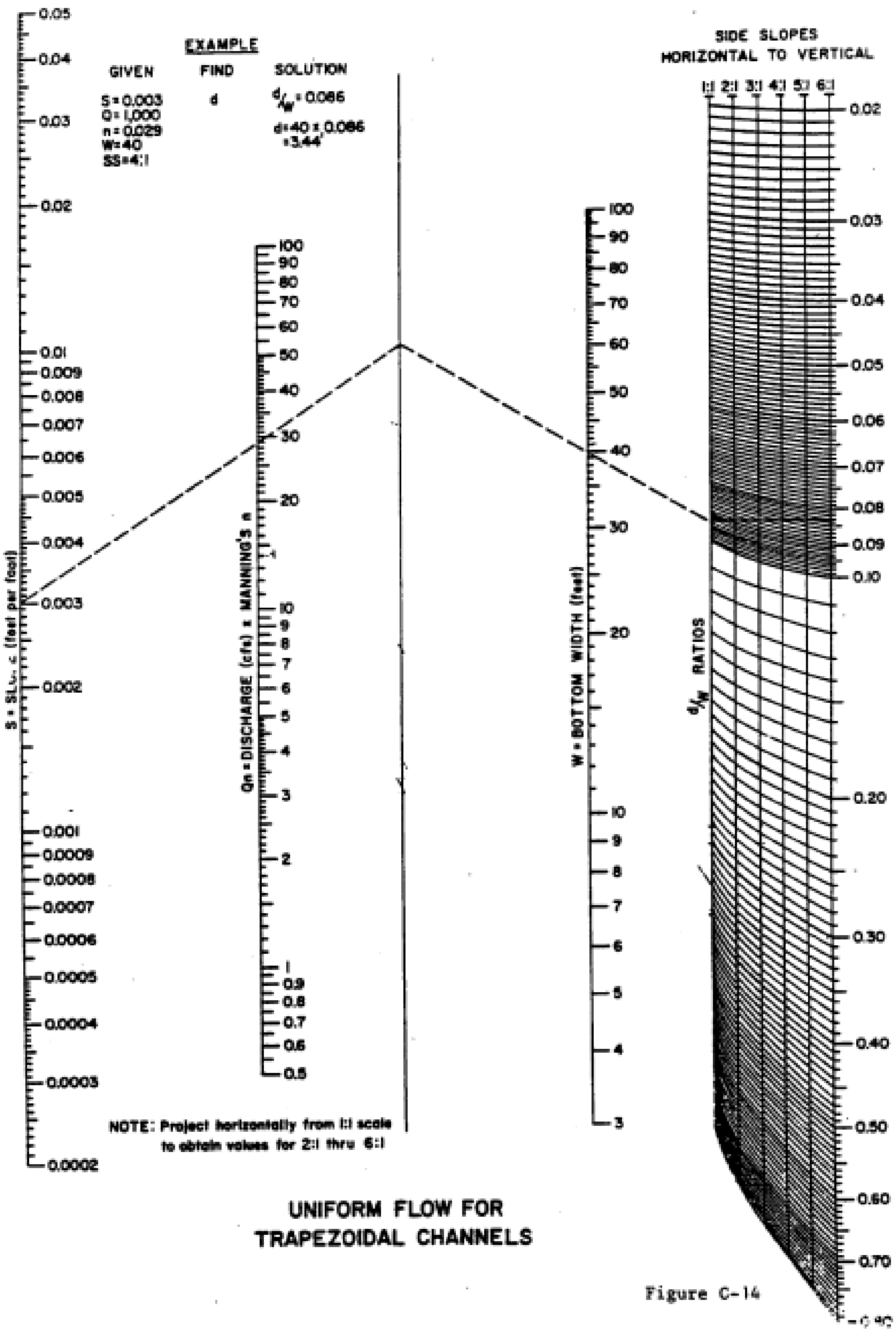


UNIFORM FLOW FOR
TRAPEZOIDAL CHANNELS

Figure C-14

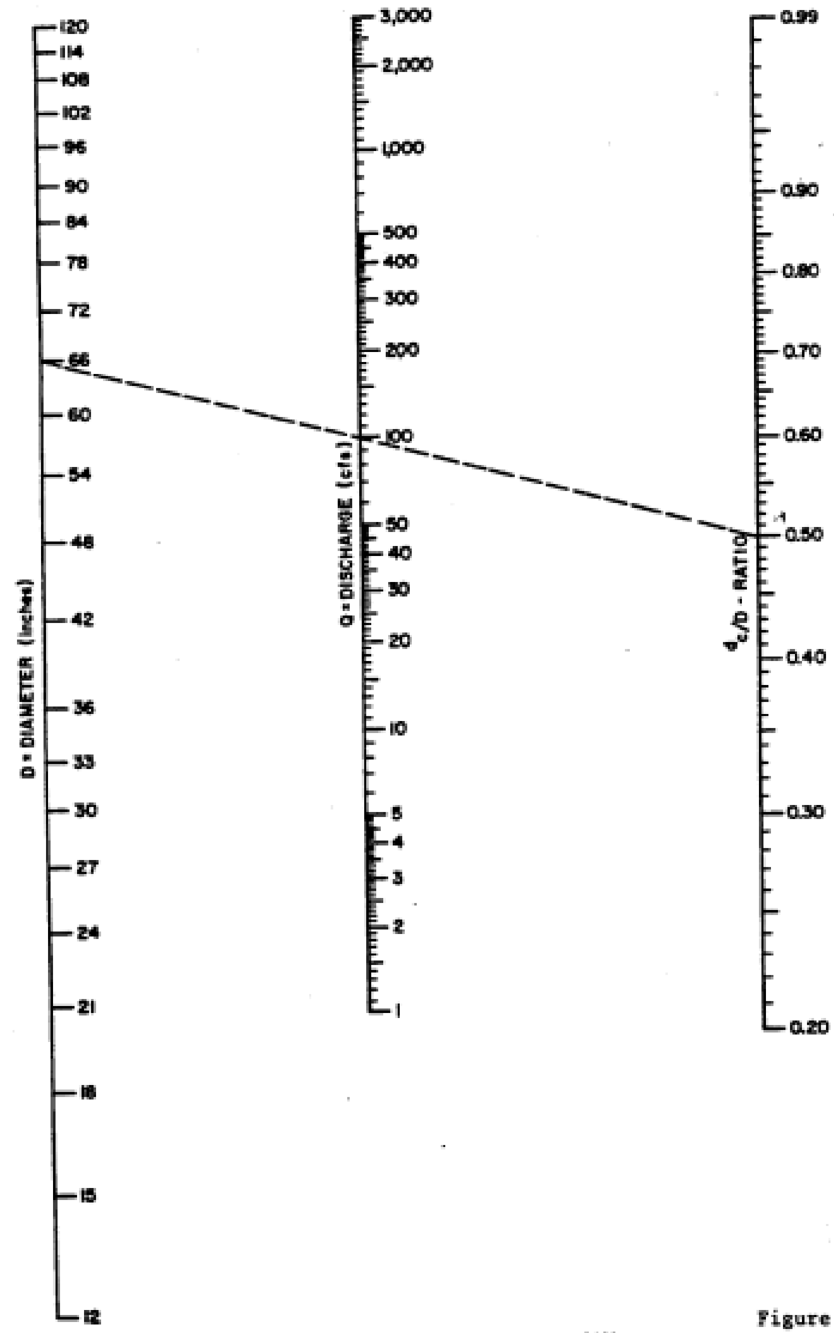


