PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
8.0	.81
10.0	.87
12.0	.92
14.0	.96
16.0	1.00
20.0	1.06
25.0	1.14

SLOPES - STEEP

CURVE NUMBER - 60

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

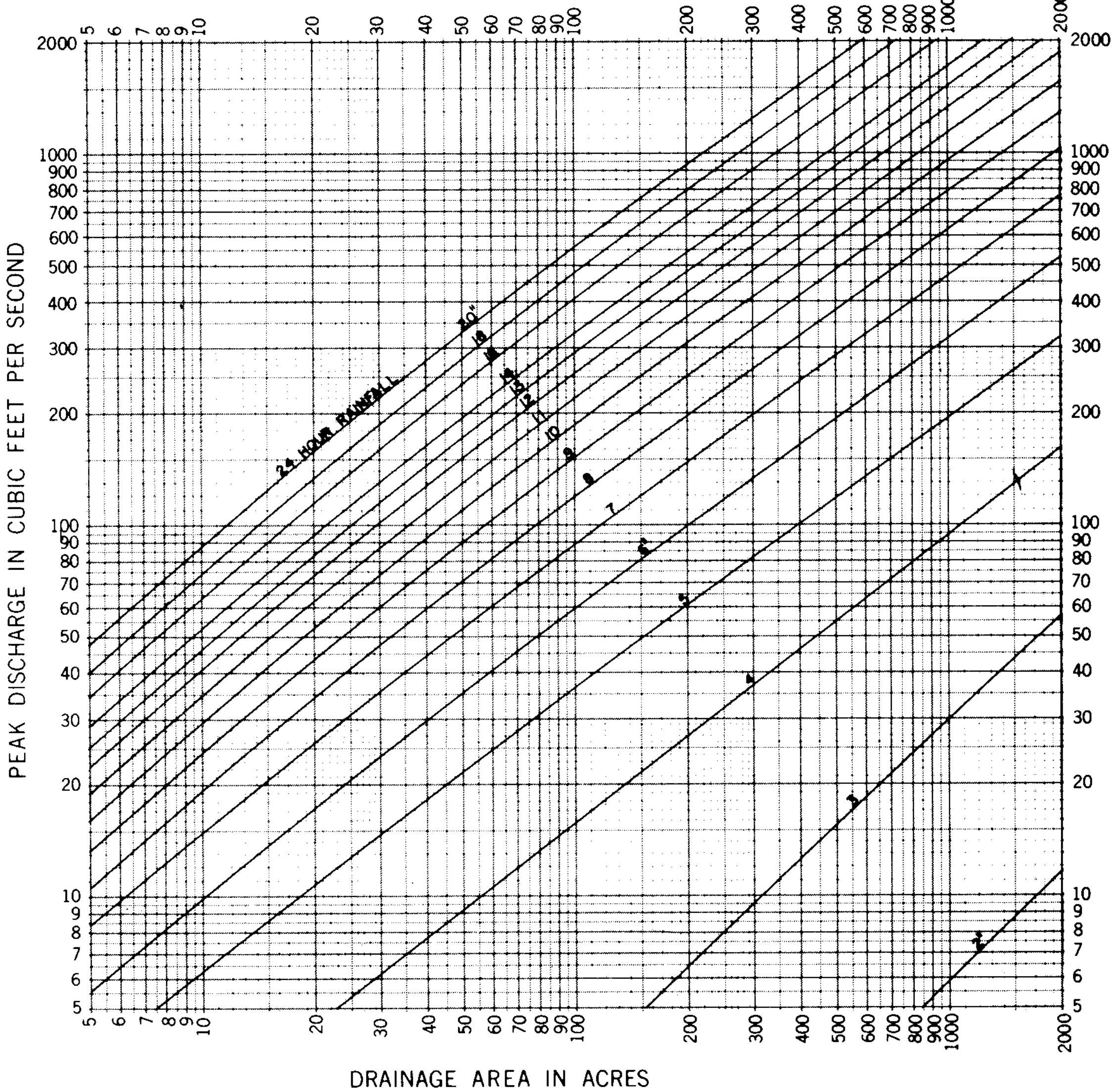


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
8.0	.81
10.0	.87
12.0	.92
14.0	.96
16.0	1.00
20.0	1.06
25.0	1.14

SLOPES - STEEP

CURVE NUMBER - 65

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

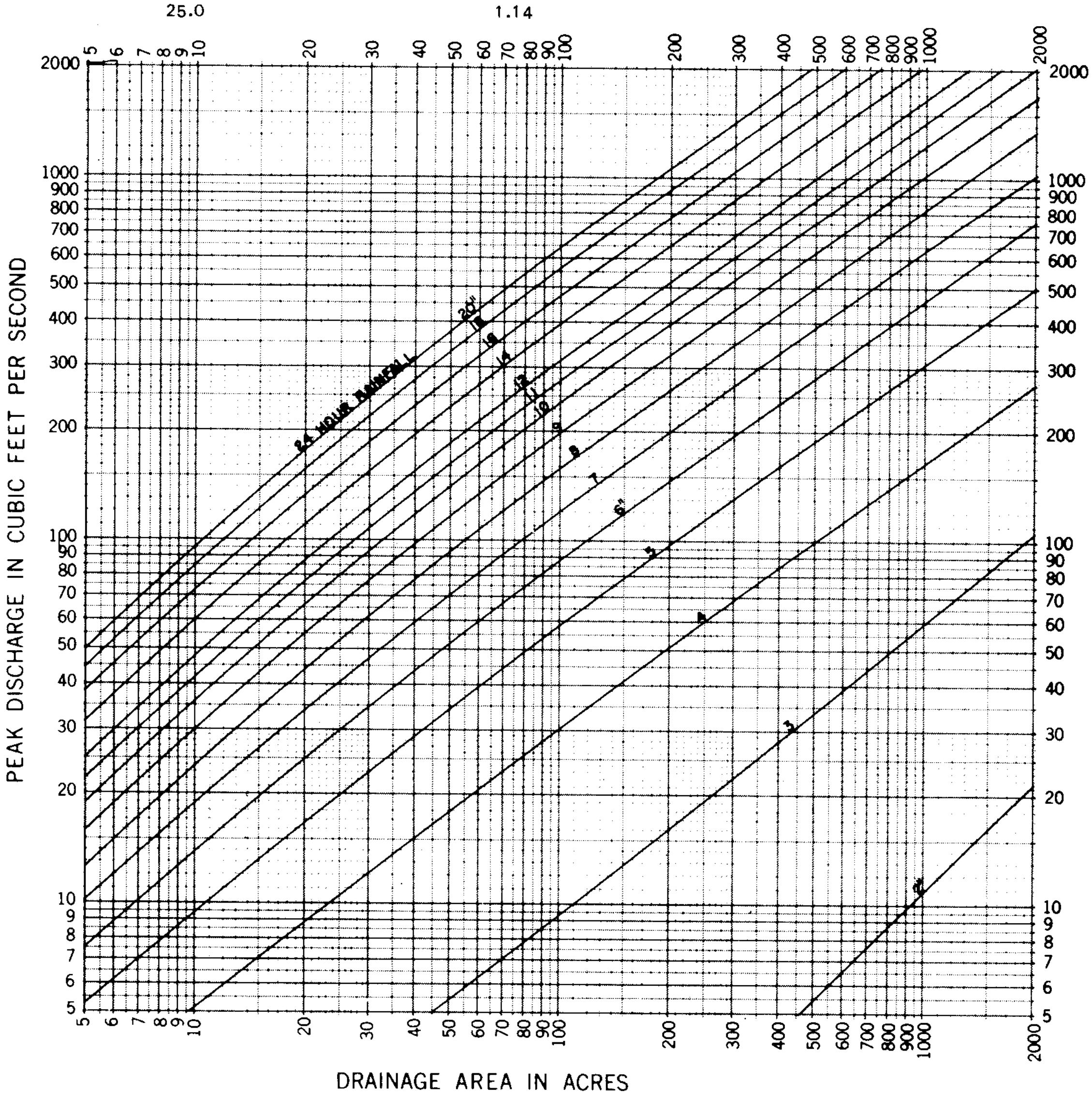


FIGURE 5–4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
8.0	.81
10.0	.87
12.0	.92
14.0	.96
16.0	1.00
20.0	1.06
25.0	1.14

SLOPES - STEEP

CURVE NUMBER - 70

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

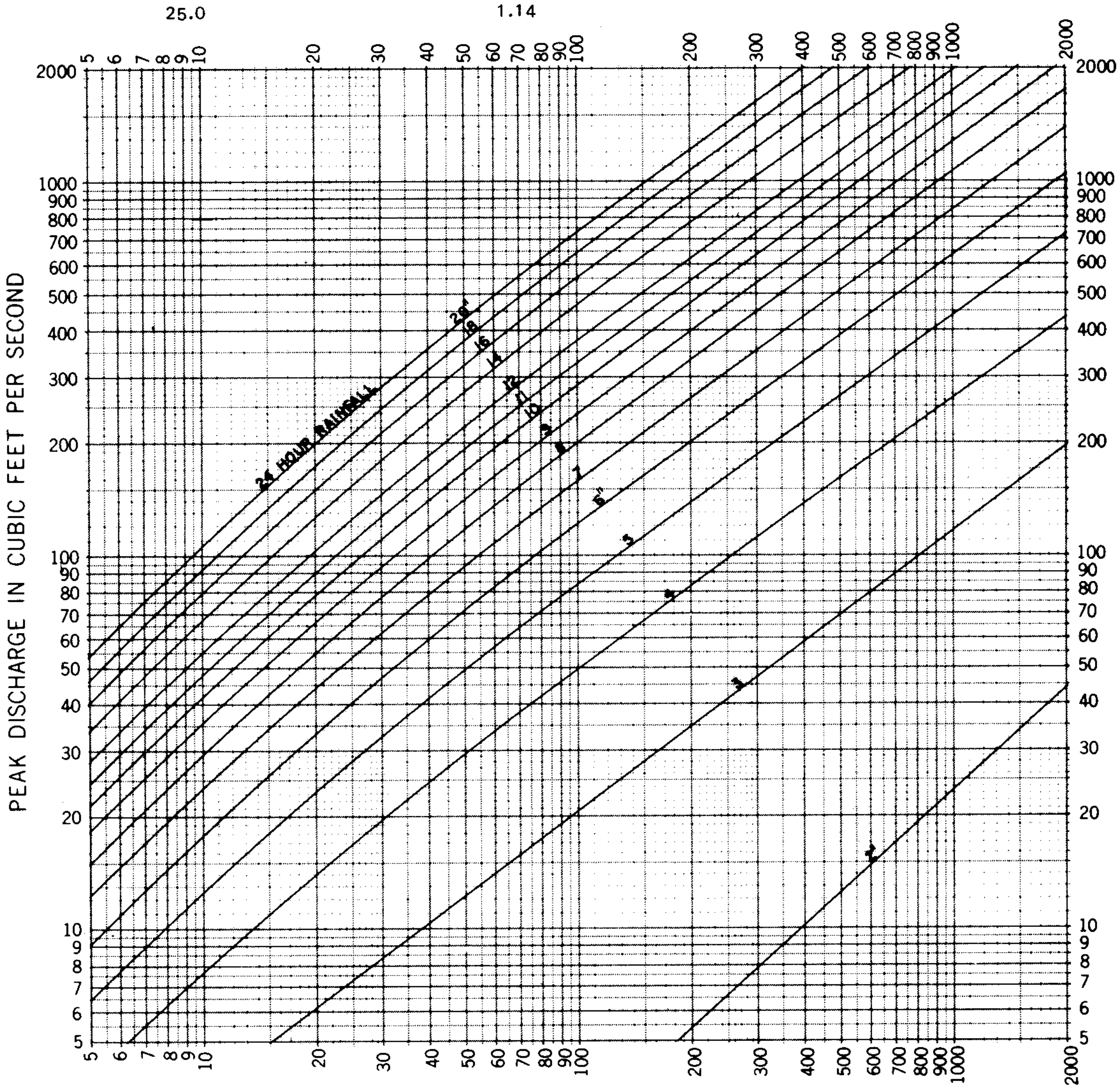


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
8.0	.81
10.0	.87
12.0	.92
14.0	.96
16.0	1.00
20.0	1.06
25.0	1.14

