Kitsap County Stormwater Design Manual

Figures & Tables

November 2009

DRAFT

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CHAPTER 3–FIGURES

Figure 3.1 — Covered Fuel Island

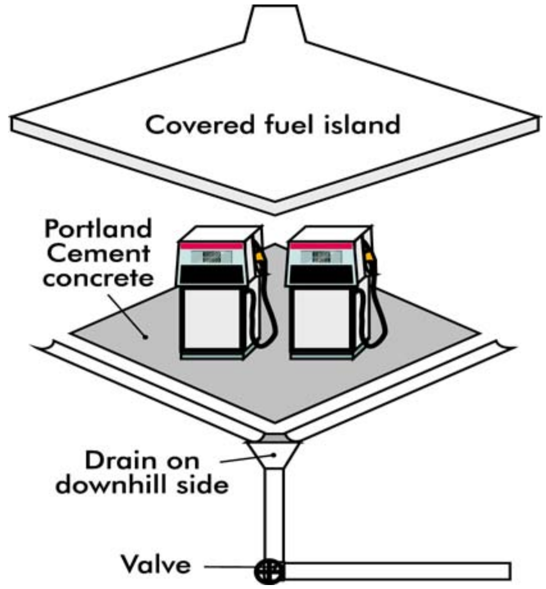


Figure 3.2 — Drip Pan

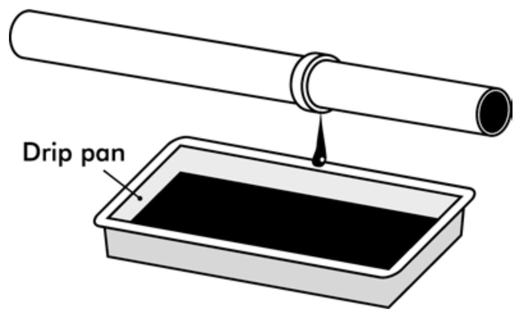


Figure 3.3 — Drip Pan Within Rails

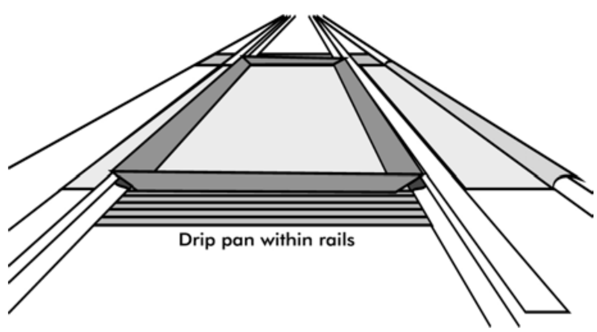


Figure 3.4 — Loading Dock with Door Skirt

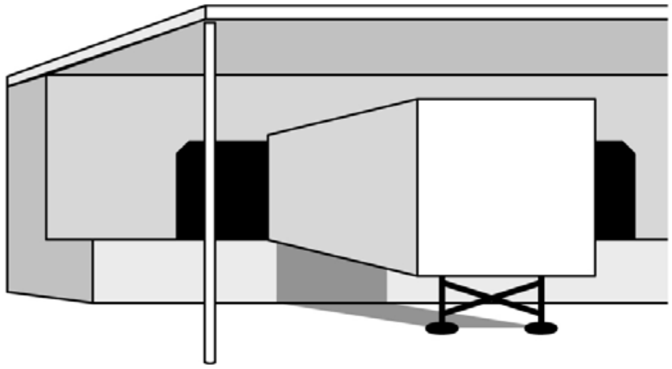


Figure 3.5 — Loading Dock with Overhang

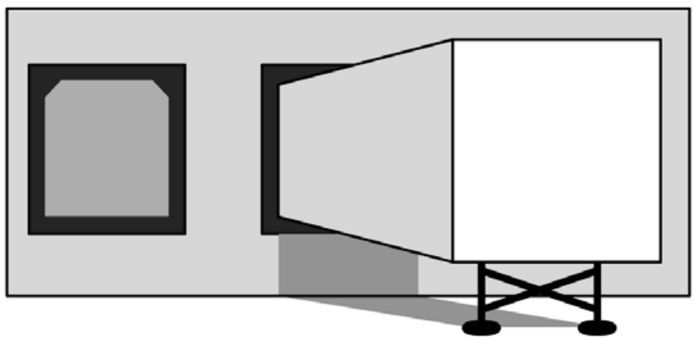


Figure 3.6 — Enclose the Activity

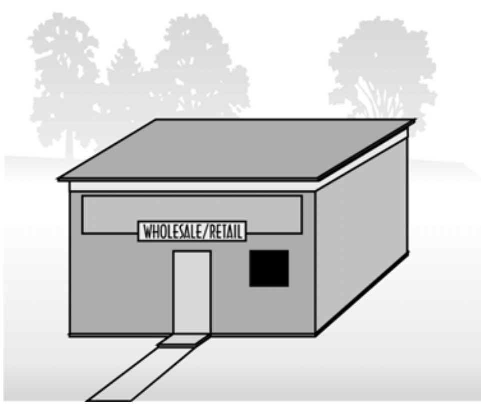


Figure 3.7 — Cover the Activity

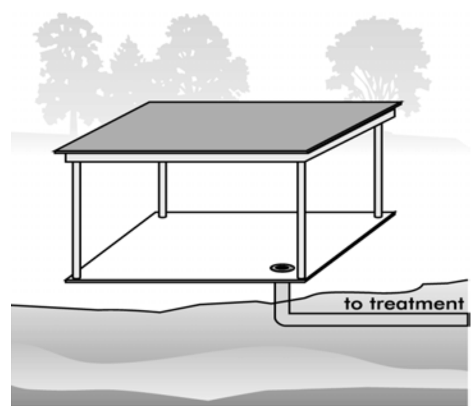


Figure 3.8 — Secondary Containment System

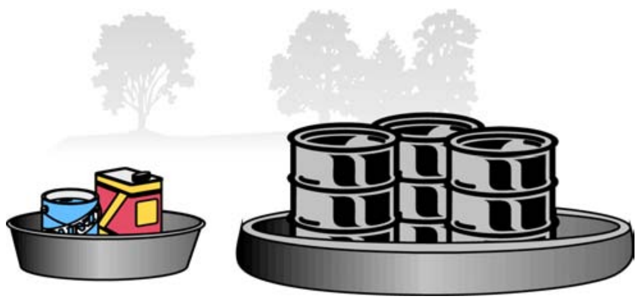


Figure 3.9 — Locking System for Drum Lid

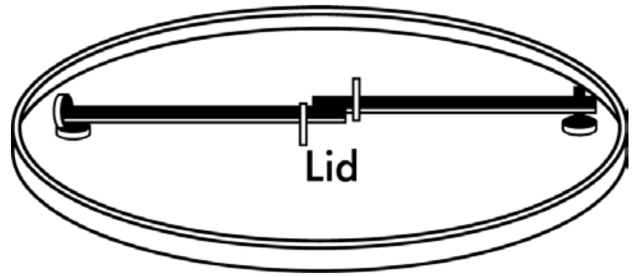


Figure 3.10 — Covered & Bermed Containment Area

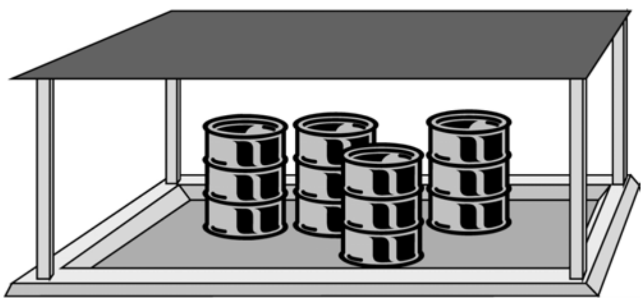


Figure 3.11 — Mounted Container with Drip Pan

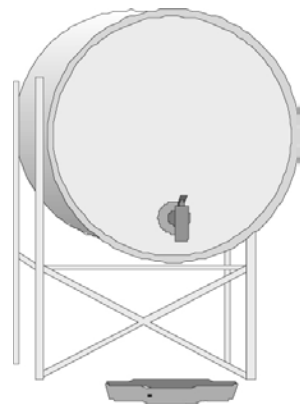


Figure 3.12 — Above-ground Tank Storage

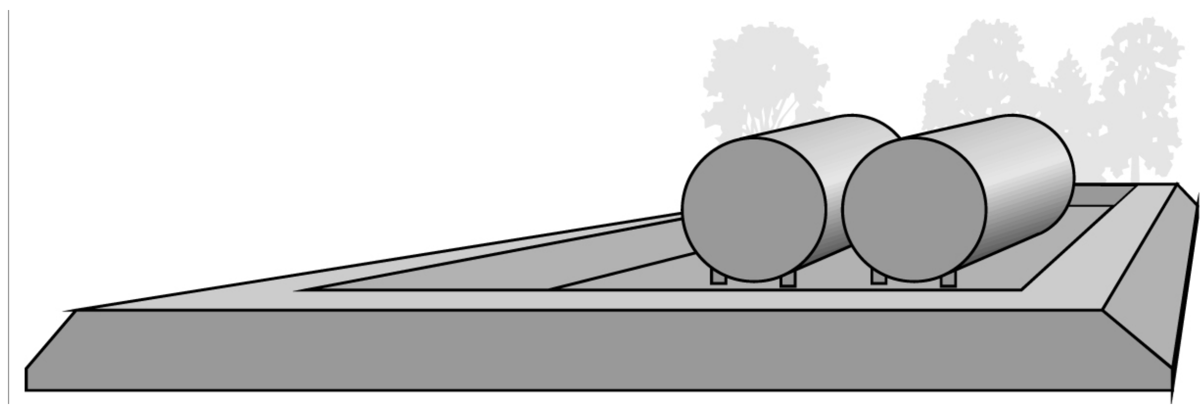
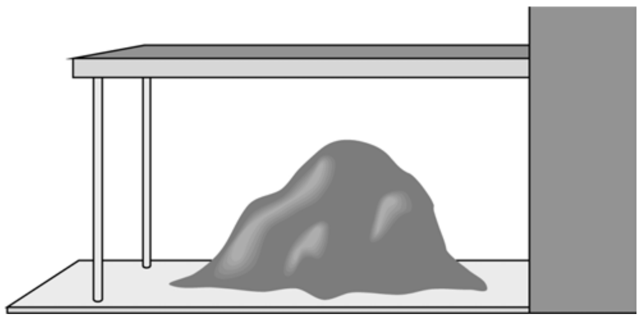


Figure 3.13 — Covered Storage for Bulk Solids



Note: Include berm if needed

Figure 3.14 — Material Covered with Plastic Sheeting

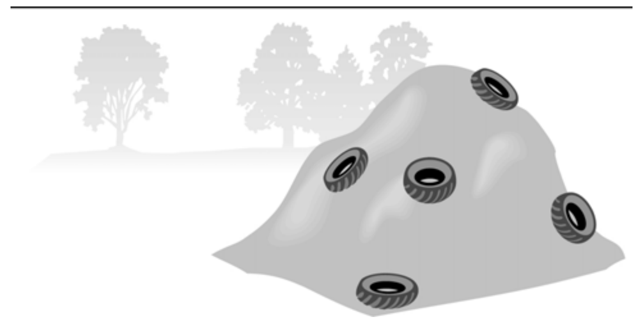
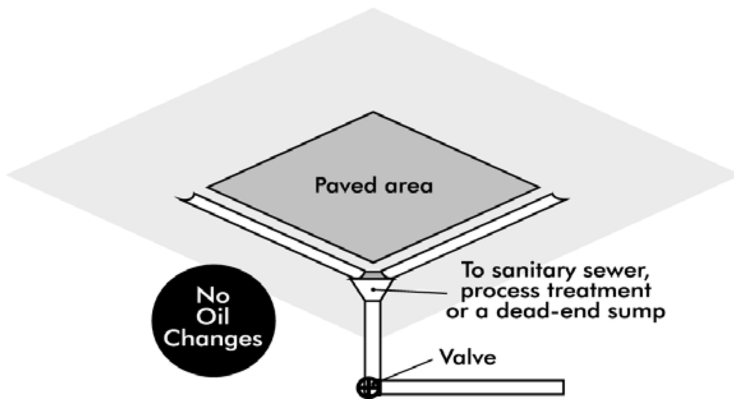


Figure 3.15 — Uncovered Wash Area



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CHAPTER 4–FIGURES

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Figure 4.1 — Rainfall Intensity-Duration Curves

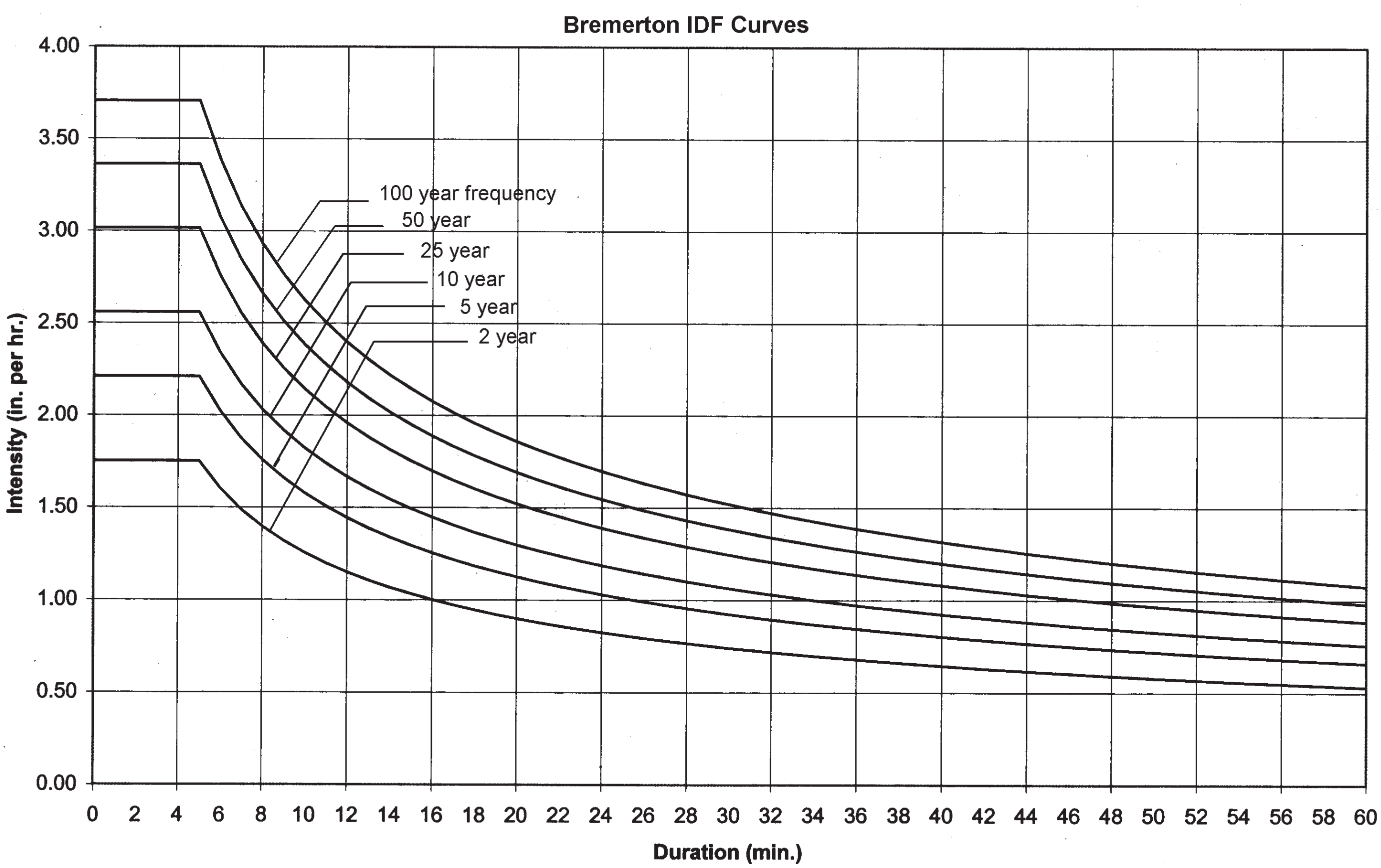
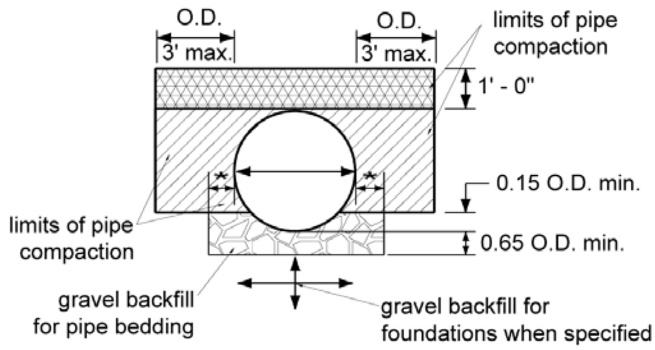
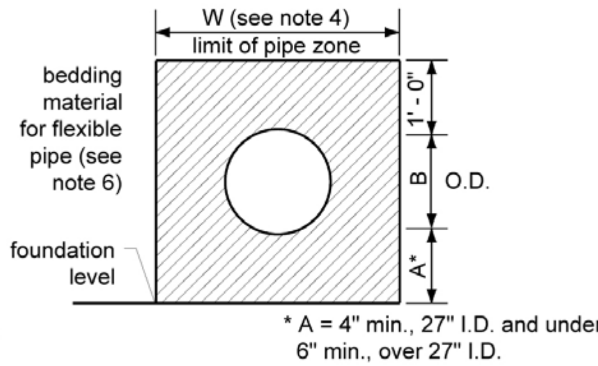


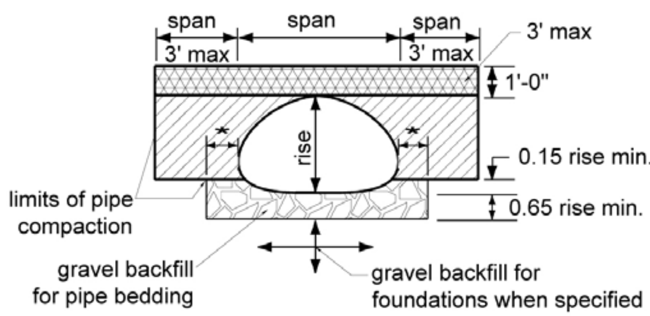
Figure 4.2 — Pipe Compaction Design and Backfill



A. Metal and Concrete Pipe



Bedding for Flexible Pipe



B. Pipe - Installation

Rigid Pipe NOTES:

1. Pipe compaction limits shown on this plan are for pipe construction in an embankment. For pipe construction in a trench, the horizontal limits of the pipe compaction zone shall be the walls of the trench.
2. All steel and aluminum pipe and pipe-arches shall be installed in accordance with design A.
3. Concrete pipe with elliptical reinforcement shall be installed in accordance with design A.
4. Concrete pipe, plain or with circular reinforcement, shall be installed with design A.
5. O.D. is equal to the outside diameter of a pipe or the outside span of pipe-arch. The dimensions shown as O.D. with 3' maximum shall be O.D. until O.D. equals 3'; at which point 3' shall be used.

* 1'-0" for diameters 12" through 42" and spans through 50". 2'-0" for diameters greater than 42" and spans greater than 50".

Flexible Pipe NOTES:

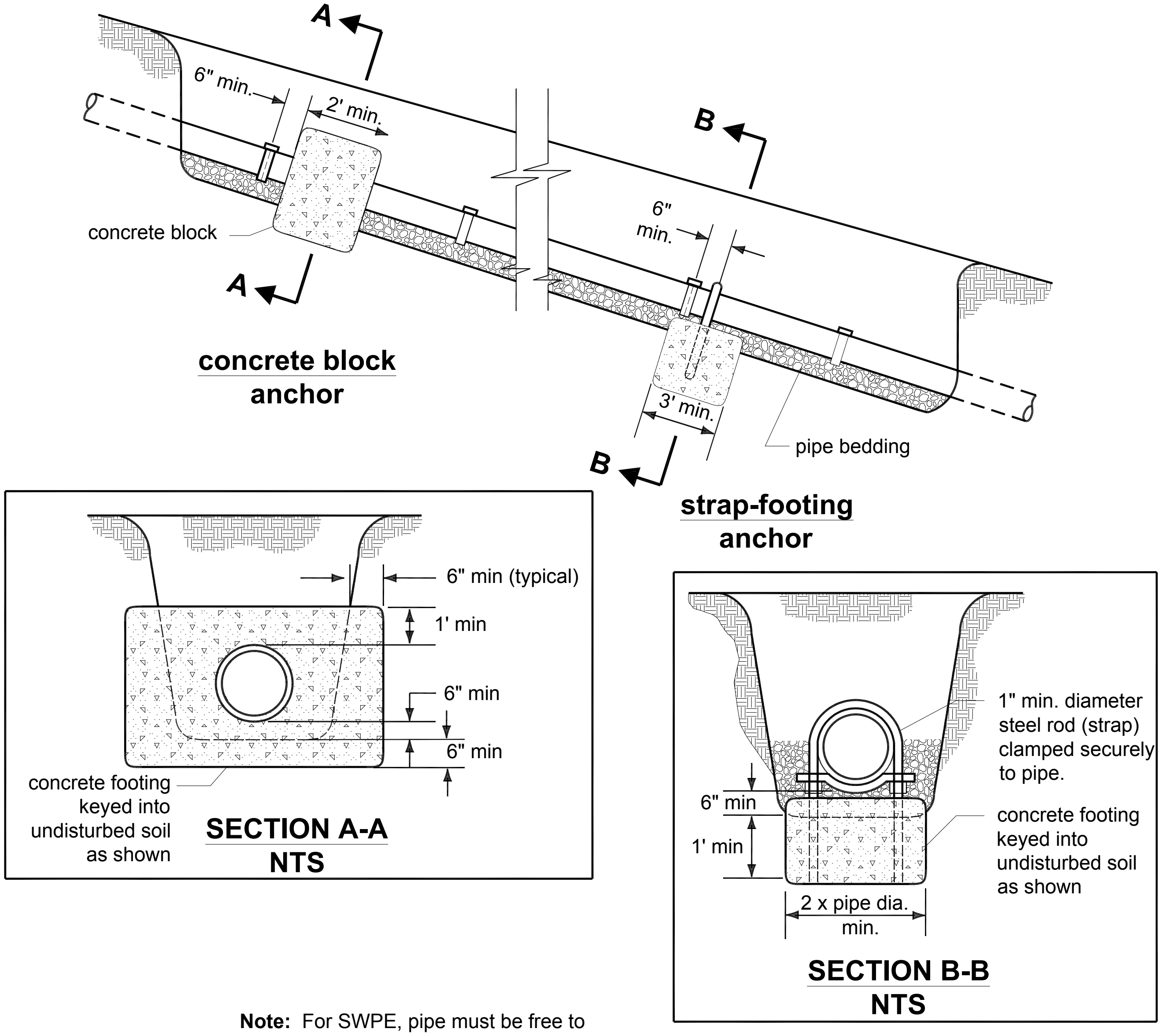
1. Provide uniform support under barrels.
2. Hand tamp under haunches.
3. Compact bedding material to 95% max. density; directly over pipe, hand tamp only.
4. See "Excavation and Preparation of Trench" in sanitary sewers section of the standard WSDOT/APWA specifications for trench width "W" and trenching options. The pipe zone will be the actual trench width. The minimum concrete width shall be 1 $\frac{1}{2}$ I.D. + 18".
5. Trench backfill shall conform to "Backfilling Sewer Trenches" in the sanitary sewers section of the WSDOT/APWA standard specifications, except that rocks or lumps larger than 1" per foot of pipe diameter shall not be used in the backfill material.
6. See "Bedding Material for Flexible Pipe" in aggregates section of the WSDOT/APWA standard specifications for the material specifications.

Backfill material placed in 0.5' loose layers and compacted to 95% maximum density.

Method B or C compaction (WSDOT/APWA) standard specifications.)

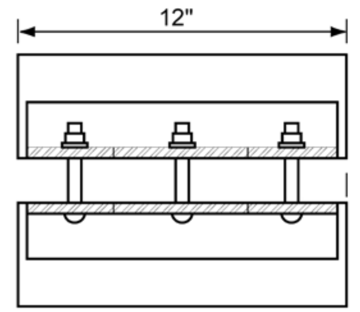
Pipe	Size	Min. dist. between barrels
circular pipe conc., LCPE, CMP (diameter)	12" to 24"	12"
	30" to 96"	diam. / 2
	102" to 180"	48"
pipe - arch metal only (span)	18" to 36"	12"
	43" to 142"	span / 3
	148" to 199"	48"

Figure 4.3 — Pipe Anchor Detail



Note: For SWPE, pipe must be free to slide inside a 4' long section of pipe one size diameter larger.

Figure 4.4 — Corrugated Metal Pipe Coupling and/or General Pipe Anchor Assembly



Smooth Coupling Band for Smooth Pipe

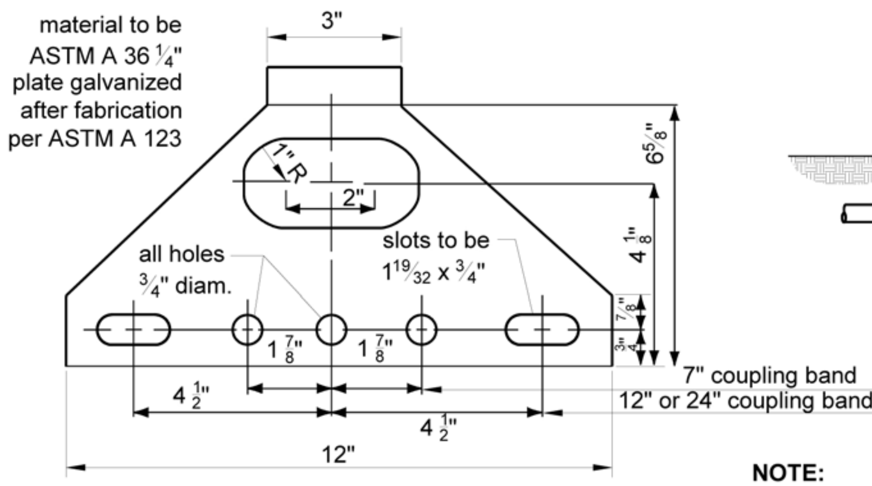
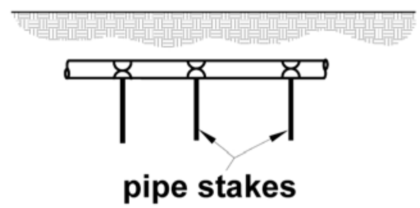
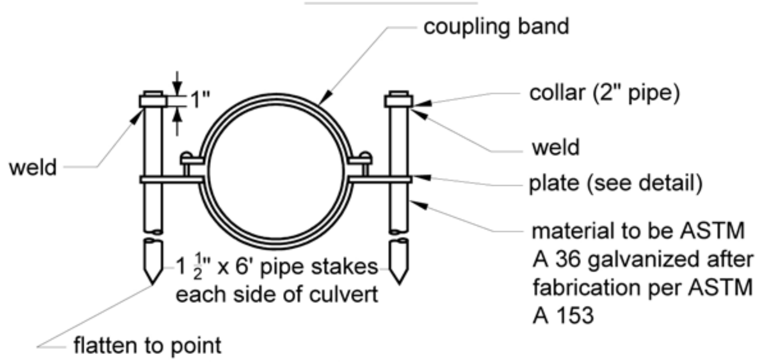


Plate Detail





Anchor Assembly Corrugated Metal Pipe

NOTE:

1. The smooth coupling band shall be used in combination with concrete pipe.
2. Concrete pipe without ball and spigot shall not be installed on grades in excess of 20%.
3. The first anchor shall be installed on the first section of the lower end of the pipe and remaining anchors evenly spaced throughout the installation.
4. If the pipe being installed has a manhole or catch basin on the lower end of the pipe, the first pipe anchor may be eliminated.
5. When CMP is used, the anchors may be attached to the coupling bands used to join the pipe as long as the specified spacing is not exceeded.
6. All pipe anchors shall be securely installed before backfilling around the pipe.

Figure 4.5 — Debris Barrier (Off Road Right-of-Way)

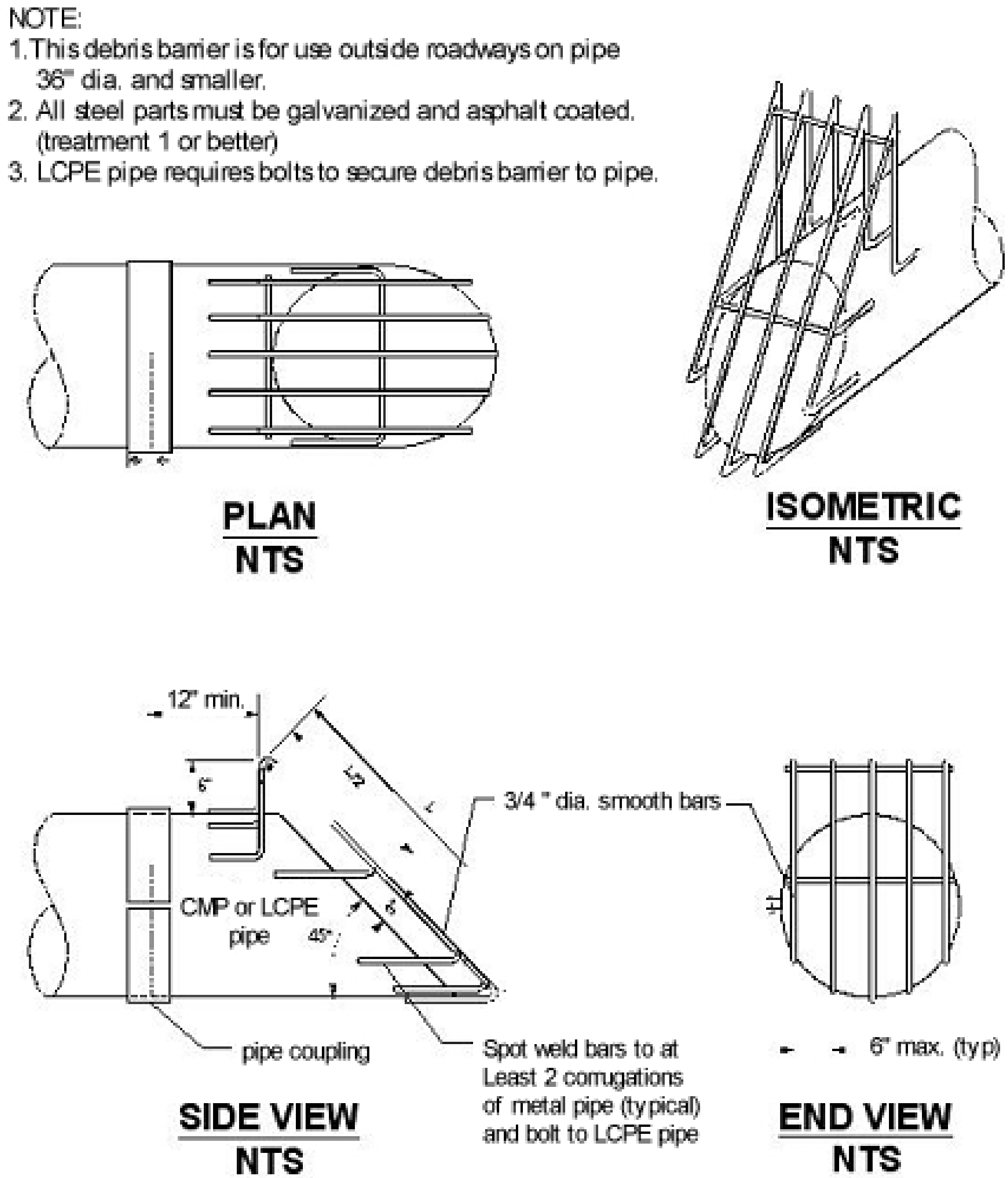


Figure 4.6 — Debris Barrier (In Road Right-of-Way)

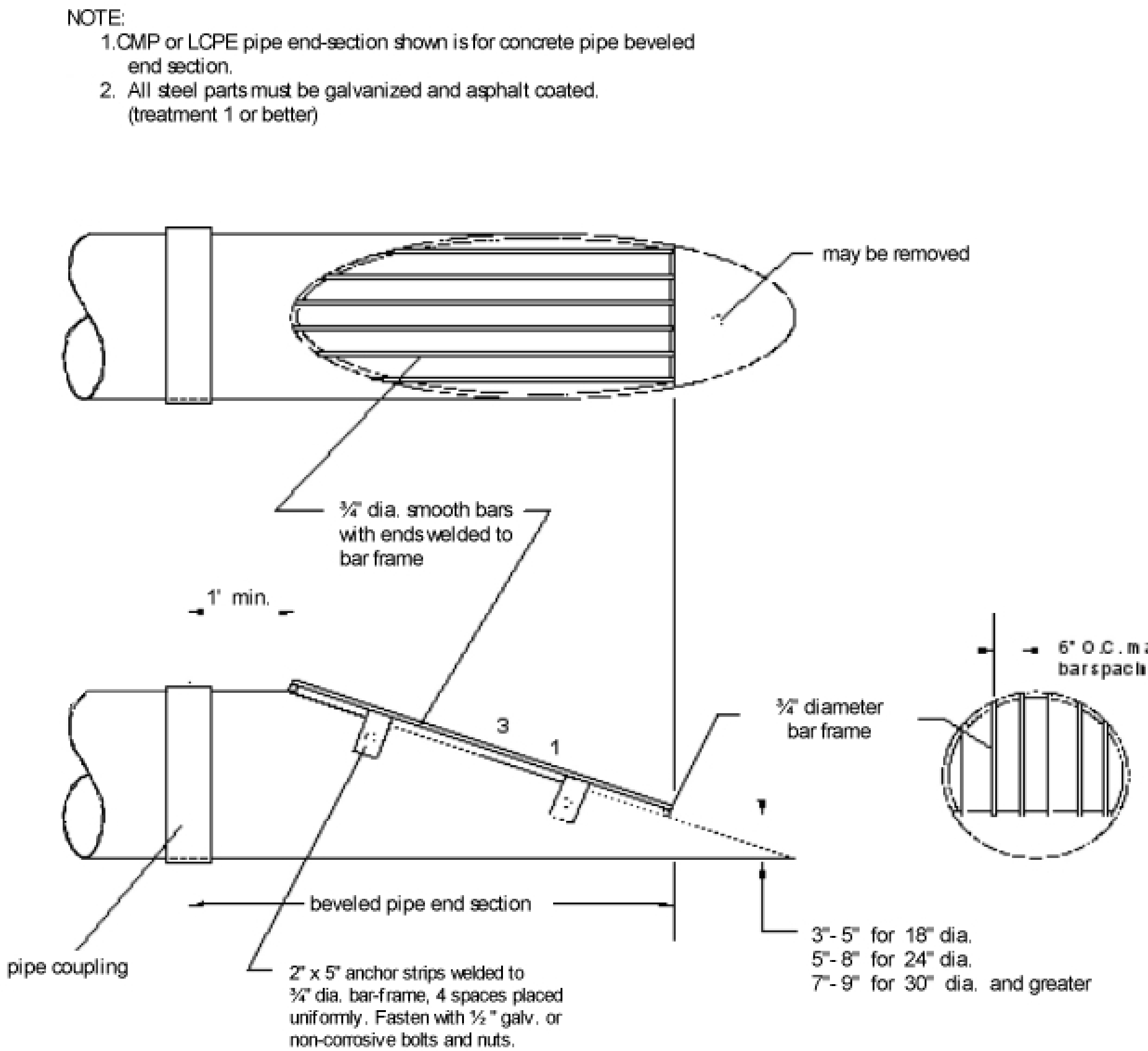


Figure 4.7 — Nomograph for Sizing Circular Drains Flowing Full

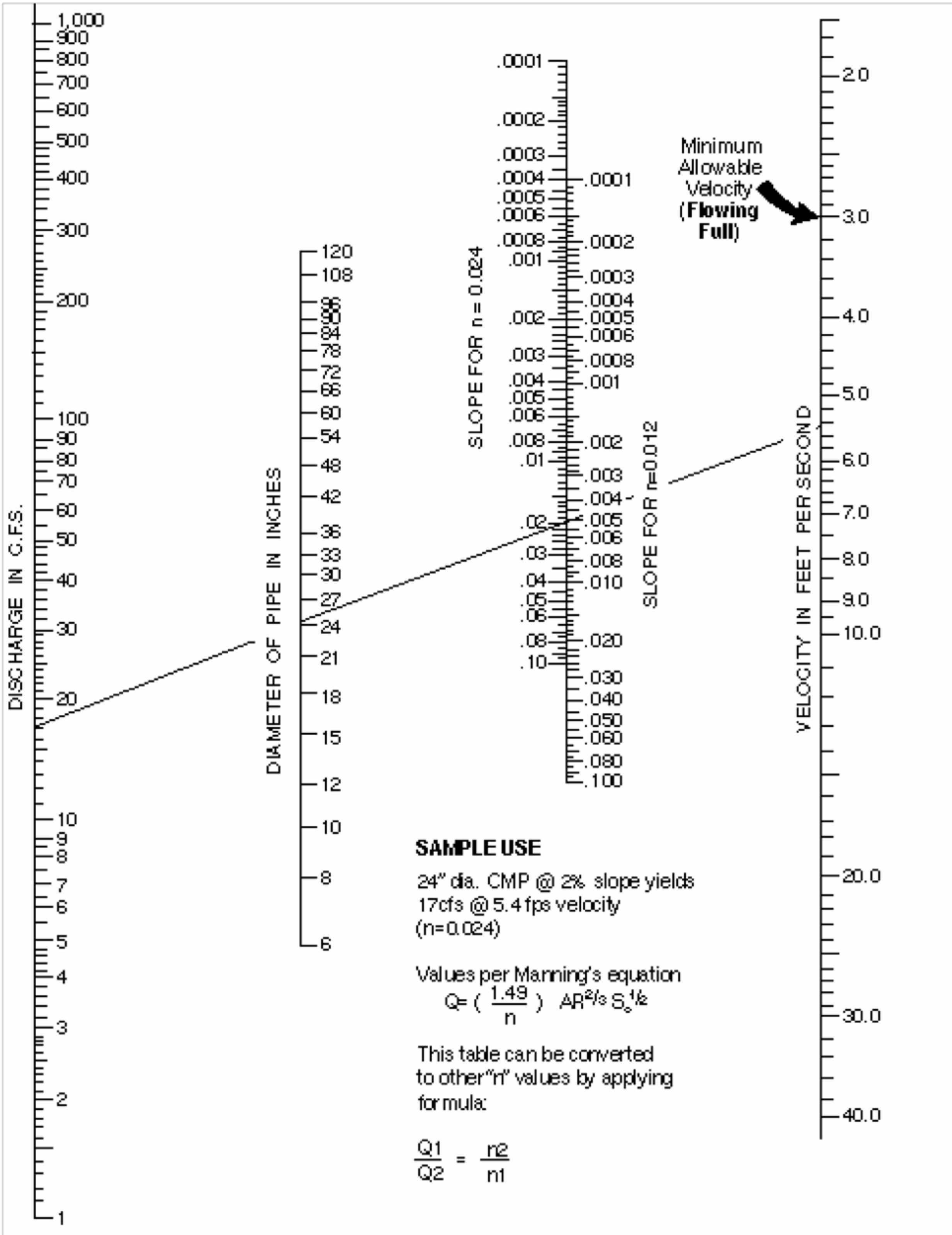


Figure 4.8 — Circular Channel Ratios

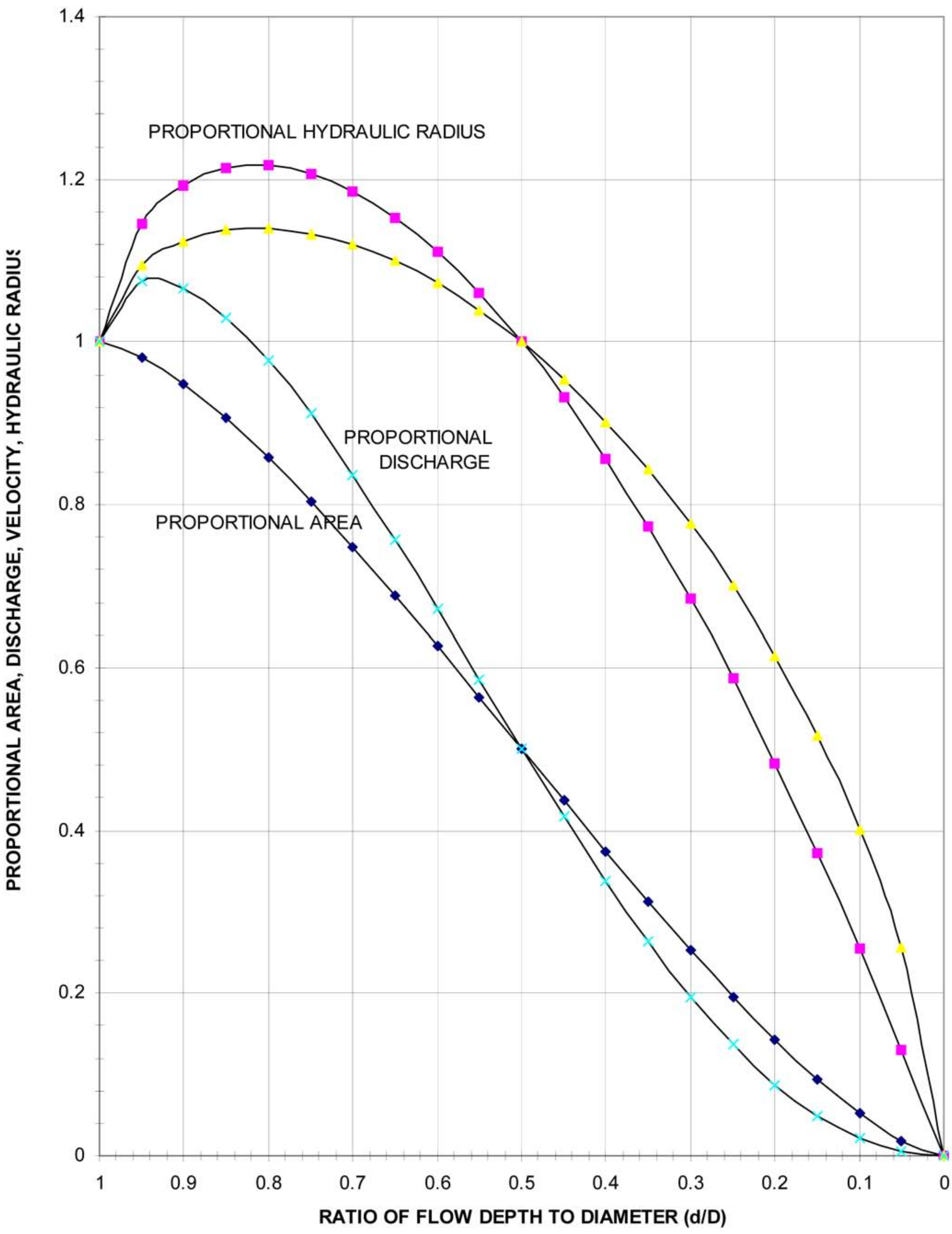


Figure 4.9 — Backwater Calculation Sheet

Pipe Segment CB to CB	(1) Q (cfs)	(2) Length (ft)	(3) Pipe Size	(4) "n" Value	(5) Outlet Elevation (ft)	(6) Inlet Elevation (ft)	(7) Barrel Velocity (fps)	(8) Barrel Velocity (fps)	(9) Barrel Velocity Head (ft)	(10) TW Elevation (ft)	(11) Friction Loss (ft)	(12) Entrance HGL Elevation (ft)	(13) Entrance Head Loss (ft)	(14) Exit Head Loss (ft)	(15) Outlet Control Elevation (ft)	(16) Inlet Control Elevation (ft)	(17) Approach Velocity Head (ft)	(18) Bend Head Loss (ft)	(19) Junction Head Loss (ft)	(20) HW Elevation (ft)

Figure 4.10 — Backwater Calculation Sheet Notes

Column (1) Design flow to be conveyed by pipe segment.

