2. 0 HYDROLOGY AND RUNOFF DETERMINATION

By definition, hydrology is the scientific study of water and its properties, distribution, and effects on the earth's surface, soil, and atmosphere. Hydrologic analyses include estimation of peak runoff rates, volumes, and time distribution of storm water runoff flows and are fundamental in the design of storm water management facilities. This chapter addresses the movement of water over land resulting directly from precipitation in the form of storm water runoff.

Land development changes how a watershed responds to precipitation. The most common effects are reduced infiltration and decreased travel time. Increased impervious surfaces and runoff velocities increase peak flow discharge volumes and rates. Total runoff volume is determined by the total drainage area of the receiving watershed, its infiltration characteristics, and the amount of precipitation.

2.1 GENERAL DESIGN CRITERIA

The following guidelines should be followed when selecting hydrologic computation standards:

- The design storm duration shall be the 24-hour rainfall event, using the National Resource Conservation Service (NRCS), formerly known as Soil Conservation Service (SCS), Type III rainfall distribution with a maximum 6-minute time increment.
- If the contributing drainage area is 20 acres or less and if no storage design or runoff volume is required, the Rational Method or the NRCS (SCS) Method of runoff calculation shall be acceptable.
- If the contributing drainage area is greater than 20 acres, or if storage or runoff volume design is required, only the NRCS (SCS) Method of runoff calculation shall be acceptable.

2.2 DRAINAGE AREA CHARACTERISTICS

Drainage area (also called watershed or drainage basin) is an area receiving precipitation which generates runoff flow that drains into a single point of discharge. The use of contour maps is recommended for drainage area delineation. Identifying the area from which the rainfall runoff will be evaluated is one of the basic requirements for design of storm water management facilities.

Watershed runoff discharge is determined by the following characteristics:

- Size
- Shape
- Slope
- Soils
- Land-Use
- Ponding/Storage
- Soil Moisture

2.2.1 Size

Size of the watershed dictates how much of the precipitation will fall on the area contributing to the flow at the point of interest.

2.2.2 Shape

Shape of the basin influences the timing of the peak flow hydrograph (i.e.; how fast water is being transported from the edge of the watershed to the point of interest). Long, narrow or short, wide basins usually have larger runoff peak rates than basins which are approximately equal in length and width.

2.2.3 Slopes

Slope of a basin significantly impacts the runoff rate. Runoff from a drainage area with steep slopes will travel along its flow path faster than it will from an area with shallow, rolling topography. How the basin slope directly impacts the time of concentration is shown in Section 2.4.1.

2.2.4 Soils

Soil properties influence the relationship between rainfall and runoff with their various rates of infiltration. Based on the infiltration rates, the NRCS (SCS) has divided the soils into four hydrologic soil groups (HSG) A, B, C, and D. The soils in hydrologic group A have the most (0.30 – 0.45 in/hr) infiltration capacity while soils in the hydrologic group D have the least (less than 0.05 in/hr).

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 and 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 consist primarily of either 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 clay layer at or near the surface, and shallow soils over nearly impervious underlying material.

A list of soils for Georgetown County and their hydrologic classification (HSG) is presented in Table 2-1. Soil Survey maps can be obtained from local NRCS (SCS) office. Note: A/D and B/D indicate the drained/un-drained situation.

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 hydrologic soil group selection. Also runoff curve numbers (CN) vary with the antecedent soil moisture conditions (AMC). Average antecedent moisture conditions (AMC II) are recommended for all hydrologic analysis. See Section 2.4.2 for more details antecedent soil moisture conditions.

TABLE 2-1
HYDROLOGIC SOILS GROUPS (HSG) FOR GEORGETOWN COUNTY

Series Name	HSG	Series Name	HSG
Beaches	D	Johnston	D
Bladen	D	Lakeland	A
Blanton	A	Leon	B/D
Bohicket	D	Levy	D
Cape fear	D	Lynn haven	B/D
Centenary	A	Newhan	A
Chastain	D	Norfolk	B
Chipley	C	Rutlege	B/D
Chisolm	A	Udorthents	B
Echaw	A	Wahee	D
Eulonia	C	Wakulla	A
Grifton	D	Witherbee	A/D
Hobcaw	D	Yauhannah	B
Hobonny	D	Yemassee	C

Source: South Carolina Department of Health and Environmental Control, Stormwater Management and Sediment Control Handbook, August 2003

2.2.5 Land Use

Also known as land use cover, land use represents the surface characteristic of the drainage area and consists of a combination of pervious and impervious surfaces.

