United States
Department of
Agriculture

Soil
Conservation
Service

Hydrology Training Series

Module 106 - Peak Discharge

Study Guide

Engineering Hydrology Training Series Module 106

Peak Discharge

National Employee Development Staff
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Preface

This module consists of a study guide that contains a discussion of several methods for estimating peak discharge and a step by step process for calculating peak discharge using the revised Chapter 2, Engineering Field Manual, dated 1988.

Proceed through this module at your own pace. Be sure you completely understand each section before moving on. If you have questions or need help, please request assistance from your supervisor. If your supervisor cannot clear up your problems, he/she will contact the state-appointed resource person. The resource person is familiar with the material and should be able to answer any questions you may have.

Be sure to write your answers to the included activities. This will help to reinforce your learning. After completing each activity, compare your answers with the included solution.

Acknowledgment

The design and development of this training module is the result of a concentrated effort by practicing engineers in the Soil Conservation Service. The contributions from many technical and procedural reviews have helped make this module one that will provided needed knowledge of hydrology and hydraulics to SCS employees.

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

Length

Participant should take as long as necessary to complete this module. Training time for this module is approximately two hours.

Who May Take The Module

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

Method of Completion

This module is self-study, but the state or NTC should select a resource person to answer any questions that the participant's supervisor cannot handle.

Content

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

Contents

Introduction

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.

Peak Discharge Data

The peak discharge (q_p) commonly referred to by the Soil Conservation Service (SCS) 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 (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 SCS in the design of conservation practices that convey or store water. Peaks are used to size or proportion waterways, diversions, ponds, and other structures.

SCS 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. SCS uses 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. SCS 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. SCS 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 SCS 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.

Watershed Characteristics

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 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.

Activity 1

At this time, complete Activity 1 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

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	______	______

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	Peak Discharge 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

Selection of Peak Discharge Method Method

SCS Methods

The Soil 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, SCS perfected its current runoff curve number and hydrograph development concepts for the Public Law 566 (PL-566) watershed program. These new procedures were tested and used by SCS engineers to develop peak discharges for design of structural measures and to evaluate their downstream effects. These research-based procedures use SCS 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.

SCS 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 SCS 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.

Engineering Field Manual, Chapter 2 Method (1988 Version or later)

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 SCS 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 SCS 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 SCS 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 (T_c), but with limited understanding of hydrology.

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

The SCS 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 (T_c) 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 SCS 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 (T_c) and some understanding of hydrology.

Technical Release No. 20 (1985 Version or later)

The SCS 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.

Summary of Method Selection

In summary, the primary methods and applications in SCS are:

Level	Method	Application	Special Requirements
1.	EFM, Chapter 2	Design of farm engineering practices	none
2.	TR-55, Chapter 4 (Graphical Method)	Design small urban or rural engineering practices	Time of Concentration
3.	TR-55, Chapter 5 (Tabular Hydrograph Method)	Design small urban or rural practices in complex watersheds	Subwatersheds, Time of Concentration Travel Times
4..	TR-20	Evaluation of project measures in complex watersheds	Hydrology and computer program training

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 are 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

Activity 2

At this time, complete Activity 2 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

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 cropland watershed of 20 acres.	______________
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, which drains into a sediment basin, and the lower 2/3 is parkland.	______________
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.	______________

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 cropland watershed of 20 acres.	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, which drains into a sediment basin, and the lower 2/3 is parkland.	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

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.

Selection of Graphs

Depending on the climatic region, the proper graph, based on the storm type designated for that region, must be used.

Since the intensity of rainfall varies considerably during a storm period, SCS 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 II 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 III represents the Gulf of Mexico and Atlantic coastal areas where tropical storms occur with large 24-hour rainfalls. The Type II 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 SCS State Conservation Engineer.

Storm Type	Exhibit Graph*	
I	Exhibit 2-I	
IA	Exhibit 2-IA	
II	Exhibit 2-II	(Included in Appendix A, page A15)
III	Exhibit 2-III	

** Additional peak discharge graphs may be authorized for use with these storm types that include regional variations in other watershed factors that influence peak discharge rates. An example is for extremely flat* watersheds.

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

Table 2-2 of EFM, Runoff depth for selected CN's and rainfall amounts, is page A5 of Appendix. A.

Input Requirements

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 (A) 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 (l) 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

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 (Y) 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 calculated as

$$Y = \frac{H}{L}(100)$$

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 SCS 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 (M), 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:

$$Y = \frac{MN}{A}(100)$$

If you are unsure about either method, your Resource Person should be able to help you.

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 SCS 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 (I_a) 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.

Procedure

To determine the peak discharge from EFM, Chapter 2 (1988 Version or later), the following procedure is recommended:

EFM Description		Step Referral
1.	Determine contributing drainage area (A)	—
2.	Determine average watershed slope (Y).	—
3.	Determine runoff curve number (CN).	Table 2-3 (Appendix A, pages A6-A9)
4.	Obtain the design return period from SCS standards in the Field Office Technical Guide, Section 4.	
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.	Figure 2-1 (Appendix, page A4)
7.	Determine the flow length (l).	
8.	Determine T_c in hours.	Figure 2-27 (Appendix, page A13)
9.	Determine the runoff volume (Q) for the P and CN. Module 105 gives the details of computation.	Table 2-2 (Appendix, page A5)
10.	Determine I_a and then the I_a/P ratio. If the $I_a/P < 0.1$, use 0.1; if the $I_a/P > 0.5$, use 0.5	Table 2-4 (Appendix, page A14)
11.	Locate the proper graph of T_c versus unit peak discharge, q_u.	Exhibit 2 (Appendix, page A15)
12.	Determine q_u for appropriate rainfall distribution.	
13.	$q_p = q_u (A) (Q)$	

A copy of Worksheet 2 (page 19) can be used to determine peak discharge in a systematic method.

