3.1.5 SCS Hydrologic Method

The SCS* hydrologic method requires basic data similar to the Rational Method: drainage area, a runoff factor, time of concentration, and rainfall. However, the SCS approach is more sophisticated in that it also considers the time distribution of the rainfall, the initial rainfall losses due to interception and depression storage, and an infiltration rate that decreases during the course of a storm. A typical application of the SCS method includes the following basic steps:

1. determination of curve numbers that represent different land uses within the drainage area;
2. calculation of time of concentration to the study point;
3. use of the SCS Type II rainfall distribution in this area; and
4. use of the unit hydrograph approach to develop the hydrograph of direct runoff from the drainage basin.

The SCS method can be used for both the estimation of stormwater runoff peak rates and the generation of hydrographs for the routing of stormwater flows. The SCS method can be used for most design applications, including storage facilities and outlet structures, storm drain systems, culverts, small drainage ditches and open channels, and energy dissipators.

3.1.5.1 Equations and Concepts

The hydrograph of outflow from a drainage basin is the sum of the elemental hydrographs from all the sub-areas of the basin, modified by the effects of transit time through the basin and storage in the stream channels. Since the physical basin characteristics including shape, size and slope are constant, the unit hydrograph approach assumes that there is considerable similarity in the shape of hydrographs from storms of similar rainfall characteristics. Thus, the unit hydrograph is a typical hydrograph for the basin with a runoff volume under the hydrograph equal to one (1.0) inch from a storm of specified duration. For a storm of the same duration but with a different amount of runoff, the hydrograph of direct runoff can be expected to have the same time base as the unit hydrograph and ordinates of flow proportional to the unit hydrograph's runoff volume. Therefore, a storm that produces two inches of runoff would have a hydrograph with a flow equal to twice the flow of the unit hydrograph. With 0.5 inches of runoff, the total flow of the hydrograph would be one-half of the flow of the unit hydrograph.

The following discussion outlines the equations and basin concepts used in the SCS method.

Drainage Area - The drainage area of a watershed is determined from topographic maps and field surveys. For large drainage areas it might be necessary to divide the area into sub-drainage areas to account for major land use changes, obtain analysis results at different points within the drainage area, combine hydrographs from different sub-basins as applicable, and/or route flows to points of interest.

Rainfall - The SCS method applicable to Knox County is based on a storm event that has a Type II time distribution. This distribution is used to distribute the 24-hour volume of rainfall for the different storm frequencies.

Rainfall-Runoff Equation - A relationship between accumulated rainfall and accumulated runoff was derived by SCS from experimental plots for numerous soils and vegetative cover conditions. The SCS runoff equation (Equation 3-12) is used to estimate direct runoff from 24-hour or 1-day storm rainfall.

Equation 3-12

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where:

Q = accumulated direct runoff (in)
P = accumulated rainfall or potential maximum runoff (in)

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* The Soil Conservation Service is now known as the Natural Resources Conversation Service (NRCS)

I_a = initial abstraction including surface storage, interception, evaporation, and infiltration prior to runoff (in)
S = potential maximum soil retention (in) = 1000/CN-10

An empirical relationship used in the SCS method for estimating I_a is presented in Equation 3-13. This is an average value that could be adjusted for flatter areas with more depressions if there are calibration data to substantiate the adjustment.

Equation 3-13

$$I_a = 0.2S$$

Substituting 0.2S for I_a in Equation 3-12, the SCS rainfall-runoff equation becomes Equation 3-14.

