

# APPENDIX B

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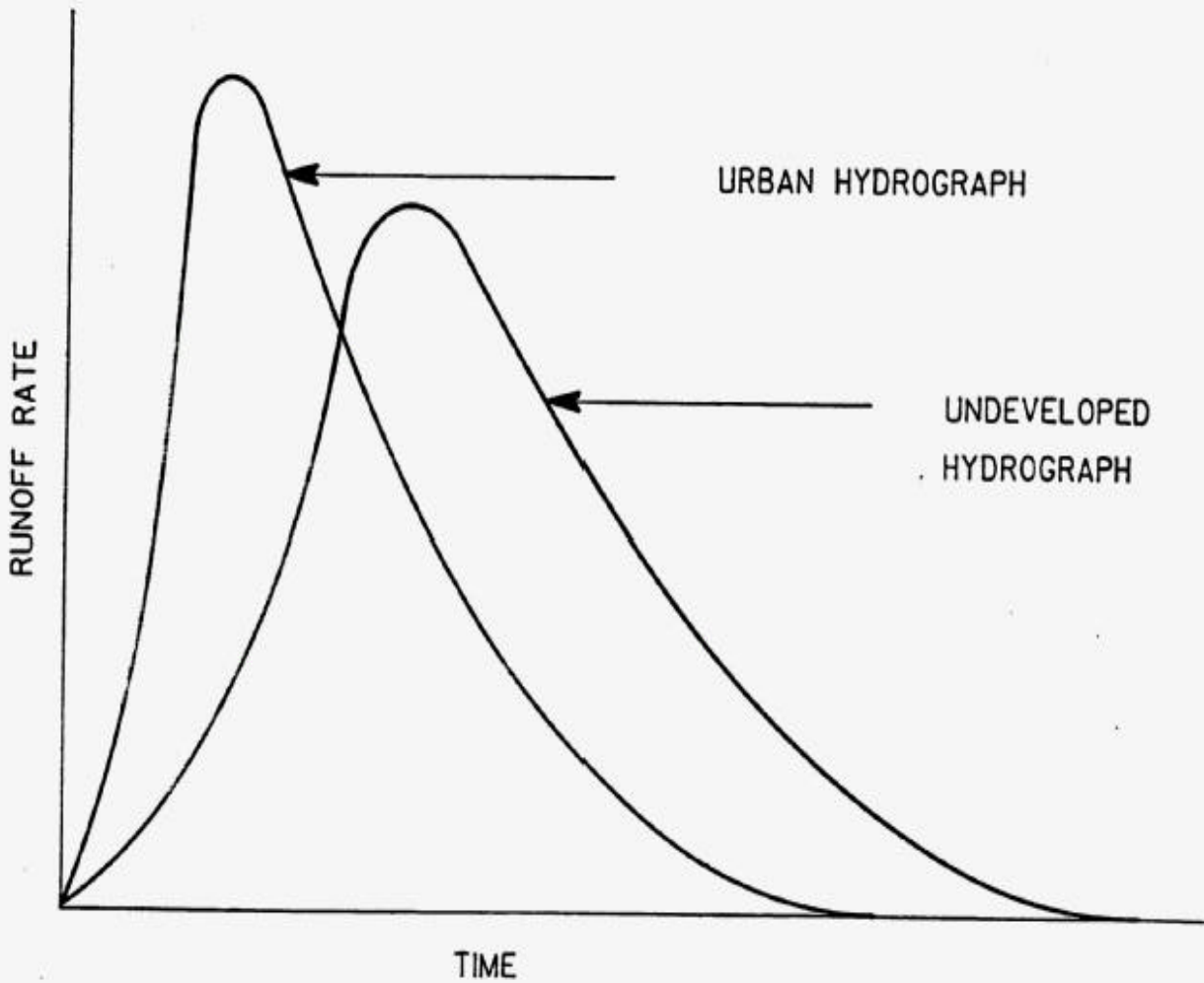
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# Drainage Criteria Manual

## [APPENDIX B. FIGURE AND DIAGRAMS](#)

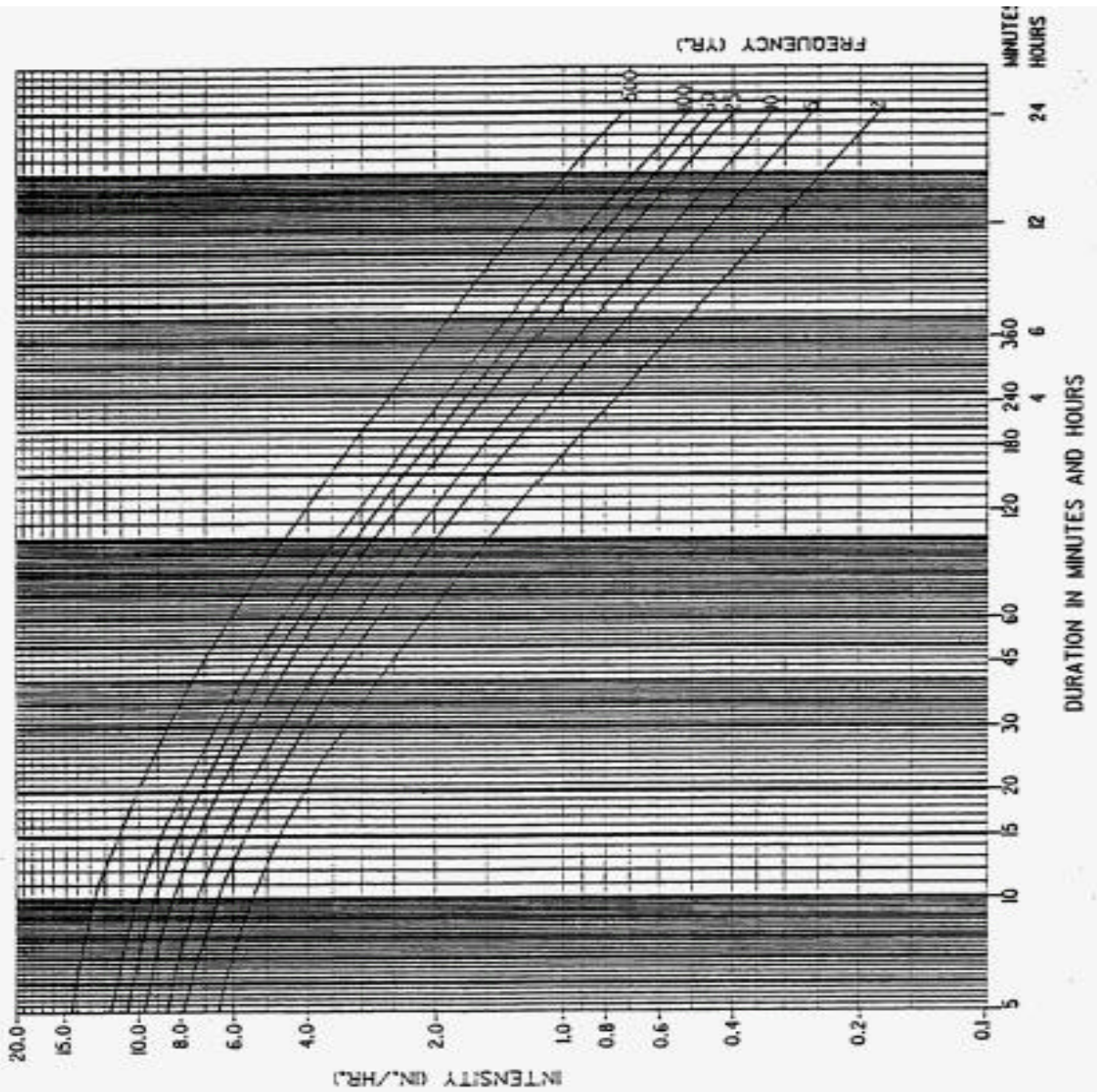
### FIGURES FROM SECTION 2

Figure 2-1 Effects of Urbanization on Flood Hydrograph



Source: City of Austin, Watershed Management Division

Figure 2-2 Austin Intensity-Duration-Frequency Curves



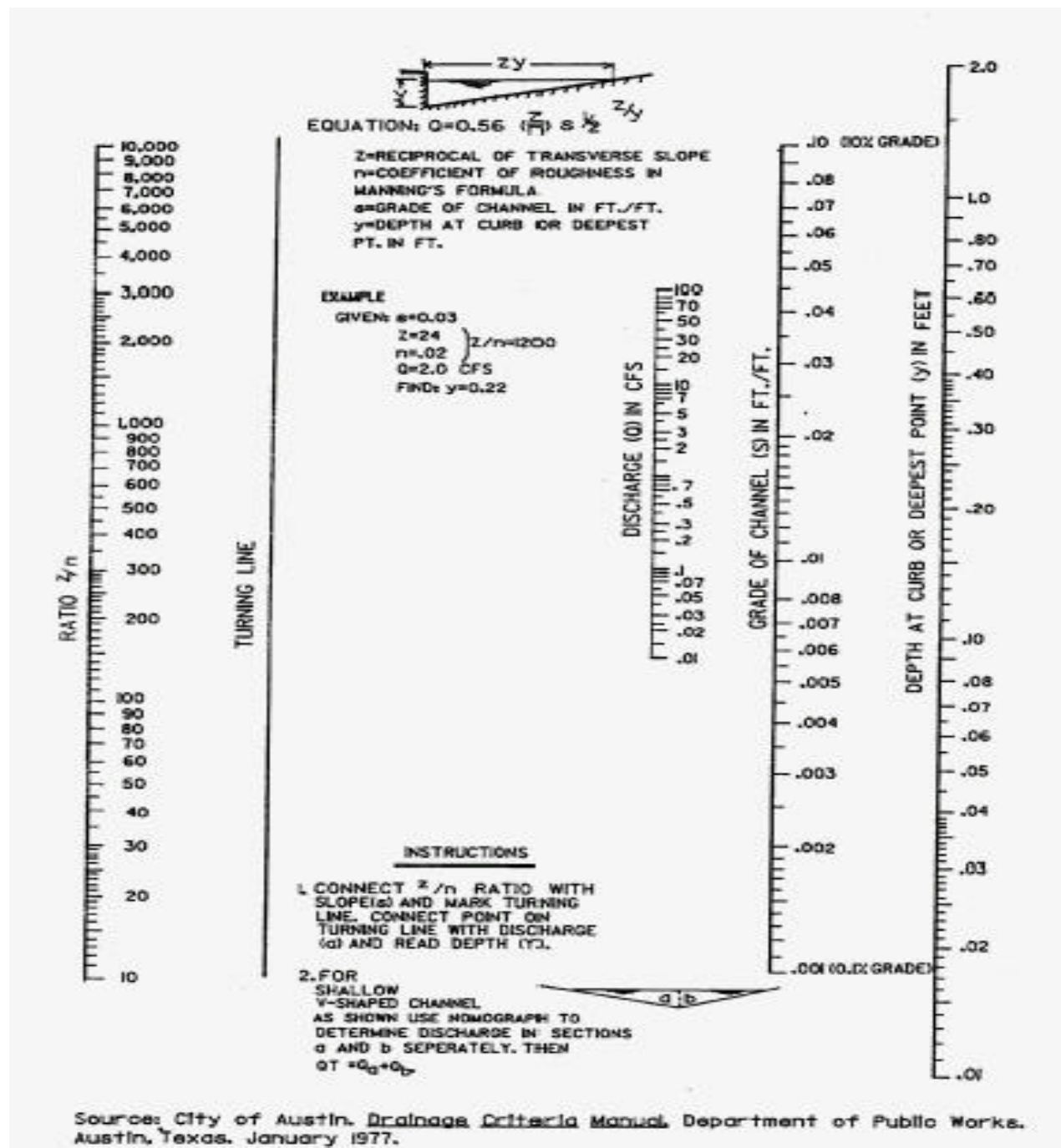
Source: City of Austin, *Design Criteria Manual*, Department of Public Works, Austin, Texas, January 1977.





### FIGURES FROM SECTION 3

Figure 3-1 Nomograph for Flow in Gutters



## FIGURES FROM SECTION 4

Figure 4-1 Curb Opening Inlet in a Sump (Type S-1)

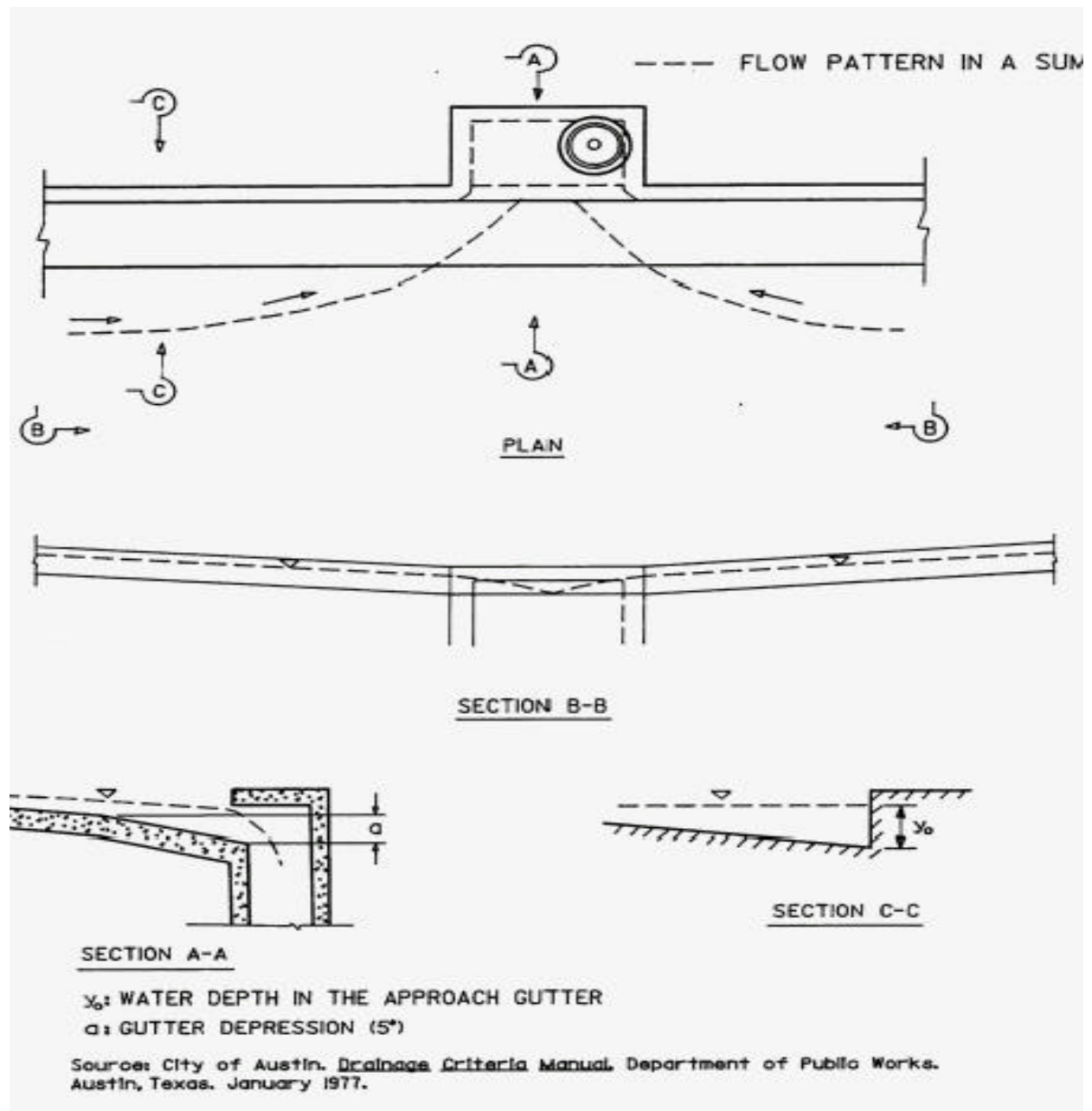


Figure 4-2 Grate Inlet in a Sump (Type S-2)

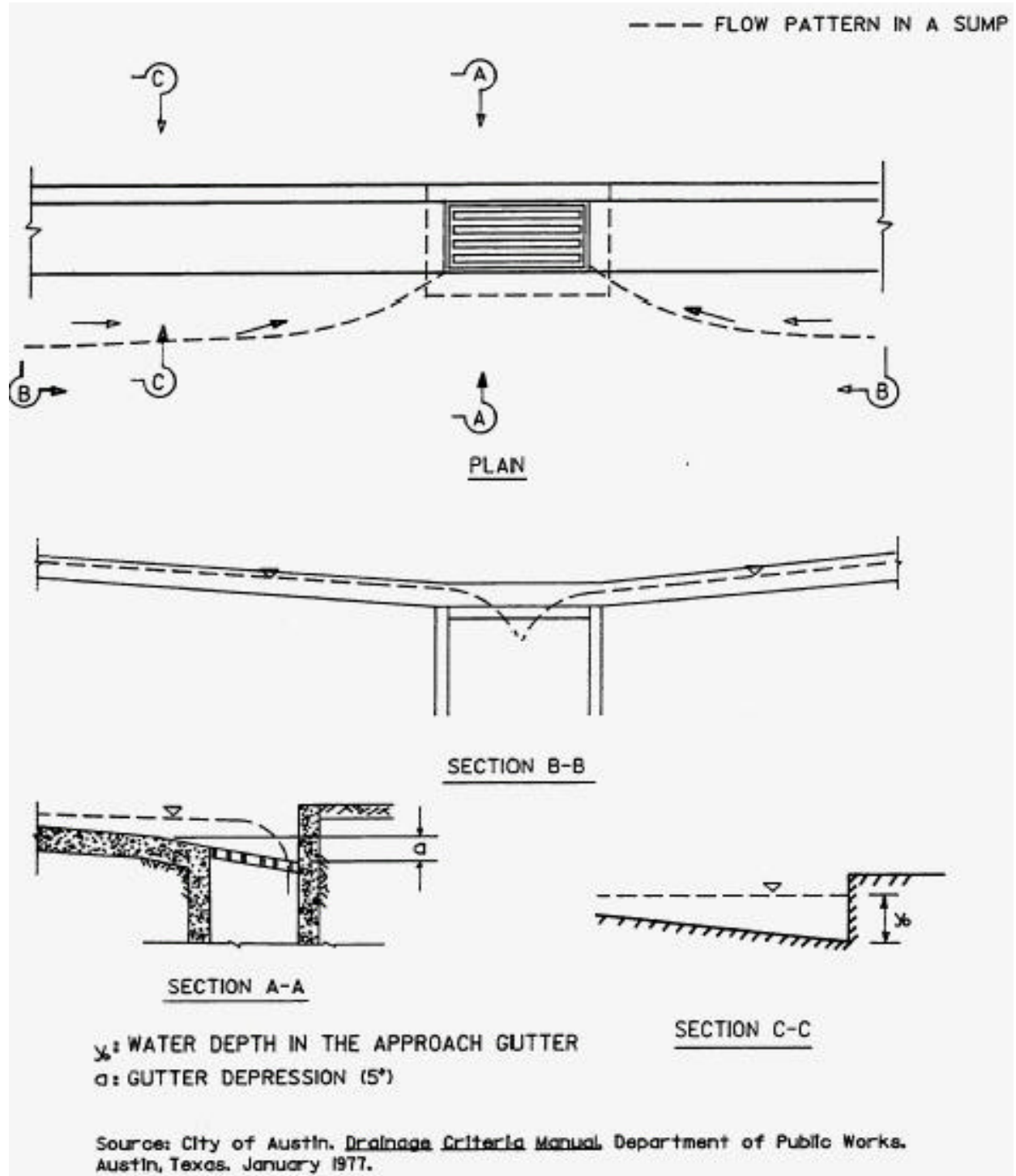


Figure 4-3 Combination Inlet in a Sump (Type S-3)

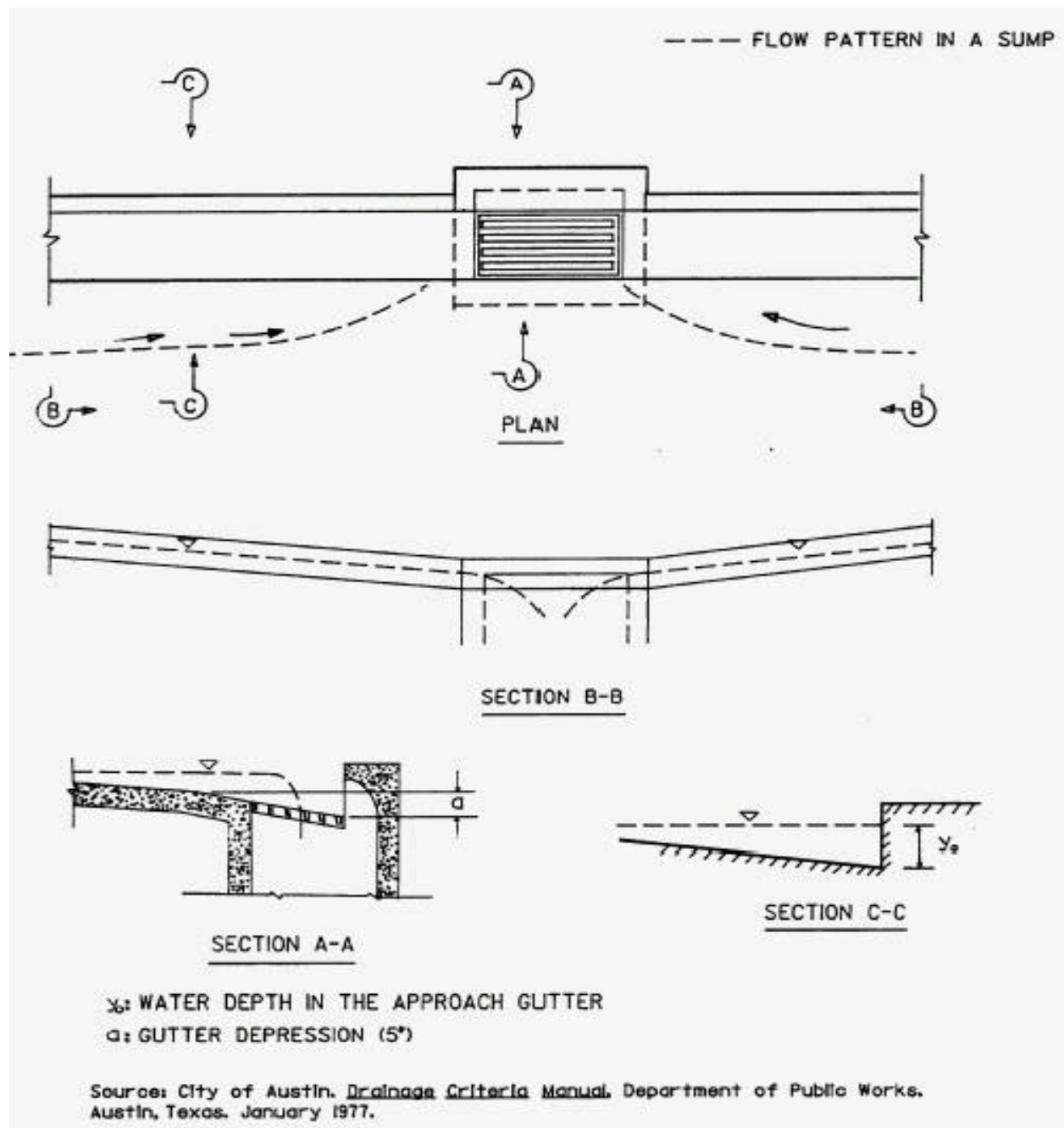
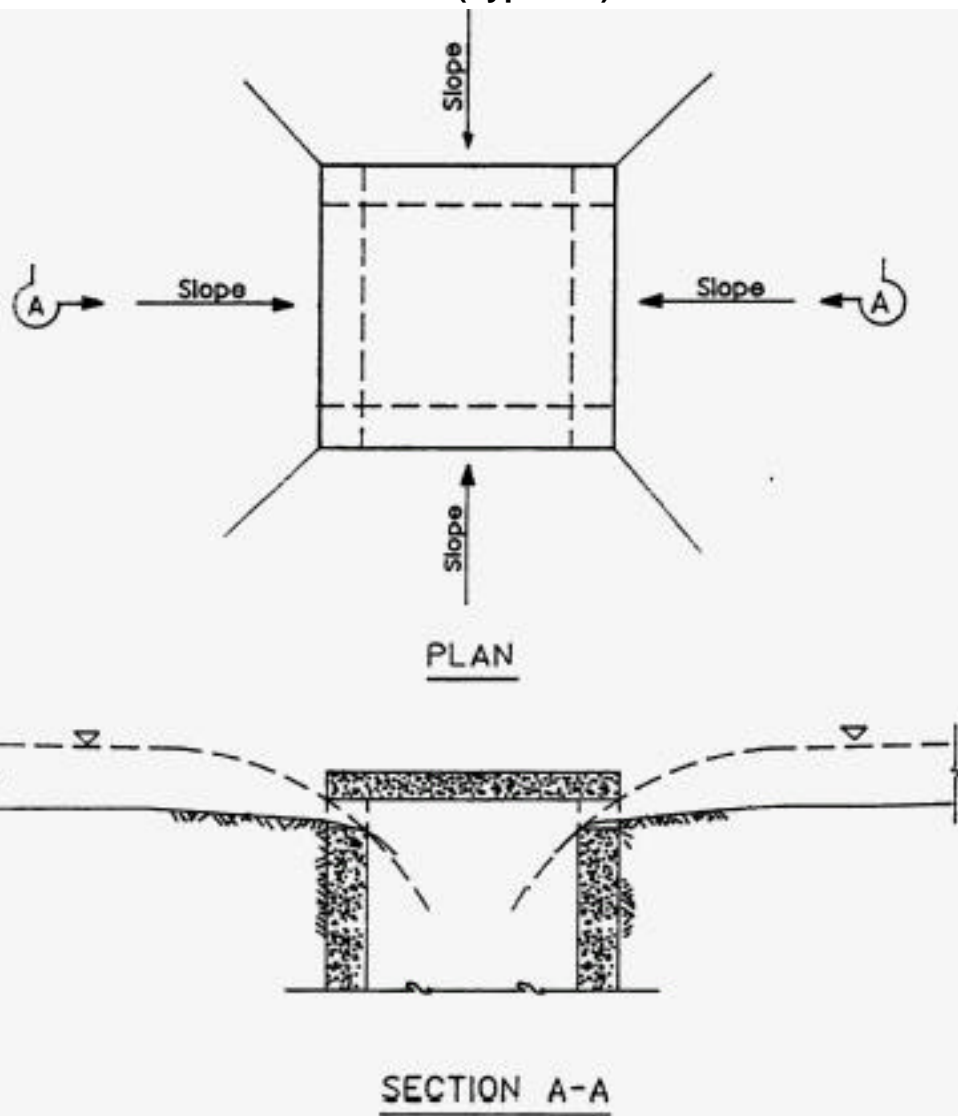
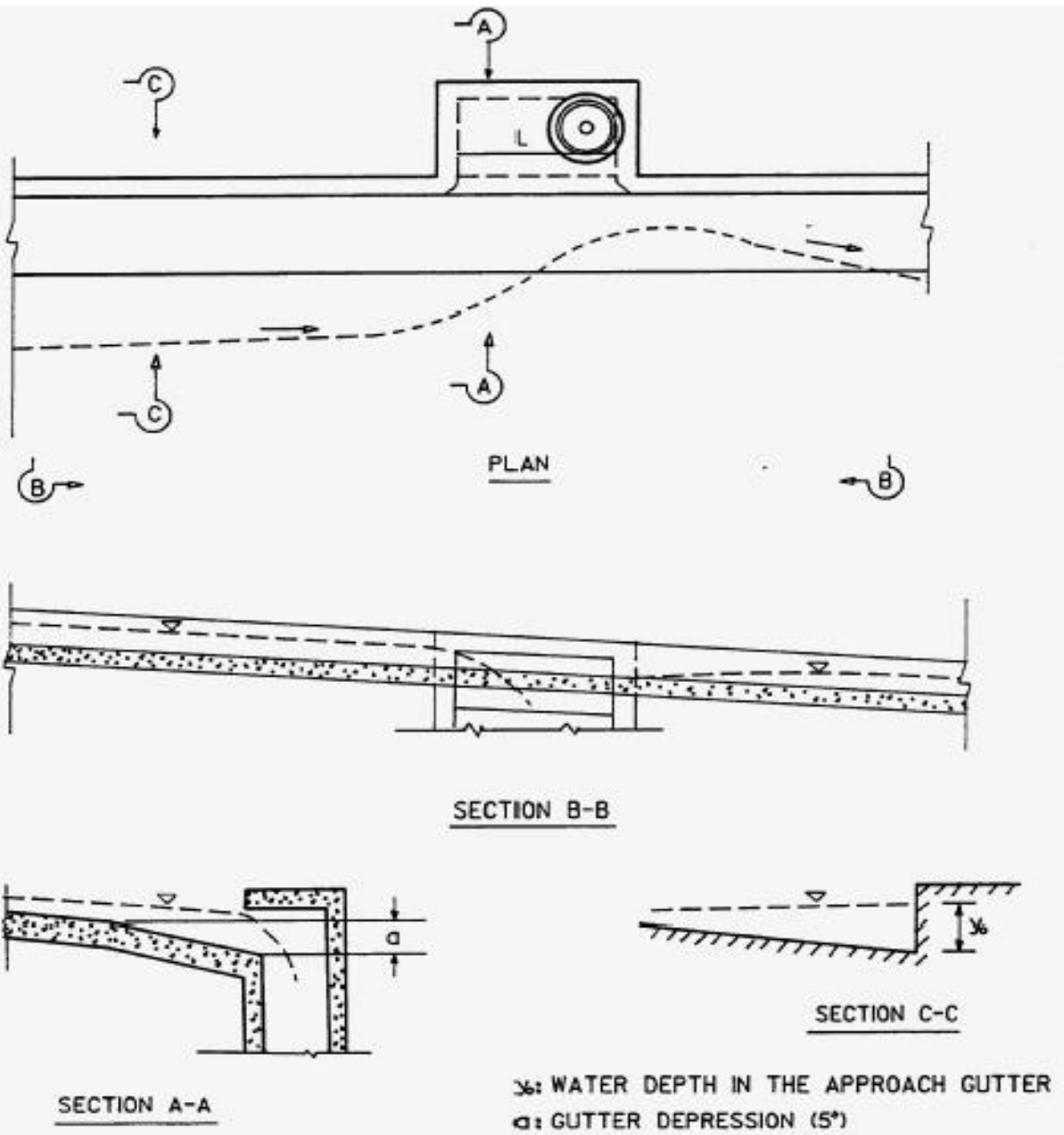


