ORDINANCE APPENDIX F

STORMWATER MANAGEMENT DESIGN CRITERIA

TABLE F-1
DESIGN STORM RAINFALL AMOUNT

FIGURE F-1
ALTERNATING BLOCK METHOD FOR
RAINFALL DISTRIBUTION

FIGURE F-2
PENNDOT DELINEATED REGIONS

FIGURE F-3
NRCS (SCS) TYPE II RAINFALL DISTRIBUTION – S CURVE

FIGURE F-4
PENNDOT REGION 5 STORM INTENSITY-DURATION-FREQUENCY CURVE

TABLE F-2
RUNOFF CURVE NUMBERS

TABLE F-3
RATIONAL RUNOFF COEFFICIENTS

TABLE F-4
MANNING'S ROUGHNESS COEFFICIENTS

TABLE F-5
NONSTRUCTURAL STORMWATER MANAGEMENT MEASURES

TABLE F-1

DESIGN STORM RAINFALL AMOUNT (INCHES)

The design storm rainfall amount chosen for design should be obtained from the PennDOT region in which the site is located according to Figure F-2.

	Region 5						
	Precipitation Depth (in)						
Duration	1 Yr	2 Yr	5 Yr	10 Yr	25 Yr	50 Yr	100 Yr
5 min	0.33	0.38	0.45	0.50	0.56	0.63	0.68
15 min	0.64	0.75	0.90	1.00	1.15	1.35	1.50
1 hr	1.10	1.35	1.61	1.85	2.15	2.60	2.98
2 hrs	1.34	1.66	2.00	2.34	2.70	3.26	3.76
3 hrs	1.50	1.86	2.28	2.67	3.09	3.69	4.29
6 hrs	1.86	2.28	2.82	3.36	3.90	4.62	5.40
12 hrs	2.28	2.76	3.48	4.20	4.92	5.76	6.72
24 hrs	2.64	3.36	4.32	5.28	6.24	7.20	8.40

Source: “Field Manual of Pennsylvania Department of Transportation,”
Storm Intensity-Duration-Frequency Charts, PDT- IDF, May 1986.

FIGURE F-1

ALTERNATING BLOCK METHOD FOR RAINFALL DISTRIBUTION

The Alternating Block Method can be utilized to develop design hydrographs from the PennDOT Storm Intensity-Duration-Frequency (PDT-IDF) curves. This method redistributes the incremental rainfall values developed from the PDT-IDF curves in a quasi-symmetrical form, where the block of maximum incremental depth is positioned at the middle of the required duration and the remaining blocks of rainfall are arranged in descending order, alternately to the right and to the left of the central block. Example F-1 below shows this method for a 100-year, 2-hour duration storm with 10- minute time intervals.

Example F-1

100- year, 2- hour Duration Storm Hydrograph Development Region 5

(1)	(2)	(3)	(4)	(5)
Time (min)	100- yr Rainfall Intensity (inches/hr)	100- yr Accumulated Rainfall Depth (inches)	100- yr Incremental Rainfall Depth (inches)	100- yr Rainfall Distribution (inches)
0	0.00	0.00	0.00	0.00
10	6.91	1.15	1.15	0.07
20	5.34	1.78	0.63	0.15
30	4.41	2.21	0.43	0.21
40	3.78	2.52	0.32	0.26
50	3.33	2.78	0.26	0.43
60	2.98	2.98	0.21	1.15
70	2.75	3.20	0.22	0.63
80	2.51	3.35	0.15	0.32
90	2.28	3.42	0.07	0.22
100	2.15	3.58	0.16	0.16
110	2.01	3.69	0.11	0.11
120	1.88	3.76	0.07	0.07

Source: *Applied Hydrology*, Chow, Maidment, Mays, 1988

Notes :

Values from Column (2) are derived from the appropriate rainfall chart based on the location of the site under analysis. (Region 5 in this example, therefore, use Figure F-3)

