Graphical Peak Discharge Method (TR-55) ESCH V-31

$$q_p = q_n \times A_m \times Q \times F_p$$

Where:

q_p = *Peak Discharge (cubic feet / second)*
q_u = *Unit Peak Discharge (csm / in)*
A_m = *Drainage Area (square miles)*
Q = *Runoff (inches)*
F_p = *Pond and Swamp Adjustment Factor*

1. **If the soil is nearly impervious clay with a high water table and has a high runoff potential, what is the Hydrologic Soil Group?**

From Tables 5-4, ESCH V-32:
Hydrologic Soil Group = ( )

2. **Given a residential district with ½ acre lots, what is the Runoff Curve Number for Hydrologic Soil Group C?**

From Table 5-5, ESCH V-56 to 59:
Runoff Curve Number, CN = ( )

3. **Given a site with soils consisting of deep well-drained sands with 3 acres of impervious area, 2 acres of grass in fair condition, and 4 acres of woods in fair condition, what is the weighted Curve Number?**

From Table 5-4, ESCH V-32:
Hydrologic Soil Group = ( )

From Table 5-5, ESCH V-56 to 59:

Land use:	Curve Number	x	Area	=	CN x A
Impervious	( )	x	( )	=	( )
Grass	( )	x	( )	=	( )
Woods	( )	x	( )	=	( )
			Total CN x A	=	( )

CN, Weighted Average Runoff Curve Number = Total CN x A / Total A(acres) = ( )

4. **If 3% of the watershed consists of ponds and swamps, what is the Pond and Swamp Adjustment Factor, Fp?**

Percentage of pond and swamp areas = ( ).
From Table 5-10, ESCH V-65, Fp = ( ).

TABLE 5-4

HYDROLOGIC SOIL GROUPS

Soil Group A	Represents soils having a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well-drained sands and gravels.
Soil Group B	Represents soils having a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep, moderately well-drained to well-drained soils with moderately fine to moderately coarse textures.
Soil Group C	Represents soils having a moderately high runoff potential due to slow infiltration rates. These soils consist primarily of soils in which a layer exists near the surface that impedes the downward movement of water, or soils with moderately fine to fine texture.
Soil Group D	Represents soils having a high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high water tables, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.

Example 5-5 (developed condition):

The same watershed as in the previous examples is subdivided and developed. The project is named Defiance Ridge. 40% of the 250 acres is 1/2 acre lots on the Appling soil; 10% is commercial on the Appling soil; 30% is 1/2 acre lots on the Helena soil; and 20% is open space on the Helena soil. All hydrologic conditions are good cover. The streets are paved with curb and gutter. They are laid out in such a way as to decrease overland flow to 100' in a lawn. Then water flows onto the streets and paved gutters and continues until it reaches the natural channel. (This is the same point at which channel flow began in pre-developed conditions.) Total length of street and gutter flow is 700' at an average of 3% grade.

Find: The post-development runoff curve number for the drainage area, the runoff for the 2-year and 10-year storms, the time of concentration, and the peak discharges for the 2-year and 10-year storms.

Solution: See worksheets 2, 3, and 4, labeled example 5-5 "developed condition," (next three pages) for the solutions.

Since the development of Defiance Ridge will increase the peak discharge of the 2-year storm over the pre-developed conditions, provisions must be made to address the increase in runoff. (The 1/100 rule does not apply since the project area is greater than one percent of total drainage area at the discharge end of the project. See Chapter 4 for more details.)

The site design could include measures that would reduce the volume of runoff (by using infiltration and retention), reduce the peak discharge rate (detention), or improve the receiving channel to convey the increased runoff. Note that any improvements to the channel should be based on the post-development hydrology. See Chapter 4 and the E&S Regulations, Minimum Standard #19, for more details. Detention storage can be provided at the lower end of the development to store and release the post-development 2-year storm runoff at the pre-development 2-year storm peak. See Chapter 5, Part II, Stormwater Detention, for more information.

