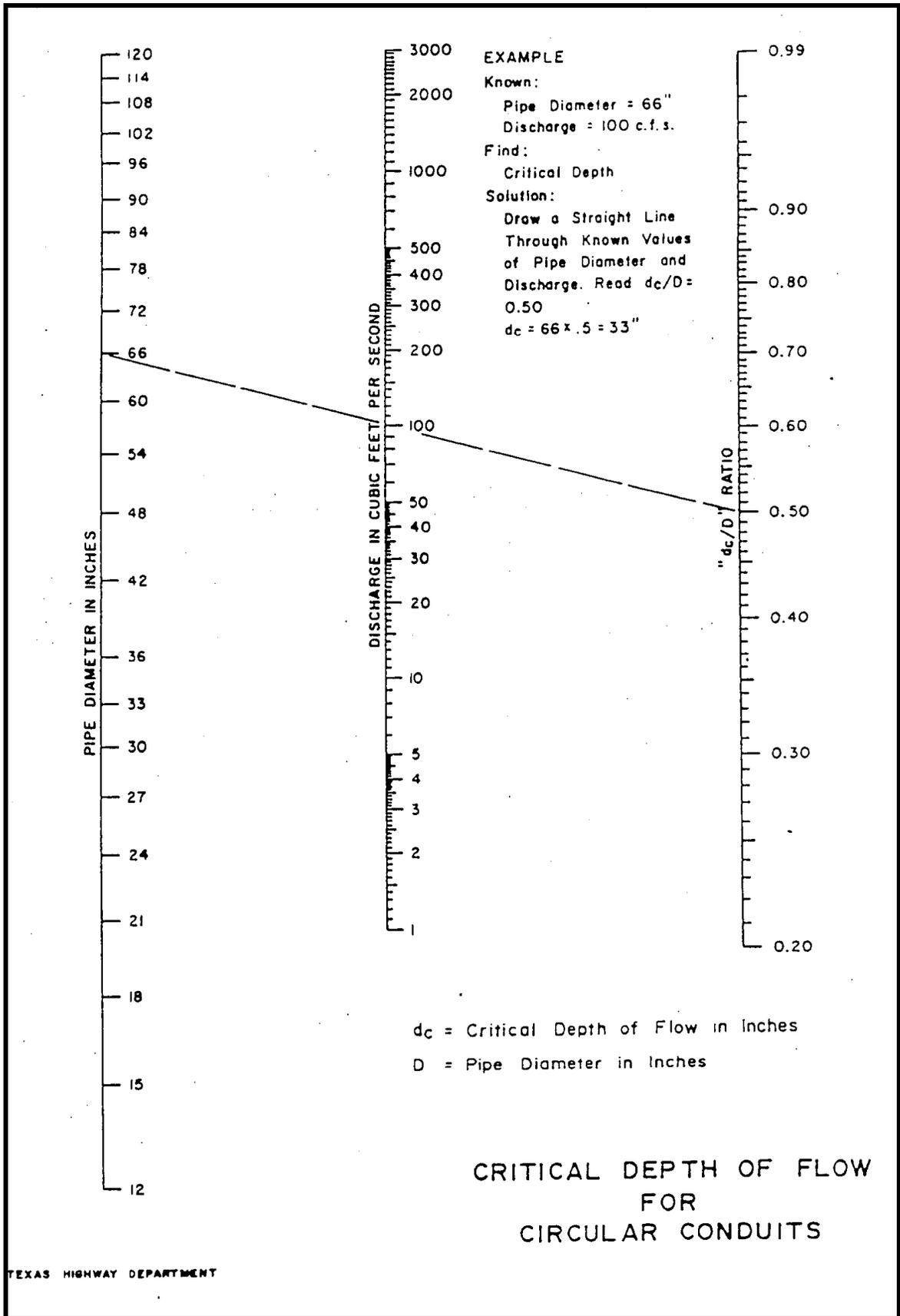


FIGURE 3.23

### 3.3 Detention

- A. All non-residential development shall construct detention facilities. The Modified Rational Method shall be utilized to determine detention volume. Residential developments shall also construct detention facilities unless it is determined that the downstream storm sewer system has capacity or can be increased to allow the conveyance of the developed flows. Any necessary downstream improvements, including easement acquisitions will be the responsibility of the developer. The proposed development will construct detention facilities to detain the increase in runoff between the existing 100-year flows (C-undeveloped, Tc = 20 minute) and the fully developed flows (C — depends on zoning, Tc = 10 minute). The detention design calculations and outfall rating curves shall be included in the plans. Sometimes a detention facility will be utilized by several developments, then a pro-rata agreement may be entered into with the development constructing the facility and the other developments utilizing the facility.
- B. Detention ponds with a side slope greater than 5:1 or a depth greater than two feet will have a four-foot (4') fence with an access gate around the perimeter. The fence shall be wrought iron, tubular steel or black vinyl coated chain link fence (as accepted by the City).
- C. Detention ponds shall be stabilized with pinned solid sod, and/or turf reinforcement if required, immediately following the installation of the inlet and outlet structures.
- D. The City encourages the reduction of runoff and pollutants into existing water ways by incorporating bio-retention areas (rain gardens) into the planning and design of detention facilities. When rain gardens are utilized in detention ponds, ponding depths shall not exceed 12-inches, with 6 to 8-inch depths desirable. Soil infiltration rates shall be determined. If required, a well-draining soil mix or under drain may be required to improve absorption rates. The ponding duration shall not exceed 24-hours. Plant selection is critical in the proper operation of a rain garden. Native plant materials shall be utilized to improve the site's biodiversity. Rain gardens shall be maintained by the Developer or incorporated into a Home Owner's Association maintenance requirements.

### 3.4 Storm Drainage Management Plan:

- A. General: Storm drainage facilities shall include all elements of a drainage system consisting of streets, alleys, storm drains, channels, culverts, bridges, swales and any other facility through which or over which storm water flows, all of which the City must have a right in, either in the form of a dedicated right-of-way, floodway or drainage easements.
- B. Site Drainage: All new subdivisions shall provide as part of the subdivision review process a complete storm drainage management plan. This plan will include, but not be limited to, the following: a complete review of all on-site, upstream and downstream drainage within the impacted watershed; determine all on-site and downstream drainage facility improvements due to the increased runoff from the

