

# Local Design Storm Vol. III



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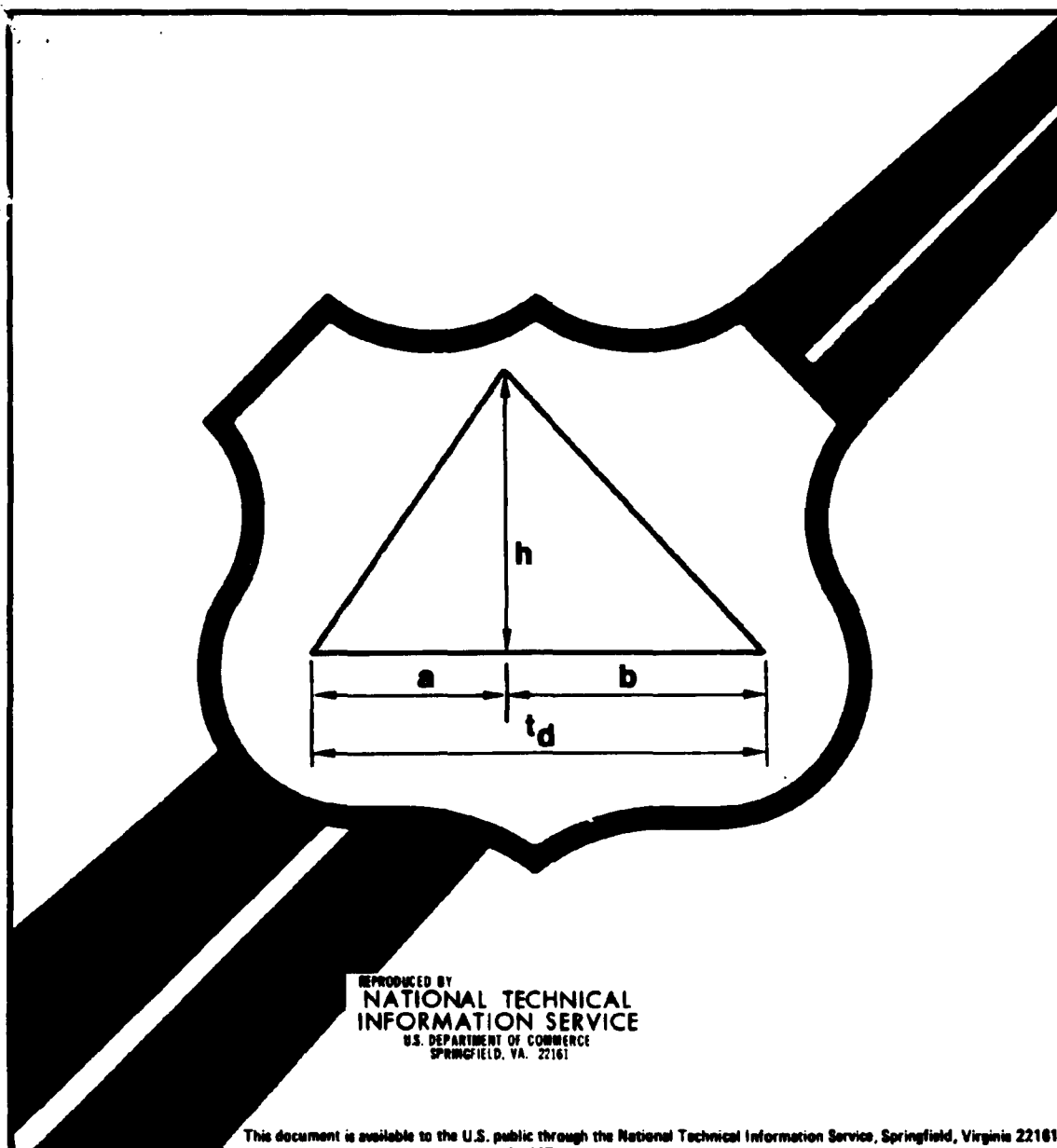
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User's Manual

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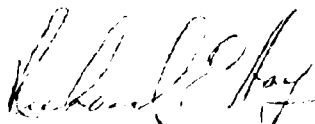
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## FOREWORD

This report presents a user's guide for the newly developed triangular hyetograph method in deriving local design storms for use in the design of highway storm drainage structures. Examples are provided to illustrate this procedure. Also included are listings of two computer programs for performing statistical analysis of rainfall moments for triangular hyetographs and for frequency analysis of rainfall depth-duration-return period relation.

Research in urban and rural highway storm drainage is included in the Federally Coordinated Program of Highway Research and Development as Tasks 2 and 3 of Project 5H "Protection of the Highway System from Hazards Attributed to Flooding."

Sufficient copies of this report are being distributed to provide a minimum of two copies to each FHWA regional office, one copy to each division office, and one copy to each State highway agency. Direct distribution is being made to the division offices.



Richard E. Hay, Director  
Office of Engineering  
and Highway Operations  
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16. Abstract Recently developed improved methods for highway storm water drainage require information on the temporal distribution of rainfall (i.e., hyetograph) in addition to the average rain intensity. The triangular design hyetograph method is developed as a practical method to provide the local storm hyetograph for design of small highway drainage facilities. The method is based on the methods of moments, using and preserving the statistical mean of the first time moment of rainstorms. The method is proposed as a trade-off between theoretical sophistication and practical simplicity. A total of 293,946 rainstorms from the hourly precipitation data of 222 National Weather Service stations and 5 to 60 minute data of 13 raingage stations of USDA Agricultural Research Service were analyzed to provide the statistical values of the hyetograph parameters for the United States.  In this Volume, a user's guide of the procedure to establish the local design hyetograph is presented. In addition, user's guides and listings of two computer programs to perform statistical analysis of rainfall moments for triangular hyetographs and for frequency analysis of rainfall depth-duration-return period relation are also presented.  The other three volumes of this report set are Vol. I. Executive Summary (FHWA/RD-82/063) Vol. II. Methodology and Analysis (FHWA/RD-82/064) Vol. IV. Tabulation of Sample Detail Results of Statistical Analysis (FHWA/RD-82/066)					
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## LIST OF SYMBOLS

- $a$  = time from commencement of rainfall to peak intensity;
- $a^0$  = nondimensional time to peak intensity, =  $a/t_d$ ;
- $b$  = time from peak intensity to end of rainfall;
- $b^0$  = nondimensional time after peak intensity of nondimensional hydrograph, =  $b/t_d$ ;
- $D$  = rain depth of a storm;
- $E$  = elevation;
- $h$  = height of hyetograph, i.e., peak rain intensity;
- $h^0$  = nondimensional peak intensity, = 2 for triangular hyetographs
- $i$  = rainfall intensity;
- $j$  = index;
- $K$  = constant in Table 1 for Eq. 2.7;
- $L$  = length; also, basin length;
- $L_c$  = channel length;
- $L_j$  =  $j$ th segment along a flow path;
- $L_o$  = overland length;
- $m$  = rank of event in maximum series;
- $N$  = number of years in annual maximum series;
- $n$  = surface roughness factor given in Table 2 for Eq. 2.7;
- $S$  = slope;
- $S_c$  = channel slope;
- $S_o$  = overland slope;
- $T_r$  = return period;
- $t$  = time;

LIST OF SYMBOLS (continued)

$t_d$  = duration of rainfall;

$t_f$  = channel flow time;

$t_o$  = overland flow time;

$t_t$  = total flow time of a flow path, =  $t_o + t_f$ ;

$V$  = velocity;

$V_j$  = velocity of  $j$ th segment of a flow path;

$V_o$  = overland flow velocity.



## I. INTRODUCTION

The user's manual presents a procedure for rapidly developing a design storm (triangular rainfall hyetograph) to facilitate the use of rainfall-runoff models such as EPA's Storm Water Management Model (SWMM). Since these rainfall-runoff models can provide more accurate estimates of runoff characteristics than existing empirical methods such as the Rational Equation, highway engineers can develop more cost-effective storm drainage systems through their use.

This third volume of the four-volume report set on local design hyetograph (temporal pattern of storm rainfall) gives the procedure, related information, and example on applying the nondimensional triangular hyetograph method to establish the local design storm for design of small rural and urban highway drainage facilities. Four user's guides are described in this volume. Chapter II gives the procedures to determine the dimensional triangular design hyetograph. Chapter III describes the methods to estimate the depth and intensity of rainstorms if the user does not have better methods for their determination. Chapters II and III, with the figures and tables included, are self-content and normally sufficient for an engineer to develop his design hyetograph without using the information provided in Chapters IV and V of this volume.

However, the user may prefer not to use the national map of parameter values of nondimensional triangular hyetographs presented in Chapter II. Instead, he may prefer to establish his own local values of the parameters when the standard National Weather Service (NWS) hourly precipitation data is available for the design location. In this case he can apply the computer program SATH (Statistical analysis for triangular hyetograph) to establish the parameter values. The user's guide of the program SATH is described in Chapter IV.

Likewise, should the user prefer to establish the local intensity (or depth)-duration-frequency relationship instead of using the NWS Technical Paper No. 40, NOAA Technical Memorandum NWS HYDRO-35, or NOAA Atlas 2, and the local hourly rainfall data is available in the standard NWS format, he may use the computer program FANHP (Frequency analysis for NWS hourly precipitation data) for this purpose. The user's guide for the program FANHP is given in Chapter V.

Although they are interrelated, Chapters II through V in this volume are prepared in such a way that each chapter can be used alone. Likewise, this volume can be read and used independently of other volumes of this report set, although the user is suggested to refer to Volume II for the theory and justification of using the nondimensional triangular hyetograph method to develop local design storms.

The procedures and user's guides in this volume have been formulated as simple as possible for field applications. In developing and preparing these procedures and guides, trade-off between simplicity and practicality has been carefully weighted. Nevertheless, this does not prevent those who would prefer to improve the methods by sacrificing simplicity.

## II. USER'S GUIDE TO ESTABLISH LOCAL TRIANGULAR DESIGN HYETOGRAPH

This Chapter describes the procedures to establish the local design hyetograph for the design of small drainage facilities. The size of the drainage basin should be smaller than 20 square miles ( $50 \text{ km}^2$ ) or, have a time of concentration less than five hours. Section A, the most important part of this chapter, gives the standard procedure to establish the design hyetograph. Section B presents a method to estimate the critical duration of the design rainstorm. The user should refer to Vol. 2 of this report set if he is interested in methodology development.