Two widely used methods characterizing the land surface are Rational Method's "C" value and NRCS (SCS) method's curve number (CN). The surface identifying number of the drainage area may be calculated as a composite number from the sub-areas of the uniform land cover.

2.2.6 Ponding/Storage

If part (up to 5%) of drainage area is available for the runoff retention/detention, this should be included in the peak runoff analysis. The Rational Method is not an appropriate hydrologic methodology for drainage areas with these considerations.

2.2.7 Soil Moisture

Antecedent moisture condition is the index of runoff potential before a storm event. Refer to Section 2.4.2 for more details antecedent moisture condition.

2.3 PRECIPITATION DATA

The majority of Georgetown County precipitation occurs as rain. The period in which rainfall begins, intensifies, peaks, and subsides during one storm is categorized as a storm event. Individual storm events are generally defined, or separated, by a minimum 6-hour time interval without precipitation. Variants of an event may be complicated by tropical storm "bands". The storm magnitude is estimated from the storm event volume, duration, and intensity. Statistical calculations are used to establish the probability of a specific storm event. The following items characterize a storm event.

- Depth/Volume/Duration
- Intensity
- Spatial Distribution
- Recurrence Interval

2.3.1 Depth/Volume/Duration

The depth of precipitation over an area generates a certain volume. This volume can be derived from the rainfall intensity that falls during the storm duration (or time period) over the area. Rainfall depths are typically provided based on a return period or the period a certain magnitude will occur in any given year. Table 2-2 presents the 24-hour storm events within Georgetown County 2-, 5-, 10-, 25-, 50-, and 100-year.

TABLE 2-2
RAINFALL DEPTH (Inches) FOR GEORGETOWN COUNTY

Georgetown County	**Return Period** [years]					
	2	5	10	25	50	100
	4.5	5.7	6.7	7.7	8.7	9.8

Source: South Carolina Department of Health and Environmental Control, Stormwater Management and Sediment Control Handbook, August 2003

2.3.2 Intensity

Intensity represents the rate at which rainfall occurs. The average intensity for a period is the total rainfall event depth divided by the time over which the rainfall occurred. The rainfall intensity values may be also computed using the following equation:

$$i = a / (b + t_c)^c \qquad (2\text{-}1)$$

Where:

i = rainfall intensity, in inches per hour
t_c = time of concentration, in minutes
a , b, and c are coefficients

The coefficients for the 2-, 5-, 10-, 25-, 50-, and 100-year rainfalls and the intensity values for a time of concentration of 5, 10, and 15 minutes for Georgetown County are listed in Table 2-3.

TABLE 2-3
RAINFALL INTENSITY COEFFICIENTS FOR GEORGETOWN COUNTY

Frequency (years)	a	b	c	i (in/hr) t_c=5min	i (in/hr) t_c=10min	i (in/hr) t_c=15min
2	249.76	34.10	1.026	5.80	5.13	4.59
5	261.38	32.32	1.015	6.63	5.84	5.21
10	269.35	31.13	1.007	7.26	6.37	5.68
25	288.87	29.41	0.996	8.51	7.43	6.60
50	288.87	28.24	0.989	9.04	7.87	6.97
100	296.41	27.09	0.981	9.86	8.55	7.55

Source: South Carolina Department of Transportation, September 1997

2.3.3 Spatial Distribution

Spatial distribution relates to whether the rainfall depth (volume or intensity) at various locations in a drainage basin are equal for the same event. In practice, spatial variations for a relatively small drainage area can be neglected.

2.3.4 Recurrence Interval

The probability that a rainfall event of a certain magnitude will occur in any given year is expressed in terms of recurrence interval (also called return period or event frequency). The recurrence interval is the average length of time expected to elapse between rainfall events of equal or greater magnitude. The recurrence interval is expressed in years, but is actually based on a storm event's exceedance probability. For example, the 100-year storm, also known as one percent annual chance storm, is the storm that has one percent chance of being equal or exceeded in any given year. The relationship between recurrence interval and exceedance probability is given by

$$T = 1/P \qquad (2\text{-}2)$$

Where:

T = return period, in years
P = exceedance probability

Storms of different magnitude with different recurrence intervals will be set as design criteria for individual parts of storm water management facilities. For example, a culvert under a freeway will be designed to safely carry flow from a 100-year storm event, but a culvert under residential flow is only required to carry flow from a 25-year storm event.

