Section 4

STORM DRAINAGE DESIGN STANDARDS

4.0 General: The Richland County Stormwater Management Ordinance, which is contained in Section 3, applies to all storm drainage construction in Richland County unless specifically exempted. The County Engineer is responsible for review and approval of plans for all drainage construction to which the ordinance applies. These standards are intended to supplement the ordinance by providing design criteria and data not contained in the ordinance but necessary for preparation of plans in accordance with the County Engineer's requirements. All provisions of the South Carolina Stormwater Management and Sediment Reduction Act of 1991 and South Carolina Pollution Control Act of 1976 are also applicable to construction activities in Richland County. These standards, together with the County's Stormwater Management Ordinance, satisfy the requirements of the acts. Richland County has been delegated responsibility for plan review, inspection and enforcement by the S.C. Department of Health and Environmental Control under the provisions of the acts as of September 16, 1996.

4.0.1 Plans: Complete construction plans and specifications together with all appropriate design calculations shall be submitted and approved before the commencement of construction. Submittals should contain the following:

A. General
   1. Project Summary
      a. Linear feet of road
      b. Number of lots
      c. Total acreage
   2. USGS Quadrangle Map (portion w/ site highlighted)
   3. Richland County Soil Survey Map (portion w/ site highlighted)
   4. Digital Copy of Site Plan adjusted to SC State Plane Coordinate System and utilizing County standard layer names.
   5. 3” x 4” Space at Lower Right Hand Corner Reserved for County Stamp
   6. Stormwater Management Facility Maintenance Plan and Agreement
   7. DHEC Stormwater Application
      a. 2 acres or less (DHEC is moving to 1 acre)
      b. More than 2 acres
      c. Greater than 5 acres requires NPDES permitting
   8. Provide 3, 24” x 36” sets of plans, 1 each for Co. Eng., Co. Insp., and Site (an approved copy must be on site at all times)

B. Streets
   1. Horizontal Alignment
   2. Vertical Alignment
   3. Pavement Design
   4. Street Cross Section
   5. Traffic Control Signs

C. Drainage
   1. Drainage Scenario (Watershed, Soils, Pre & Post-development conditions, etc.)
   2. Drainage Areas
      a. On-site
      b. Off-site

3. Runoff Coefficients / Curve Numbers
4. Rainfall Intensities
5. Pre and Post Development Calculations
6. Inlet Capacities and Design
7. Open Channels
8. Ponds
    a. Plan view showing contours, sediment traps and fore bays
    b. Table showing Stage, Elevation, Surface Area, Volume, and Discharge
    c. Outlet Structure Details
    d. Infiltration Rates
9. 100 Year Floodplain Elevations with delineation of floodplain and floodway
10. Profiles (Pipe size, material, gauge, etc.)
11. Design Statements
12. Dedicated easements (Utility, conservation, and buffers)

D. Sediment & Erosion Control
1. Temporary and permanent BMPs
2. Silt Fence Locations
3. Sediment Basins w/ Maintenance Schedule
4. Seeding Schedule
5. Certification Schedule

E. Miscellaneous
1. Vicinity Map (1” = 1000’)
2. 12” X 18” reduced set of plans
3. SCDOT or Richland County Encroachment Approval
4. FEMA, CLOMR, etc.

4.0.2 Record Drawings: Record drawings on both 12-inch by 18-inch sheets and digital format in accordance with the County Digital Data Submissions Standards shall be provided before a final approval will be issued.

4.0.3 Dedication: As prescribed in the Stormwater Management Ordinance, eligible drainage and stormwater management systems designed and constructed in accordance with these standards and approved by the County Engineer's office may be dedicated to Richland County for maintenance. This is accomplished through the submittal and acceptance of a drainage easement and right-of-way deed. Standard easement forms for this purpose are available from the County Engineer's office. Executed easements must be provided as a prerequisite to issuance of final approval.

4.0.4 Inspection: All elements of the storm drainage system must be inspected by the County Engineer's office during construction as a prerequisite for acceptance by Richland County. It is the contractor's responsibility to insure that the office is notified and has the opportunity to make those inspections before the work is backfilled.

The inspections conducted by the County Engineer's office are for the protection of Richland County only. They are not intended to certify the contractor's satisfactory discharge of his contractual obligation to the owner, nor do they relieve the engineer-of-record from any of his responsibilities concerning certification of the project.

4.0.5 Fees: Fees for plan review and inspection are collected as part of the fees assessed under the Subdivision Regulations. No grading permit fee is assessed.

A separate fee of $75.00, made out to SCDHEC, for the NPDES general permit for construction is collected when plans are submitted and then forwarded to them. This only applies, however, to projects on which 5.0 acres or more are to be disturbed.

4.1 Calculation of Runoff

4.1.1 Rainfall Frequency: The rainfall frequency, or return period, is the average time interval between equal magnitude storms. The rainfall frequency to be used in storm drainage design in Richland County varies with the watershed size for the drainage structure under consideration, as presented in Table 1.

Table 1
Design Storm Recurrence Interval

Size-Acres (rounded to the nearest acre)	*Design Storm Recurrence Interval (years)*
300 and larger	50-year
40-299	25-year
0-39	10-year

In addition, the 100-year rainfall is required for determination of minimum building elevations, floodplain boundaries, etc.

4.1.2 Watershed Areas (A): Watershed area shall be determined using the following procedures.

1) On-site watershed areas shall be determined from the topographic maps of the proposed development, which are to be drawn to a scale no smaller than 1 inch = 200 feet, with a contour interval not to exceed 5 feet. This topographic map, with the watershed area delineated for each drainage structure, is to be submitted to the County Engineer's office together with the drainage plans and calculations for any project requiring the review and approval of that office.

2) Off-site watershed areas may be determined using United States Geological Survey (USGS) or Richland Lexington Joint Planning Commission topographic maps. In all cases, drainage systems shall be designed to accommodate the runoff from those portions of the natural watershed located off the development site as well as on-site areas. The future use of any undeveloped land located in off-site watershed areas shall be evaluated by considering such factors as zoning, location relative to transportation facilities and nearby development trends. Runoff coefficients and curve numbers appropriate to the expected future land use of off-site watershed areas are to be used in all drainage calculations and design.

4.1.3 Rational Formula: The design discharge rate for a single pipe or culvert draining a watershed of 20 acres or less may be calculated using the Rational Formula[1],

$$Q = CIAC_f$$

Where: Q = discharge rates in cubic feet per second (cfs),

C = runoff coefficient for the watershed,

I = rainfall intensity (for duration equal to time of concentration) in inches per hour,

A = area of watersheds contributing to the design location, in acres,

And C_f is a coefficient defined by:

Recurrence Interval (Years)	C_f
2-10	1.00
25	1.10
50	1.20
100	1.25

4.1.3.1 Rainfall Intensity (I): Rainfall intensity (I) is the average rainfall rate, in inches per hour, for duration equal to the time of concentration for a selected rainfall frequency. Rainfall intensities are to be computed using the following formula[2]:

$$i = \frac{a}{(b + t_c)^c}$$

Where: i = rainfall intensity in inches per hour,

t_c = time of concentration in minutes,

And a, b, and c are coefficients as presented below.

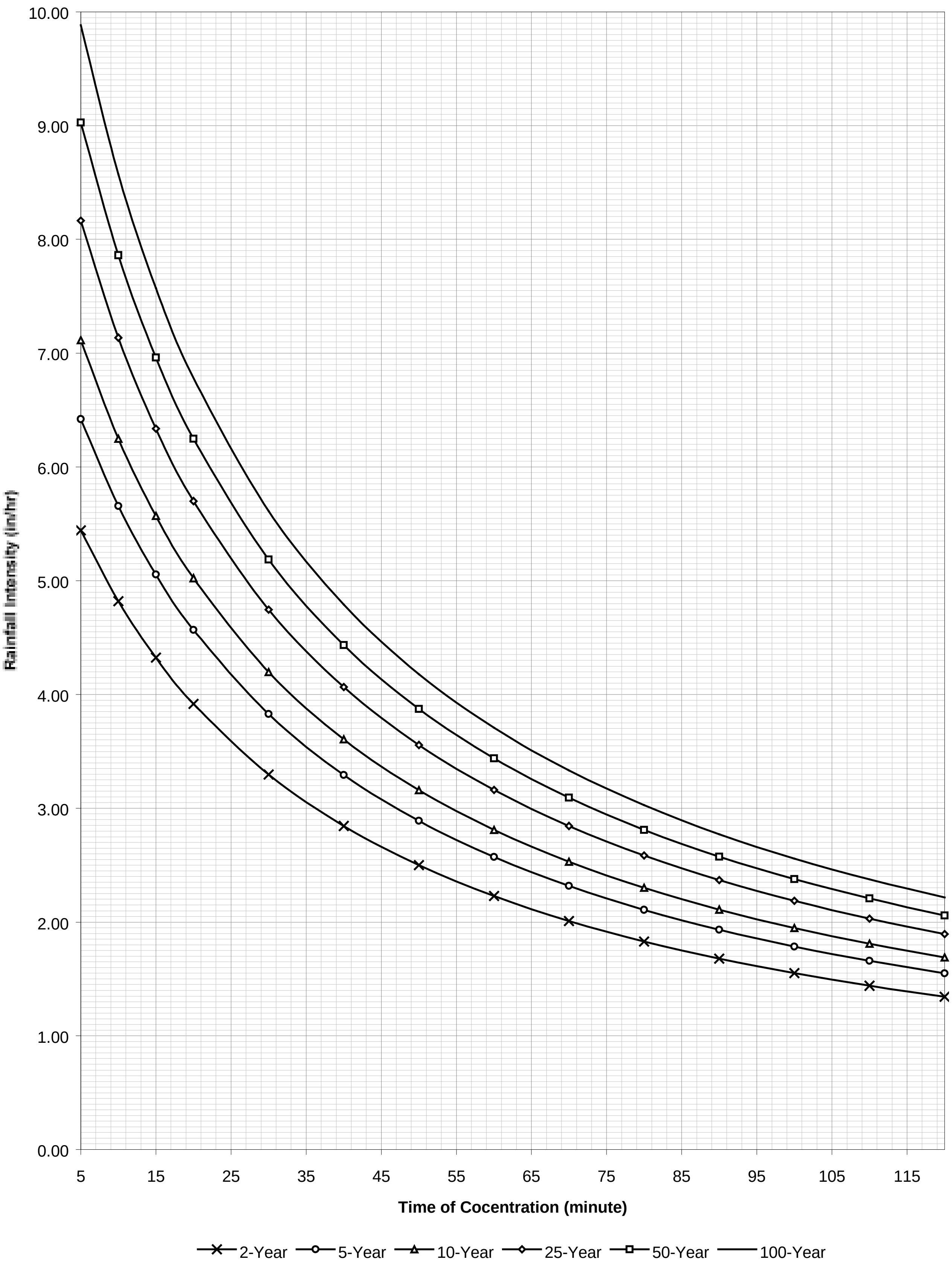
Recurrence Interval (years)	***a***	***b***	***c***
2	244.34492	34.95806	1.03155
5	258.50572	32.75684	1.01773
10	267.54247	31.39986	1.00904
25	279.77346	29.59043	0.99735
50	288.71309	28.26125	0.98879
100	296.66217	27.04859	0.98111

Rainfall intensities for times ranging from 5 minutes to 2 hours, for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals are shown in Richland County Design Chart No. 1.

[1] South Carolina Department of Transportation Requirements for Hydraulic Design Studies (2000)
[2] Rainfall Intensity Values Used by the South Carolina Department of Transportation (undated)

Richland County Storm Drainage Design Chart No. 1

Rainfall Intensities for Richland County



Time of concentration should be determined using the SCS Upland Method[3]:

$$T_c = \sum T_i \text{ and } T_i = \frac{aL_i}{\sqrt{S_i}}$$

Where: T_c = time of concentration at the point under consideration (minutes),

T_i = overland flow time on surface i (minutes),

L_i = length of overland flow on surface i (feet),

S_i = average slopes of surface i (percent)

And *a* is a coefficient related to the surface characteristics as defined below:

Surface Characteristics[4]	***a***
Forest with heavy ground litter; hay meadow (overland flow)	0.0668
Trash fallow or minimum tillage cultivation; contour or strip cropped; woodland (overland flow)	0.0334
Short grass pasture (overland flow)	0.0238
Cultivated straight row crop (overland flow)	0.0185
Nearly bare and untilled (overland flow)	0.0167
Grassed waterway (shallow concentrated flow)	0.0111
Developed Conditions: Unpaved (shallow concentrated flow)	0.0103
Developed Conditions: Paved areas and shallow gutters (shallow concentrated flow)	0.0082

4.1.3.2 Runoff Coefficient (C): Runoff coefficients appropriate for expected future land uses shall be used for all storm drainage design. Table 2 summarizes recommended values for the runoff coefficient, C.

In areas of with multiple land cover types, compute composite runoff coefficient based on the area weighted percentage of different types of surfaces in the drainage areas.

$$C_W = \frac{\sum (C_i \times A_i)}{\sum A_i}$$

Where: C_W = area weighted runoff coefficient,

C_i = runoff coefficient for land cover *i*,

And A_i = area of land cover *i*

[3] Natural Resource Conservation Service (NRCS, formerly Soil Conservation Service) National Engineering Handbook, Part 630, Chapter 16 (1972) and NRCS Technical Release No. 55, Urban Hydrology for Small Watersheds (1986)

[4] Federal Highway Administration, Hydraulic Design Series No. 2: Highway Hydrology (1996)

Table 2
Recommended Runoff Coefficients

Land Cover Description		*Range of Runoff Coefficients*	*Recommended Runoff Coefficient*
Business, Industrial, and Commercial		0.80 to 0.90	0.85
Apartments		0.65 to 0.75	0.70
Schools		0.50 to 0.60	0.55
Residential:	10,000 $ft.^2$ lots	0.40 to 0.50	0.45
	12,000 $ft.^2$ lots	0.40 to 0.45	0.42
	17,000 $ft.^2$ lots	0.35 to 0.45	0.40
	lots ½ acre or more	0.30 to 0.40	0.35
Parks, cemeteries, and unimproved areas		0.20 to 0.35	0.30
Paved and Roof Areas		-	0.90
Cultivated Areas		0.50 to 0.70	0.60
Pasture		0.35 to 0.45	0.40
Forest		0.20 to 0.30	0.25
Lawns		0.20 to 0.40	0.30

4.1.3.3 Area (A): Watershed area as discussed in 4.1.2.

4.1.3.4 Calculations: All runoff calculations shall be included with the Stormwater Management Plan submittal.

4.1.3.5 Certifications: Stormwater Management Plans and calculations performed using the Rational Formula must be certified by a South Carolina Registered Professional Engineer, Registered Landscape Architect or Tier B Land Surveyor in accordance with State Law.

4.1.4 Computer Models: Runoff calculations involving any watershed of over 20 acres, multiple sub-watersheds or multiple drainage inlets and pipes must be analyzed using numerical models that model complex watershed responses. Only those models that incorporate the SCS unit hydrograph methodology are acceptable. The preferred model is DRAINEDGE, which was developed by the University of South Carolina, College of Engineering.

Analyses performed in support of a requested change in floodplain or floodway boundaries or flood elevations shown on the Richland County effective Flood Insurance Study (FIS) and Flood Insurance Rate Map (FIRM) shall be performed using the same numerical models used to prepare the FIS. In areas that are identified as Zone A, approximate floodplain delineations without Base Flood Elevations (BFEs), analyses shall be performed using methods and/or numerical models approved by FEMA.

4.1.4.1 Curve Number (CN): Curve Number (*CN*) combines soil conditions and land uses to indicate the runoff potential of an area. A higher *CN* value indicates a higher runoff potential. Table 3 lists curve numbers for various land uses and hydrologic soil groups as published by the NRCS in TR-55, Urban Hydrology for Small Watersheds. Curve numbers appropriate for expected future land uses should be used for all storm drainage and stormwater management design.

Table 3
Runoff Curve Numbers of Urban Areas[5]

---------- Cover Description ----------		Curve Number for Hydrologic Soil Group			
Cover Type and Hydrologic Condition	*% Imp. Area*[6]	*A*	*B*	*C*	*D*
Cultivated land:					
· Without conservation treatment		72	81	88	91
· With conservation treatment		62	71	78	81
Pasture, grassland or range - continuous forage or grazing:					
· Poor condition		68	79	86	89
· Good condition		39	61	74	80
Meadow: continuous grass, protected from grazing and generally mowed for hay		30	58	71	78
Woods or forest:					
· Poor condition (thin stand, minimal forest litter)		45	66	77	83
· Good condition (good cover, litter and brush adequately cover soil)		30	55	70	77
Open space (lawn, parks, golf courses, cemeteries, etc,)[7]					
· Poor condition (grass cover < 50%)		68	79	86	89
· Fair condition (grass cover 50% to 75%)		49	69	79	84
· Good condition (grass cover 75%)		39	61	74	80
Impervious areas: paved parking lots, roofs, driveways, etc. (excluding right of way)		98	98	98	98
Streets and roads:					
· Paved, curbs and storm drains (excluding right of way)		98	98	98	98
· Paved, open ditches (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 average lot size:					
· $^1/_8$ acre or less (town houses)	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	70	80	85
· 1 acre	20%	51	68	79	84
· 2 acres	12%	46	65	77	82
Developing urban areas and newly graded areas (pervious area only, no vegetation)		77	86	91	94

In areas of with multiple land cover - soils combinations, compute composite curve number

[5] Average runoff condition (antecedent moisture condition 2 (AMC II)), and I_a=0.2S

[6] The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. If the impervious area is not connected, the SCS method has an adjustment to reduce the effect.

[7] CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space cover type.

based on the area-weighted percentage of different types of surfaces in the drainage areas.

$$CN_W = \frac{\sum (CN_i \times A_i)}{\sum A_i}$$

Where: CN_W = area weighted curve number,

CN_i = curve number for land cover - soil combination *i*,

And A_i = area of land cover - soil combination *i*

4.1.4.2 Hydrologic Soil Group: Table 4 shows the hydrologic soil group for NRCS soil classifications occurring in Richland County.

Table 4
Hydrologic Soil Group Classifications[8]

Soil Name	*Map Symbol*	*Hydrologic Soil Group*[9]	*Soil Name*	*Map Symbol*	*Hydrologic Soil Group*
Ailey	AeC	B	Lucy	LuB	A
Altavista	AtA	C	Marlboro	MaA	B
Blanton	BaB	A		MaB	B
Cantey	Ca	D	Nason	NaB	C
Chastain	Cd	D		NaC	C
Chewacla	Ce	C		NaE	C
	Ch	C	Norfolk	NoA	B
Clarendon	Cn	C		NoB	B
Congaree	Co	B	Orange	OaB	D
Coxville	Cx	D	Orangeburg	ObA	B
Dorovan	Dn	D		ObB	B
Dothan	DoA	B		ObC	B
	DoB	B		OgB	B
	DuB	B		OgD	B
Faceville	FaA	B	Pelion	PeB	B/D
	FaB	B		PeD	B/D
Fuquay	FuA	B		PnC	B/D
	FuB	B	Persanti	Ps	C
	FyB	B	Rains	Ra	B/D
Georgeville	GeB	B	Smithboro	Sm	D
	GeC	B	Wickham	StA	B
Goldsboro	GoA	B	Tawcaw	Tc	C
Herndon	HeB	B	Toccoa	To	B
	HeC	B	Troup	TrB	A
	HnB	B	Udorthents	Ud	B
Johnston	Jo	D	Vaucluse	VaC	C
Kershaw	KeC	A		VaD	C
Kirksey	KrB	C	Wedowee	WeB	B
Lakeland	LaB	A		WeE	B
	LaD	A			
	LkB	A			

[8] Soil Survey of Richland County, Natural Resource Conservation Service (formerly Soil Conservation Service, SCS) (1978)

[9] A soil assigned to two hydrologic groups (ex. B/D) represents the artificially drained/undrained condition of that soil.

4.1.4.3 Rainfall: The storm duration for computational purposes shall be the 24-hour rainfall event; SCS Type II distribution with a 0.1 hour burst duration time increment. Table 5 contains the 24-hour rainfall depths for the 2-, 5-, 10-, 25-, 50-, and 100-year rainfalls for Richland County.

Table 5
24-Hour Rainfall Depths[10]

Recurrence Interval (years)	*24-Hour Cumulative Rainfall Amount (inches)*
2	3.7
5	4.8
10	5.7
25	6.4
50	7.3
100	7.9

4.1.5 Design Information: In addition to the watershed map, input data files, and printout of results, a schematic drawing of the drainage system showing all watersheds, including the connecting pipes and channels, must be provided.

4.1.6 Certifications: Stormwater Management Plans prepared using the above referenced runoff models must be certified by a South Carolina Registered Professional Engineer in accordance with State Law.

4.2 Culverts

4.2.1 Culverts: A culvert is a relatively short conduit conveying stormwater through an embankment. Its capacity depends on, among other things, the depth to which headwater is allowed to pond at its inlet. The headwater depth will be different depending on whether the culvert is functioning under "inlet control" or "outlet control" conditions. In designing the culvert, both conditions must be investigated.

4.2.2 Analysis of Inlet and Outlet Control Conditions: Inlet control occurs when the capacity of the culvert barrel exceeds the capacity of the entrance. Under this condition, the culvert flows only part full. The configuration and size of the inlet and the headwater elevation determine its capacity. Outlet control occurs when the capacity of the culvert entrance exceeds the capacity of the barrel. Under this condition, the culvert flows full; its capacity is dependent on the tailwater depth, the slope, length, roughness and size of the barrel, the inlet configuration and the hydraulic head available.

Presented in FHWA Hydraulic Design Series No. 5 (HDS-5), Hydraulic Design of Highway Culverts (1985) is a thorough assessment of culvert hydraulics. HDS-5 includes nomographs for analysis of culvert hydraulics under inlet control and outlet control and culvert barrel capacity, which are incorporated in the Richland County design standards (see Table 6). Use of the FWHA culvert analysis program HY-8, or other computer model based on FHWA procedures, is

[10] Source: South Carolina Department of Health and Environmental Control, Bureau of Water

acceptable.

4.2.3 Design Criteria: The headwater required to convey the design discharge must be determined under both inlet and outlet control conditions. The control requiring the highest headwater governs. The culvert should be designed such that:

1) The headwater at the design discharge does not exceed an elevation one-foot below the top of curb or edge of road shoulder at the lowest point.

2) The headwater depth at the design discharge does not exceed the culvert diameter by a factor greater than 2.0 or by 4.0 feet; whichever is smaller.

3) The headwater depth at the design discharge does not cause water to rise above the top of approach channels or beyond established flooding easements.

4) The headwater at the 100-year discharge does not exceed an elevation two feet below the elevation of adjacent building sites.

4.2.4 Discharge Velocity: Discharge velocities shall be reduced to provide a non-erosive velocity flow from the culvert or the velocity of the design storm runoff under predevelopment conditions. Outlet protection measures, such as riprap, may be required to minimize erosion and scour potential.

4.2.5 Plans and Calculations: Drainage calculations for a project shall include headwater calculations for both the design storm and the 100-year storm. These depths shall be plotted on the road profiles and the corresponding floodplains delineated on the topographic map of the project.

4.2.6 Materials: Culverts may be constructed using any of the materials listed below. In selecting the culvert material, the engineer shall consider structural requirements and corrosion potential at the site as well as hydraulic requirements. Culverts are to be designed to support a minimum of an AASHTO HS-20 live load together with the appropriate dead load. Heavier live loads may be required if conditions dictate. Minimum life expectancy for all culvert materials is 50 years.

4.2.6.1 Reinforced Concrete Pipe (RCP): No less than class III reinforced concrete pipe will be accepted for maintenance by Richland County. Mastic type joint sealer is required.

4.2.6.2 Corrugated Metal Pipe (CMP): Corrugated aluminum and aluminized steel pipe and pipe arches are acceptable. Appropriate gage and corrugation size, however, must be selected for the fill height and diameter and specified on the drainage plans. The manufacturer's design data concerning minimum and maximum allowable fill heights must be provided and utilized in the design of the culvert.

Corrosion potential of the water and fill material at the site must also be investigated. Plan submittal must include manufacturer's data and life expectancy calculations.

4.2.6.3 Concrete Box Culverts: Cast in place or precast concrete box culverts are acceptable. Project plans should include structural details for cast in place concrete, or shop plans for precast.

4.2.6.4 Prefabricated Structures: Prefabricated culvert structures such as CONSPAN® or similar structures are acceptable if designed and installed in accordance with the manufacturer's recommendations.

4.2.6.5 High Density Polyethylene (HDPE) Pipe: HDPE pipe culverts must comply with the AASHTO M 294, Standard Specifications for Corrugated Polyethylene Pipe, 12-inches to 36-inches diameter. HDPE pipe culverts are acceptable when designed and constructed in accordance with the manufacturer's recommendation and authorized, in advance, by the County Engineer's Office. The County Engineer may disallow HDPE pipe under conditions where its performance has been found unsatisfactory.

4.2.7 Minimum Size: The minimum diameter pipe culvert allowable is 15 inches.

4.2.8 Construction Specifications: The specifications referenced in Sections 6.6.1, 6.6.2, and 6.6.4 will apply.

Table 6
FHWA Culvert Design Nomographs

Richland County Design Chart No.	HDS-5 Design Chart No.	Description
2	1	Headwater Depth for Concrete Pipe Culverts with Inlet Control
3	2	Headwater Depth for C.M. Pipe With Inlet Control
4	3	Headwater Depth for Circular Pipe Culverts with Beveled Ring Control
5	4	Critical Depth - Circular Pipe
6	5	Head for Concrete Pipe Culverts Flowing Full, n=0.012
7	6	Head for Standard C.M. Pipe Culverts Flowing Full, n = 0.024
8	7	Head for Structural Plate Corrugated Metal Pipe Culverts Flowing Full, n=0.0328 to 0.0302
9	8	Headwater Depth for Box Culverts with Inlet Control
10	9	Headwater Depth for Inlet Control Rectangular Box Culverts, Flared Wingwalls 18 Degrees to 33.7 Degrees and 45 Degrees with Beveled Edge at Top of Inlet
11	10	Headwater Depth for Inlet Control Rectangular Box Culverts, 90 Headwall Chamfered or Beveled Edges
12	11	Headwater Depth for Inlet Control, Single Barrel Box Culverts, Skewed Headwalls, Chamfered or Beveled Inlet Edges
13	12	Headwater Depth for Inlet Control, Rectangular Box Culverts, Flared Wingwalls, Normal and Skewed Inlets 3/4-in. Chamfer at Top of Opening
14	13	Headwater Depth for Inlet Control, Rectangular Box Culverts, Offset Flared Wingwalls and Beveled Edge at Top of Inlet
15	14	Critical Depth, Rectangular Section
16	15	Head for Concrete Box Culverts Flowing Full, n=0.012
17	16	Inlet Control Corrugated Metal Box Culverts, Rise/Span less than 0.3
18	17	Inlet Control Corrugated Metal Box Culverts, Rise/Span greater than 0.3, less than 0.4
19	18	Inlet Control Corrugated Metal Box Culverts, Rise/Span greater than 0.4, less than 0.5

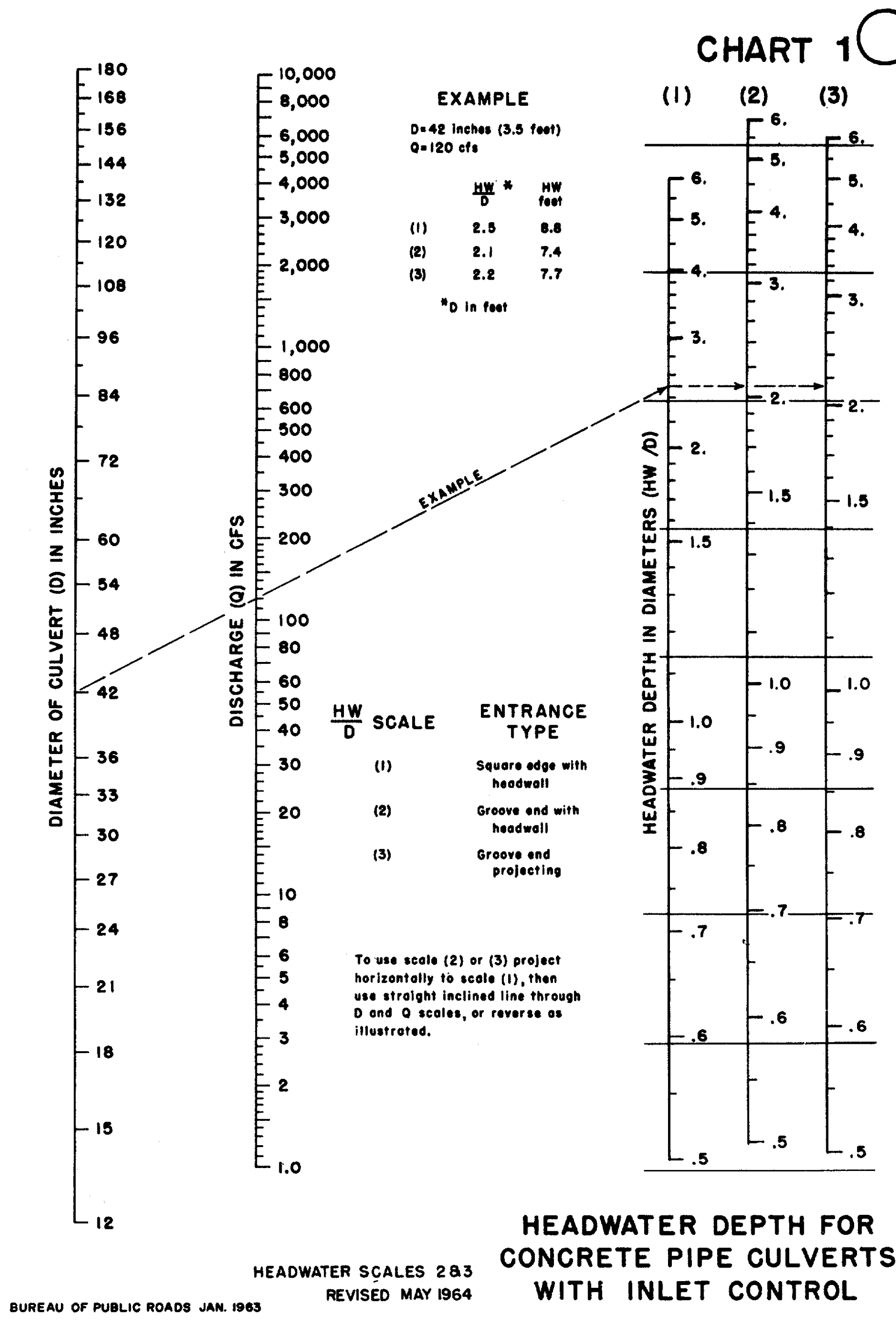
Table 6 (continued)
FHWA Culvert Design Nomographs

Richland County Design Chart No.	HDS-5 Design Chart No.	Description
20	19	Inlet Control Corrugated Metal Box Culverts, Rise/Span less than 0.5
21	20	Dimensionless Critical Depth Chart, Corrugated Metal Boxes
22	21	Head for Corrugated Metal Box Culverts Flowing Full with Concrete Bottom, Rise/Span less than 0.3
23	22	Head for Corrugated Metal Box Culverts Flowing Full with Concrete Bottom, Rise/Span greater than 0.3, less than 0.4
24	23	Head for Corrugated Metal Box Culverts Flowing Full with Concrete Bottom, Rise/Span greater than 0.4, less than 0.5
25	24	Head for Corrugated Metal Box Culverts Flowing Full with Metal Bottom, Rise/Span greater than 0.3
26	25	Head for Corrugated Metal Box Culverts Flowing Full with Corrugated Metal Bottom, Rise/Span less than 0.3
27	26	Head for Corrugated Metal Box Culverts Flowing Full with Corrugated Bottom, Rise/Span greater than 0.3, less than 0.4
28	27	Head for Corrugated Metal Box Culverts Flowing Full with Corrugated Bottom, Rise/Span greater than 0.4, less than 0.5
29	28	Head for Corrugated Metal Box Culverts Flowing Full with Corrugated Bottom, Rise/Span greater than 0.5
30	29	Headwater for Oval Concrete Pipe Culverts Long Axis Horizontal with Inlet Control
31	30	For Oval Concrete Pipe Culverts Long Axis Vertical with Inlet Control
32	31	Critical Depth - Oval Concrete Pipe Long Axis Horizontal
33	32	Critical Depth - Oval Concrete Pipe Long Axis Vertical
34	33	Head for Oval Concrete Pipe Culverts Long Axis Horizontal or Vertical Flowing Full, n=0.012
35	34	Headwater Depth for C.M. Pipe-arch Culverts with Inlet Control
36	35	Headwater Depth for Inlet Control Structural Plate Pipe-Arch Culverts, 18-in. Radius Corner Plate, Projecting or Headwall Inlet, Headwall with or without Edge Bevel
37	36	Headwater Depth for Inlet Control Structure Plate Pipe-Arch Culverts, 31-inch Radius Corner Plate, Projecting or Headwall Inlet, Headwall with or without Edge Bevel
38	37	Critical Depth - Standard Corrugated Metal Pipe-Arch
39	38	Critical Depth - Structural Plate C.M. Pipe-Arch 16-inch Corner Radius
40	39	Head for Standard C.M. Pipe-Arch Culverts Flowing Full, n=0.024
41	40	Head for Structural Plate Corrugated Metal Pipe-Arch Culverts, 18-inch Corner Radius Flowing Full, n=0.0327 to 0.0306
42	41	Headwater Depth for Corrugated Metal Arch Culverts with Inlet Control, Rise/Span greater than or equal to 0.3, less than 0.4
43	42	Headwater Depth for Corrugated Metal Arch Culverts with Inlet Control, Rise/Span greater than or equal to 0.4, less than 0.5

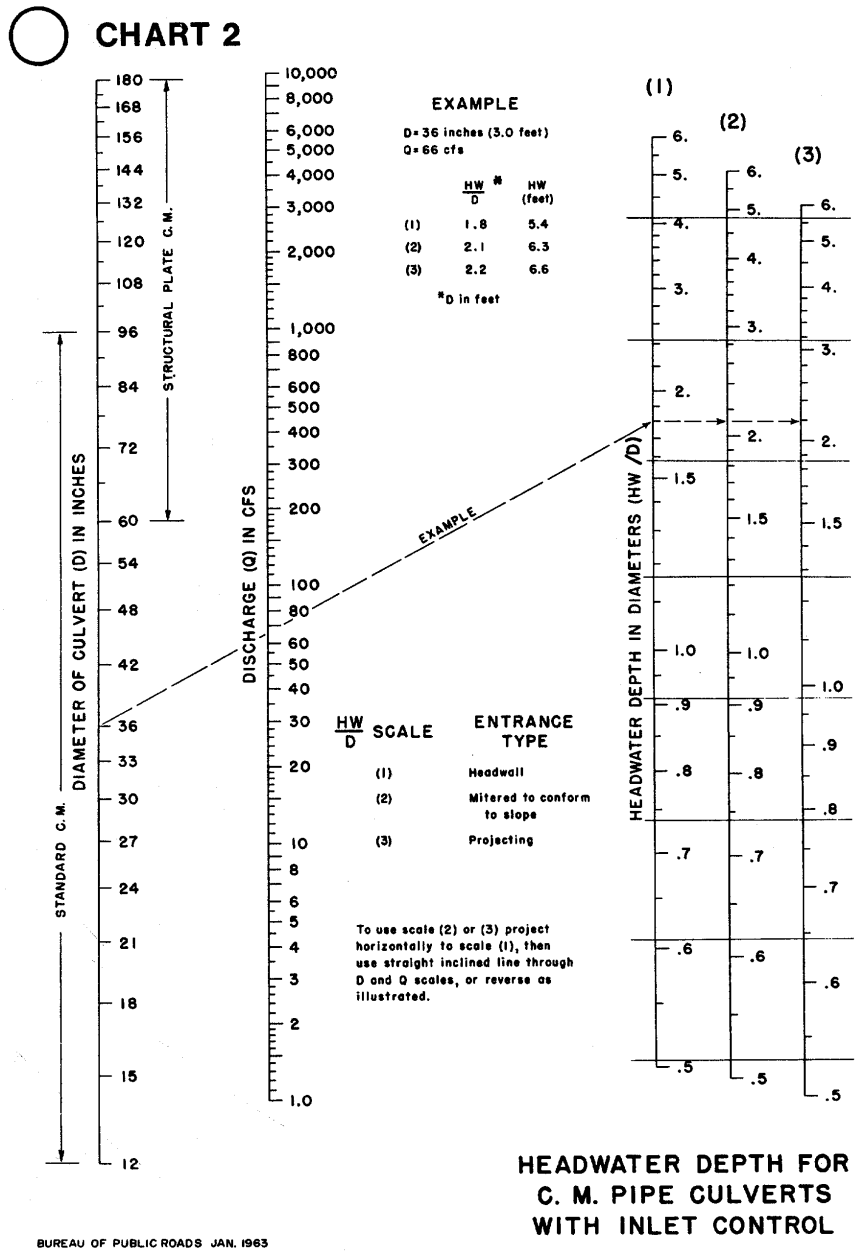
Table 6 (continued)
FHWA Culvert Design Nomographs

Richland County Design Chart No.	HDS-5 Design Chart No.	Description
44	43	Headwater Depth for Corrugated Metal Arch Culverts with Inlet Control, Rise/Span greater than or equal to 0.5
45	44	Headwater Depth for Corrugated Metal Arch Culverts with Inlet Control, Rise/Span greater than or equal to 0.5
46	45	Head for Corrugated Metal Arch Culverts, Flowing Full with Concrete Bottom, Rise/Span greater than or equal to 0.3, less than 0.4
47	46	Head for Corrugated Metal Arch Culverts, Flowing Full with Concrete Bottom, Rise/Span greater than or equal to 0.4, less than 0.5
48	47	Head for Corrugated Metal Arch Culverts, Flowing Full with Concrete Bottom, Rise/Span greater than or equal to 0.5
49	48	Head for Corrugated Metal Arch Culverts, Flowing Full with Earth Bottom, Rise/Span greater than or equal to 0.3, less than 0.4
50	49	Head for Corrugated Metal Arch Culverts, Flowing Full with Earth Bottom, Rise/Span greater than or equal to 0.4, less than 0.5
51	50	Head For Corrugated Metal Arch Culverts, Flowing Full, Earth Bottom, Rise/Span greater than or equal to 0.5
52	51	Circular or Elliptical Structural Plate CMP with Inlet Control
53	52	High and Low Profile Structural Plate Arches with Inlet Control
54	53	Dimensionless Critical Depth Chart, Structural Plate Ellipse Long Axis Horizontal
55	54	Dimensionless Critical Depth Chart, Structural Plate Low and High Profiles
56	55	Throat Control for Side-Tapered Inlets to Pipe Culvert (circular section only)
57	56	Face Control for Side-Tapered Inlets To Pipe Culverts (Non-Rectangular Sections Only)
58	57	Throat Control for Box Culverts with Tapered Inlets
59	58	Face Control for Box Culverts with Side-Tapered Inlets
60	59	Face Control for Box Culverts with Slope-Tapered Inlets

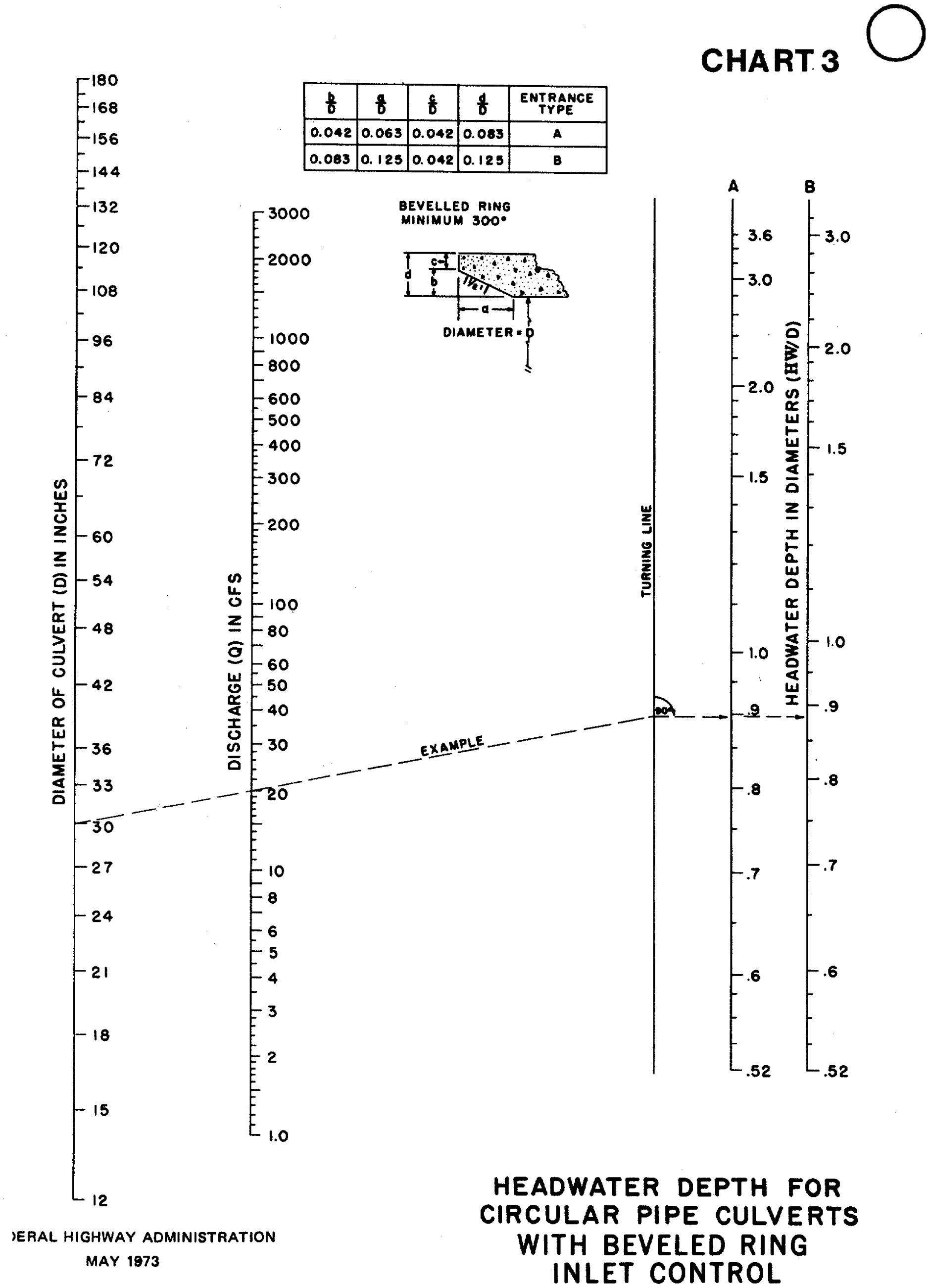
Richland County Design Chart No. 2



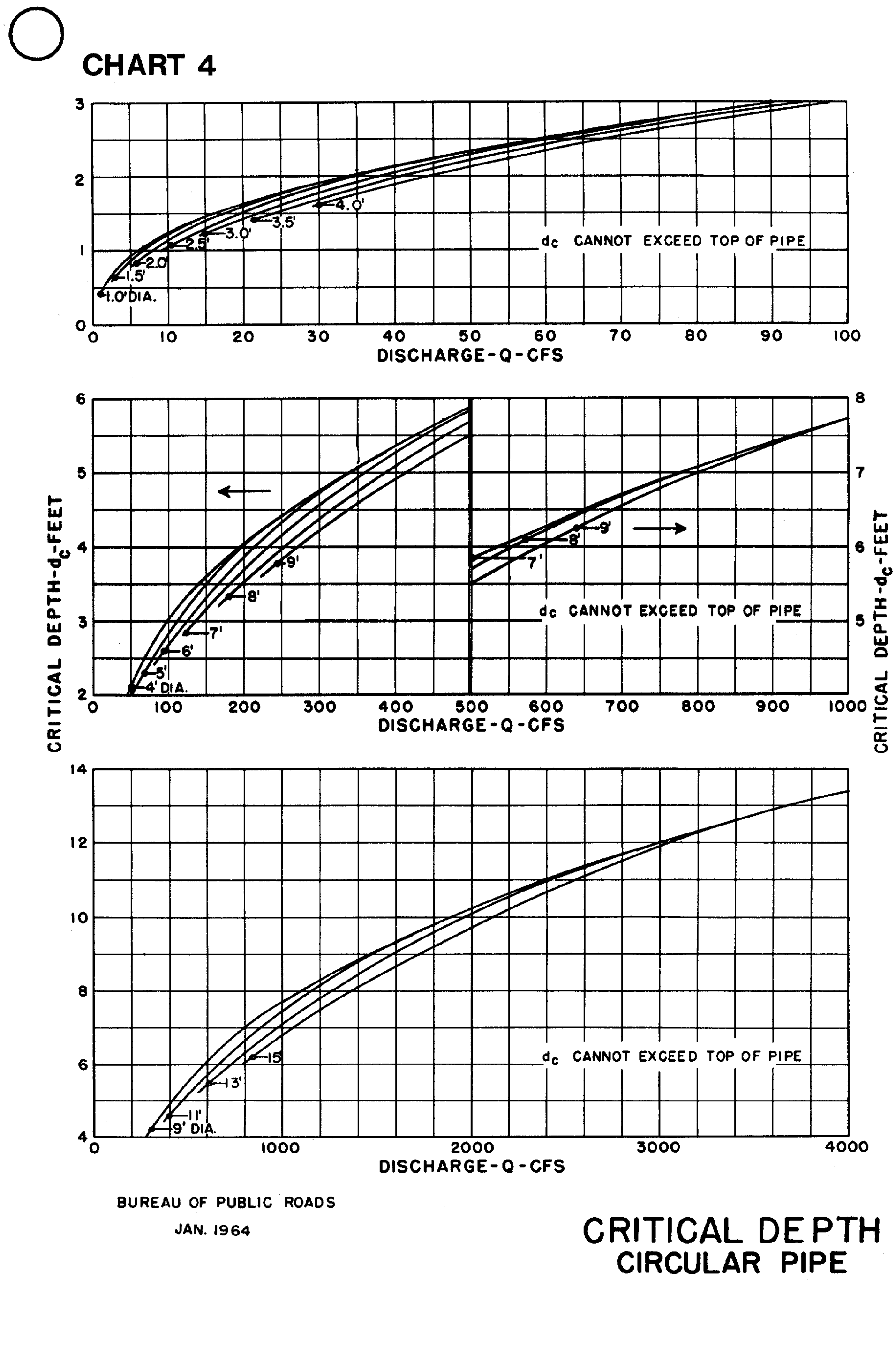
Richland County Design Chart No. 3



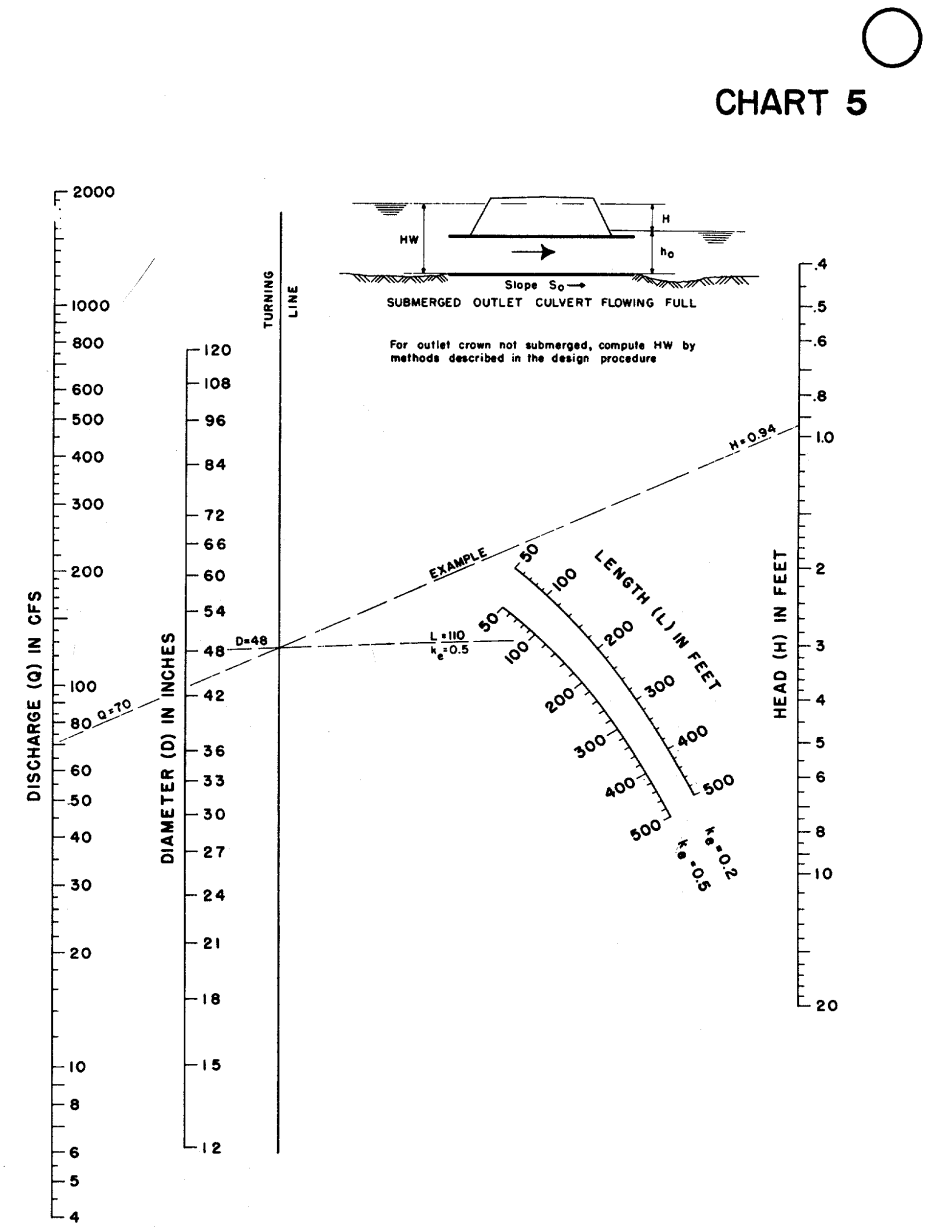
Richland County Design Chart No. 4



Richland County Design Chart No. 5



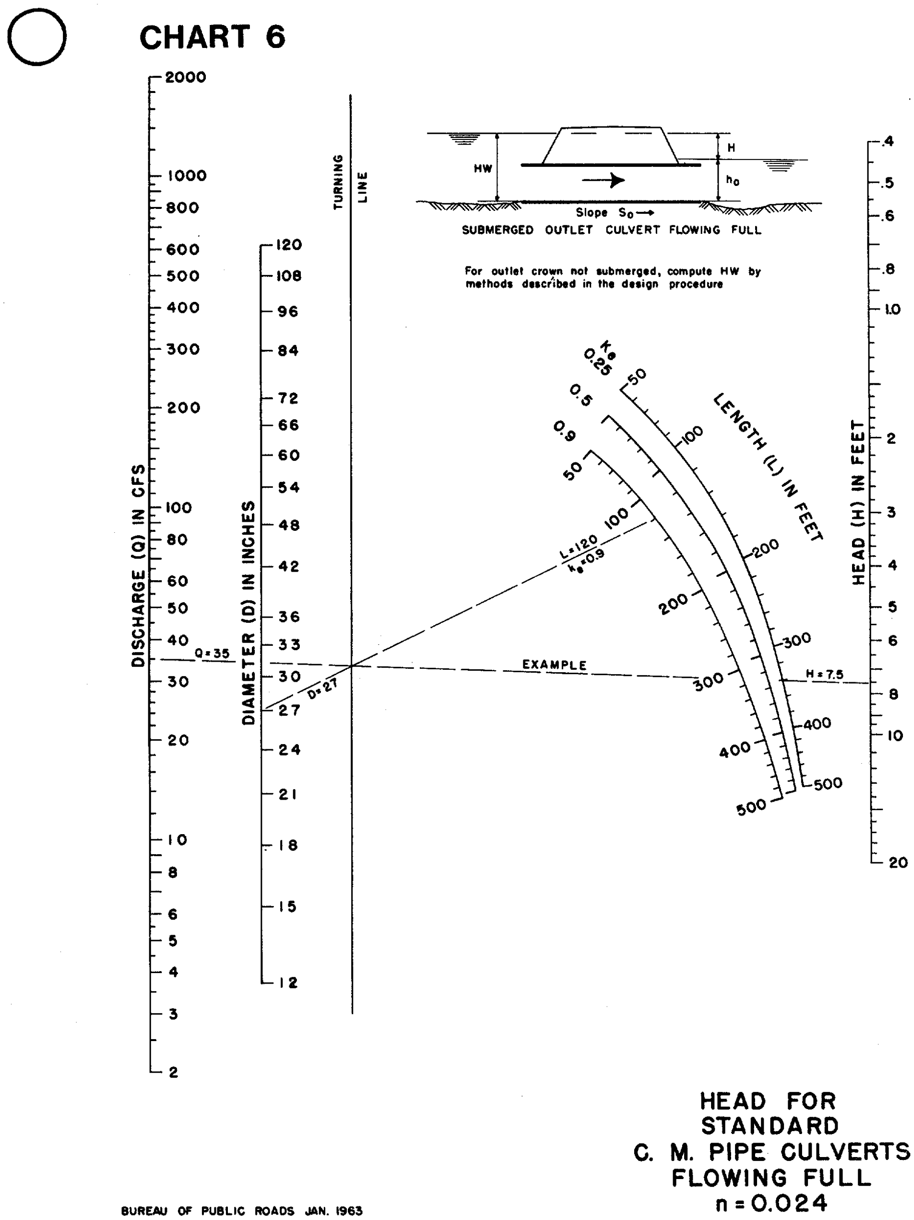
Richland County Design Chart No. 6



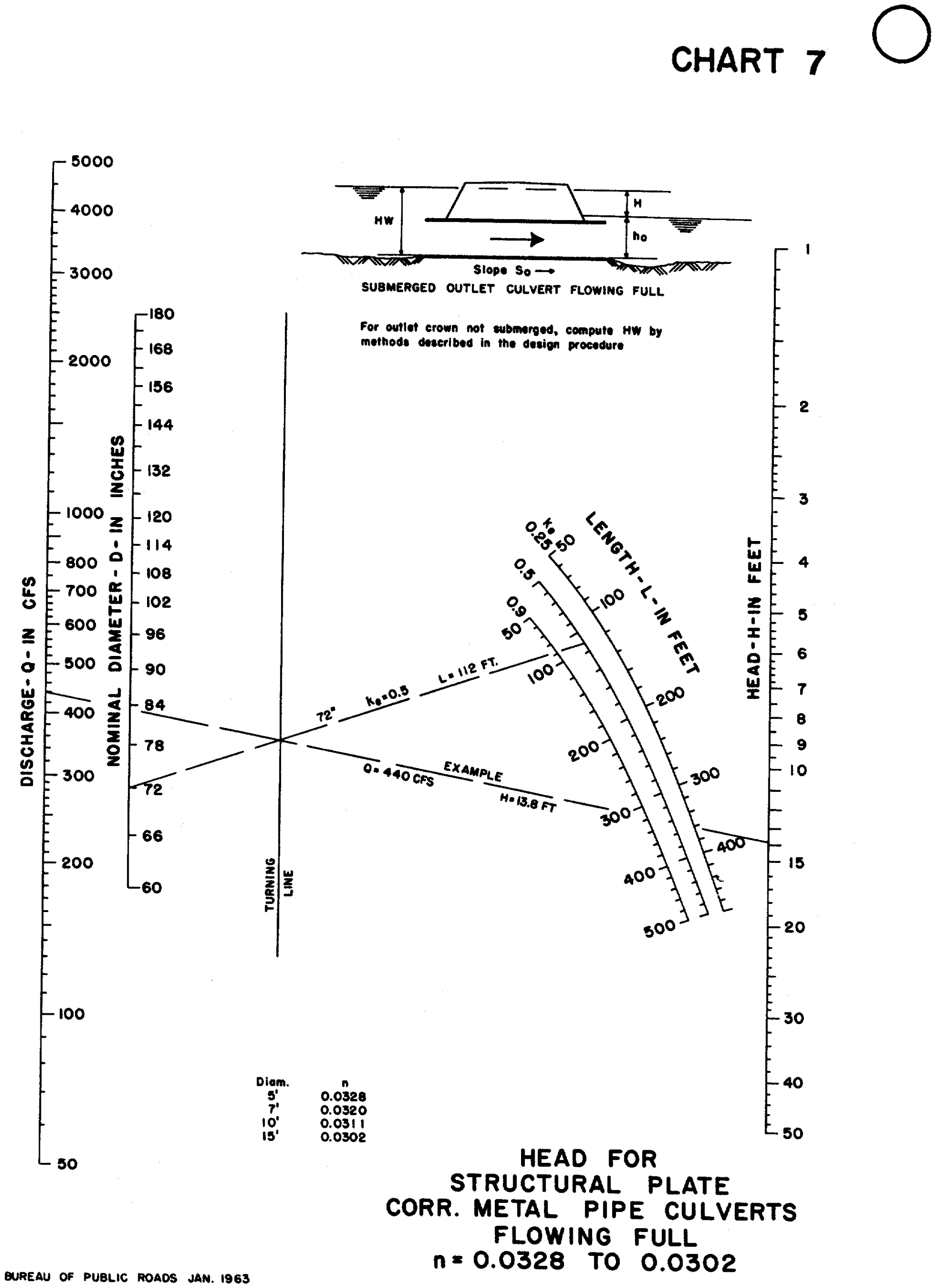
HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