### A. Standard Procedure

The standard procedure to establish the triangular hyetograph for design of a small highway drainage facility at a specified location is as follows:

- (1) Determine the duration of the design rainstorm,  $t_d$ , in hours -- It is recommended that the duration of the design rainstorm be taken as the critical, longest flow time of the area drained.  
The recommended method to determine this critical flow time is described in Section B. The user may use other appropriate methods if preferred.
- (2) Determine the design return period,  $T_r$ , in years -- The design return period should be determined on the basis of acceptable risk.  
[Yen, 1970; Yen and Tang, 1976; Tseng et al., 1975; Young et al., 1970]
- (3) Determine the nondimensional triangular hyetograph parameter value,  $a^\circ$  -- From Fig. 1 the user select the value of  $a^\circ$  at the location of the drainage basin and corresponding to the design duration and return period. Interpolate the  $a^\circ$  values if necessary.

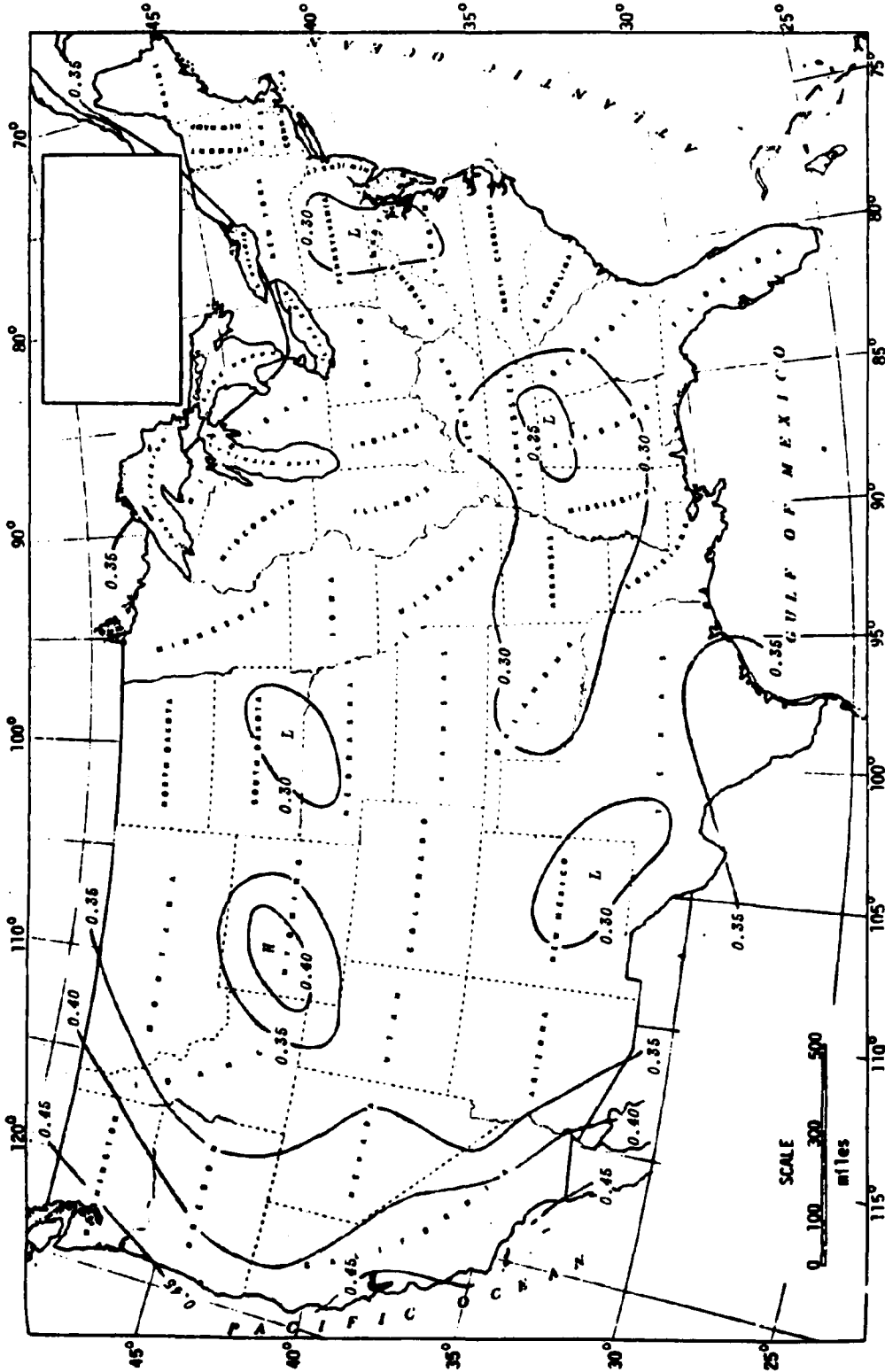


Fig. 1. National map of recommended  $a^\circ$  for design hyetograph

- (4) Determine the rainfall depth,  $D$ , in inches or mm -- The depth of the design rainstorm of the specified return period and duration is determined by using the following National Weather Service (NWS) published values.
- For contiguous United States east of  $105^\circ\text{W}$  meridian and for duration not exceeding 1 hour, use NOAA Technical Memorandum NWS HYDRO-35 [Frederick et al., 1977].
  - For the United States east of  $105^\circ\text{W}$  with rainstorms longer than 1 hour in duration, use the National Weather Service (formerly Weather Bureau) Technical Paper No. 40 (TP-40) [Hershfield, 1961].
  - For the eleven states west of  $105^\circ\text{W}$ , use NOAA Atlas 2 [Miller et al., 1973] and extrapolate as described in the atlas for design durations less than 6 hours.

Use of TP-40 to determine the rainfall depth is described in Section A of next chapter. Use of HYDRO-35 is described in Section B in Chapter III. Alternatively, the user may prefer to use the local rainfall record, if available, to determine the depth of the design storm through a frequency analysis of the rainfall data. This alternative procedure is described in Chapter V using the NWS standard hourly precipitation data.

If the drainage area upstream of the design location is larger than 8 square miles ( $20 \text{ km}^2$ ), an area reduction factor should be applied to the point rainfall depth obtained from TP-40, HYDRO-35, or frequency analysis. The value of the area reduction factor can be estimated from Fig. 2. This figure should not be used in mountain regions where the orographic effect on rainfall is significant.

- (5) Compute the values of dimensional parameters of the triangular design hyetograph -- With the values of  $D$  and  $t_d$  known, the values of parameters of the triangular design hyetograph (Fig. 3) can be computed by using the following equation