2.3.5 Form of Rainfall Data

Rainfall data for probable precipitation depths are based upon historical records. Calculation of resulting peak runoff flow or flow volume is a primary objective of data collection and analysis. Several forms of data useful for peak runoff flow calculation or computer simulation are shown below.

- **Intensity-Duration-Frequency (IDF) Curves** illustrate the average rainfall intensities corresponding to various durations and storm recurrence intervals, such as 100-, 50-, 25-, 10-, 2-year storms.
- **NRCS (SCS) Peak Discharge Method** produces a peak discharge and requires the 24-hour total rainfall depths for the selected recurrence interval.
- **NRCS (SCS) Unit Hydrograph** can be used with any rainfall distribution, however, the 24-hour total rainfall depths and 24-hour rainfall temporal distribution (Type III) will be used in this manual.

2.4 RUNOFF DETERMINATION

The travel time, or time of concentration, of the watershed is directly related to the slope, flow path length, depth of flow, and roughness of the flow surfaces due to the type of ground cover. The time of concentration is used in Rational as well as NRCS (SCS) Methods for the peak flow determination.

2.4.1 Time of Concentration (T_c)

TR-55 Method

TR-55 method (Natural Resource Conservation Service (NRCS), Urban Hydrology for Small Watersheds, Technical Release No. 55, June 1986) is used to compute T_c by summing all the travel times of consecutive flow segments of the drainage conveyance system along the path extending from the hydraulically most distant point of the drainage area to the point of interest within this area.

$$T_c = T_1 + T_2 + T_3 + \ldots + T_n \quad (2\text{-}3)$$

Where:

T_1 = time of travel through one segment, in hours
N = number of segments

Water moves through the drainage area as sheet flow, shallow concentrated flow, open channel, or a combination of these.

Sheet Flow

Sheet flow is the flow of water over a plane surface usually taking place in the headwater of the basin. The sheet flow occurs over a distance of up to 300 feet before it forms rills or paths. A maximum of 100 feet shall be used for the design of storm water systems.

$$T_t = [0.007\,(nL)^{0.8} / (P_2)^{0.5}\,(s)^{0.4}] \quad (2\text{-}4)$$

Where:

T_t	=	travel time, in hours
n	=	Manning's roughness coefficient for shallow depths of about 0.1 foot
L	=	flow length, in feet
P_2	=	2-year 24-hour rainfall, in inches
s	=	land slope, in feet per foot

TABLE 2-4
ROUGHNESS COEFFICIENTS (MANNING'S "n") FOR SHEET FLOW

Surface Description	"n"[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover 20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods[3]:	
Light underbrush	0.40
Dense underbrush	0.80

Source: NRCS (SCS), TR-55, Second Edition, June 1986.
[1]The "n" values are a composite of information compiled by Engman (1986)
[2] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3] When selecting "n", consider cover to a height of about 0.1 ft. This is the only part of the plant cover that hat will obstruct sheet flow.

Shallow Concentrated Flow

Average velocities for estimating travel time for shallow concentrated flow can be computed from the following equations. These equations can also be used for slopes less then 0.005 ft/ft.

$$V = 16.1345(S)^{0.5} \quad \text{for unpaved surface} \qquad (2\text{-}5)$$
$$V = 20.3282(S)^{0.5} \quad \text{for paved surface} \qquad (2\text{-}6)$$

Where:

V	=	average velocity, in feet per second
S	=	slope of hydraulic grade line (watercourse slope), in feet per foot

These two equations are based on the solution of Manning’s Equation with different assumptions for "n" (Manning's roughness coefficient) and "r" (hydraulic radius, in feet). For unpaved areas "n" is 0.05 and "r" is 0.4 feet; for paved areas, "n" is 0.025 and "r" is 0.2 feet.

After determining average velocity, travel time for the shallow concentrated flow segment can be estimated by dividing the flow length by the velocity.

Open Channel Flow

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning’s Equation for water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bankfull elevation. Manning’s Equation for this is:

$$V = 1.49 / n (R)^{2/3} (s)^{1/2} \quad (2\text{-}7)$$

Where:

V	=	average velocity, in feet per second
n	=	Manning's roughness coefficient
s	=	slope of the hydraulic grade line, in feet per foot
R	=	hydraulic radius, in feet and is defined by the equation

$$R = a/p_w \quad (2\text{-}8)$$

a	=	cross sectional flow area, in square feet
p_w	=	wetted perimeter, in feet

After average velocity is computed using above equation, T_t for the channel segment can be estimated by dividing the flow length by the velocity. Velocity in channels should be calculated from Manning’s Equation. Cross sections from all channels that have been field checked should be used in the calculations. This is particularly true of areas below dams or other flow control structures.

