APPENDIX F
TABLES AND FIGURES

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TABLES

TABLE 2.2.2.2

NRCS RUNOFF COEFFICIENTS

Runoff curve numbers for urban areas[1]					
Cover description		**Curve numbers for hydrologic soil group**			
Cover type and hydrologic condition	**Average percent impervious area[2]**	**A**	**B**	**C**	**D**
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses,cementeries etc.)[3]					
Poor condition (grass cover<50%)		**68**	**79**	**86**	**89**
Fair (grass cover 50%-75%)		**49**	**69**	**79**	**84**
Good (grass cover>75%)		**30**	**61**	**74**	**80**
Impervious areas					
Pavement, roof, etc.		**98**	**98**	**98**	**98**
Streets and roads					
Paved w/ curb (excluding right-of-way)		**98**	**98**	**98**	**98**
Paved w/ roadside swale (including right-of-way)		**83**	**89**	**92**	**93**
Gravel (including right-of-way)		**76**	**85**	**89**	**91**
Dirt (including right-of-way)		**72**	**82**	**87**	**89**
Urban Districts					
Commercial and business	**85**	**89**	**92**	**94**	**95**
Industrial	**72**	**81**	**88**	**91**	**93**
Residential districts by avg. lot size					
1/8 acre or less	**65**	**77**	**85**	**90**	**92**
1/4 acre	**38**	**61**	**75**	**83**	**87**
1/3 acre	**30**	**57**	**72**	**81**	**86**
1/2 acre	**25**	**54**	**79**	**80**	**85**
1 acre	**20**	**51**	**68**	**79**	**84**
2 acre	**12**	**46**	**65**	**77**	**82**
Developing urban areas					
Newly graded areas					
(pervious areas only, no vegetation)[4]		**77**	**86**	**91**	**94**

From USDA, TR-55, Urban Hydrology for Small Watersheds, 1986

[1]Average runoff condition, and Ia=0.2S.

[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious are considered equivalent to open space in good hydrologic condition. CN's for other combination of conditions may be computed as shown in TR-55, 1986—Figure 2-3 or 2-4.

[3]CN's shown are equivalent to those of pasture. Composite DN's may be computed for other combinations of open space cover type.

[4]Composite CN's to use for the design of temporary measures during grading and construction should be computed as shown in TR-55, 1986—Figure 2-3 or 2-4.

TABLE 2.2.2.2 Continued

Runoff curve numbers for undeveloped areas[1]					
		Curve numbers for hydrologic soil group			
Cover description	**Hydrologic Condition**	**A**	**B**	**C**	**D**
Pasture, grassland or range-continuos grazing[2]	**Poor**	**68**	**79**	**86**	**89**
	Fair	**49**	**69**	**79**	**84**
	Good	**39**	**61**	**74**	**80**
Meadow-continous grass, protected from grazing, generally mowed for hay.		**30**	**58**	**71**	**78**
Brush-brush/weed/grass mix with brush the major element[3]	**Poor**	**48**	**67**	**77**	**83**
	Fair	**35**	**56**	**70**	**77**
	Good	**30[4]**	**48**	**65**	**73**
Woods-grass combination (orchard or tree farm)[5]	**Poor**	**57**	**73**	**82**	**86**
	Fair	**43**	**65**	**76**	**82**
	Poor	**32**	**58**	**72**	**79**
Woods[6]	**Poor**	**45**	**66**	**77**	**83**
	Fair	**36**	**60**	**73**	**79**
	Good	**30[4]**	**55**	**70**	**77**
Farmsteads-buildings, lanes, driveways, and surrounding lots		**59**	**74**	**82**	**86**

[1]Average runoff condition, and I_a=0.2S.
[2]Poor: <50% fround cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and not heavily grazed.
[3]Poor: <50% fround cover
Fair: 50 to 75% ground cover
Good: >75% ground cover
[4]Actual curve number is less than 30; use CN = 30 for runoff computations.
[5]CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
[6]Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 3.1.1.1

MANNING'S ROUGHNESS COEFFICIENT

Type of Channel	n
Closed Conduits	
Reinforced Concrete Pipe (RCPs)	0.013
Reinforced Concrete Elliptical Pipe	0.013
Corrugated Metal Pipe (CMPs):	
2⅔ x ½in. Annular or Helical Corrugations unpaved - plain	0.024
2⅔ x ½in. Annular or Helical Corrugations paved invert	0.021
3x1 in. Annular or Helical Corrugations unpaved - plain	0.027
3x1 in. Annular or Helical Corrugations paved invert	0.023
6x2 in. Corrugations unpaved - plain	0.033
6x2 in. Corrugations paved invert	0.028
Vitrified Clay Pipe	0.013
Asbestos Cement Pipe	0.012
Open Channels (Lined)	
Gabions	0.025
Concrete	
Trowel Finish	0.013
Float Finish	0.015
Unfinished	0.017
Concrete, bottom float finished, with sides of	
Dressed Stone	0.017
Random Stone	0.020
Cement Rubble masonry	0.025
Dry Rubble or Riprap	0.030
Gravel bottom, side of	
Random Stone	0.023
Riprap	0.033
Grass (Sod)	0.030
Riprap	0.035
Grouted Riprap	0.030
Open Channels (Unlined) Excavated or Dredged	
Earth, straight and uniform	0.027
Earth, winding and sluggish	0.035
Channels, not maintained, weeds & brush uncut	0.090
Natural Stream	
Clean stream, straight	0.030
Stream with pools, sluggish reaches, heavy underbrush	0.100
Flood Plains	
Grass, no brush	0.030
With some brush	0.090
Street Curbing	0.014

Table 3.1.1.2

HEAD LOSS (so-called minor loss) COEFFICIENT k

Condition $\left(Loss = k\,\dfrac{v^2}{2g} \right)$	**k**
Manhole, junction boxes and inlets with shaped inverts*:	
Thru flow	0.15
Junction	0.4
Contraction transition	0.1
Expansion transition	0.2
90 degree bend	0.4
45 degree and less bends	0.3
Culvert inlets:	
Pipe, Concrete	
Projecting from fill, socket end (grove end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove end)	0.2
Square edge	0.5
Round (radius=1/12D)	0.2
Mitered to conform to fill slope	0.7
Standard end section	0.5
Beveled edges, 33.7º or 45º bevels	0.2
Side or slope-tapered inlet	0.2
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, paved or unpaved slope	0.7
Standard end section	0.5
Beveled edges, 33.7º or 45º bevels	0.2
Side or slope-tapered inlet	0.2
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 dim. or beveled edges on 3 sides	0.2
Wingwalls at 30º to 75º to barrel	
Square edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension or beveled top edge	0.2
Wingwalls at 10º to 25º to barrel - square edged at crown	0.5
Wingwalls parallel (extension of sides) - square edged at crown	0.7
Side or slope-tapered inlet	0.2

***Note:** When 50 percent or more of the discharge enters the structure from the surface, "k" shall be 1.0.

Table 5.1.4.1
CRITICAL SHEAR STRESSES FOR CHANNEL MATERIALS
(Solely for use in stream assessments as described in Chapter 5.1.4.
Not to be used as allowable shear stresses for design)

	psf
Granular Material	
Boulders (100 cm)	20.295
Boulders (75 cm)	15.222
Boulders (50 cm)	10.148
Boulders (25.6 cm)	5.196
Rip Rap	3.132
Cobbles (6.4 cm)	1.299
Cobbles and shingles	1.100
Cobbles and shingles, **clear water**	0.910
Coarse sand (1mm)	0.015
Coarse sand (1mm)	0.015
Coarse gravel, noncolloidal (GW), **clear water**	0.300
Coarse gravel, noncolloidal, (GW)	0.670
Gravel (2cm)	0.406
Fine gravel	0.320
Fine gravel, **clear water**	0.075
Fine sand (0.125 mm)	0.002
Fine sand (0.125 mm) (SP)	0.002
Fine sand (SW), (SP), colloidal	0.075
Fine sand, colloidal, (SW), (SP), **clear water**	0.027
Graded loam to cobbles, noncolloidal (GM)	0.660
Graded loam to cobbles, noncolloidal,(GM), **clear water**	0.380
Graded silts to cobbles, colloidal (GC)	0.800
Graded silts to cobbles, colloidal, (GC), **clear water**	0.430
Fine Grained	
Resistant cohesive (CL), (CH)	1.044
Stiff clay, very colloidal, (CL)	0.460
Stiff clay, very colloidal, (CL), **clear water**	0.260
Moderate cohesive (ML-CL)	0.104
Ordinary firm loam (CL-ML)	0.150
Ordinary firm loam, (CL-ML), **clear water**	0.075
Alluvial silts, colloidal (CL-ML)	0.460
Alluvial silts, colloidal,(CL-ML), **clear water**	0.260
Alluvial silts, noncolloidal (ML)	0.150
Alluvial silts, noncolloidal, (ML), **clear water**	0.048
Sandy loam, noncolloidal (ML)	0.075

Table 5.1.4.1
CRITICAL SHEAR STRESSES FOR CHANNEL MATERIALS
(Solely for use in stream assessments as described in Chapter 5.1.4. Not to be used as allowable shear stresses for design)

Sandy loam, noncolloidal, (ML), **clear water**	0.037
Silt loam, noncolloidal (ML)	0.110
Silt loam, noncolloidal, (ML), **clear water**	0.048
Shales and hardpans	0.67
<u>Others</u>	
Jute net	0.46
Plant cuttings	2.09
Well established dense vegetation to the normal low water	2.16
Geotextile (synthetic)	3.01
Large Woody Debris	3.13

Note: For non-cohesive soils, the table values are based on spherical particles and Shield equation, as follows: $\tau_c = \Theta(\gamma_s - \gamma)\, D$ where γ_s is the specific weight of sediment (165 pcf), γ is specific weight of water, D is the reference particle size, and Θ is the Shield's parameter (0.06 for gravel to cobble, 0.044 for sand). For cohesive soils the values are based on limited testing as reported in Chow (1988) and USDA (2001).

Project: ____

Stream Name and Location: ______________________________

Evaluated by: ______________Firm: _____________ Date:_________

Table 5.1.4.2
CHANNEL CONDITION SCORING MATRIX
(adapted from Johnson, et al 1999)

Stability Indicator	Good (1)	Fair (2)	Poor (3)	Score (S)	Weight (W)	Rating S*W= (R)
Bank soil texture and coherence	cohesive materials, clay (CL), silty clay (CL-ML), massive limestone, continuous concrete, clay loam (ML-CL), silty clay loam (ML-CL), thinly bed limestone	sandy clay (SC), sandy loam (SM), fractured thinly bedded limestone	non-cohesive materials, shale in bank, (SM), (SP), (SW), (GC), (GM), (GP), (GW)		0.6	
Average bank slope angle	slopes ≤ 2:1 on one or occasionally both banks	slopes up to1.7:1 (60˚) common on one or both banks	bank slopes over 60˚ on one or both banks		0.6	
Average bank height	less than 6 feet	greater than 6 and less than 15 feet	greater than 15 feet		0.8	
Vegetative bank protection	wide to medium band of woody vegetation with 70-90% plant density and cover. Majority are hardwood, deciduous trees with well-developed understory layer, minimal root exposure	narrow bank of woody vegetation, poor species diversity, 50-70% plant density, most vegetation on top of bank and not extending onto bank slope, some trees leaning over bank, root exposure common	thin or no band of woody vegetation, poor health, monoculture, many trees leaning over bank, extensive root exposure, turf grass to edge of bank		0.8	
Bank cutting	little to some evident along channel bends and at prominent constrictions, some raw banks up to 4 foot	Significant and frequent. Cut banks 4 feet high. Root mat overhangs common.	Almost continuous cut banks, some over 4 feet high. Undercut trees with sod-rootmat overhangs common. Bank failures frequent		0.4	

Table 5.1.4.2 CHANNEL CONDITION SCORING MATRIX (adapted from Johnson, et al 1999)						
Stability Indicator	**Good (1)**	**Fair (2)**	**Poor (3)**	**Score (S)**	**Weight (W)**	**Rating S*W= (R)**
Mass wasting	little to some evidence of slight or infrequent mass wasting, past events healed over with vegetation. Channel width relatively uniform with only slight scalloping	Evidence of frequent and significant mass wasting events. Indications that higher flows aggravated undercutting and bank wasting. Channel width irregular with bank scalloping evident	Frequent and extensive mass wasting evident. Tension cracks, massive undercutting and bank slumping are considerable. Highly irregular channel width.		0.8	
Bar development	narrow relative to stream width at low flow, well-consolidated, vegetated and composed of coarse bed material to slight recent growth of bar as indicated by absence of vegetation on part of bar	Bar widths wide relative to stream width with freshly deposited sand to small cobbles with sparse vegetation	Bar widths greater than ½ the stream width at low flow. Bars are composed of extensive deposits of finer bed material with little vegetation		0.6	
Debris jam potential	slight – small amounts of debris in channel. Small jams could form	moderate – noticeable debris of all sizes present	significant – moderate to heavy accumulations of debris apparent		0.2	
Obstructions, flow deflectors (walls, bluffs) and sediment traps	negligible to few or small obstructions present causing secondary currents and minor bank and bottom erosion but no major influence on meander bend	moderately frequent and occasionally unstable obstructions, noticeable erosion of channel. Considerable sediment accumulation behind obstructions	frequent and unstable causing continual shift of sediment and flow		0.2	
Channel bed material consolidation and armoring	massive competent to thinly bed limestone, continuous concrete, hard clay,	shale in bed, soft silty clay, little consolidation of particles, no apparent overlap, moderate %	silt, weathered, thinly bedded, fractured shale, high slaking potential, very poorly		0.8	

Table 5.1.4.2 **CHANNEL CONDITION SCORING MATRIX** (adapted from Johnson, et al 1999)						
Stability Indicator	**Good (1)**	**Fair (2)**	**Poor (3)**	**Score (S)**	**Weight (W)**	**Rating S*W= (R)**
	moderately consolidated with some overlapping. Assorted sizes of particles, tightly packed and overlapped, possibly imbricated. Small % of particles < 4mm	of particles < 4mm	consolidated, high % of material < 4mm			
Sinuosity	1.2 ≤ Sinuosity ≤ 1.4	1.1<Sinuosity <1.2	Sinuosity <1.1		0.8	
Ratio of radius of curvature to channel width	$3 \leq R_c/W_b \leq 5$	$2 < R_c/W_b < 3$, $5 < R_c/W_b < 7$	$2 > R_c /W_b$, R_c /Wb > 7		0.8	
Ratio of pool-riffle spacing to channel width at elevation of 2-year flow	$4 \leq \text{Length}/W_b < 8$	$3 \leq \text{Length}/W_b < 4$, $8 < \text{Length}/W_b \leq 9$	$3 > \text{Length}/W_b$, Length/Wb > 9, unless long pool or run because of geologic influence		0.8	
Percentage of channel constriction	< 25%	26-50%	> 50%		0.8	
Sediment movement	little to no loose sediment	scour and/or deposition, some loose sediment	near continuous scour and/or deposition and/or loose sediment		0.8	

TOTAL ____

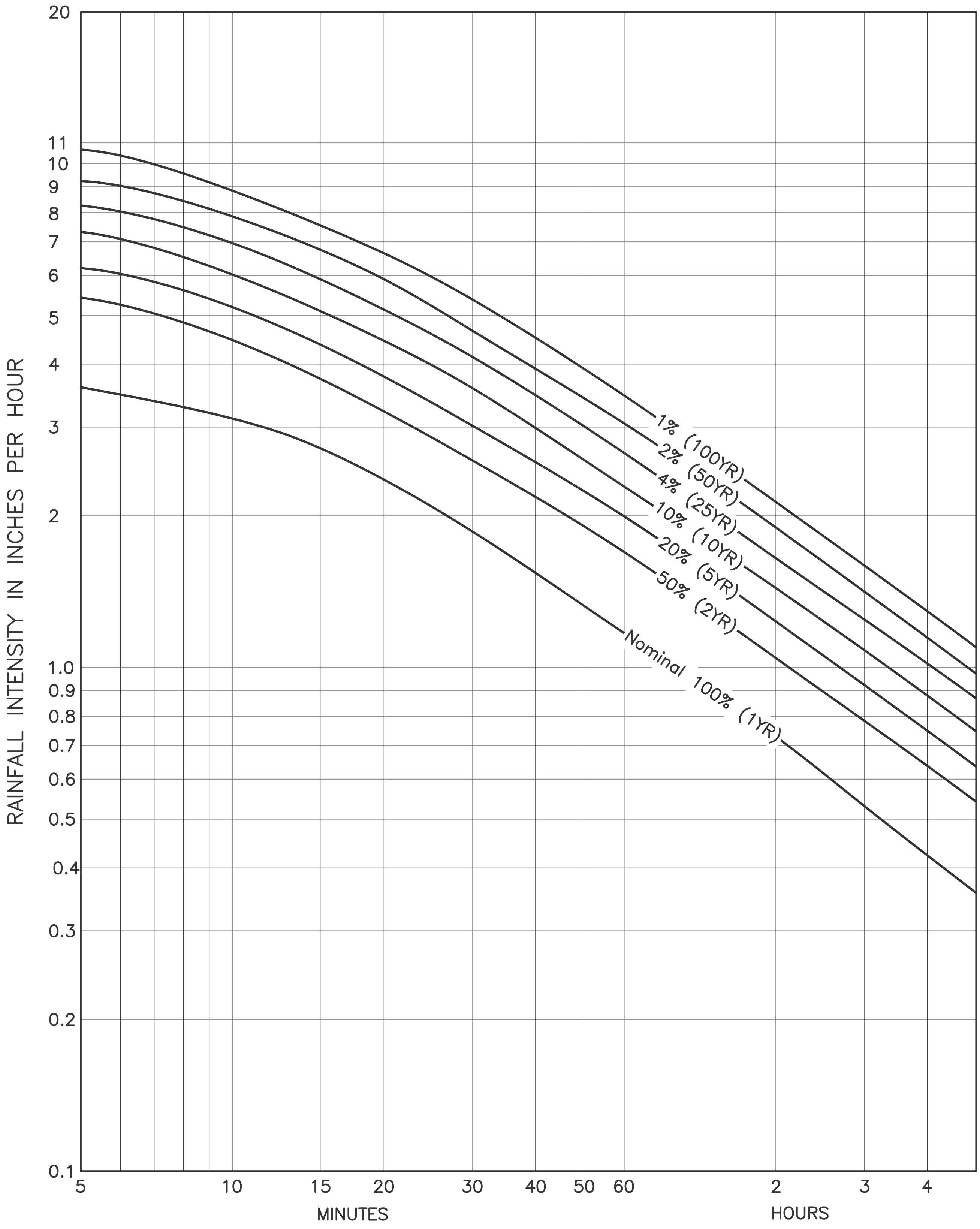
Table 5.2.7.1
Permissible Shear Stresses for Lining Material