$$a = a^\circ t_d \quad (2.1)$$

$$b = b^\circ t_d \quad (2.2)$$

$$h = h^\circ D / t_d = 2D / t_d \quad (2.3)$$

where  $a^\circ + b^\circ = 1$

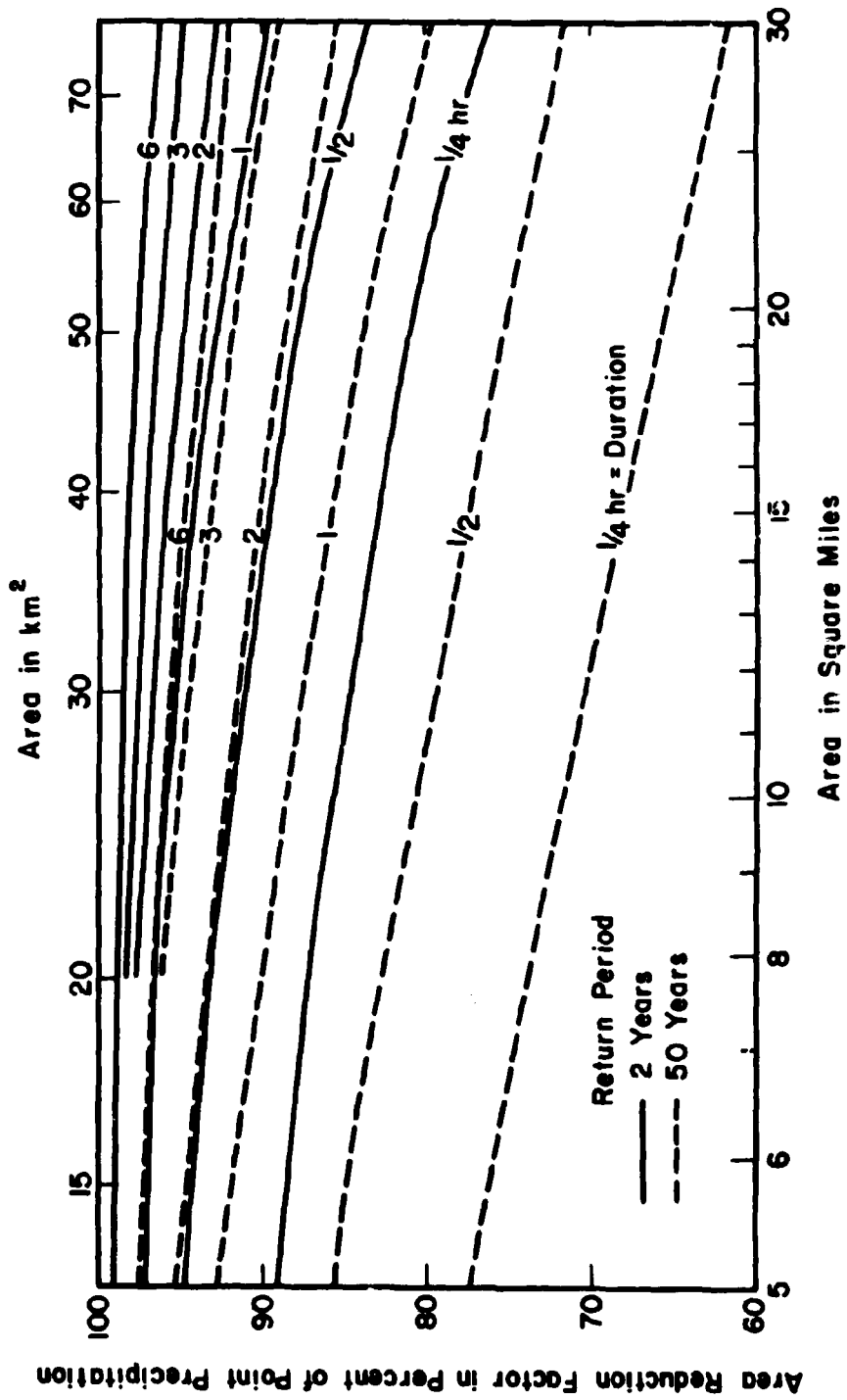


Fig. 2. Area reduction factor of rainfall depth (a) 2 and 50-year return periods

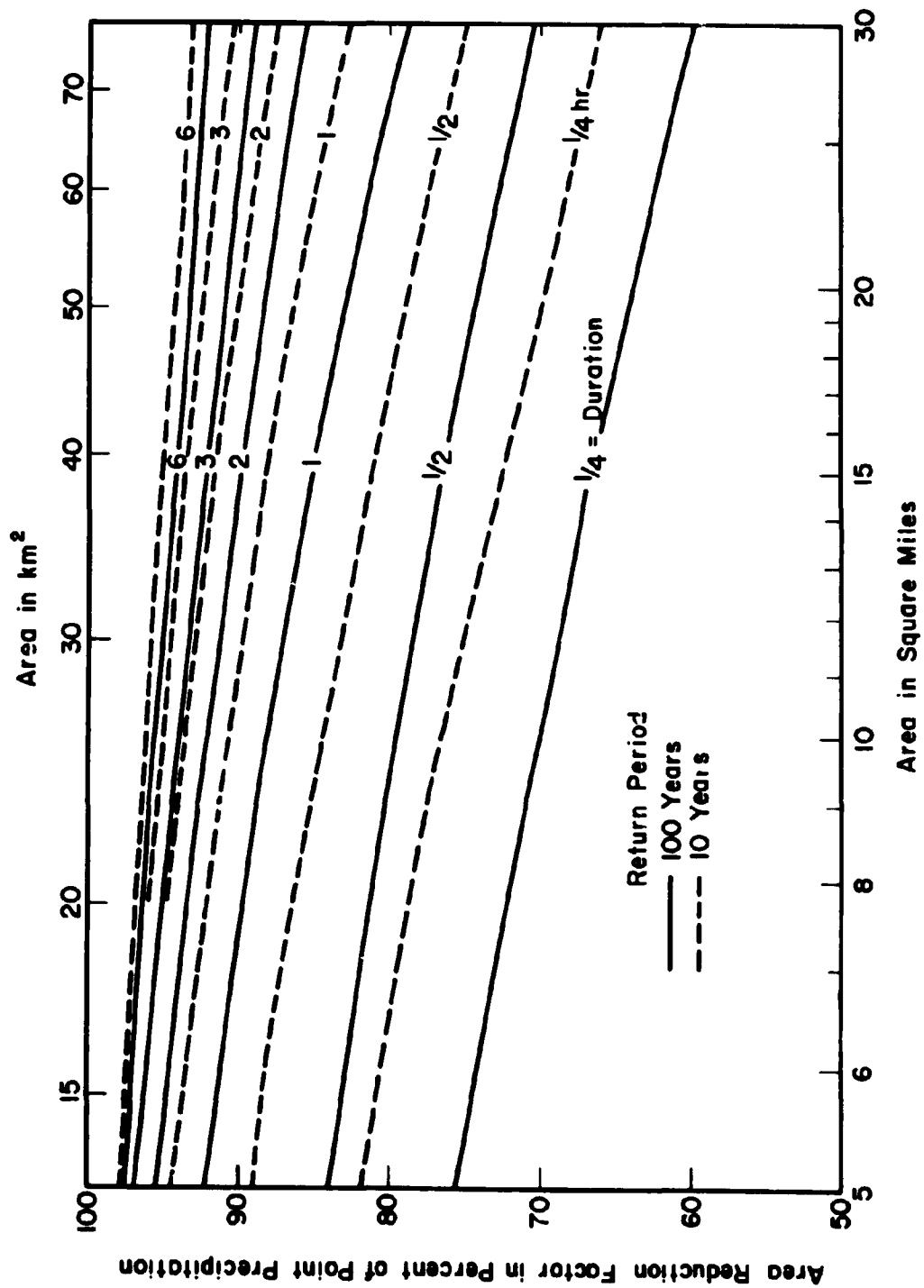


Fig. 2. Area reduction factor of rainfall depth (b) 10 and 100-year return periods

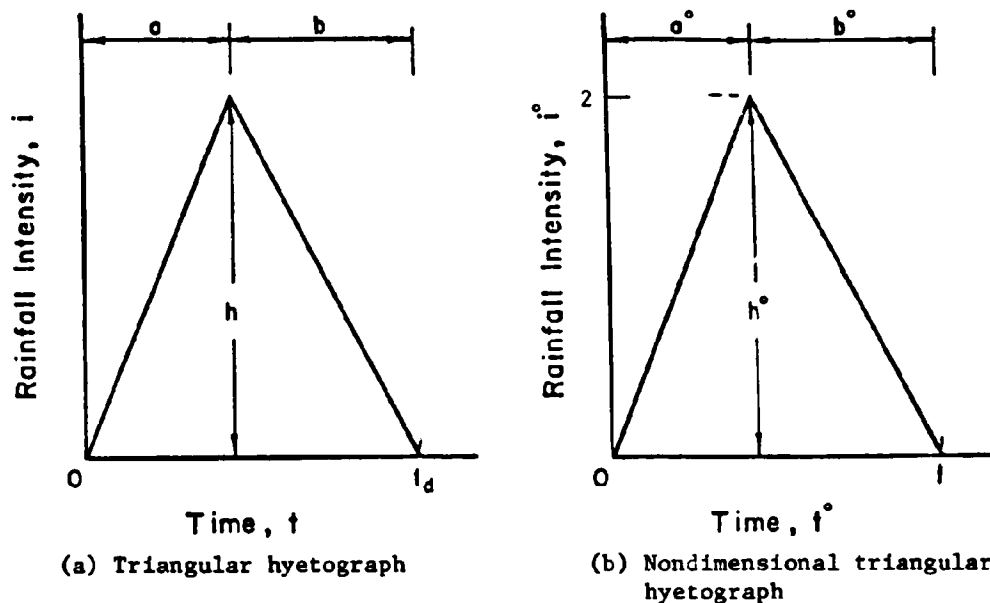


Fig. 3. Triangular hyetographs

- (6) Construct dimensional triangular design hyetograph -- The design hyetograph is triangular in shape with a base equal to the duration  $t_d$  and the apex equal to the peak rainfall intensity,  $h$ , at a time  $a$  after the beginning of the rainfall (Fig. 3).

#### B. Duration of Design Storm

The critical duration of the design rainstorm,  $t_d$ , can be computed from the critical flow time required for a typical water particle to flow from a critical point at the boundary of the drainage basin to the outlet of the area drained. The critical point is the point having the longest flow time among the different flow times of the different flow paths in the drainage basin. The underlining reason of this assumption is that under this critical duration situation, at least for a short moment, the entire drainage area contributes to the outflow of the basin [Yen, 1978]. Normally, the critical point is the farthest upstream point along the longest flow path of the drainage basin and it is not difficult to be identified from topographic maps. However, under relatively complicated cases the critical point may be the upstream end point of a slightly shorter but flatter flow path, as the case of the basin shown in Fig. 4 for which the critical path is the central path. It should also be noted that if



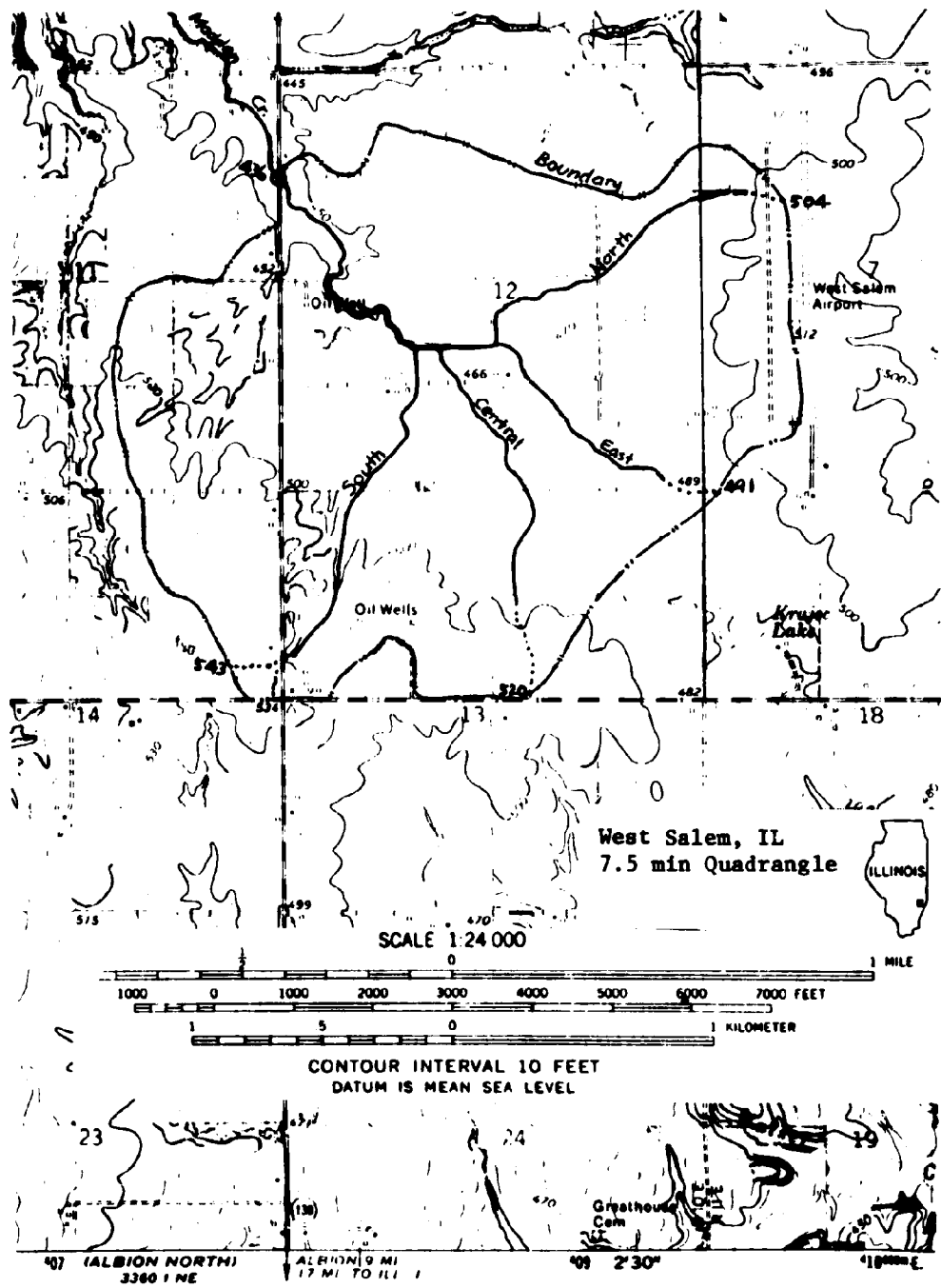


Fig. 4. Example drainage basin -- Madden Creek Basin near West Salem, Illinois

the project involves design of several channels, each channel should have its own design storm duration corresponding to the drainage area and critical flow time upstream of the channel being considered [Yen, 1980].