Column (2) Length of pipe segment.

Column (3) Pipe Size; indicate pipe diameter or span x rise.

Column (4) Manning's "n" value.

Column (5) Outlet Elevation of pipe segment.

Column (6) Inlet Elevation of pipe segment.

Column (7) Barrel Area; this is the full cross-sectional area of the pipe.

Column (8) Barrel Velocity; this is the full velocity in the pipe as determined by:

$V = Q/A$ or Col.(8) = Col.(1) / Col.(7)

Column (9) Barrel Velocity Head = $V^2 / 2g$ or $(\text{Col.}(8))^2 / 2g$

where $g = 32.2$ ft/sec2 (acceleration due to gravity)

Column (10) Tailwater (*TW*) Elevation; this is the water surface elevation at the outlet of the pipe segment. If the pipe's outlet is not submerged by the *TW* and the *TW* depth is less than $(D+d_c) / 2$, set TW equal to (D+dc)/2 to keep the analysis simple and still obtain reasonable results (D = pipe barrel height and d_c = critical depth, both in feet. See Figure 4.24 (p. 48) for determination of d_c).

Column (11) Friction Loss = $S_f \times L$ [or S_f x Col.(2)] where S_f is the friction slope or head loss per linear foot of pipe as determined by Manning's equation expressed in the form:

$S_f = (nV)^2 / 2.22\, R^{1.33}$

Column (12) Hydraulic Grade Line (HGL) Elevation just inside the entrance of the pipe barrel; this is determined by adding the friction loss to the *TW* elevation:

Col.(12) = Col.(11) + Col.(10)

If this elevation falls below the pipe's inlet crown, it no longer represents the true HGL when computed in this manner. The true HGL will fall somewhere between the pipe's crown and either normal flow depth or critical flow depth, whichever is greater. To keep the analysis simple and still obtain reasonable results (i.e., erring on the conservative side), set the HGL elevation equal to the crown elevation.

Column (13) Entrance Head Loss = $K_e \times V^2 / 2g$ [or K_e x Col.(9)] where K_e = Entrance Loss Coefficient (from Table 4.8,). This is the head lost due to flow contractions at the pipe entrance.

Column (14) Exit Head Loss = $1.0 \times V^2 / 2g$ or 1.0 x Col.(9). This is the velocity head lost or transferred downstream.

Column (15) Outlet Control Elevation = Col.(12) + Col.(13) + Col.(14). This is the maximum headwater elevation assuming the pipe's barrel and inlet/outlet characteristics are controlling capacity. It does not include structure losses or approach velocity considerations.

Column (16) Inlet Control Elevation ,for computation of inlet control on culverts); this is the maximum headwater elevation assuming the pipe's inlet is controlling capacity. It does not include structure losses or approach velocity considerations.

Column (17) Approach Velocity Head; this is the amount of head/energy being supplied by the discharge from an upstream pipe or channel section, which serves to reduce the headwater elevation. If the discharge is from a pipe, the approach velocity head is equal to the barrel velocity head computed for the upstream pipe. If the upstream pipe outlet is significantly higher in elevation (as in a drop manhole) or lower in elevation such that its discharge energy would be dissipated, an approach velocity head of zero should be assumed.

Column (18) Bend Head Loss = $K_b \times V^2 / 2g$ [or K_b x Col.(17)] where K_b = Bend Loss Coefficient (from Figure 4.12). This is the loss of head/energy required to change direction of flow in an access structure.

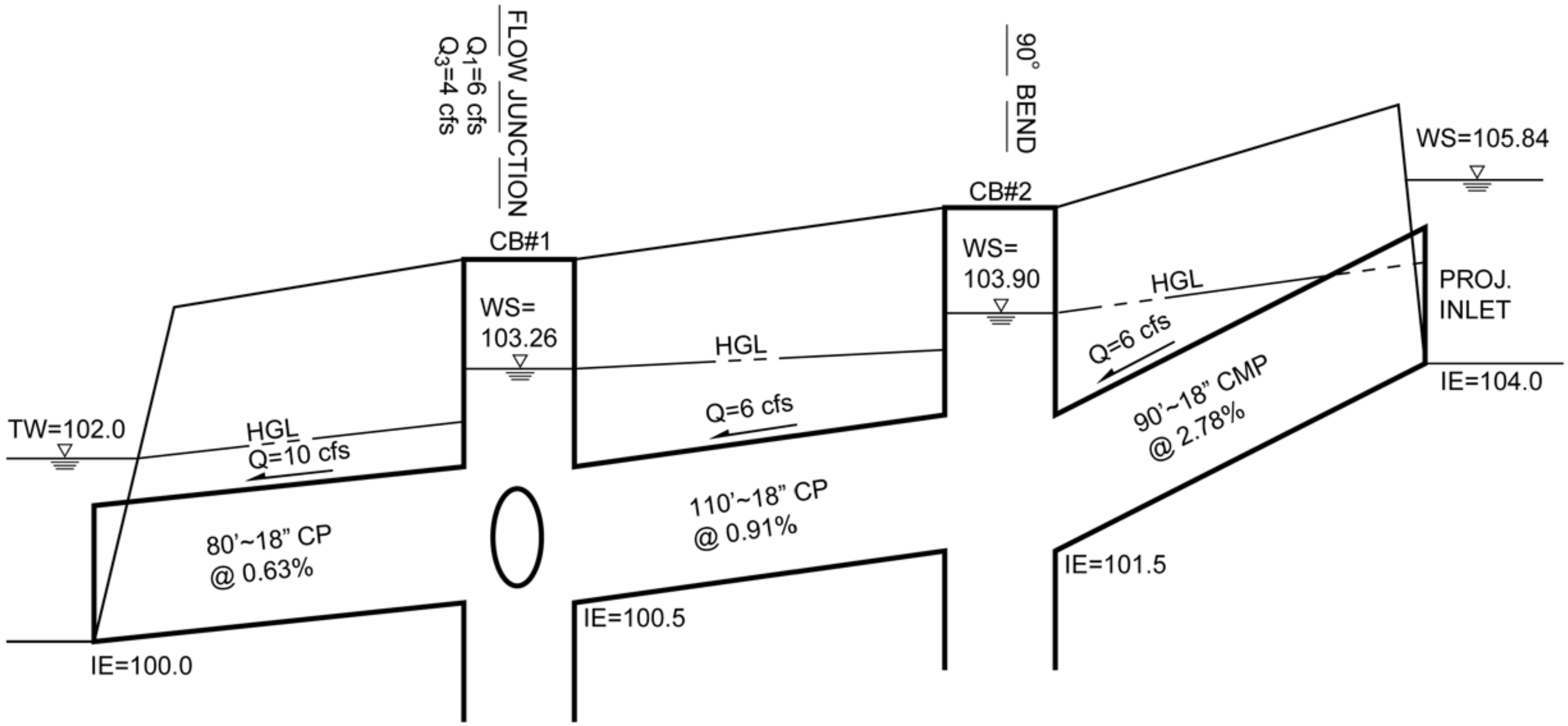
Column (19) Junction Head Loss. This is the loss in head/energy that results from the turbulence created when two or more streams are merged into one within the access structure. Figure 4.13) may be used to determine this loss, or it may be computed using the following equations derived from Figure 4.13:

Junction Head Loss = $K_j \times V^2 / 2g$ [or K_j x Col.(17)] where K_j is the Junction Loss Coefficient determined by

$K_j = (Q_3 / Q_1) / (1.18 + 0.63\,(Q_3 / Q_1))$

Column (20) Headwater (HW) Elevation; this is determined by combining the energy heads in Columns 17, 18, and 19 with the highest control elevation in either Column 15 or 16, as follows: Col.(20) = Col.(15 or 16) - Col.(17) + Col.(18) + Col.(19)

Figure 4.11 — Backwater Pipe Calculation Example



B A C K W A T E R   C A L C U L A T I O N   S H E E T

Select the greater elevation: (15) and (16)

Pipe Segment CB to CB		(1) Q (cfs)	(2) Length (ft)	(3) Pipe Size	(4) "n" Value	(5) Outlet Elev (ft)	(6) Intlet Elev (ft)	(7) Barrel Area (sqft)	(8) Barrel Vel (fps)	(9) Barrel Vel Head (ft)	(10) TW Elev (ft)	(11) Fric-tion Loss (ft)	(12) Entr HGL Elev (ft)	(13) Entr Head Loss (ft)	(14) Exit Head Loss (ft)	(15) Outlt Contr Elev (ft)	(16) Inlet Contr Elev (ft)	(17) Appr Vel Head (ft)	(18) Bend Head Loss (ft)	(19) Junc Head Loss (ft)	(20) HW Elev (ft)
Out fall	1	10	80	18"	0.012	100.00	100.50	1.77	5.65	0.50	102.00	0.62	102.62	0.25	0.50	103.37	102.75	-0.18	0.002	0.07	103.26
1	2	6	110	18"	0.012	100.50	101.50	1.77	3.39	0.18	103.26	0.31	103.57	0.09	0.18	103.84	102.95	-0.18	0.24	0.0	103.90
2	Inlet	6	90	18"	0.024	101.50	104.00	1.77	3.39	0.18	103.90	1.00	(104.9) 105.5	0.16	0.18	105.84	105.80	-0.0	0.0	0.0	105.84

Figure 4.12 — Bend Head Losses In Structure

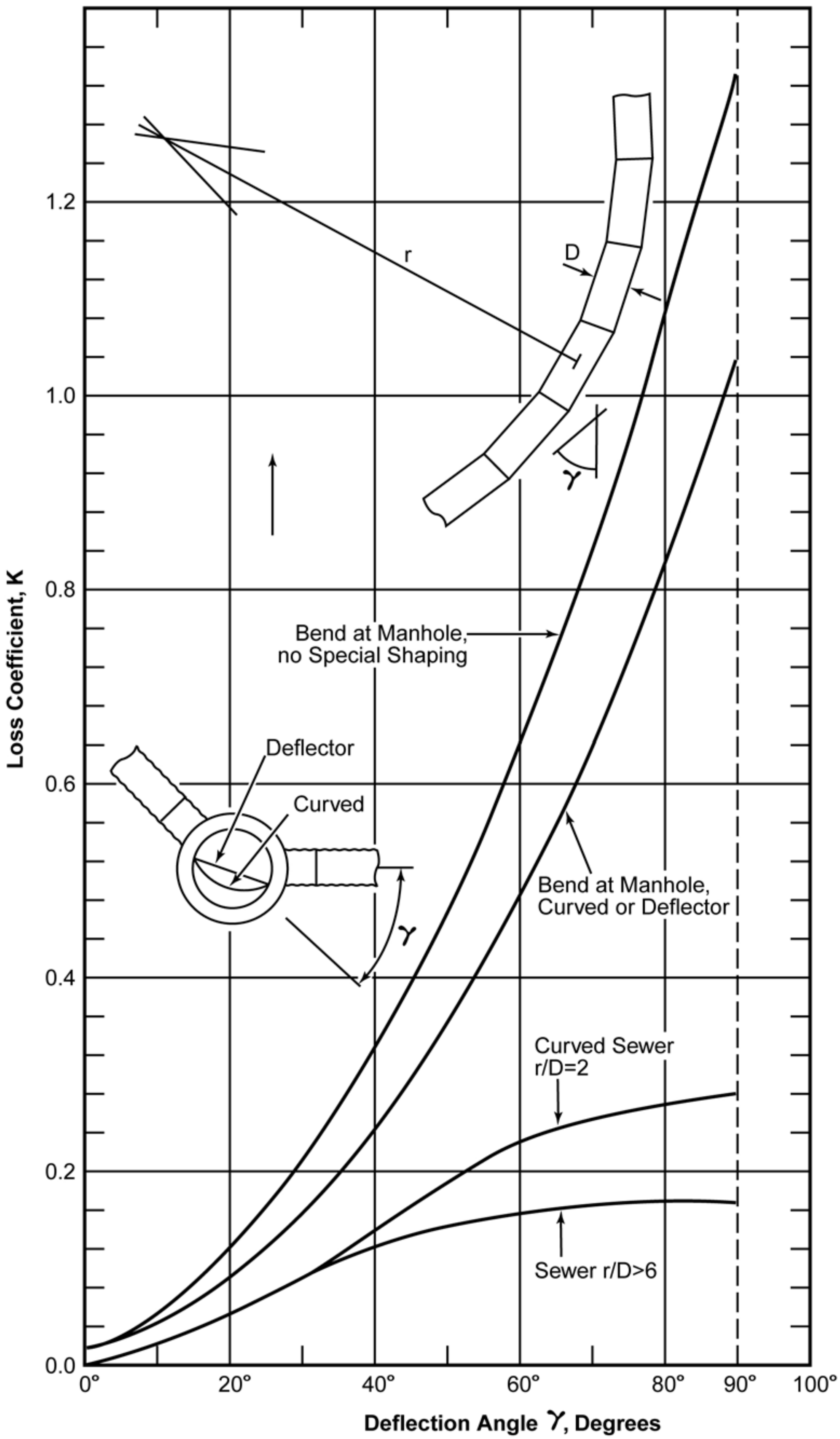


Figure 4.13 — Junction Head Loss in Structures

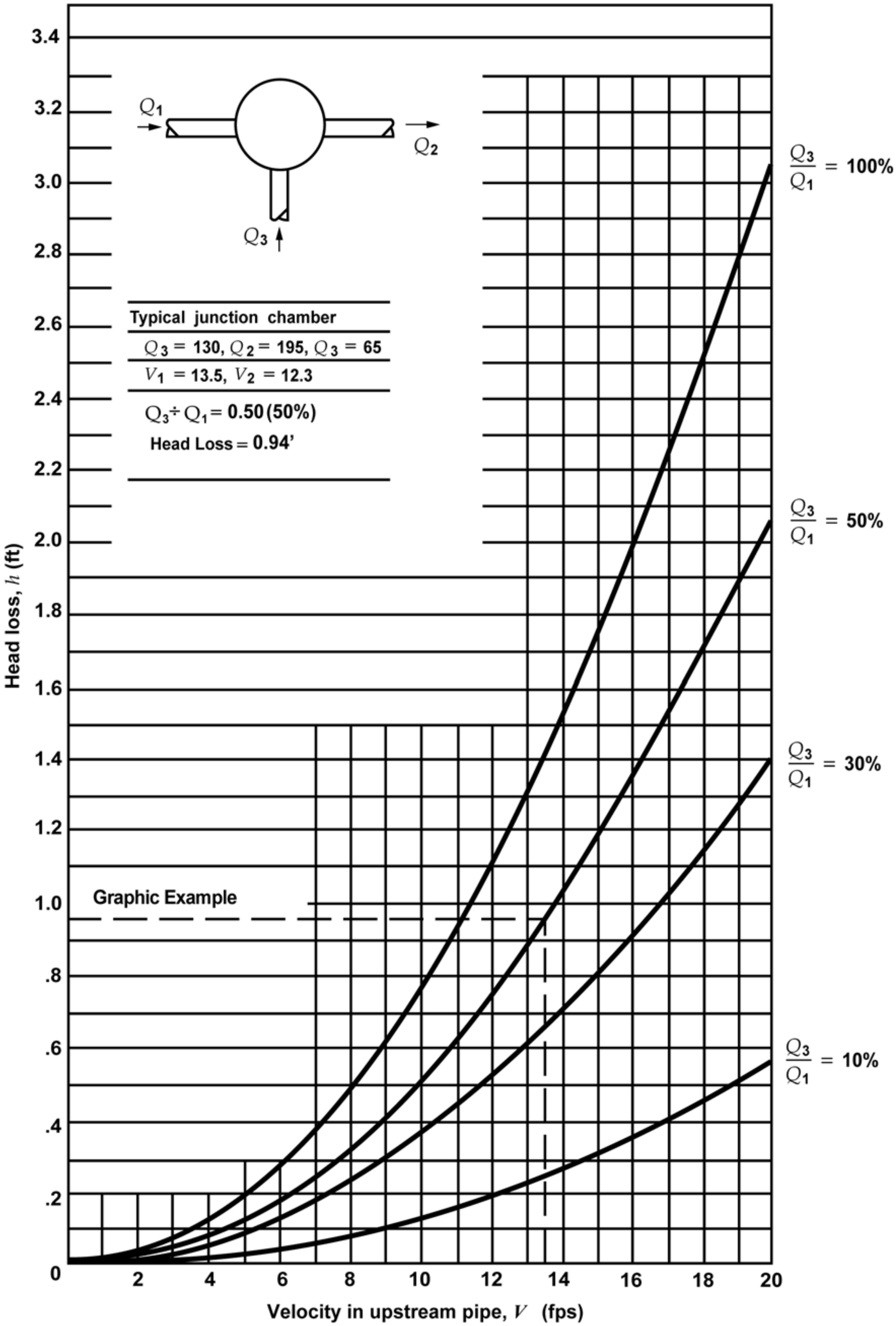


Figure 4.14 — Tee Type Energy Dissipater

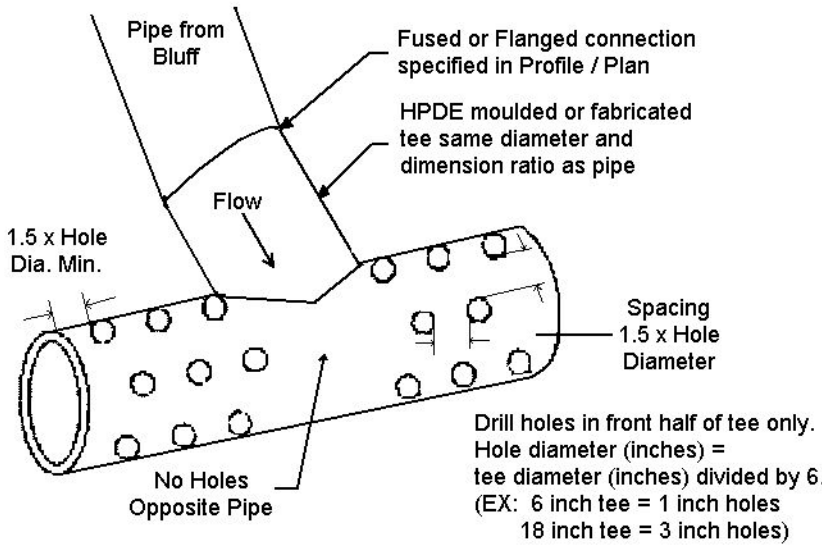
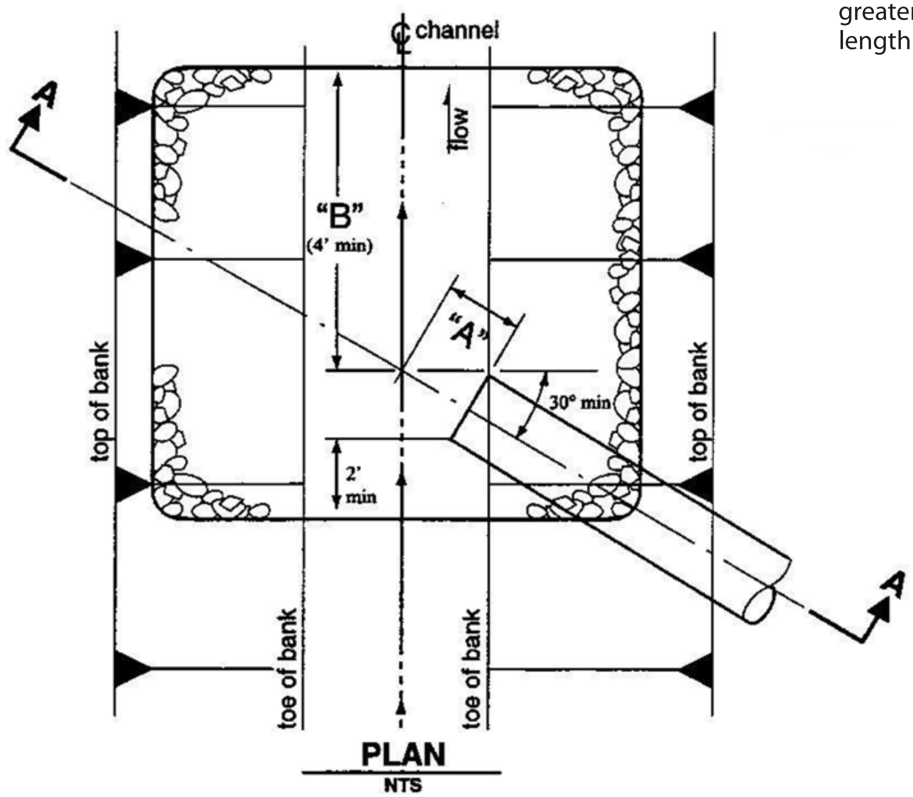


Figure 4.15 — Pipe Culvert Discharge Protection

A + B must be equal to or greater than the minimum length shown in table 4.6



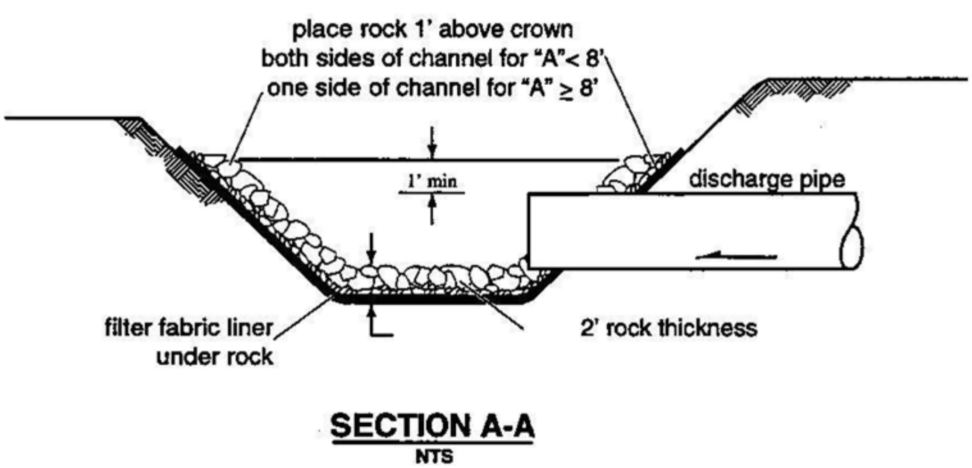
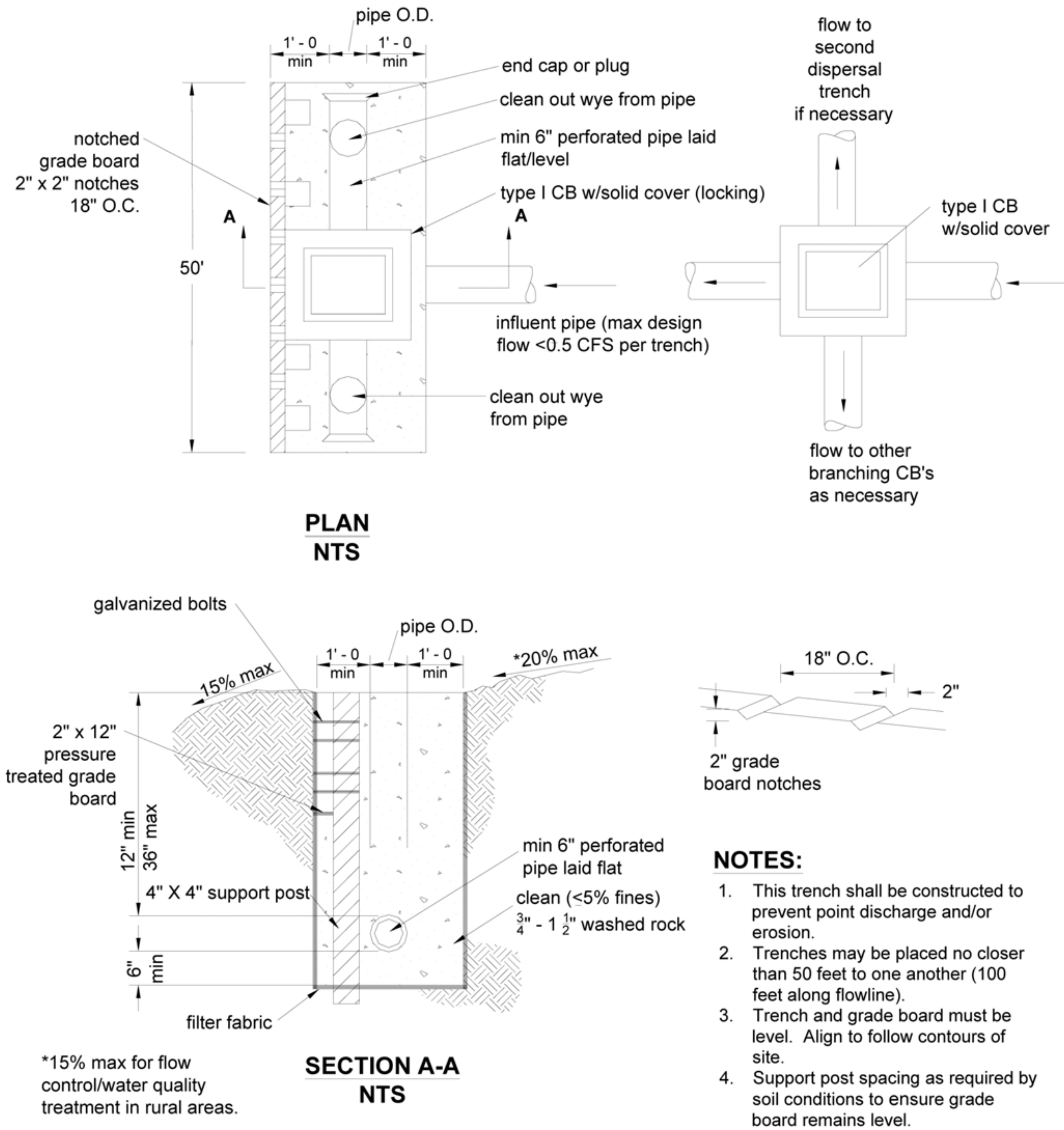


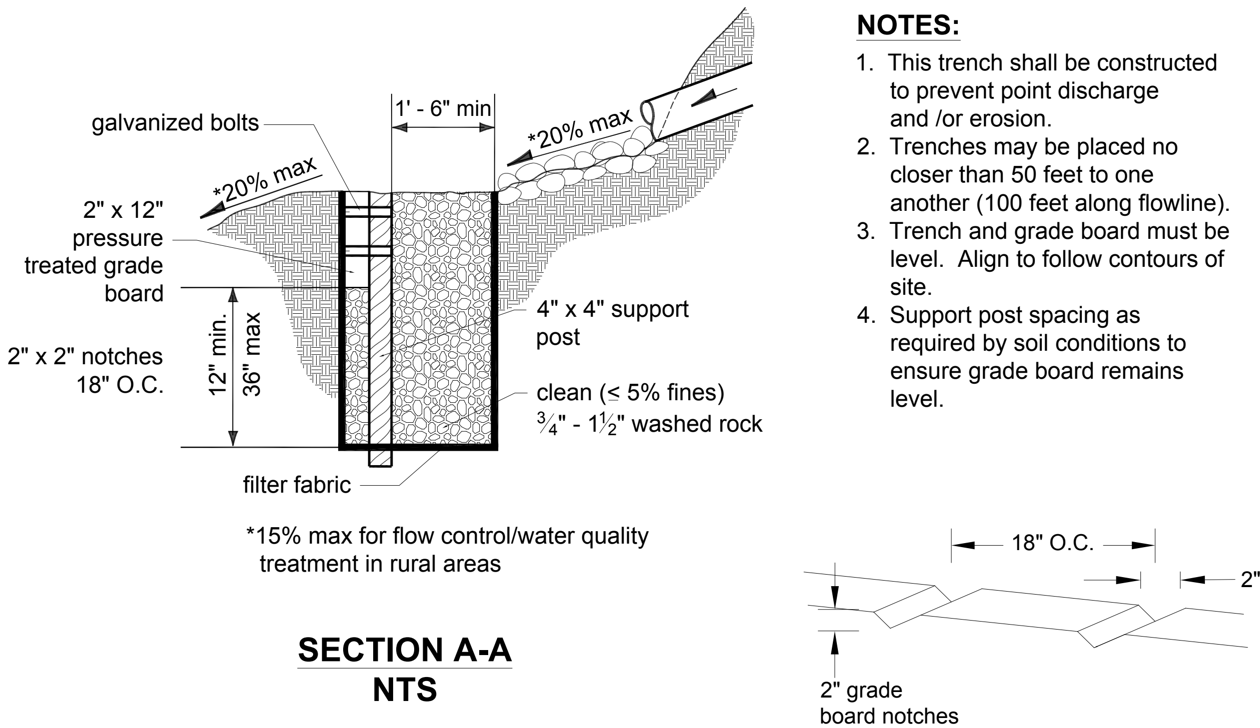
Figure 4.16 — Flow Dispersal Trench



NOTES:

1. This trench shall be constructed to prevent point discharge and/or erosion.
2. Trenches may be placed no closer than 50 feet to one another (100 feet along flowline).
3. Trench and grade board must be level. Align to follow contours of site.
4. Support post spacing as required by soil conditions to ensure grade board remains level.

Figure 4.17 — Alternative Flow Dispersal Trench



NOTES:

1. This trench shall be constructed to prevent point discharge and /or erosion.
2. Trenches may be placed no closer than 50 feet to one another (100 feet along flowline).
3. Trench and grade board must be level. Align to follow contours of site.
4. Support post spacing as required by soil conditions to ensure grade board remains level.

Figure 4.18 — Gabion Mattress Dissipater Detail

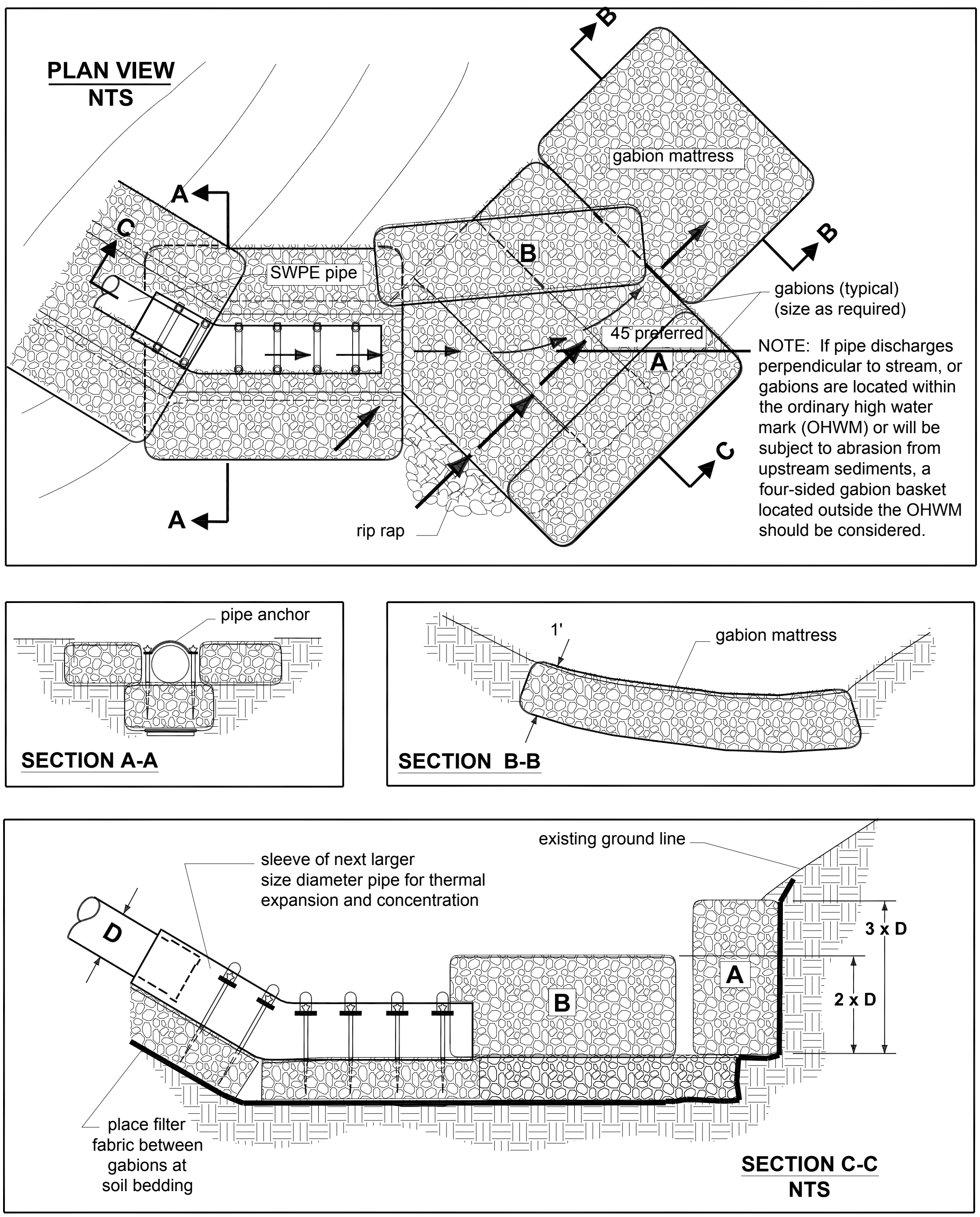
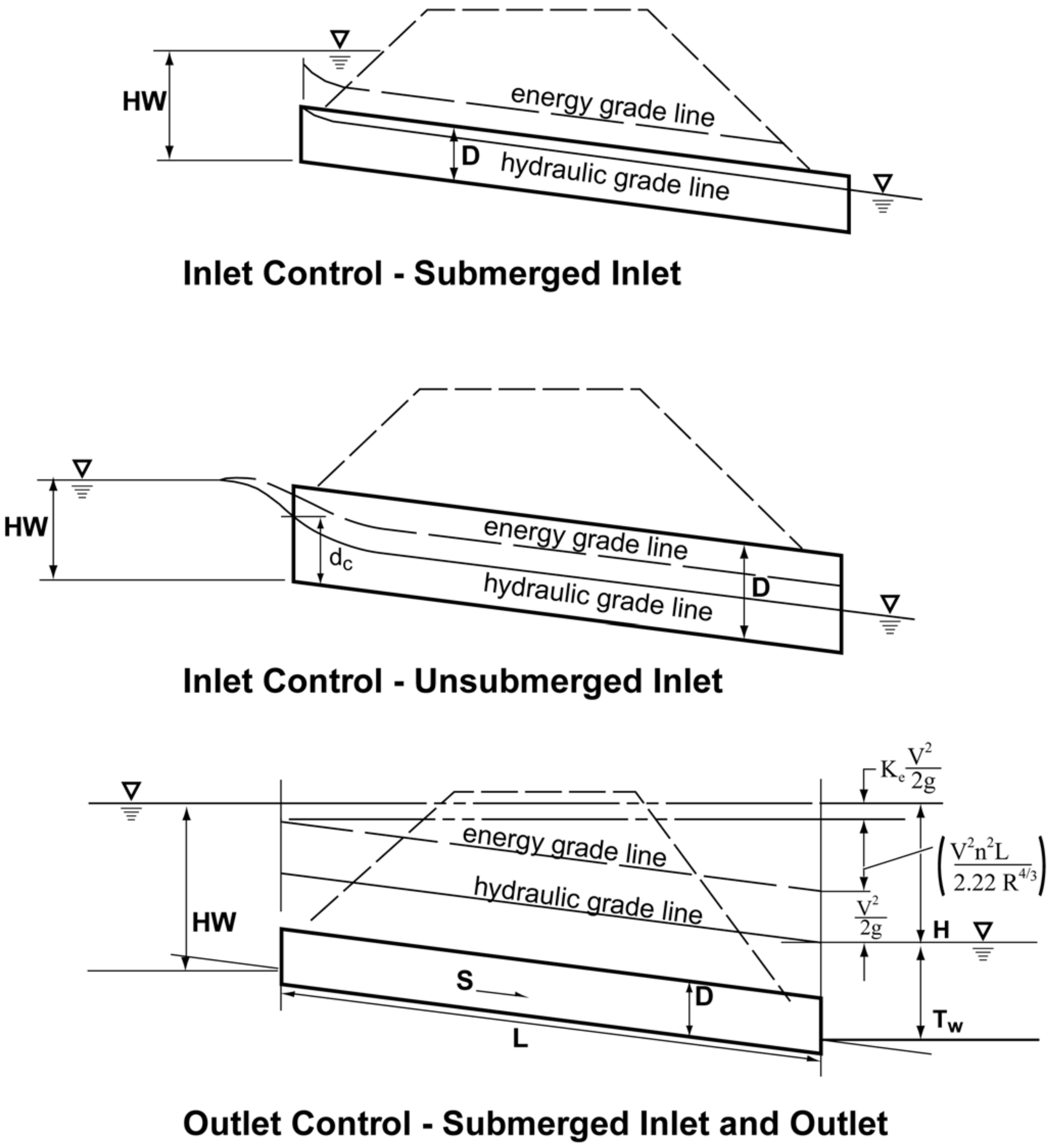


Figure 4.19 — Inlet / Outlet Control Conditions



NOTE: See FHWA no. 5 for other possible conditions

Figure 4.20 — Headwater Depth for Smooth Interior Pipe Culverts with Inlet Control

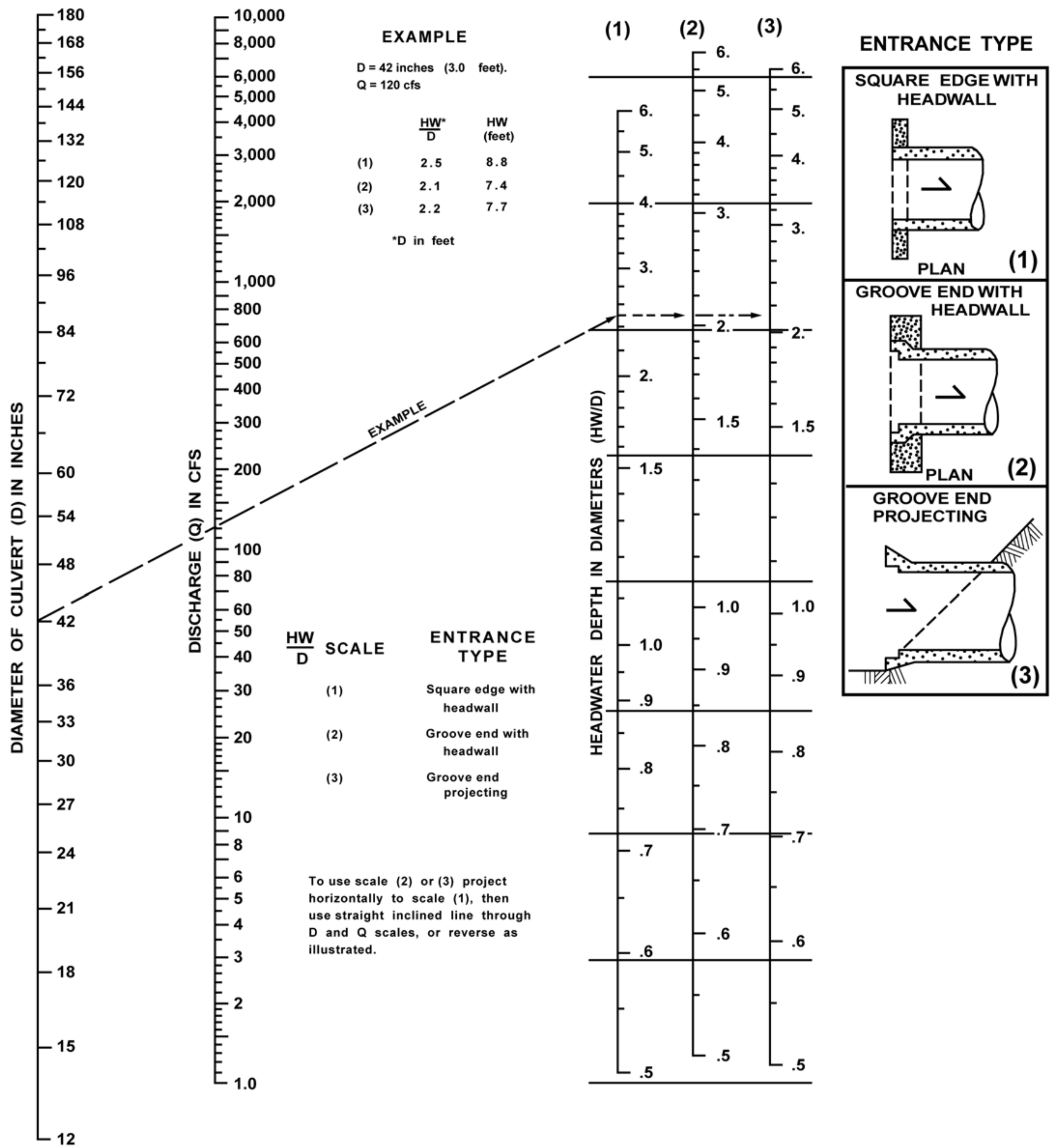


Figure 4.21 — Headwater Depth for Corrugated Pipe Culvert with Inlet Control

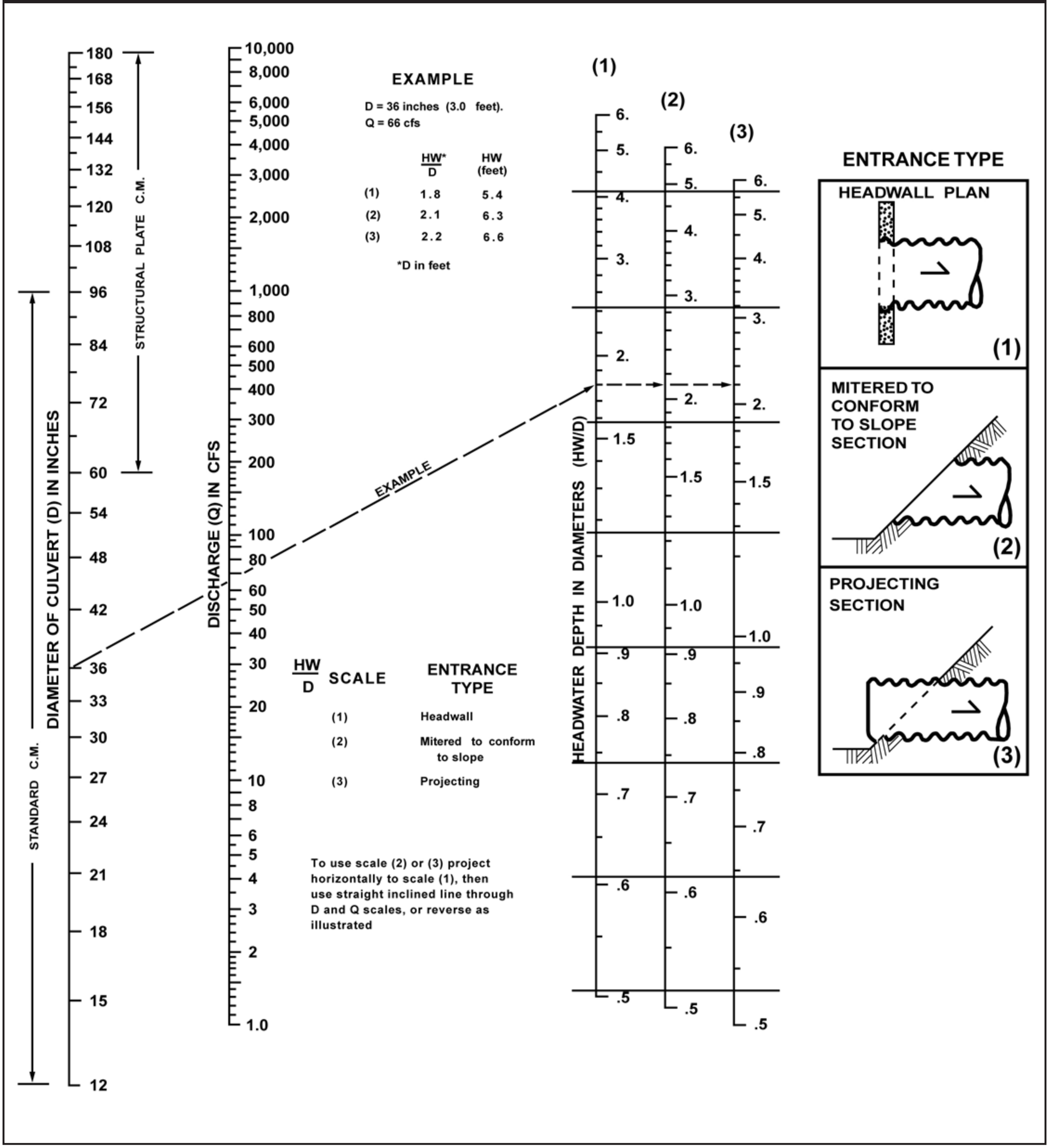


Figure 4.22 — Head for Culverts (Pipe *W* / *"n"* = 0.012) Flowing Full with Outlet Control