2.4.2 Flow Determination Methods

This section describes the recommended procedures for calculating the runoff generated from a project site. Correct utilization of these procedures should result in the best available estimation of existing and projected runoff. Their use will also provide the consistency of results necessary when applied to project sites throughout Georgetown County. All hydrologic computational methods shall be accomplished using a method acceptable by Georgetown County.

The following guidelines should be followed when selecting hydrologic computation standards:

- The design storm duration shall be the 24-hour rainfall event, using the NRCS (SCS) Type III rainfall distribution with a maximum 6-minute time increment.

- If the contributing drainage area is 20 acres or less and if no storage design or runoff volume is required, the Rational Method or the NRCS (SCS) Method of runoff calculation shall be acceptable.
- If the contributing drainage area is greater than 20 acres, or if storage or runoff volume design is required, only the NRCS (SCS) Method of runoff calculation shall be acceptable.

Rational Method

The Rational Method formula is utilized to determine peak flow rates in urban areas and small watersheds for the following situations:

- Total drainage area of 20 acres or less.
- No storage or volume design required.
- Sizing culverts and small ditches that do not have a total contributing drainage area greater than 20 acres.

The Rational Method is recommended for small, highly impervious drainage areas such as parking lots and roadways draining into inlets and gutters. The Rational Method calculates peak discharge only as opposed to developing a runoff hydrograph for an area. It makes a basic assumption that the design storm has constant rainfall intensity for a time period equaling the drainage area time of concentration (T_c), the time required for water to flow from the most remote point of the basin to the point of interest.

$$Q = C\, i\, A \qquad (2\text{-}9)$$

Where:

Q	=	maximum rate of runoff, in cubic feet per second
C	=	runoff coefficient representing a ratio of runoff to rainfall, Table 2-6
i	=	average rainfall intensity for a duration equal to the T_c, in inches per hour
A	=	drainage area contributing to the design location, in acres

Less Frequent Storms

The runoff coefficients given in Table 2-6 are applicable for storms equal to or more frequent than the 10-year frequency (such as 2-, 5-, and 10-year storms). Less frequent, higher intensity storms, such as 25-, 50-, and 100-year storms require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on the runoff. Adjustment of the Rational Method for use with major storms can be made by multiplying the runoff coefficient by a frequency factor, C_f, shown in Table 2-5.

For infrequent storm events, the rational equation is then expressed as:

$$Q = C\, C_f\, i\, A \qquad (2\text{-}10)$$

Where:

Q	=	maximum rate of runoff, in cubic feet per second
C	=	runoff coefficient based on 5- to 10-year storms, Table 2-6
C_f	=	frequency factor based on recurrence interval (dimensionless), Table 2-5
i	=	average rainfall intensity, in inches per hour
A	=	drainage area contributing to the design location, in acres

TABLE 2-5
RATIONAL METHOD RUNOFF COEFFICIENT FREQUENCY FACTORS

Recurrence Interval (years)	Frequency Factor, C_f
25	1.1
50	1.2
100	1.25

Note: The product of C_f times C shall not exceed 1.0.

Runoff Coefficient C

The runoff coefficient "C" is the variable of the Rational Method least susceptible to precise determination and requires judgment and understanding on the part of the design professional. While engineering judgment will always be required in the selection of runoff coefficients, recommended runoff coefficients for the Rational Method representing the integrated effects of many drainage basin parameters are listed in Table 2-6.

Composite Coefficients

It is often desirable to develop a composite runoff coefficient based on the percentage of different types of surfaces in the drainage areas. Composites can be made with the values from Table 2-6 by using percentages of different land uses. In addition, more detailed composites can be made with coefficients for different surface types such as roofs, asphalt and concrete streets, drives and walks. The composite procedure can be applied to an entire drainage area or to typical sample block as a guide to the selection of reasonable values of the coefficient for an entire area.

It should be remembered that the Rational Method assumes that all land uses within a drainage area are uniformly distributed throughout the area. If it is important to locate a specific land use within the drainage area then another hydrologic method should be used where hydrographs can be generated and routed through the drainage system.