Figure 4-4 Area Inlet Without Grate (Type S-4)



Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

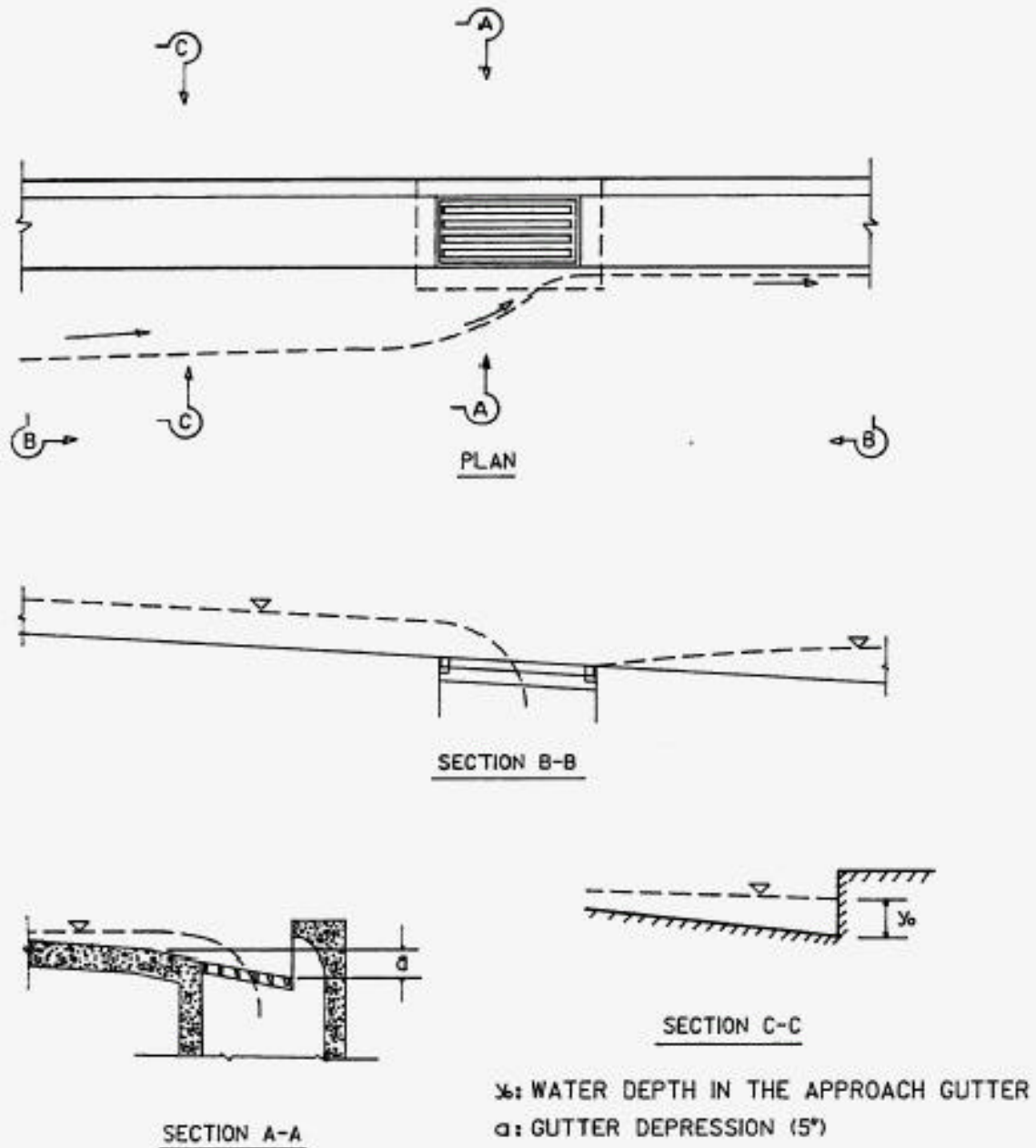
Figure 4-5 Curb Opening, Inlet on Grade (Type G-1)



Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

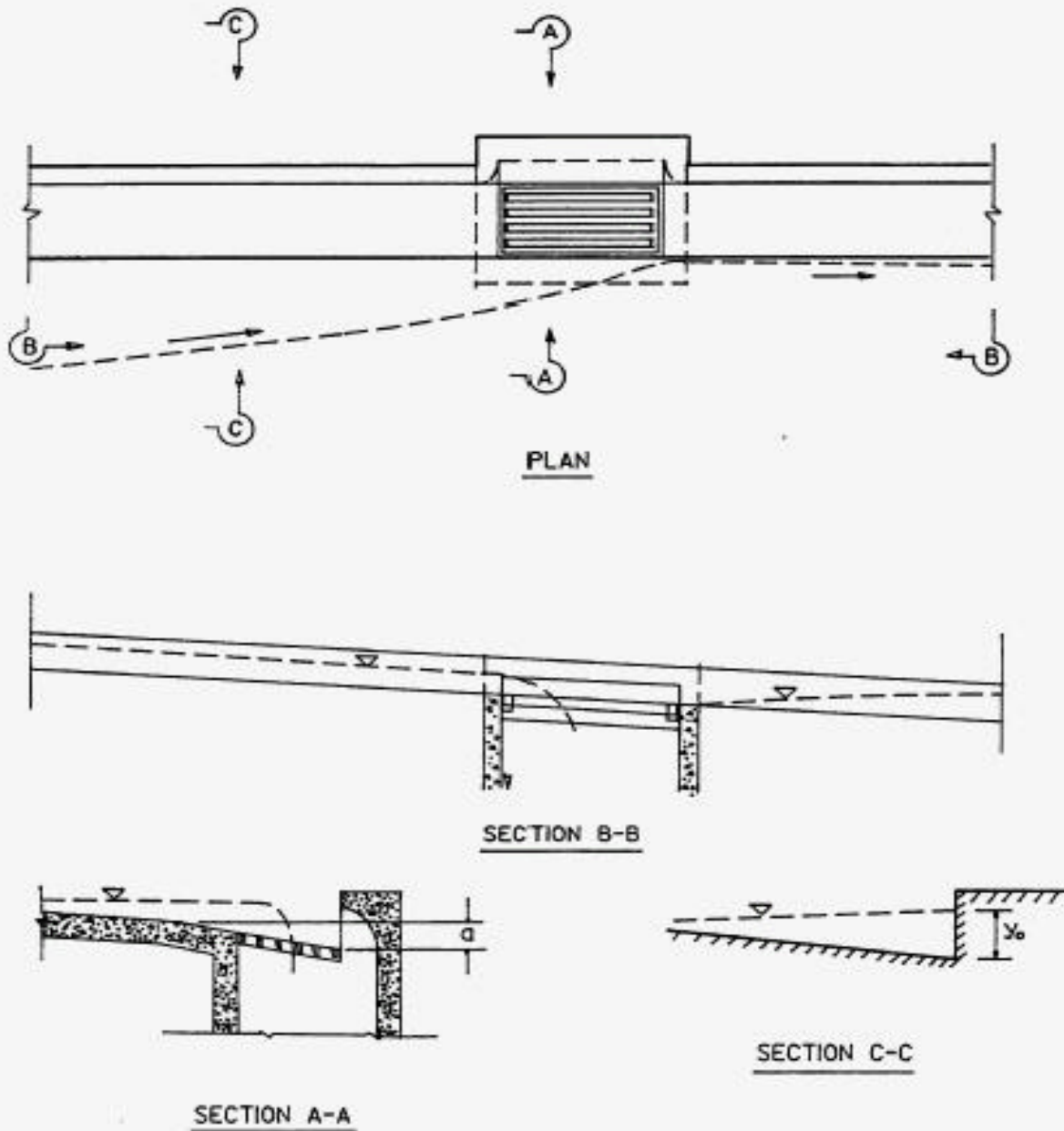


Figure 4-6 Grate, Inlet on Grade (Type G-2)



Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

Figure 4-7 Combination Inlet on Grade (Type G-3)



$y_0$ : WATER DEPTH IN THE APPROACH GUTTER  
 $a$ : GUTTER DEPRESSION (5°)

Source: City of Austin. Drainage Criteria Manual. Department of Public Works. Austin, Texas. January 1977.

Figure 4-8 Inlet Capacity for Type S-1 and S-3

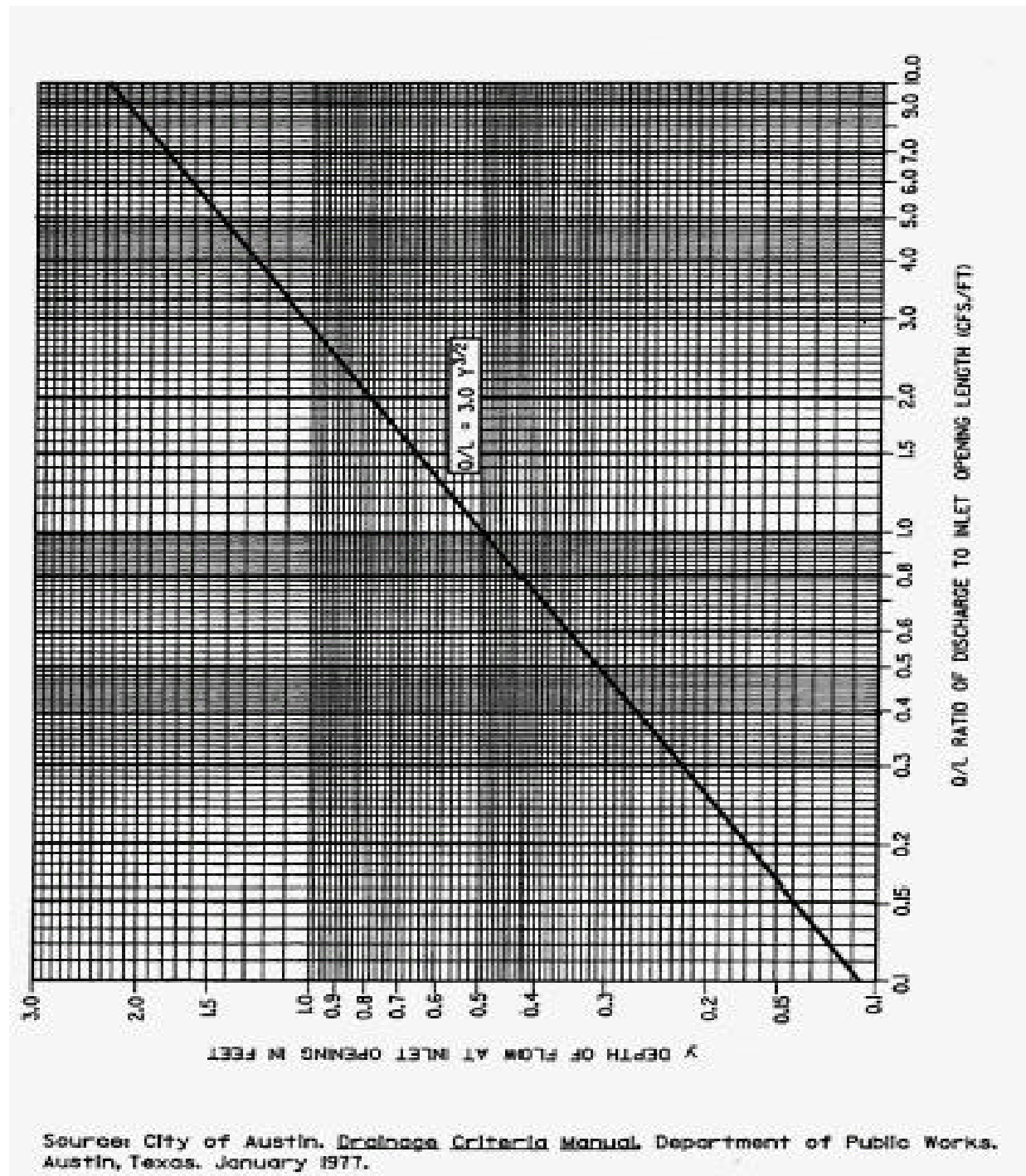
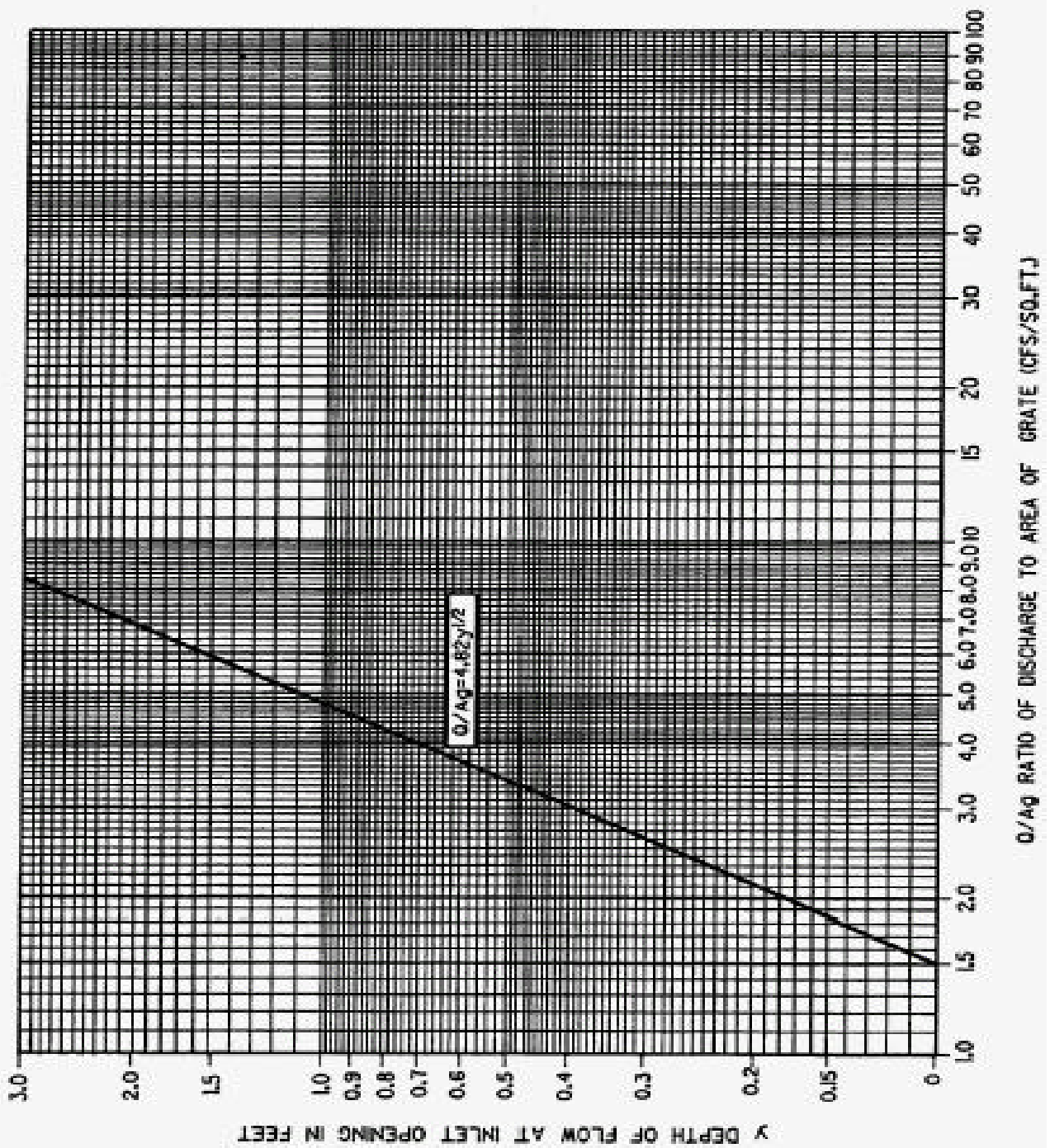
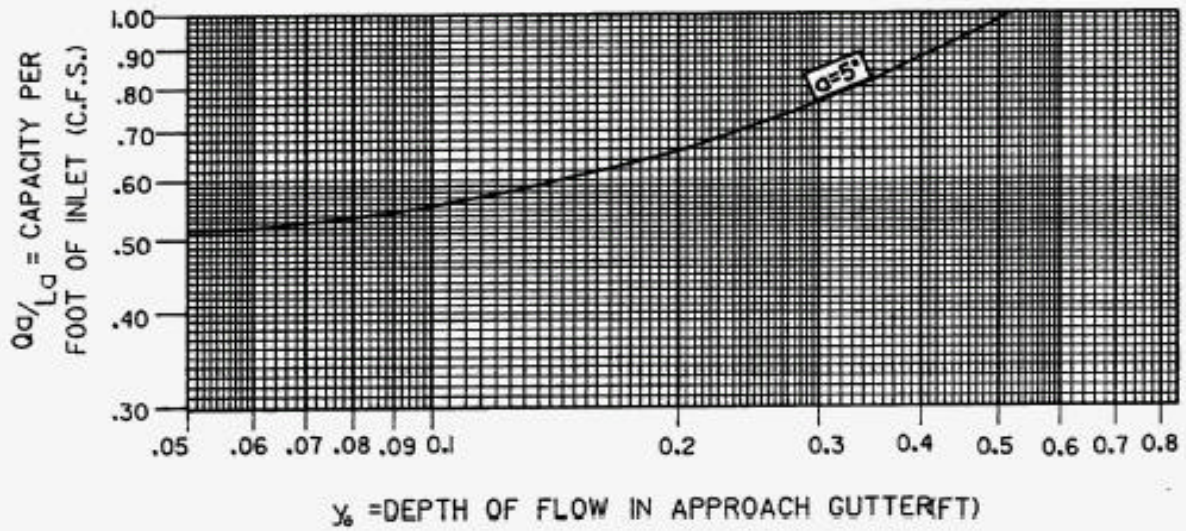


Figure 4-9 Inlet Capacity for Type S-2



Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

Figure 4-10 Capacity for Inlets on Grade



$$Q_a/L_a = 0.7 \left[ \frac{1}{H_1 - H_2} \right] \left[ (H_1)^{5/2} - (H_2)^{5/2} \right]$$

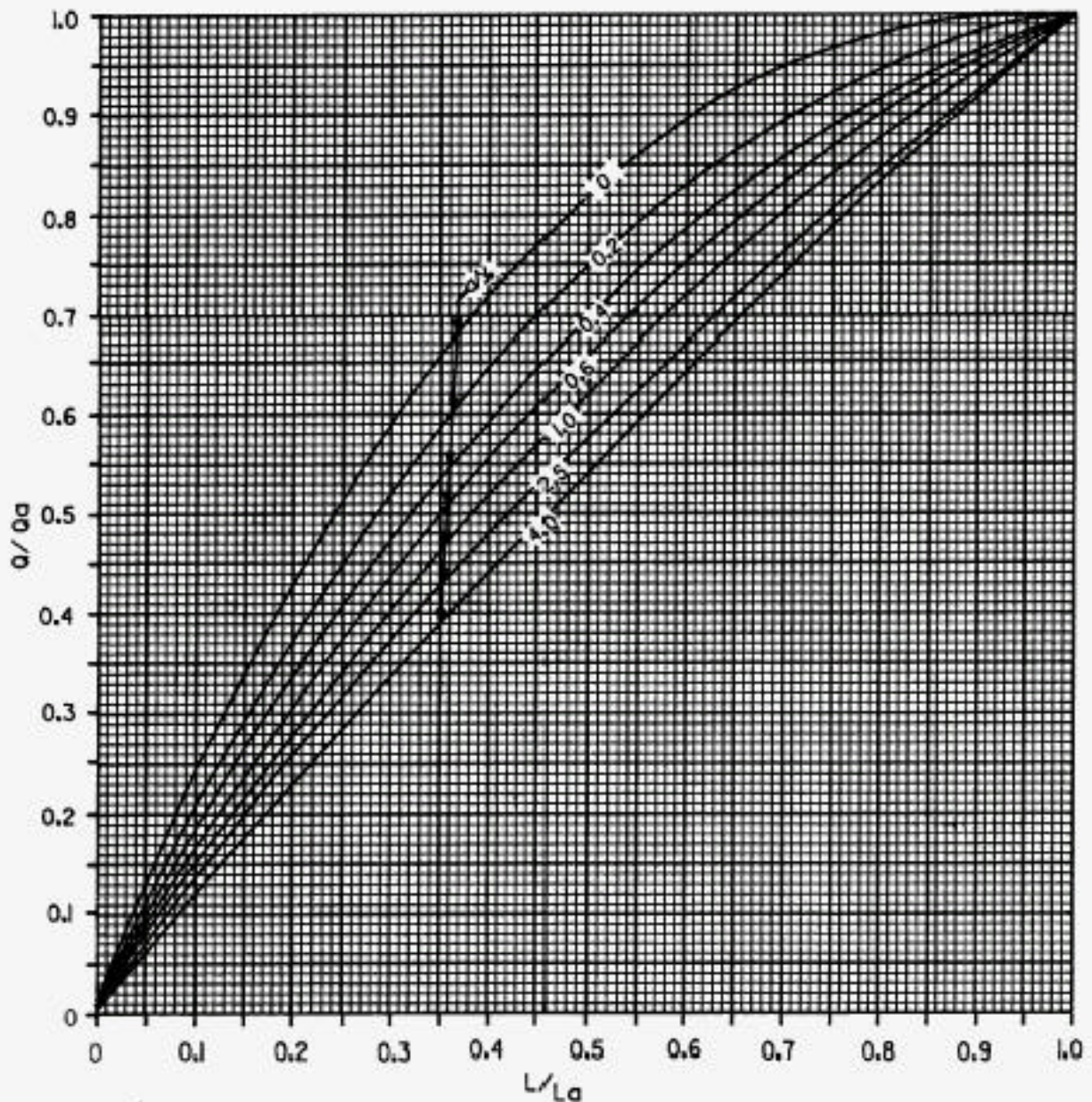
$$H_1 = a + y_0$$

$$H_2 = a = \text{GUTTER DEPRESSION}$$

Source: City of Austin. Drainage Criteria Manual. Department of Public Works. Austin, Texas. January 1977.