Figure C-15

CRITICAL DEPTH OF FLOW
FOR CIRCULAR CONDUITS

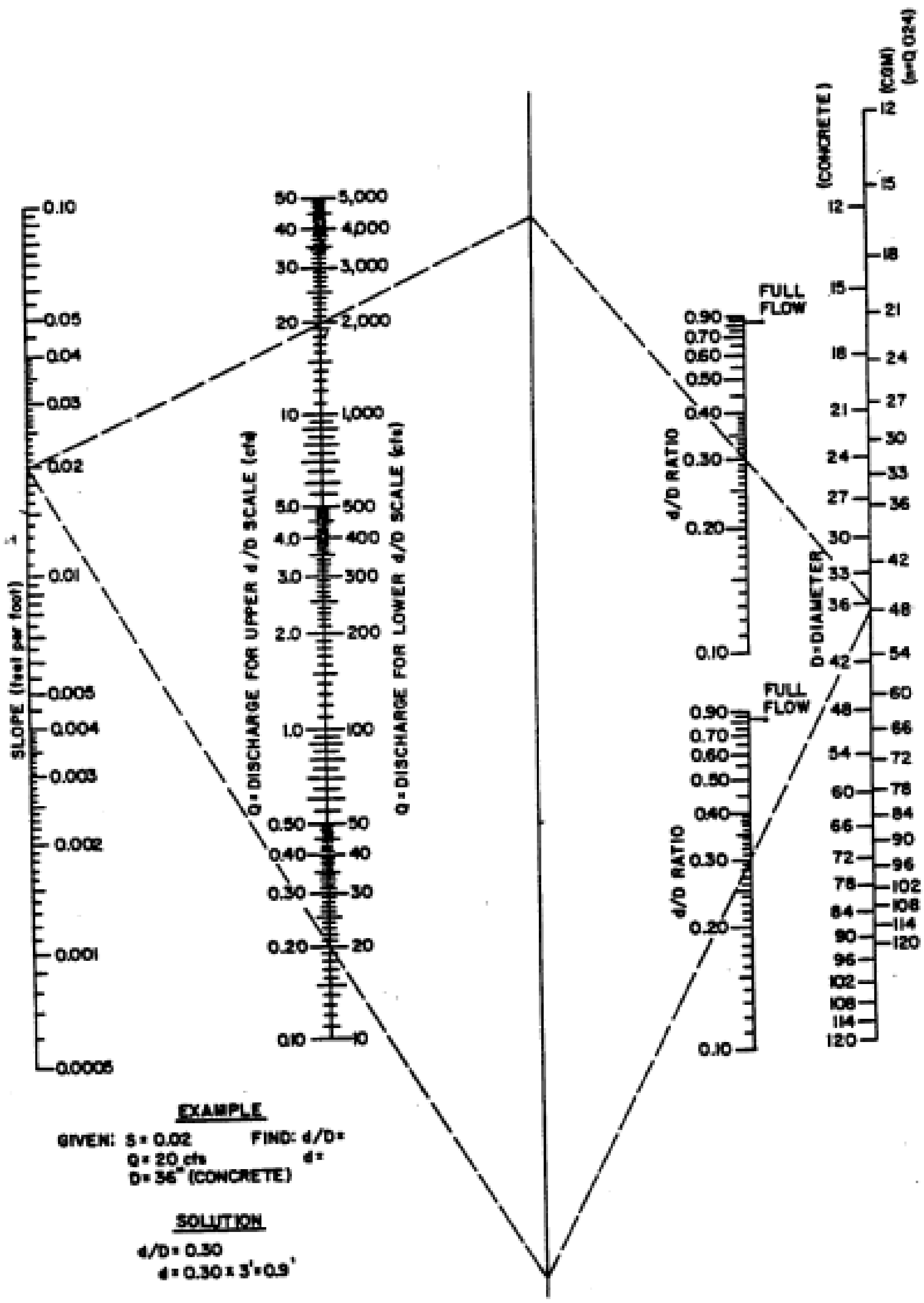