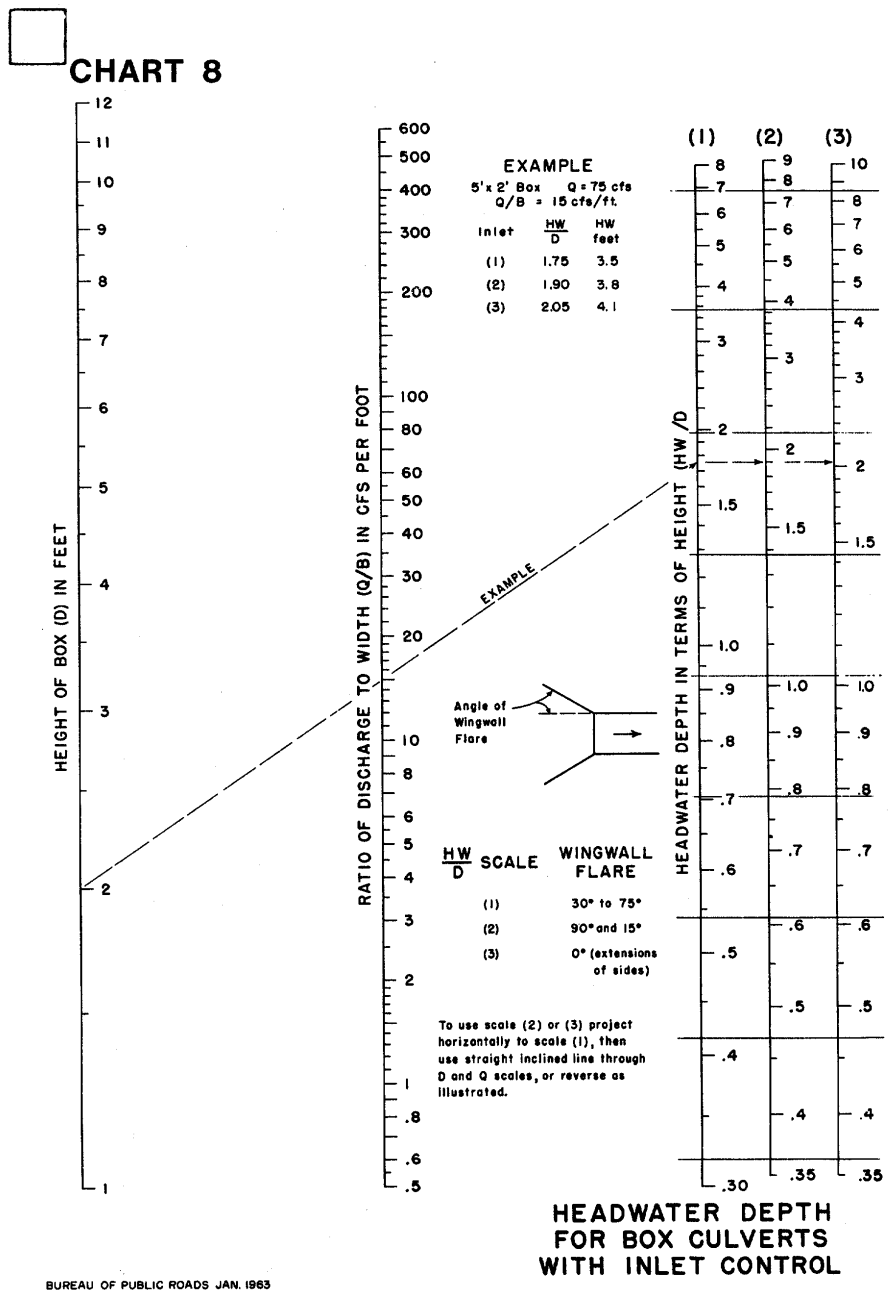
Richland County Design Chart No. 7



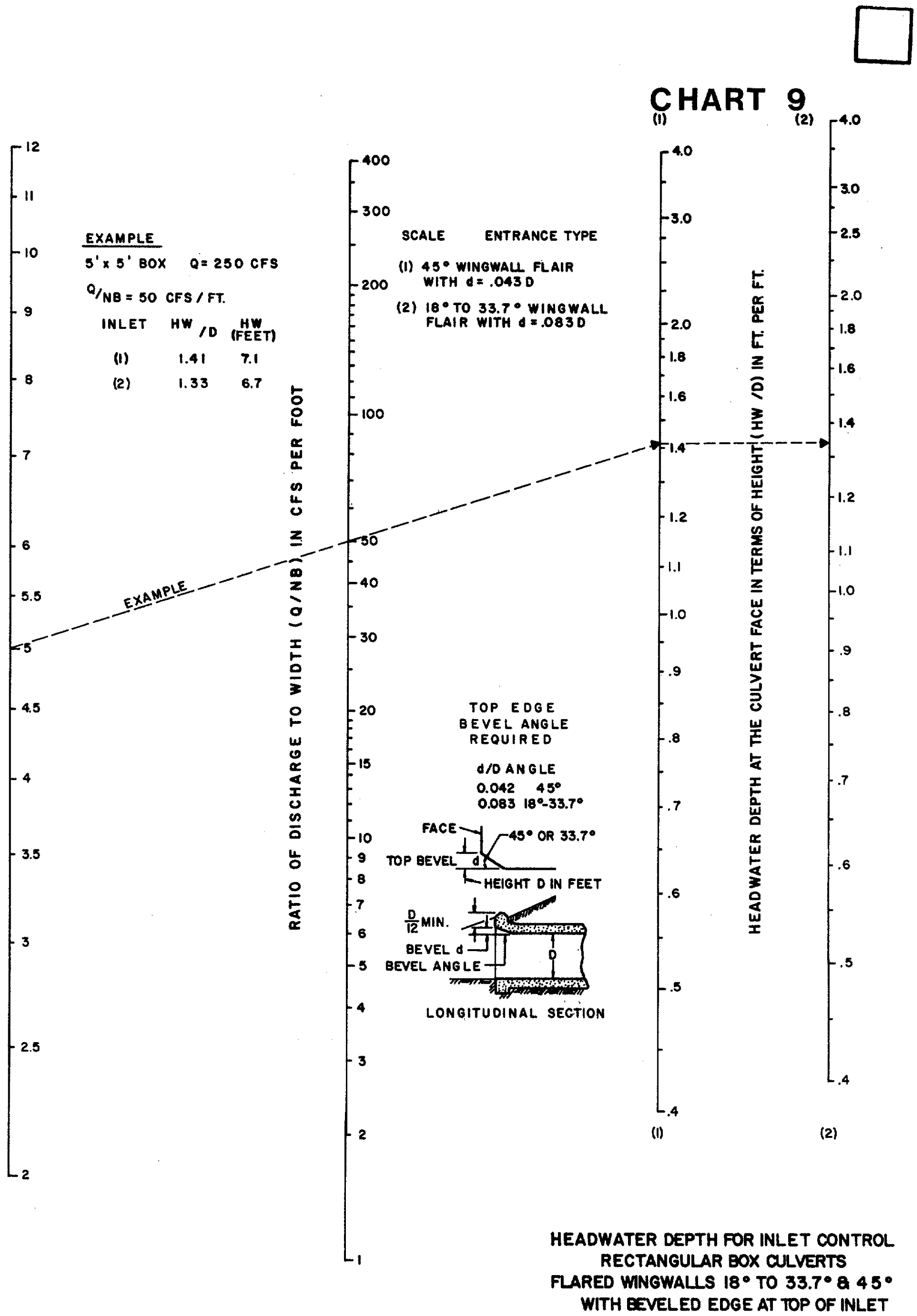
Richland County Design Chart No. 8



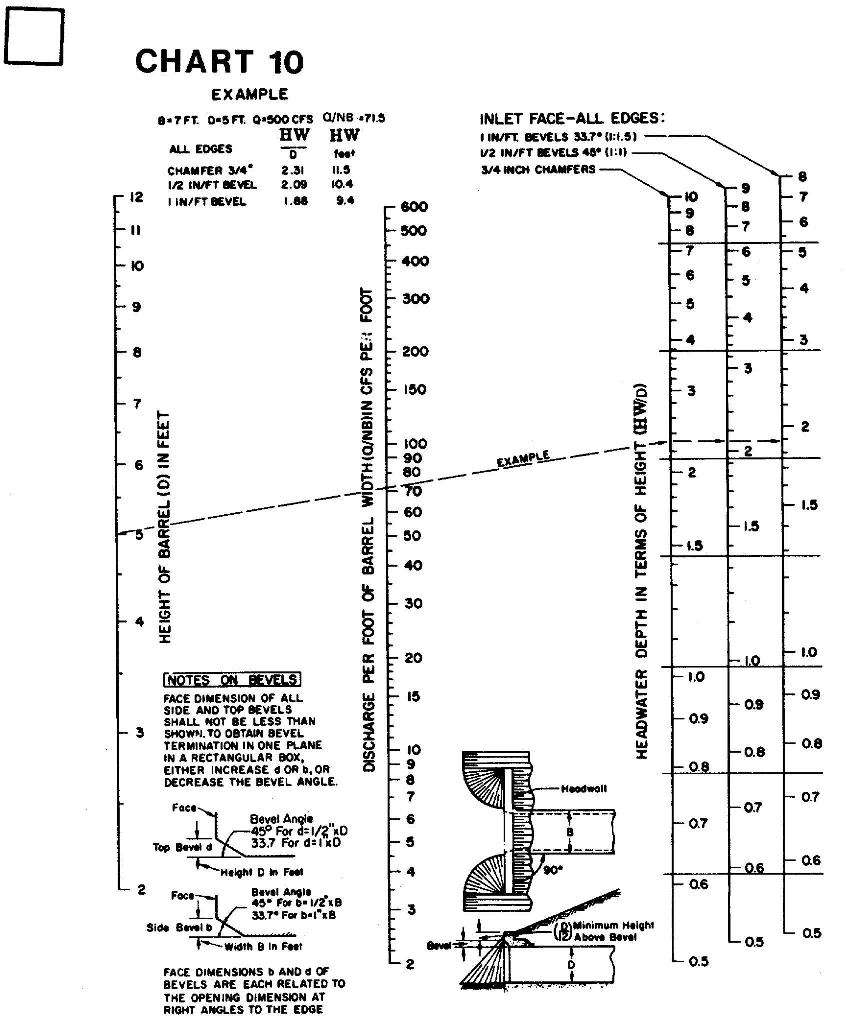
Richland County Design Chart No. 9



Richland County Design Chart No. 10



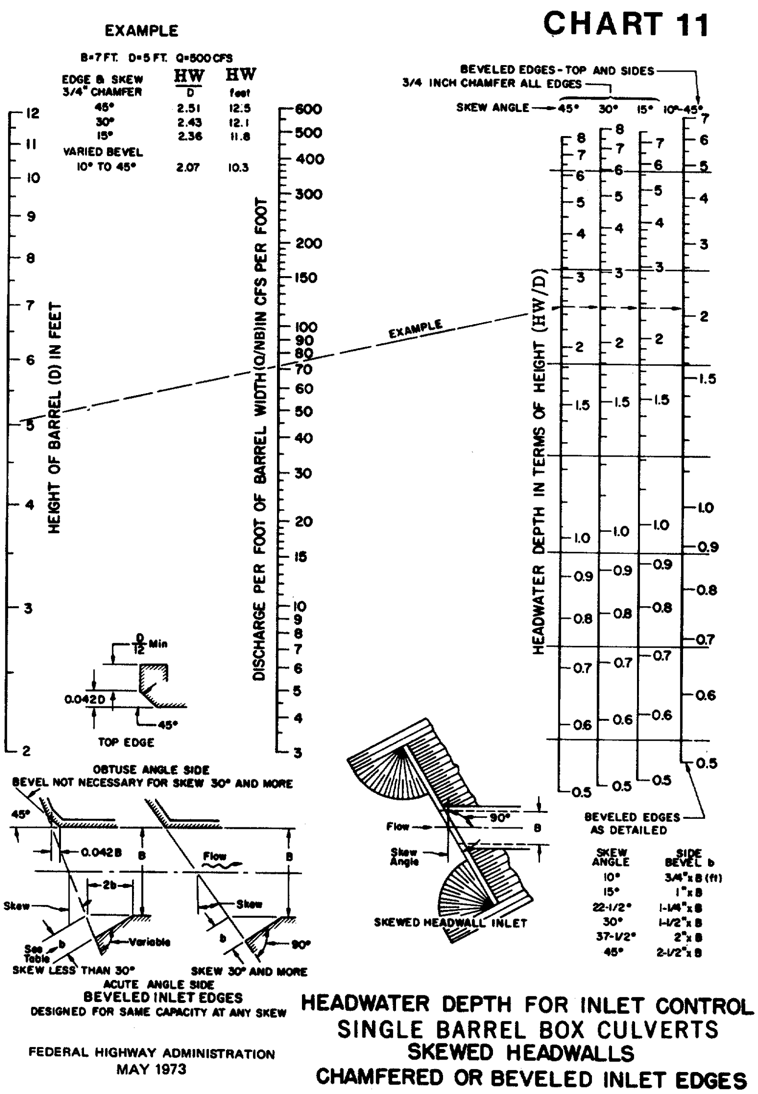
Richland County Design Chart No. 11



HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
90° HEADWALL
CHAMFERED OR BEVELED INLET EDGES

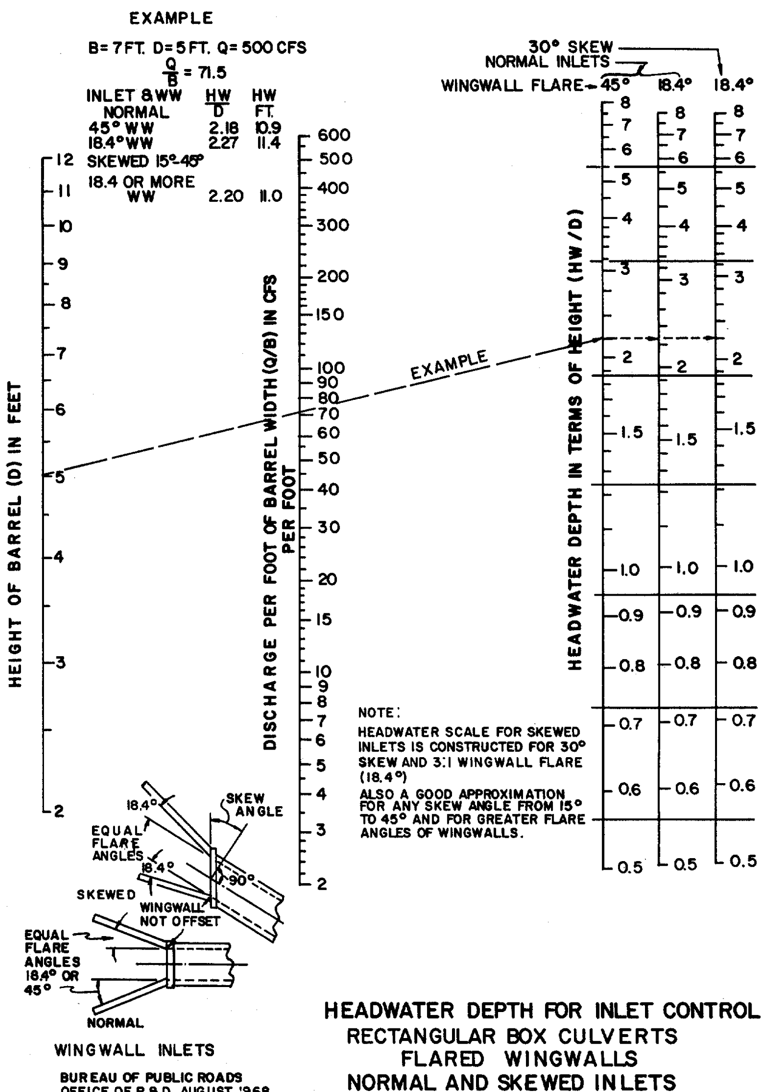
FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

Richland County Design Chart No. 12



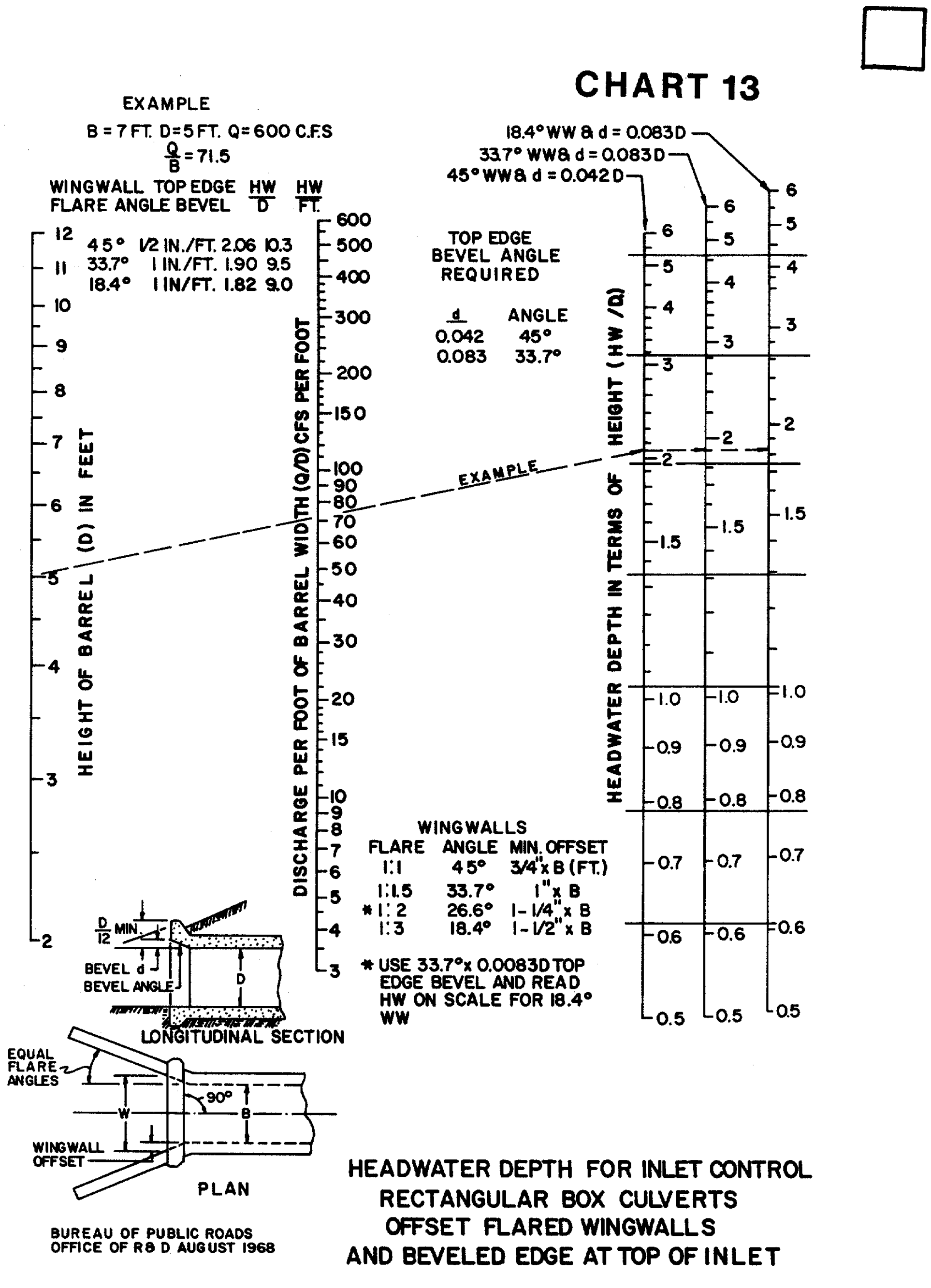
Richland County Design Chart No. 13

CHART 12



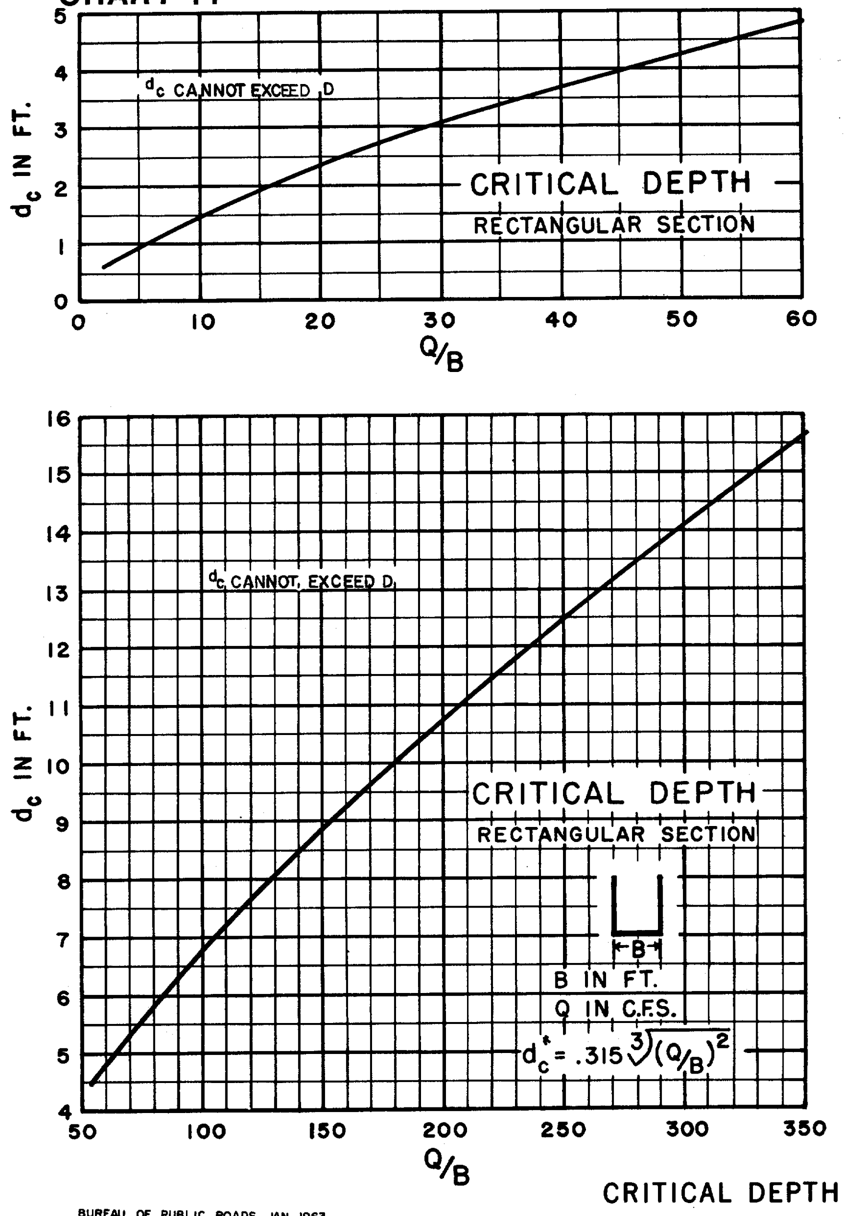
HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS
NORMAL AND SKEWED INLETS
3/4" CHAMFER AT TOP OF OPENING

Richland County Design Chart No. 14



Richland County Design Chart No. 15

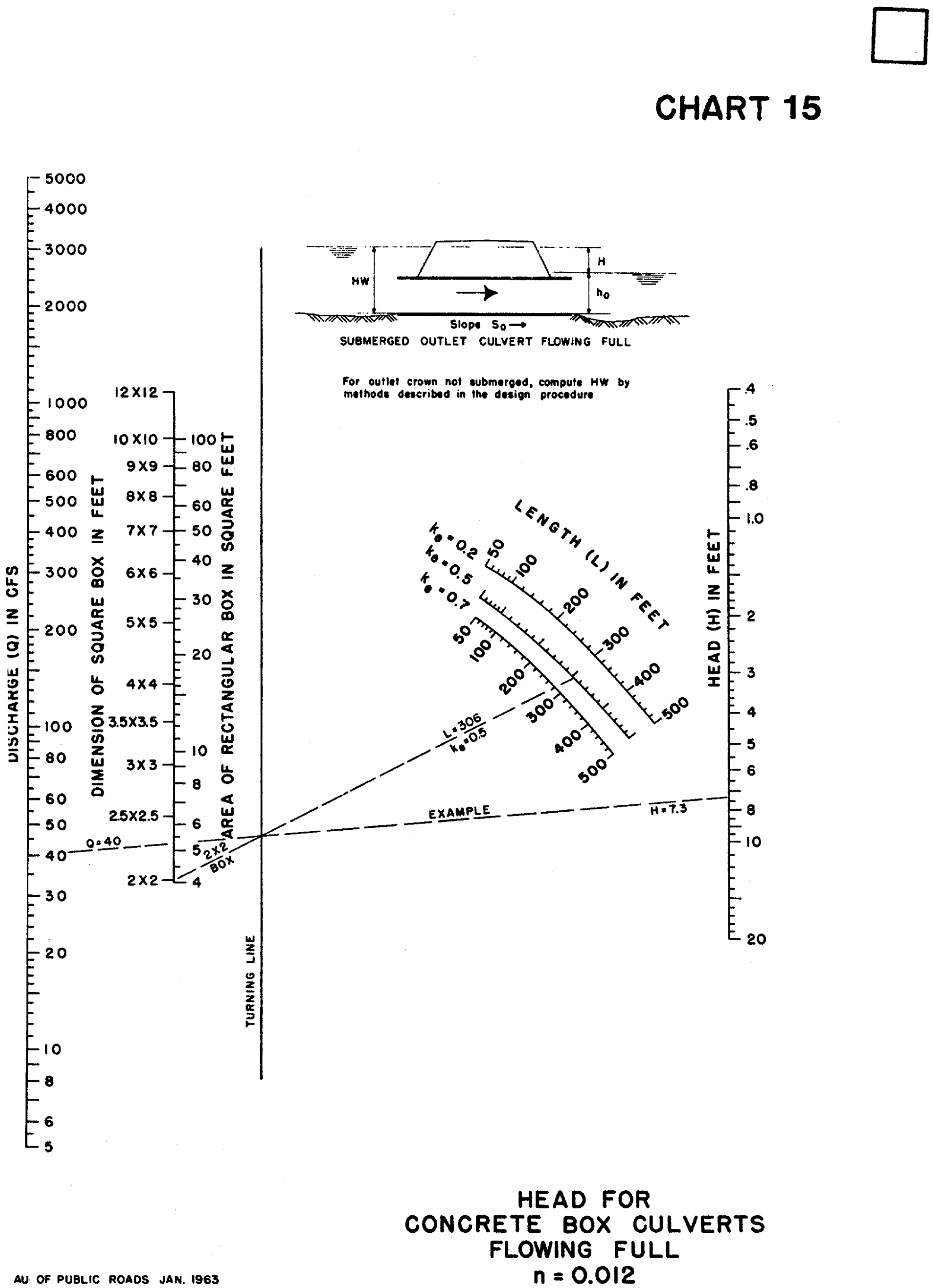
CHART 14



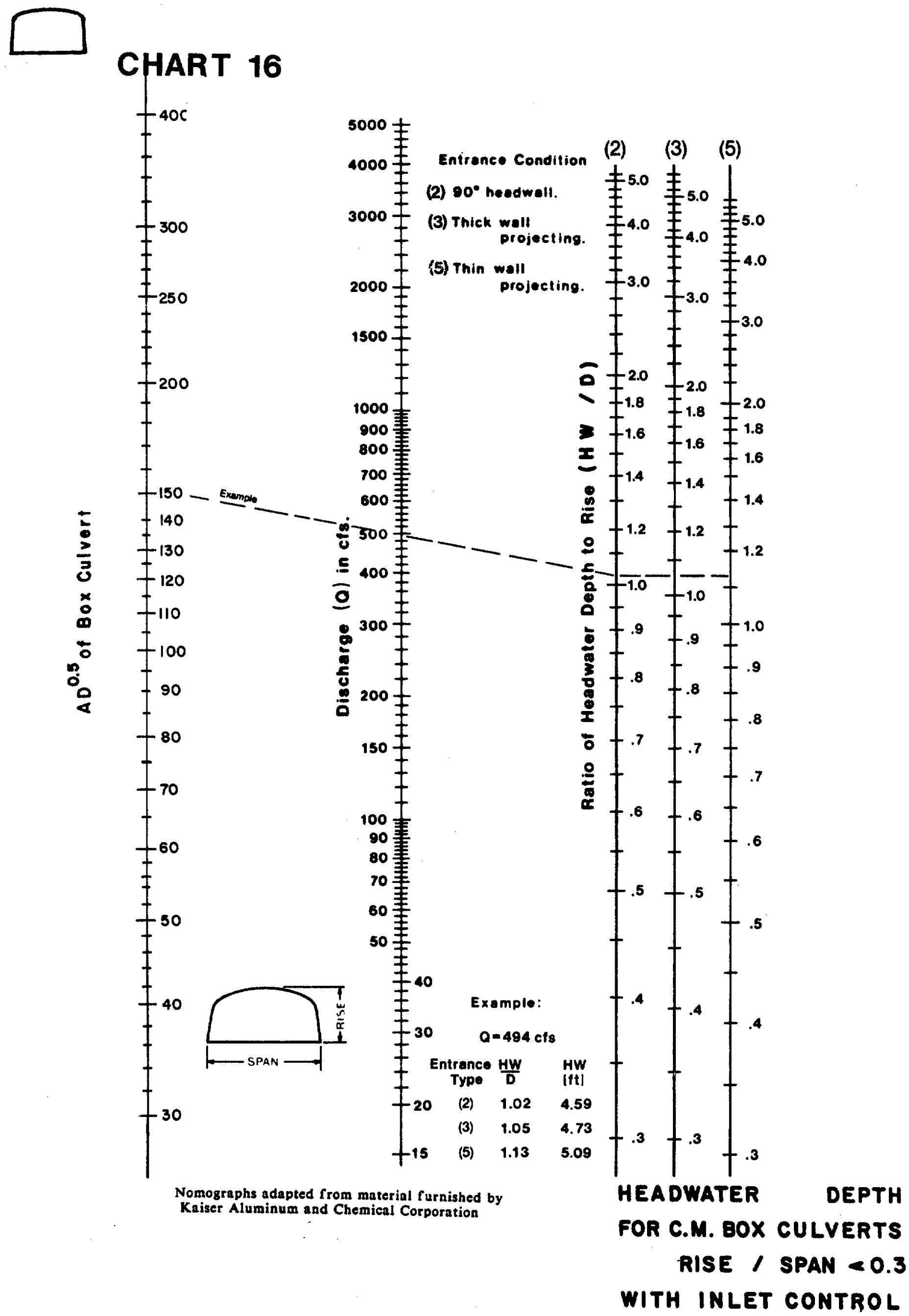
5-38

CRITICAL DEPTH
RECTANGULAR SECTION

Richland County Design Chart No. 16



Richland County Design Chart No. 17



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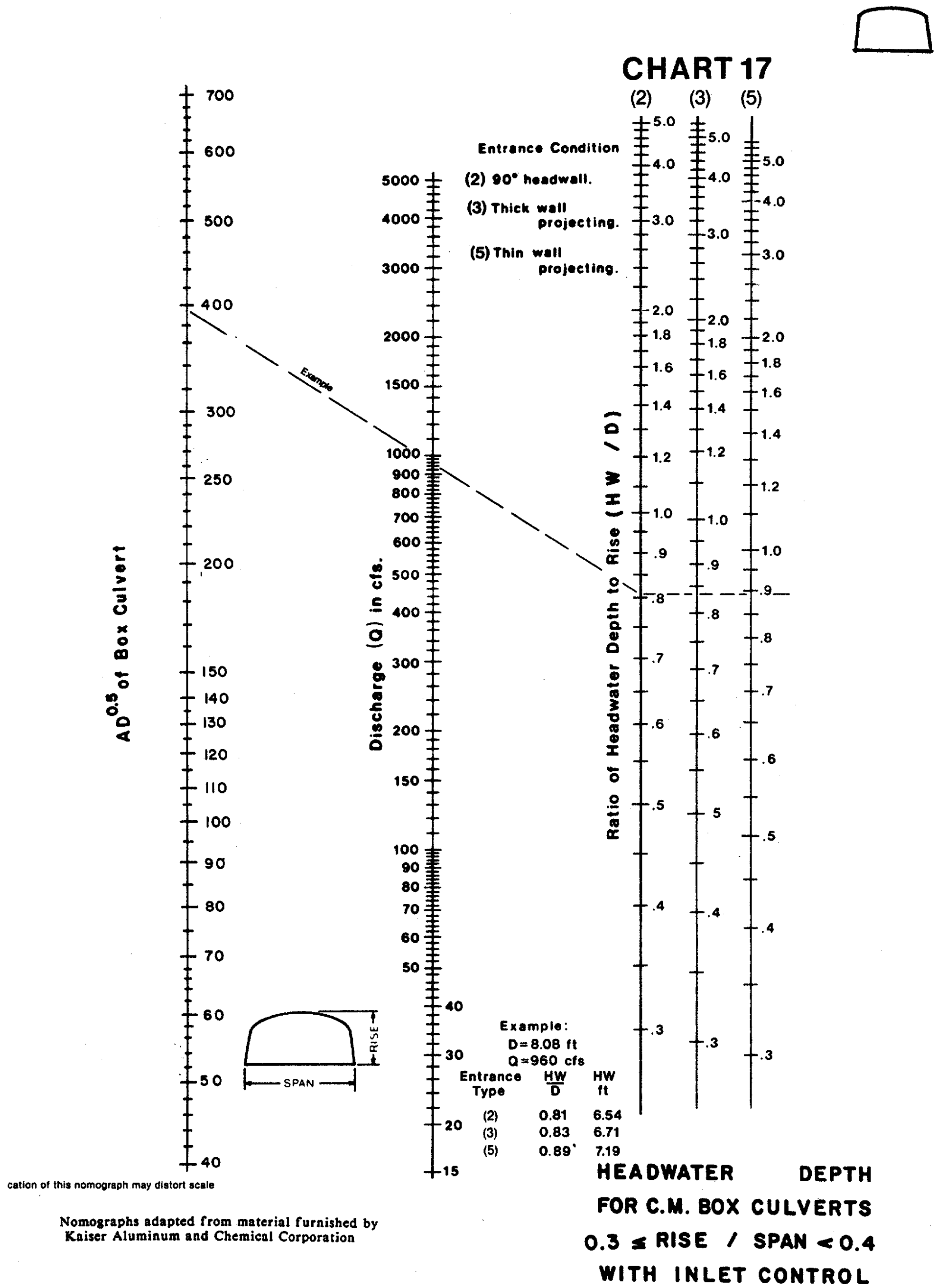

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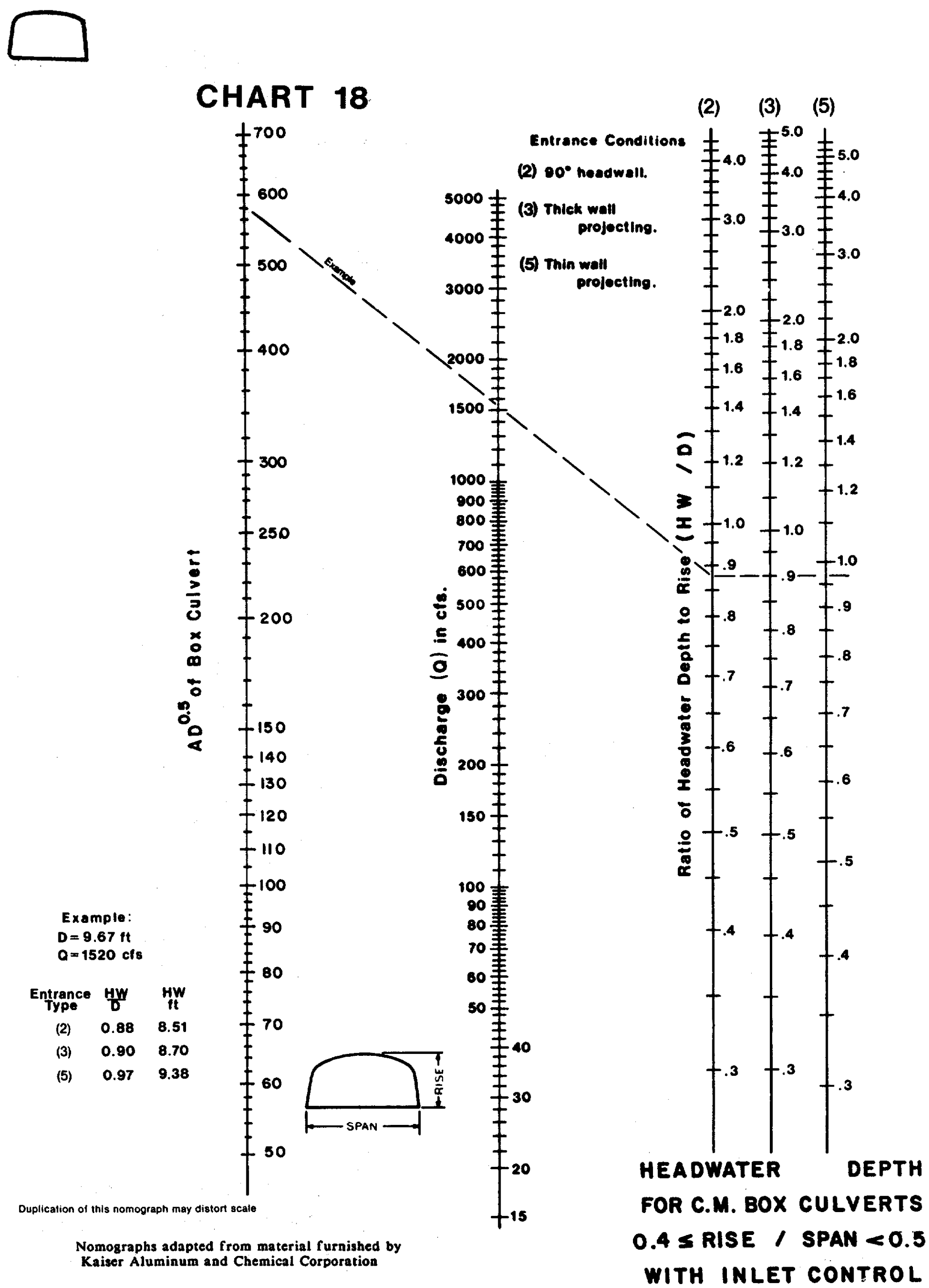
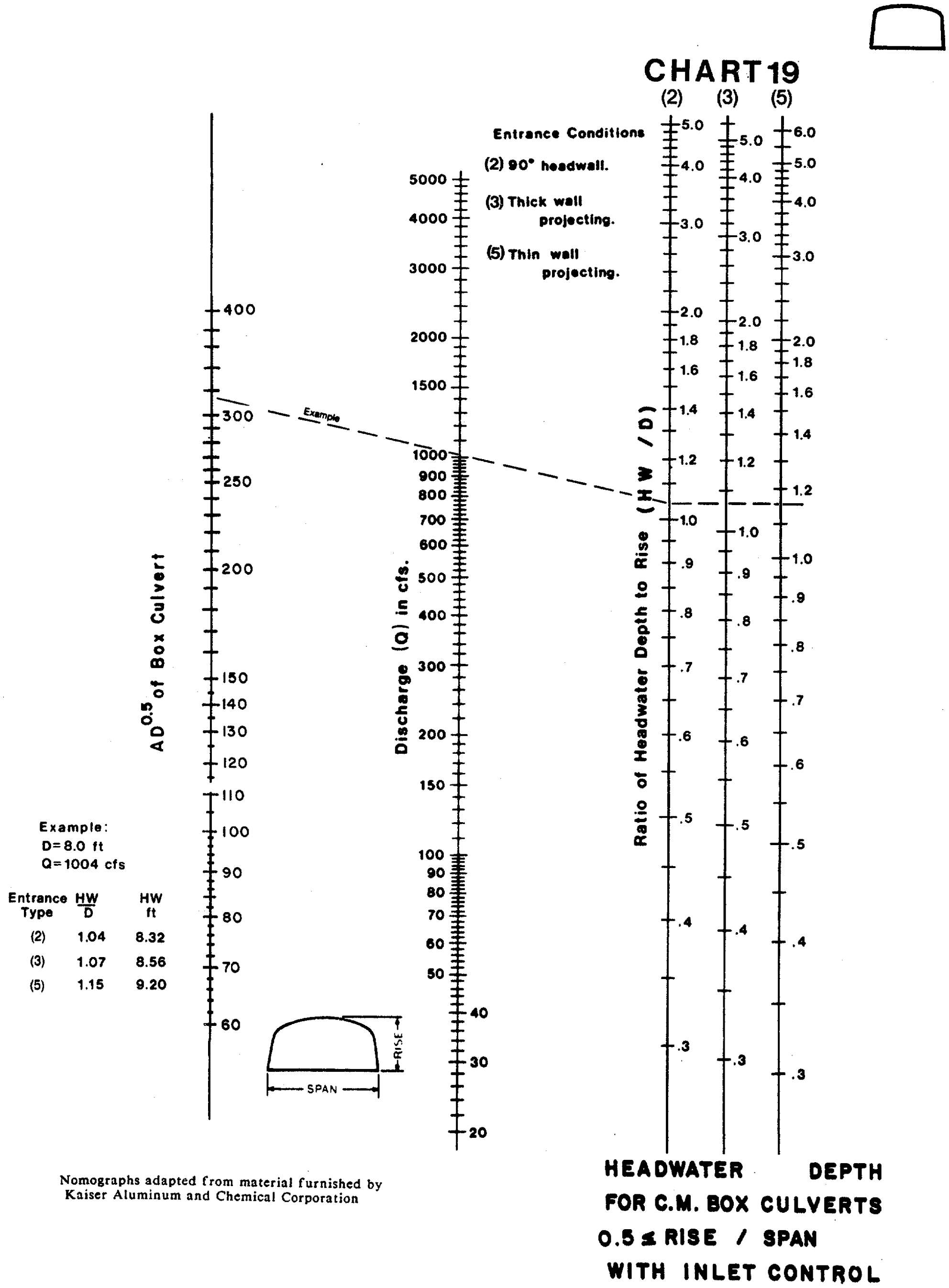
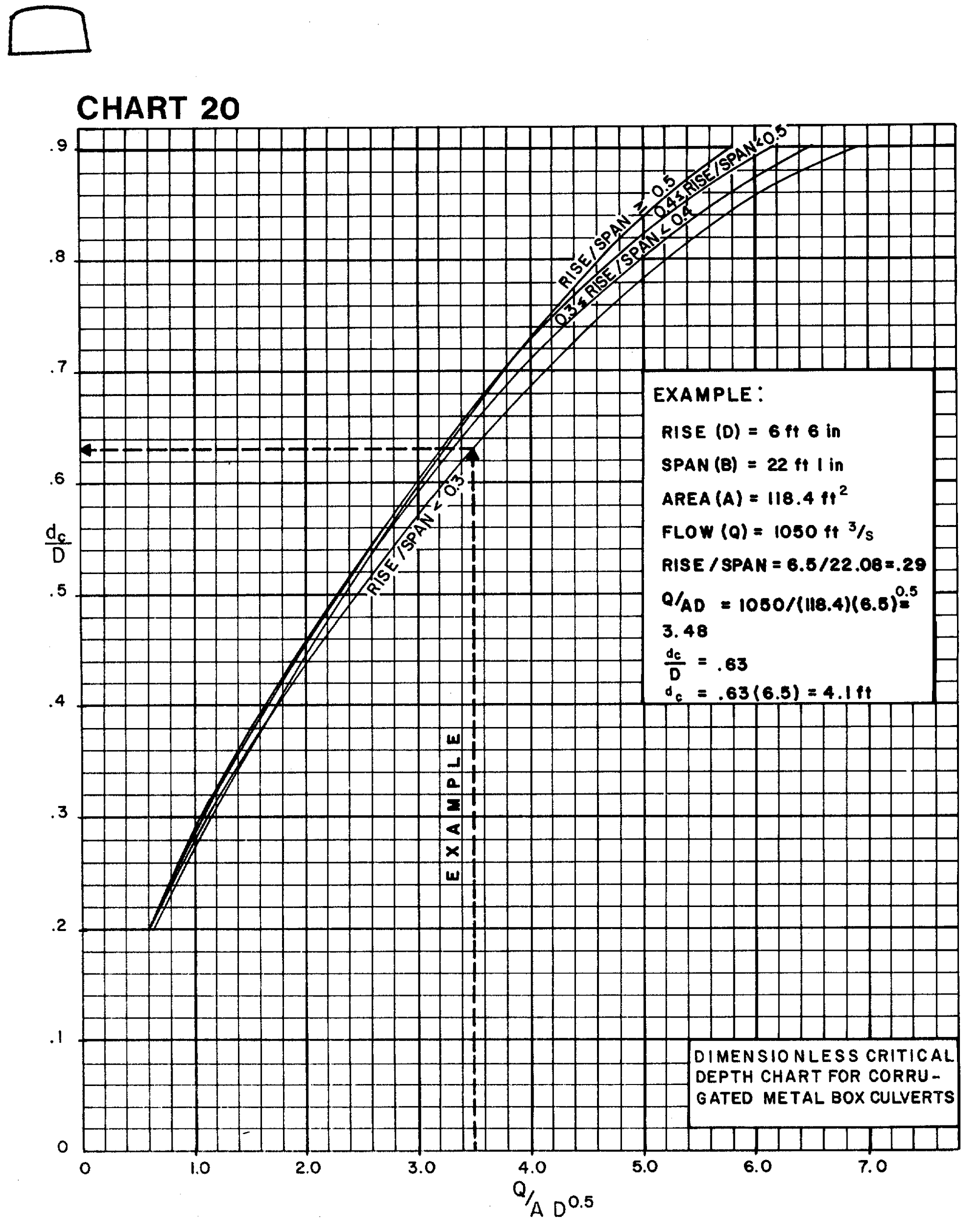


Richland County Design Chart No. 20



Richland County Design Chart No. 21



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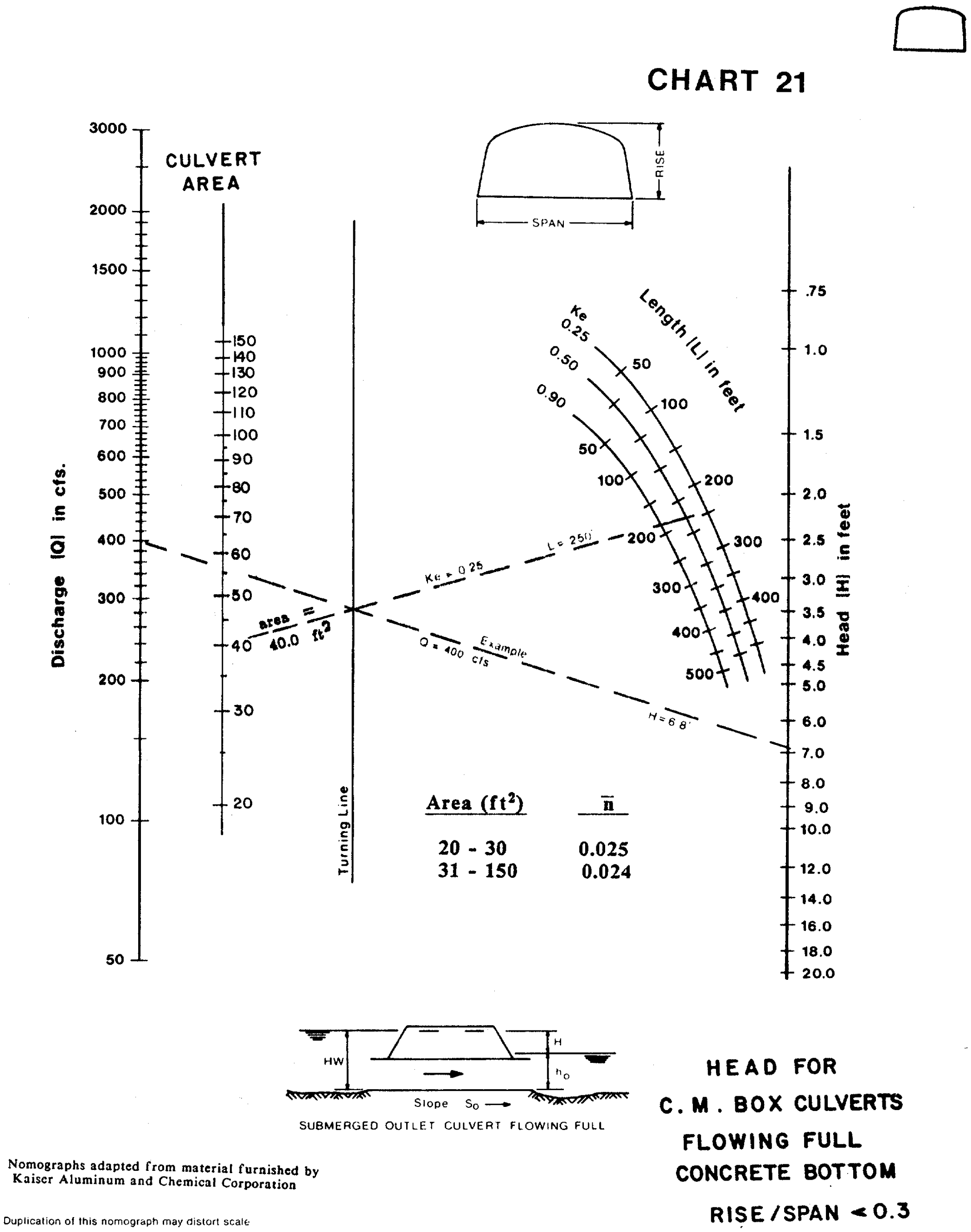
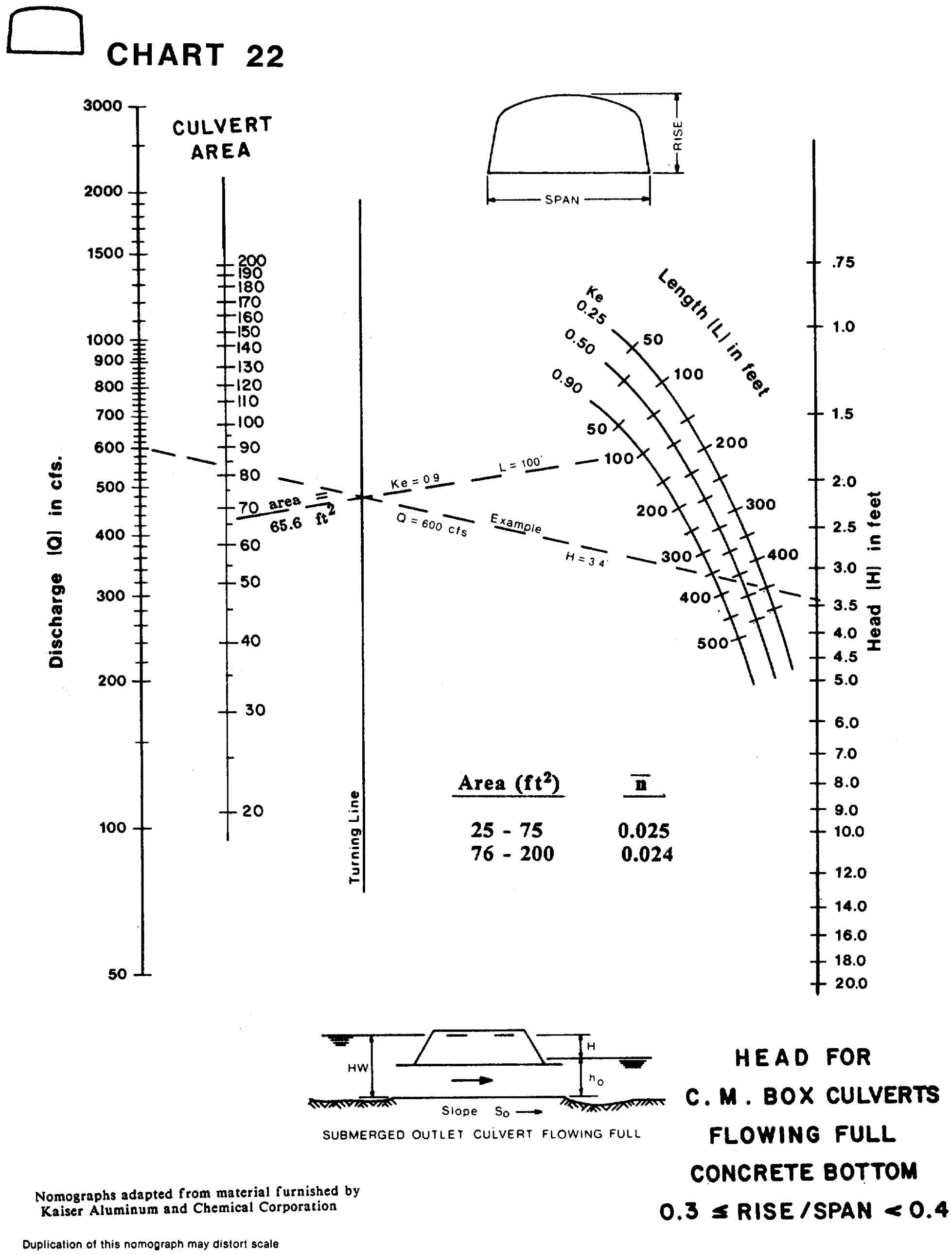
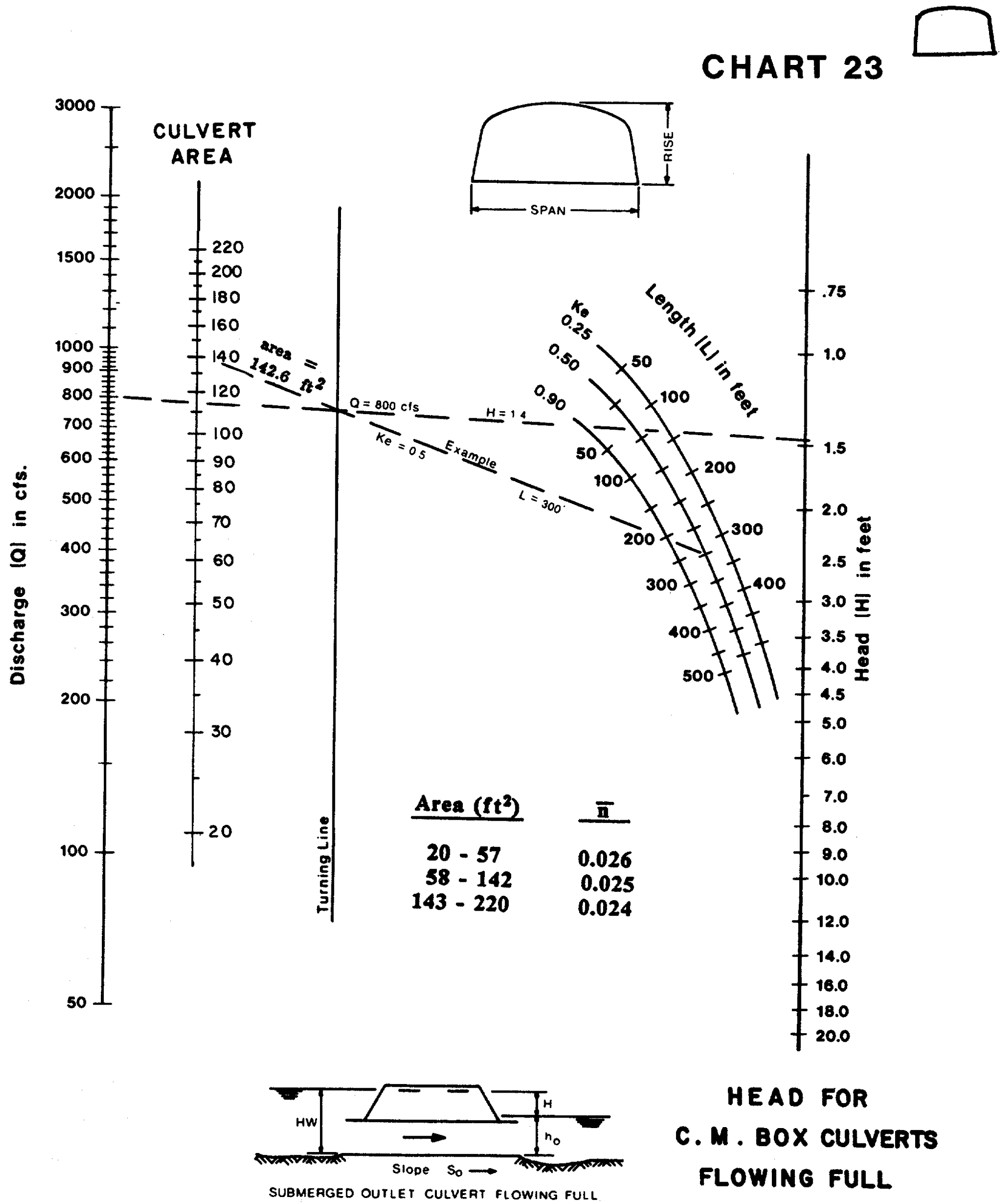


Richland County Design Chart No. 23



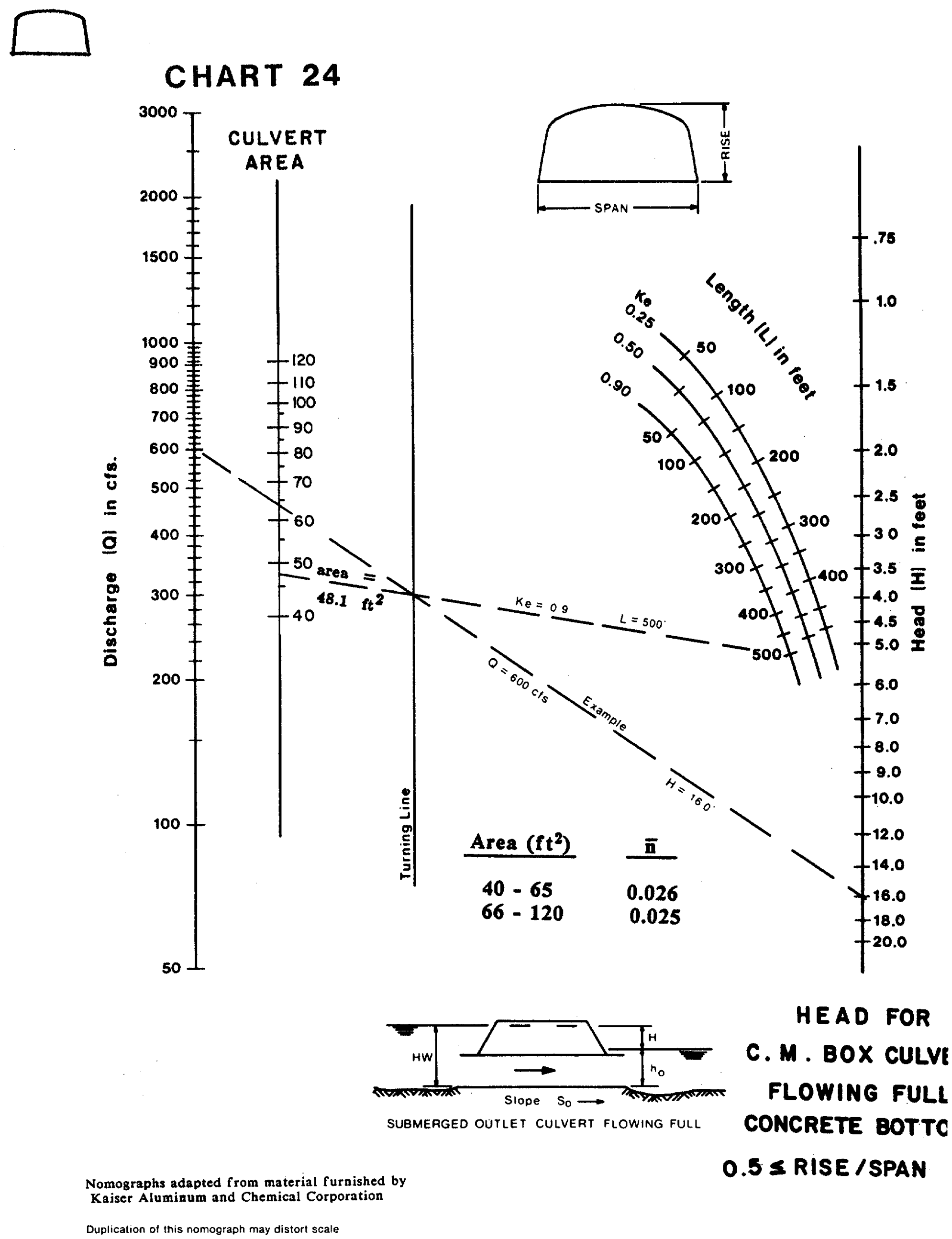
Richland County Design Chart No. 24



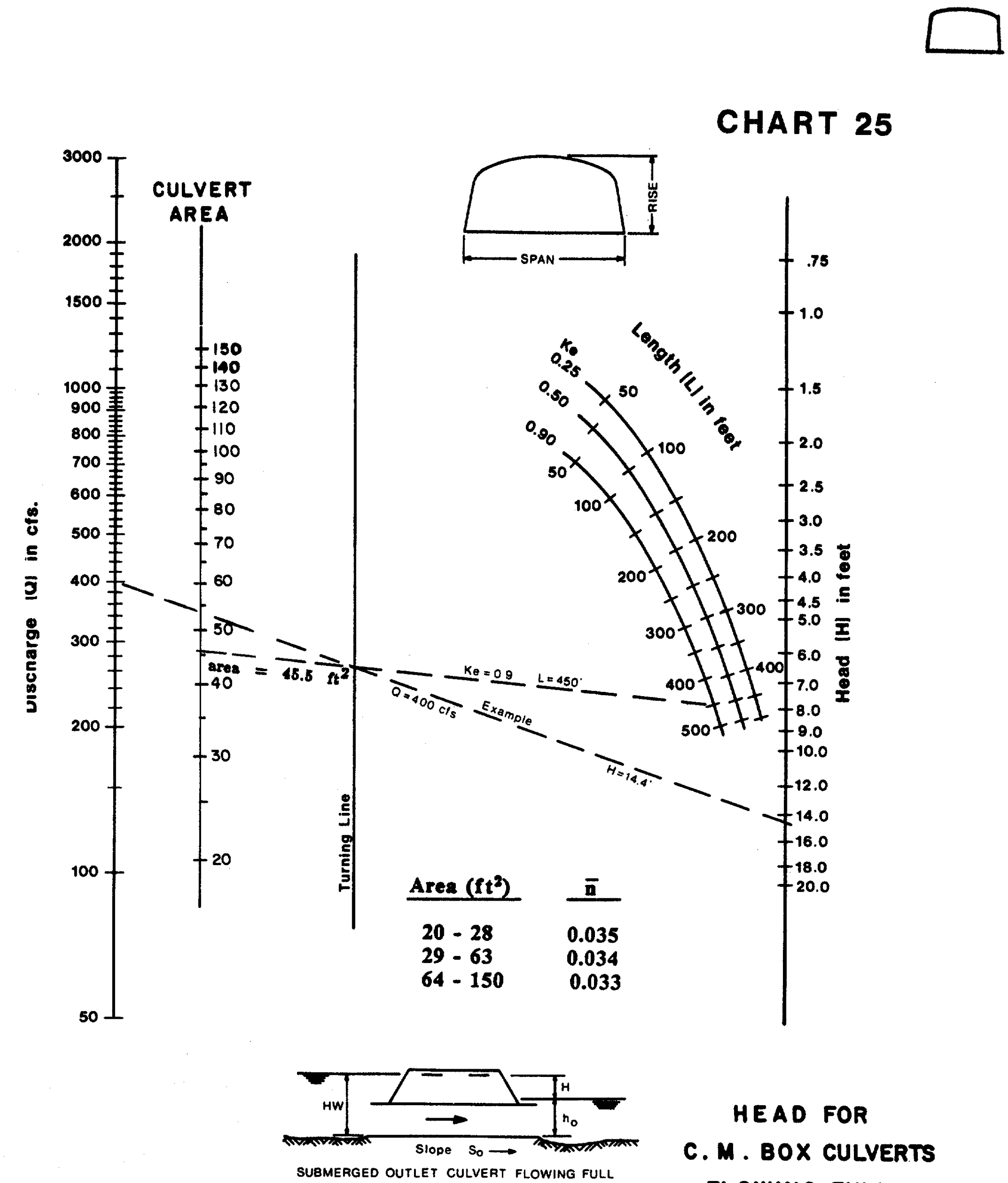
Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

Richland County Design Chart No. 25



Richland County Design Chart No. 26

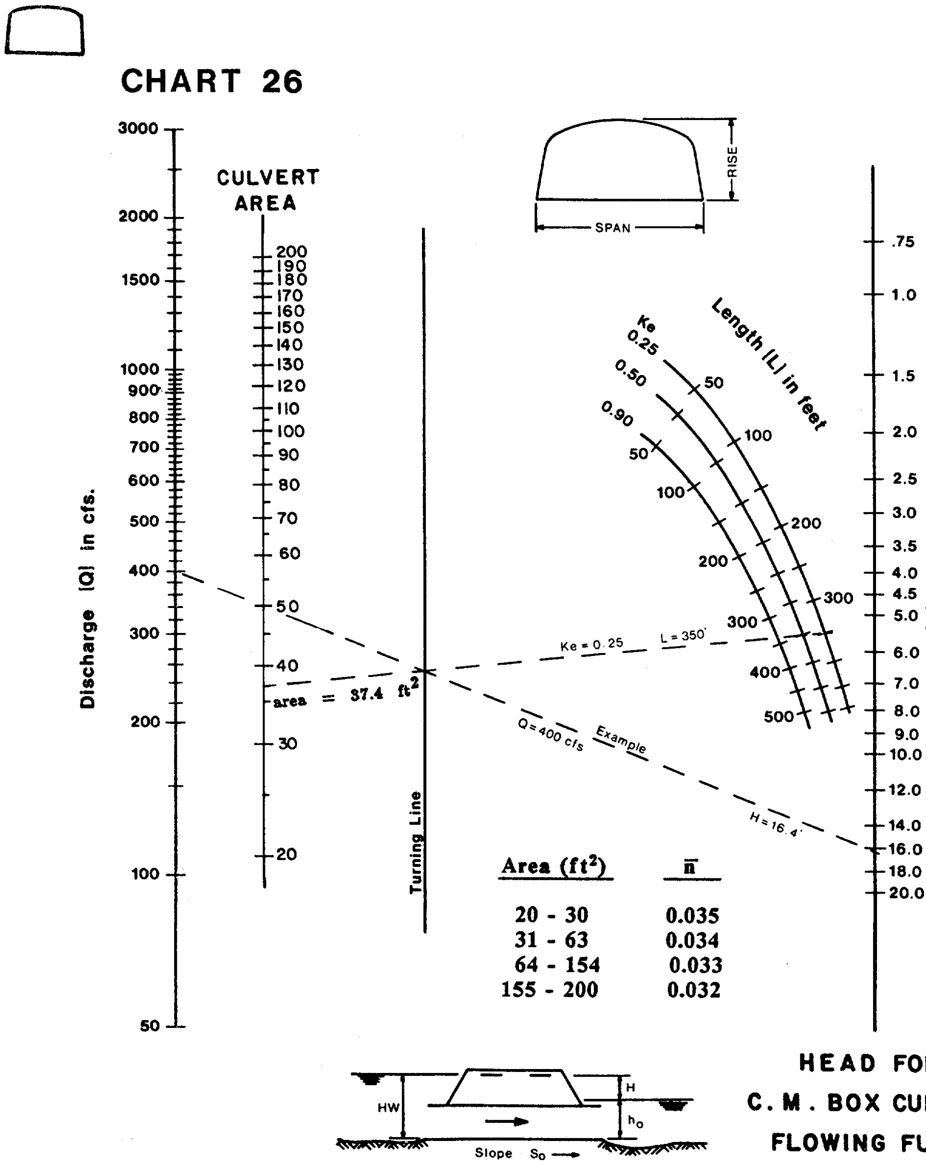


HEAD FOR
C. M. BOX CULVERTS
FLOWING FULL
CORRUGATED METAL BOTTOM
RISE/SPAN < 0.3

.raphs adapted from material furnished by
r Aluminum and Chemical Corporation

ion of this nomograph may distort scale

Richland County Design Chart No. 27



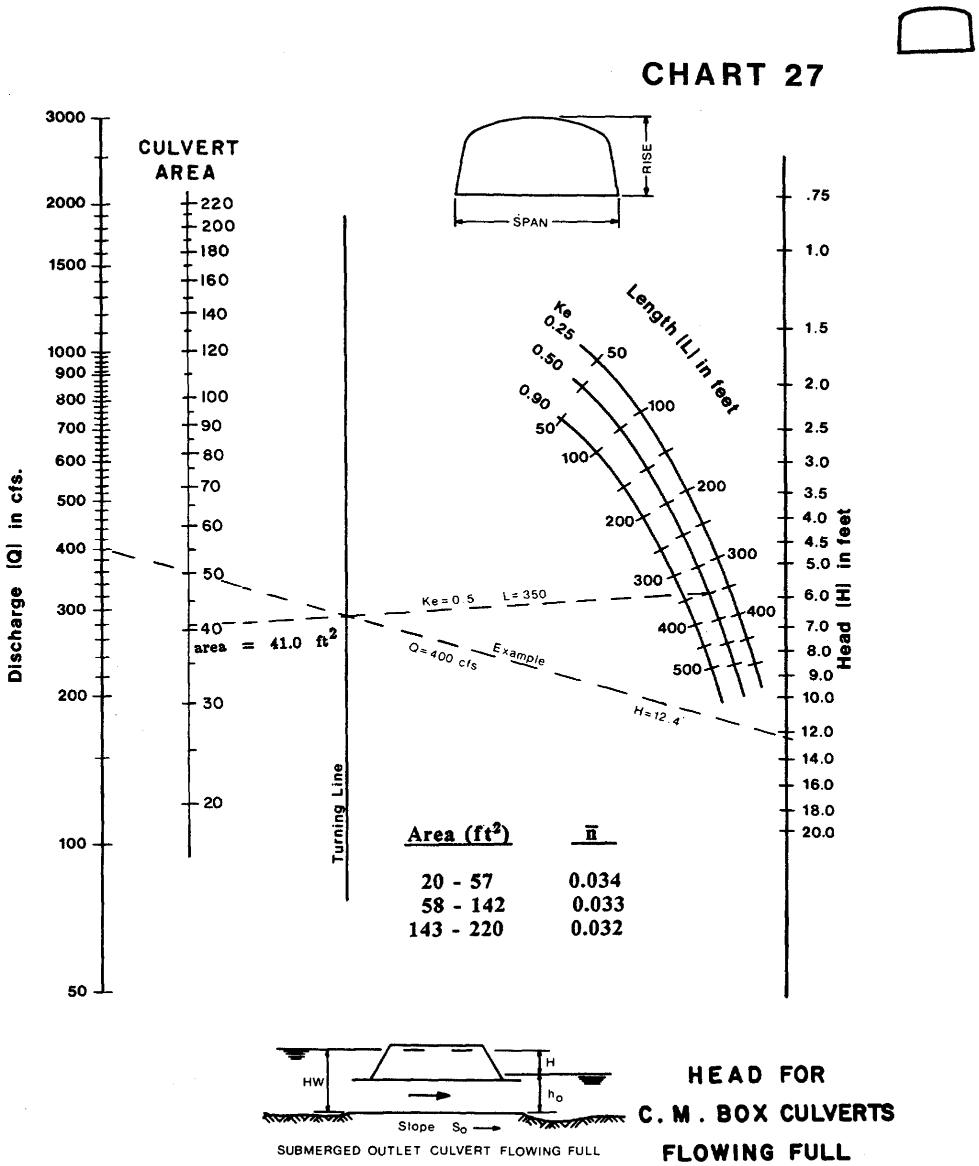
Area (ft²)	n
20 - 30	0.035
31 - 63	0.034
64 - 154	0.033
155 - 200	0.032