Worksheet 2: Runoff curve number and runoff

1992

Project Defiance Ridge By ESC Date 2-4-91

Location Campbell County, Virginia Checked SWM Date 2-5-91

Circle one: Present (Developed) D.A. 250 acs.

1. Runoff curve number (CN)

Soil name and hydrologic group (ESCH VI-50 Appendix 6C)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ (ESCH V-56 Table 5-5)	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☐ acres ☐ mi² ☒ %	Product of CN x area
Appling, B	1/2 Ac. Lots, Good Condition	70			40	2800
Appling, B	Commercial	92			10	920
Helena, C	1/2 Ac. Lots, Good Condition	80			30	2400
Helena, C	Open Space, Good Condition	74			20	1480
				Totals =	100	7600

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{7600}{100} = 76$; Use CN = 76

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr	2	10	
Rainfall, P (24-hour) (Plates 5-19, 5-20) (ESCH V-49, 50) in	3.5	5.5	
Runoff, Q ..... in (Use P and CN with table 5-6, Plate 5-20 (ESCH V-60) or eqs. Plate 5-22) (ESCH V-52) (ESCH V-50)	1.36	2.95	

Worksheet 3: Time of concentration (T_c) or travel time (T_t) 1992

Project Defiance Ridge By ESC Date 2-4-91

Location Campbell County, Virginia Checked SWM Date 2-5-91

Circle one: Present (Developed)

Circle one: (T_c) T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only)		Segment ID	AB		
1. Surface description (table 5-7)			Lawn		
2. Manning's roughness coeff., n (table 5-7) ..		ESCH V-61	0.24		
3. Flow length, L (total L ≤ 300 ft)	ft		100		
4. Two-yr 24-hr rainfall, P_2	in	(Worksheet 2)	3.5		
5. Land slope, s	ft/ft	(From Problem # 5-3)	0.02		
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr		0.23	+	= 0.23

Shallow concentrated flow		Segment ID	BC		
7. Surface description (paved or unpaved)			Paved		
8. Flow length, L	ft		700		
9. Watercourse slope, s	ft/ft		0.03		
10. Average velocity, V (Plate 5-23).....	ft/s	ESCH V-53	3.5		
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		0.06	+	= 0.06

Channel flow		Segment ID	CD	DE		
12. Cross sectional flow area, a	ft^2		8	27		
13. Wetted perimeter, P_w	ft		7.6	21.6		
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft		1.05	1.25		
15. Channel slope, s	ft/ft		0.02	0.005		
16. Manning's roughness coeff., n			0.08	0.06		
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s		2.70	2.04		
18. Flow length, L	ft		1500	2500		
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		0.15	+ 0.34	=	0.49
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr					0.78

Worksheet 4: Graphical Peak Discharge method 1992

Project Defiance Ridge By ECC Date 2-4-91

Location Campbell County, Virginia Checked SWM Date 2-5-91

Circle one: Present (Developed)

1. Data:

Drainage area ..... A_m = 0.39 mi^2 (acres/640)

Runoff curve number .... CN = 76 (From worksheet 2)

Time of concentration .. T_c = 0.78 hr (From worksheet 3)