Lining Category	Lining Type	lb/ft^2
General	Erosion Control Blankets	1.55-2.35
	Turf-Reinforced Matrix (TRMs):	-------------------------
	Unvegetated:	3.0
	Vegetated:	8.0
	Geosynthetic Materials	3.01
	Cellular Containment	8.1
	Woven Paper Net	0.15
	Jut Net	0.45
	Fiberglass Roving:	-------------------------
	Single	0.60
	Double	0.85
	Straw With Net	1.45
	Curled Wood Mat	1.55
	Synthetic Mat	2.00
Vegetative	Class A (see Table 5606-2)	3.70
	Class B (see Table 5606-2)	2.10
	Class C (see Table 5606-2)	1.00
	Class D (see Table 5606-2)	0.60
	Class E (see Table 5606-2)	0.35
Gravel Riprap	25 mm	0.33
	50 mm	0.67
Rock Riprap	150 mm	2.00
	300 mm	4.00
Bare Soil	Non-Cohesive	See Figure 5606-2
	Cohesive	See Figure 5606-3

FIGURES

FIGURE 2.2.1.1

RAINFALL/INTENSITY/DURATION FREQUENCY CURVES



Lines 1% through 50% are from TP40, 1961
Line Nominal 100% is from Bulletin 71, 1992 RAINFALL DURATION

k:\projects\78-storm-drain_drainage_manual\figure 2.2.1.1 idf curves.dwg

Figure 2.2.1.2

OVERLAND FLOW (INLET TIME) NOMOGRAPH

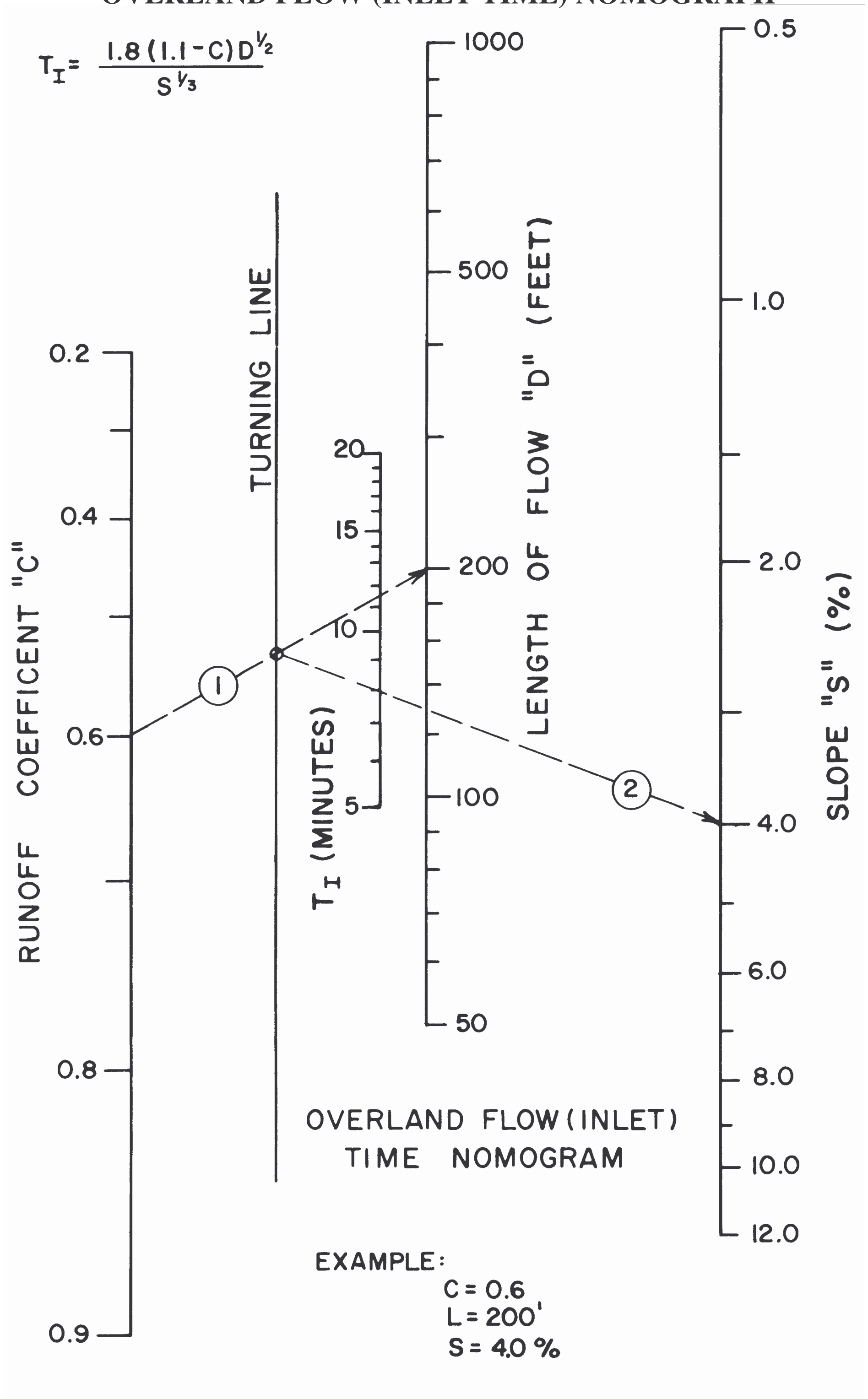
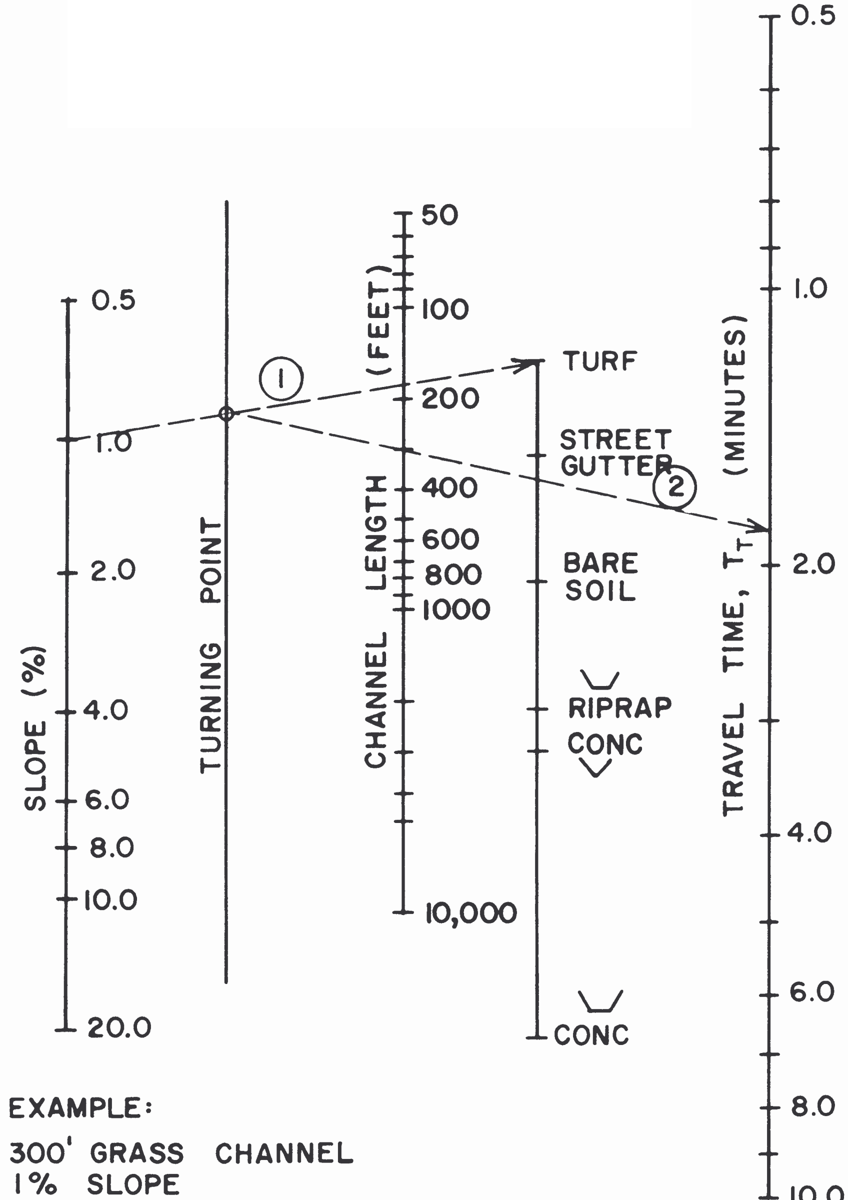


Figure 2.2.1.3

CHANNEL TIME FLOW NOMOGRAPH



EXAMPLE:

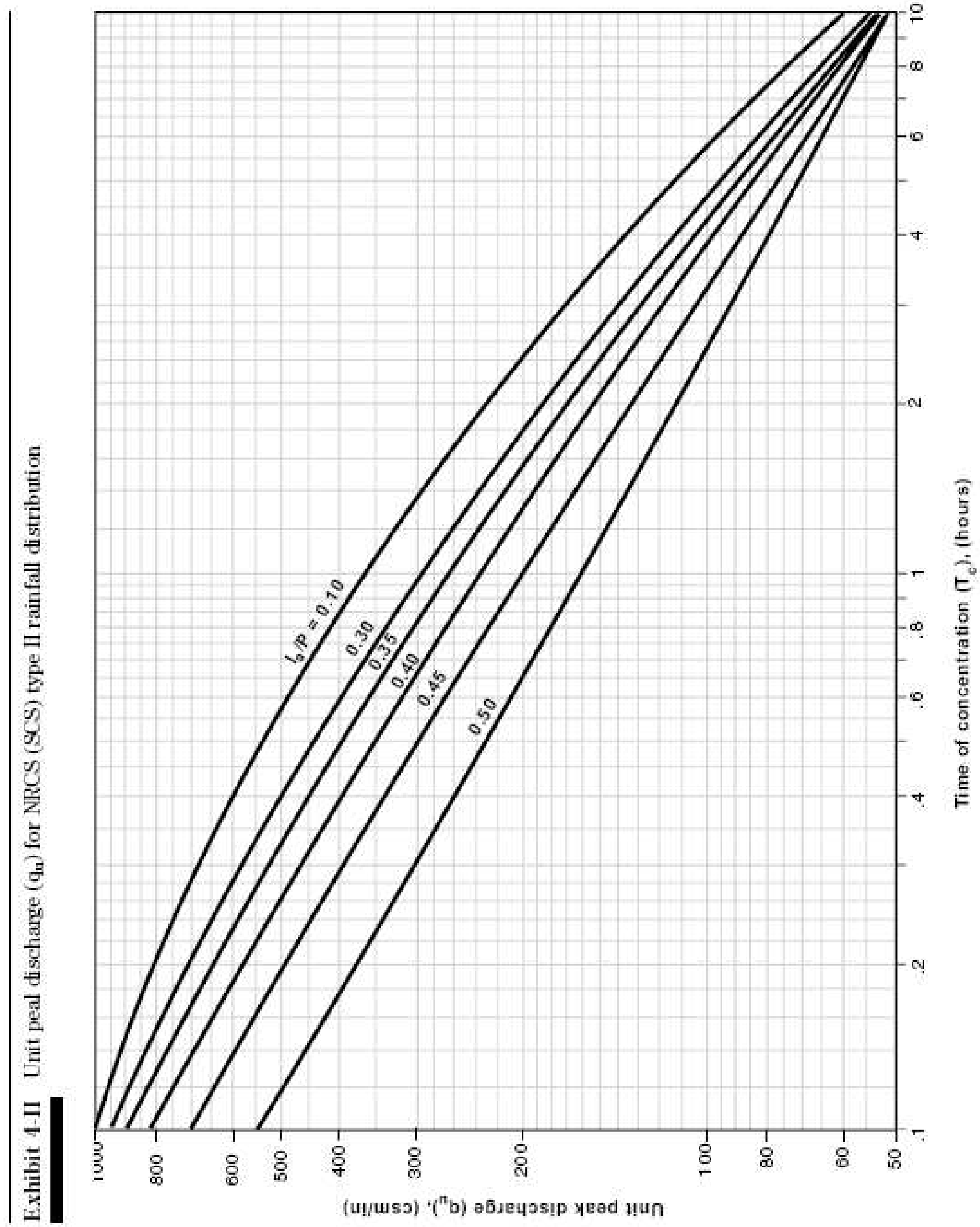
300' GRASS CHANNEL
1% SLOPE
T_T = 1.85 MIN.