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, l = 5000 ft
8. Using Figure 2-27, read T_c = 1.44 hr
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_a = 0.564 in
    Determine I_a/P: I_a/P = 0.564 in/3.0 in = 0.19
11. Using Exhibit 2-II for the Type II storm distribution, find q_u = 0.40 cfs/ac/in
12. Calculate the peak discharge:
    $q_p = q_u\ A\ Q$ = (0.40) (200) (1.13) = 90.4 or 90 cfs

Example 1

Worksheet 2: *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 = ________ (Worksheet 1)

   Watershed slope .... Y = ________ %

   Flow length .... l = ________ ft

2. T_c using l, Y, CN and Figure 2-27 .... = ________ hrs

   or using equation 2 – 5

3. $$T_c = \frac{l^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\, Y^{0.5}} = \frac{(\quad)^{0.8}(\quad)^{0.7}}{1140\,(\quad)^{0.5}} = \_\_\_\_\_\_ \text{hrs}$$

Estimating peak discharge

	Storm #1	Storm #2	Storm #3
1. Frequency .... yr	________	________	________
2. Rainfall, P (24-hour) .... in	________	________	________
3. Initial abstraction, I_a. .... in (Use CN with table 2-4.)	________	________	________
4. Compute I_a/P ratios	________	________	________
5. Unit peak discharge, q_u. .... 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 $q_p = q_u AQ$) [A x 5 x 6]	________	________	________

Example 1 – Solution

Worksheet 2: *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

1. Data:

Rainfall distribution type .... = II (I, IA, II, III)

Drainage area .... A = 200 ac

Runoff curve number .... CN = 78 (Worksheet 1)

Watershed slope .... Y = 2 %

Flow length .... l = 5000 ft

2. T_c using l, Y, CN and Figure 2-27 .... = 1.44 hrs

or using equation 2 – 5

3. $$T_c = \frac{l^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\,Y^{0.5}} = \frac{(\quad)^{0.8}(\quad)^{0.7}}{1140(\quad)^{0.5}} = \underline{\qquad}\text{ hrs}$$

Estimating peak discharge

		Storm #1	Storm #2	Storm #3
1. Frequency .... yr	5			
2. Rainfall, P (24-hour) .... in	3			
3. Initial abstraction, I_a .... in (Use CN with table 2-4.)	0.564			
4. Compute I_a/P ratios	0.19			
5. Unit peak discharge, q_u, ... cfs/ac/in (Use T_c and I_a/P with exhibit 2 – II)	0.40			
6. Runoff, Q .... in (Use P and CN with figure 2-6 or table 2-2)	1.13			
7. Peak discharge, q_p, ... cfs (Where $q_p = q_uAQ$) [A x 5 x 6]	90			

Compare your Worksheet 2 with the solution copy.

Example 2

Using the EFM, Chapter 2 Method and Worksheet 2, estimate the peak discharge from a 175 acre watershed with a 1% average slope and a hydrologic soil group of D. The watershed is all cultivated cropland that is contoured and terraced. The planned structure, a waterway, has been given a return period (frequency) of 10 years. The location is western Nebraska. Flow length = 4,500 ft.

All exhibits used in this example are in Appendix A of this module.

For ease in completing Worksheet 2, the given data are listed on the next page.

Given data for example 2:

1. Given: Drainage area, A = 175 ac
2. Given: Average watershed slope, Y = 1%
3. Using hydrologic soil group D, cropland that is contoured and terraced, and in good condition, enter Table 2-3 and read CN = 81.
4. Given: Return period = 10 yr
5. Using the 10-yr, 24-hr rainfall chart (Exhibit 2-3, Sheet 2 of 5), locate western Nebraska, and read P = 3.5 in.
6. From Figure 2-1, determine that western Nerbaska has a Type II storm distribution.
7. Given: l = 4500 ft
8. Using Figure 2-27, read T_c = 1.71 hr.
9. For CN = 81 and P = 3.5 in, use Table 2-2 to find runoff volume, Q = 1.71 in.
10. Using Table 2-4, find I_a = 0.469 in.
    Determine I_a/P: I_a/P = 0.469 in / 3.5 in = 0.13
11. Using Exhibit 2-II for the type II storm distribution, find q_u = 0.38 cfs/ac/in.
12. Calculate the peak discharge:
    $q_p = q_u A Q$ = (0.38) (175) (1.71) = 113.7 or 114 cfs

Example 2

Worksheet 2: *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 = ________ (Worksheet 1)

Watershed slope ....Y = ________ %

Flow length .... l = ________ ft

2. T_c using l, Y, CN and Figure 2-27 .... = ________ hrs

or using equation 2 – 5

3. $$T_c = \frac{l^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\ Y^{0.5}} = \frac{(\qquad)^{0.8}(\qquad)^{0.7}}{1140\ (\qquad)^{0.5}} = \underline{\qquad\quad \text{hrs}}$$

Estimating peak discharge

	Storm #1	Storm #2	Storm #3
1. Frequency ....yr	________	________	________
2. Rainfall, P (24-hour) ....in	________	________	________
3. Initial abstraction, I_a. ....in (Use CN with table 2-4.)	________	________	________
4. Compute I_a/P ratios	________	________	________
5. Unit peak discharge, q_u. .... 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 x 5 x 6]	________	________	________

Example 2– Solution

Worksheet 2: *Time of Concentration and Peak Discharge*

Client Module 106 By DEW Date 4/14/88

County ______ State NE Checked MH Date 8/88

Practice Example2

Estimating time of concentration

1. Data:

Rainfall distribution type	=	II	(I, IA, II, III)
Drainage area	A =	175	ac
Runoff curve number	CN =	81	(Worksheet 1)
Watershed slope	Y =	1	%
Flow length	*l* =	4500	ft

2. T_c using *l*, Y, CN and Figure 2-27 .... = 1.71 hrs

or using equation 2 – 5

3. $$T_c = \frac{l^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\ Y^{0.5}} = \frac{(\quad)^{0.8}(\quad)^{0.7}}{1140\ (\quad)^{0.5}} = \underline{\qquad} \text{ hrs}$$

Estimating peak discharge

		Storm #1	Storm #2	Storm #3
1. Frequency	yr	10		
2. Rainfall, P (24-hour)	in	3.5		
3. Initial abstraction, I_a. (Use CN with table 2-4.)	in	0.469		
4. Compute I_a/P ratios		0.13		
5. Unit peak discharge, q_u. (Use T_c and I_a/P with exhibit 2– II)	cfs/ac/in	0.38		
6. Runoff, Q (Use P and CN with figure 2-6 or table 2-2)	in	1.71		
7. Peak discharge, q_p. (Where $q_p = q_u AQ$) [A x 5 x 6]	cfs	114		

Activity 3

At this time, complete Activity 3 in your Study Guide to review the material just covered. After finishing the Activity, compare your answers with the solution provided. When you are satisfied that you understand the material, continue with the Study Guide text.