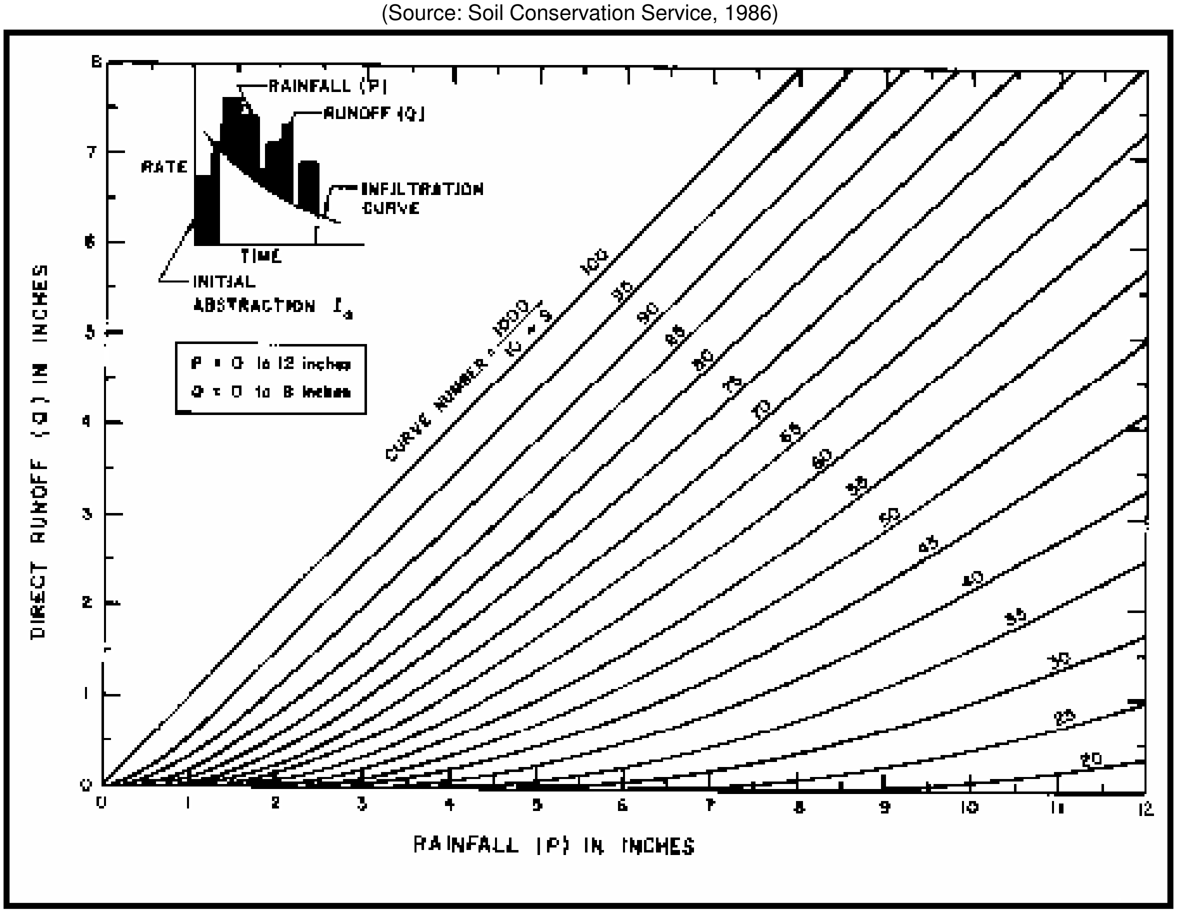
Equation 3-14

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where:
S = 1000/CN - 10
CN = SCS curve number

Figure 3-3 presents a graphical solution of this equation. For example, 4.1 inches of direct runoff would result if 5.8 inches of rainfall occurs on a watershed with a curve number of 85.

Figure 3-3. SCS Solution of the Runoff Equation
(Source: Soil Conservation Service, 1986)



Equation 3-14 can be rearranged so that the curve number can be estimated if the rainfall and runoff volume are known, as shown in Equation 3-15 (Pitt, 1994).

Equation 3-15

$$CN = \frac{1000}{10 + 5P + 10Q - 10\left(Q^2 + 1.25QP\right)^{1/2}}$$

where:

CN = SCS curve number
P = accumulated rainfall or potential maximum runoff (in)
Q = accumulated direct runoff (in). Can be Q_{wv}, Q_2, Q_{10}, etc…

3.1.5.2 Runoff Factor/Curve Numbers

The principal physical watershed characteristics affecting the relationship between rainfall and runoff are land use, land treatment, soil types, and land slope. The SCS method uses a combination of soil conditions and land uses (ground cover) to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CN), indicate the runoff potential of an area. The higher the CN, the higher the runoff potential. Soil properties influence the relationship between runoff and rainfall since soils have differing rates of infiltration. Based on infiltration rates, the SCS has divided soils into four hydrologic soil groups (HSG).

Group A Soils having a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well-drained sands and gravels.

Group B Soils having a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

Group C 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.

Group D Soils having a high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high swelling potential, soils with permanently high water tables, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.

A list of soils throughout Knox County and their hydrologic classification can be found in the reference SCS, 1986. Soil survey maps can be obtained from the local Natural Resources Conservation Service or the Knox County Soil Conservation office for use in estimating soil type.

Consideration should be given to the effects of urbanization on the natural hydrologic soil group. If heavy equipment can be expected to compact the soil during construction or if grading will mix the surface and subsurface soils, appropriate changes should be made in the soil group selected. Also, runoff curve numbers vary with the antecedent soil moisture conditions. Average antecedent soil moisture conditions (AMC II) are recommended for most hydrologic analyses, except in the design of developments in sinkhole drainage areas where AMC III may be allowed. Areas with high water table conditions may want to consider using AMC III antecedent soil moisture conditions. This should be considered a calibration parameter for modeling against real calibration data. Table 3-13 gives recommended curve number values for a range of different land uses assuming AMC II.

Table 3-13. SCS Method Runoff Curve Numbers[1]

Cover Description	Cover Type and Hydrologic Condition	Average Percent Impervious Area[2]	Curve numbers for Hydrologic Soil Groups			
			A	B	C	D
Cultivated land:	without conservation treatment		72	81	88	91
	with conservation treatment		62	71	78	81
Pasture or range land:	poor condition		68	79	86	89
	good condition		39	61	74	80
Meadow	Generally mowed for hay		30	58	71	78
Wood or forest land:	thin stand, poor cover		45	66	77	83
	good cover		25	55	70	77
Open space (lawns, parks, golf course, cemeteries, etc.)[3]	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:	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 areas only, no vegetation)			77	86	91	94

1- Average runoff condition, and Ia = 0.2S

2- The average % impervious area shown was used to develop the composite CNs. Other assumptions are: 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.