(1) Connect Slope & Channel Condition to locate point on Turning Line

(2) Extend line from Turning Line through Channel Length, Read T_T

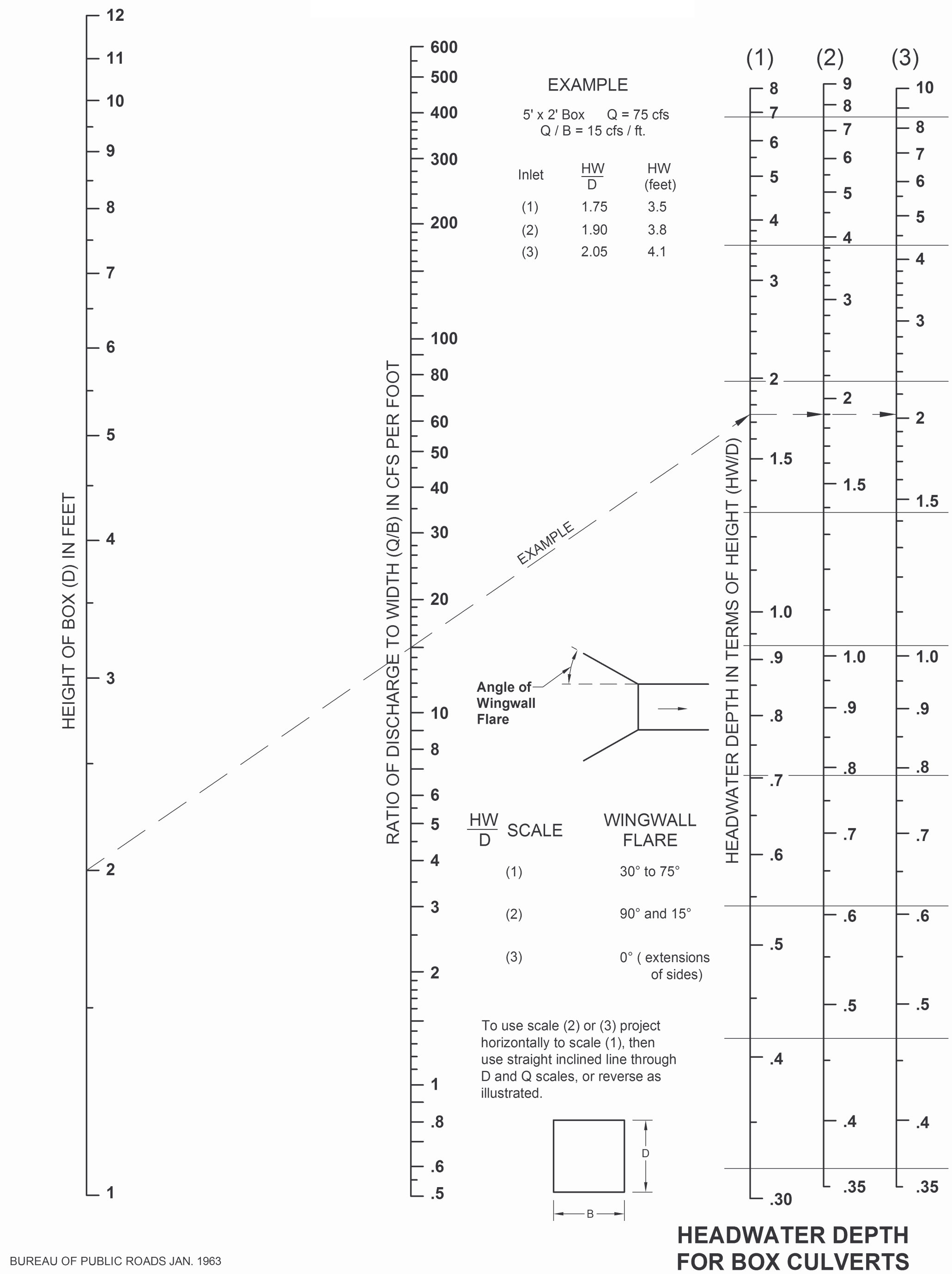
Figure 2.3.1

UNIT PEAK DISCHARGE IN CFS/SQUARE MILE/INCH OF RUNOFF



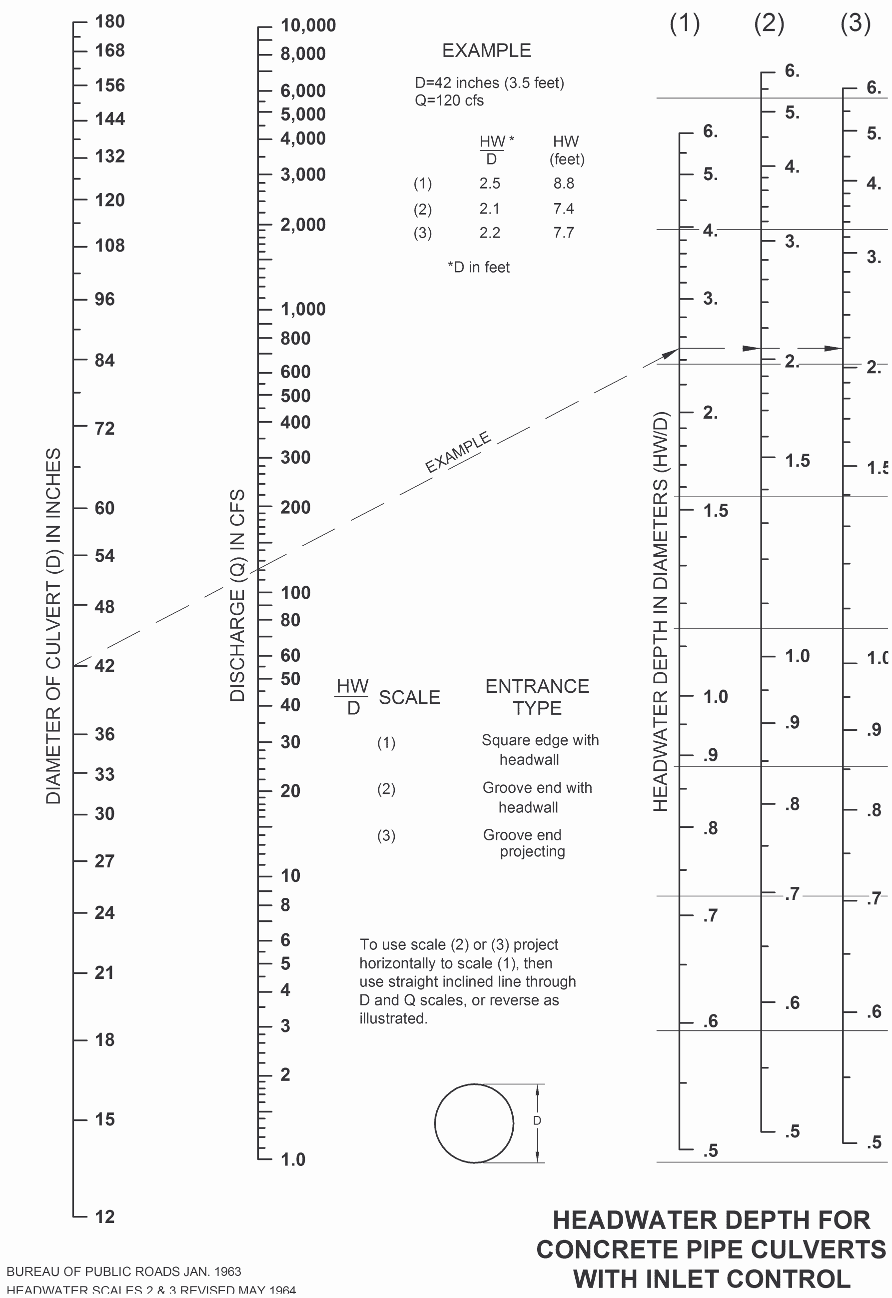
From USDA, TR-55, Urban Hydrology for Small Watersheds, 1986

Figure 3.1.2.1



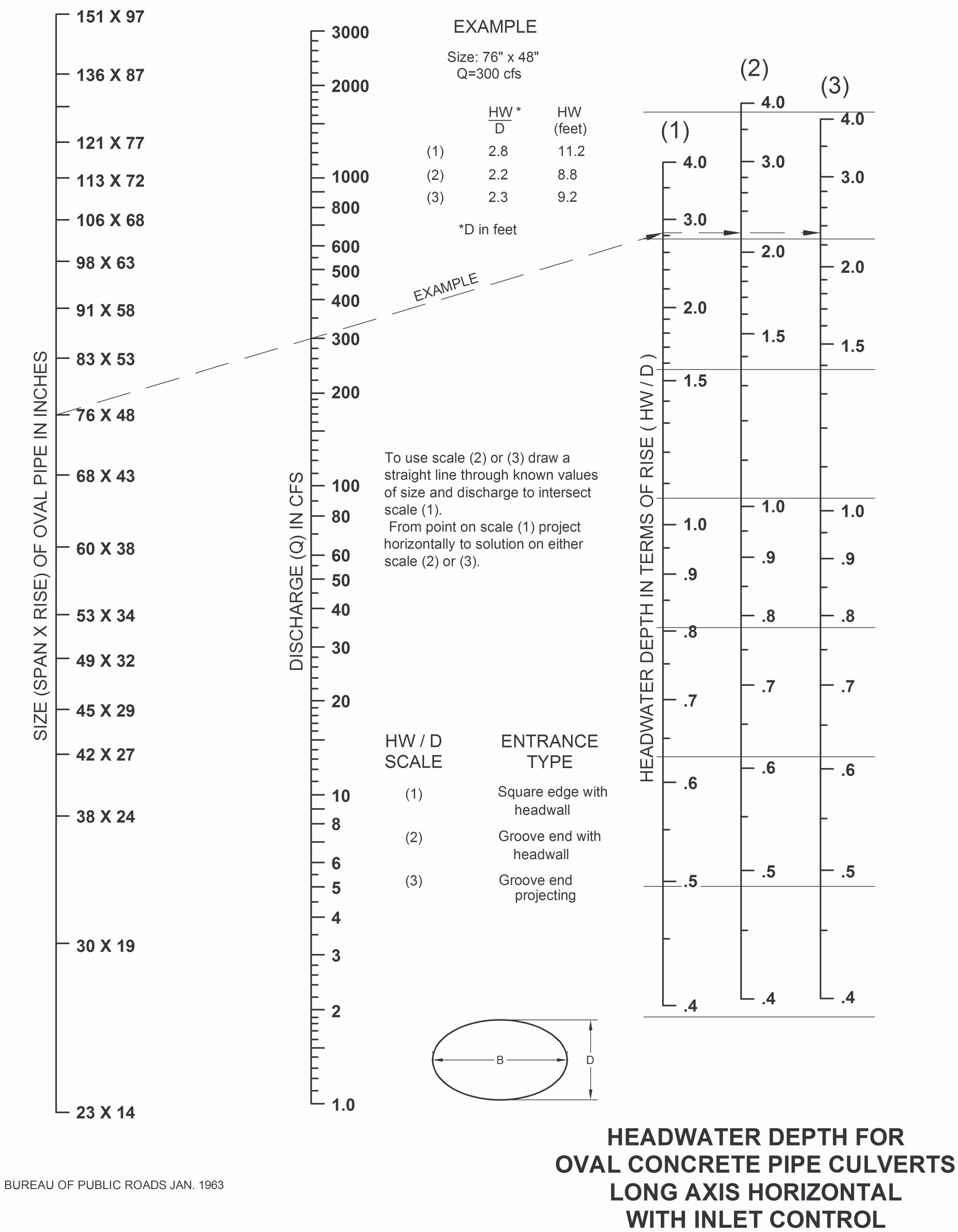
HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

Figure 3.1.2.2



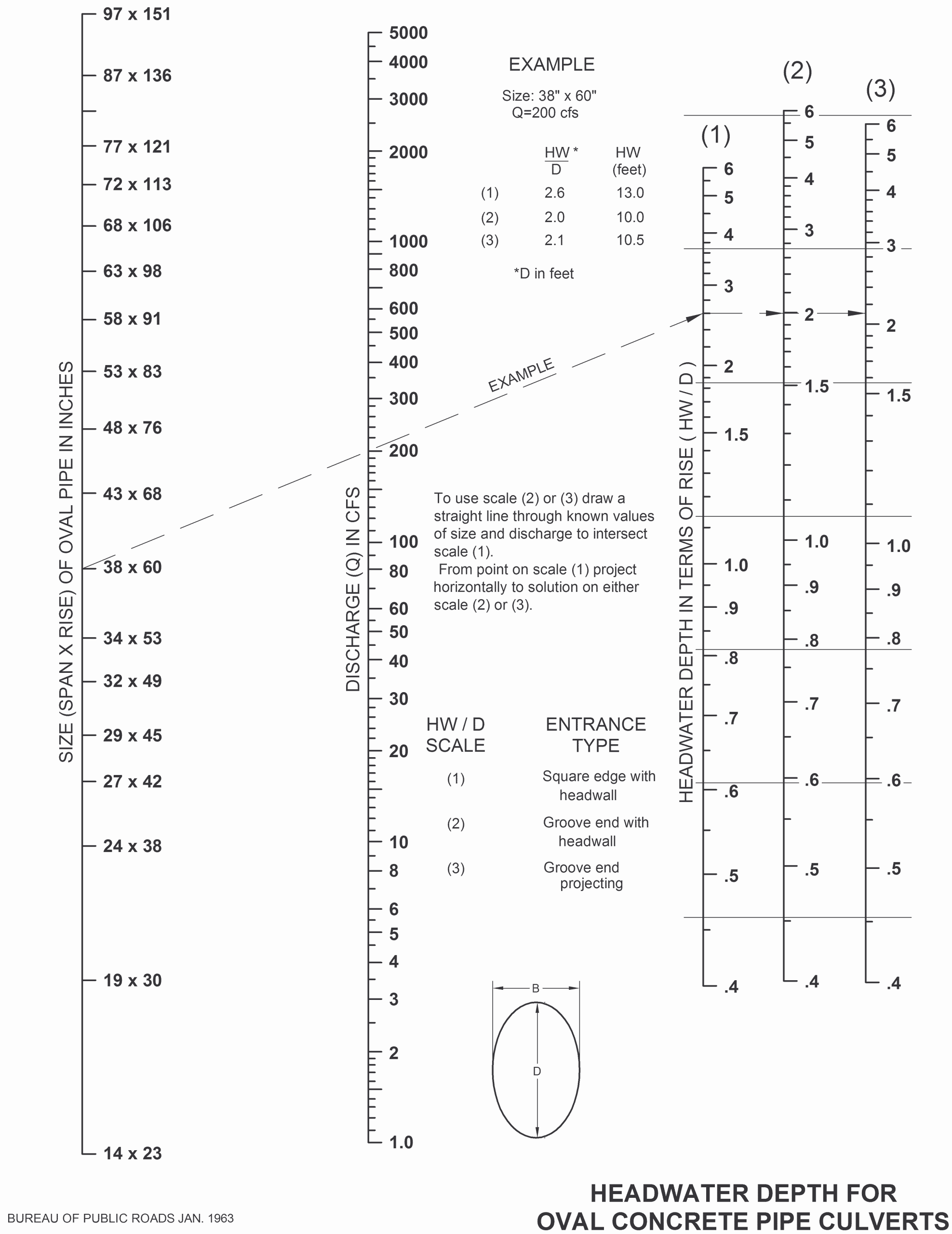
HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

Figure 3.1.2.3



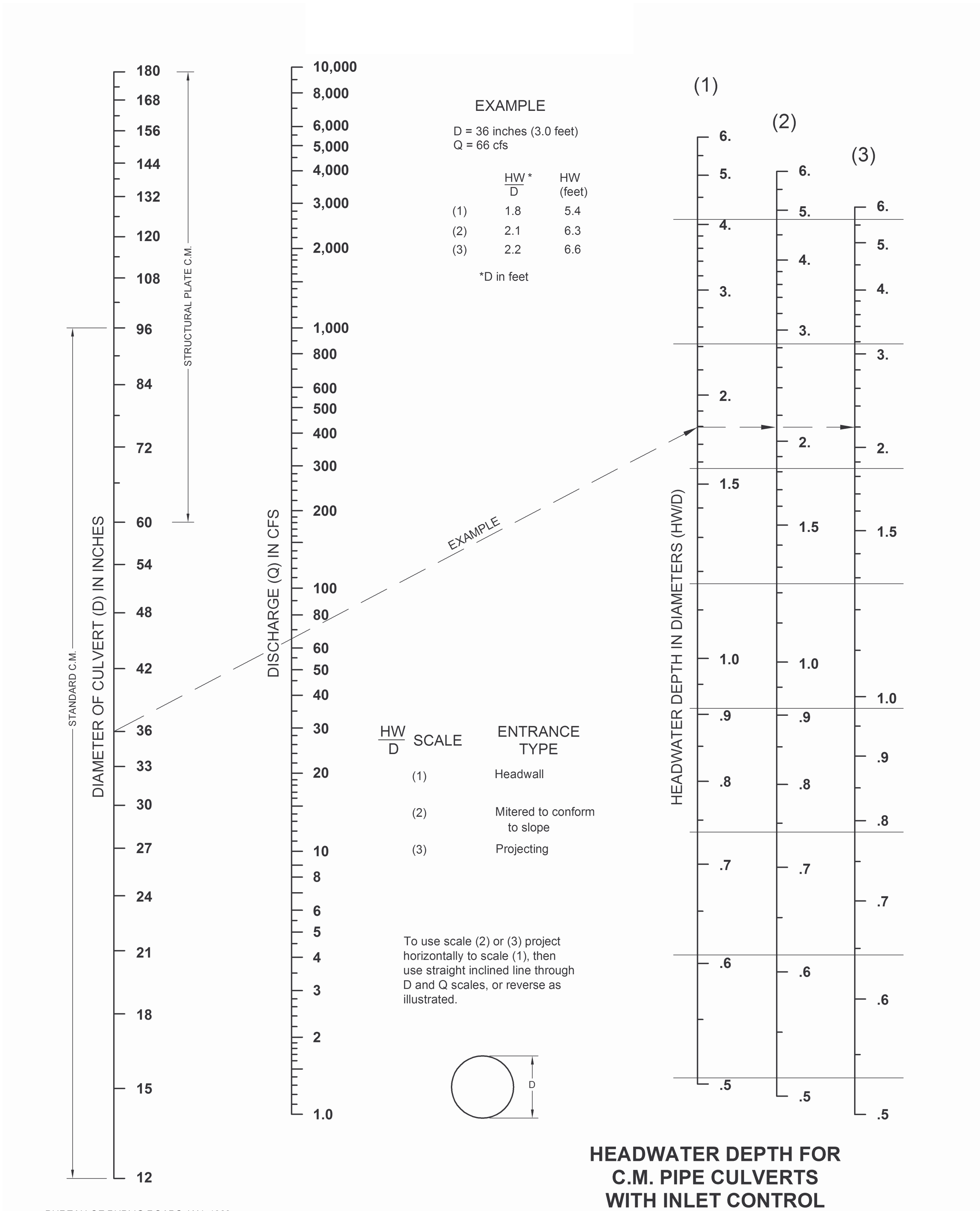
SIZE (SPAN X RISE) OF OVAL PIPE IN INCHES
151 X 97
136 X 87
121 X 77
113 X 72
106 X 68
98 X 63
91 X 58
83 X 53
76 X 48
68 X 43
60 X 38
53 X 34
49 X 32
45 X 29
42 X 27
38 X 24
30 X 19
23 X 14
DISCHARGE (Q) IN CFS
3000
2000
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1.0
EXAMPLE
Size: 76" x 48"
Q=300 cfs
HW* / D
HW (feet)
(1) 2.8 11.2
(2) 2.2 8.8
(3) 2.3 9.2
*D in feet
EXAMPLE
To use scale (2) or (3) draw a straight line through known values of size and discharge to intersect scale (1).
From point on scale (1) project horizontally to solution on either scale (2) or (3).
HW / D SCALE
ENTRANCE TYPE
(1) Square edge with headwall
(2) Groove end with headwall
(3) Groove end projecting
B
D
HEADWATER DEPTH IN TERMS OF RISE (HW / D)
(1)
(2)
(3)
4.0
3.0
2.0
1.5
1.0
.9
.8
.7
.6
.5
.4
BUREAU OF PUBLIC ROADS JAN. 1963
HEADWATER DEPTH FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS HORIZONTAL
WITH INLET CONTROL

Figure 3.1.2.4



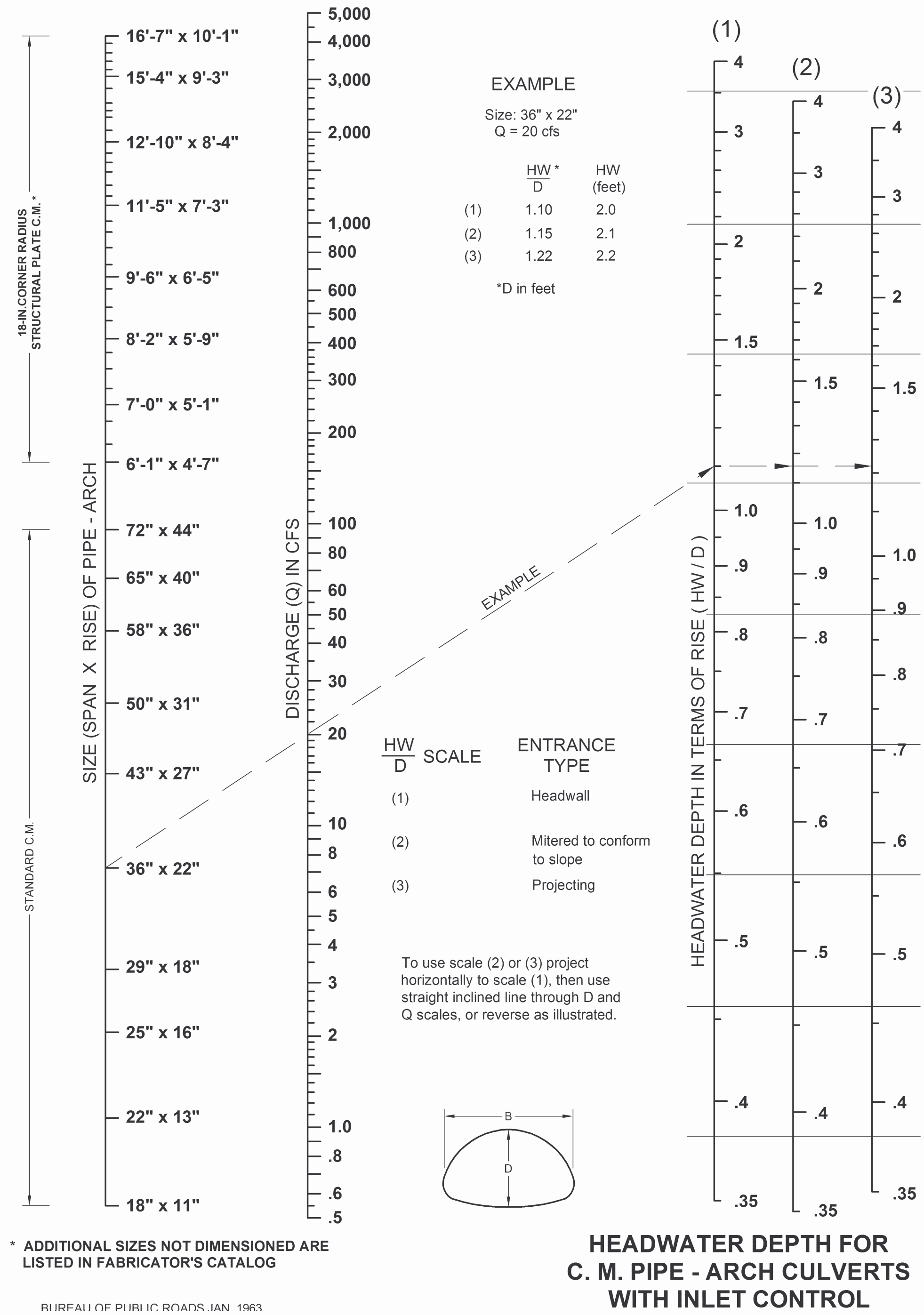
HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS VERTICAL WITH INLET CONTROL

