Hydrology Training Series

Module 106

Peak Discharge Study Guide

Module Description

Objectives

Upon completion of this module, the participant will be able to:

1. Define peak discharge.

2. List the factors that affect peak discharge.

3. Identify and select the appropriate methods for computing peak discharge. 4. Compute peak discharge using Chapter 2, Engineering Field Manual.

The participant should be able to perform at ASK Level 3 (Perform with Supervision) after completing this module.

Prerequisites

Modules 102 - Precipitation; 103 - Runoff Concepts; 104 - Runoff Curve Number Computations; 105 - Runoff Computations; or their equivalent.

References

Chapter 2, Engineering Field Manual

Who May Take This Module

This module is intended for all SCS personnel who calculate peak discharge.

Content

Factors affecting peak discharge and methods of estimating peak discharge using Chapter 2, EFM are presented.

Introduction

Peak Discharge Data

Discharge is the rate of flow in a stream. Many different factors affect the discharge and need to be considered when planning a conservation practice. Peak discharge is the maximum rate of flow for a given condition and is used in the design of conservation measures.

The peak discharge commonly referred to by the Natural Resources Conservation Service is that flow which occurs when the maximum flood stage, or depth, is reached in a stream or water control structure as a result of a storm event. The peak, or maximum, rate of flow for a watershed will usually occur after the period of maximum rainfall intensity and when most of the watershed is contributing runoff. Peak discharges can also be caused by the melting of accumulated snow or by a combination of rain and snow melt in certain climatological regions. Peak discharge is also referred to as peak rate of discharge or peak rate of runoff. It is usually referred to in units of cubic feet per second, or cfs. That is the amount of water in cubic feet that would flow past the point of interest in one second at the maximum flood stage.

Peak discharges in small watersheds (under 2000 acres) are primarily used by BCS in the design of conservation practices that convey or store water. Peaks are used to size or proportion waterways, diversions, ponds, and other structures.

NRCS is primarily concerned with estimating the amount of the peak discharge in relation to a specified set of synthetic storm conditions. These specified conditions are stated in the conservation practice standards. The storm conditions are based on past experience and the consequences of partial or complete failure of the practice.

Factors That Affect Peak Discharge

Meteorological Factors

In nature, peak discharges are caused by complex interaction of many meteorological and watershed factors. In small watersheds, the key meteorological factors can be summarized as:

1. Amount of rainfall - An increase in the total amount of storm rainfall that occurs on a watershed within a specific time period should directly increase the peak discharge. NRCS amounts from National Weather Service maps for specified return periods.

2. Duration of rainfall - For a given amount of total storm rainfall, the shorter the time period it occurs in, the greater the peak discharge should be. If the same amount of rainfall occurs in a longer period, the peak discharge should decrease. NRCS adopted a 24-hour duration period for consistency.

3. Distribution of rainfall with time - The rainfall pattern within a given time period can have almost unlimited variations. The more uniform (constant rate) rainfall should result in a lower peak discharge than the same amount of rainfall occurring over the same time period, but starting at a low rate, then increasing rapidly to a maximum rate before tapering off. NRCS has adopted generalized storm distributions from measured rainfall data to approximate intensity relationships for the major climatological regions of the United States.

4. Temperature - In certain climatological regions where snow cover is prevalent during the storm season, temperature directly affects the peak discharge. High temperatures, especially with rainfall added to snow melt, should create higher peak discharges than lower temperatures when the snow melt processes are slowed. The generalized peak discharge estimating procedure used by NRCS assumes that snow melt is not a significant factor during the high intensity thunderstorm type events that cause the majority of the major flood peaks on small watersheds.

The smaller the watershed, the more significant individual watershed characteristics become in influencing peak discharges. The key watershed factors affecting peak discharges are:

1. Size - The larger the watershed, given similar characteristics, the larger the peak discharge.

2. Shape - The more compact a watershed, the larger the peak discharge would normally be (as compared to the peak from an elongated watershed of the same size and characteristics). This is related to the relative length of the major flow path and the size, duration, and intensity of the rainfall. It takes a shorter time for the entire compact watershed to contribute runoff to the peak rate, thus causing the higher discharge.

3. Slope - Like shape, the watershed with steeper slopes should produce the larger peak discharge, if the watershed characteristics and size were kept constant.

4. Cover - The type of cover, vegetative or impervious surfaces, directly affects the amount of runoff. This, in turn, affects the peak discharge. Everything else equal, the less vegetative cover or more impervious the surface, the higher the peak discharge.

5. Hydrologic condition - Decreased density of vegetation will normally increase runoff by lowering the interception and infiltration potential. This, in turn, increases the peak discharge rate.

6. Hydrologic soil groups - The higher the infiltration potential of the soil, the lower the potential peak discharge rate.

7. Surface storage - The greater the surface storage, everything else being equal, the smaller the peak discharge. Water can be trapped in surface depressions where it can infiltrate over a period of time. Man-made or natural ponded areas can also capture runoff and release it, over time, at lower rates. Thus, storage can reduce total runoff and prolong the time it takes for the entire watershed to contribute runoff to the peak rate. This causes a lower discharge.

8. Antecedent Runoff Condition - The soil moisture content prior to a storm has a major affect on the peak discharge. The amount and distribution of prior rainfall and the infiltration potential contribute to the soil moisture content. The wetter the Antecedent Runoff Condition, the larger the amount of storm runoff and the larger the peak discharge.

9. Agricultural practices - Tillage, management, and land treatment practices can affect the amount of runoff contributing to peak discharge. Practices that increase infiltration and surface storage potential, and lengthen flow paths tend to decrease peak discharge. Practices that shorten flow paths usually increase peak discharge. These effects are greater for small storms and may not be significant for major flood producing storms.

The Natural Resources Conservation Service has been estimating peak discharge for design of conservation practices since the 1930's. The earlier methods were adaptations of empirical equations, like the rational equation in vogue by engineering professionals at the time.

Agricultural research stations were established. Precipitation, runoff, and peak discharge data were collected and analyzed to provide more physical parameters for agricultural practices in the estimating procedure.

In the 1950's, NRCS perfected its current runoff curve number and hydrograph development concepts for the Public Law 566 watershed program. These new procedures were tested and used by NRCS engineers to develop peak discharges for design of structural measures and to evaluate their downstream effects. These research-based procedures use NRCS soil classification information and can account for changes in watershed characteristics.

The procedures were well suited for small ungaged watersheds and even gaged watersheds affected by man-made improvements. Runoff and peak discharge estimates were complicated, but standardized for consistency with parameters based on evaluation of physical data. In the early 1960's, the procedures were simplified for use in the design of conservation and water control practices.

NRCS usually uses four levels of peak discharge estimating procedures. The choice for a specific use should be based on the size and complexity of the watershed, the importance of the use, the potential for adverse affects, and the knowledge and skills of the user. The four most widely used NRCS handbook methods for estimating peak discharge are listed below for your information in order of simplicity and level of knowledge required to use them properly. The Engineering Field Manual, Chapter 2, method is the easiest to apply and is recommended for most field office applications. Each method will be briefly discussed, with its intended applications, limitations, and requirements noted.

The EFM, Chapter 2 method was developed for:

1. Low risk applications in primarily agricultural areas.

2. Drainage areas under 2000 acres.

3. Homogeneous watersheds that can be represented by one curve number.

4. Watersheds where the time in which the peak discharge occurs is not critical in the determination of detailed effects of surface storage or downstream peak discharge.

5. Climatological areas where the NRCS standard, 24-hour rainfall distributions are applicable.

6. Single storm events where the runoff exceeds 0.5 inches.

7. Users with limited knowledge and experience in hydrology.

Technical Release No. 55, Chapter 4 Method (1986 Version or later)

The NRCS Technical Release No. 55, Chapter 4, Graphical Peak Discharge Method, revised in 1986, was developed for:

1. Low to medium risk applications in primarily urban or urbanizing areas. It can also be used in agricultural areas.

2. Drainage areas where the time of flow from the headwater to the peak discharge estimate point (time of concentration) does not exceed 10 hours.

3. Homogenous watersheds that can be represented by one curve number.

4. Watersheds where the time in which the peak discharge occurs is not critical in the determination of detailed effects of available storage or downstream peak discharges.

5. Climatological areas where the NRCS standard, 24-hour rainfall distributions are applicable.

6. Single storm events where runoff exceeds 0.5 inches.

7. Users with knowledge and experience in computing time of concentration, but with limited understanding of hydrology.

Technical Release No. 55, Chapter 5 Method (1986 Version or later)

The NRCS Technical Release No. 55, Chapter 5, Tabular Hydrograph Method, revised in 1986, was developed for:

1. Low to medium risk applications in urban, urbanizing and rural areas.

2. Drainage areas subdivided into homogeneous subwatersheds where the time of concentration does not exceed two hours and the time it takes for flow to pass from the subwatershed outlet to the peak discharge estimate point (travel time) does not exceed three hours.

3. Watersheds that are not homogeneous, but can be subdivided into homogeneous subwatersheds, each represented by one curve number.

4. Climatological areas where the sas standard, 24-hour rainfall distributions are applicable.

5. Single storm events where runoff exceeds 0.5 inches.

6. Users with knowledge and experience in computing time of concentration and some understanding of hydrology.

Technical Release No. 20 (1985 Version or later)

The NRCS Computer Program for Project Formulation - Hydrology (TR-20) was developed for:

1. Medium to high risk applications and complex agricultural or urban areas.

2. Complex drainage areas that need to be subdivided.

3. Non-homogeneous watersheds that can be subdivided into homogeneous subwatersheds, each represented by one CN.

4. Single storm events with various storm durations and distributions, but where runoff exceeds 0.5 inches.

5. Users with good working knowledge and experience in hydraulics and hydrology.

The TR-20 computer program was used to develop the procedures in the simplified methods. The above methods, as shown by the special requirements, are listed in order of simplicity. Due to assumptions and techniques. the methods can produce different results. This is to be expected. The simplifications require less input by generalizing some of the individual watershed characteristics. Therefore, the peak discharge computation level must be chosen considering the risk associated with an application.