Figure C-16

UNIFORM FLOW FOR PIPE CULVERTS

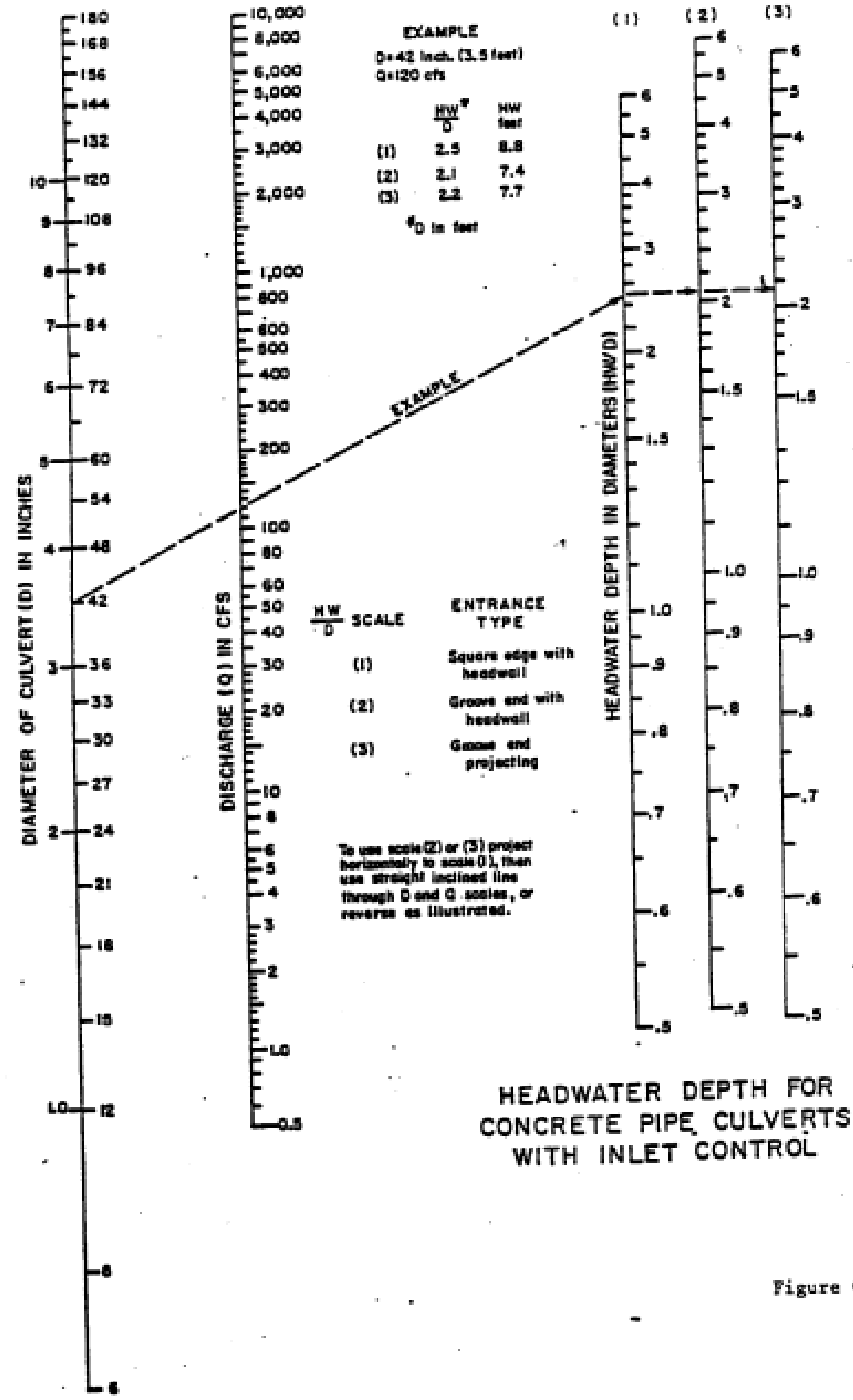
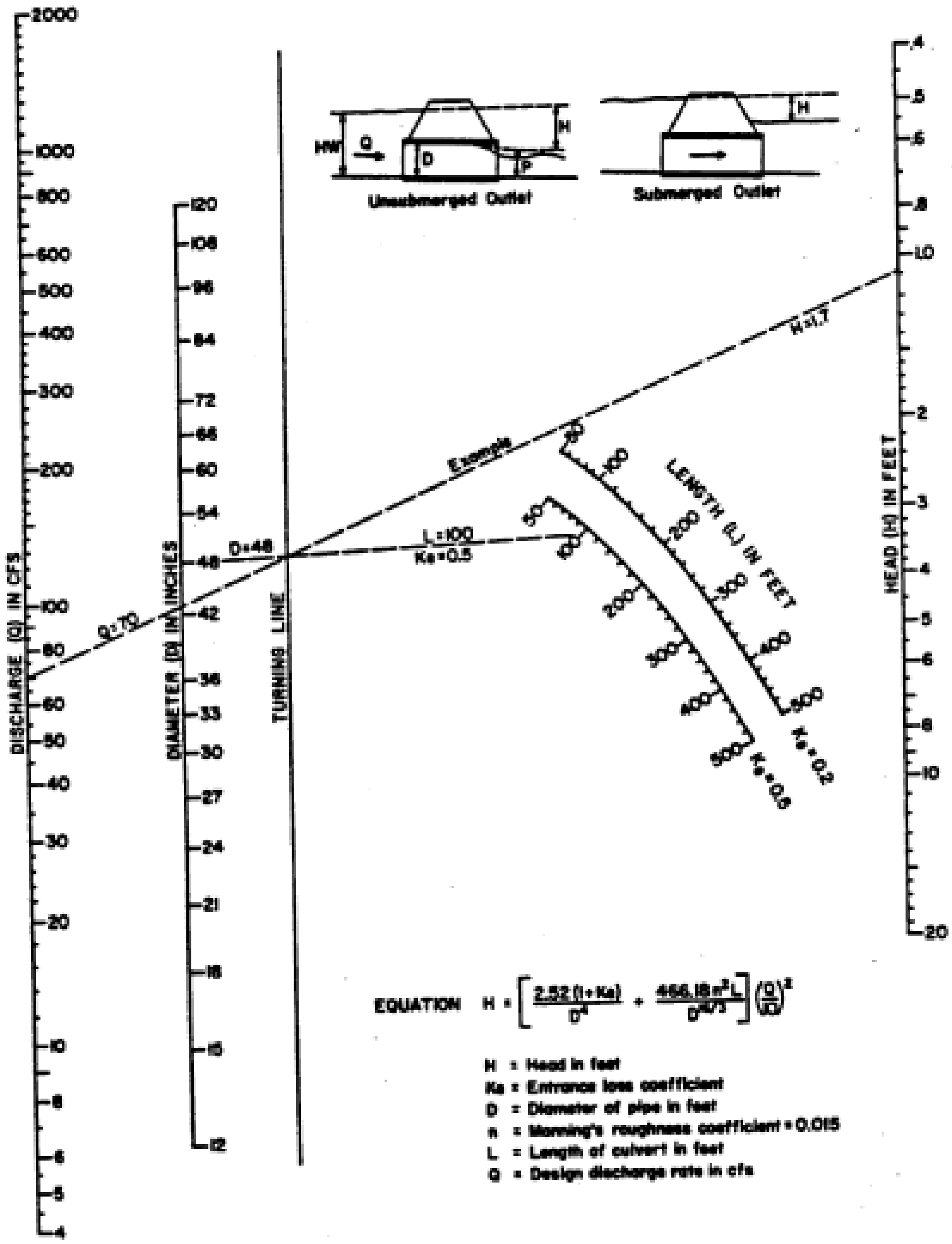

