Hydrology Training Series

Module 206 D - Peak Discharge (Other Methods)

Study Guide

Module Description

Objectives

Upon completion of this module, the participant wiU be able to identify and use three non-standard methods to compute peak discharges for specific geographic regions.

Prerequisites

Modules l06-Peak Discharge; 206A-Time of Concentration; 206B-Peak Discharge (Graphical Method, TR-55).

Reference

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

Who May Take The Module

This module is intended for Area-level employees who have a need for special peak discharge procedures.

Content

This module presents the Cypress Creek Formula, USGS Regional Equations, and the rational equation. The background, limitations and procedures appropriate to each method are discussed.

Introduction

Estimating peak discharges is necessary for the design of water control structures. Other modules have discussed SCS procedures such as TR-55 and Chapter 2 of the Engineering Field Manual. These are used when more detailed methods are not warranted. For watersheds having large drainage areas or complex watersheds, a hydrograph should be developed and detailed flood routing procedures used.

The evaluation of flood potential is necessary for the design and location of structures that either control flood flows or that are subject to possible flooding, and is essential for establishing flood insurance rates. Some structures must be d~signed so that they will not be damaged or flooded by any probable flood. However, for most structures, the probable damage to the structure, the cost of repairing or replacing damaged property, or the inconvenience to the public must be balanced against the cost of designing to withstand rare flood events.

It is not possible to anticipate where flood information might be needed, nor is it economically feasible to collect data at all potential sites. At the present time, analysis of past flood events is considered the best method of evaluating the magnitude and frequency of probable future events.

Peak flows at gaging stations can be analyzed for frequency of occurrence and related to topographic and climatic factors of the drainage basin. These relationships, determined for gaged areas, can be used to predict probable magnitude and frequency of flood events on ungaged areas.

This module outlines various regional peak flow methods that are unique to specific locations and explains the use of the appropriate regional method. These methods are in addition to standard SCS methods and are unique to specific geographical areas.

Cypress Creek Formula

The nature of flood flows has been found to be dependent on the physiographic and climatological characteristics of the stream drainage basin. This relationship can be expressed by an equation such as the following:

Q=$A^x * B^y * C^2 * N^2$
where

Q = peak flow for a given return frequency

A, B,C, and N = measurable characteristics ofthe basin, such as size, main channel gradient, land slope, etc.

x, y, z, n = power functions, obtained by regression analysis.

Studies show that the dominant, and often the only obtainable, basin characteristic of flatland watersheds is size. In this case, the complex general equation may be reduced to the relationship, Q = *CN,* which is similar in form to the Cypress Creek formula.

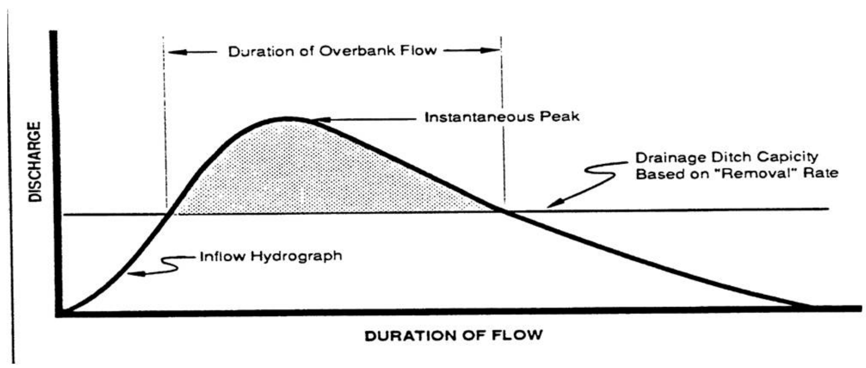


Figure 1. *Graphical depiction of Cypress Creek formula.*

The Cypress Creek formula is: Q = CMS/6

where

Q = average runoff rate, cfs for the 24-hour period of greatest runoff for a particular storm event

C = a coefficient, mainly dependent upon the degree of protection desired

M = drainage area, square miles

The Cypress Creek formula (see Figure 1) is used by engineers as a means of determining the design capacity of drainage canals. It is an average removal rate for a 24-hour period and is not an instantaneous peak flow rate. Data were developed for this approach on flatland areas ofthe coastal plain and adjacent flatland resource areas.

Development of C

The value of C varies with runoff, which can be related to rainfall frequency for a 24-hour period, and was computed based on maximum runoff rates. C reflects frequency, rainfall excess, cover, intensity, etc. For the experimental watersheds,

$Q = CM5/6$

and is based on the 24-hr average runoff. Next, the coefficient C is evaluated in terms of rainfall excess and this is related to storm recurrence interval.

Based on numerous runoff events and computed by the method of]east squares, the regression equation for flatland watersheds is:

$y = 16.39 + 14.75\ R.$

where

$y =$ predicated value of the coefficient C

$R. =$ rainfall excess for an individual storm, in

This is known as the Stephens-Mills formula.

Normally, the value of the coefficient C is selected to give the flow rate that provides optimum drainage at the least cost by weighing expenditures for construction and maintenance against the occasional loss of a crop or structure. Since loss of life is not involved, protection is not provided for the probable maximum flood, and only seldom provided for rare floods. The selection of C values is therefore essentially a calculated risk based on available information and the engineer's best judgnlent.