Rainfall distribution type = II (I, IA, II, III) Table 5-26A, ESCH V-94

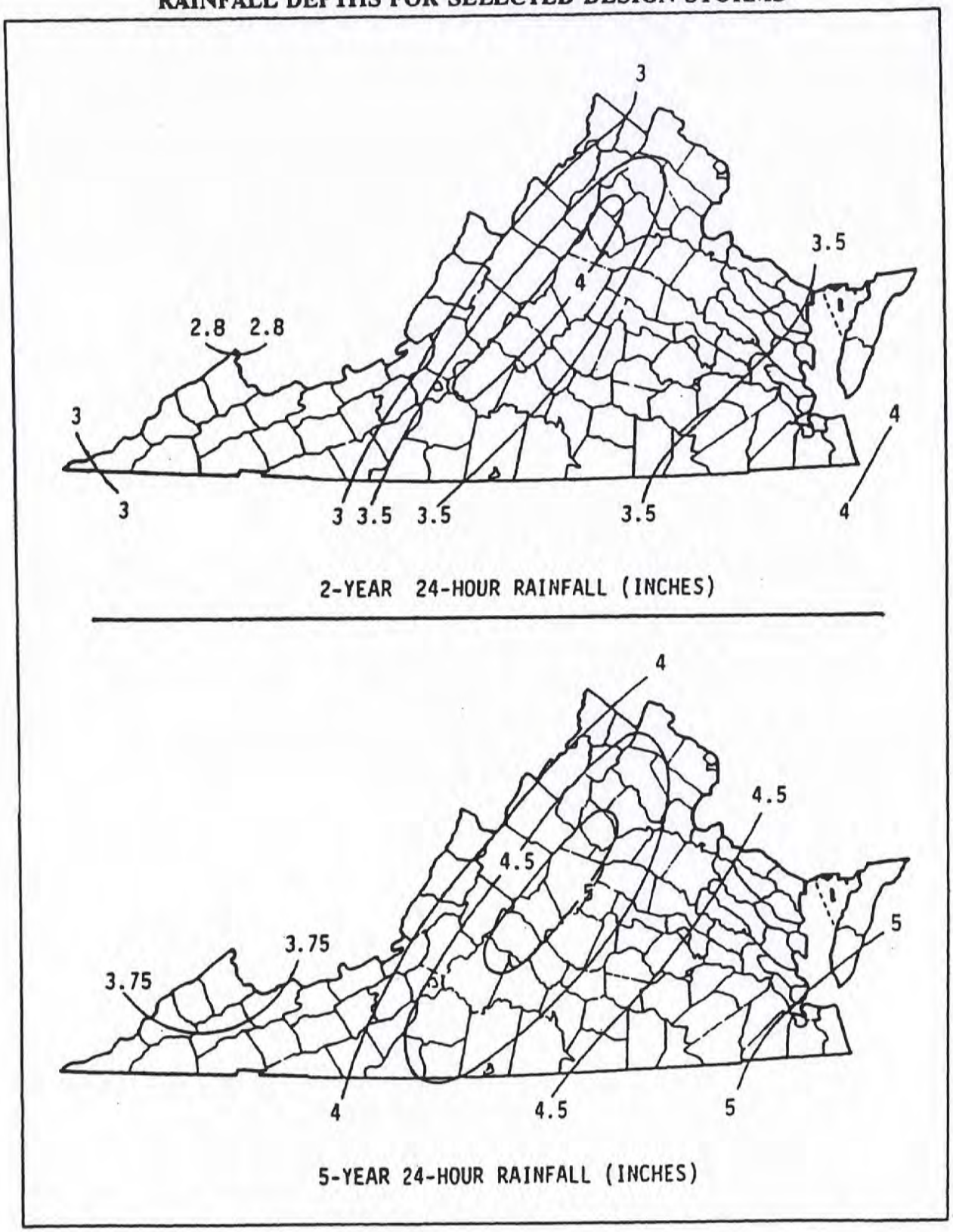
Pond and swamp areas spread throughout watershed ..... = 0 percent of A_m (0 acres or mi^2 covered) ESCH V-65

		Storm #1	Storm #2	Storm #3
2. Frequency	yr	2	10	
3. Rainfall, P (24-hour) ..(Worksheet 2.)...	in	3.5	5.5	
4. Initial abstraction, I_a ..... (Use CN with table 5-5) ESCH V-56 Table 5-9 ESCH V-64	in	0.632	0.632	
5. Compute I_a/P		0.18	0.11	
6. Unit peak discharge, q_u ..... (Use T_c and I_a/P with Plate 5-25) ESCH V-55	csm/in	380	410	
7. Runoff, Q ..... (From worksheet 2).	in	1.36	2.95	
8. Pond and swamp adjustment factor, F_p .... (Use percent pond and swamp area with table 5-10. Factor is 1.0 for zero percent pond and swamp area.) ESCH V-65		1.0	1.0	
9. Peak discharge, q_p ..... (Where $q_p = q_u A_m Q F_p$)	cfs	202	472	