HEAD FOR C. M. BOX CULVERTS FLOWING FULL CORRUGATED METAL BOTTOM $0.3 \leq$ RISE/SPAN < 0.4

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

Richland County Design Chart No. 28



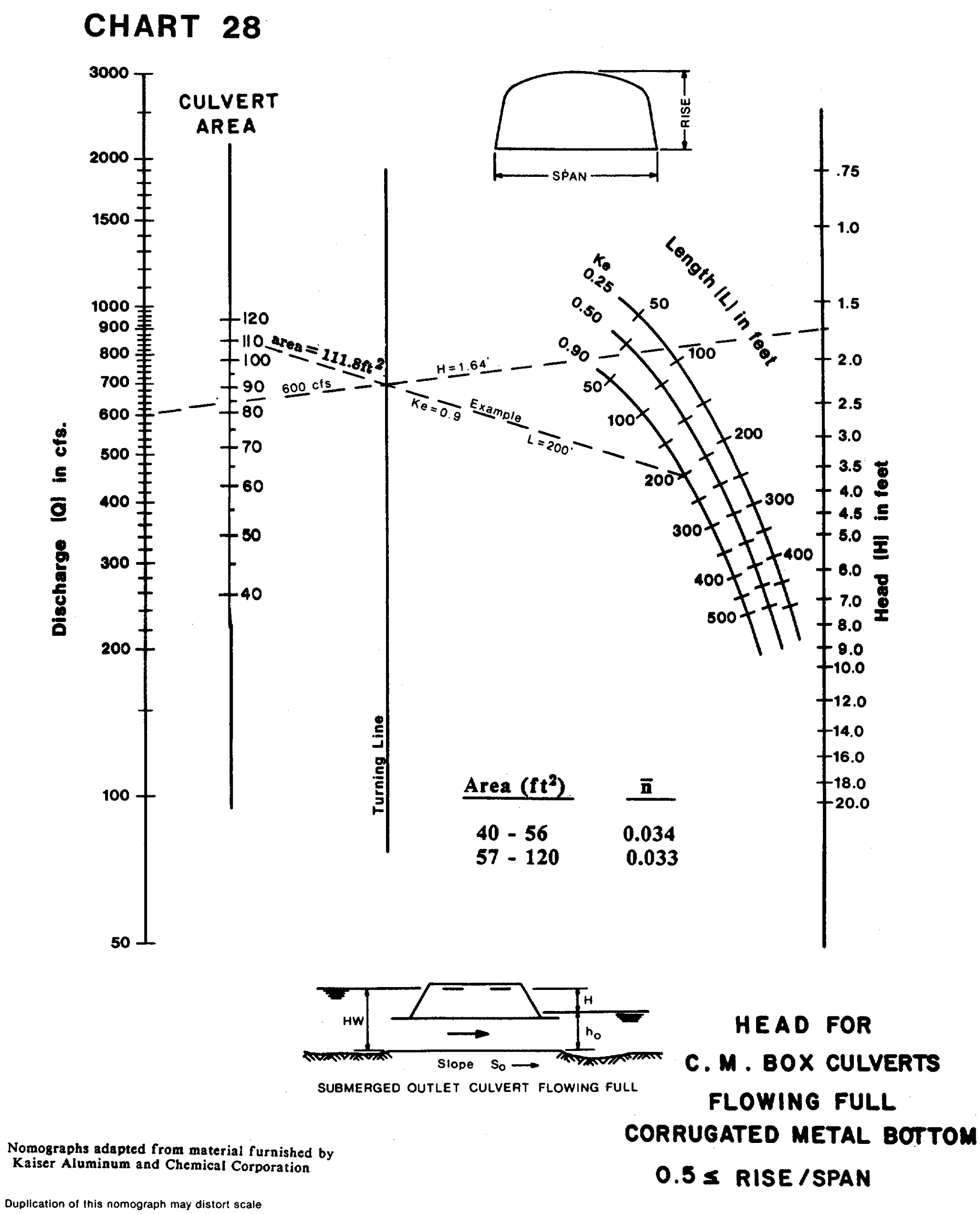
Area (ft²)	n
20 - 57	0.034
58 - 142	0.033
143 - 220	0.032

HEAD FOR C. M. BOX CULVERTS FLOWING FULL CORRUGATED METAL BOTTOM $0.4 \leq$ RISE/SPAN < 0.5

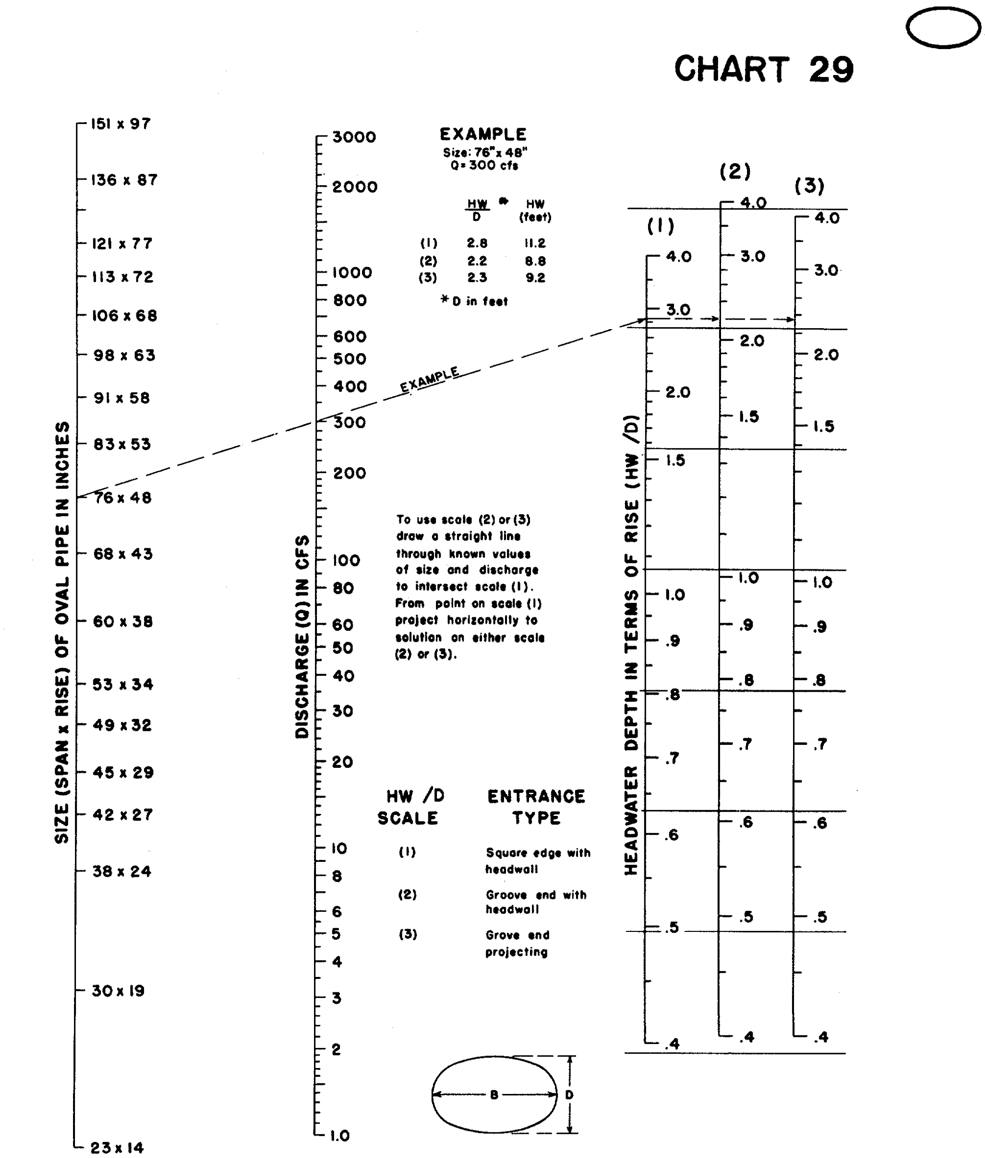
Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

Richland County Design Chart No. 29



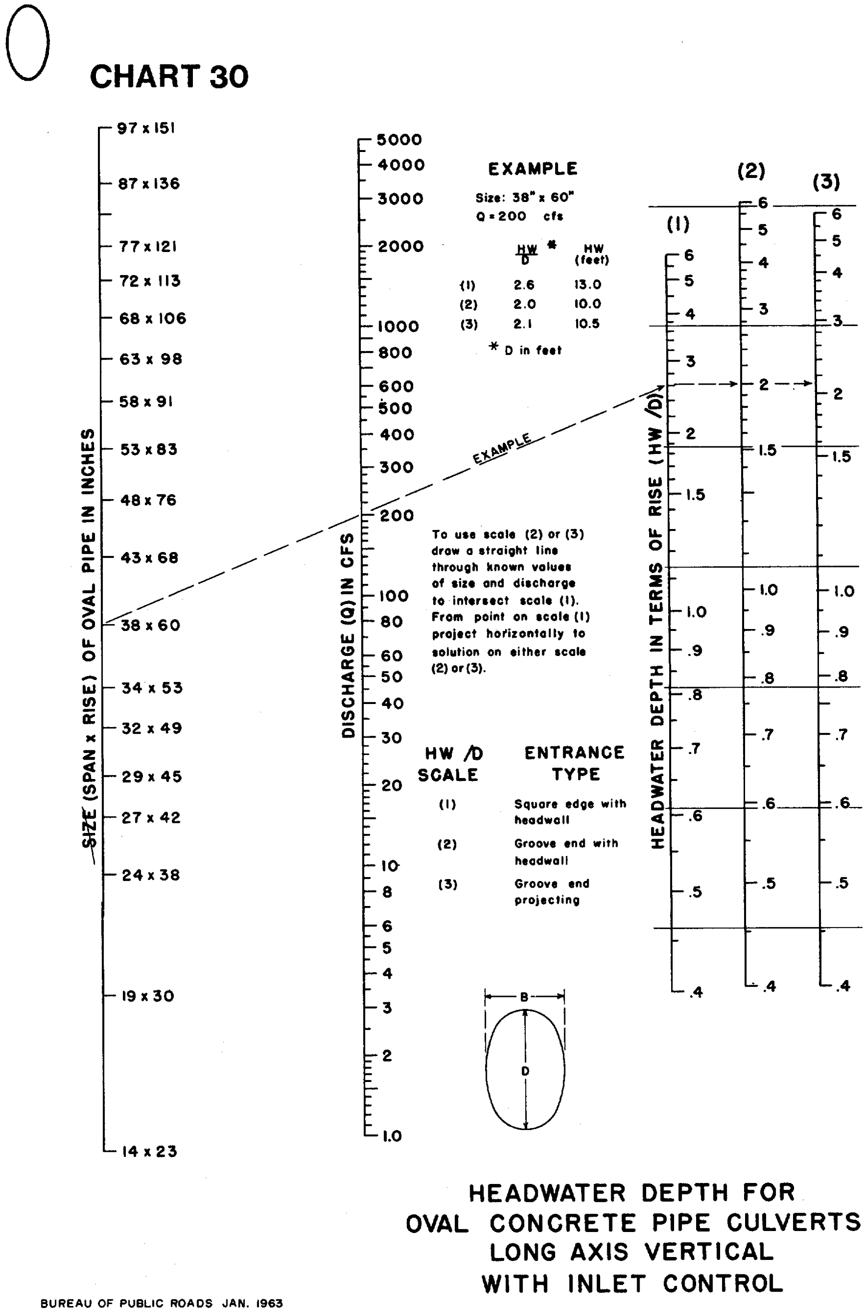
Richland County Design Chart No. 30



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

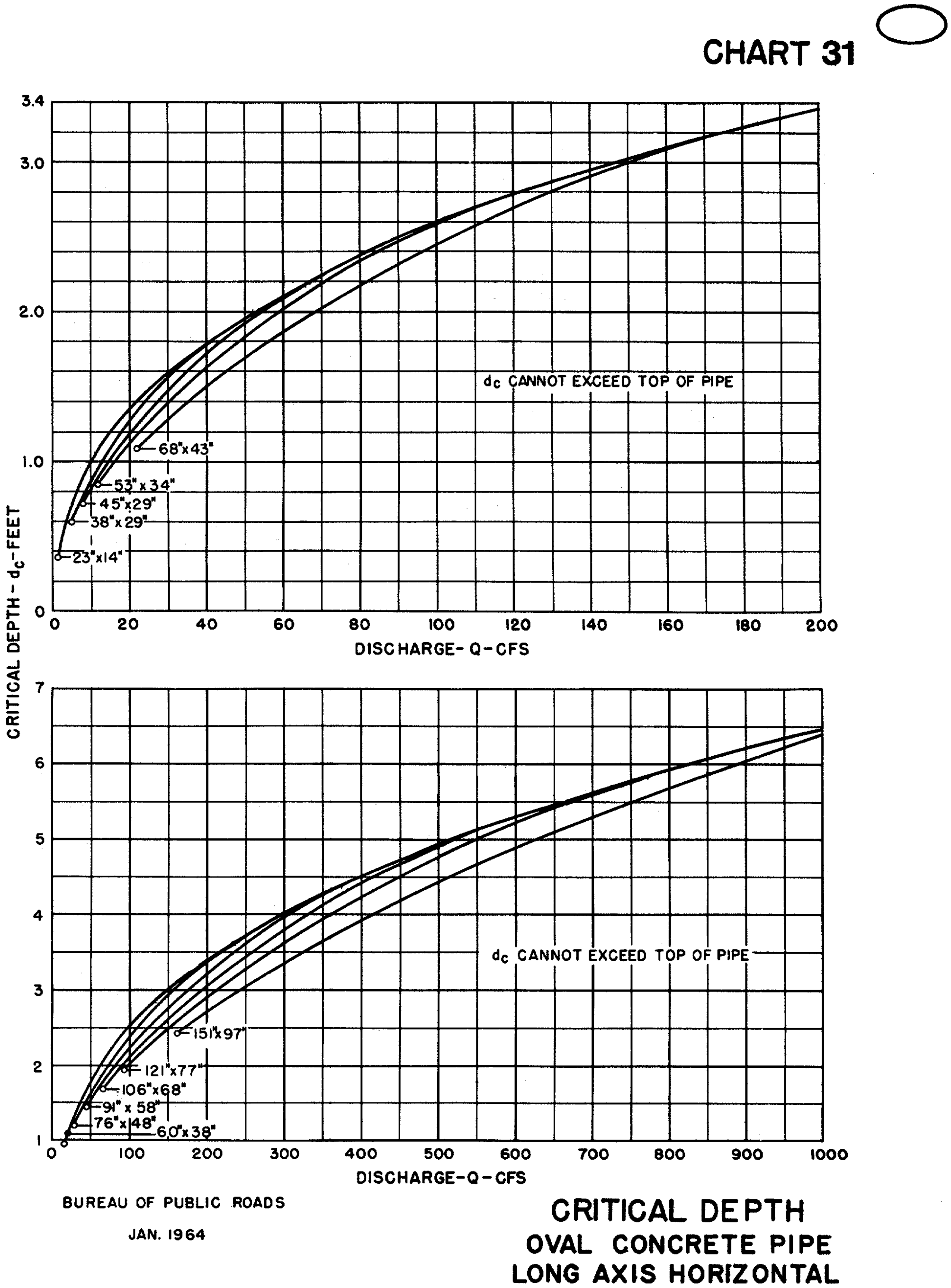
BUREAU OF PUBLIC ROADS JAN. 1963

Richland County Design Chart No. 31

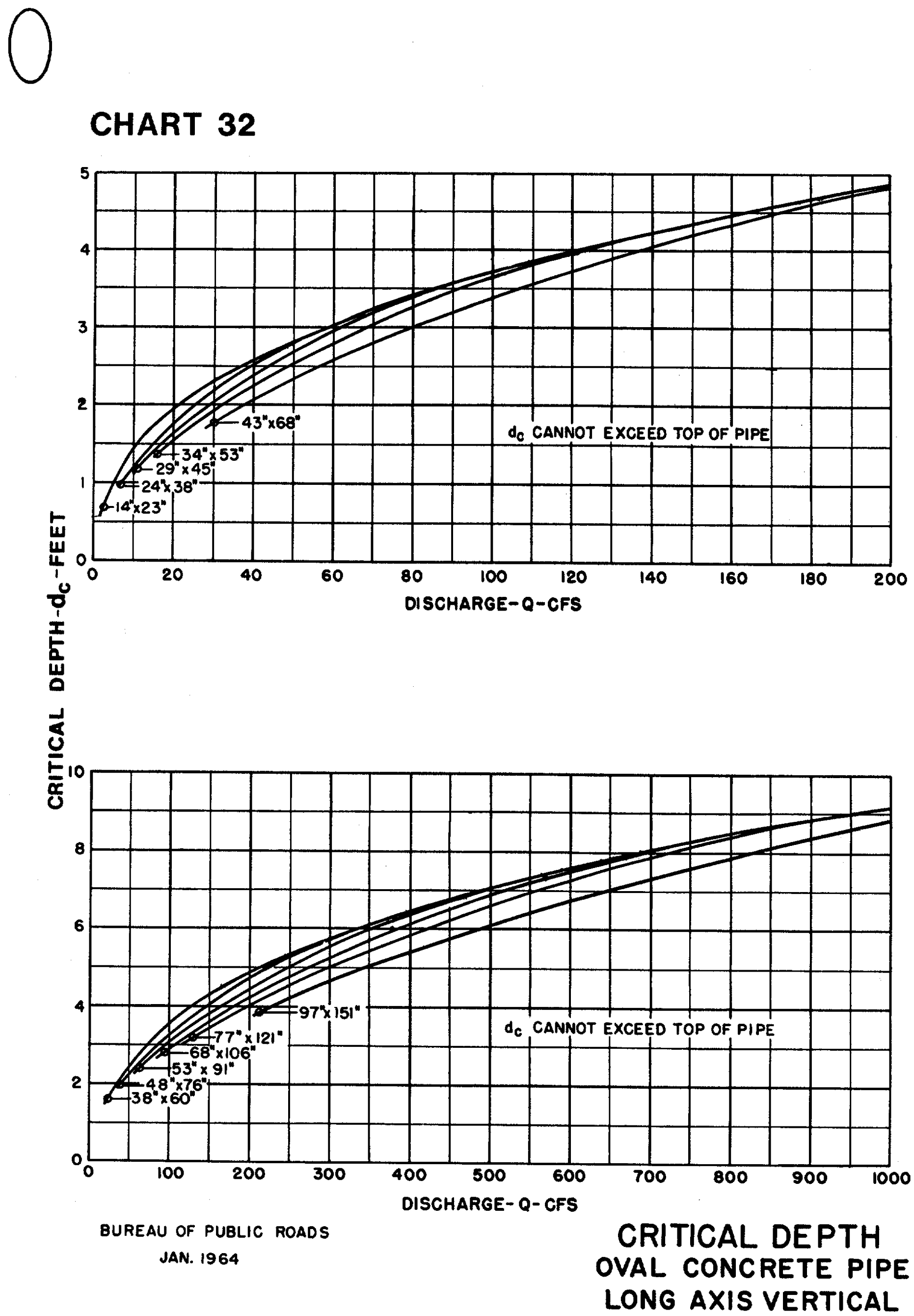


HEADWATER DEPTH FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS VERTICAL
WITH INLET CONTROL

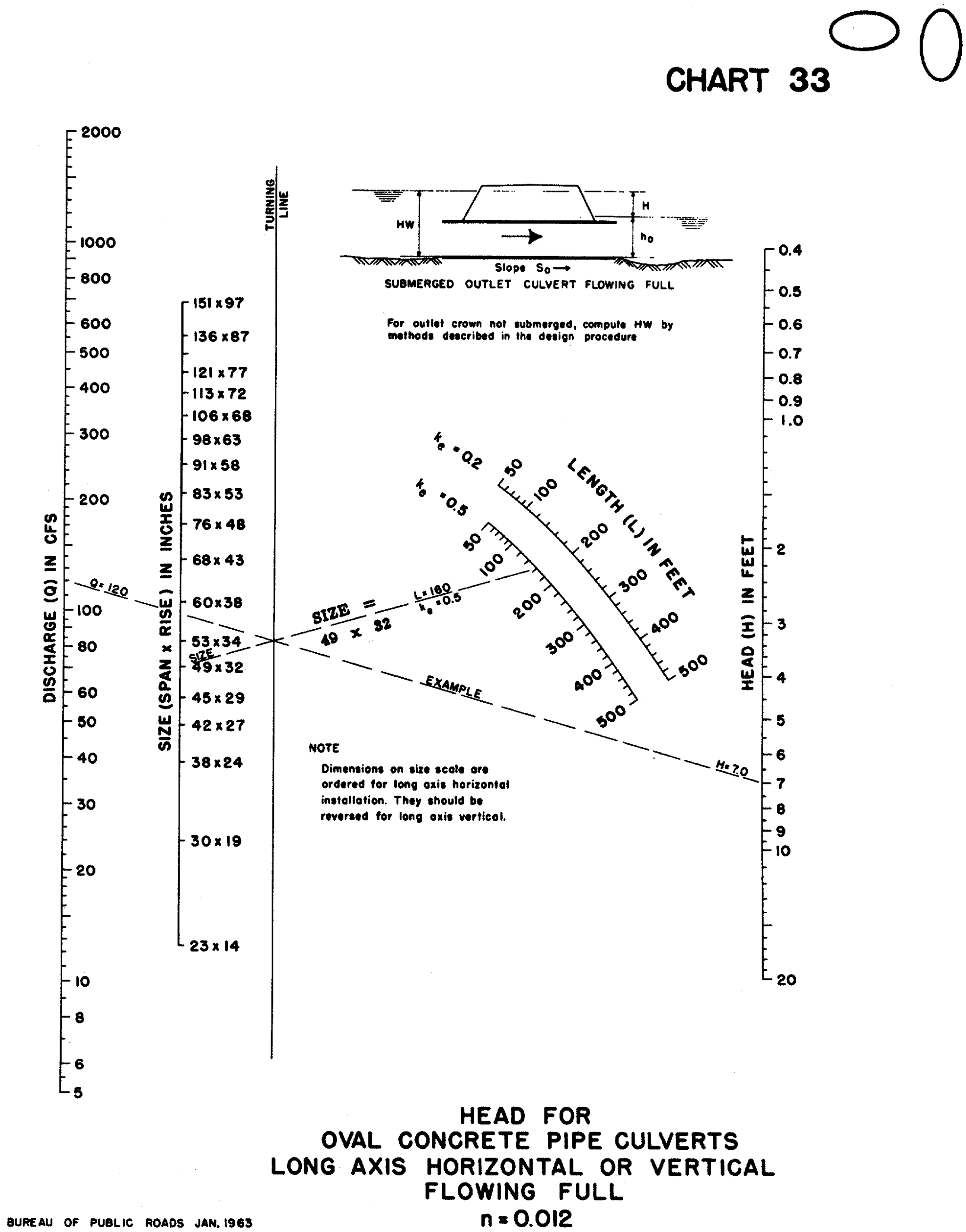
Richland County Design Chart No. 32



Richland County Design Chart No. 33

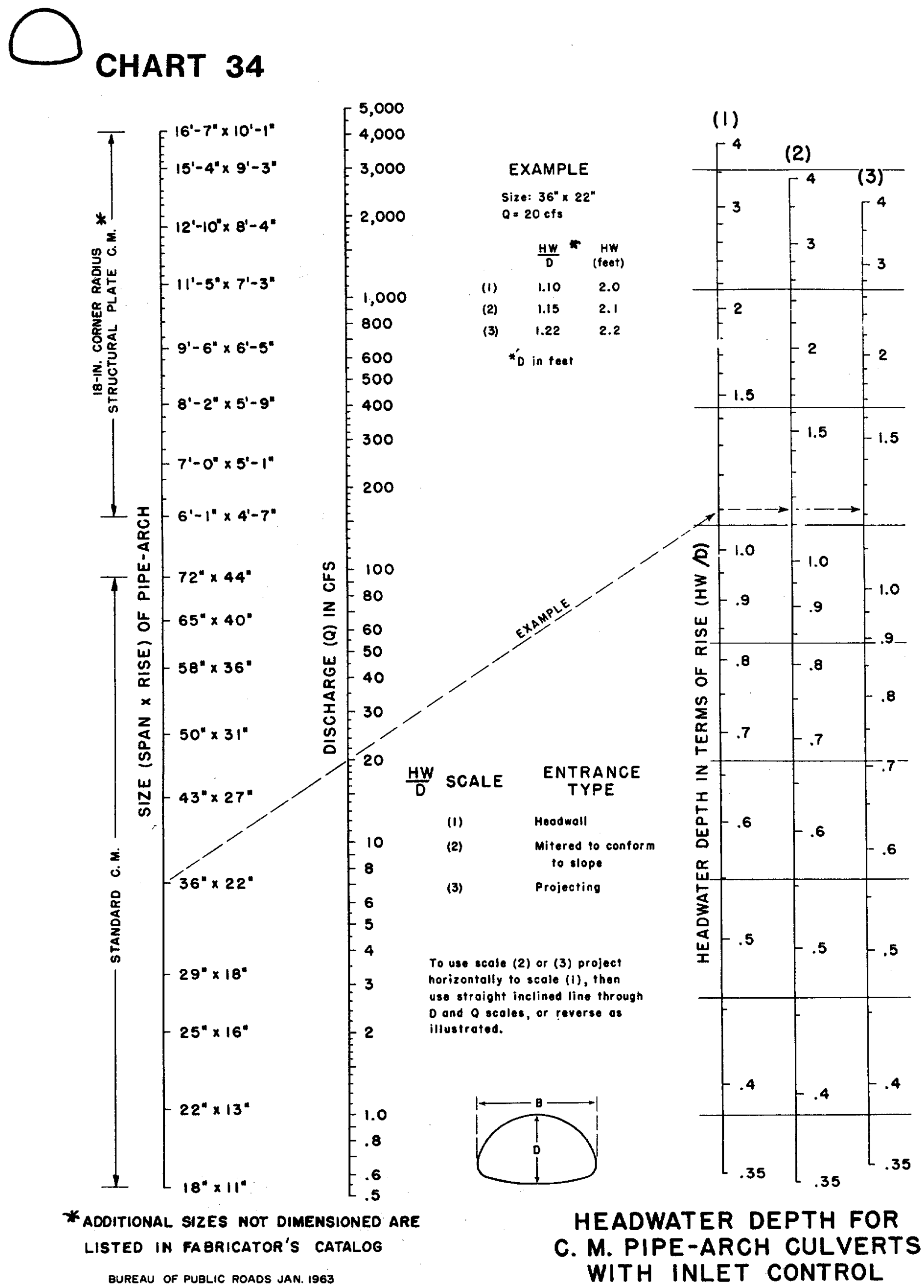


Richland County Design Chart No. 34



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

Richland County Design Chart No. 35



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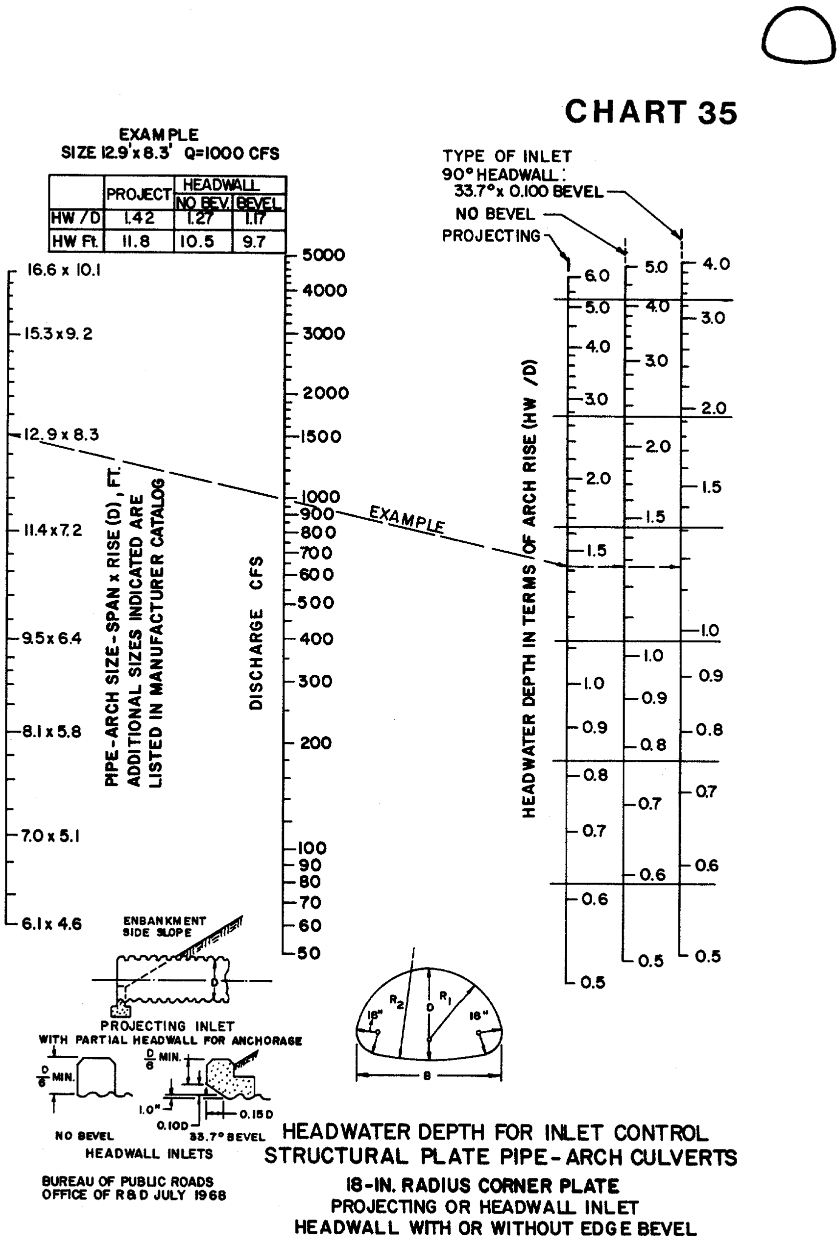

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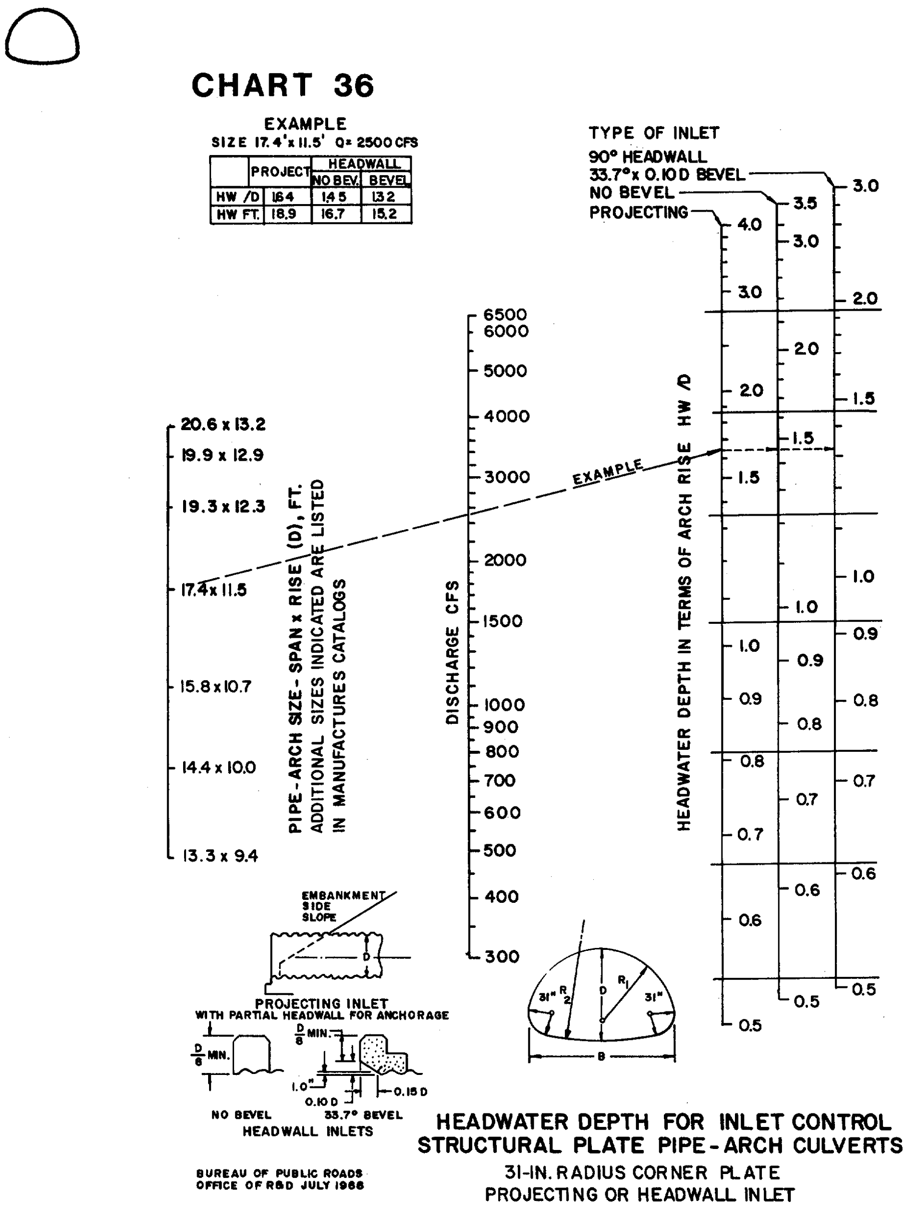
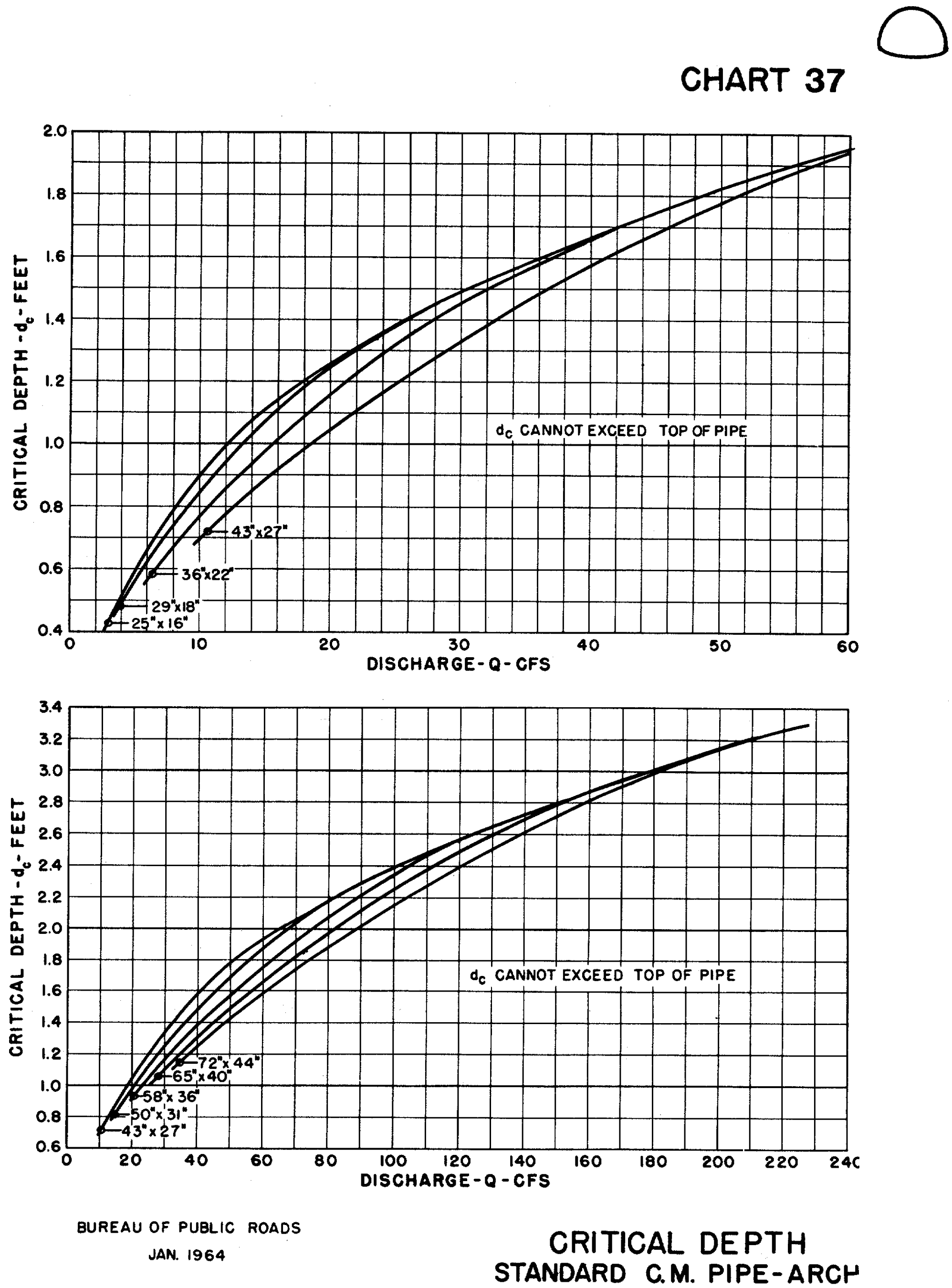


HEADWATER DEPTH FOR INLET CONTROL
STRUCTURAL PLATE PIPE-ARCH CULVERTS
31-IN. RADIUS CORNER PLATE
PROJECTING OR HEADWALL INLET
HEADWALL WITH OR WITHOUT EDGE BEVEL

Richland County Design Chart No. 38



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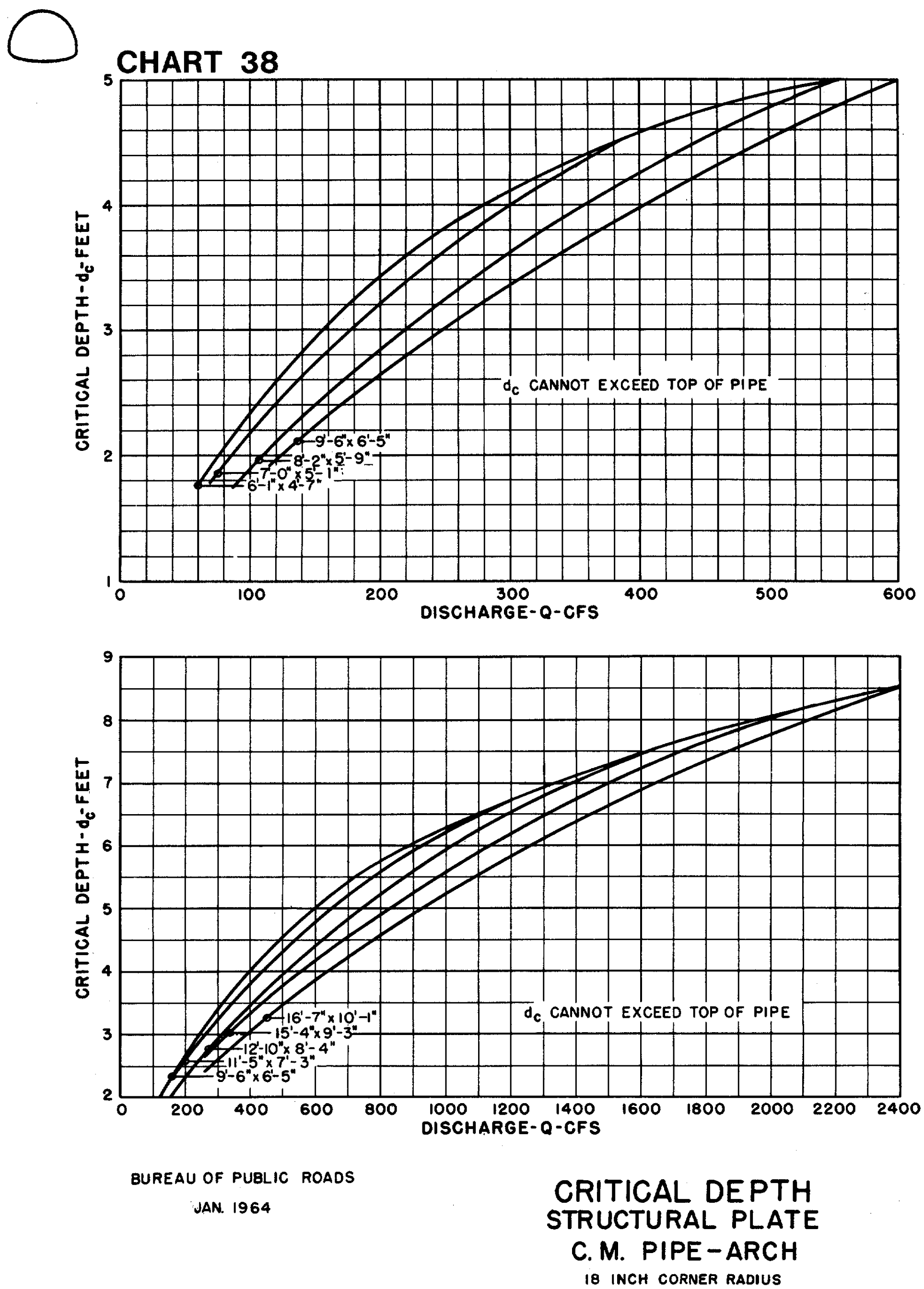

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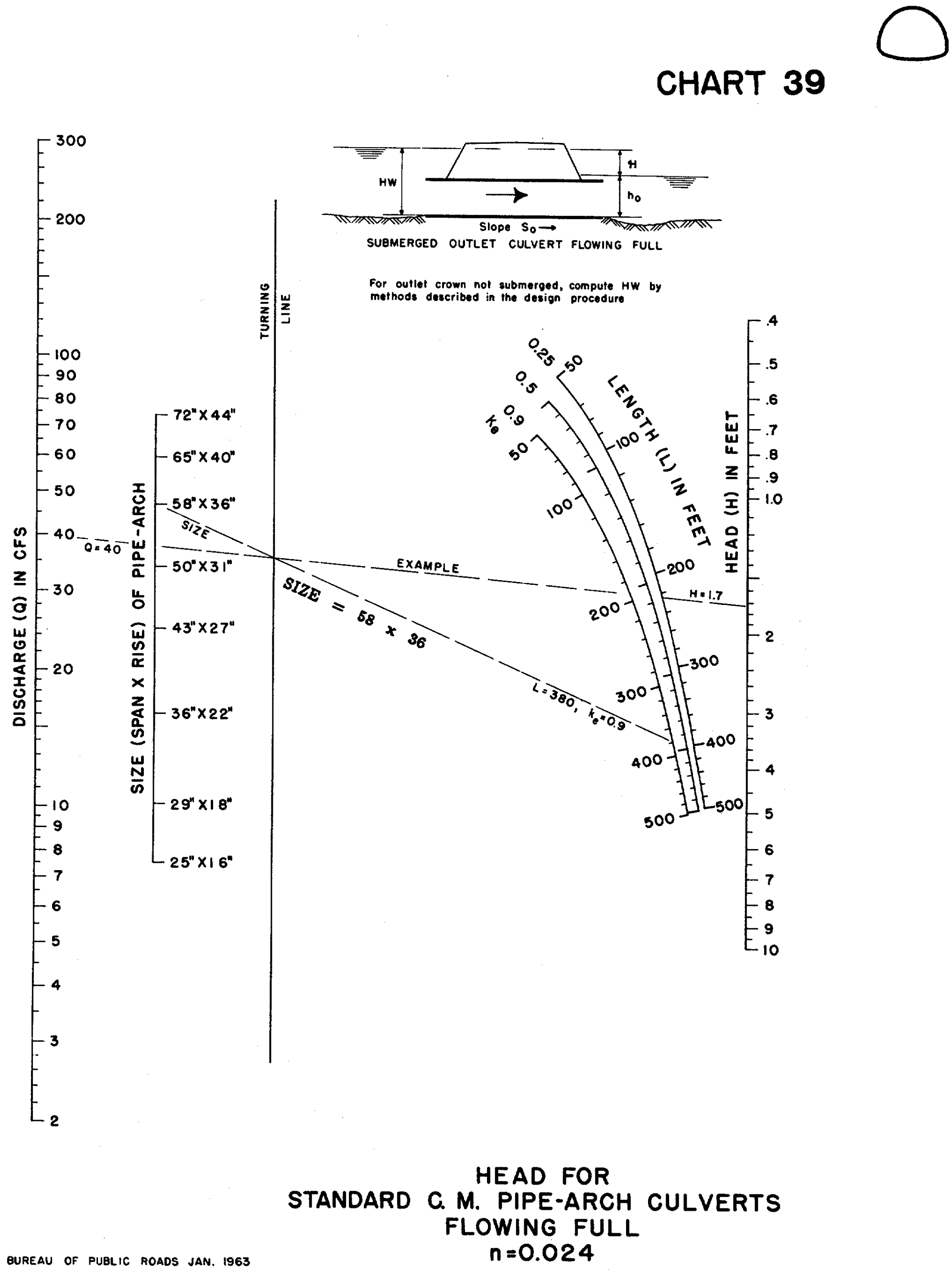
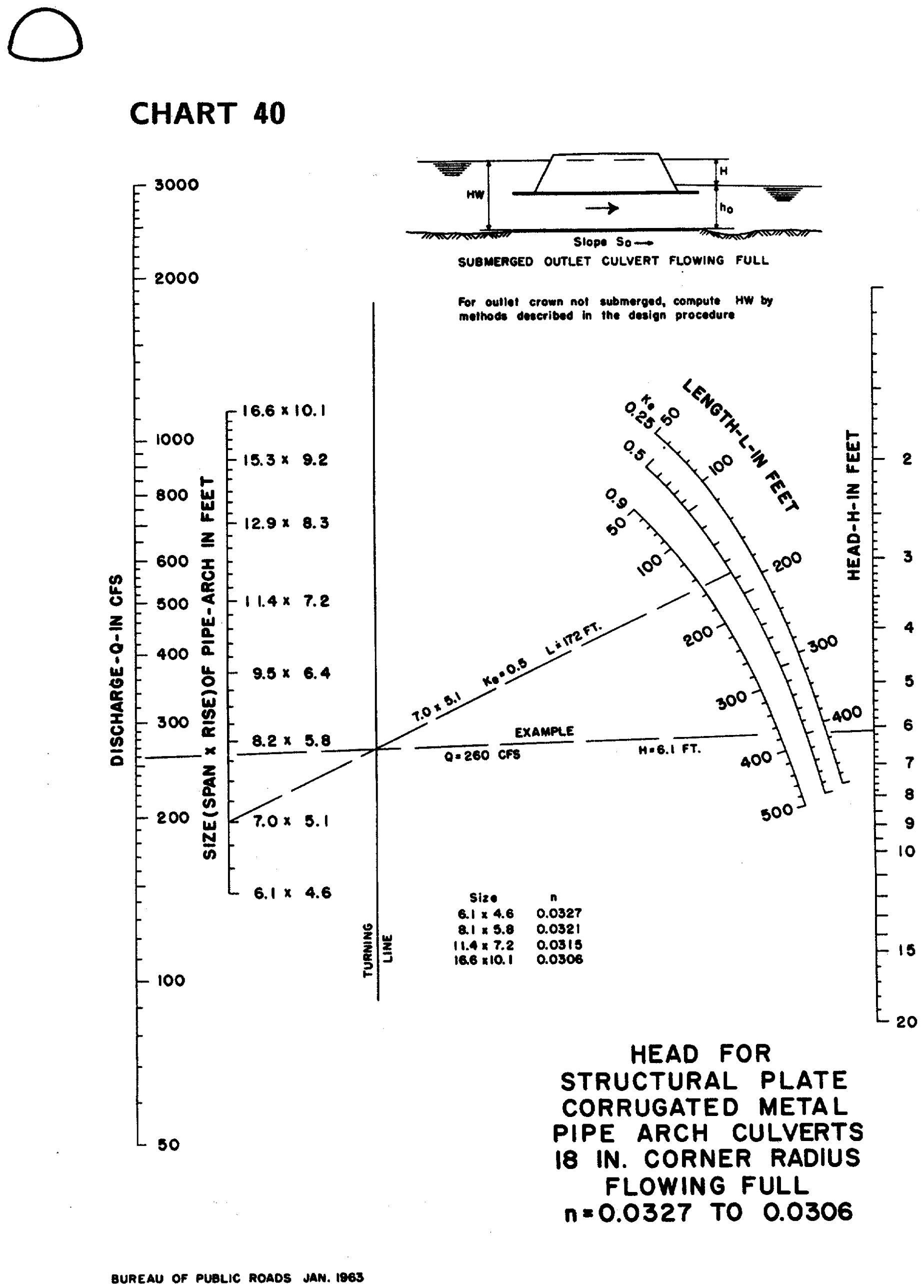
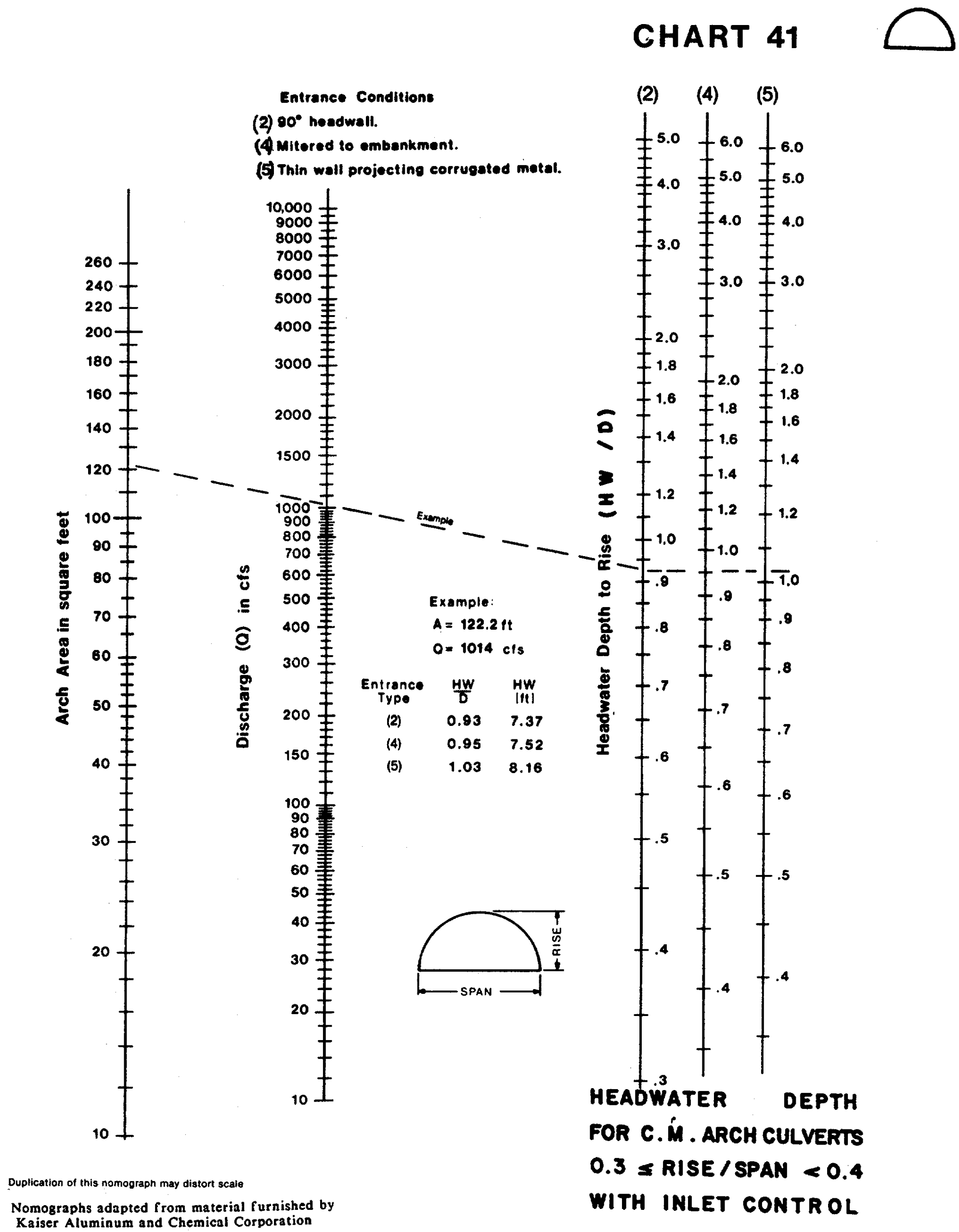