SLOPES - STEEP

CURVE NUMBER - 75

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

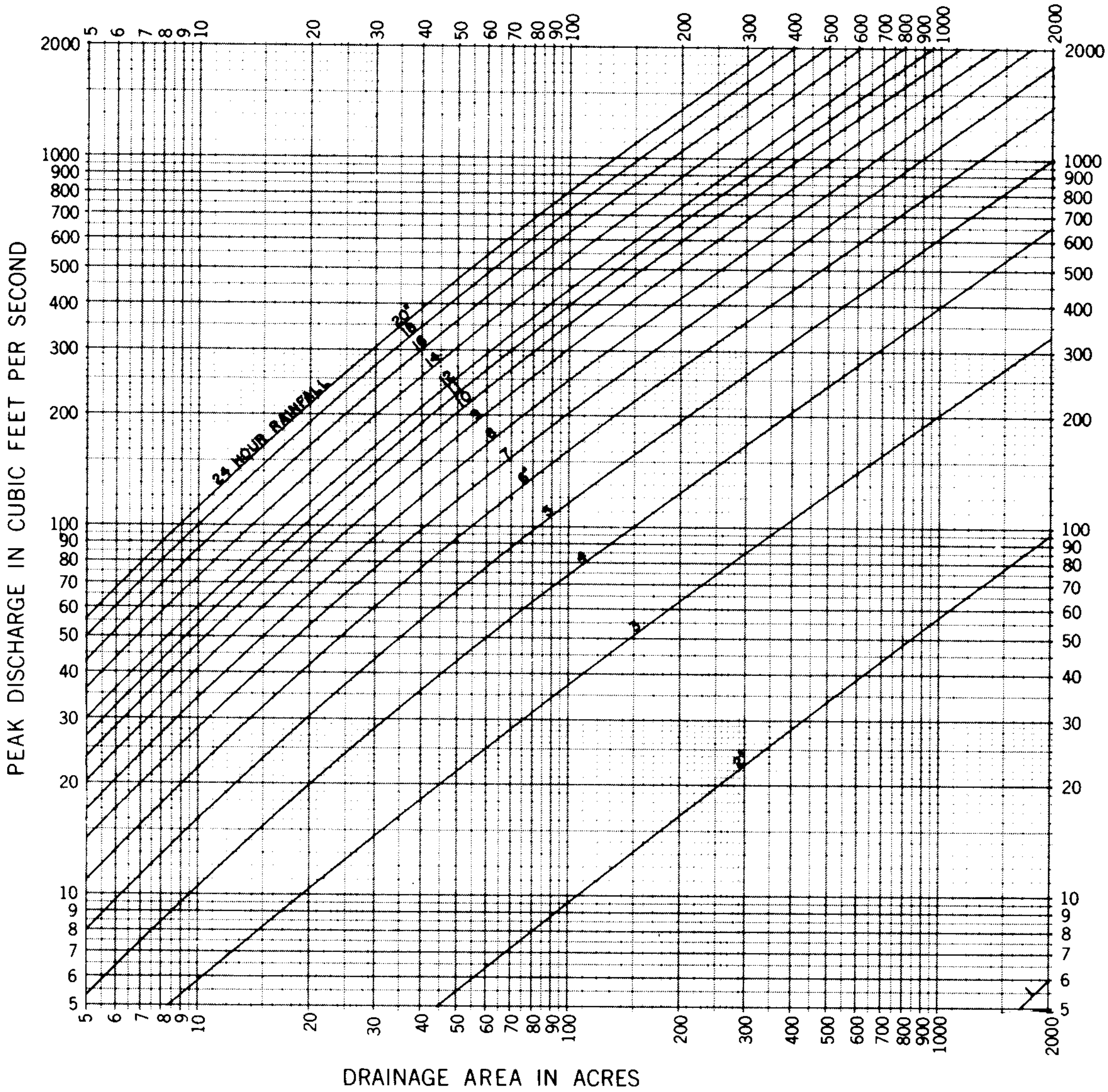


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
8.0	.81
10.0	.87
12.0	.92
14.0	.96
16.0	1.00
20.0	1.06
25.0	1.14

SLOPES - STEEP

CURVE NUMBER - 80

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

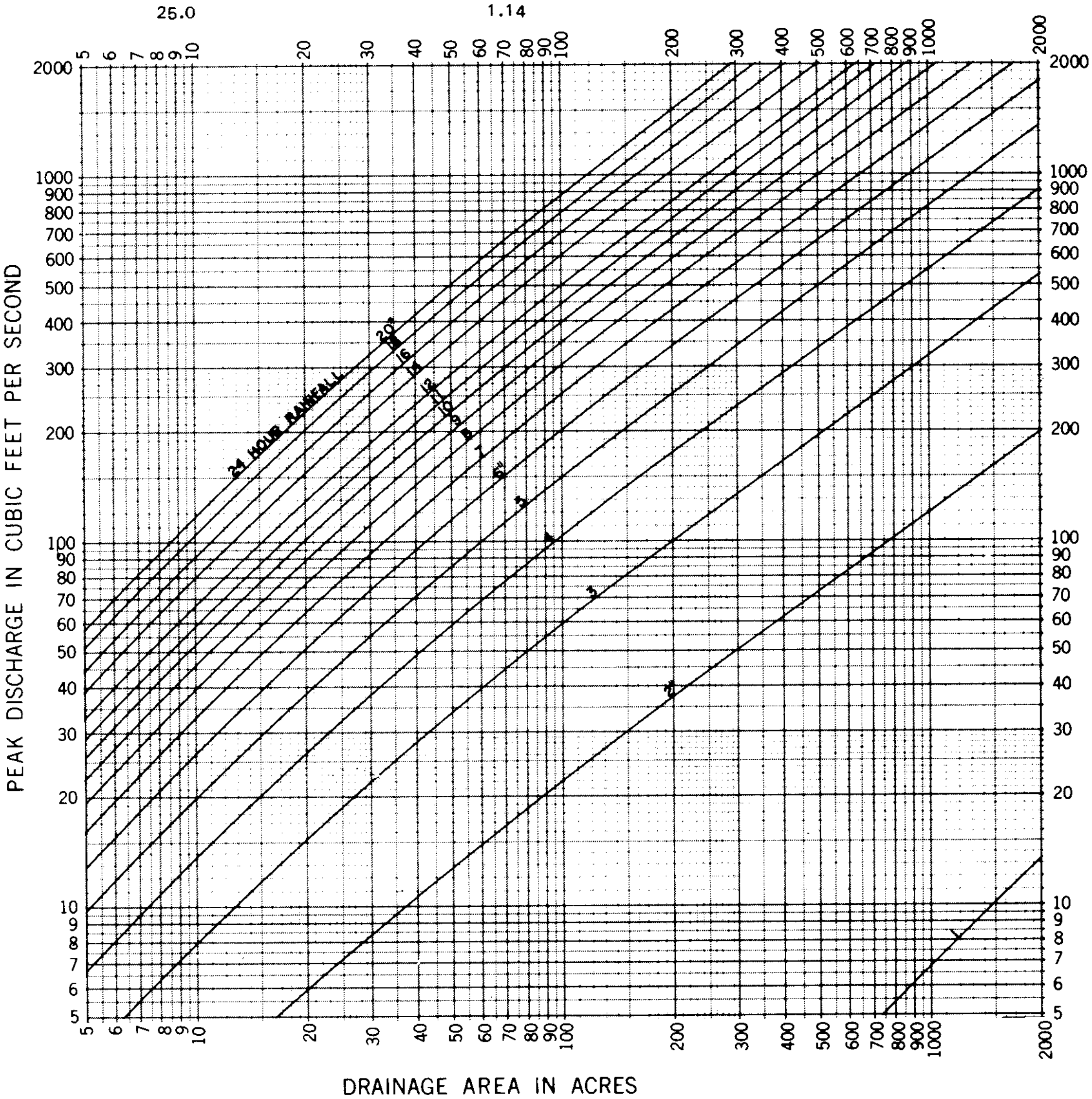


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
8.0	.81
10.0	.87
12.0	.92
14.0	.96
16.0	1.00
20.0	1.06
25.0	1.14