Figure 4-11 Ratio of Intercepted to Total Flow for Inlets on Grade



$L$  = LENGTH OF CURB OPENING (FT.)  
 $L_a$  = LENGTH OF CURB OPENING FOR 100% INTERCEPTION (FT.)  
 $Q$  = FLOW INTERCEPTED BY INLET OF LENGTH " $L$ " (C.F.S.)  
 $Q_a$  = TOTAL FLOW IN APPROACH GUTTER (C.F.S.)  
 $a$  = GUTTER DEPRESSION (FT.)  
 $y_0$  = DEPTH OF FLOW IN APPROACH GUTTER

Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

# FIGURES FROM SECTION 5

## Figure 5-1 Uniform Flow For Pipe Culverts

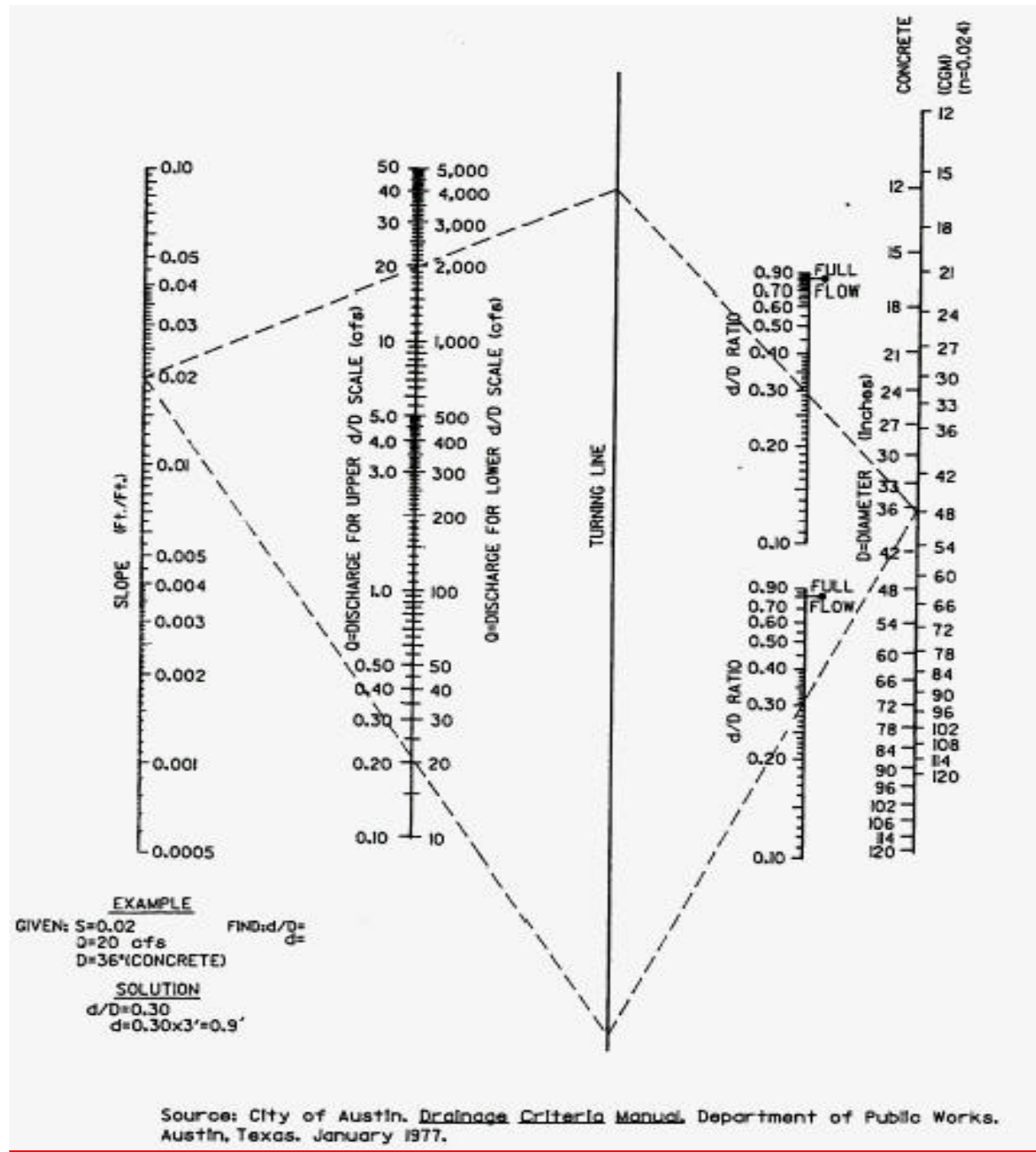
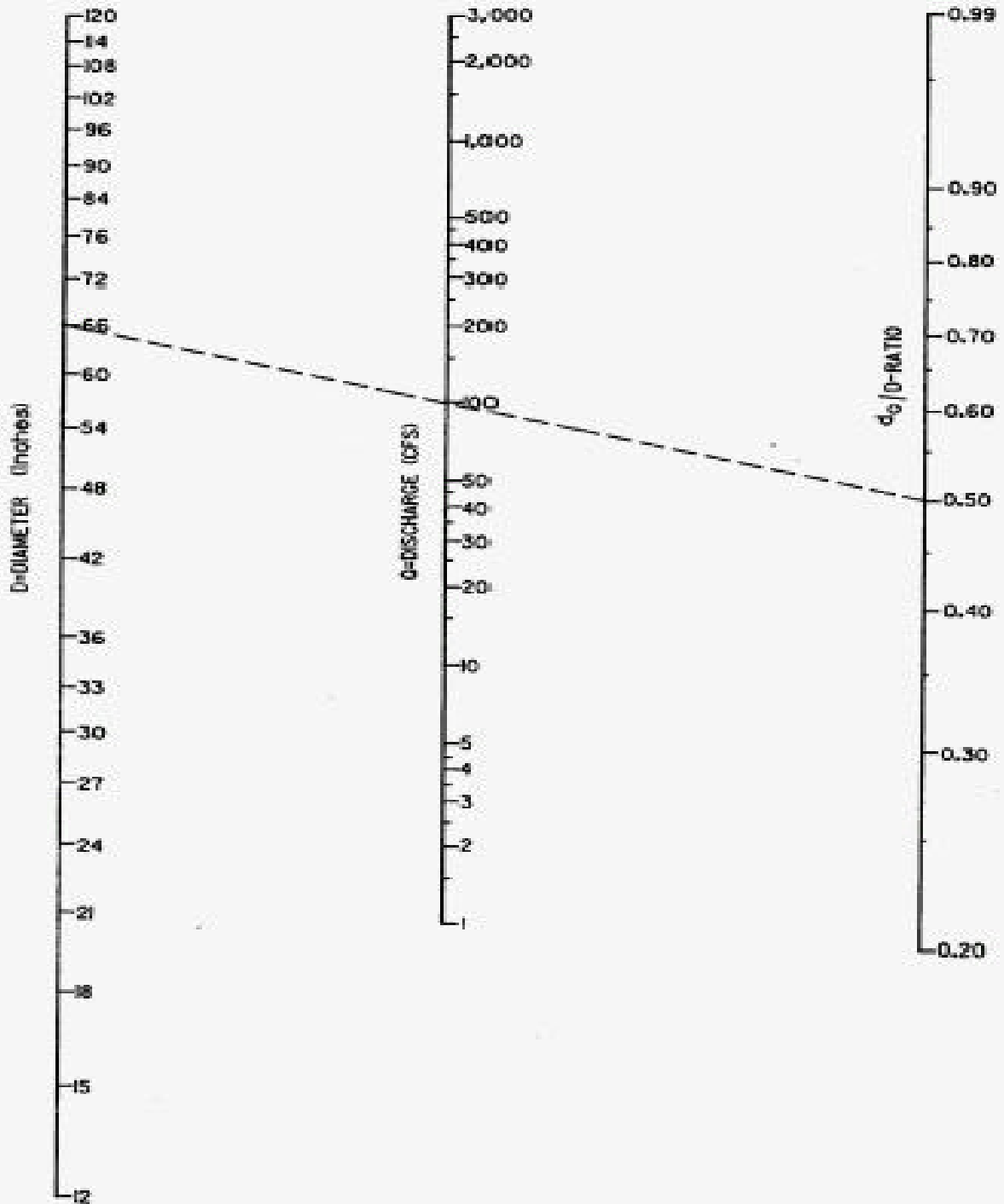


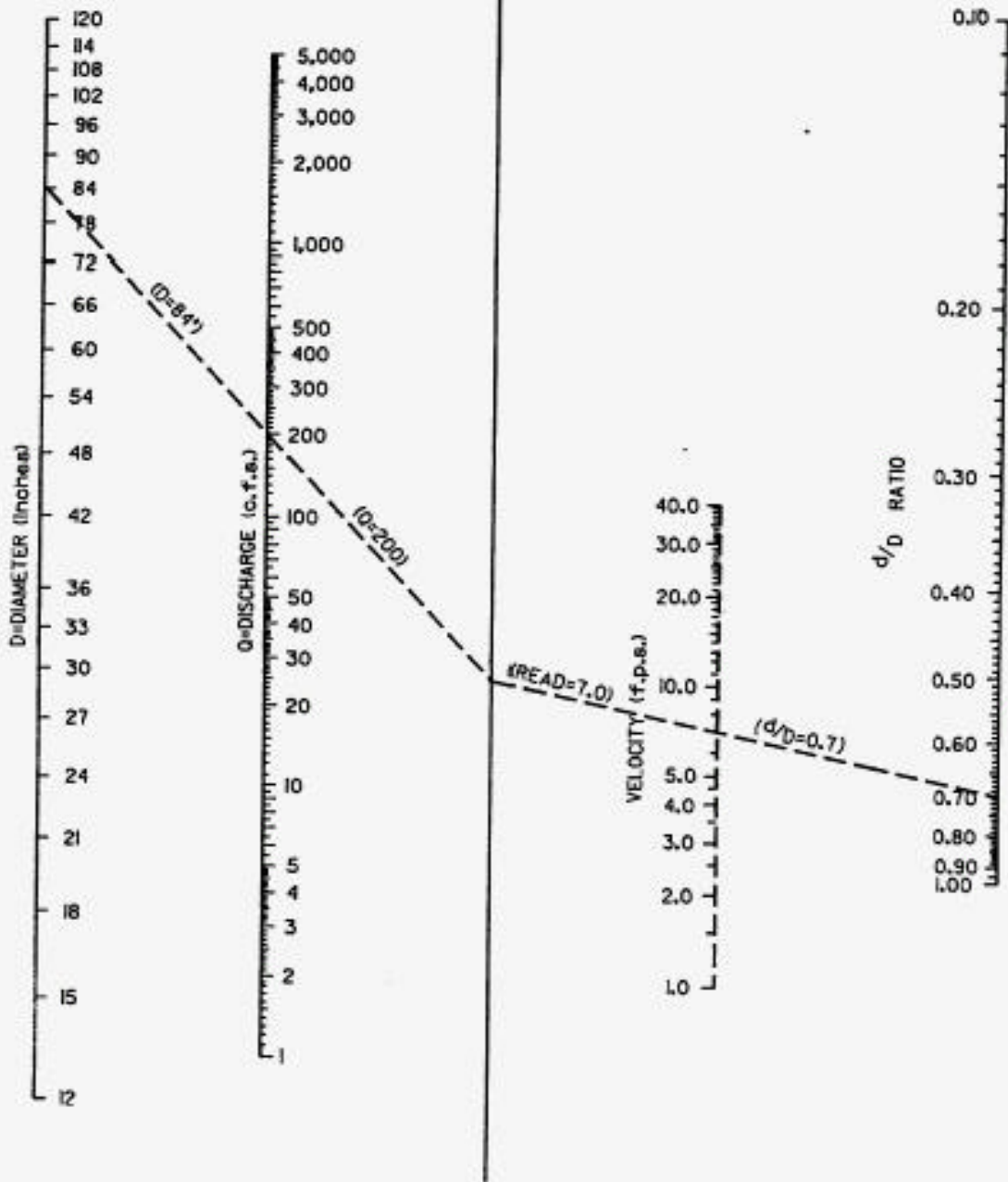


Figure 5-2 Critical Depth of Flow For Circular Conduits



Source: City of Austin. Drainage Criteria Manual. Department of Public Works. Austin, Texas. January 1977.

Figure 5-3 Velocity in Pipe Conduits



Source: City of Austin. Drainage Criteria Manual, Department of Public Works. Austin, Texas. January 1977.

Figure 5-4 Uniform Flow For Concrete Elliptical Pipe

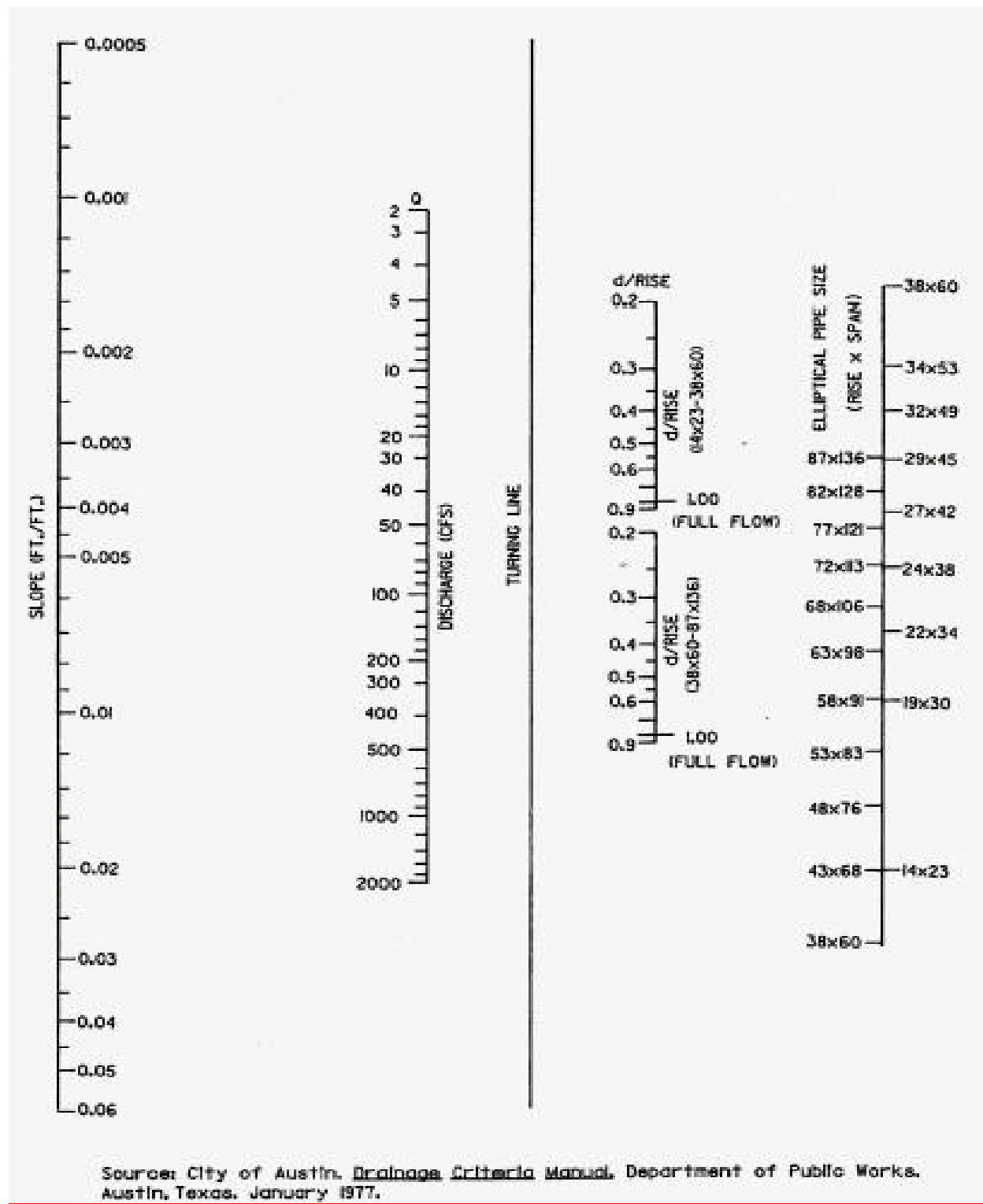


Figure 5-5 Critical Depth For Elliptical Pipe

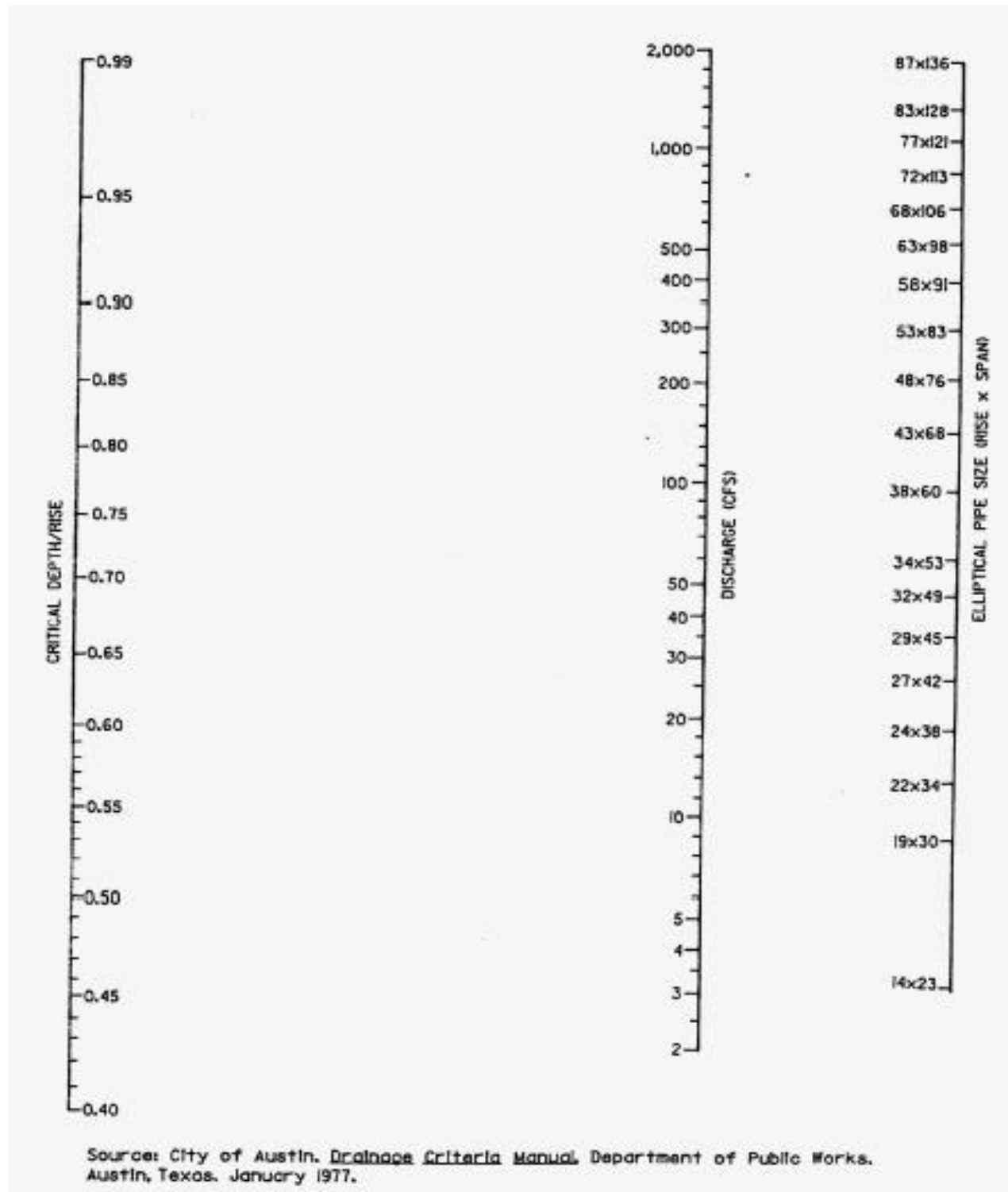


Figure 5-6 Velocity in Elliptical Pipe

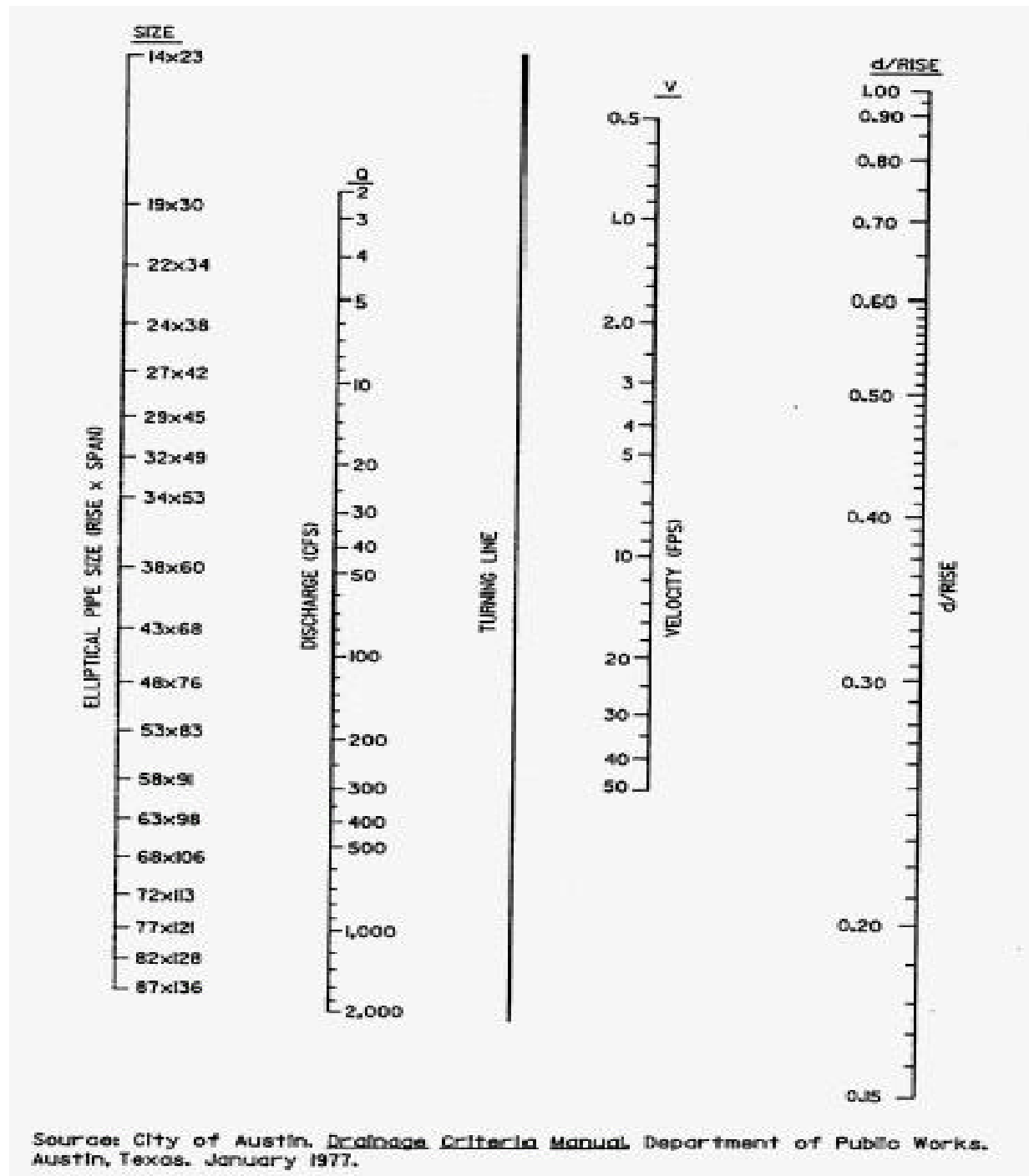


Figure 5-7 Uniform Flow For Pipe Arch

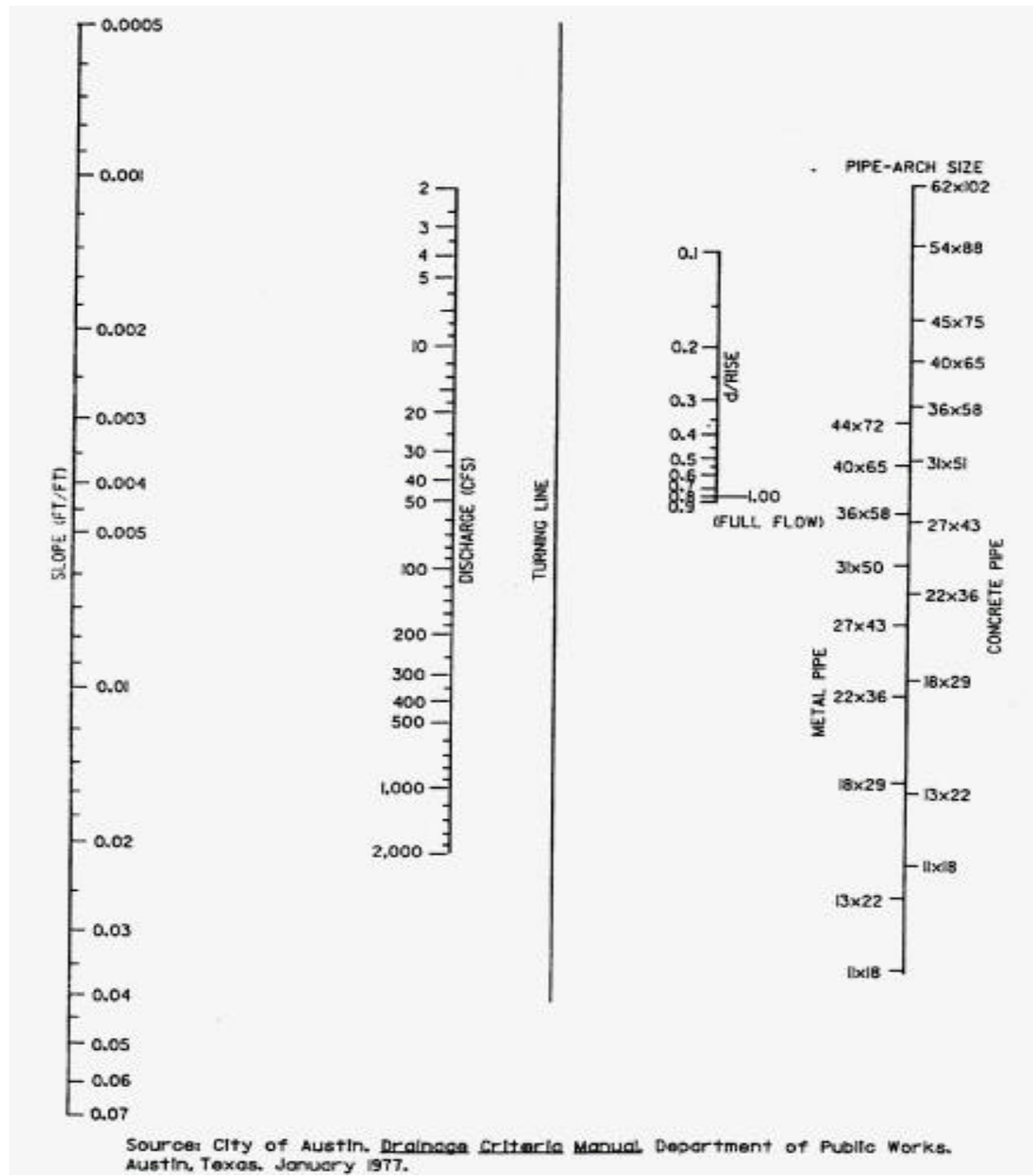
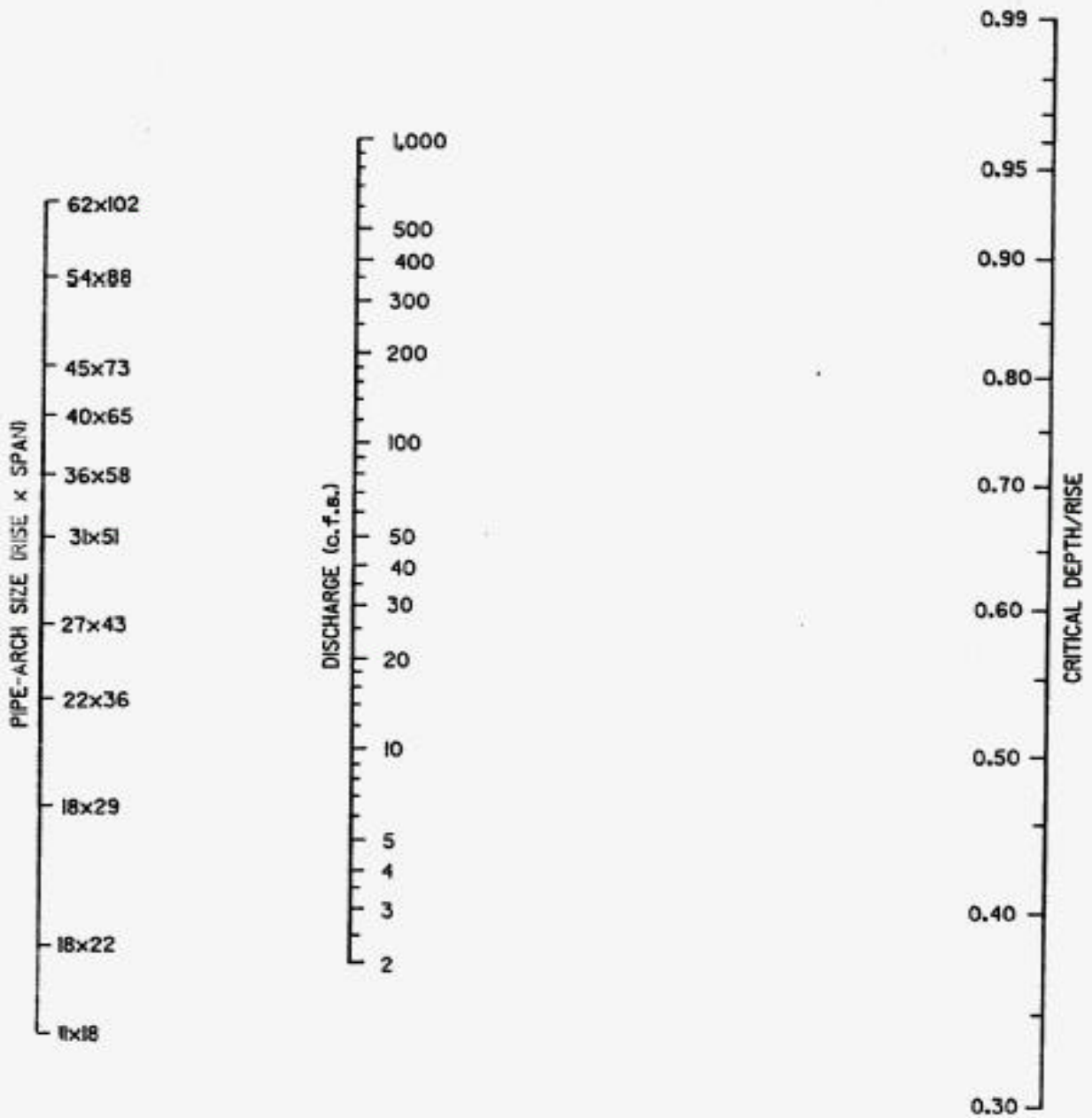


Figure 5-8 Critical Depth of Flow For Pipe-Arch



Source: City of Austin. Drainage Criteria Manual. Department of Public Works. Austin, Texas. January 1977.