TABLE 2-6
RECOMMENDED RUNOFF COEFFICIENT "C" VALUES
RATIONAL METHOD

Description of Area	Runoff Coefficients "C"
Lawns:	
Sandy soil, flat, 2%	0.10
Sandy soil, average, 2 - 7%	0.15
Sandy soil, steep, > 7%	0.20
Clay soil, flat, 2%	0.17
Clay soil, average, 2 - 7%	0.22
Clay soil, steep, > 7%	0.35
Business:	
Downtown areas	0.95
Neighborhood areas	0.70
Residential:	
Single-family areas	0.50
Multi-units, detached	0.60
Multi-units, attached	0.70
Suburban	0.40
Apartment dwelling areas	0.70
Industrial:	
Light areas	0.70
Heavy areas	0.80
Parks and cemeteries	0.25
Playgrounds	0.35
Railroad yard areas	0.40
Unimproved areas (forest)	0.30
Streets:	
Asphalt and Concrete	0.95
Brick	0.85
Drives, walks, and roofs	0.95
Gravel areas	0.50
Graded or no plant cover	
Sandy soil, flat, 0 - 5%	0.30
Sandy soil, flat, 5 - 10%	0.40
Clayey soil, flat, 0 - 5%	0.50
Clayey soil, average, 5 - 10%	0.60

Rainfall Intensity, i

Rainfall intensity is the average rainfall rate (typically reported in inches per hour) for duration equal to the time of concentration for a selected return period. Once a return period has been selected for design and a time of concentration calculated, the rainfall intensity can be determined from Rainfall-Intensity-Duration data. Table 2-7 lists the rainfall intensity data. Straight-line interpolation can be used to obtain rainfall intensity values for storm durations between the values given in Table 2-7.

TABLE 2-7
RAINFALL INTENSITY FOR GEORGETOWN COUNTY

Rainfall Intensity (inches/hour)[1]						
Storm Duration	**Storm Recurrence Interval**					
	2-year	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
5 minutes	5.88	6.67	7.28	8.23	8.97	9.72
10 minutes	5.10	5.81	6.36	7.21	7.88	8.54
15 minutes	4.40	5.02	5.51	6.24	6.82	7.40
30 minutes	3.23	3.86	4.32	4.99	5.52	6.05
1 hour	2.15	2.63	2.97	3.47	3.86	4.25
6 hours	0.55	0.70	0.80	0.93	1.03	1.15
12 hours	0.32	0.42	0.48	0.57	0.62	0.69
24 hours	0.19	0.23	0.28	0.32	0.36	0.40
24-hour Volume (in)[2]	4.5	5.7	6.7	7.7	8.7	9.8

[1]Source: National Weather Service, Precipitation-Frequency Atlas of the United States, NOAA Atlas 14, Volume 2, Version 2, August 2003.
[2]Source: SCDHEC, Stormwater Management and Sediment Control Handbook for Land Disturbance Activities, Environmental Quality Control Division, August 2003.

NRCS (SCS) Curve Number (CN) Method

The NRCS (SCS) hydrologic method requires basic data similar to the Rational Method: drainage area, a runoff factor, time of concentration, and rainfall. Details of the methodology can be found in the NRCS (SCS) TR-55 and the NRCS Engineering Field Manual for Conservation Practices.

The NRCS (SCS) curve number method begins with a rainfall amount uniformly imposed on the watershed over a specified time distribution. Mass rainfall is converted to mass runoff by using a runoff CN that is based on soil type, plant cover, impervious areas, interception, and surface storage.

Runoff is then transformed into a hydrograph by using unit hydrograph theory and routing procedures that depend on runoff travel time through segments of the watershed. The NRCS (SCS) Method is used to determine storm water runoff peak flow rates, runoff volumes, and the generation of hydrographs for the routing of storm flows in urban areas and project sites. The following are requirements of its use:

- NRCS (SCS) CN Method is required for total drainage areas greater than 20 acres.
- NRCS (SCS) CN Method may be used for total drainage areas less than 20 acres.
- Runoff volume.
- Routing.
- Design of storage facilities and outlet structure.

The NRCS (SCS) method includes the following basic steps:

- Determination of CN representing different land uses within the drainage area.
- Calculation of T_c to the study point.
- Selection of design storm event.
- Use of the Type III rainfall distribution to determine the total and excess rainfall quantity.
- Use of the unit hydrograph approach including development of triangular and composite hydrographs for the drainage area.