Activity 3

Using EFM, Chapter 2 and Worksheet 2, estimate the peak discharge from a 250 acre watershed with a 4% slope and a hydrologic soil group of C. The watershed is all range in poor condition. The watershed is located in the northwest tip of the Texas panhandle (NW corner of state). The structure is a farm pond spillway which has been given a return period (frequency) of 50 years. The flow length is 6000 ft. Show your computations and fill in Worksheet 2. When you have finished, compare your work with the solution.

Solution:

Activity 3

Worksheet 2: *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 = ________ (Worksheet 1)

Watershed slope .... Y = ________ %

Flow length .... l = ________ ft

2. T_c using l, Y, CN and Figure 2-27 .... = ________ hrs

or using equation 2 – 5

3. $$T_c = \frac{l^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\,Y^{0.5}} = \frac{(\qquad)^{0.8}(\qquad)^{0.7}}{1140\,(\qquad)^{0.5}} = \underline{\qquad\quad \text{hrs}}$$

Estimating peak discharge

	Storm #1	Storm #2	Storm #3
1. Frequency .... yr	________	________	________
2. Rainfall, P (24-hour) .... in	________	________	________
3. Initial abstraction, I_a. .... in (Use CN with table 2-4.)	________	________	________
4. Compute I_a/P ratios	________	________	________
5. Unit peak discharge, q_u. .... 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 $q_p = q_u AQ$) [A x 5 x 6]	________	________	________

Activity 3 – Solution

Using EFM, Chapter 2 and Worksheet 2, estimate the peak discharge from a 250 acre watershed with a 4% slope and a hydrologic soil group of C. The watershed is all range in poor condition. The watershed is located in the northwest tip of the Texas panhandle (NW corner of state). The structure is a farm pond spillway which has been given a return period (frequency) of 50 years. The flow length is 6,000 ft. Show your computations and fill in Worksheet 2. When you have finished, compare your work with the solution.

Solution:

1. Given: Drainage area, A = 250 ac
2. Given: Average watershed slope, Y = 4%
3. Using hydrologic soil group C, range in poor condition, enter Table 2-3 and read CN = 86.
4. Given: Return period = 50 yr
5. Using the 50-yr, 24-hr rainfall chart (Exhibit 2-3, Sheet 5 of 5), locate northwestern Texas, and read P = 5.0 in.
6. From Figure 2-1, determine that northwestern Texas has a Type II storm distribution.
7. Given: Flow length, l = 6000 ft
8. Using Figure 2-27, read T_c = 0.91 hr.
9. For CN = 86 and P = 5.0 in, use Table 2-2 to find runoff volume, Q, is 3.47 in.
10. Using Table 2-4, find I_a = 0.326 in.

    Determine I_a/P: I_a/P =0.326 in / 5.0 in = 0.06
11. Using Exhibit 2-II for the Type II storm distribution, find q_u = 0.59 cfs/ac/in.
12. Calculate the peak discharge:
    $q_p = q_u A Q$ = (0.59)(250)(3.47) = 511.8 or 512 cfs

Activity 3 – Solution

Worksheet 2: *Time of Concentration and Peak Discharge*

Client Module 106 By ______ Date ______

County ______ State NE Checked X2 Date 5/4/88

Practice Activity 3

Estimating time of concentration

1. Data:

   Rainfall distribution type .... = II (I, IA, II, III)

   Drainage area .... A = 250 ac

   Runoff curve number .... CN = 86 (Worksheet 1)

   Watershed slope .... Y = 4 %

   Flow length .... l = 6000 ft

2. T_c using l, Y, CN and Figure 2-27 .... = 0.91 hrs

   or using equation 2 – 5

3. $$T_c = \frac{l^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\ Y^{0.5}} = \frac{(\quad)^{0.8}(\quad)^{0.7}}{1140(\quad)^{0.5}} = \underline{\qquad} \text{ hrs}$$

Estimating peak discharge

	Storm #1	Storm #2	Storm #3
1. Frequency .... yr	50		
2. Rainfall, P (24-hour) .... in	5		
3. Initial abstraction, I_a. .... in (Use CN with table 2-4.)	0.326		
4. Compute I_a/P ratios	0.06		
5. Unit peak discharge, q_u. .... cfs/ac/in (Use T_c and I_a/P with exhibit 2– II)	0.59		
6. Runoff, Q .... in (Use P and CN with figure 2-6 or table 2-2)	3.471		
7. Peak discharge, q_p. .... cfs (Where $q_p = q_u AQ$) [A x 5 x 6]	512		

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.