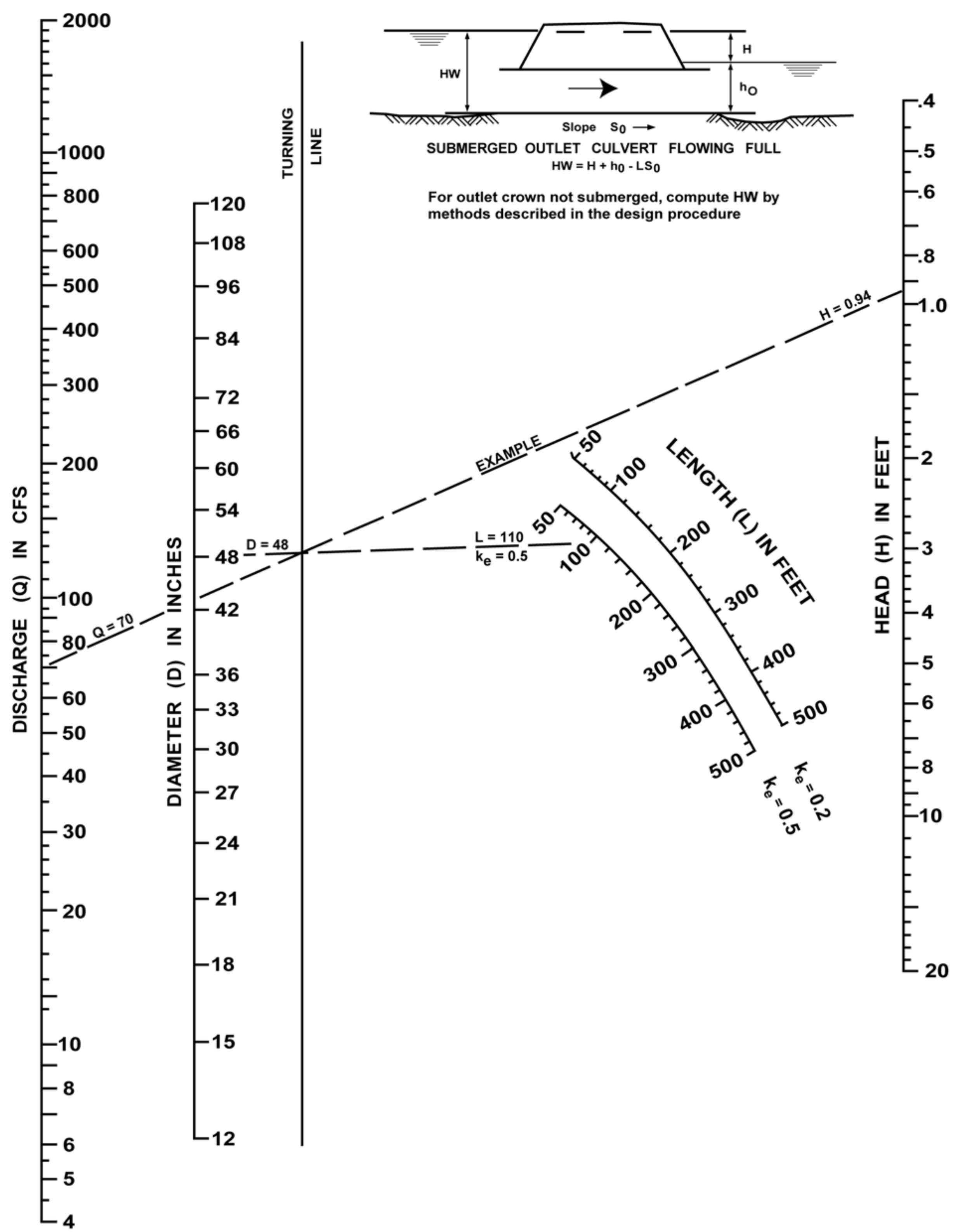


Figure 4.23 — Head for Culverts (Pipe *W* / "*n*" = 0.024) Flowing Full with Outlet Control

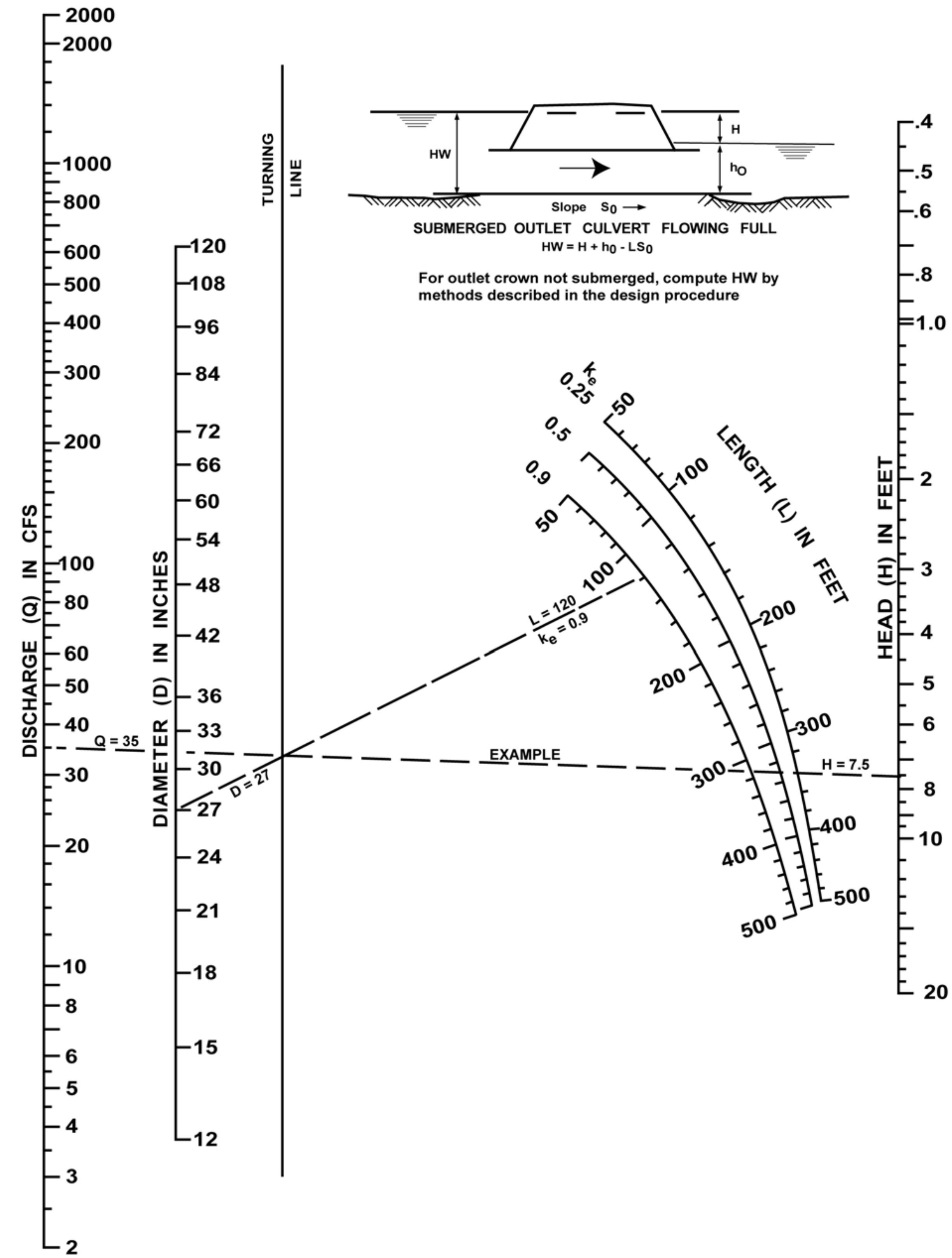
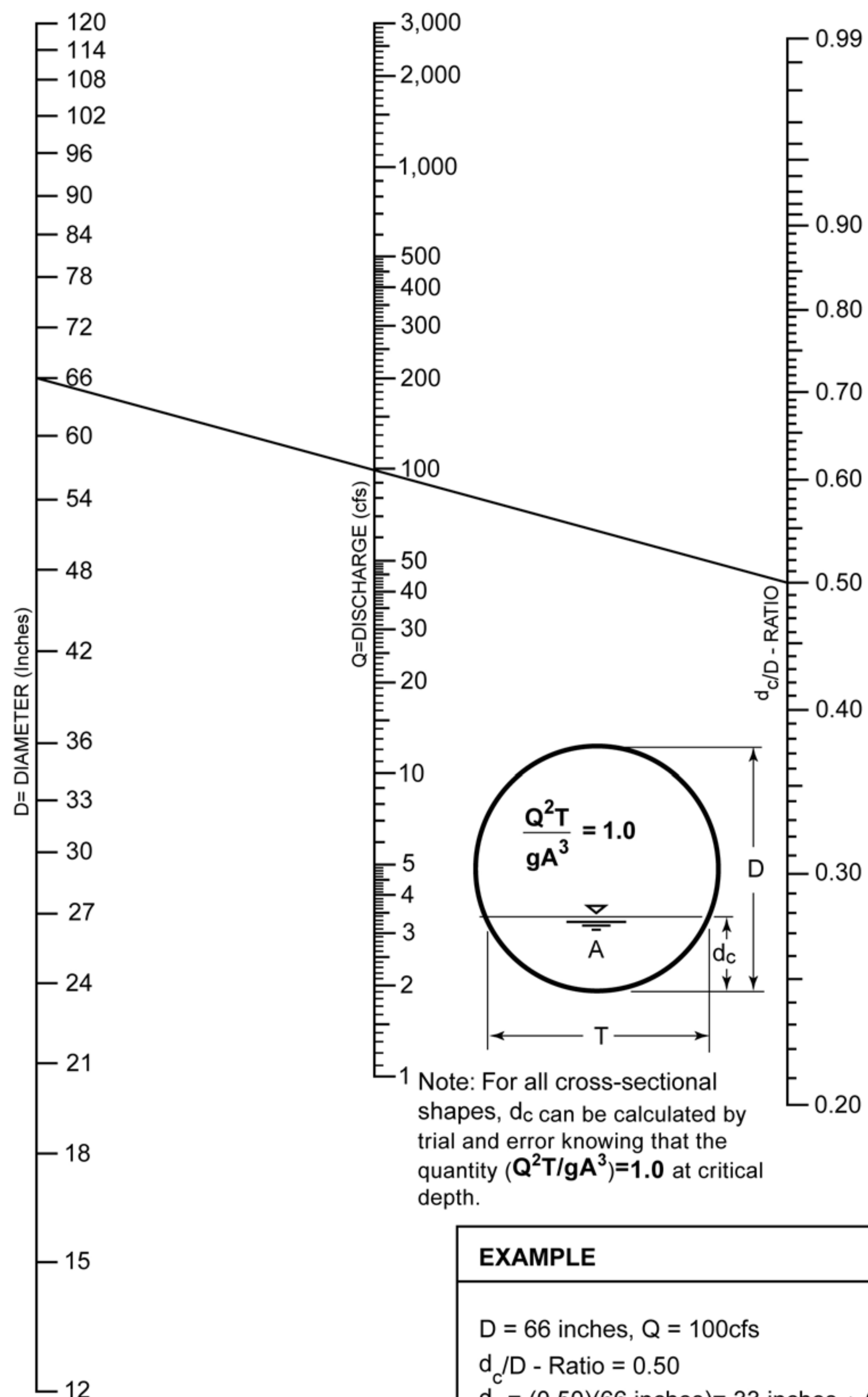


Figure 4.24 — Critical Depth of Flow for Circular Culverts



Note: For all cross-sectional shapes, d_c can be calculated by trial and error knowing that the quantity (**Q^2T/gA^3)=1.0** at critical depth.

EXAMPLE
D = 66 inches, Q = 100cfs d_c/D - Ratio = 0.50 d_c = (0.50)(66 inches)= 33 inches ÷ (12 inches/ft) d_c= 2.75 feet

Figure 4.25 — Mean Channel Velocity vs. Medium Stone Weight (W_{50}) and Equivalent Stone Diameter

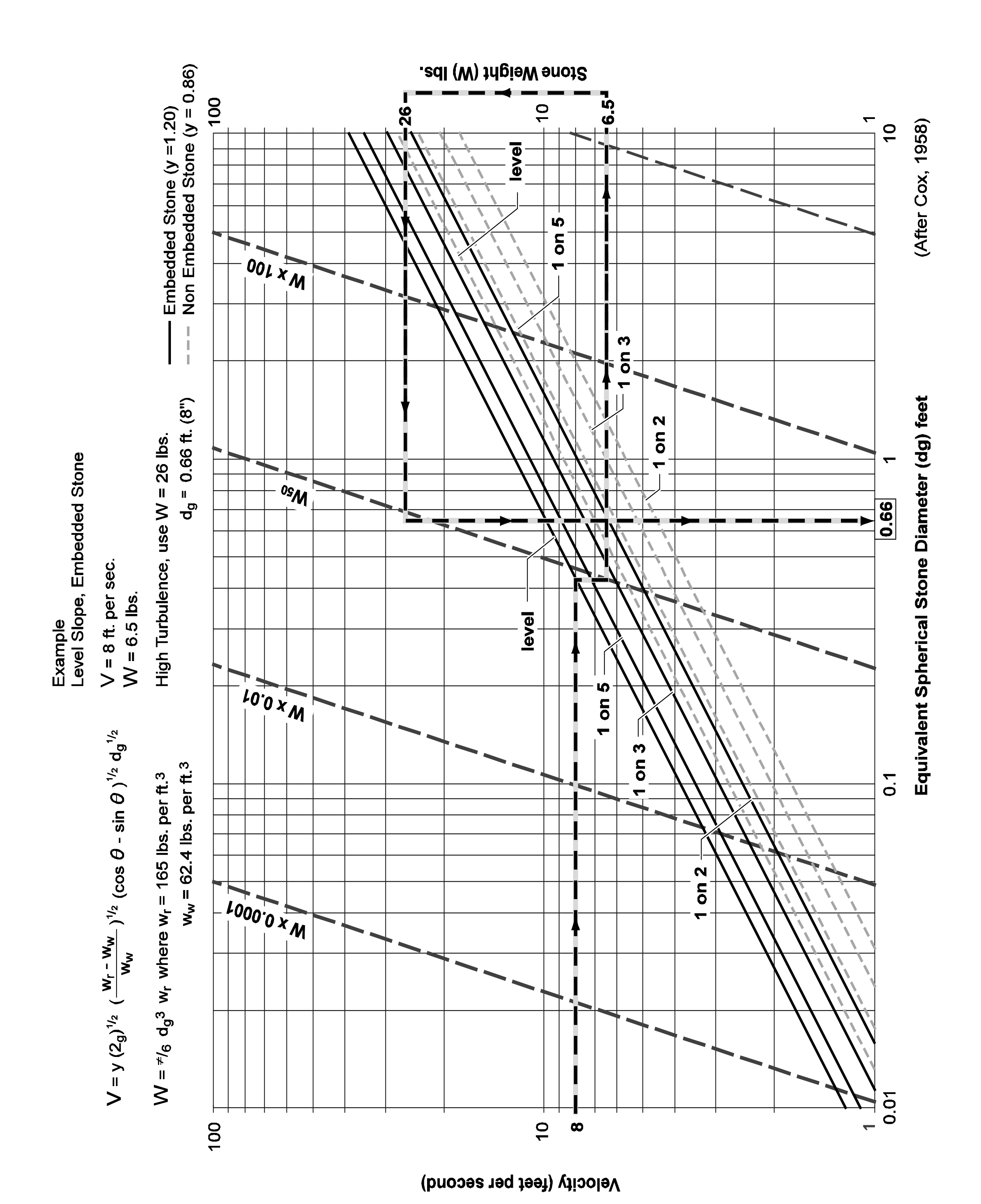


Figure 4.26 — Riprap / Filter Example Gradation Curve

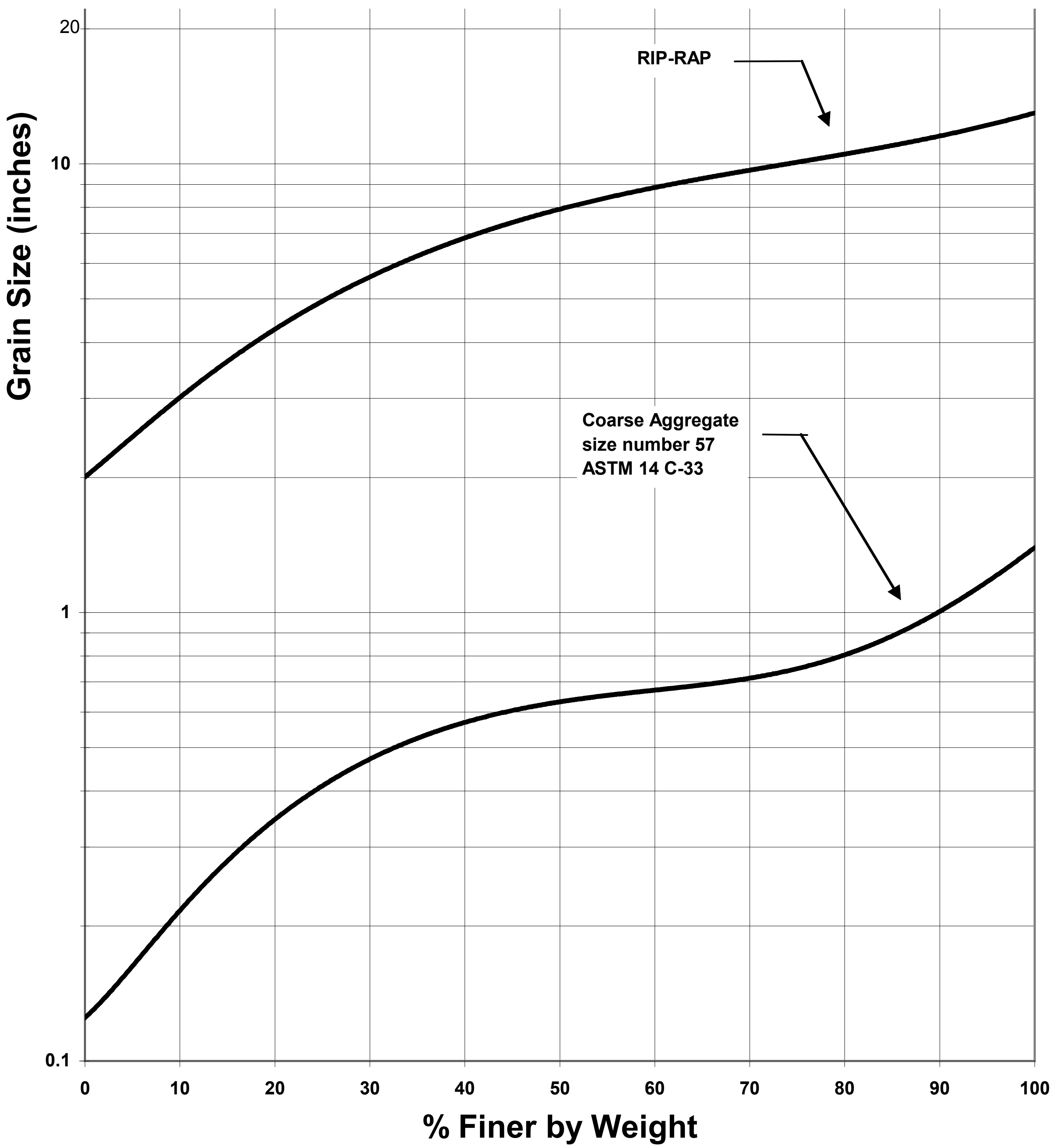
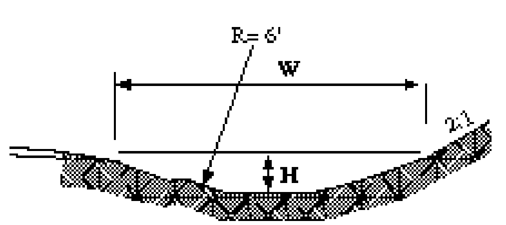
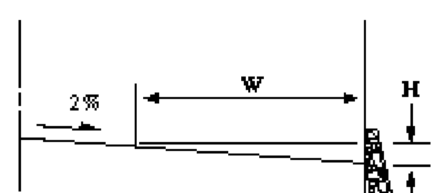


Figure 4.27 — Ditches Common Sections

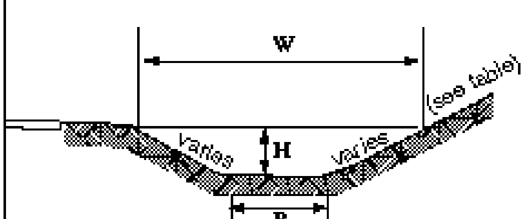
Properties of Ditches								
	Dimensions				Hydraulics			
NO.	Side Slopes	B	H	W	A	WP	R	$R^{(2/3)}$
D-1	--	--	6.5"	5'-0"	1.84	5.16	0.356	0.502
D-1C	--	--	6"	25'-0"	6.25	25.50	0.245	0.392
D-2A	1.5:1	2'-0"	1'-0"	5'-0"	3.50	5.61	0.624	0.731
B	2:1	2'-0"	1'-0"	6'-0"	4.00	6.47	0.618	0.726
C	3:1	2'-0"	1'-0"	8'-0"	5.00	8.32	0.601	0.712
D-3A	1.5:1	3'-0"	1'-6"	7'-6"	7.88	8.41	0.937	0.957
B	2:1	3'-0"	1'-6"	9'-0"	9.00	9.71	0.927	0.951
C	3:1	3'-0"	1'-6"	12'-0"	11.25	12.49	0.901	0.933
D-4A	1.5:1	3'-0"	2'-0"	9'-0"	12.00	10.21	1.175	1.114
B	2:1	3'-0"	2'-0"	11'-0"	14.00	11.94	1.172	1.112
C	3:1	3'-0"	2'-0"	15'-0"	18.00	15.65	1.150	1.098
D-5A	1.5:1	4'-0"	3'-0"	13'-0"	25.50	13.82	1.846	1.505
B	2:1	4'-0"	3'-0"	16'-0"	30.00	16.42	1.827	1.495
C	3:1	4'-0"	3'-0"	22'-0"	39.00	21.97	1.775	1.466
D-6A	2:1	--	1'-0"	4'-0"	2.00	4.47	0.447	0.585
B	3:1	--	1'-0"	6'-0"	3.00	6.32	0.474	0.608
D-7A	2:1	--	2'-0"	8'-0"	8.00	8.94	0.894	0.928
B	3:1	--	2'-0"	12'-0"	12.00	12.65	0.949	0.965
D-8A	2:1	--	3'-0"	12'-0"	18.00	13.42	1.342	1.216
B	3:1	--	3'-0"	18'-0"	27.00	18.97	1.423	1.265
D-9	7:1	--	1'-0"	14'-0"	7.00	14.14	0.495	0.626
D-10	7.1	--	2'-0"	28'-0"	28.00	28.28	.0990	0.993
D-11	7.1	--	3'-0"	42'-0"	63.00	42.43	1485	1.302



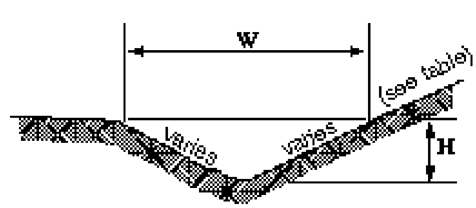
D-1 Segmental (parabolic)



D-1c Curbed crowned street



D-2, D-3, D-4, D-5 Trapezoidal



Isosceles triangular D-6 through D-11

Figure 4.28 — Drainage Ditches–Common Sections

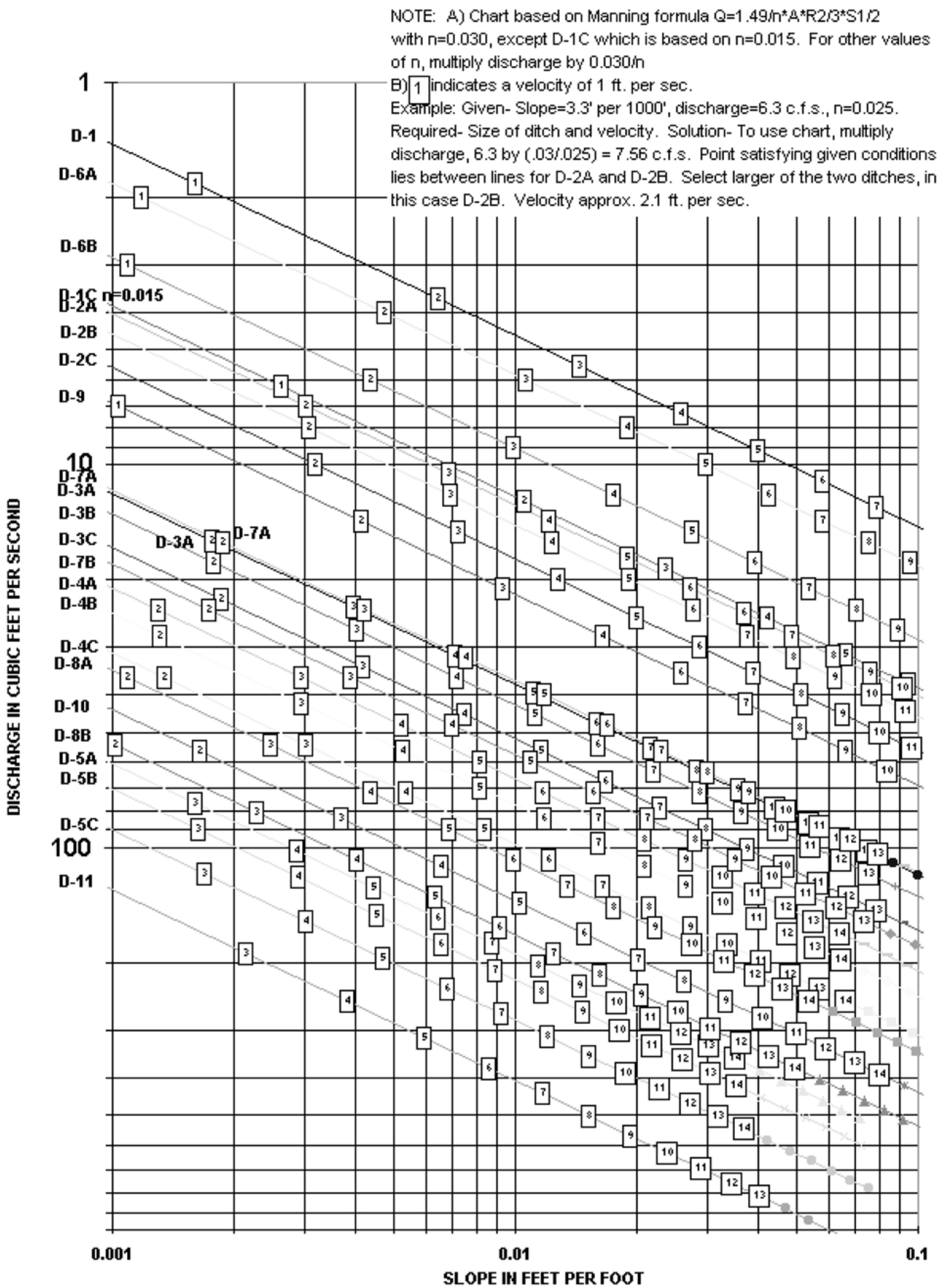
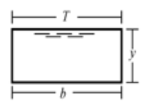
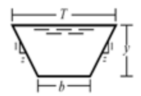
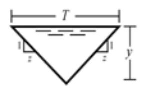
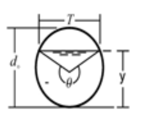
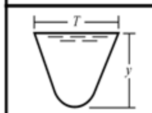
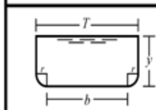
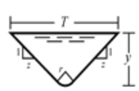


Figure 4.29 — Geometric Elements of Common Sections

Section	Area A	Wetted perimeter P	Hydraulic radius R	Top width W	Hydraulic depth D	Section factor Z
 Rectangle	by	$b + 2y$	$\frac{by}{b + 2y}$	b	y	$by^{1.5}$
 Trapezoid	$(b + zy)y$	$b + 2y\sqrt{1 + z^2}$	$\frac{(b + zy)y}{b + 2y\sqrt{1 + z^2}}$	$b + 2zy$	$\frac{(b + zy)y}{b + 2zy}$	$\frac{[(b + zy)y]^{1.5}}{\sqrt{b + 2zy}}$
 Triangle	zy^2	$2y\sqrt{1 + z^2}$	$\frac{zy}{2\sqrt{1 + z^2}}$	$2zy$	$^1/_2 y$	$\frac{\sqrt{2}}{2} zy^{2.5}$
 Circle	$^1/_8(\theta - \sin\theta)d_\circ^2$	$^1/_2 \theta d_\circ$	$^1/_4\left(1 - \frac{\sin\theta}{\theta}\right)d_\circ$	$(\sin(^1/_2\theta)d_\circ)$ *or* $2\sqrt{y(d_\circ - y)}$	$^1/_8\left(\frac{\theta - \sin\theta}{\sin {}^1/_2\theta}\right)d_\circ$	$\frac{\sqrt{2}}{32}\frac{(\theta - \sin\theta)^{1.5}}{(\sin {}^1/_2\theta)^{0.5}} d_\circ^{2.5}$
 Parabola	$^2/_3 Ty$	$T + \frac{8y^2}{3T}$ *	$\frac{2T^2 y}{3T^2 + 8y^2}$ *	$\frac{3A}{2y}$	$^2/_3 y$	$^2/_9\sqrt{6}Ty^{1.5}$
 Round-cornered Rectangle ($y>r$)	$(\frac{\pi}{2} - 2)r^2 + (b + 2r)y$	$(\pi - 2)r + b + 2y$	$\frac{(\frac{\pi}{2} - 2)r^2 + (b + 2r)y}{(\pi - 2)r + b + 2y}$	$b + 2r$	$\frac{(\frac{\pi}{2} - 2)r^2}{(b + 2r)} + y$	$\frac{[(\frac{\pi}{2} - 2)r^2 + (b + 2r)y]^{1.5}}{\sqrt{b + 2y}}$
 Round-bottomed Triangle	$\frac{T^2}{4z} - \frac{r^2}{z}(1 - z\cot^{-1}z)$	$\frac{T}{z}\sqrt{1 + z^2} - \frac{2r}{z}(1 - z\cot^{-1}z)$	$\frac{A}{P}$	$2[z(y - r) + r\sqrt{1 + z^2}]$	$\frac{A}{T}$	$A\sqrt{\frac{A}{T}}$

*Satisfactory approximation for the interval 0<x≤1, where x=4y/T. When x>1, use the exact expression $P = (^T/_2)\left[\sqrt{1 + x^2} + {}^1/_x \ln\left(x + \sqrt{1 + x^2}\right)\right]$

Figure 4.30 — Open Channel Flow Profile Computation

Q = ____________ n = ____________ So = ____________ α = ____________ Y_n = ____________

y	A	R	$R^{4/3}$	V	$\alpha V^2 / 2g$	E	ΔE	S_f	S_f	$S_o - S_f$	Δx	x
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)

Figure 4.31 — Open Channel Flow Profile Computation (Example)

Q = ____________ n = ____________ So = ____________ α = ____________ Y_n = ____________

y	A	R	$R^{4/3}$	V	$\alpha V^2/2g$	E	ΔE	S_f	$\bar{S}_f$	$S_o - \bar{S}_f$	Δx	x
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
6.0	72.0	2.68	3.72	0.42	0.0031	6.0031	-	0.00002	-	-	-	-
5.5	60.5	2.46	3.31	0.50	0.0040	5.5040	0.4990	0.00003	0.000025	0.00698	71.50	71.5
5.0	50.0	2.24	2.92	0.60	0.0064	5.0064	0.4976	0.00005	0.000040	0.00696	71.49	142.9
4.5	40.5	2.01	2.54	0.74	0.0098	4.5098	0.4966	0.00009	0.000070	0.00693	71.64	214.63
4.0	32.0	1.79	2.17	0.94	0.0157	4.0157	0.4941	0.00016	0.000127	0.00687	71.89	286.52
3.5	24.5	1.57	1.82	1.22	0.0268	3.5268	0.4889	0.00033	0.000246	0.00675	72.38	358.90
3.0	18.0	1.34	1.48	1.67	0.0496	3.0496	0.4772	0.00076	0.000547	0.00645	73.95	432.85
2.5	12.5	1.12	1.16	2.40	0.1029	2.6029	0.4467	0.00201	0.001387	0.00561	79.58	512.43
2.0	8.0	0.89	0.86	3.75	0.2511	2.2511	0.3518	0.00663	0.004320	0.00268	131.27	643.70

The step computations are carried out as shown in the above table. The values in each column of the table are explained as follows:

Column	Explanation
1	Depth of flow (ft) assigned from 6 to 2 feet
2	Water area (ft^2) corresponding to depth y in Col. 1
3	Hydraulic radius (ft) corresponding to y in Col. 1
4	4/3 power of the hydraulic radius
5	Mean velocity (fps) obtained by dividing Q (30 cfs) by the water area in Col. 2
6	Velocity head (ft)
7	Specific energy (ft) obtained by adding the velocity head in Col. 6 to depth of flow in Col. 1
8	Change of specific energy (ft) equal to the difference between the E value in Col. 7 and that of the previous step.
9	Friction slope S_f, computed from V as given in Col. 5 and $R^{4/3}$ in Col. 4
10	Average friction slope between the steps, equal to the arithmetic mean of the friction slope just computed in Col. 9 and that of the previous step
11	Difference between the bottom slope, S_o, and the average friction slope, S_f
12	Length of the reach (ft) between the consecutive steps; Computed by $\Delta x = \Delta E / (S_o - S_f)$ or by dividing the value in Col. 8 by the value in Col. 11
13	Distance from the beginning point to the section under consideration. This is equal to the cumulative sum of the values in Col. 12 computed for previous steps.

Figure 4.32 — Flow Splitter, Option A

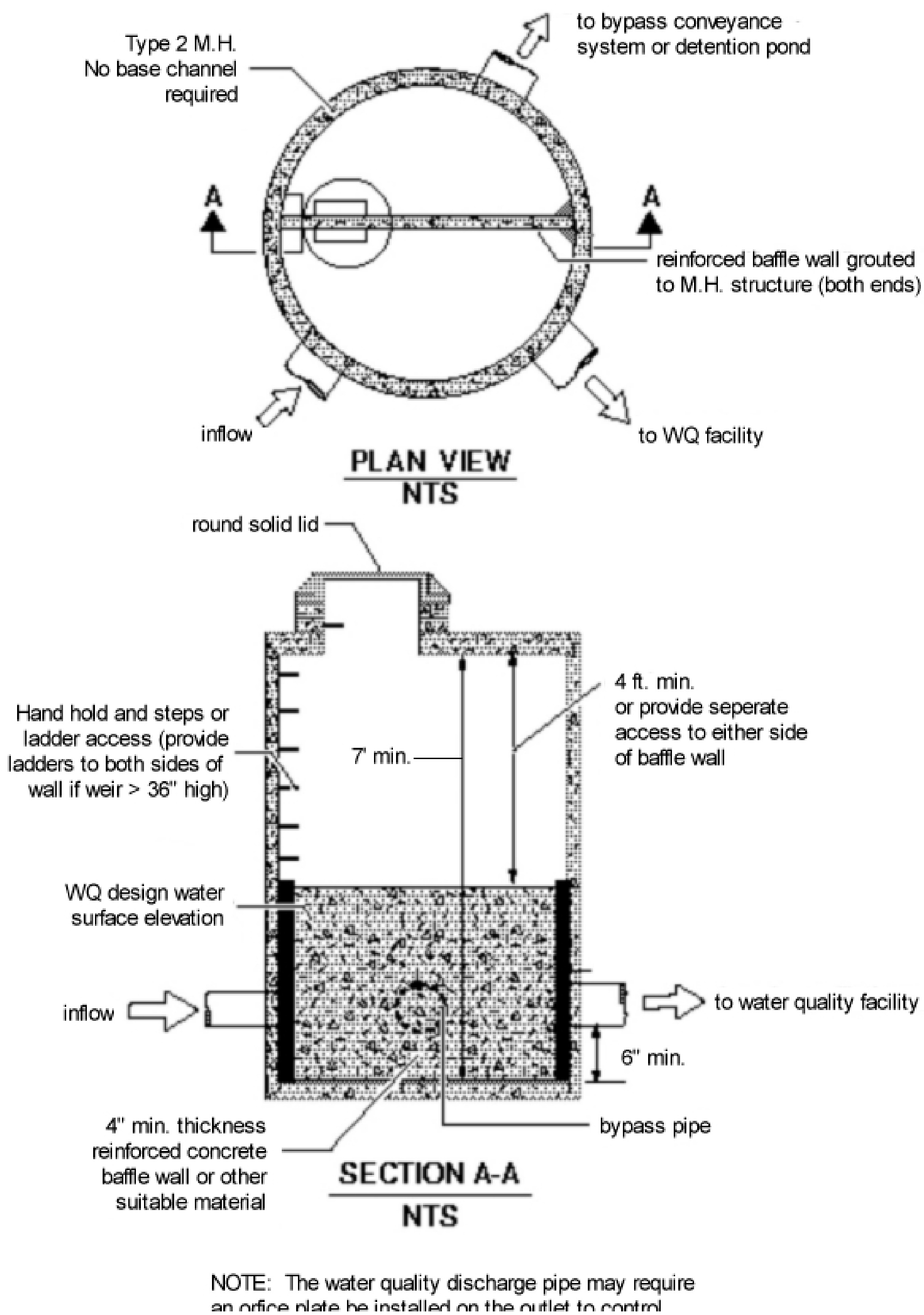
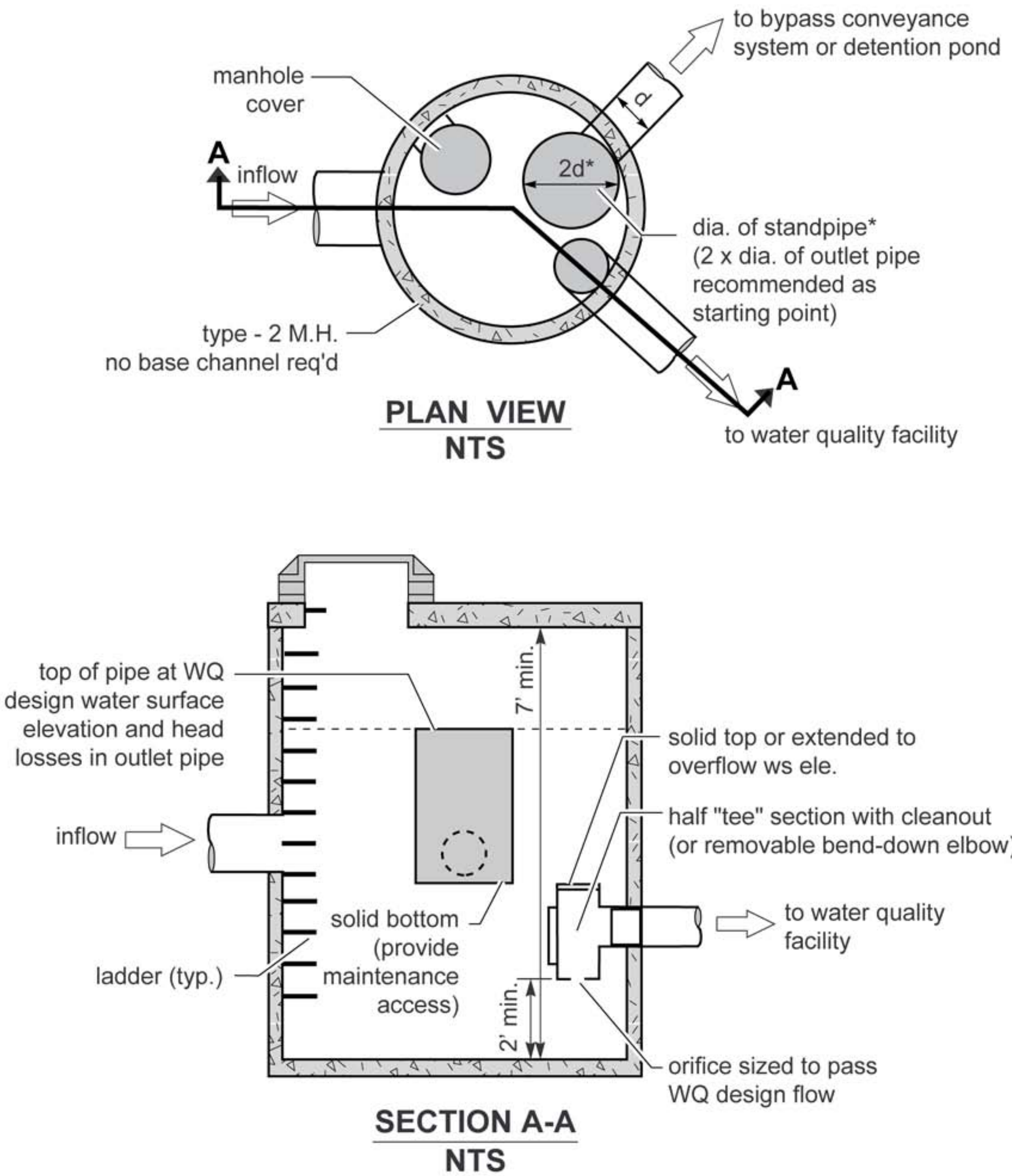


Figure 4.33 — Flow Splitter, Option B



***NOTE:** Diameter (d) of standpipe should be large enough to minimize head above W.Q. design W.S. and to keep W.Q. design flows from increasing more than 10% during 100-year flows.