SLOPES - STEEP

CURVE NUMBER - 85

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

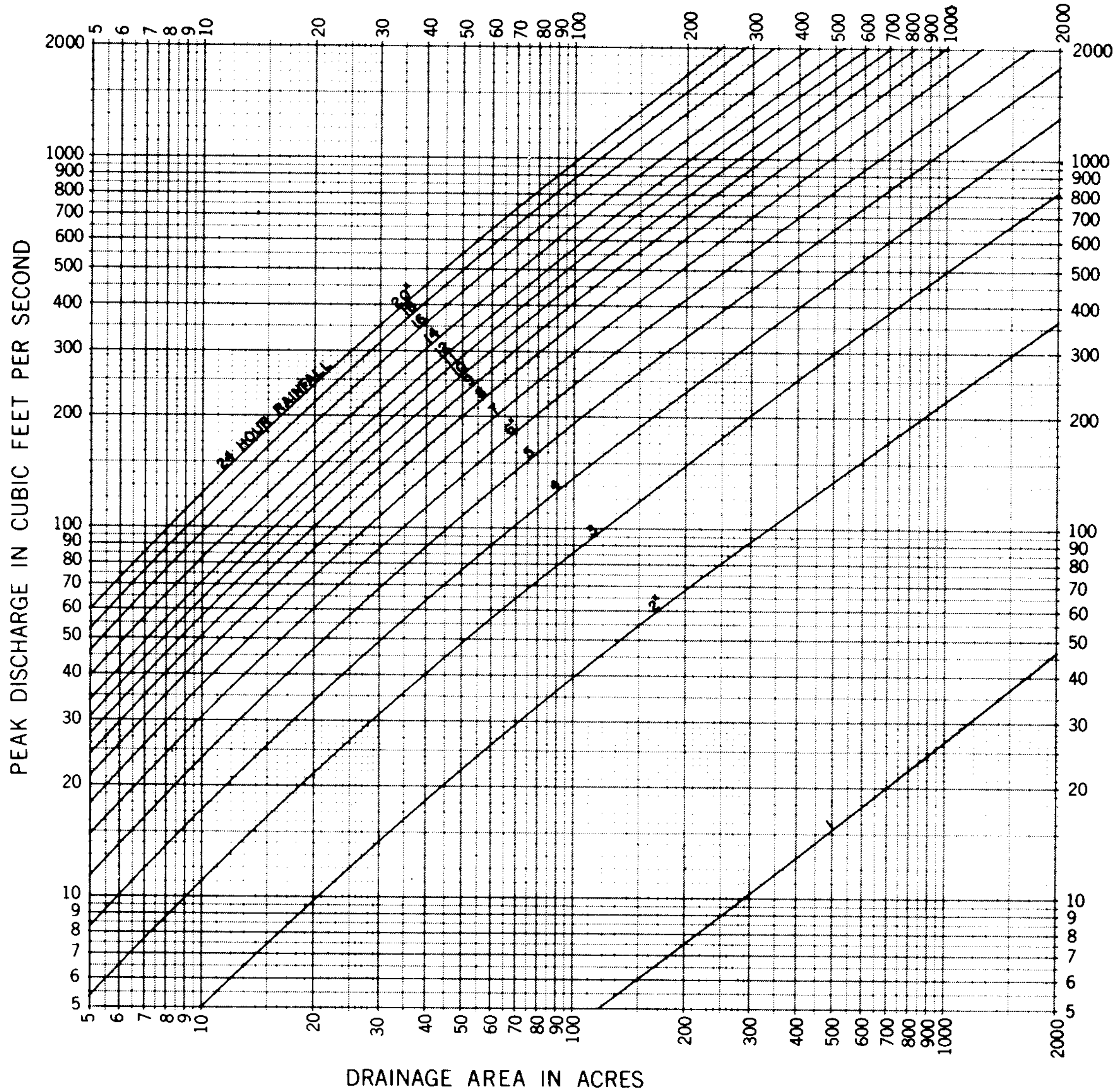


FIGURE 5-4

PEAK RATES OF DISCHARGE FOR SMALL WATERSHEDS
TYPE I STORM DISTRIBUTION

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent)	Factor
8.0	.81
10.0	.87
12.0	.92
14.0	.96
16.0	1.00
20.0	1.06
25.0	1.14

SLOPES - STEEP

CURVE NUMBER - 90

24 HOUR RAINFALL FROM US WB TP-43, TP-47, & (Revised) TP-40

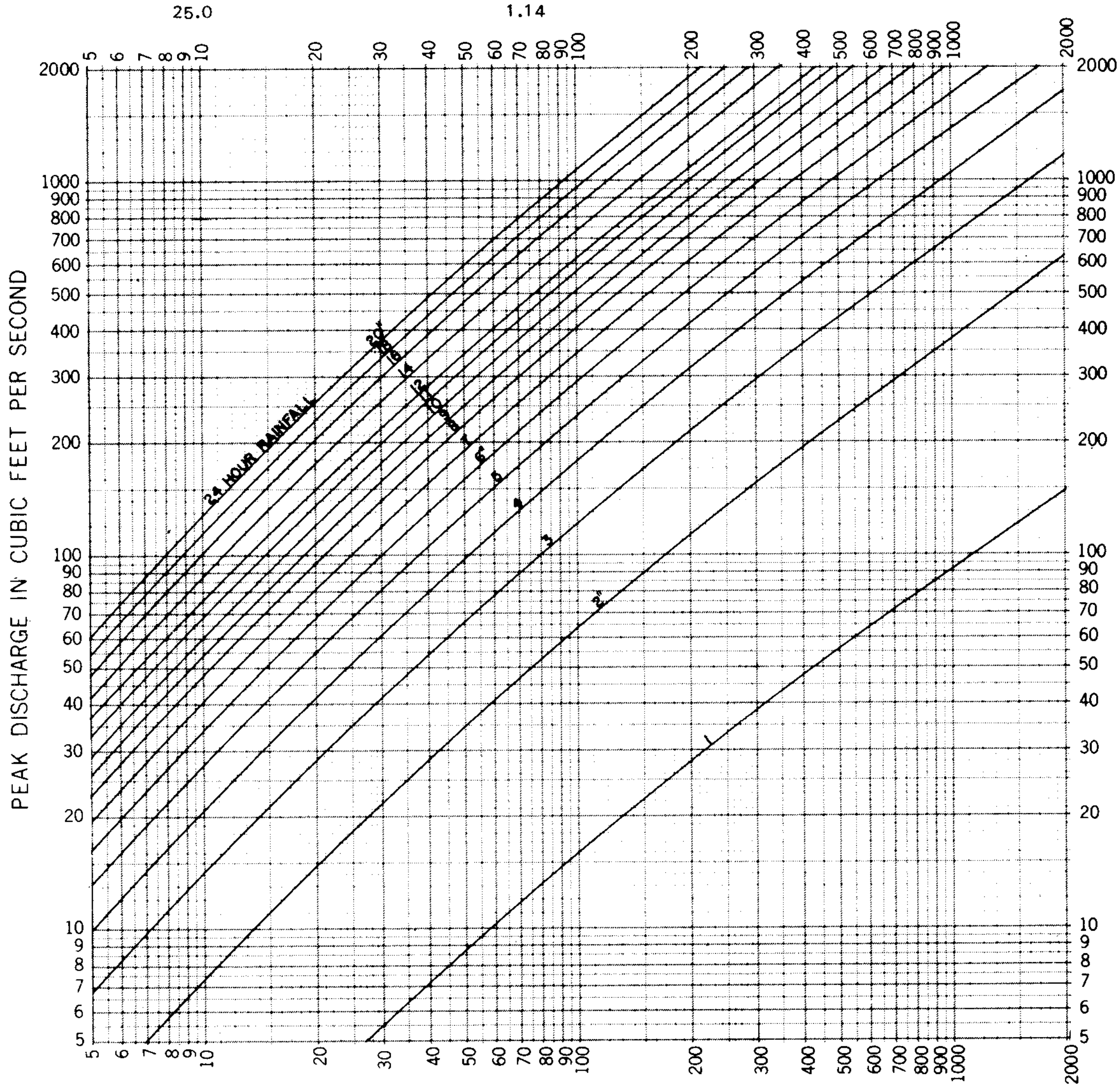


FIGURE 5–4

PEAK DISCHARGES USING PEAK DISCHARGE CURVE

Peak discharge frequency curves were developed for drainage areas of 3 to 20 square miles. Peaks are either snowmelt or rainfall. This is the highest peak discharge occurring during the year. In the eastern part of North Dakota the peak occurs about 70% of the time from accumulations of snow. In the western part of North Dakota the peak occurs about 50% of the time from accumulations of snow.

In making the stream gage studies only watersheds with approximately 1% slope were used, therefore, it is necessary to correct for slopes above or below. (Page 5-32) These gage data were used in defined areas so a correction for the lakes, swamps and potholes is also necessary.

The peak discharges can be read directly using Fig. 5-5, Page 5-32. The only corrections necessary are those for slope (Fig. 5-5b) and the adjustment for water areas (Fig. 5-5a).

The following example is used to illustrate the use of this section:

Example: Location - Barnes County, ND

D.A. = 15 square miles with 10% potholes

Watershed slope = 3%

Frequency of design = 10% chance (10 year)

Peak discharge is 510 cfs (Fig. 5-5)

Slope correction is 510 cfs X 1.42 (slope corr., Fig. 5-5b) = 724 cfs

Pothole correction is 724 cfs X .78 (pothole corr., Fig. 5-5a) = 565 cfs

FIG. 5-5a

ADJUSTMENT FACTOR FOR PERCENT LAKES, SWAMPS, AND POTHOLES

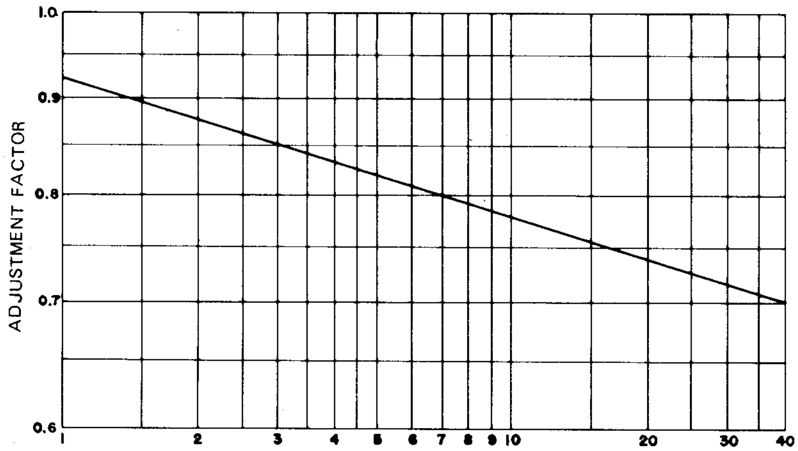


FIG. 5-5b

SLOPE ADJUSTMENT FACTORS

Average Watershed Slope (Percent):	Factor
0.2	.52
0.5	.76
1.0	1.00
2.0	1.31
3.0	1.42

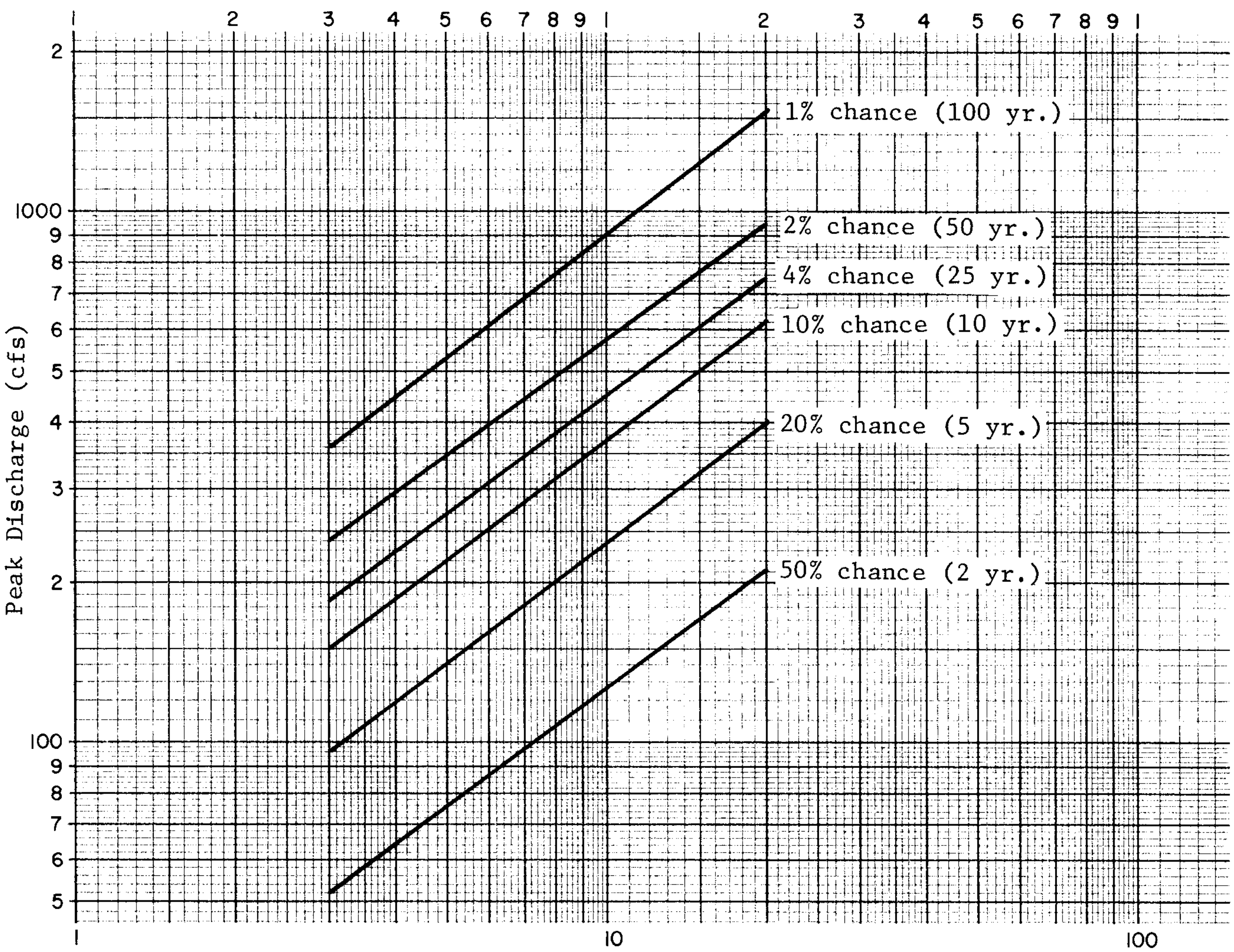


FIG. 5-5

DESIGN DISCHARGES FOR DRAINAGE WORK

Design discharges may be obtained from Figures 5-6 and 5-7 when typical drainage projects are being designed. The discharges obtained from drainage curves are based on removal rates of the water within a 24-hour period of time. The use of these curves should be limited to only drainage work where its use is permitted by the North Dakota Standards for Conservation Practices.