EXAMPLE
D=42 inch. (3.5 feet)
Q=120 cfs
HW* / D   HW feet
(1) 2.5 8.8
(2) 2.1 7.4
(3) 2.2 7.7
*D in feet
DIAMETER OF CULVERT (D) IN INCHES
DISCHARGE (Q) IN CFS
HEADWATER DEPTH IN DIAMETERS (HW/D)
EXAMPLE
(1)
(2)
(3)
HW/D SCALE
ENTRANCE TYPE
(1) Square edge with headwall
(2) Groove end with headwall
(3) Groove end projecting
To use scale (2) or (3) project horizontally to scale (1), then use straight inclined line through D and Q scales, or reverse as illustrated.
HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

Figure C-17



HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL

Figure C-18

HEADWATER DEPTH FOR C.M. PIPE CULVERTS WITH INLET CONTROL

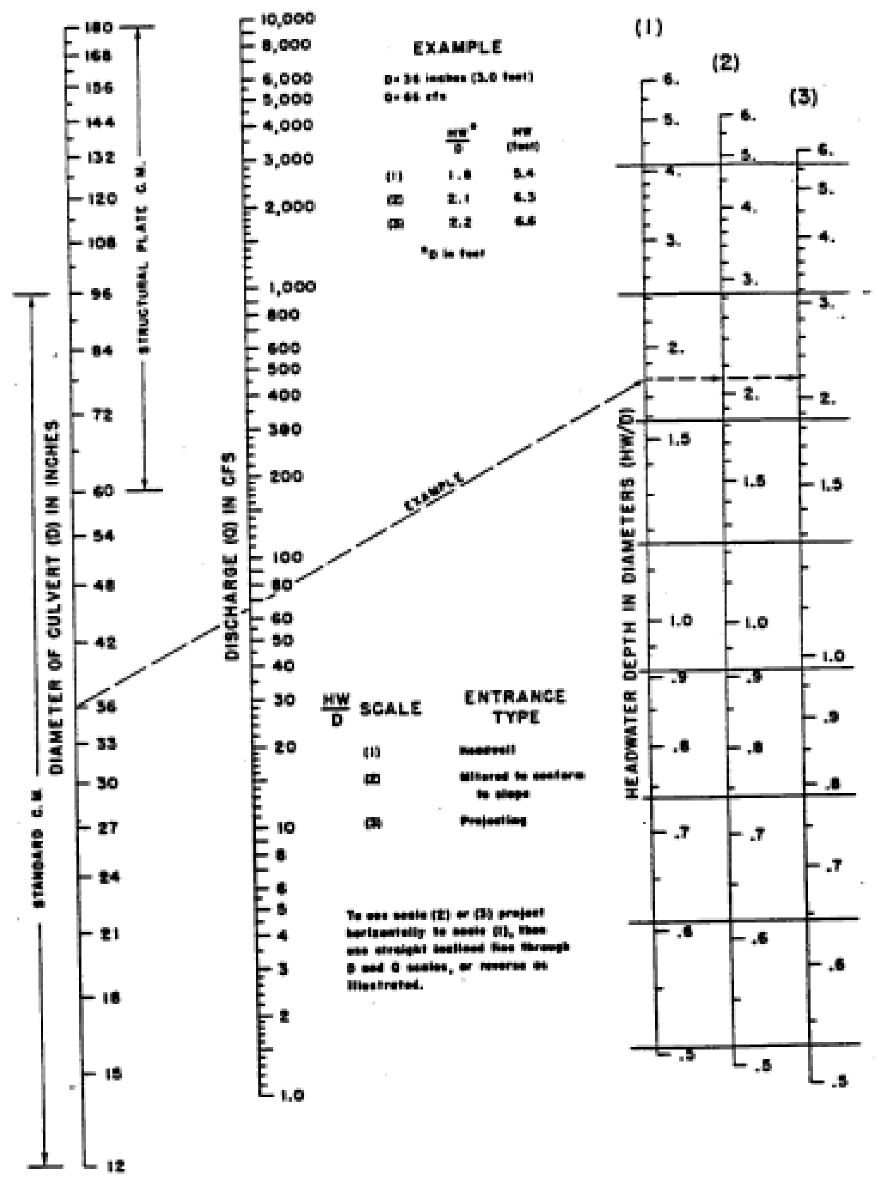


Figure C-19

COLUMBIA, MO.