The flow path in a drainage basin can be divided into two parts: overland flow and channel flow. The total flow time,  $t_t$ , along a flow path is the sum of the overland flow time,  $t_o$ , and the channel flow time,  $t_f$ , i.e.,

$$t_t = t_o + t_f \quad (2.4)$$

In this chapter all the times are in hours. The design duration,  $t_d$ , is taken as the longest  $t_t$ .

In order to compute these flow times, the user should first determine the channel length,  $L_c$ , and overland length,  $L_o$ , using topographic maps or field survey, from the outlet of the drainage basin (point of interest) along the flow path to the upstream basin divide. The elevations at the basin divide and at the upstream end and outlet point of the channel,  $E_1$ ,  $E_2$ , and  $E_3$ , respectively, should also be determined. Next, the overland slope,  $S_o$ , is computed as

$$S_o = \frac{E_1 - E_2}{L_o} \quad (2.5)$$

and the channel slope,  $S_c$ , as

$$S_c = \frac{E_2 - E_3}{L_c} \quad (2.6)$$

in which the lengths and elevations are all in feet or meters.

- (1) Estimation of overland flow time  $t_o$  -- The overland flow time,  $t_o$  in hours, is estimated by the following formula:

$$t_o = K \left( \frac{nL_o}{\sqrt{S_o}} \right)^{0.6} \quad (2.7)$$

in which  $L_o$  is in feet or meters not exceeding 3000 ft (900 m);  $S_o$  is nondimensional (i.e., ft/ft or m/m); the value of the constant K is given in Table 1; and the surface roughness factor n is given in Table 2.

TABLE 1. Values of K for Eq. 2.7

Rain intensity (in./hr) (mm/hr)	Light rain	Moderate rain	Heavy rain
	< 0.8 < 20	0.8 - 1.5 20 - 40	> 1.5 > 40
For L <sub>o</sub> in feet	0.02	0.015	0.01
For L <sub>o</sub> in m	0.04	0.03	0.02

Equation 2.7 is based on the kinematic wave formula modified for composite land surfaces of heterogeneous nature [Yen, 1981].

- (2) Estimation of channel flow time  $t_f$  -- The channel flow time,  $t_f$  in hours, is computed as

$$t_f = \frac{L_c}{3600 V} \quad (2.8)$$

in which  $L_c$  is the channel length along the flow path and  $V$  is the channel flow velocity. For English measurement units,  $L_c$  is in feet and  $V$  is in feet per second. For SI units,  $L_c$  is in m and  $V$  in m/s.

If there are clear changes in channel slope, cross section, roughness, or other channel hydraulic characteristics, the channel part of the flow path may be subdivided into segments, or reaches, such that

$$L_c = \sum_j L_j \quad j = 1, 2, \dots \quad (2.9)$$

where  $L_j$  is the length of the  $j$ th reach of the channel of the flow path. If the flow velocity of the  $j$ th reach is  $V_j$ , the channel flow time,  $t_f$  in hours, can then be estimated as

$$t_f = \sum_j \frac{L_j}{3600 V_j} \quad j = 1, 2, \dots \quad (2.10)$$

TABLE 2. Surface Roughness Factor n for Eq. 2.7

SURFACE	n
Smooth asphalt pavement	0.011-0.014
Tar and sand pavement	0.012-0.016
Smooth impervious surface	0.012-0.015
Concrete pavement	0.013-0.016
Tar and gravel pavement	0.015-0.020
Rough impervious surface	0.016-0.022
Smooth bare packed soil	0.018-0.025
Moderate bare packed soil	0.025-0.030
Rough bare packed soil	0.030-0.040
Gravel soil	0.025-0.035
Mowed poor grass	0.030-0.040
Cultivated rows, no crop	0.030-0.040
Average (lawn) grass, closely clipped sod	0.040-0.055
Pasture	0.045-0.060
Cultivated rows, with crops	0.040-0.070
Deciduous timberland	0.050-0.075
Deciduous timberland with deep forest litter	0.060-0.100
Conifer timberland	0.060-0.100
Dense grass	0.060-0.100
Shrubs and bushes	0.100-0.150
LAND USE	n
Business	0.015-0.035
Semi-business	0.025-0.050
Heavy industrial	0.020-0.040
Light industrial	0.025-0.050
Dense residential	0.030-0.060
Suburban residential	0.040-0.080
Parks and lawns	0.050-0.100

the units of  $L_j$  and  $V_j$  are the same as  $L_c$  and  $V$  in Eq. 2.8.

Computation of the channel flow velocity,  $V$  or  $V_j$ , requires knowledge of hydraulics and channel geometry. However, when time variation of rainfall depth or intensity with duration is not rapid, the approximation given in Table 3 often yields acceptable design hyetographs.

Table 3. Approximate Channel Flow Velocity

Return period Years	Estimated Channel Velocity	
	ft/sec	m/s
1	4	1.2
10	6	1.8
50	8	2.5
100	10	3.0

The suggested approximate values should be lowered for channels with small slopes or many obstacles. Conversely, they should be increased for channels with large slopes or straight clean channels.

### C. Example

Suppose the local design storm is to be established for use in the design of a highway culvert draining the Madden Creek basin near West Salem, Illinois. The drainage basin is shown in Fig. 4. The design return period is 25 years. Following Section A, the procedure to establish the design hyetograph is as follows.

#### (1) Determine $t_d$

The duration of the design storm,  $t_d$ , is determined following the procedure described in the preceding section, Eqs. 2.7 and 2.8 or 2.10, and the computation is given in Table 4. The elevations and lengths of the overland and channel of the different potentially critical flow paths are taken from the U.S. Geological Survey 7.5-minute map, West Salem, Illinois quadrangle. This is a rather complicated drainage basin in terms of the determination of the critical flow path. This example illustrates that the longest path in length does not always produce the longest flow time. Nevertheless it usually gives an acceptable approximation of the design duration  $t_d$ , which is 0.8 hours from the central path in this case.

- (2) Determine  $T_r$

The design return period  $T_r$  has been specified as 25 years.

- (3) Determine  $a^\circ$

From the map shown in Fig. 1, for the design location  $a^\circ = 0.33$ .

- (4) Determine the rain depth  $D$

Since the duration is less than one hour, HYDRO-35 is used to determine  $D$ . The detail is given in Section III-B. The rain depth for this location for  $t_d = 0.8$  hour and  $T_r = 25$  years is 2.4 inches. No area reduction of  $D$  is required since the draining basin is less than 8 square miles ( $20 \text{ km}^2$ ) in size.

- (5) Compute the values of triangular design hyetograph parameters

The dimensional parameters are computed using Eqs. 2.1, 2.2, and 2.3.

$$a = a^\circ t_d = 0.33 \times 0.8 = 0.264 \text{ hours}$$

$$b = t_d - a = 0.536 \text{ hours}$$

$$h = 2D/t_d = 2 \times 2.4/0.8 = 6.0 \text{ inches/nours}$$

It should be noted that the peak rain intensity,  $h$ , is equal to twice the average intensity ( $\bar{i} = D/t_d$ ) used in the well known rational formula.

- (6) Construct the design hyetograph

The design hyetograph from this example is shown in Fig. 5.

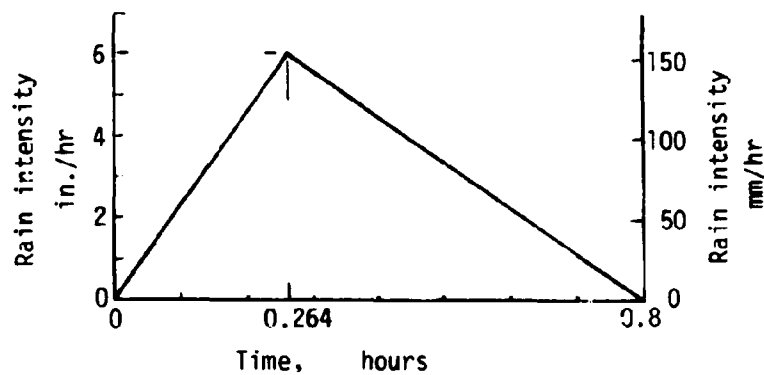


Fig. 5. Example design hyetograph

TABLE 4. Example Computation of Critical Flow Time for  
Madden Creek Basin near West Salem, Illinois

Flow path	West	Central	East	North
Upstream elev. at divide, ft	543	520	491	504
Elev. at upstream end of channel, ft	525	492	481	490
Elev. at culvert site, ft	436	436	436	436
Overland length $L_o$ , ft	800	1100	800	500
Channel length $L_c$ , ft	8600	7800	7600	8700
Total length $L_o+L_c$ , ft	<u>9400</u>	8900	8400	9200
Overland slope, $S_o$	0.0225	0.0254	0.0125	0.0280
Channel slope, $S_c$	0.010	0.007	0.006	0.006
Basin slope $S$	0.0114	0.0094	0.0065	0.0074
$t_o$ , hr ( $n=0.06$ )	0.32	0.37	0.38	0.23
Channel flow Velocity, $V$ , fps	6	5	5	5
$t_f = L_c/V$ , hr	0.40	0.43	0.42	0.48
$t_t$ , hr	0.72	0.80	0.80	0.71

### III. DETERMINATION OF RAINFALL DEPTH AND INTENSITY

As discussed in Section II-A of this manual, the rainfall depth or average intensity of a design storm can be estimated from NWS atlases or from using actual records and formulas. This chapter presents the use of TP-40, HYDRO-35, and rainfall record for this purpose.