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

When a drainage area has more than one land use, a composite curve number can be calculated and used in the analysis. It should be noted that when composite curve numbers are used, the analysis does not take into account the location of the specific land uses, but sees the drainage area as a uniform land use represented by the composite curve number. Composite curve numbers for a drainage area can be calculated by using the weighted method as presented in Example 3-2.

Example 3-2. Composite Curve Number Calculation

Calculate the composite SCS curve number for a variable watershed. A watershed contains two primary land uses: 80% high density residential with HSG B soils and 20% meadow with HSG C soils. The watershed can be assumed to be divided into two sub-areas as shown in the table:

Step 1. Determine the curve number values for the given land uses and HSGs using Table 3-13.

Step 2. Calculate the weighted curve number for each sub-area of the watershed, and combine to obtain the composite curve number.

Land Use	% of Total Land Area	CN	Weighted CN (% area x CN)
Residential 1/8 acre Soil group B	0.8	85	68
Meadow Good condition Soil group C	0.2	71	14

The composite curve number =68 + 14 = 82.

The different land uses within the basin should reflect a uniform hydrologic group represented by a single curve number. Any number of land uses can be included. However, if the land use spatial distribution is important to the hydrologic analysis, then sub-basins should be developed and separate hydrographs developed and routed to the study point.

3.1.5.3 Urban Modifications of the SCS Method

Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system, should be considered in computing CN for developed areas. For example, consider whether the impervious areas connect directly to the drainage system or outlet onto lawns or other pervious areas where infiltration can occur. The curve number values given in Table 3-13 are based on directly connected impervious area. An impervious area is considered directly connected if runoff from it flows directly into the drainage system. It is also considered directly connected if runoff from it occurs as concentrated shallow flow that runs over pervious areas and then into a drainage system. It is possible to reduce curve number values from urban areas by not directly connecting impervious surfaces to the drainage system, but instead allowing runoff to flow as sheet flow over significant pervious areas. Chapter 5 (in Volume 2 of this manual) explains the benefits of using better site design techniques such as disconnected areas impervious area.

The following discussion will give some guidance for adjusting curve numbers for different types of impervious areas.

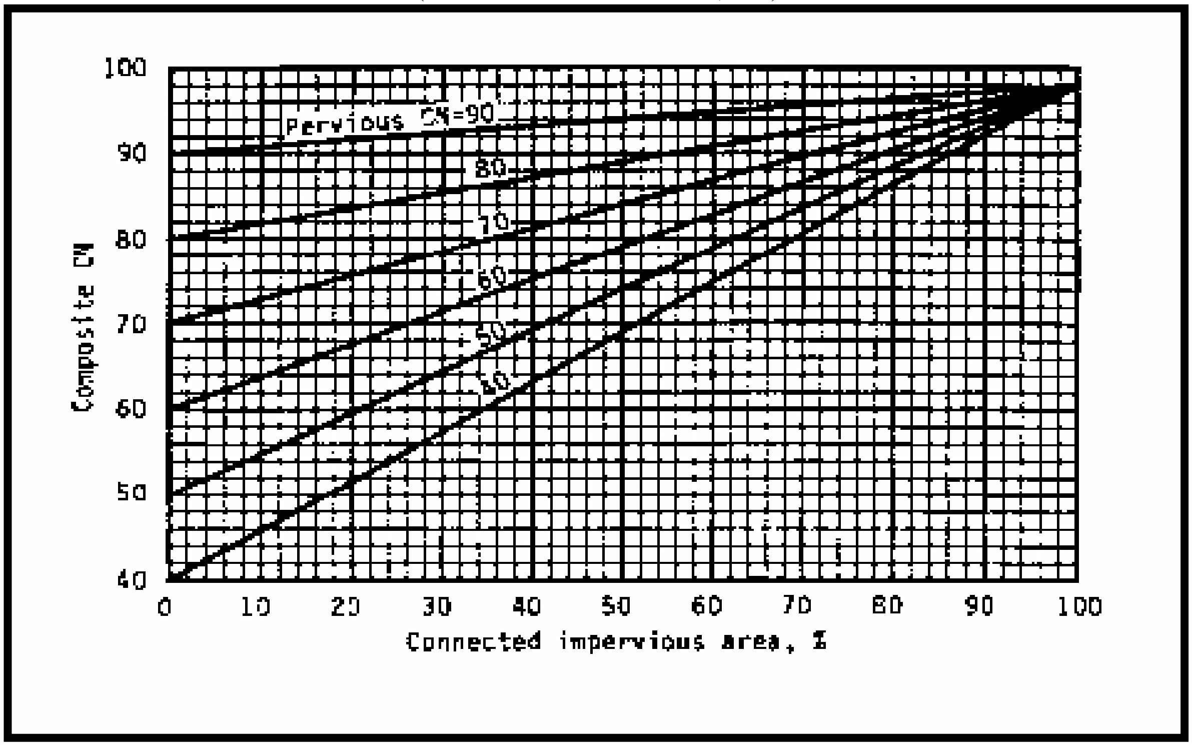
Connected Impervious Areas

The curve numbers provided in Table 3-13 for various land cover types were developed for typical land use relationships based on specific assumed percentages of impervious area. These CN values were developed on the assumptions that:

1. pervious urban areas are equivalent to pasture in good hydrologic condition, and
2. impervious areas have a CN of 98 and are directly connected to the drainage system.

If all of the impervious area is directly connected to the drainage system, but the impervious area percentages or the pervious land use assumptions in Table 3-13 are not applicable, use Figure 3-4 to compute a composite CN.

Figure 3-4. Composite CN with Connected Impervious Areas
(for use with areas having a total % imperviousness equal to or greater than 30%)
(Source: Soil Conservation Service, 1986)



Disconnected Impervious Areas

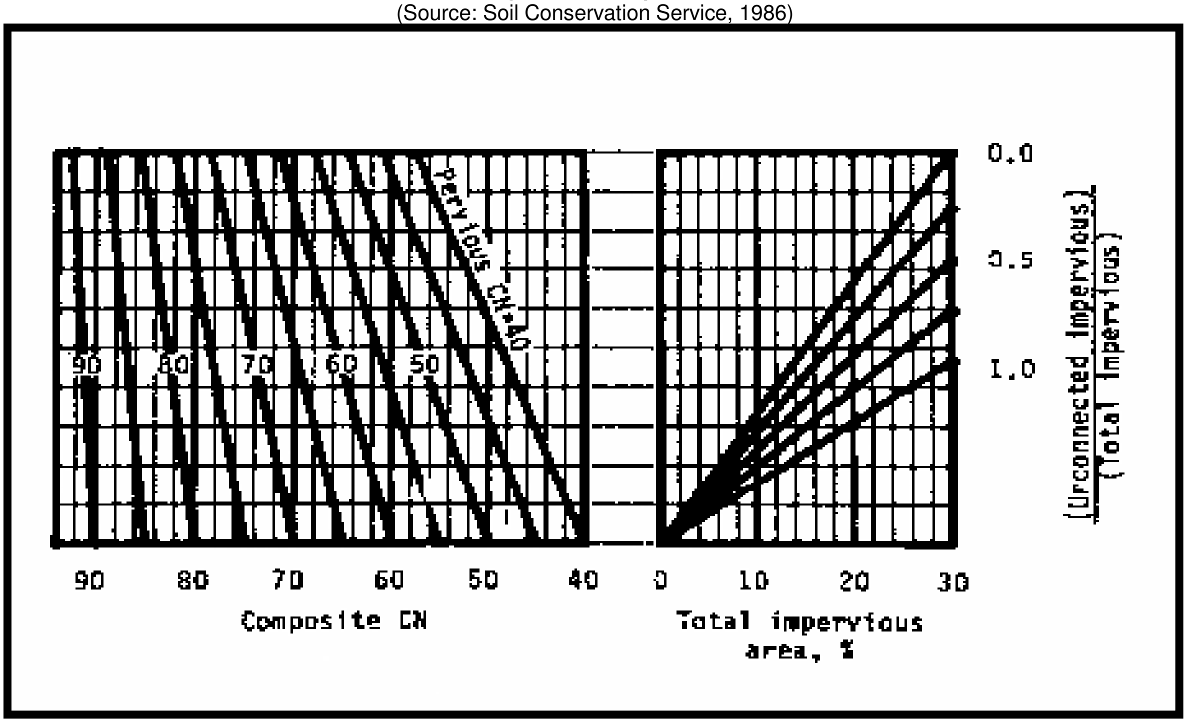
Runoff from these areas is spread over a pervious area as sheet flow. To determine the CN when all or part of the impervious area is not directly connected (i.e., “disconnected”) to the drainage system, either (1) use Figure 3-5 if total impervious area is less than 30% or (2) use Figure 3-4 if the total impervious area is equal to or greater than 30%, because the absorptive capacity of the remaining pervious areas will not significantly affect runoff. When impervious area is less than 30%, obtain the composite CN by entering the right half of Figure 3-5 with the percentage of total impervious area and the ratio of total unconnected impervious area to total impervious area.

Examples 3-3 and 3-4 present the calculation of composite curve numbers for directly connected and disconnected impervious areas, respectively.

Figure 3-5. Composite CN with Disconnected Impervious Areas

(for use with areas having a total % imperviousness less than 30%)

(Source: Soil Conservation Service, 1986)



<u>Example 3-3. Curve Number Calculation for a Directly Connected Impervious Area Example</u>

Assume a residential ½ acre lot with HSG B soils and an actual impervious area of 20%. Calculate the curve number for the directly connected area.