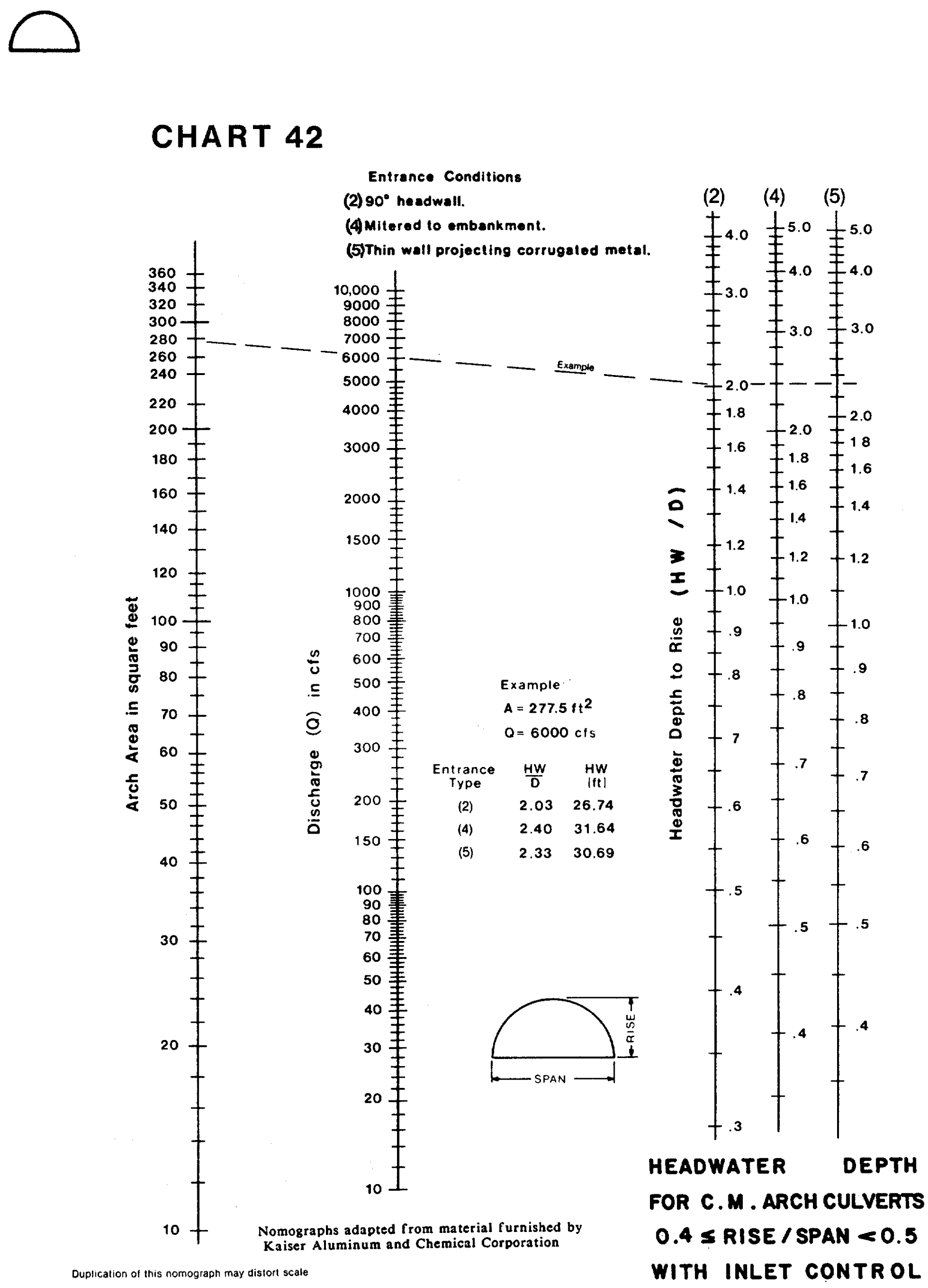
Richland County Design Chart No. 41



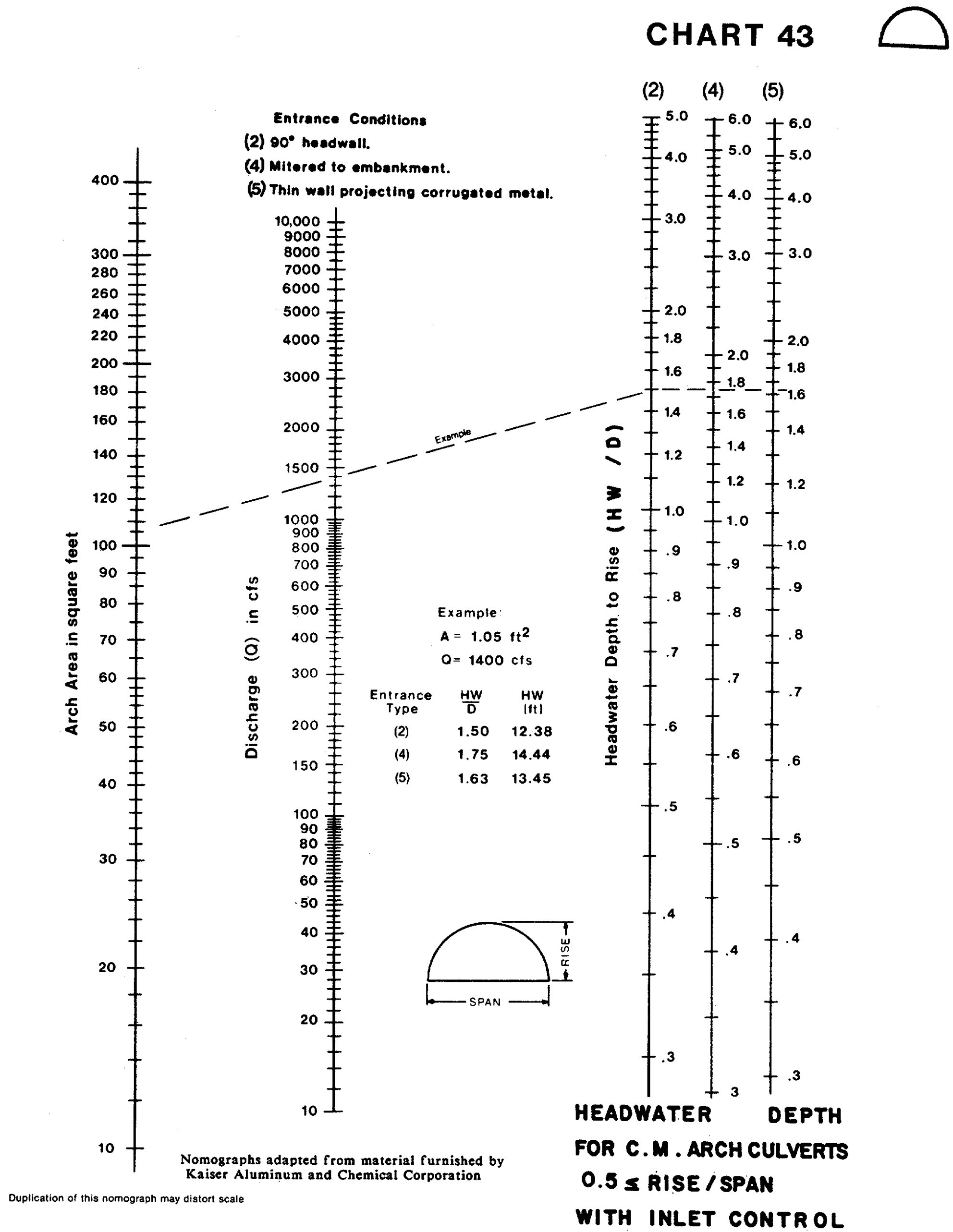
Richland County Design Chart No. 42



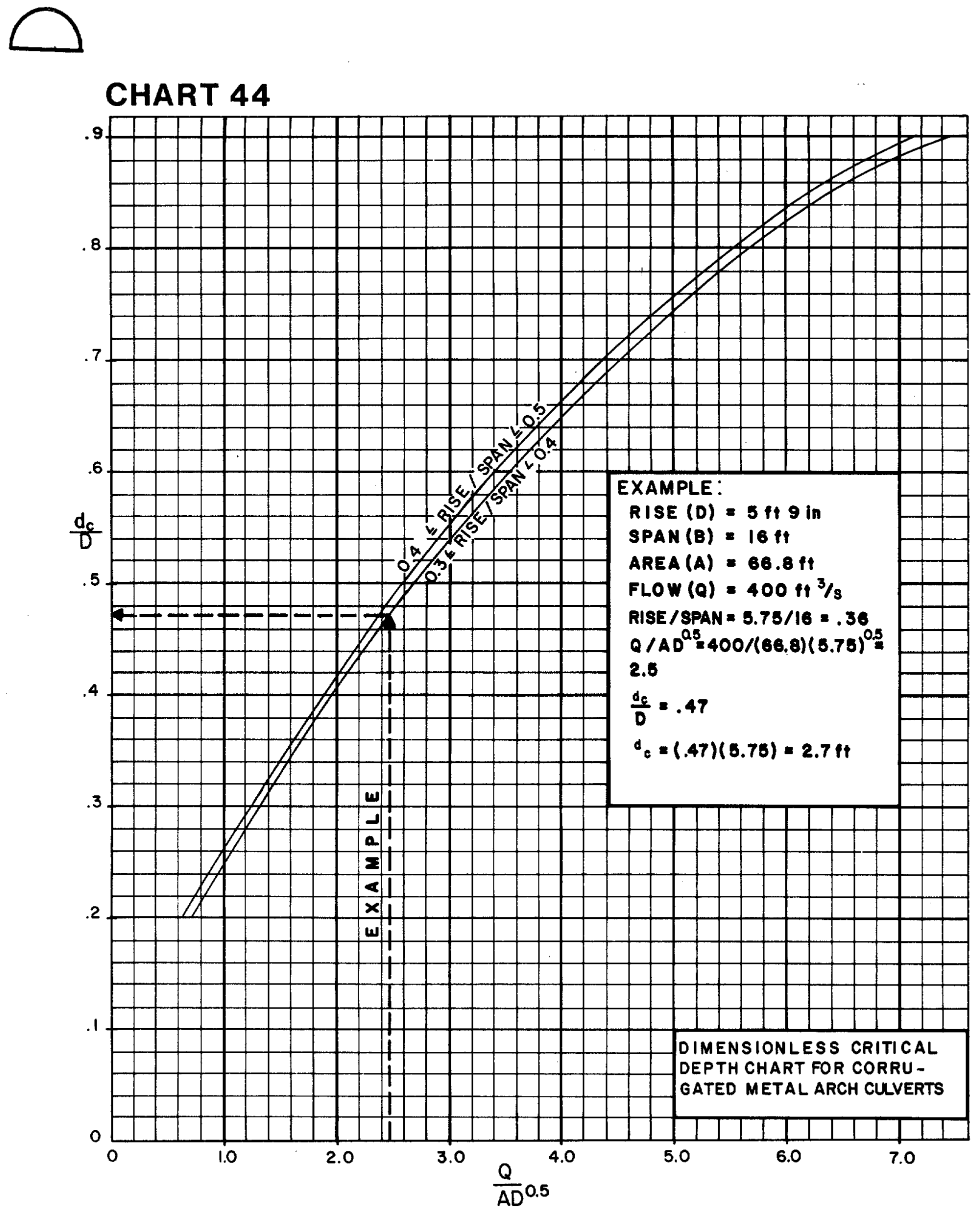
Richland County Design Chart No. 43



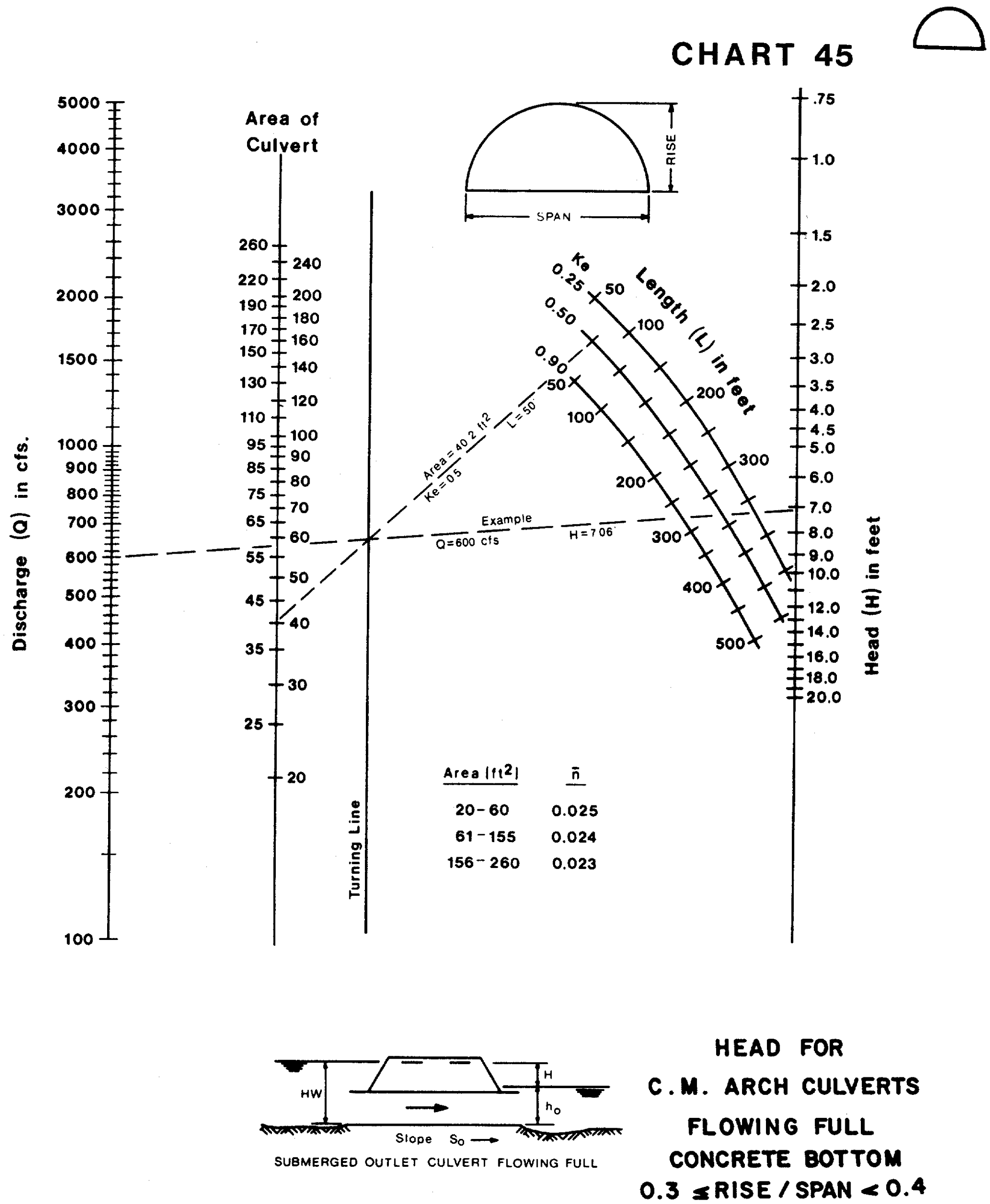
Richland County Design Chart No. 44



Richland County Design Chart No. 45



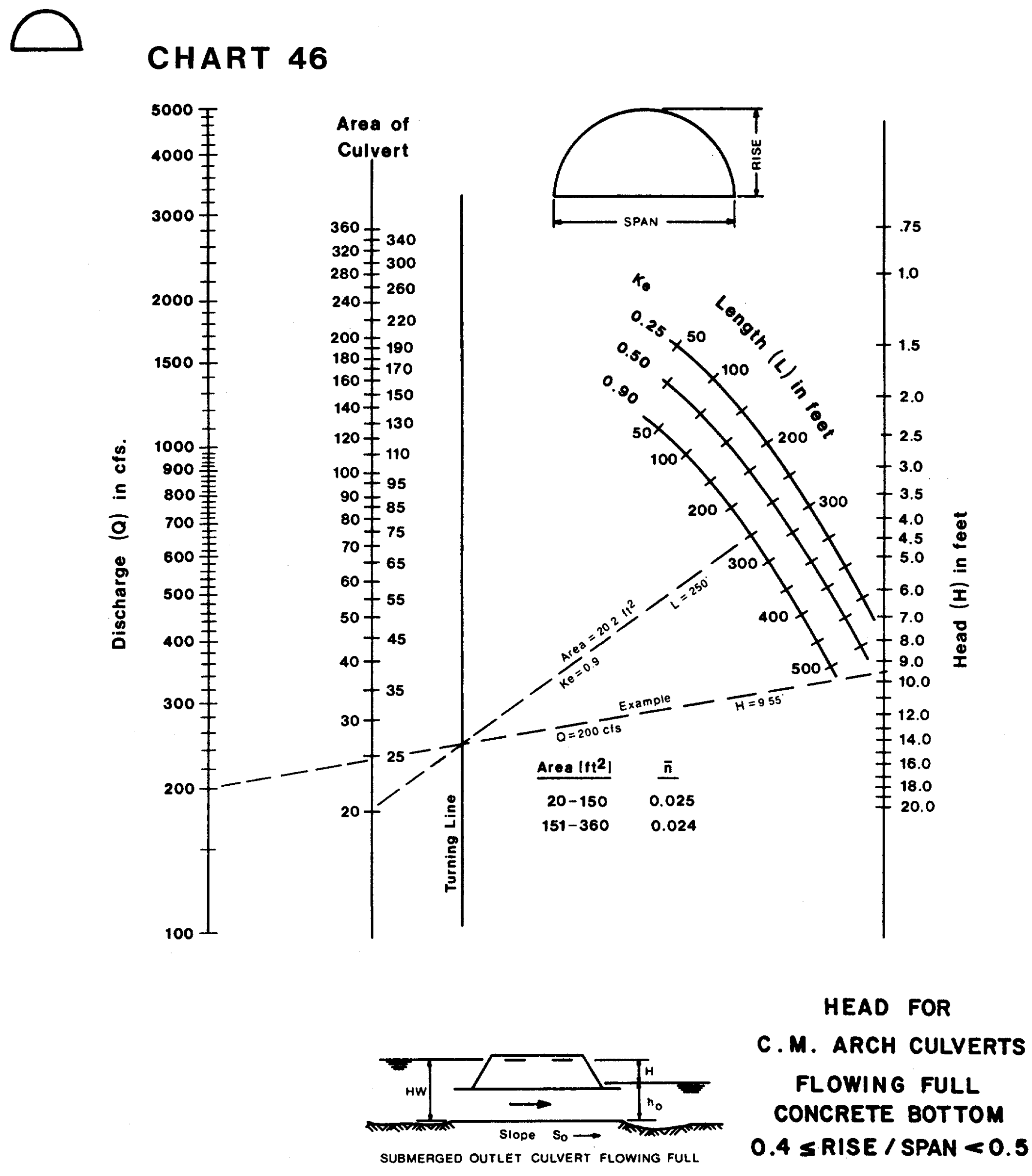
Richland County Design Chart No. 46



Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

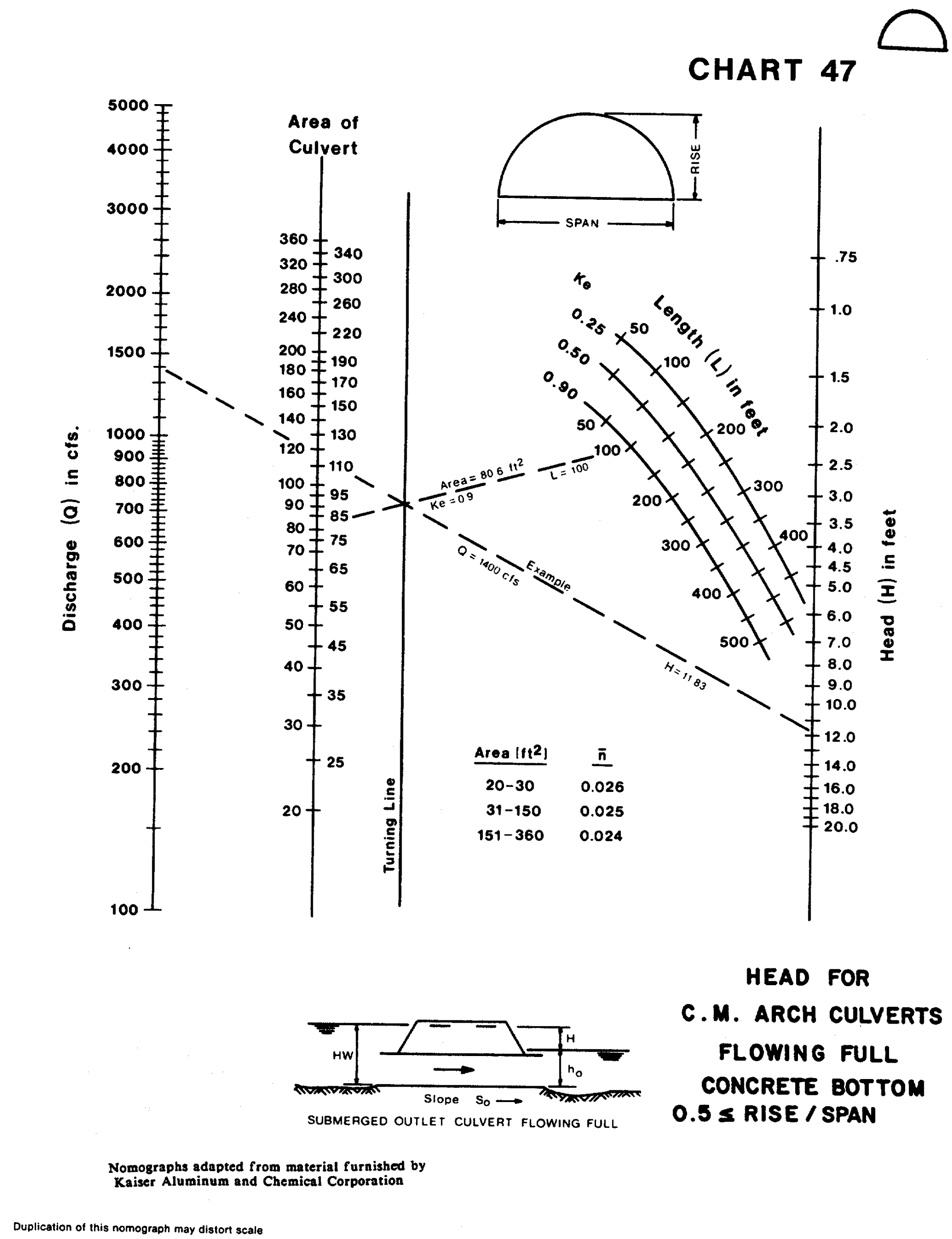
Richland County Design Chart No. 47



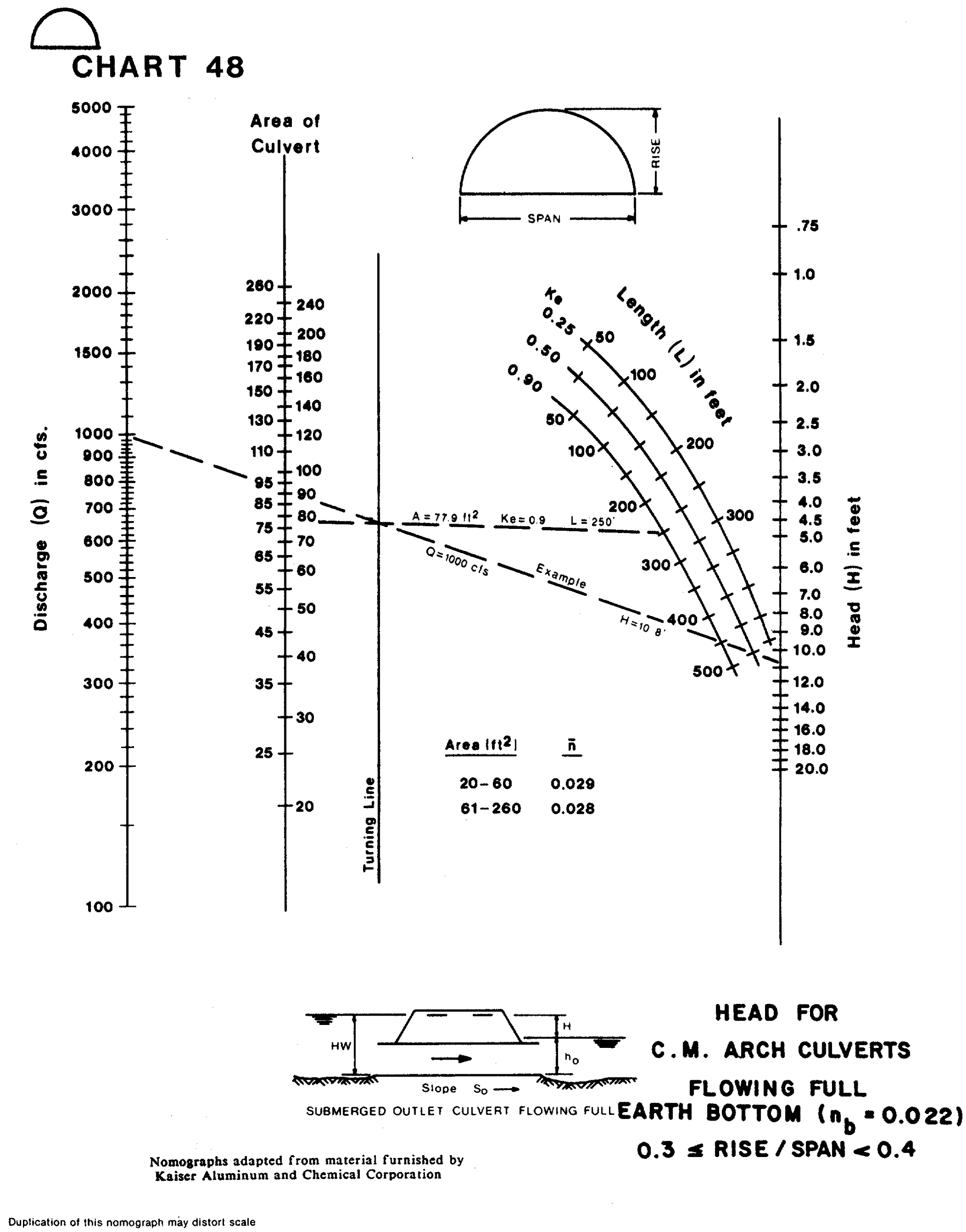
Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

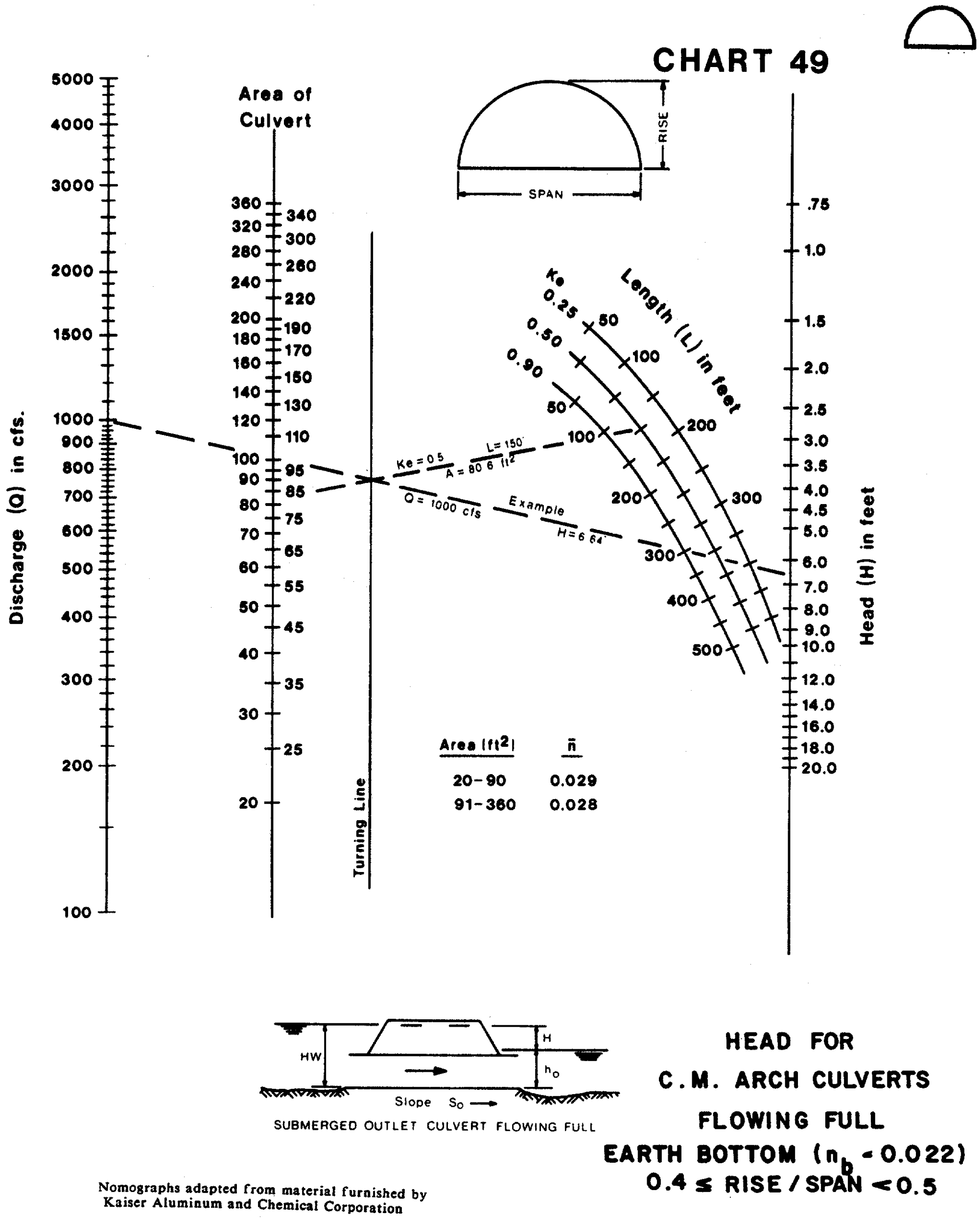
Richland County Design Chart No. 48



Richland County Design Chart No. 49

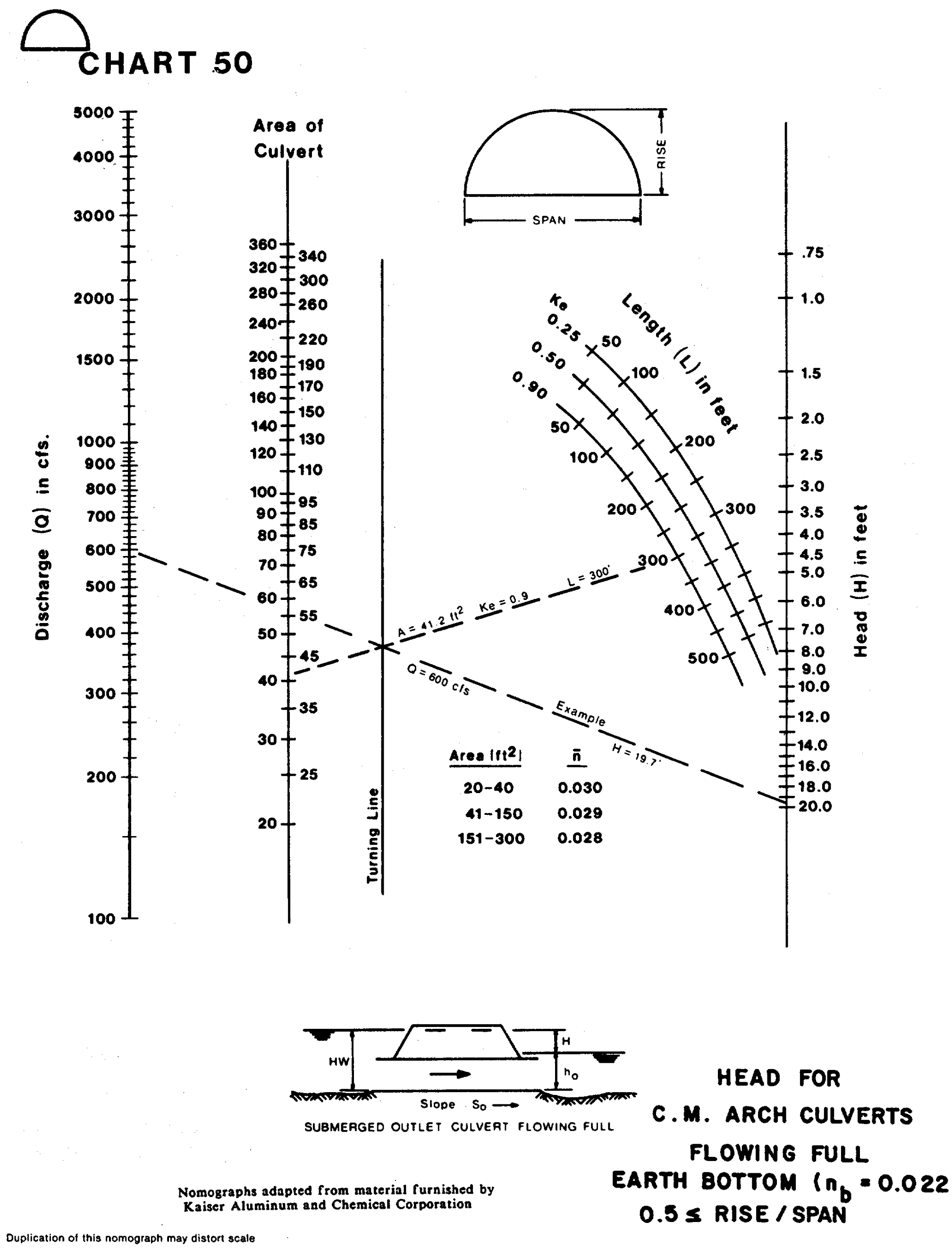


Richland County Design Chart No. 50



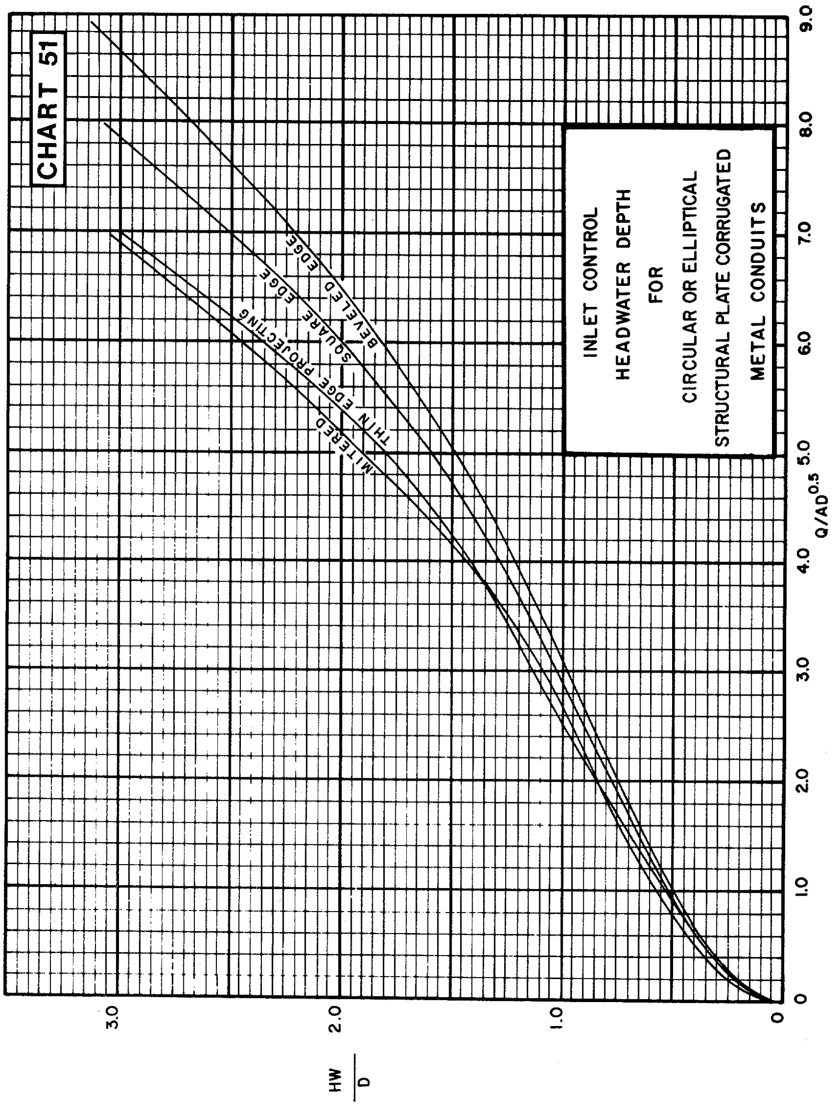
Duplication of this nomograph may distort scale

Richland County Design Chart No. 51



Richland County Design Chart No. 52

CHART 51



Richland County Design Chart No. 53

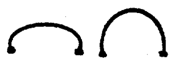
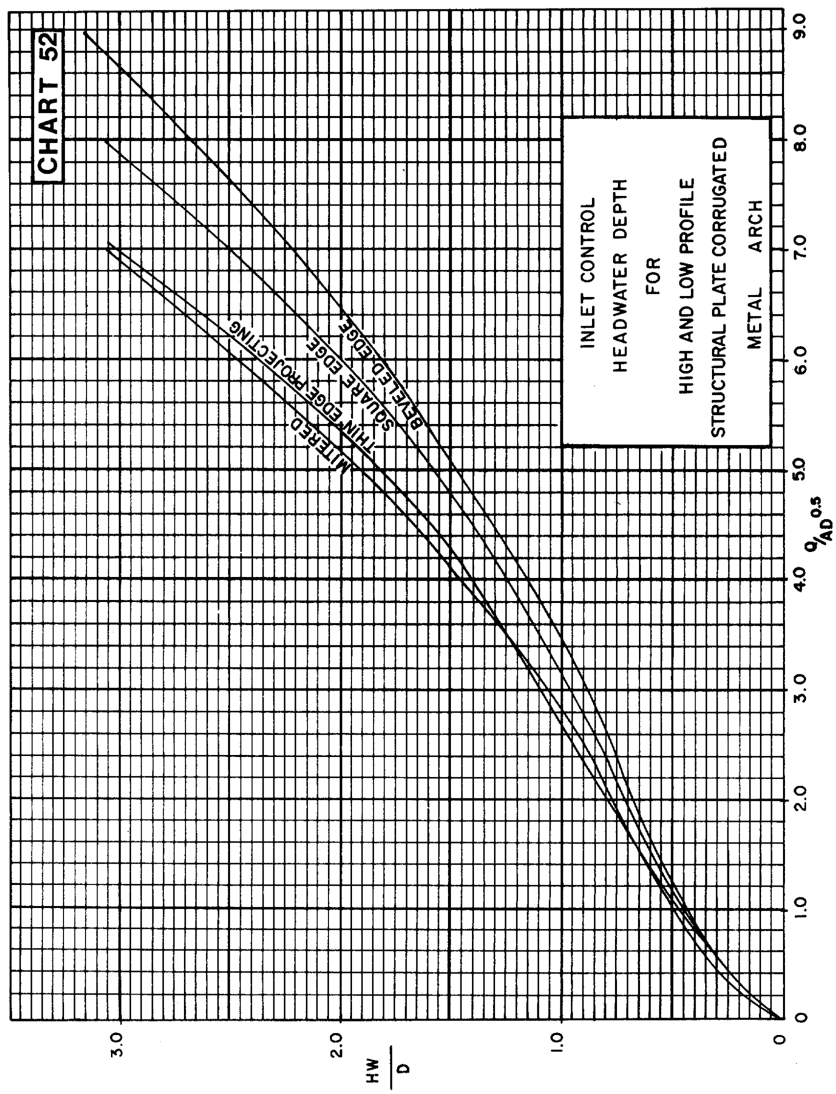
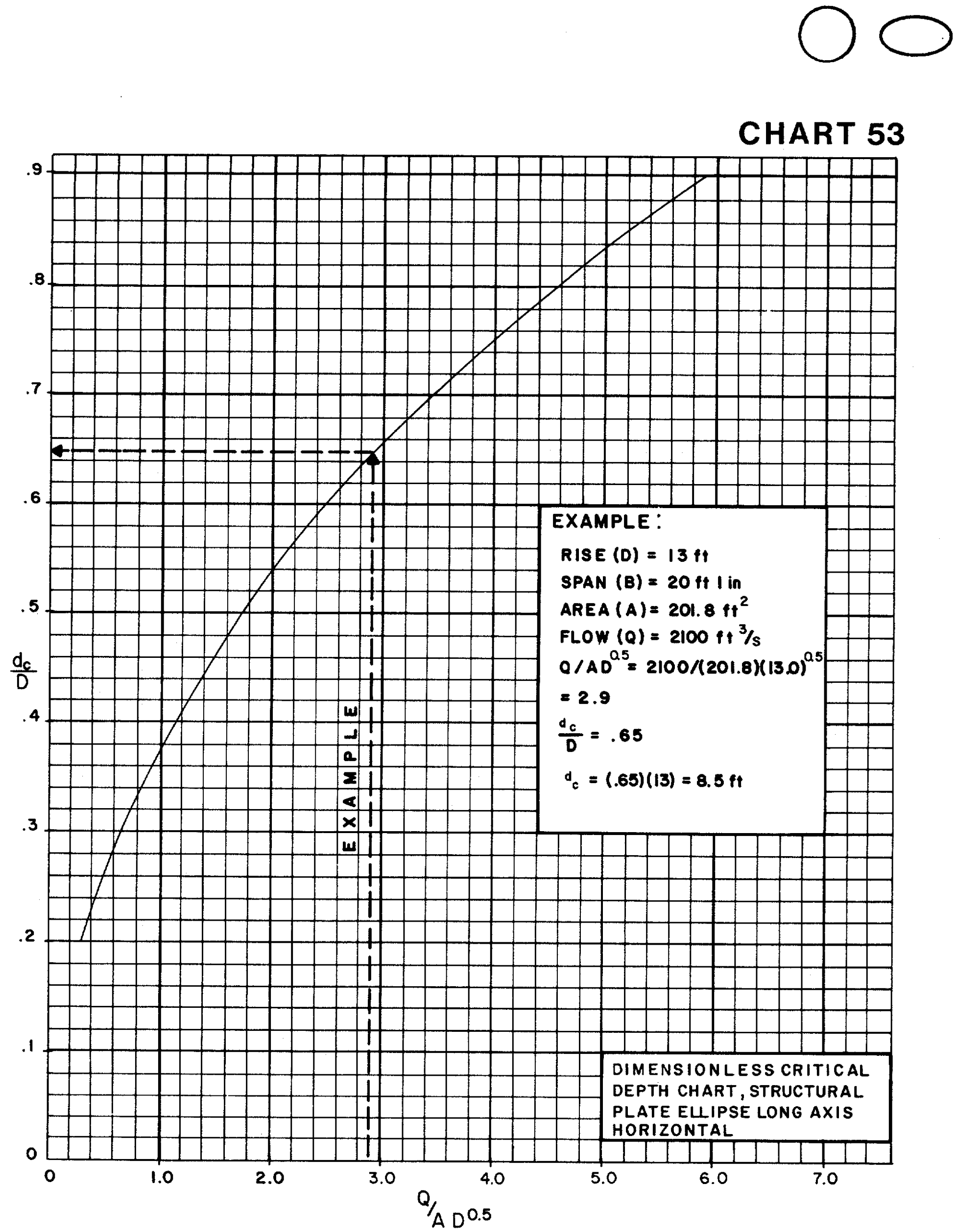


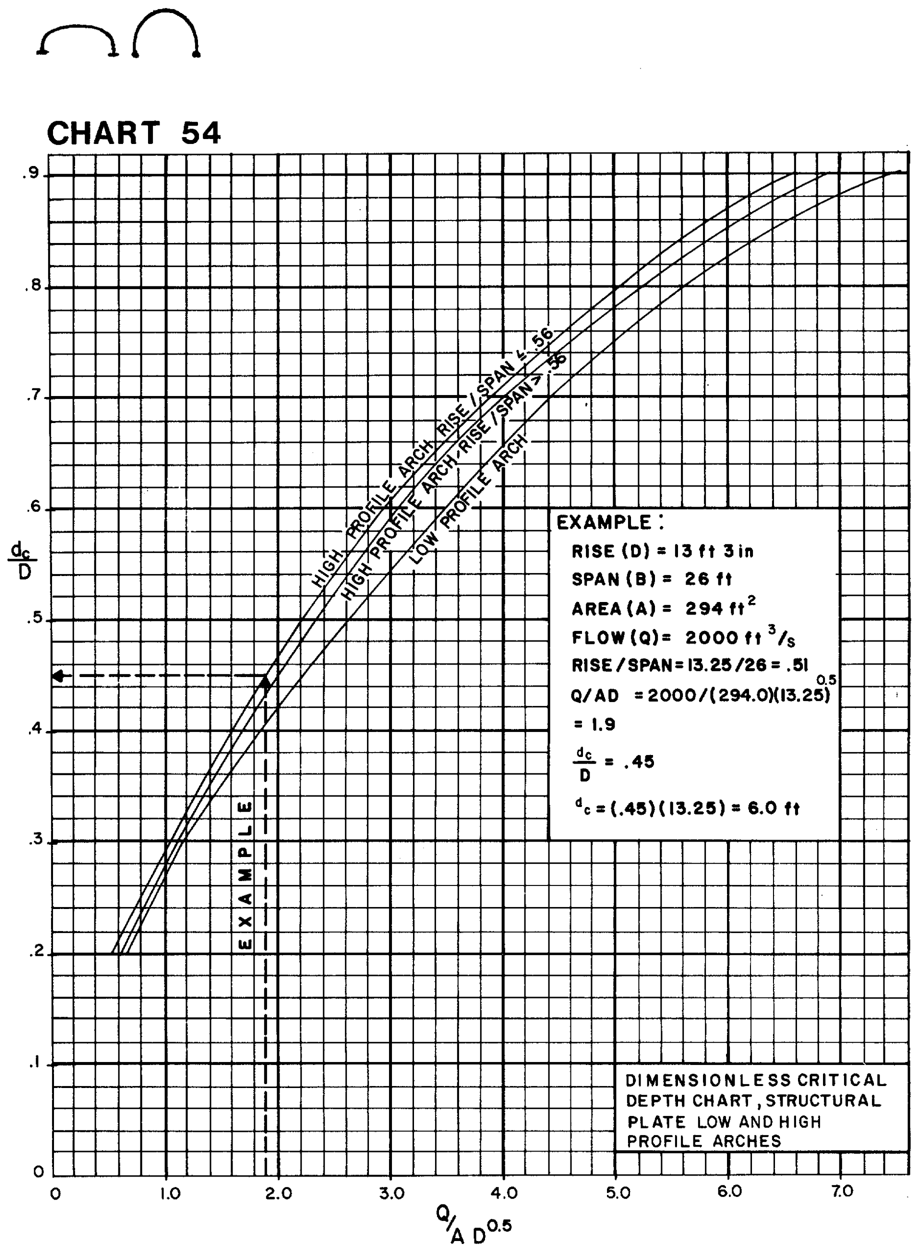
CHART 52



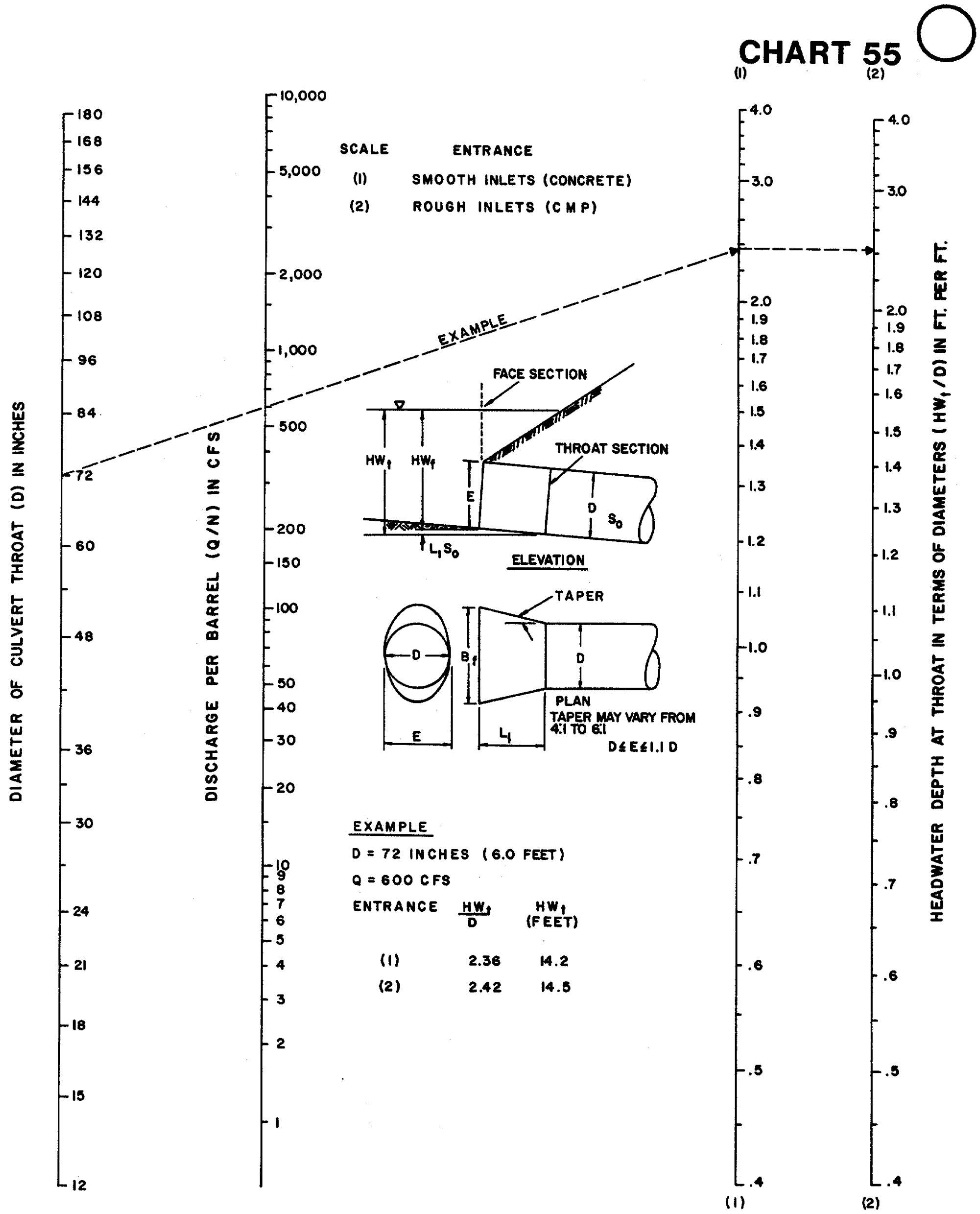
Richland County Design Chart No. 54



Richland County Design Chart No. 55

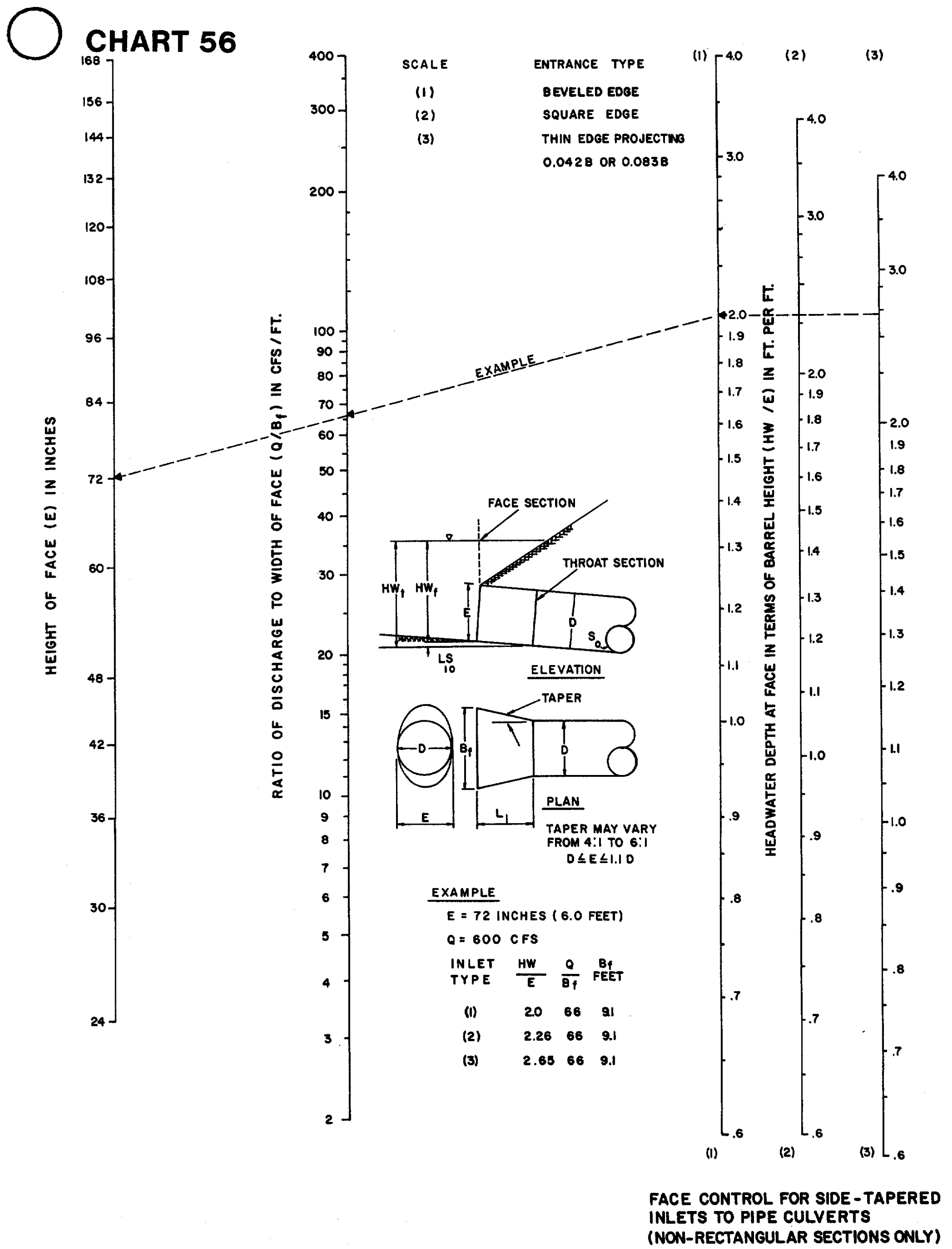


Richland County Design Chart No. 56

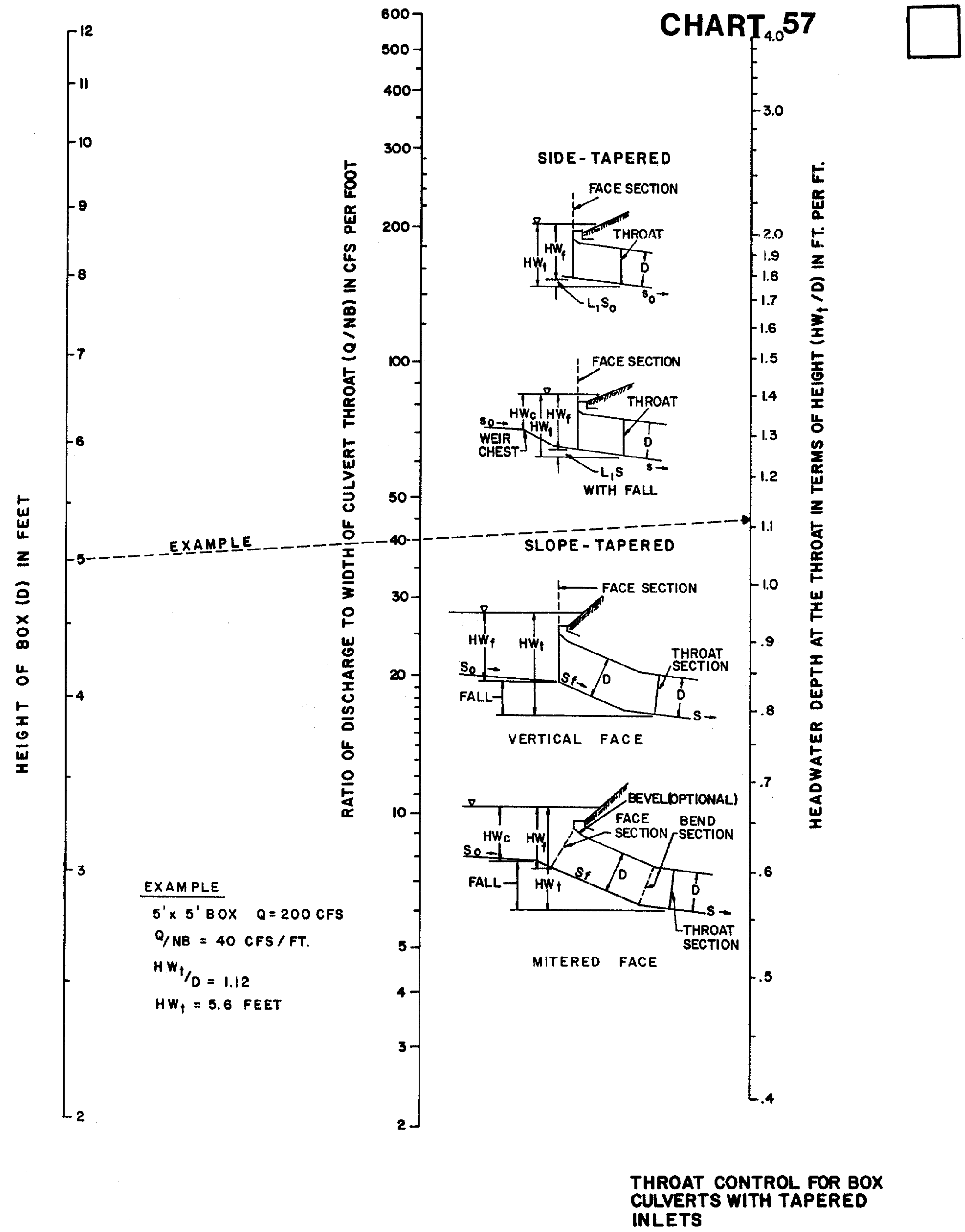


THROAT CONTROL
FOR SIDE-TAPERED INLETS TO PIPE CULVERT
(CIRCULAR SECTION ONLY)

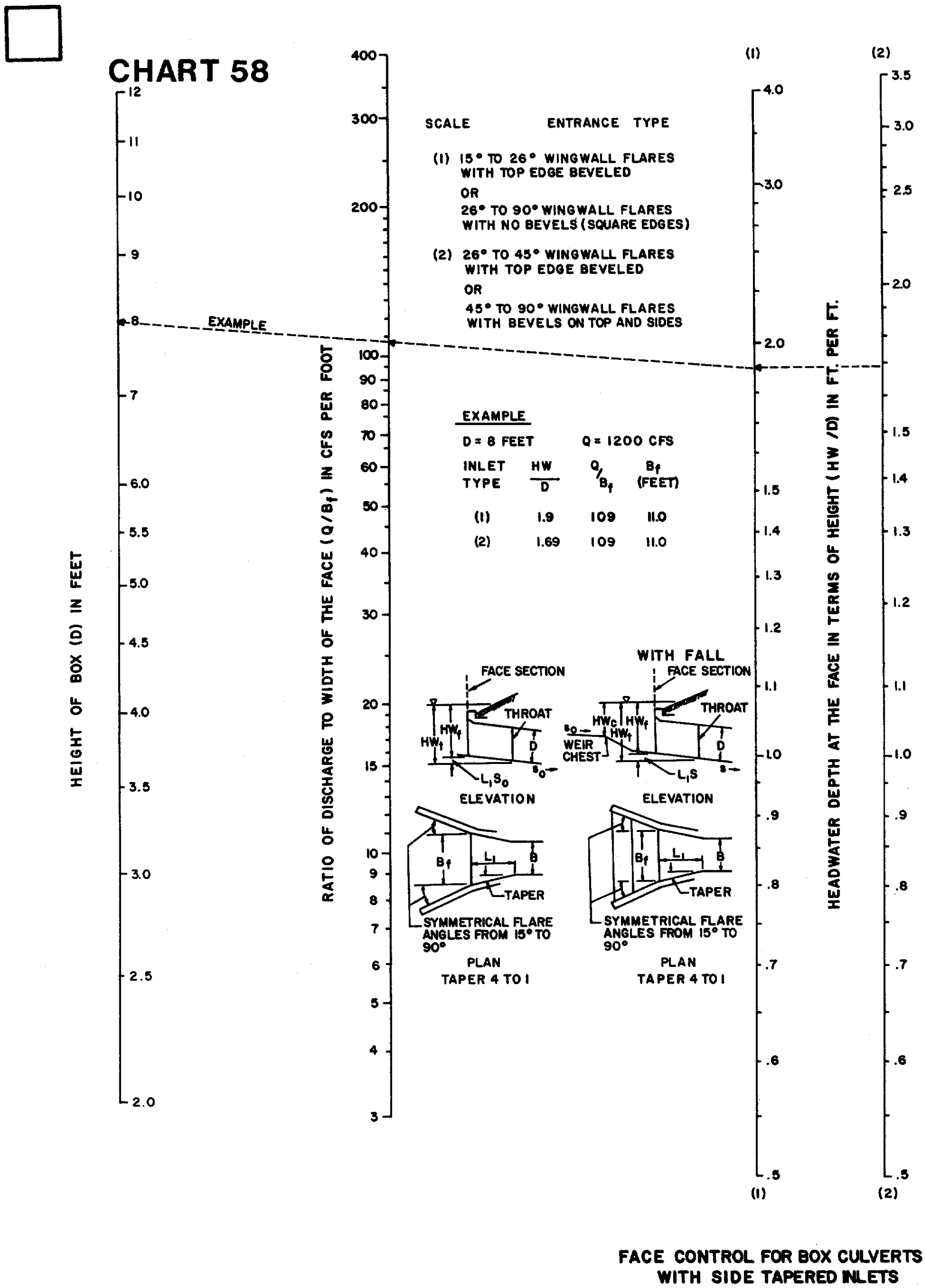
Richland County Design Chart No. 57



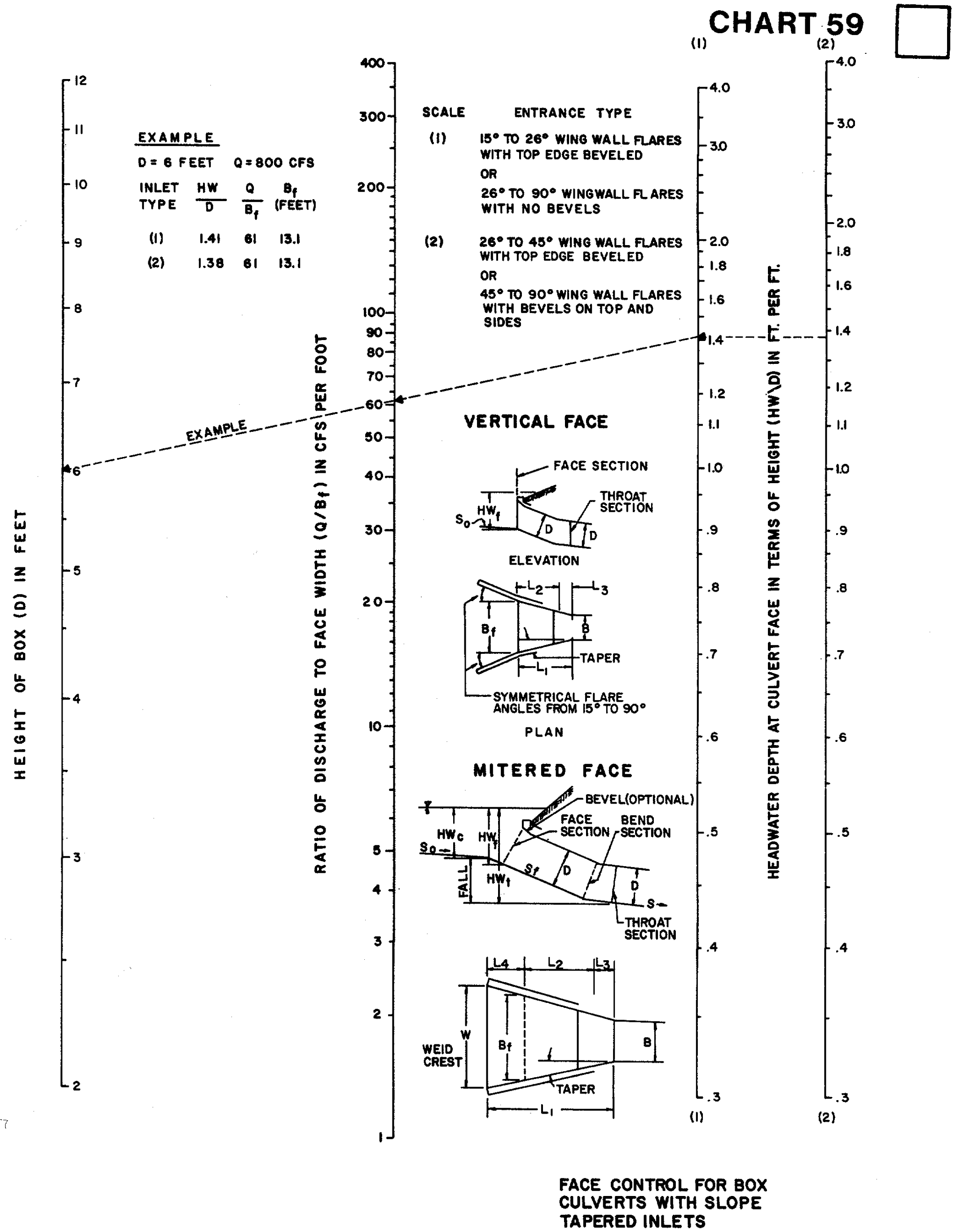
Richland County Design Chart No. 58



Richland County Design Chart No. 59



Richland County Design Chart No. 60



4.3 Storm Sewer Lines

4.3.1 Design Criteria: Pipe that are part of a storm sewer system consisting of catch basins, junction boxes and connecting pipes are to be sized to flow approximately 85 percent full under open channel flow at the design discharge using the Manning Equation.

$$Q = \frac{1.486}{n} A r^{2/3} s^{1/2}$$

Where: Q = discharge in cubic feet per second (cfs),

A = cross sectional area of flow in square feet (ft^2),

r = hydraulic radius where $r = \frac{A}{\text{Wetted Perimeter}}$, in feet,

s = slope of pipe in feet per foot,

And n = Manning's roughness coefficient for the pipe

Since discharge at 85 percent full approximately equals the discharge at full flow, the pipe geometry and discharge for the pipe flowing full can be used. Minimum allowable velocity to reduce sedimentation in the storm sewer system is 2 feet per second.

The design aids and charts listed in Table 7 may be used for the solution of the Manning's Equation for pipes flowing full or partially full. Manning's roughness coefficients for various types of pipes are tabulated in Table 8.