Other Training

This module provides training in the use of the EFM, Chapter 2 method for peak discharge estimation. Detailed training on the other methods discussed is given in:

Module 206B: TR-55. Chapter 4. Graphical Peak Discharge Method Module 206C: TR-55. Chapter 5, Tabular Hydrograph Method

Module 252: TR-20. Computer Program for Project Formulation - Hydrology

Computing Peak Discharge Using EFM, Chapter 2 Method

The Engineering Field Manual, Chapter 2 Method was designed to provide a quick peak discharge directly from a graph. It should only be used for low risk applications on small , homogeneous watersheds, or as a check for "reasonableness- on more complex methods.

Since the intensity of rainfall varies considerably during a storm period, NRCS has developed four typical 24-hour storm distribution types for the climatic regions of the United States. These synthetic distributions, based on U.S. National Weather Service data, are shown in Figure B-1 (Appendix A, page A3).

Type IA contains the least intense and Type 2 the most intense short duration rainfall that contributes to peak discharge. Short duration rainfall intensities are nested within longer duration intensities of the same probability level to provide distributions that will result in comparable peaks for the range of drainage areas considered in Chapter 2, EFM.

Type I and IA distributions are typical of the Pacific maritime climate with wet winters and dry summers. Type 3 represents the Gulf of Mexico and Atlantic coastal areas where tropical storms occur with large 24-hour rainfalls. The Type 2 storm distribution is typical of the rest of the United States, Puerto Rico, and the Virgin Islands. Figure 2-1, Chapter 2, EFM shows the approximate geographic boundaries for these rainfall distributions (Appendix A, page A4).

Responsibility for establishing the storm type to use in a state rests on the NRCS State Conservation Engineer.

Usually, only the peak discharge graphs that apply to an NRCS field office are distributed, but it is the user's responsibility to s~ that the proper ones are being used. Each standard NRCS 24-hour distribution (see Module 202 for complete description of storm types) has its own graph.

The only requirements for the EFM, Chapter 2 method of determining peak discharge are:

1. Drainage area.
2. Flow length.
3. Average watershed slope.
4. Runoff curve number.
5. 24-hour rainfall amount.
6. Initial abstraction/total rainfall ratio.

Drainage Area

The drainage area is the watershed upstream of the point where the peak discharge estimate is to be made. It consists of the area, in acres that contributes discharge to that point. The drainage boundary can be identified and outlined on maps or photos. The area within the boundary should be measured by grid counters or planimeters and converted to acres.

The drainage area is usually the entire watershed area, but potholes and marshland areas may be excluded if they do not contribute to the peak discharge. A rule of thumb is that, if potholes or marshland areas make up one-third or less of the total watershed area and they do not intercept the drainage from the remaining two-thirds, they may be excluded from the drainage area. If these areas are greater than one-third of the total watershed or, if they intercept the drainage area, the EFM, Chapter 2, method should not be used to compute the peak discharge. A more complex method requiring time of concentration and, possibly, subdividing and storage routing should be used.

Flow Length

The flow length is usually the longest flow path in the drainage area from the watershed divide to the point where the peak discharge estimate is desired. This flow path can be identified and marked on maps or photos with known scales. The flow length can be measured by a map wheel, or by marking the length along the edge of a sheet of paper and measuring its length and converting the scale to feet.

Flow length in non-contributing drainage areas may be excluded from the flow path, but other flow paths should be considered that would result in longer flow lengths.

Average Watershed Slope

The average watershed slope is the average slope of the land within the drainage area and not the water-course slope. It is expressed in percent.

Land slope is available at most field office locations from existing soil survey data. Land slope can also be measured on hillsides using a level in the direction of overland flow or by measuring the distance between contours (L) on a USGS topographic quad sheet, and noting the vertical distance (H) between the end contours. The land slope in percent can then be calcu1ated as

$$Y = H/L*100$$

The average watershed slope is obtained by weighing or averaging the individual land slope measurements to represent a composite, single slope value for the watershed. In most low risk cases, this composite slope value can be estimated accurately enough by NRCS personnel familiar with the area.

If the average watershed slope needs to be determined more systematically, it can be weighed by a grid method or total contour method. Other, more precise methods are not warranted.

In the grid-method, a transparent grid, or dot counter, is placed over a soils map or quad sheet with the watershed outlined. The land slope in the vicinity of each of the grid intersections or dots, within the watershed, is estimated and tabulated. The average watershed slope is computed by summarizing the land slopes and dividing by the number of values. The accuracy of the peak discharge method does not warrant use of a small grid. Five to ten points would define most small watersheds.

In the total contour method, the average watershed slope is computed from the quad sheet by measuring the total lengths of all contours within the watershed, in feet, with a map wheel or similar device. For the computations, the contour interval (N) in feet and drainage area (A) are needed. The
average watershed slope in percent, is equal to:
If you are unsure about either method, your Resource Person should be able to help you.

$$Y = MN/A * 100$$

Runoff Curve Number

A single composite runoff curve number (CN) is required for the watershed, based on the average Runoff Condition. The procedure to calculate the composite curve number is given in Module 104 - Runoff Curve Numbers. When using the Type IA rainfall graph, a special table of runoff curve numbers should be used. This module will not cover its use.

Rainfall

The 24-hour rainfall amount (P) has to be determined based on the selected return period .The return period is usually set by NRCS state practice standards.

The amount can be determined directly from National Weather Service maps, which are reproduced in Chapter 2, EFM. Some states have furnished supplements which have blown-up state rainfall maps or tabulated amounts by counties.

Initial Abstraction

Initial abstraction is all rainfall losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration.

Additional information on rainfall amounts, return periods, and distributions is given in Module 102 - Precipitation. .

EFM	Step
1. Determine contributing drainage area (A) 2. Determine average watershed slope (Y).	
3. Determine runoff curve number (CN). 4. Obtain the design return period from SCS standards in the Field Office Technical Guide, Section 4.	Table 2-3 (Appendix A, pages AS-A9)
5. Determine the 24-hour rainfall amount (P) from maps or tables.	Figure 2-2 to 2-5 (Appendix, pages A10-A12)
6. Find which type 24-hour storm distribution is recommended for the area. 7. Determine the flow length (I).	Figure 2-1 (Appendix, page A4)
8. Determine Te in hours.	Figure 2-27 (Appendix, page A13)
9. Determine the runoff volume (a) for the P and CN. Module 10S gives the details of computation.	Table 2-2 (Appendix, page AS)
10. Determine I. and then the lIP ratio. If the lIP< 0.1, use 0.1; if the IJP> 0.5, use O.S	Table 2-4 (Appendix, page A14)
11. Locate the proper graph of Te versus unit peak discharge, qu.	Exhibit 2 (Appendix, page A15)
12. Determine for appropriate rainfall distribution.	

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Example 1 Using the EFM, Chapter 2 method and Worksheet 2 (page 19), estimate the peak discharge from a watershed of 200 acres with an average slope of 2% and a hydrologic soil group of C. The watershed is all row crops that are contoured and terraced and are in good hydrologic condition. The planned structure is low value and has a return period (frequency) of 5 years. The location is western Nebraska. The flow length is 5000 ft.

All exhibits used in this example are in Appendix A of this module. Enter your data on Worksheet 2.

1. Given: Drainage area, A = 200 ac

2. Given: Average watershed slope, Y = 2%

3. Using hydrologic soil group C, row crops that are contoured and terraced, and are in good conditions, enter Table 2·3 and read CN = 78.

4. Given: Return period = 5 yr

5. Using the 5·yr, 24·hr rainfall chart (Exhibit 2·3, Sheet 2 of 5), locate western Nebraska, and read P = 3.0 in.

6. From figure 2·1, determine that western Nebraska has a Type II storm distribution.

7. Given: Flow length, 1 = 5000 ft

8. Using Figure 2·27, read T = 1.44 hrc

9. For CN = 78 and P = 3.0 in, use Table 2·2 to find runoff volume, Q = 1.13 in

10. Using Table 2·4, find I = 0.564 in a Determine lip: liP = 0.564 in/3.0 in = 0.19

11. Using Exhibit 2·II for the Type II storm distribution, find <I.. = 0.40 cfs/ac/in

12. Calculate the peak discharge: = <I.. A = (0.40) (200) (1.13) = 90.4 or 90 cfs

Example 1

Worksheet 2Estimating Time of Concentration and peak discharge

Client ___________________________ By____________ Date__________

County______________________ State_________ Checked____________ Date__________

Practice_______________________________

Estimating time of concentration

1. Data			
Rainfall distribution type	=		(I,IA,II,III)
Drainage area	A=		Ac
Runoff curve number	CN=		
Watershed slope	Y=		%
Flow length	ℓ		Ft
2. T_c using /,Y,CN and figure 2-27 or equation 2-5			
3. $T_c = \frac{\left[l^{.8}\left(\frac{1000}{CN}-9\right)^{.7}\right]}{1140Y^{.5}} = \frac{[(\quad)^{.8}(\quad)^{.7}]}{1140(\quad)^{.5}} = \_\_\_\_\_ hrs$			

Estimating peak discharge	Storm#1	Storm#2	Storm #3
1. Frequency……………………………….……yr			
2. Rainfall,P (24hour)……………….……….in			
3. Initial abstraction,I_a……………………….in			
4. Compute I_a/P ratio…………………………….			
5. Unit peak discharge q_w……………cfs/ac/in (Use T_c and I_a/P with exhibit 2-__)			
6. Runoff Q……………………………………..in (use P and CN with figure 2-6 or table 2-2)			
7. Peak discharge, q_p……………………..cfs (where q_p=q_uAQ) [A*5*6]			

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Example 1- Solution

Worksheet 2Estimating Time of Concentration and peak discharge

Client ______Module 106________ By___DEW_____ Date_5/3/88___

County______________________ State____NE____ Checked__X2___ Date___5/4/88__

Practice_______Example 1______________________

Estimating time of concentration

4. Data			
Rainfall distribution type	=	II	(I,IA,II,III)
Drainage area	A=	200	Ac
Runoff curve number	CN=	78	
Watershed slope	Y=	2	%
Flow length	ℓ	5000	Ft
5. T_c using /,Y,CN and figure 2-27 or equation 2-5		1.44	
6. $T_c = \frac{\left[l^{.8}\left(\frac{1000}{CN}-9\right)^{.7}\right]}{1140Y^{.5}} = \frac{[(\quad)^{.8}(\quad)^{.7}]}{1140(\quad)^{.5}} = \_\_\_\_ hrs$			

Estimating peak discharge	Storm#1	Storm#2	Storm #3
8. Frequency……………………………………yr	5		
9. Rainfall,P (24hour)……………………….in	3		
10. Initial abstraction,I_a……………………..in	.564		
11. Compute I_a/P ratio……………………………	.19		
12. Unit peak discharge q_w…………..cfs/ac/in (Use T_c and I_a/P with exhibit 2-__)	.40		
13. Runoff Q……………………………………in (use P and CN with figure 2-6 or table 2-2)	1.13		
14. Peak discharge, q_p…………………….....cfs (where $q_p=q_uAQ$) [A*5*6]	90		

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Summary

By now you have proven that you can compute peak runoff using the Engineering Field Manual, Chapter 2 method. This will allow you to work with small watersheds. As you complete other training modules, or learn other methods for computing peak discharges, you may want to compare the results. Above all, remember to use only computation methods that have been approved for use in your Field Office or area.