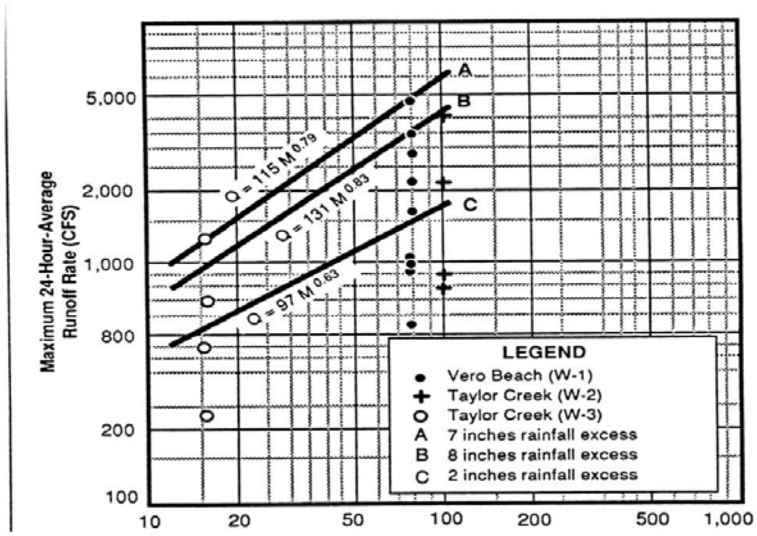
Relating rainfall excess to probable recurrence periods requires judgment and knowledge of the capacity for infiltration of the soil involved. However, a useful estimate of rainfall excess is obtained in many instances by subtracting approximately three inches from the predicted maximum 24-hr storm rainfall.

In NEH-16, SCS suggests that the maximum 24-hr average flow for the 2-yr to 5-yr recurrence period be used as a guide in selecting drainage coefficients for general crops. For the coastal plains of the Southeast, C values of 10 for forest, 25 for improved pasture, and 45 for general crops are presently recommended, with additional drainage capacity advised for good protection in hilly areas. See your State's drainage guide.

Establishment of Mx Relations

A graphical analysis of the equation, Q = CM&, was made by making a log-log plot of the annual maximum 24-hr average runoff rates against watershed areas for the annual maximum storms for the experimental watersheds.

Figure 2 shows the resultant equation fitted to peak daily flows from rainfall excess amounts of 7, 5, and 2 inches. The corresponding total rainfall for the individual storms were approximately 10, 8, and 5 inches. Most of the storms lasted about 24 hours and were estimated to be about 50-yr, lO-yr, and 2-yr frequencies at the experimental watersheds.



The best fitting equation, Q = $131M^{.83}$, was obtained from maximum 24-hour average runoff rates following the largest storm of record. The two lower lines, Q = $115M^{.79}$and Q = $97M^{.63}$, were located by interpolating for computed rainfall excess amounts of 5 and 2 inches. Since the exponent 0.83 is the best fit, it was selected to be used.

Example

Given:

Drainage area = 1. 75 mi²

CN = 80

25-yr, 24-hr rainfall: P = 7.0 in

Find:

The removal rate discharge, Q, in cfs, using the Cypress Creek formula.

Solution:

1. Determine the direct runoff, Re' in inches from Figure 3, Solution ofRunoffEquati~n. or by using the following equations:

$R_e = \frac{P-.2S}{p-.8S}$ where S $=\left(\frac{1000}{CN}\right)-10$

Therefore, $S=\left(\frac{1000}{80}\right)-10=2.5$

and $R_e=\frac{[7.0in-(2.0)(2.50)]^2}{7.0+(.8)(2.50)}=\frac{42.25}{9.0}=4.69in$

2. C = 16.39 + 14.75 (R_e)

= 16.39 + 14.75 (4.69 in) = 16.39 + 69.18 = 85.57

Q = $CM^{\frac{5}{6}}$

3. = 85.57 $(1.75mi^2)^{\frac{5}{6}}$

= 85.57 (1. 57)

= 136 cfs

Summary - Cypress Creek Formula I The Cypress Creek formula, Q = CMSf6, gives reliable estimates of maximum 24-hr average runoff rates from small agricultural watersheds and in the southern coastal plain.

Values of the coefficient C can be obtained with reasonable accuracy from the relationship, C = 16.39 + 14.75 R., where R. is rainfall excess in inches.

USGS Regional Equations

Flood Frequencies at Gaging Stations

US Geological Survey has developed techniques for estimating the magnitude and frequency of floods in each state and various regions.

Flood frequency regression equations should serve as an order-of-magnitude check on the reasonableness of peak flows detennined by other methods presented in this section. Regression equations are generally best suited to watersheds that are not subject to a change in the hydrologic conditions which existed when the stream flow measurements were observed. Therefore, regression equations are generally best suited to medium or large watersheds since a change in hydologic conditions generally occurs on a small percentage of the watershed.

Methods of flood frequency analysis usually consists of two steps. The first step is the analysis of annual peaks at gaging stations (the highest peak discharge occurring each year) to determine the magnitude and frequency of floods at individual gaging stations. The second step is the development of methods for transferring flood frequency data at gaging stations so that flood characteristics may be estimated for ungaged sites.

Regression equations seek to relate a causal factor, such as rainfall and/or watershed characteristics, with an effect, such as peak discharge, runoff volume, or annual mean flows, through statistical correlation. Their applicability to urban storm water systems is minimal, mainly because of the constantly changing watershed characteristics where urbanization is in process. Most peakflow regression equations do not contain a change in land use factors such as an increase in percent imperviousness. These models do not generally predict the total hydrograph and are of limited use whenever storage in the system is being considered.