Table 7
Design Aids and Charts for Solution of Manning's Equation for Pipe Flow

Richland County Design Chart No.	*Description*
61	Nomograph for solution of Manning's equation[11]
62	Nomograph for computing required size of circular drain, flowing full, n = 0.012 or 0.013[12]
63	Nomograph for computing required size of circular drain, flowing full, n = 0.021 or 0.024[13]
64	Nomograph for computing required size of circular drain, flowing full, n = 0.023 or 0.027[14]
65	Nomograph for computing required size of circular drain, flowing full, n = 0.031[15]

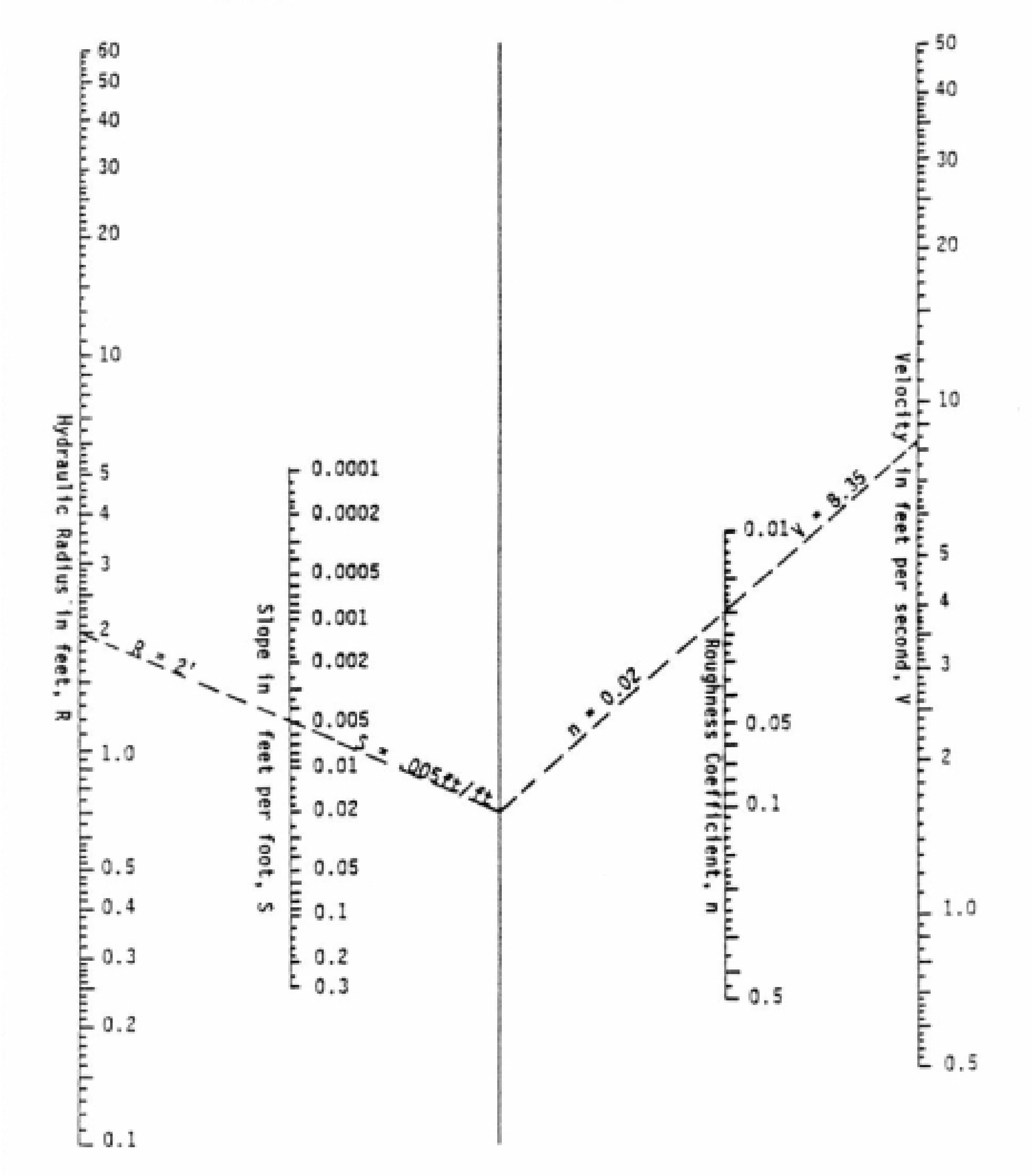
[11] Source: Virginia Department of Transportation
[12] Federal Aviation Administration, Airport Drainage (1970)
[13] Federal Aviation Administration, Airport Drainage (1970)
[14] Federal Aviation Administration, Airport Drainage (1970)
[15] Federal Aviation Administration, Airport Drainage (1970)

Table 8
Design Manning's *n* Values for Storm Sewer (Closed) Conduits[16]

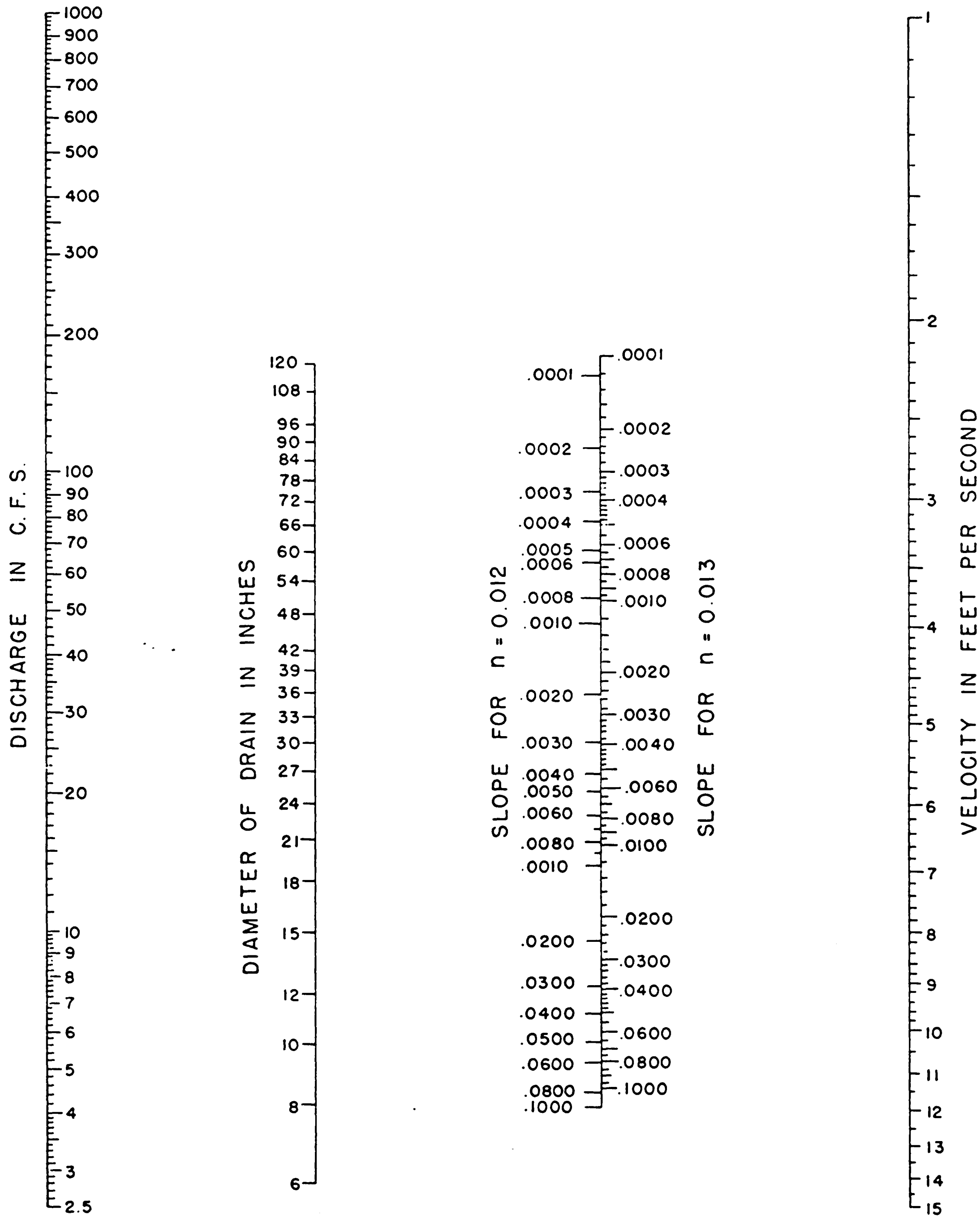
Conduit Material	Manning Coefficient, "*n*"
Concrete pipe	0.011 - 0.013
Corrugated metal pipe or pipe arch:	
1) 60 by 120 mm (2.375 by 0.5 in) corrugations	0.024
a) Plain or fully coated	
b) Paved invert (range represents 25 and 50 percent circumference paved):	
i) Full flow depth	0.021 - 0.018
ii) Flow 80 percent of depth	0.021 - 0.016
iii) Flow 60 percent of depth	0.019 - 0.013
2) 75 by 25 mm (3 by 1 in) corrugations	0.027
3) 150 by 50 mm (6 by 2 in) corrugations	0.032
4) Spiral rib	0.012 - 0.013
5) Helically Wound - Diameter, mm (in)	
a) 305 (12)	0.013
b) 381 (15)	0.014
c) 457 (18)	0.015
d) 533 (21)	0.016
e) 610 (24)	0.017
f) 686 (27)	0.018
g) 762 (30)	0.019
h) 838 (33)	0.020
i) 914 (36)	0.021
j) 1067 (42)	0.022
k) 1219 (48)	0.023
Plastic pipe:	
1) Smooth	0.011 - 0.015
2) Corrugated	0.024
Vitrified clay pipe	0.012 - 0.014
Cast-iron pipe, uncoated	0.013
Steel pipe	0.009 - 0.011
Brick	0.014 - 0.017
Monolithic concrete	
1) Wood forms, rough	0.015 - 0.017
2) Wood forms, smooth	0.012 - 0.014
3) Steel forms	0.012 - 0.014

[16] FHWA Hydraulic Engineering Circular (HEC) No. 22, Urban Drainage Design Manual (1996)

Richland County Design Chart No. 61
Nomograph for Solution of Manning's Equation

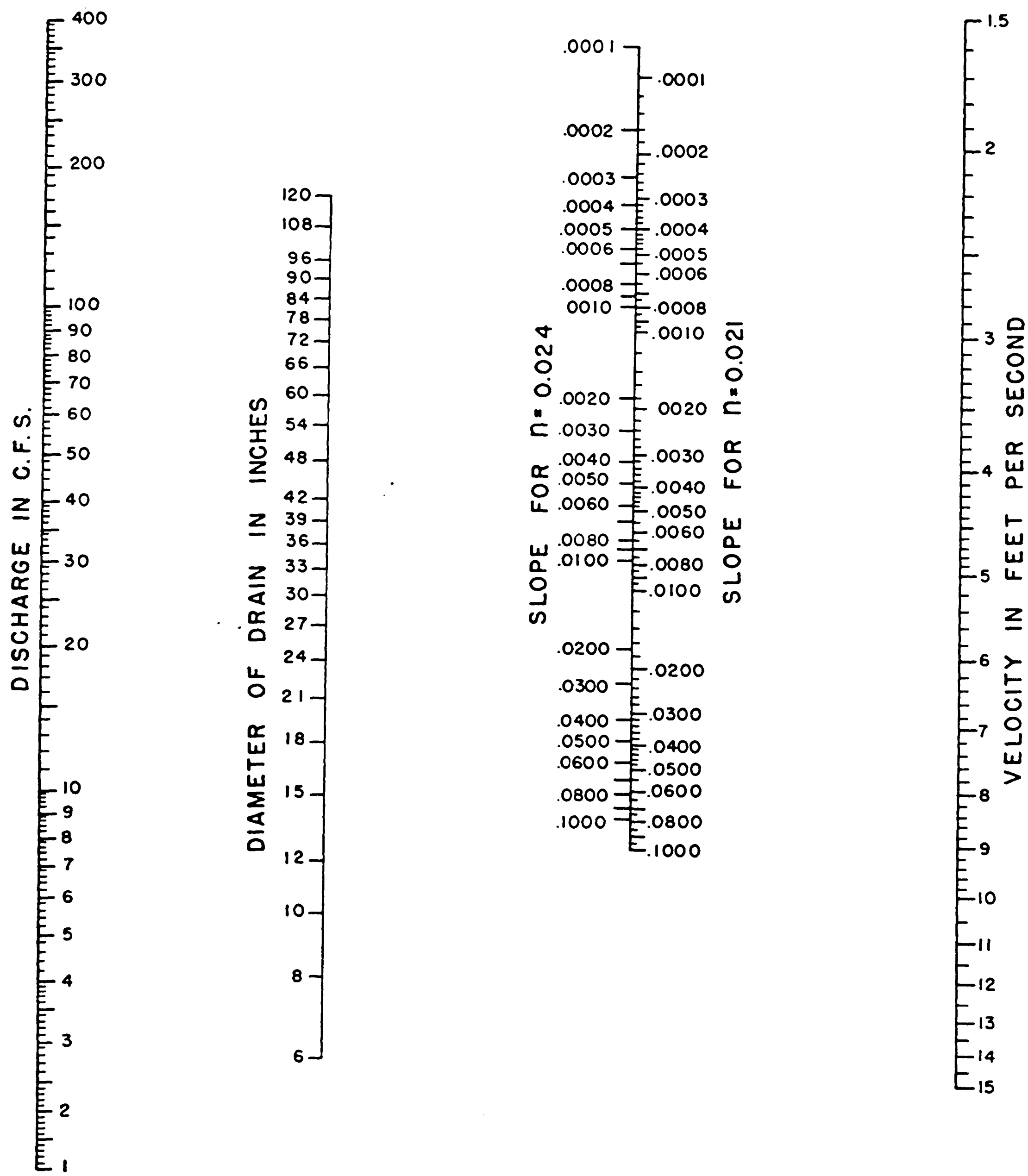


Richland County Design Chart No. 62



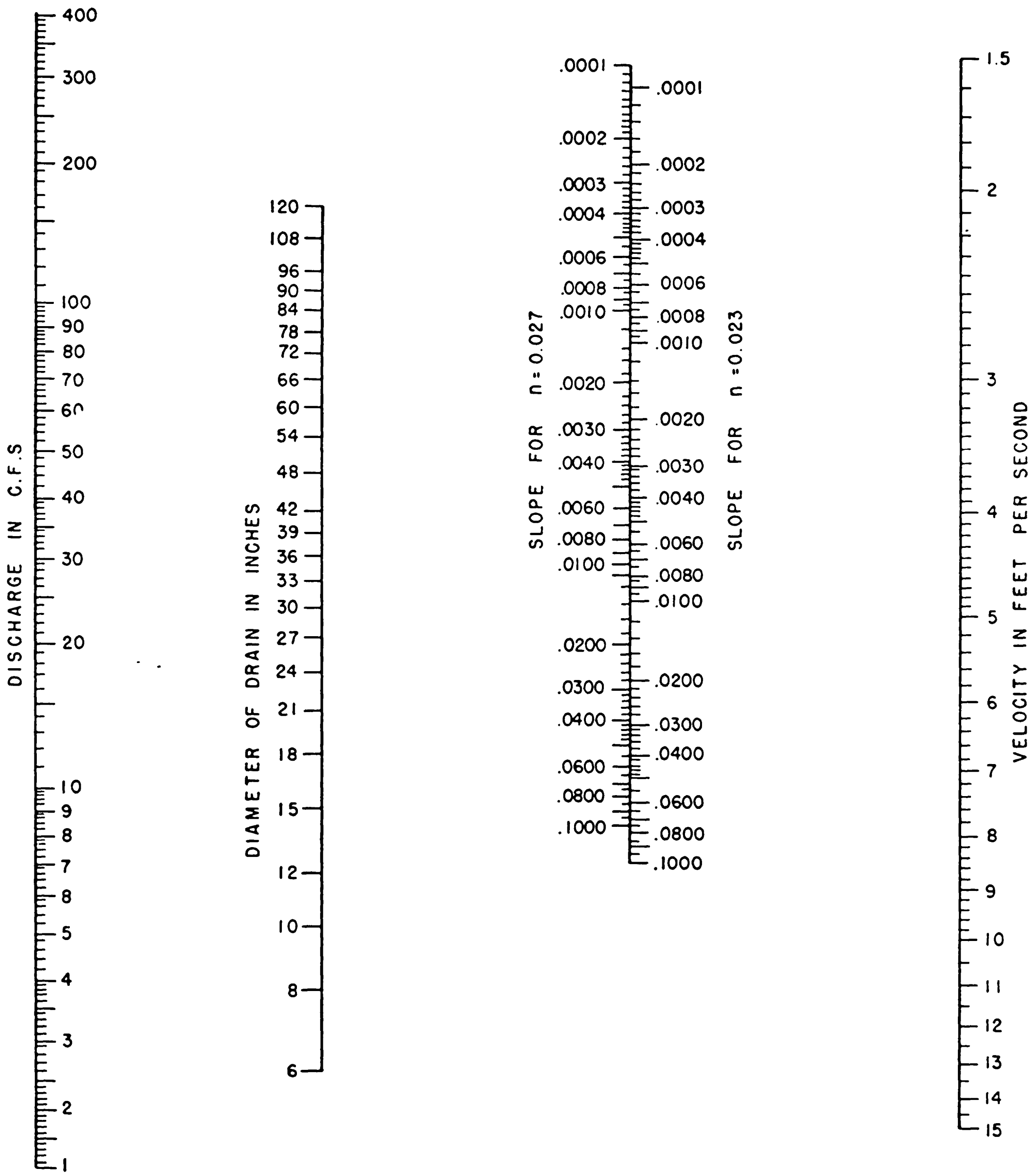
Nomograph for computing required size of circular drain, flowing full - n = 0.012 OR 0.013

Richland County Design Chart No. 63



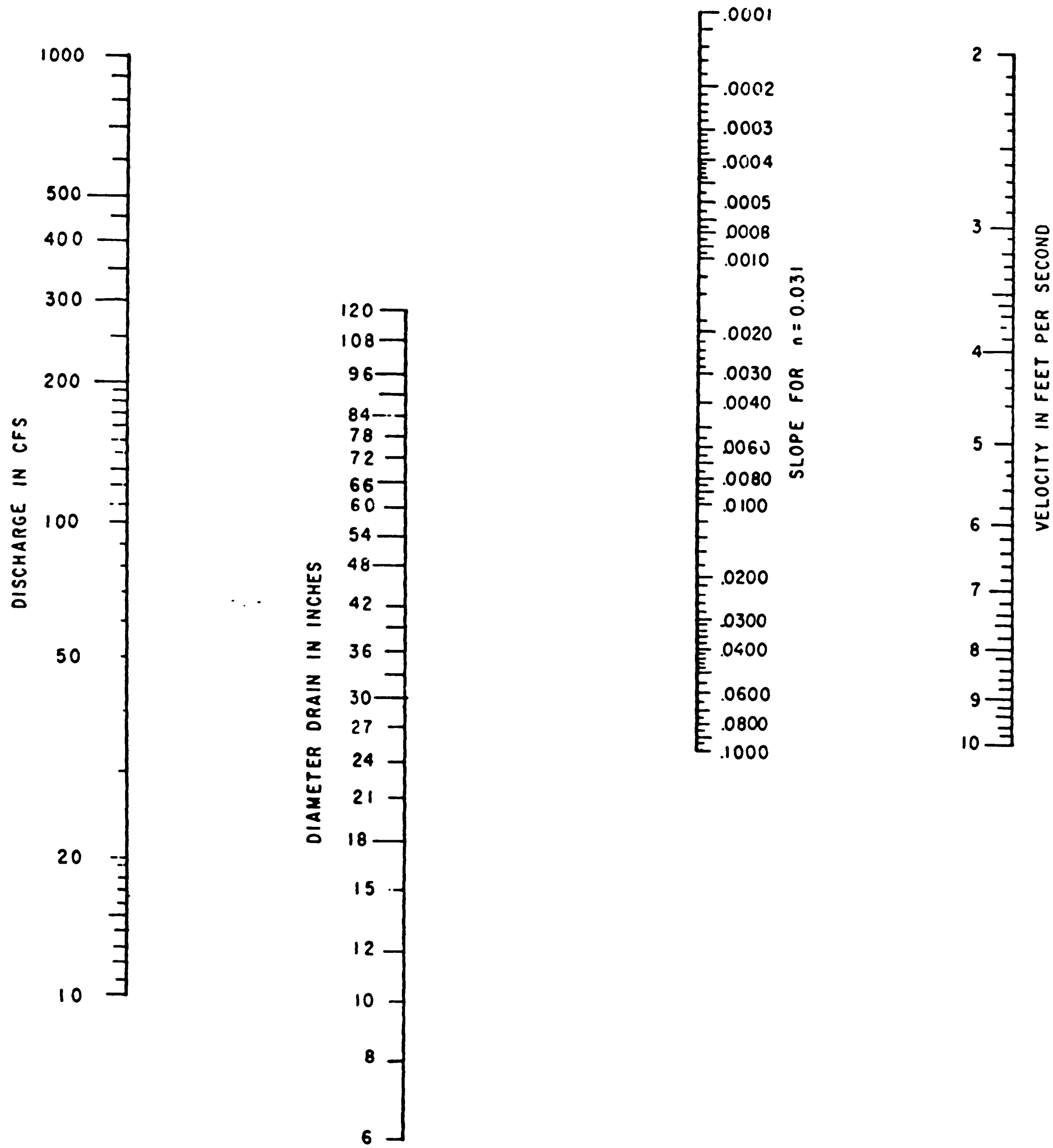
Nomograph for computing required size of circular drain,
flowing full - n=0.021 OR 0.024

Richland County Design Chart No. 64



Nomograph for computing required size of circular drain
flowing full – n = 0.023 OR 0.027

Richland County Design Chart No. 65



NOMOGRAPH FOR COMPUTING REQUIRED SIZE OF CIRCULAR DRAIN FLOWING FULL

The energy loss in the junction may be estimated by the equation,

$$H = H_i + H_o + H = 0.1\left(\frac{V_i^2}{2g}\right) + 0.05\left(\frac{V_o^2}{2g}\right) + K_b\left(\frac{V_i^2}{2g}\right)$$

Where: H = total energy loss in feet,

H_i = expansion loss (flow into junction) in feet,

H_o = contraction loss (flow out of junction) in feet,

H = bend loss in feet,

V_i = velocity in incoming pipe in ft/second,

V_o = velocity in outgoing pipe in ft/second,

g = acceleration due to gravity, 32.2 ft/second^2,

And K_b = bend loss coefficient as shown below:

	K_b	
Angle of Change in Degrees	***Standard Box***	***Modified Box***
0 - 10	0.06	0.06
10 - 20	0.12	0.09
20 - 30	0.20	0.15
30 - 40	0.32	0.23
40 - 50	0.47	0.34
50 - 60	0.64	0.48
60 - 70	0.83	0.63
70 - 80	1.06	0.81
80 - 90	1.32	1.02

Care should be take to avoid junctions that create excessive energy loss.

Several public domain and commercial computer programs have the capability of analyzing the hydraulic capacity of proposed storm drain pipelines. Computer models using the criteria presented above are acceptable.

4.3.2 Pressure Flow: Storm sewers may be designed to flow under pressure only in unusual circumstances and only with the prior approval of the County Engineer. In these instances, the hydraulic grade line is to be calculated and plotted on the storm drain profiles and submitted along with the drainage plans and calculations. The pipe is to be sized such that the hydraulic grade line remains a minimum of 1.0 feet below the ground surface at all inlets and junction boxes.

The hydraulic gradient for storm sewers flowing under pressure is to be calculated using either:

1) The Darcy-Weisbach Equation,

$$H = \left(\frac{fL}{D}\right)\left(\frac{V^2}{2g}\right)$$

Where:	H	=	head loss due to friction in feet
	L	=	length of pipe in feet,
	V	=	mean velocity in $^{ft}/_{second}$,
	D	=	pipe diameter in feet,
	g	=	acceleration due to gravity, 32.2 $^{ft}/_{second^2}$,
And	f	=	function of Reynolds Number R and the relative roughness k/D; with k representing effective absolute roughness of the conduit

or

2) The Hazen-Williams Equation,

$$H = L\left(\frac{V}{1.318CR^{0.63}}\right)^{1.8519}$$

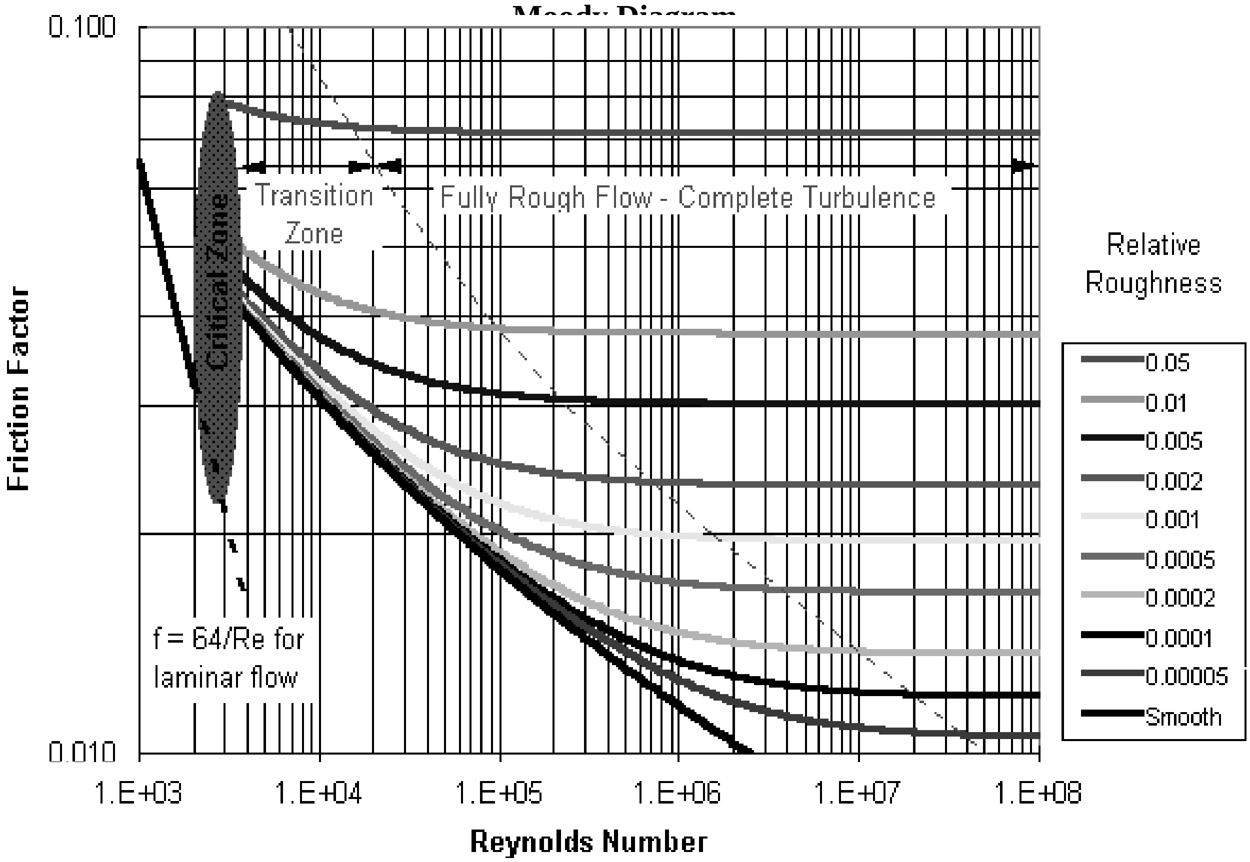
Where	H	=	head loss due to friction in feet,
	L	=	length of pipe in feet,
	V	=	mean velocity in $^{ft}/_{second}$,
	C	=	Hazen-Williams coefficient,
And	R	=	hydraulic radius in feet ($^{D}/_{4}$ for pipes flowing full)

Values for the Hazen-Williams Coefficient C and the Darcy-Weisbach absolute roughness for various pipe materials are presented in Table 9. The Moody Diagram (Richland County Design Chart No. 66), relating the Darcy-Weisbach friction factor (f) to absolute roughness (k), is required for use of the Darcy-Weisbach formula.

Table 9
Darcy-Weisbach Effective Absolute Roughness (*k*) and Hazen-Williams Coefficient (*C*) for Select Closed Conduit Materials

Conduit Material	*Effective Absolute Roughness (Darcy-Weisbach) k (ft)*	*Hazen-Williams C*
Asbestos-cement pipe	0.001 - 0.01	100 - 140
Cast iron pipe		
1) Uncoated (new)	0.00085	-
2) Asphalt dipped (new)	0.0004	-
3) Cement-lined and seal coated	0.001 - 0.01	100 - 140
Concrete pipe	0.001 - 0.01	100 - 140
Corrugated metal pipe ($^1/_2$-in. by $2^2/_3$-in. corrugations)		
1) Plain	0.01 - 0.2	-
2) Paved invert	0.02 - 0.1	-
3) Spun asphalt lined	0.001 - 0.01	100 - 140
Plastic pipe (smooth)	0.01	100 - 140
Vitrified clay pipe		
1) Pipes	0.001 - 0.01	100 - 140
2) Liner Plates	0.005 - 0.01	-

Richland County Design Chart No. 66
Moody Diagram



4.3.3 Discharge Velocity: Discharge velocities shall be reduced to provide a non-erosive velocity flow at the storm sewer outfall or the velocity of the design storm runoff under predevelopment conditions. Outlet protection measures, such as riprap, may be required to minimize erosion and scour potential.

4.3.4 Materials: Reinforced concrete pipe, corrugated metal pipe and HDPE pipe as specified and described in Sections 4.2.6.1, 4.2.6.2 and 4.2.6.5 respectively are acceptable.

4.3.5 Minimum Size: The minimum acceptable diameter of storm sewer pipe is 15 inches.

4.3.6 Easements: The minimum acceptable widths for drainage easements are as follows:

Pipe Size (in.)	***Easement Width (ft.)***
15, 18	10
24 - 36	15
42 - 60	20
> 60	24

4.3.7 Construction Specifications: The specifications referenced in Sections 6.6.1 and 6.6.2 will apply.

4.4 Catch Basins, Junction Boxes and Manholes

A catch basin, junction box, or manhole shall be required at all changes of grades, size, or direction of a pipe and at junctions of two or more pipe. They may be constructed of reinforced concrete or concrete brick masonry. Precast concrete junction boxes, either round or rectangular, are also acceptable. Cast in place or precast concrete junction boxes are required for pipe sizes larger than 36-inches in diameter. Shop drawings must be provided for all precast concrete junction boxes. Construction plans must be provided for all cast-in-place junction boxes.

4.4.1 Prefabricated Bends: Prefabricated reinforced concrete or corrugated metal pipe bends are acceptable when the pipe size remains constant. The design of the bend should provide for the addition of a catch basin or manhole for surface access. Shop plans must be provided for all such installations.

4.4.2 Invert Elevations: Invert elevations for incoming and outgoing pipes shall be set such that the elevation drop (see Section 4.3.1) across a junction box, manhole or catch basin equals or exceeds the energy loss across it or the change in pipe diameter, whichever is larger.

4.4.3 Catch Basins

4.4.3.1 Placement: Catch basins are to be placed at close enough intervals along a street so that the curb and gutter are not overtopped during the 10-year rainfall. A sufficient number of catch basins should be provided so that the peak discharge delivered to each one does not exceed its calculated inlet capacity for this condition.

4.4.3.2 Standard Catch Basins: Where Richland County is to accept maintenance responsibility for the streets and drainage system, Richland County standard catch basins are to be used. Standard details for catch basin types A, B, and C may be obtained from the County Engineer's office. Calculated inlet capacities for these catch basins, when located in a sump, are as follows:

Table 10
Inlet Capacity for Richland County Standard Catch Basins

Catch Basin Type	*Inlet Capacity (cfs)*
A	12.1
B	10.6
C	9.4

4.4.4 Construction Specifications: The specifications referenced in Section 6.6.3 will apply.

4.4.5 Access: When the depth of a catch basin, junction box, or manhole exceeds 4 feet, metal rungs or a suitable alternative will be provided for safe ascent and descent.

4.5 Open Channels:

4.5.1 General: The Stormwater Management Ordinance permits the use of open drainage channels under the following circumstances:

1) Improved open channels may be used instead of closed storm sewers when the watershed tributary to the channel exceeds 40 acres or when the channel is part of a stormwater water quality management plan. The County Engineer for environmental or aesthetic purposes may require a natural channel. These determinations will be made on a case by case basis.

2) An improved open channel may also be used instead of a closed storm sewer larger than 30 inches in diameter, regardless of watershed size, as determined on a case-by-case basis.

4.5.2 Design Considerations: The following factors should be considered in the design of open channels:

1) Hydraulic capacity
2) Erosion potential and water quality degradation
3) Future maintenance requirements
4) Safety

<u>In no case will a bank slope less than 2:1 be approved.</u>

4.5.3 Capacity: Open channels shall be designed to contain the design discharge within their banks by use of the Manning (normal) Equation. Richland County Design Chart No. 61 in conjunction with Richland County Design Charts 67 through 70 (see Table 11) may be used for the solution of the Manning equation for trapezoidal channels. Recommended Manning's roughness coefficients for various types of channels and channel linings are tabulated in Table 12.

Table 11
Design Aids and Charts for Solution of Manning's Equation for Channel Flow

Richland County Design Chart No.	*Description*
66	Dimensions of trapezoidal channels with 2½ to 1 side slopes[17]
67	Dimensions of trapezoidal channels with 3 to 1 side slopes
68	Dimensions of trapezoidal channels with 4 to 1 side slopes
69	Dimensions of triangular channels

Outfall conditions will be analyzed to confirm that the channel can discharge its peak design flow at the computed normal depth. For conditions in which capacity of the channel to discharge its design flow is governed by conditions on the receiving stream (e.g. high tailwater condition) or the channel is traversed by one or more stream crossings, either bridge or culvert, then analysis of these conditions using acceptable engineering models (e.g. HEC-2 or HEC-RAS) must demonstrate that the channel can contain the design discharge within the channel banks.

4.5.4 Discharge Velocity: Discharge velocities shall be reduced to provide a non-erosive velocity flow at the confluence with an existing stream or channel, or the velocity of the design storm runoff under predevelopment conditions. Outlet protection measures, such as riprap, may be required to minimize erosion and scour potential.

4.5.5 Plan Requirements: Plans for any open channel should include plan and profile, typical cross section, cross sections at no less than 100 foot intervals and a water surface profile for the design discharge. The flow velocity at the design discharge should also be provided.

4.5.6 Erosion Protection: Bank and channel protective measures shall be used whenever flow velocities at the design discharge exceed 2.0 feet per second in easily eroded soils or 3.0 feet per second in erosion resistant soils. This determination should be made in consultation with either the County Engineer's office or the Natural Resource Conservation Service (NRCS) office.

Acceptable bank and channel protective measures include:

1) Reinforced concrete
2) Fabric formed concrete (Fabriform® or equivalent product)
3) Articulated concrete block (ACB) mats
4) Geogrid or similar geotextile erosion control measures
5) Riprap
6) Bio-engineered stream restoration/stabilization measures

Construction plans, details, and supporting calculations and analyses shall be submitted for the proposed bank and channel protective measures.

[17] Federal Aviation Administration, Airport Drainage (1970)

Richland County Design Chart No. 67

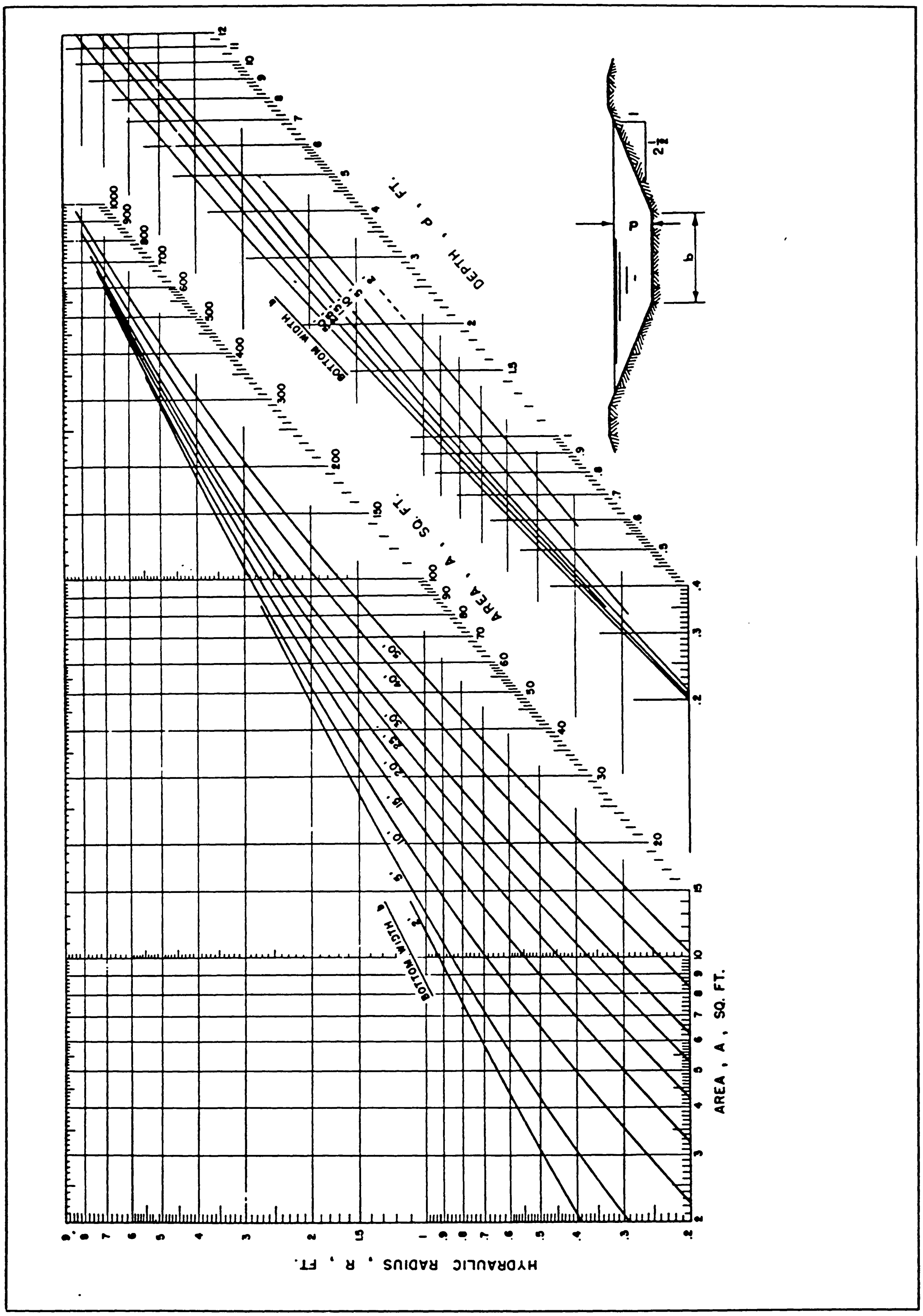


FIGURE 14. Dimensions of trapezoidal channels with 2½ to 1 side slope.

Richland County Design Chart No. 67

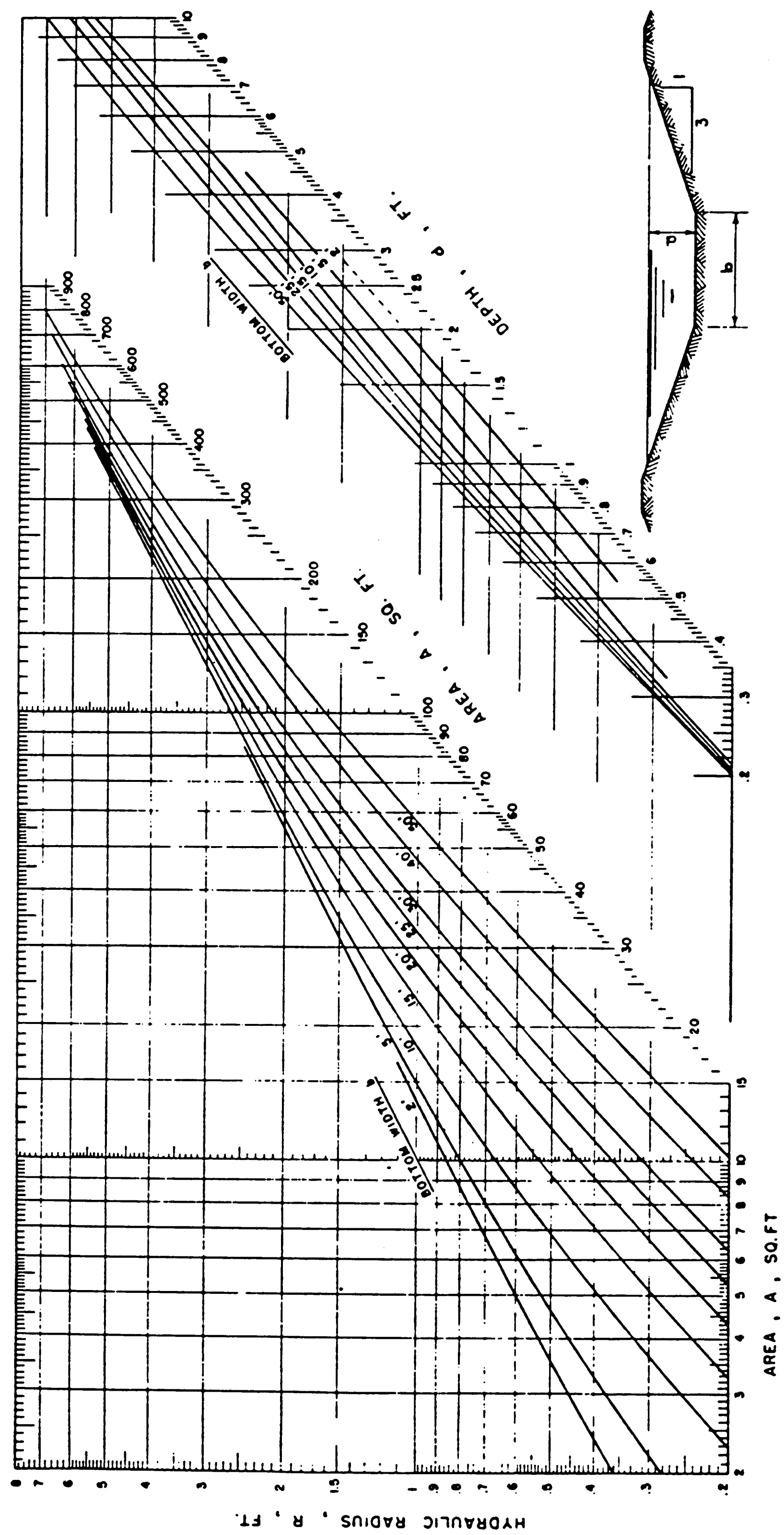


Figure 15. Dimensions of trapezoidal channels with 3 to 1 side slopes.

Richland County Design Chart No. 69

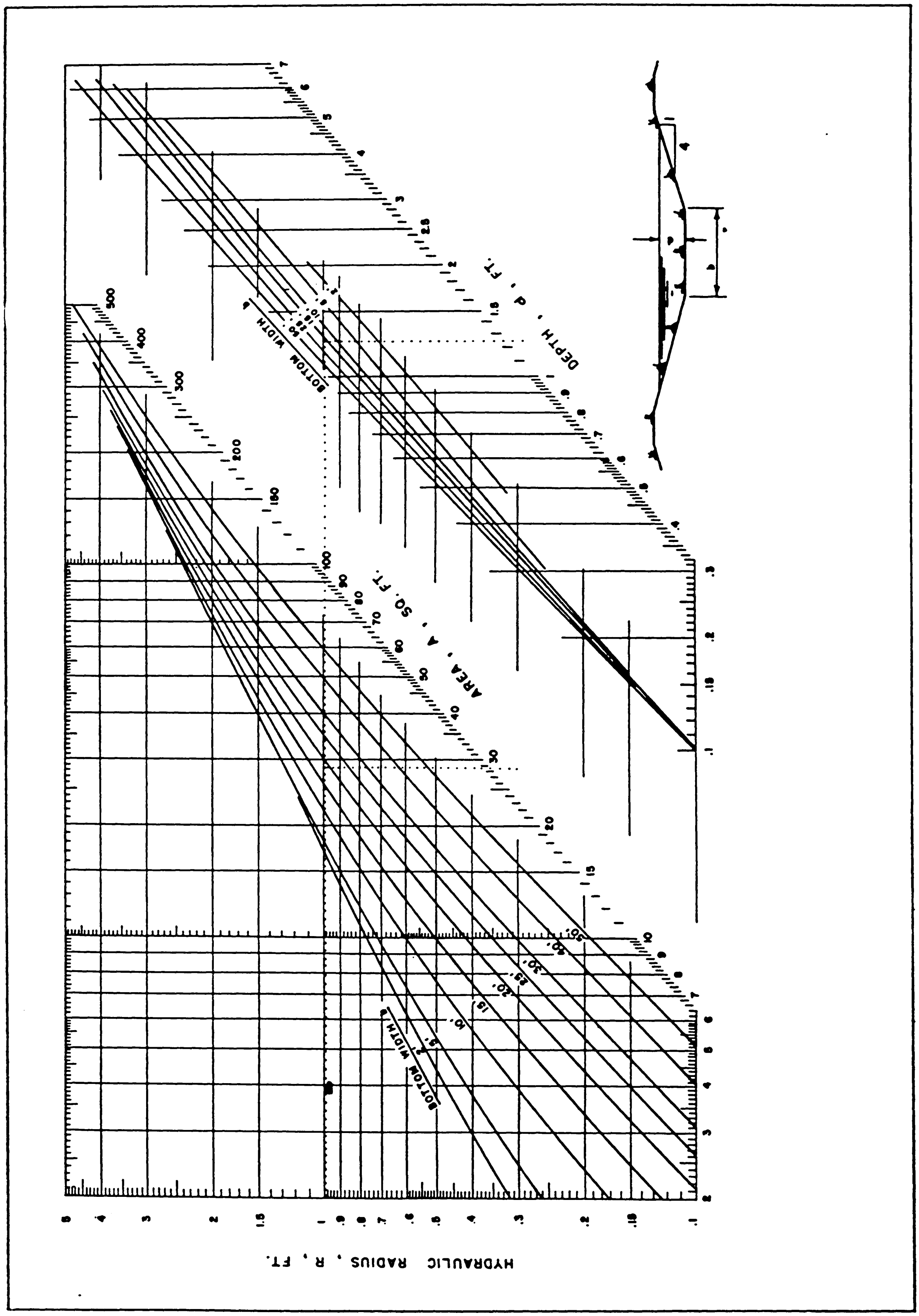


FIGURE 16. Dimensions of trapezoidal channels with 4 to 1 side slopes.

Richland County Design Chart No. 70

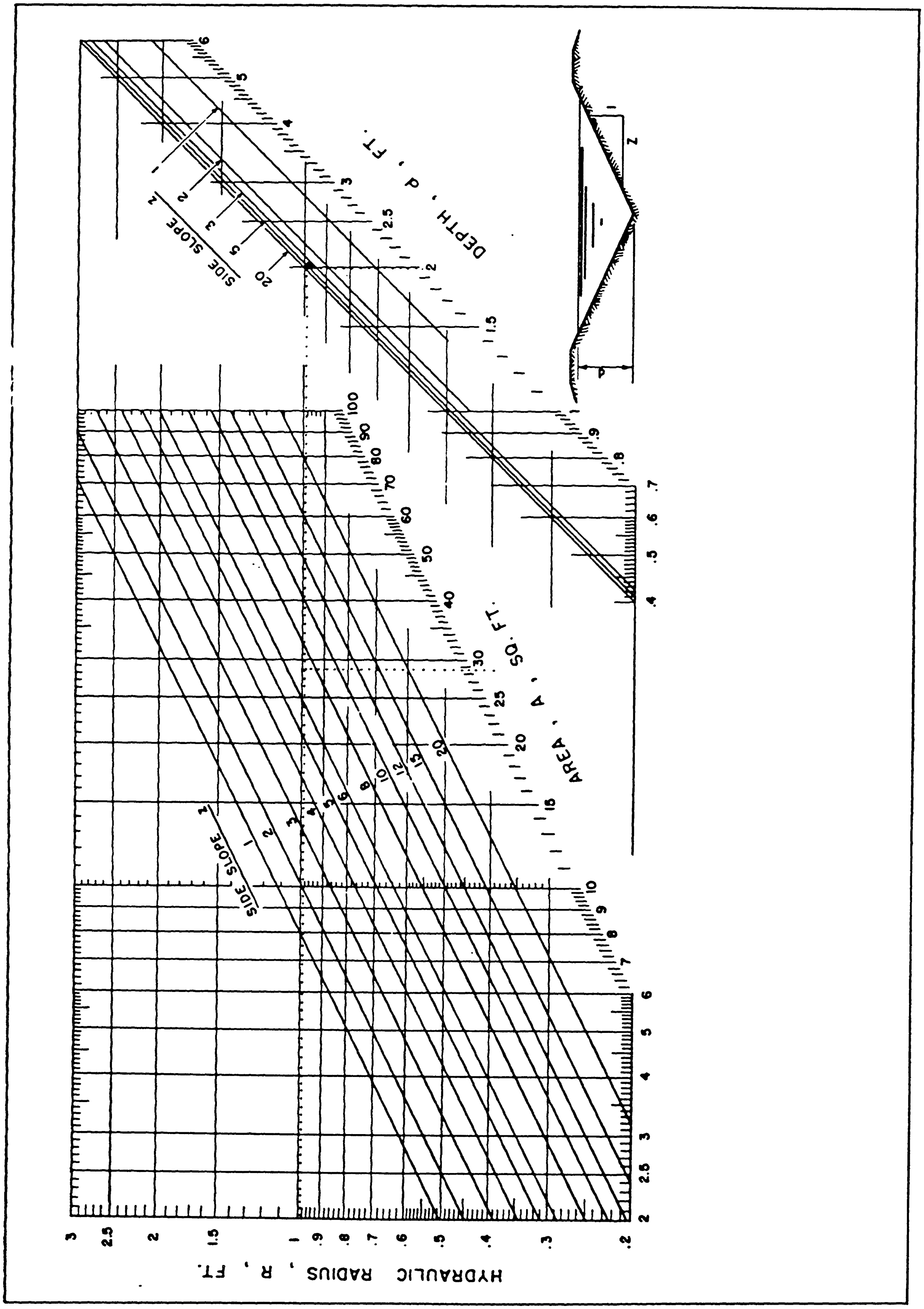


FIGURE 17. Dimensions of triangular channels.

Table 12
Manning's n Values for Open Channels[18]

-- *Channel Description* --	*Manning's n Range*
Lined Open Channels:	
1) Concrete, with surfaces as indicated:	
a) Formed, no finish	0.013 - 0.017
b) Trowel finish	0.012 - 0.014
c) Float finished	0.013 - 0.015
d) Float finished, some gravel on bottom	0.015 - 0.017
e) Gunite, good section	0.016 - 0.019
f) Gunite, wavy section	0.018 - 0.022
2) Concrete bottom float finished, sides as indicated:	
a) Dressed stone in mortar	0.015 - 0.017
b) Random stone in mortar	0.017 - 0.020
c) Cement rubble masonry	0.020 - 0.025
d) Cement rubble masonry, plastered	0.016 - 0.020
e) Dry rubble (riprap)	0.018 - 0.022
3) Gravel bottom, sides as indicated:	
a) Formed concrete	0.017 - 0.020
b) Random stone in mortar	0.020 - 0.023
c) Dry rubble (riprap)	0.023 - 0.033
4) Brick	0.014 - 0.017
5) Asphalt	
a) Smooth	0.013
b) Rough	0.016
6) Wood, planed, clean	0.011 - 0.013
7) Concrete-lined excavated rock:	
a) Good section	0.017 - 0.020
b) Irregular section	0.022 - 0.027

[18] Federal Highway Administration, Hydraulic Design Series No. 4, Design of Roadside Channels (1965)

Table 12 (continued)

Manning's n Values for Open Channels

--- *Channel Description* ---	*Manning's n Range*
Unlined Channels:	
1) Earth, uniform section:	
a) Clean, recently completed	0.016 - 0.018
b) Clean, after weathering	0.018 - 0.020
c) With short grass, few weeds	0.022 - 0.027
d) In gravely soil, uniform section, clean	0.022 - 0.025
2) Earth, fairly uniform section:	
a) No vegetation	0.022 - 0.025
b) Grass, some weeds	0.025 - 0.030
c) Dense weeds or aquatic plants in deep channel	0.030 - 0.035
d) Sides, clean, gravel bottom	0.025 - 0.030
e) Sides, clean, cobble bottom	0.030 - 0.040
3) Dragline excavated or dredged:	
a) No vegetation	0.028 - 0.033
b) Light brush on banks	0.035 - 0.050
4) Rock	
a) Based on design section	0.035
b) Based on actual mean section	
i) Smooth and uniform	0.035 - 0.040
ii) Jagged and irregular	0.040 - 0.045
5) Channels not maintained, weeds and brush uncut:	
a) Dense weeds, high as flow depth	0.08 - 0.12
b) Clean bottom, brush on sides	0.05 - 0.08
c) Clean bottom, brush on sides, highest stage of flow	0.07 - 0.11
d) Dense brush, high stage	0.10 - 0.14
Highway channels/swales with maintained vegetation (velocities of 2 and 6 fps):	
1) Depth of flow up to 0.7 foot:	
a) Bermuda grass, Kentucky bluegrass, buffalo grass:	
i) Mowed to 2 inches	0.07 - 0.045
ii) Length 4 to 6 inches	0.09 - 0.05
b) Good stand, any grass:	
i) Length about 12 inches	0.18 - 0.09
ii) Length about 24 inches	0.30 - 0.15
c) Fair stand, any grass	
i) Length about 12 inches	0.14 - 0.08
ii) Length about 24 inches	0.25 - 0.13

Table 12 (continued)

Manning's n Values for Open Channels

--- *Channel Description* ---	*Manning's n Range*
Highway channels/swales with maintained vegetation (velocities of 2 and 6 fps) (cont.):	
2) Depth of flow 0.7 to 1.5 feet	
a) Bermuda grass, Kentucky bluegrass, buffalo grass:	
i) Mowed to 2 inches	0.05 - 0.035
ii) Length 4 to 6 inches	0.06 - 0.04
b) Good stand, any grass:	
i) Length about 12 inches	0.12 - 0.07
ii) Length about 24 inches	0.20 - 0.10
c) Fair stand, any grass	
i) Length about 12 inches	0.10 - 0.06
ii) Length about 24 inches	0.17 - 0.09
Streets and expressway gutters:	
1) Concrete gutter, trowel finished:	0.012
2) Asphalt pavement:	
a) Smooth texture	0.013
b) Rough texture	0.016
3) Concrete gutter with asphalt pavement:	
a) Smooth	0.013
b) Rough	0.015
4) Concrete pavement:	
a) Float finish	0.014
b) Broom finish	0.016
5) For gutters with small slope, where sediment may accumulate, increase n by	0.002
Natural stream channels:[19]	
1) Minor streams (surface at flood stage less than 100 ft.)	
a) Fairly regular section:	
i) Some grass and weeds, little or no brush	0.030 - 0.035
ii) Dense growth of weeds, depth of flow materially greater than weed height	0.035 - 0.05
iii) Some weeds, light brush on banks	0.04 - 0.05
iv) Some weeds, heavy brush on banks	0.05 - 0.07
v) Some weeds, dense willows on banks	0.06 - 0.08
vi) For trees within channel, with branches submerged at high stage, increase above values by	0.01 - 0.10
2) Irregular section, with pools, slight channel meander; increase 1)a) i - vi about	0.01 - 0.02
3) Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage:	
a) Bottom of gravel, cobbles, and few boulders	0.04 - 0.05
b) Bottom of cobbles, with large boulders	0.05 - 0.07

[19] The tentative values of *n* cited are principally derived from measurements made on fairly short but straight reaches of natural streams. Where slopes calculated from flood elevations along a considerable length of channel, involving meanders and bends, are to be used in velocity calculations by the Manning's formula, the value of *n* must be increased to provide for additional loss of energy caused by bends. The increase may be in the range of perhaps 3 to 15 percent.

Table 12 (continued)

Manning's n Values for Open Channels

-- *Channel Description* --	*Manning's n Range*
Floodplains (adjacent to natural streams):[20]	
1) Pasture, no brush:	
a) Short grass	0.030 - 0.035
b) High grass	0.035 - 0.05
2) Cultivated areas:	
a) No crop	0.03 - 0.04
b) Mature row crops	0.035 - 0.045
c) Mature field crops	0.04 - 0.05
3) Heavy weeds, scattered brush	0.05 - 0.07
4) Light brush and trees:	
a) Winter	0.05 - 0.06
b) Summer	0.06 - 0.08
5) Medium to dense brush:	
a) Winter	0.07 - 0.011
b) Summer	0.10 - 0.16
6) Dense willows, summer, not bend over by current	0.15 - 0.20
7) Cleared land with tree stumps, 100 - 150 per acres:	
a) No sprouts	0.04 - 0.05
b) With heavy growth of sprouts	0.06 - 0.08
8) Heavy stand of timber, few down trees, little undergrowth:	
a) Flood depth below branches	0.10 - 0.12
b) Flood depth reaches branches	0.12 - 0.16
Major streams (surface width at flood stage more than 100 ft.): Roughness coefficient is usually less than for minor streams or similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Values of n may be somewhat reduced. The value of n for most larger streams of regular section, with no boulders or brush, may be in the range of	0.028 - 0.033

4.6 Headwalls:

Reinforced concrete headwall, similar or identical to one of Richland County's standard headwalls or a "flared end section" shall be placed at the ends of any culvert or closed storm sewer system. Precast or cast-in-place concrete headwalls are acceptable. Richland County's standard headwall details may be obtained from the County Engineer's office.

[20] The tentative values of *n* cited are principally derived from measurements made on fairly short but straight reaches of natural streams. Where slopes calculated from flood elevations along a considerable length of channel, involving meanders and bends, are to be used in velocity calculations by the Manning's formula, the value of *n* must be increased to provide for additional loss of energy caused by bends. The increase may be in the range of perhaps 3 to 15 percent.

4.7 Stormwater Management:
Urban stormwater runoff contains many types and forms of constituents. When compared to stormwater runoff from pre-development conditions, higher concentrations and some contaminants that are not naturally present in surface runoff from undeveloped local lands are found. Once developed, pollutant loads increase because surface runoff volumes increase and the sources of many of these pollutants increase. Supplemental applications of compounds, such as fertilizers, also tend to increase the availability of some pollutants to stormwater runoff.

Runoff water quality in urban areas can be extremely harmful to local habitat. Paved surfaces and standing water bodies for stormwater management control elevate the temperature of water entering streams. Chemicals in standing water and ponds are oxidized, resulting in depressed levels of dissolved oxygen. Increased runoff volumes and rates creates scour and deposition damage to in-stream habitat. Activities in urbanized areas, such as vehicular traffic, deposit pollutants such as heavy metals and oil & grease on paved surfaces where they easily wash off into the streams.

To help mitigate the adverse effects of land development activities, the County Stormwater Management Ordinance requires <u>that no land disturbing activity be started without an approved Stormwater Management Plan</u>. Specific requirements for each plan are generally based on the extent of the land disturbing activity, as described in the Ordinance.

4.7.1 General Requirements:
Facilities for the proper management and controlled release of stormwater shall be required in new developments for stormwater quantity and/or quality.

4.7.1.1 Stormwater Quantity Control:
Post-development stormwater peak flow rates shall not exceed pre-development peak discharge rates for the 2-year through the design frequency (see Section 4.1.1) 24-hour duration storm event. Stormwater management facilities shall be used as needed to satisfy this requirement.

The appropriateness of stormwater storage facilities for mitigating peak flow increases should be determined in consultation with the County Engineer's office. At the request of the County, a comprehensive hydrology study of a receiving stream or drainage system under pre-development and post-development conditions may be required to assess potential impacts. Based on the finding of such studies, the design criteria for stormwater quantity management may be revised.

4.7.1.2 Stormwater Quality Control:
Best Management Practices (BMPs) are required to control and minimize water quality degradation resulting from construction activities and post-construction land uses. Richland County has implemented a performance standard that defines BMP effectiveness in terms of removal of total suspended sediment (TSS) from polluted stormwater. Specifically, Richland County has adopted a BMP performance standard that requires all temporary and permanent BMPs shall be designed and constructed to accommodate the expected sediment loading, from both construction activities and post-construction land use with a removal efficiency of 80% of total suspended solids or 0.5 $^{ML}/_{L}$ peak settleable solids concentration, whichever is less.

Water quality impairment results, in part, because a number of pollutants are preferentially absorbed onto mineral or organic particles found in fine sediment. This interconnected process of erosion (detachment of the soil particles), sediment transport, and delivery is an important conduit for introducing other key pollutants, such as nutrients (particularly phosphorus), metals, and organic compounds into surface waters. Thus, TSS is a good indicator for many stormwater pollutants in evaluating a BMP's effectiveness in pollutant removal.

Most BMPs designed for TSS removal are based on the concept of a "first flush." Pollutants deposited onto exposed areas can be dislodged and entrained by the rainfall-runoff process. Usually the stormwater that initially runs off an area will be more polluted than the stormwater that runs off later, after the rainfall has "cleansed" the catchment. The stormwater containing this high initial pollutant load is called the "first flush." The existence of this first flush of pollutants provides an opportunity for controlling stormwater pollution from a broad range of land uses and is the fundamental concept in storm water quality management prescribed by South Carolina Department of Health and Environmental Control.

4.7.1.3 Exceptions and Waivers: Waivers may be granted from these conditions if:

1) the proposed project will not change the pre-development runoff and the pre-development land use will not change, or

2) the proposed project will not have a significant adverse impact on the receiving natural waterway or properties, or

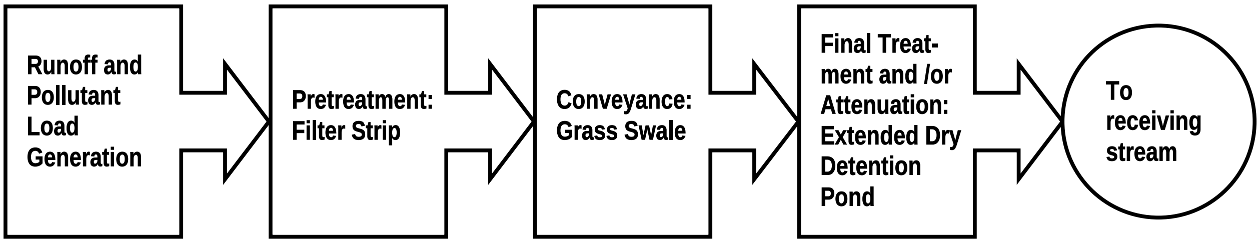
3) the requirement of on-site retention/detention for peak stormwater flow control would worsen downstream flooding.

4.7.1.4 Construction Pollution Control: Performance standards presented in Sections 4.7.1.1 and 4.7.1.2 apply. Sediment basins shall be used on all land development projects on which ten (10) acres or more are disturbed during construction. Sediment basins may be converted to permanent use for detention or water quality after construction is completed provided all accumulated silt is removed from the basin and disposed of after all disturbed areas have been stabilized.

4.7.1.5 Post-Construction Pollution Control: Performance standards presented in Sections 4.7.1.1 and 4.7.1.2 apply. Selection of a particular BMP to achieve the required pollutant removal efficiency shall be determined through review of monitoring studies of similar BMPs (Table 13), application of computer models such as SEDIMOT, SEDCAD or HEC.

4.7.1.6 Computation of Estimated BMP Pollutant Removal Capabilities: BMPs can be used independently as the only management practice employed for a specific area or combined as components in an overall BMP plan, frequently called a stormwater "treatment train." Estimation of BMP efficiency, i.e. the pollutant removal rate, for a single BMP measure is simple and straightforward. For two or more BMPs used in series (Figure 1), the pollutant removal rates are not additive. For example, for two BMPs in series, the second BMP will function very differently than if it was the only BMP used to treat the polluted stormwater. The first BMP will capture the more easily removed larger sediment sizes, passing on an outflow with a lower concentration, but with a considerably higher proportion of finer particle sizes. Upstream BMPs in a treatment train thus reduce downstream structural control average pollutant removal percentages. When calculating removal of pollutants to achieve a target, the removal efficiency of a downstream control must be reduced to account for the pollutant removal achieved by an upstream control(s).

Figure 1
Example Stormwater Treatment Train



To estimate the pollutant removal rate of structural controls in series, a method is used in which the removal efficiency of a downstream structural control is reduced to account for the pollutant removal of the upstream control(s). The following steps are used to determine the pollutant removal:

1. For each drainage area list the structural controls in order, upstream to downstream, along with their expected average pollutant removal rates for the pollutants of concern.

2. Apply the following equation for calculation of approximate total accumulated pollution removal for Controls in series:

Final Pollutant Removal = *(Total load*$\times$*Control*$_1$ *removal rate) + (Remaining load*$\times$*Control*$_2$ *removal rate) + … for other Controls in series.*

Figure 2 below demonstrates these calculations for the example stormwater treatment train presented in Figure 1.

Figure 2
Example Stormwater Treatment Train

Stage in Stormwater Treatment Train	Inflow Pollutant Load	x	Pollutant Removal Efficiency	=	Remaining Pollutant Load (% TSS)
Runoff and Pollutant Load Generation	-		-		100%
Pretreatment: Filter Strip	100%	x	50%	=	50%
Conveyance: Grass Swale	50%	x	30%	=	15%
Final Treatment and/or Attenuation: Extended Dry Detention Pond	15%	x	45%	=	7%
	Initial TSS Load				100%
	Final TSS Load			—	7%
	TSS Removal Efficiency				93%

Table 13
Estimated Effectiveness of Common Structural Best Management Practices

	TSS Removal Efficiency (%)			
Management Practice	***Reported Range***	***Probable Range***	***Design***	***Factors Affecting Efficiency***
Retention ponds, including wet pond, wet extended detention pond, and micropool extended detention pond.	50 - 100	-	80	• Pool volume • Pool shape
Constructed stormwater wetlands	-20 - 100	50 - 90	85	• Storage volume • Detention time • Pool shape • Wetland biota • Seasonal variation
Extended detention dry pond	5 - 90		45	• Storage volume • Detention time • Pond shape
Infiltration trench, including dry wells	45 - 100	HSG A: 60 - 100 HSG B: 50 -80	HSG A: 80 HSG B: 65	• Soil percolation • Trench surface area • Storage volume
Vegetated Filter Strip	20 - 80	40 - 90	50	• Runoff volume • Slope • Soil infiltration rate • Vegetative cover • Buffer length
Grass Swale	0 - 100	20 - 40	30	• Runoff volume • Slope • Soil infiltration rates • Vegetative cover • Swale length • Swale geometry
Enhanced Grass Swale	63 - 100	-	80	• Storage volume • Slope • Soil infiltration rates • Vegetative cover • Swale length • Swale geometry
Sand Filter	60 - 95	60 - 90	80	• Maintenance • Sediment Storage Volume
Gravity Separator	0 - 25	10 - 25	15	• Sediment storage volumes • Outlet configurations

4.7.1.7 Estimation of Sediment Load: Estimates of sediment load are required to determine sediment storage and maintenance requirements of BMPs. The Universal Soil Loss Equation (USLE) or other approved method shall be used to estimate average erosion (sediment load). The Universal Soil Loss Equation is:

$$A = RKLSCP$$

Where	A	=	average annual soil loss in tons per acre per year,
	R	=	rainfall and runoff erosivity index for a given location,
	K	=	soil erodibility factor,
	L	=	slope length factor,
	S	=	slope steepness factor,
	C	=	cover and management factor,
And	P	=	conservation or support practice factor,

The long-term average annual rainfall and runoff erosivity, *R*, factor for Richland County to be used in soil loss calculations is 290.

Soil erodibility is a measure of the susceptibility of a given soil to erosion by rainfall and runoff. The properties of a soil that influence its erodibility are soil texture, soil structure, organic matter content, and soil permeability. The Natural Resources Conservation Service has computed soil erodibility (*K*) factors for Richland County, which are shown in Table 14.

The topographic factors *L* and *S* are used to adjust the erosion rated based upon the length and steepness of the slope. The erosivity of runoff increases with the velocity of the runoff water. Steep slopes produce high runoff velocities. Soil loss increases with increasing slope due to the greater volume of runoff accumulating on the longer slope lengths. The slope length is the distance from the point of origin of the runoff to the point where the slope steepness decreases sufficiently to cause deposition or to the point where runoff enters a well-defined channel. Often the L and S factors are combined into a single topographic factor, *LS*. If the slope length and steepness are known, this combined LS factor can be determined from Richland County Design Chart No. 71 and is presented after Table 14.

The cover and management factor, *C*, is the ratio of soil loss from land use under specified conditions to that from continuously fallow and tilled land. The USLE was developed for use on agricultural fields. It is adapted to use in nonagricultural conditions by appropriate selection of the C factor. Relating the land use conditions to some agricultural situation often does this. For example, lawns with a grass cover might be assumed similar to a pasture. Annual values of *C* for various cover and management conditions are presented in Table 15.

The conservation practice factor, *P*, is used to account for the positive impacts of such management practices as planting on the contour, strip cropping, and use of terraces or the potentially negative impacts of land disturbance activities. In land development, two conditions exist, construction and post-construction. Annual values for *P* for construction conditions are shown in Table 16. In the post-development condition, the primary conservation practice factor of interest will be grading to step down or terrace steep land for development. Terraces reduce the slope length, and sometimes the slope steepness that, in turn, reduce the *L* and *S* factors in the USLE. Thus, the *P* factor for post-construction conditions is taken to be 1.0.