The NRCS (SCS) method applicable to Georgetown County is based on a storm event which has a Type III time distribution. To use this distribution, the user has to obtain the 24-hour rainfall volume. A relationship between accumulated rainfall and accumulated runoff was derived by NRCS (SCS) from experimental plots for numerous soils and vegetative cover conditions. The following NRCS (SCS) runoff equation is used to estimate direct runoff from a 24-hour storm event. The equation is:

$$Q = (P - 0.2S)^2 / (P + 0.8S) \qquad (2\text{-}11)$$

Where:

Q	=	total runoff volume for the specified storm event, in inches
P	=	rainfall volume for the specified storm event, in inches from Table 2-2.
S	=	potential maximum retention after runoff begins, in inches and is defined by the following equation:

$$S = (1000/CN) - 10 \qquad (2\text{-}12)$$

Where:

CN	=	NRCS (SCS) curve number

Initial Abstractions (I_a) are all losses in the watershed before runoff begins. These abstractions include water retained in surface depressions, water intercepted by vegetation, evaporation and infiltration. I_a is highly variable but is generally correlated with soil and cover parameters. Through the study of many small agricultural watersheds, I_a is approximated by the following empirical equation:

$$I_a = 0.2S \qquad (2\text{-}13)$$

CNs represents the combined hydrologic effect of the soil type, land use, hydrologic soil group (HSG), and antecedent moisture condition. It may be necessary to create a composite CN by weighting distinct land use-HSG combinations and summing them for the total drainage area. The CN indicates the runoff potential of soil which is not frozen. Higher CN reflects a higher runoff potential.

Another factor of consideration is whether impervious areas are directly connected to the system or if the system is unconnected and flows from impervious areas spread over pervious areas before reaching the outfall point. The CN is similar to the Rational Method's "C" coefficient in that it is based on the surface condition of the drainage area. NRCS (SCS) TR-55 presents a method for analyzing unconnected impervious areas, as discussed later in this section.

The following conditions apply when using the NRCS (SCS) CNs, based on HSG and surface cover, as shown in Table 2-8, to estimate runoff:

- CNs are based on AMC II.
- Understand that initial abstraction (I_a) consists of interception, initial infiltration, surface depression storage, and evapotranspiration.
- Runoff from frozen ground cannot be estimated using this procedure.
- The curve number method becomes less accurate when runoff is less than 0.5 inches. When this situation occurs, use of another procedure is recommended as check. If a discrepancy exists, then other procedures should be explored for approval by the County Storm Water Engineer.
- This procedure applies only to direct runoff.
- If the weighted CN is less than 30, use CN = 30 for runoff computations.

Antecedent moisture condition is the index of runoff potential before a storm event. The AMC is an attempt to account for the variation in CN at a particular site for various storm conditions. The CNs listed in Table 2-8 are for average AMC II, which are used primarily for design applications. The three AMC classifications are:

AMC I – Little rain or drought conditions preceding studied rainfall event. The CNs for AMC I can be calculated using the following equation:

$$CN_{(AMC\ I)} = 4.2\ CN_{(AMC\ II)} / (10 - 0.058\ CN_{(AMC\ II)}) \qquad (2\text{-}14)$$

AMC II – Standard CNs developed from rainfall and runoff data.

AMC III – Considerable rainfall prior to studied rainfall event. The CNs for AMC III can be calculated using the following equation:

$$CN_{(AMC\ III)} = 23\ CN_{(AMC\ II)} / (10 + 0.13\ CN_{(AMC\ II)}) \qquad (2\text{-}15)$$

Urban Modifications

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 CNs for urban areas.

It is possible that CN values from urban areas could be reduced through the use of structural storm water BMPs and strategic placement of vegetated areas to disconnect impervious surfaces for infiltration of runoff.

An impervious area is considered connected if runoff from it flows directly into the storm drainage system. It is also considered connected if runoff from the area occurs as concentrated shallow flow that runs over a pervious area and then into a drainage system.