Retain this Study Guide as a reference until you are satisfied that you have successfully mastered all the methods covered. It will provide an easy review at any time if you should encounter a problem.

If you have had problems understanding the module or if you would like to take additional, related modules, contact your supervisor.

Table 2-3b.-Runoff curve numbers for other agricultural lands'

Cover description Cover type	Hydrologic condition	Curve numbers for hydrologic soil group-			
		A	B	C	D
Pasture, grassland, or range-continuous forage for grazing.2	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.3	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	34	48	65	73
Woods-grass combination (orchard or tree farm).5	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	3()4	55	70	77
		59	74	82	86

Farmsteads-buildings, lanes, driveways, and surrounding lots.

'Average runoff condition.
2Poor: <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.
2Poor: <50% ground cover.
Fair: 50 to 75% ground cover.
Good: > 75% ground cover.
~Actual curve number is less than 30; use CN . 30 for runoff computations.
ICN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture. .
'Poor: Forest, litter, small trees, and brush have been destroyed by heavy grazing or regular burning.
FBir: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 2-3c.-Runoff curve numbers for 8'Id and farmland rangeland.'

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Figure B-1.—SCS 24-*Hour rainfall distributions.*

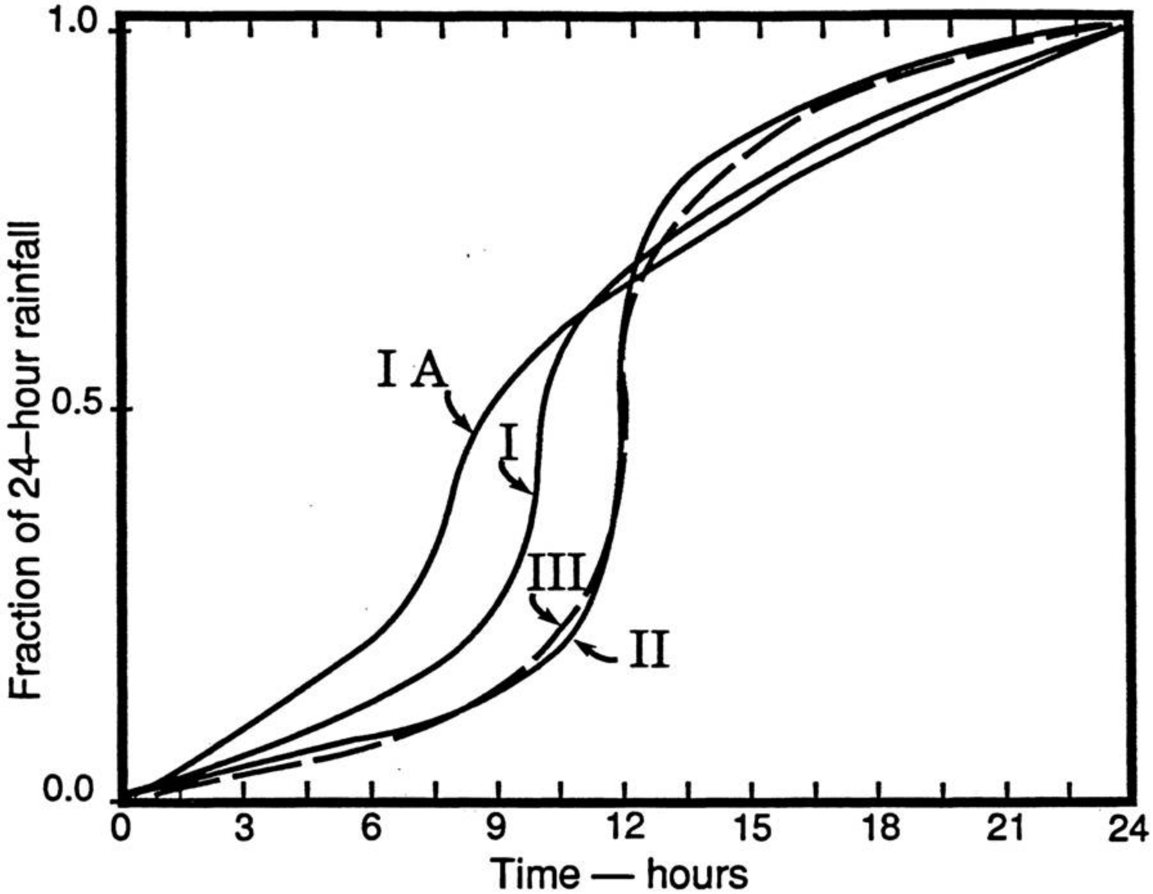

Figure 2-1 —Approximate geographic boundaries for SCS rainfall distributions

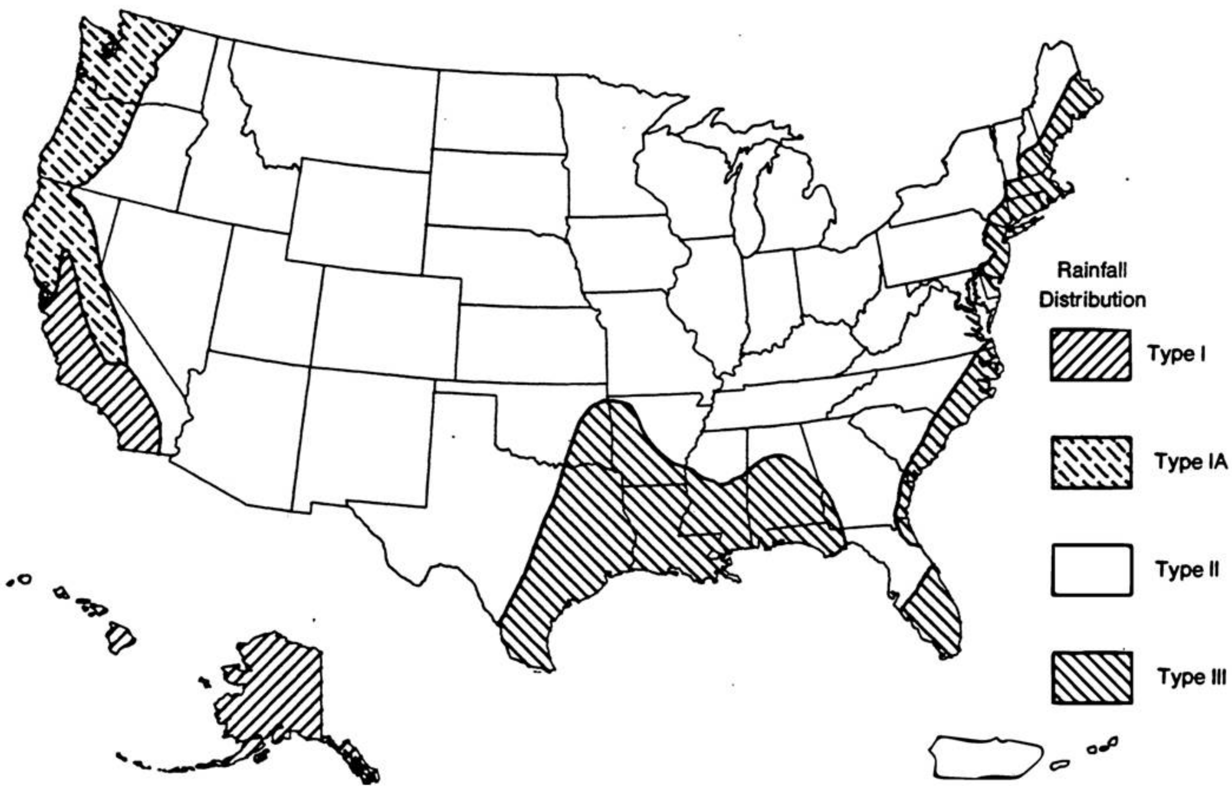

Table 2-2.-Runoff depth for selected CN'. and rainfall amount.1												
Runoff (Q) for curve number of-												
Rainfall	40	45	50	55	60	65	70	75	80	85	90	95
	--	-	-	-	-	-	-	-	-	-	---	-
1	0	0	0	0	0	0	0	0.03	0.08	0.17	0.32	0.56
1.2	0	0	0	0	0	0	0.03	0.07	0.15	0.27	0.46	0.74
1.4	0	0	0	0	0	0.02	0.06	0.13	0.24	0.39	0.61	0.92
1.6	0	0	0	0	0.01	0.05	.1 1	0.2	0.34	0.52	0.76	1.11
1.8	0	0	0	0	0.03	0.09	0.17	0.29	0.44	0.65	0.93	1.29
2	0	0	0	0.02	0.06	0.14	0.24	0.38	0.56	0.8	1.09	1.48
2.5	0	0	0.02	0.08	0.17	0.3	0.46	0.65	0.89	1.18	1.53	1.96
3	0	0.02	0.09	.1 9	0.33	0.51	0.71	0.96	1.25	1.59	1.98	2.45
3.5	0.02	0.08	0.2	0.35	0.53	0.75	1.01	1.3	1.64	2.02	2.45	2.94
4	0.06	0.18	0.33	0.53	0.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43
4.5	0.14	0.3	0.5	0.74	1.02	1.33	1.67	2.05	2.46	2.91	3.4	3.92
5	0.24	0.44	0.69	0.98	1.3	1.65	2.04	2.45	2.89	3.37	3.88	4.42
6	0.5	0.8	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.3	4.85	5.41
7	0.84	1.24	1.68	2.1 2	2.6	3.1	3.62	4.15	4.69	5.25	5.82	6.41
8	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.4
9	1.71	2.29	2.88	3.49	4.1	4.72	5.33	5.95	6.57	7.18	7.79	8.4
10	2.23	2.89	3.56	4.23	4.9	5.56	6.22	6.88	7.52	8.16	8.78	9.4
11	2.78	3.52	4.26	5	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39
12	3.38	4. 19	5	5.79	6.56	7.32	8.05	8.76	9.45	10.1 1	10.76	11 .39
13	4	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42-	11.1	11.76	12.39
14	4.65	5.62	6.55	7.44	8.3	9.1 2	9.91	10.67	11 .39	12.08	12.75	13.39
15	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39