HEAD FOR STANDARD C.M. PIPE CULVERTS FLOWING FULL

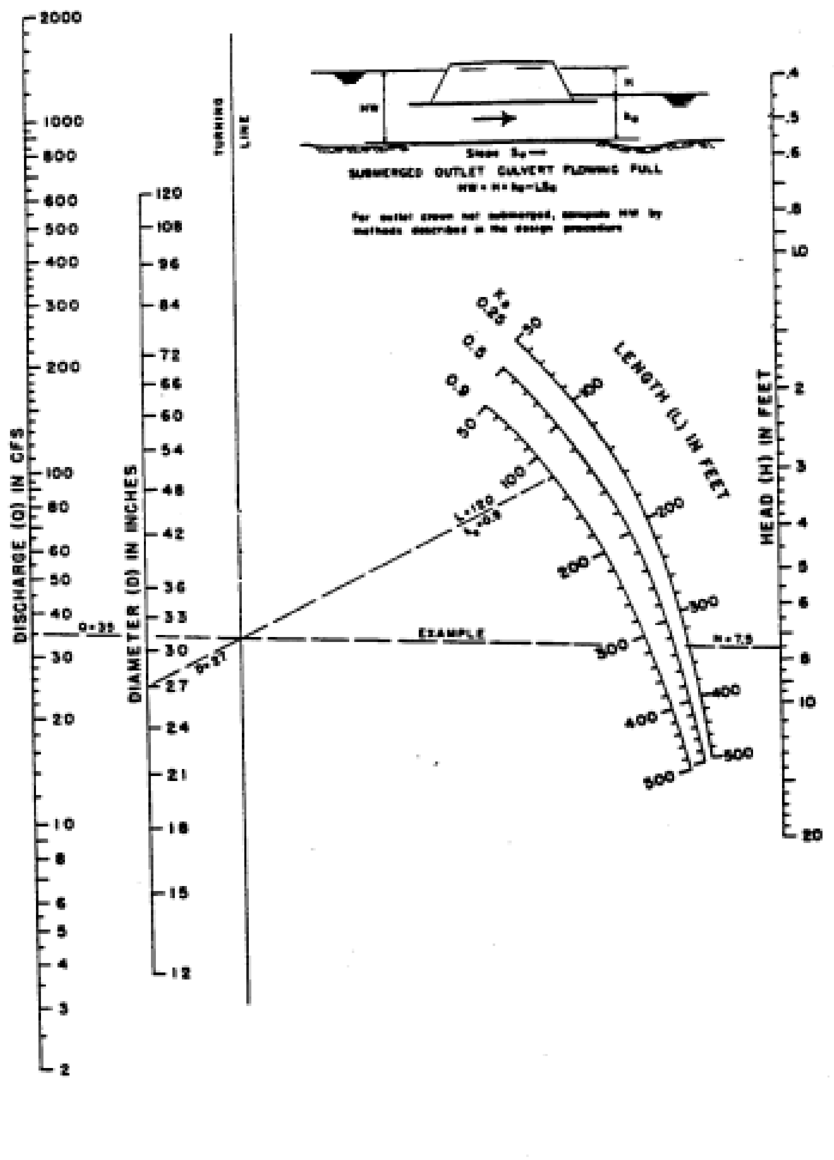
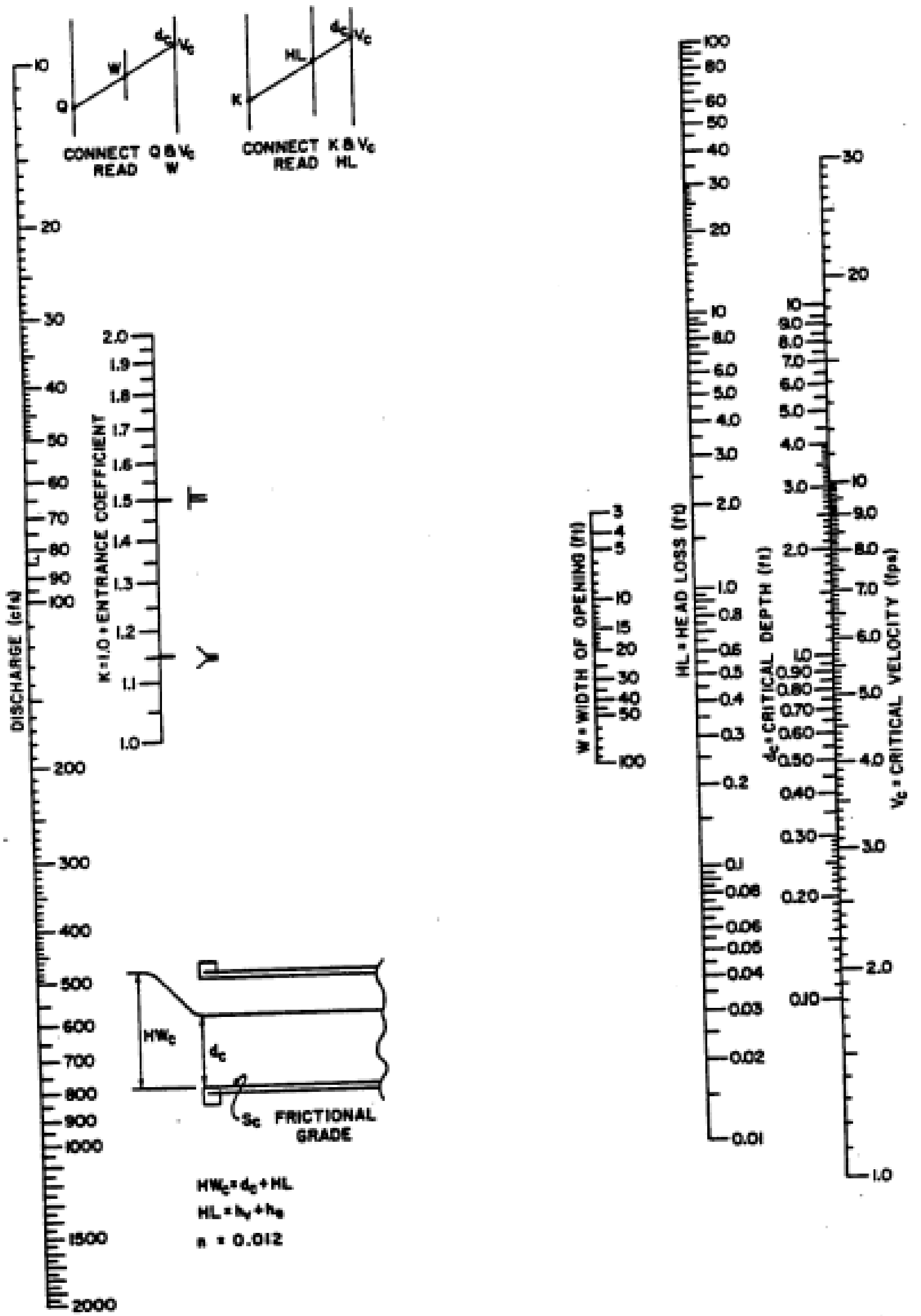