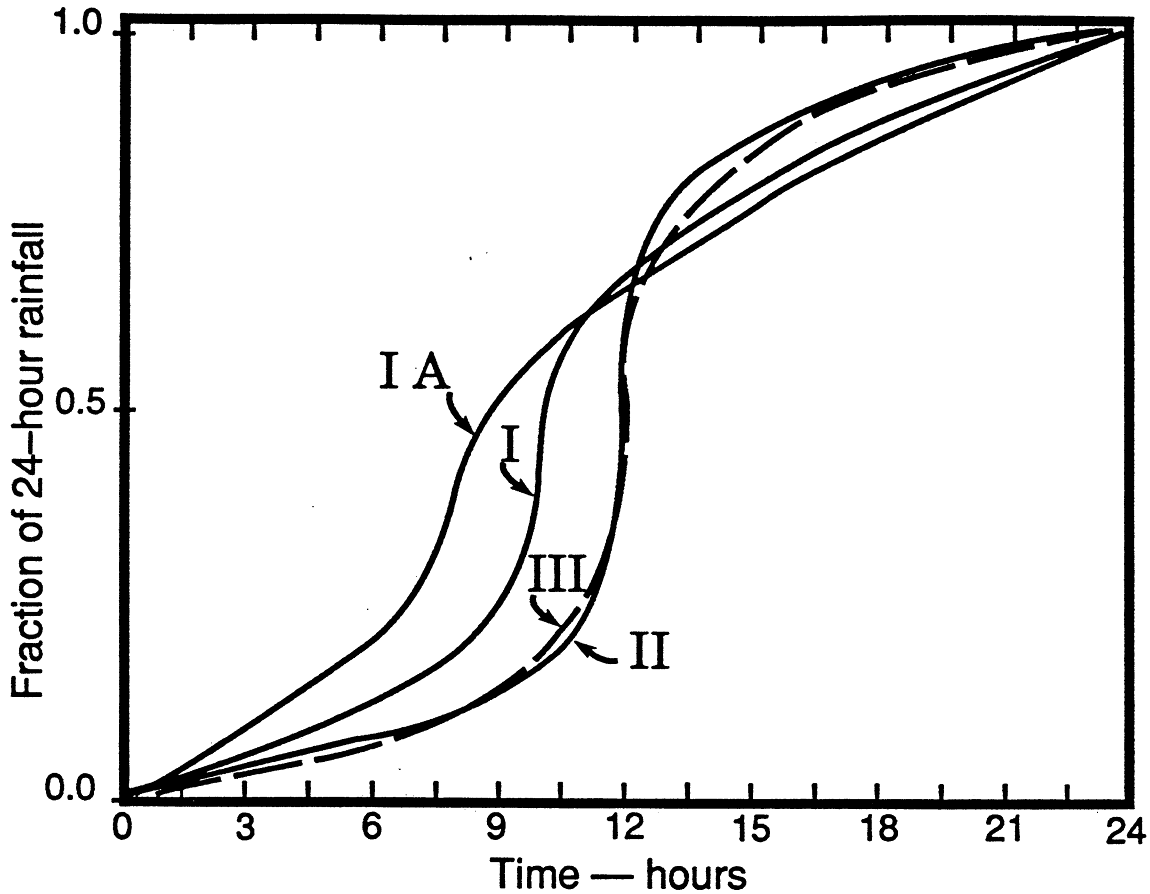
Retain this Study Guide as a reference until you are satisfied that you have successfully mastered all the methods covered. It will provide an easy review at any time if you should encounter a problem.

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

When you are satisfied that you have completed this module, remove the Certification of Completion sheet (last page of the Study Guide), fill it out, and give it to your supervisor to submit, through channels, to your State or NTC Training Officer.