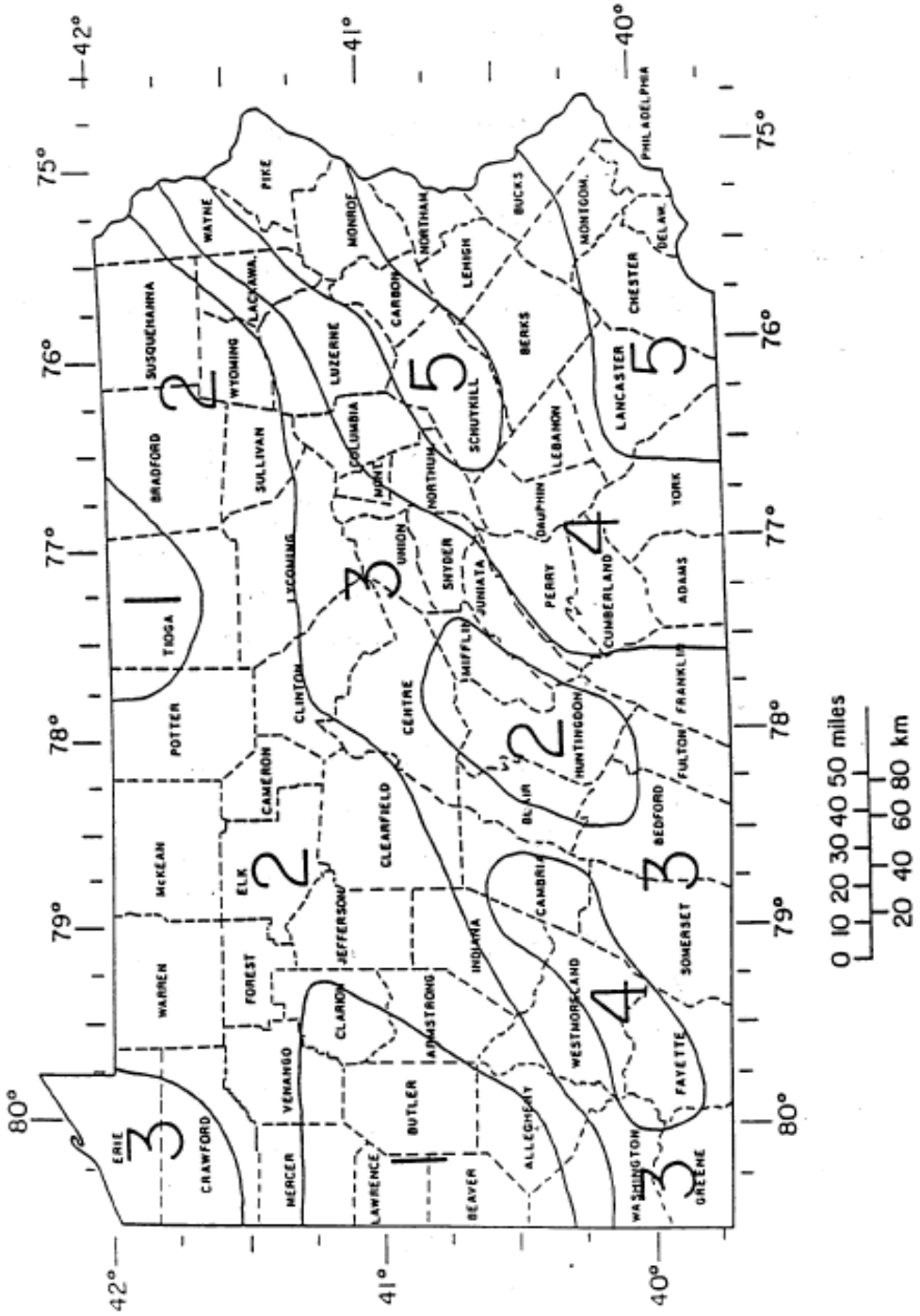
Column (3) = Column (2) * Column (1) / 60 minutes (i.e., 6.91 inches / hr * 10 min / 60 = 1.15).