Figure 5-9 Velocity in Pipe-Arch

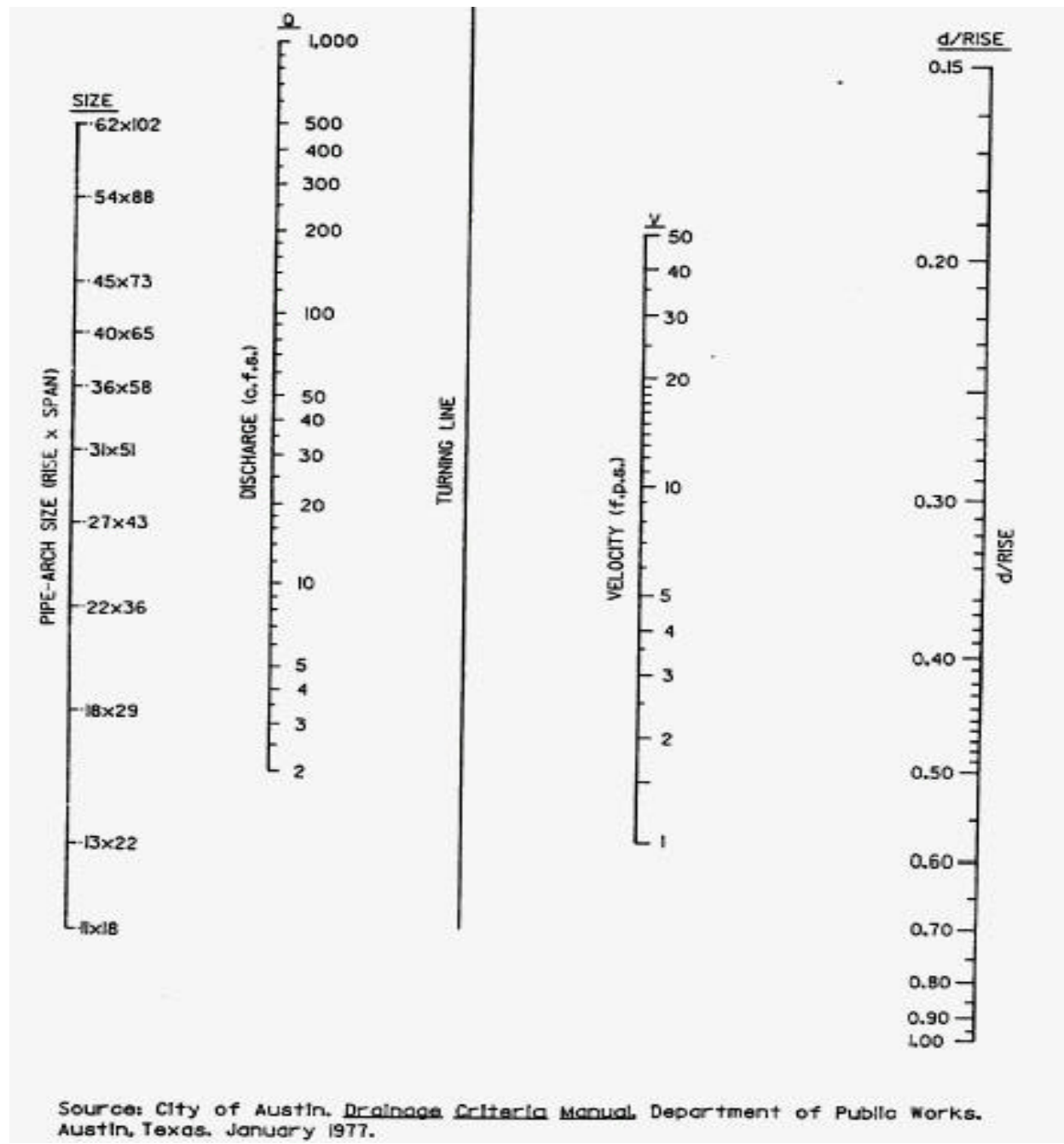
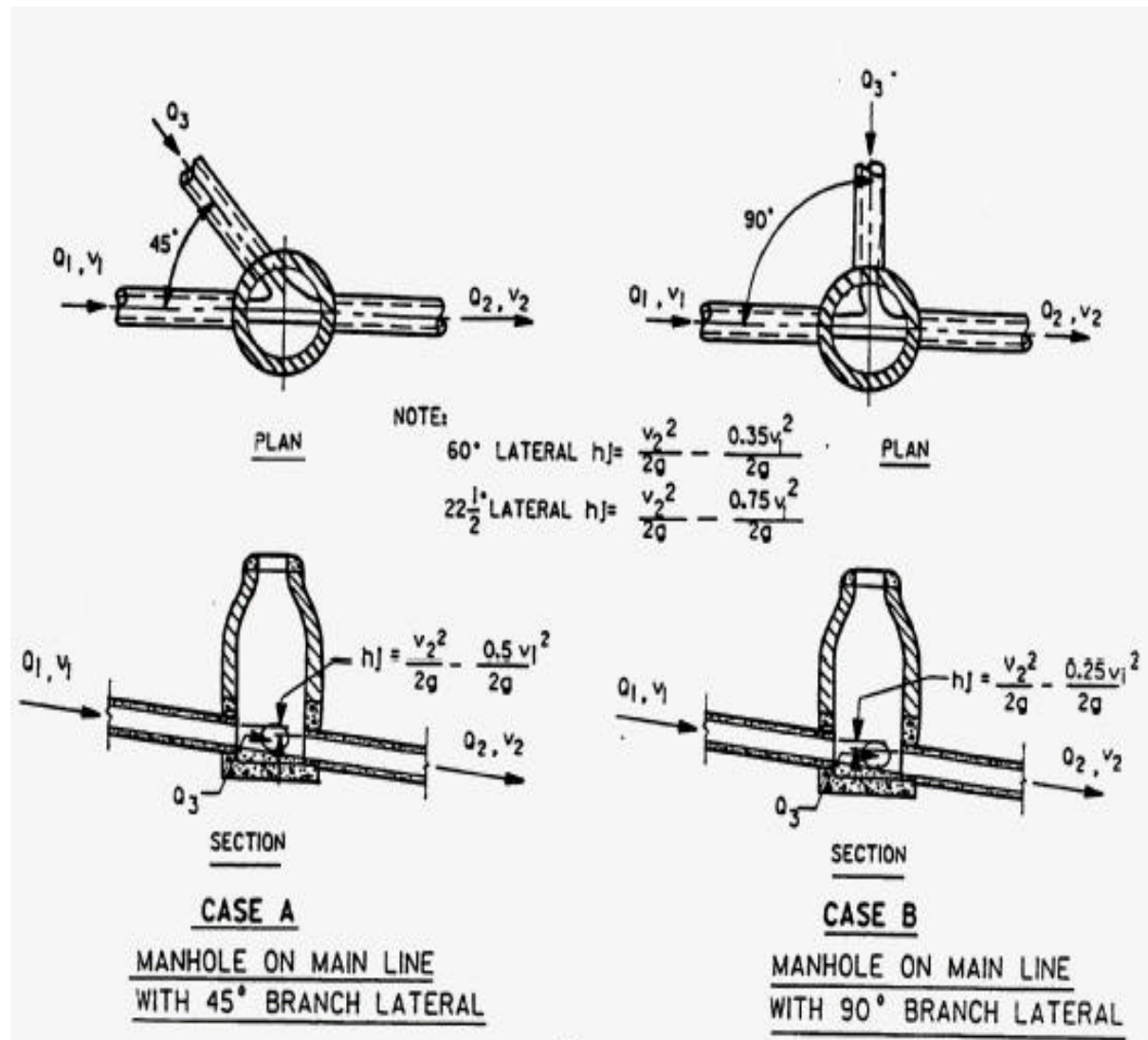
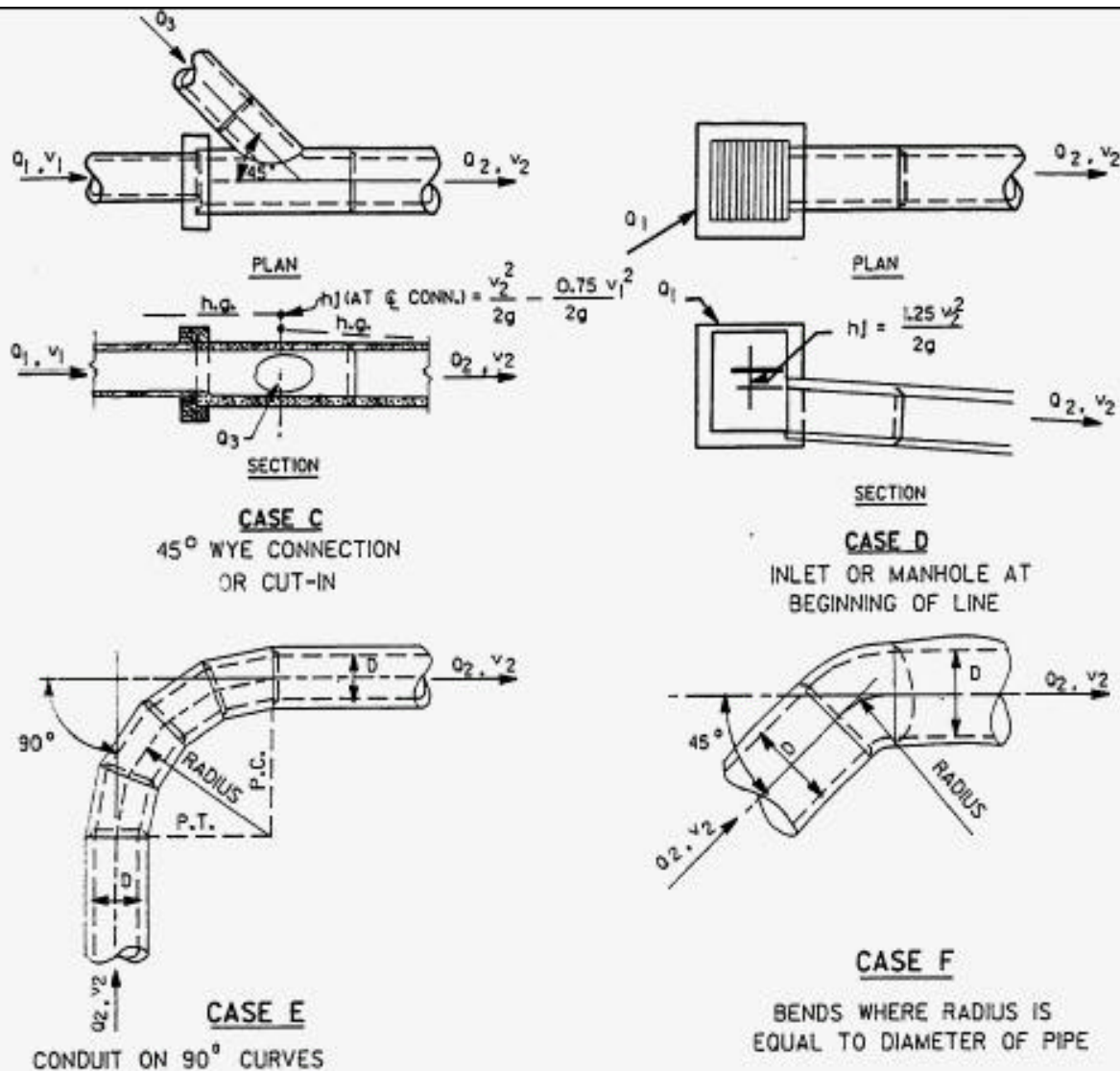


Figure 5-10 Minor Head Losses Due to Turbulence at Structures



Source: City of Austin, Drainage Criteria Manual, Department of Public Works, Austin, Texas, January 1977.

Figure 5-11 Minor Head Losses Due to Turbulence at Structures



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

RADIUS = DIA. OF PIPE  $h_j = 0.05 \frac{v^2}{2g}$

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

RADIUS = (8-20) DIA. OF PIPE  $h_j = 0.40 \frac{v^2}{2g}$

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

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

60° CURVES 85%

45° CURVE 70%

22½° CURVE 40%

NOTE: HEAD LOSS APPLIED AT BEGINNING OF BEND

90° BEND  $h_j = 0.50 \frac{v^2}{2g}$

60° BEND  $h_j = 0.43 \frac{v^2}{2g}$

45° BEND  $h_j = 0.35 \frac{v^2}{2g}$

22½° BEND  $h_j = 0.20 \frac{v^2}{2g}$

Source: City of Austin, *Drainage Criteria Manual*, Department of Public Works, Austin, Texas, January 1977.

Figure 5-12 Sample Stormsewer Layout

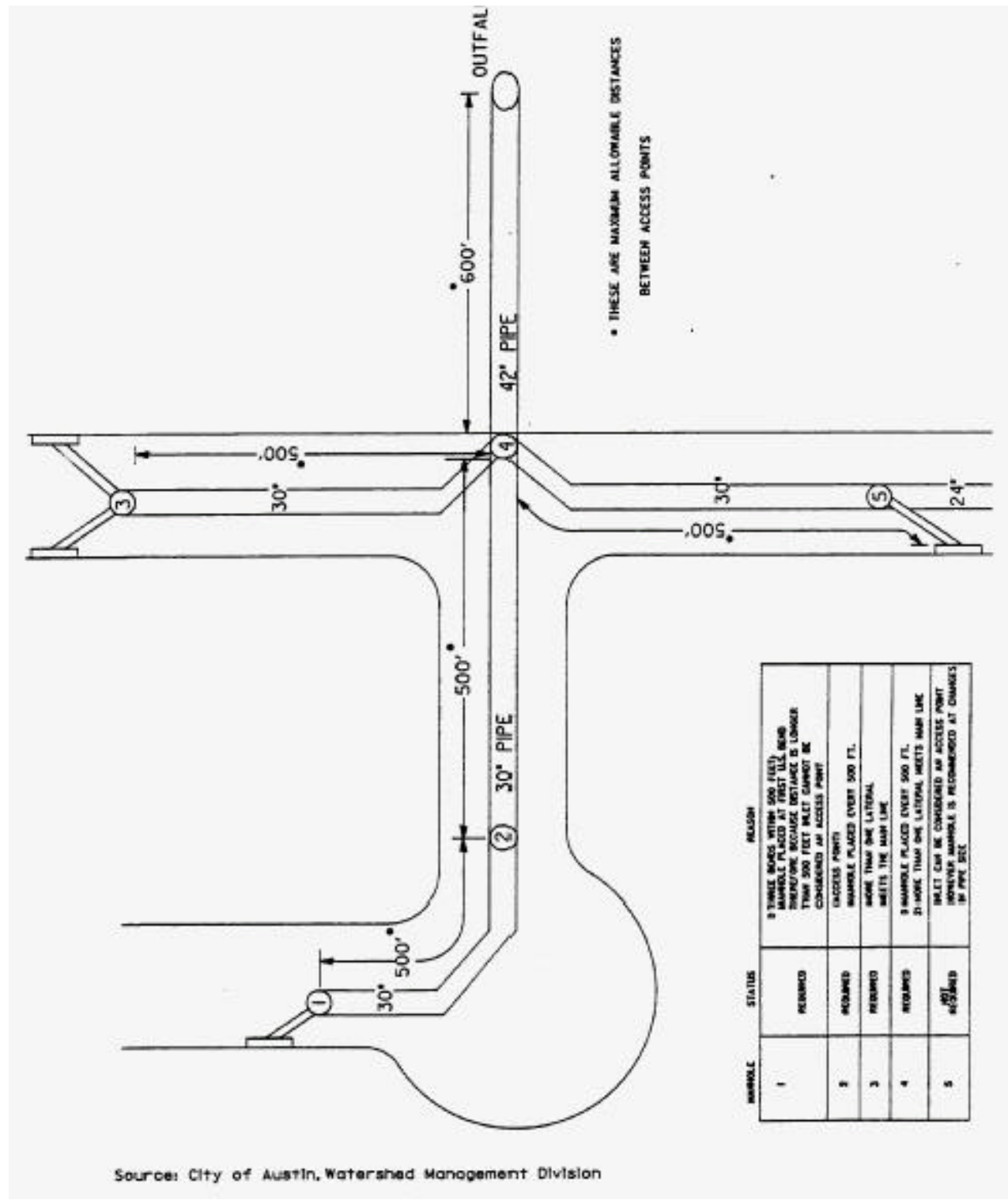




Figure 5-13 Flow For Circular Pipe Flowing Full ( $n=0.010$ )

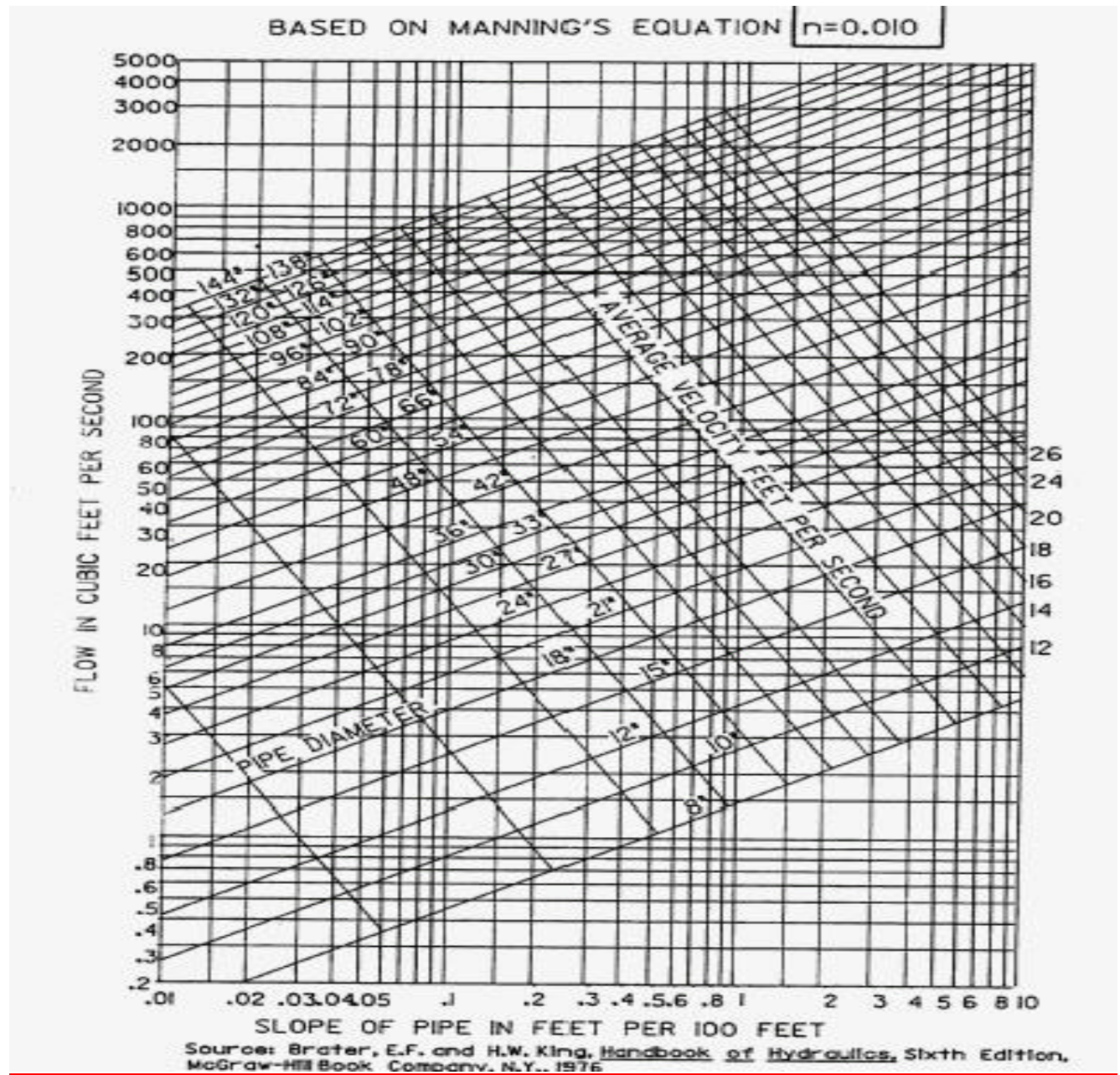


Figure 5-14 Flow For Circular Pipe Flowing Full ( $n=0.011$ )

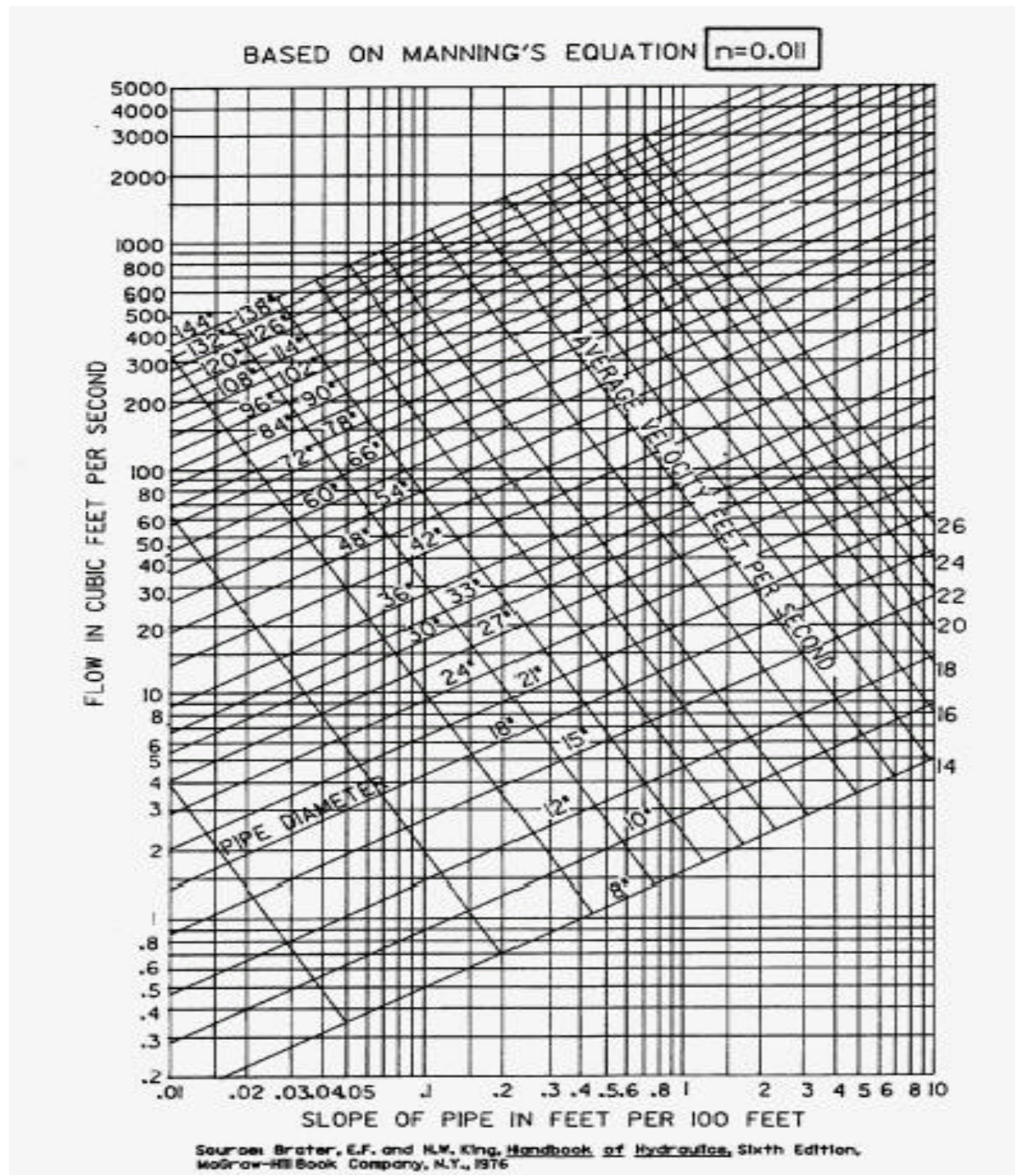


Figure 5-15 Flow For Circular Pipe Flowing Full ( $n=0.012$ )