Peak flow data are collected at gaging stations. Flood peaks at gaging stations are analyzed by the annual flood series method in which only the maximum peak discharge for each year is used, as contrasted with the partial duration series method in which all peaks higher than a selected base are used without regard to the time of occurrence.

Analysis of peak flow data at gaging stations defines the relation between the magnitude ofthe peak flow and its recurrence interval or probability of occurrence. In the annual flood series, a flood discharge that has a recurrence interval of 50 years may be expected to be exceeded as an annual maximum on the average of once in 50 years, and a discharge that has a recurrence interval of 5 years is expected to be exceeded as the annual maximum on the average of once in 5 years. The probability of exceedence is the reciprocal of the recurrence interval; thus, a flood having a recurrence interval of 5 years has a 20-percent chance of occurring during any year (1/5 = 0.20, or 20%).

Regional Analysis

Frequency curves may be defined from a series of flood discharges by using either mathematically fitted probability distributions or graphical curves. As recommended by the Water Resources Council (1967), the mathematically fitted log-Pearson Type III probability distribution is used to define frequencY curves for unregulated gaging station records 10 or more years in length. In this method, the peak discharge for selected recurrence intervals is computed by the equation:

$\log Q = M + KS$

where:

$Q =$ annual peak discharge for a selected recurrence interval

$M =$ mean of the logarithms of the annual peaks

$K =$ Pearson Type, III coordinates, expressed in number of standard deviations for the selected recurrence interval and the skew.

$S =$ standard deviation of the logarithms of the annual peaks

Values of K may be obtained for a wide range of recurrence intervals from standard tables in statistical textbooks.

A high degree of correlation generally exists between flows for most of the stations having less than about 20 years of record and those for nearby longterm stations.

An extremely high or low value among the series of annual peaks may cause a distortion in the shape of a mathematically computed frequency curve. To insure that frequency curves computed by the log-Pearson method are realistic, each curve should be compared to a data plot.

Peak discharge data for various recurrence intervals for gaging stations are analyzed and listed in tables. The accuracy of discharges computed for recurrence intervals greater than twice the period of record at a gaging station is questionable.

An effective way for estimating flood flow characteristics at ungaged sites is to develop a mathematical relationship between stream flow characteristics and basin parameters by multiple regression analysis of data collected at gaged sites. Once the equation is defined, streamflow characteristics for ungaged sites can be computed by determining the appropriate values of the parameters and substituting these values in the equation.

The flood-peak data used in the multiple regression analysis are the discharges from flood frequency curves developed from gaging-station data. Separate regression equations are developed from peak flows usually having recurrence intervals of 2 to 100 years.

Regression Analysis

The following topographic and climatic parameters have been used in existing studies. They are determined for the drainage basin upstream from each of the gaging stations used in the multiple regression analysis:

1. Drainage area (A), mi2 - usually determined by planimeter from the best available maps.

2. Main-channel length (L), mi - from the gauging station to the basin divide.

3. Main channel slope (8), ftlmi - The average slope between points 10 and 85 percent of the distance along the main stream channel, from the gaging site to the basin divide.

4. Mean basin elevation (E), ft above mean sea level.

5. Vegetative cover.

6. Mean annual precipitation (P), in.

7. Area of lakes and ponds, % of drainage area.

8. Rainfall intensity, in - the maximum 24-hr precipitation that will occur on the average of once in 2 years.

Generally, the drainage area and stream slope parameters explain most of the variation in analysis. They are the singnificant variables.

After the discharge-recurrence relation is defined and basin parameters are determined for gaging stations, the next step is to relate the peak discharge for each recurrence interval to basin parameters in equations developed by using multiple-regression techniques. The equation has the form:

Q = AX x BY x Cz x Nn

You will recognize this to be the same general formula that was used in the Cypress Creek Equation.

Calculations are made using all the topographic and climatic parameters and the significance of each basin parameter is determined. Repeated calculations are made omitting the least significant parameter in each calculation until only the most significant parameter for a flow characteristic remains in the last equation. Loss in accuracy resulting from eliminating a parameter is indicated by the change in standard error of the estimate.

Regression analysis should not be used for estimates at sites where flood flow is materially effected by storage such as farm ponds or reservoirs. Diversions and urban or suburban development of a significant part of the basin can greatly effect flood flows.

While natural valley storage is a factor that affects the magnitude of peak flows, it is difficult to evaluate. In most instances, this factor is at least partly incorporated in other parameters such as slope and stream length.

Example

Figure 7 A provides graphical discharge formula solutions for 2-yr and Figure 7B for 25-yr frequency peak discharges. These formulas were developed by USGS and are typical of the peak flow regression equations.

Given:

Drainage Area = 120 mi²

Slope = 8.0 ft/mi

Slope is the average slope between points 10 and 85 percent of the distance along the main stream channel from the gaging site to the basin divide.

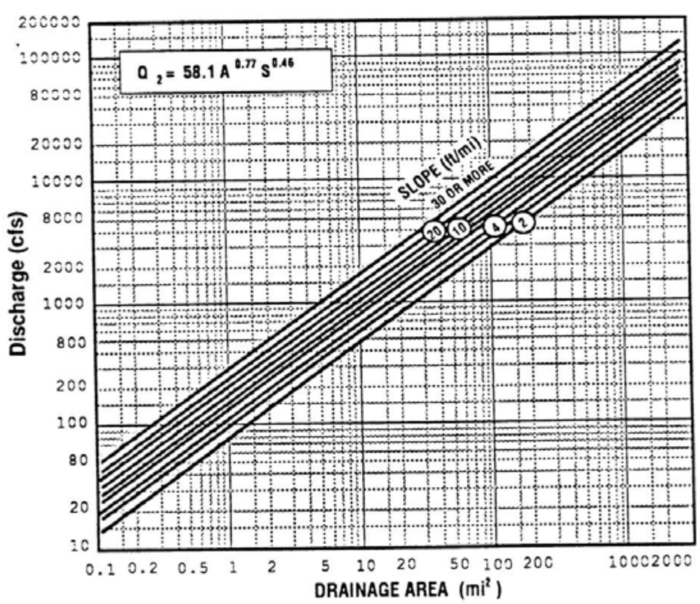
Find:

Solution:

The 25-yr frequency peak discharge for design of a structure.