5. What is the peak rate of runoff for a 10 year storm?

q_p = ( )csm/in x ( )sq.mi. x ( )in. x ( ) = ( )cfs

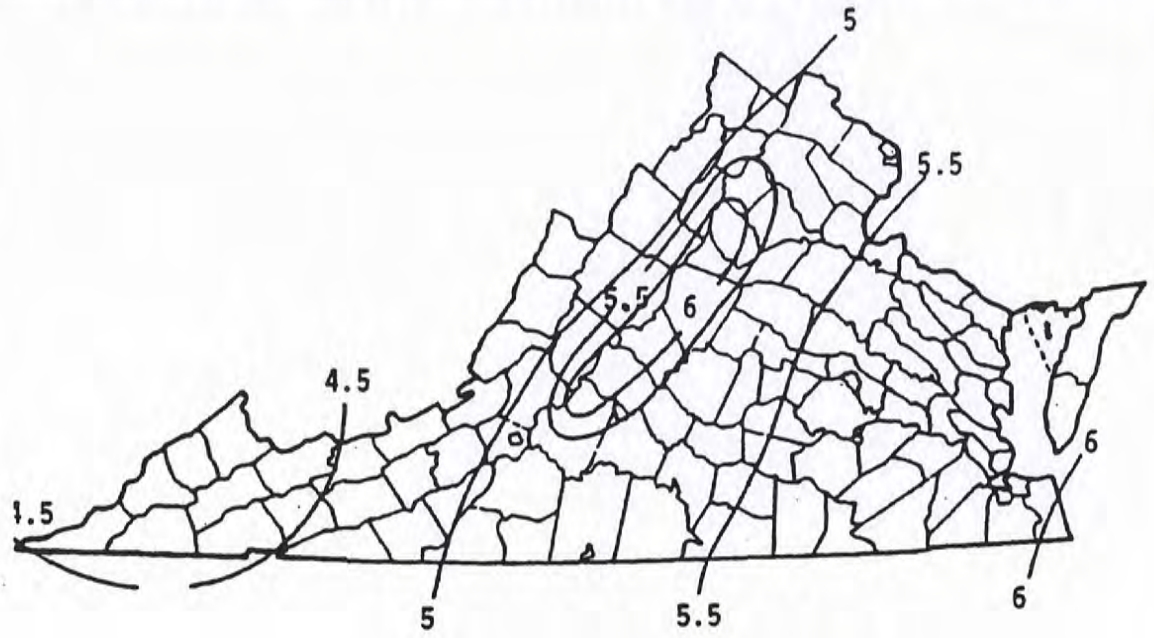
RAINFALL DEPTHS FOR SELECTED DESIGN STORMS