Table 14
Soil Erodibility Factors (*K*) for Richland County

Soil Map Symbol (See Table 4)	Depth (in)	Soil Texture [21]	*K*, Erosion Factor With Rock Fragments	*K*, Erosion Factor Rock Fragments Free	Wind Erosion Group	Rock Fract > 10" (pct) (low)	Rock Fract > 10" (pct) (high)	Rock Fract 3"-10" (pct) (low)	Rock Fract 3"-10" (pct) (high)	Unified Soil Classification	AASHTO Soil Classification
AeC	0 - 30	LS		0.15	1						
	30 - 38	SL SCL	0.24	0.24		0	0	0	0	SM SC SM-SC	A-2 A-4 A-6
	38 - 69	SL SCL	0.17	0.24		0	0	0	0	SM SC SM-SC	A-2 A-4 A-6
AtA	0 - 7	L	0.24	0.24		0	0	0	0	ML CL-ML SM SM-SC	A-4 A-2
	7 - 46	CL SCL L	0.24	0.24		0	0	0	0	CL CL-ML SC SM-SC	A-4 A-6 A-7
	46 - 49	VAR									
BaB	0 - 50	S	0.10	0.10	2	0	0	0	0	SP-SM SM	A-3 A-2-4
	50 - 61	SL LS LCOS	0.15	0.15		0	0	0	0	SM	A-2-4
	61 - 96	SCL SL FSL	0.20	0.20		0	0	0	0	SC SM-SC SM	A-4 A-2-4 A-2-6 A-6
Ca	0 - 5	L	0.28	0.28	5	0	0	0	0	ML	A-4 A-6 A-7
	5 - 57	C SC SIC	0.24	0.24		0	0	0	0	CL ML MH CH	A-6 A-7
	57 - 81	C SIC SCL	0.24	0.24		0	0	0	0	SC CL MH SM	A-4 A-6 A-7
Cd	0 - 4	SICL	0.32	0.32	5	0	0	0	0	ML CL CL-ML	A-4 A-6 A-7
	4 - 41	SICL SIC C	0.37	0.37		0	0	0	0	CL CH ML MH	A-6 A-7
	41 - 82	LS S FS	0.10	0.10		0	0	0	0	SP SM SP-SM	A-2 A-3
Ce	0 - 7	L	0.28	0.28		0	0	0	0	ML CL CL-ML	A-4 A-6 A-7
	7 - 58	SCL L SL	0.28			0	0	0	0	SM SM-SC ML CL	A-4 A-7-6 A-6
	58 - 75	SIL CL SICL	0.32			0	0	0	0	ML MH CL CH	A-4 A-6 A-7
Ch	0 - 7	L	0.28	0.28		0	0	0	0	ML CL CL-ML	A-4 A-6 A-7
	7 - 58	SCL L SL	0.28			0	0	0	0	SM SM-SC ML CL	A-4 A-7-6 A-6
	58 - 75	SIL CL SICL	0.32			0	0	0	0	ML MH CL CH	A-4 A-6 A-7
Cn	0 - 10	SL	0.20	0.20	3	0	0	0	0	SM SC SM-SC	A-2 A-4
	10 - 36	SCL	0.20	0.20		0	0	0	0	SC CL SM-SC CL-ML	A-4 A-6
	36 - 73	SCL SL SC	0.15	0.15		0	0	0	0	SC CL SM-SC CL-ML	A-2 A-4 A-6

[21] Soil Texture Codes: C: Clay; CL; Clay Loam; COS: Coarse Sand; COSL: Coarse Sandy Loam; FS: Fine Sand; FSL: Fine Sandy Loam; L: Loam; LCOS: Loamy coarse sand; LFS: Loamy Fine Sand; LVFS: Loamy Very Fine Sand; S: Sand; SC: Sandy Clay; SCL: Sandy Clay Loam; SI: Silt; SIC: Silty Clay; SCL: Sandy Clay Loam; SI: Silt; SIC: Silty Clay; SICL: Silty Clay Loam; SIL: Silt Loam; SL: Sandy Loam; VFS: Very Fine Sand; VFSL: Very Fine Sandy Loam

Table 14 (continued)

Soil Erodibility Factors (*K*) for Richland County

Soil Map Symbol (See Table 4)	Depth (in)	Soil Texture	*K*, Erosion Factor With Rock Fragments	*K*, Erosion Factor Rock Fragments Free	Wind Erosion Group	Rock Fract > 10" (pct) (low)	Rock Fract > 10" (pct) (high)	Rock Fract 3"-10" (pct) (low)	Rock Fract 3"-10" (pct) (high)	Unified Soil Classification	AASHTO Soil Classification
Co	0 - 8	L	0.37	0.37	6	0	0	0	0	CL-ML ML CL	A-4
	8 - 38	SICL FSL L	0.37	0.37		0	0	0	0	SC ML CL SM	A-4 A-6 A-7
	38 - 80	VAR									
Cx	0 - 9	FSL	0.24	0.24		0	0	0	0	SM ML CL-ML CL	A-4 A-6 A-7
	9 - 65	CL SC C	0.32	0.32		0	0	0	0	CL CH	A-6 A-7
Dn	0 - 58	MUCK				0	0	0	0	PT	
	58 - 76	MUCK				0	0	0	0	PT	
DoA	0 - 17	LS	0.15	0.15		0	0	0	0	SM	A-2
	17 - 37	SCL SL FSL	0.28	0.28		0	0	0	0	SM-SC SC SM	A-2 A-4 A-6
	37 - 78	SCL SC	0.28	0.28		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6 A-7
DoB	0 - 17	LS	0.15	0.15		0	0	0	0	SM	A-2
	17 - 37	SCL SL FSL	0.28	0.28		0	0	0	0	SM-SC SC SM	A-2 A-4 A-6
	37 - 78	SCL SC	0.28	0.28		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6 A-7
DuB	0 - 17	LS	0.15	0.15		0	0	0	0	SM	A-2
	17 - 37	SCL SL FSL	0.28	0.28		0	0	0	0	SM-SC SC SM	A-2 A-4 A-6
	37 - 78	SCL SC	0.28	0.28		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6 A-7
	0 - 60	VAR									
FaA	0 - 7	SL	0.28	0.28		0	0	0	0	SM SM-SC	A-2 A-4
	7 - 12	SCL SC	0.37	0.37		0	0	0	0	SC ML CL SM	A-4 A-6
	12 - 84	SC C CL	0.37	0.37		0	0	0	0	CL SC CH ML	A-6 A-7
FaB	0 - 7	SL	0.28	0.28		0	0	0	0	SM SM-SC	A-2 A-4
	7 - 12	SCL SC	0.37	0.37		0	0	0	0	SC ML CL SM	A-4 A-6
	12 - 84	SC C CL	0.37	0.37		0	0	0	0	CL SC CH ML	A-6 A-7
FuA	0 - 35	S	0.10	0.10		0	0	0	0	SP-SM SM	A-1 A-2 A-3
	35 - 48	SL FSL SCL	0.20	0.20		0	0	0	0	SM SC SM-SC	A-2 A-4 A-6
	48 - 75	SCL	0.20	0.20		0	0	0	0	SC SM-SC CL-ML	A-2 A-4 A-6 A-7-6
FuB	0 - 35	S	0.10	0.10		0	0	0	0	SP-SM SM	A-1 A-2 A-3
	35 - 48	SL FSL SCL	0.20	0.20		0	0	0	0	SM SC SM-SC	A-2 A-4 A-6
	48 - 75	SCL	0.20	0.20		0	0	0	0	SC SM-SC CL-ML	A-2 A-4 A-6 A-7-6

Table 14 (continued)

Soil Erodibility Factors (*K*) for Richland County

Soil Map Symbol (See Table 4)	Depth (in)	Soil Texture	*K*, Erosion Factor With Rock Fragments	*K*, Erosion Factor Rock Fragments Free	Wind Erosion Group	Rock Fract > 10" (pct) (low)	Rock Fract > 10" (pct) (high)	Rock Fract 3"-10" (pct) (low)	Rock Fract 3"-10" (pct) (high)	Unified Soil Classification	AASHTO Soil Classification
FyB	0 - 35	S	0.10	0.10		0	0	0	0	SP-SM SM	A-1 A-2 A-3
	35 - 48	SL FSL SCL	0.20	0.20		0	0	0	0	SM SC SM-SC	A-2 A-4 A-6
	48 - 75	SCL	0.20	0.20		0	0	0	0	SC SM-SC CL-ML	A-2 A-4 A-6 A-7-6
	0 - 60	VAR									
GeB	0 - 9	SIL	0.43	0.49	5			0	2	ML	A-4 A-6
	9 - 52	SICL CL	0.32	0.32				0	1	CL ML	A-6 A-7 A-4
	52 - 72	C SIC SICL	0.28	0.28		0	0	0	1	MH ML	A-7
GeC	0 - 9	SIL	0.43	0.49	5			0	2	ML	A-4 A-6
	9 - 52	SICL CL	0.32	0.32				0	1	CL ML	A-6 A-7 A-4
	52 - 72	C SIC SICL	0.28	0.28		0	0	0	1	MH ML	A-7
GoA	0 - 13	SL	0.20	0.20		0	0	0	0	SM SM-SC SC	A-2 A-4 A-6
	13 - 80	SCL SL	0.24	0.24		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6
HeB	0 - 11	SIL	0.43	0.43	5			0	2	ML CL CL-ML	A-4 A-6
	11 - 57	SICL SIC C	0.28	0.28		0	0	0	1	MH ML	A-7
	57 - 66	SIL L FSL	0.32	0.37		0	0	0	2	MH ML	A-7 A-5
HeC	0 - 11	SIL	0.43	0.43	5			0	2	ML CL CL-ML	A-4 A-6
	11 - 57	SICL SIC C	0.28	0.28		0	0	0	1	MH ML	A-7
	57 - 66	SIL L FSL	0.32	0.37		0	0	0	2	MH ML	A-7 A-5
HnB	0 - 11	SIL	0.43	0.43	5			0	2	ML CL CL-ML	A-4 A-6
	11 - 57	SICL SIC C	0.28	0.28		0	0	0	1	MH ML	A-7
	57 - 66	SIL L FSL	0.32	0.37		0	0	0	2	MH ML	A-7 A-5
	0 - 60	VAR									
Jo	0 - 38	L	0.20	0.20		0	0	0	0	ML SM	A-2 A-4
	38 - 66	SR- FSL SL	0.17	0.17		0	0	0	0	SM	A-2 A-4
KeC	0 - 80	S	0.10	0.10	1	0	0	0	0	SP SP-SM SW	A-2 A-3
KrB	0 - 8	L	0.43	0.43	5	0	0	0	2	ML CL-ML CL	A-4
	8 - 40	SICL CL SIL	0.43	0.43		0	0	0	1	CL ML	A-4 A-6 A-5 A-7
	40 - 56	SIL FSL L	0.43	0.43				0	2	ML CL-ML CL	A-4 A-6

Table 14 (continued)

Soil Erodibility Factors (*K*) for Richland County

Soil Map Symbol (See Table 4)	Depth (in)	Soil Texture	*K*, Erosion Factor With Rock Fragments	*K*, Erosion Factor Rock Fragments Free	Wind Erosion Group	Rock Fract > 10" (pct) (low)	Rock Fract > 10" (pct) (high)	Rock Fract 3"-10" (pct) (low)	Rock Fract 3"-10" (pct) (high)	Unified Soil Classification	AASHTO Soil Classification
LaB	0 - 29	S	0.10	0.10	2	0	0	0	0	SP-SM	A-3 A-2-4
	29 - 99	S FS	0.10	0.10		0	0	0	0	SP SP-SM	A-3 A-2-4
LaD	0 - 29	S	0.10	0.10	2	0	0	0	0	SP-SM	A-3 A-2-4
	29 - 99	S FS	0.10	0.10		0	0	0	0	SP SP-SM	A-3 A-2-4
LkB	0 - 29	S	0.10	0.10	2	0	0	0	0	SP-SM	A-3 A-2-4
	29 - 99	S FS	0.10	0.10		0	0	0	0	SP SP-SM	A-3 A-2-4
	0 - 60	VAR									
LuB	0 - 26	LS	0.15	0.10		0	0	0	0	SM SP-SM	A-2
	26 - 32	SL FSL SCL	0.24	0.24		0	0	0	0	SM SC SM-SC	A-2 A-4 A-6
	32 - 75	SL SCL CL	0.28	0.28		0	0	0	0	SC SM-SC SM	A-2 A-6 A-4
MaA	0 - 8	SL	0.20	0.20	3	0	0	0	0	SM SM-SC ML CL-ML	A-2 A-4
	8 - 64	SC CL C	0.20	0.20		0	0	0	0	CL ML CL-ML	A-4 A-6 A-7
	64 - 80	SCL SC C	0.20	0.20		0	0	0	0	CL ML SM SC	A-4 A-6 A-7
MaB	0 - 8	SL	0.20	0.20	3	0	0	0	0	SM SM-SC ML CL-ML	A-2 A-4
	8 - 64	SC CL C	0.20	0.20		0	0	0	0	CL ML CL-ML	A-4 A-6 A-7
	64 - 80	SCL SC C	0.20	0.20		0	0	0	0	CL ML SM SC	A-4 A-6 A-7
NaB	0 - 11	SIL	0.43	0.49				0	5	ML CL-ML CL	A-4
	11 - 34	SICL SIC C	0.28	0.32				0	5	CL CH MH	A-7
	34 - 41	CN-SIL SIL L	0.28	0.55				0	5	CL-ML SC GM-GC	A-2 A-4 A-6
NaC	0 - 11	SIL	0.43	0.49				0	5	ML CL-ML CL	A-4
	11 - 34	SICL SIC C	0.28	0.32				0	5	CL CH MH	A-7
	34 - 41	CN-SIL SIL L	0.28	0.55				0	5	CL-ML SC GM-GC	A-2 A-4 A-6
NaE	0 - 11	SIL	0.43	0.49				0	5	ML CL-ML CL	A-4
	11 - 34	SICL SIC C	0.28	0.32				0	5	CL CH MH	A-7
	34 - 41	CN-SIL SIL L	0.28	0.55				0	5	CL-ML SC GM-GC	A-2 A-4 A-6
NoA	0 - 13	LS	0.17	0.17		0	0	0	0	SM	A-2
	13 - 85	SL SCL CL	0.24	0.24		0	0	0	0	SC SM-SC CL CL-ML	A-2 A-4 A-6

Table 14 (continued)

Soil Erodibility Factors (*K*) for Richland County

Soil Map Symbol (See Table 4)	Depth (in)	Soil Texture	*K*, Erosion Factor With Rock Fragments	*K*, Erosion Factor Rock Fragments Free	Wind Erosion Group	Rock Fract > 10" (pct) (low)	Rock Fract > 10" (pct) (high)	Rock Fract 3"-10" (pct) (low)	Rock Fract 3"-10" (pct) (high)	Unified Soil Classification	AASHTO Soil Classification
NoB	0 - 13	LS	0.17	0.17		0	0	0	0	SM	A-2
	13 - 85	SL SCL CL	0.24	0.24		0	0	0	0	SC SM-SC CL CL-ML	A-2 A-4 A-6
OaB	0 - 11	L	0.43	0.32		0	0	0	0	SM ML CL-ML SM-SC	A-4
	11 - 40	C SIC SICL	0.28	0.43		0	0	0	0	CH	A-7
ObA	0 - 12	LS	0.10	0.10		0	0	0	0	SM	A-2
	12 - 18	SL	0.20	0.20		0	0	0	0	SM	A-2
	18 - 57	SCL SL	0.24	0.24		0	0	0	0	SC CL SM SM-SC	A-6 A-4
	57 - 90	SCL SC SL	0.24	0.24		0	0	0	0	SC CL	A-6 A-4 A-7
ObB	0 - 12	LS	0.10	0.10		0	0	0	0	SM	A-2
	12 - 18	SL	0.20	0.20		0	0	0	0	SM	A-2
	18 - 57	SCL SL	0.24	0.24		0	0	0	0	SC CL SM SM-SC	A-6 A-4
	57 - 90	SCL SC SL	0.24	0.24		0	0	0	0	SC CL	A-6 A-4 A-7
ObC	0 - 12	LS	0.10	0.10		0	0	0	0	SM	A-2
	12 - 18	SL	0.20	0.20		0	0	0	0	SM	A-2
	18 - 57	SCL SL	0.24	0.24		0	0	0	0	SC CL SM SM-SC	A-6 A-4
	57 - 90	SCL SC SL	0.24	0.24		0	0	0	0	SC CL	A-6 A-4 A-7
OgB	0 - 12	LS	0.10	0.10		0	0	0	0	SM	A-2
	12 - 18	SL	0.20	0.20		0	0	0	0	SM	A-2
	18 - 57	SCL SL	0.24	0.24		0	0	0	0	SC CL SM SM-SC	A-6 A-4
	57 - 90	SCL SC SL	0.24	0.24		0	0	0	0	SC CL	A-6 A-4 A-7
	0 - 60	VAR									
OgD	0 - 12	LS	0.10	0.10		0	0	0	0	SM	A-2
	12 - 18	SL	0.20	0.20		0	0	0	0	SM	A-2
	18 - 57	SCL SL	0.24	0.24		0	0	0	0	SC CL SM SM-SC	A-6 A-4
	57 - 90	SCL SC SL	0.24	0.24		0	0	0	0	SC CL	A-6 A-4 A-7
	0 - 60	VAR									

Table 14 (continued)

Soil Erodibility Factors (*K*) for Richland County

Soil Map Symbol (See Table 4)	Depth (in)	Soil Texture	*K*, Erosion Factor With Rock Fragments	*K*, Erosion Factor Rock Fragments Free	Wind Erosion Group	Rock Fract > 10" (pct) (low)	Rock Fract > 10" (pct) (high)	Rock Fract 3"-10" (pct) (low)	Rock Fract 3"-10" (pct) (high)	Unified Soil Classification	AASHTO Soil Classification
PeB	0 - 7	LS	0.15	0.15	2	0	0	0	0	SM SP-SM	A-2 A-3
	7 - 25	SCL CL	0.17	0.17		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6
	25 - 43	SCL SC C	0.20	0.20		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6
	43 - 58	SCL SL	0.15	0.15		0	0	0	0	SM SC SM-SC	A-2 A-4 A-6
PeD	0 - 7	LS	0.15	0.15	2	0	0	0	0	SM SP-SM	A-2 A-3
	7 - 25	SCL CL	0.17	0.17		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6
	25 - 43	SCL SC C	0.20	0.20		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6
	43 - 58	SCL SL	0.15	0.15		0	0	0	0	SM SC SM-SC	A-2 A-4 A-6
PnC	0 - 7	LS	0.15	0.15	2	0	0	0	0	SM SP-SM	A-2 A-3
	7 - 25	SCL CL	0.17	0.17		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6
	25 - 43	SCL SC C	0.20	0.20		0	0	0	0	SM-SC SC CL-ML CL	A-2 A-4 A-6
	43 - 58	SCL SL	0.15	0.15		0	0	0	0	SM SC SM-SC	A-2 A-4 A-6
	0 - 6	VAR									
Ps	0 - 7	VFSL	0.28	0.28	3	0	0	0	0	SM ML	A-4
	7 - 58	C SIC	0.20	0.20		0	0	0	0	CL CH	A-6 A-7
	58 - 80	C CL SICL	0.20	0.20		0	0	0	0	CL ML CH MH	A-4 A-6 A-7
Ra	0 - 8	SL	0.20	0.20	3	0	0	0	0	SM ML	A-2 A-4
	8 - 46	SCL CL	0.24	0.24		0	0	0	0	SC SM-SC CL CL-ML	A-2 A-4 A-6
	46 - 62	SCL CL SC	0.28	0.28		0	0	0	0	SC SM-SC CL CL-ML	A-4 A-6 A-7
	62 - 68	SL SCL SC	0.28	0.28		0	0	0	0	SM SC ML CL	A-2 A-4 A-6
Sm	0 - 8	L	0.28	0.28	5	0	0	0	0	ML CL CL-ML	A-4
	8 - 63	C CL SIC	0.32	0.32		0	0	0	0	CL ML CH MH	A-6 A-7
StA	0 - 9	SL	0.24	0.24		0	0	0	0	SM SM-SC ML CL-ML	A-4
	9 - 44	SCL CL L	0.24	0.24		0	0	0	0	CL-ML CL SC SM-SC	A-2 A-4 A-6 A-7-6
	44 - 63	VAR									
Tc	0 - 4	SICL	0.28	0.28	6	0	0	0	0	CL CH	A-6 A-7 A-4
	4 - 61	SICL SIC C	0.37	0.37		0	0	0	0	CL CH	A-6 A-7
To	0 - 11	L	0.24	0.24		0	0	0	0	SM ML	A-2 A-4
	11 - 68	SL L	0.10	0.20		0	0	0	0	SM ML	A-2 A-4

Table 14 (continued)

Soil Erodibility Factors (*K*) for Richland County

Soil Map Symbol (See Table 4)	Depth (in)	Soil Texture	*K*, Erosion Factor With Rock Fragments	*K*, Erosion Factor Rock Fragments Free	Wind Erosion Group	Rock Fract > 10" (pct) (low)	Rock Fract > 10" (pct) (high)	Rock Fract 3"-10" (pct) (low)	Rock Fract 3"-10" (pct) (high)	Unified Soil Classification	AASHTO Soil Classification
TrB	0 - 48	S	0.10	0.10		0	0	0	0	SM SP-SM	A-2
	48 - 75	SCL SL FSL	0.20	0.20		0	0	0	0	SC SM-SC CL-ML CL	A-4 A-2 A-6
Ud	0 - 60	SL	0.28					0	3	CL CL-ML SC SM-SC	A-2 A-4 A-6 A-7
Ur	0 - 60	VAR									
VaC	0 - 15	LS	0.15	0.15	2	0	0	0	5	SM SP-SM	A-2 A-3
	15 - 29	SCL SL	0.24	0.24		0	0	0	5	SC SM-SC	A-2 A-4 A-6
	29 - 58	SCL SL SC	0.24	0.24		0	0	0	5	SC SM-SC SM	A-2 A-4 A-6
	58 - 72	SL SCL LS	0.17	0.17		0	0	0	2	SM SC SM-SC	A-2 A-4 A-6
VaD	0 - 15	LS	0.15	0.15	2	0	0	0	5	SM SP-SM	A-2 A-3
	15 - 29	SCL SL	0.24	0.24		0	0	0	5	SC SM-SC	A-2 A-4 A-6
	29 - 58	SCL SL SC	0.24	0.24		0	0	0	5	SC SM-SC SM	A-2 A-4 A-6
	58 - 72	SL SCL LS	0.17	0.17		0	0	0	2	SM SC SM-SC	A-2 A-4 A-6
WeB	0 - 5	SL	0.24	0.24		0	0	0	0	SM SM-SC	A-4 A-2-4
	5 - 9	L SCL	0.28	0.28		0	0	0	0	SM SC CL ML	A-4 A-6
	9 - 35	SC CL C	0.28	0.28		0	0	0	0	SC ML CL MH	A-6 A-7
	35 - 80	SCL CL SL	0.28	0.28		0	0	0	0	SC SM-SC CL CL-ML	A-2 A-4 A-6
WeE	0 - 5	SL	0.24	0.24		0	0	0	0	SM SM-SC	A-4 A-2-4
	5 - 9	L SCL	0.28	0.28		0	0	0	0	SM SC CL ML	A-4 A-6
	9 - 35	SC CL C	0.28	0.28		0	0	0	0	SC ML CL MH	A-6 A-7
	35 - 80	SCL CL SL	0.28	0.28		0	0	0	0	SC SM-SC CL CL-ML	A-2 A-4 A-6

Richland County Design Chart No. 71
Topographic LS Factor

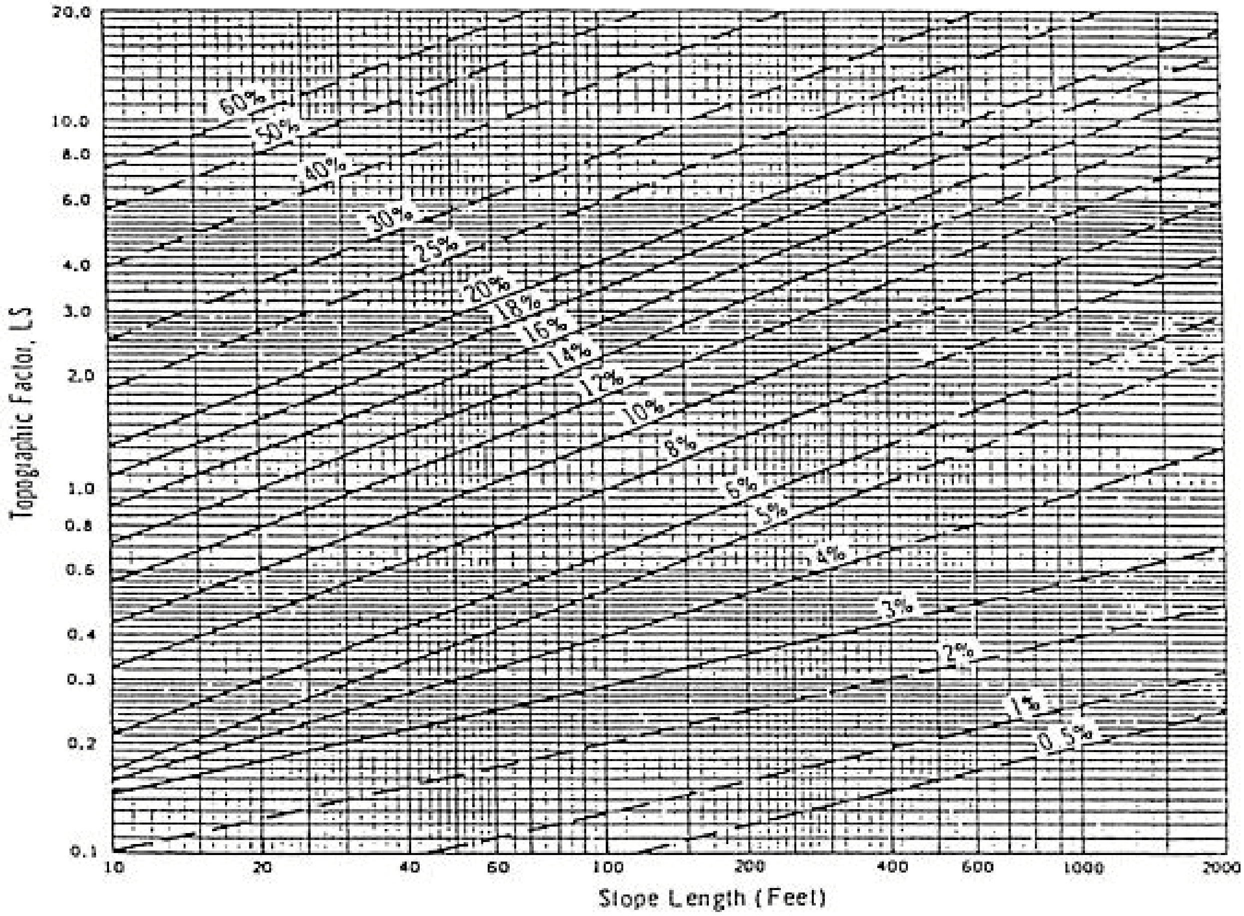


Table 15

Cover Management, *C* Factors for Permanent Pasture, Rangeland, and Idle Land[22]

<------------------ *Vegetative Canopy* ------------------>		<------------ *Cover That Contacts Soil Surface* -------->						
			<----------- *Percent Ground Cover* -------->-					
Type and Height[23]	***Percent Cover***[24]	***Type***[25]	***0***	***20***	***40***	***60***	***80***	***95+***
No appreciable canopy	~ 0	G	0.45	0.20	0.10	.042	.013	.003
		W	0.45	0.24	0.15	.090	.043	.011
Canopy of tall weeds or short brush, 0.5 m (1.6 ft.) tall ht.	25	G	0.36	0.17	0.09	.038	.012	.003
		W	0.36	0.20	0.13	.082	.041	.011
	50	G	0.26	0.13	0.07	.035	.012	.003
		W	0.26	0.16	0.11	.075	.039	.011
	75	G	0.17	0.10	0.06	.031	.011	.003
		W	0.17	0.12	0.09	.068	.038	.011
Appreciable brush or bushes, 2 m (6.6 ft.) tall ht.	25	G	0.40	0.18	0.09	.040	.013	.003
		W	0.40	0.22	0.14	.085	.042	.011
	50	G	0.34	0.16	.085	.038	.012	.003
		W	0.34	0.19	0.13	.081	.041	.011
	75	G	0.28	0.14	0.08	.036	.012	.003
		W	0.28	0.17	0.12	.077	.040	.011
Trees but no appreciable low brush, 4 m (13.1 ft.) tall ht.	25	G	0.42	0.19	0.10	.041	.013	.003
		W	0.42	0.23	0.14	.087	.042	.011
	50	G	0.39	0.18	0.09	.040	.013	.003
		W	0.39	0.21	0.14	.085	.042	.011
	75	G	0.36	0.17	0.09	.039	.012	.003
		W	0.36	0.20	0.13	.083	.041	.011

[22] All values shown assume (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years.

[23] Average fall height of water drops from canopy to soil surface.

[24] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[25] Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep. W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface, and/or undecayed residue).

Table 16

Erosion Control Practice Factor *P* for Construction Sites[26]

Surface Condition With No Cover	***P***
1) Compact, smooth, scraped with bulldozer or scraper up and down hill	1.30
2) Same as above, except raked with a bulldozer root, raked up and down hill	1.20
3) Compact, smooth, scraped with bulldozer or scraper across the slope	1.20
4) Same as above, except raked with bulldozer root, raked across slope	0.90
5) Loose, as in a disked plow layer	1.00
6) Rough irregular surface, equipment tracks in all directions	0.90
7) Loose with rough surface greater than 12 in. depth	0.80
8) Loose with smooth surface greater than 12 in. depth	0.90
Structures	***P***
1) Small sediment basins:	
a) 0.04 basin/acre	0.50
b) 0.06 basin/acre	0.30
2) Downstream sediment basin:	
a) with chemical flocculants	0.10
b) without chemical flocculants	0.20
3) Erosion control structures	
a) normal rate usage	0.50
b) high rate usage	0.40
4) Strip building	0.75

4.7.1.8 Infiltration Characteristics of Soils in Richland County: Infiltration is one of the most effective means of controlling storm water runoff since it reduces the volume of runoff that is discharged to receiving waters and the associated water quality and quantity impacts that runoff can cause. Infiltration is also an important mechanism for pollutant control. As runoff infiltrates into the ground, particulates and attached contaminants such as metals and nutrients are removed by filtration, and dissolved constituents can be removed by adsorption.

Infiltration is not appropriate in all areas. Low soil infiltration rates, high or perched groundwater tables, or bedrock may limit the feasibility and/or the effectiveness of infiltration practices. To aid in the planning and use of infiltration BMPs, general drainage characteristics and soil horizon permeability characteristics for soils in Richland County are listed in Tables 17 and Table 18, respectively.

[26] Ports, M.A. 1973, Use of Universal Soil Loss Equation as a Design Standard. ASCE Water Resources Engineering Meetings, Washington D.C.

Table 17

General Drainage Characteristics of Soils in Richland County[27]

	High Water Table			Bedrock				
Soil Map Symbol (See Table 4)	Depth (ft)	Type	Months	Depth (in)	Hardness	Hydrologic Soil Group	Drainage Class	Hydric Soil?
AeC	> 6	-	-	> 60	-	B	Well Drained	N
AtA	1.5 - 2.5	Apparent	Dec - Mar	40 - 50	Soft	C	Moderately Well Drained	N
BaB	> 6	-	-	> 60	-	A	Moderately Well Drained	N
Ca	0 - 1	Apparent	Nov - Apr	> 60	-	D	Poorly Drained	Y
Cd	0 - 1	Apparent	Nov - May	> 60	-	D	Poorly Drained	Y
Ce	0.5 - 1.5	Apparent	Nov - Apr	> 60	-	C	Somewhat Poorly Drained	N
Ch	0.5 - 1.5	Apparent	Nov - Apr	> 60	-	C	Somewhat Poorly Drained	N
Cn	1.5 - 2.5	Apparent	Dec - Mar	> 60	-	C	Moderately Well Drained	N
Co	2.5 - 4	Apparent	Nov - Apr	> 60	-	B	Well Drained	N
Cx	0 - 2.5	Apparent	Nov - Apr	> 60	-	D	Poorly Drained	Y
Dn	< 0.5	Apparent	Jan - Dec	> 60	-	D	Very Poorly Drained	Y
DoA	3 - 5	Perched	Jan - Apr	> 60	-	B	Well Drained	N
DoB	3 - 5	Perched	Jan - Apr	> 60	-	B	Well Drained	N
DuB	3 - 5	Perched	Jan - Apr	> 60	-	B	Well Drained	N
FaA	> 6	-	-	> 60	-	B	Well Drained	N
FaB	> 6	-	-	> 60	-	B	Well Drained	N
FuA	4 - 6	Perched	Jan - Mar	> 60	-	B	Well Drained	N
FuB	4 - 6	Perched	Jan - Mar	> 60	-	B	Well Drained	N
FyB	4 - 6	Perched	Jan - Mar	> 60	-	B	Well Drained	N
GeB	> 6	-	-	> 60	-	B	Well Drained	N
GeC	> 6	-	-	> 60	-	B	Well Drained	N
GoA	2 - 3	Apparent	Dec - Apr	> 60	-	B	Moderately Well Drained	N
HeB	> 6	-	-	> 60	-	B	Well Drained	N
HeC	> 6	-	-	> 60	-	B	Well Drained	N
HnB	> 6	-	-	> 60	-	B	Well Drained	N
Jo	0 - 1.5	Apparent	Nov - Jun	> 60	-	D	Very Poorly Drained	Y
KeC	> 6	-	-	> 60	-	A	Excessively Drained	N
KrB	1.5 - 3	Perched	Dec - Mar	40 - 60	Soft	C	Moderately Well Drained	N
LaB	> 6	-	-	> 60	-	A	Excessively Drained	N
LaD	> 6	-	-	> 60	-	A	Excessively Drained	N
LkB	> 6	-	-	> 60	-	A	Excessively Drained	N
LuB	> 6	-	-	> 60	-	A	Well Drained	N
MaA	> 6	-	-	> 60	-	B	Well Drained	N
MaB	> 6	-	-	> 60	-	B	Well Drained	N
NaB	> 6	-	-	40 - 60	Soft	C	Well Drained	N
NaC	> 6	-	-	40 - 60	Soft	C	Well Drained	N
NaE	> 6	-	-	40 - 60	Soft	C	Well Drained	N
NoA	4 - 6	Apparent	Jan - Mar	> 60	-	B	Well Drained	N

[27] Soil Survey of Richland County, Natural Resource Conservation Service (NRCS) (formerly Soil Conservation Service, SCS) (1978)

Table 17

General Drainage Characteristics of Soils in Richland County (continued)

	-------- High Water Table -------			---- Bedrock ----				
Soil Map Symbol (See Table 4)	*Depth (ft)*	*Type*	*Months*	*Depth (in)*	*Hardness*	*Hydrologic Soil Group*	*Drainage Class*	*Hydric Soil?*
NoB	4 - 6	Apparent	Jan - Mar	> 60	-	B	Well Drained	N
OaB	1 - 3	Perched	Dec - May	40 - 60	Hard	D	Somewhat Poorly Drained	N
ObA	> 6	-	-	> 60	-	B	Well Drained	N
ObB	> 6	-	-	> 60	-	B	Well Drained	N
ObC	> 6	-	-	> 60	-	B	Well Drained	N
OgB	> 6	-	-	> 60	-	B	Well Drained	N
OgD	> 6	-	-	> 60	-	B	Well Drained	N
PeB	1 - 2.5	Perched	Nov - Apr	> 60	-	B/D	Moderately Well Drained	N
PeD	1 - 2.5	Perched	Nov - Apr	> 60	-	B/D	Moderately Well Drained	N
PnC	1 - 2.5	Perched	Nov - Apr	> 60	-	B/D	Moderately Well Drained	N
Ps	2 - 3.5	Apparent	Dec - Apr	> 60	-	C	Moderately Well Drained	N
Ra	0 - 1	Apparent	Nov - Apr	> 60	-	B/D	Poorly Drained	Y
Sm	0.5 - 1.5	Apparent	Dec - Mar	> 60	-	D	Somewhat Poorly Drained	N
StA	> 6	-	-	> 60	-	B	Well Drained	N
Tc	1.5 - 2.5	Apparent	Nov - Apr	> 60	-	C	Somewhat Poorly Drained	N
To	2.5 - 5	Apparent	Dec - Apr	> 60	-	B	Moderately Well Drained	N
TrB	> 6	-	-	> 60	-	A	Somewhat Excessively Drained	N
Ud	> 6	-	-	> 60	-	B	Moderately Well Drained	N
VaC	> 6	-	-	> 60	-	C	Well Drained	N
VaD	> 6	-	-	> 60	-	C	Well Drained	N
WeB	> 6	-	-	> 60	-	B	Well Drained	N
WeE	> 6	-	-	48 - 60	Soft	B	Well Drained	N

Table 18
Permeability Characteristics of Soils in Richland County

Soil Map Symbol(See Table 4)	*Layer (in)*	*Clay (%)*	*Classification*		*Available Water Capacity (in)*	*Organic Matter (%)*	*pH*	*Permeability (in/hr)*	*Shrink-Swell Potential*
			Unified	*AASHTO*					
AeC	0 - 30	5 - 10	SM SP-SM	A-2 A-3	0.03 - 0.05	0.5 - 1	4.5 - 6.5	6.0 - 20	Low
	30 - 38	15 - 35	SM SC SM-SC	A-2 A-4 A-6	0.09 - 0.12	-	4.5 - 5.5	0.6 - 2.0	Low
	38 - 69	18 - 32	SM SC SM-SC	A-2 A-4 A-6	0.06 - 0.1	-	4.5 - 5.5	0.06 - 0.20	Low
AtA	0 - 7	10 - 24	ML CL-ML SM SM-SC	A-4 A-2	0.12 - 0.2	0.5 - 3	3.6 - 6	2.0 - 6.0	Low
	7 - 46	18 - 35	CL CL-ML SC SM-SC	A-4 A-6 A-7	0.12 - 0.2	-	3.6 - 6	0.6 - 2.0	Low
	46 - 49	-	-	-	-	-	-	-	-
BaB	0 - 50	1 - 7	SP-SM SM	A-3 A-2-4	0.03 - 0.07	0.5 - 1	4.5 - 6	6.0 - 20	Low
	50 - 61	10 - 18	SM	A-2-4	0.1 - 0.15	-	4.5 - 5.5	2.0 - 6.0	Low
	61 - 96	12 - 30	SC SM-SC SM	A-4 A-2-4 A-2-6 A-6	0.1 - 0.15	-	4.5 - 5.5	0.6 - 2.0	Low
Ca	0 - 5	10 - 20	ML	A-4 A-6 A-7	0.14 - 0.18	1 - 5	3.6 - 6.5	0.6 - 2.0	Low
	5 - 57	35 - 60	CL ML MH CH	A-6 A-7	0.11 - 0.16	-	3.6 - 5.5	0.06 - 0.2	Moderate
	57 - 81	30 - 65	SC CL MH SM	A-4 A-6 A-7	0.1 - 0.15	-	3.6 - 5.5	0.06 - 0.6	Moderate
Cd	0 - 4	15 - 35	ML CL CL-ML	A-4 A-6 A-7	0.12 - 0.18	2 - 6	4.5 - 6	0.2 - 0.6	Moderate
	4 - 41	35 - 60	CL CH ML MH	A-6 A-7	0.12 - 0.16	-	4.5 - 6	0.06 - 0.2	Moderate
	41 - 82	2 - 10	SP SM SP-SM	A-2 A-3	0.03 - 0.06	-	4.5 - 6	6.0 - 20	Low
Ce	0 - 7	10 - 27	ML CL CL-ML	A-4 A-6 A-7	0.15 - 0.24	1 - 4	4.5 - 6.5	0.6 - 2.0	Low
	7 - 58	18 - 35	SM SM-SC ML CL	A-4 A-7-6 A-6	0.12 - 0.2	-	4.5 - 6.5	0.6 - 2.0	Low
	58 - 75	18 - 35	ML MH CL CH	A-4 A-6 A-7	0.15 - 0.24	-	4.5 - 7.8	0.6 - 2.0	Low

Table 18

Permeability Characteristics of Soils in Richland County (continued)

Soil Map Symbol(See Table 4)	Layer (in)	Clay (%)	Classification: Unified	Classification: AASHTO	Available Water Capacity (in)	Organic Matter (%)	pH	Permeability (in/hr)	Shrink-Swell Potential
Ch	0 - 7	10 - 27	ML CL CL-ML	A-4 A-6 A-7	0.15 - 0.24	1 - 4	4.5 - 6.5	0.6 - 2.0	Low
	7 - 58	18 - 35	SM SM-SC ML CL	A-4 A-7-6 A-6	0.12 - 0.2	-	4.5 - 6.5	0.6 - 2.0	Low
	58 - 75	18 - 35	ML MH CL CH	A-4 A-6 A-7	0.15 - 0.24	-	4.5 - 7.8	0.6 - 2.0	Low
Cn	0 - 10	5 - 15	SM SC SM-SC	A-2 A-4	0.1 - 0.14	0.5 - 3	4.5 - 6.5	2.0 - 6.0	Low
	10 - 36	18 - 35	SC CL SM-SC CL-ML	A-4 A-6	0.1 - 0.15	-	4.5 - 5.5	0.6 - 2.0	Low
	36 - 73	15 - 40	SC CL SM-SC CL-ML	A-2 A-4 A-6	0.08 - 0.12	-	4.5 - 5.5	0.2 - 0.6	Low
Co	0 - 8	10 - 25	CL-ML ML CL	A-4	0.12 - 0.2	0.5 - 4	4.5 - 7.3	0.6 - 2.0	Low
	8 - 38	18 - 35	SC ML CL SM	A-4 A-6 A-7	0.12 - 0.2	-	4.5 - 7.3	0.6 - 2.0	Low
	38 - 80	-	-	-	-	-	-	-	-
Cx	0 - 9	5 - 27	SM ML CL-ML CL	A-4 A-6 A-7	0.12 - 0.17	2 - 4	3.6 - 5.5	0.6 - 2.0	Low
	9 - 65	35 - 60	CL CH	A-6 A-7	0.14 - 0.18	-	3.6 - 5.5	0.2 - 0.6	Moderate
Dn	0 - 58	0 -	PT	-	0.25 - 0.5	60 - 99	3.6 - 4.4	0.6 - 2.0	-
	58 - 76	0 -	PT	-	0.25 - 0.5	-	3.6 - 4.4	0.6 - 2.0	-
DoA	0 - 17	5 - 15	SM	A-2	0.06 - 0.1	0.5 - 0.5	4.5 - 6	2.0 - 6.0	Low
	17 - 37	18 - 35	SM-SC SC SM	A-2 A-4 A-6	0.12 - 0.16	-	4.5 - 6	0.6 - 2.0	Low
	37 - 78	18 - 40	SM-SC SC CL-ML CL	A-2 A-4 A-6 A-7	0.08 - 0.12	-	4.5 - 6	0.2 - 0.6	Low
DoB	0 - 17	5 - 15	SM	A-2	0.06 - 0.1	0.5 - 0.5	4.5 - 6	2.0 - 6.0	Low
	17 - 37	18 - 35	SM-SC SC SM	A-2 A-4 A-6	0.12 - 0.16	-	4.5 - 6	0.6 - 2.0	Low
	37 - 78	18 - 40	SM-SC SC CL-ML CL	A-2 A-4 A-6 A-7	0.08 - 0.12	-	4.5 - 6	0.2 - 0.6	Low

Table 18

Permeability Characteristics of Soils in Richland County (continued)

Soil Map Symbol(See Table 4)	Layer (in)	Clay (%)	Classification: Unified	Classification: AASHTO	Available Water Capacity (in)	Organic Matter (%)	pH	Permeability (in/hr)	Shrink-Swell Potential
DuB	0 - 17	5 - 15	SM	A-2	0.06 - 0.1	0.5 - 0.5	4.5 - 6	2.0 - 6.0	Low
	17 - 37	18 - 35	SM-SC SC SM	A-2 A-4 A-6	0.12 - 0.16	-	4.5 - 6	0.6 - 2.0	Low
	37 - 78	18 - 40	SM-SC SC CL-ML CL	A-2 A-4 A-6 A-7	0.08 - 0.12	-	4.5 - 6	0.2 - 0.6	Low
	0 - 60	-	-	-	-	-	-	-	-
FaA	0 - 7	5 - 20	SM SM-SC	A-2 A-4	0.06 - 0.09	0.5 - 2	4.5 - 5.5	6.0 - 20	Low
	7 - 12	20 - 36	SC ML CL SM	A-4 A-6	0.12 - 0.15	-	4.5 - 5.5	0.6 - 2.0	Low
	12 - 84	35 - 55	CL SC CH ML	A-6 A-7	0.12 - 0.18	-	4.5 - 6	0.6 - 2.0	Low
FaB	0 - 7	5 - 20	SM SM-SC	A-2 A-4	0.06 - 0.09	0.5 - 2	4.5 - 5.5	6.0 - 20	Low
	7 - 12	20 - 36	SC ML CL SM	A-4 A-6	0.12 - 0.15	-	4.5 - 5.5	0.6 - 2.0	Low
	12 - 84	35 - 55	CL SC CH ML	A-6 A-7	0.12 - 0.18	-	4.5 - 6	0.6 - 2.0	Low
FuA	0 - 35	1 - 7	SP-SM SM	A-1 A-2 A-3	0.03 - 0.07	0.5 - 2	4.5 - 6	6.0 - 20	Low
	35 - 48	10 - 35	SM SC SM-SC	A-2 A-4 A-6	0.12 - 0.15	-	4.5 - 6	0.6 - 2.0	Low
	48 - 75	20 - 35	SC SM-SC CL-ML	A-2 A-4 A-6 A-7-6	0.1 - 0.13	-	4.5 - 6	0.06 - 0.2	Low
FuB	0 - 35	1 - 7	SP-SM SM	A-1 A-2 A-3	0.03 - 0.07	0.5 - 2	4.5 - 6	6.0 - 20	Low
	35 - 48	10 - 35	SM SC SM-SC	A-2 A-4 A-6	0.12 - 0.15	-	4.5 - 6	0.6 - 2.0	Low
	48 - 75	20 - 35	SC SM-SC CL-ML	A-2 A-4 A-6 A-7-6	0.1 - 0.13	-	4.5 - 6	0.06 - 0.2	Low
FyB	0 - 35	1 - 7	SP-SM SM	A-1 A-2 A-3	0.03 - 0.07	0.5 - 2	4.5 - 6	6.0 - 20	Low
	35 - 48	10 - 35	SM SC SM-SC	A-2 A-4 A-6	0.12 - 0.15	-	4.5 - 6	0.6 - 2.0	Low
	48 - 75	20 - 35	SC SM-SC CL-ML	A-2 A-4 A-6 A-7-6	0.1 - 0.13	-	4.5 - 6	0.06 - 0.2	Low
	0 - 60	-	-	-	-	-	-	-	-

Table 18

Permeability Characteristics of Soils in Richland County (continued)

Soil Map Symbol(See Table 4)	Layer (in)	Clay (%)	Classification: Unified	Classification: AASHTO	Available Water Capacity (in)	Organic Matter (%)	pH	Permeability (in/hr)	Shrink-Swell Potential
GeB	0 - 9	5 - 27	ML	A-4 A-6	0.15 - 0.2	0.5 - 2	4.5 - 6	0.6 - 2.0	Low
	9 - 52	27 - 35	CL ML	A-6 A-7 A-4	0.13 - 0.18	-	4.5 - 5.5	0.6 - 2.0	Low
	52 - 72	35 - 60	MH ML	A-7	0.13 - 0.18	-	4.5 - 5.5	0.6 - 2.0	Low
GeC	0 - 9	5 - 27	ML	A-4 A-6	0.15 - 0.2	0.5 - 2	4.5 - 6	0.6 - 2.0	Low
	9 - 52	27 - 35	CL ML	A-6 A-7 A-4	0.13 - 0.18	-	4.5 - 5.5	0.6 - 2.0	Low
	52 - 72	35 - 60	MH ML	A-7	0.13 - 0.18	-	4.5 - 5.5	0.6 - 2.0	Low
GoA	0 - 13	5 - 15	SM SM-SC SC	A-2 A-4 A-6	0.08 - 0.12	0.5 - 2	3.6 - 6	2.0 - 6.0	Low
	13 - 80	18 - 30	SM-SC SC CL-ML CL	A-2 A-4 A-6	0.11 - 0.15	-	3.6 - 5.5	0.6 - 2.0	Low
HeB	0 - 11	5 - 27	ML CL CL-ML	A-4 A-6	0.14 - 0.2	0.5 - 1	4.5 - 6.5	0.6 - 2.0	Low
	11 - 57	35 - 60	MH ML	A-7	0.13 - 0.18	-	3.6 - 5.5	0.6 - 2.0	Low
	57 - 66	10 - 30	MH ML	A-7 A-5	0.05 - 0.08	-	3.6 - 5.5	0.6 - 2.0	Low
HeC	0 - 11	5 - 27	ML CL CL-ML	A-4 A-6	0.14 - 0.2	0.5 - 1	4.5 - 6.5	0.6 - 2.0	Low
	11 - 57	35 - 60	MH ML	A-7	0.13 - 0.18	-	3.6 - 5.5	0.6 - 2.0	Low
	57 - 66	10 - 30	MH ML	A-7 A-5	0.05 - 0.08	-	3.6 - 5.5	0.6 - 2.0	Low
HnB	0 - 11	5 - 27	ML CL CL-ML	A-4 A-6	0.14 - 0.2	0.5 - 1	4.5 - 6.5	0.6 - 2.0	Low
	11 - 57	35 - 60	MH ML	A-7	0.13 - 0.18	-	3.6 - 5.5	0.6 - 2.0	Low
	57 - 66	10 - 30	MH ML	A-7 A-5	0.05 - 0.08	-	3.6 - 5.5	0.6 - 2.0	Low
	0 - 60	-	-	-	-	-	-	-	-
Jo	0 - 38	5 - 18	ML SM	A-2 A-4	0.1 - 0.2	3 - 8	4.5 - 5.5	2.0 - 6.0	Low
	38 - 66	5 - 20	SM	A-2 A-4	0.06 - 0.12	-	4.5 - 5.5	6.0 - 20	Low
KeC	0 - 80	0 - 5	SP SP-SM SW	A-2 A-3	0.02 - 0.05	0.5 - 1	4.5 - 6	> 20	Low
KrB	0 - 8	4 - 20	ML CL-ML CL	A-4	0.15 - 0.22	0.5 - 2	5.1 - 6.5	0.6 - 2.0	Low
	8 - 40	18 - 35	CL ML	A-4 A-6 A-5 A-7	0.12 - 0.18	-	4.5 - 5.5	0.2 - 0.6	Low
	40 - 56	5 - 25	ML CL-ML CL	A-4 A-6	0.11 - 0.15	-	3.6 - 5.5	0.6 - 2.0	Low

Table 18

Permeability Characteristics of Soils in Richland County (continued)

Soil Map Symbol(See Table 4)	Layer (in)	Clay (%)	Classification: Unified	Classification: AASHTO	Available Water Capacity (in)	Organic Matter (%)	pH	Permeability (in/hr)	Shrink-Swell Potential
LaB	0 - 29	2 - 8	SP-SM	A-3 A-2-4	0.05 - 0.09	0.5 - 1	4.5 - 6	6.0 - 20	Low
	29 - 99	1 - 6	SP SP-SM	A-3 A-2-4	0.02 - 0.08	-	4.5 - 6	6.0 - 20	Low
LaD	0 - 29	2 - 8	SP-SM	A-3 A-2-4	0.05 - 0.09	0.5 - 1	4.5 - 6	6.0 - 20	Low
	29 - 99	1 - 6	SP SP-SM	A-3 A-2-4	0.02 - 0.08	-	4.5 - 6	6.0 - 20	Low
LkB	0 - 29	2 - 8	SP-SM	A-3 A-2-4	0.05 - 0.09	0.5 - 1	4.5 - 6	6.0 - 20	Low
	29 - 99	1 - 6	SP SP-SM	A-3 A-2-4	0.02 - 0.08	-	4.5 - 6	6.0 - 20	Low
	0 - 60	-	-	-	-	-	-	-	-
LuB	0 - 26	1 - 12	SM SP-SM	A-2	0.06 - 0.1	0.5 - 1	5.1 - 6	6.0 - 20	Low
	26 - 32	10 - 30	SM SC SM-SC	A-2 A-4 A-6	0.1 - 0.12	-	4.5 - 5.5	2 .0- 6.0	Low
	32 - 75	15 - 35	SC SM-SC SM	A-2 A-6 A-4	0.12 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
MaA	0 - 8	5 - 20	SM SM-SC ML CL-ML	A-2 A-4	0.09 - 0.14	0.5 - 2	5.1 - 6.5	2.0 - 6.0	Low
	8 - 64	35 - 65	CL ML CL-ML	A-4 A-6 A-7	0.14 - 0.18	-	4.5 - 6	0.6 - 2.0	Low
	64 - 80	30 - 60	CL ML SM SC	A-4 A-6 A-7	0.12 - 0.18	-	4.5 - 6	0.6 - 2.0	Low
MaB	0 - 8	5 - 20	SM SM-SC ML CL-ML	A-2 A-4	0.09 - 0.14	0.5 - 2	5.1 - 6.5	2.0 - 6.0	Low
	8 - 64	35 - 65	CL ML CL-ML	A-4 A-6 A-7	0.14 - 0.18	-	4.5 - 6	0.6 - 2.0	Low
	64 - 80	30 - 60	CL ML SM SC	A-4 A-6 A-7	0.12 - 0.18	-	4.5 - 6	0.6 - 2.0	Low
NaB	0 - 11	10 - 27	ML CL-ML CL	A-4	0.14 - 0.2	1 - 3	4.5 - 6.5	0.6 - 2.0	Low
	11 - 34	35 - 50	CL CH MH	A-7	0.12 - 0.19	-	4.5 - 5.5	0.6 - 2.0	Moderate
	34 - 41	10 - 25	CL-ML SC GM-GC	A-2 A-4 A-6	0.15 - 0.2	-	4.5 - 5.5	0.6 - 2.0	Low

Table 18

Permeability Characteristics of Soils in Richland County (continued)

Soil Map Symbol(See Table 4)	Layer (in)	Clay (%)	Classification: Unified	Classification: AASHTO	Available Water Capacity (in)	Organic Matter (%)	pH	Permeability (in/hr)	Shrink-Swell Potential
NaC	0 - 11	10 - 27	ML CL-ML CL	A-4	0.14 - 0.2	1 - 3	4.5 - 6.5	0.6 - 2.0	Low
	11 - 34	35 - 50	CL CH MH	A-7	0.12 - 0.19	-	4.5 - 5.5	0.6 - 2.0	Moderate
	34 - 41	10 - 25	CL-ML SC GM-GC	A-2 A-4 A-6	0.15 - 0.2	-	4.5 - 5.5	0.6 - 2.0	Low
NaE	0 - 11	10 - 27	ML CL-ML CL	A-4	0.14 - 0.2	1 - 3	4.5 - 6.5	0.6 - 2.0	Low
	11 - 34	35 - 50	CL CH MH	A-7	0.12 - 0.19	-	4.5 - 5.5	0.6 - 2.0	Moderate
	34 - 41	10 - 25	CL-ML SC GM-GC	A-2 A-4 A-6	0.15 - 0.2	-	4.5 - 5.5	0.6 - 2.0	Low
NoA	0 - 13	2 - 8	SM	A-2	0.06 - 0.11	0.5 - 2	4.5 - 6	6.0 - 20	Low
	13 - 85	18 - 35	SC SM-SC CL CL-ML	A-2 A-4 A-6	0.1 - 0.2	-	4.5 - 5.5	0.6 - 2.0	Low
NoB	0 - 13	2 - 8	SM	A-2	0.06 - 0.11	0.5 - 2	4.5 - 6	6.0 - 20	Low
	13 - 85	18 - 35	SC SM-SC CL CL-ML	A-2 A-4 A-6	0.1 - 0.2	-	4.5 - 5.5	0.6 - 2.0	Low
OaB	0 - 11	10 - 25	SM ML CL-ML SM-SC	A-4	0.14 - 0.2	1 - 3	5.1 - 6.5	0.6 - 2.0	Low
	11 - 40	35 - 60	CH	A-7	0.1 - 0.19	-	5.1 - 6.5	0.06 - 0.2	High
ObA	0 - 12	4 - 10	SM	A-2	0.06 - 0.09	0.5 - 1	4.5 - 6	2.0 - 6.0	Low
	12 - 18	7 - 18	SM	A-2	0.09 - 0.12	-	4.5 - 6	2.0 - 6.0	Low
	18 - 57	18 - 35	SC CL SM SM-SC	A-6 A-4	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
	57 - 90	20 - 45	SC CL	A-6 A-4 A-7	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
ObB	0 - 12	4 - 10	SM	A-2	0.06 - 0.09	0.5 - 1	4.5 - 6	2.0 - 6.0	Low
	12 - 18	7 - 18	SM	A-2	0.09 - 0.12	-	4.5 - 6	2.0 - 6.0	Low
	18 - 57	18 - 35	SC CL SM SM-SC	A-6 A-4	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
	57 - 90	20 - 45	SC CL	A-6 A-4 A-7	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low

Table 18

Permeability Characteristics of Soils in Richland County (continued)

Soil Map Symbol(See Table 4)	Layer (in)	Clay (%)	Classification Unified	Classification AASHTO	Available Water Capacity (in)	Organic Matter (%)	pH	Permeability (in/hr)	Shrink-Swell Potential
ObC	0 - 12	4 - 10	SM	A-2	0.06 - 0.09	0.5 - 1	4.5 - 6	2.0 - 6.0	Low
	12 - 18	7 - 18	SM	A-2	0.09 - 0.12	-	4.5 - 6	2.0 - 6.0	Low
	18 - 57	18 - 35	SC CL SM SM-SC	A-6 A-4	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
	57 - 90	20 - 45	SC CL	A-6 A-4 A-7	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
OgB	0 - 12	4 - 10	SM	A-2	0.06 - 0.09	0.5 - 1	4.5 - 6	2.0 - 6.0	Low
	12 - 18	7 - 18	SM	A-2	0.09 - 0.12	-	4.5 - 6	2.0 - 6.0	Low
	18 - 57	18 - 35	SC CL SM SM-SC	A-6 A-4	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
	57 - 90	20 - 45	SC CL	A-6 A-4 A-7	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
	0 - 60	-	-	-	-	-	-	-	-
OgD	0 - 12	4 - 10	SM	A-2	0.06 - 0.09	0.5 - 1	4.5 - 6	2.0 - 6.0	Low
	12 - 18	7 - 18	SM	A-2	0.09 - 0.12	-	4.5 - 6	2.0 - 6.0	Low
	18 - 57	18 - 35	SC CL SM SM-SC	A-6 A-4	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
	57 - 90	20 - 45	SC CL	A-6 A-4 A-7	0.11 - 0.14	-	4.5 - 5.5	0.6 - 2.0	Low
	0 - 60	-	-	-	-	-	-	-	-
PeB	0 - 7	2 - 10	SM SP-SM	A-2 A-3	0.03 - 0.06	0.5 - 2	4.5 - 6.5	6.0 - 20	Low
	7 - 25	18 - 35	SM-SC SC CL-ML CL	A-2 A-4 A-6	0.12 - 0.16	-	3.6 - 5.5	0.6 - 2.0	Low
	25 - 43	25 - 50	SM-SC SC CL-ML CL	A-2 A-4 A-6	0.06 - 0.1	-	3.6 - 5.5	0.06 - 0.6	Low
	43 - 58	10 - 40	SM SC SM-SC	A-2 A-4 A-6	0.06 - 0.1	-	3.6 - 5.5	0.6 - 2.0	Low
PeD	0 - 7	2 - 10	SM SP-SM	A-2 A-3	0.03 - 0.06	0.5 - 2	4.5 - 6.5	6.0 - 20	Low
	7 - 25	18 - 35	SM-SC SC CL-ML CL	A-2 A-4 A-6	0.12 - 0.16	-	3.6 - 5.5	0.6 - 2.0	Low
	25 - 43	25 - 50	SM-SC SC CL-ML CL	A-2 A-4 A-6	0.06 - 0.1	-	3.6 - 5.5	0.06 - 0.6	Low
	43 - 58	10 - 40	SM SC SM-SC	A-2 A-4 A-6	0.06 - 0.1	-	3.6 - 5.5	0.6 - 2.0	Low

Table 18

Permeability Characteristics of Soils in Richland County (continued)

Soil Map Symbol(See Table 4)	Layer (in)	Clay (%)	Classification: Unified	Classification: AASHTO	Available Water Capacity (in)	Organic Matter (%)	pH	Permeability (in/hr)	Shrink-Swell Potential
PnC	0 - 7	2 - 10	SM SP-SM	A-2 A-3	0.03 - 0.06	0.5 - 2	4.5 - 6.5	6.0 - 20	Low
	7 - 25	18 - 35	SM-SC SC CL-ML CL	A-2 A-4 A-6	0.12 - 0.16	-	3.6 - 5.5	0.6 - 2.0	Low
	25 - 43	25 - 50	SM-SC SC CL-ML CL	A-2 A-4 A-6	0.06 - 0.1	-	3.6 - 5.5	0.06 - 0.6	Low
	43 - 58	10 - 40	SM SC SM-SC	A-2 A-4 A-6	0.06 - 0.1	-	3.6 - 5.5	0.6 - 2.0	Low
	0 - 6	-	-	-	-	-	-	-	-
Ps	0 - 7	10 - 20	SM ML	A-4	0.11 - 0.15	0.5 - 3	4.5 - 6.5	0.2 - 2.0	Low
	7 - 58	40 - 70	CL CH	A-6 A-7	0.12 - 0.15	-	3.6 - 5.5	0.06 - 0.2	Moderate
	58 - 80	30 - 60	CL ML CH MH	A-4 A-6 A-7	0.12 - 0.15	-	3.6 - 5.5	0.06 - 0.2	Moderate
Ra	0 - 8	5 - 20	SM ML	A-2 A-4	0.1 - 0.14	1 - 6	3.6 - 6.5	2.0 - 6.0	Low
	8 - 46	18 - 35	SC SM-SC CL CL-ML	A-2 A-4 A-6	0.11 - 0.15	-	3.6 - 5.5	0.6 - 2.0	Low
	46 - 62	18 - 40	SC SM-SC CL CL-ML	A-4 A-6 A-7	0.1 - 0.15	-	3.6 - 5.5	0.6 - 2.0	Low
	62 - 68	15 - 45	SM SC ML CL	A-2 A-4 A-6	0.1 - 0.15	-	3.6 - 5.5	0.6 - 2.0	Low
Sm	0 - 8	10 - 20	ML CL CL-ML	A-4	0.15 - 0.2	0.5 - 3	4.5 - 6	0.6 - 2.0	Low
	8 - 63	35 - 60	CL ML CH MH	A-6 A-7	0.14 - 0.18	-	3.6 - 5.5	0.06 - 0.2	Moderate
StA	0 - 9	8 - 15	SM SM-SC ML CL-ML	A-4	0.11 - 0.16	0.5 - 2	4.5 - 6	2.0 - 6.0	Low
	9 - 44	18 - 25	CL-ML CL SC SM-SC	A-2 A-4 A-6 A-7-6	0.12 - 0.17	-	4.5 - 6	0.6 - 2.0	Low
	44 - 63	-	-		-	-	-	-	
Tc	0 - 4	30 - 40	CL CH	A-6 A-7 A-4	0.12 - 0.18	2 - 5	4.5 - 6.5	0.06 - 0.6	Moderate
	4 - 61	35 - 70	CL CH	A-6 A-7	0.12 - 0.16	-	4.5 - 6.5	0.06 - 0.2	Moderate
To	0 - 11	3 - 17	SM ML	A-2 A-4	0.09 - 0.12	1 - 2	5.1 - 6.5	2.0 - 6.0	Low
	11 - 68	2 - 19	SM ML	A-2 A-4	0.09 - 0.12	-	5.1 - 6.5	2.0 - 6.0	Low

Table 18

Permeability Characteristics of Soils in Richland County (continued)

			Classification						
Soil Map Symbol(See Table 4)	***Layer (in)***	***Clay (%)***	***Unified***	***AASHTO***	***Available Water Capacity (in)***	***Organic Matter (%)***	***pH***	***Permeability (in/hr)***	***Shrink-Swell Potential***
TrB	0 - 48	1 - 10	SM SP-SM	A-2	0.05 - 0.1	0.5 - 1	4.5 - 6	6.0 - 20	Low
	48 - 75	15 - 35	SC SM-SC CL-ML CL	A-4 A-2 A-6	0.1 - 0.13	-	4.5 - 5.5	0.6 - 2.0	Low
Ud	0 - 60	10 - 50	CL CL-ML SC SM-SC	A-2 A-4 A-6 A-7	0.1 - 0.17	0 - 1	4.5 - 7.8	0.06 - 2.0	Moderate
Ur	0 - 60	-	-	-	-	-	-	-	-
VaC	0 - 15	2 - 10	SM SP-SM	A-2 A-3	0.04 - 0.08	0.5 - 1	4.5 - 6	6.0 - 20	Low
	15 - 29	18 - 35	SC SM-SC	A-2 A-4 A-6	0.1 - 0.15	-	3.6 - 5.5	0.6 - 6.0	Low
	29 - 58	18 - 45	SC SM-SC SM	A-2 A-4 A-6	0.04 - 0.08	-	3.6 - 5.5	0.06 - 0.6	Low
	58 - 72	5 - 30	SM SC SM-SC	A-2 A-4 A-6	0.04 - 0.08	-	3.6 - 5.5	2.0 - 6.0	Low
VaD	0 - 15	2 - 10	SM SP-SM	A-2 A-3	0.04 - 0.08	0.5 - 1	4.5 - 6	6.0 - 20	Low
	15 - 29	18 - 35	SC SM-SC	A-2 A-4 A-6	0.1 - 0.15	-	3.6 - 5.5	0.6 - 6.0	Low
	29 - 58	18 - 45	SC SM-SC SM	A-2 A-4 A-6	0.04 - 0.08	-	3.6 - 5.5	0.06 - 0.6	Low
	58 - 72	5 - 30	SM SC SM-SC	A-2 A-4 A-6	0.04 - 0.08	-	3.6 - 5.5	2.0 - 6.0	Low
WeB	0 - 5	6 - 20	SM SM-SC	A-4 A-2-4	0.1 - 0.18	0.5 - 1	4.5 - 5.5	2.0 - 6.0	Low
	5 - 9	14 - 30	SM SC CL ML	A-4 A-6	0.12 - 0.18	-	4.5 - 5.5	0.6 - 2.0	Low
	9 - 35	35 - 45	SC ML CL MH	A-6 A-7	0.12 - 0.18	-	4.5 - 5.5	0.6 - 2.0	Moderate
	35 - 80	15 - 30	SC SM-SC CL CL-ML	A-2 A-4 A-6	0.08 - 0.15	-	4.5 - 5.5	0.6 - 2.0	Low
WeE	0 - 5	6 - 20	SM SM-SC	A-4 A-2-4	0.1 - 0.18	0.5 - 1	4.5 - 5.5	2.0 - 6.0	Low
	5 - 9	14 - 30	SM SC CL ML	A-4 A-6	0.12 - 0.18	-	4.5 - 5.5	0.6 - 2.0	Low
	9 - 35	35 - 45	SC ML CL MH	A-6 A-7	0.12 - 0.18	-	4.5 - 5.5	0.6 - 2.0	Moderate
	35 - 80	15 - 30	SC SM-SC CL CL-ML	A-2 A-4 A-6	0.08 - 0.15	-	4.5 - 5.5	0.6 - 2.0	Low

4.7.2 Selecting and Locating BMPs: BMP selection is a complex process. There are a number of competing factors that need to be addressed when selecting the appropriate BMP or suite of BMPs for an area. It should be stressed that BMPs should be incorporated into a comprehensive stormwater management program. Without proper BMP selection, design, construction, and maintenance, BMPs will not be effective in managing urban runoff. BMP selection can be tailored to address the various sources of runoff produced from urbanized areas. Site suitability for selecting a particular BMP strategy is key to successful performance. Most BMPs have limitations for their applicability and therefore cannot be applied in all areas. A few considerations to incorporate into BMP selection are:

1) drainage area
2) land uses
3) average rainfall frequency, duration and intensity
4) runoff volumes and flow rates
5) soil types
6) site slopes
7) geology/topography
8) availability of land
9) future development/land use in watershed
10) depth to groundwater table
11) availability of supplemental water to support vegetative BMPs
12) susceptibility to freezing
13) safety and community acceptance
14) maintenance accessibility
15) periodic and long-term maintenance and rehabilitation needs

In addition to meeting the criteria specified in Sections 4.7.1.1 and 4.7.1.2, stormwater management plans must also meet the following criteria for selecting and locating BMPs.