proposed development and future upstream and downstream developments; and shall contain calculations necessary to determine compliance with the Standards of Design herein. The plan shall be done, using current zoning conditions or land use prescribed by the City's Land Use Plan (whichever creates the greatest storm water runoff), with maximum development considered throughout the watershed. The storm drainage plan shall show all necessary improvements with flow data provided at each point of interception of water. As part of the storm drainage plan, the developer shall show a lot grading plan to direct all water to proper intersection points avoiding cross flow of water from lot to lot. Cross lot drainage is not permitted. All upstream discharge shall be intercepted and carried through the proper intersection points avoiding cross flow of water from lot to lot. All upstream discharge shall be intercepted and carried through the proposed development in compliance with the Standards of Design herein. All discharge from the proposed development shall be designed in accordance with the Standards of Design herein with all necessary improvements being installed by the developer to protect downstream property from damage. The determination of necessary improvements to existing drainage facilities downstream of a proposed development shall be reviewed by the City's Engineer for compliance and adequacy.

- C. Subdivision Development: All subdivision developments shall be built in complete compliance with a storm drainage plan as outlined herein. All lots shall be graded at the time of development in accordance with the plan. All grading shall not exceed a slope of 3 to 1 unless approved by the City's Engineer. In applicable situations, the City's Engineer may require 4 to 1 slope or greater. Approved erosion control shall be provided as part of the development construction on any or all lots within the development to protect the drainage, lot development and adjacent property. Temporary erosion control is further described in Section D.
- D. Erosion Control: It shall be the full responsibility of the Developer or Contractor to acquire and comply with any and all permits as may be required to avoid the delay of starting or completing a Project.

The City Manager or his/her designee may require an ECP for any soil disturbing activity. Normal construction soil disturbing activity shall have at minimum an accompanying Erosion Control Plan ("ECP"). Those activities disturbing one or more acres shall require preparation of a Storm Water Pollution Prevention Plan ("SWP3").

As necessary, the Developer or Contractor shall prepare and provide a SWP3 prior to construction. The SWP3 shall be prepared in accordance with the Texas Commission on Environmental Quality ("TCEQ") Construction General Permit TXR150000 and shall also comply with Federal storm water management regulations. The plan shall employ measures to prevent erosion and siltation caused by, or arising out of the construction disturbance from reaching streambeds, channels, storm water structures, ponds, etc. The plan shall employ recommendations of the "iSWM™ Design Manual for Construction" published by NCTCOG. In the event of a conflict between NCTCOG manuals and Federal and State pollution control laws, rules, and regulations or other Federal, State or Local agency laws, rules, and regulations, the more restrictive shall apply. The release

of the plan for construction by the City in no way relieves the Developer or Contractor of any responsibility and liability for the pollution control.