Figure 4.34 — Flow Spreader Option A: Anchored Plate

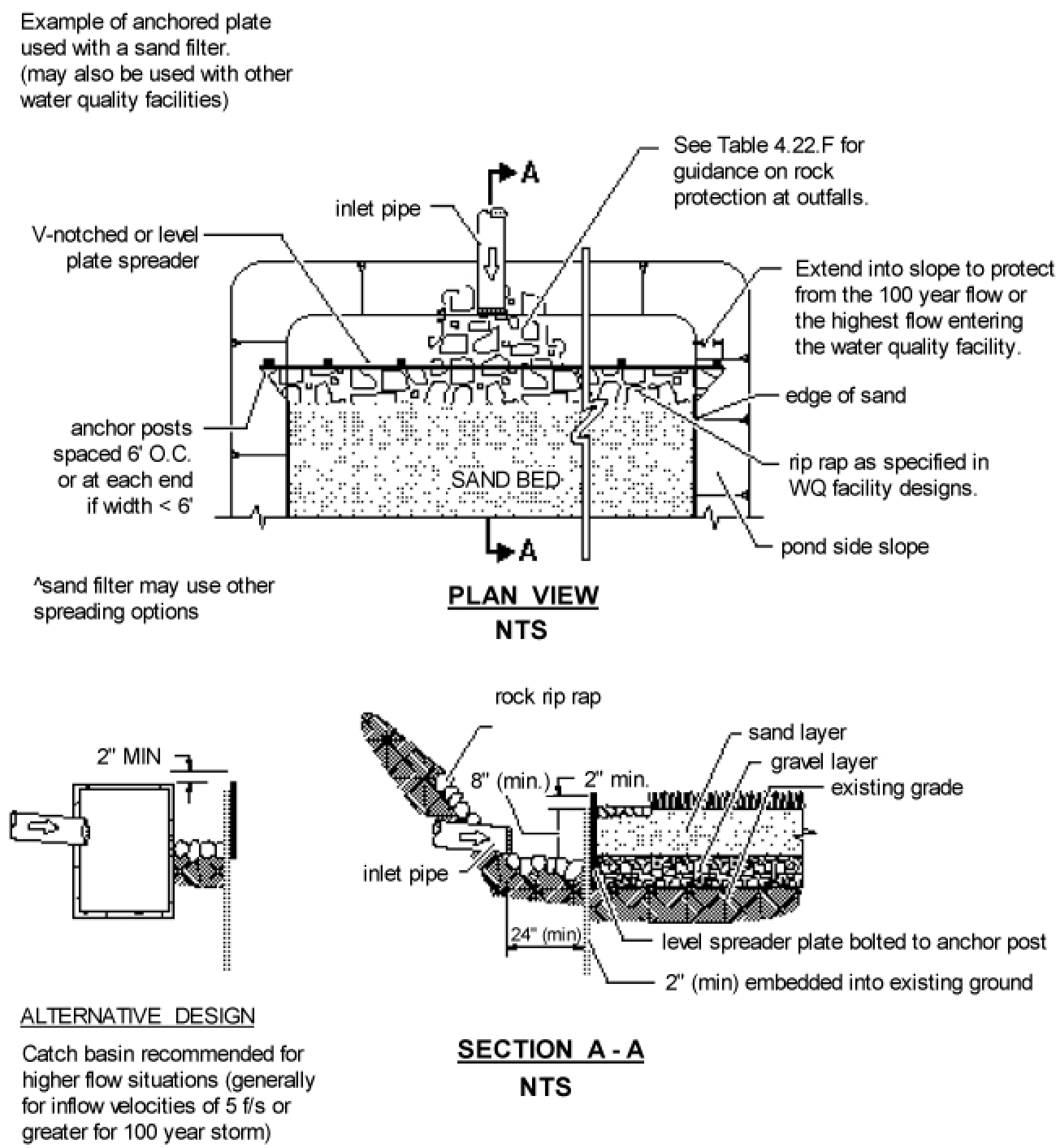
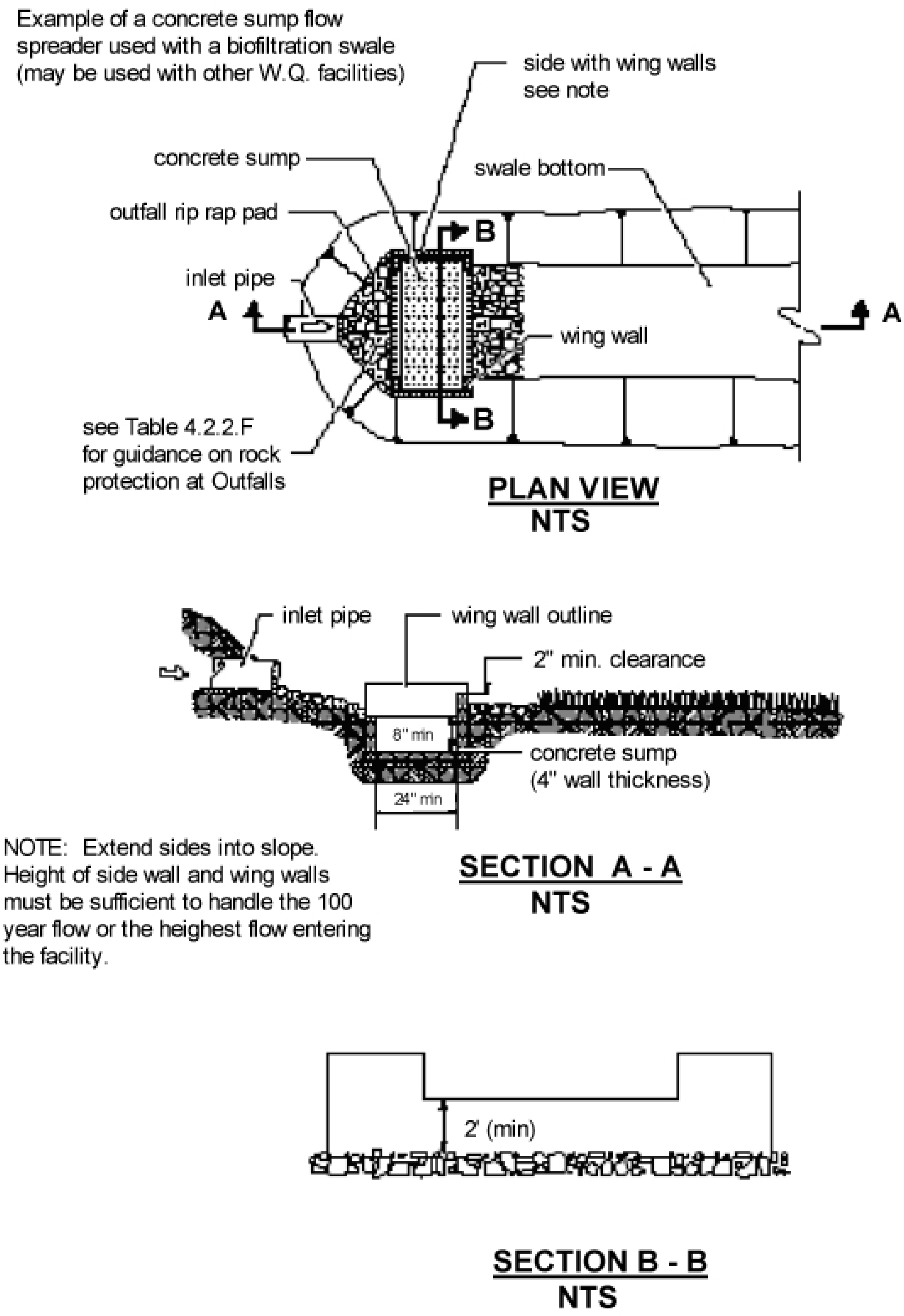


Figure 4.35 — Flow Spreader Option B: Concrete Sump Box



NOTE: Extend sides into slope. Height of side wall and wing walls must be sufficient to handle the 100 year flow or the heighest flow entering the facility.

Figure 4.36 — Flow Spreader Option C: Notched Curb Spreader

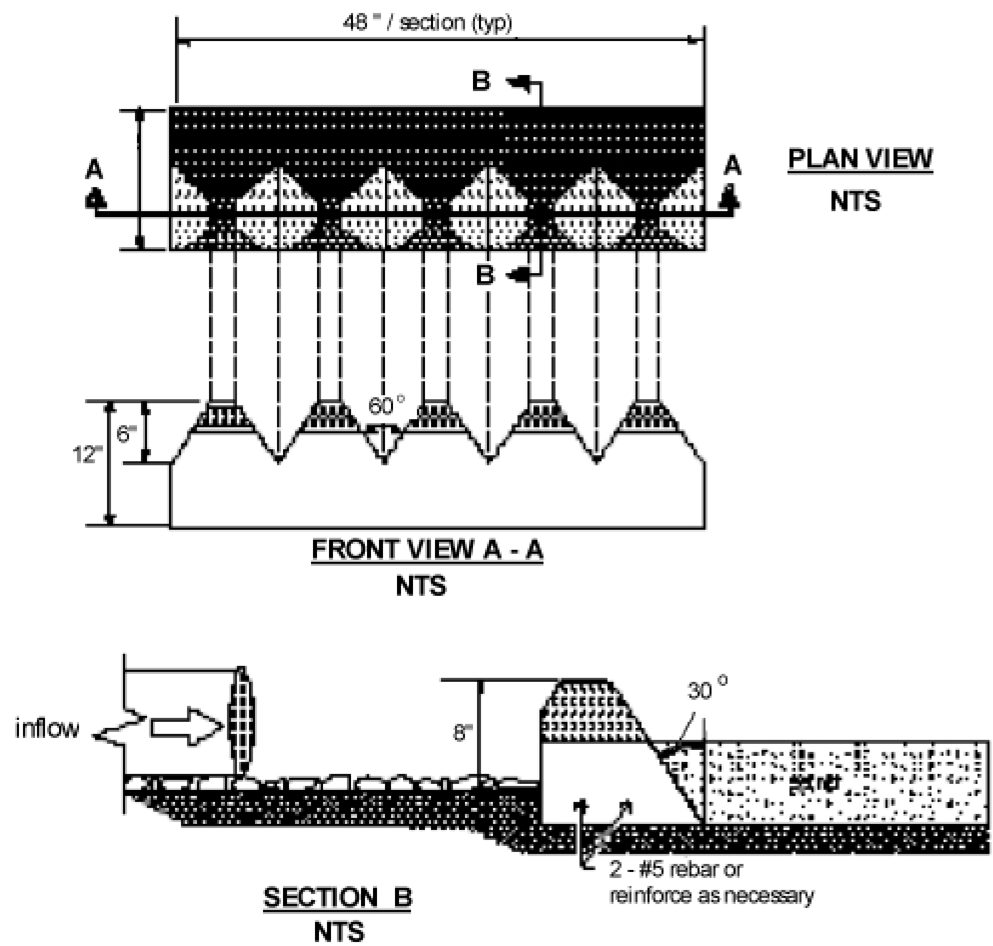
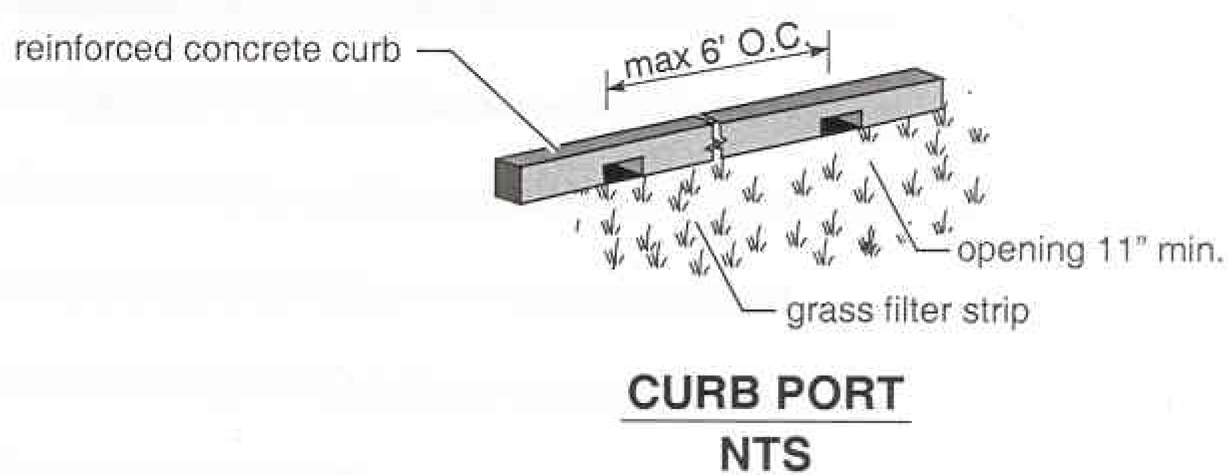


Figure 4.37 — Flow Spreader Option D: Through-Curb Port



Kitsap County Stormwater Design Manual

CHAPTER 5–FIGURES

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Figure 5.1 — BMP 5.01 Rock-filled Infiltration Trench

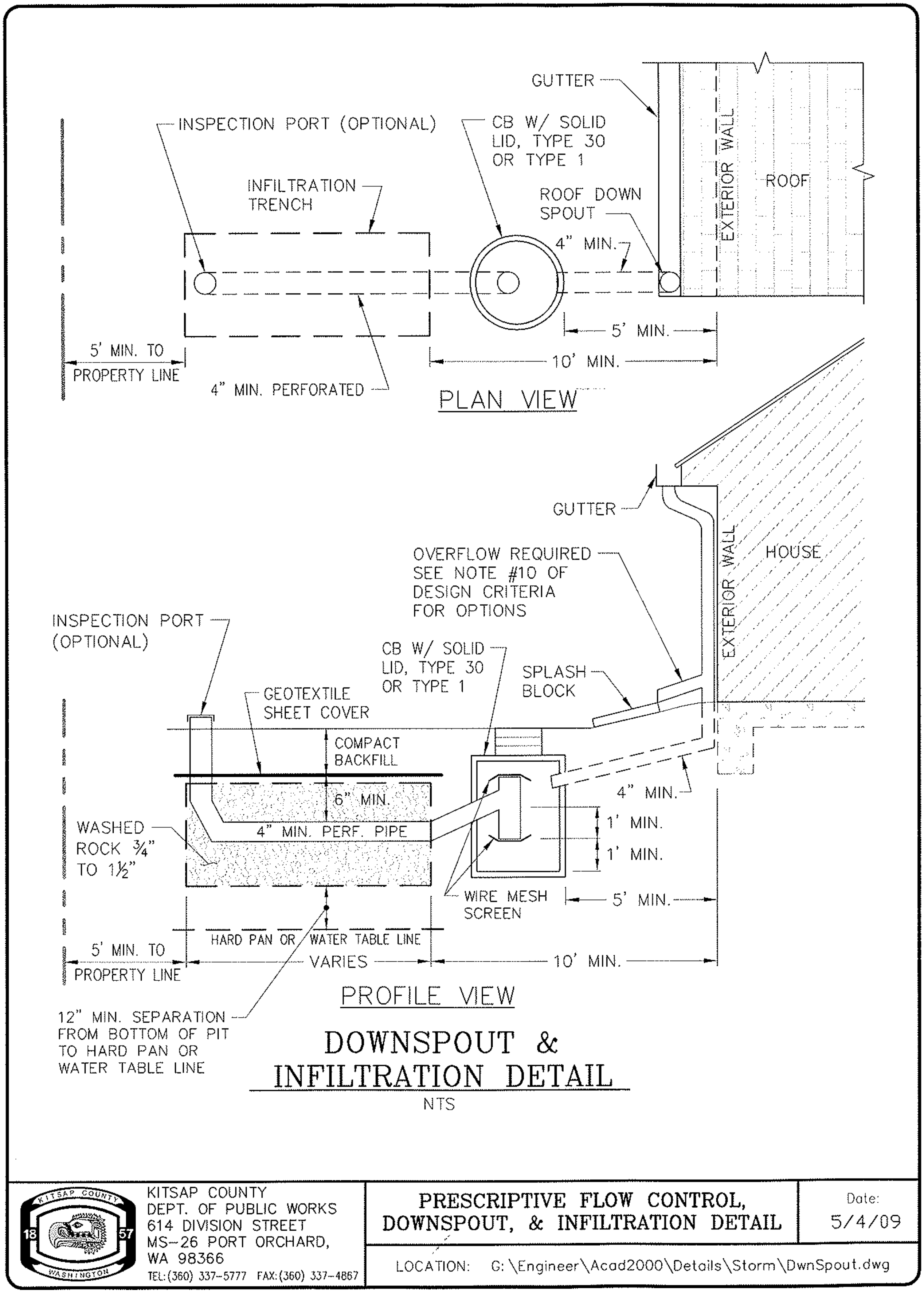


Figure 5.2 — Alternative Rock-filled Infiltration Trench System

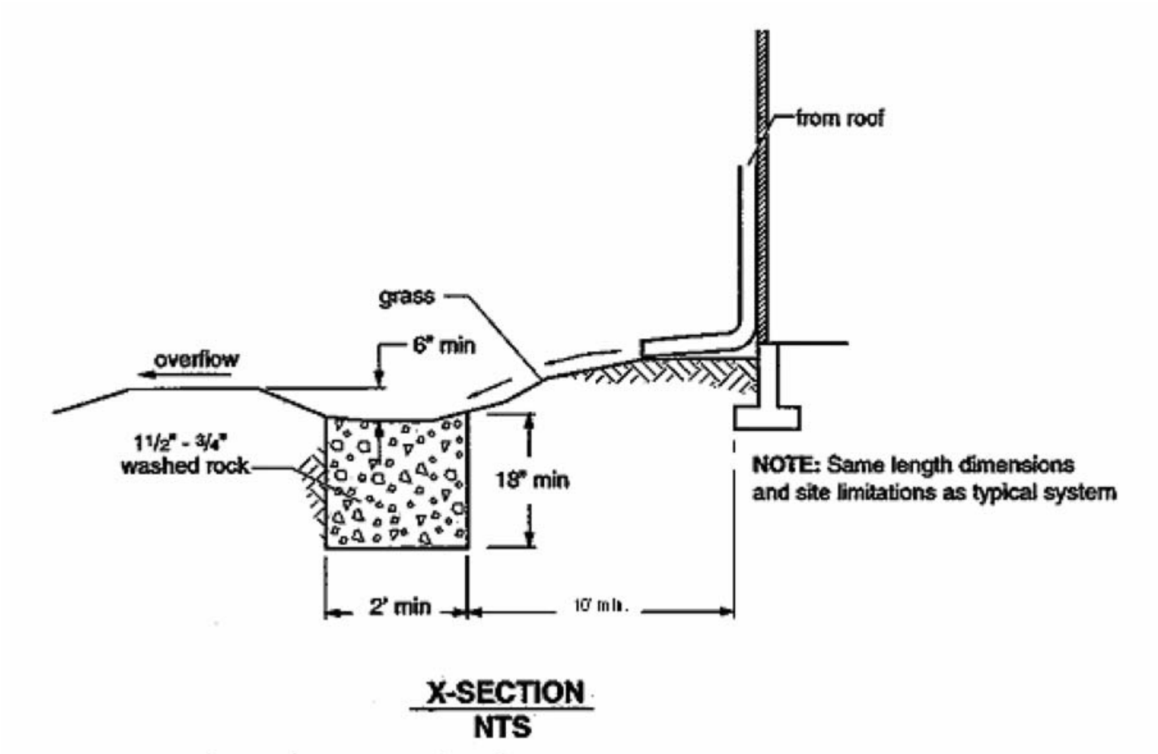
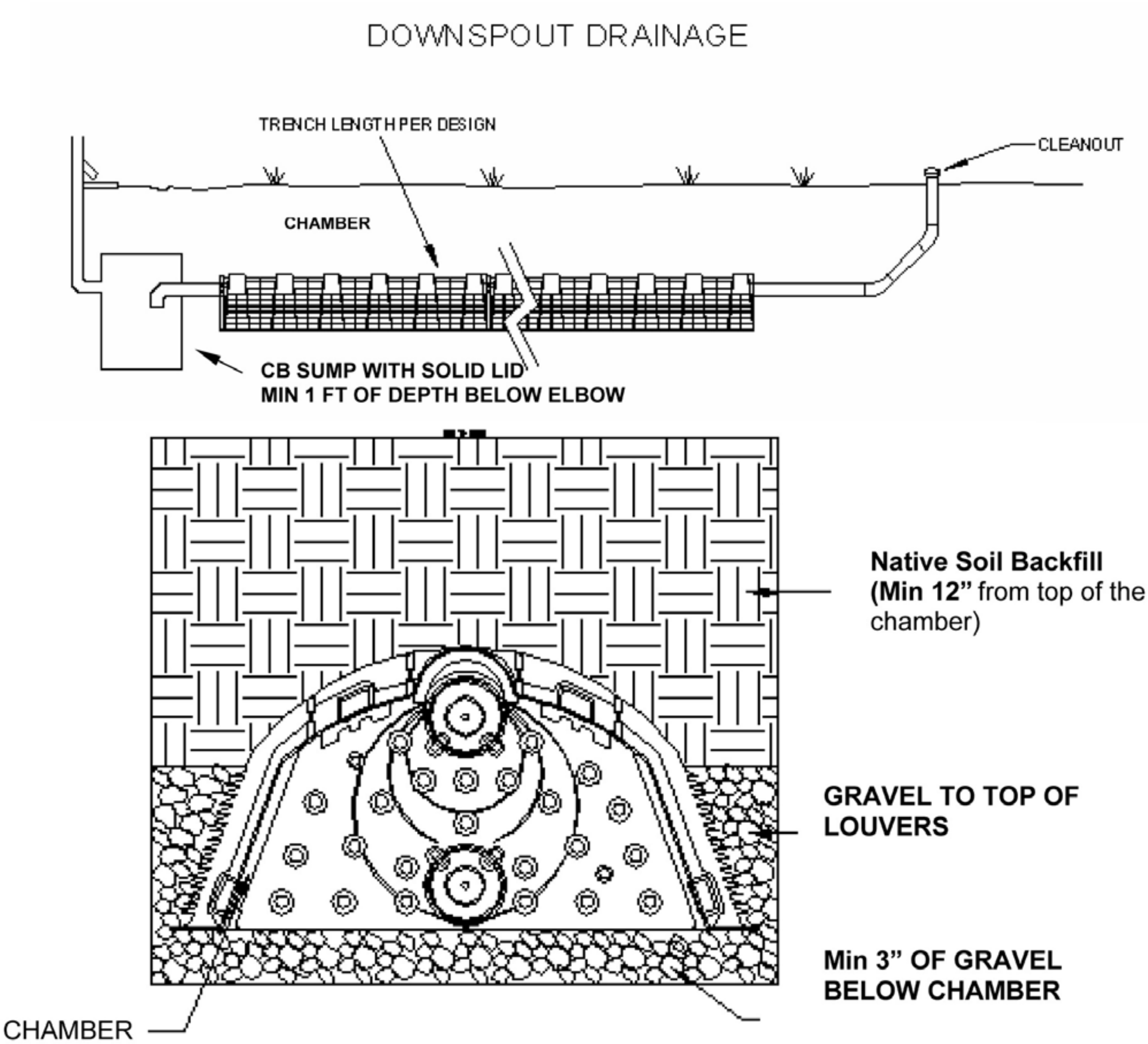


Figure 5.3 — Gravelless Chamber Infiltration Trench

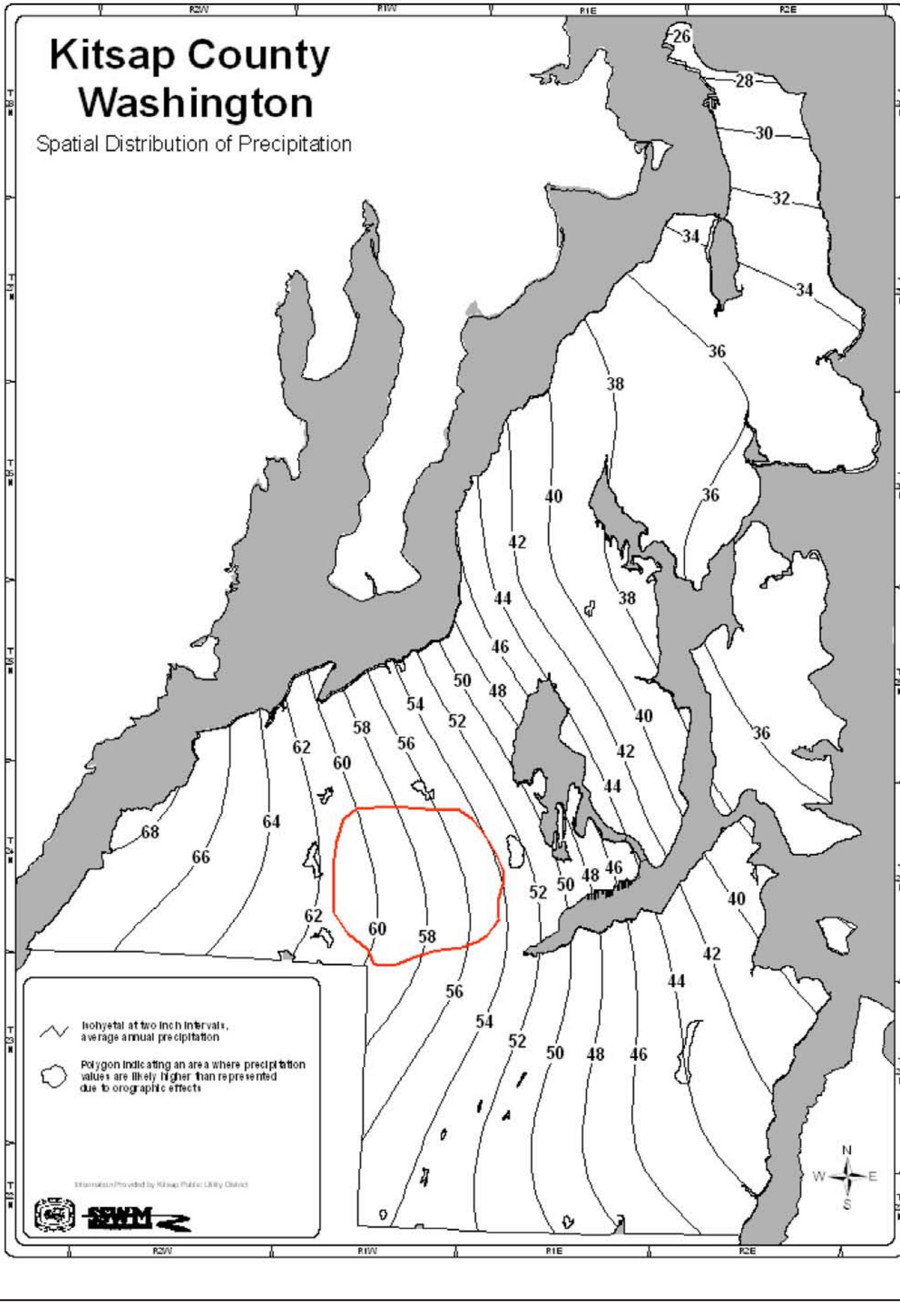


A gravelless chamber infiltration trench. Void space per linear foot shall be at least 2.6 cubic feet. The infiltrative surface per linear foot shall be at least 2.8 square feet.

The following products are known to meet these criteria:

Infiltrator© High Capacity by Infiltrator Systems, Inc.
EnviroChamber© High Capacity by Hancor, Inc.
Stormtech© SC-310 by Infiltrator Systems, Inc

Figure 5.4 — Average Annual Rainfall in Kitsap County



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CHAPTER 6–FIGURES

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Figure 6.1 — Water Quality Treatment BMP Selection Flow Chart

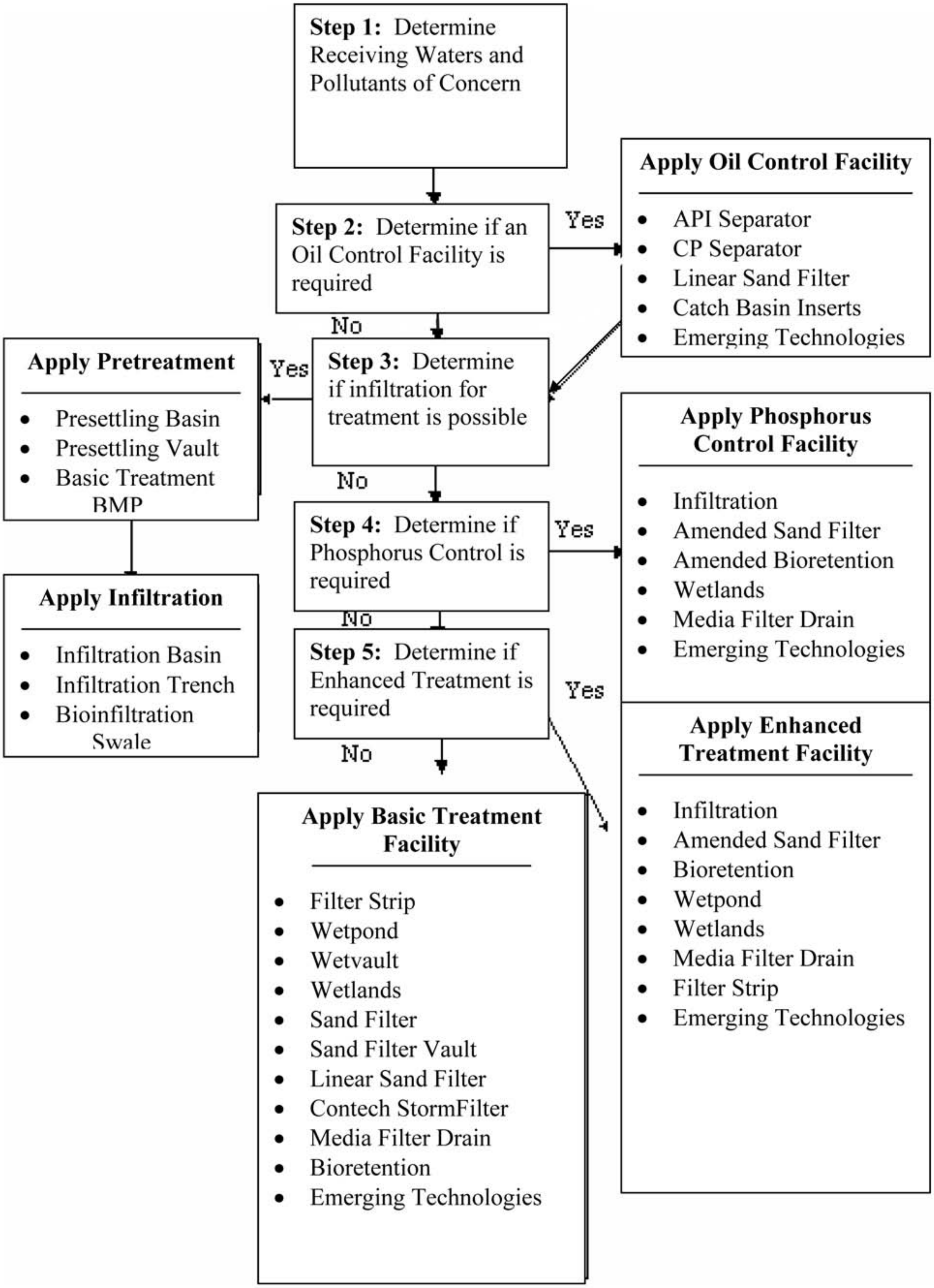
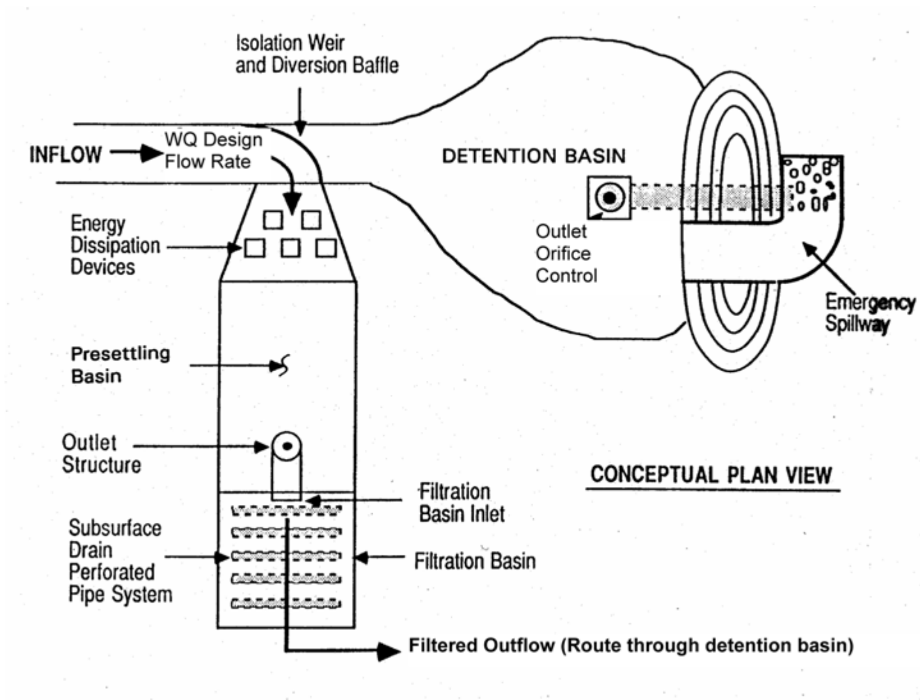


Figure 6.2 — Sand Filtration Basin Preceded by Presettling Basin (Variation of a Basic Sand Filter)