#### A. Rainfall Depth Determination from TP-40

The U.S. National Weather Service (NWS, formerly Weather Bureau) Technical Paper No. 40 (TP-40) entitled "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years" [Hershfield, 1961] has been widely used by engineers to determine the depth of rainfall for storms of specified duration and return period. This publication can be ordered from the U.S. Government Printing Office. It is available in major public and university libraries, and in many major engineering firms and public works offices. Therefore, only the pertinent maps that are used in the following example to demonstrate the use of TP-40 are reproduced in this section (Figs 6, 7, and 8).

There are 49 rainfall depth maps in TP-40 for durations of 1/2, 1, 2, 3, 6, 12, and 24 hours and return periods of 1, 2, 5, 10, 25, 50, and 100 years. For the application of the triangular design hyetograph those for 1, 2, 3, and 6 hour durations are useful. The user should also be aware that for rainstorms with duration of one hour or less in the central and eastern United States the rainfall should be determined from NWS HYDRO-35 which superseded TP-40 for short durations.

For a design storm having its duration or return period different from those given in TP-40 interpolation is required. An example is illustrated in Figs. 9 and 10 to determine the depth of a 2.5-hour 30-year design storm at Chicago. Since neither 2.5-hour duration nor 30-year return period is presented in TP-40, interpolations are required on both duration and return period. First the rain depths at Chicago for 2 and 3-hour durations are read from Figs. 6, 7, and 8 for return periods of 10, 25, and 50 years, respectively. These depths are plotted as marked points in Fig. 9 showing depth vs. duration for different return periods. Also read from TP-40 and plotted in Fig. 9 are the depth values for 1-hour and 6-hour durations -- these values are not essential but helpful to improve