Figure 3.1.2.5



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

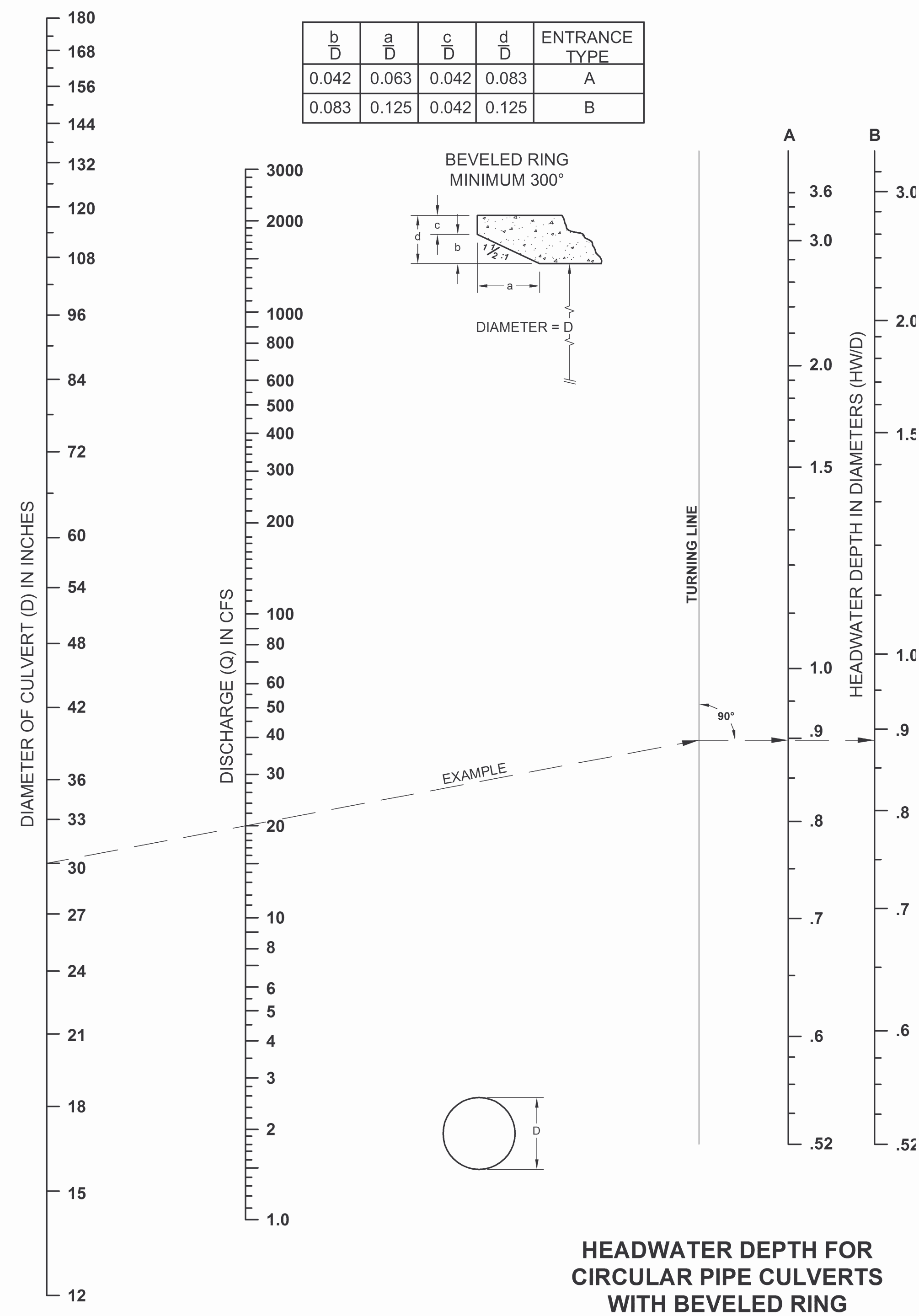
Figure 3.1.2.6



18-IN.CORNER RADIUS STRUCTURAL PLATE C.M. *
STANDARD C.M.
SIZE (SPAN X RISE) OF PIPE - ARCH
16'-7" x 10'-1"
15'-4" x 9'-3"
12'-10" x 8'-4"
11'-5" x 7'-3"
9'-6" x 6'-5"
8'-2" x 5'-9"
7'-0" x 5'-1"
6'-1" x 4'-7"
72" x 44"
65" x 40"
58" x 36"
50" x 31"
43" x 27"
36" x 22"
29" x 18"
25" x 16"
22" x 13"
18" x 11"
DISCHARGE (Q) IN CFS
5,000
4,000
3,000
2,000
1,000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1.0
.8
.6
.5
EXAMPLE
Size: 36" x 22"
Q = 20 cfs
HW/D * HW (feet)
(1) 1.10 2.0
(2) 1.15 2.1
(3) 1.22 2.2
*D in feet
EXAMPLE
HW/D SCALE ENTRANCE TYPE
(1) Headwall
(2) Mitered to conform to slope
(3) 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.
B
D
HEADWATER DEPTH IN TERMS OF RISE (HW / D)
(1)
(2)
(3)
4
3
2
1.5
1.0
.9
.8
.7
.6
.5
.4
.35
* ADDITIONAL SIZES NOT DIMENSIONED ARE LISTED IN FABRICATOR'S CATALOG
BUREAU OF PUBLIC ROADS JAN. 1963
HEADWATER DEPTH FOR C. M. PIPE - ARCH CULVERTS WITH INLET CONTROL

Figure 3.1.2.7

b/D	a/D	c/D	d/D	ENTRANCE TYPE
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B



HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELED RING INLET CONTROL

FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

Figure 3.1.2.8

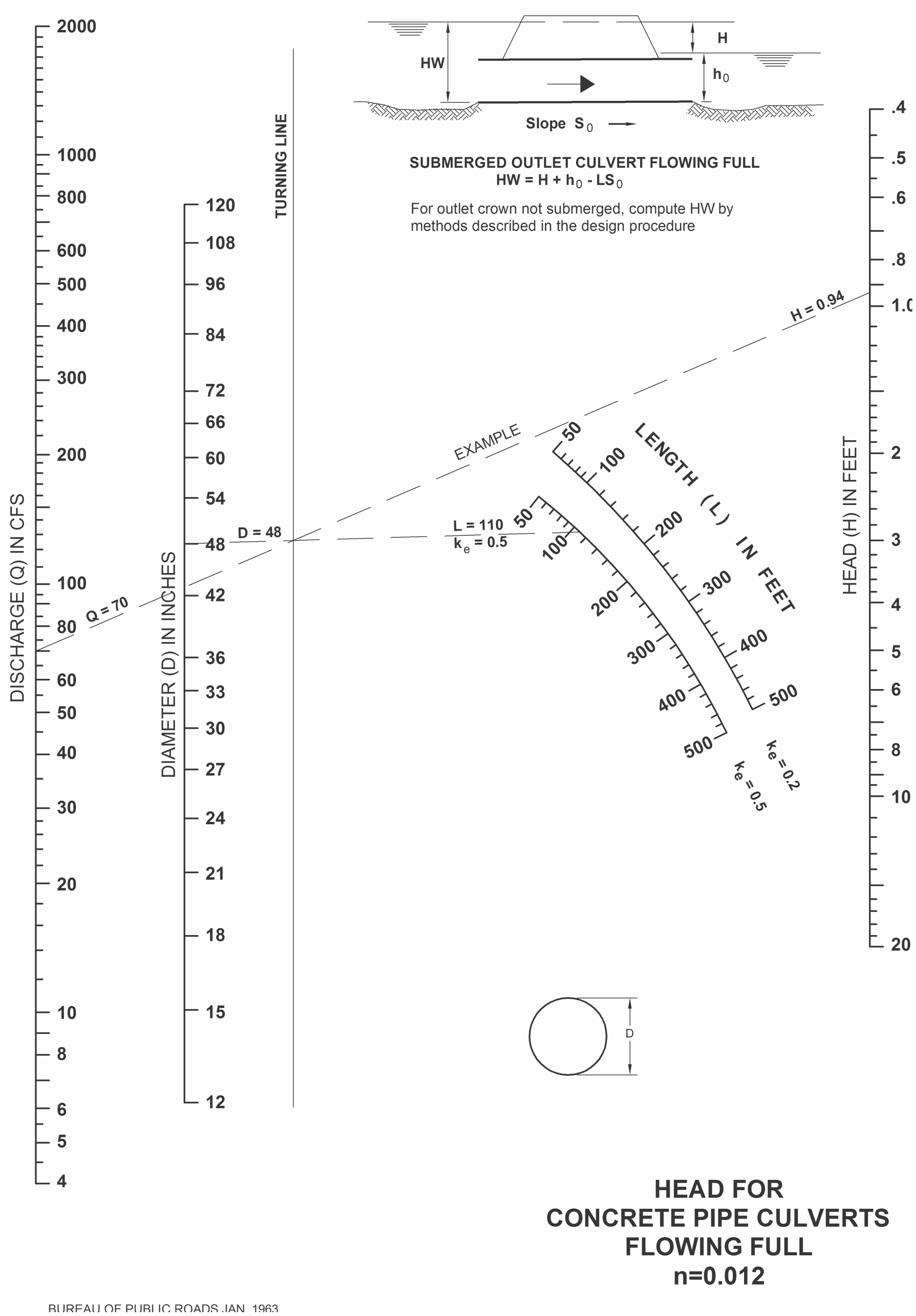

SUBMERGED OUTLET CULVERT FLOWING FULL
HW = H + h0 - LS0
For outlet crown not submerged, compute HW by methods described in the design procedure
HW
H
h0
Slope S0
TURNING LINE
DISCHARGE (Q) IN CFS
DIAMETER (D) IN INCHES
LENGTH (L) IN FEET
HEAD (H) IN FEET
EXAMPLE
Q = 70
D = 48
L = 110
ke = 0.5
H = 0.94
ke = 0.2
ke = 0.5
D
HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n=0.012
BUREAU OF PUBLIC ROADS JAN. 1963

Figure 3.1.2.9

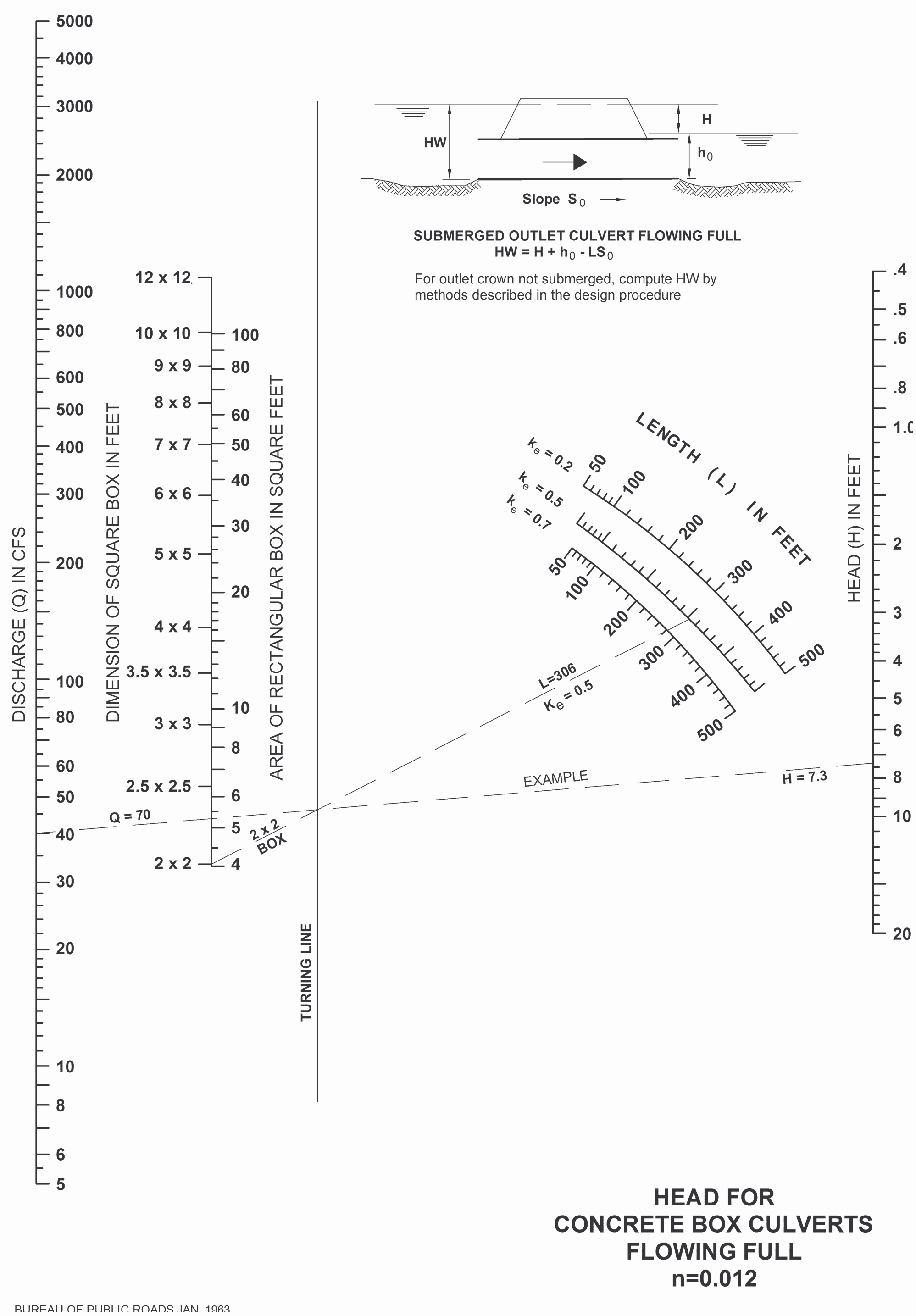
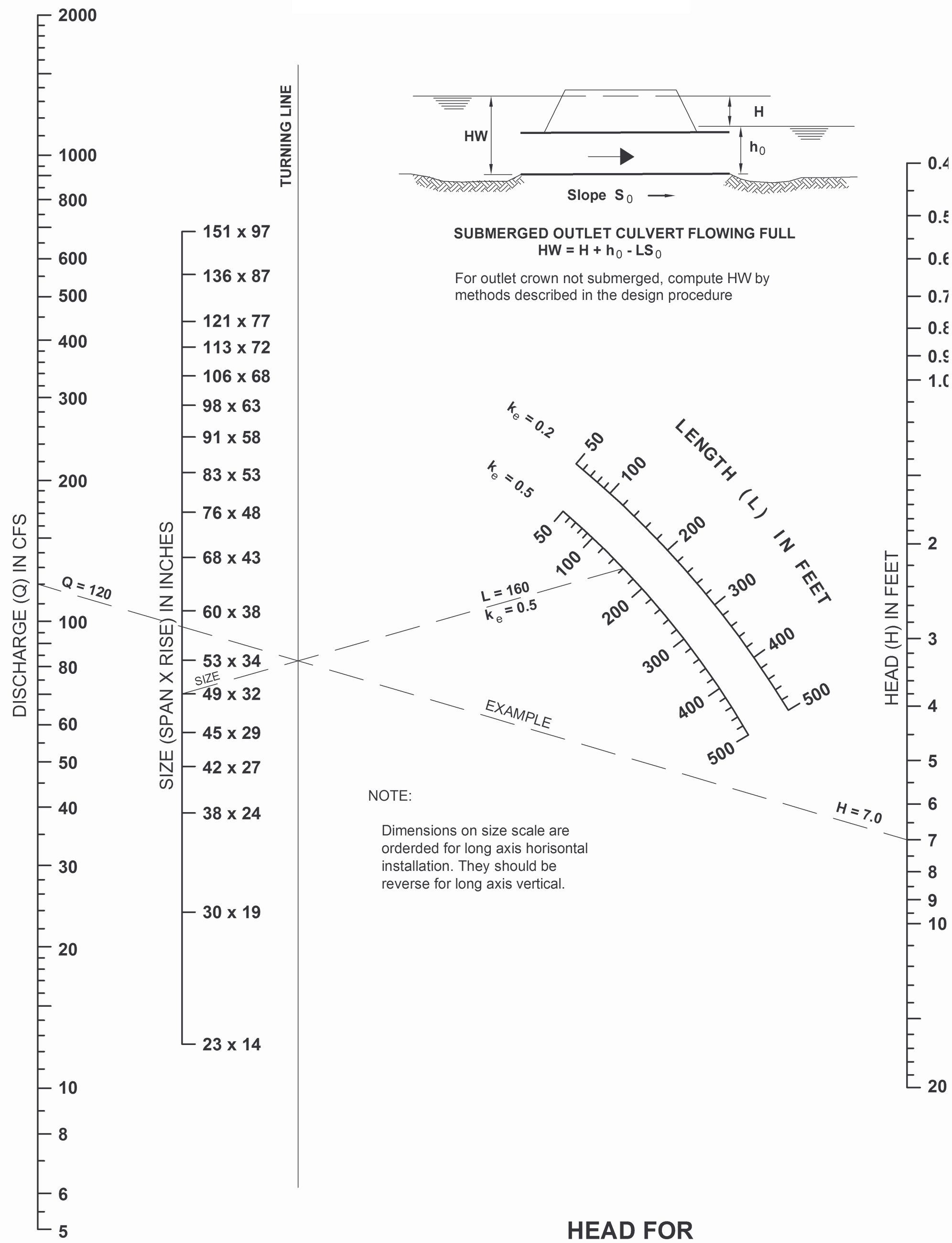