<u>Step 1.</u> Read the curve number of 70 for the given land use and HSG from Table 3-13. Note that this curve number is based on assumed impervious area of 25%.

<u>Step 2.</u> Adjust the curve number from the table to reflect less impervious area by using the connected impervious area of 20% and the pervious CN of 61 by using Figure 3-5. Enter Figure 3-5 along the bottom @ 20%, go vertically until the 61 CN line is met, then go to the left vertical axis to read the composite CN. The composite CN obtained from Figure 3-5 is 68. The CN difference between 70 and 68 reflects the difference in percent impervious area.

<u>Example 3-4. Curve Number Calculation for an Unconnected Impervious Area Example</u>

Assume a residential ½ acre lot with a pervious CN of 61 and 20% total impervious area (75% of which is unconnected). Calculate the composite curve number for the lot.

<u>Step 1.</u> Enter the right half of Figure 3-5 with the percentage of total impervious area and the ratio of total unconnected impervious area to total impervious area. The ratio of unconnected impervious area to total impervious area is 0.75.

<u>Step 2.</u> Then, move left to the appropriate pervious CN and read down to find the composite CN. The composite CN is 66.

<u>Step 3.</u> If all of the impervious area is connected, the resulting CN (from Figure 3-4) would be 68.

3.1.5.4 Simplified SCS Peak Runoff Rate Calculation

These calculation presented in this section is applicable to drainage areas less than 2,000 acres that have homogeneous land uses that can be described by a single CN value (SCS, 1986). The SCS peak discharge equation is presented as Equation 3-16.

Equation 3-16

$$Q_p = q_u A Q F_p$$

where:

Q_p = peak discharge (cfs)
q_u = unit peak discharge (cfs/mi^2/in)
A = drainage area (mi^2)
Q = runoff (in)
F_p = pond and swamp adjustment factor

The computation sequence for the peak discharge method is presented in steps 1 through 6 below.

1. The 24-hour rainfall depth is determined from rainfall Table 3-5 for the selected location and return frequency.
2. The runoff curve number, CN, is estimated from Table 3-13 and direct runoff, Q, is calculated using Equation 3-15.
3. The CN value is used to determine the initial abstraction, I_a, from Table 3-14, and the ratio I_a/P is then computed (P = accumulated 24-hour rainfall).

Table 3-14. Initial Abstraction (I_a) for Runoff Curve Numbers

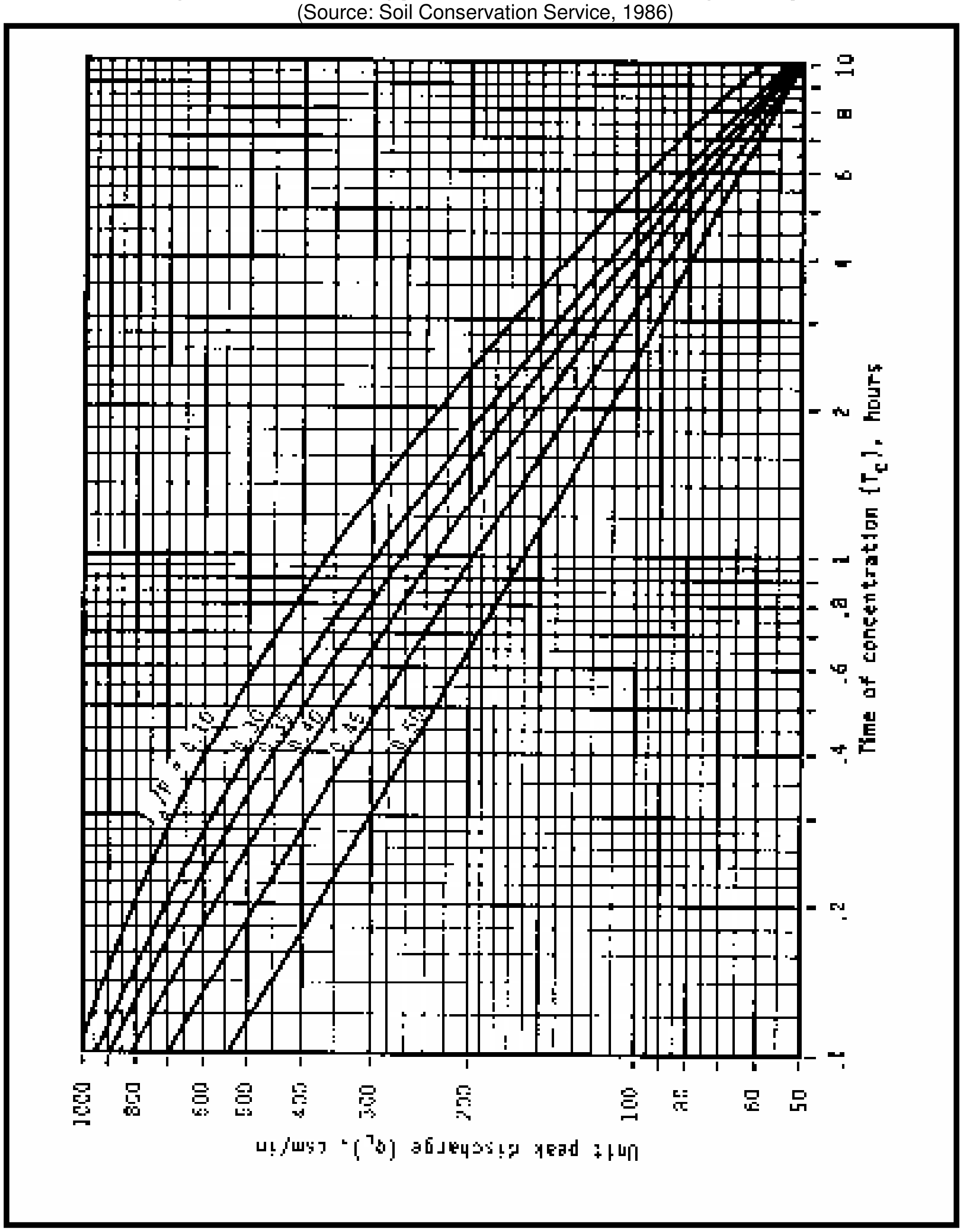
Curve Number	I_a (in)	Curve Number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704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