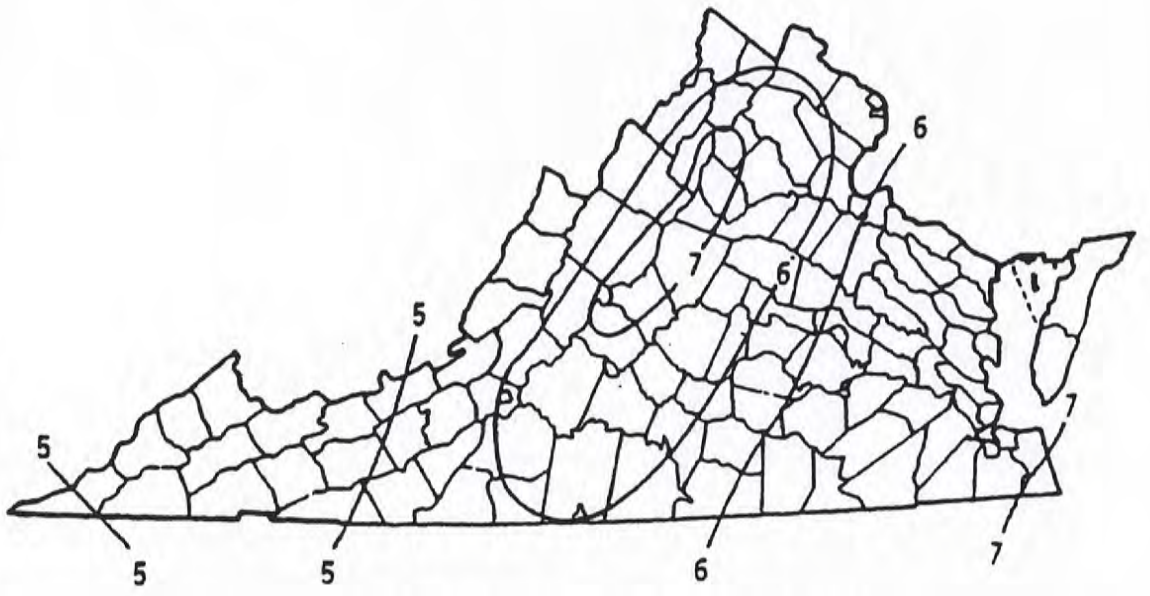
Source: USDA-SCS and U.S. Weather Bureau

Plate 5-19

RAINFALL DEPTHS FOR SELECTED DESIGN STORMS (continued)



10-YEAR 24-HOUR RAINFALL (INCHES)