Solution A - Using the chart

1. U sing the 25-yr frequency curve in Figure 7B, read 120 mi² on the drainage area scale.
2. Move up to the 8.0 ft/mi slope curve, and read the vertical axis.
3. Q = 17,000 cfs



Graphical solutions to 2-year frequency peak discharges.

Graphical Solution to $Q_2 = 58.1\ A^{.77} S^{.63}$

Application to Gaged Streams

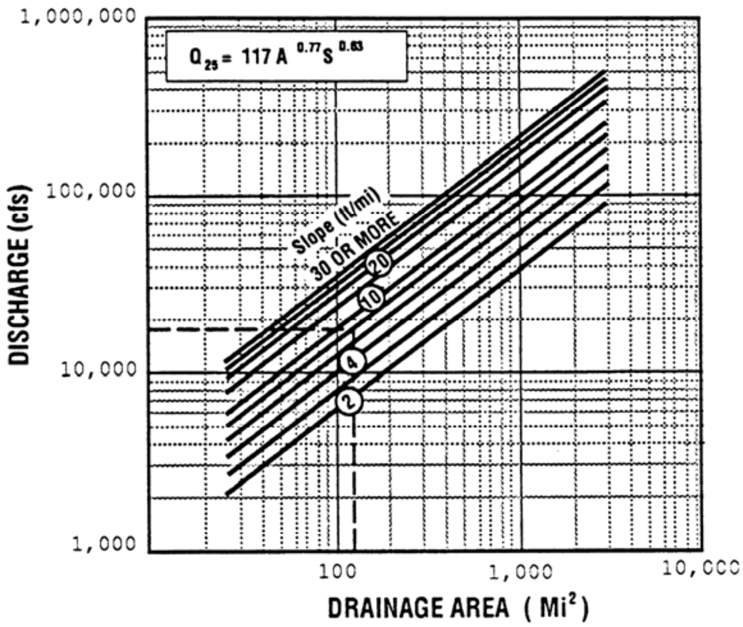


Figure 7B. *Graphical solutions to 25-year frequency peak discharges.*

Graphical solution to $Q_{25} = 117\ A^{.77} S^{.63}$

Solution B - 'C'sing a calculator

1. Solve the equation:

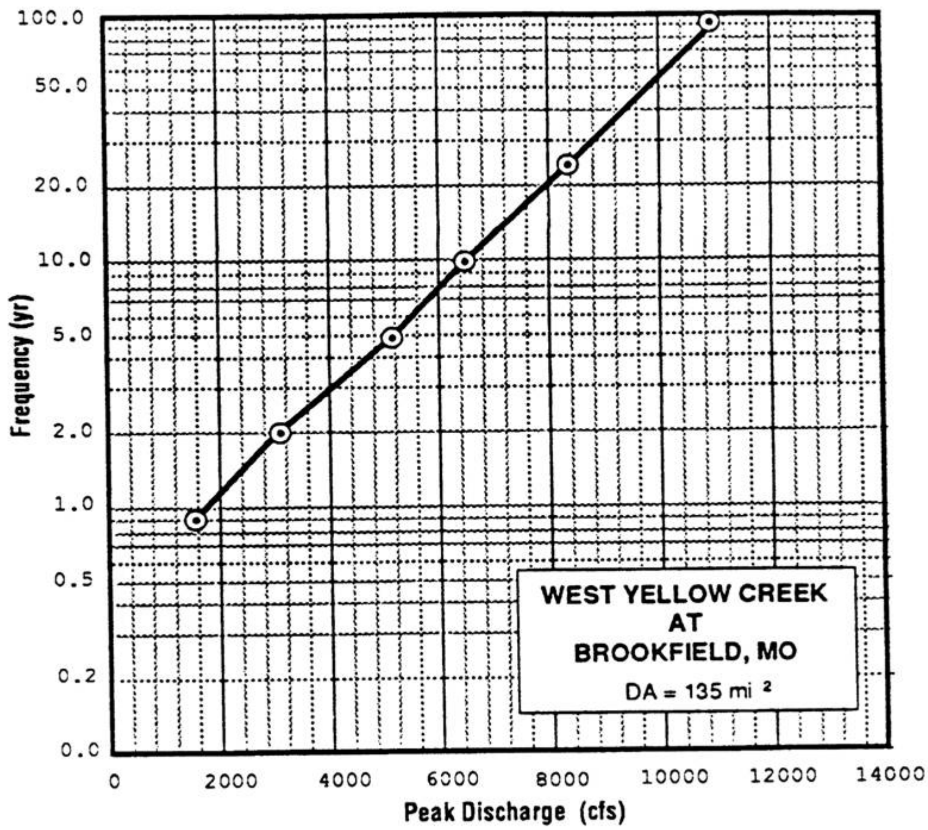
$Q = 117\ A^{.77} S^{.63}$

$= 117$ (120 mi² 0.77) (8.0 ft/mi$^{.63}$)