Table 2.3 runoff curve numbers for cultivated agricultural lands

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Cover description	curve numbers for hydrologic soil group-					
Cover type	Treatment2	Hydrologic condition3	A	B	C	D
Fallow	Bare soil		n	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row + CR	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured + CR	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

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Table 2-3b.-Runoff curve numbers for other agricultural lands1					
Cover description	Curve numbers for hydrologic soil group-				
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range-continuous forage for grazing.2 .	Poor Fair Good	68 49 39	79 69 61	86 79 74	89 84 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.3	Poor Fair Good	48 35 34	67 66 48	77 70 65	83 77 73
Woods-grass combination (orchard or tree farm).5	Poor Fair Good	57 43 32	73 65 58	82 76 72	86 82 79
Woods'	Poor Fair Good	45 36 34	66 60 55	77 73 70	83 79 77
Farmsteads-buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

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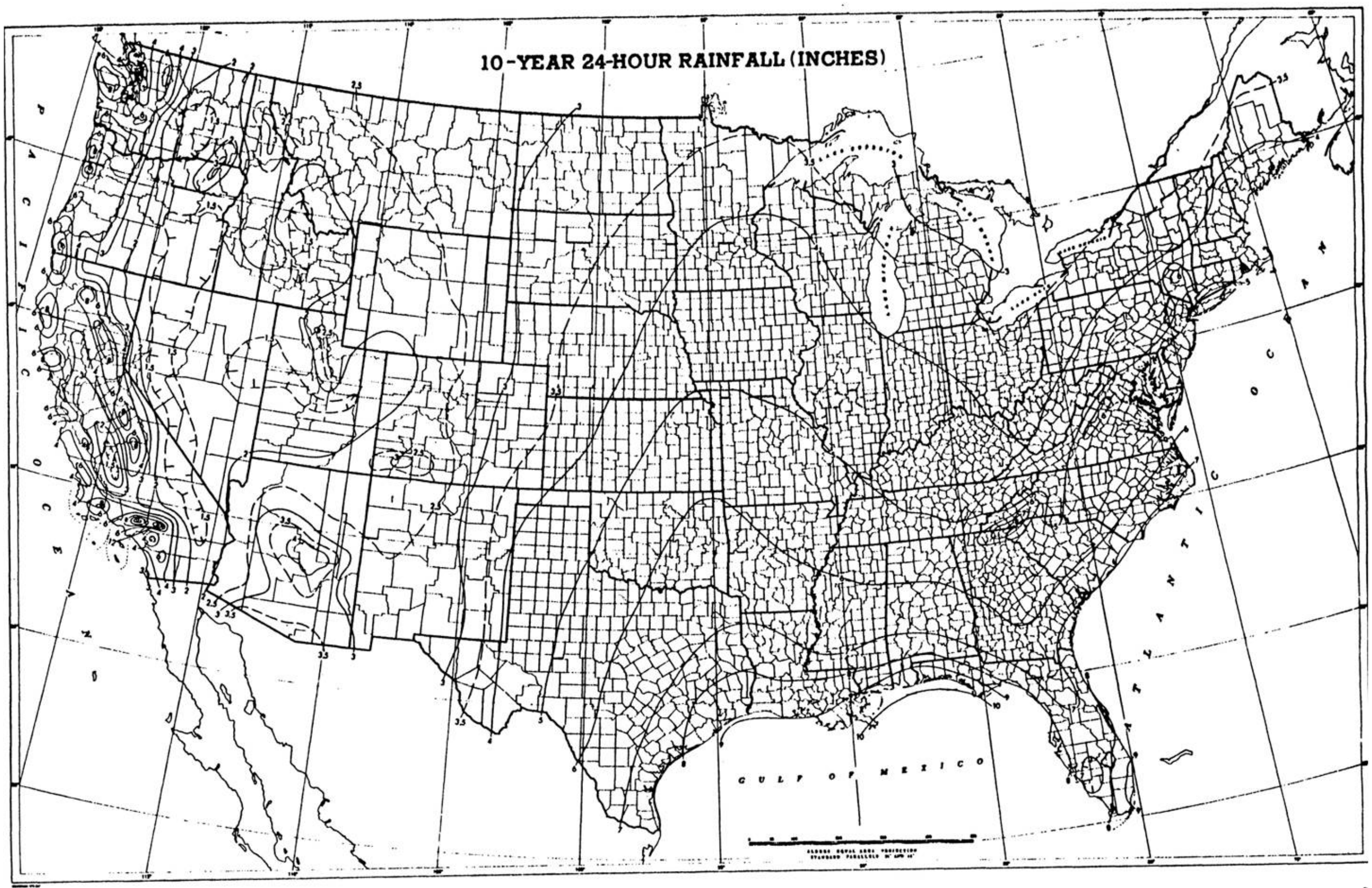
5-YEAR 24-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO


10-YEAR 24-HOUR RAINFALL (INCHES)
GULF OF MEXICO

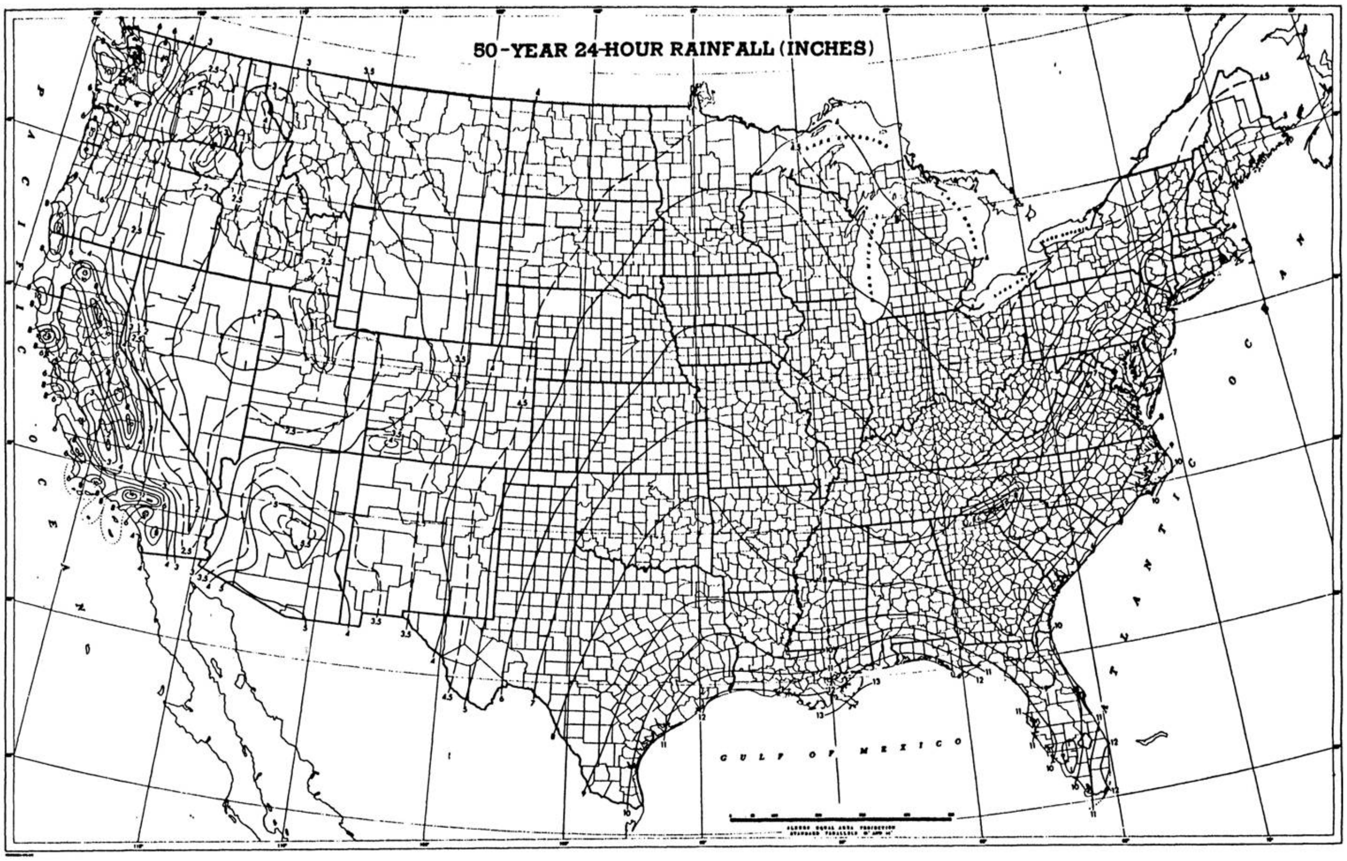
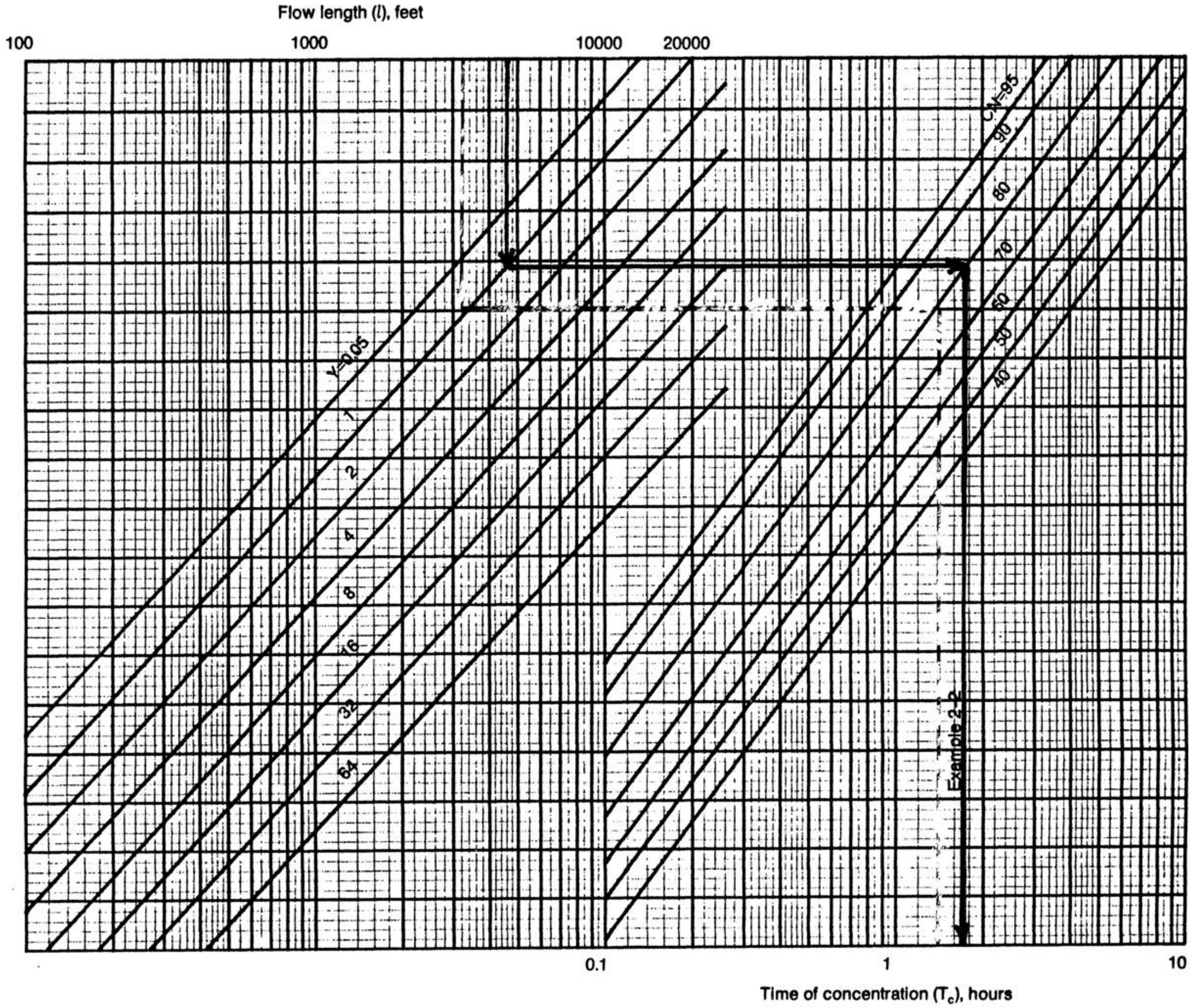