Erosion control measures to be incorporated in the ECP and/or SWP3 shall be detailed in the construction Plans.

For activities disturbing one or more acres, the appropriate Construction Site Notice (“CSN”) shall be completed and posted prior to commencement of activities. For activities disturbing five or more acres, it is required that a Notice of Intent (“NOI”) be prepared and submitted to TCEQ prior to commencement of activities. A copy of the NOI and/or appropriate CSN shall be provided to the City prior to issuance of a grading permit. The ECP shall be provided to City’s Public Works Department prior to grading.

The appropriate CSN shall be posted in a location viewable to the public. If the activity requires NOI submittal, the Letter of Acknowledgement (upon receipt) shall be posted with the CSN. These shall remain posted until construction is complete and Notice of Termination (“NOT”) submitted. The SWP3 shall be readily available for review by Federal, State, or local officials.

Following a pre-construction conference, the City will issue a Notice to Proceed for the preparation of the ECP and SWP3 documents and installation of Best Management Practices. No soil disturbing activities will occur until the following have been implemented:

1. SWP3 (if appropriate) is signed by both the Developer or Contractor
2. Developer or Contractor submits NOI to the State (if appropriate)
3. CSN/Letter of Acknowledgement (as appropriate) posted on site and viewable to the public
4. SWP3, ECP, and associated Best Management Practices (“BMPs”) being fully implemented and inspected by Roysse City’s Public Works Department

When the above items have been approved the City’s Public Works Department the City will issue the second Notice to Proceed allowing the developer and contractor to proceed with construction.

The Developer or Contractor shall comply with the TPDES General Construction Permit TXR150000 and any other State and/or Local regulations.

The site shall be reviewed by the Contractor or his representative weekly, and after any major storm. Adjustments/repairs to the erosion control measures will then be made as needed and inspected and approved by City’s Public Works Department. Any changes to the ECP must be incorporated into the SWP3 as appropriate. Changes to the SWP3 shall include date of change and reason for modification.

Final acceptance of a site shall be contingent upon perennial vegetation being established per the TPDES General Construction Permit TXR150000, and a

proper NOT submitted to the State. A copy of the NOT shall be provided to the City. Until such final acceptance of the erosion control has been determined, the City will not approve the completion of the project

- E. Lot Development: All lot developments shall include a drainage plan preventing all diversion of water from the approved path of discharge. The builder at the time of permit application shall furnish a grading plan in compliance with the appropriate chapter of the building code adopted by the City, the grading plan for the development and the storm drainage plan approved for that particular development. If the re-grading of a lot is necessary, the builder shall be required to furnish a new drainage plan indicating the diversion and rerouting of the affected storm water. When the re-grading of a lot prevents the drainage from flowing to the proper structures as designated in the drainage plan, then the builder will furnish an engineer's (Licensed in the State of Texas) review for adequacy of existing structures to which the water is diverted. If improvements are necessary to provide for adequate drainage due to re-grading of a lot, then the improvement must be made at the builder's expense before a grading permit or other permits for construction will be issued by the City. The City's Engineer will review the information submitted for compliance with the approved grading and drainage management plan.
- F. Off-Site Cost Sharing: The developer shall be fully responsible for the construction of off-site drainage improvements necessary for his subdivision and the surrounding area. Provisions for reimbursement of cost in excess of those necessary to serve his subdivision, and any other provisions, shall be made a part of a facilities agreement. For any subsequent subdivision utilizing such facilities, any cost due prior developers shall be pro-rated based on the increased contribution of storm water runoff. Such pro-rated amounts shall be made a part of any subsequent agreement, collected by the City and repaid to the original developer making such improvements.

The original developer shall provide the City with acceptable documentation of actual construction cost from which calculation of reimbursable amounts will be made for inclusion in the facilities agreement.

- G. Exemptions: when a development is of two lots or less and in the City's Engineer's opinion does not affect existing drainage facilities or affect the adjacent property, the City's Engineer may allow the developer to waive any off-site pro-rata costs.