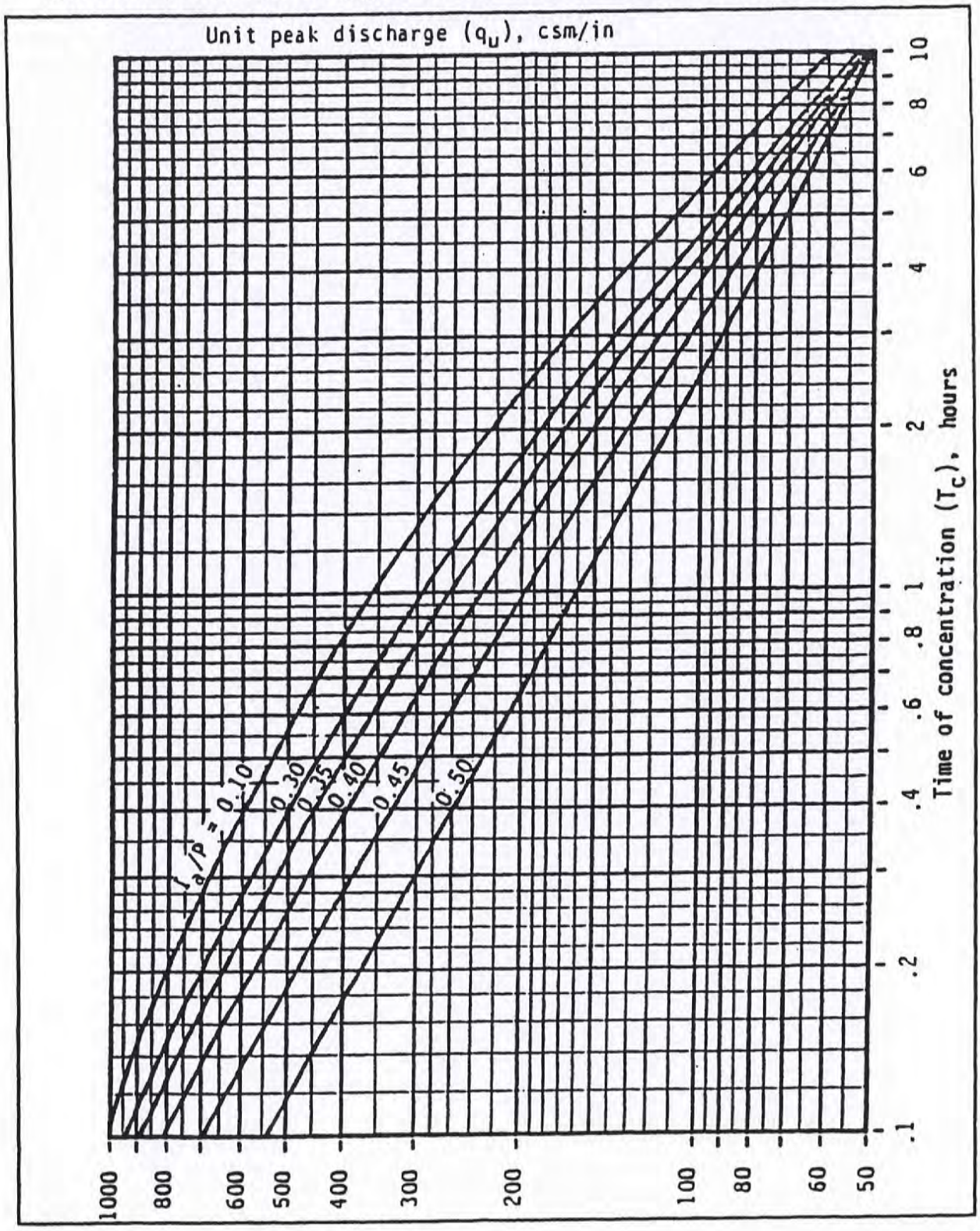


25-YEAR 24-HOUR RAINFALL (INCHES)

Source: USDA-SCS and U.S. Weather Bureau

Plate 5-20

UNIT PEAK DISCHARGE (q_u) FOR SCS TYPE II RAINFALL DISTRIBUTION



Source: USDA-SCS

Plate 5-25

TABLE 5-5*

RUNOFF CURVE NUMBERS FOR GRAPHICAL PEAK DISCHARGE METHOD

COVER DESCRIPTION			HYDROLOGIC SOIL GROUP			
			A	B	C	D
Fully Developed Urban Areas (Vegetation Established)						
Open Space (lawns, parks, etc.)	Poor Condition; Grass		68	79	86	89
	Fair Condition; Grass 50 - 75% cover		49	69	79	84
	Good Condition; Grass > 75% cover		39	61	74	80
Impervious Areas	Paved parking lots, roofs, driveways		98	98	98	98
Streets and Roads	Paved; curbs and storm sewers		98	98	98	98
	Paved; open ditches (w/right-of-way)		83	89	92	93
	Gravel (with right-of-way)		76	85	89	91
	Dirt (with right-of-way)		72	82	87	89
Urban Districts		Average % Impervious				
	Commercial and Business	85	89	92	94	95
	Industrial	72	81	88	91	93

* Refer to the TR-55 document for a complete table of runoff curve numbers and additional information on selecting the runoff curve number.

Source: USDA-SCS

TABLE 5-5* (continued)
RUNOFF CURVE NUMBERS FOR
GRAPHICAL PEAK DISCHARGE METHOD

COVER DESCRIPTION			HYDROLOGIC SOIL GROUP			
			A	B	C	D
Residential Districts (by average lot size)		Average % Impervious				
	1/8 acre (town house)	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
Urban Areas - Development Underway, No Vegetation Established						
Newly graded area			81	89	93	95
Pavement and Roofs, Commercial & Business Areas			98	98	98	98
Row Houses, Town Houses and Residential w/lot sizes:	1/8 acre or less		93	96	97	98
	1/4 acre		88	93	95	97
	1/2 acre		85	91	94	96
	1 acre		82	90	93	95
	2 acres		81	89	92	94
Cultivated Agricultural Lands						
Fallow:	Bare Soil		77	86	91	94
	Crop Residue (CR) poor		76	85	90	93
	Crop Residue (CR) good		74	83	88	90

* Refer to the TR-55 document for a complete table of runoff curve numbers and additional information on selecting the runoff curve number.