50-YEAR 24-HOUR RAINFALL (INCHES)
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN

Figure 2-27 .—Time of concentration (T_c) nomograph



0Table 2-4.-1. values for runoff curve numbers			
Curve number	18 (in)	Curve number	18 (in)
40	3.000	68	0.941
41	2.878	69	0.899
42	2.762	70	.0.85 7
43	2.651	71	0.817
44	2.545	72	0.778
45	2.444	73	0.740
46	2.348	74	0.703
47	2.255	75	0.667
48	2.167	76	0.632
49	2.082	77	0.597
50	2.000	78	0.564
51	1.922	79	0.532
52	1.846	80	0.500
53	1.774	81	0.469
54	1.704	82	0.439
55	1.636	83	0.410
56	1.571	84	0.381
57	1.509	85	0.353
58	1.448	86	0.326
59	1.390	87	0.299
60	1.333	88	0.273
61	1.279	89	0.247
62	1.226	90	0.222
63	1.175	91	0.198
64	1.125	92	0.174
65	1.077	93	0.151
66	1.030	94	0.128
67	0.985	95	0.105

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Exhibit 2-II —**Unit peak discharge (q_u) for SCS Type II rainfall distribution**

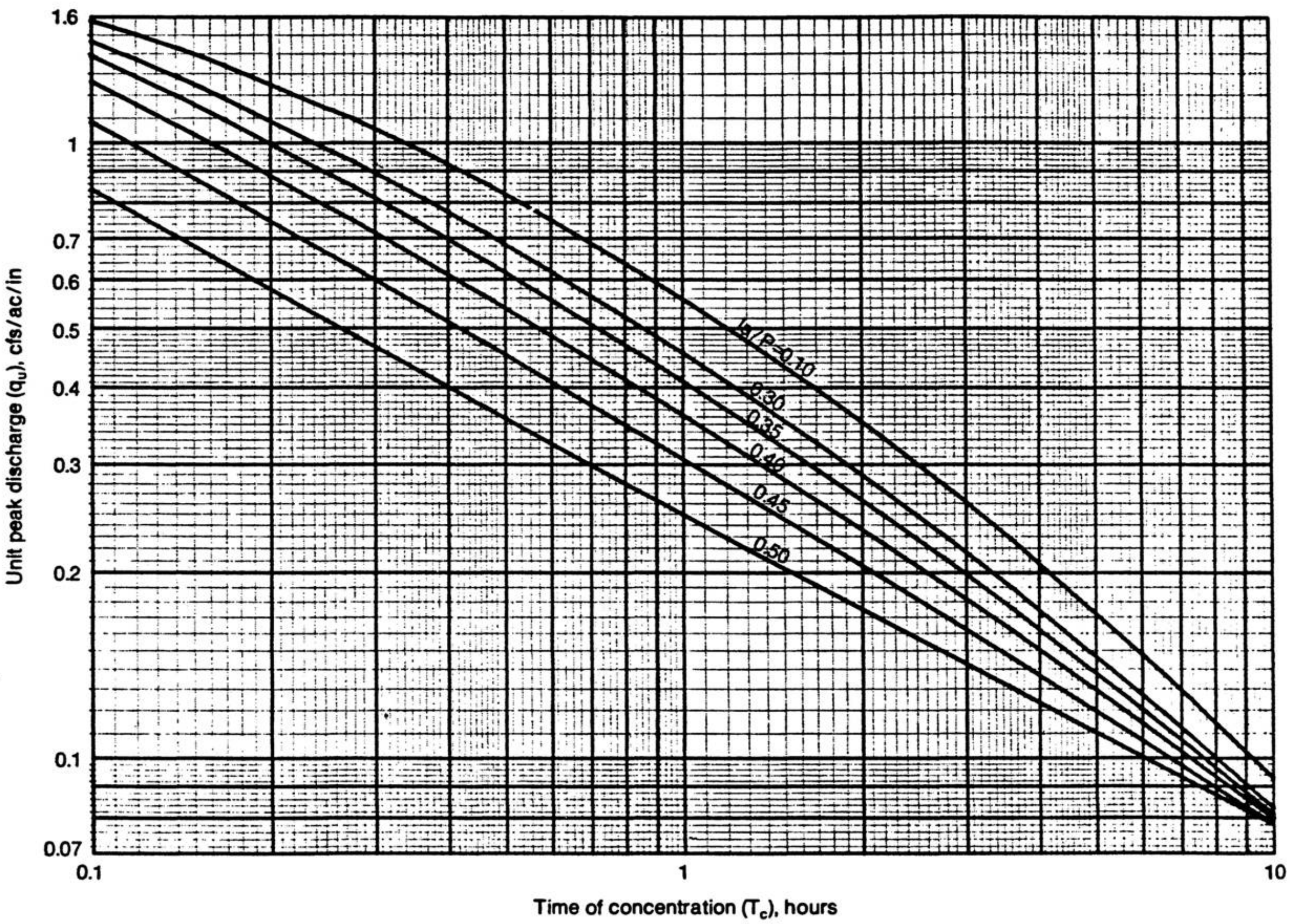

Exhibit 2-II-Unlt peak discharge (q_u) for NRCS Type II rainfall distribution

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ENG - Hydrology Training Series.

Example 1

Worksheet 2Estimating Time of Concentration and peak discharge

Client ________________________ By___________ Date_________

County____________________ State_______ Checked___________ Date_________

Practice____________________________

Estimating time of concentration

7. Data			
Rainfall distribution type	=		(I,IA,II,III)
Drainage area	A=		Ac
Runoff curve number	CN=		
Watershed slope	Y=		%
Flow length	ℓ		Ft
8. T_c using /,Y,CN and figure 2-27 or equation 2-5			
9. $T_c = \frac{\left[l^{.8}\left(\frac{1000}{CN}-9\right)^{.7}\right]}{1140Y^{.5}} = \frac{[(\quad)^{.8}(\quad)^{.7}]}{1140(\quad)^{.5}} =$ _____ hrs			

Estimating peak discharge	Storm#1	Storm#2	Storm #3
15. Frequency……………………………………yr			
16. Rainfall,P (24hour)……………………….in			
17. Initial abstraction,I_a……………………..in			
18. Compute I_a/P ratio………………………….			
19. Unit peak discharge q_w…………..cfs/ac/in (Use T_c and I_a/P with exhibit 2-__)			
20. Runoff Q………………………………….…..in (use P and CN with figure 2-6 or table 2-2)			
21. Peak discharge, q_p……………….……..cfs (where q_p=q_uAQ) [A*5*6]			

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Activity 1

Assume that only a single factor is changed on each of the 13 watershed factors listed below. Indicate whether there would be an increase or decrease in peak discharge.

	Meteorological Factors	Change From	To	Peak Discharge Increase	Peak Discharge Decrease
1.	Amount of storm rainfall	3 inches	6 inches		
2.	Duration of storm rainfall	2 hours	12 hours		
3.	Storm distribution with time	Steady rate	Highly variable rate		
4.	Storm distribution with area	Complete coverage	Partial coverage		
5.	Temperature snow melt	25°F	50°F		
	Watershed Characteristics				
6.	Size	10 acres	20 acres		
7.	Shape	Elongated	Round		
8.	Slope	Steep	Flat		
9.	Cover	Pasture	Corn		
10.	Hydraulic condition	Heavily grazed	Fenced off		
11.	Surface storage	Smooth surface	Marsh		
12.	Antecedent Runoff Condition	Dry	Wet		
13.	Agricultural practices	Straight uphill rows	Terraces		

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Activity 2 .