Source: City of Austin

Figure 6.3 — Sand Filter with Pretreatment Cell

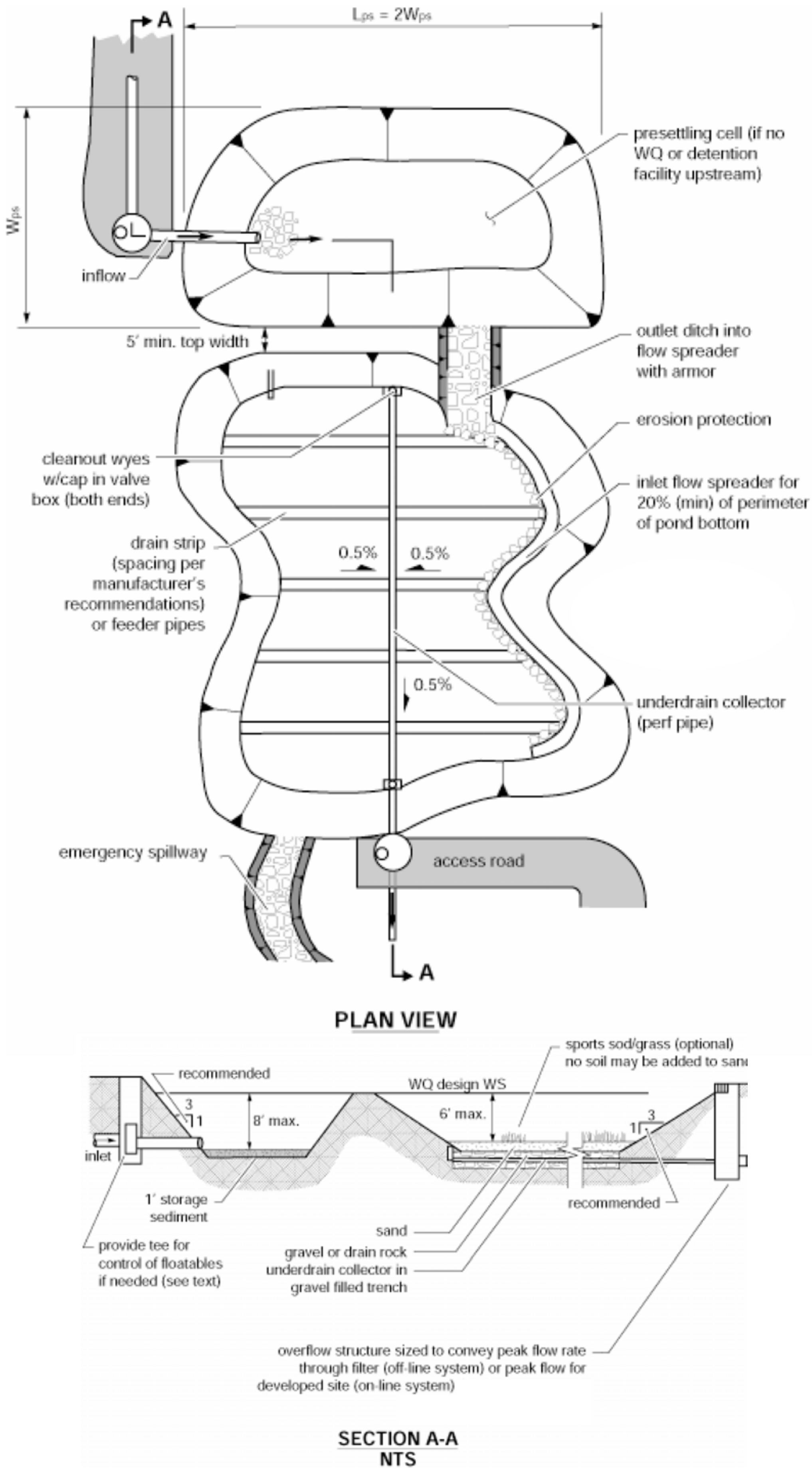


Figure 6.4 — Sand Filter with Level Spreader

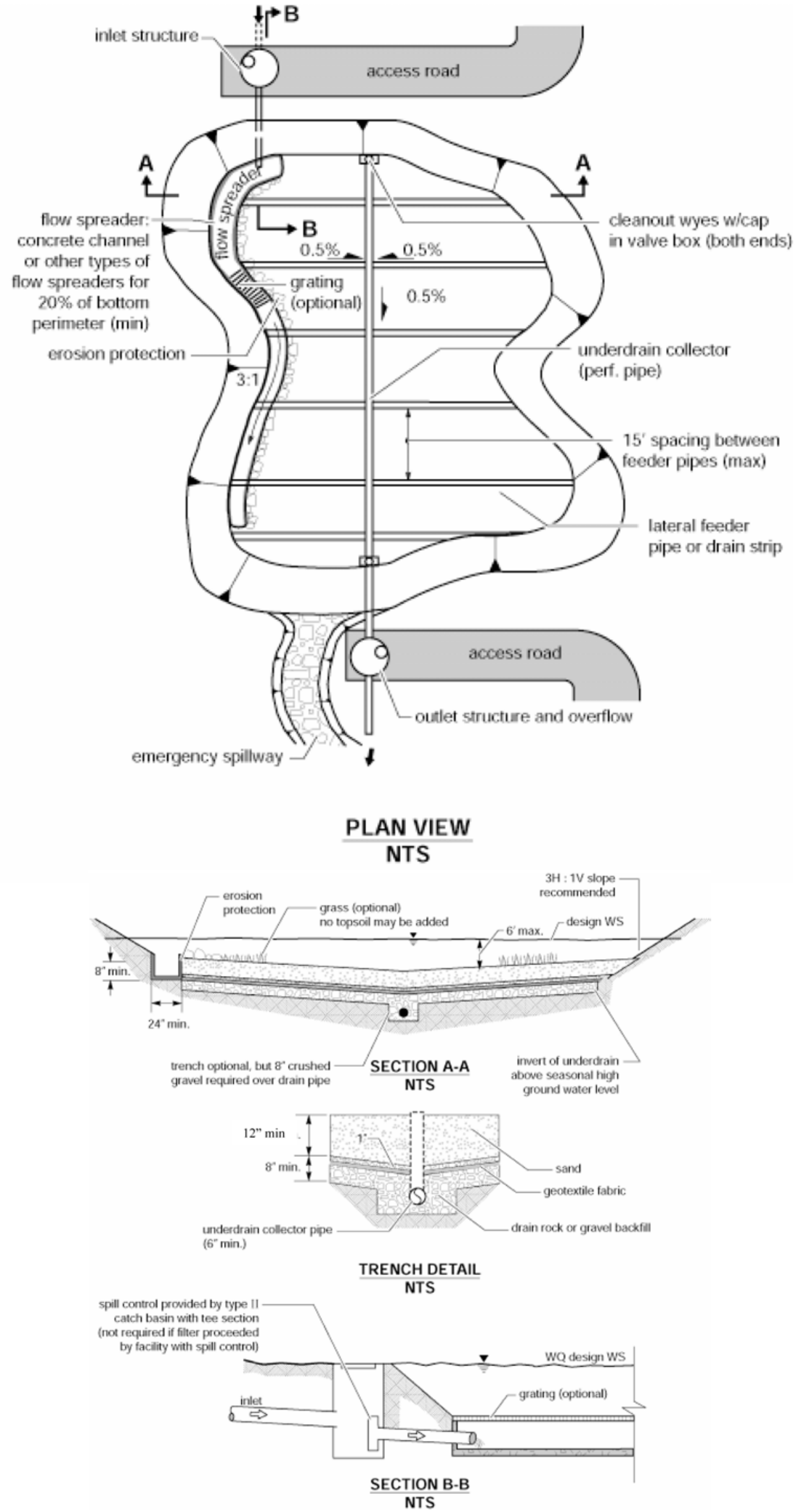


Figure 6.5 — Sand Filter Vault

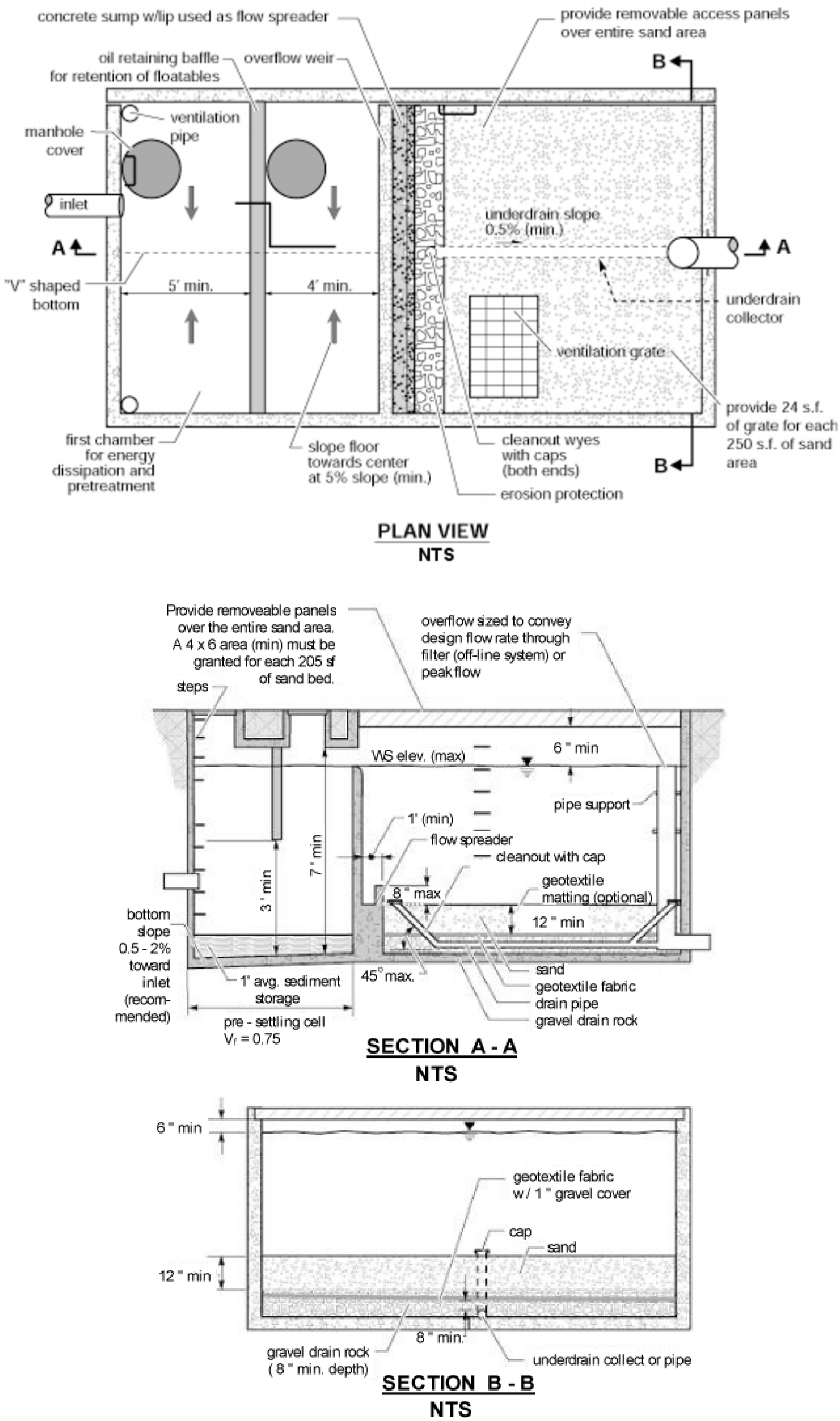


Figure 6.6 — Linear Sand Filter

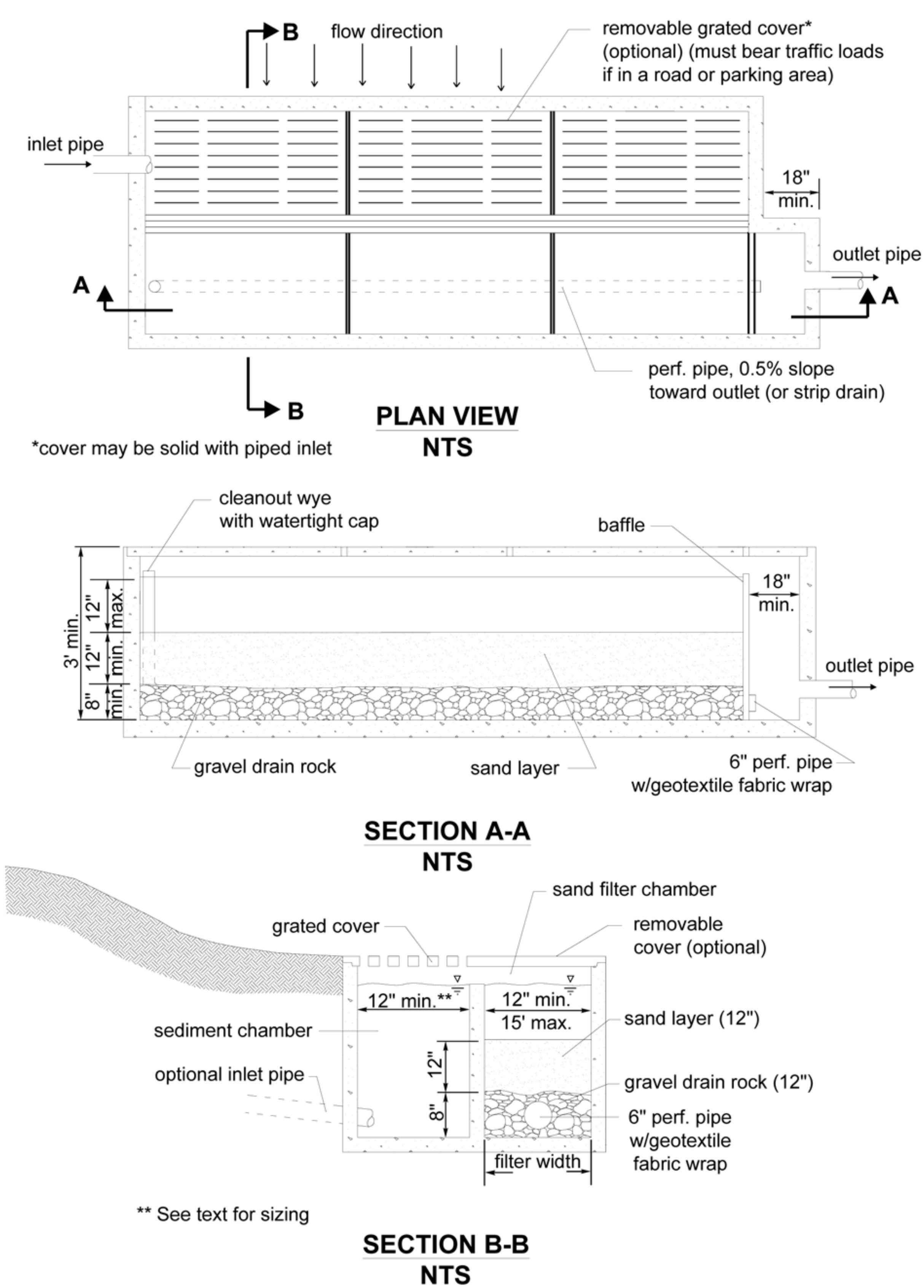


Figure 6.7 — Shallow Plastic Drainage Channel

Vault Diameter	Speci ed Treatment Capacity [a,b]

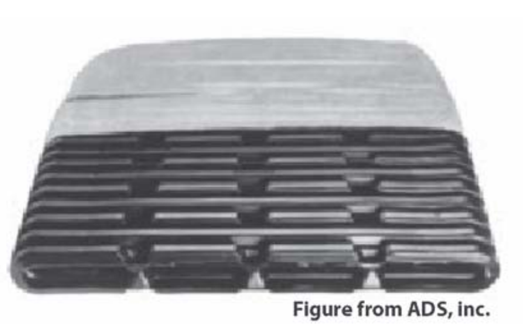


Figure 6.8 — StormFilter Schematic

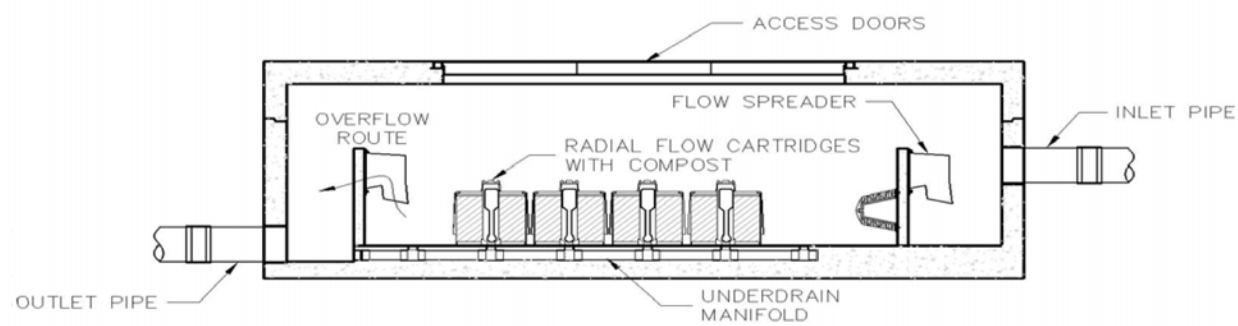


Figure 6.9 — Typical Filter Strip

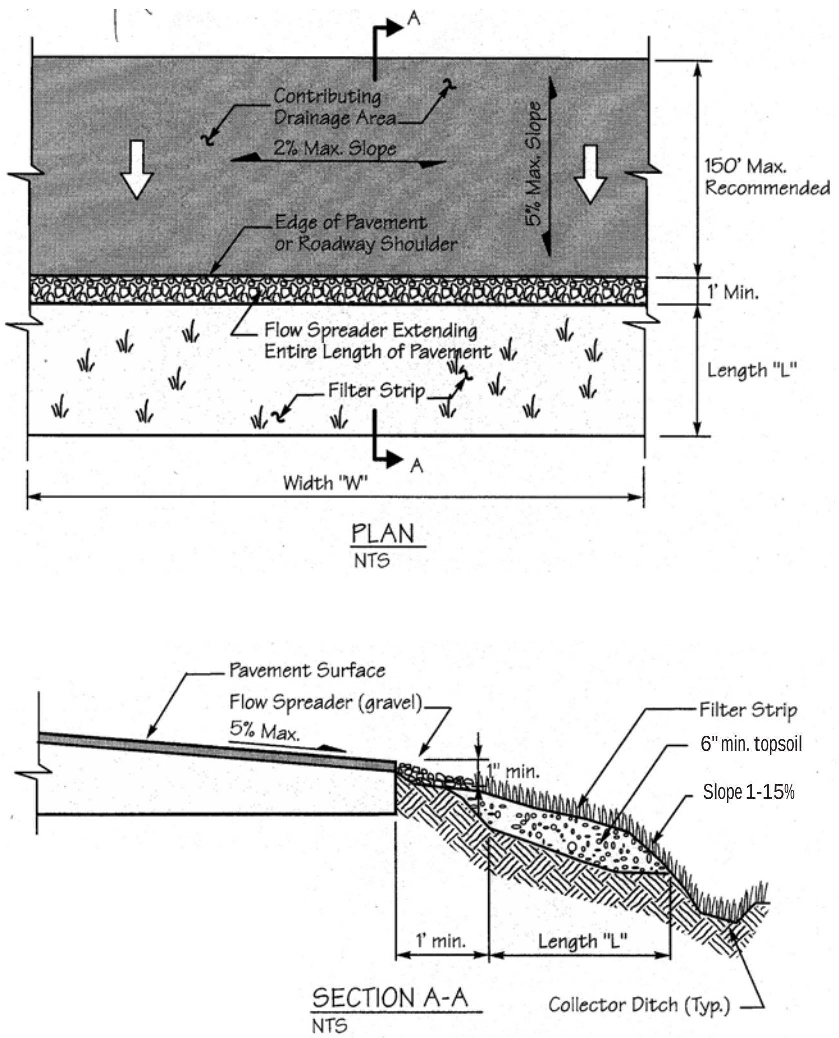
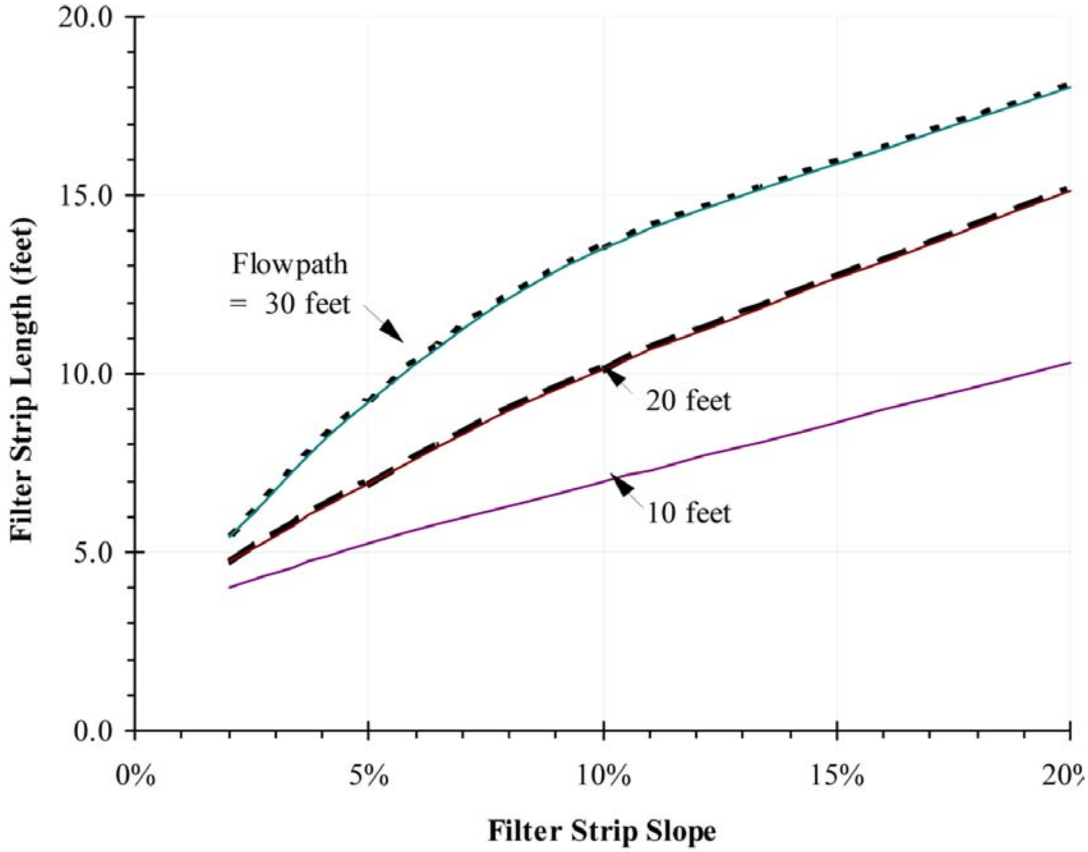


Figure 6.10 — Filter Strip Lengths for Narrow Right-of-Way



Note: minimum allowable filter strip length is 4 feet

Figure 6.11 — Kitsap Mean Annual Storm

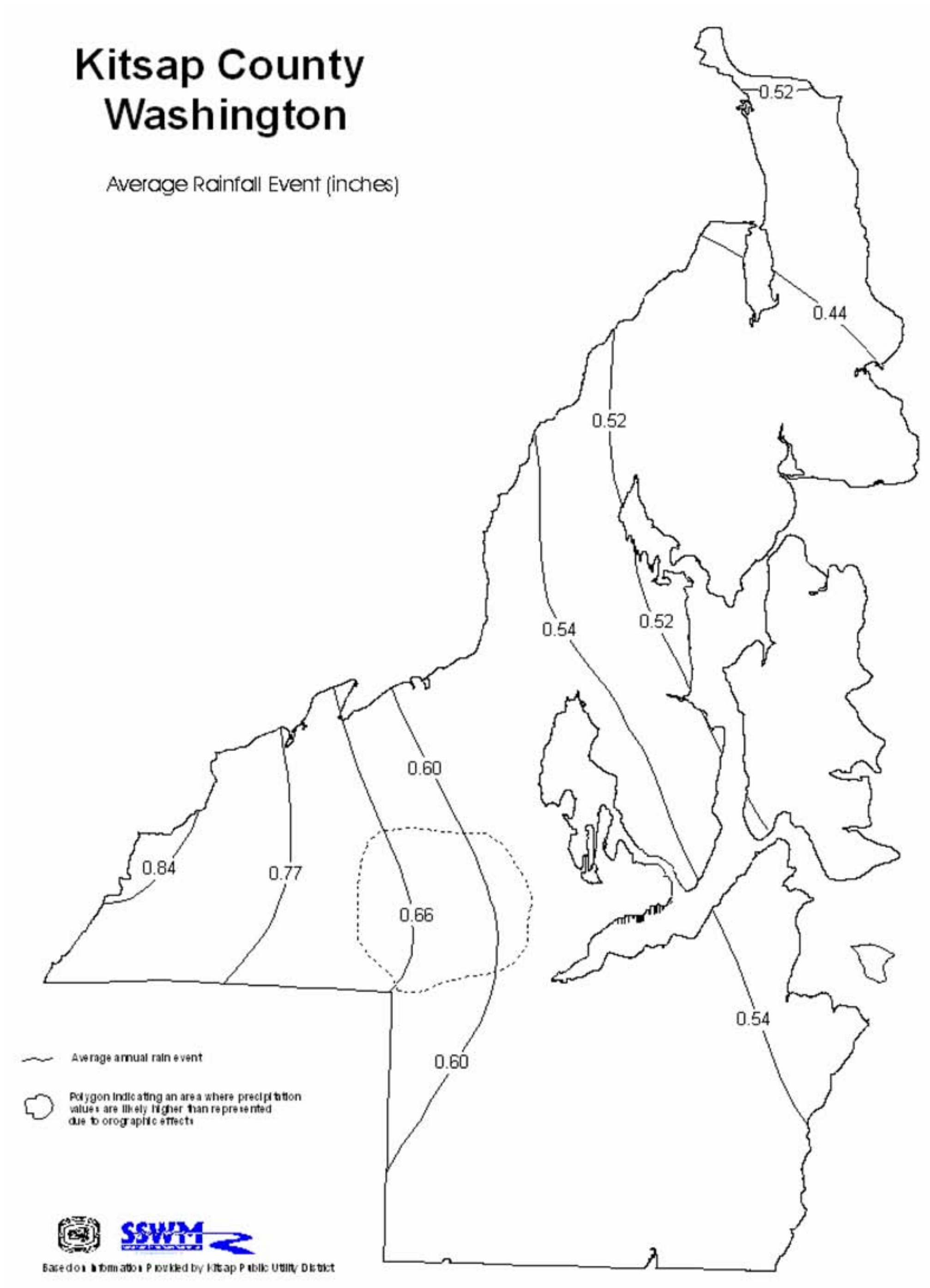
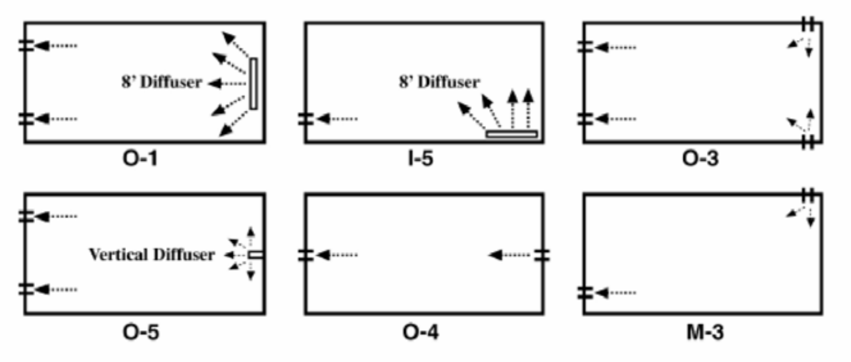


Figure 6.12 — Possible Wetpond Inlet / Outlet Configurations



The ranking of the configurations from best to worst is

I-5>M-3>O-5>O-1>O-3>O-4.

Figure 6.13 — Wetpond

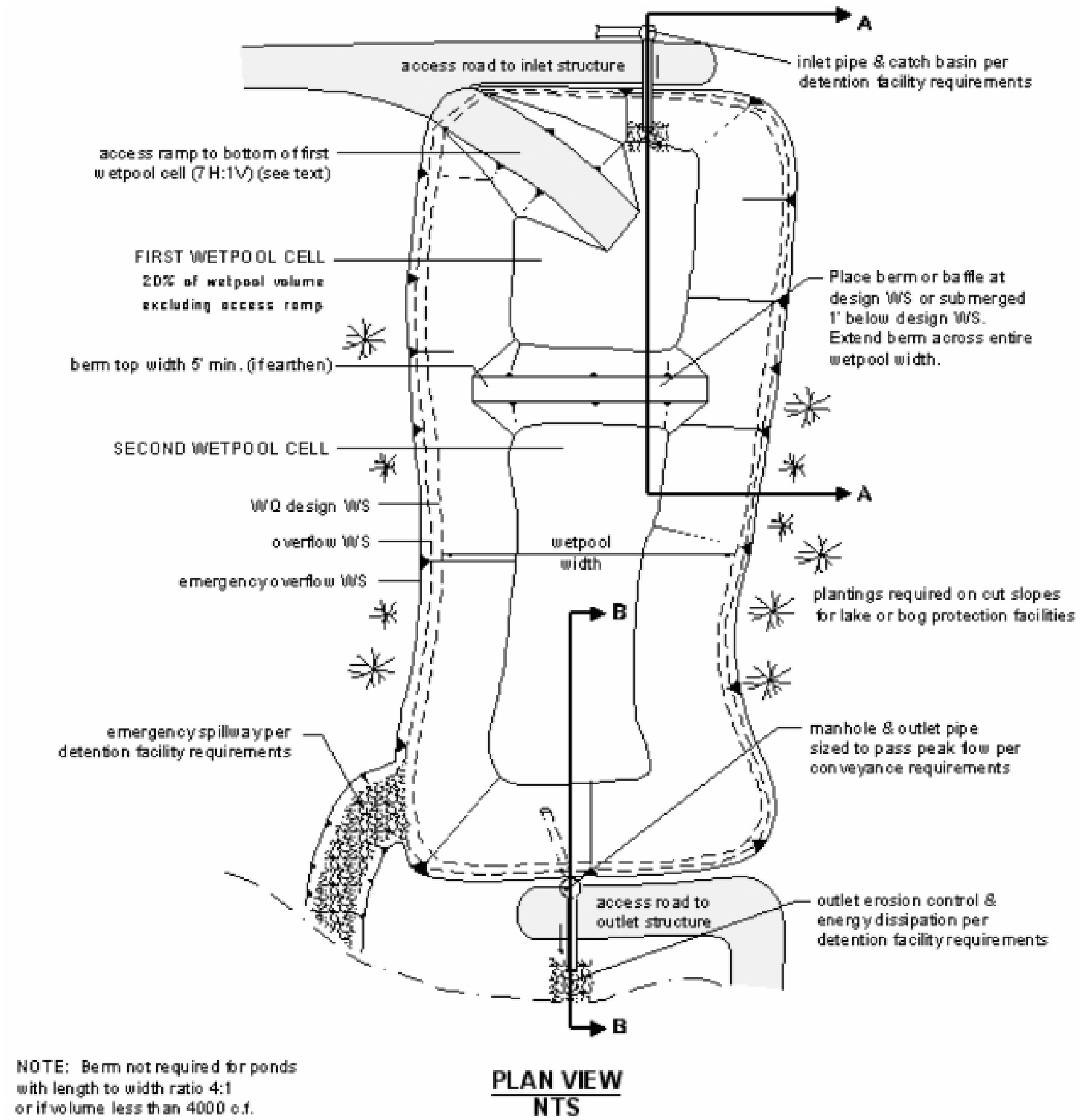
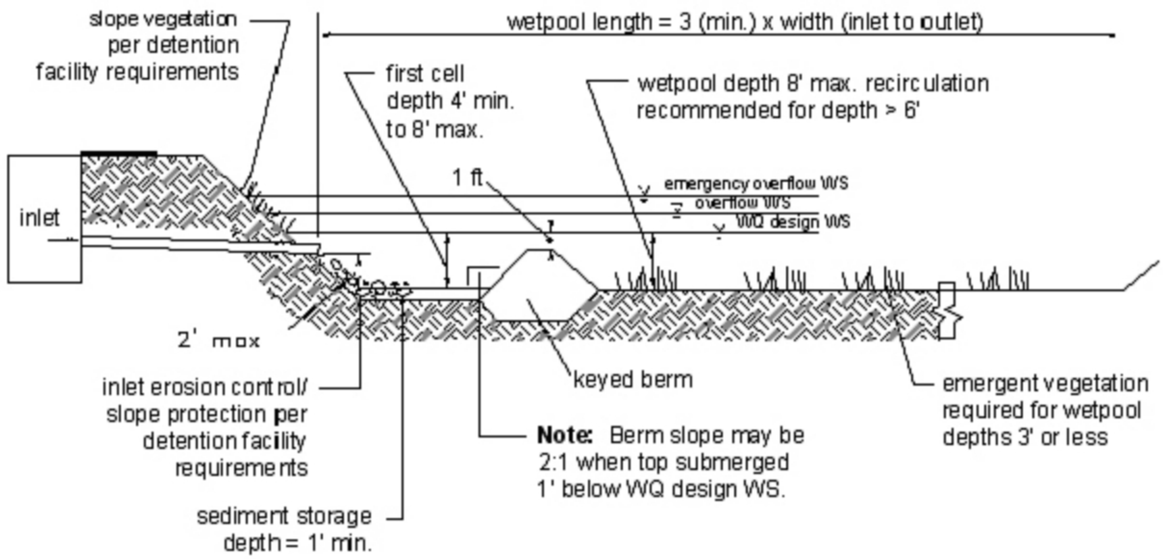
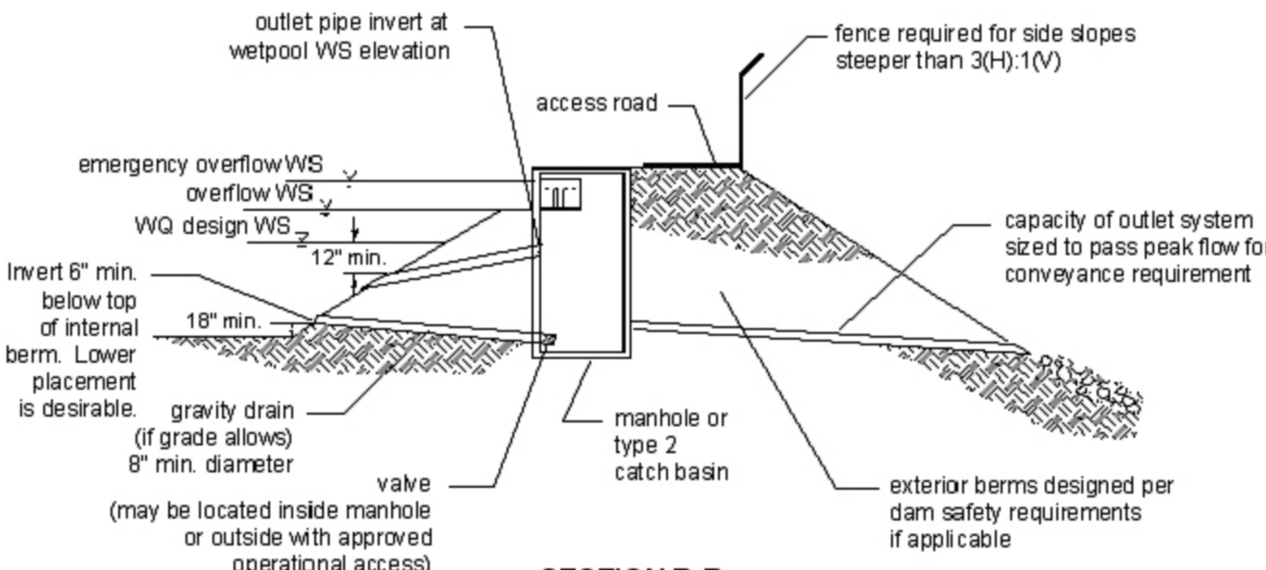


Figure 6.13 (continued) — Wetpond



SECTION A-A
NTS



SECTION B-B
NTS

NOTE: see detention facility requirements for location and setback requirements.

Figure 6.14 — Wetvault

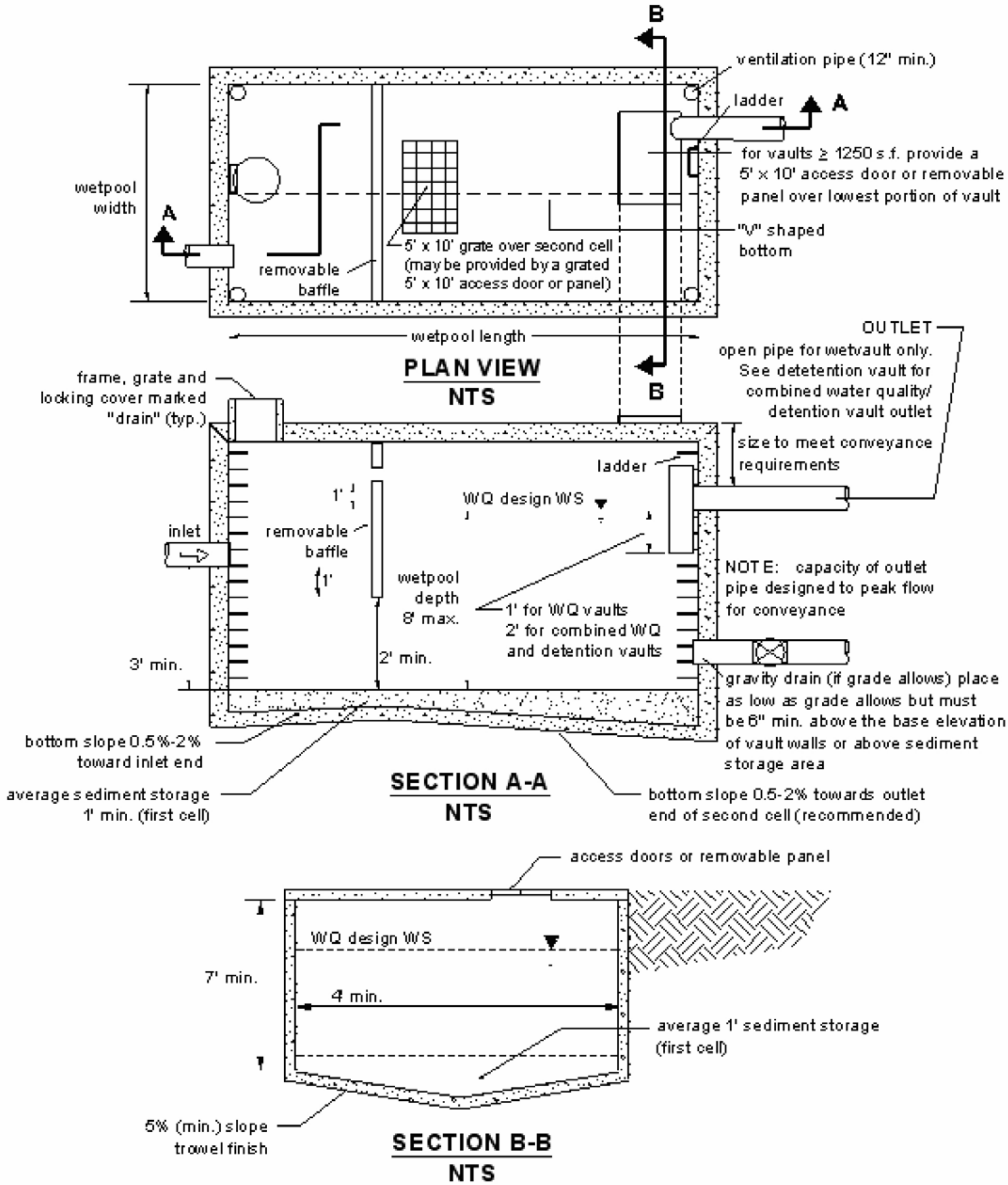
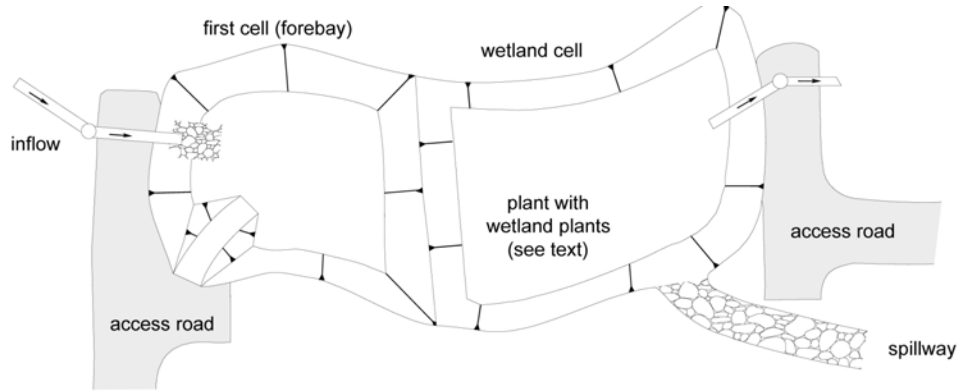
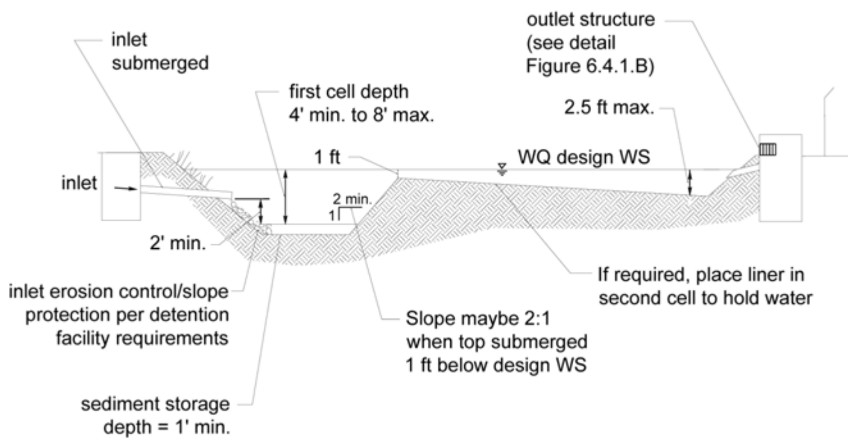


Figure 6.15 — Stormwater Treatment Wetland — Option A



PLAN VIEW Option A
NTS



SECTION Option A
NTS

Note: See detention facility requirements for location and setback requirements.

Figure 6.16 — Stormwater Treatment Wetland (Option B)

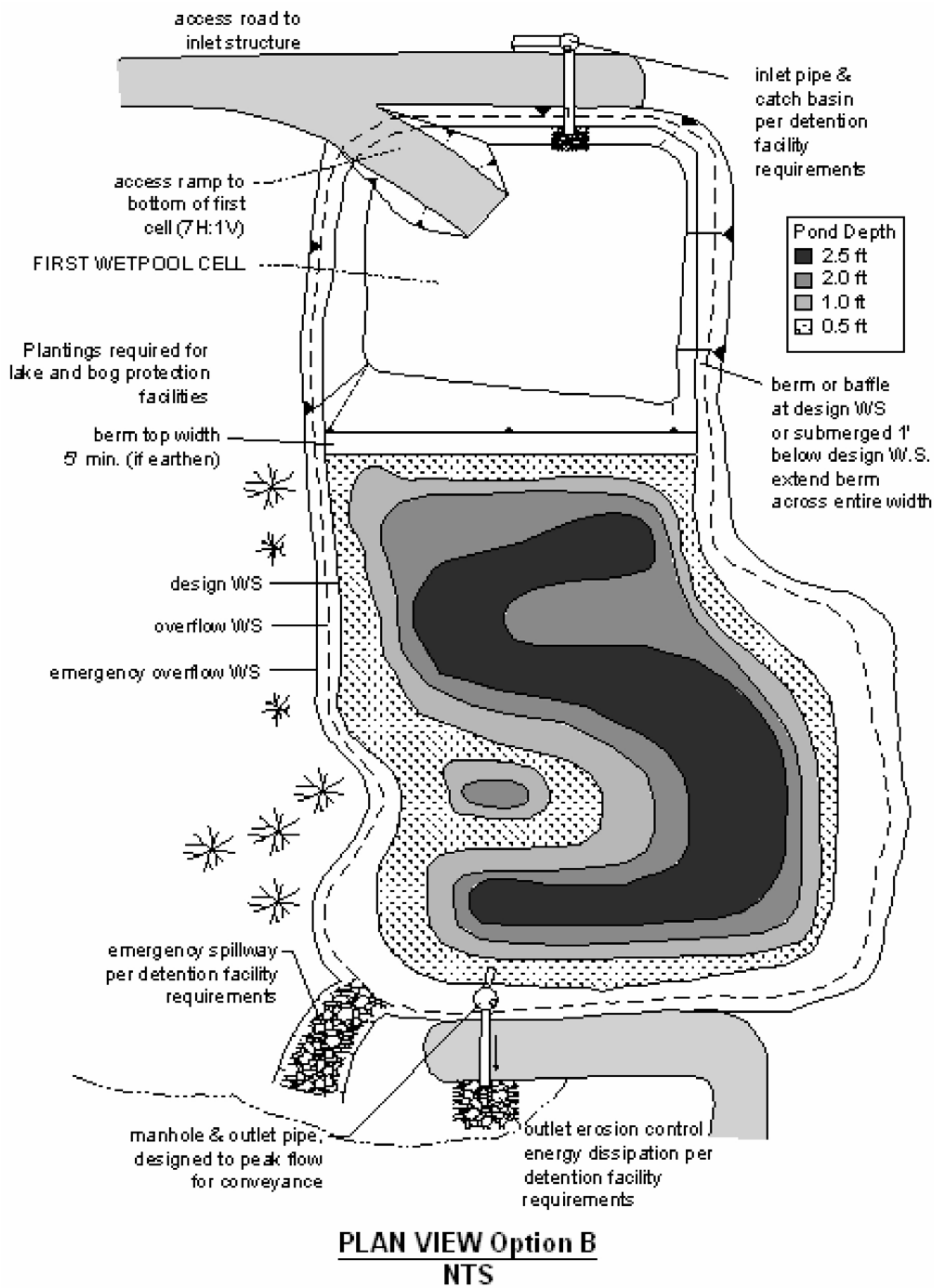


Figure 6.17 — Headwater Depth for Smooth Interior Pipe Culverts with Inlet Control