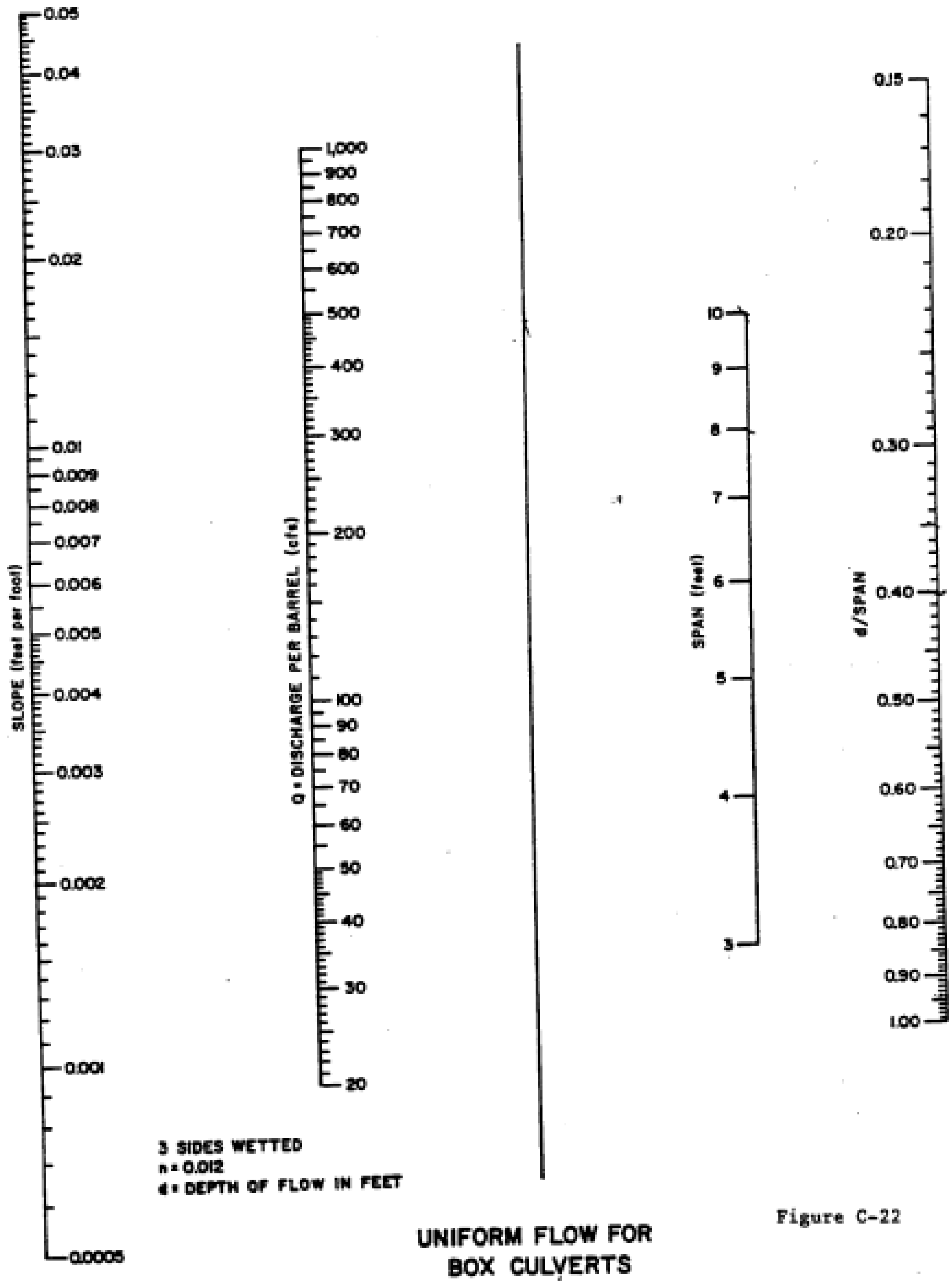
Figure C-20

COLUMBIA, MO.