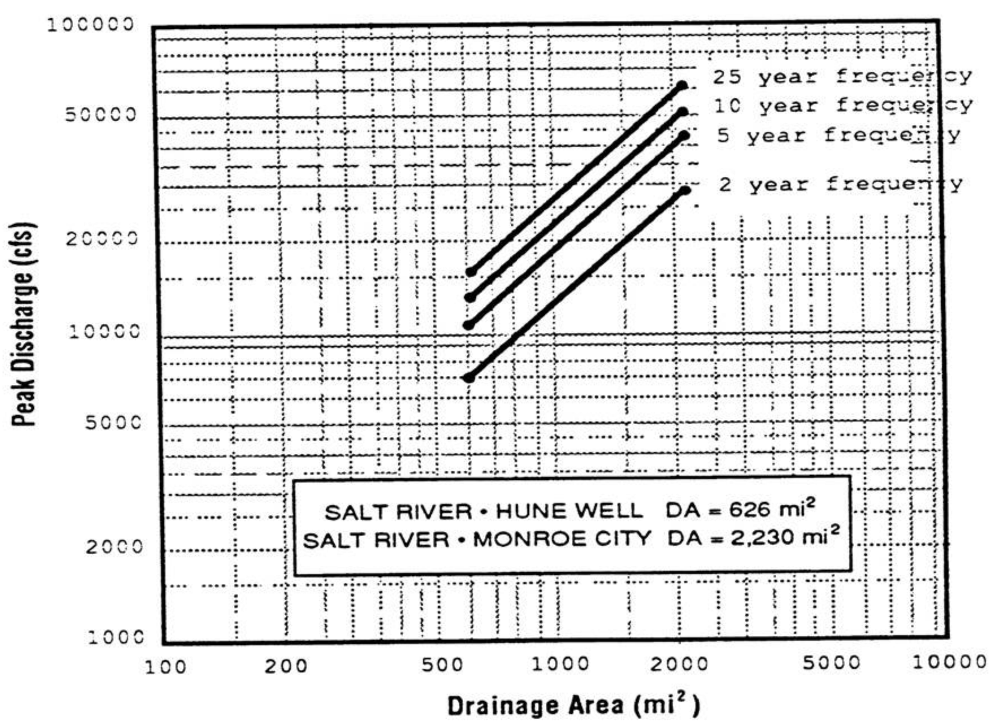
= 117 (39.90) (3.71)

= 17,319 cfs

If an analysis is made of flood flow characteristics at or near one of the long term gaging stations, that data should be used. Figure 8 is an example of a frequency plot at a stream gage on West Yellow Creek near Brookfield, Missouri. If you desire to know the five-year frequency peak discharge, you read 5,100 cfs. However, in the case of stream gaging stations having short periods of record, flood flow characteristics probably can best be determined from regression equations. On the basis of a theoretical relation of standard error to index of variability of annual peak flows for station data used in the analysis, the regression equations developed will give the same accuracy as about 15-20 years of record. As a general rule, use gaging station data if the period of record exceeds 15 years. Use regression equations if there are no peak flow data, or if the period of record is 15 years or less.



100.0
50.0
20.0
10.0
5.0
2.0
1.0
0.5
0.2
0.0
Frequency (yr)
0
2000
4000
6000
8000
10000
12000
14000
Peak Discharge (cfs)
WEST YELLOW CREEK
AT
BROOKFIELD, MO
DA = 135 mi 2



100000
50000
20000
10000
5000
2000
1000
Peak Discharge (cfs)
25 year frequency
10 year frequency
5 year frequency
2 year frequency
SALT RIVER • HUNE WELL DA = 626 mi2
SALT RIVER • MONROE CITY DA = 2,230 mi2
100
200
500
1000
2000
5000
10000
Drainage Area (mi2)

If information is desired at a point between two long-term gaging stations on a stream, peak flow values may be computed by interpolation, on the basis of drainage area, frequency, peak discharge values at each gage. Interpolation can be done by plotting discharge versus drainage area on logarithmic plotting paper for the two gaged sites, connecting these two points with a straight line, and then entering this relation with the value of the drainage area at the site where information is desired. Figure 9 shows an example of plotting data of two stream gages. If 25-year frequency peak discharge values were needed at a location having 1000 square miles of drainage area, you would read 26,000 cfs. Interpolation is not always recommended if the drainage area of the upstream station is less than about half that of the downstream station.

When flood frequency data are needed at a site upstream or downstream from a long-term gaging station for which flood frequency relations have been defined, it is recommended that the appropriate regression equation be used.

It is recommended that. this method not be used for drainage areas more than twice, or less than one-half, the size of the drainage area of the gaged site.

A brief description of each gaging station is usually included in each state report. One of two types of tabulation of gage data is usually presented: (1) A listing of all the peaks higher than a selected base at each gaging station, along with the station history; or (2) The second display of gaging station data may be in the form of the annual frequency curve peak discharge values developed using Bulletin 17B procedures.

Bulletin 17B was developed by the Water Resource Council because of the need for a consistent approach to accurately estimate stream flows and make stream gage analyses. The stations with sufficient detail to promote uniform application were selected and used.