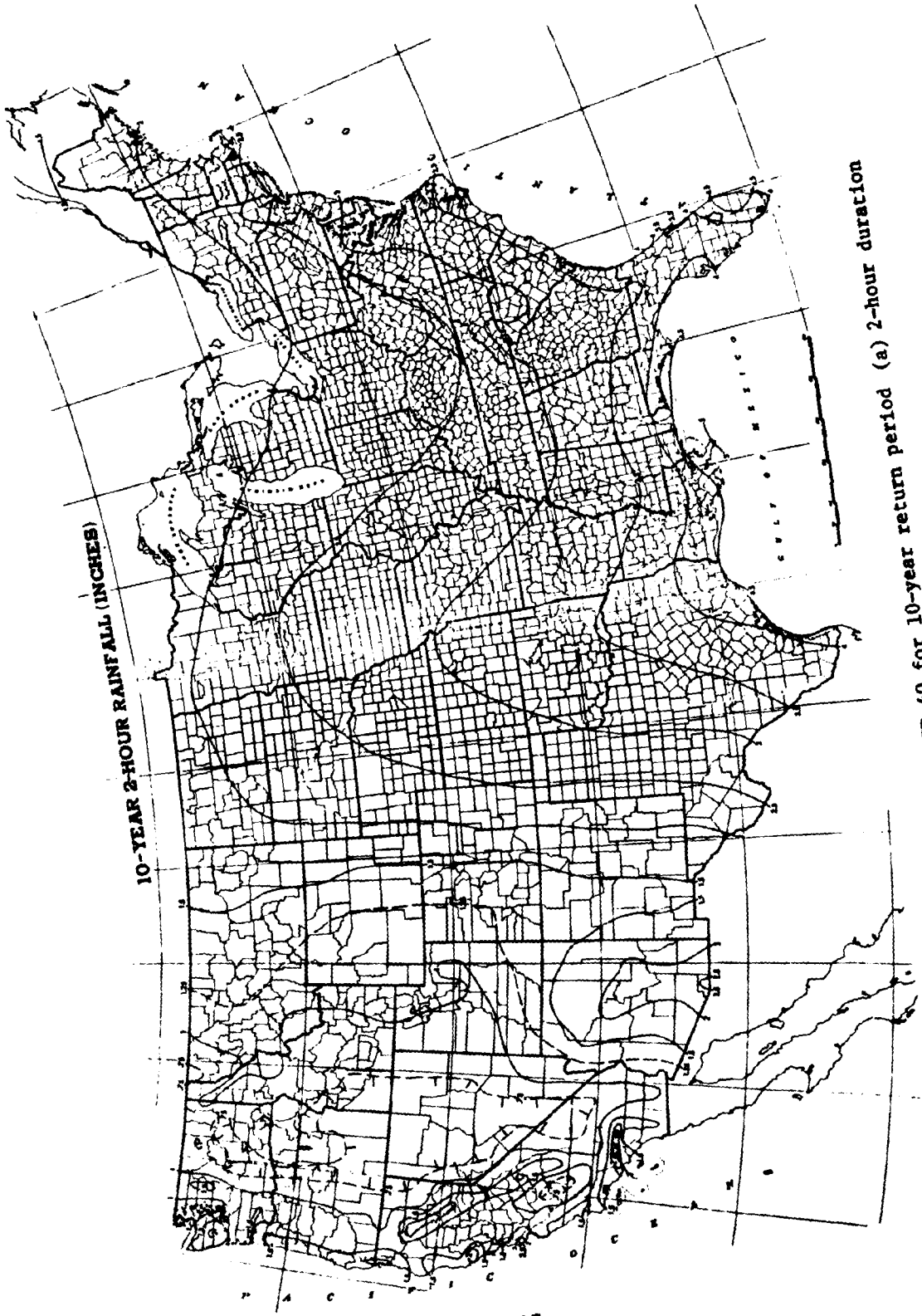


FIG. 6. Rainfall depth from TP-40 for 10-year return period (a) 2-hour duration

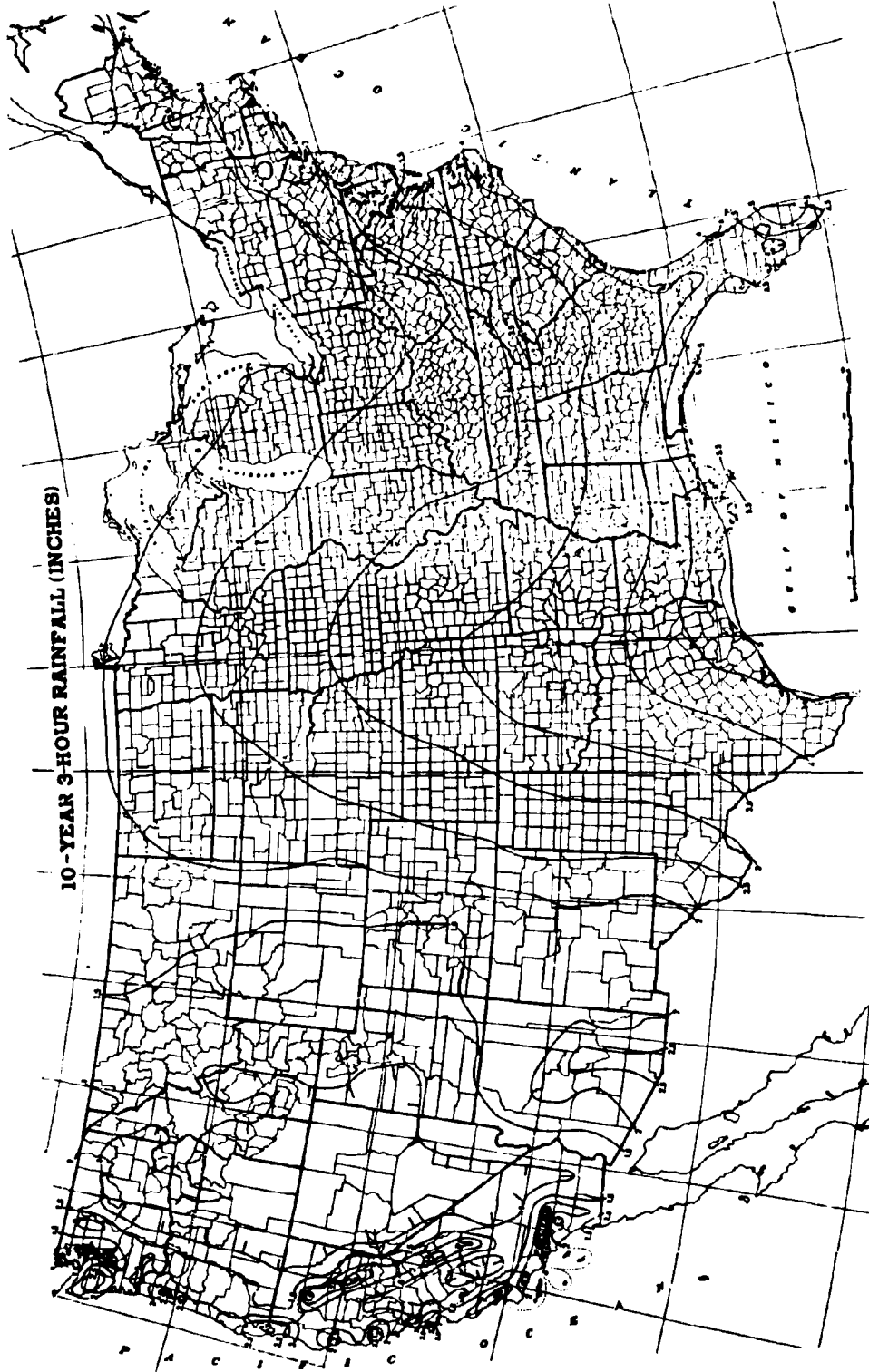


Fig. 6. Rainfall depth from TP-40 for 10-year return period (b) 3-hour duration

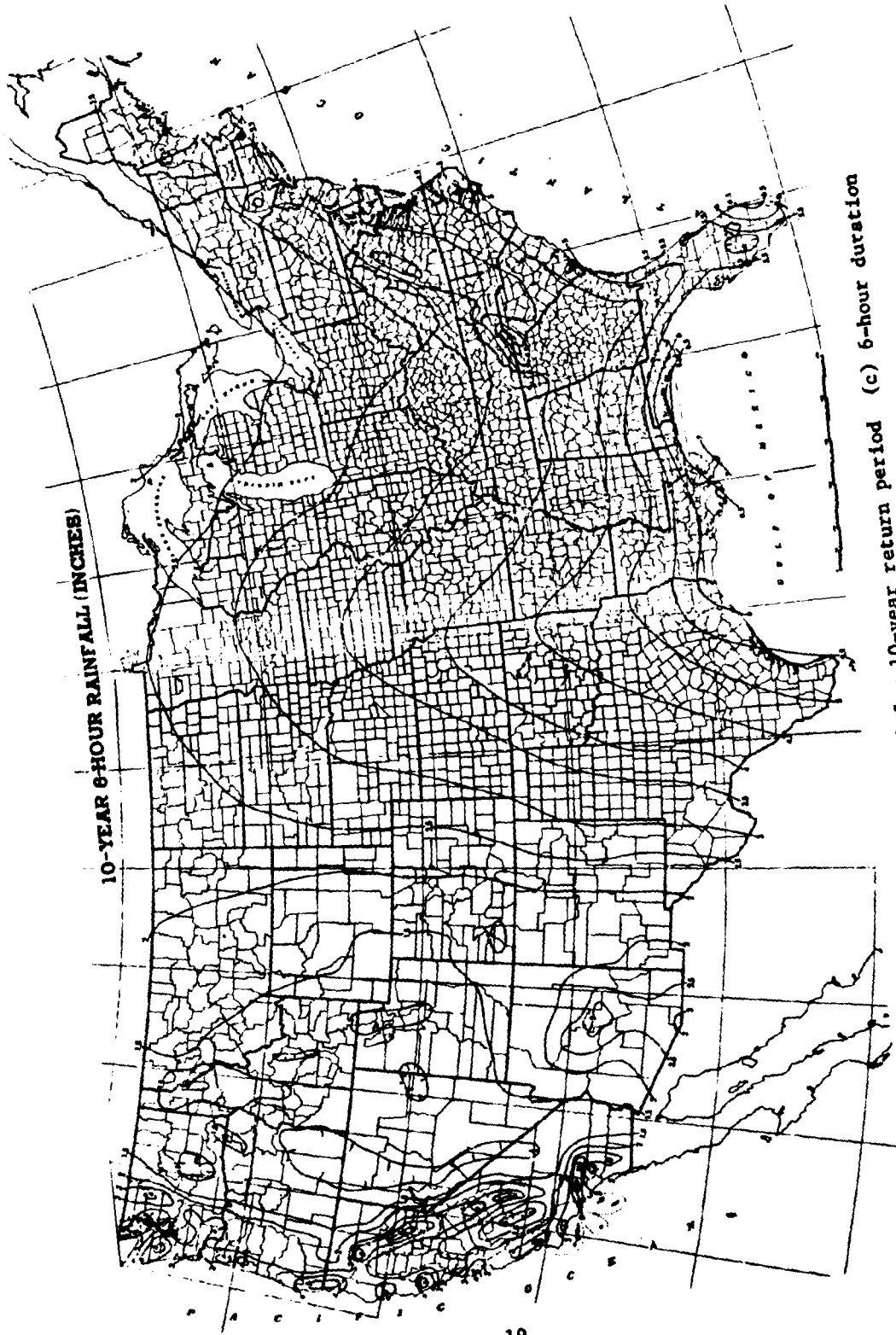


Fig. 6. Rainfall depth from TP-40 for 10-year return period (c) 6-hour duration

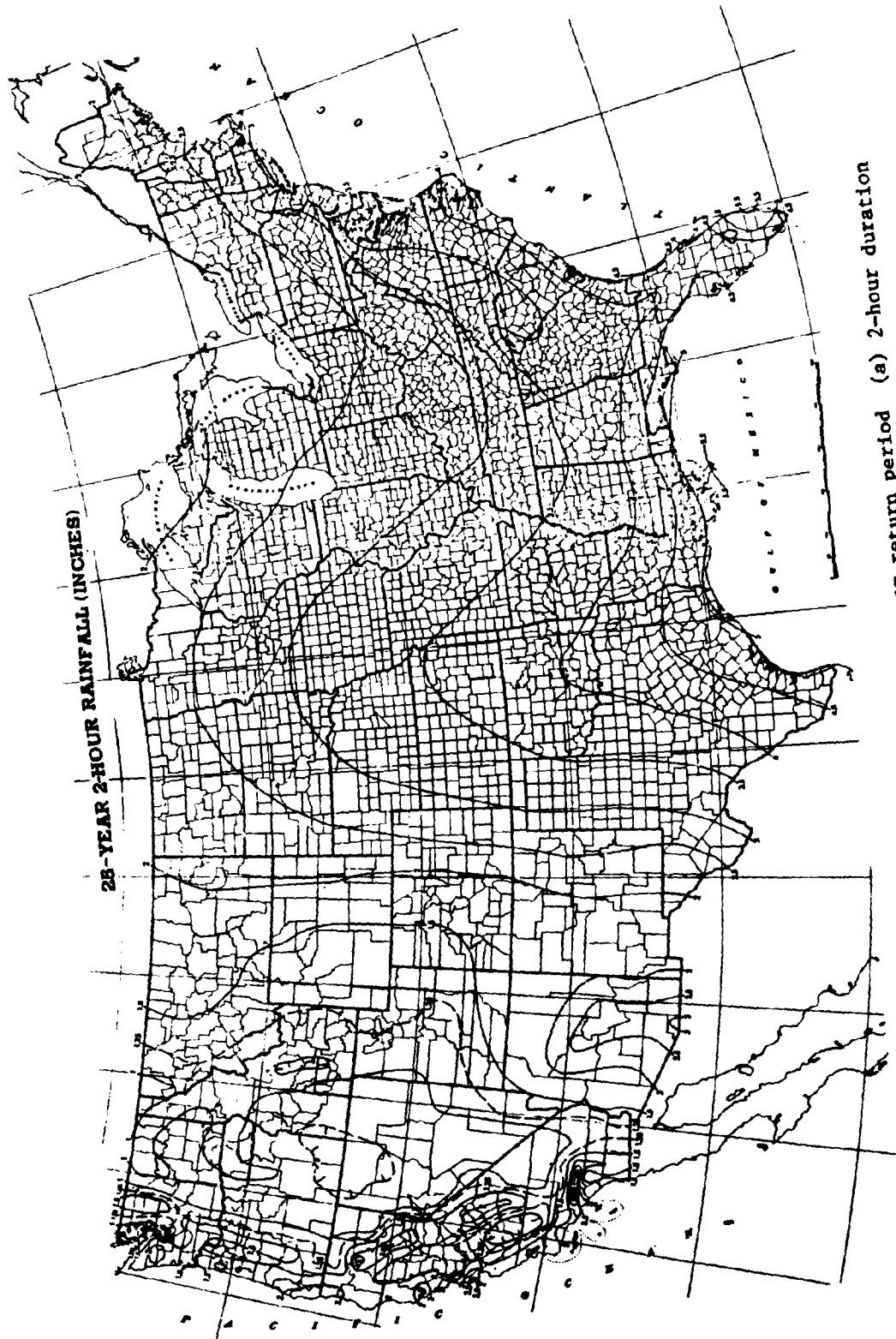


Fig. 7. Rainfall depth from TP-40 for 25-year return period (a) 2-hour duration

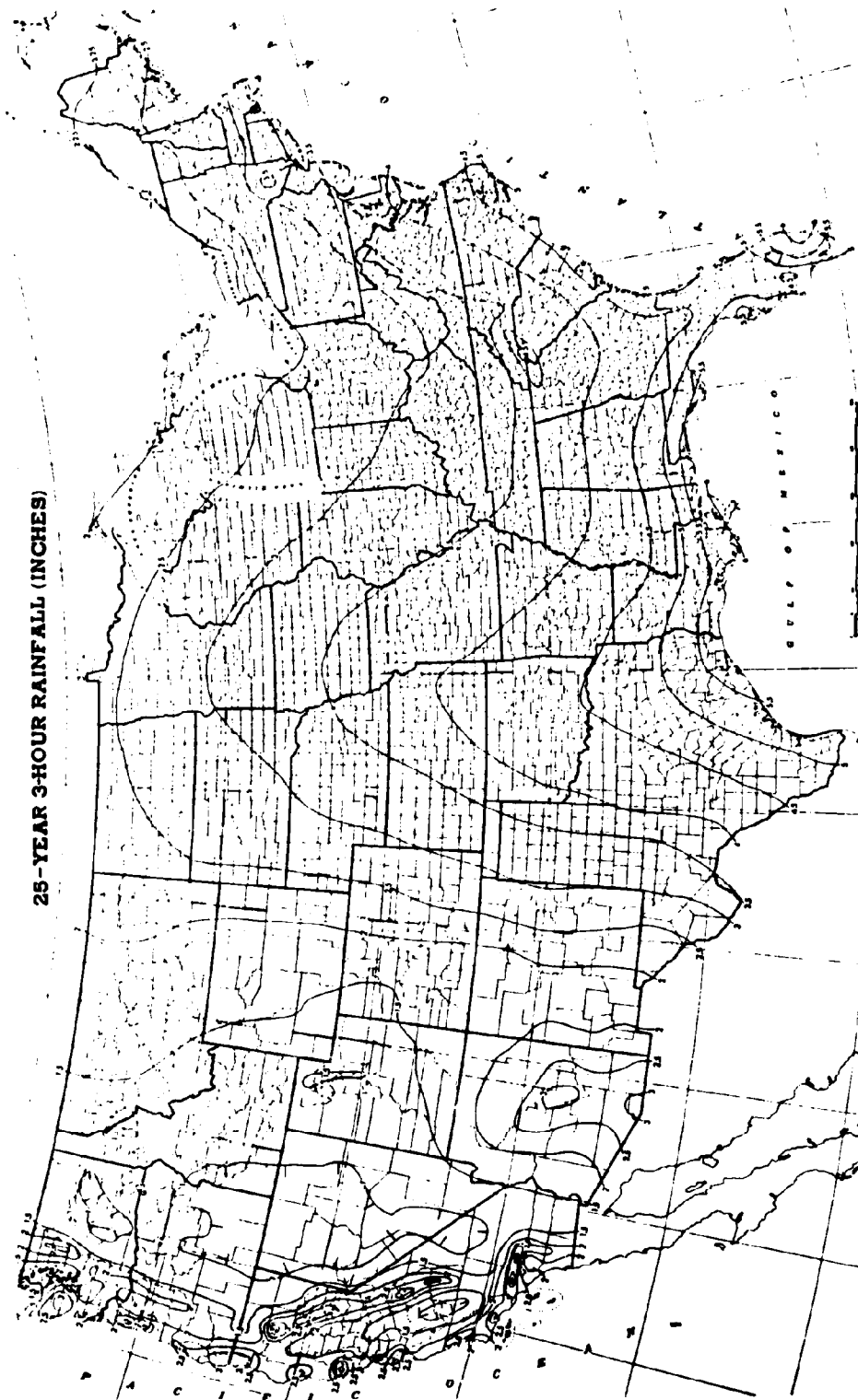


Fig. 7. Rainfall depth from TP-40 for 25-year return period (b) 3-hour duration

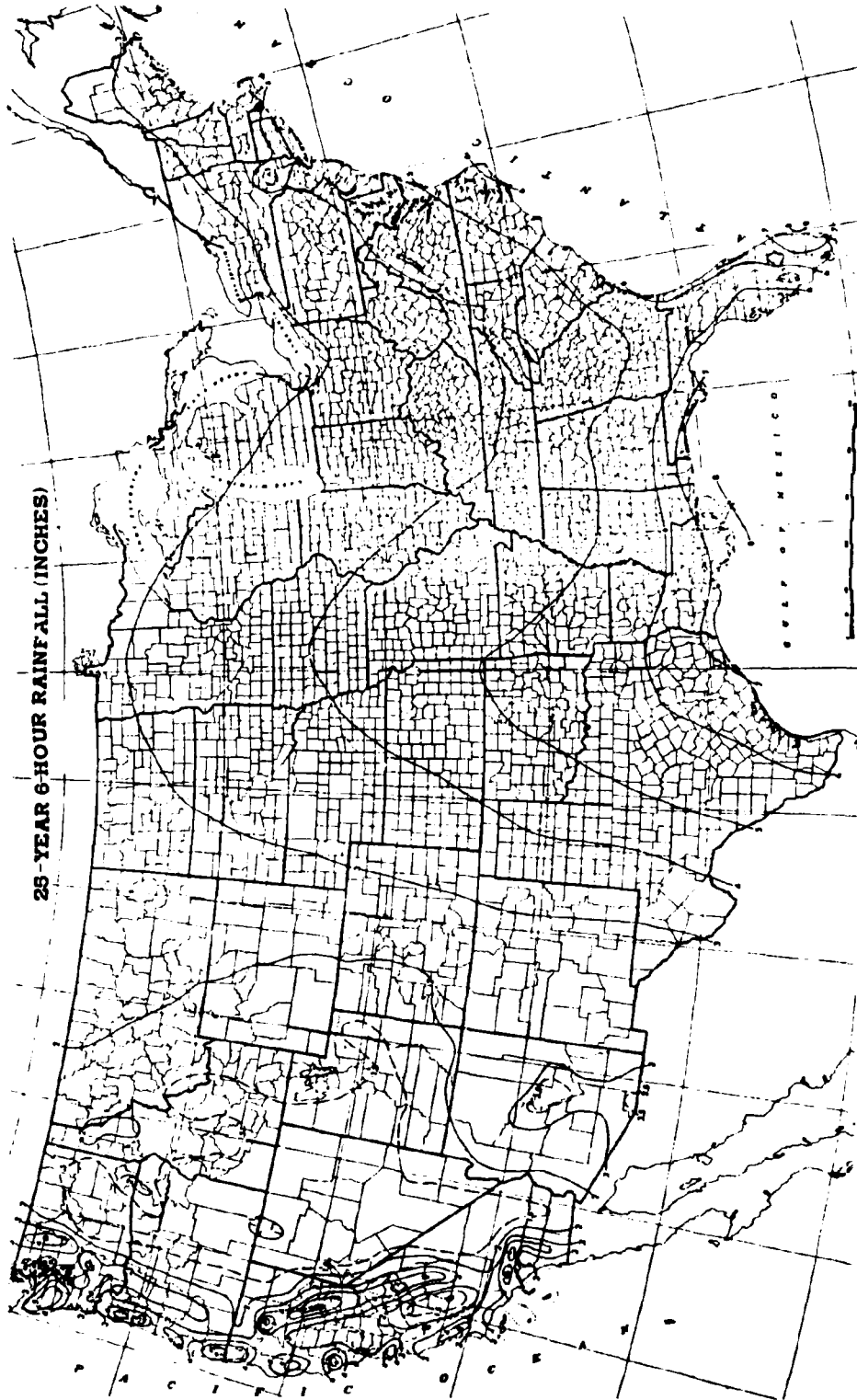


Fig. 7. Rainfall depth from TP-40 for 25-year return period (c) 6-hour duration