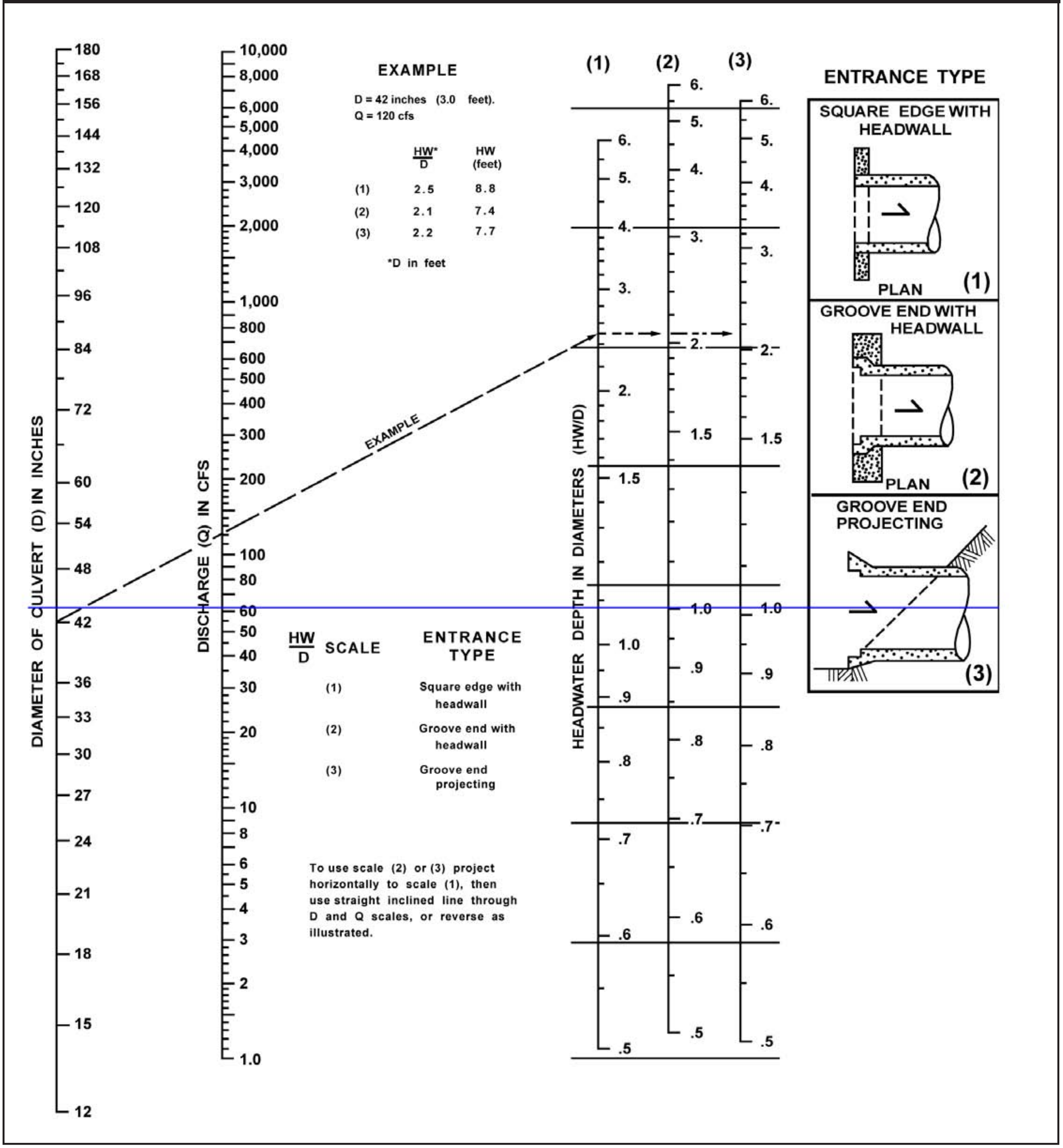


Figure 6.18 — Headwater Depth for Corrugated Pipe Culverts with Inlet Control

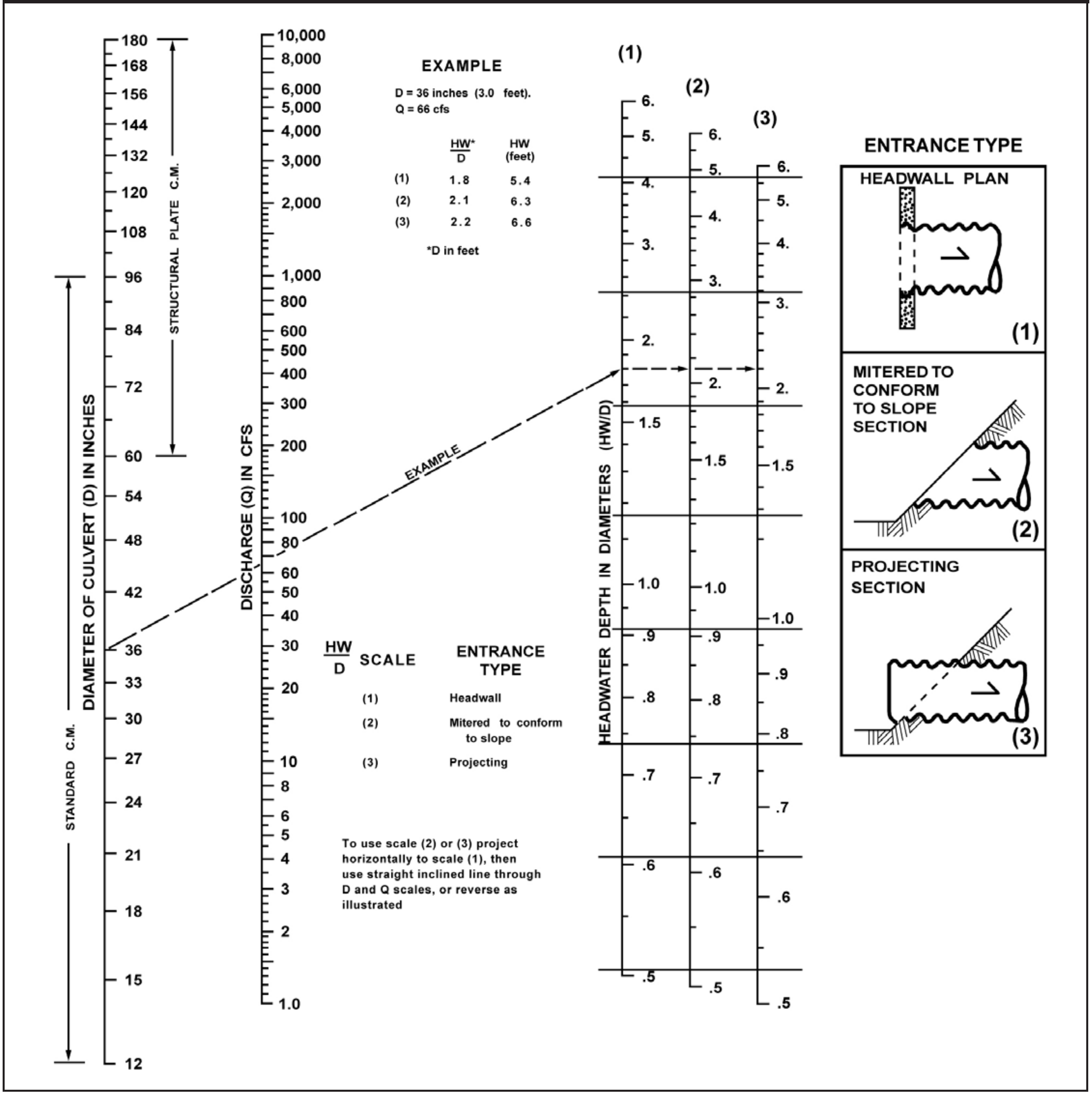
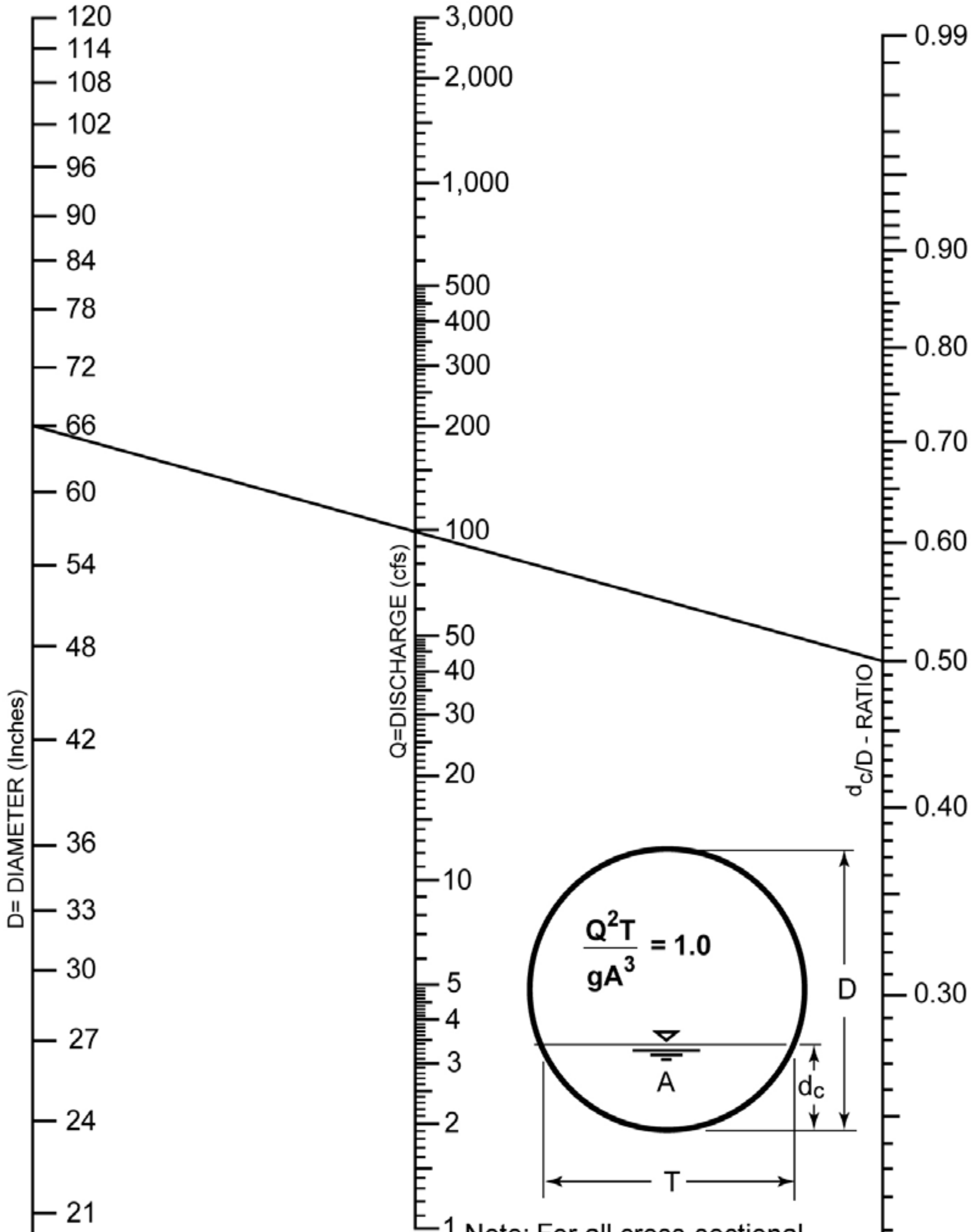


Figure 6.19 — Critical Depth of Flow for Circular Culverts



Note: For all cross-sectional shapes, d_c can be calculated by trial and error knowing that the quantity (**Q^2T/gA^3)=1.0** at critical depth.

EXAMPLE
D = 66 inches, Q = 100cfs d_c/D - Ratio = 0.50 d_c = (0.50)(66 inches)= 33 inches ÷ (12 inches/ft) d_c= 2.75 feet

Figure 6.20 — Circular Channel Ratios

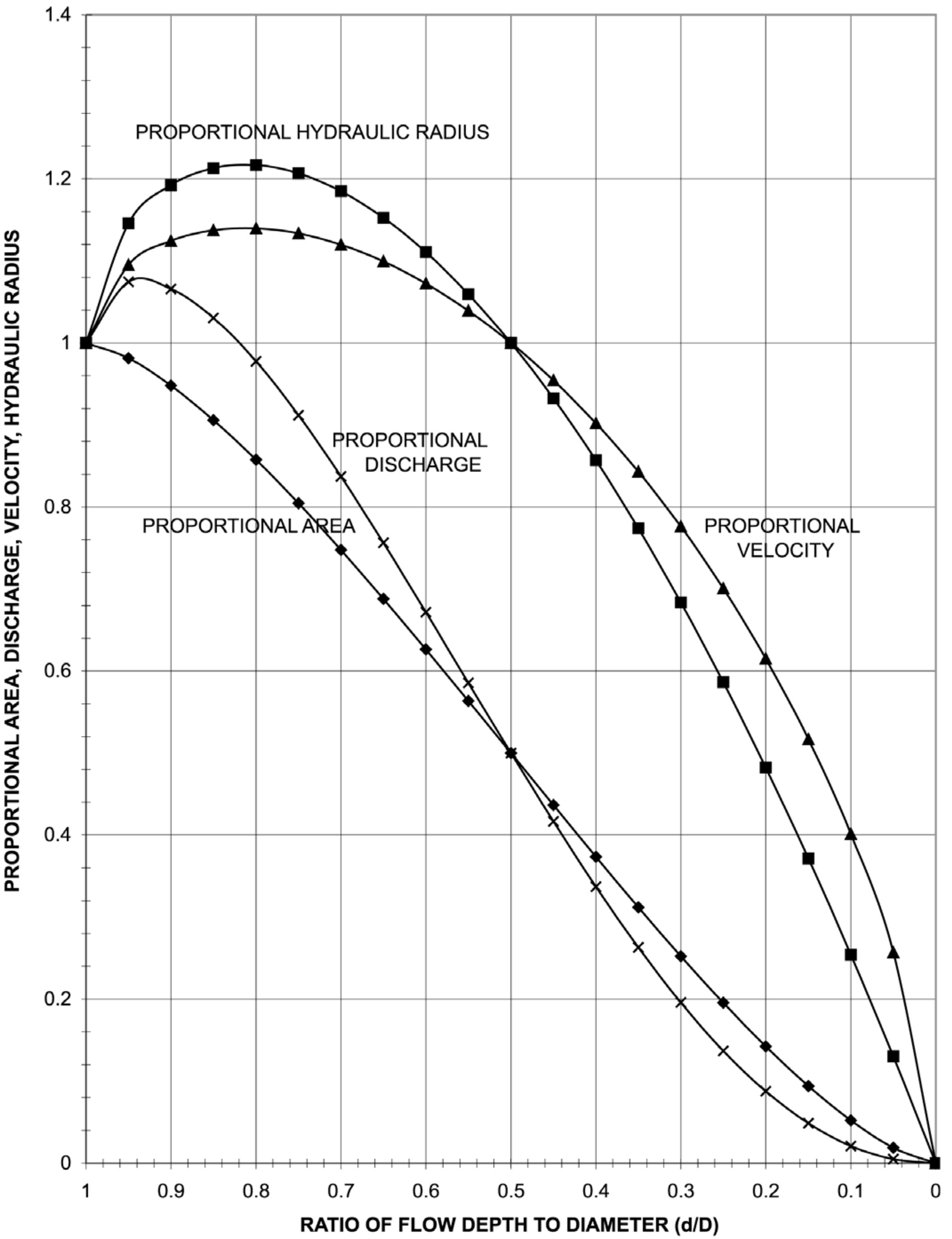


Figure 6.21 — Turbulence Factor Plot

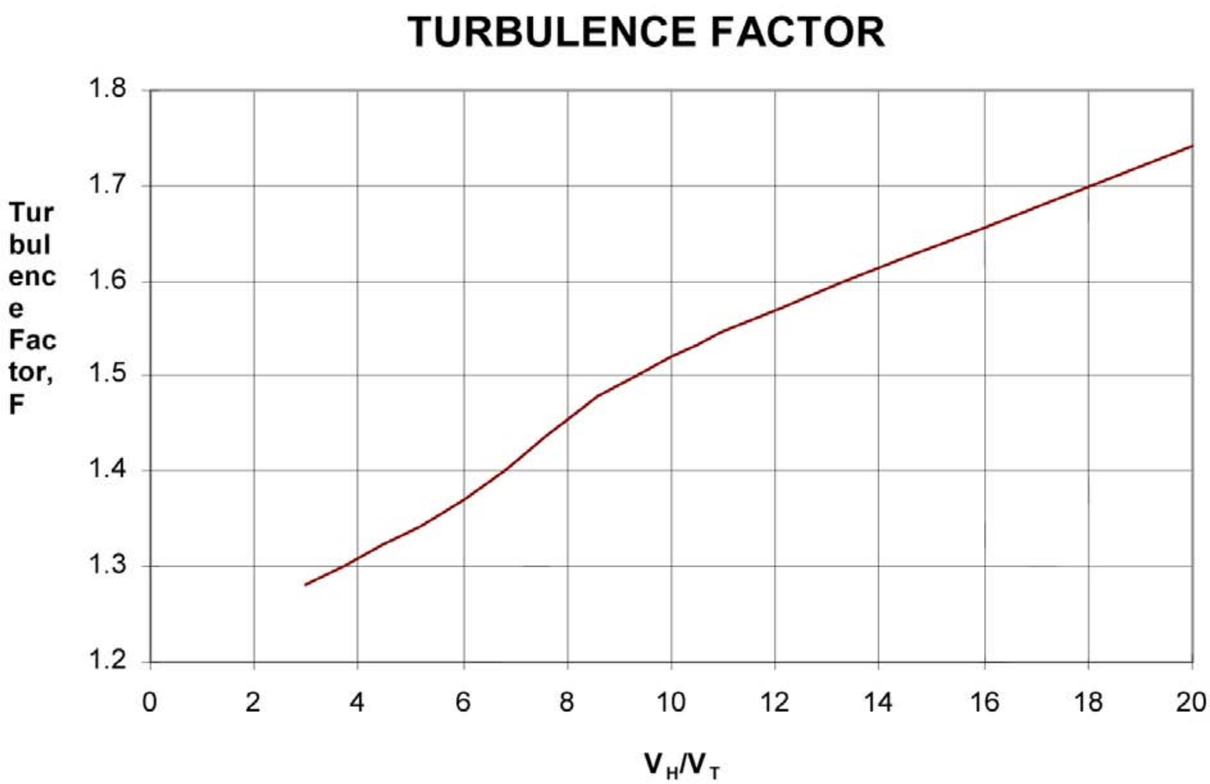


Figure 6.22 — Effective Separation Surface vs. Flow Rate

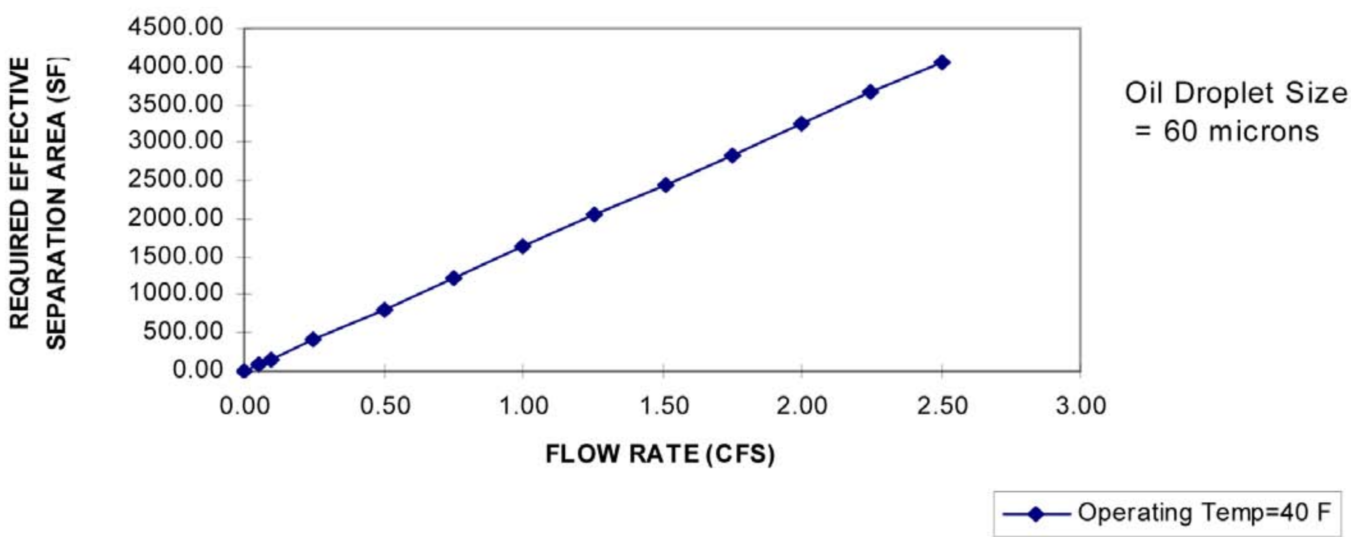


Figure 6.23 — Projected Horizontal Plate Area for Coalescing Plate Oil / Water Separator

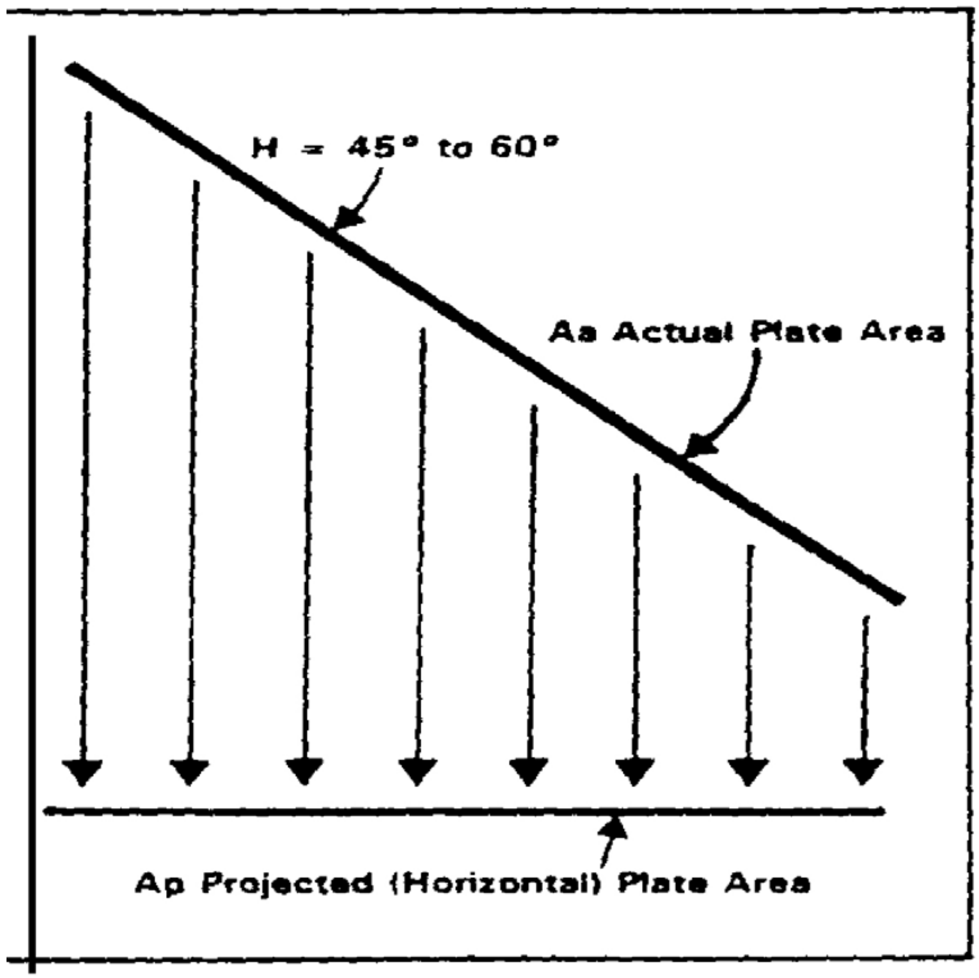


Figure 6.24 — Baffle Oil / Water Separator

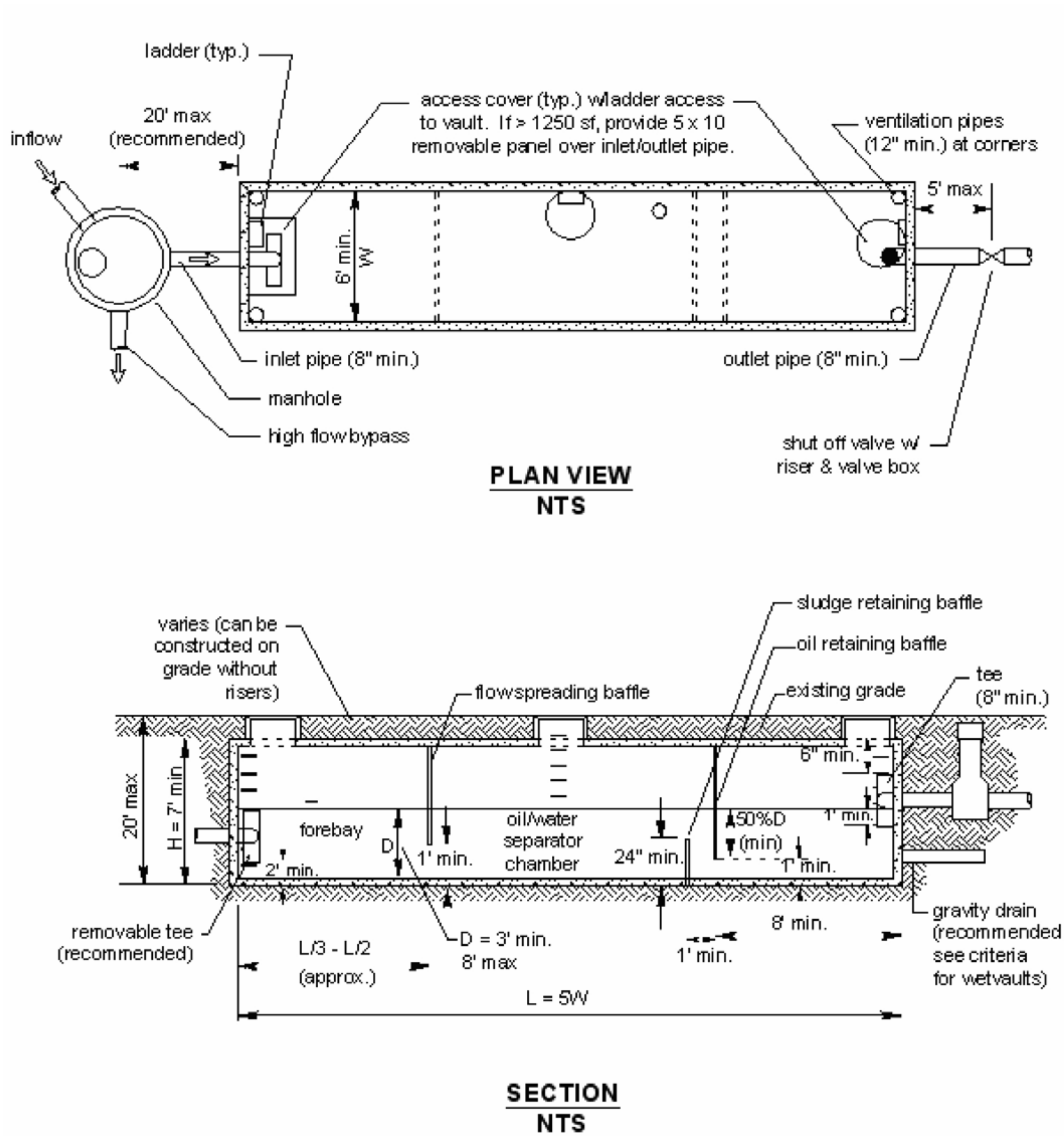


Figure 6.25 — Coalescing Plate Oil / Water Separator

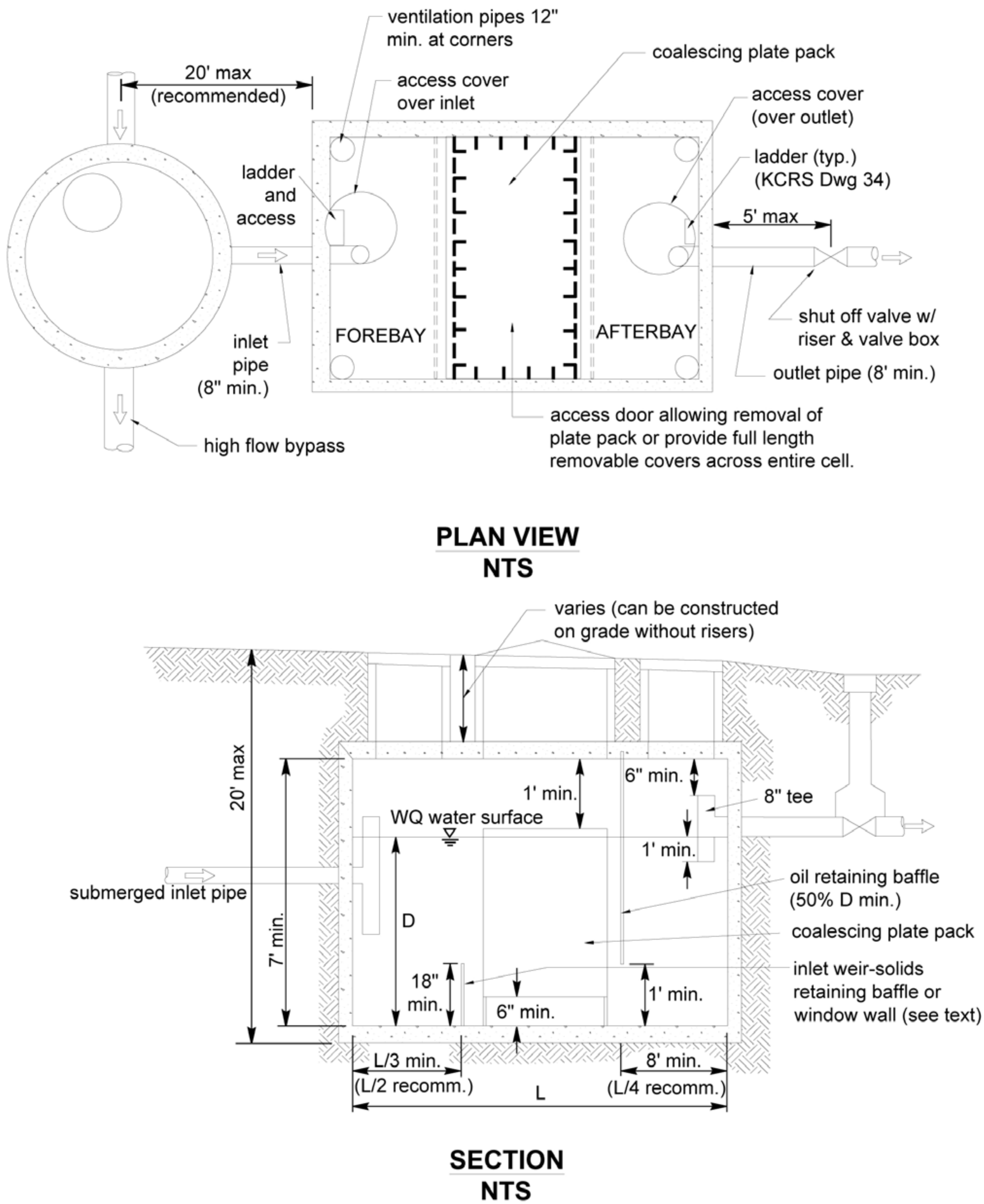
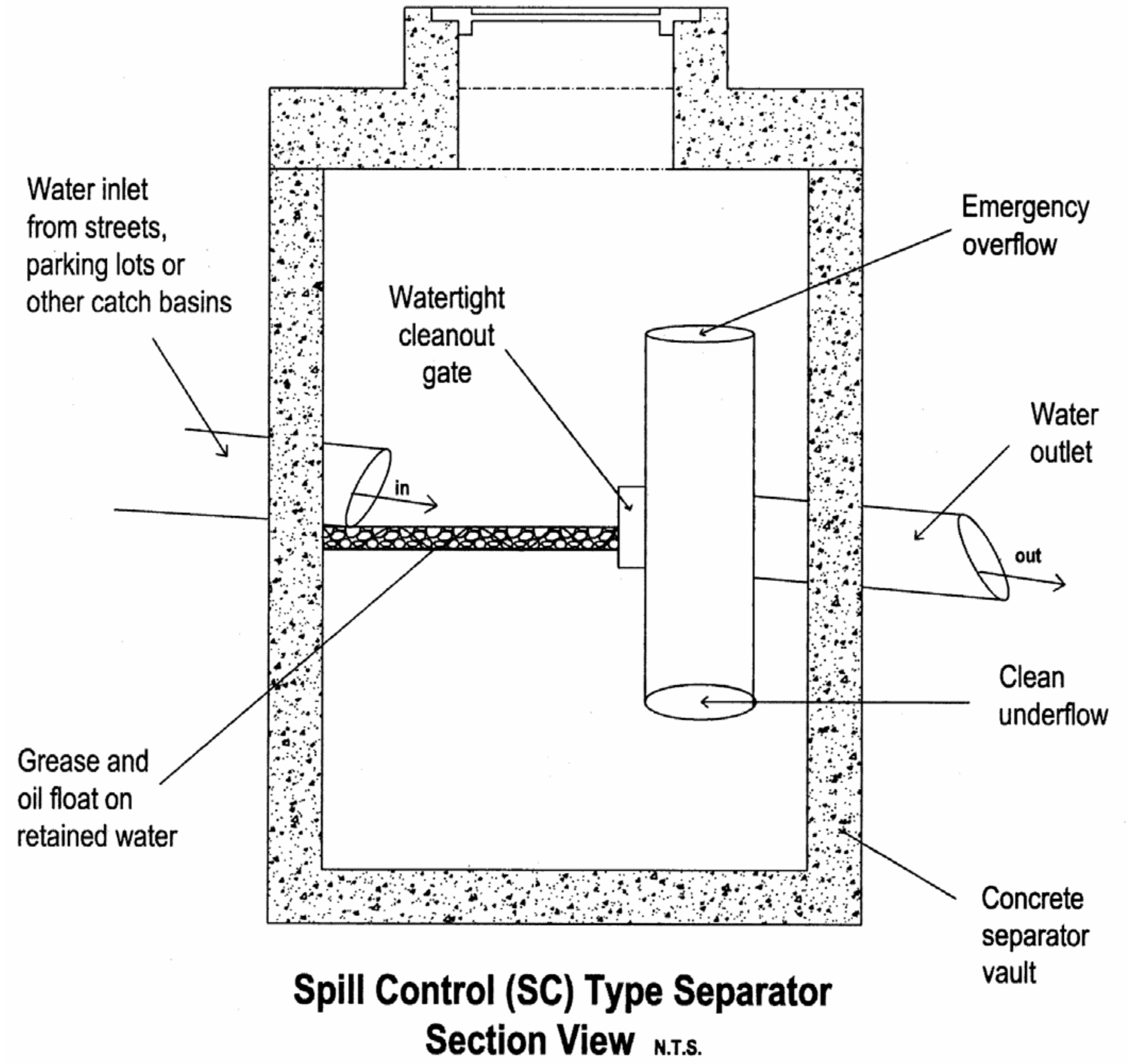


Figure 6.26 — Spill Control Separator (Not for Oil Treatment)



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Kitsap County Stormwater Design Manual

CHAPTER 7–FIGURES

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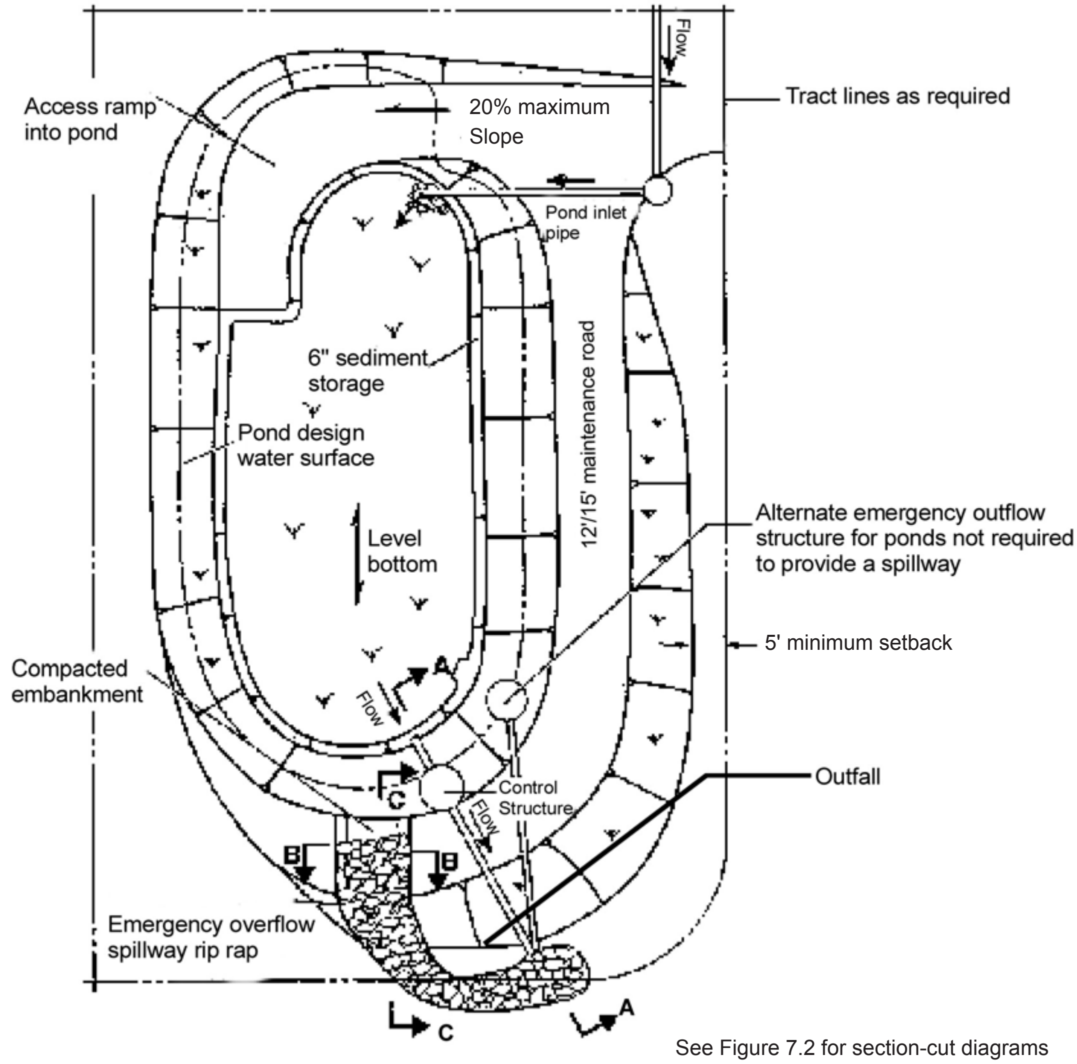
Figure 7.1 — Typical Detention Pond



Note:
This detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 7.2 — Typical Detention Pond Sections

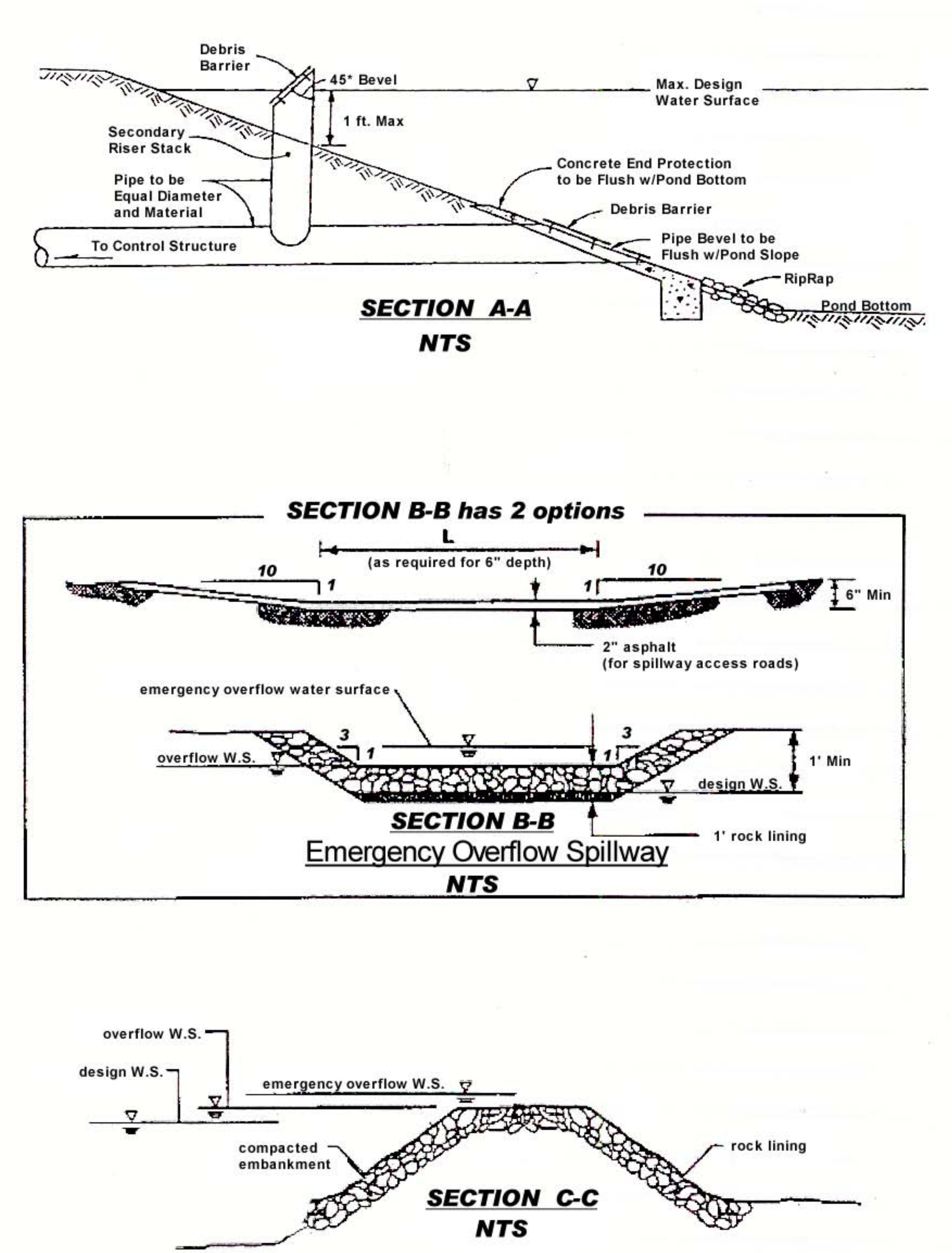
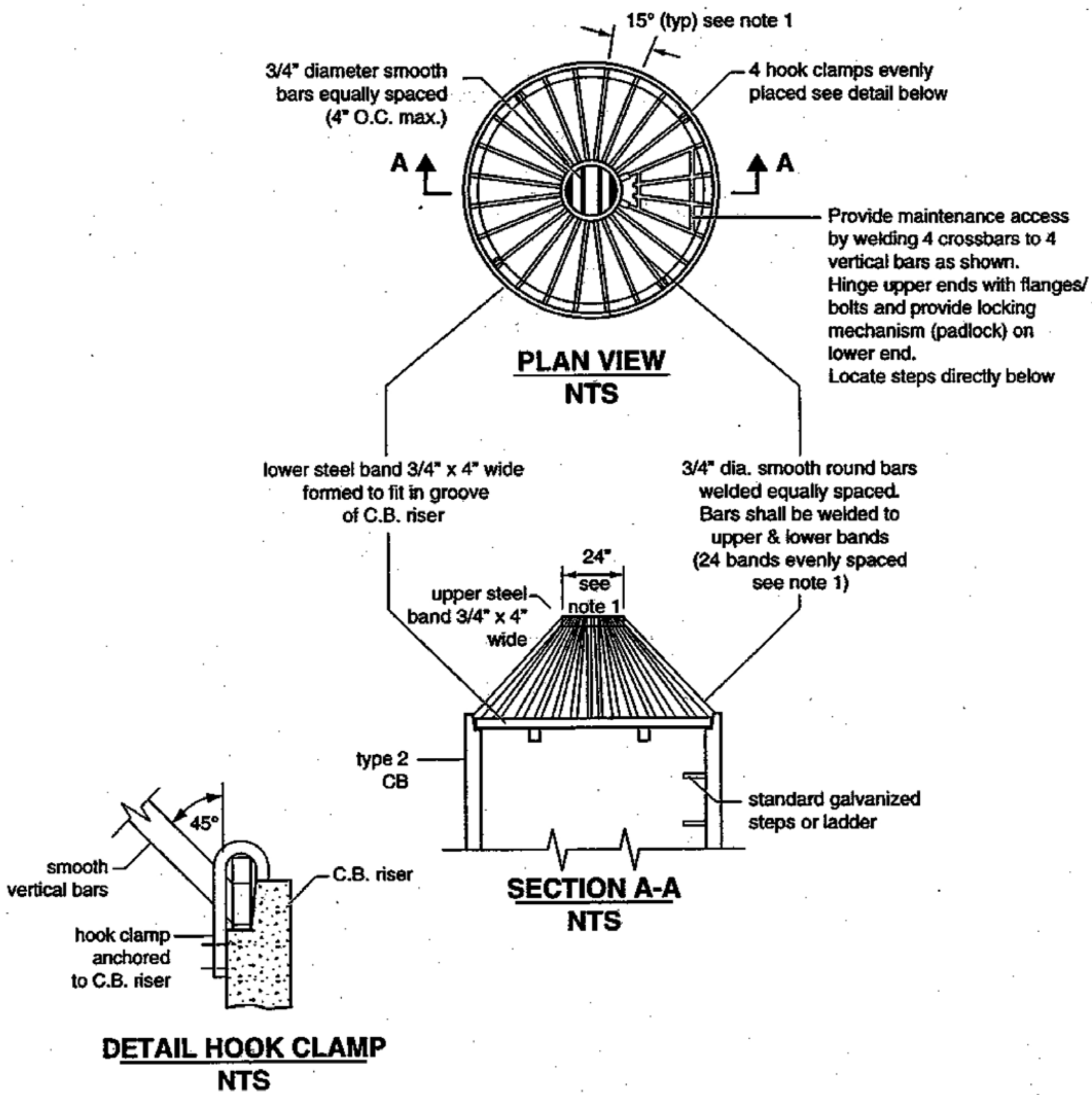


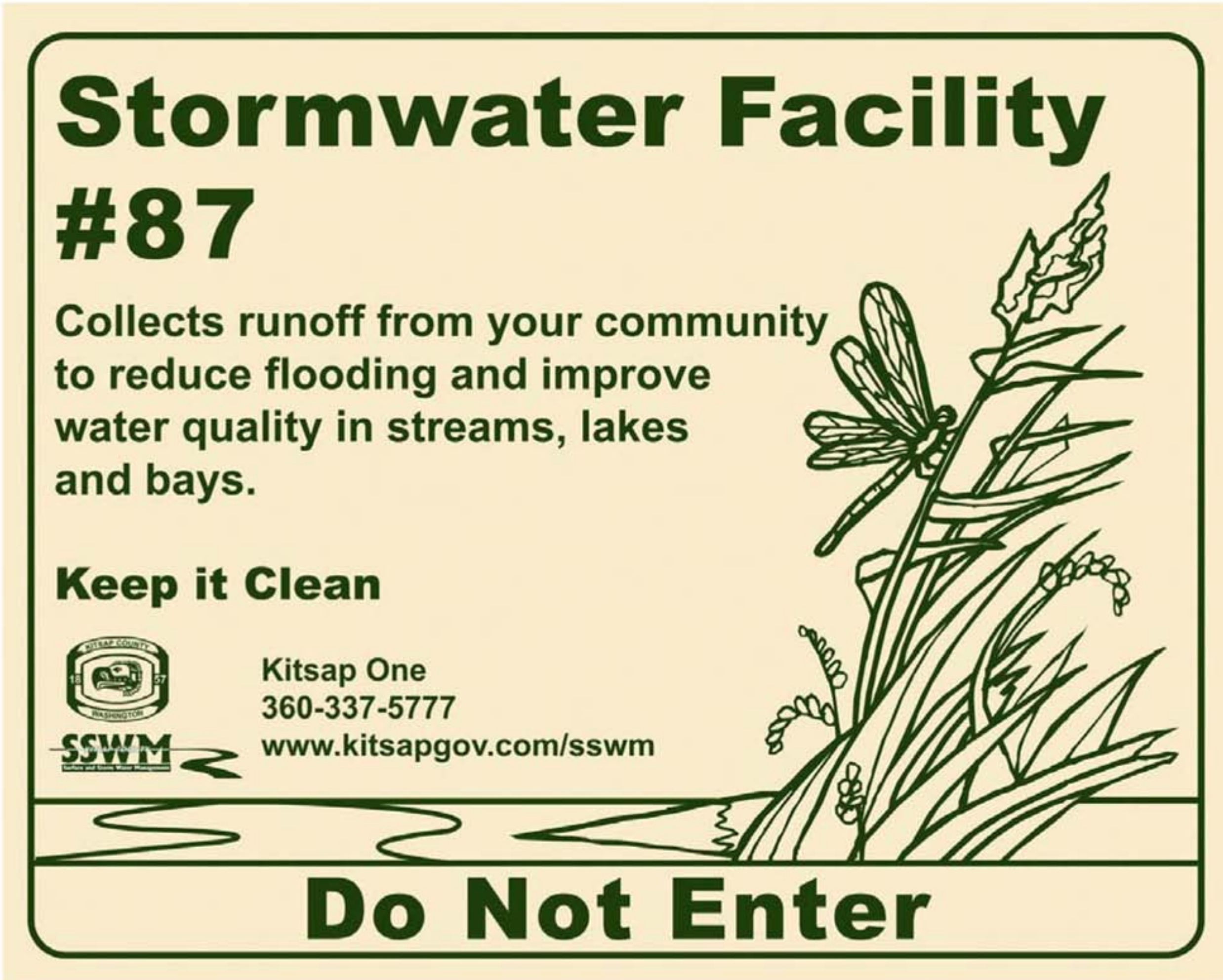
Figure 7.3 — Overflow Structure



NOTES:

1. Dimensions are for illustration on 54" diameter CB For different diameter CB's adjust to maintain 45° angle on "vertical" bars and 7" o.c. maximum spacing of bars around lower steel band.
2. Metal parts must be corrosion resistant; steel bars must be galvanized.
3. This debris barrier is also recommended for use on the inlet to roadway cross-culverts with high potential for debris collection (except on type 2 streams)

Figure 7.4 — Permanent Surface Water Control Pond Sign



Specifications

Size: 30” x 24”
Material: .080 aluminum with non-reflective sheeting and rounded corners
Colors: Beige background, teal letters and graphic
Installation: Secured to chain link fence if available, otherwise installed on 8’ x 4” x 4” post buried 30” into the ground.