SUBMERGED OUTLET CULVERT FLOWING FULL
HW = H + h0 - LS0
For outlet crown not submerged, compute HW by methods described in the design procedure
HW
H
h0
Slope S0
DISCHARGE (Q) IN CFS
DIMENSION OF SQUARE BOX IN FEET
AREA OF RECTANGULAR BOX IN SQUARE FEET
TURNING LINE
LENGTH (L) IN FEET
HEAD (H) IN FEET
ke = 0.2
ke = 0.5
ke = 0.7
L=306
Ke = 0.5
Q = 70
2 x 2 BOX
EXAMPLE
H = 7.3
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n=0.012
BUREAU OF PUBLIC ROADS JAN. 1963

Figure 3.1.2.10



HEAD FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS HORIZONTAL OR VERTICAL
FLOWING FULL
n=0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Figure 3.1.2.11

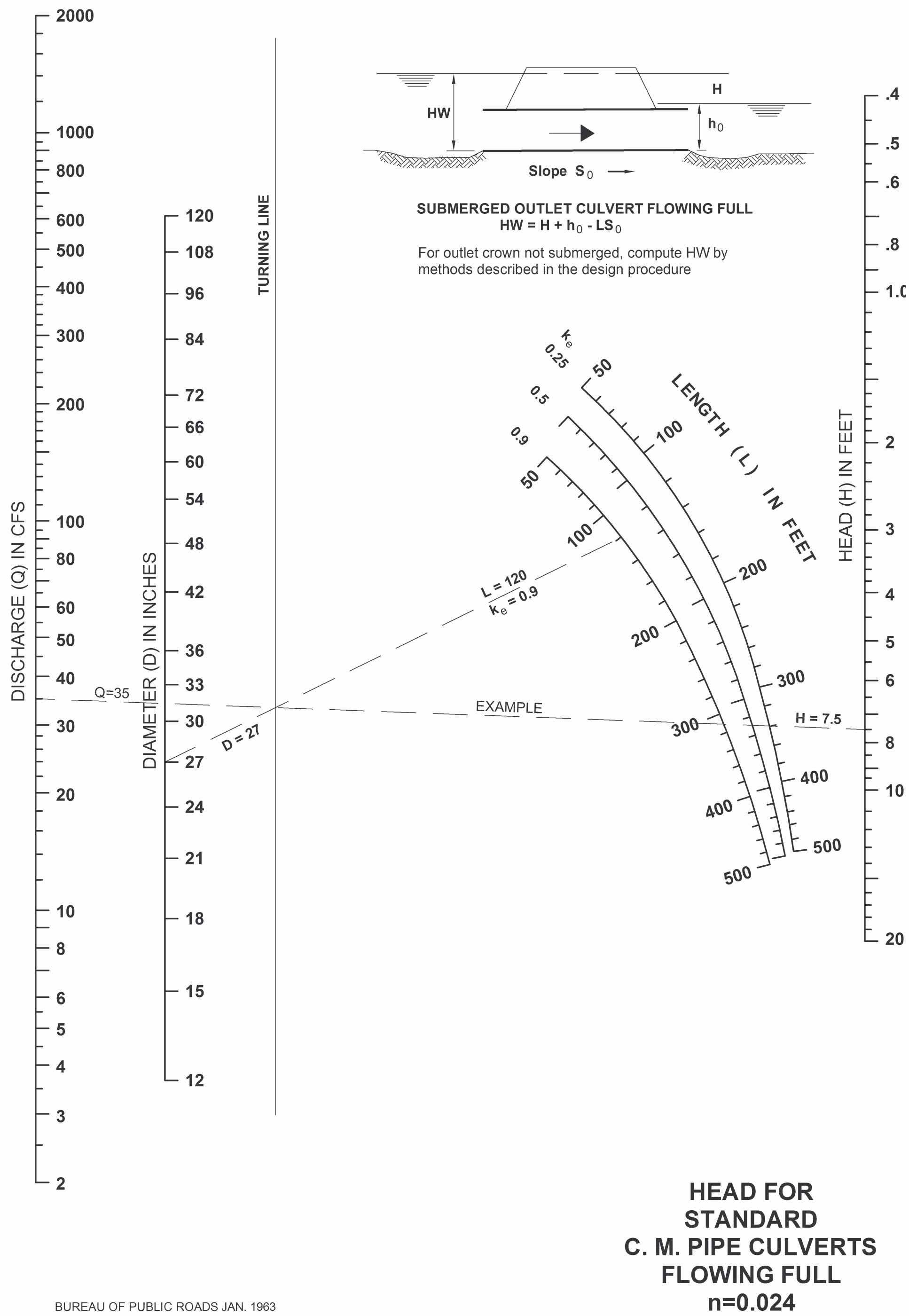
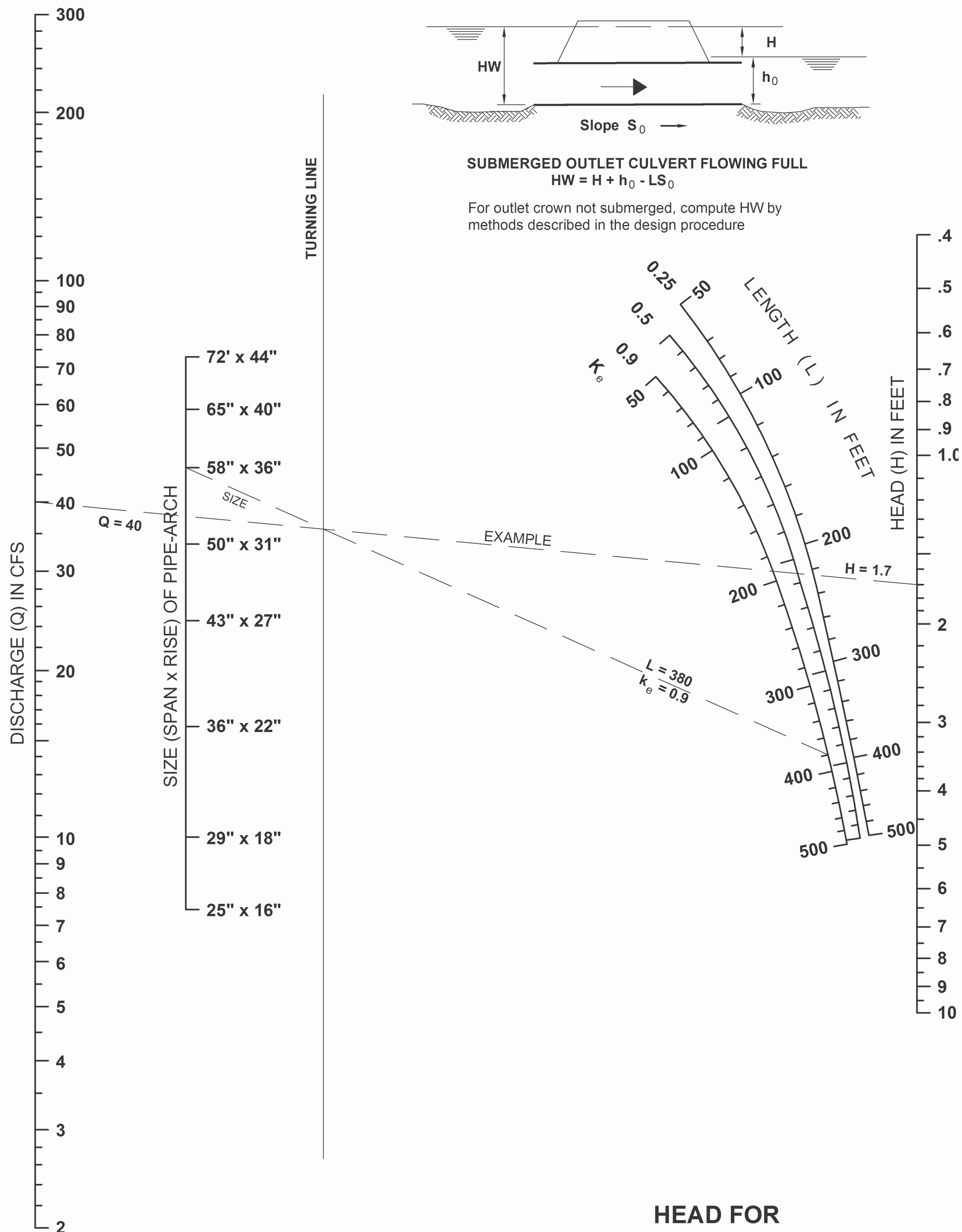


Figure 3.1.2.12



HEAD FOR
STANDARD C.M. PIPE-ARCH CULVERTS
FLOWING FULL
n=0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Figure 3.1.2.13

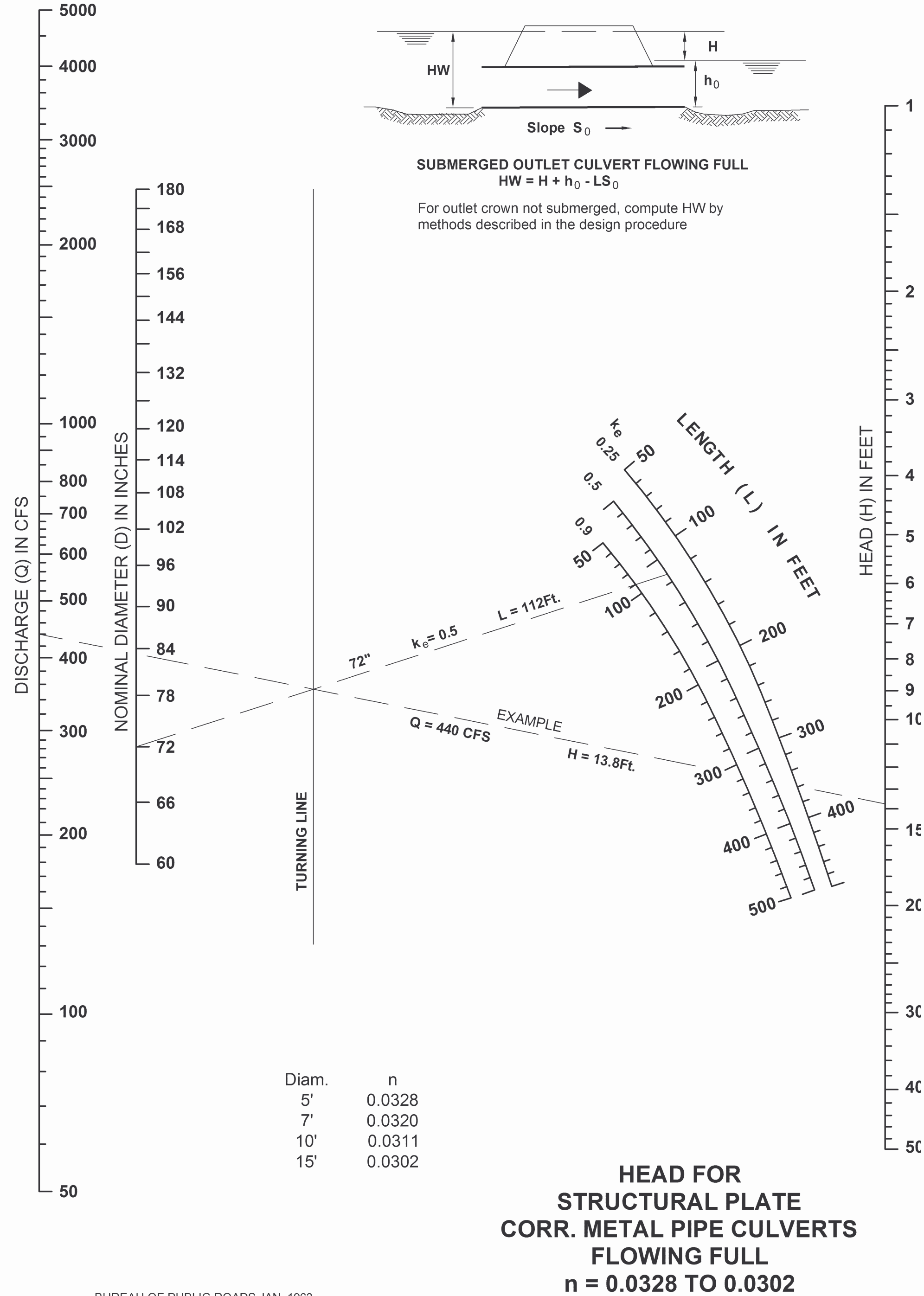


Figure 3.1.2.14

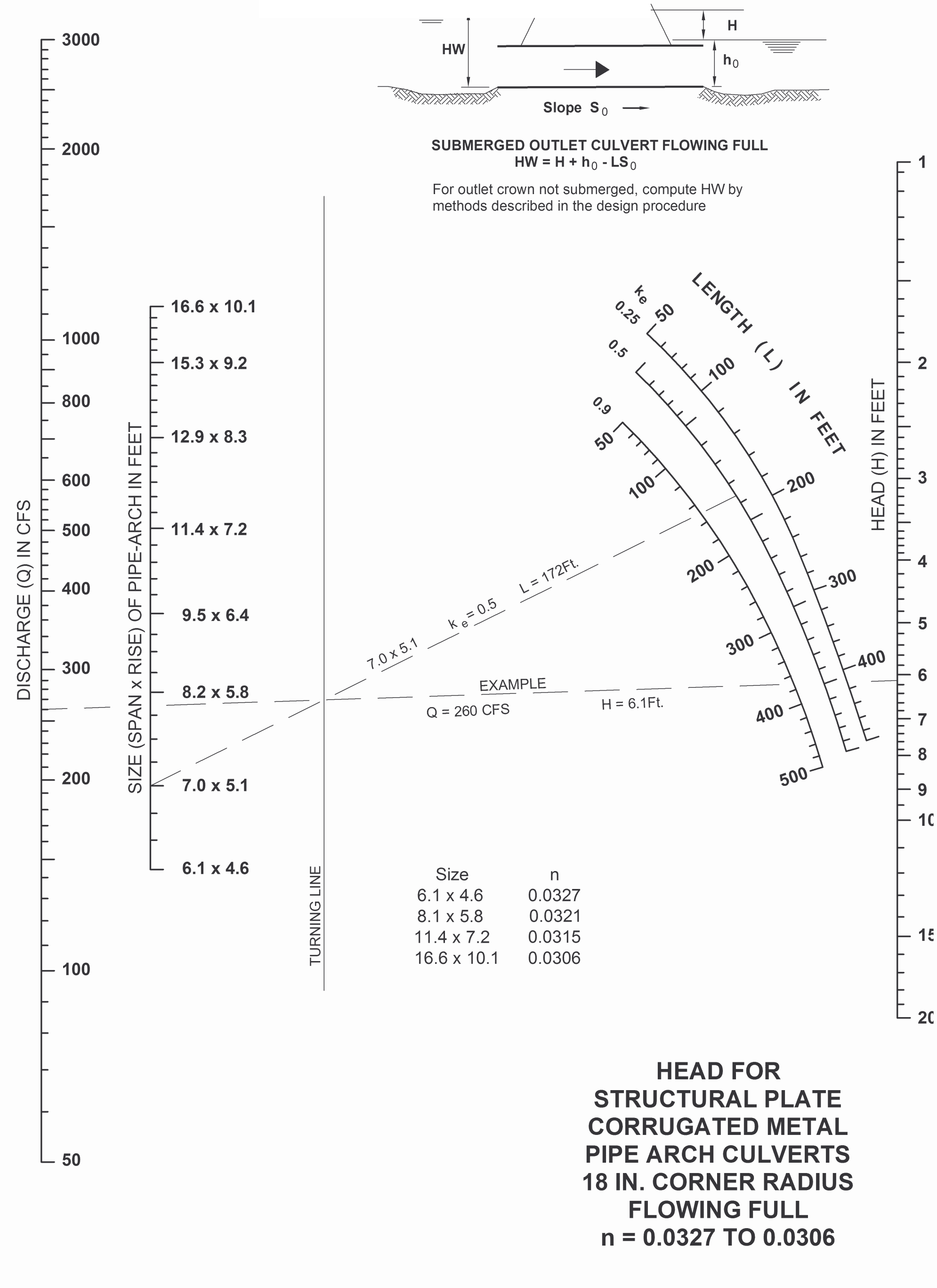
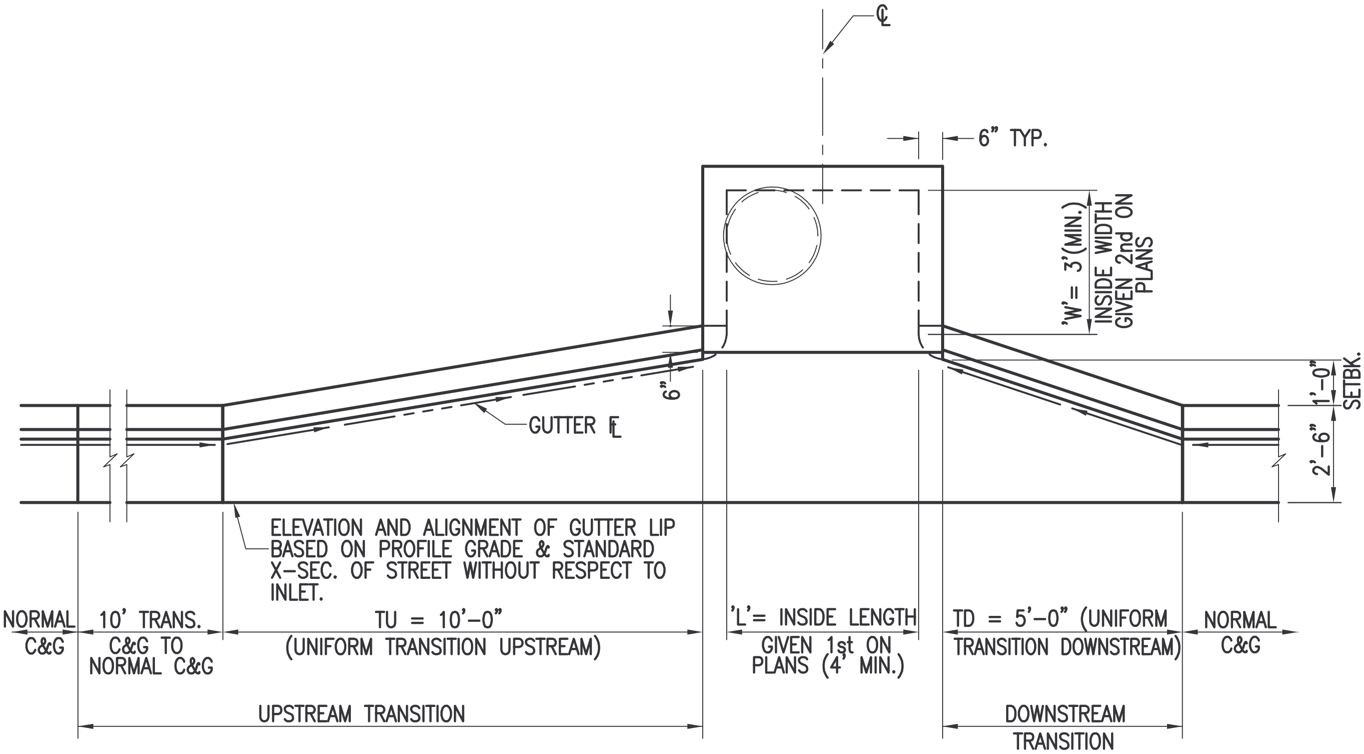
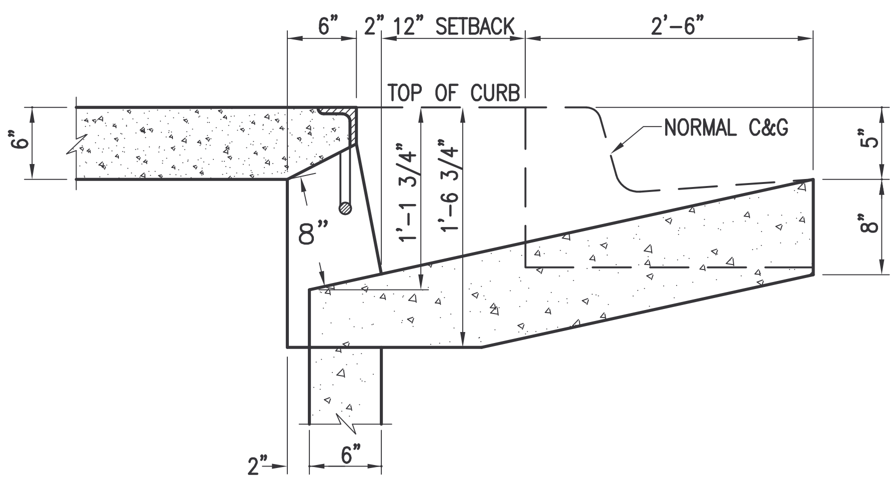