Drainage curves are restricted to the flat lake plain of the Red River Valley, and those areas flat and full of potholes where peak discharges are difficult to determine. Drainage curves are to be used on flat lands where spillover occurs from one watershed to the other. When spillover occurs, it is difficult to establish a frequency discharge because the peaks are influenced by snow blockage in drainage structures, roads and inadequate drainage systems. In these flat lands, very minor obstructions can direct the water from one watershed to another. Most of the drainage work in North Dakota has been restricted to the "M" Drainage Curve.

Drainage Curves A, B, C and D should be used where a high degree of protection for property and agricultural activity is required in flat lands, particularly where minor flooding and duration of flooding is critical to sustain agricultural production.

For non-homogeneous watersheds the drainage discharges should be determined by using the 20-40 rule found on Page 5-23 of Section 16, National Engineering Handbook.

The following example illustrates the use of the drainage curves:

Name: St. Thomas Lodema

Location: Pembina County, North Dakota, Section II - T. 160 N., R. 53 W.

Hydraulic Data

From "M" Curve (Fig. 5-6) read 11.8 cfs per sq. mile
11.8 cfs X 25.5 sq. miles = 301 cfs

Sta. 927+34 to Sta. 967+92

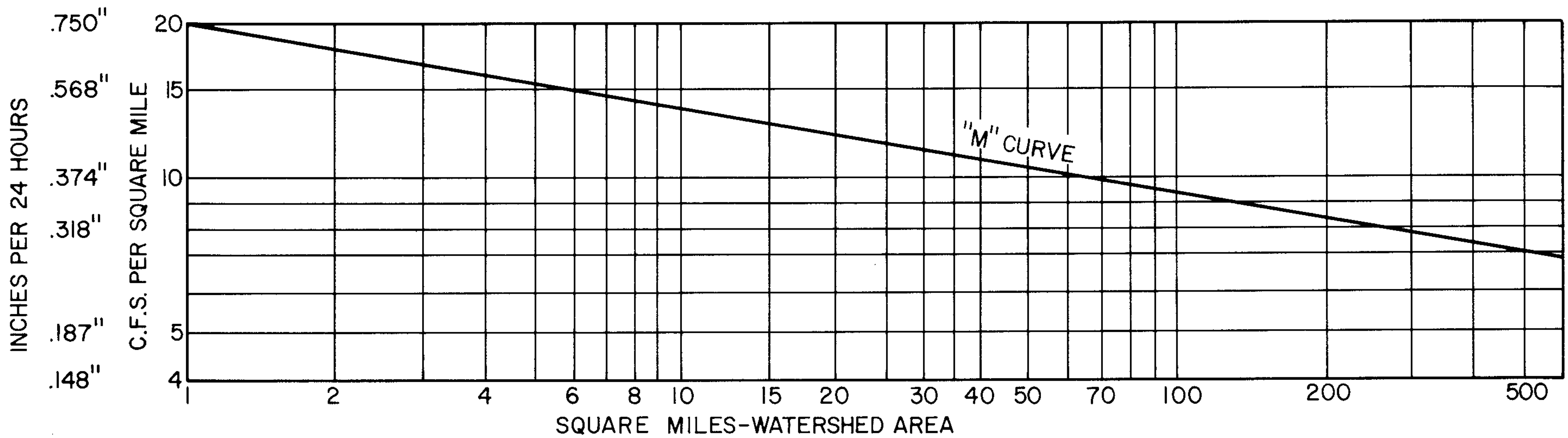
D. A. = 25.5 sq. mi.	q (required)= 301 cfs (Fig. 5-6)
S = 0.0007	
D = 5.0	S/S = 4:1
B = 8.0	V = 2.15 Ft./Sec.
N = 0.035	q (actual) = 301 cfs

DRAINAGE STANDARDS

Soil Conservation Service

Drainage Coefficients for Red River Valley and similar areas, and relatively flat areas containing a large number of potholes.

FIGURE 5-6



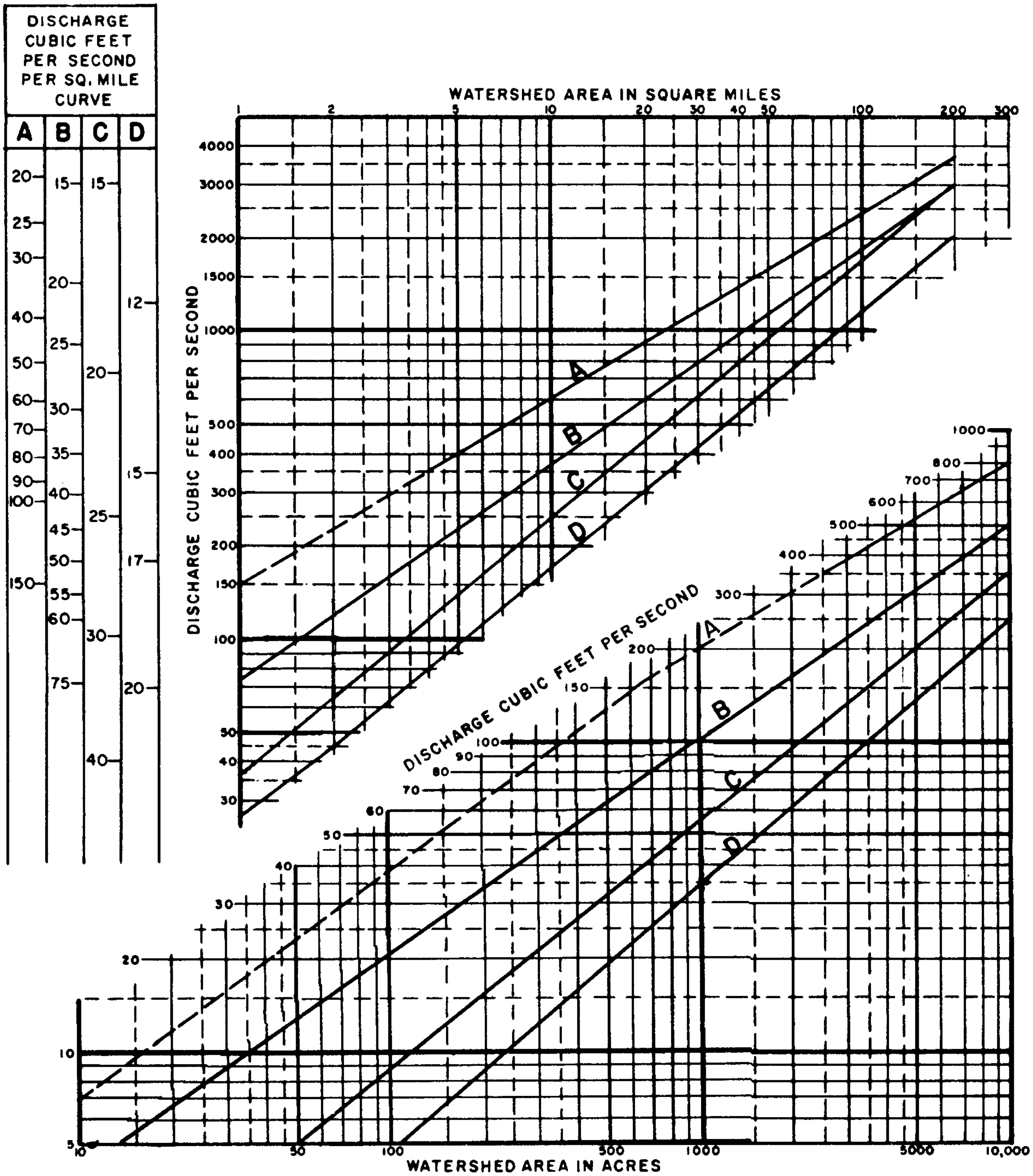
Note:
"M" curve should be used for flat lake plain areas and flat areas with a large number of potholes including: impervious soils, crops requiring better drainage, and areas having intensely developed systems of Farm Drainage.

Example:

Determine design capacity q
D. A. 6.0 square miles
q = 6.0 sq. mi. x 15 cfs/sq. mi. = 90 cfs

Determine inches removed per 24 hours
D. A. 6.0 square miles
Inches removed in 24 hours = .568 inches/24 hours

FIGURE 5-7

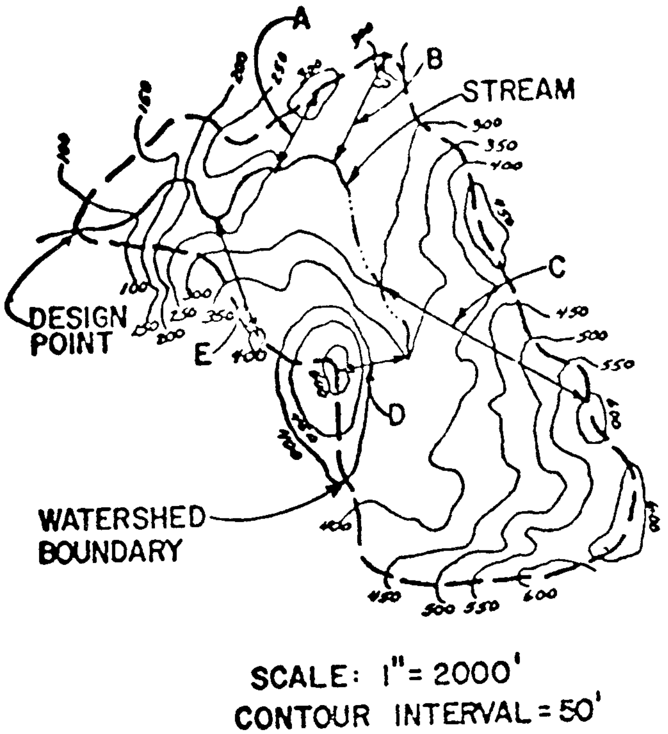


GENERAL USE OF CURVES - FOR FLAT LANDS. AVERAGE SLOPE LESS THAN 25 FEET PER MILE.