Which peak discharge procedure would be recommended for the following situations? Please identify the procedure by number. as shown below:

1 = EFM Chapter 2
2 = TR-55 Chapter 4 - Graphical
3 = TR-55 Chapter 5 - Tabular Hydrograph
4 = TR-20 Computer Program

Requirement	Procedure
1. Design a waterway for a aopland watershed of 20 acres. and the lower 2J3 is parkland.	
2. Evaluate a large drainage inlet structure above a road at the outlet of the 300 acre watershed. The upper third of the drainage area is converted to housing, \ftt1ich drains into a sediment basin,	
3. Evaluate a 300 acre agricultural watershed that is converted to a housing development with 1/4 acre lots.	
4. Evaluate the above watershed if only the upper third was allowed to be developed.	

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Activity 1- Solution

Assume that only a single factor is changed on each of the 13 watershed factors listed below. Indicate whether there would be an increase or decrease in peak discharge.

Meteorological Factors	Change From	To	Peak Discharge Increase	Decrease
1.Amount of storm rainfall	3 inches	6 inches	X	
2.Duration of storm rainfall	2 hours	12 hours		X
3.Storm distribution with time	Steady rate	Highly variable rate	X	
4.Storm distribution with area	Complete coverage	Partial coverage		X
5.Temperature snow melt	25°F	50°F	X	
Watershed Characteristics				
6.Size	10 acres	20 acres	X	
7.Shape	Elongated	Round	X	
8.Slope	Steep	Flat		X
9.Cover	Pasture	Corn	X	
10.hydraulic condition	Heavily grazed	Fenced off		X
11.Surface storage	Smooth surface	Marsh		X
12.Antecedent Runoff Condition	Dry	Wet	X	
13.Agricultural practices	Straight uphill rows	Terraces		X

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Activity 2 - Solution

Which peak discharge procedure would be recommended for the following situations? Please identify the procedure by number, as shown below:

1 = EFM Chapter 2
2 = TR-55 Chapter 4 - Graphical

3 = TR-55 Chapter 5 - Tabular Hydrograph 4 = TR-20 Computer Program

Requirement	Procedure
1. Design a waterway for a aopland watershed of 20 acres and the lower 2/3 is parkland.	1
2. Evaluate a large drainage inlet structure above a road at the outlet of the 300 acre watershed. The upper third of the drainage area is converted to housing, \ftt1ich drains into a sediment basin,	4
3. Evaluate a 300 acre agricultural watershed that is converted to a housing development with 1/4 acre lots.	2
4. Evaluate the above watershed if only the upper third was allowed to be developed.	3

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Table 2-3b.-Runoff curve numbers for other agricultural lands'					
Cover description Cover type	Hydrologic condition	Curve numbers for hydrologic soil group-			
		A	B	C	D
Pasture, grassland, or range-continuous forage for grazing.2	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.3	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	34	48	65	73
Woods-grass combination (orchard or tree farm).5	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	3()4	55	70	77
		59	74	82	86

Farmsteads-buildings, lanes, driveways, and surrounding lots.

'Average runoff condition.
2*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.
2*Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: > 75% ground cover.
~Actual curve number is less than 30; use CN . 30 for runoff computations.
ICN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture. .
'Poor: Forest, litter, small trees, and brush have been destroyed by heavy grazing or regular burning.
FBir: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 2-3c.-Runoff curve numbers for 8'Id and farmland rangeland.'