Figure 7.5 — Weir Section for Emergency Over󰀀ow Spillway

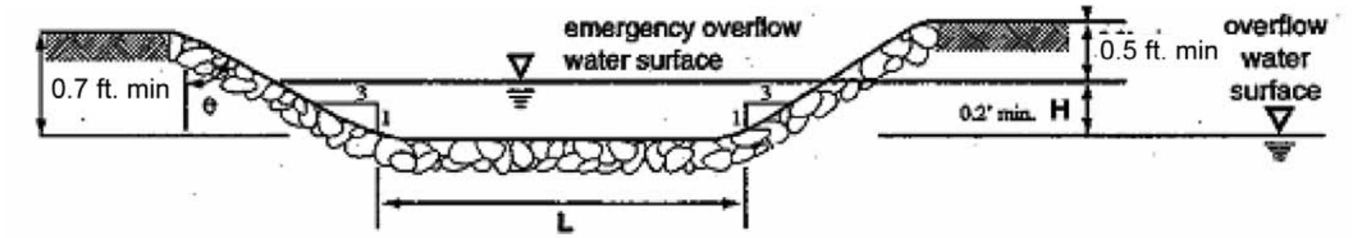


Figure 7.6 — Typical Detention Tank

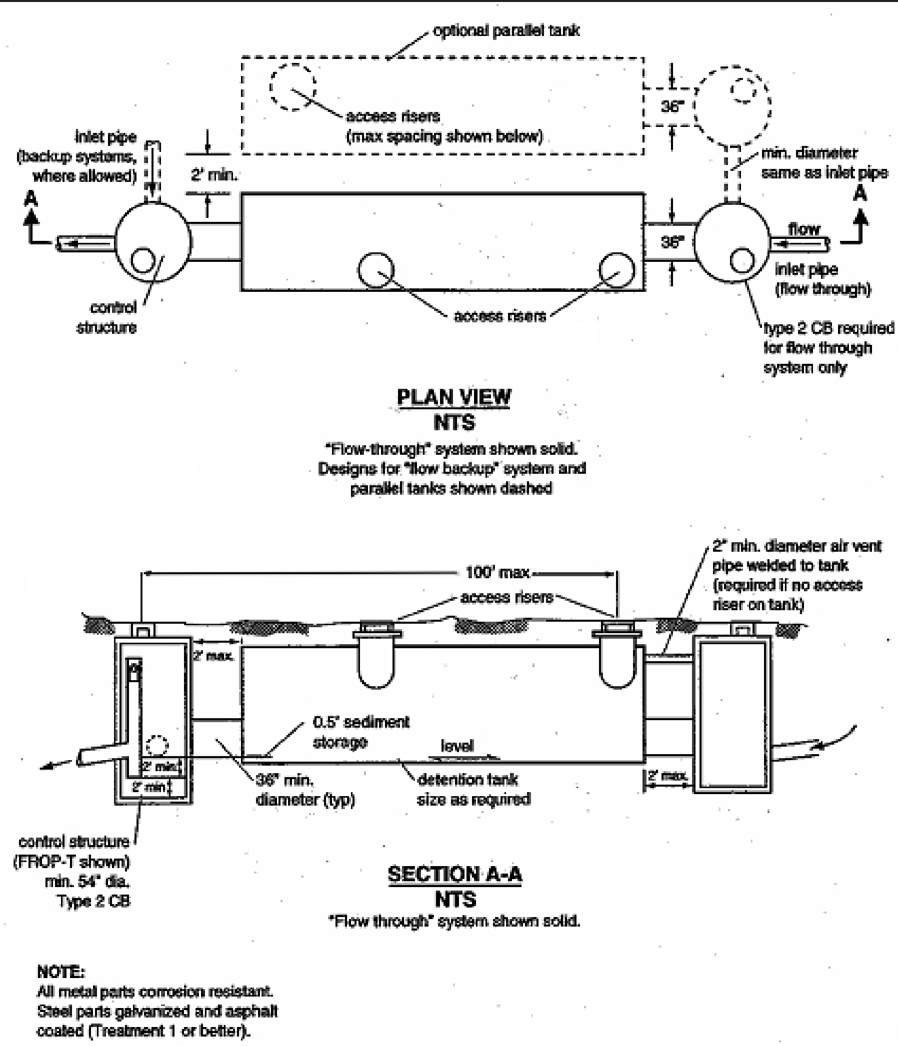
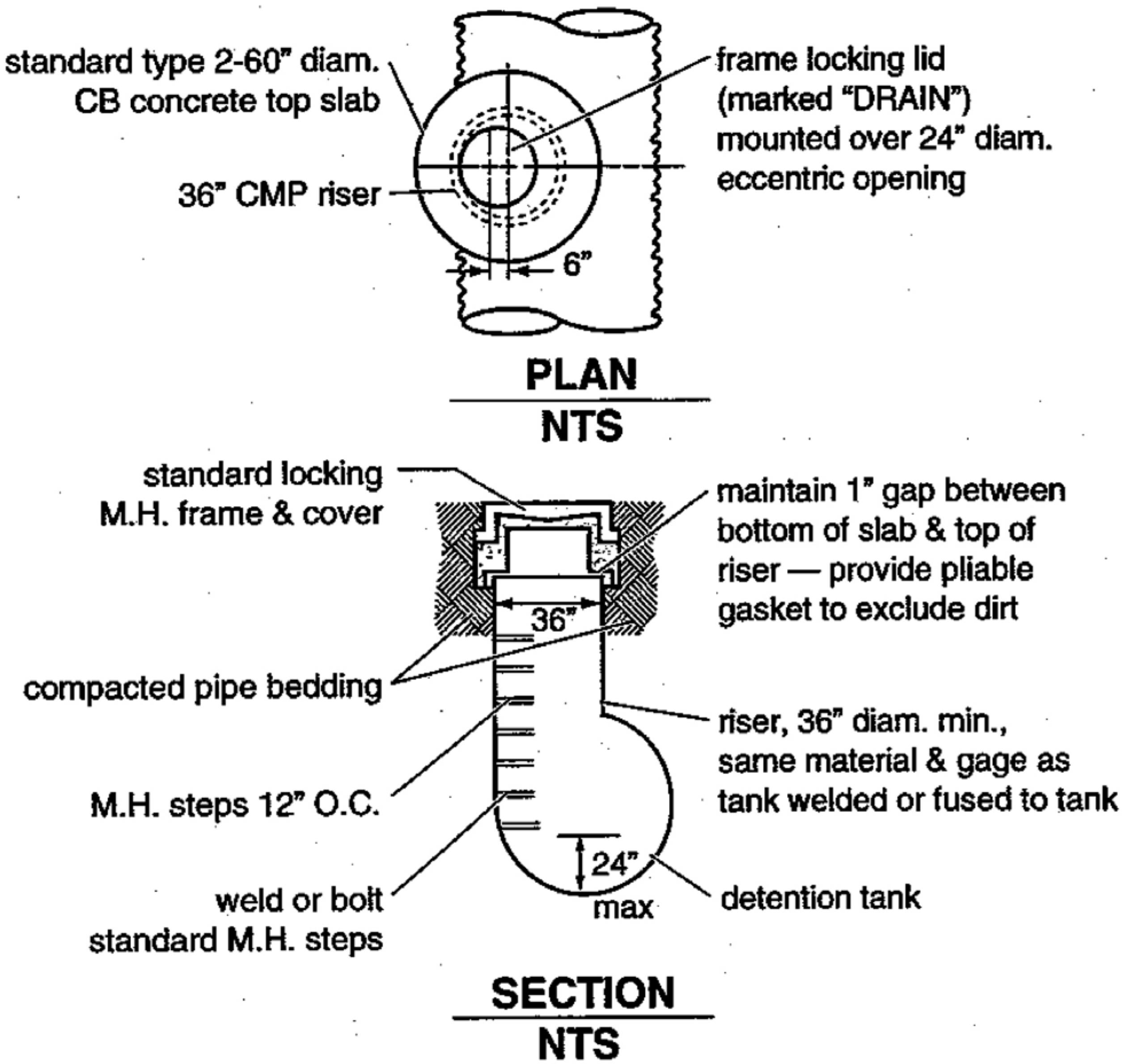


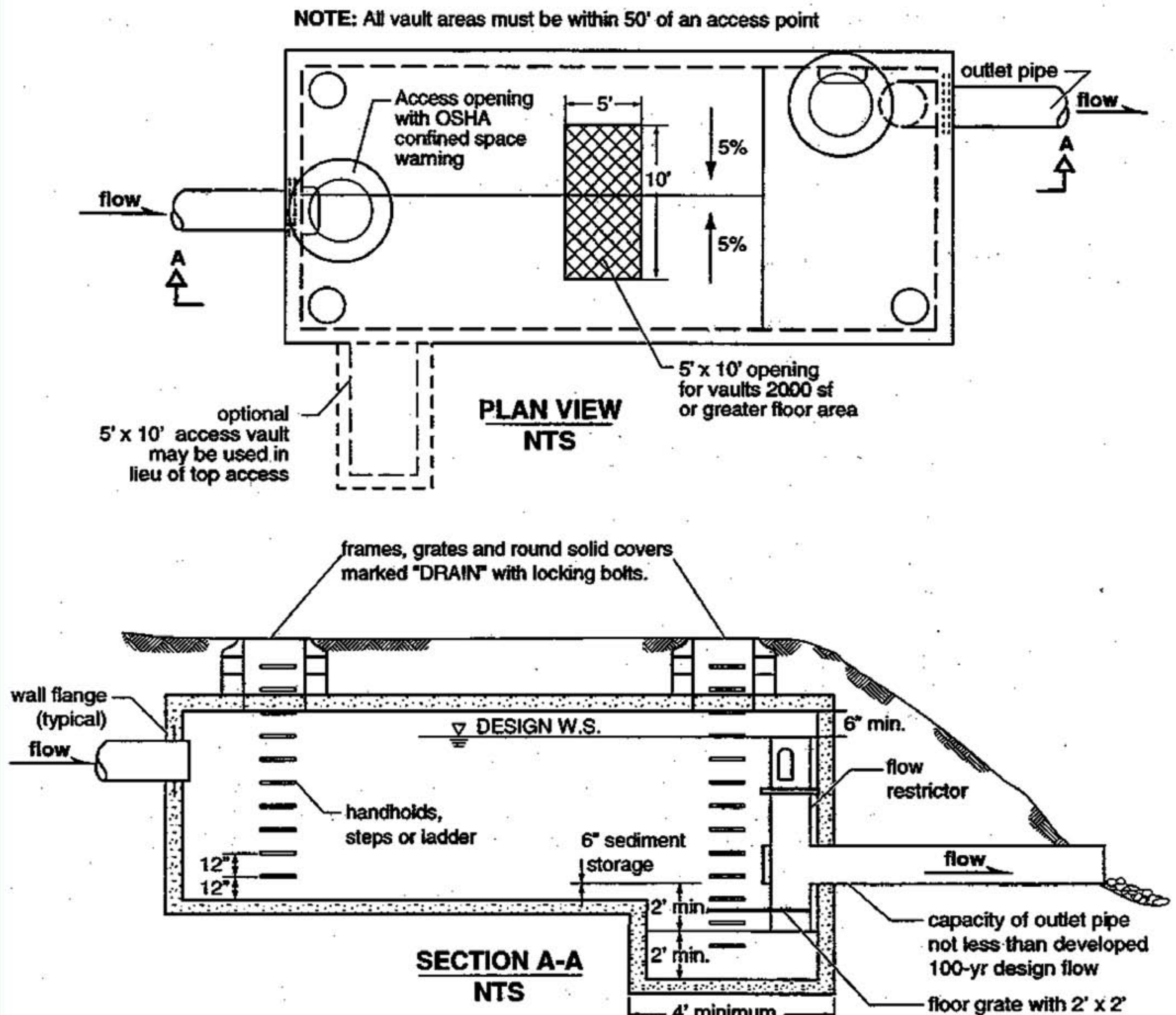
Figure 7.7 — Detention Tank Access Detail



Notes:

1. Use adjusting blocks as required to bring frame to grade.
2. All materials to be aluminum or galvanized and asphalt coated (Treatment 1 or better).
3. Must be located for access by maintenance vehicles.
4. May substitute WSDOT special Type IV manhole (RCP only).

Figure 7.8 — Typical Detention Vault



NOTES:

1. All metal parts must be corrosion resistant. Steel parts must be galvanized and asphalt coated (Treatment I or better).
2. Provide water stop at all cast-in-place construction joints. Precast vaults shall have approved rubber gasket system.
3. Vaults ≤ 10' wide must use removable lids.
4. Prefabricated vault sections may require structural modifications to support 5' x 10' opening over main vault. Alternatively, access can be provided via a side vestibule as shown.

Figure 7.9 — Flow Restrictor (TEE)

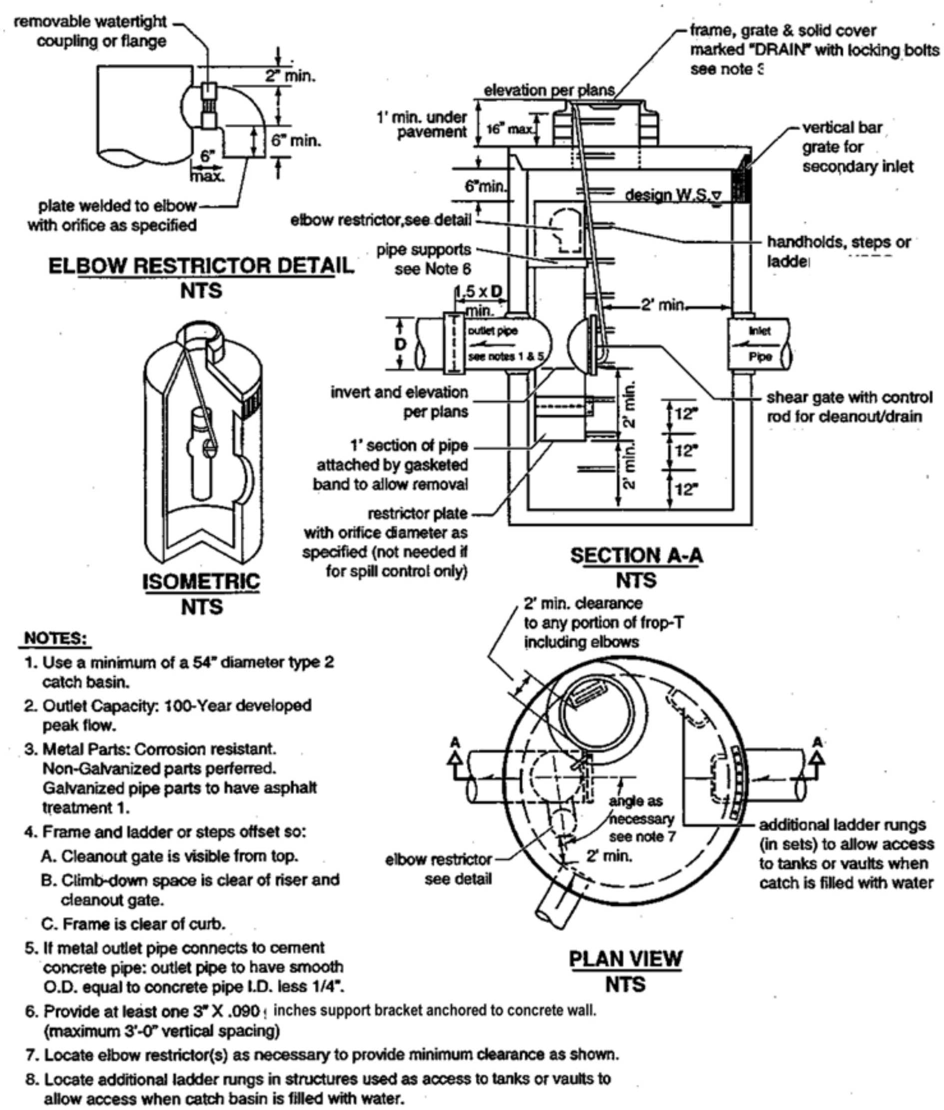


Figure 7.10 — Flow Restrictor (Baffle)

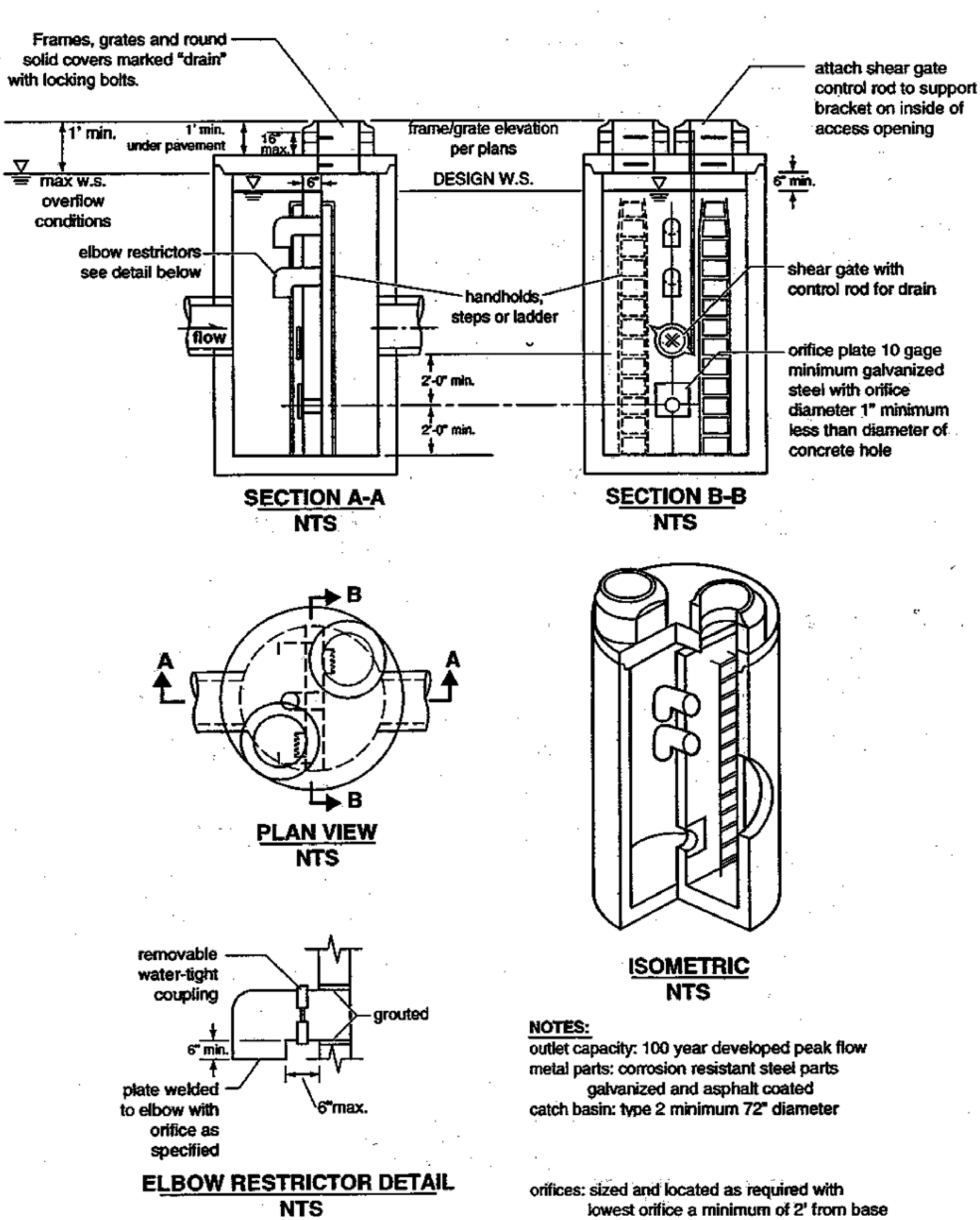
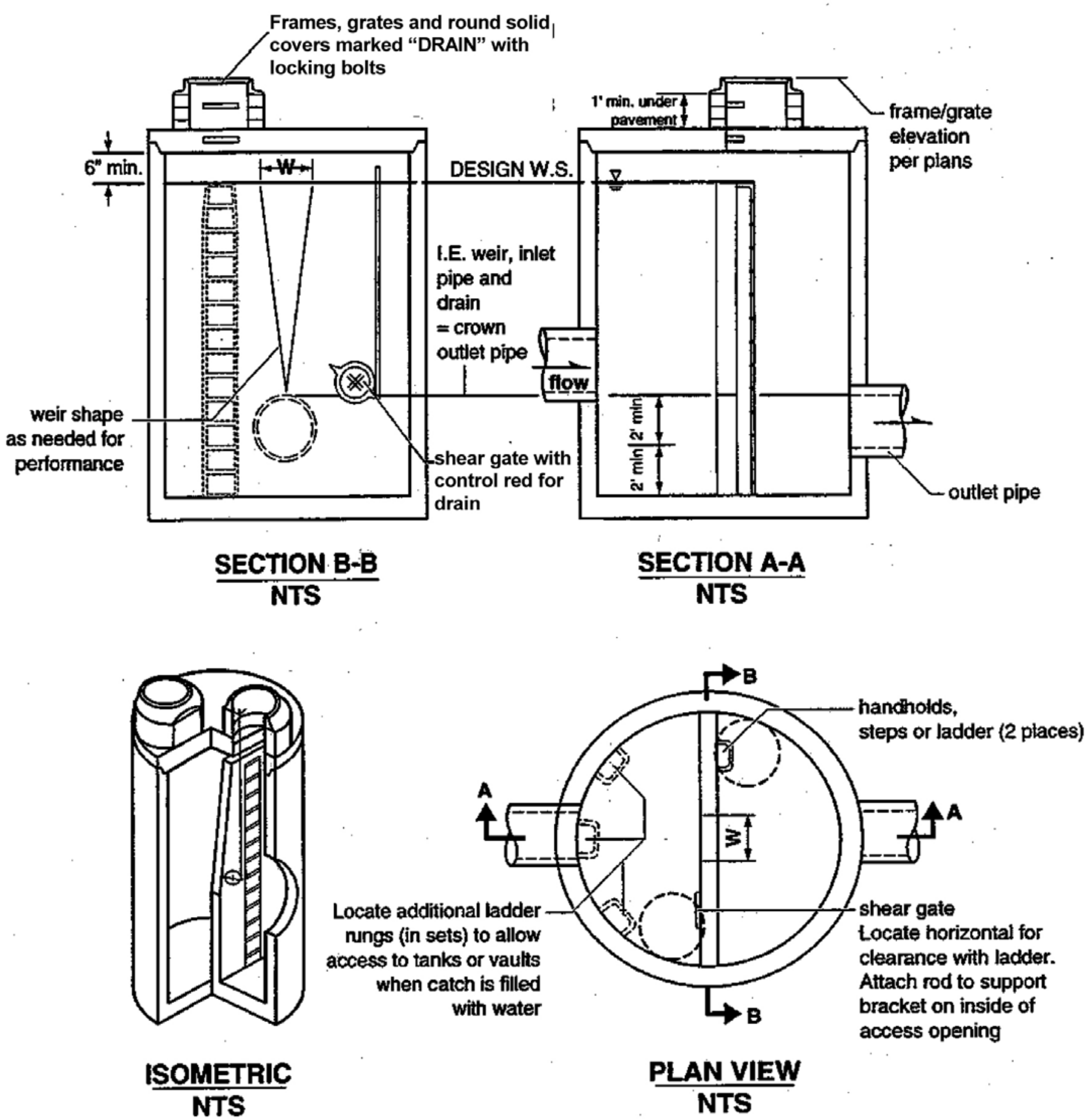


Figure 7.11 — Flow Restrictor (Weir)



NOTES:

Outlet Capacity: 100-year developed peak flow.

Metal Parts: corrosion resistant steel parts galvanized and asphalt coated.

Catch Basin: type 2 Min. 72" diameter

Baffle Wall: to be designed with concrete reinforcing as required.

Spill containment must be provided to temporarily detain oil or floatable pollutants in runoff due to accidental spill or illegal dumping.

Figure 7.12 — Simple Orifice

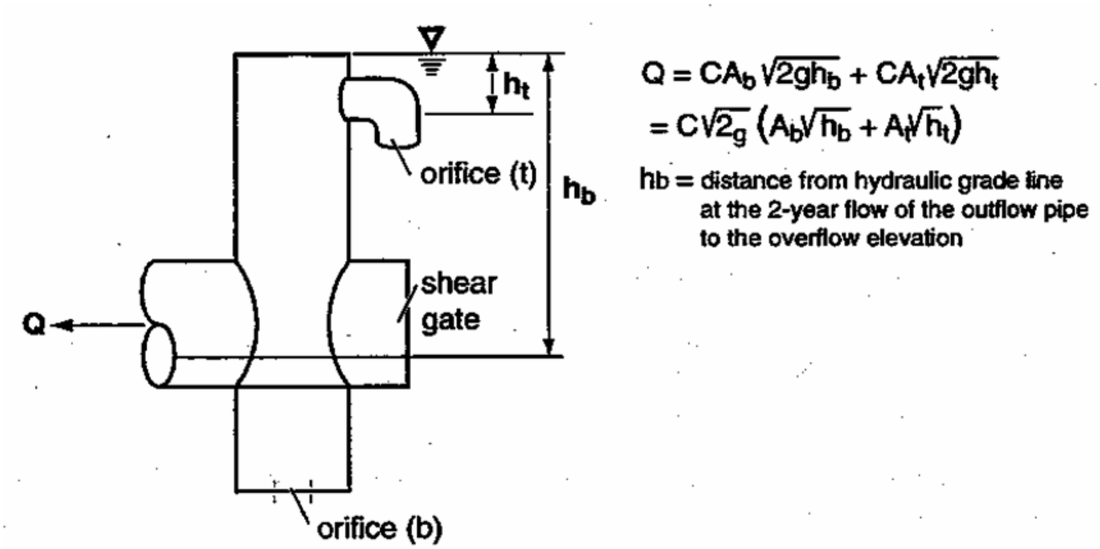


Figure 7.13 — Rectangular, Sharp-Crested Weir

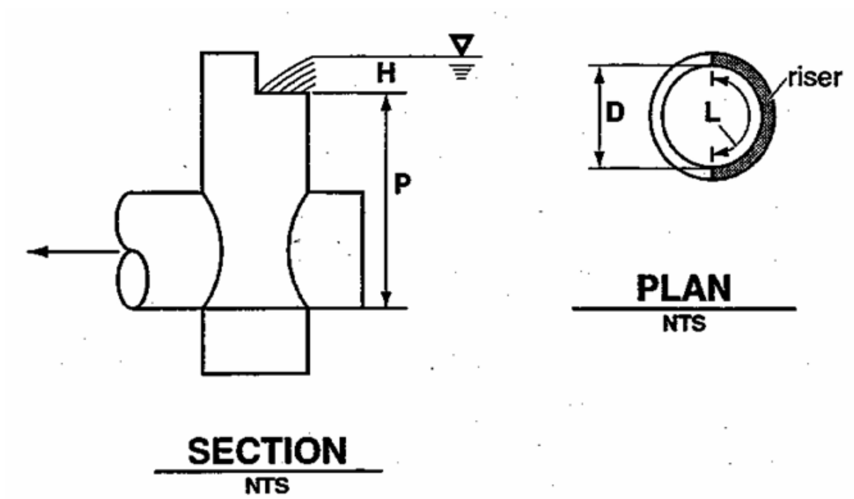
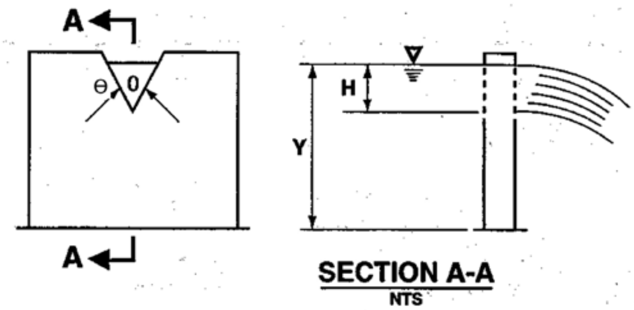


Figure 7.14 — V-Notch, Sharp-Crested Weir



$Q = C_d(\text{Tan } \Theta/2)H^{5/2}$, in cfs

Where values of C_d may be taken from the following chart:

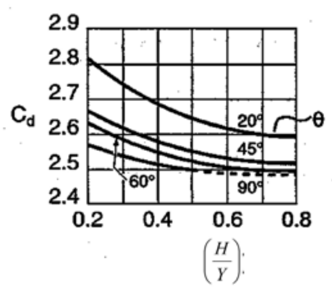


Figure 7.15 — Sutro Weir

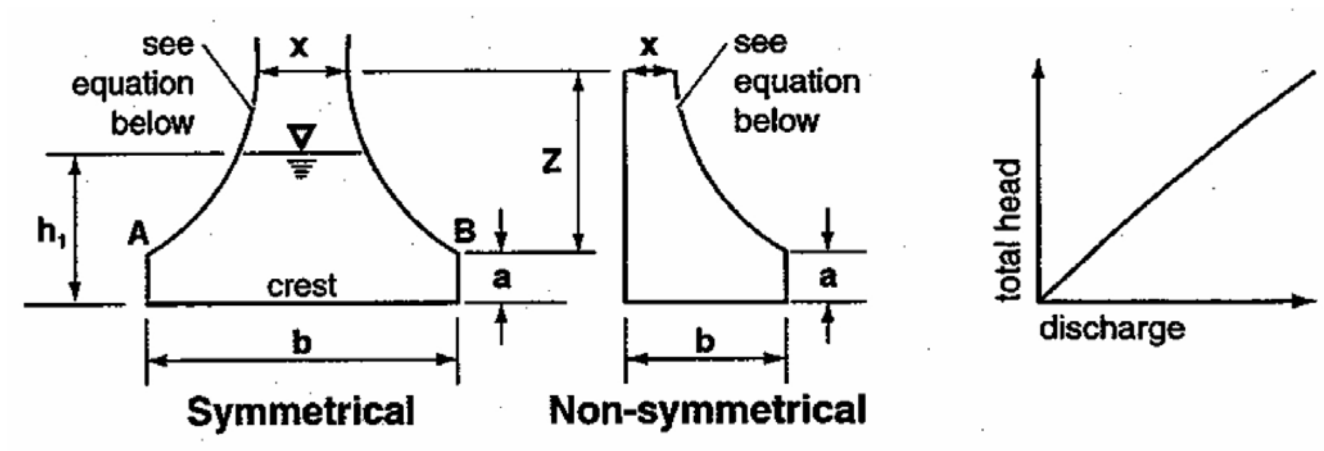


Figure 7.16 — Riser Inflow Curves

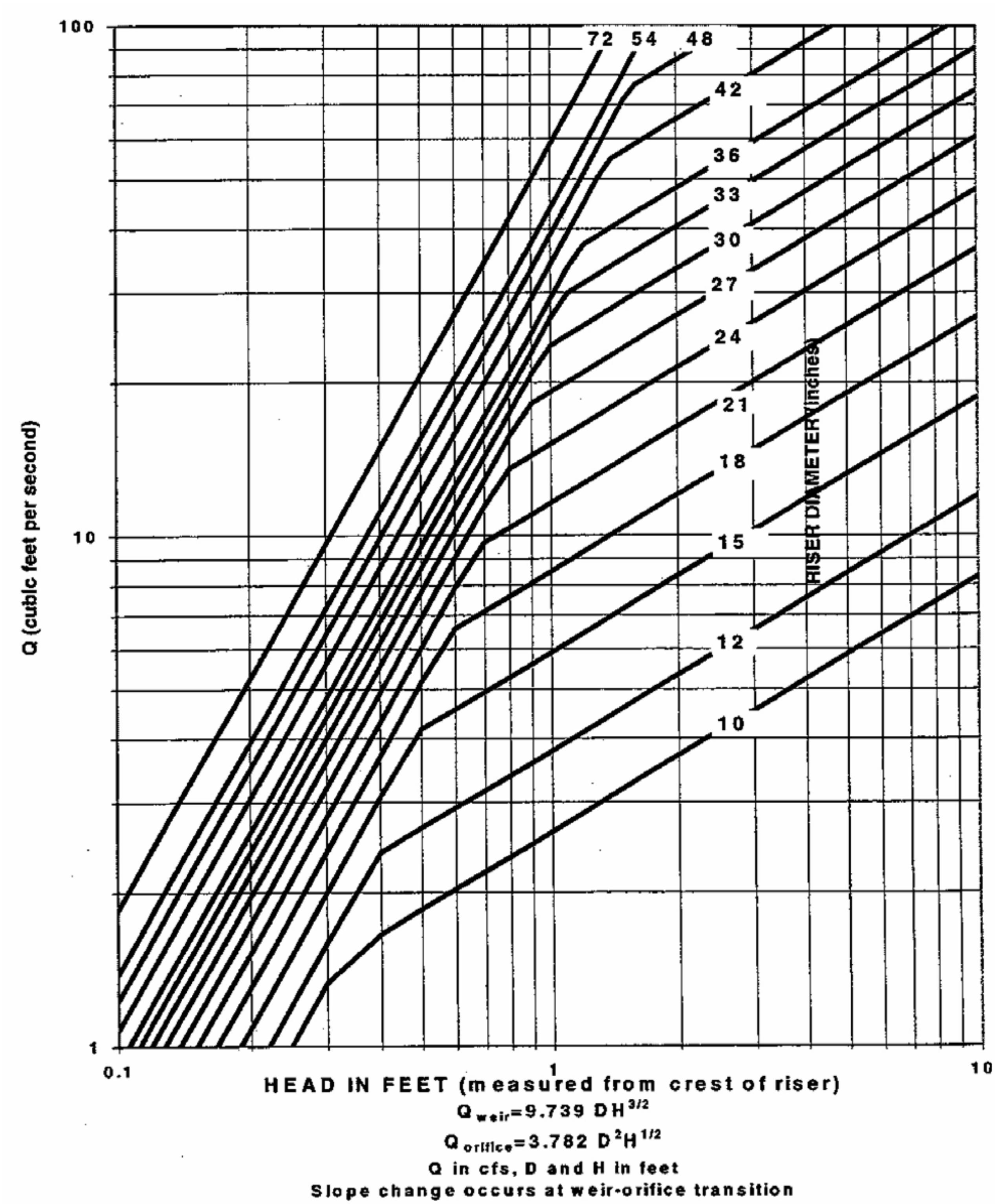


Figure 7.17 — USDA Textural Triangle

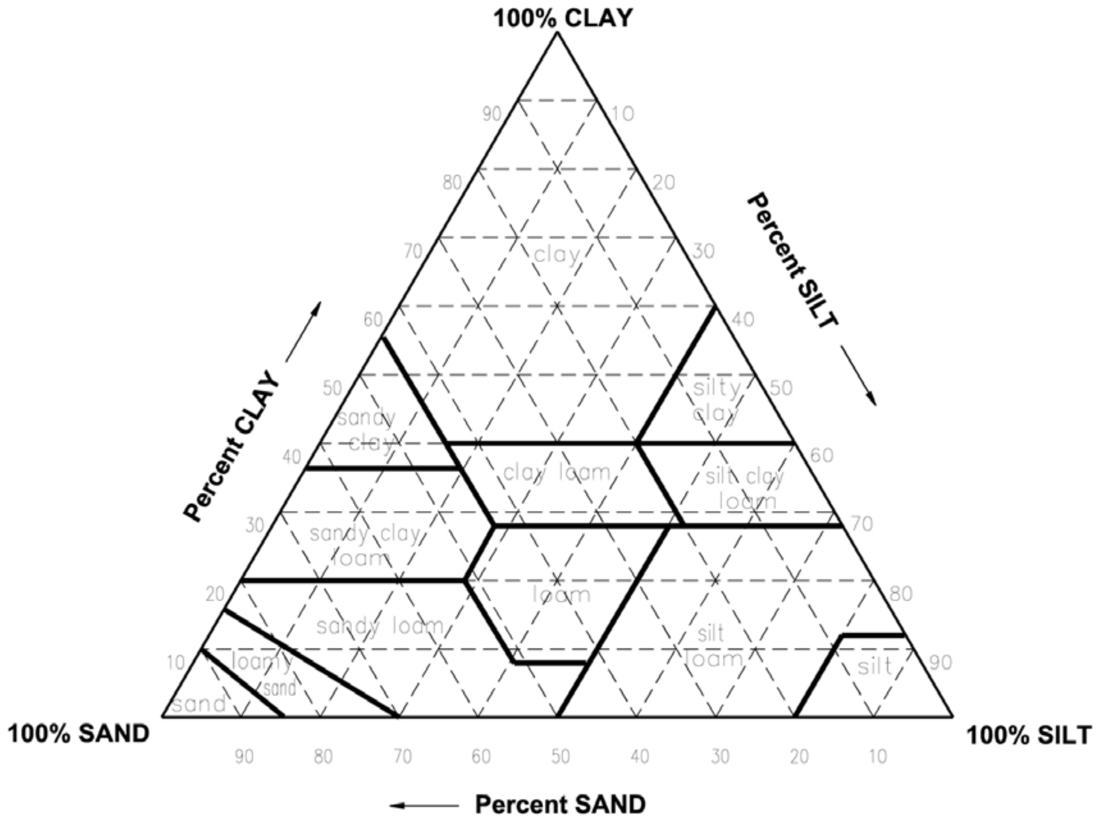
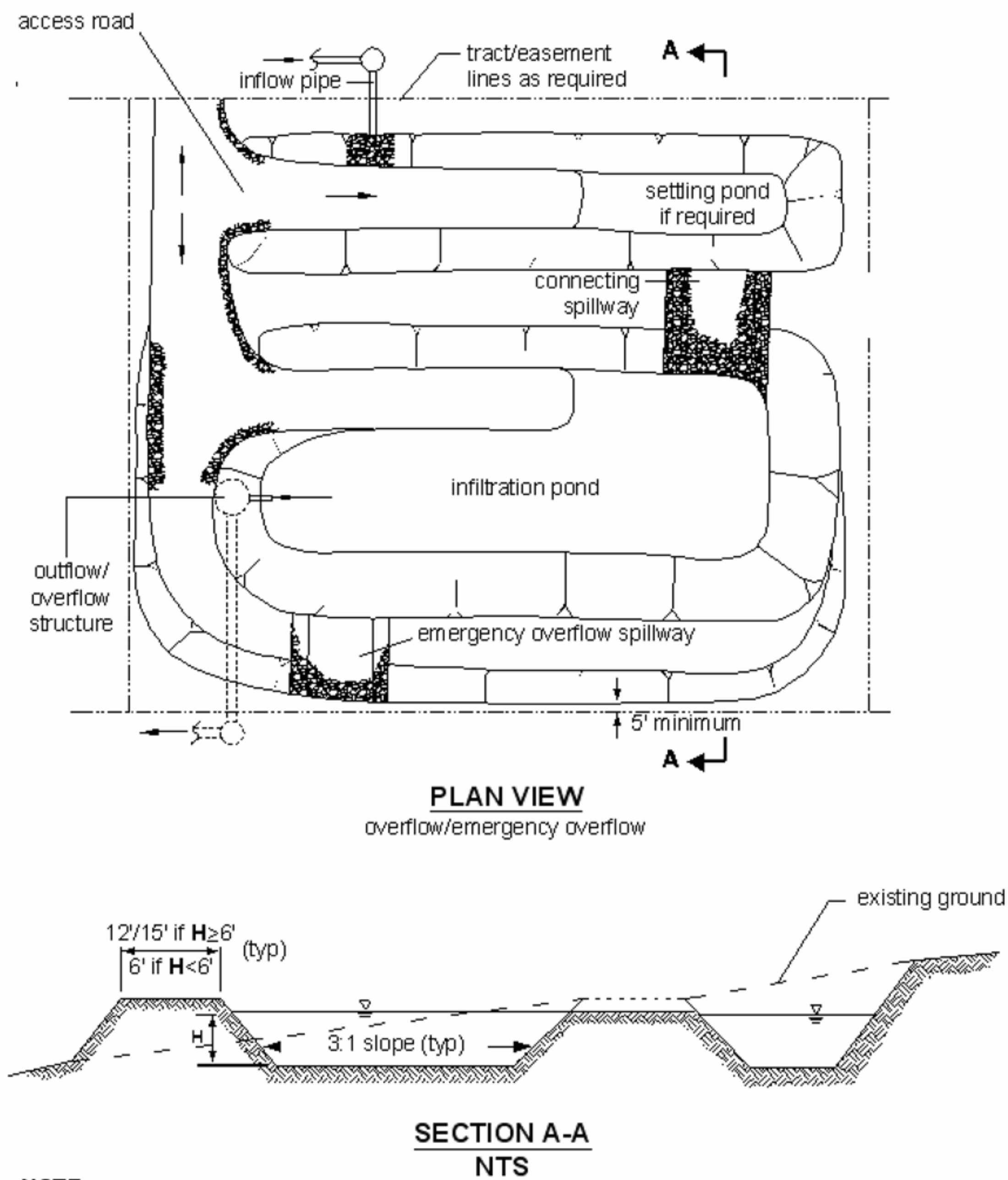