1) Permanent retention ponds shall be used on all development projects with more than twenty-five (25) acres in size draining to an outfall for both stormwater quantity and quality control. Smaller drainage areas will be considered for retention ponds on a case-by-case basis. Other practices may be acceptable to the County, if they can be shown to achieve equivalent or superior sediment removal efficiency and provide adequate peak flow control. Use of other BMP practices shall be pre-approved by the County Engineer or his designee.

2) Placement of stormwater BMPs within a designated 100-year floodplain as shown on FEMA's Flood Insurance Rate Map (FIRM), is strongly discouraged. In case of a large flood, floodwaters could cause significant damage to the BMP. No stormwater BMP will be allowed in the designated "floodway" without a Conditional Letter of Map Revision (CLOMR) obtained from FEMA certifying that the proposed BMP will not adversely affect flood elevations. Stormwater BMPs placed in the floodplain should be appropriately constructed to prevent damage from floodwaters.

3) Stream buffers (within 25-feet of stream bank) protect the overall quality of the stream, by achieving pollutant removal as runoff flows through the buffer, by providing shade for the stream and habitat for wildlife. Although stormwater BMPs may be allowed in stream buffers, other alternative locations should be examined. Whenever there is a practical alternative, structural BMPs should not be placed in stream buffers. If encroachment into the stream buffer is needed, the amount of stream buffer area that is impacted should be minimized and the distance between the impact and the stream channel should be maximized. In addition, consideration should be given to the design of the BMP discharge to prevent erosion in the buffer zones and of stream banks.

4) It is the intent in most cases to design stormwater management devices to remove pollutants before they have a chance to enter “waters of the United States." Stormwater BMPs should be constructed outside of perennial streams and natural wetland areas unless no practical alternative exists. In addition, natural or existing lakes, ponds, and wetlands should not be considered for stormwater BMP retrofits until Federal and State Permits for such purpose have been obtained. The U.S. Army Corps of Engineers (USACE) requires that all impacts to jurisdictional waters and wetlands are reported. Depending on the impact, the USACE and other federal and state agencies may require the applicant to obtain permits, prepare environmental documents, mitigate for the impact, etc.

5) Stormwater BMPs designed to impound water may pose a potential hazard to downstream citizens and property. Because stormwater BMPs are mostly used in urbanized areas or rapidly growing areas, potential hazards related to water impoundments and dams are increased. Construction of a dam to create a stormwater impoundment (pond) shall be classified according to size and potential hazard to downstream areas and meet South Carolina dam safety regulations applicable for those size and hazard classifications.

4.7.3 Retention Ponds: Retention ponds (Figure 3) are constructed basins that have a permanent pool (or micropool). Runoff from each rain event is detained and treated in the pool until it is displaced by runoff from the next storm.

Design Specifications

1) Retention ponds are appropriate for both residential and non-residential development and are restricted to sites with a minimum drainage area of 25 acres. Smaller drainage areas will be considered for retention ponds on a case-by-case basis. If a permanent retention pond is part of the design submittal for the stormwater management facility, site-specific information describing the soils and hydrology, including supporting documentation must be included with the submittal.

2) Design as both quantity and quality control structures. Sediment storage volume shall be calculated considering the clean out and maintenance schedules specified by the designer during the land disturbing activity. The Universal Soil Loss Equation or other acceptable methods may predict sediment storage volumes.

3) Retention basins should control at least 80 percent of the total project area. Multiple retention basins may be necessary to achieve 80 percent coverage of large sites. Also, supplemental BMPs may be required to obtain the 80 percent equivalent removal efficiency for suspended solids or the 0.5 $^{ML}/_{L}$ peak settleable solids concentration, whichever is less.

4) Where existing wetlands are intended as a component of an overall stormwater management system, the approved stormwater management and sediment control plan shall not be implemented until all necessary federal and state permits have been obtained.

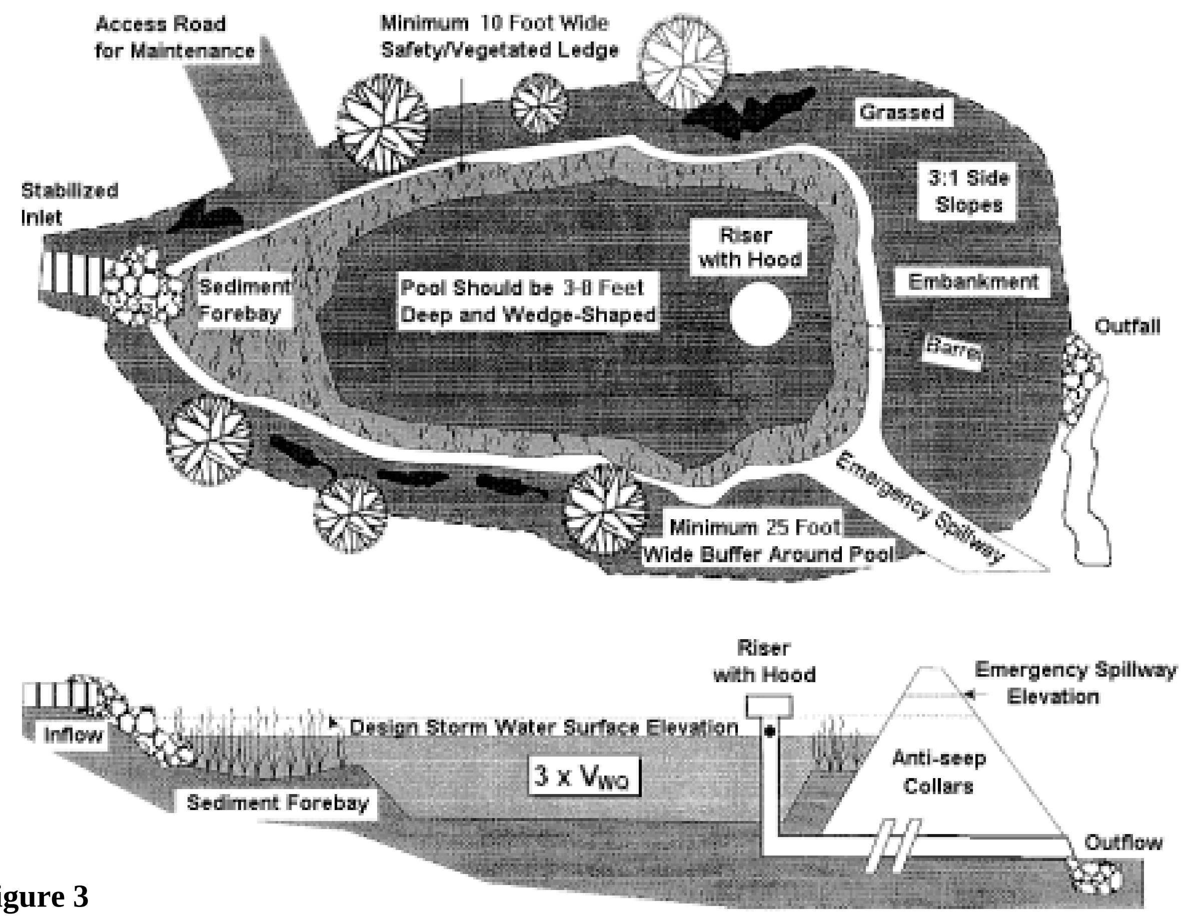


Figure 3

Retention Pond

Source: Controlling Urban Runoff

5) Hydrologic and Hydraulic Analyses:

   a) All hydrologic computations shall be accomplished using a volume-based hydrograph method. The storm duration for computational purposes shall be the 24-hour rainfall event; SCS Type II distribution with a 0.1 hour burst duration time increment.

   b) When required, an analysis of the impacts of stormwater flows downstream in the watershed for the 10- and 100-year frequency storm event shall be performed. The analysis shall include hydrologic and hydraulic calculations necessary to determine the impact of hydrograph timing modifications of the proposed development, with and without the pond. The results of the analysis will determine the need to modify the pond design or to eliminate the pond requirement. Lacking a clearly defined downstream point of constriction, the downstream impacts shall be established by the County Engineer or his designee.

6) Permanent Pool Volume:

   a) Water quality design volume (V_{WQ}) shall be shall be either 1 inch of runoff per acre or 1.5 inches of runoff per impervious acre, whichever is greater. The minimum permanent storage volume shall be 3 times the water quality volume ($3\times V_{WQ}$).

   b) Mean depth of the permanent pool should be a minimum of 3 feet and a maximum of 7 feet to minimize thermal stratification and re-suspension of settled pollutants. Mean depth is calculated by dividing the storage volume by the surface area.

$$D_M = \frac{S_V}{S_A}$$

Where: D_M = Mean depth in feet,

S_V = Storage volume of permanent pool in ft^3,

And S_A = Surface area of permanent pool in ft^2

c) Permanent pool mean depth greater than 12 feet is not allowed.

d) Adequate length/width ratio is required to enhance sedimentation, reduce short-circuiting, and prevent vertical stratification. Minimum length/width ratio of 3:1 is recommended for the permanent pool.

7) Additional volume may be required as needed for peak flow control.

8) Peak Flow Control:

a) Post-development peak discharge rates shall not exceed pre-development discharge rates for the 2-year through the design frequency (see Section 4.1.1) 24-hour duration storm event.

b) Pond outfall device or system design shall take into account the total drainage area flowing through the disturbed area to be served by the basin.

9) Velocities:

a) Discharge velocities shall be reduced to provide a nonerosive velocity flow from a structure, channel, or other control measure or the velocity of design frequency (see Section 4.1.1), 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater.

b) Energy dissipaters such as riprap should be used as needed at points of inflow and outflow to reduce the velocity of flow and prevent erosion and scour.

10) Runoff Pretreatment: Use pretreatment measures to reduce the frequency of sediment removal from the permanent pool.

a) Sediment forebay for larger ponds (often designed for 5 to 15 percent of total volume). Forebay should have separate drain for de-watering. General criteria sediment forebay design include:

i) Forebay should consist of a separate cell, formed by an acceptable barrier.

ii) Forebay should be sized to contain at least 0.1 inches of runoff per impervious acre of contributing drainage. Forebay storage volume counts toward the total water quality storage requirements.

iii) Exit velocities from the forebay should be non-erosive.

iv) Direct maintenance access for appropriate equipment should be provided to the forebay.

v) Bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.

vi) Fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time.

b) Grass biofilters for smaller ponds.

11) Embankment Design:

a) Embankment shall have a minimum top width of 15 feet with side slopes no steeper than 3:1 horizontal to vertical.

b) Side slopes shall be planted with turf-forming grass. No woody vegetation allowed on the embankment without special designs.

c) Elevation of the water surface in the basin, with the emergency spillway flowing at design depth, shall be at least 1 foot below the minimum elevation at the top of the settled embankment during the 100-year post-development storm.

12) Outlet Structure:

a) Outlet capacity shall be based on the post-development design runoff.

b) Outlet shall include a single or multi-stage riser pipe or box of corrugated metal or reinforced concrete with a watertight connection to a horizontal pipe extending through the embankment beyond the toe of the fill.

c) Drainpipe shall be installed for each stage. The pipe shall be capable or completely draining the permanent pool within 24 hours for maintenance or emergency.

d) Outlet shall be anchored to prevent flotation.

e) Anti-seep collars are required around the barrel of horizontal outlet pipe.

f) Crest of the riser shall correspond to the elevation in pond as required to maintain the permanent pool.

g) If reinforced concrete pipe is used for the principal spillway, O-ring gaskets (ASTM C361) should be used to create watertight joints.

h) Trash rack with anti-vortex device shall be attached to top of the outlet riser.

13) Emergency Spillway: Emergency spillway shall be sized to allow runoff from the entire drainage area, including off-site areas, to pass through the retention pond under post-development conditions for the 100-year storm without damage to the impoundment. County Engineer may specify other design storms for specific projects based upon downstream flooding hazard or other reasonable concerns. Earthen spillways should have a trapezoidal cross-section and shall be designed for non-erosive velocities. Discharge from the emergency spillway should not impinge upon the toe of the dam or the embankment.

14) Site/Civil Design Requirements:

a) Side slopes no steeper than 3:1 horizontal to vertical.

b) Storage capacity shall be provided above the permanent pool to limit the peak discharge rate to the pre-development peak for the 2-year through the design frequency (see Section 4.1.1) 24-hour duration storm event. .

c) Inlet and outlet locations should maximize travel time between them.

d) Bottom of pond should be graded and have a slope not less than 0.5 percent.

e) There should be no depressions where water can collect and stagnate as the water level recedes.

f) Include a 10-foot littoral zone (aquatic bench) abutting the edges of the permanent pool extending outward.

g) Side slopes shall be topsoiled, mucked, or planted from 2 feet below to 1 foot above the permanent pool elevation to promote wetland vegetation.

h) 10-foot bench should be provided around permanent pool for safety considerations and maintenance activities.

i) 25-foot maintenance buffer should be included around the pond.

Operation and Maintenance Requirements

1) Ease of maintenance must be considered as a site design component. Access to the stormwater management structure must be provided.

2) Sediment Removal

   a) Sediment Forebay: Sediment removal on a 1-year design cycle. Sediment removal in forebay annually or when 50% of the total capacity has been lost.

   b) Permanent Pool: Sediment removal on a 20-year design cycle.

3) Remove debris after major storm events.

4) Harvest/move vegetation annual or as needed. An aquatic weed control program should be used to prevent an overgrowth of vegetation. Manual harvesting is preferred.

5) Inspect and repair embankment and side slopes annually or as needed.

6) Inspect and repair outlet structure annually or as needed.

Operation and Maintenance Responsibility

1) Clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

2) If the owner will maintain the retention pond, a maintenance plan and schedule shall be submitted for approval. Routine maintenance includes activities such as inspections, grass mowing, debris, and trash removal, bank stabilization, weed control, insect/mosquito control, fence repair and record keeping. Non-routine maintenance includes activities such as structural repairs and major clean outs - material removal, basin stabilization and offsite sediment disposal.

3) If the County will ultimately maintain the retention pond, easements will be required around the perimeter of the facility and for access to the retention basin. Adequate grading and

widths shall be provided to safely accommodate the County's operation and maintenance vehicles.

Other Criteria

1) As appropriate, warning signs should be posted identifying the pond as a stormwater management facility and prohibiting swimming and other inappropriate activities. The County Engineer will approve warning sign locations on a case-by-case basis.

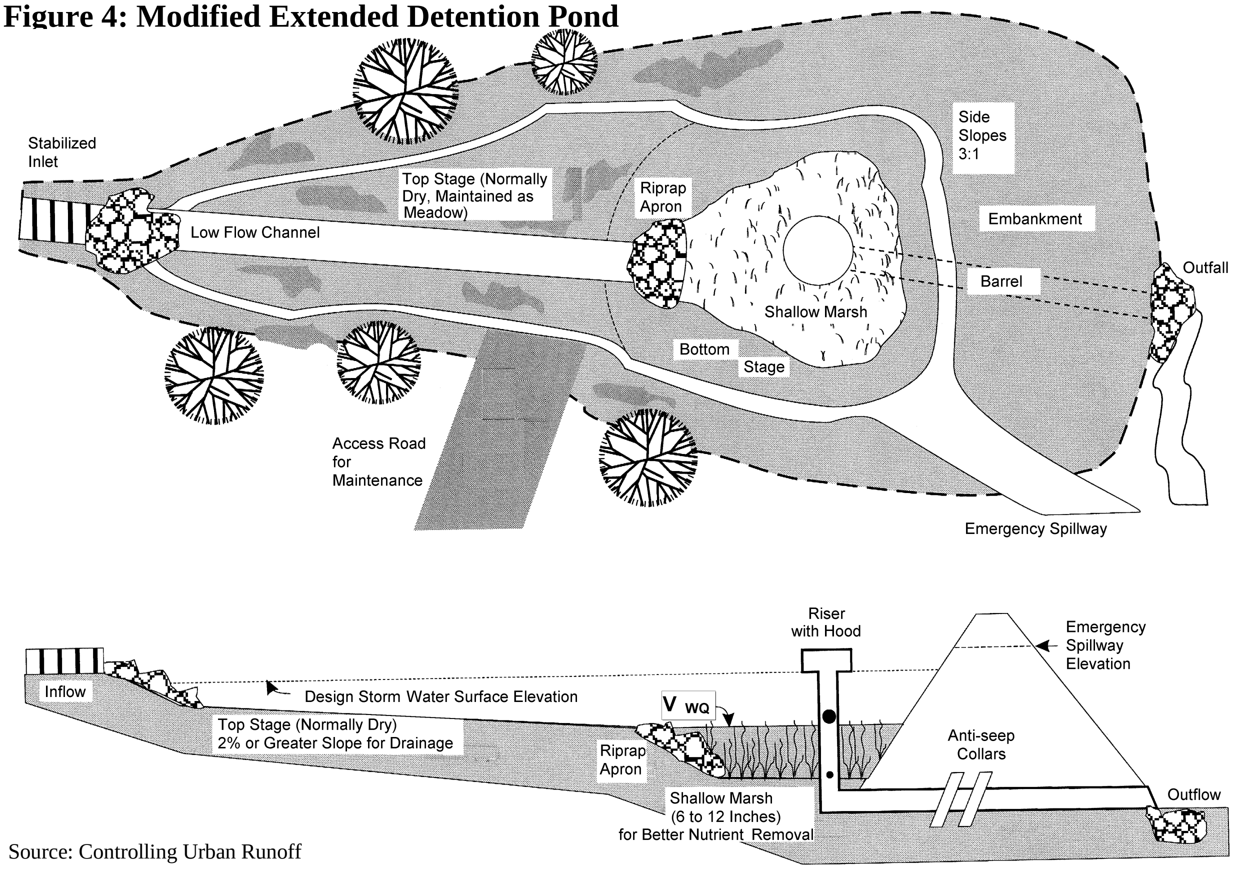
2) Protective barriers may be required to prevent entry to facilities that present a hazard to children and, to a lesser extent, all persons. Entry prevention practices may be required for storage basins where one or more of the following conditions exist:

   a) Rapid stage increases would make escape practically impossible where small children frequent the area.

   b) Water depths either exceed 2.5 feet for more than 24 hours or are permanently wet and have side slopes steeper than 3:1.

4.7.4 Modified Extended Detention Ponds: A modified extended detention pond (Figure 4) is a two-stage extended detention basin with a shallow marsh in the bottom stage. Pollutant removal occurs through sedimentation as the modified extended detention basin dewaters after a storm event, with ongoing nutrient removal in the shallow marsh. Modified extended detention ponds also provide water quantity control by storing volumes greater than are necessary for water quality alone.

Figure 4: Modified Extended Detention Pond



Source: Controlling Urban Runoff

Design Specifications

1) Modified extended detention ponds are appropriate for both residential and non-residential development and are restricted to sites with a maximum drainage area of 25 acres. Larger drainage areas will be considered for extended detention ponds if the designer can show that under normal conditions, the site will not support a retention pond. If a permanent extended detention pond is part of the design submittal for the stormwater management facility, site-specific information describing the soils and hydrology, including supporting documentation must be included.

2) Modified extended detention ponds are more effective than extended detention ponds, but are not as effective as retention ponds, in the removal of pollutants. Therefore, for larger development sites or highly impervious ones, retention ponds and other BMPs are preferable.

3) Secondary BMPs may be necessary to achieve the required pollutant removal efficiencies.

4) Hydrologic and Hydraulic Analyses:

   a) All hydrologic computations shall be accomplished using a volume-based hydrograph method. The storm duration for computational purposes method shall be the 24-hour rainfall event; SCS Type II distribution with a 0.1 hour burst duration time increment.

   b) When required, an analysis of the impacts of stormwater flows downstream in the watershed for the 10- and 100-year frequency storm event shall be performed. The analysis shall include hydrologic and hydraulic calculations necessary to determine the impact of hydrograph timing modifications of the proposed development, with and without the pond. The results of the analysis will determine the need to modify the pond design or to eliminate the pond requirement. Lacking a clearly defined downstream point of constriction, the downstream impacts shall be established by the County Engineer or his designee.

5) Detention Volume:

   a) Permanent pool shall be designed to store and release the first ½ inch of runoff from the site over a 24-hour period.

   b) Minimum water quality design volume (V_{WQ}) shall be either 1 inch of runoff per acre or 1.5 inches of runoff per impervious acre, whichever is greater. Additional volume may be required for peak flow control.

6) Peak Flow Control:

   a) Post-development peak discharge rates shall not exceed pre-development discharge rates for the 2-year through the design frequency (see Section 4.1.1) 24-hour duration storm event.

   b) Pond outfall device or system design shall take into account the total drainage area flowing through the disturbed area served by the basin.

7) Velocities:

   a) Discharge velocities shall be reduced to provide a nonerosive velocity flow from a structure, channel, or other control measure or the velocity of the 10-year, 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater.

8) Energy dissipaters such as riprap should be used as needed at points of inflow and outflow to reduce the velocity of flow and prevent erosion and scour.

9) Embankment Design:

   a) Embankment shall have a minimum top width of 15 feet with side slopes no steeper than 3:1 horizontal to vertical.

   b) Side slopes shall be planted with turf-forming grass. No woody vegetation allowed on the embankment without special designs.

   c) Elevation of the water surface in the basin, with the emergency spillway flowing at design depth, shall be at least 1 foot below the minimum elevation at the top of the settled embankment during the 100-year post-development storm.

10) Outlet Structure:

   a) Slow draining primary outlet shall be designed to release the water quality volume over 24 hours and 50 percent of the total volume in 16 hours. Permanent detention ponds shall be designed to release the first inch of runoff from the site over a 24-hour period.

      i) Vertical perforated/slotted risers with 0.75 to 1-inch perforations are preferred.

      ii) Gravel should be placed around the primary outlet to minimize clogging.

   b) Secondary outlet(s) as required to satisfy minimum water quantity storage requirements.

   c) Secondary outlet(s) capacity shall be based on the post-development design runoff.

   d) Outlet shall include a multi-stage riser pipe or box of corrugated metal or reinforced concrete with a watertight connection to a horizontal pipe extending through the embankment beyond the toe of the fill.

   e) Drainpipe shall be installed for each stage. The pipe shall be capable or completely draining the pond within 24 hours for maintenance or emergency.

   f) Primary and secondary outlets can be the same outlet structure, or separate structures.

   g) Outlet shall be anchored to prevent flotation.

   h) Anti-seep collars are required around the barrel of horizontal outlet pipe.

   i) Crest of the riser shall correspond to the elevation in the pond as required to maintain the permanent pool.

   j) If reinforced concrete pipe is used for the principal spillway, O-ring gaskets (ASTM C361) should be used to create watertight joints.

   k) Trash rack with anti-vortex device shall be attached to top of the outlet riser.

11) Emergency Spillway: Emergency spillway shall be sized to allow runoff from the entire drainage area, including off-site areas, to pass through the retention pond under post-development conditions for the 100-year storm without damage to the impoundment. County Engineer may specify other design storms for specific projects based upon

downstream flooding hazard or other reasonable concerns. Earthen spillways should have a trapezoidal cross-section and shall be designed for non-erosive velocities. Discharge from the emergency spillway should not impinge upon the toe of the dam or the embankment.

12) Site/Civil Design Requirements:

a) Two-stage pond design is required.

i) Top stage should be dry with the exception of larger storm events.

ii) Bottom stage should be 1 to 2 feet deeper than the top stage, but shall not exceed 3 feet deeper than the top stage.

iii) Bottom stage should be sized to accept 50 percent of the water quality volume.

b) Bottom stage should include a permanent pool with hi marsh (surface of permanent pool to six inches below) and lo marsh (six to eighteen inches below permanent pool) zones. Surface area of the hi marsh zone should equal the surface area of the low marsh zone. Lo marsh volume should be approximately double the volume of the hi marsh zone. The permanent pool shall have a maximum depth of 1.5 feet.

c) Surface area of the permanent pool should be at least one percent of the BMP drainage area. Permanent storage volume calculations shall be included with the application for a modified extended detention basin design.

d) Adequate length/width ratio is required to enhance settling. Minimum length/width ratio of 3:1 in the modified detention basin is recommended. Length/width ratio in the permanent pool should be approximately 2:1 to prevent short-circuiting.

e) Inlet and outlet locations should maximize travel time between them.

f) Basin side slopes should be no steeper than 4:1 horizontal to vertical.

g) Basin floor should maintain a minimum 2 percent slope towards the low flow channel.

h) Paved low flow channel should be provided to carry water from inlet to outlet during small, frequent storms. If a two-stage design is selected, erosion protection should be provided where the low flow channel discharges into the bottom stage.

i) Storage capacity shall be provided above the permanent pool to limit the peak discharge rate to the pre-development peak during the design rainfall and the two-year rainfall.

j) Bottom stage (marsh) should be graded and have a slope not less than 0.5 percent.

k) There should be no depressions where water can collect and stagnate as the water level recedes.

l) Should be designed to drain completely within three (3) days.

m) Should be constructed with a gravel blanket or other measure to minimize the creation of tire ruts during maintenance activities.

n) 25-foot maintenance buffer should be included around the pond.

Operation and Maintenance Requirements

1) Ease of maintenance must be considered as a site design component. Access to the stormwater management structure must be provided.

2) Sediment removal schedule:

   a) Sediment Forebay: Sediment removal on a 1-year design cycle. Remove sediment in forebay annually or when 50% of the total capacity has been lost.

   b) Detention Pond: Sediment removal on a 1-year design cycle. Re-vegetate after sediment removal.

3) Remove debris after major storm events.

4) Harvest/move vegetation annual or as needed. An aquatic weed control program should be used to prevent an overgrowth of vegetation. Manual harvesting is preferred.

5) Inspect and repair embankment and side slopes annually or as needed.

6) Inspect and repair outlet structure annually or as needed.

Operation and Maintenance Responsibility

1) Clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

2) If the owner will maintain the modified extended detention pond, a maintenance plan and schedule shall be submitted for approval. Routine maintenance includes activities such as inspections, grass mowing, debris, and trash removal, bank stabilization, weed control, insect/mosquito control, fence repair and record keeping. Non-routine maintenance includes activities such as structural repairs and major clean outs - material removal, basin stabilization and offsite sediment disposal.

3) If the County will ultimately maintain the modified extended detention pond, easements will be required around the perimeter of the facility and for access to the retention basin. Adequate grading and widths shall be provided to safely accommodate the County's operation and maintenance vehicles.

Other Criteria

1) As appropriate, warning signs should be posted identifying the pond as a stormwater management facility and prohibiting swimming and other inappropriate activities. The County Engineer will approve warning sign locations on a case-by-case basis.

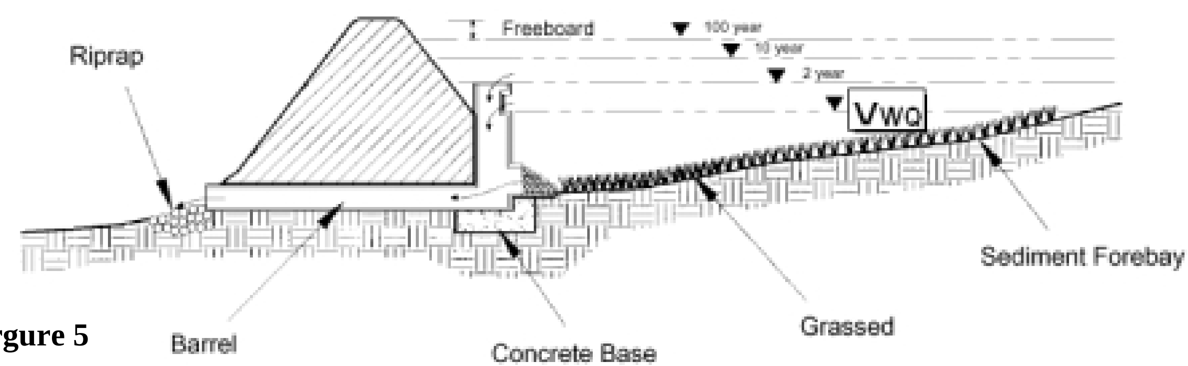
2) Protective barriers may be required to prevent entry to facilities that present a hazard to children and, to a lesser extent, all persons. Entry prevention practices may be required for storage basins where one or more of the following conditions exist:

   a) Rapid stage increases would make escape practically impossible where small children frequent the area.

   b) Water depths either exceed 2.5 feet for more than 24 hours or are permanently wet and have side slopes steeper than 3:1.

c) Entry prevention practices should be considered for modified extended detention pond with design depths more than 2.5 feet for 24 hours, unless the basin is within a fenced, limited access facility. Entry prevention practices can include special landscaping, vegetative planting using thorny shrubs, or fencing.

4.7.5 Extended Detention Ponds: An extended detention pond (Figure 5) is an impoundment formed by constructing an embankment, with or without excavation, with an outlet to temporarily detain stormwater for up to twenty-four hours during and immediately after a storm event. Such extended detention allows urban pollutants to settle out. The extended ponds are normally dry between storm events and do not have any permanent standing water. Extended detention ponds can also provide water quantity control by storing volumes greater than are necessary for water quality alone.



Firgure 5

Extended Detention Pond

Source: Controlling Urban Runoff

Design Specifications

1) Extended detention ponds are appropriate for both residential and non-residential development and are restricted to sites with a maximum drainage area of 25 acres. Larger drainage areas will be considered for extended detention ponds if the designer can show that under normal conditions, the site will not support a retention pond. If a permanent extended detention pond is part of the design submittal for the stormwater management facility, site-specific information describing the soils and hydrology, including supporting documentation must be included.

2) Extended detention ponds are not as effective as retention ponds in the removal of pollutants; therefore, for larger development sites or highly impervious ones, retention ponds and other BMPs are preferable.

3) Extended ponds provide moderate but variable removal of particulate pollutants and therefore are not suitable as a primary or self-sufficient BMP. Secondary BMPs may be necessary to achieve the required pollutant removal efficiencies.

4) Hydrologic and Hydraulic Analyses:

   a) All hydrologic computations shall be accomplished using a volume-based hydrograph method. The storm duration for computational purposes shall be the 24-hour rainfall event; SCS Type II distribution with a 0.1 hour burst duration time increment.

b) When required, an analysis of the impacts of stormwater flows downstream in the watershed for the 10- and 100-year frequency storm event shall be performed. The analysis shall include hydrologic and hydraulic calculations necessary to determine the impact of hydrograph timing modifications of the proposed development, with and without the pond. The results of the analysis will determine the need to modify the pond design or to eliminate the pond requirement. Lacking a clearly defined downstream point of constriction, the downstream impacts shall be established by the County Engineer or his designee.

5) Detention Volume:

a) Minimum water quality design volume (V_{WQ}) shall be either 1 inch of runoff per acre or 1.5 inches of runoff per impervious acre, whichever is greater. Additional volume may be required for peak flow control.

6) Peak Flow Control:

a) Shall be designed to store and release the first ½ inch of runoff from the site over a 24-hour period.

b) Post-development peak discharge rates shall not exceed pre-development discharge rates for the 2-year through the design frequency (see Section 4.1.1) 24-hour duration storm event.

c) Pond outfall device or system design shall take into account the total drainage area flowing through the disturbed area to be served by the basin.

7) Velocities:

a) Discharge velocities shall be reduced to provide a nonerosive velocity flow from a structure, channel, or other control measure or the velocity of the design frequency (see Section 4.1.1), 24-hour storm runoff in the receiving waterway prior to the land disturbing activity, whichever is greater.

b) Energy dissipaters such as riprap should be used as needed at points of inflow and outflow to reduce the velocity of flow and prevent erosion and scour.

8) Embankment Design:

a) Embankment shall have a minimum top width of 15 feet with side slopes no steeper than 3:1 horizontal to vertical.

b) Side slopes shall be planted with turf-forming grass. No woody vegetation allowed on the embankment without special designs.

c) Elevation of the water surface in the basin, with the emergency spillway flowing at design depth, shall be at least 1 foot below the minimum elevation at the top of the settled embankment during the 100-year post-development storm.

9) Outlet Structure:

a) Slow draining primary outlet shall be designed to release the water quality volume over 24 hours and 50 percent of the total volume in 16 hours.

i) Vertical perforated/slotted risers with 0.75 to 1-inch perforations are preferred for the primary outlet.

ii) Gravel should be placed around the primary outlet to minimize clogging.

b) Secondary outlet(s) as required to satisfy minimum water quantity storage requirements.

c) Secondary outlet capacity shall be based on the post-development design runoff.

d) Combined primary/secondary outlet structure(s) should be designed to drain completely within three (3) days.

e) Outlet shall include a multi-stage riser pipe or box of corrugated metal or reinforced concrete with a watertight connection to a horizontal pipe extending through the embankment beyond the toe of the fill.

f) Drainpipe shall be installed for each stage. Pipe shall be capable or completely draining the pond within 24 hours for maintenance or emergency.

g) Primary and secondary outlets can be the same outlet structure, or separate structures.

h) Outlet(s) shall be anchored to prevent flotation.

i) Anti-seep collars are required around the barrel of the horizontal outlet pipe.

j) Crest of the riser shall correspond to the elevation in the pond as required to maintain the permanent pool.

k) If reinforced concrete pipe is used for the principal spillway, O-ring gaskets (ASTM C361) should be used to create watertight joints.

l) Trash rack with anti-vortex device shall be attached to the top of the outlet riser.

10) Emergency Spillway: An emergency spillway shall be sized to allow runoff from the entire drainage area, including off-site areas, to pass through the retention pond under post-development conditions for the 100-year storm without damage to the impoundment. The County Engineer may specify other design storms for specific projects based upon downstream flooding hazard or other reasonable concerns. Earthen spillways should have a trapezoidal cross-section and shall be designed for non-erosive velocities. Discharge from the emergency spillway should not impinge upon the toe of the dam or the embankment.

11) Site/Civil Design Requirements:

a) Adequate length/width ratio is required to enhance settling. Minimum length/width ratio of 3:1 is recommended.

b) Inlet and outlet locations should maximize travel time between them.

c) Basin side slopes should be no steeper than 4:1 horizontal to vertical.

d) Basin floor should maintain a minimum 2 percent slope towards the low flow channel.

e) Paved low flow channel should be provided to carry water from inlet to outlet during small, frequent storms. If a two-stage design is selected, erosion protection should be provided where the low flow channel discharges into the bottom stage.

f) Inlet and outlet locations should maximize travel time between them.

g) Bottom of ponds should be graded and have a slope not less than 0.5 percent.

h) There should be no depressions where water can collect and stagnate as the water level recedes.

i) Should be constructed with a gravel blanket or other measure to minimize the creation of tire ruts during maintenance activities.

j) 25-foot maintenance buffer should be included around the pond.

Operation and Maintenance Requirements

1) Ease of maintenance must be considered as a site design component. Access to the stormwater management structure must be provided.

2) Sediment removal schedule:

   a) Sediment Forebay: Sediment removal on a 1-year design cycle. Remove sediment in forebay annually or when 50% of the total capacity has been lost.

   b) Detention Pond: Sediment removal on a 1-year design cycle. Re-vegetate after sediment removal.

3) Remove debris after major storm events.

4) Harvest/move vegetation annual or as needed. An aquatic weed control program should be used to prevent an overgrowth of vegetation. Manual harvesting is preferred.

5) Inspect and repair embankment and side slopes annually or as needed.

6) Inspect and repair outlet structure annually or as needed.

Operation and Maintenance Responsibility

1) Clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

2) If the owner will maintain the extended detention pond, a maintenance plan and schedule shall be submitted for approval. Routine maintenance includes activities such as inspections, grass mowing, debris, and trash removal, bank stabilization, weed control, insect/mosquito control, fence repair and record keeping. Non-routine maintenance includes activities such as structural repairs and major clean outs - material removal, basin stabilization and offsite sediment disposal.

3) If the County will ultimately maintain the extended detention pond, easements will be required around the perimeter of the facility and for access to the retention basin. Adequate grading and widths shall be provided to safely accommodate the County's operation and maintenance vehicles.

Other Criteria

1) As appropriate, warning signs should be posted identifying the pond as a stormwater management facility and prohibiting swimming and other inappropriate activities. The County Engineer will approve warning sign locations on a case-by-case basis.

2) Protective barriers may be required to prevent entry to facilities that present a hazard to

children and, to a lesser extent, all persons. Entry prevention practices may be required for storage basins where one or more of the following conditions exist:

a) Rapid stage increases would make escape practically impossible where small children frequent the area.

b) Water depths either exceed 2.5 feet for more than 24 hours or are permanently wet and have side slopes steeper than 3:1.

c) Entry prevention practices should be considered for dry extended detention basins with design depths more than 2.5 feet for 24 hours, unless the basin is within a fenced, limited access facility. Entry prevention practices can include special landscaping, vegetative planting using thorny shrubs, or fencing.

4.7.6 Riparian Buffers: Buffers adjacent to stream systems and coastal areas provide numerous environmental protection and resource management benefits that can include the following:

1) Restoring and maintaining the chemical, physical, and biological integrity of the water resources,
2) Removing pollutants delivered from urban stormwater,
3) Reducing erosion and sediment entering the stream,
4) Stabilizing stream banks,
5) Providing infiltration of stormwater runoff,
6) Maintaining base flow of streams,
7) Contributing organic matter that is a source of food and energy for the aquatic ecosystem,
8) Providing tree canopy to shade streams and promote desirable aquatic organisms,
9) Providing riparian wildlife habitat, and
10) Furnishing scenic value and recreational opportunity.

4.7.6.1 Design Standards for Riparian Buffers

1) A riparian buffer for a stream system should consist of a forested or vegetative strip of land extending along both sides of a stream and its adjacent wetlands, floodplains, or slopes.

2) The riparian buffer width should be adjusted to include contiguous sensitive areas, such as steep slopes or erodible soils, where development or disturbance may adversely affect water quality, streams, wetlands, or other water bodies.

3) The riparian buffer should begin at the edge of the stream bank of the active channel.

4) The required width for all riparian buffers (i.e., the base width) should be a minimum of 40 feet, with the requirement to expand the buffer depending on percent slope;

   10%-15%, add 20 feet; 15%-20%, add 35 feet; 20%-25%, add 50 feet;

25% and above, add 2-ft times % of slope (ex. 37% slope times 2-ft = 74 ft of buffer added)

4.7.6.2 Buffer Management and Maintenance: The forest buffer, including wetlands and floodplains, shall be managed to enhance and maximize the unique value of these resources. Management includes specific limitations on alteration of the natural conditions of these resources. Inspection of the buffer should occur annually and immediately following severe storms for evidence of sediment deposition, erosion, or concentrated flow channels and corrective actions taken to ensure the integrity and functions of the forest buffer.

4.7.7 Constructed Stormwater Wetlands: Constructed stormwater wetlands (Figure 6) are shallow pools that allow growth of marsh plants, and are designed to maximize pollutant removal through uptake, retention, and settling. Stormwater wetlands are constructed systems, and are not typically located within delineated natural wetland areas. Constructed stormwater wetlands also differ from natural wetlands because they do not replicate all of the ecological functions of natural wetlands.

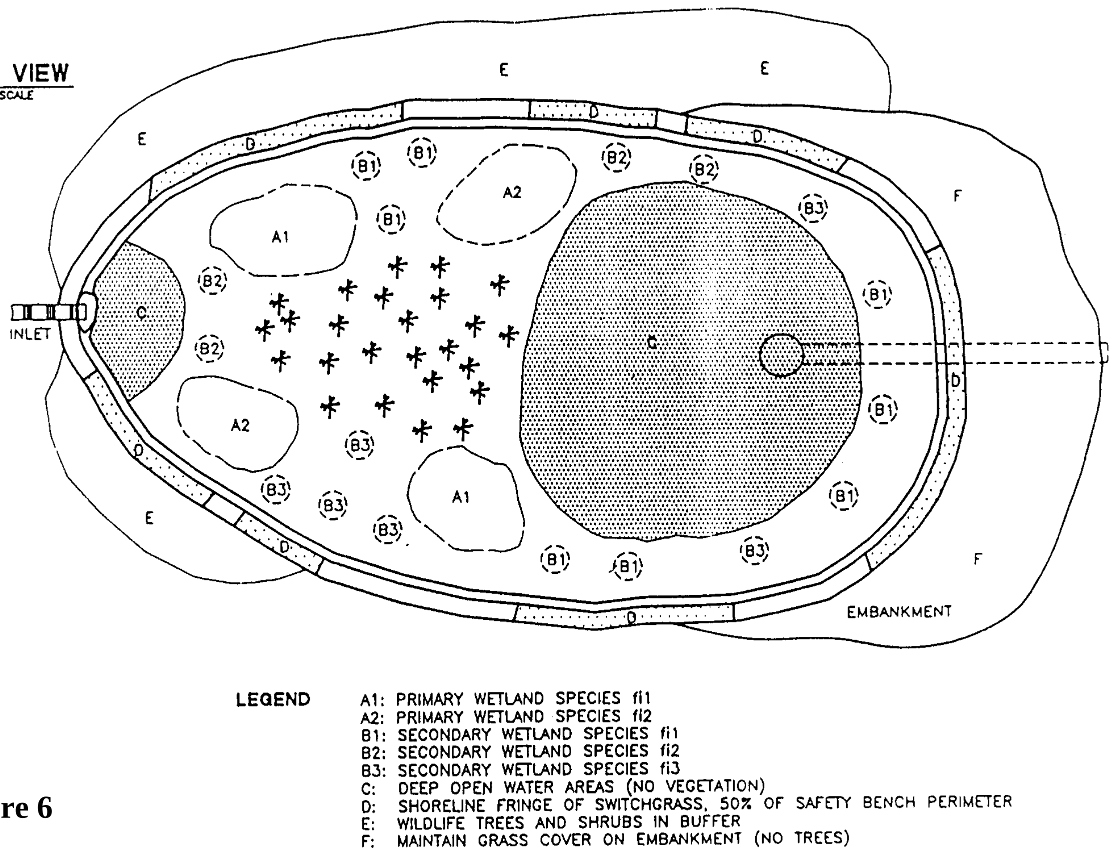


Figure 6

Constructed Stormwater Wetland

Design Criteria

1) Constructed stormwater wetlands can be used for drainage areas greater than five acres, and can be used for a variety of different land uses.

2) Constructed stormwater wetlands consist of a combination of shallow marsh areas, open water and semi-wet areas above the permanent water surface.

3) Surface area of the wetland shall account for a minimum of 1 percent of the area of the watershed draining into it.

4) Generally, constructed stormwater wetlands are not feasible as a primary BMP due to sizing

criteria for water quantity control. However, constructed stormwater wetlands can also serve as conveyance systems to other BMPs to achieve the necessary water quality and quantity control.

5) Hydrologic and Hydraulic Analyses:

a) Hydrologic and hydraulic analysis shall also include analysis of baseflow conditions of site to confirm the adequacy of baseflow for maintaining viable wetlands.

i) Water balance should be performed to demonstrate that a stormwater wetland could withstand a thirty-day drought at summer evaporation rates without completely drawing down.

ii) Inflow of water must be greater than that leaving the basin by infiltration or exfiltration.

b) Hydraulic analyses must indicate that stormwater inflow velocities are sufficient low enough for initial sedimentation into the constructed stormwater wetland so that the wetland can be maintained periodically.

6) Permanent Pool:

a) Minimum permanent storage volume (i.e. design water quality volume, V_{WQ}) shall be either 1 inch of runoff per acre or 1.5 inches of runoff per impervious acre, whichever is greater.

b) Length to width ratio shall be at least 2 to 1.

c) Nominal hydraulic residence time and distribution of inflows should be maximized over the treatment area, avoiding short-circuiting.

d) Minimum of 35% of total surface area should have a depth of 6 inches or less; 10% - 20% of surface area should be deep pool (1.5 - 6 foot depth).

7) Runoff Pretreatment:

a) Forebay shall be constructed at each pond inflow points to capture larger sediments.

b) Forebay should consist of a separate cell, at least 3 feet deep, formed by an acceptable barrier.

c) Forebay(s) should be sized to contain approximately 10% of the water quality design volume (V_{WQ}). The forebay storage volume counts toward the total water quality storage requirements.

d) Forebay should have separate drain for de-watering.

e) Exit velocities from the forebay should be non-erosive. Provide riprap or other outlet protection as needed.

f) Bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.

g) Fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time.

h) Direct maintenance access to the forebay shall be provided with access 25-feet wide minimum and 5:1 slope maximum.

8) Outlet Structure:

a) Designed outlet structure to store and release the first ½ inch of runoff from the site over a 24-hour period.

b) Deeper area of the wetland shall include the outlet structure so outflow from the basin is not affected by sediment buildup. Outfall should be fitted with a skimmer or other device to retain oil and grease.

c) Orifices will be vulnerable to blockage from plant material or other debris that will enter the basin with stormwater runoff. Therefore, some form of protection against blockage shall be installed (such as some type of non-corrodible wire mesh).

d) Outlet structure or system shall be able to convey higher flows through or around the constructed stormwater wetland.

9) Site/Civil/Vegetative Design Requirements:

a) As much vegetation as feasible and as much distance as possible should separate the basin inlet from the outlet.

b) Water should gradually get shallower about 10 feet from the edge of the pond.

c) Soil types conducive to wetland vegetation should be used during construction.

d) Soil depth of at least 4 inches shall be used for shallow wetland basins.

e) Wetland mulch, if used, shall be spread over the high marsh area and adjacent wet zones (-6 to +6 inches of depth) to depths of 3 to 6 inches.

f) Designer shall maximize use of existing- and post-grading pondscaping design to create both horizontal and vertical diversity and habitat.

g) It is recommended that the frequently flooded zone surrounding the wetland be located within approximately 10 to 20 feet from the edge of the permanent pool.

h) Thirty to fifty percent of the shallow (12 inches or less) area of the basin shall be planted with wetland vegetation. The optimal depth requirements for several common species of emergent wetland plants are often six inches of water or less.

i) Minimum of two aggressive wetland species (primary species - Figure 6) of vegetation shall be established in quantity on the wetland. Design should include a substantial native emergent vegetative component. Plants must be chosen to withstand the pollutant loadings and frequent fluctuation in water depths.

j) Three additional wetland species (secondary species- Figure 6) of vegetation shall be planted on the wetland, although in far less numbers than the two primary species.

k) Approximately 50 individuals of each secondary species shall be planted per acre; set out in 10 clumps of approximately 5 individuals and planted within 6 feet of the edge of the pond in the shallow area leading up to the ponds edge; spaced as far apart as possible, but no need to segregate species to different areas of the wetland.

l) Anaerobic sediment conditions should be ensured to allow for long-term burial of organic matter and phosphorus.

m) Local assistance should be obtained for information concerning plants to be used, planting schedule, soil requirements, mulch requirements, etc.

n) Minimum 25-foot buffer shall be established and planted with riparian and upland vegetation (50 foot buffer if wildlife habitat value required in design). In addition, an additional 15 feet setback to structures shall be included.

o) Surrounding slopes shall be stabilized by planting in order to trap sediments and some pollutants and prevent them from entering the wetland.

Operation and Maintenance Requirements

1) Remove sediment in forebay annually or when 50% of the total capacity has been lost.

2) Replace wetland vegetation to maintain at least 50% surface area coverage annual or as required.

3) Remove invasive vegetation annually or as required.

Operation and Maintenance Responsibility:

1) Clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

2) If stormwater wetlands will be maintained by the owner, a maintenance plan and schedule shall be submitted for approval. Initially, wetlands should be inspected regularly to ensure vegetative establishment and to remove undesirable or opportunistic species. Routine wetland maintenance includes vegetation monitoring and periodic sediment removal. Wetland species should remain dense and vigorous in a properly constructed wetland area. Maintenance activities should be performed using hand tools (rake, shovel, and wheelbarrow).

3) If the stormwater wetland will ultimately be maintained by the County, easements will be required for access. Adequate grading and widths shall be provided to safely accommodate the County's operation and maintenance vehicles. In residential areas, constructed stormwater wetlands shall be restricted to small systems and shall be maintained by the Owner.

4.7.8 Infiltration Trenches and Dry Wells[28]: An infiltration trench (Figure 7) is a shallow, excavated trench that has been backfilled with stone to create an underground reservoir. Storm water runoff diverted into the trench gradually exfiltrates from the bottom of the trench into the subsoil and eventually into the water table.

Infiltration trenches are not intended to trap sediment and must always be designed with a sediment forebay and grass channel or filter strip, or other appropriate pretreatment measures to

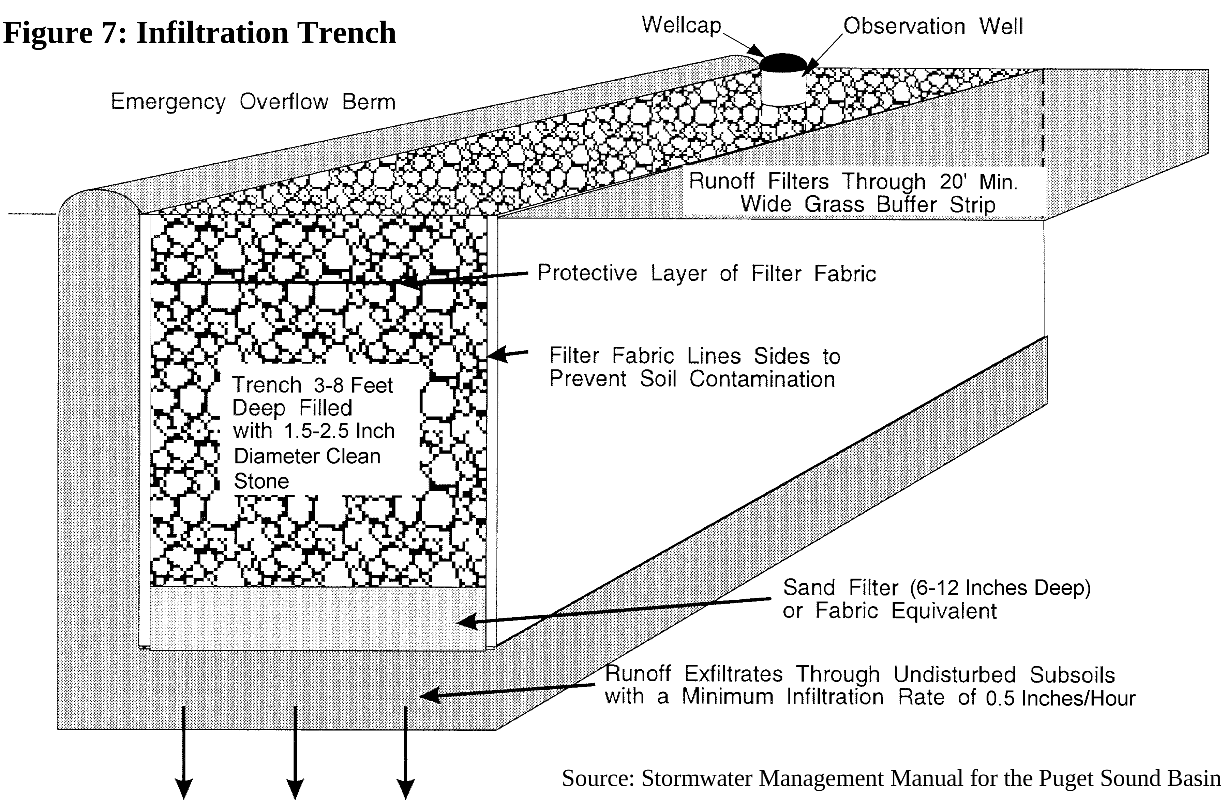
[28] Infiltration trenches should not be confused with infiltration basins. Infiltration basins are impoundments where incoming storm water runoff is stored until it gradually exfiltrates through the soil of the basin floor. Studies have indicated that regular maintenance activities of infiltration basins apparently cannot prevent rapid clogging. Once clogged, it has been very difficult to restore their original function; thus, many have been converted to retention basins or wetlands. Consequently, infiltration basins do not have long life spans, with many no longer exfiltrating runoff after five years. Therefore, use of infiltration basins in Richland County for runoff quality control is prohibited.

prevent clogging and failure. Due to their high potential for failure, these facilities must only be considered for sites where upstream sediment control can be assured.

A design variation is a dry well to control small volumes of runoff, such as roof top runoff. Dry wells are appropriate to capture rooftop runoff for non-residential applications less than 5 acres in size. Dry wells may also be used as a secondary BMP for larger developments. Generally, dry wells are cost prohibitive as a primary BMP due to sizing criteria for water quantity control. Secondary BMPs may also be necessary to achieve the required pollutant removal efficiencies.

Significant maintenance is required to enhance longevity and maintain performance of infiltration trenches and dry wells. Most conventional trenches do not appear to be regularly maintained in the field and thus many will require costly rehabilitation or replacement to maintain their function.

Figure 7: Infiltration Trench



Source: Stormwater Management Manual for the Puget Sound Basin

Design Specifications

1) Feasibility study required for use of infiltration trenches and dry well BMPs. Study will demonstrate that other more reliable and lower maintenance BMPs are:

    a) are cost prohibitive or,

    b) jeopardize the economic viability of the development project with excessive land requirements, etc.

2) Site Constraints:

    a) Shall not be installed in fill material to avoid piping along the fill/natural ground interface and potential slope failure.

    b) Shall not be installed on or atop a slope whose natural angle of incline exceeds 6 percent.

c) Shall be located at least 10 feet down slope from foundation/basement walls.

d) Shall be a minimum of 150 feet down slope from any public or private water supply well if designed to handle runoff from impervious parking areas.

3) Soil/Geologic Constraints:

a) Limited to soils having a field-verified infiltration rate of between 0.5 and 2.5 inches per hour (loam, sandy loam and loamy sand, typically hydrologic group "A", some group "B" soils).

i) Initial consideration will be based on the appropriate soil survey and may serve as basis for rejection.

ii) On-site soil borings, textural classifications, and infiltration tests required verify the actual site conditions. A minimum of one soils boring is required for every 50 feet of trench length, and no less than two soils logs for each proposed trench location. Borings should be taken to a depth of at least five feet below the trench depth. Document evidence of impermeable or dissimilar soil layers.

b) Soils should have clay content of less than 15 percent and a silt/clay content of less than 40 percent.

c) Soils that have a 30 percent or greater clay content are not suitable for infiltration practices.

d) Bottom of infiltration practice shall be at least 4 feet above seasonal high water table, whether perched or regional, determined by direct piezometer measurements or by the depth in the soil at which mottling first occurs. Piezometer measurements must be representative of the maximum height of the water table on an annual basis, during years of normal precipitation.

e) An analysis should be made to determine any possible adverse effects of seepage zones when there are nearby building foundations, basements, roads, parking lots, or sloping sites.

f) Calculations showing the expected water surface elevations immediately following complete drainage of the infiltration trench shall be provided.

4) Infiltration Performance Criteria:

a) Permanent infiltration practices shall be designed to accept the design water quality volume (V_{WQ}) which is, at a minimum, 0.5 inches of runoff per acre or 1 inch per impervious acre, whichever is greater.

b) Maximum allowable drainage area is 5 acres.

c) Infiltration practice shall be designed to completely drain within 72 hours.

d) Assume voids ratio (V_R) of 0.4 for the aggregate material used in the infiltration practice.

e) Design infiltration rate (f) should be equal to one-half the infiltration rate found from the soil textural analysis.

f) Required depth and surface area of infiltration practice are computed as follows:

$$d = \frac{fT}{V_R}$$

Where: d = maximum depth of infiltration practice in feet,

f = design infiltration rate $^{ft}/_{hr}$,

T = maximum storage time, 72 hrs,

And V_R = void ratio (assumed to be 0.4)

$$A = \frac{V_{WQ}}{V_R d}$$

Where: A = infiltration practice surface area in ft^2,

V_{WQ} = water quality volume in ft^3,

d = depth of infiltration practice in feet,

And V_R = void ratio (assumed to be 0.4)

i) For sites with multiple trenches and/or dry wells, surface area should be calculated based on individual contributing drainage areas.

5) Runoff Pretreatment:

a) Drainage areas must be stabilized and vegetative filters established before allowing runoff to enter the infiltration practice.

b) If vegetation is intended filter, there shall be at least a 20-foot length of vegetative filter before stormwater runoff entering the infiltration practice. Vegetative filters shall be designed based on principles presented in Section 4.7.8.

c) Use oil and grit chambers when receiving large parking lot and roadway runoff.

6) Civil/Site Design Requirements:

a) Slope of bottom of the infiltration practice shall not exceed five percent.

b) Aggregate material for the trench should consist of a clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches.

c) Filter fabric shall have higher permeability than the surrounding soil.

d) Clean outs shall be spaced at 100 feet or close intervals along the infiltration practice to allow for access and maintenance.

e) Direct inlets are not required for an infiltration trench with aggregate surface. For vegetated surface, inlets shall consist of grates covering 2 to 3 foot diameter perforated inlet pipes.

f) If rooftop runoff enters an infiltration BMP via downspout and connector pipe, then:

i) Place screens at top of downspout to prevent leaves/debris from entering system.

ii) Minimize hole cut in the filter fabric for the connector pipe.

g) Observation well consisting of perforated 4- to 6-inch PVC pipe with locking cap shall be installed in the center of infiltration practice. Additional observation wells shall be provided for every 50 feet of trench length. Perforations shall be sized and spaced to allow water and finer sediment to flow freely in and out.

h) By-pass runoff in excess of the design volume. Provide a non-erosive overflow channel or flow path, along length of infiltration practice and at the outfall, for runoff exceeding design capacity.

i) Additional stormwater quantity and/or quality BMPs may be required to meet stormwater quantify and quality requirements.

7) Civil/Site Design Options:

a) Addition of a layer of very sandy soil over the gravel trench increases removal rates as high as 60 percent for suspended sediment and trace metal loads, 50 percent for oxygen demand, and 40 percent for nutrient loads.

b) Use sand layer rather than filter fabric at the bottom of infiltration practice to extend useful life of BMP.

c) Can be installed under a swale to increase the storage of the infiltration system.

d) Installation of back-up underdrain may extend the life of infiltration practice by essentially converting it into a sand filter. Drain will remain capped until exfiltration is no longer effective.

Recommended Construction Practices

1) Stabilize drainage area before construction of infiltration practice.

2) Excavated using a backhoe or wheel and ladder trencher to reduce soil smearing and compaction.

3) Excavated materials shall be kept away from the infiltration trench to prevent sidewall cave-ins and to reduce the reintroduction of excavated soils into or onto the trench. Covered excavation daily to prevent sediment from entering. Upon completion of excavation, inspect excavation to ensure conformance to plans and specifications.

4) Rototill of trench bottom to preserve infiltration rates.

5) Filter fabric shall be placed along the top, sides and bottom of the infiltration trench, with sufficient length to overlap 6 inches or more following placement of aggregate. Filter fabric shall be free of large holes. Overlaps between rolls shall be a minimum of 2 feet with the upstream roll atop the downstream roll. Follow manufacturer's recommendations regarding allowable exposure to UV light, alkalites, acidic materials, asphalt components and fuel oil.

6) Inlet pipes shall be placed at the beginning of aggregate placement process and seated firmly on the trench floor above the filter fabric. Grates shall be flush with finished grade.

7) Bottom of observation wells shall be flush with the finished (excavated) grade. The hole cut in the filter fabric for well shall be as small as possible. Top of observation well shall be flush with final design elevation of the aggregate or fill.

8) Conducted visual inspection following fabric placement and installation of the observation well(s) and inlet(s) to ensure the construction conforms to plans and specifications.

9) Evaluate aggregate quality to confirm materials used are clean and free of defects.

10) Aggregate shall be carefully lain in the trench and onto the filter fabric by a backhoe or front-end loader, rather than dumped by truck. The aggregate shall be placed in loose, 12-inch (maximum) lifts and compacted using plate compactors.

11) Inspect aggregate placement to confirm that aggregate is free of foreign material.

12) Top course aggregates or fill (vegetated surface) cover shall be lain carefully on top of the filter fabric to final grade. Wrap perforated portions of the observation well and inlets with impermeable cloth above the filter fabric before final filling. Minimum of six inches of cover shall be placed on the filter fabric.

13) All vegetated areas shall be seeded and protected. Vegetated facilities should not be put in use until the entire drainage area is stabilized.

Operation and Maintenance Requirements

1) Monitor after every large storm (rainfall greater than 1 inch in 24 hours) for the first year after completion of construction.

2) As needed:

    a) Provide weed control.

    b) Provide insect/mosquito control.

    c) Clean and remove debris from infiltration practice and pretreatment BMPs after major storm events.

3) Quarterly:

    a) Inspect and clean inlets (and outlets).

    b) Check for standing water in observation wells.

4) Annually:

    a) Mow and maintain upland vegetated areas.

    b) Remove accumulated sediment in pre-treatment BMP.

    c) Inspect and clean inlets (and outlets).

    d) Inspect filter fabric for sediment deposits by removing a small section of the top layer.

    e) Verify infiltration rate by monitoring of the observation well to confirm that the trench is draining within the specified time.

5) Replace surface layer of aggregate and the filter fabric over the top of the aggregate if sediment deposits are observed on filter fabric during annual inspection.

6) Restore to design condition when time necessary to infiltrate design water volume (V_{WQ}) has increased by 25 percent or more or standing water is observed in infiltration practice.

Operation and Maintenance Responsibility

a) Clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

b) If the infiltration practice will be maintained by the owner, a maintenance plan and schedule shall be submitted for approval. Routine maintenance includes activities such as grass mowing, debris removal, weed control, insect/mosquito control, monitoring well inspections and record keeping. Non-routine maintenance includes activities such as replacing the surface layer of aggregate and the filter fabric over the top of the aggregate, which can be expected on a semi-annual basis. Clogging of the entire aggregate shell can also occur. Complete rehabilitation is required at that time.

c) If the infiltration practice will ultimately be maintained by the County, easements will be required for access to the trench. Adequate grading and widths shall be provided to safely accommodate the County's operation and maintenance vehicles.

4.7.9 Vegetated Filter Strip: Vegetative filter strips (Figure 8) are vegetated sections of land designed to accept runoff as overland sheet flow from upstream development. The filter strip may be a replanted forested area, a densely grassed area, or a natural undisturbed area meeting the appropriate design criteria. They may adopt any natural vegetated form, from grassy meadow to small forest. The dense vegetative cover facilitates pollutant removal. Filter strips cannot treat high velocity flows; therefore, they have generally been recommended for use in agriculture and low density development.