Curve Number	I_a (in)	Curve Number	I_a (in)
69	0.899	-	

4. The watershed time of concentration is computed using the procedures in Section 3.1.3.5 and is used with the ratio I_a/P to obtain the unit peak discharge, q_u, from Figure 3-6 for the Type II rainfall distribution. If the ratio I_a/P lies outside the range shown in the figure, either use the limiting values or use another peak discharge method. Note: Figure 3-6 is based on a peaking factor of 484. If a peaking factor of 300 is needed, this figure is not applicable and the simplified SCS method should not be used. See Section 3.1.5.5 for additional information about peaking factor.

Figure 3-6. SCS Type II Unit Peak Discharge Graph

(Source: Soil Conservation Service, 1986)



5. If pond and swamp areas are spread throughout the watershed and are not considered in the t_c computation, an adjustment is needed. The pond and swamp adjustment factor, F_p, is estimated from Table 3-15 below:

Table 3-15. Adjustment Factors for Ponds and Swamps

Pond and Swamp Areas (%[1])	F_p
0	1.00
0.2	0.97
1	0.87
3	0.75
5 or greater	0.72

[1] Percent of entire drainage basin

6. The peak runoff rate is computed using Equation 3-16.

Example 3-5. Calculate the 100-year peak discharge using the SCS Peak Discharge Equation.

Compute the 100-year peak discharge for a 50-acre wooded watershed located in Knox County, which will be developed as follows:

1. Forest land - good cover (hydrologic soil group B) = 10 ac
2. Forest land - good cover (hydrologic soil group C) = 10 ac
3. Residential - 1/3 acre lots (hydrologic soil group B) = 20 ac
4. Industrial development (hydrological soil group C) = 10 ac

Other data include the following: Total impervious area = 18 acres, % of pond/swamp area = 0

Step 1. Calculate the rainfall excess:

The 100-year, 24-hour rainfall is 6.50 inches (0.27 in/hr * 24 hrs – From Table 3-4).
The calculation of the composite runoff coefficient for the watershed is shown in the following table.

Dev. #	Area	% Total	CN[1]	Composite CN[2]
1	10 ac.	20	55	11.0
2	10 ac.	20	70	14.0
3	20 ac.	40	72	28.8
4	10 ac.	20	91	18.2
Total	50 ac.	100	-	72

[1] CN from Table 3-13
[2] Composite CN = % Total * CN

From Equation 3-14, Q (100-year) = 3.5 inches

Step 2. Calculate time of concentration. The hydrologic flow path for this watershed = 1,890 ft

Segment	Type of Flow	Length (ft)	Slope (%)
1	Overland n = 0.24	40	2.0
2	Shallow channel	750	1.7
3	Main channel[1]	1100	0.5

[1] For the main channel, n = 0.06 (estimated), width = 10 feet, depth = 2 feet, rectangular channel

Segment 1 - Travel time from Equation 3-4 with P_2 = 3.30 inches (0.14 x 24 – Table 3-4)

T_t = $0.007[(0.24)(40)]^{0.8}/(3.30)^{0.5}(0.02)^{0.4}$
= 0.113 hrs = 6.78 minutes

Segment 2 - Travel time from Figure 3-2 or Equation 3-7

V = 2.1 ft/s (from Equation 3-7)
T_t = 750/[(60)(2.1)] = 5.95 min

Segment 3 - Using Equation 3-10

V = $[(1.49)(1.43)^{0.67}(0.005)^{0.5}]/0.06$
= 2.23 ft/s
T_t = 1100/60(2.23) = 8.22 min

Therefore, using Equation 3-3

t_c = 6.75 + 5.95 + 8.22 = 21 min = 0.35 hrs
= 0.113 hrs = 6.78 minutes

Step 3. Calculate I_a/P for CN = 72), I_a = 0.778 (Table 3-14)

I_a/P = (0.778/6.60) = 0.12 (Note: Use I_a/P = 0.10 to facilitate use of Figure 3-6. Straight line interpolation could also be used.)