CURVE A - For good protection from overflow (not maximum flood runoff).
CURVE B - For excellent drainage.
CURVE C - For good agricultural drainage; basic drainage curve for grain crops.
CURVE D - For fair agricultural drainage and drainage improved pastures.
For specific uses see design criteria or technical standards.

Drainage runoff curves for Northern humid areas

PROCEDURE FOR COMPUTING AVERAGE WATERSHED SLOPE FROM TOPOGRAPHIC MAPS



NOTE: The above map was reproduced from a USGS topographic quadrangle of the 7.5 minute series with a 10-foot contour interval. For clarity, only the 50-foot contours have been reproduced.

1. Select several random slopes that typify the slopes found in the watershed.

   In the above watershed, the following slopes have been computed as typical slopes found in the watershed (elevations have been estimated in some cases):

Slope A:	(325-250)/ 900	= 75/ 900	= 8%
Slope B:	(325-270)/1200	= 55/1200	= 5%
Slope C:	(600-300)/2400	= 300/2400	= 13%
Slope D:	(525-350)/ 700	= 175/ 700	= 25%
Slope E:	(425-225)/1300	200/1300	= 15%

2. Determine the average watershed slope by adjusting each slope computed above for its proportion in the watershed.

   From a visual examination, the following proportions have been assigned to the slopes computed in step 1. A weighted product is then computed to obtain the average slope of the entire watershed:

	Product x 100
10% of watershed = 8% slope	.80
20% of watershed = 5% slope	1.00
40% of watershed = 13% slope	5.20
20% of watershed = 25% slope	5.00
10% of watershed = 15% slope	1.50
Average slope of watershed	13.50% Use 14%

PROCEDURE FOR FINDING AVERAGE WATERSHED SLOPE USING SOIL SURVEY REPORTS

1. Find and delineate drainage area on soils map.

2. Estimate (by eye or dot counter) percentage of area for each mapping unit. Tabulate by map symbol.

3. Find average land slope for each unit. Compute weighted average slope.

Example:

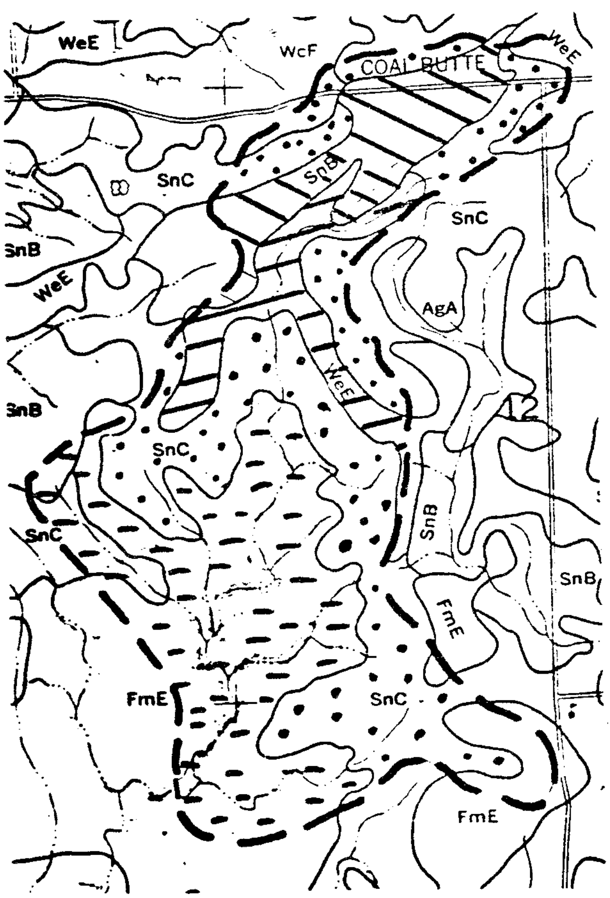
Site in parts of Sections 1, 11, 12 and 13, T. 140 N., R. 81 W., Burleigh County.

Map Symbol 1/	Estimated % of D.A. 1/	Average Slope 2/	Weighted Slope
WeE	8	9-15% (use 12%)	.08 x 12% = 0.96
SnC	41	6-9% (use 7%)	.41 x 7% = 2.87
SnB	11	3-6% (use 5%)	.11 x 5% = 0.55
FmE	40	9-15% (use 12%)	.40 x 12% = 4.80
			Total = 9.18%

Use: 9% = Steep Slope

1/ Soils maps
2/ Description of soils

SOIL SURVEY OF
BURLEIGH COUNTY, NORTH DAKOTA



Werner-Morton-Sen complex, hilly (9 to 15 percent slopes) (WeE).—This mapping unit consists of shallow, hilly to steep soils and intervening areas of deeper soils in the residual uplands. It is about 40 percent Werner soils, 35 percent Sen soils, 5 percent Morton soils, and 20 percent small inclusions of Arnegard, Flasher, and Vebar soils. Slopes are 100 feet to one-fourth mile long. Glacial boulders are common.

Sen silt loam, sloping (6 to 9 percent slopes) (SnC).—This soil is in the uplands. Slopes are long and smooth. Included in mapping were small areas of Arnegard, Morton, and Williams soils. In areas associated with glacial till, there are numerous stones and boulders on the surface. About 20 percent of the cultivated acreage is moderately eroded.

Sen silt loam, gently sloping (3 to 6 percent slopes) (SnB).—This soil is in the uplands. Included in mapping were areas of Arnegard, Morton, and Williams soils and a few small areas of a soil similar to the Sen soil, but shallower.

Flasher-Vebar complex, hilly (9 to 15 percent slopes) (FmE).—This mapping unit is about 45 percent Flasher soils and 30 percent Vebar soils. The rest is Werner, Parshall, Sen, and Arnegard soils. The Flasher soil is on ridges, and the Vebar fine sandy loam occupies the less sloping areas.

SECTION II

EFFECTS OF URBANIZATION ON RUNOFF VOLUME AND PEAK RATES OF DISCHARGE

Introduction

This section analyzes the effects of urbanization in a watershed on hydraulic and hydrologic parameters and presents methods of estimating runoff volume and peak rates of discharge. Obtaining basic data on runoff volume and peak rates of discharge is difficult because conditions are constantly changing during the transition from rural to urban land use. At this time only general empirical relationships between the parameters that affect runoff and peak rates of discharge can be developed. Much research is being undertaken to better analyze the effects of urbanization through collection of runoff data and study of watershed models.

As population density and land values increase, the effects of uncontrolled runoff become an economic burden and a serious threat to the health and well-being of a community and its citizens. Emphasis must be placed on providing solutions to the water problems caused by radical changes in land use. Estimating the magnitude and frequency of future flood events makes possible systematic planning and installation of structural and nonstructural measures to reduce hazards to acceptable levels.

Management of runoff from even minor storms is rapidly becoming an engineering requirement of local and state governments to help reduce flooding and stream erosion. Rapid deterioration of stream channels caused by increased storm runoff has had a detrimental impact on communities. Counties and states are adopting policies which limit the effects that changes in land use may have on the stream regimen within a development or watershed. These policies cover such areas as (1) assisting in the planned management of water resources, including storm drainage, throughout the watershed; (2) promoting and encouraging the inclusion of flood storage in all planned reservoirs; and (3) encouraging and assisting in planning for onsite retention of runoff through the use of temporary storage structures and infiltration devices.

There is a need for thorough understanding of the problems associated with the rapid conversion of land use and for adequate technical procedures to assist local communities, municipalities, and planning groups in assessing the effects of changed land use on streamflow.

Effects of Urban Development

An urban or urbanizing watershed can be defined as an area in which all or part of the watershed will be covered by impervious structures, such as roads, sidewalks, parking lots, and houses. Urban stream channels may also be supplemented by some form of artificial drainage system, such as paved gutters and storm sewers.

The effect of urbanization on the water regimen has long been recognized. Investigations to evaluate the factors involved have been going on for over 35 years. Ideally, hydrologic studies to determine volume and rates of runoff should be based on long-term stationary streamflow records for the area being investigated. Such records are seldom available for small drainage areas, and because of the time involved in converting a watershed from rural to urban conditions, available records normally are not adequate. It becomes necessary to estimate the magnitude and frequency of peak rates of runoff through modeling of measurable watershed characteristics. An understanding of these characteristics is required for judging how to alter parameters to reflect changing watershed conditions.

Urbanization of a watershed changes its response to precipitation. The most common effects are reduced infiltration and decreased travel time, which result in significantly higher peak rates of runoff. The volume of runoff is determined primarily by the amount of precipitation and by infiltration characteristics related to soil type, antecedent rainfall, type of vegetal cover, impervious surfaces, and surface retention. Travel time is determined primarily by slope, flow length, depth of flow, and roughness of flow surfaces. Peak rates of discharge are based on the relationship of the above parameters as well as the total drainage area of the watershed, the location of the development in relation to the total drainage area, and the effect of any flood control works or other man-made storage. Peak rates of discharge are also influenced by the distribution of rainfall within a given storm event. SCS in North Dakota uses Type I distribution.

Effect of Urbanization on Runoff

Initial abstraction consists of interception, infiltration, and depression storage that must be satisfied before runoff begins. Urban initial abstraction has been found to be correlated with slope of the impervious area. However, because of the limited scope of the research data available, no attempt has been made to revise the basic runoff equation to apply exclusively to urban areas.

Investigations have also shown that runoff from small (less than annual) rainfall events comes primarily from the impervious areas. However, both the pervious and impervious areas contribute to runoff for the larger, less frequent events. If the pervious portion of an urban area has a CN of 60 to 65, approximately 2 inches of rainfall is needed before runoff begins. Most 24-hour rainfall values used in computing peak rates of flow are over 2 inches. Therefore, for urban analysis the total watershed can be assumed to contribute to storm runoff.

Urban Runoff Curve Numbers

Several factors should be considered when computing the anticipated future CN for urban areas. The amount of runoff can vary depending on whether house gutters connect directly to storm drains, outlet onto impervious driveways, or outlet onto lawns or other pervious areas where infiltration can occur. General building practices or codes within a development may be helpful in determining runoff flow paths. Some areas have zoning ordinances on how storm runoff from individual houses must be handled.

In determining urban CN's, consideration should be given to whether heavy equipment compacted the soil significantly more than natural conditions, whether much of the pervious area is barren with little sod established, and whether grading has mixed the surface and subsurface soils causing a completely different hydrologic condition. Any one of the above could cause a soil normally in hydrologic group A or B to be classified in group B or C, respectively. In many areas of the country, lawns are heavily irrigated. This may significantly increase the moisture content in the soil over that under natural rainfall conditions.

There are a number of methods available for computing the percentage of impervious area in a watershed. Some methods include using U.S. Geological Survey topographic maps, land use maps, aerial photographs, and field reconnaissance. Care must be exercised when using methods based on such parameters as population density, street density, and age of the development as a means of determining the percentage of impervious area. The available data on runoff from urban areas are not yet sufficient to validate widespread use of these methods.

Some rainfall is retained on the surface and by vegetation before runoff begins. Interception is rainfall that is caught by foliage, twigs, branches, leaves, etc. This rainfall is lost to evaporation and thus never reaches the ground surface. Increasing the vegetal cover increases the amount of interception.

Surface depression storage begins when precipitation exceeds infiltration. Overland flow starts when the surface depressions are full. The water in depression storage is not available as direct runoff.