TABLE 5-5* (continued)

RUNOFF CURVE NUMBERS FOR
GRAPHICAL PEAK DISCHARGE METHOD

COVER DESCRIPTION		HYDROLOGIC SOIL GROUP			
		A	B	C	D
Cultivated Agricultural Lands (continued)					
Row Crops:	Straight row (SR) poor	72	81	88	91
	Straight row (SR) good	67	78	85	89
	Contoured (C) poor	70	79	84	88
	Contoured (C) good	65	75	82	86
	Contoured and Terraced (C&T) poor	66	74	80	82
	Contoured and Terraced (C&T) good	62	71	78	81
Other Agricultural Lands					
Pasture, grassland or range	poor	68	79	86	89
	fair	49	69	79	84
	good	39	61	74	80
Meadow		30	58	71	78
Brush - brush, weed, grass mix	poor	48	67	77	83
	fair	35	56	70	77
	good	30	48	65	73
Woods - grass combination	poor	57	73	82	86
	fair	43	65	76	82
	good	32	58	72	79

* Refer to the TR-55 document for a complete table of runoff curve numbers and additional information selecting the runoff curve number.

TABLE 5-5* (continued)

RUNOFF CURVE NUMBERS FOR
GRAPHICAL PEAK DISCHARGE METHOD

COVER DESCRIPTION		HYDROLOGIC SOIL GROUP			
		A	B	C	D
Other Agricultural Lands (continued)					
Woods	poor	45	66	77	83
	fair	36	60	73	79
	good	30	55	70	77
Porous Pavement**					
	Gravel Subbase Thickness (inches)				
Porous Pavement (Properly Maintained)	10	57	66	69	75
	18	53	61	64	69
	24	52	58	61	66
	36	47	52	55	58
Porous Pavement (Not Properly Maintained)	10 - 36	98	98	98	98

* Refer to the TR-55 document for a complete table of runoff curve numbers and additional information on selecting runoff curve number.

** This information is not intended for design purposes.

TABLE 5-6
RUNOFF DEPTH FOR SELECTED CN's AND RAINFALL AMOUNTS[1]

Rainfall	Runoff depth for curve number of ____												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

[1] Interpolate the values shown to obtain runoff depths for CN's or rainfall amounts not shown.

Source: USDA-SCS

TABLE 5-9

I_a VALUES FOR RUNOFF CURVE NUMBERS

Curve Number	I_a (inches)	Curve Number	I_a (inches)	Curve Number	I_a (inches)
40	3.000	60	1.333	80	0.500
41	2.878	61	1.279	81	0.469
42	2.762	62	1.226	82	0.439
43	2.651	63	1.175	83	0.410
44	2.545	64	1.125	84	0.381
45	2.444	65	1.077	85	0.353
46	2.348	66	1.030	86	0.326
47	2.255	67	0.985	87	0.299
48	2.167	68	0.941	88	0.273
49	2.082	69	0.899	89	0.247
50	2.000	70	0.857	90	0.222
51	1.922	71	0.817	91	0.198
52	1.846	72	0.778	92	0.174
53	1.774	73	0.740	93	0.151
54	1.704	74	0.703	94	0.128
55	1.636	75	0.667	95	0.105
56	1.571	76	0.632	96	0.083
57	1.509	77	0.597	97	0.062
58	1.448	78	0.564	98	0.041
59	1.390	79	0.532		

Source: USDA-SCS

TABLE 5-10

ADJUSTMENT FACTOR (F_p) FOR POND AND SWAMP AREAS SPREAD THROUGHOUT THE WATERSHED

Percentage of pond and swamp areas	F_p
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Source: USDA-SCS

APPENDIX 6C

LISTING OF SOIL TYPES IN VIRGINIA

The majority of soils currently found in Virginia along with their corresponding Hydrologic Soil Group designation are listed on the following pages.