Appendix A
Charts and Tables

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



Source: TR–55

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

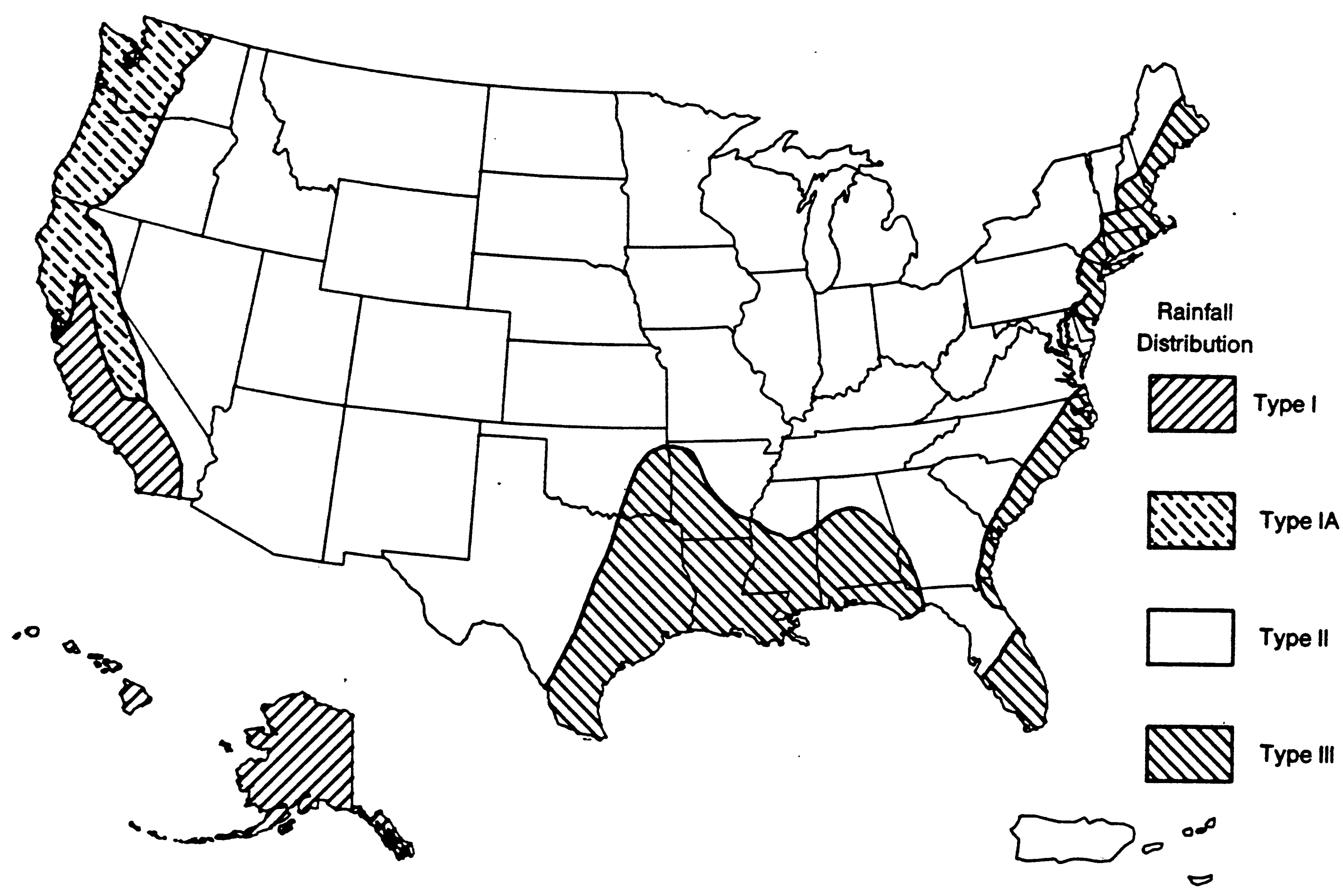


Table 2-2.—Runoff depth for selected CN's and rainfall amounts[1]

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

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

Table 2-3a.—Runoff curve numbers for cultivated agricultural lands[1]

Cover description			Curve numbers for hydrologic soil group—			
Cover type	Treatment[2]	Hydrologic condition[3]	A	B	C	D
Fallow	Bare soil	—	77	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

[1] Average runoff condition.
[2] *Crop residue cover (CR)* applies only if residue is on at least 5% of the surface throughout the year.
[3] Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good ⩾ 20%), and (e) degree of surface roughness.
Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 2-3b.—Runoff curve numbers for other agricultural lands[1]

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	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	30[4]	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[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1] 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.
[3] *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
[4] Actual curve number is less than 30; use CN = 30 for runoff computations.
[5] CN'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.
[6] *Poor:* Forest, litter, small trees, and brush have been destroyed by heavy grazing or regular burning.
Fair: 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 arid and semiarid rangelands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition[2]	A[3]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[1] Average runoff condition. For rangelands in humid regions, use table 2-3b.
[2] *Poor:* <30% ground cover (litter, grass, and brush overstory).
Fair: 30% to 70% ground cover.
Good: >70% ground cover.
[3] Curve numbers for group A have been developed only for desert shrub.

Table 2-3d.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	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
Western desert urban areas:					
Natural desert landscaping (pervious areas only).[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
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					
Newly graded areas (pervious areas only, no vegetation).[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2a).					

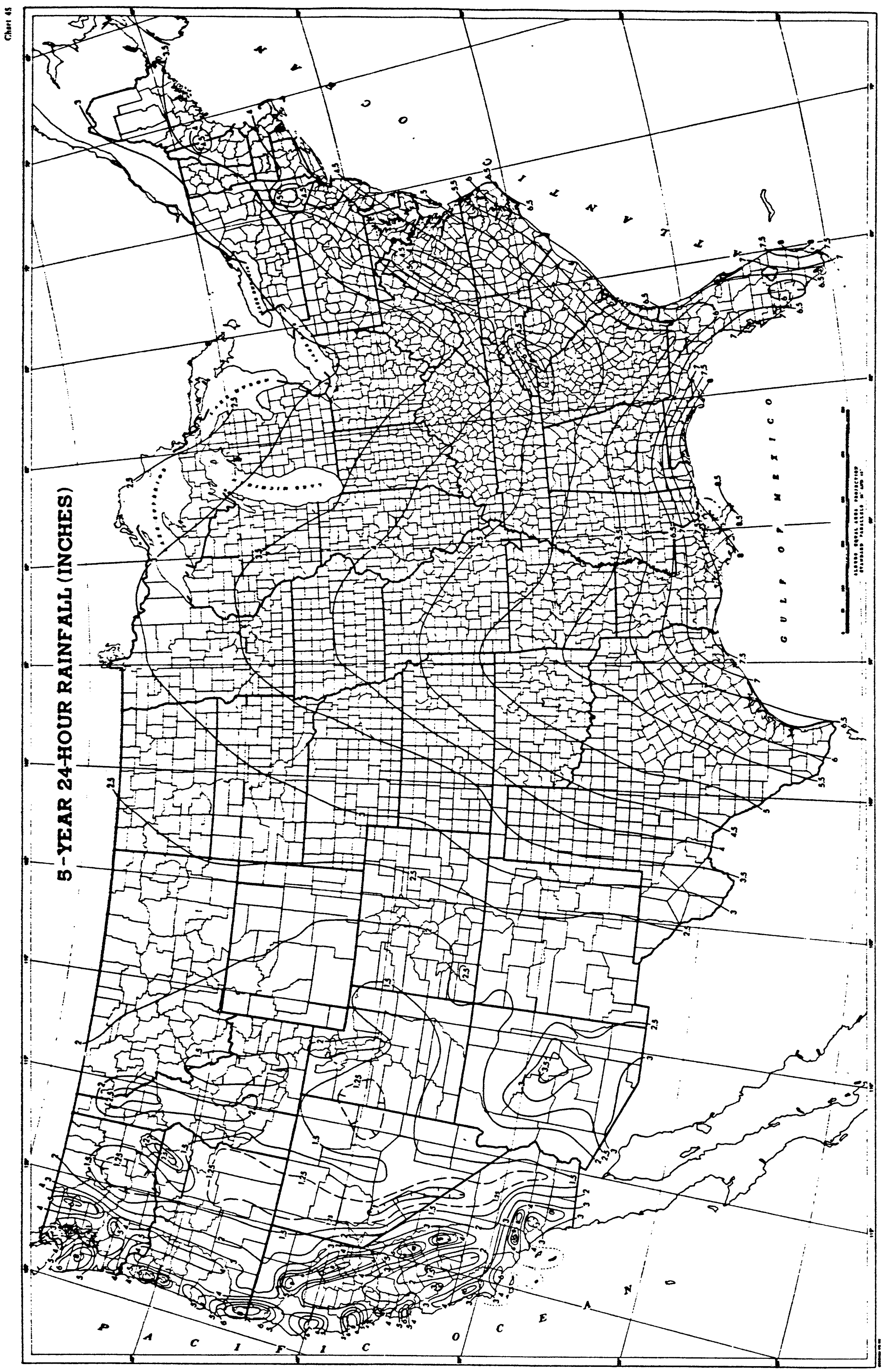
[1] Average runoff condition, $I_a = 0.2S$.