Step 4. Unit discharge q_u (100-year) from Figure 3-6= 650 csm/in,

Step 5. Calculate peak discharge with F_p = 1 using Equation 3-16

Q_{100} = 650(50/640)(3.5)(1) = 178 cfs

3.1.5.5 Hydrograph Generation

In addition to estimating the peak discharge, the SCS method can be used to estimate the entire hydrograph from a drainage area. The SCS has developed a Tabular Hydrograph procedure that can be used to generate the hydrograph for drainage areas less than 2,000 acres. The Tabular Hydrograph procedure uses unit discharge hydrographs that have been generated for a series of time of concentrations. In addition, SCS has developed hydrograph procedures to be used to generate composite flood hydrographs. For hydrograph development in homogeneous developed drainage areas, for hydrograph development for drainage areas that are not homogeneous and where multiple sub-area hydrographs need to be generated, routed and combined at a point downstream (SCS, 1986),

The unit hydrograph equations used in the SCS method for generating hydrographs include a constant to account for the general land slope in the drainage area. This constant, called a peaking factor, can be adjusted when using the method. A default value of 484 for the peaking factor represents rolling hills – a medium level of relief. SCS indicates that for mountainous terrain the peaking factor can go as high as 600, and as low as 300 for flat (coastal) areas. In Knox County, the default value of 484 must be used for the peaking factor.

The development of a runoff hydrograph from a watershed is a laborious process not normally done by hand. For that reason this discussion is limited to an overview of the process and is given here to assist the designer in reviewing and understanding the input and output from a typical computer program. There are choices of computational interval, storm length (if the 24-hour storm is not going to be used) and other "administrative" parameters that are specific to each computer program.

The development of a runoff hydrograph for a watershed or one of many sub-basins within a more complex model involves the following steps:

1. Development or selection of a design storm hyetograph (a graph of the time distribution of rainfall over a watershed). Often, the SCS 24-hour storm described in Section 3.1.5.3 is used.
2. Development of curve numbers and lag times for the watershed using the methods described in Sections 3.1.5.4, 3.1.5.5, and 3.1.5.6.
3. Development of a unit hydrograph from the standard (peaking factor of 484) dimensionless unit hydrographs. See discussion below.
4. Step-wise computation of the initial and infiltration rainfall losses and, thus, the excess rainfall hyetograph using a derivative form of the SCS rainfall-runoff equation (Equation 3-12).
5. Application of each increment of excess rainfall to the unit hydrograph to develop a series of runoff hydrographs, one for each increment of rainfall (this is called “convolution”).
6. Summation of the flows from each of the small incremental hydrographs (keeping proper track of time steps) to form a runoff hydrograph for that watershed or sub-basin.

Figure 3-7 and Table 3-16 can be used along with Equations 3-17 and 3-18 to assist the designer in using the SCS unit hydrograph in Knox County. The unit hydrograph with a peaking factor of 300 is shown in the figure for comparison purposes, but should not be used for areas in Knox County.