The following key explains some of the abbreviations found the on attached soils list. For abbreviations not listed here, consult your local soil survey.

CL	-	clay loam	LS	-	loamy sand
FS	-	fine sand	SICL	-	silt clay loam
FSL	-	fine sandy loam	SIL	-	silt loam
L	-	loam	SL	-	sandy loam
LFS	-	loamy fine sand	VFSL	-	very fine sandy loam

WTDEPL and WTDEPH refer to range of depths to the surface of the groundwater.

Soil name	surftex	hydgrp	kfact	wtdepl	wtdeph
ABELL	FSL	B	0.28	2.00	3.50
ABELL	L	B	0.32	2.00	3.50
ABELL	SIL	B	0.32	2.00	3.50
ABELL	SL	B	0.28	2.00	3.50
ABELL VARIANT	L	B	0.32	2.00	3.50
ACKWATER	SICL	D	0.37	1.50	3.00
ACKWATER	SIL	D	0.43	1.50	3.00
ACREDALE	SIL	D	0.37	0.00	1.00
ADEN	SIL	C	0.43	0.00	1.00
AIRMONT	FLV-L	C	0.10	1.50	3.00
ALAGA	FS	A	0.10	6.00	6.00
ALAGA	LS	A	0.10	4.00	6.00
ALAGA	LS	A	0.10	6.00	6.00
ALAGA	S	A	0.10	6.00	6.00
ALBANO	SIL	D	0.37	0.00	1.50
ALBEMARLE	FSL	B	0.20	6.00	6.00
ALBEMARLE	L	B	0.32	6.00	6.00
ALBEMARLE	STV-FSL	B	0.20	6.00	6.00
ALDERFLATS	SIL	D	0.43	0.00	1.00
ALDIE	SIL	D	0.37	1.50	2.50
ALDINO	SIL	C	0.43	1.50	2.50
ALLEGHENY	CB-FSL	B	0.20	6.00	6.00
ALLEGHENY	CB-L	B	0.20	6.00	6.00
ALLEGHENY	FSL	B	0.28	6.00	6.00
ALLEGHENY	L	B	0.32	6.00	6.00
ALLEGHENY	SIL	B	0.32	6.00	6.00
ALONZVILLE	CB-L	B	0.20	6.00	6.00
ALONZVILLE	CB-L	B	0.32	6.00	6.00
ALONZVILLE	FSL	B	0.20	6.00	6.00
ALONZVILLE	L	B	0.32	6.00	6.00
ALTAVISTA	FSL	C	0.24	1.50	2.50
ALTAVISTA	FSL	C	0.37	1.00	2.50
ALTAVISTA	L	C	0.24	1.50	2.50
ALTAVISTA	LS	C	0.17	1.50	2.50
ALTAVISTA	SIL	C	0.32	1.50	2.50
ALTAVISTA	SIL	C	0.37	1.00	2.50
ALTAVISTA	SL	C	0.24	1.50	2.50
ALTAVISTA VARIANT	L	C	0.24	1.50	2.50
ALTICREST	FSL	B	0.24	6.00	6.00
ALTICREST	RB-FSL	B	0.24	6.00	6.00
ALTICREST	SL	B	0.24	6.00	6.00
ANGIE	L	D	0.32	3.00	5.00
ANGIE VARIANT	L	D	0.32	3.00	5.00
APPLING	CL	B	0.24	6.00	6.00
APPLING	CL	B	0.28	6.00	6.00
APPLING	FSL	B	0.24	6.00	6.00
APPLING	GR-COSL	B	0.15	6.00	6.00
APPLING	GR-FSL	B	0.24	6.00	6.00
APPLING	GR-SL	B	0.15	6.00	6.00
APPLING	L	B	0.32	6.00	6.00
APPLING	SCL	B	0.28	6.00	6.00
APPLING	SL	B	0.24	6.00	6.00
APPLING	SL	B	0.28	6.00	6.00
APPLING	VFSL	B	0.24	6.00	6.00