Column (4) = Difference in Column(3) for each time interval (i.e., 1.78 – 1.15 = 0.63).

Column (5) is Column (4) rearranged with the maximum increment from Column (4) placed at the middle of the event (time = 60 minutes, in this example), then rearranging the remaining values from Column (4) in descending order, alternately right and left (below and above) the central block.

FIGURE F-2

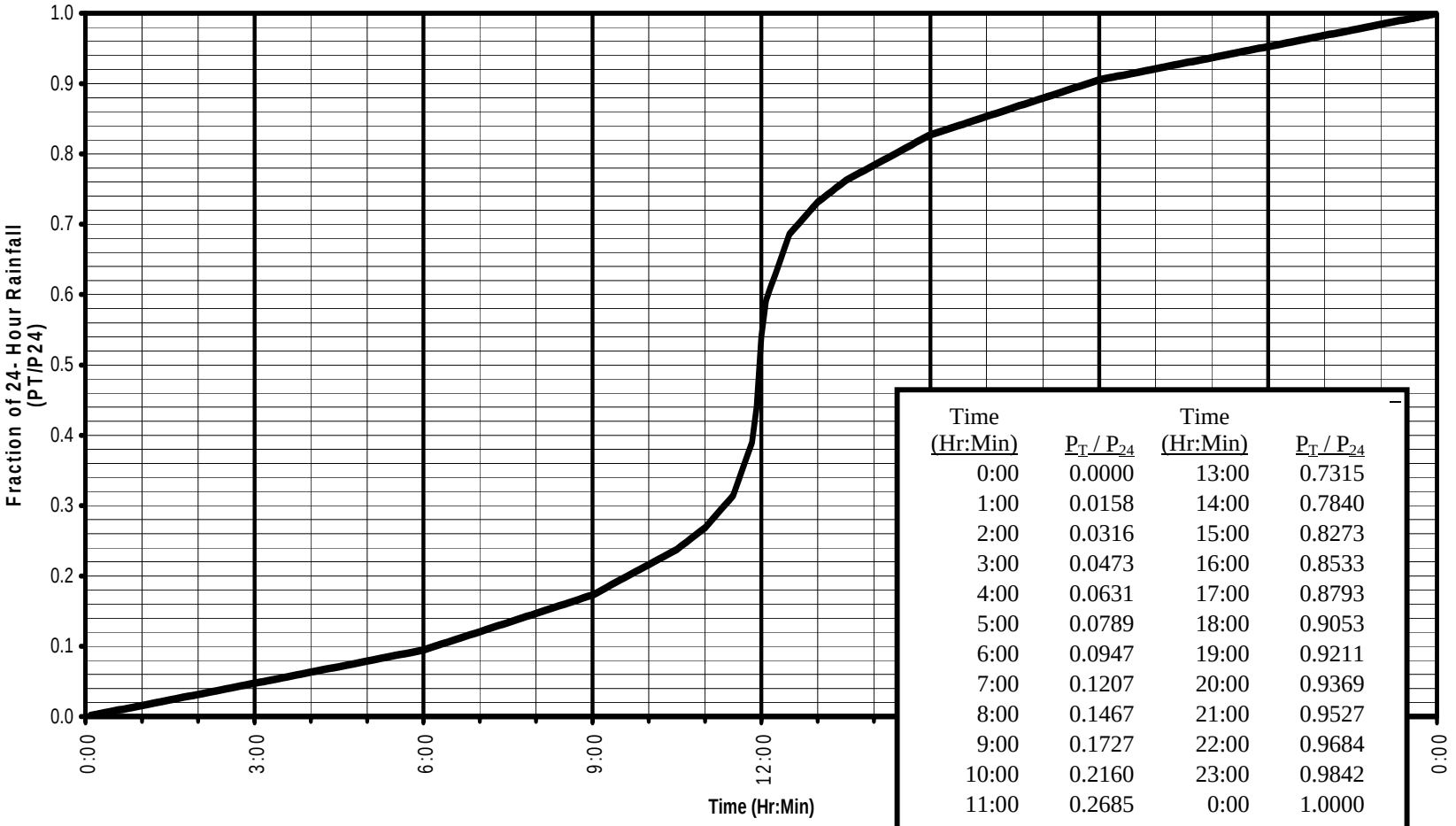
PENNDOT DELINEATED REGIONS



Source: “Field Manual of Pennsylvania Department of Transportation,” Storm Intensity-Duration-Frequency Charts, PDT- IDF, May 1986.