Figure 3-7. Dimensionless Unit Hydrographs for Peaking Factors of 484 and 300

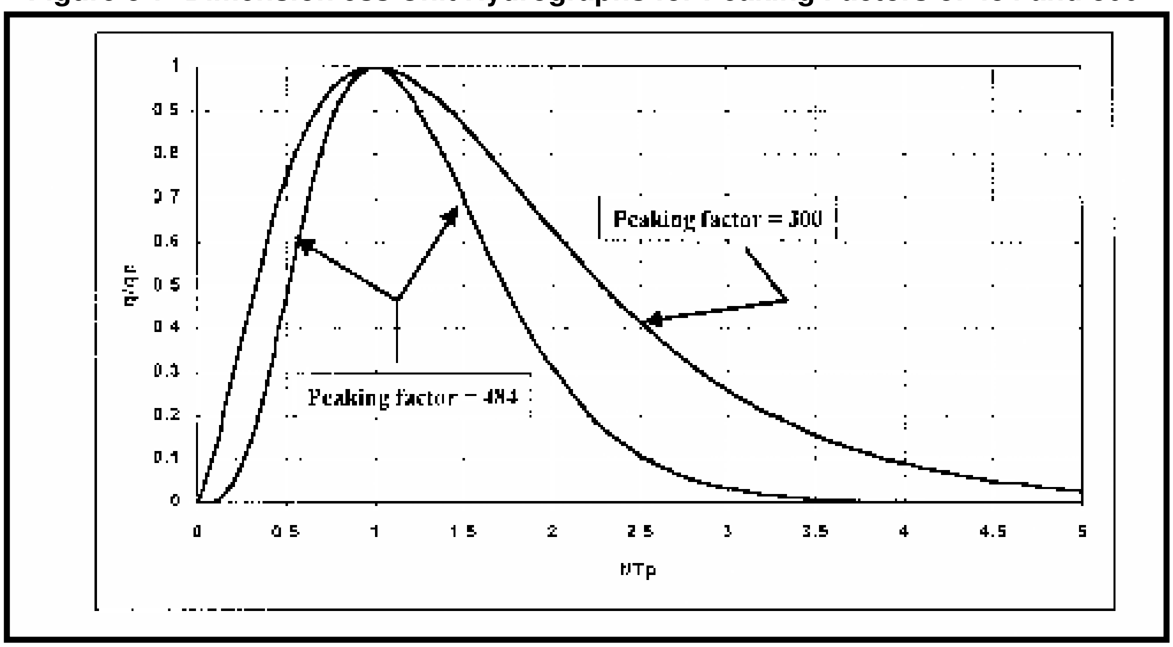


Table 3-16. Dimensionless Unit Hydrograph 484

t/T_p	484	
	q/q_u	Q/Qp
0.0	0.000	0.000
0.1	0.005	0.000
0.2	0.046	0.004
0.3	0.148	0.015
0.4	0.301	0.038
0.5	0.481	0.075
0.6	0.657	0.125
0.7	0.807	0.186
0.8	0.916	0.255
0.9	0.980	0.330
1.0	1.000	0.406
1.1	0.982	0.481
1.2	0.935	0.552
1.3	0.867	0.618
1.4	0.786	0.677
1.5	0.699	0.730
1.6	0.611	0.777
1.7	0.526	0.817
1.8	0.447	0.851
1.9	0.376	0.879
2.0	0.312	0.903
2.1	0.257	0.923
2.2	0.210	0.939
2.3	0.170	0.951
2.4	0.137	0.962
2.5	0.109	0.970
2.6	0.087	0.977
2.7	0.069	0.982
2.8	0.054	0.986
2.9	0.042	0.989
3.0	0.033	0.992
3.1	0.025	0.994
3.2	0.020	0.995
3.3	0.015	0.996
3.4	0.012	0.997
3.5	0.009	0.998
3.6	0.007	0.998
3.7	0.005	0.999
3.8	0.004	0.999
3.9	0.003	0.999
4.0	0.002	1.000

Equation 3-17 is used to multiply each time ratio value by the time-to-peak (T_p) and each value of q/q_u by q_u.

Equation 3-17

$$q_u = \frac{(PF)A}{T_p}$$

where:

q_u = unit hydrograph peak rate of discharge (cfs)
PF = peaking factor (either 484 or 300)
A = area (mi^2)
T_p = time to peak = d/2 + 0.6 T_c (hours)
d = rainfall time increment (hours)

For ease of spreadsheet calculations, the dimensionless unit hydrograph using a peaking factor of 484 can be approximated using Equation 3-18.

Equation 3-18

$$\frac{q}{q_u} = \left[\frac{t}{T_p} e^{\left(1 - \frac{t}{T_p}\right)} \right]^X$$

where:

X = 3.79 for the PF = 484 unit hydrograph.

Example 3-6. Calculation of Unit Hydrograph

Compute the unit hydrograph for the 50-acre wooded watershed in Example 3-5.

Computations

Step 1. Calculate T_p (time to peak) and time increment

The time of concentration (T_c) is calculated to be 21 minutes for this watershed. If we assume a computer calculation time increment (d), duration of excess rainfall, of 3 minutes then:

T_p = d/2 + 0.6 T_c = 3/2 + 0.6(21) = 14.1 min = 0.235 hours

Step 2. Calculate q_u

q_u = (484)(50/640)/(0.235) = 161 cfs

Step 3. Calculate the hydrograph using unit hydrograph 484. The table below was derived based on spreadsheet calculations using Equations 3-17 and 3-18.

Time		484	
t/Tp	time (min)	q/q_u	Q
0.00	0	0.00	0.00
0.21	3	0.06	9.15
0.43	6	0.35	56.32
0.64	9	0.72	116.58
0.85	12	0.96	154.41
1.00	14	1.00	160.90
1.07	15	0.99	160.14
1.28	18	0.88	142.28
1.49	21	0.70	113.61
1.71	24	0.52	83.90
1.92	27	0.36	58.37
2.14	30	0.24	38.74
2.35	33	0.15	24.75

Time		484	
t/Tp	time (min)	q/q_u	Q
2.56	36	0.09	15.32
2.78	39	0.06	9.24
2.99	42	0.03	5.45
3.20	45	0.02	3.15
3.42	48	0.01	1.79
3.63	51	0.01	1.00
3.84	54	0.00	0.55
4.06	57	0.00	0.30
4.27	60	0.00	0.16
4.48	63	0.00	0.09
4.70	66	0.00	0.05
4.91	69	0.00	0.02