Figure 4.3.2.1
Type M Inlet



NOTE: INLET ON GRADE SHOWN. FOR INLET AT SUMP, USE UP STREAM TRANSITION ON BOTH SIDES OF INLET.

PLAN



THROAT DETAIL

Figure 4.3.3.1

THEORETICAL INLET CAPACITY

4'-0" LONG DEPRESSED CURB OPENING INLET

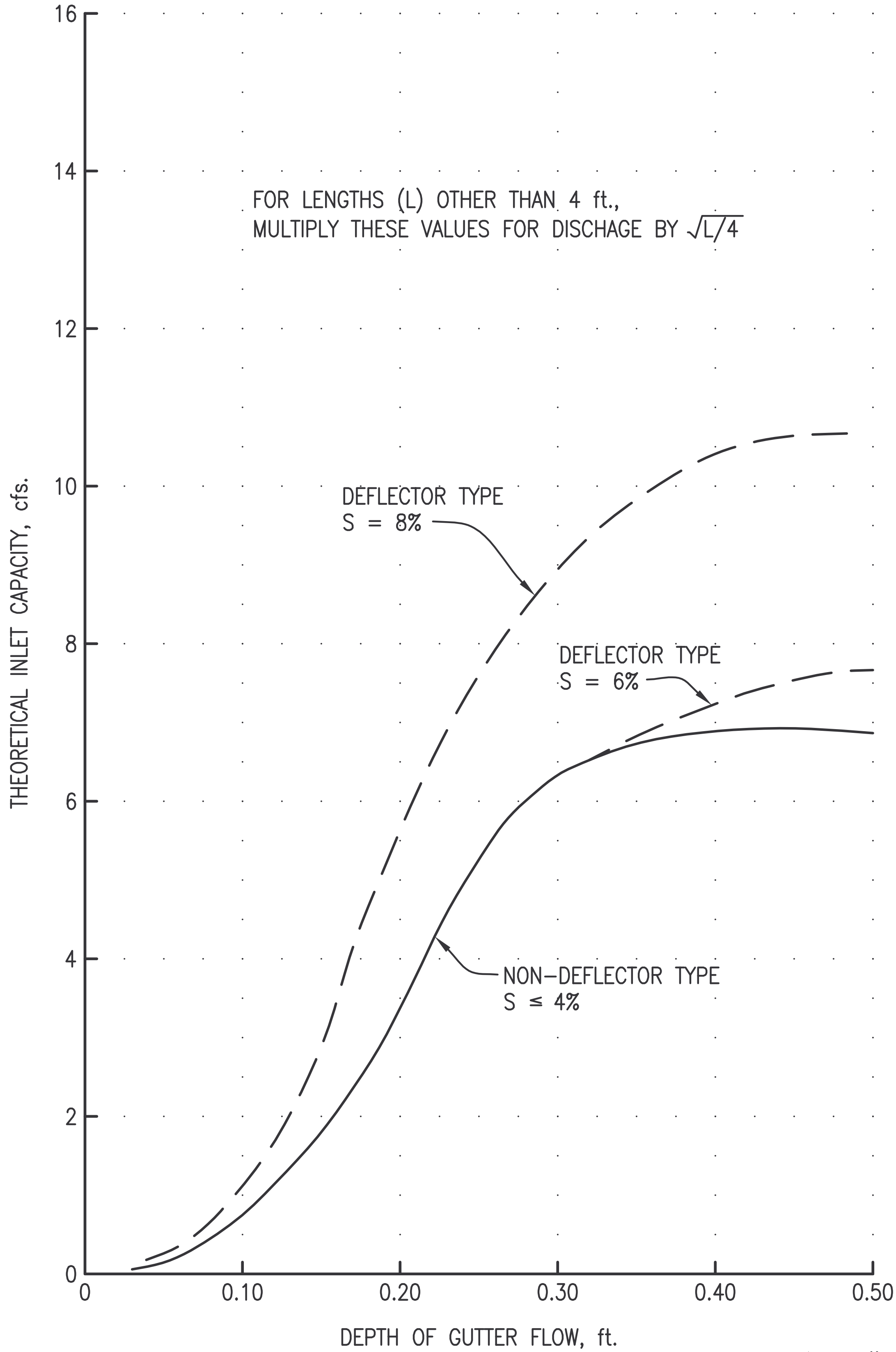
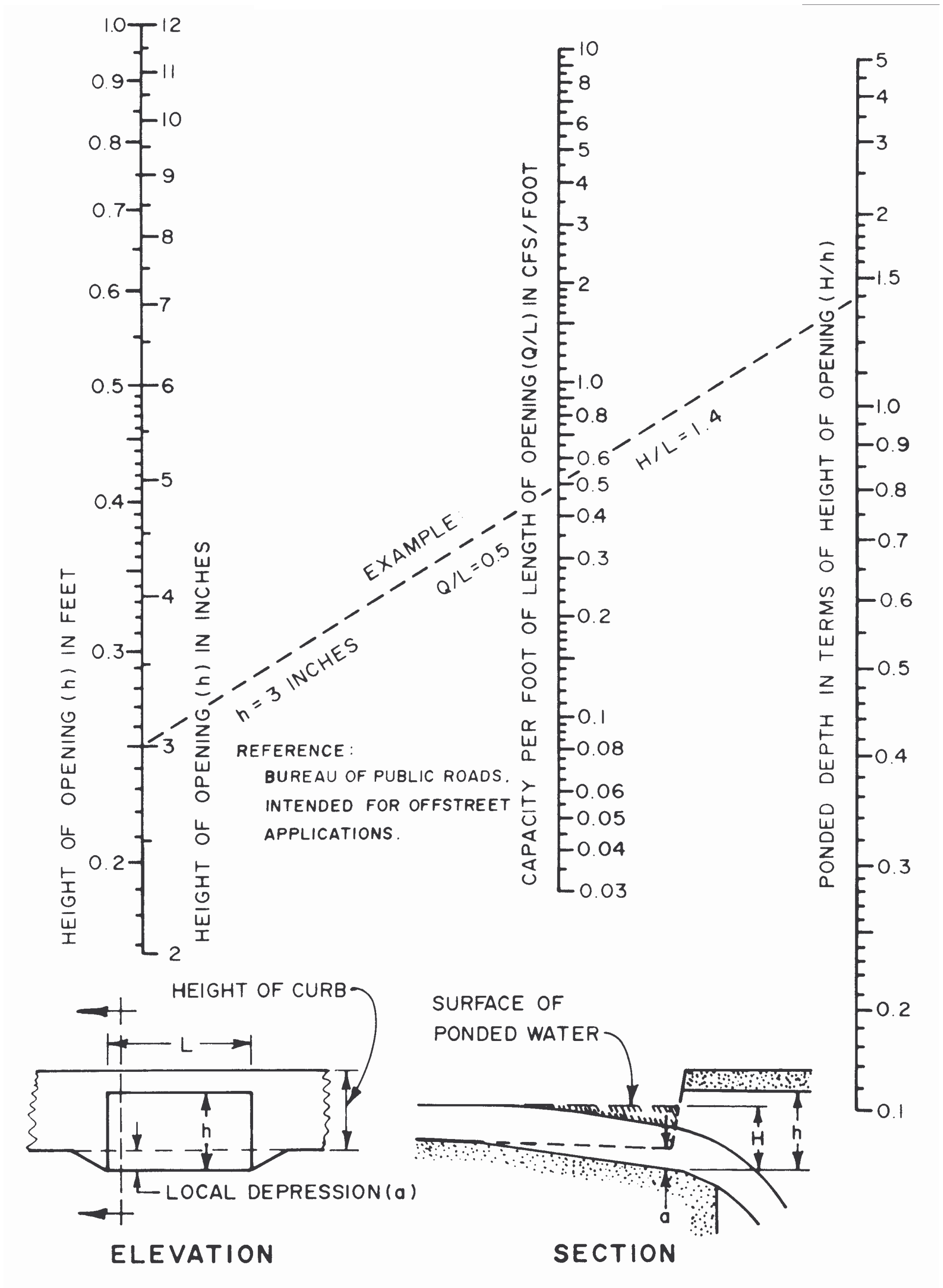
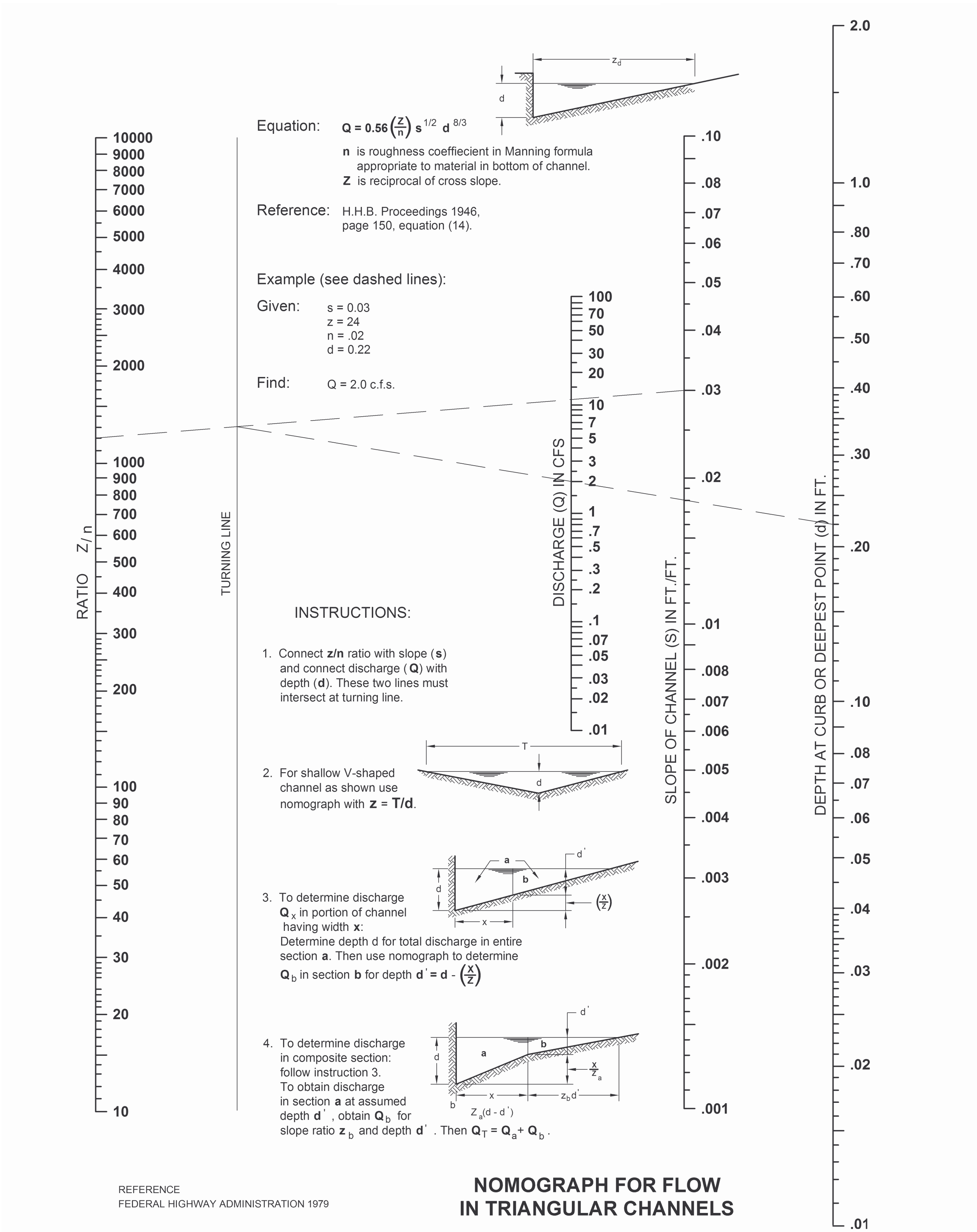


Figure 4.3.3.2



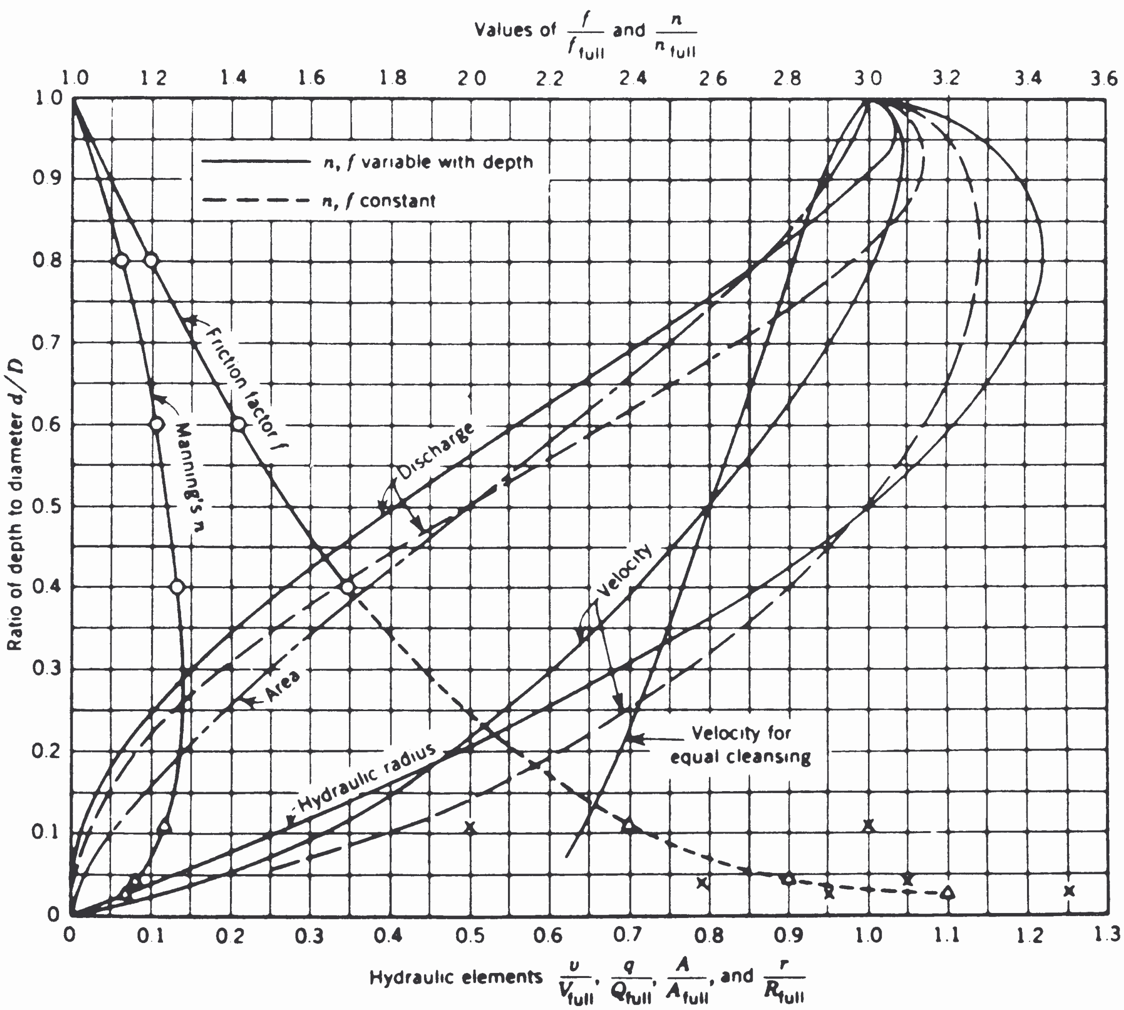
CAPACITY OF CURB OPENING INLET AT LOW POINT IN GRADE.