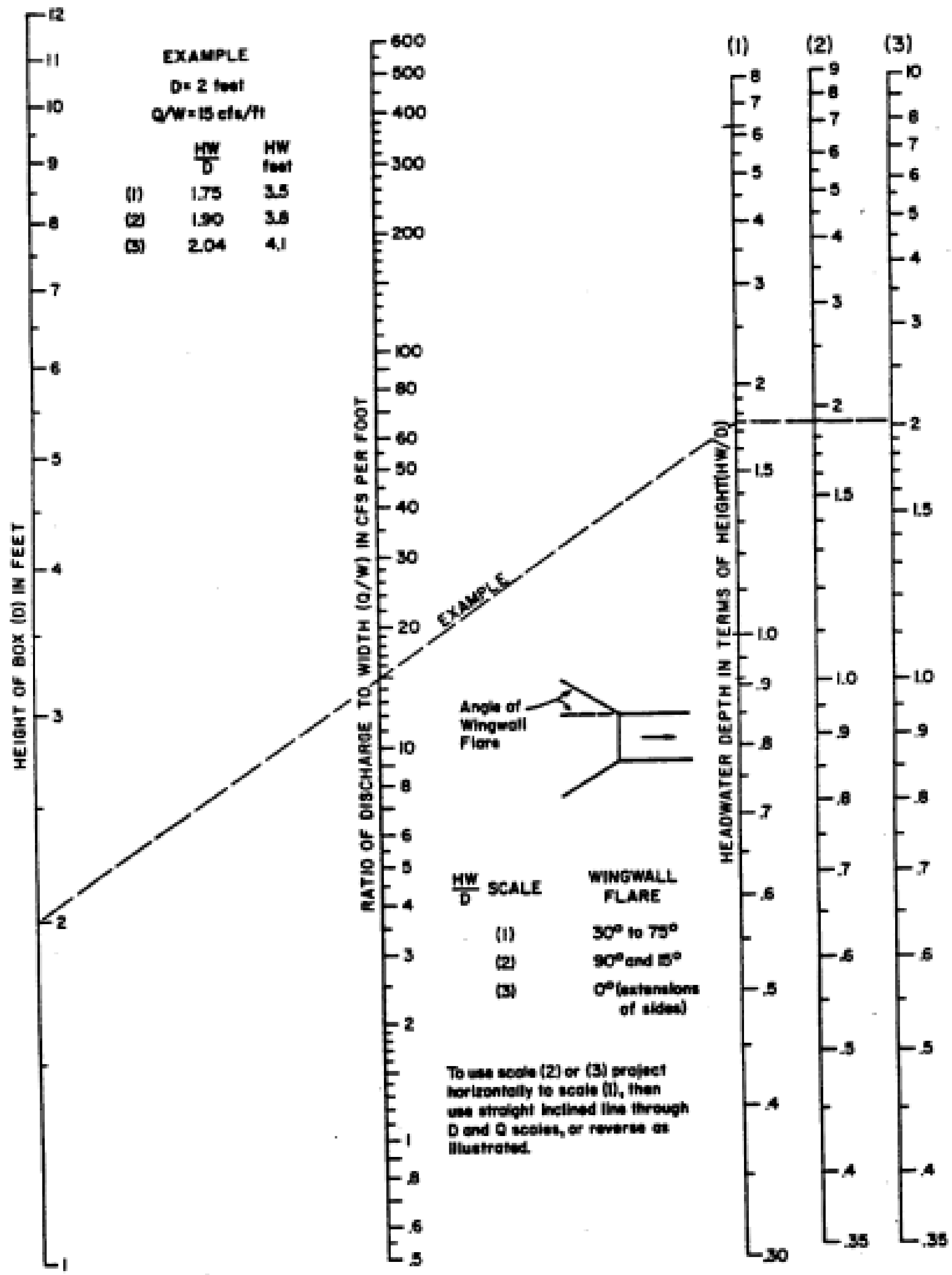
CRITICAL FLOW FOR BOX CULVERTS

Figure C-21



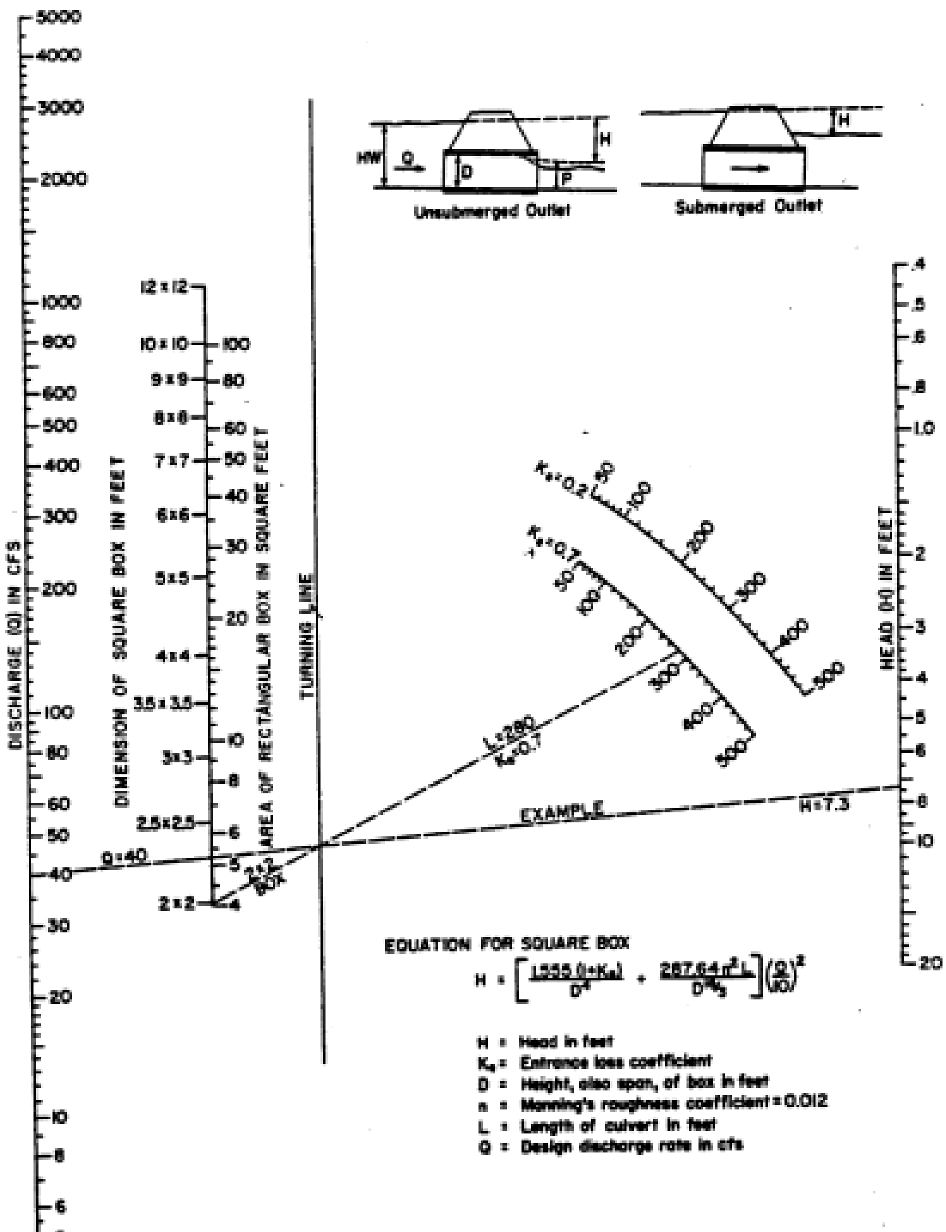
UNIFORM FLOW FOR BOX CULVERTS

Figure C-22



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

Figure C-23



HEAD FOR CONCRETE BOX
CULVERTS FLOWING FULL

Figure C-24

TABLE C-1
RATIONAL METHOD RUNOFF COEFFICIENTS BY LAND USE TYPE
For Use in Q=CiA

Runoff Coefficient (C) Return Period

Land Use District and Zoning	% I.C.**	Land Slope	6* Mo.	1* Yr.	2 Yr.	5 Yr.	10 Yr.	25 Yr.	50 Yr.	100 Yr.
Low Density		0-2%	.28	.30	.33	.36	.38	.42	.44	.46
Residential	25	2-7%	.31	.34	.37	.40	.43	.47	.50	.52
R1, R2		7%+	.35	.38	.41	.45	.48	.52	.55	.58
High Density		0-2%	.35	.38	.41	.45	.48	.52	.55	.58
Residential	45	2-7%	.39	.42	.45	.50	.53	.57	.60	.63
R3,R4,PUD		7%+	.43	.47	.50	.54	.58	.62	.65	.69
Mobile Home		0-2%	.39	.42	.45	.50	.53	.57	.60	.63
Park	60	2-7%	.43	.47	.50	.54	.58	.62	.65	.69
RMH		7%+	.48	.51	.55	.59	.63	.67	.71	.74
Commercial		0-2%	.65	.69	.73	.78	.83	.88	.91	.95
C-2, C-P	95	2-7%	.68	.72	.76	.81	.85	.90	.93	.97
		7%+	.72	.75	.79	.84	.87	.93	.96	.99
Commercial		0-2%	.56	.60	.64	.69	.73	.77	.81	.85
C-1, C-3	80	2-7%	.61	.65	.69	.74	.78	.83	.86	.90
		7%+	.65	.69	.73	.78	.83	.88	.91	.95
Industrial		0-2%	.48	.51	.55	.59	.63	.67	.71	.74
M-1, M-C,	70	2-7%	.52	.56	.60	.64	.68	.72	.76	.79
M-R		7%+	.56	.60	.64	.69	.73	.77	.81	.85
Office		0-2%	.39	.42	.45	.50	.53	.57	.60	.63
0-1, 0-2	60	2-7%	.43	.47	.50	.54	.58	.62	.65	.69
		7%+	.48	.51	.55	.59	.63	.67	.71	.74

*Special Note: All design storms utilizing wet antecedent conditions will use a "C" value not less than that for a 10-year return period.