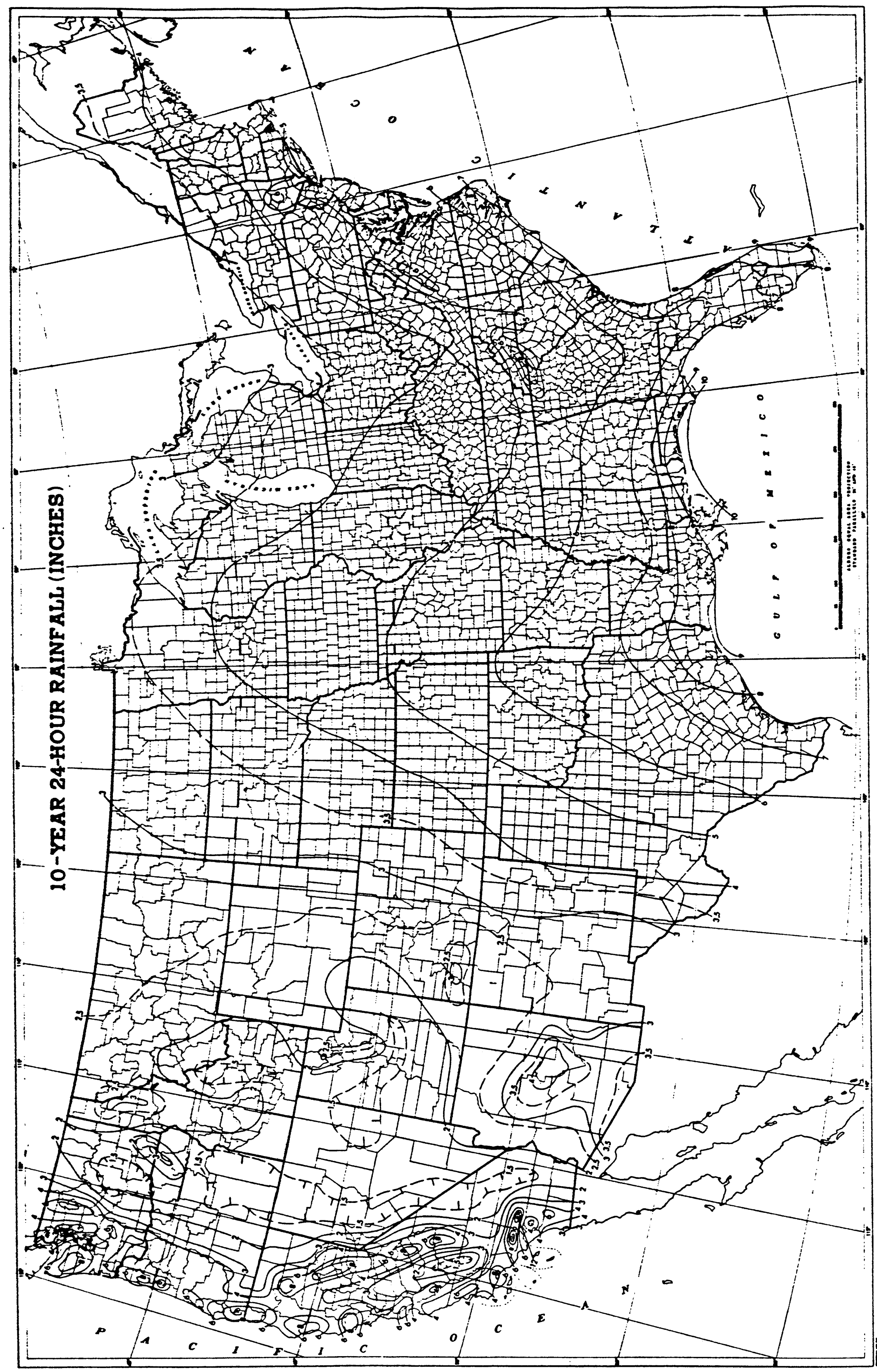
[2] The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition.