FIGURE F-3

NRCS (SCS) TYPE II
RAINFALL DISTRIBUTION – S CURVE

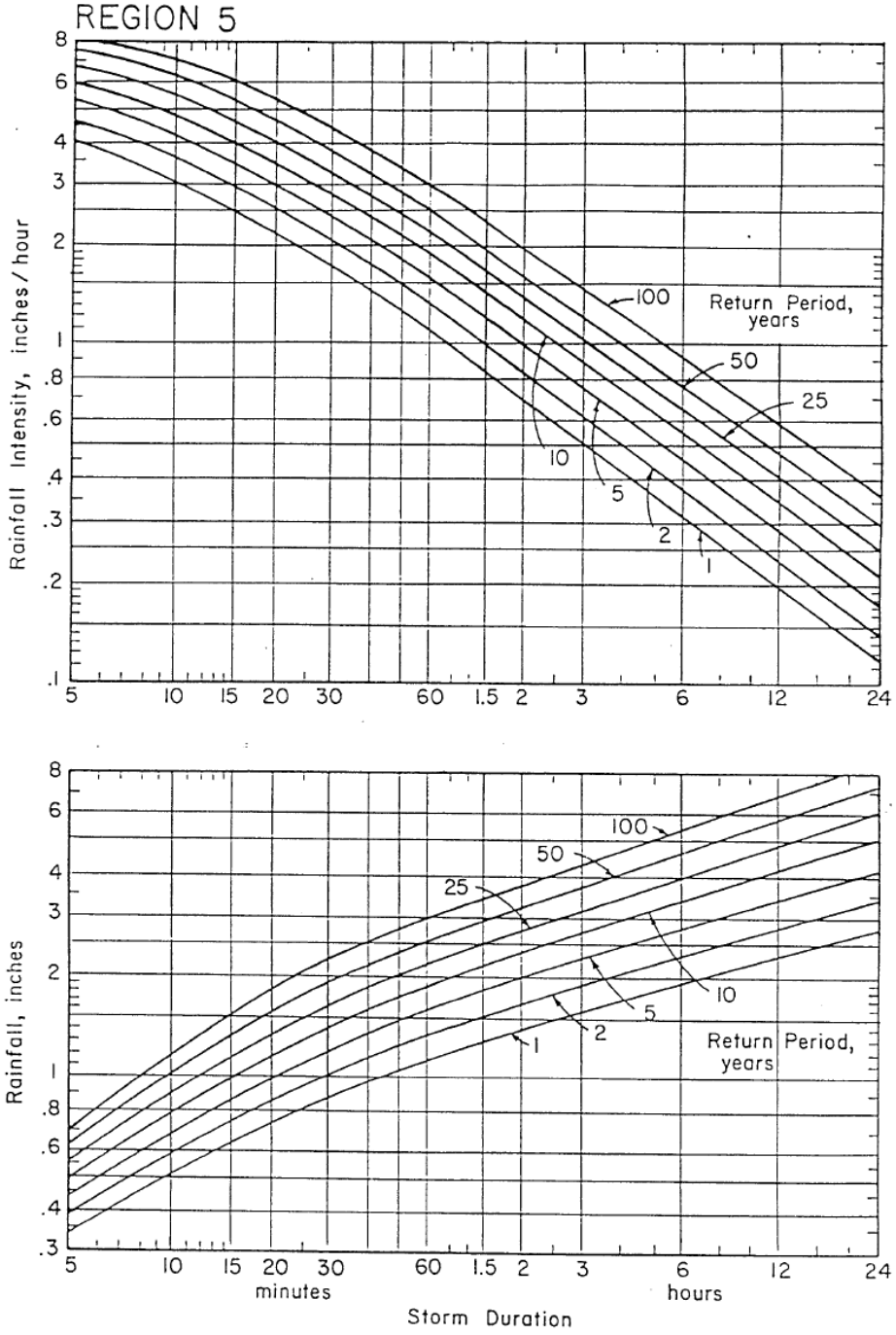


Time (Hr:Min)	P_T / P_{24}	Time (Hr:Min)	P_T / P_{24}
0:00	0.0000	13:00	0.7315
1:00	0.0158	14:00	0.7840
2:00	0.0316	15:00	0.8273
3:00	0.0473	16:00	0.8533
4:00	0.0631	17:00	0.8793
5:00	0.0789	18:00	0.9053
6:00	0.0947	19:00	0.9211
7:00	0.1207	20:00	0.9369
8:00	0.1467	21:00	0.9527
9:00	0.1727	22:00	0.9684
10:00	0.2160	23:00	0.9842
11:00	0.2685	0:00	1.0000
12:00	0.5403		

Note: Rainfall Distribution Curve developed from PennDOT Rainfall Intensity-Duration-Frequency Curves (Aron, 1986)

FIGURE F-4

PENNDOT REGION 5 STORM INTENSITY-DURATION-FREQUENCY CURVE



Source: "Field Manual of Pennsylvania Department of Transportation," Storm Intensity-Duration-Frequency Charts, PDT- IDF, May 1986.

TABLE F-2

RUNOFF CURVE NUMBERS

LAND USE DESCRIPTION	Hydrologic Condition	HYDROLOGIC SOIL GROUP A	B	C	D
Open Space					
Grass cover < 50%	Poor	68	79	86	89
Grass cover 50% to 75%	Fair	49	69	79	84
Grass cover > 75%	Good	39	61	74	80
Meadow		30	58	71	78
Agricultural					
Pasture, grassland, or range – Continuous forage for grazing	Poor	68	79	86	89
Pasture, grassland, or range – Continuous forage for grazing	Fair	49	69	79	84
Pasture, grassland, or range – Continuous forage for grazing	Good	39	61	74	80
Brush—brush-weed-grass mixture with brush the major element	Poor	48	67	77	83
Brush—brush-weed-grass mixture with brush the major element	Fair	35	56	70	77
Brush—brush-weed-grass mixture with brush the major element	Good	30	48	65	73
Fallow Bare soil	-------	77	86	91	94
Crop residue cover (CR)	Poor	76	85	90	93
	Good	74	83	88	90
Woods – grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77

Commercial	(85% impervious)	89	92	94	95
Industrial	(72% impervious)	81	88	91	93
Institutional	(50% impervious)	71	82	88	90

Residential districts by average lot size:

	% Impervious				
1/8 acre or less * (townhouses)	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
Farmstead		59	74	82	86
Smooth surfaces (concrete, asphalt, gravel, or bare compacted soil)		98	98	98	98
Water		98	98	98	98
Mining/newly graded areas (pervious areas only)		77	86	91	94

* Includes multi-family housing unless justified lower density can be provided.

Note: Existing site conditions of bare earth or fallow ground shall be considered as meadow when choosing a CN value.