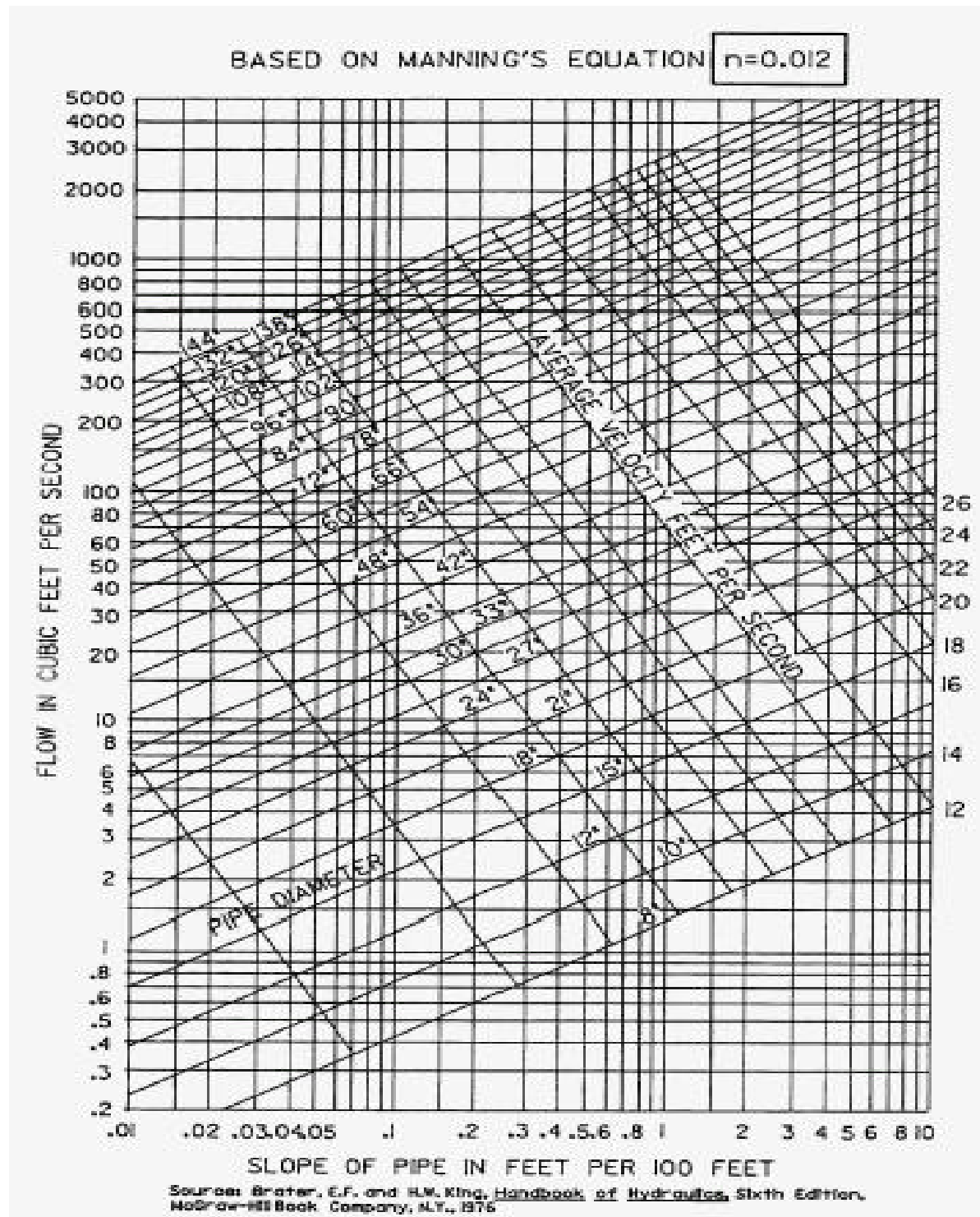
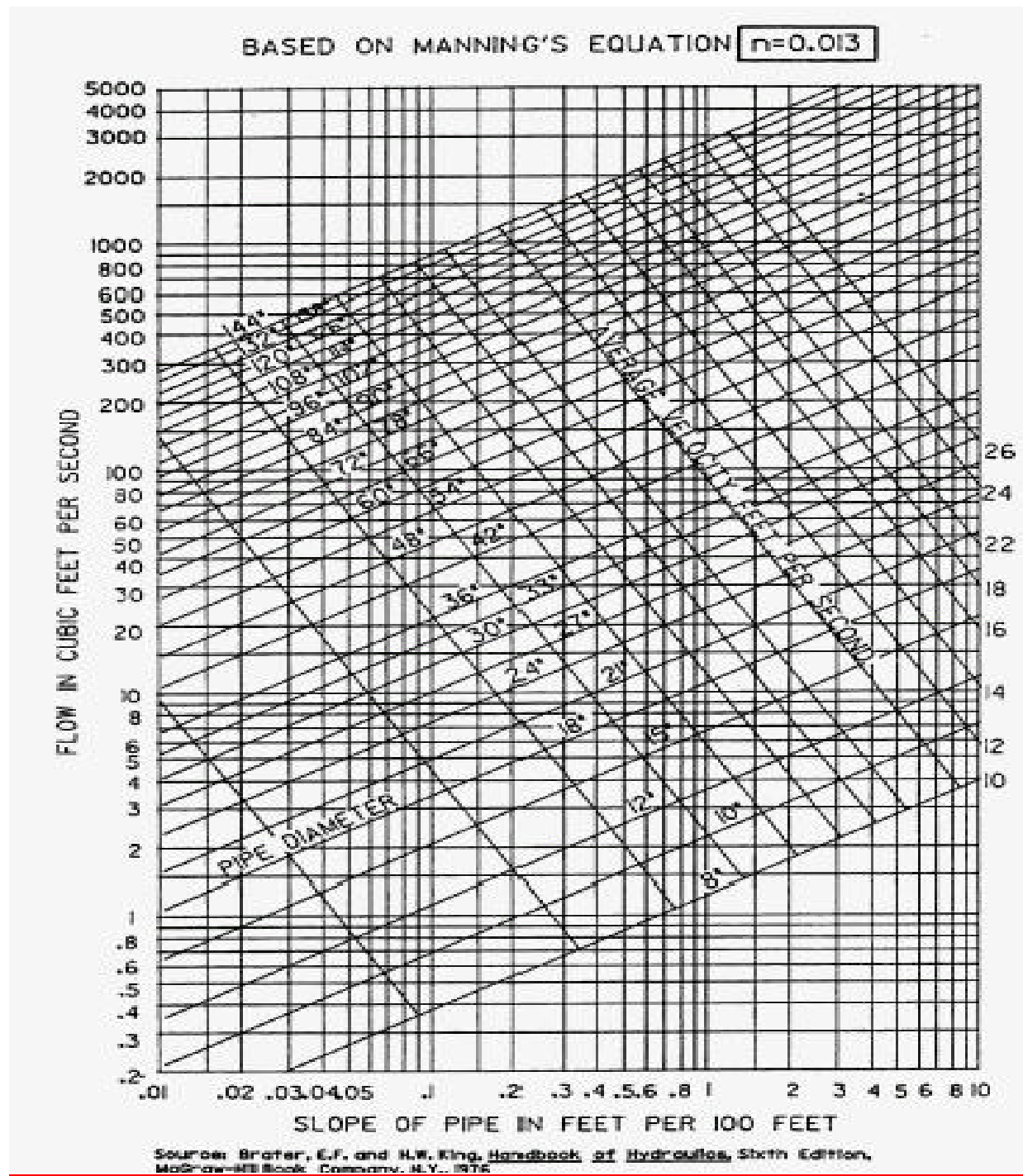




Figure 5-16 Flow For Circular Pipe Flowing Full ( $n=0.013$ )



# FIGURES FROM SECTION 6

## Figure 6-1 Uniform Flow For Trapezoidal Channels

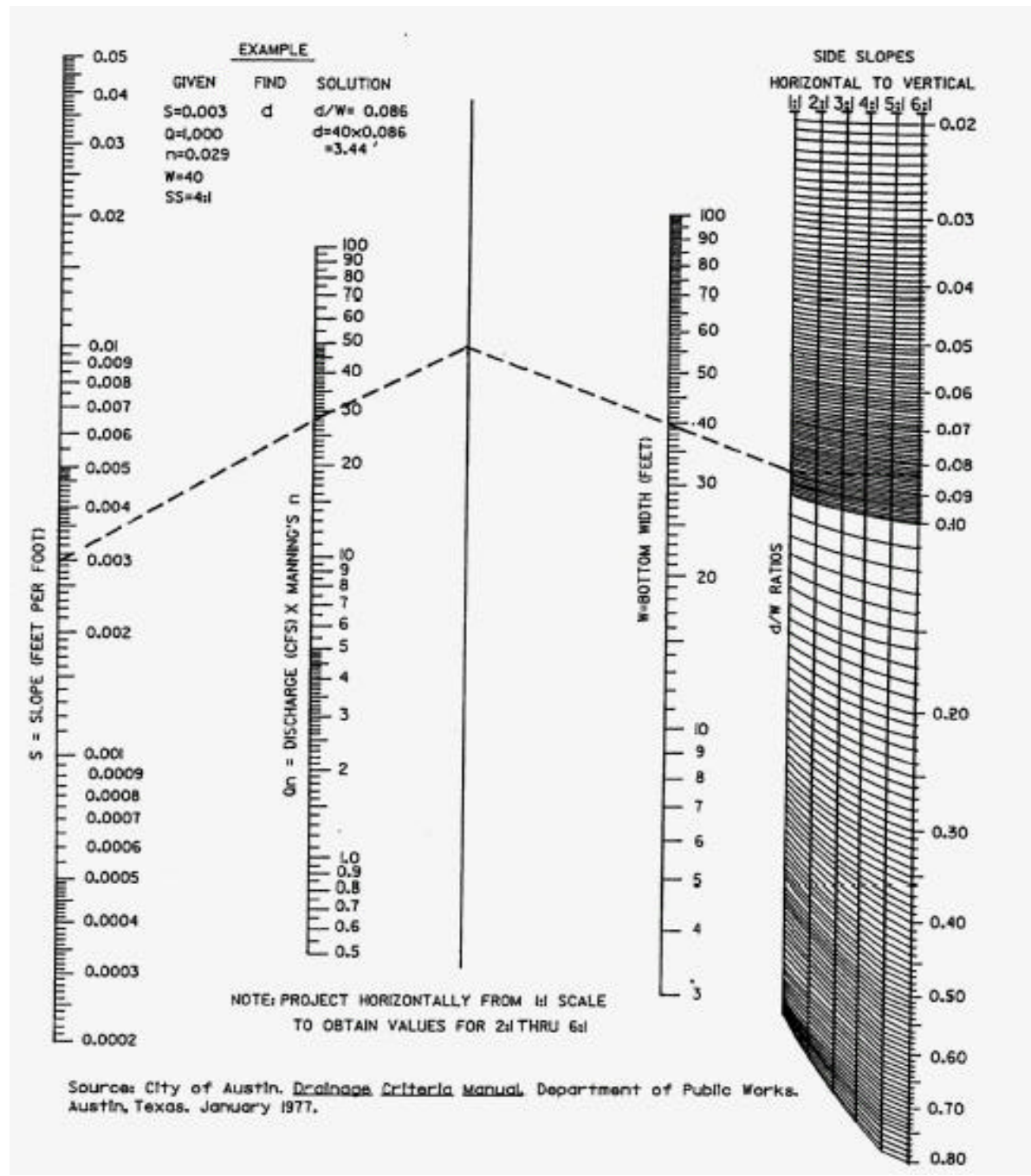
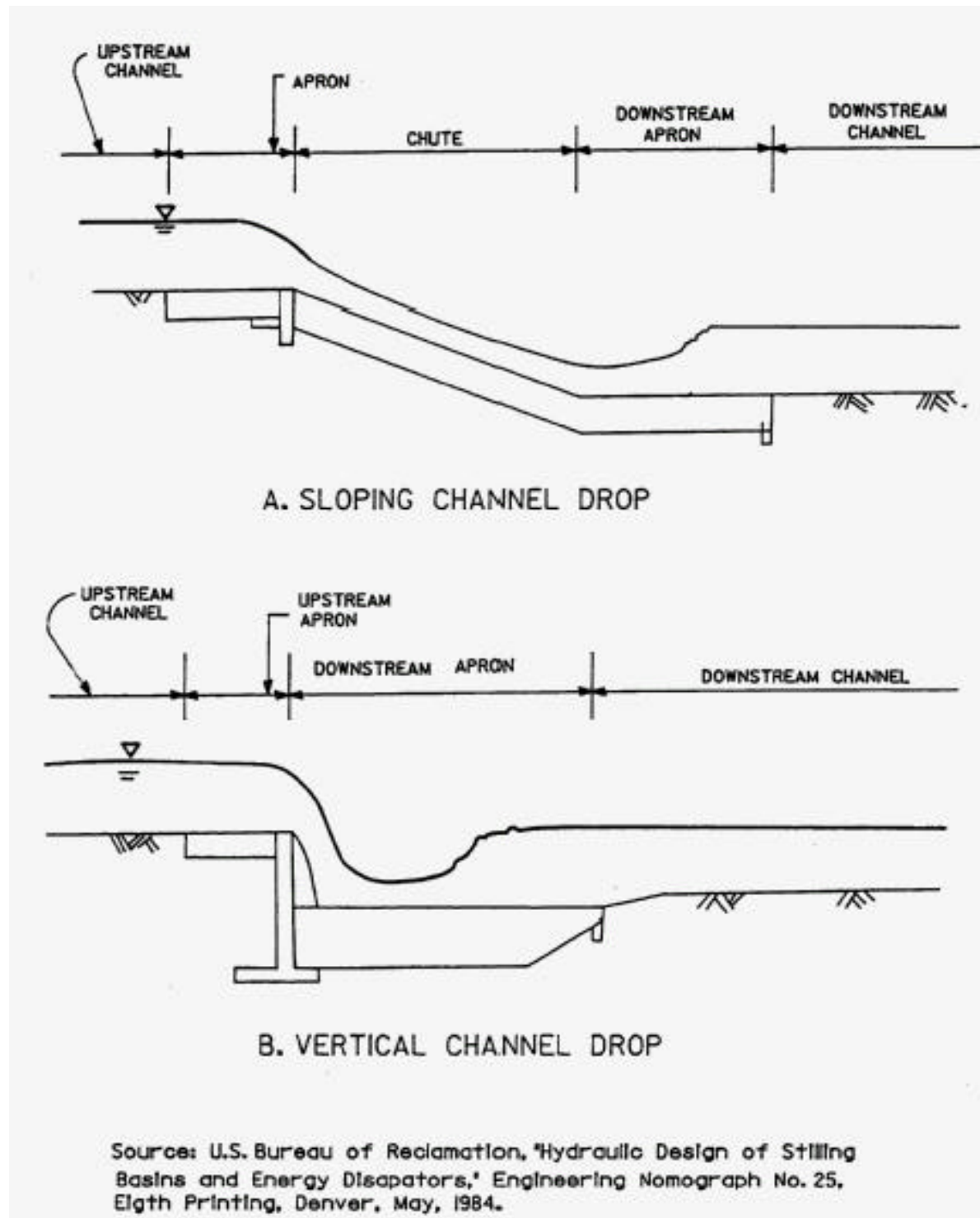


Figure 6-2 Sloping and Vertical Channel Drops







# FIGURES FROM SECTION 7

## Figure 7-1 Headwall Entrance Type

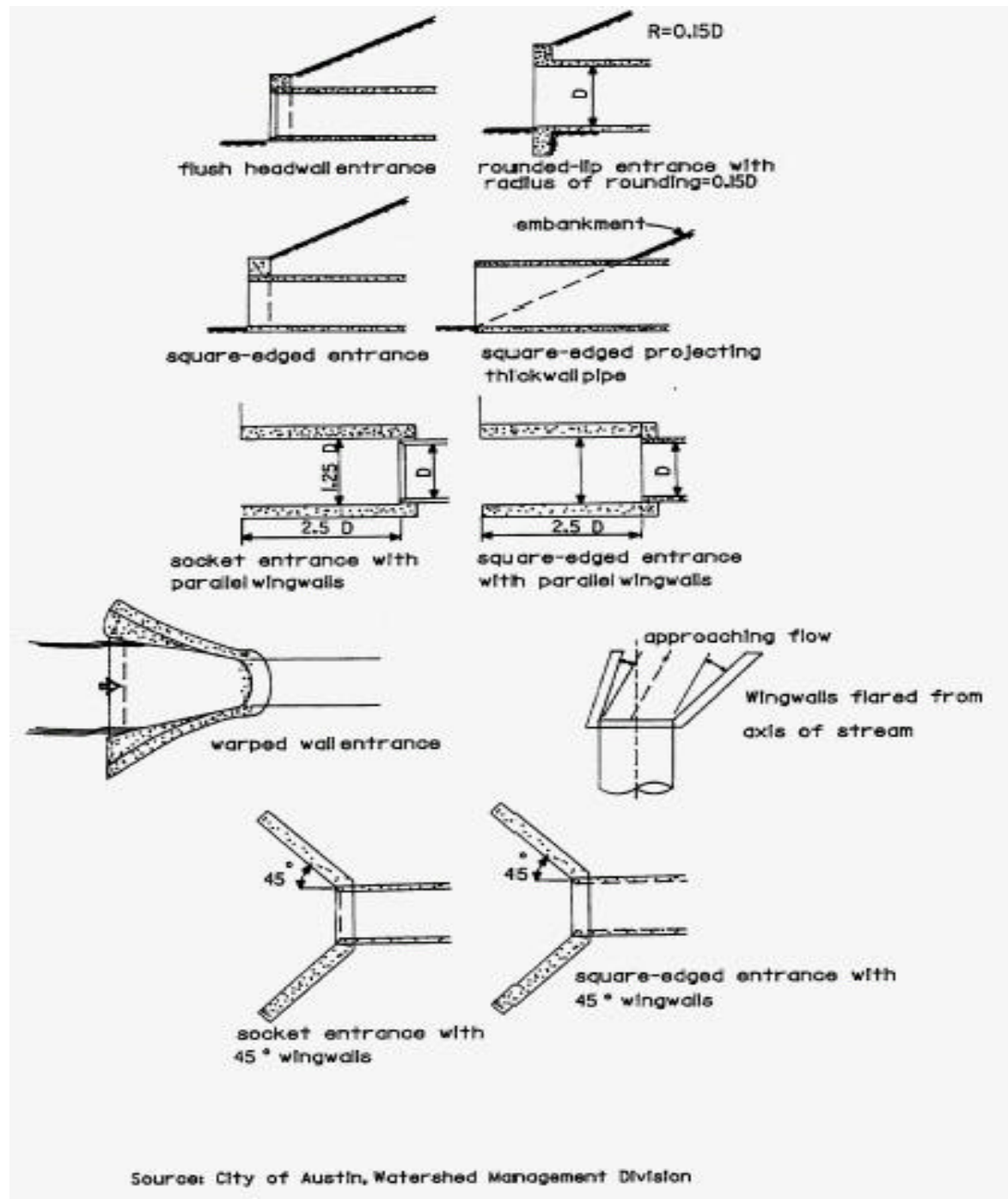




Figure 7-2 Conceptual Design of Debris Fins

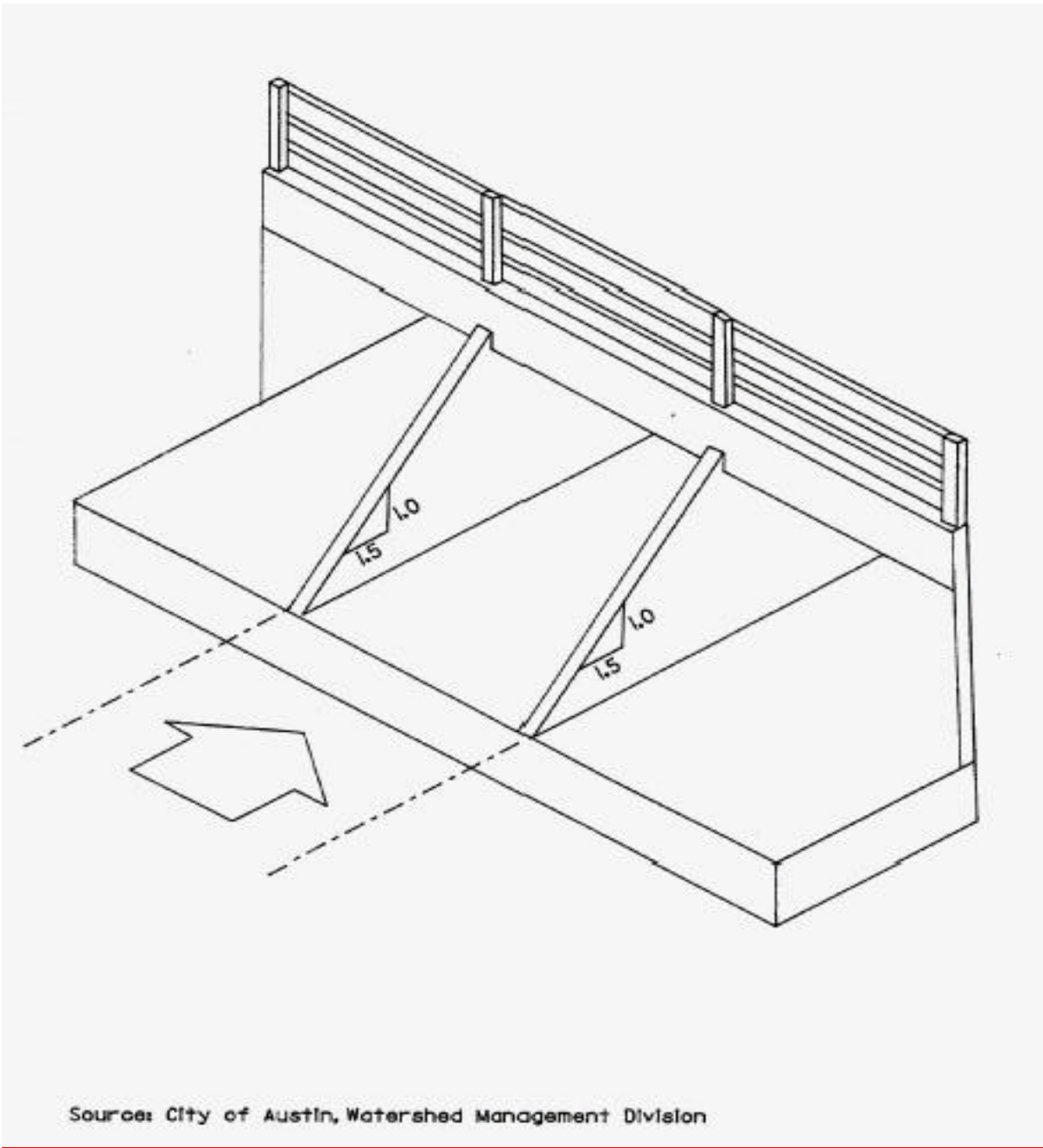
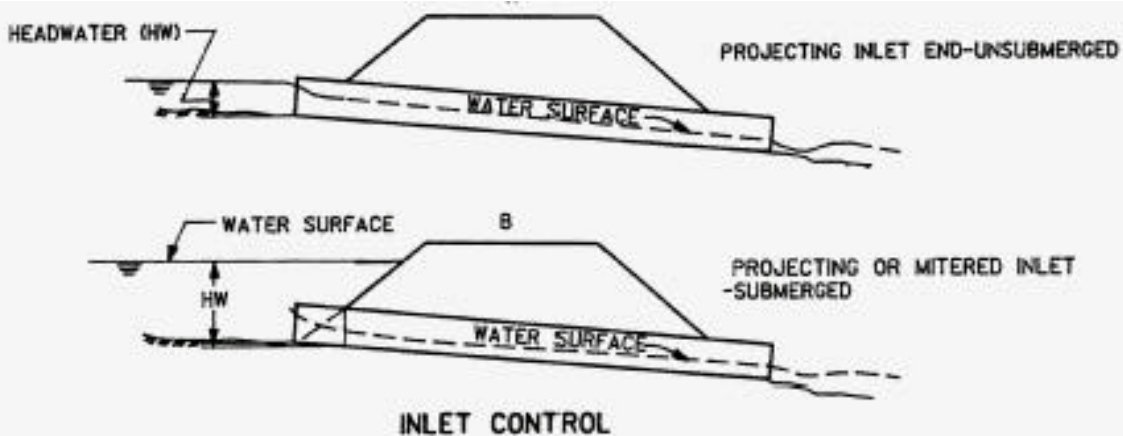
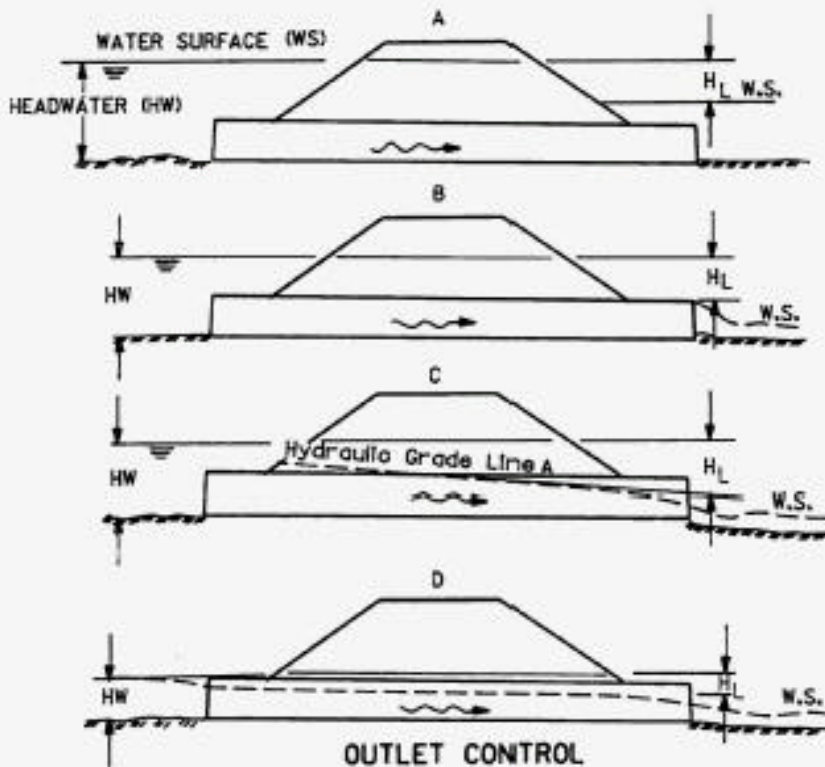


Figure 7-3 Inlet and Outlet Conditions For Culverts



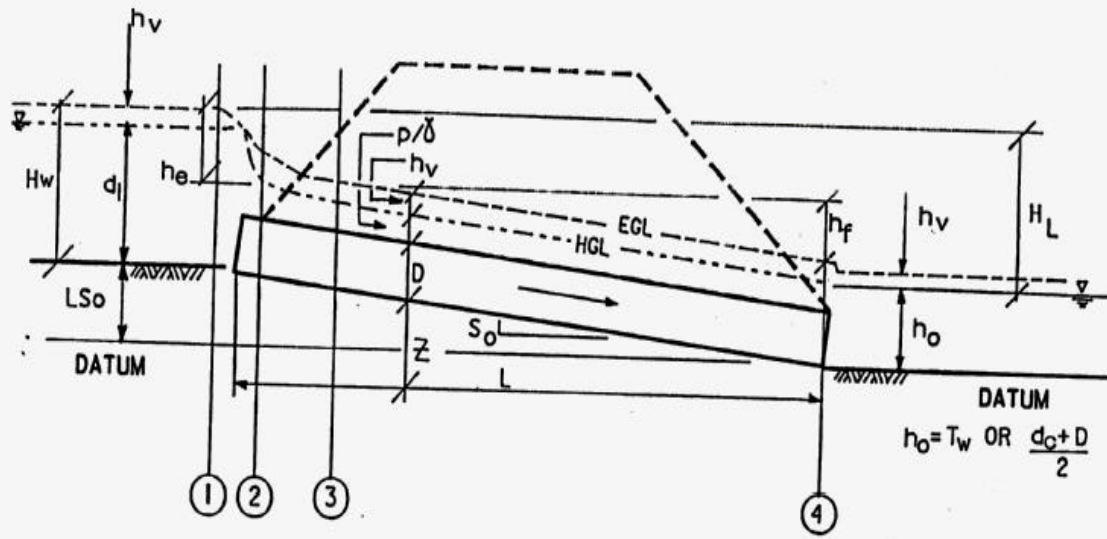
INLET CONTROL IS ONE OF THE TWO MAJOR TYPES OF CULVERT FLOW. CONDITION A WITH AN UNSUBMERGED CULVERT INLET IS PREFERRED TO THE SUBMERGED END. SLOPE, ROUGHNESS AND LENGTH OF CULVERT BARREL ARE NOT A CONSIDERATION.