Filter strips differ from natural buffers in that filter strips are not "natural" rather, they are designed and constructed specifically for the purpose of pollutant removal. A filter strip can also be an enhanced natural buffer, however, whereby the removal capability of the natural buffer is improved through engineering and maintenance activities such as land grading or the installation of a level spreader. Filter strips also differ from grassed swales in that swales are concave, vegetated conveyance systems, whereas filter strips have fairly level surfaces.

A filter strip generally provides pretreatment before runoff is discharged to other treatment systems. The vegetation or turf prevents erosion, filters sediment, and provides limited nutrient uptake. If site conditions permit, a check dam can be placed at the end of the filter strip to provide additional peak reduction and to direct discharge to a conveyance system.

Filter strips are not feasible as a primary BMP due to sizing criteria for water quantity control. Secondary BMPs may also be necessary to achieve the required pollutant removal efficiencies.

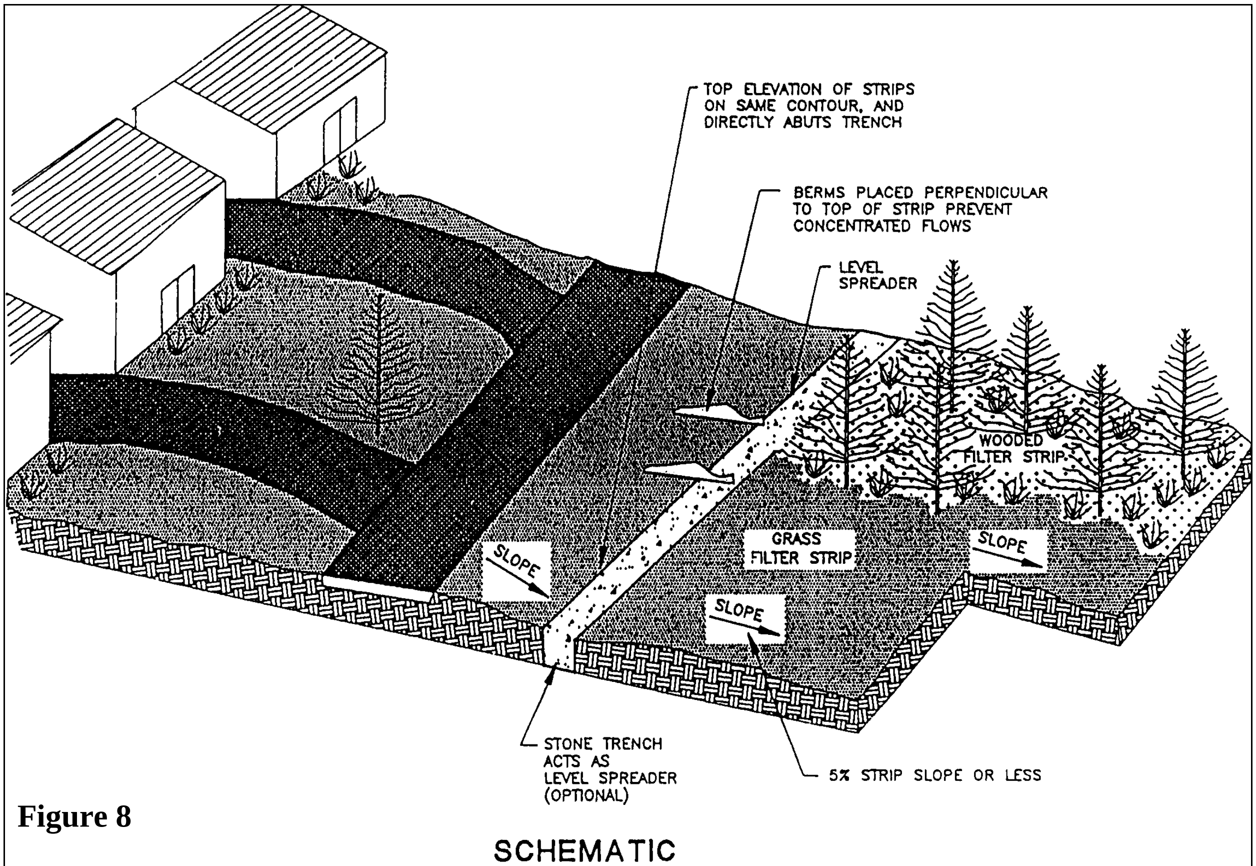


Figure 8

Vegetated Filter Strip

Source: Controlling Urban Runoff

Design Specifications

1) Filter strips should not be used on soils that cannot sustain a dense grass cover with high retardance.

2) Soils beneath a filter strip shall have infiltration rates greater than 0.3 inches per hour (silty loam, loam, sandy loam, loamy sand and sand).

3) Seasonal high water table shall be at least 1 foot below filter strip.

4) Longitudinal bottom slopes should be as close to zero as possible, and not greater than 5 percent.

5) Maximum drainage area of 5 acres or drainage area resulting in a peak flow of 30 cfs, which ever is less.

6) Slope, parallel to the direction of flow, less than or equal to 6%.

7) Hydrologic and Hydraulic Analyses

    a) Design water quality volume (V_{WQ}) shall be, at a minimum, 0.5 inches of runoff per acre or 1 inch per impervious acre, whichever is greater.

b) For the peak flow for the storm event, based on SCS methods, that results in the design water quality volume (V_{WQ}), compute maximum discharge loading per foot of filter strip for a flow depth of 1 inch.

$$q_{FS} = \frac{0.00236}{n} Y^{\frac{5}{3}} S^{\frac{1}{2}}$$

Where q_{FS} = discharge per foot of width of filter strip ($^{cfs}/_{ft}$),

Y = allowable depth of flow in inches (assume 1 inch),

S = Slope of filter strip,

And n = Manning's "n" roughness coefficient for surface condition of filter strip

Surface Condition[29]	***Manning's n***
Grass	
• Short grass prairie	0.15
• Dense grass	0.24
• Bermuda grass	0.41
Range (natural)	0.13
Woods	
• Light underbrush	0.40
• Dense underbrush	0.80

i) Compute minimum width of filter, perpendicular to flow.

$$W_{FS} = \frac{Q_P}{q_{FS}}$$

Where: W_{FS} = Minimum width of filter strip, perpendicular to flow, in feet,

Q_P = Peak discharge in cfs,

And q_{FS} = discharge per foot of width of filter strip ($^{cfs}/_{ft}$),

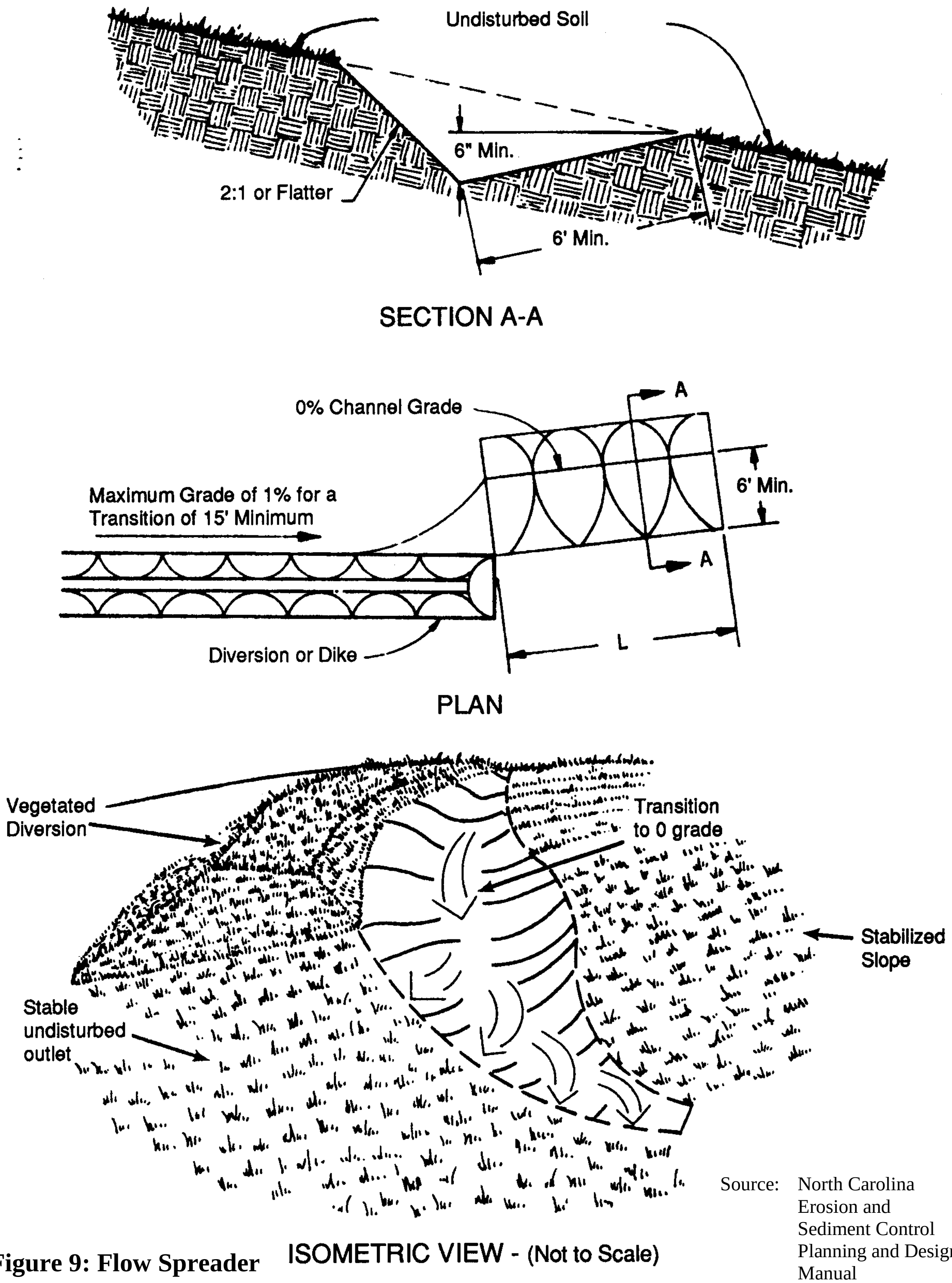
c) Compute minimum length of filter strip, parallel to the direction of flow.

$$L_{FS} = 50 + \left(4 \times \left(S - 1\right)\right)$$

Where: L_{FS} = Minimum length of filter strip, parallel to the direction of flow, in feet,

And S = Slope of filter strip, parallel to the direction of flow, in percent

[29] TR-55, Urban Hydrology for Small Watersheds, NRCS, 1986



Source: North Carolina Erosion and Sediment Control Planning and Design Manual

Figure 9: Flow Spreader

8) Civil/Site Design Criteria:

   a) Velocity should not exceed 3 feet per second at design capacity. Velocities greater than 1.5 feet per second should be avoided, when possible.

   b) Choose grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods.

c) Flow shall enter filter strip as sheet flow spread out over the width (long dimension normal to flow) of the strip, generally no deeper than one to two inches.

d) Maximum length of area to be treated, parallel to direction of flow, is 100 feet. For longer flow paths, use flow (level) spreader (Figure 9) or other provision must be made to insure design flows spread evenly across the filter strip. Other flow spreaders include a concrete sill, curb stops, or curb and gutter with "sawteeth" cut into it.

e) Filter strips should be constructed outside the natural stream buffer area whenever possible to maintain a more natural buffer along the streambank.

f) Both top and toe of slope should be as flat as possible to encourage sheet flow and prevent erosion.

g) Flows more than design flow shall move across or around strip without damaging it. As needed use, bypass channel or overflow spillway with protected channel section to handle higher flows.

h) If flow spreader (Figure 9) is used to diffuse runoff, it shall meet the following criteria:

i) Channel grade for the last 20 feet of the dike or diversion entering the flow (level) spreader should be less than or equal to 1% and designed to provide smooth transition into spreader.

ii) Grade of flow (level) spreader should be 0%.

iii) Depth of flow (level) spreader as measured from lip should be at least 6 inches.

iv) Appropriate length, width, and depth of flow spreader should be selected from the following table.

Design Flow (cfs)	Entrance Width (ft)	Depth (ft)	End Width (ft0	Length (ft)
0 - 10	10	0.5	3	10
10 - 20	16	0.6	3	20
20 – 30	24	0.7	3	30

v) Flow (level) spreader lip should be constructed on undisturbed soil (not fill material) to uniform height and zero grade over length of the spreader.

vi) Released runoff to outlet should be on undisturbed stabilized areas in sheet flow and not allowed to re-concentrate below the structure.

vii) Slope of filter strip from flow (level) spreader should not exceed 10 percent.

9) Other Recommended Criteria:

a) Pea gravel trench or flow (level) spreader should be incorporated into design to ensure uniform flow distribution (sheet flow) across filter strip.

b) Top edge of filter strip should directly abut contributing impervious area and follow same elevation contour line.

c) Treat runoff water containing high sediment loads in sediment-trapping device before release in flow spreader.

d) Protect spreader lip with erosion resistant material, such as fiberglass matting or a rigid non-erodible material for higher flows, to prevent erosion and allow vegetation to be established.

e) Check dam may be placed at end of filter strip for temporary storage, or to concentrate the flow to one point.

f) Wooded filter strips are preferred to gravel strips.

Operation and Maintenance Requirements

1) All vegetated areas shall be seeded and protected. Filter strips shall not be put in use until the entire drainage area is stabilized.

2) Inspected after every rainfall until vegetation is established. Promptly repair as needed. If necessary, replace with an alternative species.

3) Vegetation shall be kept in a healthy, vigorous condition. Grasses shall be maintained at a minimum height of 3 inches. Vertical stand of dense vegetation (6 inches or greater) is recommended.

4) Filter strip and flow spreader should be maintained in a manner to achieve sheet flow. Annually,

   a) Inspect pea gravel diaphragm for clogging and remove built-up sediment.

   b) Inspect vegetation for rills and gullies and correct. Seed or sod bare areas.

   c) Remove sediment and debris using hand tools (rake, shovel, and wheelbarrow).

Operation and Maintenance Responsibility

1) Clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

2) If filter strip will be maintained by the owner, maintenance plan and schedule shall be submitted for approval. Stormwater management easement and maintenance agreement should be required for each facility. The maintenance covenant shall require the owner of the filter strip/flow spreader to clean structure periodically.

3) If filter strip will ultimately be maintained by the County, easements will be required for access. Adequate grading and widths shall be provided to safely accommodate County's operation and maintenance vehicles.

4.7.9 Grass Swale: Grassed swales (Figure 10) are earthen conveyance systems that remove pollutants from urban storm water by filtration through grass and infiltration through soil. Grassed swale generally provides pretreatment before runoff is discharged to other treatment systems. The vegetation or turf prevents erosion, filters sediment, and provides limited nutrient uptake. Swales should be designed with relatively wide bottoms to promote even flow through the vegetation and avoid channelization, erosion, or high velocities.

Grassed swales can be used for drainage areas up to five acres can provide sufficient runoff control to replace curb and gutter in single-family residential subdivisions and on highway medians; however, their ability to control large storms and provide the target water quality benefits is limited. Therefore, in most cases, swales must be used in combination with other BMPs downstream for water quality and quantity control.

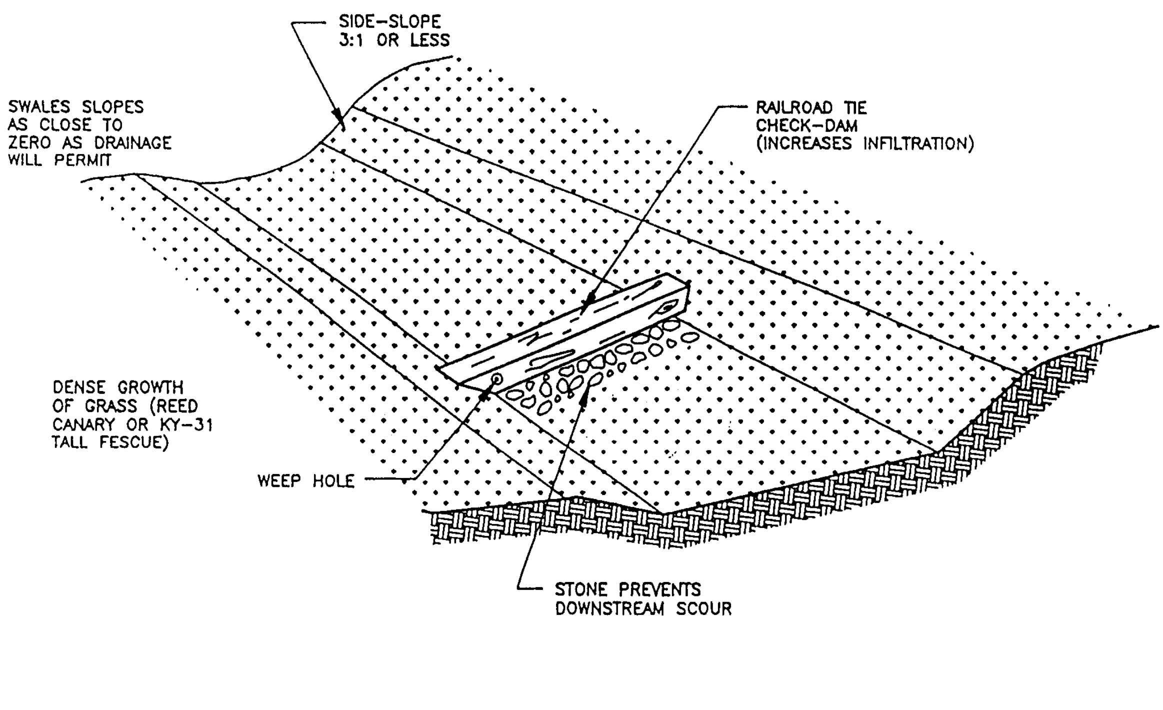


Figure 10: Grass Swale

Source: Controlling Urban Runoff

Design Specifications

1) Maximum drainage area of 5 acres.

2) Underlying soils shall have minimum infiltration rate of 0.5 inches per hour.

3) Grassed swales should only convey water following a storm. Seasonal high water table shall be at least 2 feet below the grassed swale. Pollutant removal will be reduced if dry-weather flow is present in the swale.

4) Slopes shall be less than 4%; channel slopes between 1% and 2% are recommended.

5) Hydrologic/Hydraulic Analysis:

   a) Design water quality volume (V_{WQ}) shall be, at a minimum, 0.5 inches of runoff per acre or 1 inch per impervious acre, whichever is greater.

   b) For the peak flow for the storm event, based on SCS methods, that results in the design water quality volume (V_{WQ}),

   c) Compute flow channel cross-section area using Manning's formula.

      i) Channel shall have trapezoidal or parabolic cross section with 2 to 6 foot bottom width and 3:1 or flatter side slopes.

      ii) Maximum allowable depth of flow of 4 inches for water quality design.

iii) Maximum allowable velocity of 1 foot per second for water quality design.

d) Compute minimum channel length based on minimum allowable residency time of 5 minutes for water quality peak flow design.

e) See Section 4.5, Open Channels, for more information and specifications on design of grass channels.

2) Civil/Site Design Criteria:

a) Design shall satisfy water quality design criteria and stormwater conveyance criteria specified in Section 4.5, Open Channels.

b) Velocities shall be non-erosive. Full-channel design velocity will typically govern.

c) Choose grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods.

d) See Section 4.5, Open Channels, for more information and specifications on the design of grass channels.

3) Other Considerations:

a) Constructed with gravel blanket or other measures to minimize tire rutting during maintenance activities.

b) Check dams can be installed in swales to promote additional infiltration by create a series of temporary pools to induce infiltration. Water volume detained can be included to partially fulfilling design water quality volume requirements of downstream BMPs.

i) Check dams shall be constructed using permanent, non-erodible materials and shall be designed to prevent downstream scour and scour along the contact with swale side slopes. Recommended method is to sink a railroad tie halfway into the swale.

ii) Check dams should be a minimum of 6 inches and a maximum of 12 inches in height.

iii) Riprap stone should be placed on the downstream side to prevent erosion.

iv) Maximum ponding time behind check dam to be less than 48 hours. Minimum ponding time of 30 minutes is recommended to meet water quality goals.

Operation and Maintenance Requirements

1) As needed, mow grass to maintain a height of 3 to 4 inches.

2) Fertilization when needed to maintain the health of grass, with care not to over apply the fertilizer.

3) As required, remove sediment buildup bottom of grass channel once it has accumulated to 25% of the original water quality design cross-sectional area.

4) Annually:

a) Inspect grass along side slopes for erosion and formation of rills and gullies and correct.

b) Remove trash and debris accumulated in channel.

Operation and Maintenance Responsibility

1) Clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

2) If grassed swale will be maintained by the owner, a maintenance plan and schedule shall be submitted for approval. Routine maintenance includes activities such as periodic inspections, mowing and reseeding bare spots. Grasses should be kept dense and vigorous. Sediment and debris removal using hand tools (rake, shovel and wheelbarrow) should be performed annually.

3) If grassed swale will ultimately be maintained by the County, easements will be required for access. Adequate grading and widths shall be provided to safely accommodate the County's operation and maintenance vehicles.

4.7.10 Enhanced Swale: Enhanced swales are vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means. The two types of enhanced swales are (1) dry swale (Figure 11) and (2) wet swale/wetland channel (Figure 12).

Design Specifications

3) Site Requirements:
   a) Contributing area shall be 5 acres or less
   b) Proximity to seasonal high water table:
      i) 2 feet required between bottom of dry swale and seasonal high water table
      ii) Wet swale below water table or placed in poorly drained soils
   c) For dry swale, soils shall have infiltration rates not less than 0.3 inches per hour and not greater than 1.0 inches per hour (silty loam, loam and sandy loam).

4) Water Quality Volume: Minimum water quality design volume (V_{WQ}) shall be either 1 inch of runoff per acre or 1.5 inches of runoff per impervious acre, whichever is greater.

5) Peak Flow Control: Enhanced swales are generally ineffective in peak flow rate reduction. Another structural BMP must be used in conjunction with enhanced swales for peak flow control.

6) Runoff Pretreatment:
   a) Provide sediment forebay at each inlet to both dry and wet swales.
   b) Forebay(s) should be sized to contain approximately 10% of the water quality design volume (V_{WQ}). The forebay storage volume counts toward the total water quality storage requirements.
   c) Forebay should have separate drain for de-watering.
   d) Exit velocities from the forebay should be non-erosive. Provide riprap or other outlet protection as needed.

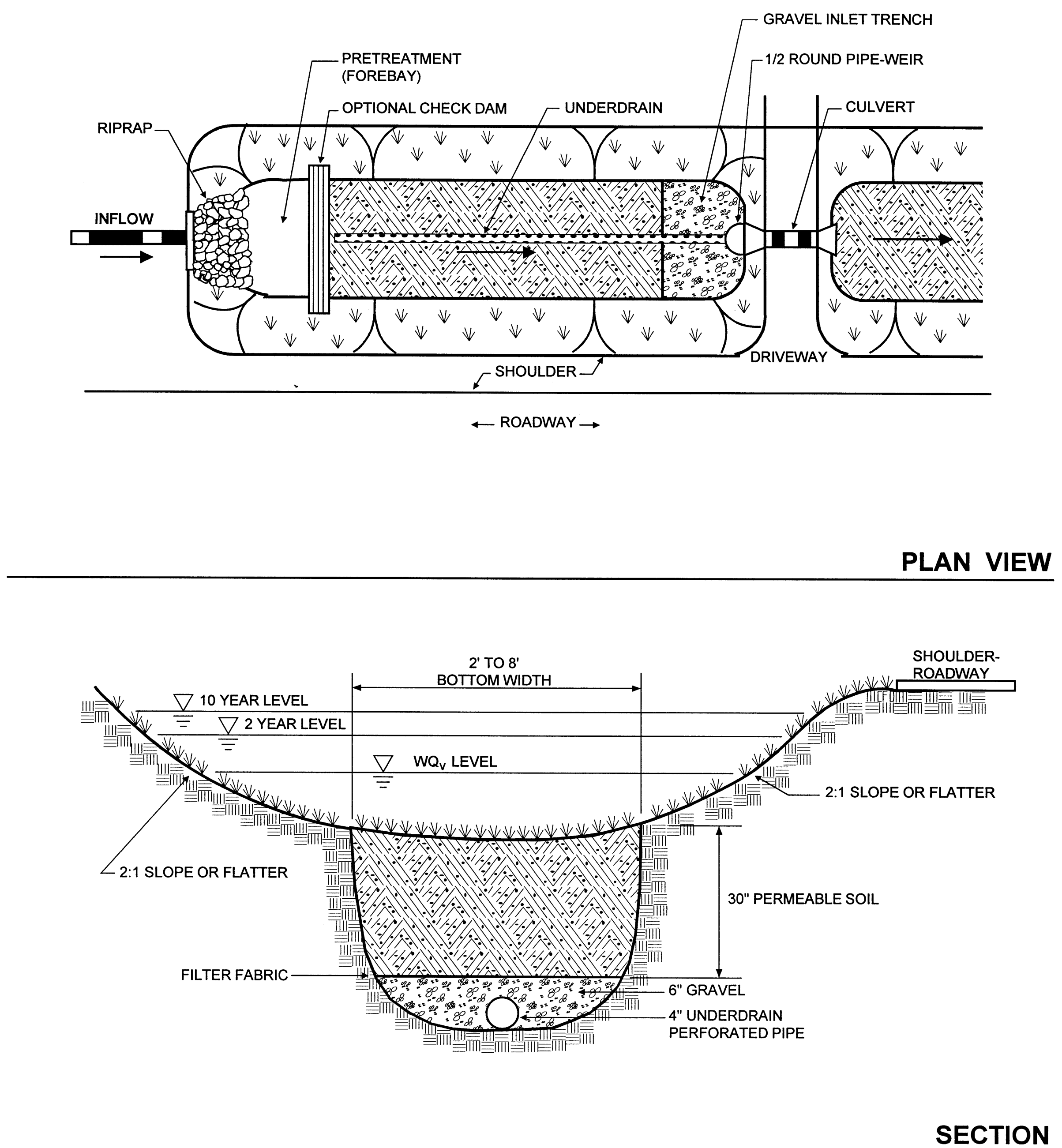


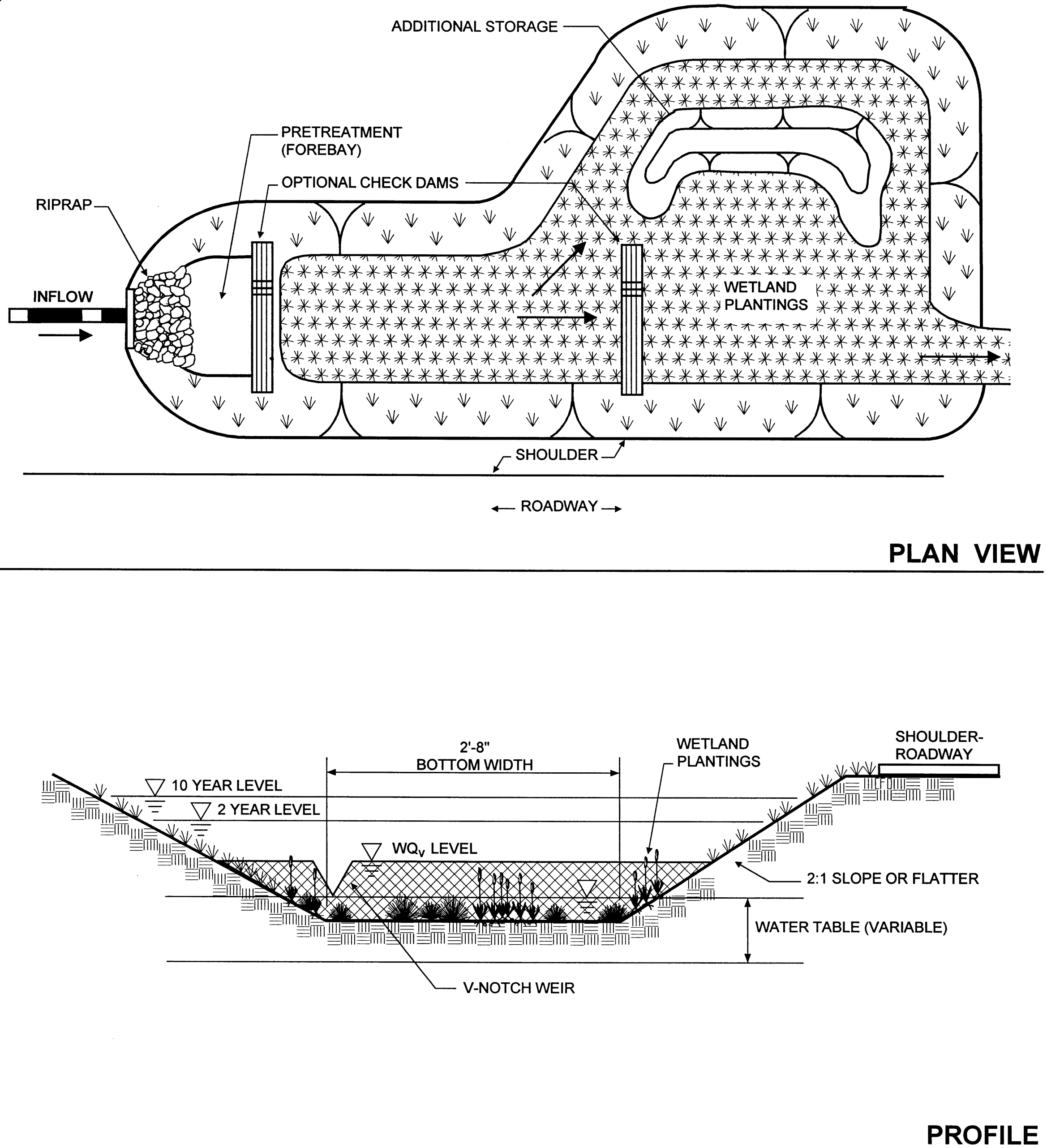
Figure 11: Enhanced Dry Swale Source: Center for Watershed Protection

e) Bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.

f) Fixed vertical sediment depth marker should be installed in the forebay to measure sediment deposition over time.

g) Direct maintenance access to the forebay shall be provided with access 25-feet wide minimum and 5:1 slope maximum.

Figure 12: Enhanced Wet Swale



Source: Center for Watershed Protection

7) Velocities:

   a) Peak velocity for the 2-year storm shall be non-erosive for soil and vegetative cover

   b) Provide flow diversion and/or design enhanced swale to safely convey water quantity design storm (see Section 4.1.1).

8) Berm (Embankment) Design:

   a) Height of earthen berm should equal design water quality depth plus 1 foot of freeboard.

   b) Berm shall have a minimum top width of 15 feet with side slopes no steeper than 3:1 horizontal to vertical.

c) Protect berm using permanent, non-erodible materials prevent downstream scour and scour along the contact with swale side slopes.

d) Side slopes shall be planted with turf-forming grass.

e) Notch in berm is acceptable to allow dewatering above the design depth following rainstorms.

9) Civil/Site/Vegetative Requirements:

a) Channel slope less than 4%, with 2%, preferred unless topography necessitates steeper slope, in which case 6 to 12-inch drop structures can be placed to limit energy slope to within the recommended range.

b) Elevation difference needed at site from inflow to outflow:

i) 3 to 5 feet for dry swale

ii) 1 foot for wet swale

c) Maximum allowable ponding depth of 18 inches for the design water quality volume (V_{WQ}). Average depth of 12 inches should be maintained.

d) Bottom width of swale shall be between 2 and 8 feet to ensure adequate filtration.

e) Use parabolic or trapezoidal cross-section, with moderate side slopes. 2:1 minimum side slope allowed; 4:1 side slope or flatter recommended for side inflow by sheet flow.

f) Dry Swale Specific Criteria:

i) Sized to store and infiltrate the entire water quality volume (V_{WQ}) with less than 18 inches of ponding and allow for full filtering through the permeable soil layer. The maximum ponding time is 48 hours; 24 hour ponding time is more desirable.

ii) Bed of the dry swale consists of a permeable soil layer of at least 30 inches in depth, above a 4 inch diameter perforated PVC pipe (AASHTO M 252) longitudinal underdrain in a 6 inch gravel layer. Soil media should have an infiltration rate of at least one foot per day (1.5 feet per day maximum) and contain a high level of organic material to facilitate pollutant removal. Permeable filter fabric is placed between the gravel layer and the overlying soil.

iii) Channel and underdrain excavation to the width and depth specified in design. The bottom of the excavated trench shall not be loaded as to cause compaction, and scarified before placement of gravel and permeable soil. The sides of the trench shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified before backfilling.

iv) Underdrain system should discharge to the storm drainage infrastructure or stable outfall.

v) Choose grass that can withstand relatively high velocity flows at the entrances, and both wet and dry periods.

g) Wet Swale Specific Criteria

i) Sized to retain the entire water quality volume (V_{WQ}) with less than 18 inches of ponding at maximum depth point.

ii) Check dams can be used to achieve multiple wetland cells. V-notch weirs in check dams can be utilized to direct low flow volumes.

iii) Provide outlet protection at any discharge point from wet swale to prevent scour and downstream erosion.

iv) Emergent vegetation should be planted, or wetland soils may be spread on swale bottom for seed stock.

v) Where wet swales do not intercept the groundwater table, a water balance calculation should be performed to ensure an adequate water budget to support the specified wetland species.

Operations and Maintenance Requirements:

1) All vegetated areas shall be seeded and protected. Swale shall not be put in use until entire drainage area is stabilized.

2) Inspected after every rainfall until vegetation is established. Promptly repair as needed. If necessary, replace with alternative species.

3) Vegetation shall be kept in a healthy, vigorous condition. Replace vegetation to maintain at least 50% surface area coverage annual or as required. Vertical stand of dense vegetation (6 inches or greater) is recommended.

4) Remove sediment in forebay annually or when 50% of the total capacity has been lost.

Operations and Maintenance Responsibility:

1) Clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

2) If enhanced swale will be maintained by the owner, a maintenance plan and schedule shall be submitted for approval. Routine maintenance includes activities such as periodic inspections, mowing and reseeding bare spots. Grasses should be kept dense and vigorous. Sediment and debris removal using hand tools (rake, shovel and wheelbarrow) should be performed annually.

3) If enhanced swale will ultimately be maintained by the County, easements will be required for access. Adequate grading and widths shall be provided to safely accommodate the County's operation and maintenance vehicles.

4.7.11 Miscellaneous Secondary BMPs: In the previous section, detailed design information was presented concerning the most common BMPs for land development which show reasonable degree of success and reliability in mitigating water quality impacts due to the land development. Other types BMPs exist, most with applicability to very specific situations; a few which are described below.

4.7.11.1 Sand Filters: Sand filters (Figure 13) remove pollutants through sedimentation, filtration, and microbial activity within the sand. Removal rates are high for sediments and trace metals, and moderate for nutrients, biological oxygen demand, and fecal coliform. Sand filters, particularly off-line self-contained facilities, have few environmental concerns.

Sand filters can be used for a variety of applications - from small, highly urbanized sites up to a maximum treatable area of about 50 acres. Depending on the application, sand filters can be built underground or perimeter or aboveground in various configurations. An underground sand filter is designed for ultra-urban applications (less than one acre) and consists of a wet sedimentation chamber, sand filtration chamber, and outlet chamber. An aboveground sand filter can be used to treat larger drainage areas and includes a sedimentation basin and sand filtration chamber. Generally, sand filters are not feasible as a primary BMP due to sizing criteria for water quantity control. Additionally, other types of primary and/or secondary BMPs may be necessary to achieve the required pollutant removal efficiencies.

Design Specifications

1) Maximum contributing drainage area to an individual stormwater filtering system is usually less than 10 acres.

2) Design water quality volume V_{WQ} is, at a minimum, 0.5 inches of runoff per acre or 1 inch per impervious acre, whichever is greater.

3) Adequate pretreatment (e.g., filter strips) is required to prevent sediment from overloading the filters.

4) Most stormwater filters normally require one to six feet of head.

5) Sand filter shall be designed to completely empty in 36 hours.

6) Inlet structure should be designed to spread flow uniformly across the surface of filter media.

7) Stone riprap or other dissipation devices should be installed to prevent gouging of sand media and to promote uniform flow.

8) Sand bed shall be a minimum of 18 inches deep. Top of sand bed shall be completely level.

9) Underdrain pipes should consist of main collector pipes and perforated lateral branch pipes.

10) Underdrain piping should be reinforced to withstand the weight of the overburden.

11) Internal diameters of lateral branch pipes should be 4 inches or greater (6 inches preferred) and perforations should be 3/8 inch.

12) Maximum spacing between rows of perforations should not exceed 6 inches.

13) All piping should be schedule 40 polyvinyl chloride or greater strength.

14) Minimum grade of piping should be 1/8 inch per foot (1% slope).

15) Access for cleaning all underdrain piping should be provided.

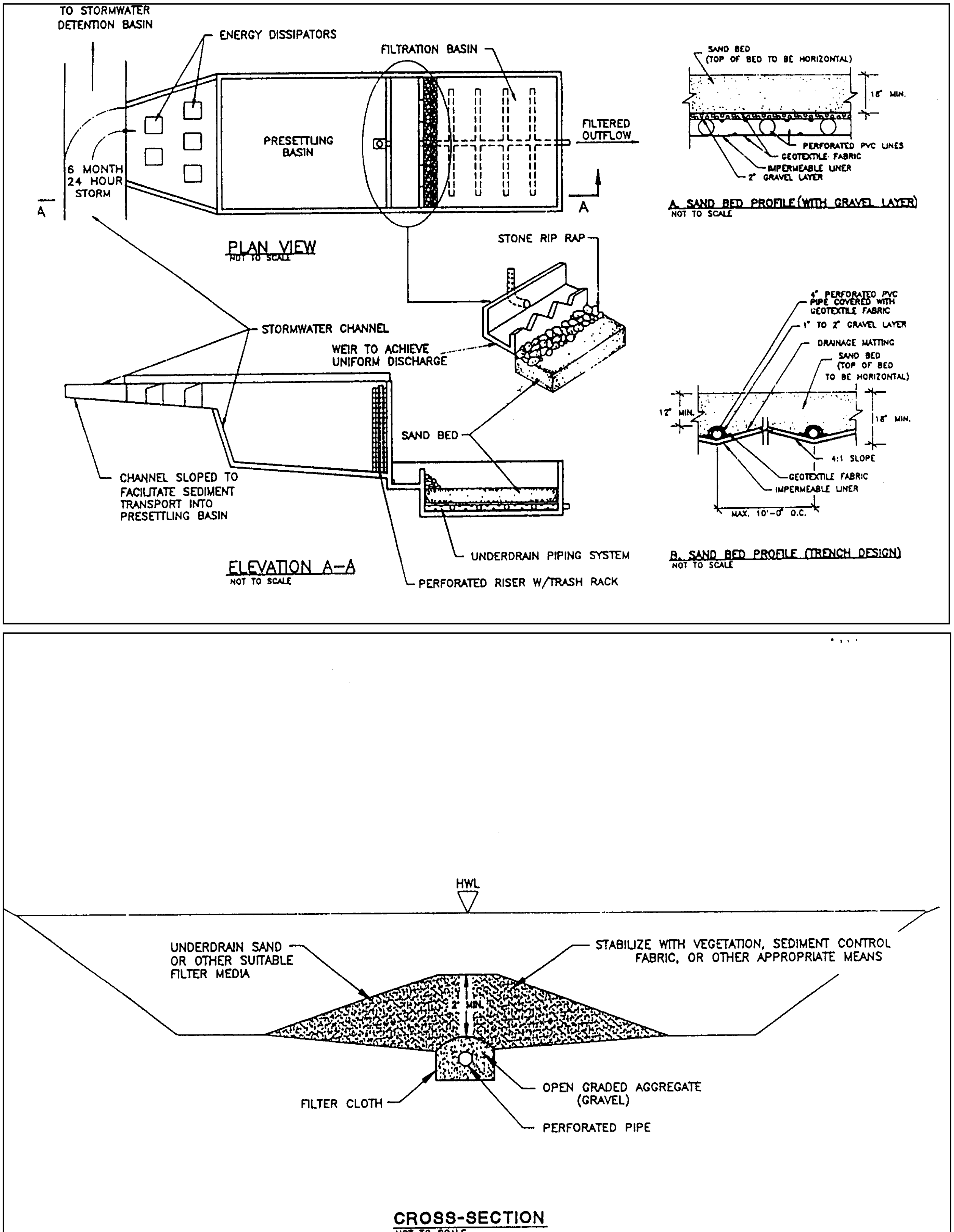
16) Surface filters may have a grass cover to aid in pollution adsorption.

17) Vegetation should be established over contributing drainage areas before runoff can be accepted into the facility.

18) For underground sand filter facilities, the minimum clearance between the top of the sand bed and the bottom of the concrete slab is 5 feet.

19) A dewatering valve shall be placed just above the top of the sand bed to drain the facility if

the sand becomes clogged.



Source: Stormwater Management Manual for the Puget Sound

Figure 13: Sand Filtration System

20) The recommended underdrain system within the sand filtration chamber consists of 6-inch

perforated schedule 40 PVC, spaced 10 feet apart, placed in an 8 to 12 inch gravel jacket. Appropriate filter fabric or a 3-inch layer of pea gravel should be placed between the sand and the gravel underdrain. The underdrain pipes may discharge to a main collector pipe or outlet chamber.

21) Off-line sand filter facilities should be designed to divert runoff from storms exceeding the storage capacity of the facility. A by-pass structure can be used to direct excess flow away from the facility.

22) For on-line sand filter facilities, an overflow shall be placed in the sediment chamber and designed to carry flow from the design storm. The overflow shall be placed as far upstream as possible to prevent the sedimentation chamber from being flushed out.

23) Adequate access shall be provided by installing doors, steps, and observation manholes for periodic inspection and maintenance.

24) Surface filters may have a grass cover to aid in pollution adsorption.

25) Vegetation shall be established over the contributing drainage areas before runoff can be accepted into the facility.

Recommended Configurations

Two sand bed configurations are recommended for use:

1) Sand Bed with Gravel Layer;

    a) Top layer of sand should be a minimum of 18 inches of 0.02 - 0.04 inch diameter sand (smaller sand size is acceptable).

    b) A layer of ½ to 2-inch diameter gravel under the sand should be provided for a minimum of 2 inches of cover over the top of the under-drain lateral pipes.

    c) No gravel is required under the lateral pipes.

    d) The sand and gravel should be separated by a layer of geotextile fabric (permeable filter fabric).

2) Sand Bed with Trench Design;

    a) Top layer of sand is to be 12-18 inches of 0.02 - 0.04 inch diameter sand (smaller size is acceptable).

    b) Laterals to be placed in trenches with a covering of one-half to 2-inch gravel and geotextile fabric.

    c) The lateral pipes are to be underlain by a layer of drainage matting.

    d) A presettling basin and/or biofiltration swale is recommended to pretreat runoff discharging to the sand filter.

    e) A maximum spacing of 10 feet between lateral underdrain pipes is recommended.

Sand Filter Options/Enhancements

1) Sand/peat beds have higher removal effectiveness due to adsorptive properties of peat.

2) Designs incorporating vegetative cover on the filter bed increase nutrient removal.

3) Pretreatment (sedimentation or oil and grease removal) will enhance the performance of the filter and will decrease the maintenance frequency required to maintain effective performance.

Operation and Maintenance Requirements

1) As needed or annually:

   a) Remove trash and debris from control openings.

   b) Repair leaks from sedimentation chamber or deterioration of structural components.

   c) Remove top few inches of sand and rake surface to restore infiltration.

   d) Clean out accumulated sediment from filter bed chamber.

   e) Clean out accumulated sediment from sedimentation chamber.

   f) Perform infiltration test.

2) Replace some or all of the sand when permeability of the filter media is reduced to unacceptable levels, which should be specified in the design of the facility. A minimum infiltration rate of 0.5 inches per hour should be used for all infiltration designs.

Operation and Maintenance Responsibility

1) Clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

2) If sand filter facility will be maintained by the owner, a maintenance plan and schedule shall be submitted for approval. Routine maintenance includes raking and removal of surface sediment, trash, debris, and litter. Non-routine maintenance includes activities such as structural repairs and major clean outs - material removal, replacement and offsite sediment disposal.

3) If sand filter facility will ultimately be maintained by the County, easements will be required for access. Adequate grading and widths shall be provided to safely accommodate the County's vehicles for routine and non-routine maintenance.

4.7.11.2 Gravity Separator: A gravity separator (Figure 14), also known as an oil/grit separator, is a three-stage underground retention system designed to remove coarse-grained sediments and absorbed hydrocarbons from stormwater runoff. Removal of silt, clay, nutrients, trace metals, and organic matter is likely to be minimal. A gravity separator provides pretreatment before runoff is discharged to the primary storm sewer system.

Gravity separator can be used for small drainage areas up to two acres and are restricted to ultra-urbanized areas where space is not available for other, more effective BMPs. Gravity separator can be used in most small development areas such as parking lots, gas stations, convenience stores, and along some roadways. Gravity separators are not feasible as a primary BMP due to sizing criteria for water quantity control. Secondary BMPs will also be necessary to achieve the required pollutant removal efficiencies.

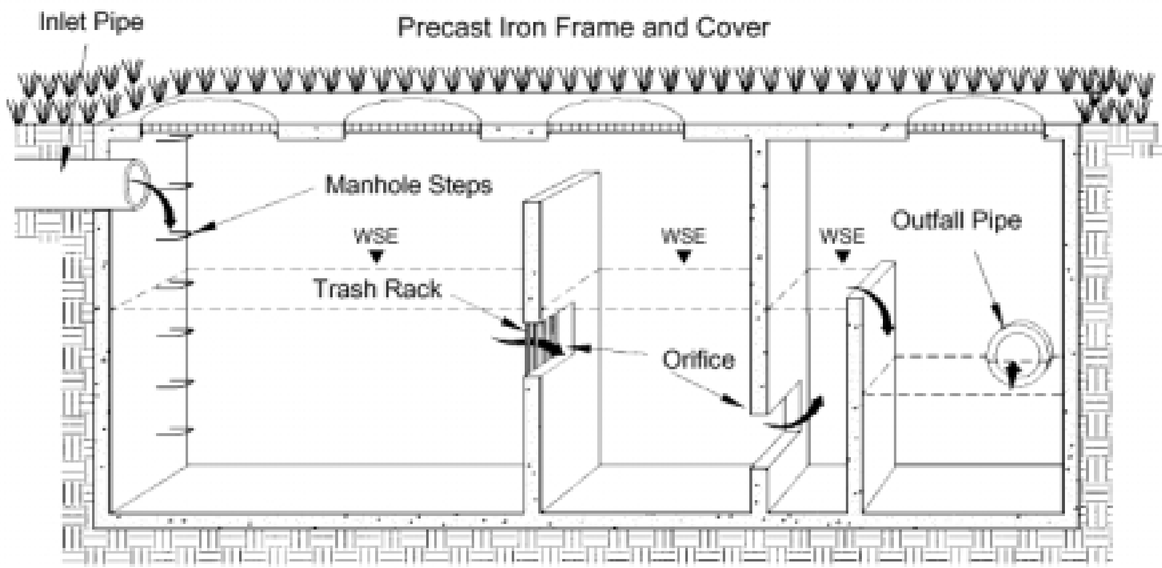


Figure 14: Gravity Separator

Source: Northern Virginia BMP Handbook

Different types and configurations of pre-manufactured gravity separators can be purchased from a variety of different vendors throughout the country. Prices for these units range from $5,000 to $15,000 or more, depending on the application.

Gravity separators are not feasible as a primary BMP due to sizing criteria for water quantity and quality control. Secondary BMPs are necessary to achieve the required pollutant removal efficiencies and peak flow control.

Design Specifications

1) Use of gravity (oil-grit) separators should be limited to the following applications:

    a) Pretreatment for other structural stormwater controls

    b) High-density, ultra urban or other space-limited development sites

    c) Hotspot areas

2) Gravity separators are typically used for areas less than one acre.

3) Gravity separator systems can be installed in almost any soil or terrain. Since these devices are underground, appearance is not an issue and public safety risks are low.

4) Gravity separators are rate-based devices. That is, they are sized based on the peak flow of a specific storm event. This contrasts with most other stormwater structural controls, which are sized based on capturing and treating a specific volume.

5) Gravity separator units are typically designed to bypass runoff flows in excess of the design flow rate. Some designs have built-in high flow bypass mechanisms. Others designs require a diversion structure or flow splitter ahead of the device in the drainage system. An adequate outfall or improved drainage system downstream of the gravity separator must also be provided.

6) Design water quality volume (V_{WQ}) shall be, at a minimum, 0.5 inches of runoff per acre or 1 inch per impervious acre, whichever is greater.

7) For the peak flow for the storm event, based on SCS methods, that results in the design water quality volume (V_{WQ}),

8) Total wet storage of the gravity separator unit should be at least 400 cubic feet per contributing impervious acre.

9) The minimum depth of the permanent pools should be 4 feet.

10) The separation chamber should provide for three separate storage volumes:

    a) A volume for separated oil storage at top of chamber,

    b) A volume for settleable solids accumulation at bottom of chamber,

    c) A volume required to give adequate flow-through detention time for separation of oil and sediment from stormwater flow.

11) Horizontal velocity through separation chamber should be 1 to 3 $^{ft}/_{min}$ or less. No velocities in the device should exceed the entrance velocity.

12) Trash rack should be included in the design to capture floating debris, preferably near inlet chamber to prevent debris from becoming oil impregnated.

13) Ideally, gravity separator design will provide an oil draw-off mechanism to a separate chamber or storage area.

14) Adequate maintenance access to each chamber must be provided for inspection and clean out of a gravity separator unit.

15) Design criteria and specifications of a commercial gravity separator unit should be obtained from manufacturer.

Recommended Specifications

1) Separator shall be located near pollutant source to minimize the potential for polluted stormwater to bypass the separator and enter storm sewers or other BMPs.

2) Oil absorbent pads, oil skimmers, or other approved methods for removing accumulated oil shall be provided.

3) Flows above 400 cubic feet per acre shall bypass separator.

4) Stormwater from rooftops and other impervious areas not likely to be polluted with oil should not discharge to the separator.

5) Storm drain inlet in third chamber shall be located above the floor to permit additional settling.

6) Center chamber may contain a coalescing medium to enhance the gravity separating process.

Operation and Maintenance Requirements

1) Inspect gravity separator unit quarterly. Remove and properly dispose of sediment, oil and

grease, and floatables as needed using catch basin cleaning equipment (vacuum pumps). Manual removal of pollutants may be necessary.

Operation and Maintenance Responsibility

1) A clear statement of defined maintenance responsibility shall be established during the plan review and approval process.

2) A stormwater management easement and maintenance agreement should be required for each facility. The maintenance covenant should require the owner of the separator to clean the structure periodically.

4.7.12 Not Recommended Structural Best Management Practices: The structural controls presented in Table 19 in are not recommended for use in Richland County to meet stormwater management objectives, as they fail to demonstrate an ability to provide long-term, reliable stormwater quantity/quality control and/or present difficulties in operation and maintenance.

Table 19

Not Recommenced Structural BMPs

BMP	***Rationale for Lack of Recommendation***
Infiltration Basin	While in theory, infiltration basins provide excellent pollutant removal capabilities, the reality is that infiltration basins have historically experienced high rates of failure due to clogging associated with poor design, construction and maintenance. Surveys indicate that sixty to one hundred percent of basins studied could no longer exfiltrate runoff after five years. Major design refinement and site investigation will be required to achieve sufficient longevity. They would typically have an unacceptably high maintenance burden.
Porous Asphalt or Concrete	The use of porous pavement other than the modular block porous pavers provides limited water storage and infiltration of runoff from small, low-intensity storm events. Porous asphalt and concrete pavement surfaces are easily clogged by clays, silts, and oils resulting in a potentially high maintenance burden to maintain the effectiveness of this structural control. Seventy-five percent of all porous pavement systems surveyed in Maryland have partially or totally clogged within five years. Failure has been attributed to inadequate construction techniques, low permeable soils and/or restricting layers, heavy vehicular traffic, and resurfacing with nonporous pavement materials.
Media Filter Inserts	Media filter inserts such as catch basin inserts and filter systems are easily clogged and require a high degree of regular maintenance and replacement to achieve the intended water quality treatment performance.

4.7.13 Using Other or New Structural Stormwater Controls: Innovative technologies should be allowed and encouraged providing there is sufficient documentation as to their effectiveness and reliability. Other stormwater controls not presented in this manual are allowed, subject to pre-approval by the County Engineer. Justification for use of other stormwater controls must be based on independently derived information concerning performance, maintenance, and use requirements and limitations.

More specifically, new structural stormwater control designs will not be accepted for inclusion in the Manual until independent pollutant removal performance monitoring data determine that the practice can meet aid in meeting County water quality/quantity objectives, and that the stormwater control conforms with local and/or State criteria for treatment, maintenance, and environmental impact.

Innovative stormwater BMP technologies combine a variety of processes into a controlled system housed in a modular unit. By combining settling, filtration and various biological processes, these BMPs can be designed to remove many different types of pollutants. In some cases, proprietary systems can obtain better removal efficiencies than conventional BMPs. Similar to water quality inlets, proprietary systems provide pretreatment before runoff is discharged to the primary storm sewer system.

Proprietary systems can be used in any location receiving concentrated flows. Proprietary systems are most effective in most small development areas such as parking lots, gas stations, convenience stores, and other ultra-urbanized applications. Proprietary systems are not feasible as a primary BMP due to sizing criteria for water quantity control. Secondary BMPs will also be necessary to achieve the required pollutant removal efficiencies.

Different types and configurations of pre-manufactured proprietary systems can be purchased from a variety of different vendors throughout the country. Proprietary systems currently available include StormFilter™ by Stormwater Management®, StormTreat™ by StormTreat™ Systems, Stormceptor by CSR Hydro Conduit, Continuous Deflective Separation (CDS) by CDS Technologies, and Storm King® by H.I.L. Technology.

Required Specifications

1) Due to the variable nature and limited performance data available for most proprietary systems, it is highly recommended that the designer meet with County staff to discuss the proposal before developing detailed plans. All available data concerning system efficiencies and performance will be evaluated at that time.

2) Follow the manufacturer's specifications for installing proprietary systems.

3) If the proprietary system will be maintained by the owner, a maintenance plan and schedule shall be submitted for approval. When maintenance guidelines are available from the manufacturer, they should be incorporated into the maintenance plan.

4) If the proprietary system will ultimately be maintained by the County, easements will be required for access. Adequate grading and widths shall be provided to safely accommodate the County's operation and maintenance vehicles.

4.7.14 Non-Structural BMPs: Many non-structural or source control practices can be used for pollution prevention and control of pollutants. In most cases, it is much easier and less costly to prevent the pollutants from entering the drainage system than trying to control pollutants with structural BMPs. If used properly, the non-structural BMPs can be very effective in controlling pollutants and greatly reduce the need for structural BMPs. Non-structural BMPs normally do not have technical or engineering designs associated with them but are measures that the County or other agencies or groups might require or implement to assist in the management water quality and the control of pollutants within the County. Following is a brief discussion of some non-structural BMPs that can be used within a stormwater quality management plan for different portions of the Richland County Drainage System.

4.7.14.1 Public Education/ Participation: Public education/participation is not so much a best management practice as it is a method by which to implement BMPs. Public education/participation are vital components of many of the individual source control BMPs. A public education and participation plan provides the County with a strategy for educating its employees, the public, and businesses about the importance of protecting stormwater from improper use, storage, and disposal of pollutants. County employees must be trained, especially those that work in departments not directly related to stormwater but whose actions affect stormwater. Residents must become aware that a variety of hazardous products are used in the home and that their improper use and disposal can pollute stormwater and groundwater supplies. Businesses, particularly smaller ones that may not be regulated by Federal, State, or local regulations, must be informed of ways to reduce their potential to pollute stormwater.

4.7.14.2 Land Use Planning/Management: This BMP presents an important opportunity to reduce the pollutants in stormwater runoff by using a comprehensive planning process to control or prevent certain land use activities in areas where water quality is sensitive to development. It is applicable to all types of land use and represents one of the most effective pollution prevention practices. Subdivision regulations, zoning ordinances, preliminary plan reviews and detailed plan reviews, are tools that may be used to mitigate stormwater contamination in newly developing areas. Also, master planning, cluster development, terracing and buffers are ways to use land use planning as a BMP in the normal design for subdivisions and other urban developments. Limiting impervious areas is one of the most effective land use management tools, since nationwide research has consistently documented increases in pollution loads with increases in impervious cover. In addition to controlling impervious area cover, directly connected impervious areas should be kept to a minimum. This is especially important for large impervious areas such as parking lots and highways and can also be effective for small impervious areas such as roof drainage.

4.7.14.3 Material Use Controls: There are three major BMPs included in this category:

1) <u>Housekeeping Practices:</u> In housekeeping practices, the goal is to promote efficient and safe practices such as storage, use, cleanup, and disposal, when handling potentially harmful materials such as fertilizers, pesticides, cleaning solutions, paint products, automotive products, and swimming pool chemicals.

2) <u>Safer Alternative Products:</u> The use of less harmful products can be promoted. Alternatives exist for most product classes including fertilizers, pesticides, cleaning solutions, and automotive and paint products.

3) <u>Pesticide/Fertilizer Use:</u> Pesticides and fertilizers have become an important component of land use and maintenance for municipalities, commercial land uses, and residential landowners. Any usage of pesticides and fertilizers increases the potential for stormwater pollution. BMPs for pesticides and fertilizers include education in their use, control runoff from affected areas, control times when they are used, provide proper disposal areas, etc.

4.7.14.4 Material Exposure Controls: There are two major BMPs included in this category:

1) <u>Material Storage Control</u>: Material storage control is used to prevent or reduce the discharge of pollutants to stormwater from material delivery and storage by minimizing the storage of hazardous materials onsite, storing materials in a designated area, installing secondary containment, conducting regular inspections, and training employees and subcontractors.

2) <u>Vehicle Use Reduction</u>: Vehicle use reduction is used to reduce the discharge of pollutants to stormwater from vehicle use by high-lighting the stormwater impacts, promoting the benefits to stormwater of alternative transportation, and integrating initiatives with existing or emerging regulations and programs.

4.7.14.5 Material Disposal and Recycling: There are three major BMPs included in this category:

1) <u>Storm Drain System Signs:</u> Stenciling of the storm drain system (inlets, catch basins,

channels, and creeks) with prohibitive language/graphic icons discourages the illegal dumping of unwanted materials. Storm drain system signs act as highly visible source controls that are typically stenciled directly adjacent to storm drain inlets.

2) Household Hazardous Waste Collection: Household hazardous wastes are defined as waste materials which are typically found in homes or similar sources, which exhibit characteristics such as: corrosivity, ignitability, reactivity, and/or toxicity, or are listed as hazardous materials by the EPA. Household hazardous waste collection programs are a preventative rather than curative measure and may reduce the need for more elaborate treatment controls. Programs can be a combination of permanent collection centers, mobile collection centers, curbside collection, recycling, reuse, and source reduction.

3) Used Oil Collection: Used oil recycling is a responsible alternative to improper disposal practices such as dumping oil in the sanitary sewer or storm drain system, applying oil to roads for dust control, placing used oil and filters in the trash for disposal to landfill, or simply pouring used oil on the ground. Commonly used oil collection alternatives are a temporary "drop off" site on designated collection days or the use of private collectors such as automobile service stations, quick oil change centers and auto parts stores.

4.7.14.6 Spill Prevention and Cleanup: There are two major BMPs included in this category:

1) Vehicle Spill Control: The purpose of a vehicle spill control program is to prevent or reduce the discharge of pollutants to stormwater from vehicle leaks and spills by reducing the chance for spills by preventive maintenance, stopping the source of spills, containing and cleaning up spills, properly disposing of spill materials, and training employees. It is also very important to respond to spills quickly and effectively.

2) Aboveground Tank Spill Control: Aboveground tank spill control programs prevent or reduce the discharge of pollutants to stormwater by installing safeguards against accidental releases, installing secondary containment, conducting regular inspections, and training employees in standard operating procedures and spill cleanup techniques.

4.7.14.7 Dumping Controls: This BMP addresses the implementation of measures to detect, correct, and enforce against illegal dumping of pollutants on streets and into the storm drain system, streams, and creeks. Substances illegally dumped on streets and into the storm drain system and creeks include paints, used oil and other automotive fluids, construction debris, chemicals, fresh concrete, leaves, grass clippings, and pet wastes.

4.7.14.8 Connection Controls: There are two major BMPs included in this category:

1) Illicit Connection Prevention, Detection and Removal: Illicit connection prevention tries to prevent unwarranted physical connections to the storm drain system from sanitary sewers, floor drains, etc., through regulation, regular inspection, testing, and education. In addition, programs include implementation control procedures for detection and removal of illegal connections from the storm drain conveyance system. Procedures include field screening, follow-up testing, and complaint investigation.

2) Leaking Sanitary Sewer Control: Leaking sanitary sewer control includes implementing control procedures for identifying, repairing, and remediating infiltration, inflow, and wet weather overflows from sanitary sewers into the storm drain conveyance system. Procedures include field screening, testing, and complaint investigation.

4.7.14.9 Street/Storm Drain Maintenance: There are six major BMPs included in this category:

1) Roadway Cleaning: Roadway cleaning may help reduce the discharge of pollutants to stormwater from street surfaces by conducting cleaning on a regular basis. Cleaning often removes the larger sizes of pollutants but not the smaller sizes. Most pollutants are deposited within three feet of the curb which is where the roadway cleaning should be concentrated.

2) Catch Basin Cleaning: Catch basin cleaning on a regular basis also helps reduce pollutants in the storm drain system, reduces high pollutant concentrations during the first flush of storms, prevents clogging of the downstream conveyance system and restores the catch basins' sediment trapping capacity.

3) Vegetation Controls: Vegetation control typically involves a combination of chemical (herbicide) application and mechanical methods. Mechanical vegetation control includes leaving existing vegetation, cutting less frequently, hand-cutting, planting low maintenance vegetation, mulching, collecting and properly disposing of clippings and cuttings, and educating employees.

4) Storm Drain Flushing: Storm drains can be "flushed" with water to suspend and remove deposited materials. Flushing is particularly beneficial for storm drain pipes with grades too flat to be self-cleansing. Flushing helps ensure pipes convey design flow and removes pollutants from the storm drain system. However, flushing will only push the pollutants into downstream receiving waters unless the discharge from the flushing is captured and removed from the drainage system.

5) Roadway/Bridge Maintenance: Roadway/bridge maintenance is used to prevent or reduce the discharge of pollutants to stormwater by paving as little are as possible, designing bridges to collect and convey stormwater to proper locations, using measures to prevent runoff from entering the drainage system, properly disposing of maintenance wastes, and training employees.

6) Detention/Infiltration Device and Drainage Channel/Creek Maintenance: Proper maintenance and silt removal is required on both a routine and corrective basis to promote effective stormwater pollutant removal efficiency for wet and dry detention ponds and infiltration devices. Also, regularly removing illegally dumped items and material from storm drainage channels and creeks will reduce pollutant levels.

4.7.14.10 Permanent Erosion Control: There are three major BMPs included in this category:

1) Permanent Vegetation: Vegetation is a highly effective method for providing long term, cost effective erosion protection for a variety of conditions. It is primarily used to protect the soil surface from the impact of rain and the energy of the wind. Vegetation is also effective in reducing the velocity and sediment load in runoff sheet flow.

2) Flow Control: Once flow is allowed to concentrate, it is more difficult to control erosion problems. Thus, every effort should be made to maintain sheet flow conditions for runoff.

Where concentrated flows are unavoidable, the following techniques can be used to control erosion and resulting water quality problems.

- Riprap
- Gabions
- Check Dams
- Level Spreaders
- Armor Protection
- Diversions

3) Channel Stabilization: Channel stabilization addresses the problem of erosion due to concentrated flows. Concentrated flows occur in channels, swales, creeks, rivers, and other watercourses in which a substantial drainage area drains into a central point. Overland sheet flow begins to collect and concentrate in the form of rills and gullies after overland flow of as little as 100 feet. Erosion due to concentrated flow is typically extensive, causing large soil loss, undermining foundations, and decreasing the flow capacity of watercourses.

Proper selection of ground cover is dependent on the type of soil, the time of year of planting, and the anticipated conditions to which the ground cover will be subjected. In addition, mulching is a form of erosion protection that is commonly used in conjunction with establishment of vegetation. It typically improves infiltration of water, reduces, runoff, holds seed, fertilizer and lime in place, retains soil moisture, helps maintain temperatures, aids in germination, retards erosion and helps establish plants in disturbed areas.

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