Figure 4.4.1.1



NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

Figure 4.6.2.1



- v = Actual velocity of flow (fps)
- V_{full} = Velocity flowing full (fps)
- q = Actual quantity of flow (cfs)
- Q_{full} = Capacity flowing full (cfs)
- A = Area occupied by flow ($ft.^2$)
- A_{full} = Area of pipe ($ft.^2$)
- r = Actual hydraulic radius (ft.)
- R_{full} = Hydraulic radius of full pipe (ft.)

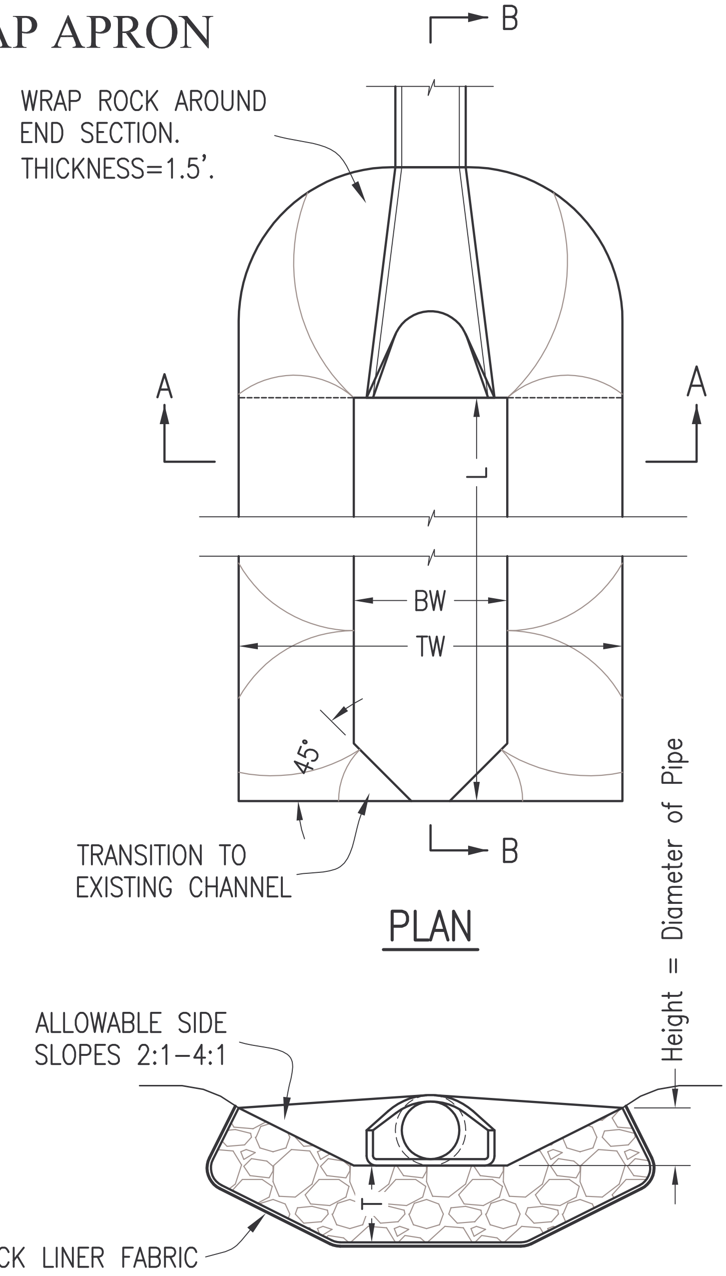
HYDRAULIC ELEMENTS OF CIRCULAR CONDUITS (2)

Figure 4.6.4.1
RIP RAP APRON

Pipe Size (in)	Maximum Pipe Slope (%)	Length L (ft)	Bottom Width BW Minimum (ft)	Top Width TW Minimum (ft)	Thickness T Minimum (ft)
12	3.50	12	4	8	2
15	2.60	15	4	9	2
18	2.00	16	4	10	2
24	1.70	20	4	12	2
30	1.40	24	6	16	2
36	1.00	28	6	18	2
42	0.80	32	6	20	3
48	0.65	36	6	22	3
54	0.55	40	8	26	3
60	0.45	44	8	28	3
72	0.40	48	8	32	3

Rip rap to be MoDOT Type I: 50% of particles greater than or equal to 1 foot in diamenter. Rock must be angular, hard and durable.

Rock Liner Fabric shall consist of a non–woven polypropylene type fabrice: Amoco 4553 or SI Geosolutions Geotex 801 or approved equal. Alternatively, an 8 inch bed of well graded sand and gravel with gravel up to 3" is acceptable.



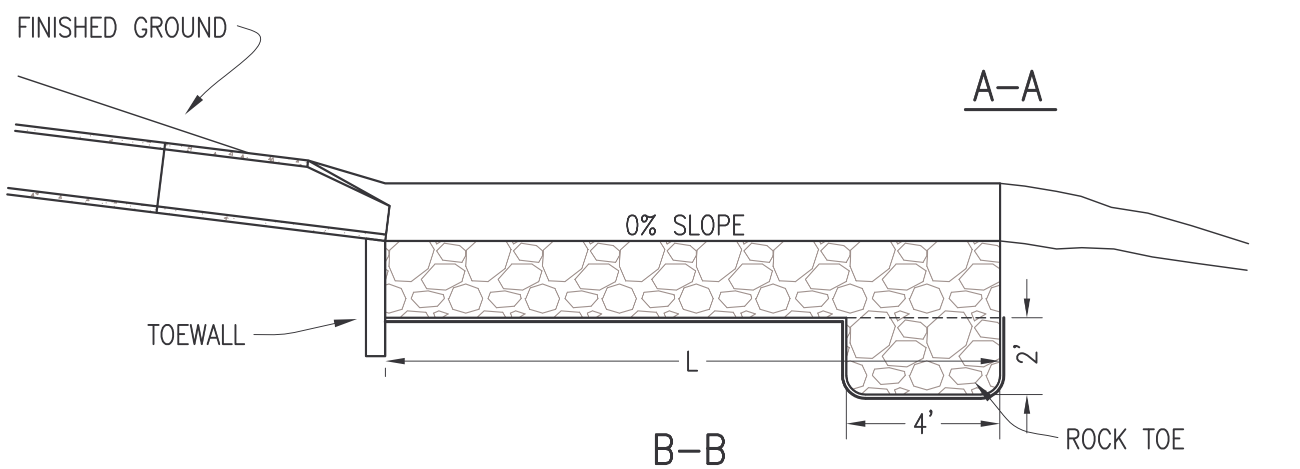


Figure 5.1.4.1A: Natural Channel Assessment

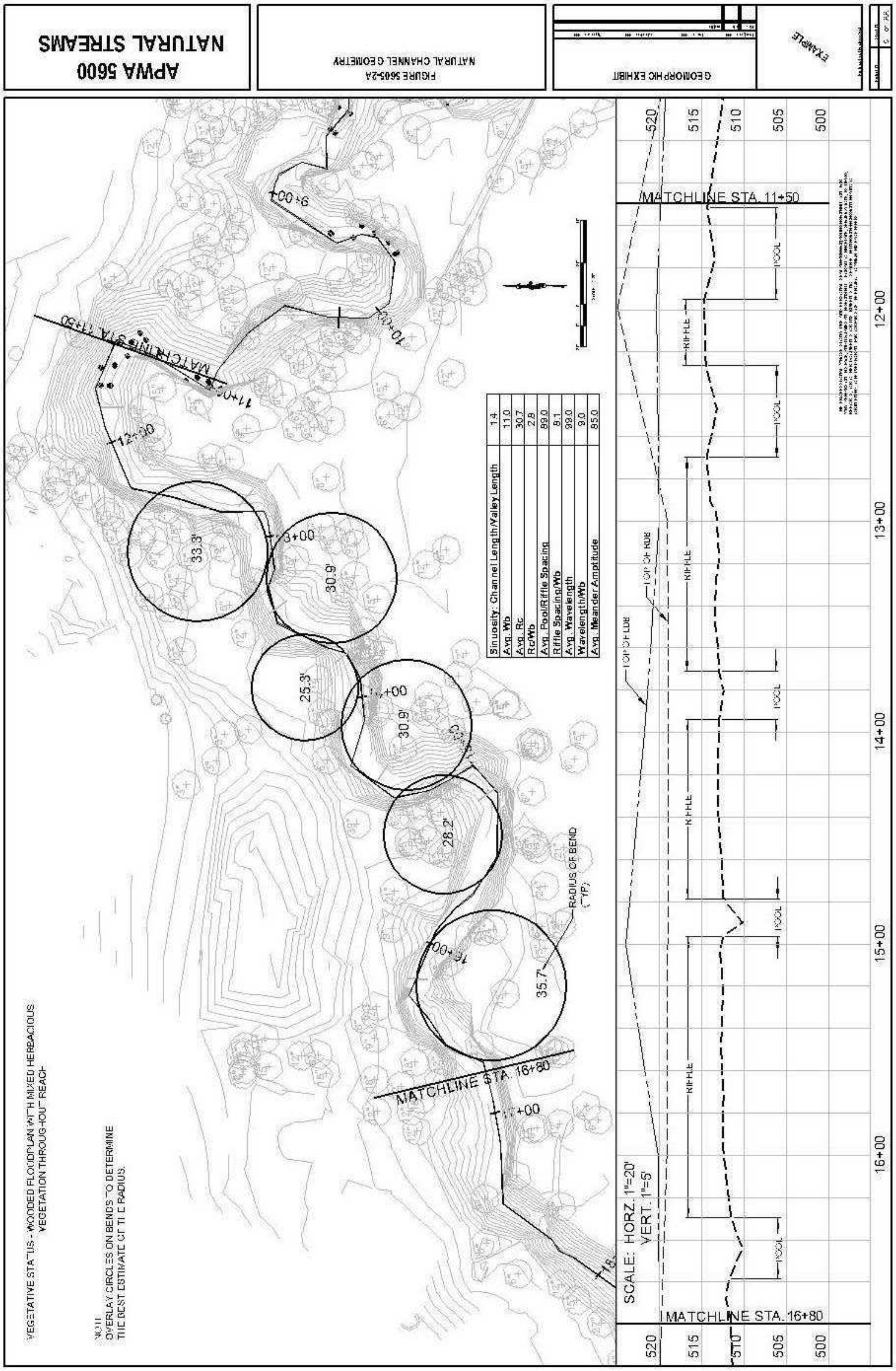


Figure 5.1.4.1B: Natural Channel

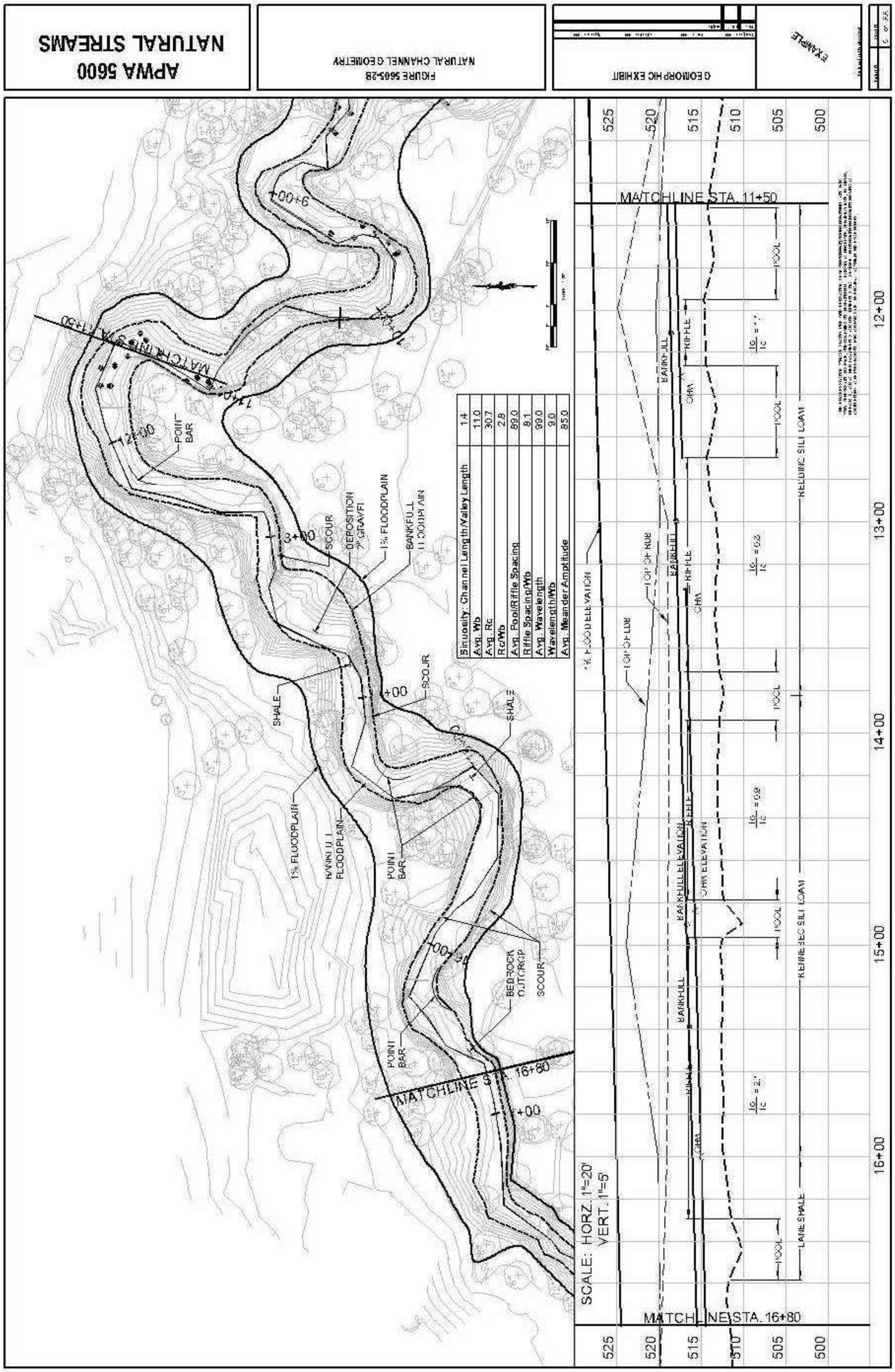
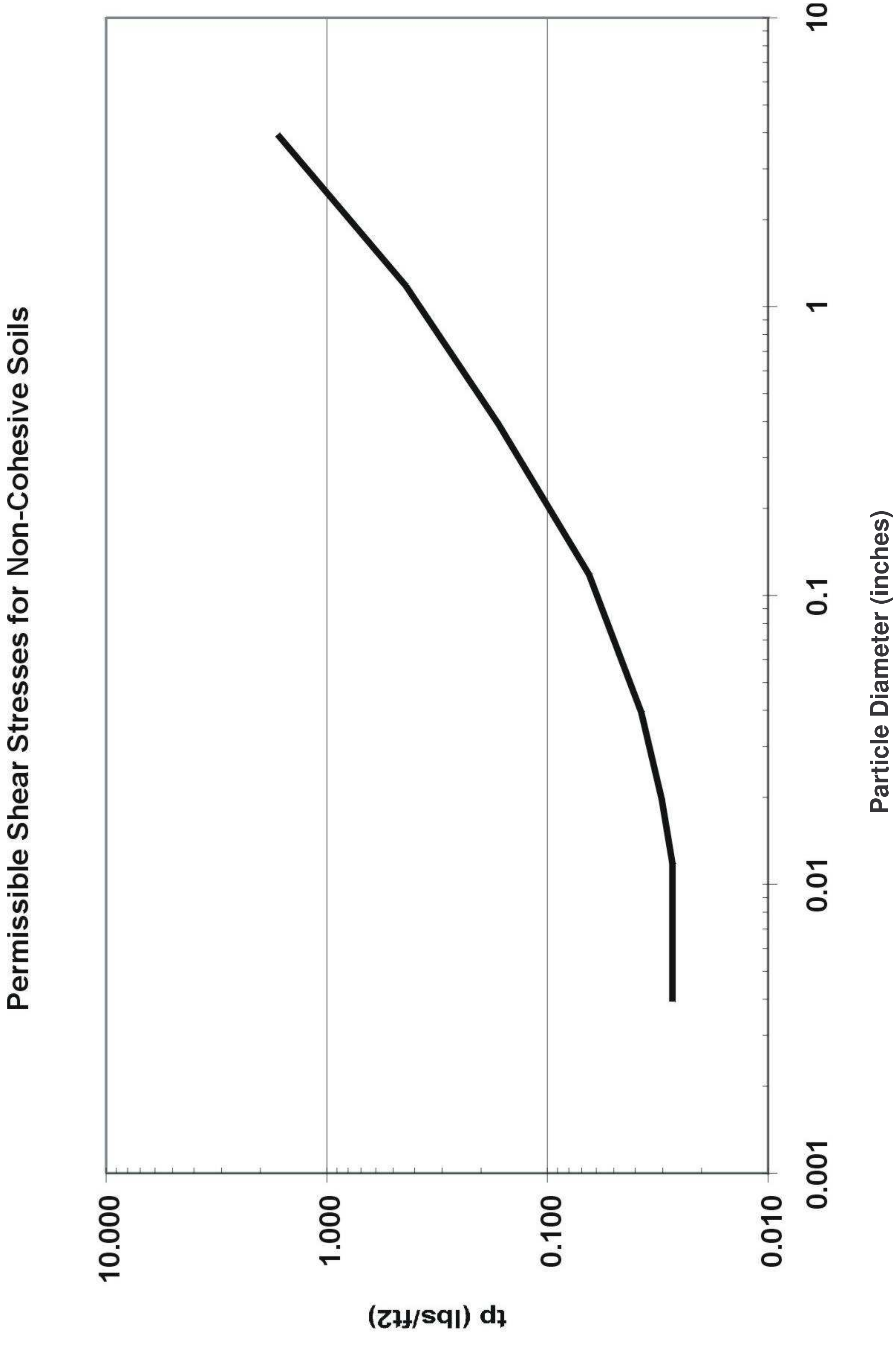