OUTLET CONTROL INVOLVES THESE FACTORS: CROSS-SECTIONAL AREA OF BARREL, INLET 'GEOMETRY', PONDING, SLOPE, ROUGHNESS, TAILWATER, AND LENGTH OF CULVERT BARREL.  
 Source: Boulder County, Storm Drainage Criteria Manual

Figure 7-4 Hydraulics of a Culvert Under Outlet Control Condition

Source: Boulder County, Storm Drainage Criteria Manual



DEFINITION OF TERMS:

- |                                  |                                  |
|----------------------------------|----------------------------------|
| L = CULVERT LENGTH               | $P/\delta$ = PRESSURE HEAD       |
| $S_o$ = CULVERT SLOPE            | HGL = HYDRAULIC GRADE LINE       |
| $H_w$ = HEADWATER DEPTH          | EGL = ENERGY GRADE LINE          |
| $h_v$ = VELOCITY HEAD            | $T_w$ = TAILWATER DEPTH          |
| $h_e$ = HEADLOSS AT THE ENTRANCE | $h_f$ = FRICTION LOSS IN CULVERT |
| $z$ = DISTANCE FROM DATUM LINE   | $d_1$ = APPROACH DEPTH           |
| $D$ = CULVERT DIAMETER OR RISE   |                                  |

$$h_o = T_w \text{ OR } \frac{d_o + D}{2}$$

Figure 7-5 Inlet Control Nomograph, Circular Pipe

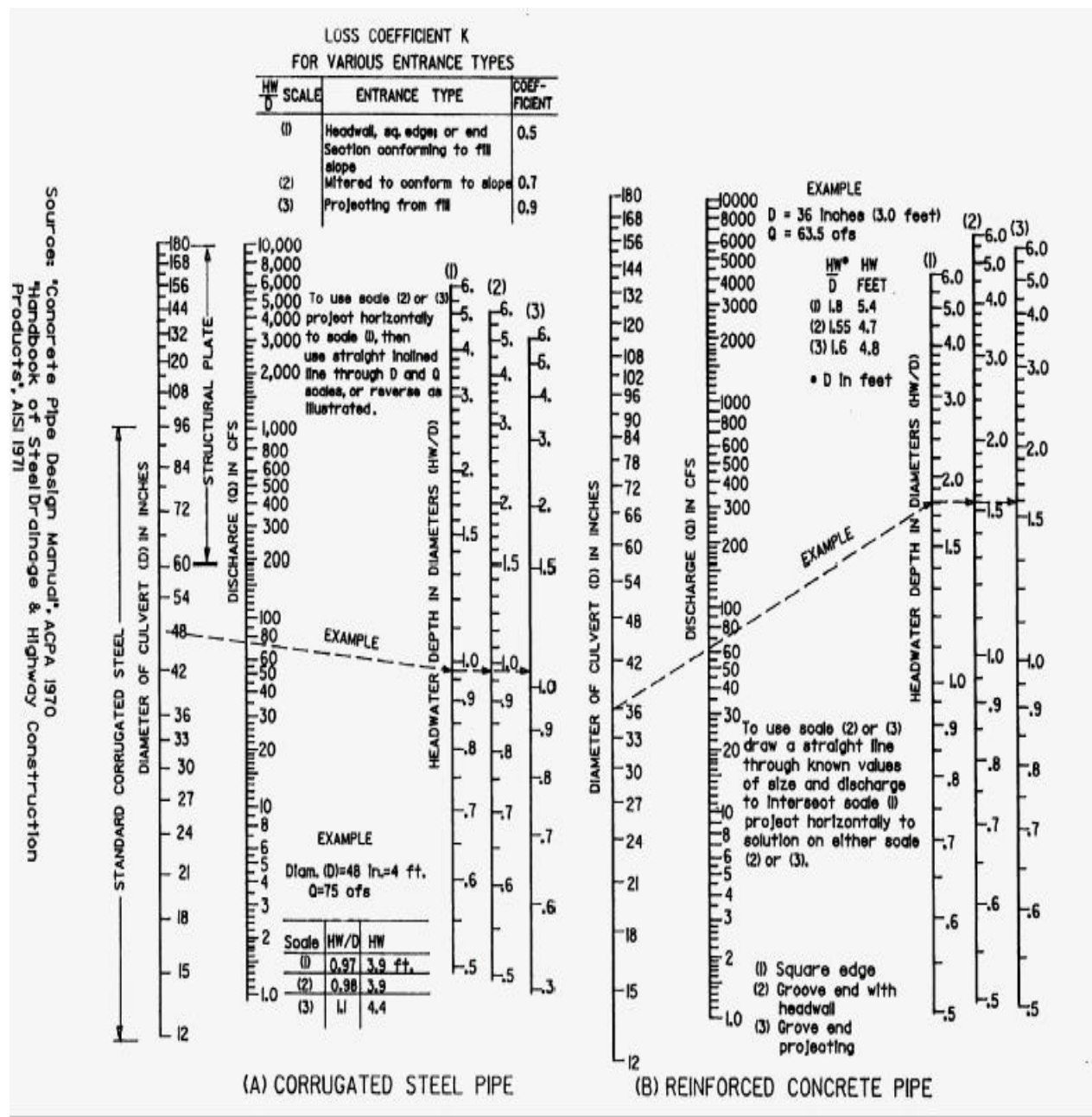


Figure 7-6 Inlet Control Nomograph, Box Culverts

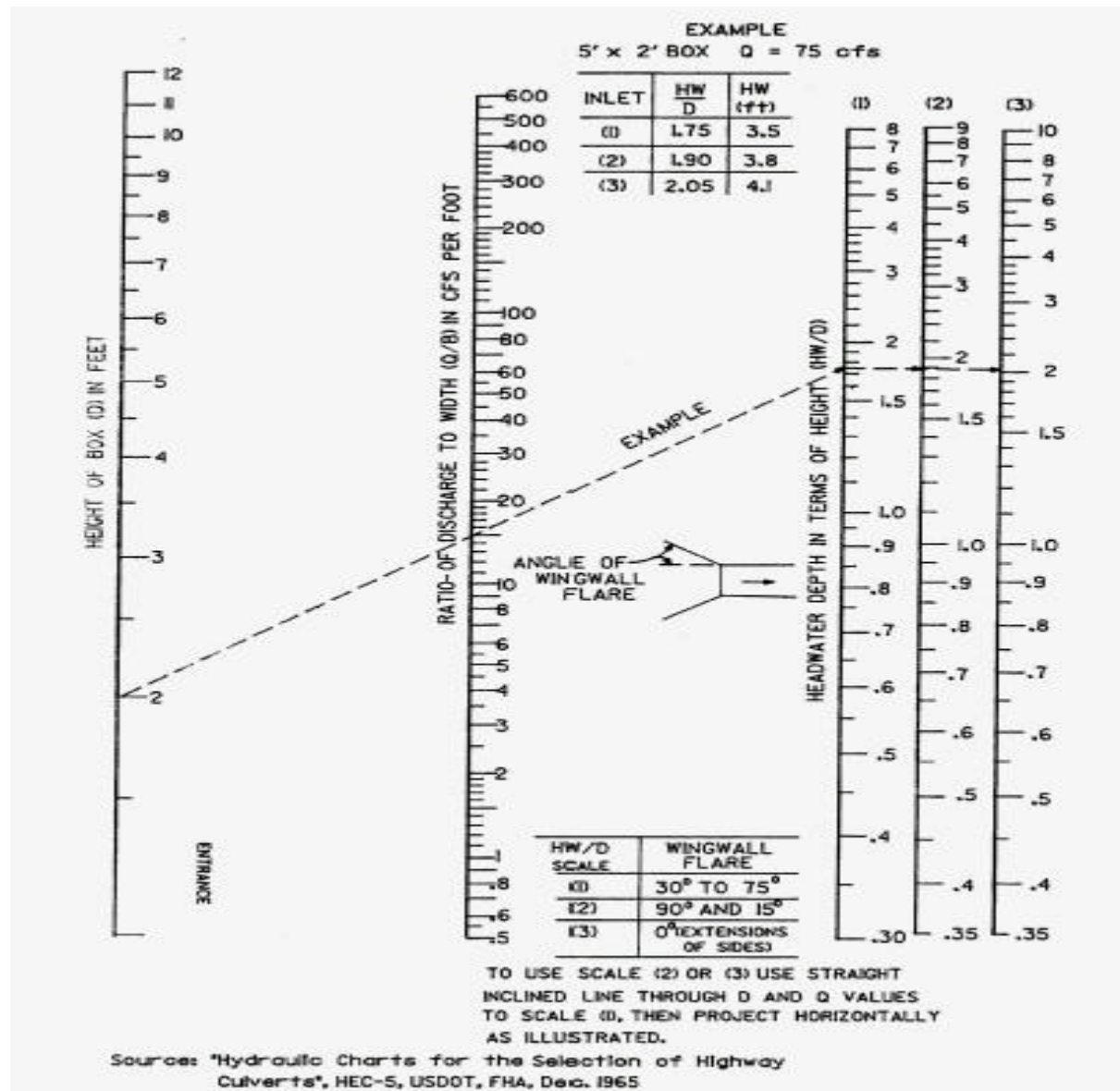


Figure 7-7 Inlet Control Nomograph, CSP Arch

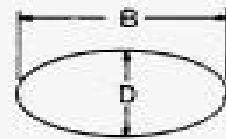
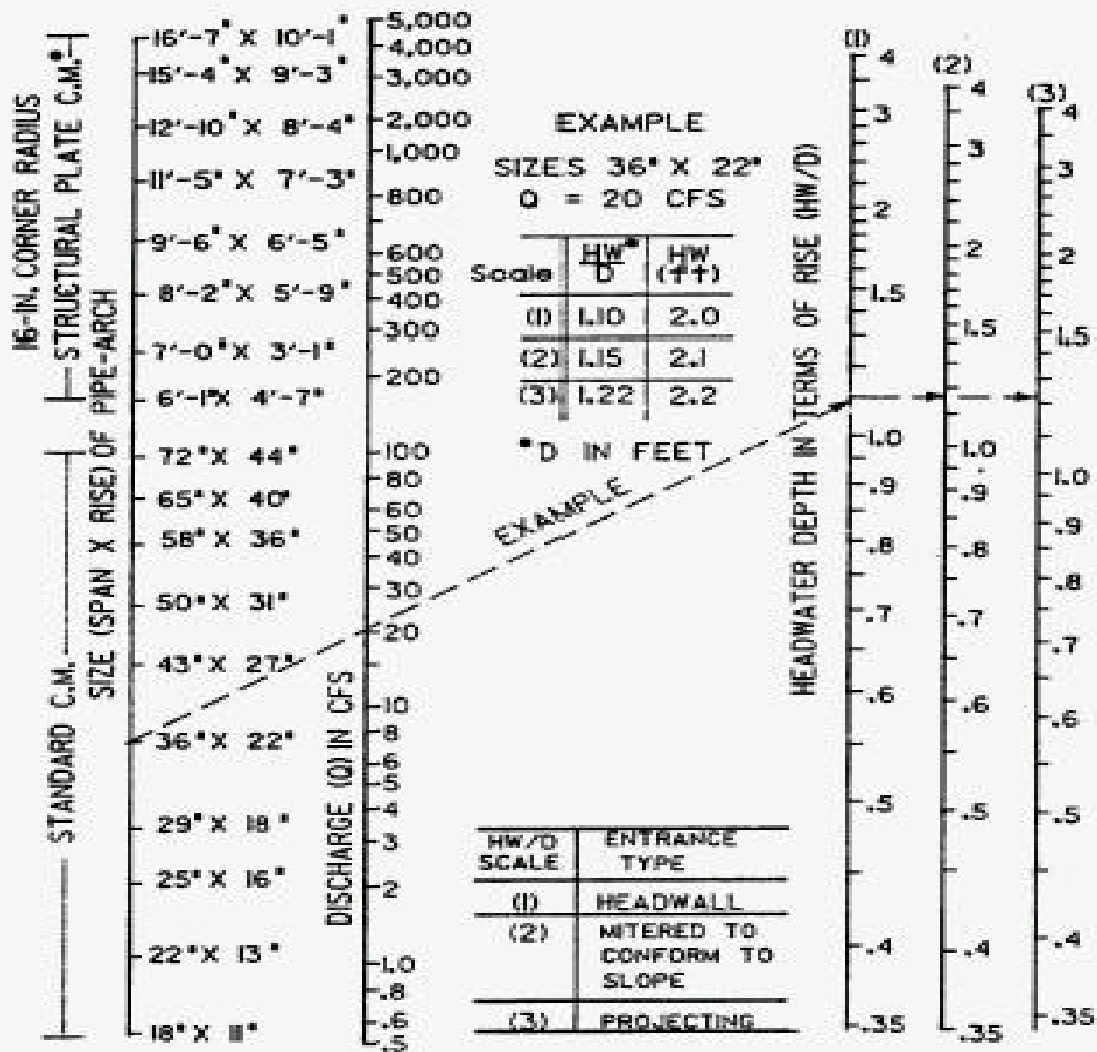




Figure 7-8 Inlet Control Nomograph, RCP Arch

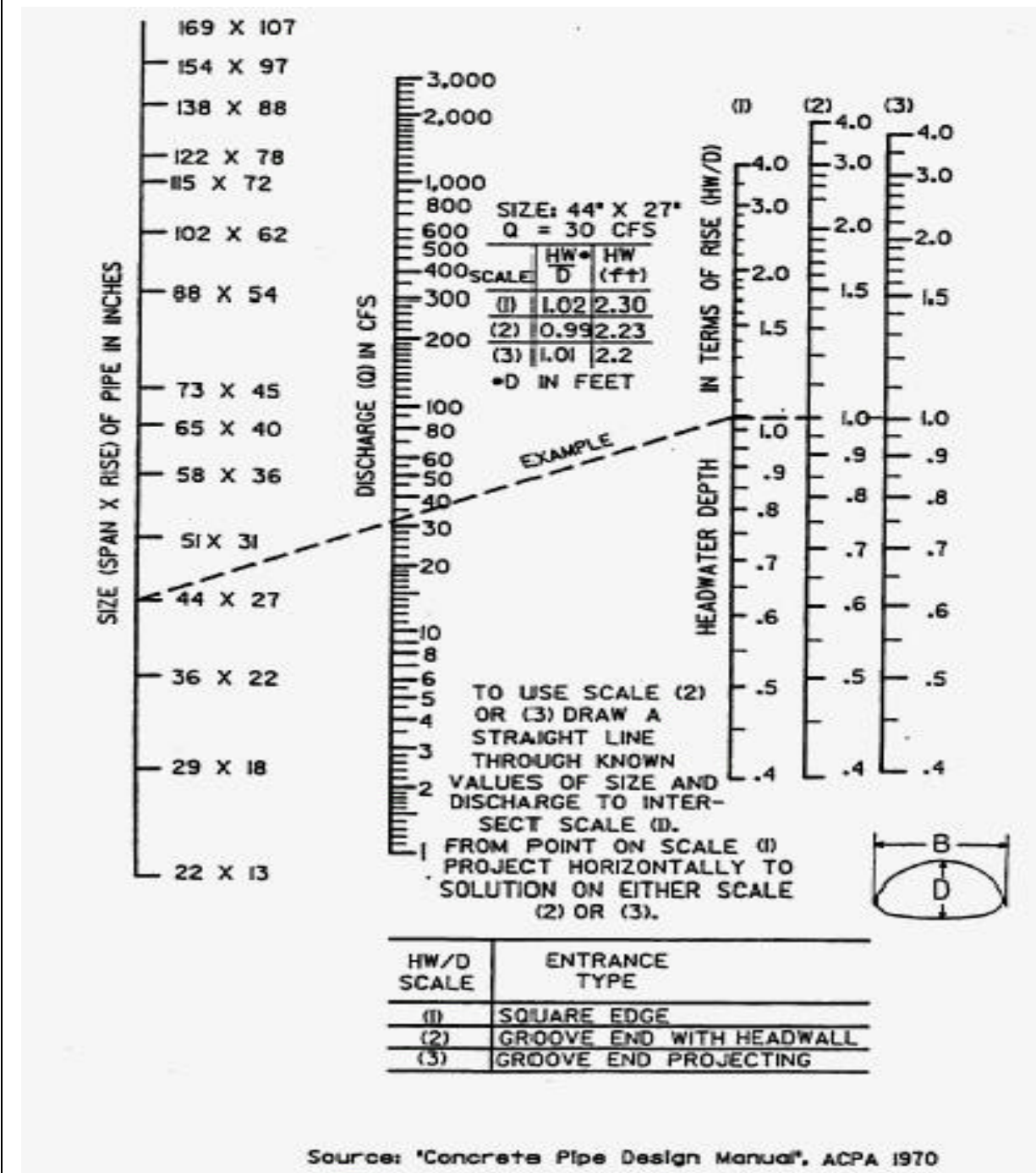


Figure 7-9 Inlet Control Nomograph, SSP Arch

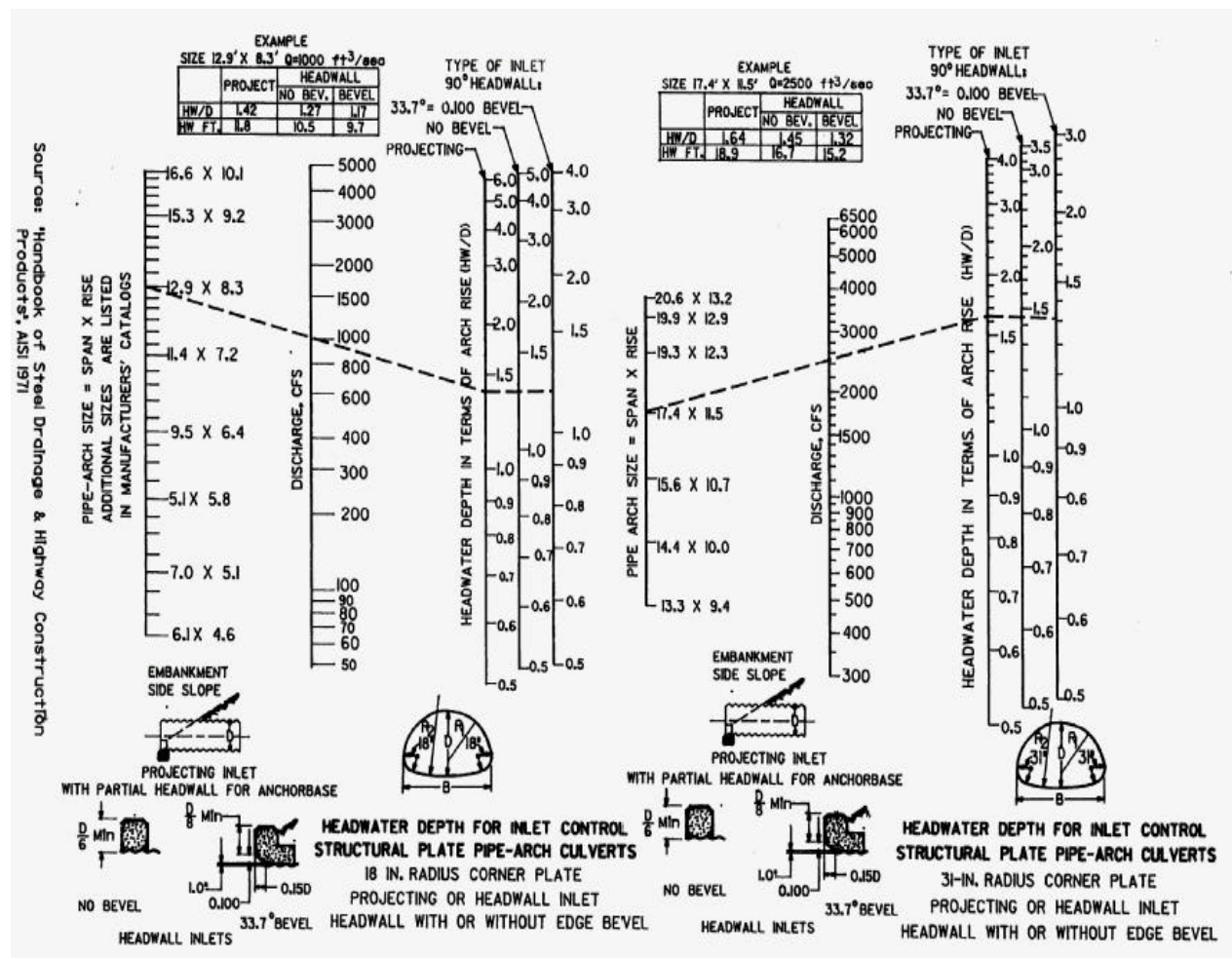
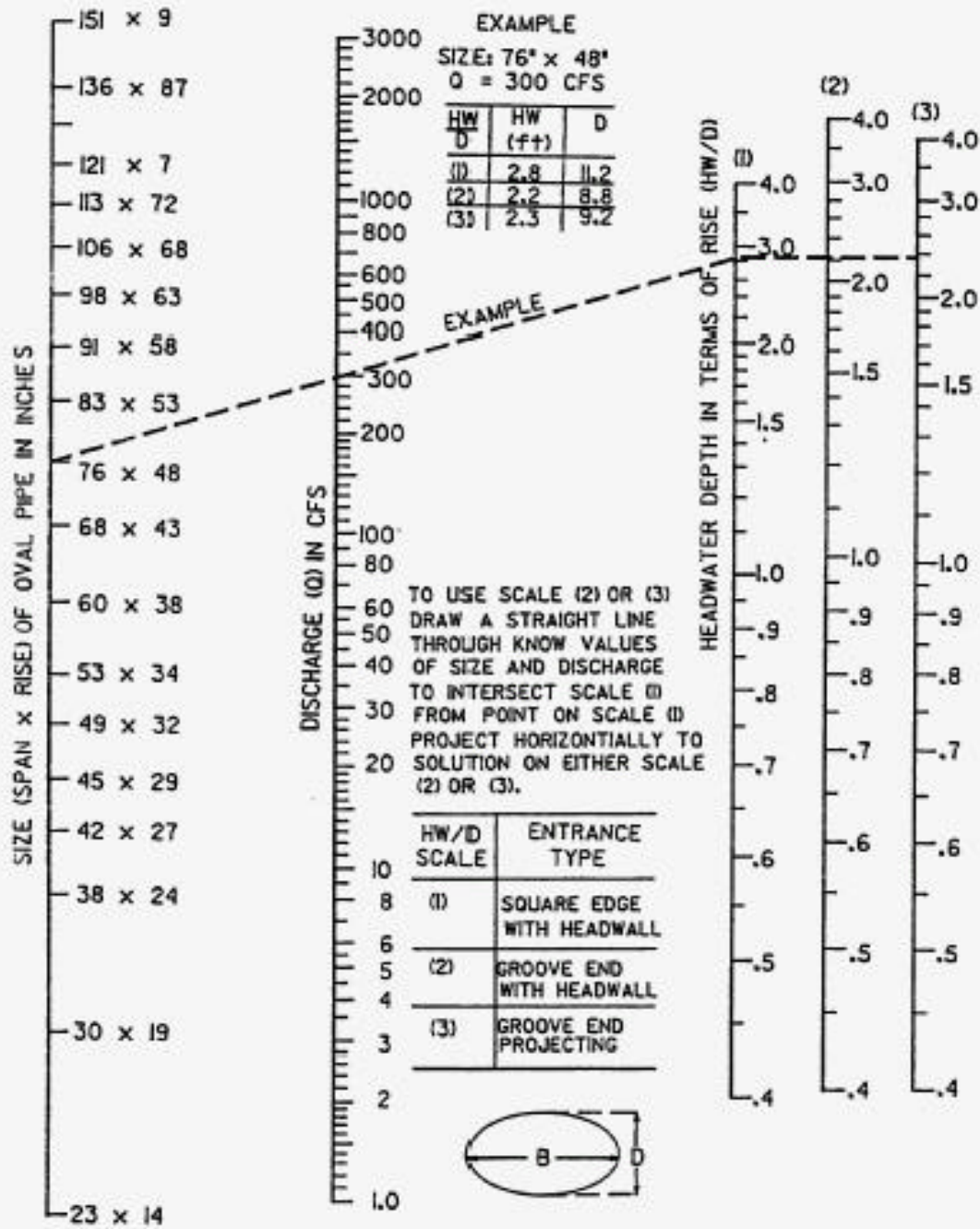


Figure 7-10 Inlet Control Nomograph, RCP Ellipse

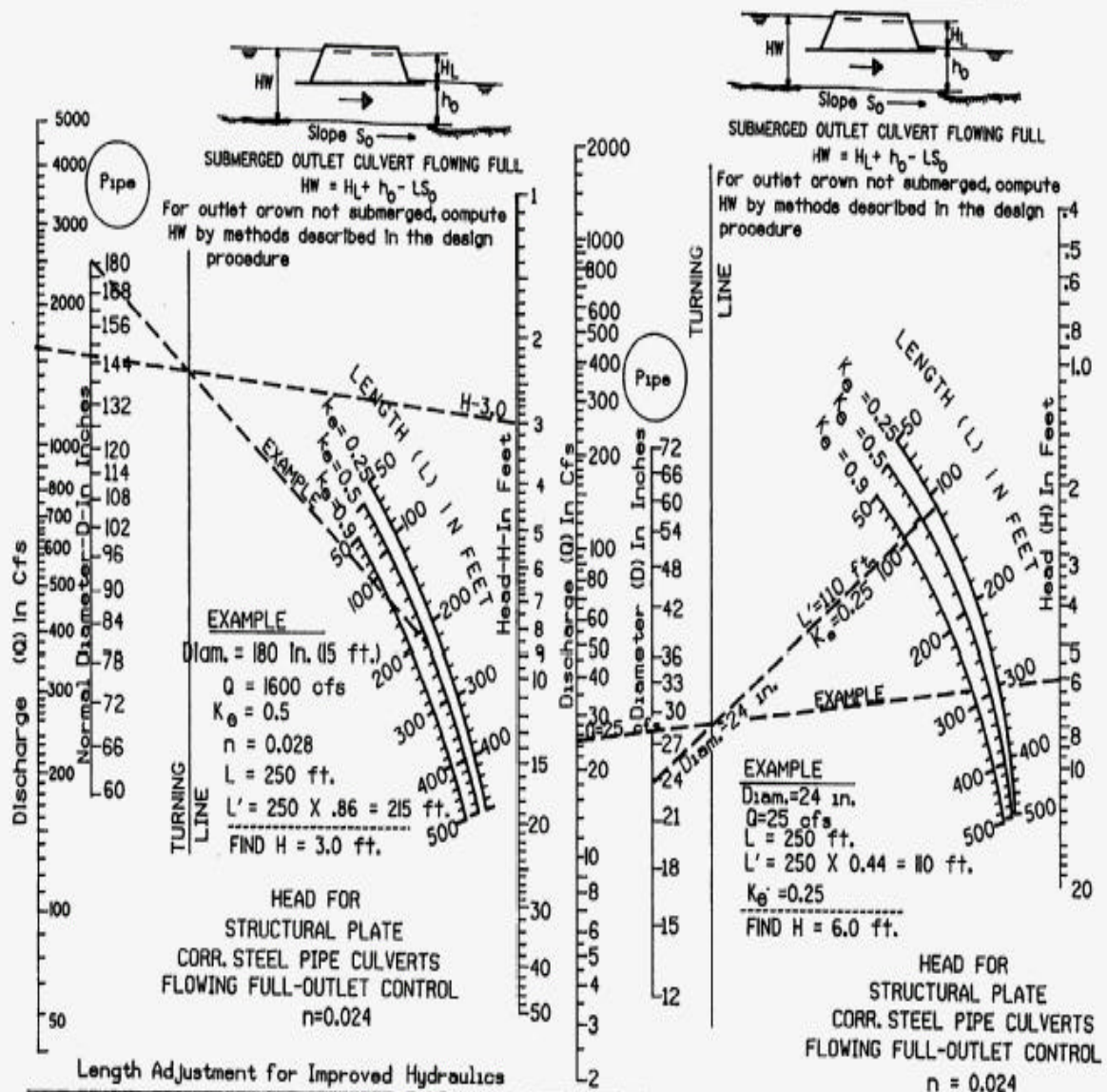


Source: 'Hydraulic Charts for the Selection of Highway Culverts', HEC-5, USDOT, FHA Dec. 1965