Initial abstraction is the sum of interception, depression storage, and infiltration before runoff begins. It occurs on all types of cover, from pasture in good condition to concrete pavement. However, the amount of initial abstraction is less on concrete pavement than on pasture.

Volume Parameters

Soil type

Since urban areas are seldom completely covered by impervious structures, soil properties are an important factor in estimating the total volume of direct runoff. The infiltration and percolation rates of soils indicate their potential to absorb rainfall and thereby reduce the amount of direct runoff. Soils having a high infiltration rate (sands or gravels) have a low runoff potential, and soils having a low infiltration rate (clays) have a high runoff potential. Urbanization on soils with a high infiltration rate increases the volume of runoff and peak discharge more than urbanization on soils with a low infiltration rate.

Cover type

The type of cover and its hydrologic condition affects runoff volume through its influence on the infiltration rate of the soil. Fallow land yields more runoff than forested land for a given soil type. Covering areas with impervious material reduces surface storage and infiltration and increases the volume of runoff.

Time Parameters

Slope
Urbanization can change the effective slope of a watershed if flow paths are altered by channelization and by terracing areas for building lots, parking lots, roads, and diversion ditches. The slopes of storm sewers, street gutters, roads, and overland flow areas as well as stream channels are significant in determining travel times through urban watersheds.

Flow length (Hydraulic Length)
Flow length may be reduced if natural meandering streams are changed to straight channels. It may be increased if overland flows are diverted through diversions, storm sewers, or street gutters to larger collection systems.

Surface roughness
Flow velocity normally increases significantly when the flow path is changed from flow over rough surfaces of woodland, grassland, and natural channels to sheet flow over smooth surfaces of parking lots, diversions, storm sewers, gutters, and lined channels.

Methodology

Procedures outlined in SCS N.D. Hydrology Manual are adequate for determining volumes, peak rates, and hydrographs of runoff from urban areas. The increase in the volume of runoff due to urbanization depends more on the percentage of impervious area than on any of the other watershed constants. Changes in the time-area relationship (lag time) can be estimated by hydraulic analysis of overland velocities and storage. Changes in channel routing can be estimated by hydraulic analysis of channel velocities and storage.

The soil-cover complex and associated runoff curve number procedure outlined in the N.D. Hydrology Manual can be used to measure the change in runoff volume caused by urbanization. Runoff curve numbers for land use and treatment practices for hydrologic soil groups were developed from daily rainfall records from small agricultural watersheds. By using land use patterns found in an urban area and accounting for impervious areas, a composite weighted curve number representing runoff potential from the watershed can be determined.

Special attention should be given, once storm drains are installed. The flow pattern may be changed significantly so that flow retardance cannot be represented by factors based on runoff curve numbers or overland flow. Velocities of flow through culverts and channels should be computed using hydraulic procedures that take into consideration the characteristics of the flow paths.

When urbanization is proposed in only part of a watershed and peak discharges are desired downstream of the development, consideration should be given to subdividing the watershed into areas of similar land use. The hydrographs from these areas are combined and routed to the outlet.

Examples in this section illustrate the effects of urbanization on volumes and peak rates of runoff using procedures outlined in the N.D. Hydrology Manual.

As more information is gathered and analyzed, better procedures may be developed to analyze the effects of urbanization. Procedures presented in this section will be revised periodically to incorporate results of future research.

PEAK DISCHARGES

METHOD I

This section presents two methods for obtaining and adjusting peak discharges. The first method adjusts discharges obtained from Figure 5-4 to reflect the shape of the watershed and the changes in peak discharge due to urbanization. The second method determines the peak discharge from rainfall runoff relationships and time of concentration (T_c). Modifications due to urbanization use "Watershed Lag" for adjusting time of concentration (T_c).

A quick reliable method of computing peak discharges from agricultural drainage areas 5 to 2,000 acres in size is given in Figure 5-4. The charts were prepared for the solution of general relationships, and are based on type I rainfall distribution.

Adjustment for Watershed Shape Factor

The equation used in computing peak discharges was based in part on a relationship between the hydraulic length and the watershed area from Agricultural Research Service's (currently Science and Education Administration - Agricultural Research) small experimental watersheds. Figure 5-11 shows the best fit line relating length to drainage area. The equation of the line is $\ell = 209a^{0.6}$. A watershed shape factor, ℓ/w (where w is the average width of the watershed), is then fixed for any given drainage area. For example, for drainage areas of 10, 100, and 1,000 acres the watershed shape factor is 1.58, 2.51, and 3.98, respectively.

There are watersheds that deviate considerable from these relationships. The peaks can be modified for other shape factors. The procedure is as follows:

1. Determine the hydraulic length of the watershed and compute an "equivalent" drainage area using $\ell = 209a^{0.6}$ or Figure 5-8.

2. Determine the "equivalent" peak flow from the charts for the "equivalent" drainage area.

3. Compute the "actual" peak discharge for the watershed by multiplying the equivalent peak discharge by the ratio of actual drainage area to the equivalent drainage area.

Adjustment Factors for Swampy and Ponding Areas

Peak flows assume that the topography is such that surface flow into ditches, drains, and streams is approximately uniform. On very flat areas and where ponding or swampy areas occur in the watershed, a considerable amount of the surface runoff may be retained in temporary storage. The peak rate of runoff should be reduced to reflect this condition. Tables 5-1, 5-2, and 5-3 provide adjustment factors to determine this reduction based on the ratio of the ponding or swampy area to the total watershed area for a range of storm frequencies.

Table 5-1 contains adjustment factors to be used when the ponding or swampy areas are located in the path of flow in the vicinity of the design point. Table 5-2 contains adjustment factors to be used when a significant amount of the flow from the total watershed passes through ponding or swampy areas and these areas are spread throughout the watershed. Table 5-3 contains adjustment factors to be used when a significant amount of the flow passes through ponding or swampy areas that are located only in the upper reaches of the watershed.

Modification of Peak Discharge Due to Urbanization

Research in the area of urban hydrology is developing rapidly. Research to date has been sufficient to identify the parameters that are affected by urbanization and to derive limited empirical relationships between those parameters for both agricultural and urban watersheds. The time to peak for urban watersheds is affected by a decrease in lag or time of concentration.

Figures 5-9 and 5-10 give factors for adjusting peaks. The factors are applied to the peaks using future-condition runoff curve numbers as follows:

$$Q_{MOD} = Q \left[Factor_{IMP} \right] \left[Factor_{HLM} \right]$$

where

Q_{MOD} = modified discharge due to urbanization

Q = discharge for future CN

$Factor_{IMP}$ = adjustment factor for percent impervious areas

$Factor_{HLM}$ = adjustment factor for percent of hydraulic length modified

The following is an example using developed computation sheets:

EXAMPLE 1: Example 1 (see Pages 5-44 and 5-45) is used to illustrate modifications of Peak Discharges due to urbanization. Steps 1 - 6 (Present Conditions) can be used to refine peak discharges for agricultural watersheds as defined in Figure 5-4, N.D. Hydrology Manual, as Figure 5-4 excludes the shape factor. Steps 7 - 9 are added for urban modifications

METHOD I

PEAK DISCHARGE COMPUTATION SHEET

PROJECT EXAMPLE PROBLEM 1 By JEN, Date 10-80

MORTON COUNTY, ND Checked JHS, Date 10-80

Steps

1. Given: *Drainage Area (DA) = 150 Acres 0.23 Square Miles
   Storm Type & Duration Type 1, 24 Hours
   *Design Frequency = 25 Years, 4 % Chance
   *Rainfall Depth (P) = 3.7 Inches
   *Average Watershed Slope = 4 %
   1/*Runoff Curve No. (Present) (CN) = 73 (See Table 3-1)
   *Runoff Curve No. (Future) (CN) = 75 (See Table 3-2)
   *Hydraulic Length = 2500 Feet

2. **Watershed Shape Adjustment (Figure 5-8):

   Equivalent Drainage Area = 64 Acres

   Watershed Shape Factor = 2.34 = $\frac{\text{Actual DA}}{\text{Equivalent DA}}$

3. Figure 5-4:

   Select Peak Discharges from Figure 5-4 and use Equivalent DA if Watershed Shape Adjustment (Step 2) is to be applied.
   (Slopes: Flat < 3%; Moderate 3% to < 8%; Steep 8% and above)

   Future Condition Peak Discharge q = 30 cfs

4. **Watershed Slope Interpolation (Top of Figure 5-4):

   Use Equivalent DA if Watershed Shape Adjustment (Step 2) is to be applied.

   Slope Adjustment Factor = 1.0

5. **Ponding & Swamp Storage Adjustment (Tables 5-1, 5-2, 5-3):

   *% of Ponding and Swampy Area = 5 % (Based on Actual DA) (Future)

   *Location in Watershed (check one):

   Design Point (5-1) ___; Center or Spreadout (5-2) ___; Upper Reaches (5-3) ✓.

   Ponding Adjustment Factor (Future) = 0.84

* Input Data
**Optional Adjustments. If the adjustment is not used, the Factor = 1.0
1/For comparative purposes.

METHOD I

COMPUTATION SHEET (Cont.)

6. Basic Peak Discharge with Watershed Adjustments (q_p):

From Step # (3)		(2)**		(4)**		(5)**
q_p = Peak Discharge	x	[Watershed Shape Factor	x	Slope Factor	x	Ponding Factor]

Future q_p = 30 cfs x [2.34 x 1.0 x 0.84] = 59 cfs

URBAN MODIFICATIONS:

7. **Impervious Area (Figure 5-9): (Future Condition only)

*% Impervious Area (IMP) = 20 % (Based on Actual DA)

IMP Modification Factor = 1.11

8. **Hydraulic Length Modified (Figure 5-10): (Future Condition only)

*% Hydr. Length Modified (HLM) = 10 %

HLM Modification Factor = 1.05

9. Peak Discharge with Urban Modifications (q_{MOD}): (Future Condition only)

From Step # (6)		(7)**		(8)**
$q_{MOD} = q_p$	x	[IMP Modification Factor	x	HLM Modification Factor]
q_{MOD} = 59 cfs	x	[1.11	x	1.05]

q_{MOD} = 69 cfs

*Input Data
**Optional Modifications. If the modification is not used, Factor = 1.0.

METHOD II

Time of Concentration, Travel Time, and Lag

Urbanization commonly increases the velocity at which water can flow from its point of impact on the watershed to the watershed outlet. Time of concentration, travel time, and watershed lag are three related watershed parameters directly affected by the increased velocity. These parameters are widely used in determining peak rates of runoff.

Time of concentration is the time it takes for runoff to travel from the hydraulically most distant part of the watershed to the point of reference. It is usually computed by determining the water travel time through the watershed. In hydrograph analysis it is the time from the end of excessive rainfall to the point of inflection on the falling limb of the hydrograph. Lag can be considered as a weighted time of concentration and is related to the physical properties of a watershed, such as area, length, and slope. In simple hydrograph analysis, lag is the time from the center of mass of excessive rainfall to the peak rate of runoff. The time of concentration determines the shape of the runoff hydrograph. Thus, changes in the time of concentration cause changes in the resulting hydrograph. The extent of urbanization and stream modification affects the travel time of water through the watershed, which changes the time of concentration.