Rational Equation

The rational method was developed about 100 years ago for the purpose of predicting peak flow rates for small, urban watersheds. It does not provide any information pertaining to the runoff hydrograph shape. The rational method is a valid hydrologic design tool for predicting peak flow rates from urban watersheds up to 50 acres.The rational method of predicting a design peak runoff rate is expressed by the equation:

$$Q = CiA$$

where

Q= design peak runoff rate, cfs

C = runoff coefficient, dimensionless - defined as the ratio of the peak runoff rate to the rainfall intensity

1 = rainfall intensity, in/hr, for the design recurrence interval and for duration equal to the time of concentration (To) of the watershed

A= watershed area, ac

Values of C are based on soil, topography, vegetation, and use. Many attempts have been made to refine these values. However, variations can still remain quite large (see Table 1).

Values for the rainfall intensity can be obtained from rainfall intensity curves in publication such as Weather Bureau Technical Paper No. 25. Figure 10 illustrates intensity curves for two locations: Kansas City, Missouri, and Asheville, North Carolina. The time of concentration of a watershed is the time required for a particle of water to flow from the hydraulically most distant point on a watershed to the outlet. It is assumed that, when the duration of a storm equals the time of concentration, all parts of the watershed are contributing simultaneously to the peak discharge at the outlet.

The ration equation only gives peak discharges. Various people have attempted to develop a method to obtain a hydrograph.

The rational method is recognized to have a number of weaknesses. It is a great oversimplification of a complicated process. The equation, Q = CiA, may not appear to be dimensionally correct. Although "i" is specified in inches per hour, 1 inch per hour is 1.008 cfs per acre, and, in using the equation, the two are taken to be numerically equal.

TABLE 1 *Values of Runoff Coefficient* C

URBAN AREAS:	
Type of drainage area	Runoff coefficient C
Lawns: Sandy soil, flat 2% Sandy soil, average, 2 - 7% Sandy soil, steep, 7% Heavy soil, flat, 2% Heavy soil, average, 2 - 7% Heavy soil, steep, 7%	0.05 - 0.10 0.10 - 0.15 0.15 - 0.20 0.13-0.17 0.18 - 0.22 0.25 - 0.35
Business: Downtown areas Neighborhood areas	0.70 - 0.95 0.50.0.70
Residential: Single-family areas Multi units, detached Multi units, attached Suburban Apartment dwelling areas	0.30 - 0.50 0.40 - 0.60 0.60 - 0.75 0.25 - 0.40 0.50 - 0.70
Industrial: Light areas Heavy areas	 0.50 - 0.80 0.60 - 0.90
Parks, cemeteries	0.10 - 0.25
Playgrounds	0.20 - 0.35
Railroad yard areas	0.20 - 0.40
Unimproved areas	0.10 - 0.30
Streets: Asphaltic Concrete Brick	0.70 - 0.95 0.80 - 0.95 0.70 - 0.85
Drives and walks Roofs	0.75 - 0.85 0.75 - 0.95

AGRICULTURAL AREAS:

Topography and Vegetation	Runoff Coefficient C Soil Texture		
	Soil Texture		
	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland Flat 0 - 5% Slope Rolling 5 - 10% Slope Hilly 10 - 30% Slope	 0.10 0.25 0.30	 0.30 0.35 0.50	 0.40 0.50 0.60
Pasture Flat Rolling Hilly	0.10 0.16 0.22	0.30 0.36 0.42	0.40 0.55 0.60
Cultivated Flat Rolling Hilly	 0.30 0.40 0.52	 0.50 0.60 0.72	 0.60 0.70 0.82

The rational equation was developed from the following assumptions:

1. Rainfall occurs at uniform intensity for a duration at least equal to the time of concentration of the watershed.

2. Rainfall occurs at a uniform intensity over the entire area of the watershed.

The major criticisms are expressing runoff as a fraction of rainfall rather than as rainfall minus losses and for combining all the complex factors that effect runoff into a single coefficient. Numerous refinements have been developed for the runoff coefficient. This has helped the consistency and uniformity of results. Many small hydraulic structures have been designed using the rational equation. Its application should be limited to small areas of 50 acres or less.