**INLET CONTROL NOMOGRAPH**

Figure 7-11 Outlet Control Nomograph, Circular CSP

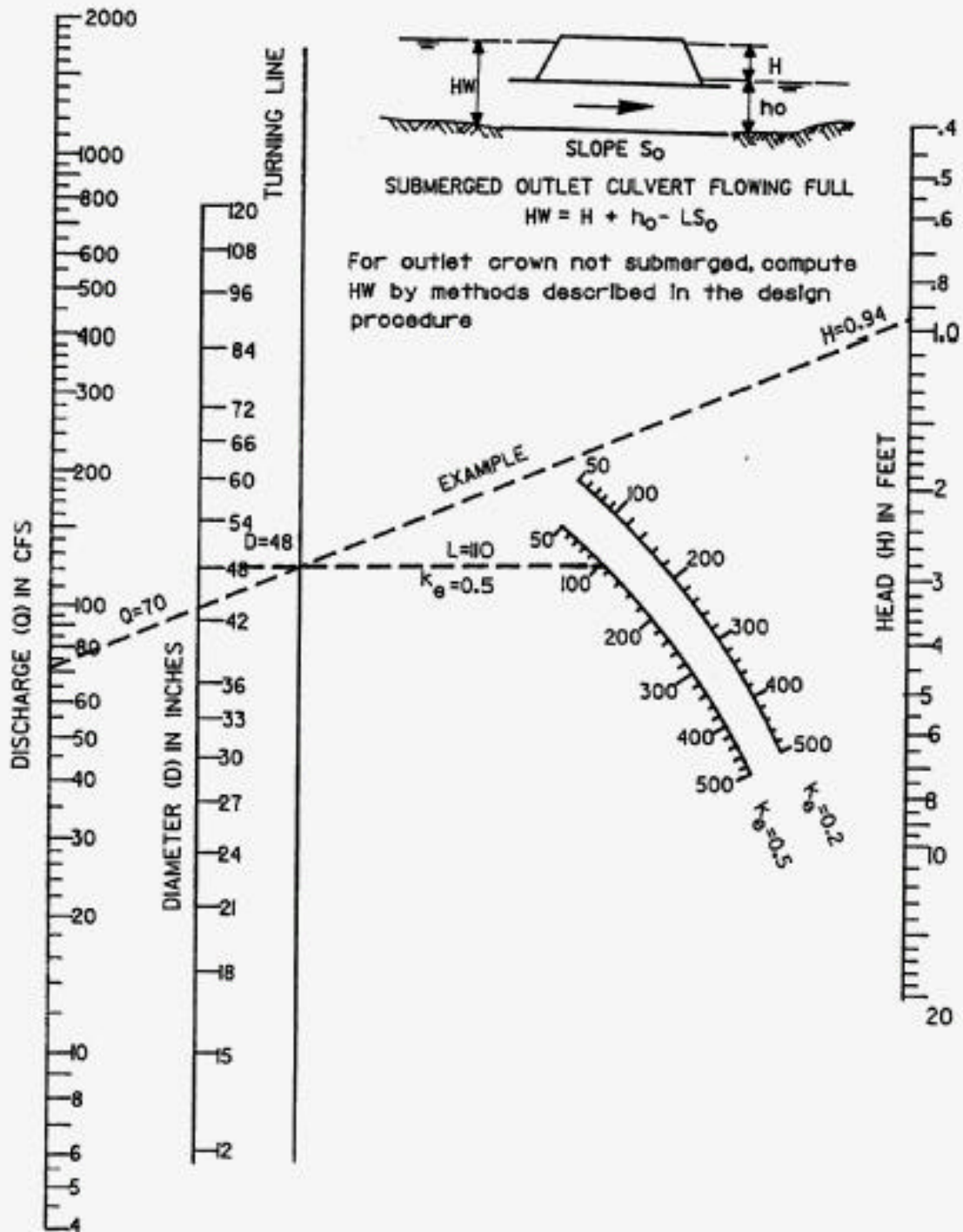
Source: Handbook of Steel Drainage & Highway Construction  
Products, AISI 1971



Pipe Diam. in Feet	Roughness Factor		Length Adjustment Factor $(\frac{n'}{n})^2$
	Curves Based on $n =$	Actual $n' = *$	
5'	.0328	.033	1.0
7'	.0320	.032	1.0
10'	.0311	.030	0.93
15'	.0302	.028	0.86



Figure 7-12 Outlet Control Nomograph, Circular RCP



Source: "Hydraulic Charts for the Selection of Highway Culverts", HEC-5, USDOT, FHA, Dec. 1965

Figure 7-13 Outlet Control Nomograph, Box Culverts

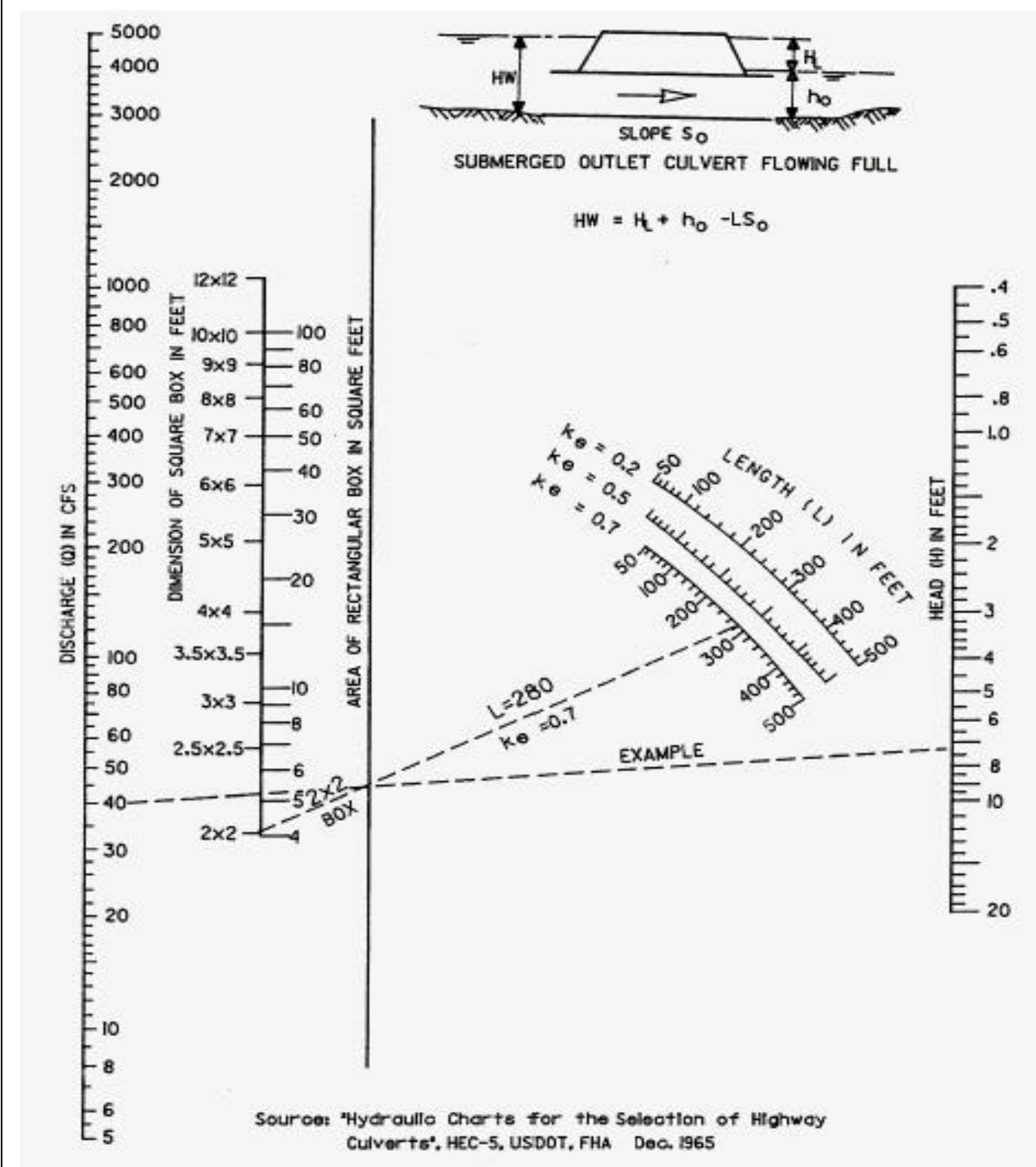




Figure 7-14 Outlet Control Nomograph, CSP Arch

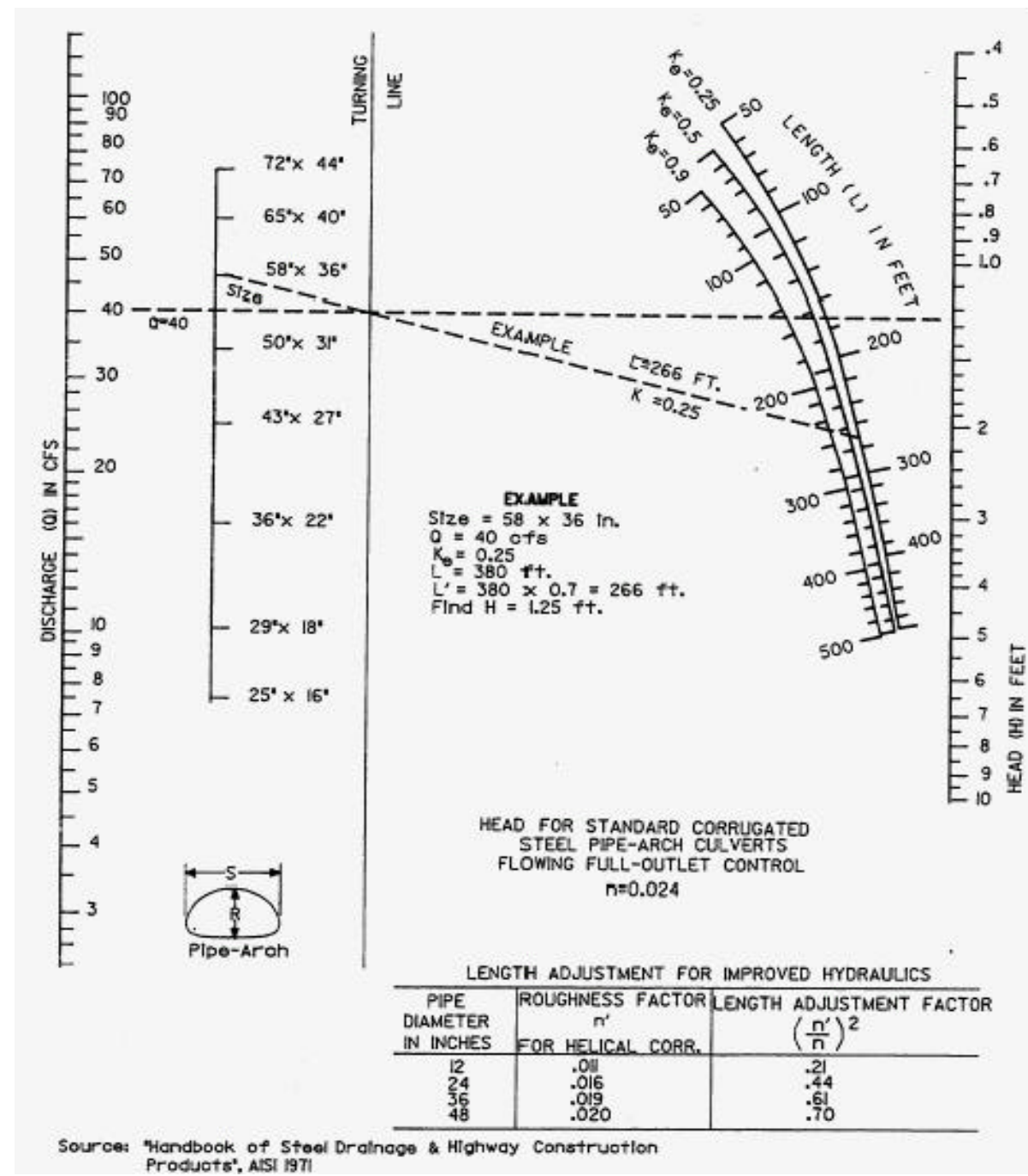
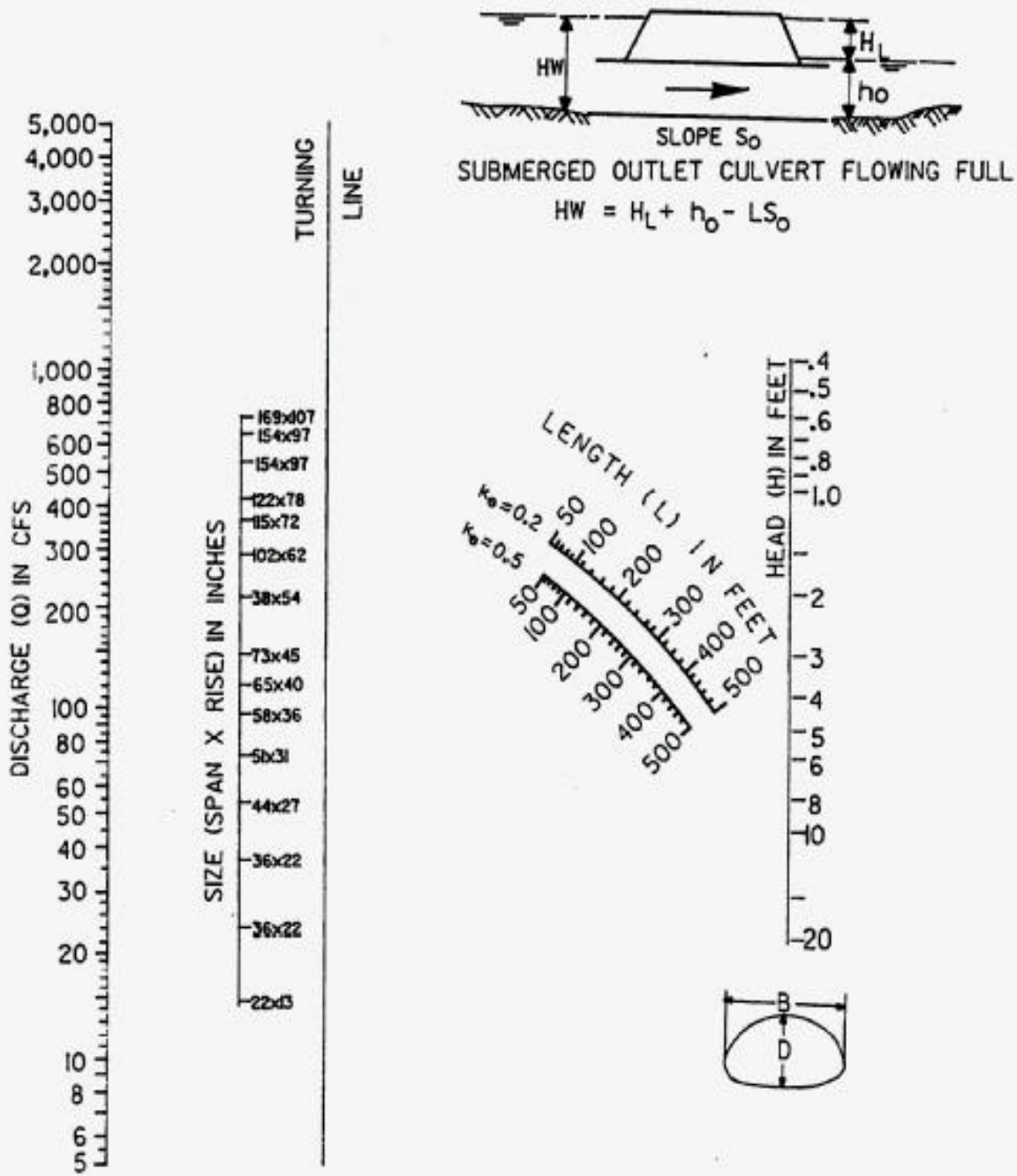