Two factors can contribute to a decrease in travel time. Urbanization generally decreases overland flow travel time by decreasing flow retardance and by reducing the interflow distance because there are more points of interception by gutters and other conveyances. Channelization decreases travel time by increasing velocities in improved channels. The travel path may be on the surface of the ground or below it (as subsurface flow) or in a combination of both. Urban hydrology studies have shown that the response time of subsurface flow is so much longer than that of surface flow that only surface (including sewer) flow travel time is of significance when determining peak discharges.

Modification of Lag due to Urbanization

Figures 5-12 and 5-13 give factors for adjusting Lag. The factors are applied as follows:

$$Lag_{MOD} = {}^{*}Lag\ (hrs) \begin{bmatrix} \text{IMP MOD} \\ \text{Factor} \end{bmatrix} \begin{bmatrix} \text{HLM MOD} \\ \text{Factor} \end{bmatrix}$$

where

Lag_{MOD} = Modified lag due to urbanization

*Lag(Hrs) = Lag for Future C.N.

$Factor_{IMP}$ = Adjustment factor for percent impervious areas

$Factor_{HLM}$ = Adjustment factor for percent of hydraulic length mod.

EXAMPLE 2: Example 2 using developed computation sheets (see pages 5-47 and 5-48) is used to illustrate the Lag-Tc Method to compute and refine peak discharges for small watersheds (2,000 acres or less) in urban or agricultural areas. Adjustments for swampy and ponding areas are the same as those in Example 1 using tables 5-1, 5-2, and 5-3.

METHOD II

PEAK DISCHARGE COMPUTATION SHEET
Using Lag-Tc Method

PROJECT EXAMPLE PROBLEM 2 By JEN, Date 10-80

MORTON COUNTY, ND Checked JHS, Date 10-80

Steps

1. Given:
   - *Drainage Area (DA) = 150 Acres 0.23 Square Miles
   - Storm Type & Duration Type I, 24 Hours
   - *Design Frequency = 25 Years, 4 % Chance
   - *Rainfall Depth (P) = 3.7 Inches
   - *Average Watershed Slope = 4 %
   - 1/ *Runoff Curve No. (Present) (CN) = 73 (See Table 3-1)
   - *Runoff Curve No. (Future) (CN) = 75 (See Table 3-2)
   - *Hydraulic Length = 2500 Feet

2. Obtain Runoff Depth (From Table 3-5):

   From Step 1 using Future CN and Rainfall Depth.

   Determine R.O. Depth = 1.44 Inches

3. Compute Watershed Lag (Figure 5-11):

   From Step 1 using Hydraulic Length, Av. Slope and Future R.O. Curve No.

   Determine Watershed Lag.

   Watershed Lag 0.4 Hours

4. **Impervious Area (Figure 5-12): (Future Condition only)

   *% Impervious Area (IMP) = 20 %

   IMP Modification Factor = 0.87

5. **Hydraulic Length Modified (Figure 5-13): (Future Condition only)

   *% Hydr. Length Modified (HLM) = 10 %

   HLM Modification Factor = 0.94

6. Modify Watershed Lag:

From Step #		(3)	**(4)		**(5)
Lag Mod.	=	Lag (Hours) x	IMP Mod. Factor	x	HLM Mod. Factor
Lag Mod.	=	0.4 Hours x	0.87	x	0.94
Lag Mod.	=	0.33 (Hours)			

Lag-Tc Method (Cont.)

7. Compute Time of Concentration (Tc):

Use Tc = 1.67 x Lag.

Tc = 1.67 x 0.33 = 0.55 Hours

8. Compute Preliminary Discharge (cfs):

From Figure 5-1 select Hydrograph Family (Use Rainfall Depth & Future CN from Step 1) — 1.5 Hyd. Family.

From Figure 5-2 select CSM Rate (Use Tc from Step 7) — 240 CSM.

From Step # (1)		(2)		(8)	
q_p = 0.23 DA (Square Miles)	x	1.44 Inches R.O.	x	240 CSM	cfs

q_p = 79 cfs

9. **Ponding & Swamp Storage Adjustment (Tables 5-1, 5-2, 5-3):

*% of Ponding and Swampy Area = 5 % (Based on Actual DA)

*Location in Watershed (check one):

Design Point (5-1) ____; Center or Spreadout (5-2) ____; Upper Reaches (5-3) ✓.

Ponding Adjustment Factor = 0.84

10. Modify Discharge for Ponding & Swamp Storage:

From Step # (8)		(9)
q_{MOD} = 79 cfs	x	0.84 Ponding adjustment

q_{MOD} = 67 cfs

* Input Data
**Optional Adjustments. If the adjustment is not used, the Factor = 1.0.
1/For comparative purposes.

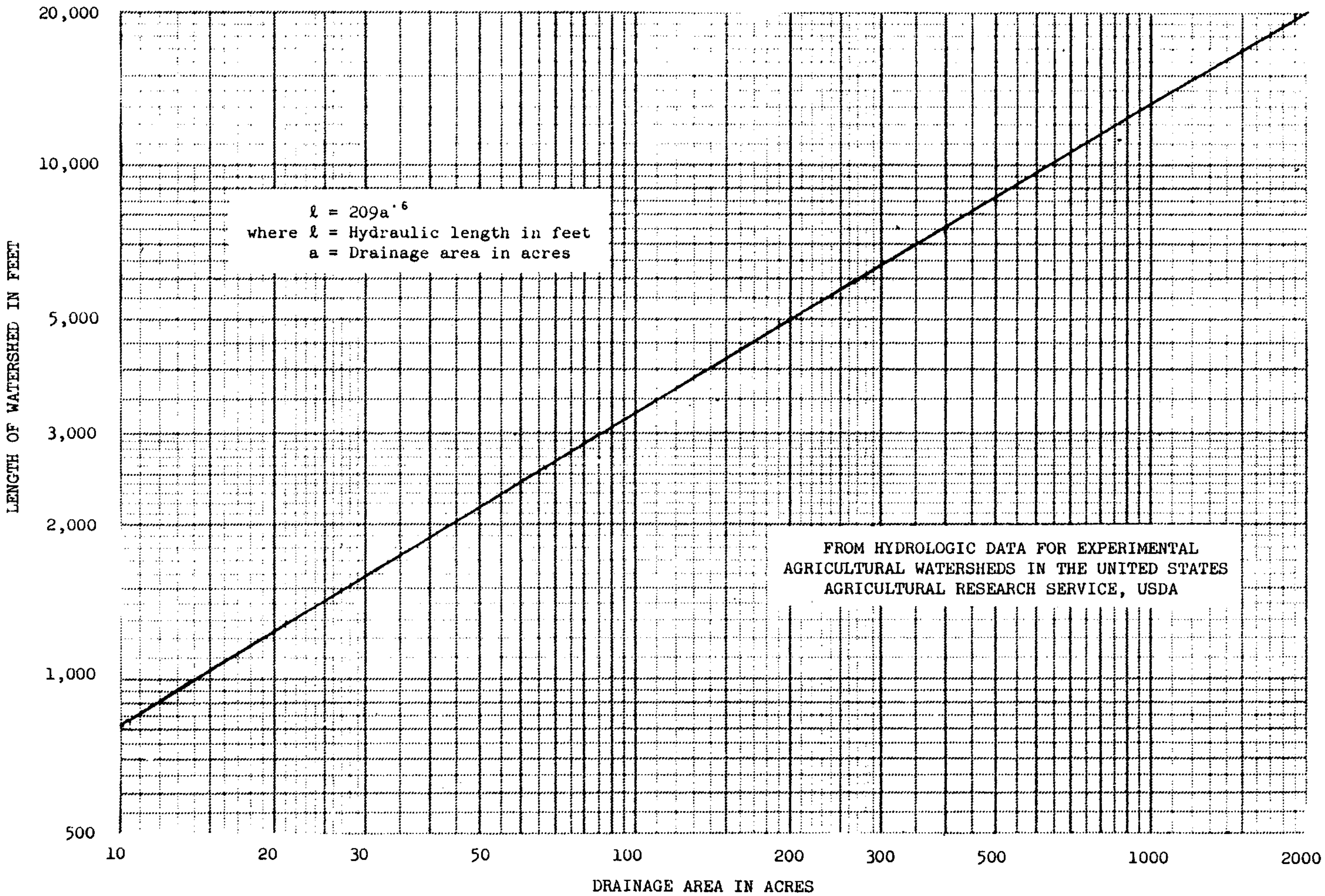


Figure 5-8 -- Hydraulic length and drainage area relationship.

Figure 5-8

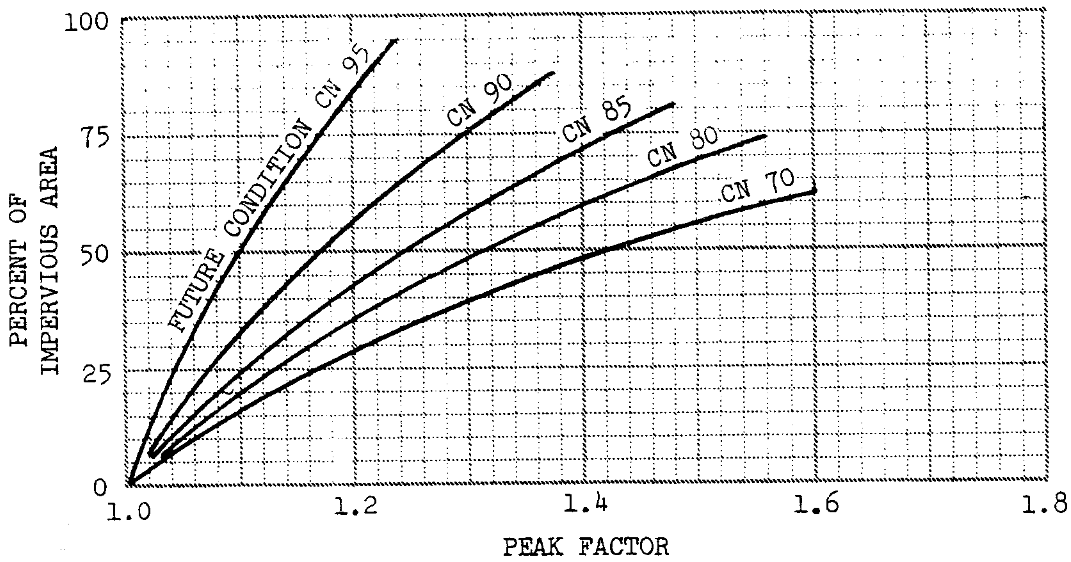


Figure 5-9. -- Factors for adjusting peak discharges for a given future-condition runoff curve number based on the percentage of impervious area in the watershed.