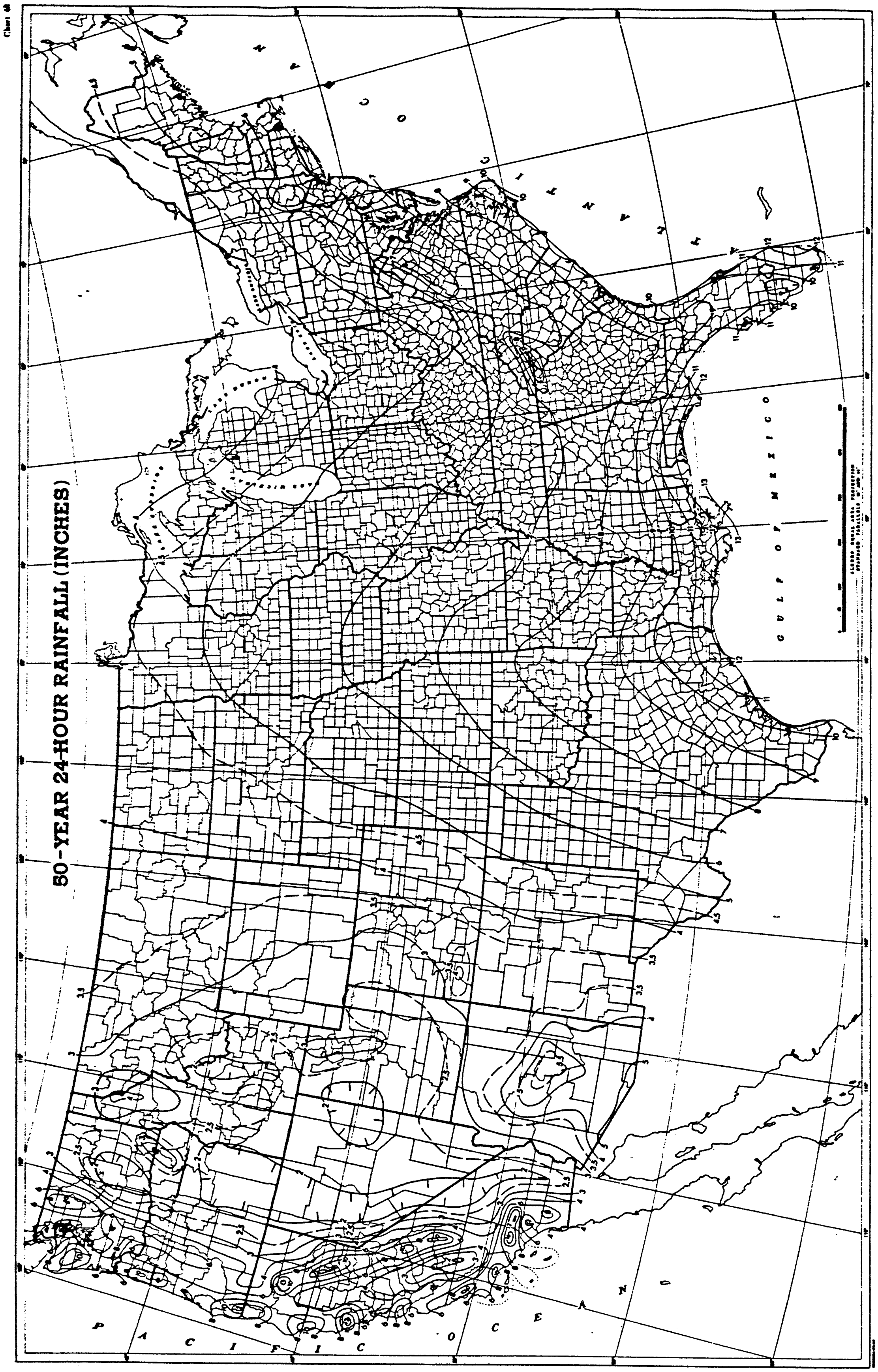
[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4] Composite CN's for natural desert landscaping should be computed based on the impervious area (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.