Figure 5.1.4.2



Permissible Shear Stresses for Non-Cohesive Soils
10.000
1.000
0.100
0.010
tp (lbs/ft2)
0.001
0.01
0.1
1
10
Particle Diameter (inches)

Figure 5.1.4.3

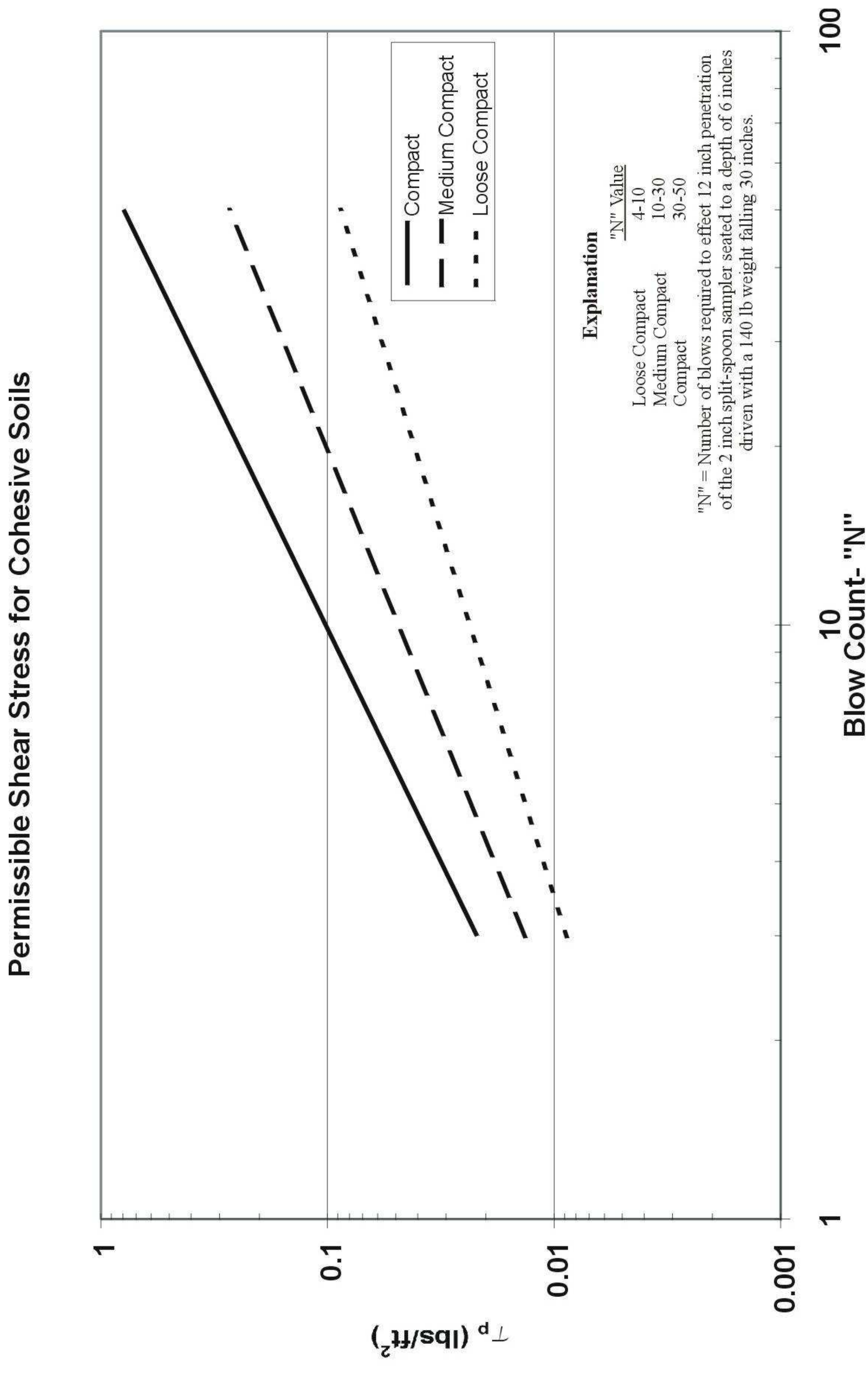
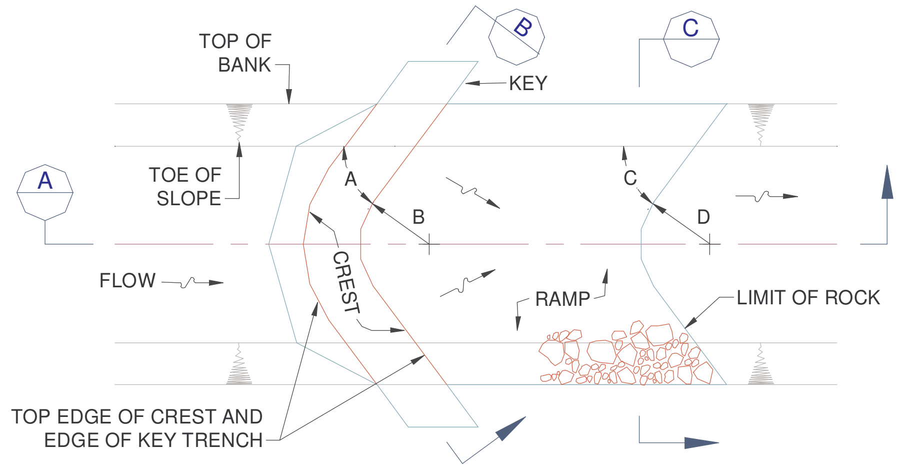
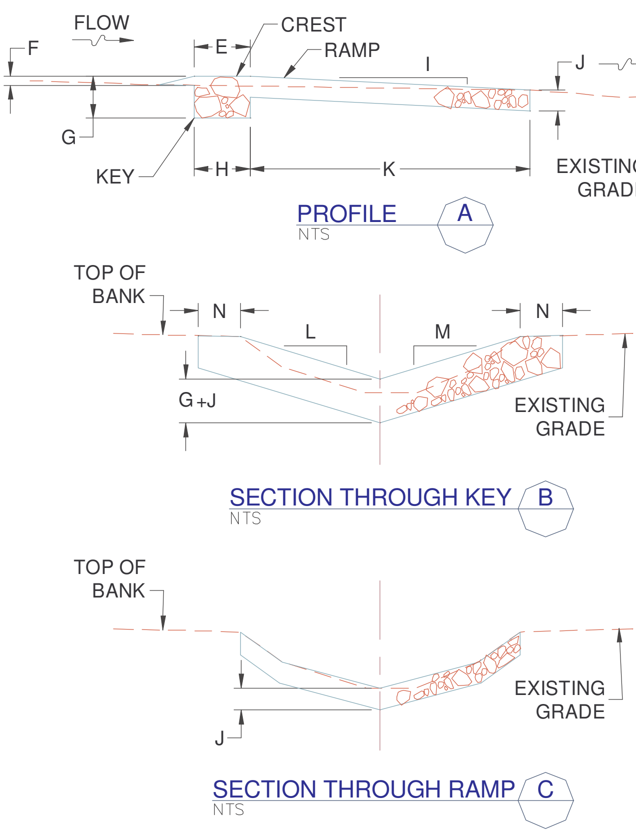

Permissible Shear Stress for Cohesive Soils
Compact
Medium Compact
Loose Compact
Explanation
"N" Value
Loose Compact 4-10
Medium Compact 10-30
Compact 30-50
"N" = Number of blows required to effect 12 inch penetration of the 2 inch split-spoon sampler seated to a depth of 6 inches driven with a 140 lb weight falling 30 inches.
1
0.1
0.01
0.001
τp (lbs/ft2)
1
10
100
Blow Count- "N"

Figure 5.1.8.1: Grade Control Structure



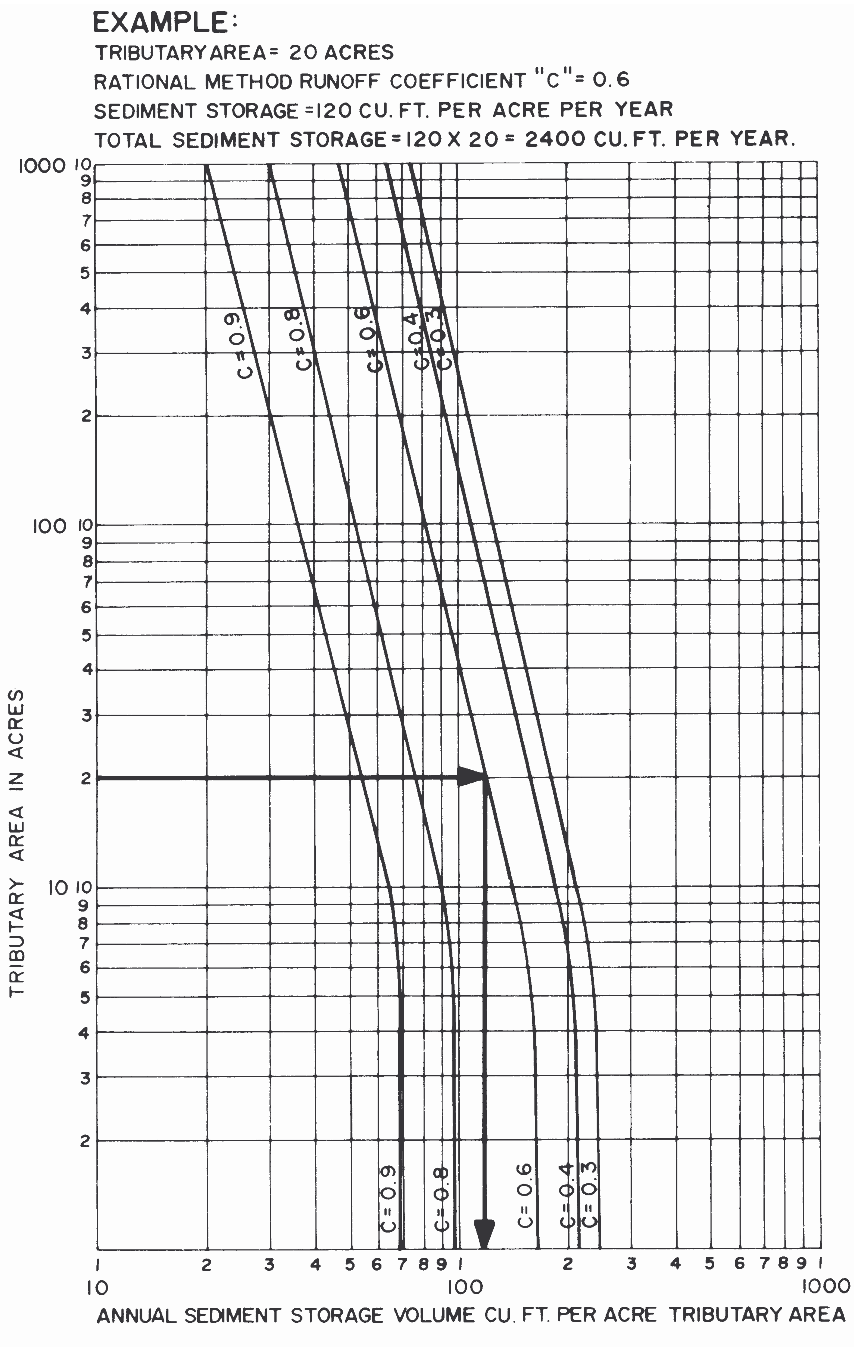


A	STREAM BANK ANGLE (50° < A < 80°)
B	CREST RADIUS
C	TAIL ANGLE(50° < A < 80°)
D	END OF RAMP RADIUS
E	CREST WIDTH
F	CREST HEIGHT
G	KEY THICKNESS ≧ 1.5 D_{90}
H	KEY WIDTH ≧ 1.5 D_{90}
I	RAMP GRADE 20H:1V
J	RAMP THICKNESS ≧ 1.5 D_{100}
K	RAMP LENGTH
L	CREST SIDE SLOPE
M	CREST SIDE SLOPE
N	EMBANKMENT KEY

Notes

1. The depth of key trench shall be a minimum of 1.5 $D_{90.}$The crest shall slope downward from the stream bank to the center of the structure to focus the flow to the channel center. The tail ramp is generally sloped at 20 horizontal to 1 vertical and dissipates energy gradually over it length. The upstream face is not perpendicular to the flow but has an upstream oriented "V" or arch shape in plan form.
2. For item A, Stream Bank Angle, and item C Tail Angle, the lower end of the range should be used for softer soils.
3. For items L and M, crest angle, the typical range is 5 to 1 to 10 to 1.

Figure 6.5.1



ANNUAL SEDIMENT STORAGE

Figure 7.3.1
Calculation Form A

Project: Calculated By: Checked By: Date:

Area Name:			Overland Flow Hydrology								Gutter and Inlet Hydraulics						
Area No.	To Inlet No.	Inlet Type	Ground Slope S	Length of Overland Flow L	Time of Concen-tration Tc	Runoff Coeff. C	Area A	Per Cent Imper-viousness CA	Rainfall Intensity i	Runoff Qr	Gutter Flow Qg	Gutter Slope Sg	Width of Gutter Flow W	Depth of Gutter Flow Yg	Theoret. Inlet Capacity Q	Design Inlet Capacity k Qi	Inlet Bypass Flow q
			ft/ft	ft	min		acres	acres	in/hr	cfs	cfs	ft/ft	ft	ft	cfs	cfs	cfs

Figure 7.3.2
Calculation Form B

Project:

Calculated By:

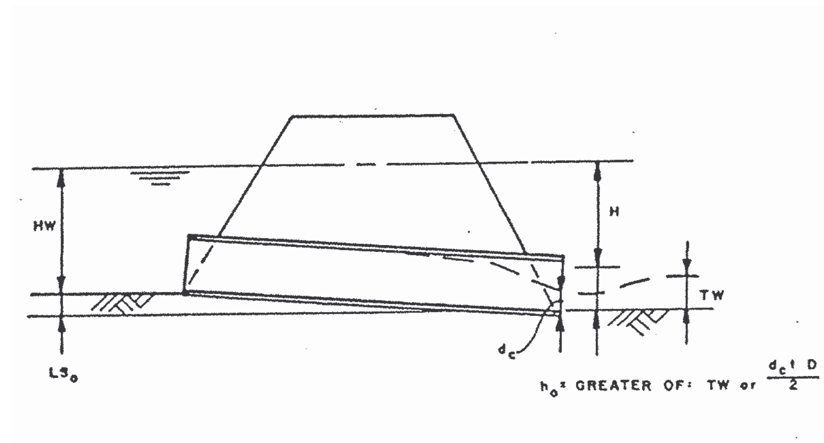
Checked By:

Date:

Area Name:		Storm Drain Hydraulics														
Area NO.	Manhole or Junction NO.	Time of Concen-tration Tc	Percent Imperviousness CA Added	Cumul.	Rainfall Intensity i	Runoff Q	Storm Drain Length L	Storm Drain Slope S	Storm Drain Diameter D	Capacity Flowing Full Qf	Velocity Flowing Full Vf	Time in Storm Drain t	Head-Losses hL	Manhole or Junction Invert Elevation Upstm	Downstm	Ground Surface Elev. @ Manhole
		min	acres	acres	in/hr	cfs	ft	ft/ft	in	cfs	fps	min	ft	ft	ft	ft

Figure 7.3.3
Calculation Form C

Hydrology						
Area NO.	Culvert NO.	Percent Imperviousness CA Added	Cumul	Time of Concentration Tc	Rainfall Intensity	Discharge Q
		acres	acres	min	in/hr	cfs



			Culvert Dimensions			Inlet Control		Outlet Control								
Culvert NO.	Culvert Type	Discharge Q	Lngth L	Slope So	Dia. D	HW/D	HW	Ke	H	dc	(dc + d)/2	TW	ho	LSo	HW	Remarks
		cfs	ft	ft/ft	in		ft		ft	ft	ft	ft	ft	ft	ft	

Figure 7.3.4

Calculation Form D

Project: ____________________ Calculated By: ____________________

Date: ____________________ Checked By: ____________________

Columbia, Missouri
Storm Drain Calculations
Calculation Form A

Area Name:
Runoff Coefficient Calculations: (Either May Be Used)

Method A

Area NO.	Land Use Category	C

Method B

Area NO.	Surface Characteristics	C

Street Configuration:

Width: ☐ 32' ☐ 38' ☐ 44' ☐ Other, Specify________

Cross Slope: ☐ 4" Para ☐ 5" Para ☐ 6" Para ☐ 2% ☐ Other, Specify:_______

Curb Type: ☐ 6" High Straight Back ☐ Other, Specify: _______

Storm Drain Material: ☐ Concrete Pipe: n = ________
☐ Corrugated Metal Pipe: n = ________
☐ Other, Specify:________________________ n = ________

Rainfall Return Frequency ____________ Years

Figure 7.3.5

Calculation Form E

Open Channel Calculations

Description	Hydrology							Channel Parameters							
	Area NO.	Area A	Runoff Coeff. C	Percent Imperv-iousness	Rainfall Return Frequency	Rainfall Intensity i	Q (total)	Channel Slope	Mannings	Left Side Slope	Right Side Slope	Bottom Width	Depth	Velocity	Capacity Q
		Acres	C	CA	Year	in/hr	cfs	ft/ft	n	X : 1	X : 1	ft	ft	fps	cfs

Project: ____________________ Calculated By: ____________________ Checked By: ____________________ Date: ______