Figure B-1.—SCS 24-*Hour rainfall distributions.*

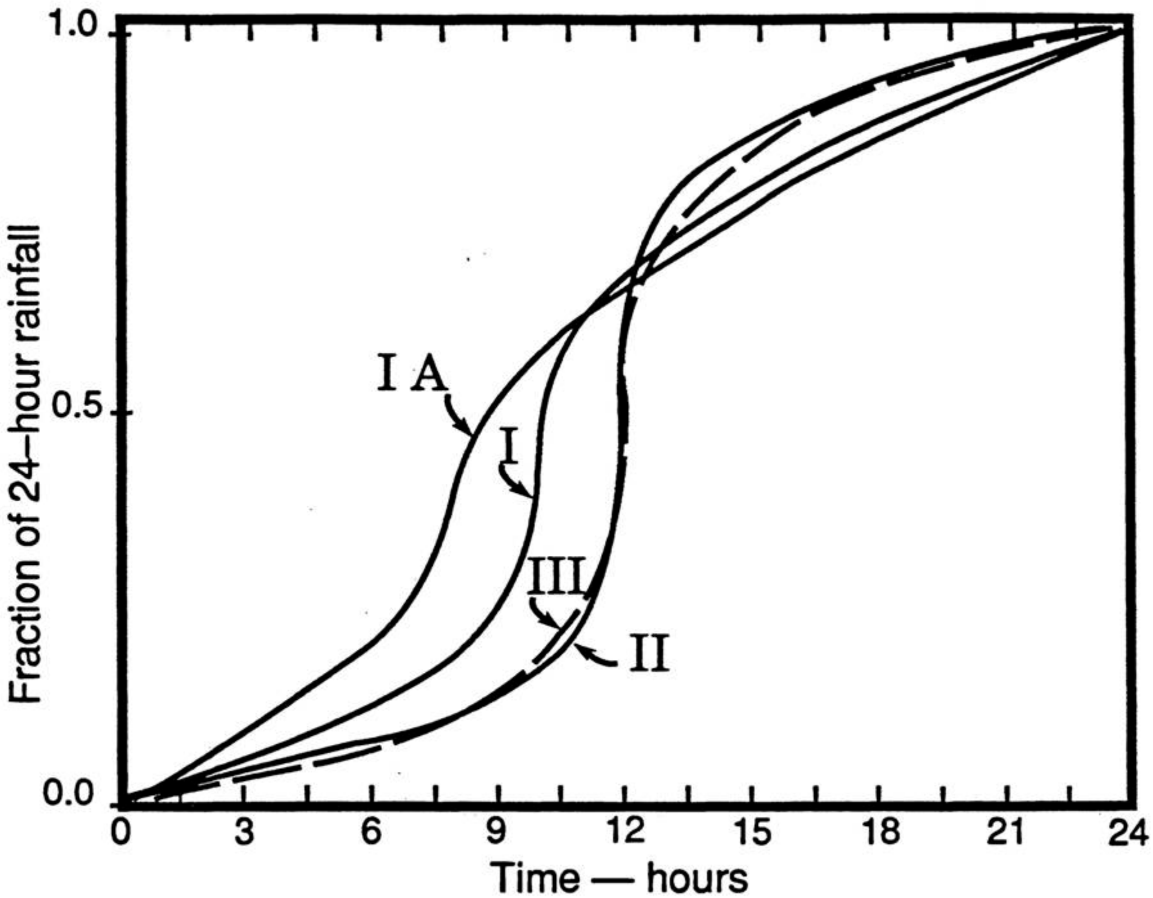


Figure 2-1 —**Approximate geographic boundaries for SCS rainfall distributions**

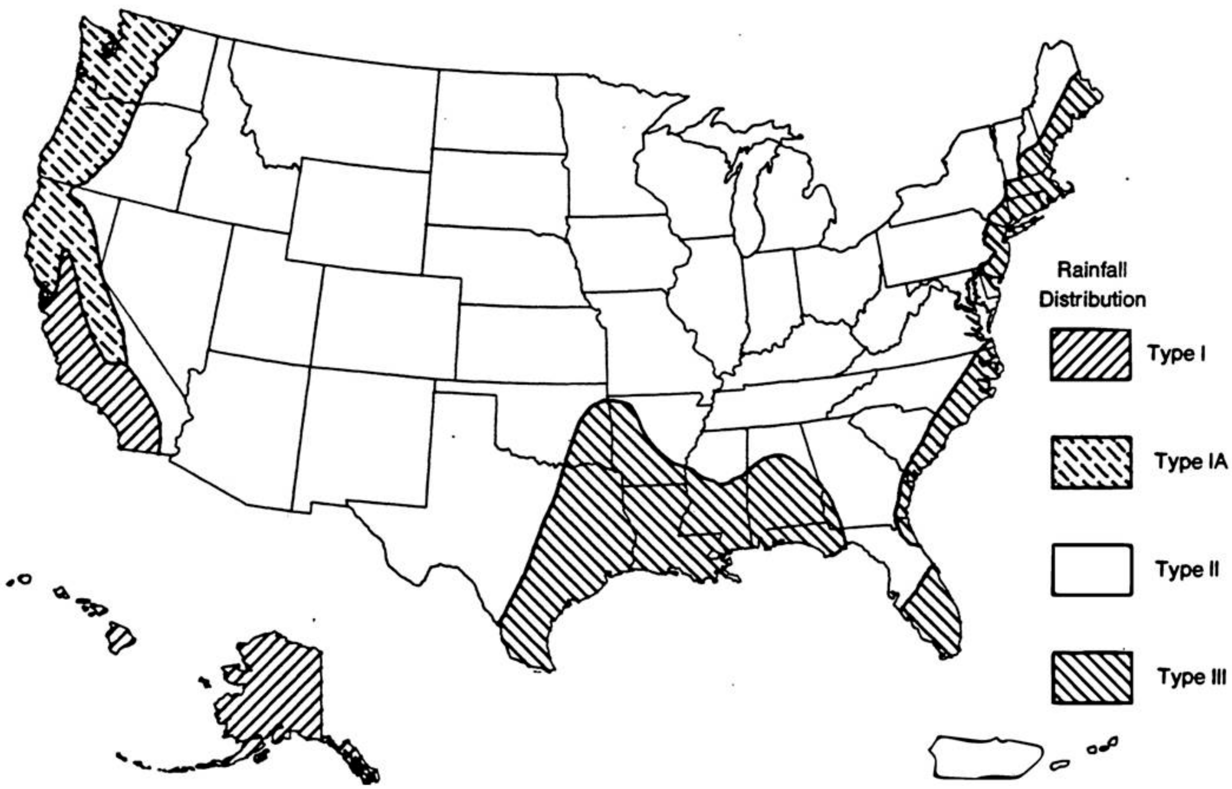


Table 2-2.-Runoff depth for selected CN'. and rainfall amount.1

Rainfall	Runoff (Q) for curve number of-										
	40	45	50	55	60	65	70	75	80	85	90	95
	--	-	-	-	-	-	-	-	-	-	---	-
1	0	0	0	0	0	0	0	0.03	0.08	0.17	0.32	0.56
1.2	0	0	0	0	0	0	0.03	0.07	0.15	0.27	0.46	0.74
1.4	0	0	0	0	0	0.02	0.06	0.13	0.24	0.39	0.61	0.92
1.6	0	0	0	0	0.01	0.05	.1 1	0.2	0.34	0.52	0.76	1.11
1.8	0	0	0	0	0.03	0.09	0.17	0.29	0.44	0.65	0.93	1.29
2	0	0	0	0.02	0.06	0.14	0.24	0.38	0.56	0.8	1.09	1.48
2.5	0	0	0.02	0.08	0.17	0.3	0.46	0.65	0.89	1.18	1.53	1.96
3	0	0.02	0.09	.1 9	0.33	0.51	0.71	0.96	1.25	1.59	1.98	2.45
3.5	0.02	0.08	0.2	0.35	0.53	0.75	1.01	1.3	1.64	2.02	2.45	2.94
4	0.06	0.18	0.33	0.53	0.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43
4.5	0.14	0.3	0.5	0.74	1.02	1.33	1.67	2.05	2.46	2.91	3.4	3.92
5	0.24	0.44	0.69	0.98	1.3	1.65	2.04	2.45	2.89	3.37	3.88	4.42
6	0.5	0.8	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.3	4.85	5.41
7	0.84	1.24	1.68	2.1 2	2.6	3.1	3.62	4.15	4.69	5.25	5.82	6.41
8	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.4
9	1.71	2.29	2.88	3.49	4.1	4.72	5.33	5.95	6.57	7.18	7.79	8.4
10	2.23	2.89	3.56	4.23	4.9	5.56	6.22	6.88	7.52	8.16	8.78	9.4
11	2.78	3.52	4.26	5	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39
12	3.38	4. 19	5	5.79	6.56	7.32	8.05	8.76	9.45	10.1 1	10.76	11 .39
13	4	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42-	11.1	11.76	12.39
14	4.65	5.62	6.55	7.44	8.3	9.1 2	9.91	10.67	11 .39	12.08	12.75	13.39
15	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39

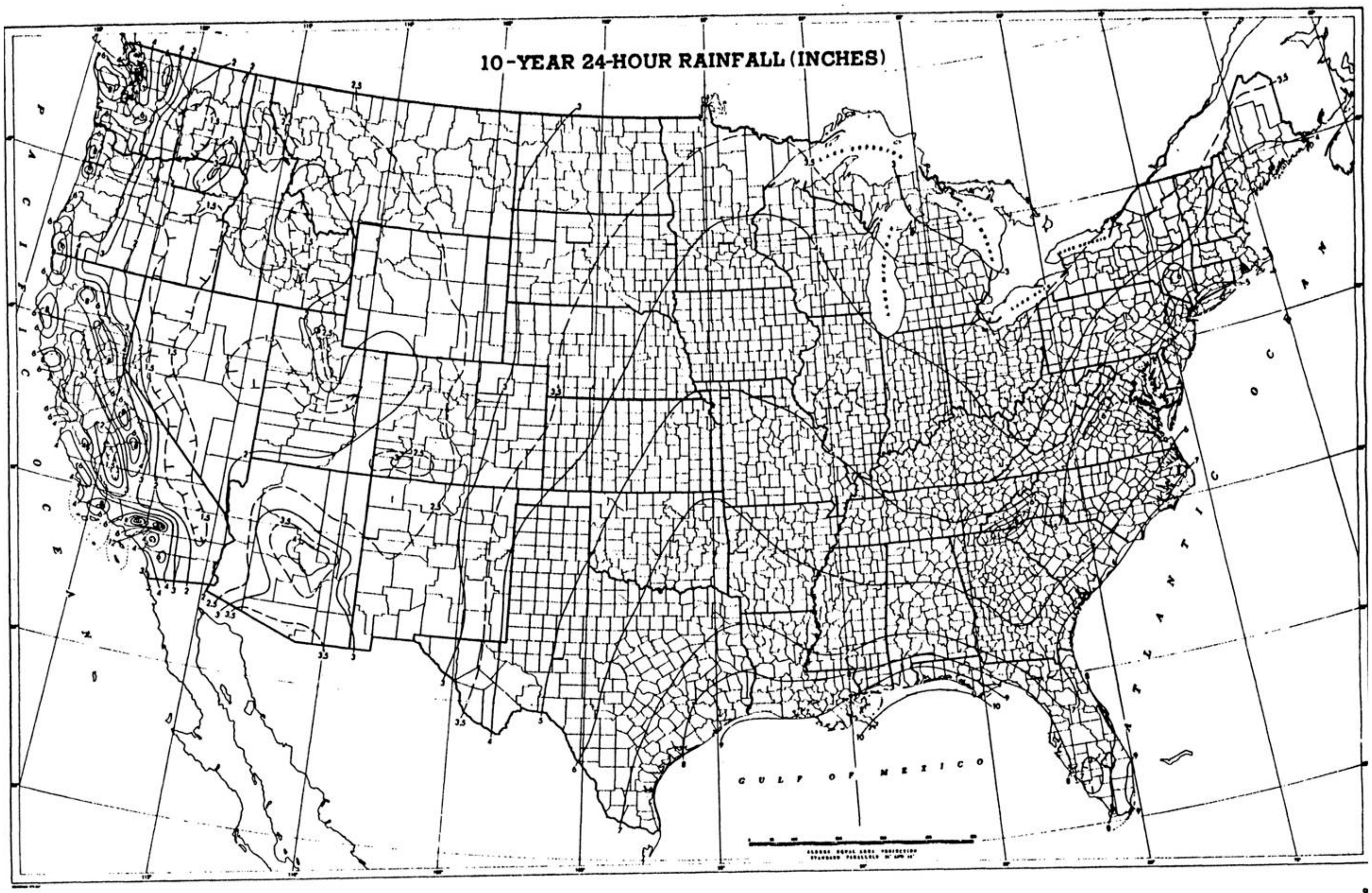
Table 2.3 runoff curve numbers for cultivated agricultural lands

Cover description	curve numbers for hydrologic soil group-					
Cover type	**Treatment2**	**Hydrologic condition3**	**A**	**B**	**C**	**D**
Fallow	Bare soil		n	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row + CR	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured + CR	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

Table 2-3b.-Runoff curve numbers for other agricultural lands1					
Cover description	Curve numbers for hydrologic soil group-				
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range-continuous forage for grazing.2 .	Poor Fair Good	68 49 39	79 69 61	86 79 74	89 84 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.3	Poor Fair Good	48 35 34	67 66 48	77 70 65	83 77 73
Woods-grass combination (orchard or tree farm).5	Poor Fair Good	57 43 32	73 65 58	82 76 72	86 82 79
Woods'	Poor Fair Good	45 36 34	66 60 55	77 73 70	83 79 77
Farmsteads-buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86


5-YEAR 24-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO

10-YEAR 24-HOUR RAINFALL (INCHES)