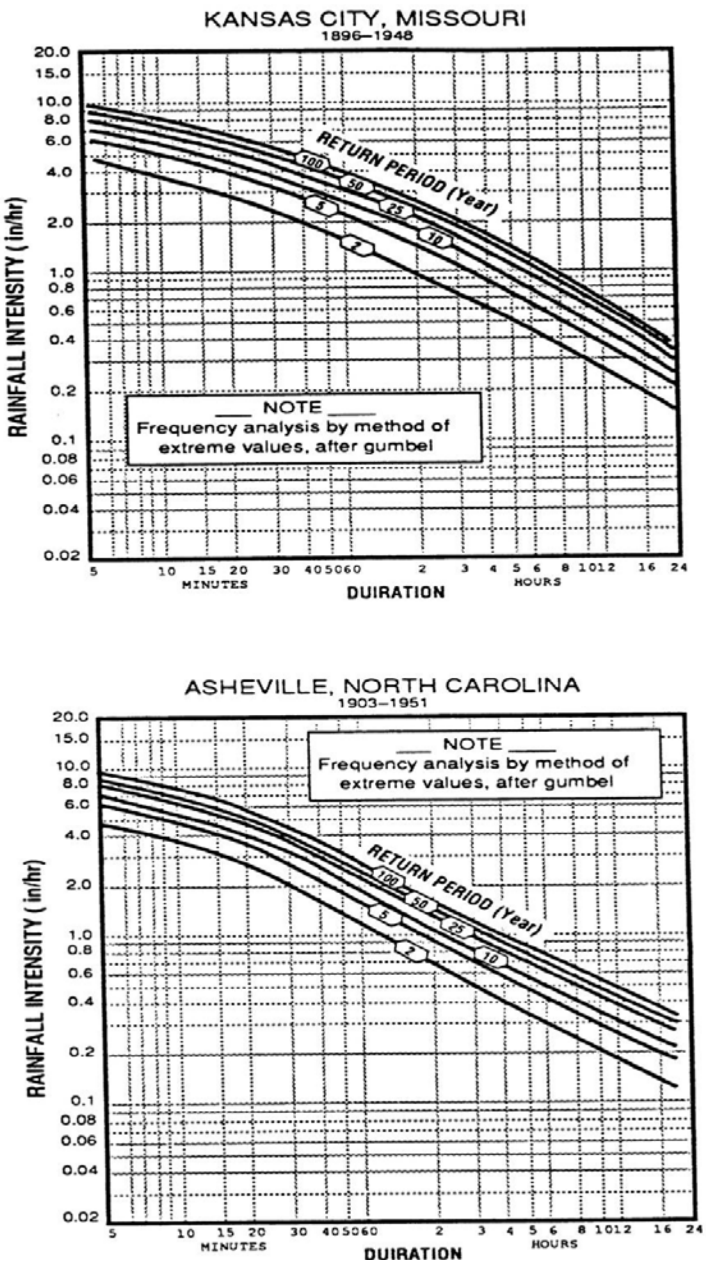


Fig.10 Intensity curves for Kansas City, MO and Asheville, NC (From Weather bureau technical paper no 25)

Example

Given:

Urban setting

Drainage Area = 12 ac,

where 6 ac = single family area 3 ac = park

3 ac = streets (concrete) Soil = clay loam

Tc = 20 min

Find:

The instantaneous peak discharge for a 25-yr frequency flood at a road crossing in an urban/rural area located in the Kansas City, Missouri area.

Solution:

1. Determine the runoff coefficient, C

a. From Table I, for a single family area,

C = 0.30 - 0.50. Since this area is a clay loam, a midpoint value would be more appropriate. Use C = 0.40.

b. or the park area, C = 0.10 - 0.25. Use C = 0.15

c. For concrete streets C = 0.80.0.95. Use C = 0.90.

d. Weight the C values:

6 ac single family 3 ac park
3 ac streets

6/12 x 0.40 = 0.20 3/12 x 0.15 = 0.04 3/12 x 0.90 = 0.23 Total = 0.4 7

2. Determine the rainfall intensity, i

The equation assumes the duration to be equal to the time of concentration. Enter Figure 10 at a duration of20 min. Move up to the 25-yr frequency curve, and read i = 5.1 in/hr.

3. Solve the equation

$Q = CiA$

$= 0.47 (5.1 \text{ in})(12 \text{ ac})$

= 28.8 cfs, rounded to 29 cfs

Summary

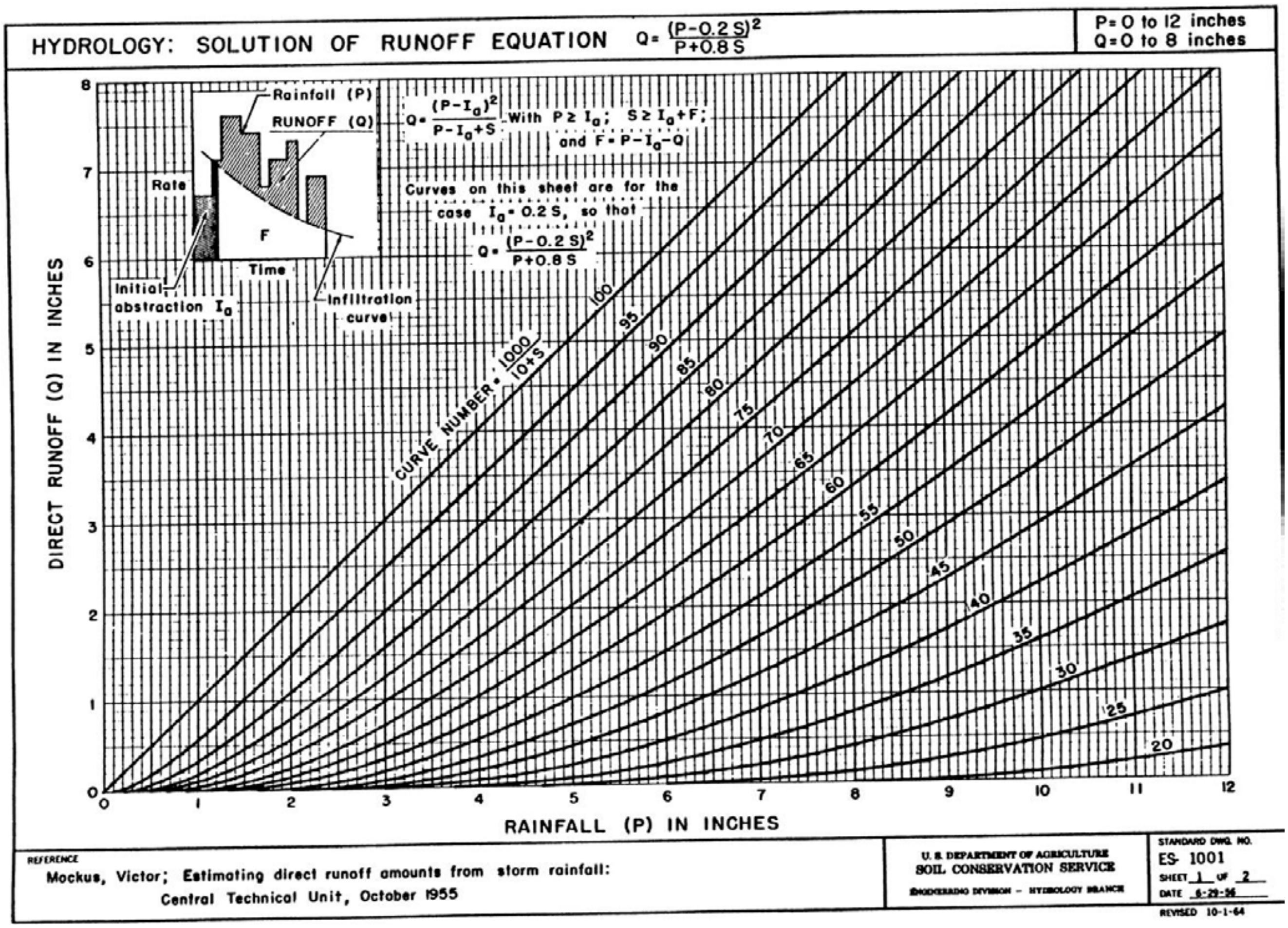
You should now be able to use three methods to compute peak discharges for specific geographical regions. You should also know how to determine where and when each of these methods may be used. If you cannot do this, you should review the methods in question until you become proficient with them.