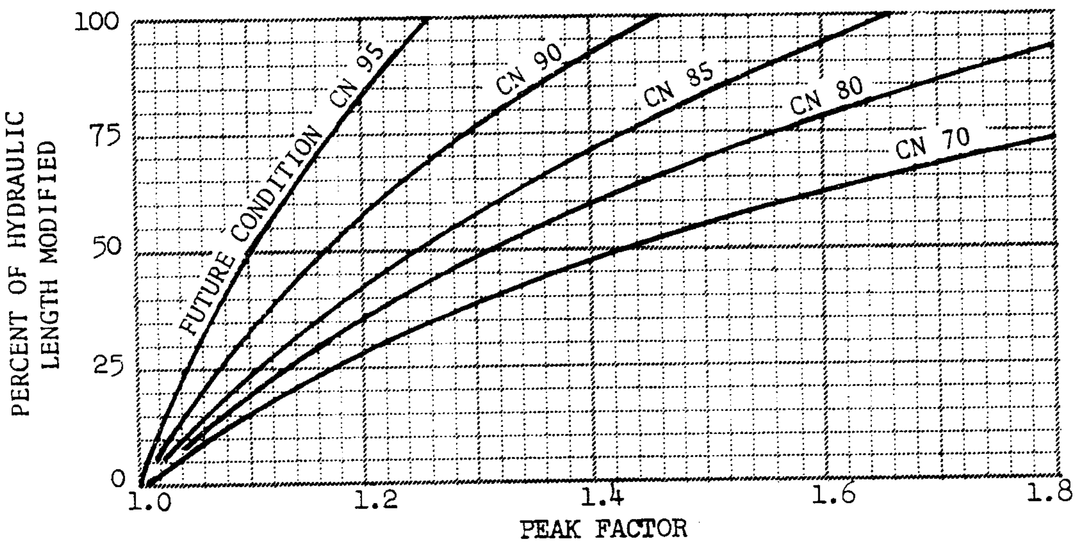


Figure 5-10. -- Factors for adjusting peak discharges for a given future-condition runoff curve number based on the percentage of hydraulic length modified.

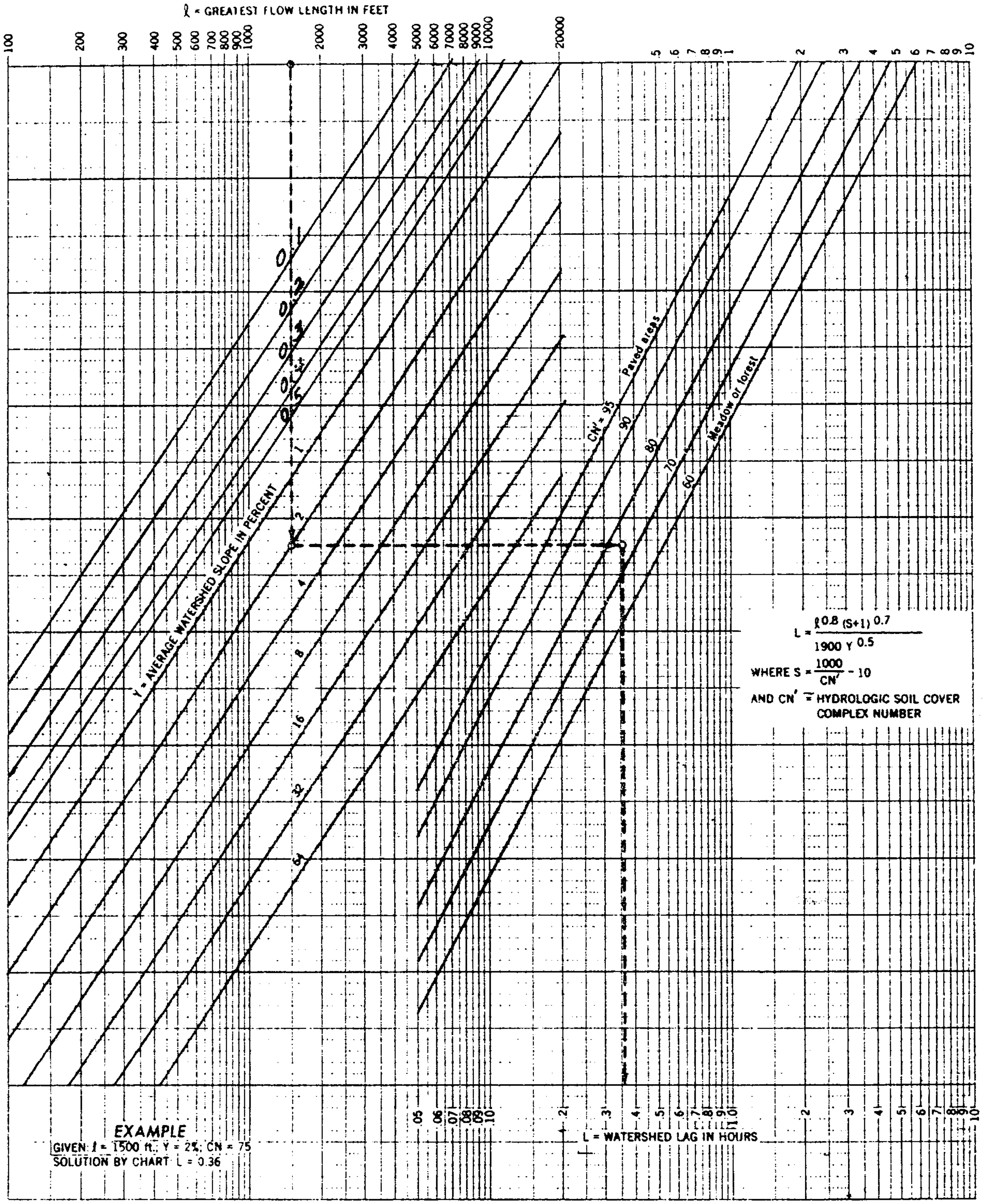


Figure 5-11.--Curve number method for estimating lag (L) for homogeneous watersheds under natural conditions up to 2,000 acres.

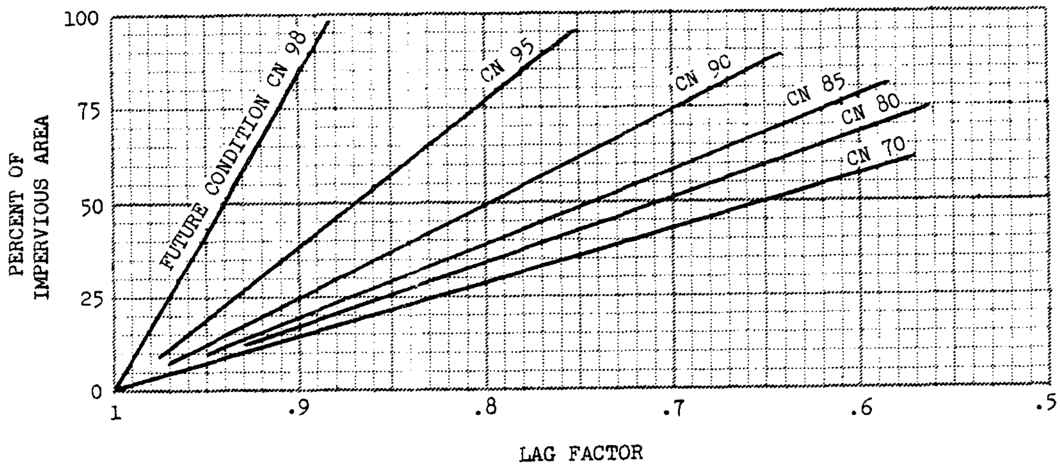


Figure 5-12. -- Factors for adjusting lag from Figure 5-11 when impervious areas occur in the watershed.

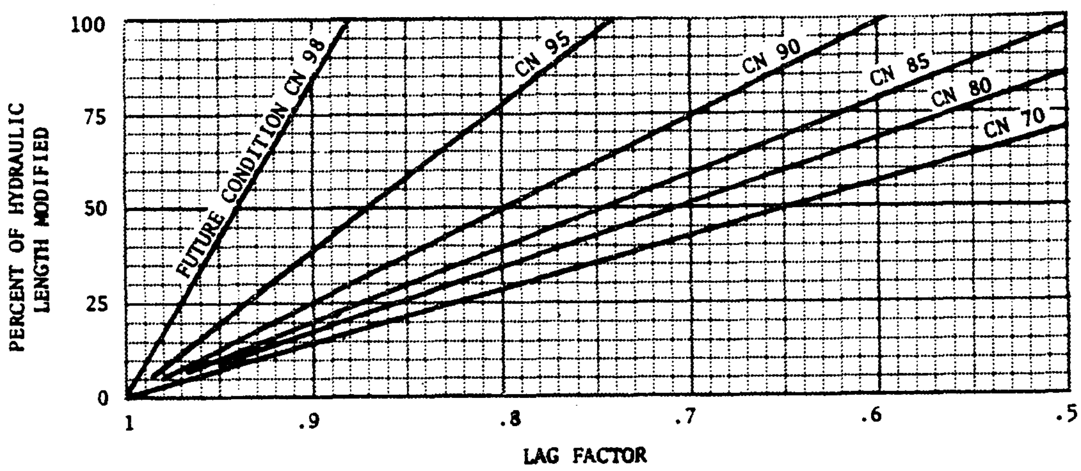


Figure 5-13. -- Factors for adjusting lag from Figure 5-11 when the main channel has been hydraulically improved.

To obtain more data on Urban Hydrology, refer to Technical Release No. 55 - Urban Hydrology for Small Watersheds, USDA, Jan. 1975, and the Guide for Use of T.R.-55, Dec. 1977.

Table 5-1. --Adjustment factors where ponding and swampy areas occur at the design point.

Ratio of drainage area to ponding and swampy area	Percentage of ponding and swampy area	Storm frequency (years)					
		2	5	10	25	50	100
500	0.2	0.92	0.94	0.95	0.96	0.97	0.98
200	.5	.86	.87	.88	.90	.92	.93
100	1.0	.80	.81	.83	.85	.87	.89
50	2.0	.74	.75	.76	.79	.82	.86
40	2.5	.69	.70	.72	.75	.78	.82
30	3.3	.64	.65	.67	.71	.75	.78
20	5.0	.59	.61	.63	.67	.71	.75
15	6.7	.57	.58	.60	.64	.67	.71
10	10.0	.53	.54	.56	.60	.63	.68
5	20.0	.48	.49	.51	.55	.59	.64

Table 5-2. --Adjustment factors where ponding and swampy areas are spread throughout the watershed or occur in central parts of the watershed

Ratio of drainage area to ponding and swampy area	Percentage of ponding and swampy area	Storm frequency (years)					
		2	5	10	25	50	100
500	0.2	0.94	0.95	0.96	0.97	0.98	0.99
200	.5	.88	.89	.90	.91	.92	.94
100	1.0	.83	.84	.86	.87	.88	.90
50	2.0	.78	.79	.81	.83	.85	.87
40	2.5	.73	.74	.76	.78	.81	.84
30	3.3	.69	.70	.71	.74	.77	.81
20	5.0	.65	.66	.68	.72	.75	.78
15	6.7	.62	.63	.65	.69	.72	.75
10	10.0	.58	.59	.61	.65	.68	.71
5	20.0	.53	.54	.56	.60	.63	.68
4	25.0	.50	.51	.53	.57	.61	.66

Table 5-3. --Adjustment factors where ponding and swampy areas are located only in upper reaches of the watershed

Ratio of drainage area to ponding and swampy area	Percentage of ponding and swampy area	Storm frequency (years)					
		2	5	10	25	50	100
500	0.2	0.96	0.97	0.98	0.98	0.99	0.99
200	.5	.93	.94	.94	.95	.96	.97
100	1.0	.90	.91	.92	.93	.94	.95
50	2.0	.87	.88	.88	.90	.91	.93
40	2.5	.85	.85	.86	.88	.89	.91
30	3.3	.82	.83	.84	.86	.88	.89
20	5.0	.80	.81	.82	.84	.86	.88
15	6.7	.78	.79	.80	.82	.84	.86
10	10.0	.77	.77	.78	.80	.82	.84
5	20.0	.74	.75	.76	.78	.80	.82