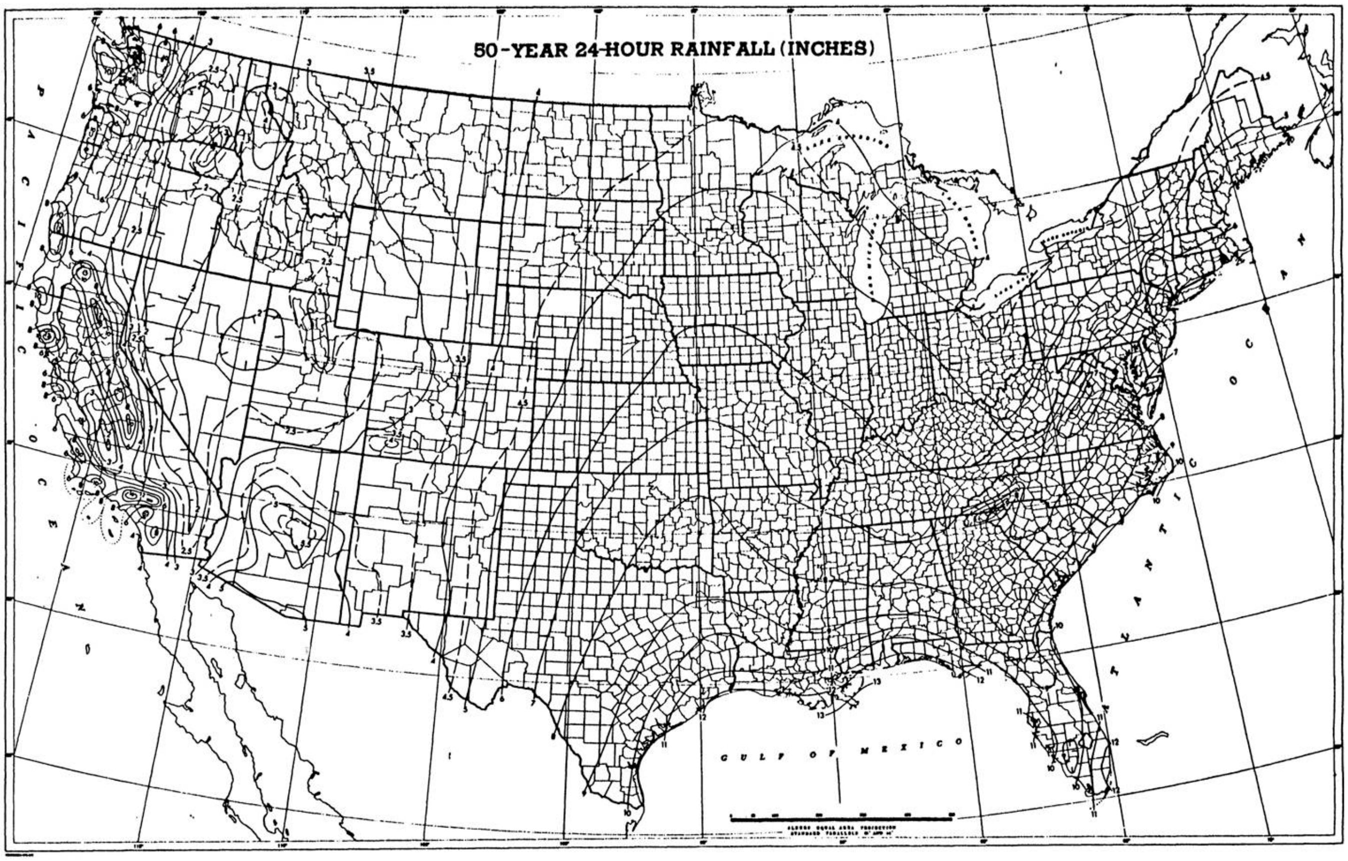

50-YEAR 24-HOUR RAINFALL (INCHES)
GULF OF MEXICO

Figure 2-27 .—**Time of concentration (T_c) nomograph**

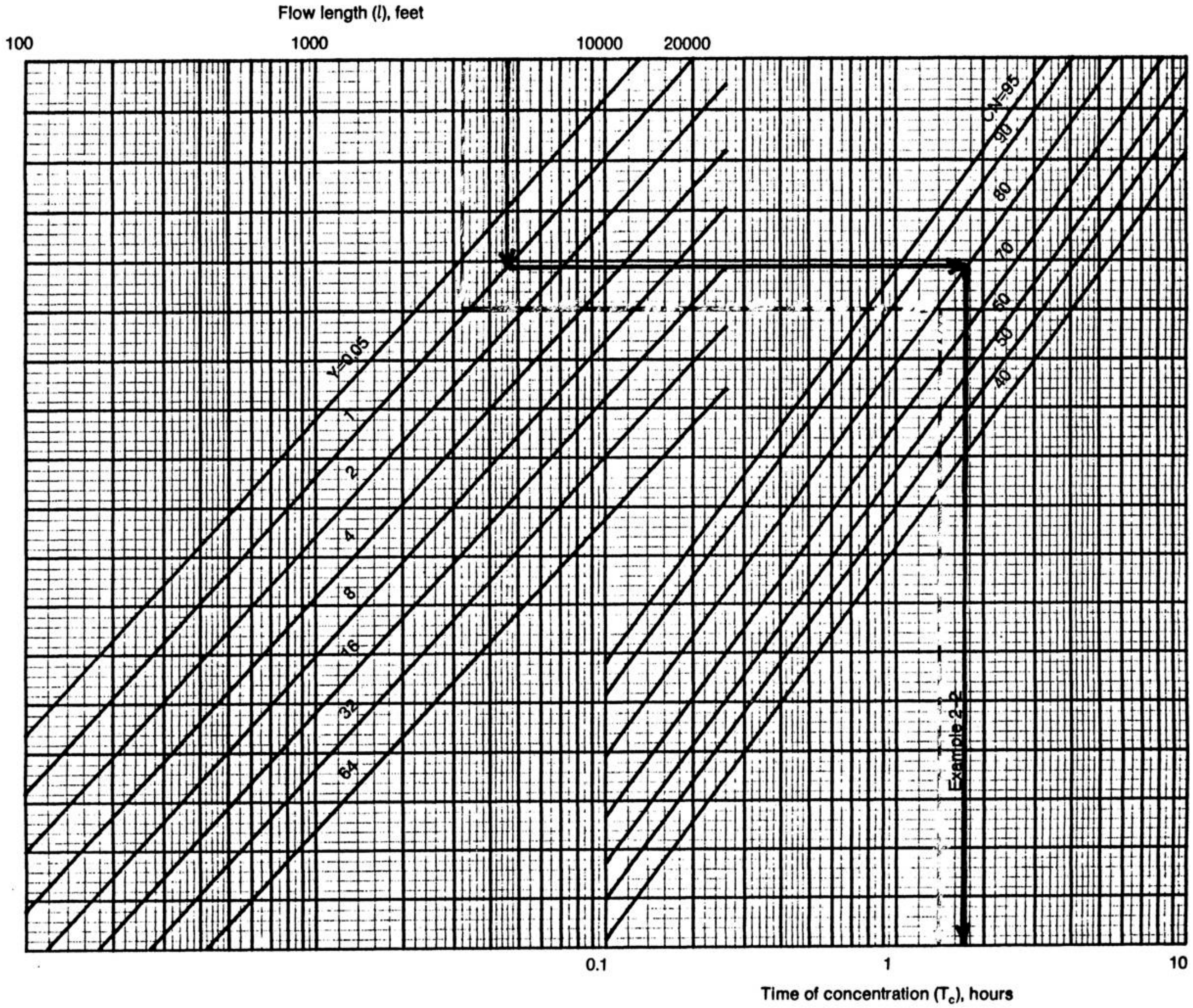


Table 2-4.-1. values for runoff curve numbers			
Curve number	18 (in)	Curve number	18 (in)
40	3.000	68	0.941
41	2.878	69	0.899
42	2.762	70	.0.85 7
43	2.651	71	0.817
44	2.545	72	0.778
45	2.444	73	0.740
46	2.348	74	0.703
47	2.255	75	0.667
48	2.167	76	0.632
49	2.082	77	0.597
50	2.000	78	0.564
51	1.922	79	0.532
52	1.846	80	0.500
53	1.774	81	0.469
54	1.704	82	0.439
55	1.636	83	0.410
56	1.571	84	0.381
57	1.509	85	0.353
58	1.448	86	0.326
59	1.390	87	0.299
60	1.333	88	0.273
61	1.279	89	0.247
62	1.226	90	0.222
63	1.175	91	0.198
64	1.125	92	0.174
65	1.077	93	0.151
66	1.030	94	0.128
67	0.985	95	0.105

Exhibit 2-II —**Unit peak discharge (q_u) for SCS Type II rainfall distribution**

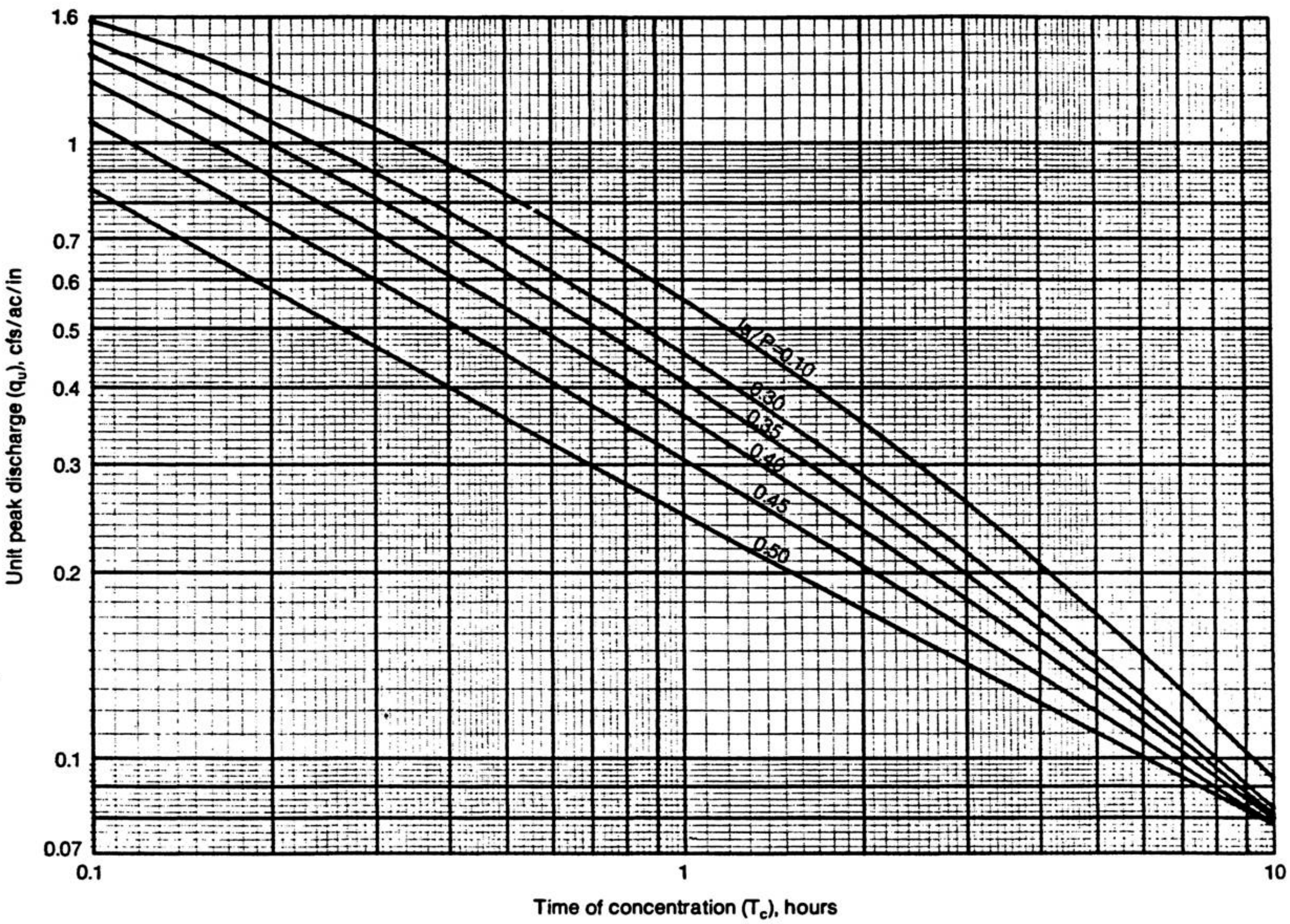


Exhibit 2-II-Unlt peak discharge (q_u) for NRCS Type II rainfall distribution

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ENG - Hydrology Training Series.

Example 1

Worksheet 2Estimating Time of Concentration and peak discharge

Client ________________________ By___________ Date_________

County____________________ State_______ Checked___________ Date_________

Practice____________________________

Estimating time of concentration

1. Data			
Rainfall distribution type	=		(I,IA,II,III)
Drainage area	A=		Ac
Runoff curve number	CN=		
Watershed slope	Y=		%
Flow length	*l*		Ft
2. using /,Y,CN and figure 2-27 or equation 2-5			
3. __________=__________			

Estimating peak discharge	Storm#1	Storm#2	Storm #3
1. Frequency……………………………….………yr			
2. Rainfall,P (24hour)……………………….…in			
3. Initial abstraction,I_a……………………….in			
4. Compute I_a/P ratio…………………………….			
5. Unit peak discharge q_w……………cfs/ac/in (Use T_c and I_a/P with exhibit 2-__)			
6. Runoff Q……………………………………..…in (use P and CN with figure 2-6 or table 2-2)			
7. Peak discharge, q_p…………………….…..cfs (where q_p=q_uAQ) [A*5*6]			