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 prob1em.Ifyou 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 your supervisor to submit, through channels, to your State or NTC Training Officer.

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.



Using the Cypress Creek Formula, solve the following problem:

Given:

Drainage area = 1.75 mi^2 CN = 80
5-yr, 24-hr rainfall, P = 5.1 in

Find:

1. Direct Runoff, Re in
2. Coefficient C
3. Peak Discharge, Q, cfs

Solution:

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.

Given:

Drainage Area = 60 mi^2 Slope = 5.0 ft/mi

Find:

The 2-yr frequency peak discharge for the design of a culvert at a farm road crossing.

Solution:

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.

Using the rational method, solve the following problem:

Given:

Urban setting

Drainage Area = 18 ac,

where 1 ac = playground

10 ac = single family area

2 ac = streets (asphaltic)

5 ac = pasture (hilly)

Soil= heavy clay

Tc = 20 min

Find:

The instantaneous 100-yr frequency peak discharge for design of a channel in a developing subdivision located in an area near Asheville, North Carolina.

Solution:

Activity 1 - Solution

Using the Cypress Creek Formula, solve the following problem:

Given:

Drainage area = 1.75 mi^2 CN = 80
5-yr, 24-hrrainfall, P = 5.1 in

Find:

1. Direct Runoff, R_e, in
2. Coefficient C
3. Peak Discharge, D, cfs

Solution:

1. Using Figure 3 of the runoff equation with P = 5.1 in and CN = 80, find Re= 2.98 in

2. $C = 16.39 + 14.75\ R_c$

$= 16.39 + 14.75(2.98 \text{ in}) = 16.39 + 43.96 = 60.35$

3. $D = CM^{5/6} =$

$= 60.35\ (1.75\ mi^2)^{5/6} = 60.35(1.59)$

= 96 cfs

Activity 2 - **Solution**

Given:

Drainage Area = 60 mi^2 Slope = 5.0 ft/mi

Find:

The 2-yr frequency peak discharge for the design of a culvert at a farm road crossing.

Solution:

Solution A - Using the chart (Figure 7A)

1. Using the 2-yr frequency curve in Figure 7A, read 60 mi^2 on the drainage area scale.

2. Move up to the 5.0 ft/mi slope curve, and read the vertical axis.

3. Q = 2,900 cfs

Solution B - Using a calculator

1. Solve the equation:

$Q = 58.1\ A^{.77}\ S^{.46}$

$= 58.1\ (60\ mi^2)^{.77}\ (5.0\ ft/mi)^{.46}$

$= 58.1\ (23.40)(2.10)$

$= 2{,}855$ cfs

Activity 3 - **Solution**

Using the rational method to solve the following problem:

Given:

Urban setting

Drainage Area = 18 ac,

where 1 ac = playground

. 10 ac = single family area

2 ac = streets (asphaltic)

5 ac = pasture (hilly)

Soil = heavy clay

Tc = 20 min

Find:

The instantaneous 100-yr frequency peak discharge for design of a channel in a developing subdivision located in an area near Asheville, North Carolina.

Solution:

1. Determine the runoff coefficient, C

a. From Table 1, for a playground, C = 0.20 - 0.35.since the area is heavy clay, C = 0.35.

b. For a single family area, C = 0.30 - 0.50. Since this area is a heavy clay, use C = 0.50.

c. For asphaltic streets, C = '0.70 - 0.95. Use C = 0.90.

d. For hilly pasture in heavy clay soil, C = 0.60.

e. Weight the C values:

1 ac playground 1/18 x 0.35 = 0.02

10 ac single family 10/18 x 0.50 = 0.28

2 ac streets 2/18xO.90= 0.10

5 ac pasture 5/18xO.60= 0.17

Total = 0.57

2. Determine the rainfall intensity, i

Enter Figure 10 at a duration of 20 min. Move up to the 100-yr frequency curve, and read i = 5.5 in/hr.

3. Solve the equation

$$Q = CiA$$
$$= 0.57\ (5.5\ \text{in})(18\ \text{ac})$$
$$= 56.4\ \text{cfs, rounded to 56 cfs}$$