Figure 7.18 — Typical Infiltration Pond



NOTE:
Detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 7.19 — Typical Infiltration Tank

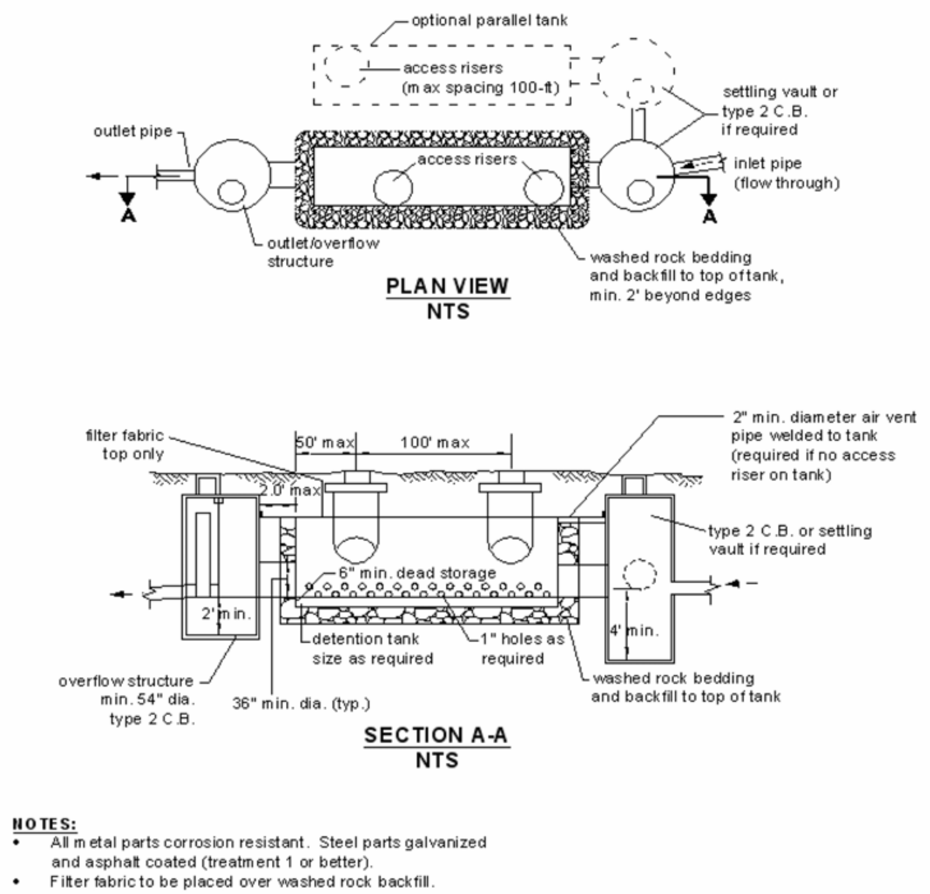


Figure 7.20 — Infiltration Vault

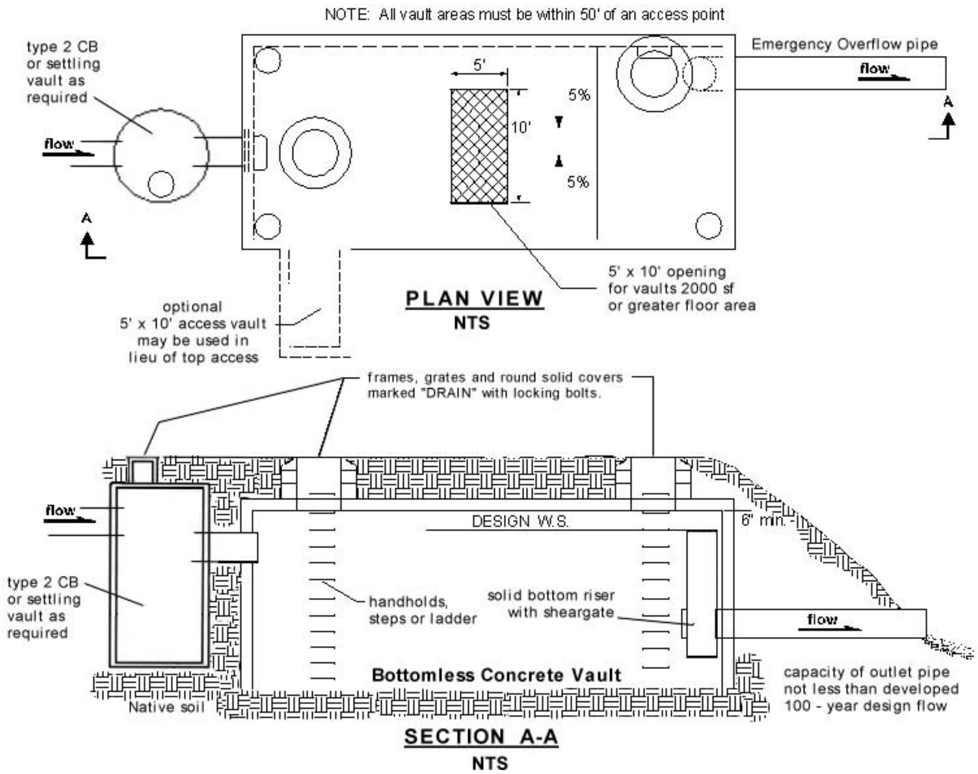
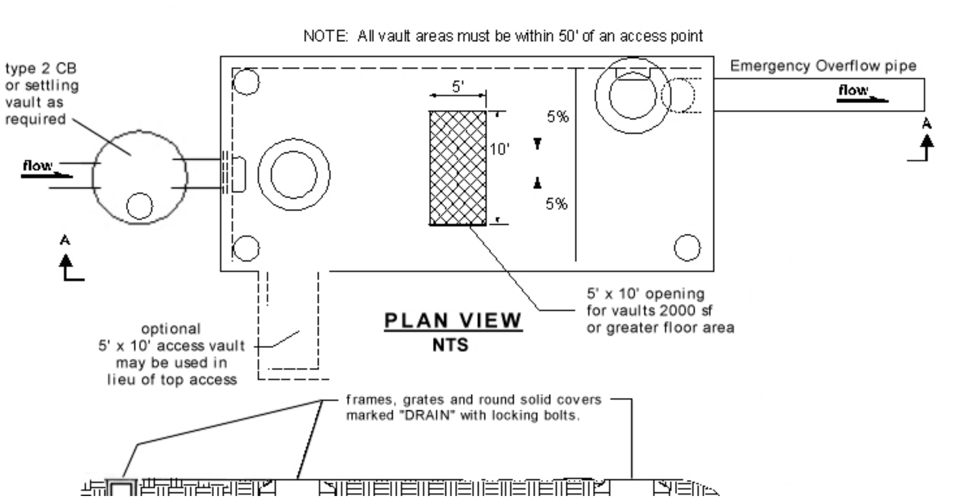


Figure 7.21 — Infiltration Trench



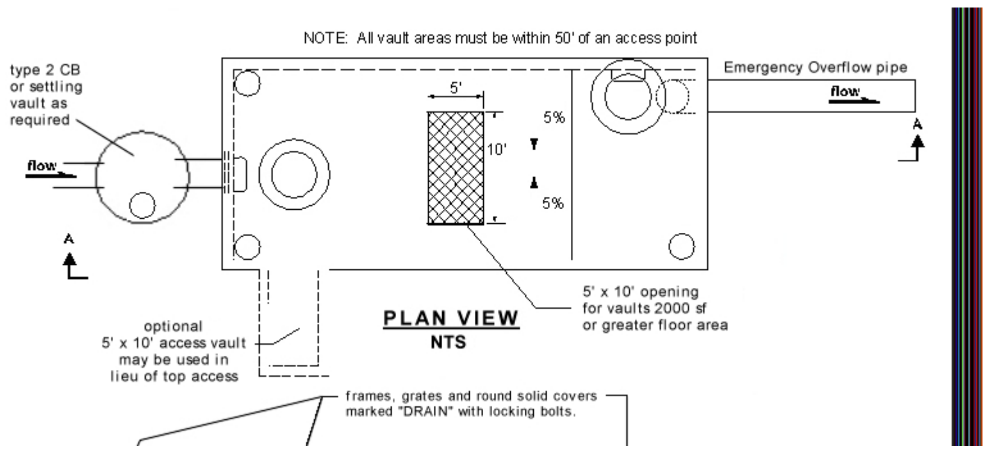
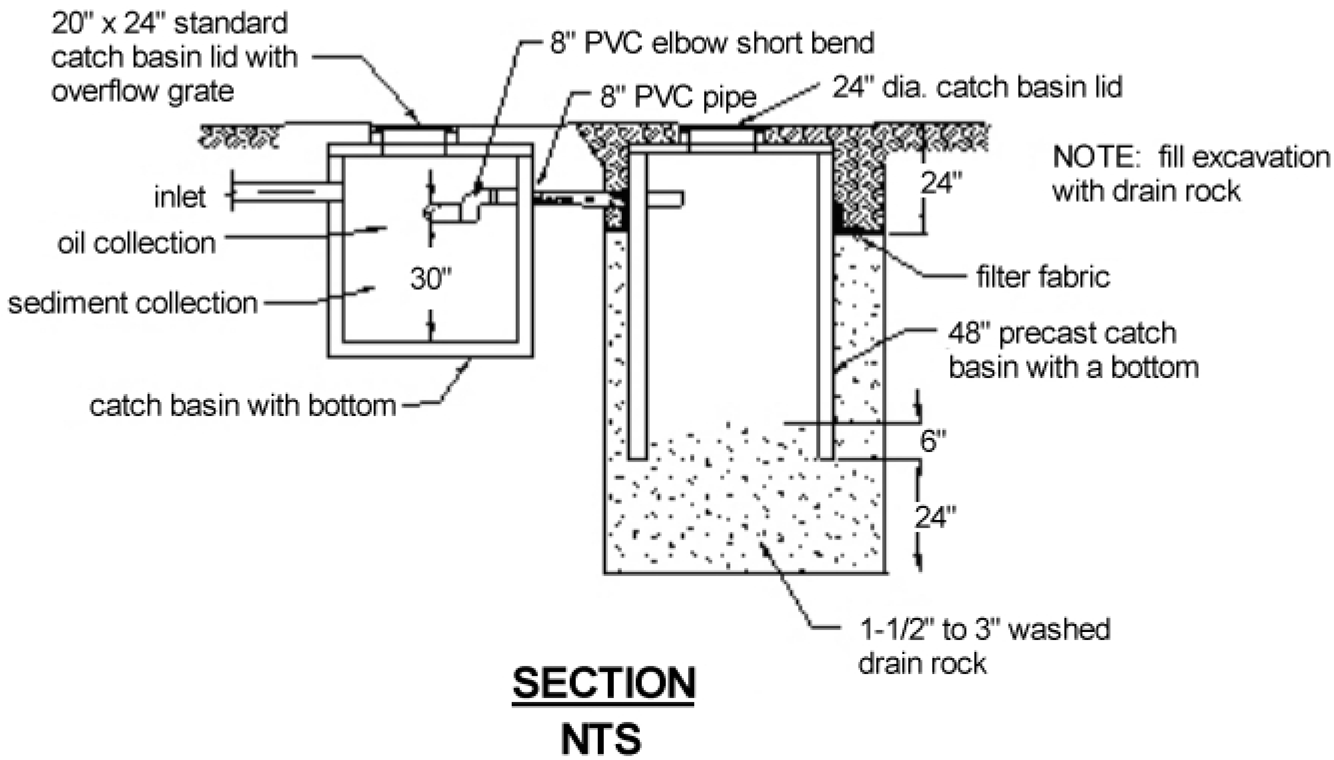


Figure 7.22 — Example of Small Infiltration Basin



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Kitsap County Stormwater Design Manual

APPENDIX 3B – TABLE

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Appendix 3B Table 1—Bacteria and Viruses											
	Concentrations (µg/l or ppb)							Ecology/USEPA Criteria (D)			
Pollutant	**Commercial**		**Industrial**		**Residential**		**Highway(C)**	**Freshwater Acute**	**Freshwater Chronic**	**Saltwater Acute**	**Saltwater Chronic**
	(A)	**(B)**	**(A)**	**(B)**	**(A)**	**(B)**					
Total Phosphorus	210	260	380	680	150	260	113-790	-	-	-	-
Total Copper	22	31	32	49	10	31	12-152	9	7	2.9	-
Total Lead	26	37	21	121	10	37	19/36	34	1.3	220	8.5
Total Zinc	115	200	251	1,324	69	200	56-638	65	59	95	86
TSS, mg/L	55	66	93	134	43	66	63-798	-	-	-	-
BOD, mg/L	7.4	8	18	12	5.8	8	12.7/111	-	-	-	-
Oil, mg/L	-	-	-	-	-	-	8.9/27	-	-	-	-
Fecal Coli	980 orgs/ 100 mls/E		-		-		-	50 colonies/ 100 mls(F)	-	-	-

A. Eric Strecker, "Analysis of Oregon Urban Runoff Water Quality Data Collected from 1990 to 1996"- 2/1997 Report
B. Santa Clara-1990: median data
C. WSDOT Stormwater Management Plan, 3/25/97, WA. and Oregon data
D. Dissolved metal criteria in freshwater at a hardness of 50 ppm (Chapter 173-201A WAC), saltwater criteria expressed as a function of water effect ratio (40 CFR Part 131)
E. Ecology geometric mean criterion for class AA waters.

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Kitsap County Stormwater Design Manual

CHAPTER 4 – TABLES

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Table 4.1 — Runo Coecients - "C" Values For The Rational Method		
Undeveloped Land	**"C" Flat (0-5%)**	**"C" Rolling (>5%)**
Wood & forest	0.05	0.10
Sparse trees & ground cover	0.10	0.15
Light grass to bare ground	0.15	0.20
Developed Area	**"C" Flat (0-5%)**	**"C" Rolling (>5%)**
Pavement and roofs	0.90	0.90
Gravel roads and parking lots	0.75	0.80
City business	0.85	0.90
Apartment dwelling areas	0.80	0.85
Industrial areas (heavy)	0.70	0.80
Industrial areas (light)	0.60	0.70
Earth shoulder	0.50	0.50
Playground		
Developed Area	**"C" Flat (0-5%)**	**"C" Rolling (>5%)**
Lawns, meadows and pastures	0.20	0.25
Parks and cemetaries	0.15	0.20
Single Family Residential Areas (Density is in dwelling units per gross acre (DU/GA)		**"C"**
1.0 DU/GA		0.30
2.0 DU/GA		0.36
3.0 DU/GA		0.42
4.0 DU/GA		0.48
5.0 DU/GA		0.60
9.0 – 15.0 DU/GA		0.70

Table 4.2 — Maximum Pipe Slopes and Velociites			
Pipe Material	**Pipe Slope Above Which Pipe Anchors Required and Minimum Anchor Spacing**	**Maxiumum Slope Allowed**	**Maximum Velocity at Full Flow**
CMP, Spiral Rib, PVC CPE(1)	20% – (1 anchor per 100 LF of pipe)	30%(3)	30 fps
Concrete or LCPE(1)	10% – (1 anchor per 50 LF of pipe)	20%(3)	30 fps
Ductile Iron(2)	20% – (1 anchor per pipe section)	None	None
SWPE(2)	20% – (1 anchor per 100 LF of pipe, cross-slope installation only)	None	None

Notes:

(1) These materials are not allowed in Geologically Hazardous Areas as deﬁned in KCC 19.

(2) Butt-fused or ﬂanged pipe joints are required; above ground installation is recommended on slopes greater than 40%.

(3) Maximum slope of 200% is allowed for these pipe materials with no joints (one section), with structures at each end, and with proper grouting.

Table 4.3 — Allowable Structures and Pipe Sizes		
	Maximum Pipe Diameter	
Catch Basin Type	**CMP, Spiral Rib, CPE, SWPE, PVC and Ductile Iron(1)**	**Concrete LCPE**
Inlet(3)	12″	12″
Type 1(2)	18″	12"
Type 1L(2)	24″	18″
Type 2 – 48″ diameter	30″	24″
Type 2 – 54″ diameter	36″	30″
Type 2 – 72″ diameter	54″	48"
Type 2 – 96″ diameter	72″	72″

Notes:

(1) Generally these pipe materials will be one size larger than concrete due to smaller wall thickness. However, for angled connections or those with several pipes on the same plane, this will not apply.

(2) A maximum of 5 vertical feet is allowed between ﬁnished grade and invert elevation.

Table 4.4 — Maximum Cover (feet) for Concrete Pipe–Compaction Design A					
Pipe Diameter	**Plain**	**Class II**	**Class III**	**Class IV**	**Class V**
12″	18	10	14	21	26
18″	18	11	14	22	28
24″	16	11	15	22	28
30″		11	15	23	29
36″		11	15	23	29
48″		12	15	23	29
60″		12	16	24	30
72″		12	16	24	30
84″		12	16	24	30
96″		12	16	24	30
108″		12	16	24	30

Notes:

Compaction Design A refers to Figure 4.2

Table 4.5 — Manning's "*n*" Values for Pipes

Type of Pipe Material	Analysis Method	
Uniform Flow Preliminary design	Uniform Flow (Preliminary design)	Backwater Flow (Capacity Verification)
A. Concrete pipe and LCPE pipe	0.014	0.012
B. Annular Corrugated Metal Pipe or Pipe Arch		
1. 2 2/3" x ½" corrugation (riveted)		
a. plain or fully coated	0.028	0.024
b. paved invert (40% of circumference paved)		
1) flow at full depth	0.021	0.018
2) flow at 80% full depth	0.018	0.016
3) flow at 60% full depth	0.015	0.013
c. treatment 5	0.015	0.013
2. 3" x 1" corrugation	0.031	0.027
3. 6" x 2" corrugation (field bolted)	0.035	0.030
C. Helical 2 2/3" x ½" corrugation and CPE pipe	0.028	0.024
D. Spiral rib metal pipe and PVC pipe	0.013	0.011
E. Ductile iron pipe cement lined	0.014	0.012
F. SWPE pipe (butt fused only)	0.009	0.009

Table 4.6 — Rock Protection at Outfalls

Discharge Velocity at Design Flow (fps)		Required Protection				
Greater Than	Less than or equal to	Minimum Dimensions (1)				
		Type	Thickness	Width	Length	Height
0	5	Rock lining (2)	1 foot	Diameter + 6 feet	8 feet or 4x diameter, whichever is greater	Crown + 1 foot
5	10	Riprap (3)	2 feet	Diameter + 6 feet or 3x diameter, whichever is greater	12 feet or 4x diameter whichever is greater	Crown + 1 foot
10	20	Gabion Outfall	As required	As required	As required	Crown + 1 foot
20	N/A	Engineered energy dissipater required				

(1) These sizes assume that erosion is dominated by outfall energy. In many cases sizing will be governed by conditions in the receiving waters.

(2) Rock lining shall be quarry spalls with gradation as follows:

Passing 8-inch square sieve:	100%
Passing 3-inch square sieve:	40 to 60% maximum
Passing 3/4-inch square sieve:	0 to 10% maximum

(3) Riprap shall be reasonably well graded with gradation as follows:

Maximum stone size:	24 inches (nominal diameter)
Median stone size:	16 inches
Minimum stone size:	4 inches

Note: Riprap sizing is governed by side slopes on outlet channel, assumed to be approximately 3:1.

Table 4.7 — Constants for Inlet Control Equations*

Shape & Material	Inlet Edge Description	Equation Form	Unsubmerged		Submerged	
			K	*M*	*c*	*Y*
Circular Concrete	Square edge with headwall	1	0.0098	2.00	0.0398	0.67
	Groove end with headwall		0.0078	2.00	0.0292	0.74
	Groove end projecting		0.0045	2.00	0.0317	0.69
Circular CMP	Headwall	1	0.0078	2.00	0.0379	0.69
	Mitered to slope		0.0210	1.33	0.0463	0.75
	Projecting		0.0340	1.50	0.0553	0.54
Rectangular Box	30° to 75° wingwall flares	1	0.0260	1.00	0.0385	0.81
	90° and 15° wingwall flares		0.0610	0.75	0.0400	0.80
	0° wingwall flares		0.0610	0.75	0.0423	0.82
CM Boxes	90° headwall	1	0.0083	2.00	0.0379	0.69
	Thick wall projecting		0.0145	1.75	0.0419	0.64
	Thin wall projecting		0.0340	1.50	0.0496	0.57
Arch CMP	90° headwall	1	0.0083	2.00	0.0496	0.57
	Mitered to slope		0.0300	1.00	0.0463	0.75
	Projecting		0.0340	1.50	0.0496	0.53
Bottomless Arch CMP	90° headwall	1	0.0083	2.00	0.0379	0.69
	Mitered to slope		0.0300	2.00	0.0463	0.75
	Thin wall projecting		0.0340	1.50	0.0496	0.57
Circular with tapered inlet	Smooth tapered inlet throat	2	0.5340	0.333	0.0196	0.89
	Rough tapered inlet throat		0.5190	0.640	0.0289	0.90

*Source: FHWA HDS No. 5

Table 4.8 — Entrance Loss Coefficients	
Type of Structure and Design Entrance	**Coefficient, K_e**
Pipe, Concrete, PVC, Spiral Rib, DI, and LCPE	
Projecting from fill, socket (bell) end	0.2
Projecting from fill, square cut end	0.5
Headwall, or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D	0.2
Mitered to conform to fill slope	0.7
End section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° bevels	0.2
Side- or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal and Other Non-Concrete or D.I.	
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
End section conforming to fill slope*	0.5
Beveled edges, 33.7° or 45° 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 dimension or beveled edges on 3 sides	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 or beveled top edge	0.2
Wingwall at 10° to 25° 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: "End section conforming to fill slope" are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections incorporating a closed taper in their design have a superior hydraulic performance.*

Table 4.9 — Channel Protection

Discharge Velocity at Design Flow (fps)		Required Protection		
Greater Than	Less than or equal to	Type	Thickness	Minimum Height Above Design Water Surface
0	5	Grass lining or bio-engineered lining	N/A	
5	8	Rock lining (1) or bio-engineered lining	1 foot	1 foot
8	12	Riprap (2)	2 feet	2 feet
12	20	Slope mattress gabion, etc.	Varies	2 feet

(1) Rock Lining shall be reasonably well graded as follows:

- Maximum stone size: 12 inches
- Median stone size: 8 inches
- Minimum stone size: 2 inches

(2) Riprap shall be reasonably well graded as follows:

- Maximum stone size: 24 inches
- Median stone size: 16 inches
- Minimum stone size: 4 inches

Note: Riprap sizing is governed by side slopes on outlet channel, assumed to be approximately 3:1.

Table 4.10 — Value of Roughness Coefficient "*n*" for Open Channels

Type of Channel & Description	Manning's "*n**" (Normal)
A. Constructed Channels	
a. Earth, straight and uniform	
1. Clean, recently completed	0.018
2. Gravel, uniform section, clean	0.025
3. With short grass, few weeds	0.027
b. Earth, winding and sluggish	
1. No vegetation	0.025
2. Grass, some weeds	0.030
3. Dense weeds or aquatic plants in deep channels	0.035
4. Earth bottom and rubble sides	0.030
5. Stony bottom and weedy banks	0.035
6. Cobble bottom and clean sides	0.040
c. Rock lined	
1. Smooth and uniform	0.035
2. Jagged and irregular	0.040
d. Channels not maintained, weeds and brush uncut	
1. Dense weeds, high as flow depth	0.080
2. Clean bottom, brush on sides	0.050
3. Same as #2, highest stage of flow	0.070
4. Dense brush, high stage	0.100
B. Natural Streams	
B-1 Minor streams (top width at flood stage < 100 ft.)	
a. Streams on plain	
1. Clean, straight, full stage no rifts or deep pools	0.030
2. Same as #1, but more stones and weeds	0.035
3. Clean, winding, some pools and shoals	0.040
4. Same as #3, but some weeds	0.040
5. Same as #4, but more stones	0.050
6. Sluggish reaches, weedy deep pools	0.070
7. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.100
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages	
1. Bottom: gravel, cobbles, and few boulders	0.040
2. Bottom: cobbles with large boulders	0.050
B-2 Floodplains	
a. Pasture, no brush	
1. Short grass	0.030
2. High grass	0.035
b. Cultivated areas	
1. No crop	0.030
2. Mature row crops	0.035
3. Mature field crops	0.040
c. Brush	
1. Scattered brush, heavy weeds	0.050
2. Light brush and trees	0.060
3. Medium to dense brush	0.070
4. Heavy, dense brush	0.100
d. Trees	
1. Dense willows, straight	0.150
2. Cleared land with tree stumps, no sprouts	0.040
3. Same as #2, but with heavy growth of sprouts	0.060
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.100
5. Same as #4, but with flood stage reaching branches	0.120

* *Note: These "n" values are "normal" values for use in analysis of channels. For conservative design of channel capacity, the maximum values listed in other references should be considered. For channel bank stability, the minimum values should be considered.*

Table 4.11 — Evidence of Existing or Predicted Problems

1. Evidence of potential for contamination of surface waters.
2. Overtopping, scouring, bank sloughing or sedimentation.
3. Significant destruction of aquatic habitat or organisms (for example, severe siltation or incision in a stream).
4. Evidence of potential for contamination of ground water.

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CHAPTER 5 –TABLE

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Table 5.1 — Recommended Infiltration Rates Based on % of Soil Retained by 200 Sieve			
	Short Term Infiltration rate (inches/hour)	**Correction Facto, CF**	**Estimated Long-term (Design) Infiltration Rate (inches/hour)**
> 87.5%	8	4	2.0
87.5% – 75%	2	4	0.5
75% – 55%	1	4	0.25
55% – 45%	0.5	4	0.13

Table 5.2 — Infiltration Trench Sizing Factors				
BMP	**Native Soil Design Infiltration Rate (inches/hour)**	**Regression Factors M**	**B**	**Regression Equation**
Rock Trench BMP 5.01	0.13	0.0244	0.4918	Length (feet) = Impervious Area (square feet) x [M x Mean Annual Precipitation (inches) + B]
	0.25	0.0097	-0.1171	
	0.5	0.0051	-0.0445	
	2.0	0.0013	+0.0101	
Gravelless Chamber BMP 5.02	0.13	0.0057	-0.0695	Length (feet) = Impervious Area (square feet) x [M x Mean Annual Precipitation (inches) + B]
	0.25	0.0038	-0.0412	
	0.5	0.0021	-0.0104	
	2.0	0.00072	-0.00303	

NOTE: (BMP 5.01 = Figure 5.1) — Rock trench = 2–feet wide

As an example, using table 5.2, the length of a rock trench receiving runoff from 1.000 square feet of impervious area at a site with a native soil design infiltration rate of 0.5 inches per hour and a mean annual precipitation depth of 48 inches (from figure 5.4) would be calculated as:

Rock Trench Length (feet) = 1,000 x [0.0051 x 48 – 0.0445] = 200 feet

Similarly, the length of a gravelless chamber receiving runoff from 2,000 square feet of impervious surface area where the native soil design infiltration rate is 0.25 inches per hour and the site mean annual precipitation depth is 34 inches (from figure 5.4) would be calculated as:

Gravelless Chamber Length (feet) = 2,000 x [0.0038 x 34 - 0.0412] = 176 feet

Table 5.3 — Bioretention and Pervious Pavement Sizing Factors

BMP	Native Soil Design Infiltration Rate (inches/hour)	Regression Factors				Regression Equation
		Flow Control		Water Quality		
		M	B	M	B	
Bioretention cell[3]–6 inch ponding depth	0.25	0.0092	-0.0573	0.0018	-0.0046	Bioretention Bottom Area (square feet) = Impervious Area (square feet) x [M x Mean Annual Precipitation (inches) + B (square feet)]
	0.5	0.0051	+0.0317	0.0012	-0.001	
	1.0	0.0034	+0.0309	0.0008	-0.00005	
Bioretention cell[3]–10 inch ponding depth	0.25	0.0067	-0.0381	0.0014	-0.0057	Bioretention Bottom Area (square feet) = Impervious Area (square feet) x [M x Mean Annual Precipitation (inches) + B]
	0.5	0.0040	+0.0067	0.0009	-0.0026	
	1.0	0.0024	+0.0283	0.0006	-0.0015	
Permeable pavement facility–6 inch storage reservoir and overflow	0.25	0.1100	-1.0536	N/A	N/A	Permeable Pavement Facility Area (square feet) = Impervious Area (square feet) x [M x Mean Annual Precipitation (inches) + B (square feet)]
	0.5	0.0187	+0.4945	N/A	N/A	
	1.0	0.0048	+0.3531	N/A	N/A	
Permeable Pavement surface[4]–not designed to manage other runoff	≥0.25	0.1	0	N/A	N/A	Minimum Aggregate Depth (inches) = M x Mean Annual Precipitation (inches)

1 BMP sized to match peak flow rates and flow durations from half of the 2-year to the 50-year recurrence interval flow to a predeveloped forest condition.

2 BMP sized to infiltrate 91 percent of the runoff file.

3 Regression constants are for bioretention facility bottom area. Total footprint area may be calculated based on side slopes (3H:1V), ponding depth, and freeboard.

4 For permeable pavement surfaces with subgrade slopes greater than 2 percent the flow control standard is not achieved. The area mitigated is calculated as 40 percent of the permeable pavement area and downstream BMP(s) are sized for 60 percent of the permeable pavement area.

N/A = Not applicable

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CHAPTER 6 –TABLES

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Table 6.1 — Treatment Facility Placement in Relation to Detention		
Water Quality Facility	**Preceding Detention**	**Following Detention**
Filter strip Media filter drain	OK	No-must be installed before flow concentrate
Stormwater treatment wetland	OK	OK-less water level fluctuation in ponds downstream of detention may improve aesthetic qualities and performance
Bioinfiltration swale	OK	OK
Bioretention filter	OK	OK
Contech Stormfilter©	OK	OK
Wetvault	OK	OK
Sand filter or sand filter vault	OK, but presettling and control of floatables needed	OK-sand filters downstream of detention facilities may require field adjustments if prolonged flows cause sand saturation and interfere with phosphorus removal

Table 6.2 — Lining Types for Runoff Treatment Facilities		
Water Quality Facility	**Area to be Lined**	**Type of Liner Recommended**
Presettling basin	Bottom & sides	Low permeability liner or treatment liner. (If the basin will intercept seasonal high ground water table a treatment liner is recommended.)
Wetpond	First cell: bottom and sides to WQ design water surface	Low permeability liner or treatment liner. (If the basin will intercept seasonal high ground water table a treatment liner is recommended.)
	Second cell: bottom & sides to WQ design water surface	Treatment line
Combined detention/water quality facility	First cell: bottom and sides to WQ design water surface	Low permeability liner or treatment liner. (If the basin will intercept seasonal high ground water table a treatment liner is recommended.)
	Second cell: bottom & sides to WQ design water surface	Treatment liner
Stormwater wetland	Bottom & sides, both cells	Low permeability liner or treatment liner. (If the basin will intercept seasonal high ground water table a treatment liner is recommended.)
Sand filtration basin	Basin sides only	Treatment liner
Sand filter vault	N/A	No liner needed
Linear sand filter	N/A if in vault Bottom & sides of presettling cell if not in vault	No liner needed Low permeability or treatment liner
Media filter drain	N/A	No liner needed
Bioretention filter	N/A	No liner needed
Media filter (in vault)	N/A	No liner needed
Wet vault	N/A	No liner needed

Table 6.3 — Compacted Till Liners	
Sieve Size	**Percent Passing**
6-inch	100
4-inch	90
#4	70 – 100
#200	20

Table 6.4 — Sizing of Presettling Vaults		
Vault Diameter	**Specified Treatment Capacity [a,b]**	
4	125 GPM	0.30 CFS
6	285 GPM	0.60 CFS
8	500 GPM	1.10 CFS
10	785 GPM	1.75 CFS

(a) Based on a hydraulic loading Rate of 10 GPM / ft^2 at the water quality design flow
(b) Each model will have a much greater hydraulic capacity, identified by the manufacturer

Table 6.5 — Sand Medium Specification	
U. S. Sieve Numer	**Percent Passing**
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

Table 6.6 — Design Flow Rates for Basic Treatment with ZPG Media			
Effective Cartridge Height (inches)	12	18	27
Cartridge Flow Rate (gpm / cartridge)	5	7.5	11.3

Table 6.7 — Filter Strip Sizing Criteria

Design Parameter	Filter strip
Longitudinal Slope	0.01 — 0.15
Maximum velocity	0.5 feet / second
Maximum water depth[2]	1 inch maximum
Manning coefficient (22)	0.35 (0.45 if compost-amended, and mowed to maintain grass height ≤ 4 inches
Bed width (bottom)	—
Freeboard height	—
Minimum hydraulic residence time at Water Quality Design Flow Rate	9 minutes
Minimum length	Sufficient to achieve hydraulic residence time in the filter strip
Maximum sideslope	Inlet edge ≥ 1 inch lower than contributing paved area
Maximum tributary drainage flowpath	150 feet
Maximum longitudinal slope of contributing area	0.05 (steeper than 0.05 need upslope flow spreading and energy dissipation)
Maximum lateral slope of contributing area	0.02 (at the edge of the strip inlet)
Ditch conveyance capacity	Per Chapter 4

Table 6.8 — Emergent Wetland Plant Species for Wetponds			
Species	**Common Name**	**Notes**	**Maximum Depth**
Inundation to 1 Foot			
Agrostis exarata (1)	Spike bent grass	Prairie to coast	to 2 feet
Carex stipata	Sawbeak sedge	Wet ground	
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	to 2 feet
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	to 2 feet
Juncus e usus	Soft rush	Wet meadows, pastures, wetland margins	to 2 feet
Juncus tenuis	Slender rush	Wet soils, wetland margins	
Oenanthe sarmentosa	Water parsley	Shallow water along stream and pond margins; needs saturated soils all summer	
Scirpus atrocinctus (formerly S. cyperinus)	Woolgrass	Tolerates shallow water; tall clumps	
Scirpus microcarpus	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sagittaria latifolia	Arrowhead		
Inundation 1 to 2 Feet			
Agrostis exarata (1)	Spike bent grass	Prairie to coast	
Alisma plantago-aquatica	Water plantain		
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	
Juncus e usus	Soft rush	Wet meadows, pastures, wetland margins	
Scirpus microcarpus	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sparganium emmersum	Bur reed	Shallow standing water, saturated soils	
Inundation 1 to 3 Feet			
Carex obnupta	Slough sedge	Wet ground or standing water	1.5 to 3 feet
Beckmania syzigachne (1)	Western sloughgrass	Wet prairie to pond margins	
Scirpus acutus (2)	Hardstem bulrush	Single tall stems, not clumping	to 3 feet
Scirpus validus (2)	Softstem bulrush		
Inundation Greater Than 3 Feet			
Nuphar polysepalum	Spatterdock	Deep water	3 to 7.5 feet
Nymphaea odorata (1)	White waterlily	Shallow to deep ponds	to 6 feet

Notes:

(1) Non-native species. *Beckmania syzigachne* is native to Oregon. Native species are preferred.

(2) *Scirpus* tubers must be planted shallower for establishment, and protected from foraging waterfowl until established. Emerging aerial stems should project above water surface to allow oxygen transport to the roots.

Primary sources: Municipality of Metropolitan Seattle, Water Pollution Control Aspects of Aquatic Plants, 1990. Hortus Northwest, Wetland Plants for Western Oregon, Issue 2, 1991. Hitchcock and Cronquist, Flora of the Paci c Northwest, 1973.

Table 6.9 — Distribution of depths in wetland cell			
Dividing Berm at WQ Design Water Surface		Dividing Berm Submerged 1 foot	
Depth Range (feet)	Percent	Depth Range (feet)	Percent
0.1 to 1	25	1 to 1.5	40
1 to 2	55	1.5 to 2	40
2 to 2.5	20	2 to 2.5	20

Table 6.10 — Coalescing Plate Oil / Water Separator Vault Dimensions*	
Area of Effective Separation (square feet)	Approximate vault volume required (cubic feet) for plates with ½ inch spacing and inclined 60° from horizontal (cubic feet)
100	150
200	240
300	330
600	530
1,200	890
2,400	1,150
3,200	2,090
4,800	2,640

* Order of magnitude estimates for planning purposes only. Actual vault volumes vary considerably depending on separator design features and pre-cast vault dimensions.

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CHAPTER 7 – TABLES

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Table 7.1 — Small Trees and Shrubs with Fibrous Roots	
Small Trees / High Shrubs	**Low Shrubs**
*Red twig dogwood *(Cornus stolonifera)*	*Snowberry *(Symporicarpus albus)*
*Serviceberry *(Amelanchier alnifolia)*	*Salmonberry *(Rubus spectabilis)*
*Filbert *(Corylus cornuta, others)*	Rosa rugosa *(avoid spreading varieties)*
Highbush cranberry *(Vaccinium opulus)*	Rock rose *(Cistus spp.)*
Blueberry *(Vaccinium spp.)*	Ceanothus spp. *(choose hardier varieties)*
Fruit trees on dwarf rootstock	New Zealand flax *(Phormium penax)*
Rhododendron *(native and ornamental varieties)*	Ornamental grasses *(e.g., Miscanthis, Pennisetum)*
* Native Species	

Table 7.2 — Stormwater Tract "Low Grow" Seed Mix	
Seed Name	**Percentage of Mix**
Dwarf tall fescue	40%
Dward perennial rye "Barclay*"	30%
Red fescue	25%
Colonial bentgrass	5%
* If wildflowers are used and sowing is done before Labor Day, the amount of dwarf perennial rye can be reduced proportionately to the amount of wildflower seed used.	

Table 7.3 — Values of C_d for Sutro Weirs

C_d Values, Symmetrical *b*(ft)					
a (ft)	**0.50**	**0.75**	**1.0**	**1.25**	**1.50**
0.02	0.608	0.613	0.617	0.6185	0.619
0.05	0.606	0.611	0.615	0.617	0.6175
0.10	0.603	0.608	0.612	0.6135	0.614
0.15	0.601	0.6055	0.610	0.6115	0.612
0.20	0.599	0.604	0.608	0.6095	0.610
0.25	0.598	0.6025	0.6065	0.608	0.6085
0.30	0.597	0.602	0.606	0.6075	0.608

C_d Values, Non-Symmetrical *b*(ft)					
a (ft)	**0.50**	**0.75**	**1.0**	**1.25**	**1.50**
0.02	0.614	0.619	0.623	0.6245	0.625
0.05	0.612	0.617	0.621	0.623	0.6235
0.10	0.609	0.614	0.618	0.6195	0.620
0.15	0.607	0.6115	0.616	0.6175	0.618
0.20	0.605	0.610	0.614	0.6155	0.616
0.25	0.604	0.6085	0.6125	0.614	0.6145
0.30	0.603	0.608	0.612)	0.635	0.614