Source: NRCS (SCS) TR-55

TABLE F-3

RATIONAL RUNOFF COEFFICIENTS

	HYDROLOGIC SOIL GROUP			
LAND USE DESCRIPTION	A	B	C	D
Cultivated land : without conservation treatment	.49	.67	.81	.88
: with conservation treatment	.27	.43	.61	.67
Pasture or range land: poor condition	.38	.63	.78	.84
: good condition	---*	.25	.51	.65
Meadow: good condition	---*	---*	.44	.61
Woods: thin stand, poor cover, no mulch	---*	.34	.59	.70
: good cover	---*	---*	.45	.59
Open spaces, lawns, parks, golf courses, cemeteries				
Good condition: grass cover on 75% or more of the area	---*	.25	.51	.65
Fair condition: grass cover on 50% to 75% of the area	---*	.45	.63	.74
Commercial and business areas (85% impervious)	.84	.90	.93	.96
Industrial districts (72% impervious)	.67	.81	.88	.92
Residential:				
Average lot size Average % impervious				
1/8 acre or less 65	.59	.76	.86	.90
1/4 acre 38	.25	.49	.67	.78
1/3 acre 30	---*	.49	.67	.78
1/2 acre 25	---*	.45	.65	.76
1 acre 20	---*	.41	.63	.74
Paved parking lots, roofs, driveways, etc.	.99	.99	.99	.99
Streets and roads:				
Paved with curbs and storm sewers	.99	.99	.99	.99
Gravel	.57	.76	.84	.88
Dirt	.49	.69	.80	.84

Notes: Values are based on SCS definitions and are average values.
Values indicated by ---* should be determined by the design engineer based on site characteristics.

Source : New Jersey Department of Environmental Protection, Technical Manual for Stream Encroachment, August 1984

TABLE F-4

MANNING'S ROUGHNESS COEFFICIENTS

Roughness Coefficients (Manning's "n") for Overland Flow

Surface Description	n
Dense growth	0.4 - 0.5
Pasture	0.3 - 0.4
Lawns	0.2 - 0.3
Bluegrass sod	0.2 - 0.5
Short grass prairie	0.1 - 0.2
Sparse vegetation	0.05 - 0.13
Bare clay-loam soil (eroded)	0.01 - 0.03
Concrete/asphalt - very shallow depths (less than 1/4 inch)	0.10 - 0.15
- small depths (1/4 inch to several inches)	0.05 - 0.10

Roughness Coefficients (Manning's "n") for Channel Flow

Reach Description	n
Natural stream, clean, straight, no rifts or pools	0.03
Natural stream, clean, winding, some pools or shoals	0.04
Natural stream, winding, pools, shoals, stony with some weeds	0.05
Natural stream, sluggish deep pools and weeds	0.07
Natural stream or swale, very weedy or with timber underbrush	0.10
Concrete pipe, culvert, or channel	0.012
Corrugated metal pipe	0.012-0.027(1)
High density polyethylene (HDPE) pipe	
Corrugated	0.021-0.029(2)
Smooth lined	0.012-0.020(2)

(1) Depending upon type, coating, and diameter
(2) Values recommended by the American Concrete Pipe Association, check manufacturer's recommended value

Source: U.S. Army Corps of Engineers, HEC-1 Users Manual

TABLE F-5

NONSTRUCTURAL STORMWATER MANAGEMENT MEASURES

Nonstructural Stormwater Measure	Description
Natural Area Conservation	Conservation of natural areas such as forest, wetlands, or other sensitive areas in a protected easement, thereby retaining their existing hydrologic and water quality characteristics.
Disconnection of Rooftop Runoff	Rooftop runoff is disconnected and then directed over a pervious area where it may either infiltrate into the soil or filter over it. This is typically obtained by grading the site to promote overland flow or by providing bioretention on single-family residential lots.
Disconnection of Nonrooftop Runoff	Disconnect surface impervious cover by directing it to pervious areas where it is either infiltrated or filtered through the soil.
Buffers	Buffers effectively treat stormwater runoff. Effective treatment constitutes capturing runoff from pervious and impervious areas adjacent to the buffer and treating the runoff through overland flow across a grassy or forested area.
Grass Channel (Open Section Roads)	Open grass channels are used to reduce the volume of runoff and pollutants during smaller storms.
Environmentally Sensitive Rural Development	Environmental site design techniques are applied to low-density or rural residential development.

Source: Maryland Department of the Environment, "Maryland Stormwater Design Manual," Baltimore, MD, 2000