**I.C. refers to impervious cover

TABLE C-2
RATIONAL METHOD RUNOFF COEFFICIENTS FOR COMPOSITE ANALYSIS
FOR USE IN Q = CiA

Character of Surface	Runoff Coefficients (C) Return Period							
	6 Mo.	1 Yr.	2 Yrs.	5 Yrs.	10 Yrs.	25 Yrs.	50 Yrs.	100 Yrs.
Streets:								
Asphaltic .70	.74	.78	.81	.85	.89	.93	.96	
Concrete	.76	.78	.82	.87	.90	.94	.97	.99
Drives and Walks								
(Concrete) .76	.78	.82	.87	.90	.94	.97	.99	
Roofs	.72	.75	.79	.84	.87	.93	.96	.99
Lawns, Clay Soil-Light (Loams)								
Flat 0-2%	.13	.14	.15	.16	.17	.19	.20	.21
Average 2-7%	.15	.16	.17	.18	.20	.21	.23	.24
Steep 7%+	.23	.24	.25	.26	.27	.29	.32	.34
Lawns, Clay Soil (Heavy)								
Flat 0.2%	.14	.15	.16	.18	.19	.20	.21	.22
Average 2-7%	.17	.18	.20	.21	.23	.24	.26	.27
Steep 7%+	.23	.25	.27	.29	.31	.33	.35	.37
Undeveloped Woodlands and Pastureland								
Clay Soils - Light (Loams)								
Flat 0-2%	.19	.21	.23	.25	.27	.29	.31	.33
Average 2-7%	.26	.28	.31	.34	.37	.40	.43	.46
Steep 7%+	.34	.37	.40	.44	.47	.51	.55	.58
Clay Soil - Heavy								
Flat 0-2%	.23	.25	.27	.29	.31	.33	.35	.37
Average 2-7%	.30	.32	.35	.38	.41	.44	.47	.50
Steed 7%+	.38	.41	.44	.48	.51	.55	.59	.62

TABLE C-3
ROUGHNESS COEFFICIENTS

Conduit Material	Mannings N
Closed Conduits	
Concrete	0.015
Corrugated metal	0.025
Corrugated metal with paved invert	0.019
Plastic pipe	0.013
Vitrified clay pipe	0.015
Open Channels	
Lined channels	
Asphalt	0.015
Brick	0.015
Concrete	0.015
Rubble or riprap	0.030
Vegetal	0.035
Excavated or dredged	
Earth, straight and uniform	0.025
Earth, winding	0.030
Rock	0.040
Unmaintained	0.050-0.140
Natural channels	
Regular section	0.050
Irregular section with pools	0.070

TABLE C-4
RETURN PERIOD

LAND USE	RETURN FREQUENCY
Residential	10 year
Commercial & industrial	25 year
Critical & flood prone areas	100 year

TABLE C-5
JUNCTION OR STRUCTURE
COEFFICIENT OF LOSS

Case No	Reference Figure	Description of Condition	Coefficient Kj
I	C-12	Inlet on Main Line	0.50
II	C-12	Inlet on Main Line with Branch Lateral	0.25
III	C-12	Manhole on Main Line with 45° Branch Lateral	0.50
IV	C-12	Manhole on Main Line with 90° Branch Lateral	0.25
V	C-13	45° Wye Connection or cut-in	0.75
VI	C-13	Inlet or Manhole at Beginning of Line	1.25
VII	C-13	Conduit on Curves for 90°*	
		Curve radius = diameter	0.50
		Curve radius = (2 to 8) diameter	0.40
		Curve radius = (8 to 20) diameter	0.25
VIII	C-13	Bends where radius is equal to diameter	
		90° Bend	0.50
		60° Bend	0.48
		45° Bend	0.35

22-1/2° Bend	0.20
Manhole on line with 60° Lateral	0.35
Manhole on Line with 22-1/2° Lateral	0.75

* Where bends other than 90° are used, the 90° bend coefficient can be used with the following percentage factor applied:
60° Bend - 85%; 45° Bend - 70%; 22-1/2% Bend - 40%

TABLE C-5

HEAD LOSS COEFFICIENTS DUE TO SUDDEN ENLARGEMENTS AND CONTRACTIONS

D2 ** / D1	SUDDEN ENLARGEMENTS Kj	SUDDEN CONTRACTIONS Kj
1.2	0.10	0.08
1.4	0.23	0.18
1.6	0.35	0.25
1.8	0.44	0.33
2.0	0.52	0.36
2.5	0.65	0.40
3.0	0.72	0.42
4.0	0.80	0.44
5.0	0.84	0.45
10.0	0.89	0.46
>10.0	0.91	0.47

**$\frac{D2}{D1}$ Ratio of larger to smaller diameter.

TABLE C-6

CULVERT LOSSES

Coefficient k_e to apply to velocity head $\frac{V^2}{2g}$ for determination of head loss at entrance to a structure, such as a culvert or conduit, operating full or partly full with <u>control as the outlet</u>.

$$\text{Entrance head loss } H_e = k_e \frac{V^2}{2g}$$

Type of Sturcture and Design of Entrance	Coefficient k_e
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (grove-end)	0.2
Square-edge	0.5
Rounder (radius = 1/12D)	0.2
Mitered to conform to fill slope.	0.7
*End-Section conforming to fill slope.	0.5
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall).	0.9
Headwall or headwall and wingwalls	
Square-edge.	0.5
Mitered to conform to fill slope.	0.7
*End-Section conforming to fill slope.	0.5
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges.	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension.	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown.	0.4
Crown edge rounded to radius of 1/12 barrel dimension.	0.2
Wingwalls at 10° to 25° to barrel	
Square-edged at crown.	0.5
Wingwalls paralled (extension of sides)	
Square-edged at crown.	0.7

*Note: "End Section conforming to fill slope", made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic teste they are equivalent in operation to a headwall in both <u>inlet</u> and <u>outlet</u> control. Some end sections, incorporating a <u>closed</u> taper in their design have a superior hydraulic performance.

TABLE C-7
COMPUTATION OF COMPOSITE ROUGHNESS COEFFICIENT FOR EXCAVATED AND NATURAL CHANNELS

$$n = (n0 + n1 + n2 + n3 + n4)m$$

	CHANNEL CONDITIONS	VALUE
Material Involved no	Earth	0.020
	Rockcut	0.025
	Fine Gravel	0.024
	Coarse Gravel	0.028
Degree of Irregularity n1	Smooth	0.000
	Minor	0.005
	Moderate	0.010
	Severe	0.020
Variation of Channel Cross Section n2	Gradual	0.000
	Alternating Occasionally	0.005
	Alternating Frequently	0.010-0.015
Relative Effect Of Obstructions n3	Negligible	0.000
	Minor	0.010-0.015
	Appreciable	0.020-0.030
	Severe	0.040-0.060
Vegetation n4	Low	0.005-0.010
	Medium	0.010-0.025
	High	0.025-0.050
	Very High	0.050-0.100
Degree of Meandering m	Minor	1.000-1.200
	Appreciable	1.200-1.500
	Severe	1.500

Roughness Coefficient For Lined Channels

Rubble RipRap - n = 0.022

From: Open Channel Hydraulics
Ven Te Chow, Ph.D