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


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



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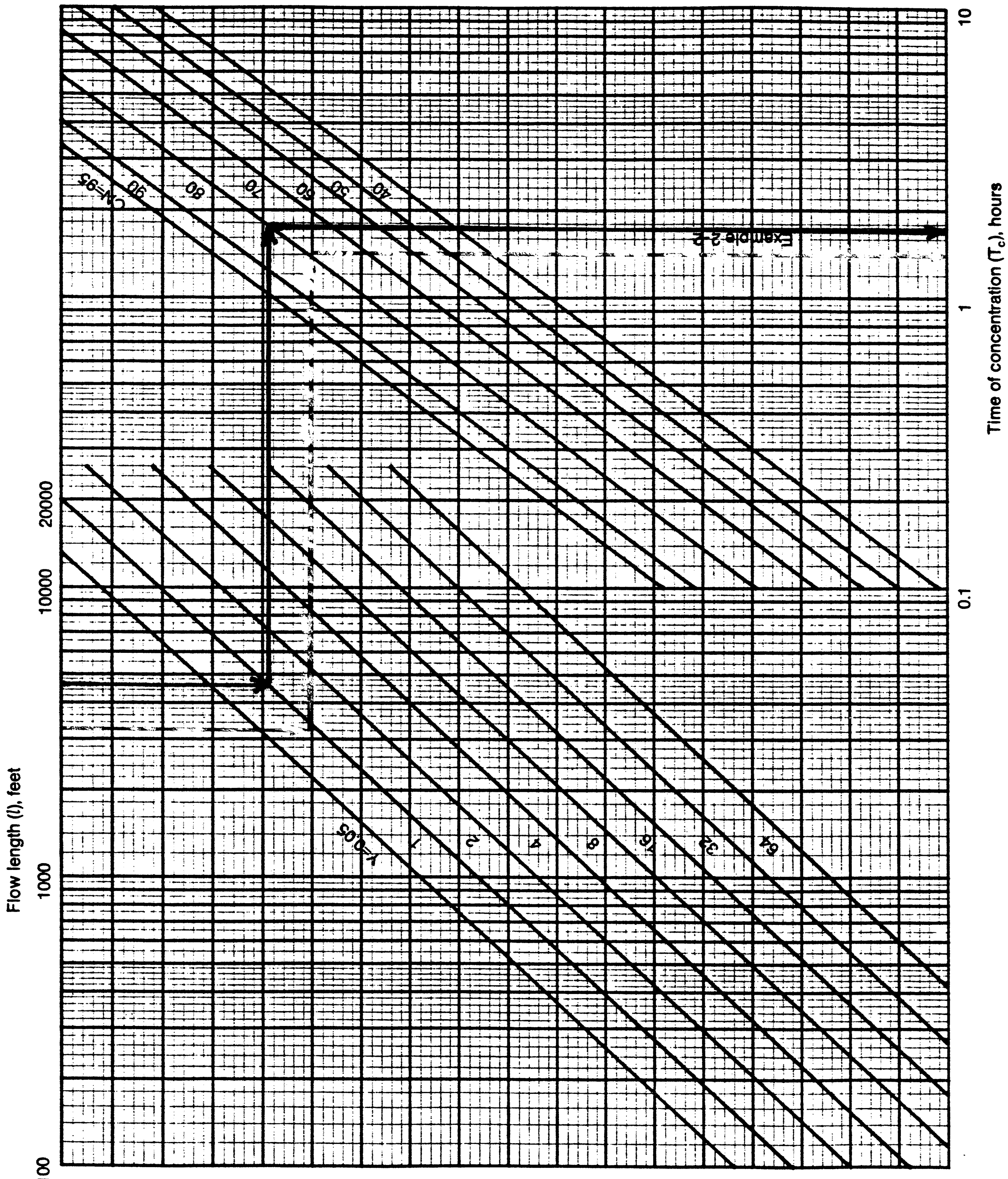
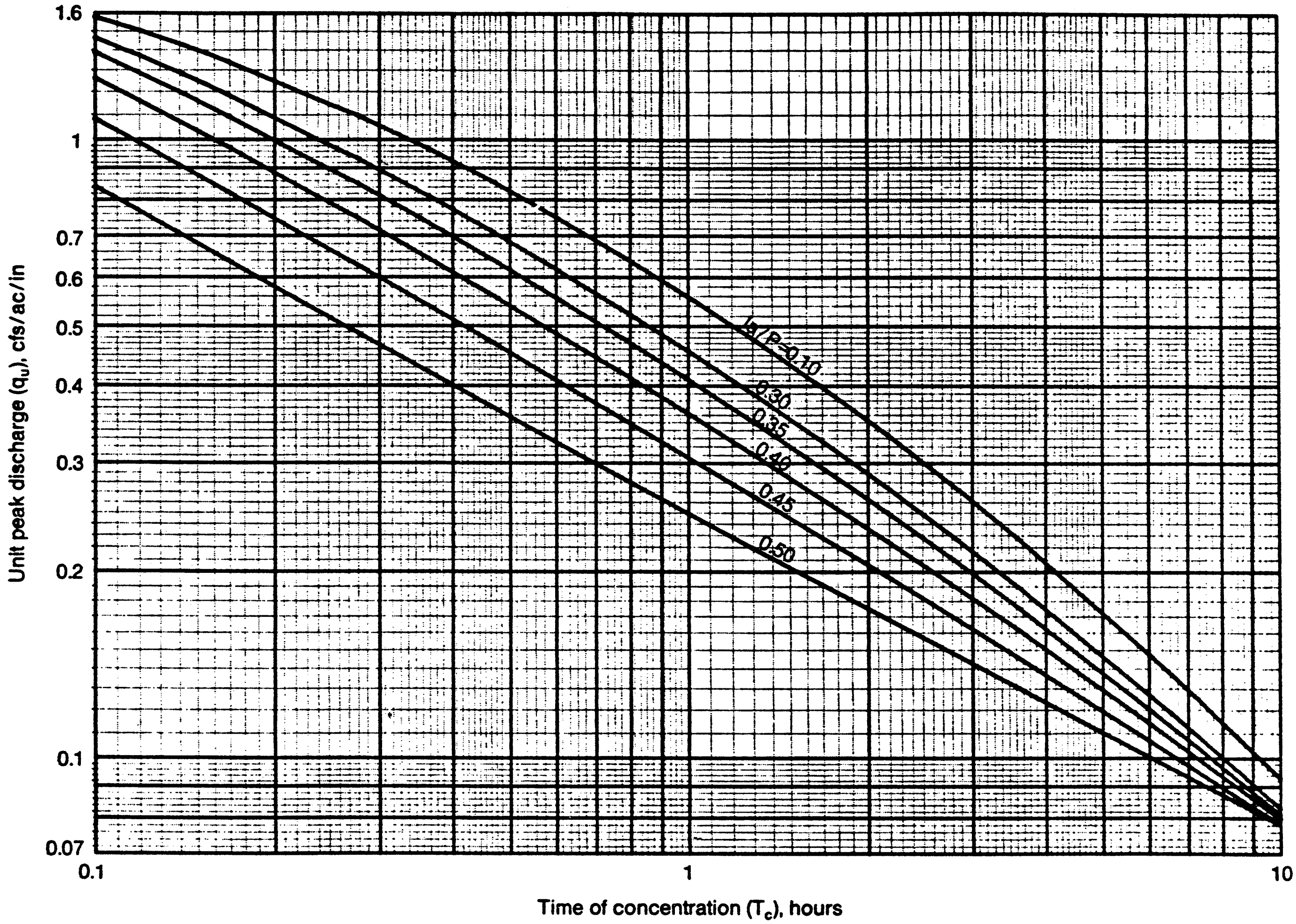


Figure 2-27 .—Time of concentration (T_c) nomograph

Table 2-4.—I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	68	0.941
41	2.878	69	0.899
42	2.762	70	0.857
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**



Example 1

Worksheet 2: *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 = ________ (Worksheet 1)

   Watershed slope .... Y = ________ %

   Flow length .... l = ________ ft

2. T_c using l, Y, CN and Figure 2-27 .... = ________ hrs

   or using equation 2 – 5

3. $$T_c = \frac{l^{0.8}\left(\frac{1000}{CN} - 9\right)^{0.7}}{1140\ Y^{0.5}} = \frac{(\qquad)^{0.8}\ (\qquad)^{0.7}}{1140\ (\qquad)^{0.5}} = \underline{\qquad\qquad \text{hrs}}$$

Estimating peak discharge

	Storm #1	Storm #2	Storm #3
1. Frequency .... yr	________	________	________
2. Rainfall, P (24-hour) .... in	________	________	________
3. Initial abstraction, I_a. .... in (Use CN with table 2-4.)	________	________	________
4. Compute I_a/P ratios	________	________	________
5. Unit peak discharge, q_u. .... 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 $q_p = q_u AQ$) [A x 5 x 6]	________	________	________

Hydrology Training Series
Module 106
Peak Discharge

CERTIFICATION OF COMPLETION

This is to certify that

____

completed Hydrology Training Series
Module 106 – Peak Discharge

on ________________ and should be credited with 2 hours of training.
Date

Signed ________________________ ________________________
Supervisor/Trainer Participant

Completion of Hydrology Training Series Module 106 – Peak Discharge, is acknowledged and documented in the above-named employee's record.

Signed ________________________ ________________________
Training Officer Date