Figure 7-15 Outlet Control Nomograph, RCP Arch



Source: "Concrete Pipe Design Manual", ACPA 1970

Figure 7-16 Outlet Control Nomograph, SPP Arch

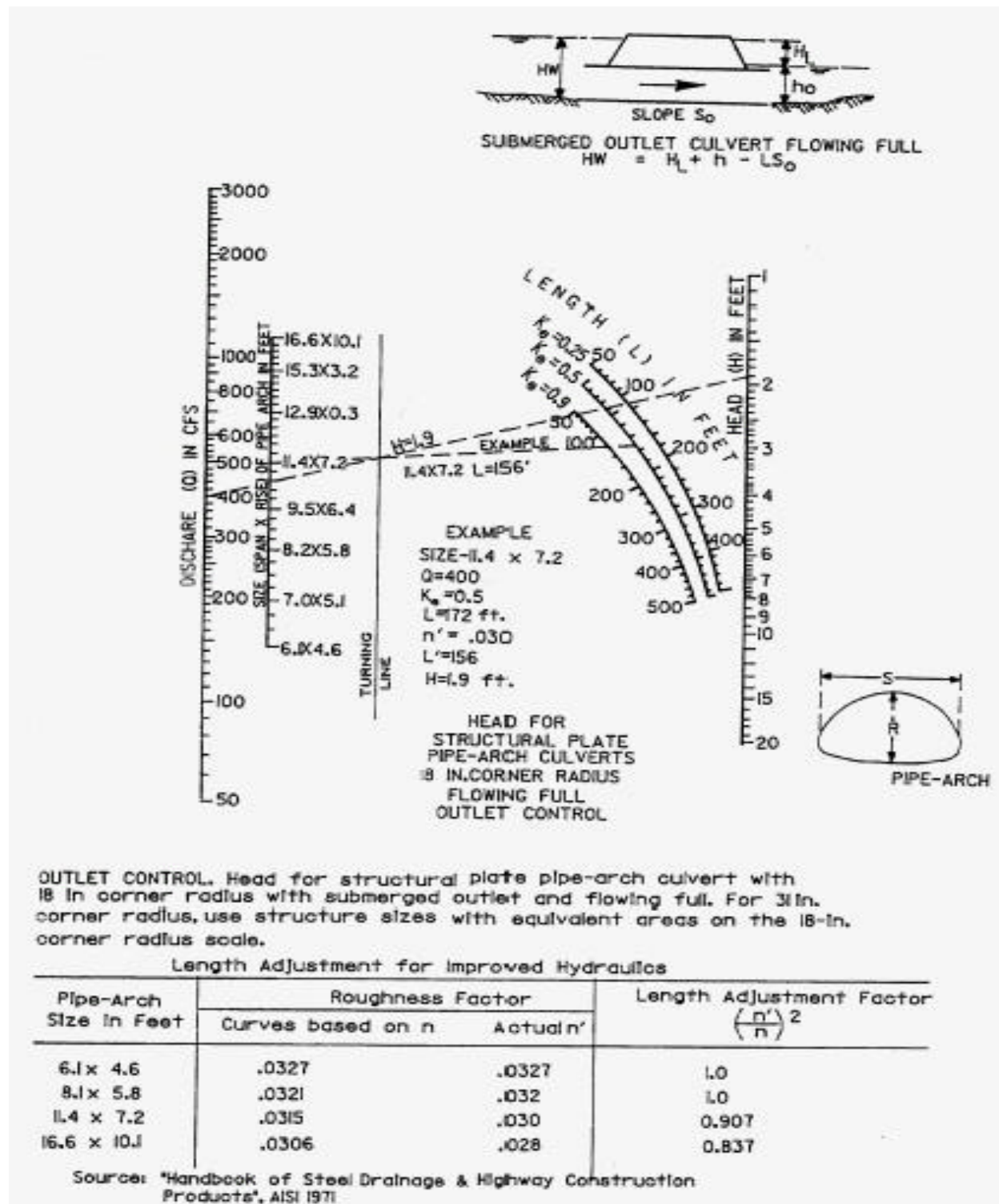


Figure 7-17 Outlet Control Nomograph, RCP Ellipse

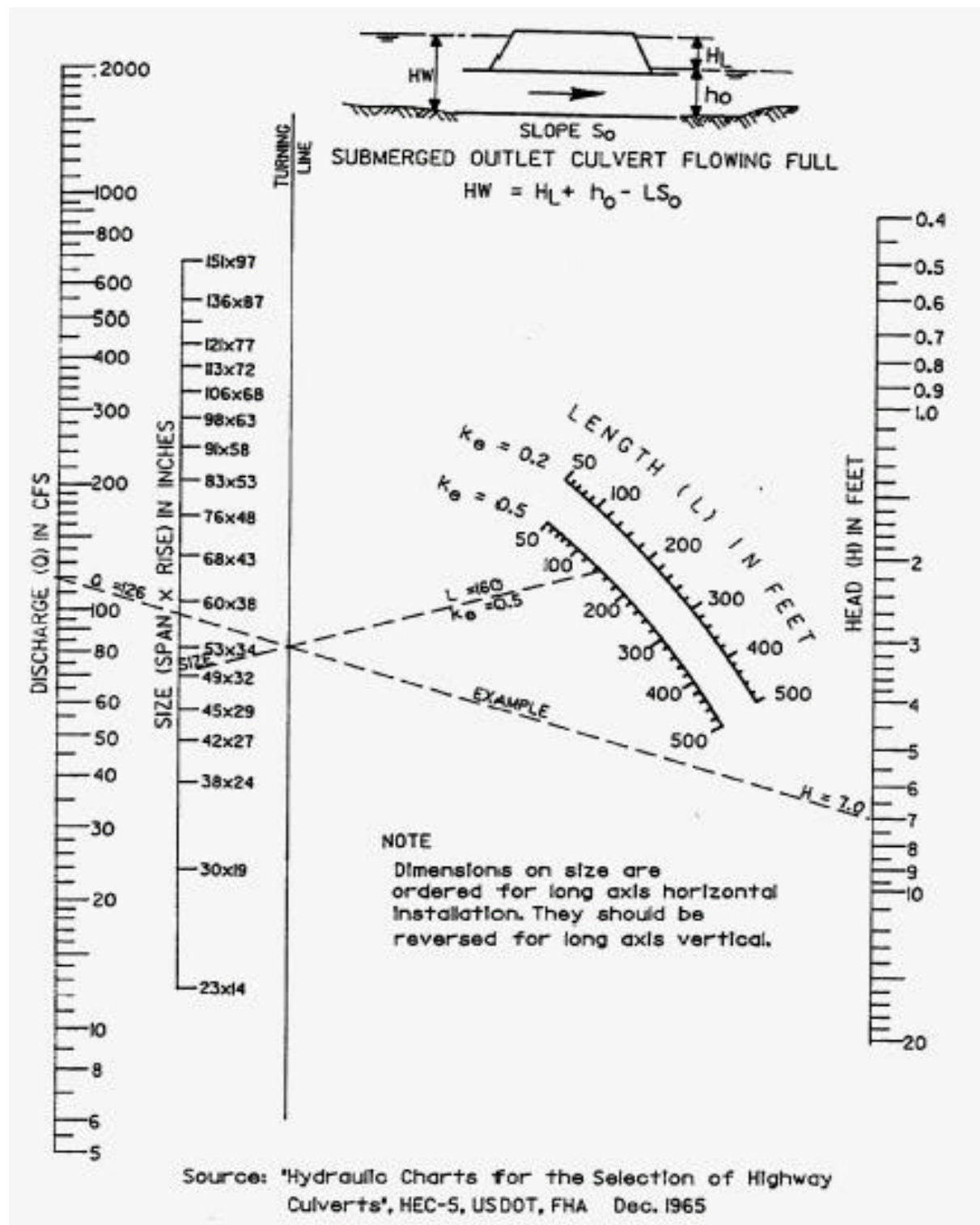


Figure 7-18 Critical Depth Curves, Circular Pipe

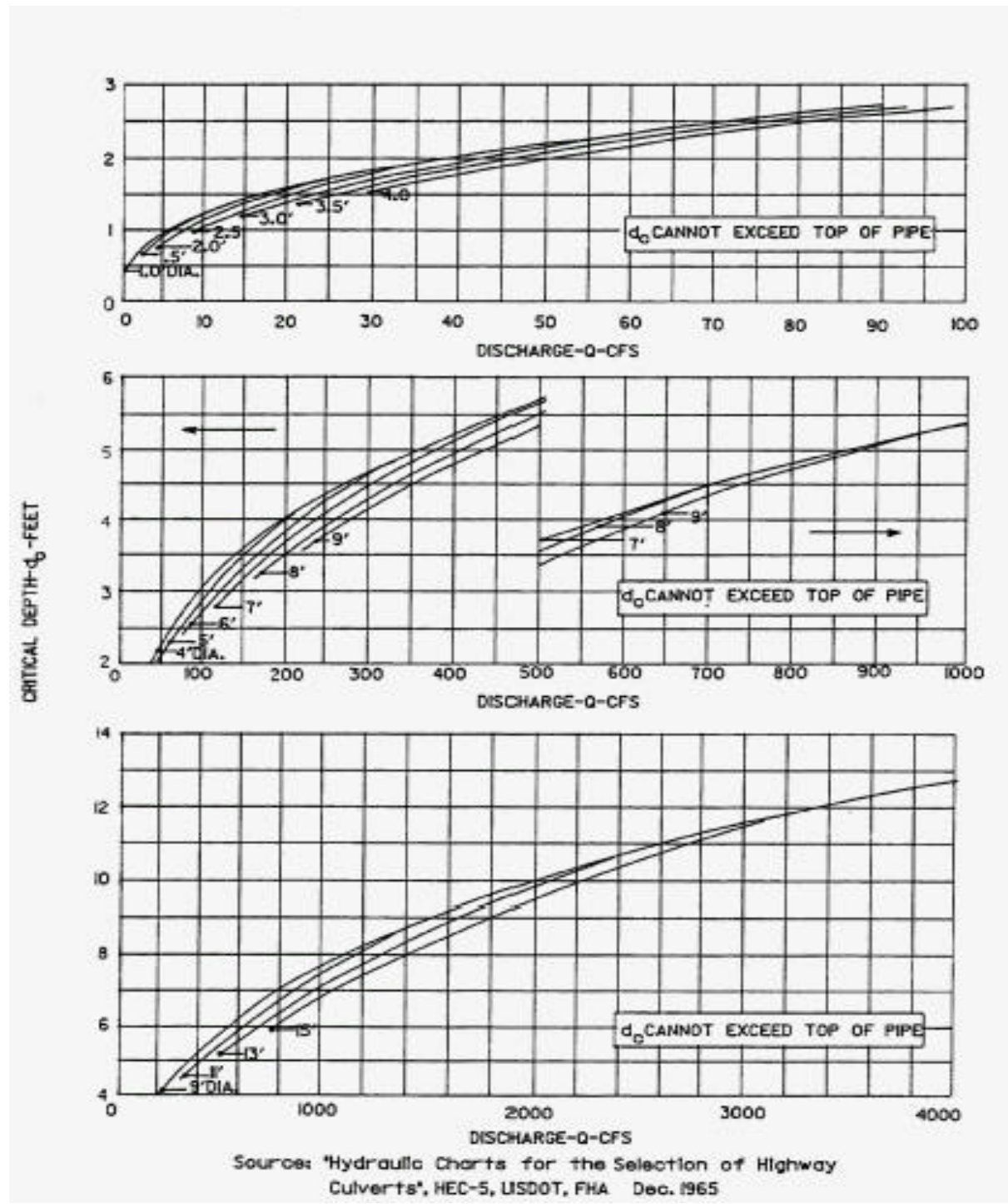
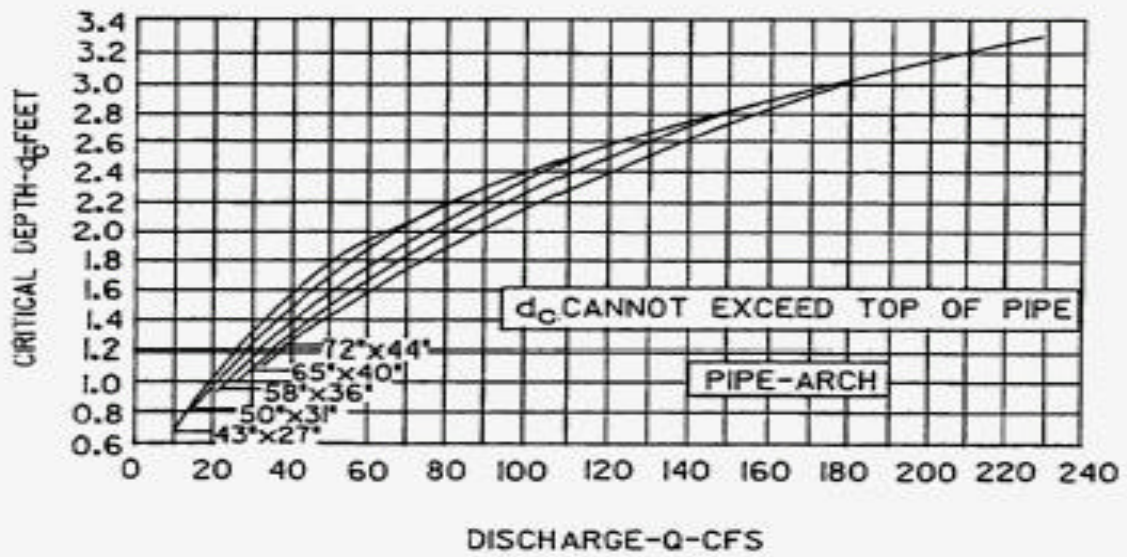
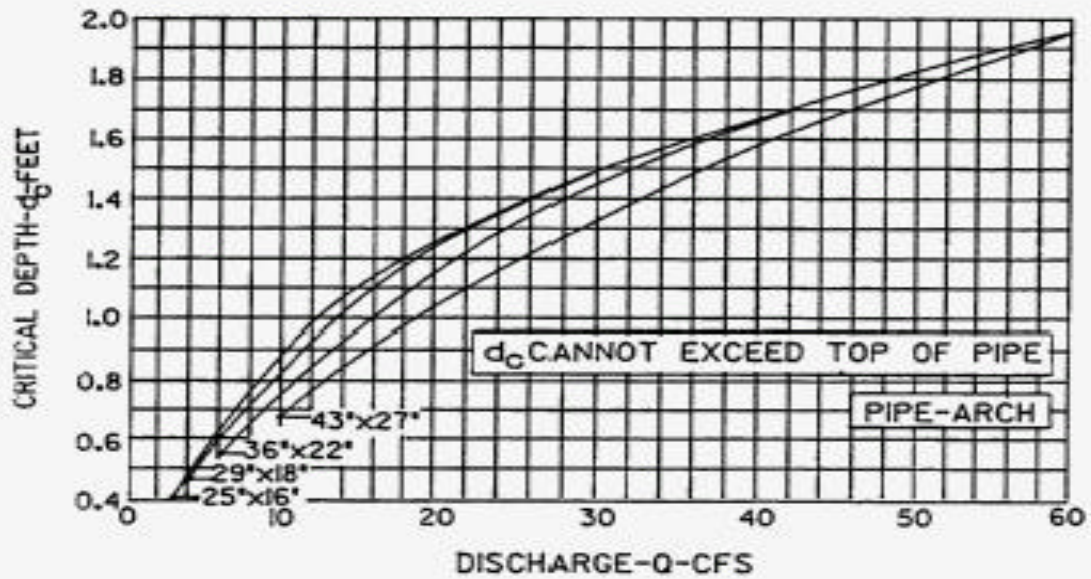




Figure 7-19 Critical Depth Curves, CSP Arch



Source: "Handbook of Steel Drainage & Highway Construction Products", AISI 1971



Figure 7-20 Critical Depth Curves, RCP Arch

Source: "Concrete Pipe Design Manual", ACPA 1970

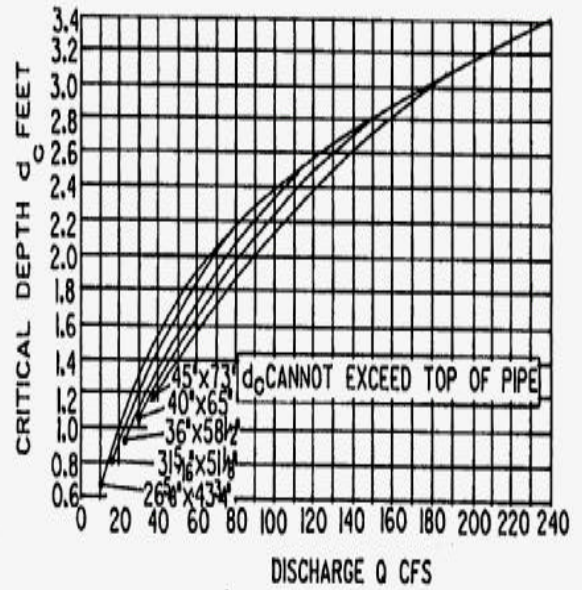
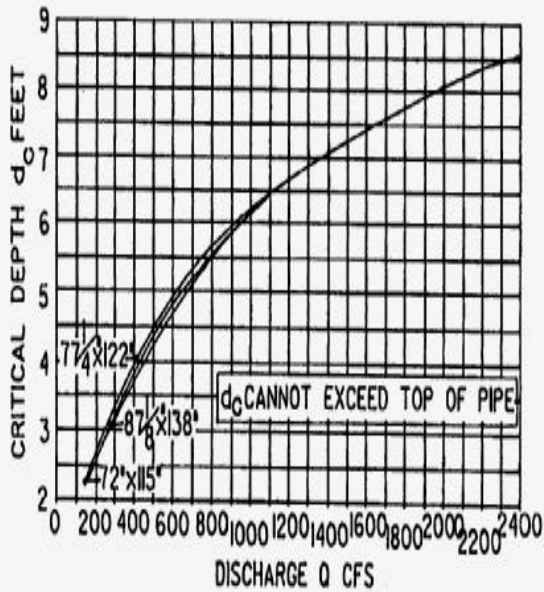
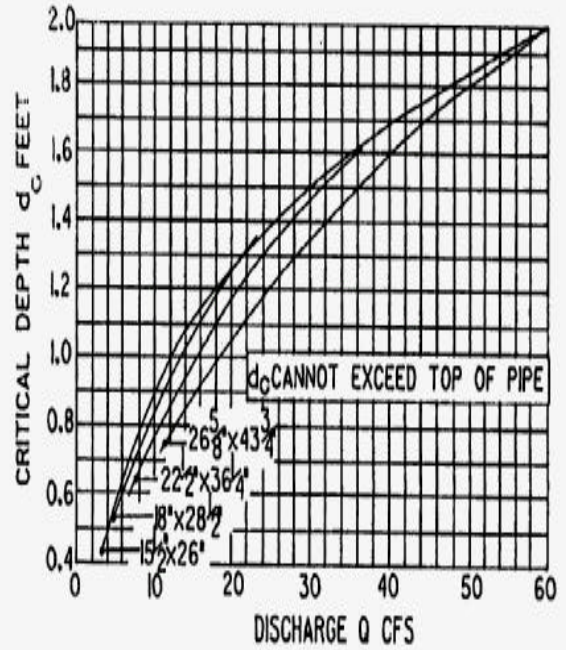
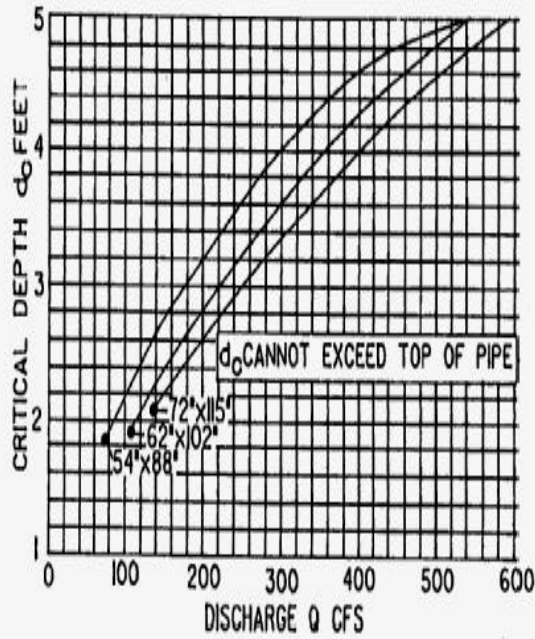
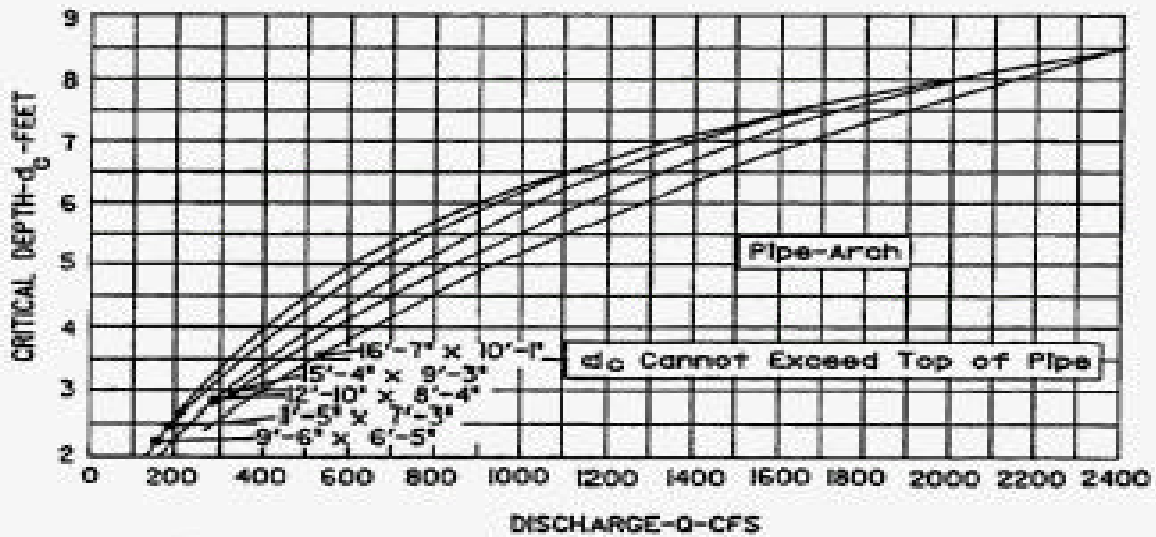
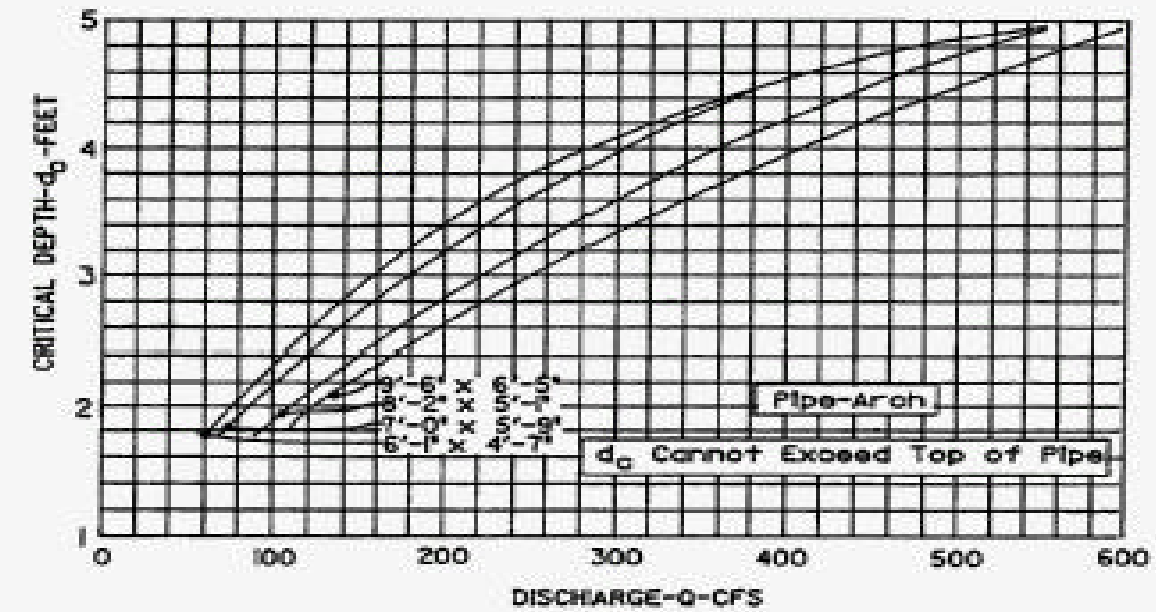
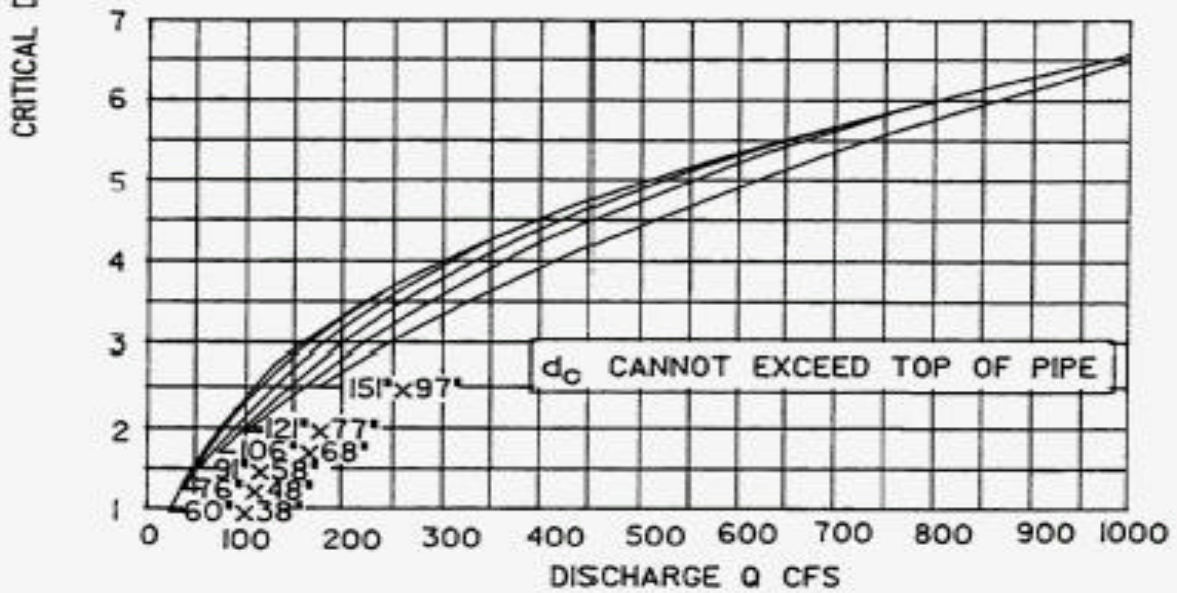
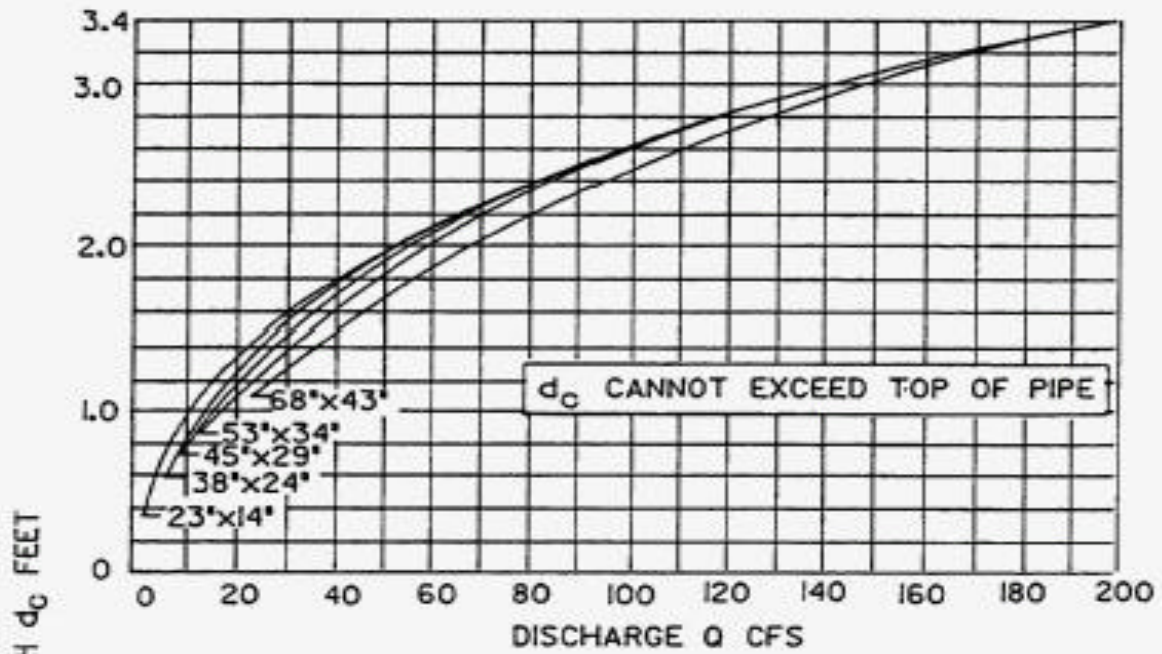


Figure 7-21 Critical Depth Curves, SSP Arch



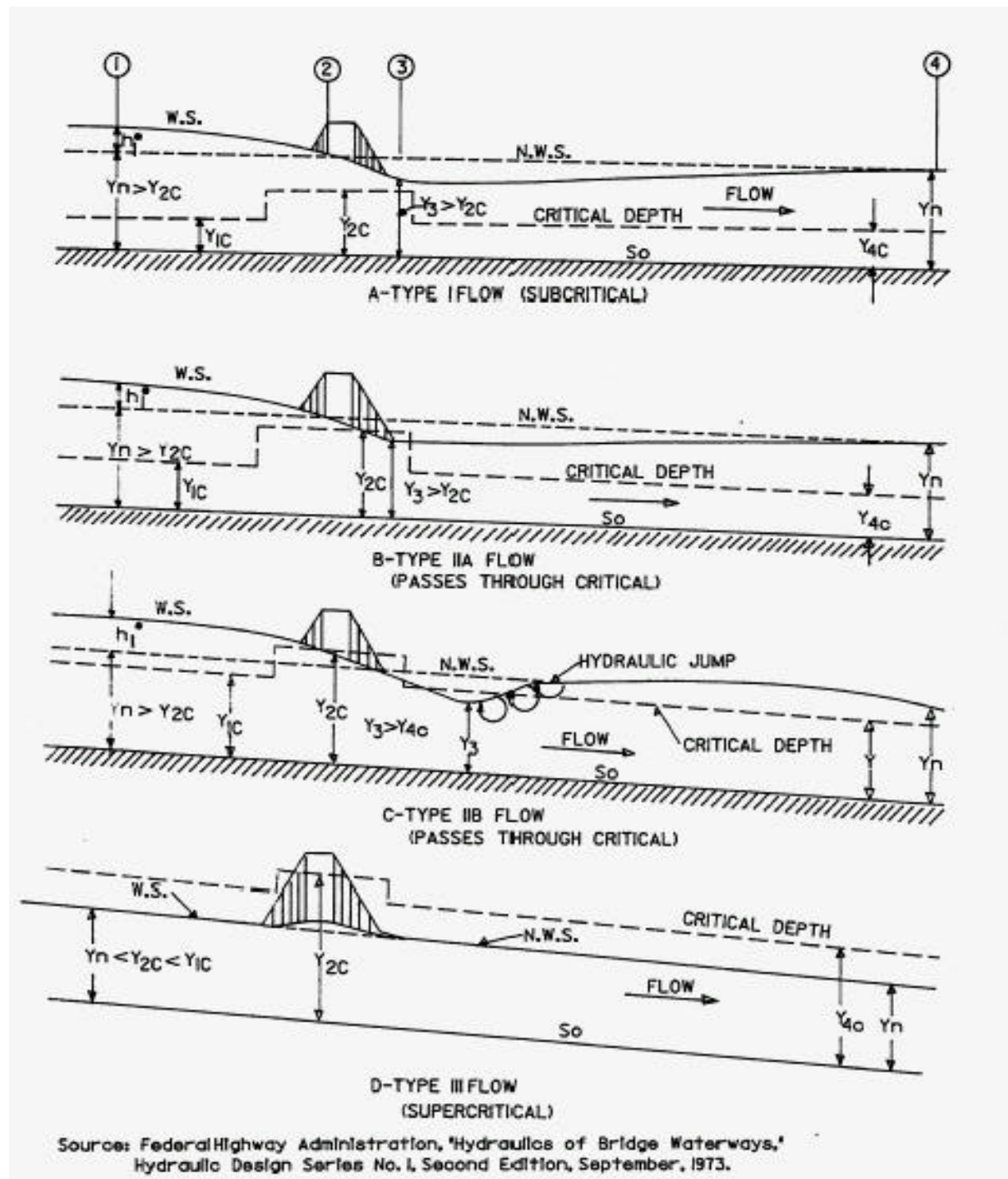
Source: "Handbook of Steel Drainage & Highway Construction Products", AISI 1971

Figure 7-22 Critical Depth Curves, RCP Ellipse



Source: "Concrete Pipe Design Manual", ACPA 1970

Figure 7-23 Types of Flow For Bridge Design





FIGURES FROM SECTION 8

Figure 8-1 Concept of Detention Pond

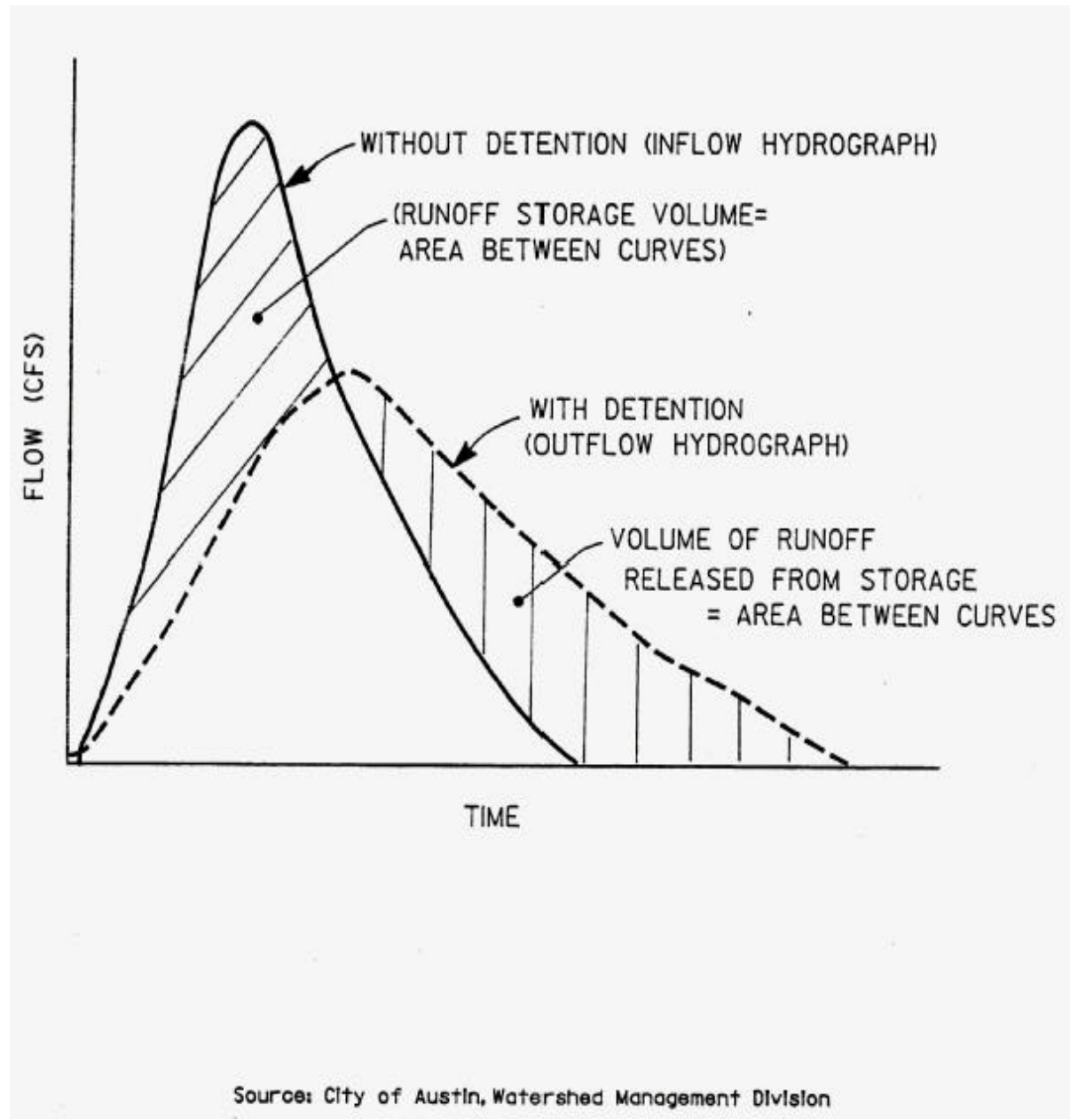


Figure 8-2 Weir and Orifice Flows