TABLE 2-8
RUNOFF CURVE NUMBER FOR URBAN AREAS AND AGRICULTURAL LANDS[1]
NRCS (SCS) CN METHOD

Cover Description Cover Type and Hydrologic Condition	Average Percent Impervious Area[2]	Curve Numbers for Hydrologic Soil Group			
		A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, 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 sewers (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 agricultural land					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94
Pasture, grassland, or range: continuous forage for grazing[4]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow: continuous grass, protected from grazing and generally mowed for hay	-	30	58	71	78
Brush-brush, weed, grass mixture with brush the major element[5]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[7]30	48	65	73

TABLE 2-8 continue
RUNOFF CURVE NUMBER FOR URBAN AREAS AND AGRICULTURAL LANDS[1]
NRCS (SCS) CN METHOD

Cover Description Cover Type and Hydrologic Condition	Average Percent Impervious Area[2]	Curve Numbers for Hydrologic Soil Group			
		A	B	C	D
Woods-grass combination (orchard or tree farm)[6]	Poor Fair Good	57 43 32	73 65 58	82 76 72	86 82 79
Woods[7]	Poor Fair Good	45 36 [4]30	66 60 55	77 73 70	83 79 77
Farmsteads-buildings, lanes, driveways, and surrounding lots.	-	59	74	82	86

Source: NRCS (SCS), TR-55, second Edition, June 1986

[1] Average runoff condition, and $I_a = 0.2S$

[2] 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 NRCS (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.

[4] Poor: <50% ground cover or heavily grazed with no mulch.
Fair: 50% to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[5] Poor: <50% ground cover
Fair: 50% to 75% ground cover
Good: >75% ground cover

[6] CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pastures.

[7] Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.

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 2-8 are not applicable, compute a composite CN using NRCS TR-55 Chapter 2 and Figure 2-3 of TR-55 for reference.

If runoff from unconnected impervious areas is spread over a pervious area as sheet flow, then all or part of the impervious area is not directly connected to the drainage system. Use NRCS TR-55 Chapter 2 for reference in determining a modified CN for the disconnected impervious areas.

Simplified NRCS (SCS) Method

Overview

The following NRCS (SCS) procedures were taken from the NRCS (SCS) TR-55 which presents simplified procedures to calculate storm runoff volume, peak rate of discharges and hydrographs. These procedures are applicable to small drainage areas and include provisions to account for urbanization. The following procedures outline the use of the NRCS (SCS) TR-55 method.

Peak Discharges

The NRCS (SCS) peak discharge method is applicable for estimating the peak runoff rate from watersheds with a homogeneous land use. The following method is based on the results of computer analyses performed using TR-20, "Computer Program for Project Formulation Hydrology," NRCS (SCS) 1992.

The peak discharge equation is:

$$Q_p = q_u A Q F_p \qquad (2\text{-}16)$$

Where:

Q_p = peak discharge, in cubic feet per second
q_u = unit peak discharge, in cubic feet per second per square mile per inch ($cfs/mi^2/in$)
A = drainage area, in square miles
Q = runoff, in inches
F_p = pond and swamp adjustment factor

The input requirements for this method are as follows:

1. T_c, in hours
2. Drainage area, in square miles
3. Type III rainfall distribution
4. 24-hour design rainfall
5. CN value
6. Pond and Swamp adjustment factor. (If pond and swamp areas are spread throughout the watershed and are not considered in the T_c computation, an adjustment is needed.)

Computations

Computations for the peak discharge method proceed as follows:

1. The 24-hour rainfall depth is in Table 2-7 for the selected return frequency.
2. The runoff CN, is estimated from Table 2-8 and direct runoff, Q, is estimated from Equation 2-11. Determine if urban modifications of CN are appropriate.

3. The CN value is used to determine the initial abstraction, I_a, from Table 2-8, and the ratio I_a/P is then computed. (P = accumulated 24-hour rainfall or potential maximum runoff.)
4. The watershed time of concentration is computed using the procedures in Section 2.4.1 and is used with the ratio I_a/P to obtain the unit peak discharge, q_u, from Figure 2-1. If the ratio I_a/P lies outside the range shown in Figure 2-1, either the limiting values or another peak discharge method should be used.
5. The pond and swamp adjustment factor, F_p, is estimated using Table 2-9.
6. The peak runoff rate is computed using Equation 2-16.

TABLE 2-9

Pond and Swamp Areas (%)*	**F_p**
0.0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

*Percent of entire drainage basin

Limitations

The accuracy of the peak discharge method is subject to specific limitations, including the following:

a. The watershed must be homogeneous in a hydrologic sense and therefore describable by a single CN value.
b. The watershed may have only one main stream, or if more than one, the individual branches must have nearly equal time of concentrations.
c. Hydrologic routing cannot be considered.
d. The pond and swamp adjustment factor, F_p, applies only to areas located away from the main flow path.
e. Accuracy is reduced if the ratio I_a/P is outside the range given in Figure 2-1.
f. The weighted CN value must be greater than or equal to 40 and less than or equal to 98.
g. The same procedure should be used to estimate existing and developed time of concentration when computing existing and developed peak discharge.
h. The watershed time of concentration must be between 0.1 and 10 hours.

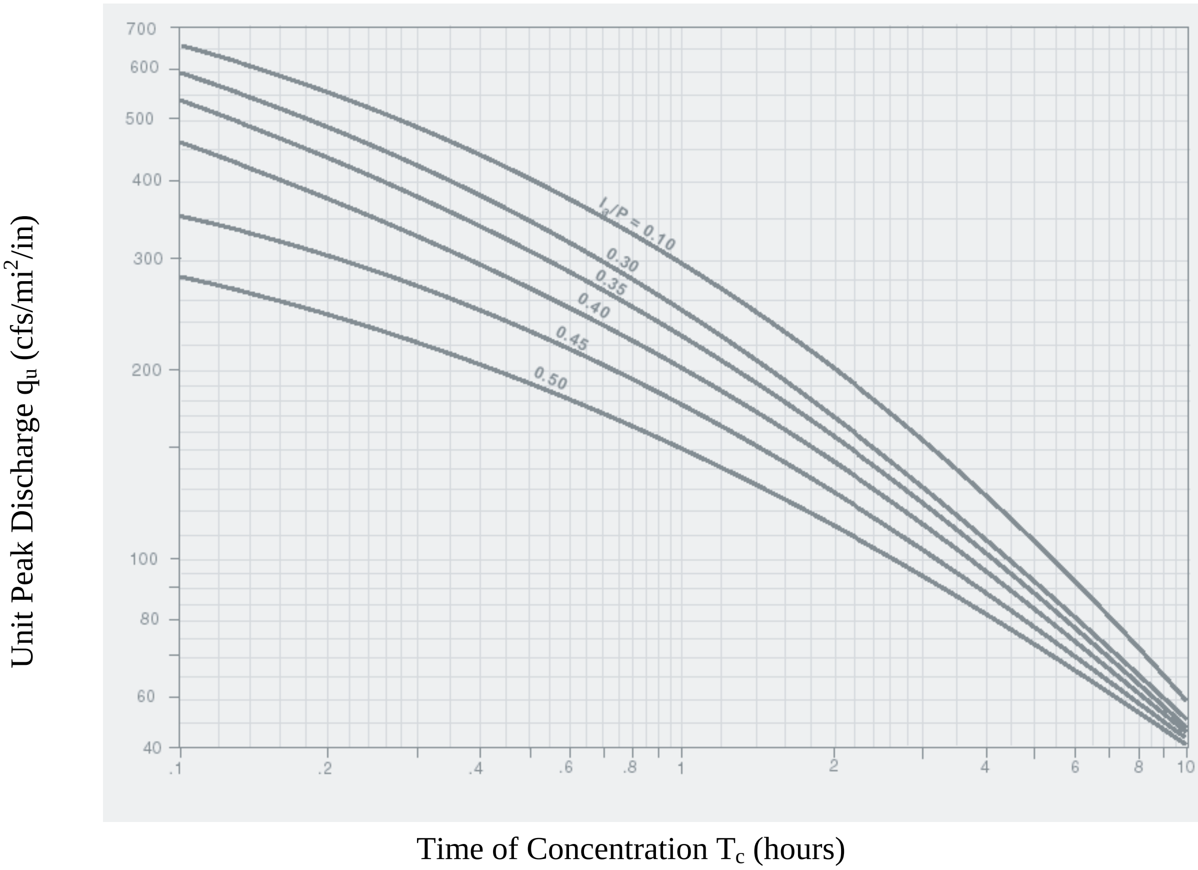

Figure 2-1 NRCS (SCS) Type III Unit Peak Discharge Graph

Hydrograph Generation

In addition to estimating the peak discharge, the NRCS (SCS) method can be used to estimate the entire hydrograph from a drainage area. The NRCS (SCS) has developed a Tabular Hydrograph procedure that can be used to generate the hydrograph for small 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, NRCS (SCS) has developed hydrograph procedures to be used to generate composite flood hydrographs.

For the development of a hydrograph from a homogeneous developed drainage area or from drainage area which is not homogeneous where hydrographs need to be generated from sub-areas and then routed and combined at a point downstream, the engineer is referred to the procedures outlined by the NRCS (SCS) in the 1986 version of TR-55 available from the National Technical Information Service in Springfield, Virginia 22161. The catalog number for TR-55, "Urban Hydrology for Small Watersheds," is PB87-101580.