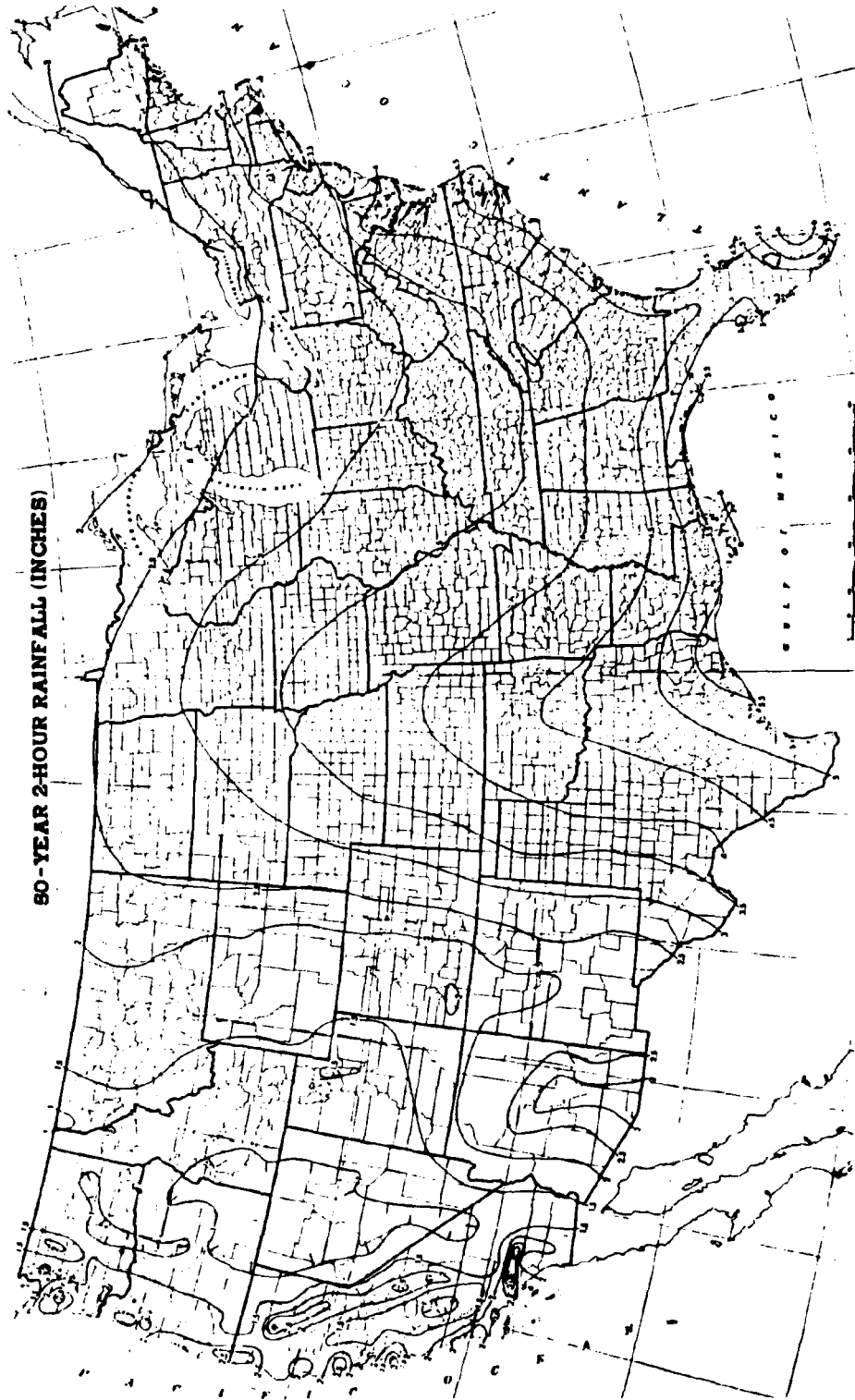


Fig. 8. Rainfall depth from TP-40 for 50-year return period (a) 2-hour duration

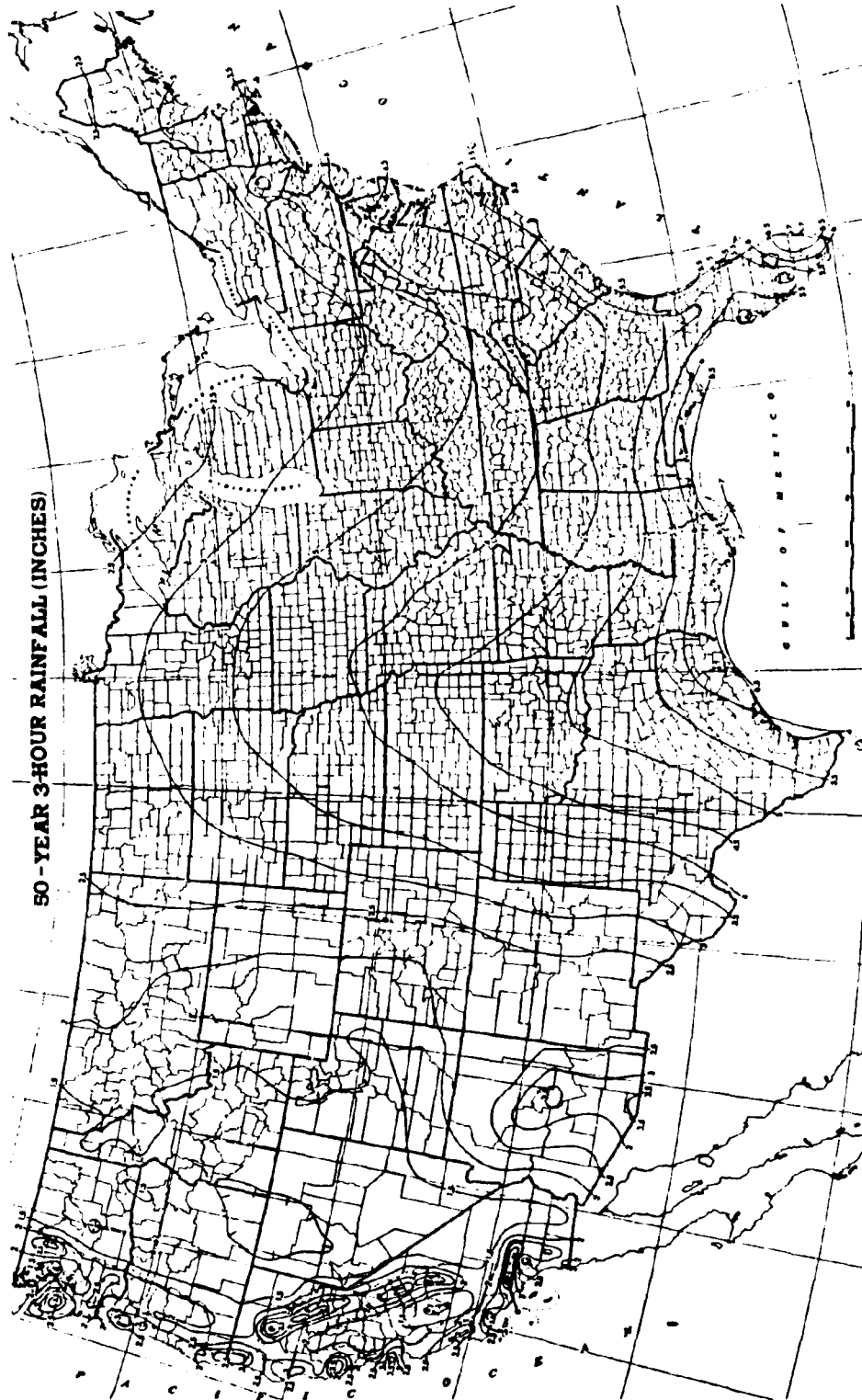


Fig. 8. Rainfall depth from TP-40 for 50-year return period (b) 3-hour duration



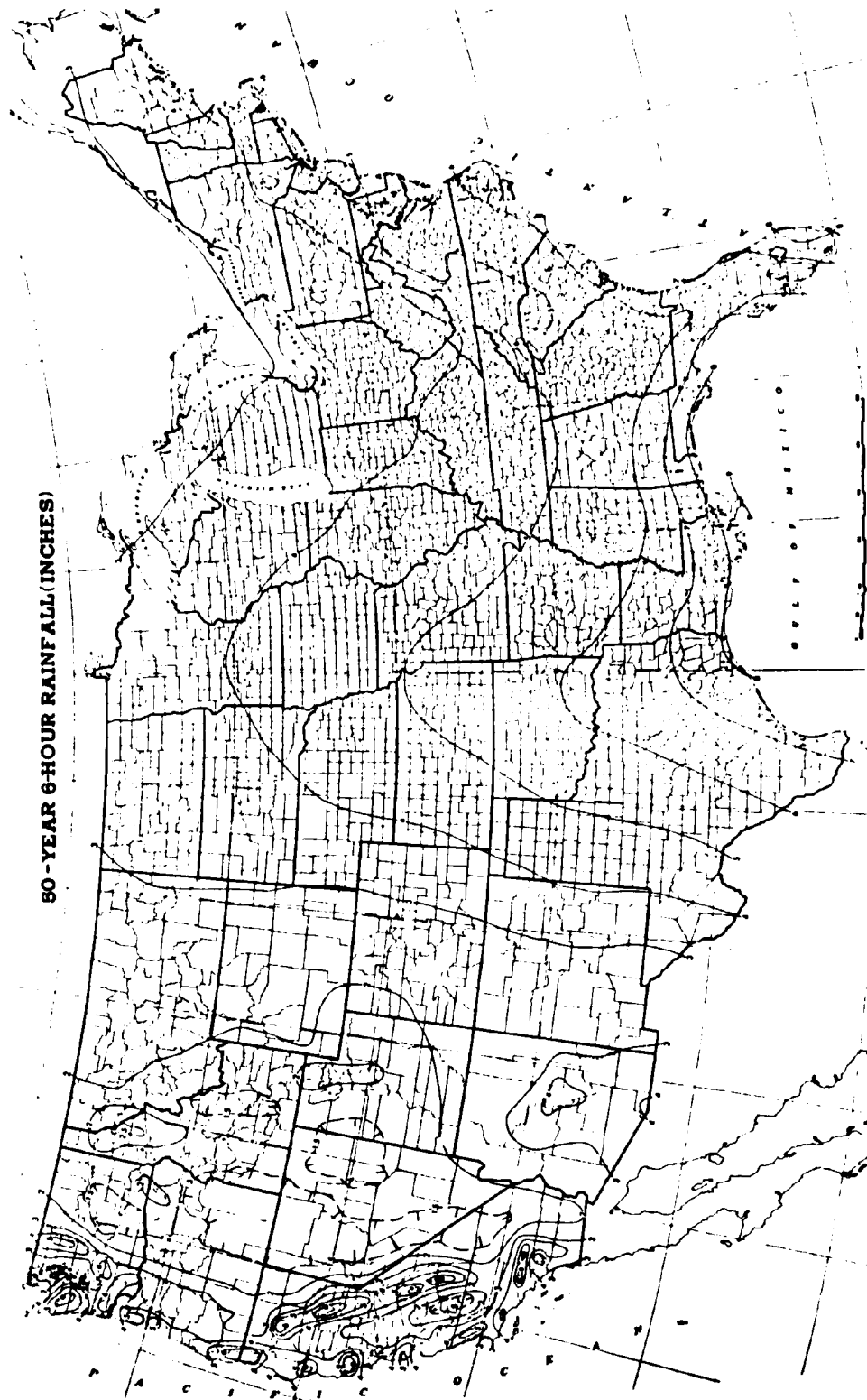


Fig. 8. Rainfall depth from TP-40 for 50-year return period (c) 6-hour duration

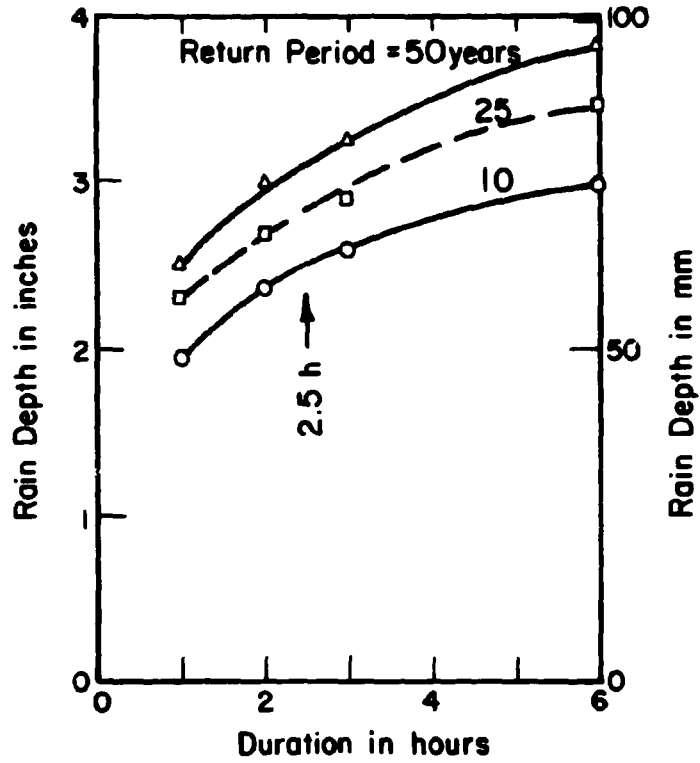


Fig. 9. Rain depth interpolation - duration

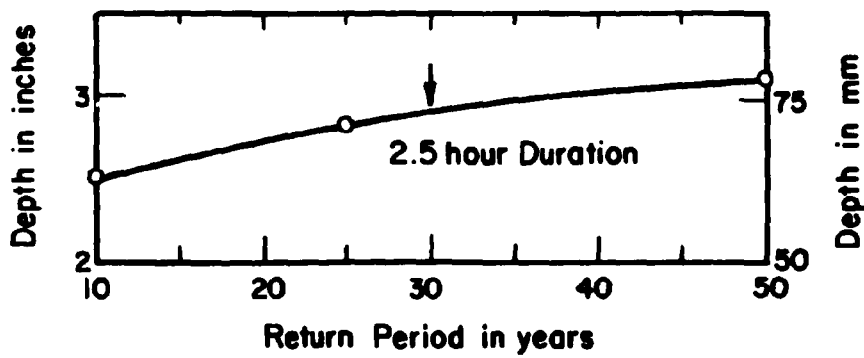


Fig. 10. Rain depth interpolation - return period

accuracy because the depth-duration relation is nonlinear. A curve is then drawn for each return period. The depths for 2.5-hour duration are read for the three different return periods (intersection points of the curves with the vertical marked 2.5 h in Fig. 9). These values of depth are subsequently plotted as a function of return period as shown in Fig. 10. The 30-year 2.5-hour storm depth can be read from this figure as 2.9 inches.

**B. Rainfall Depth Determination from HYDRO-35**

For rainfall having duration of one hour or less in the contiguous United States east of 105°W meridian, the relationship between the depth and duration for different return periods is given in the National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum NWS HYDRO-35 [Frederick et al., 1977]. Since often design storms have their durations less than an hour and HYDRO-35 is not widely distributed, the pertinent maps of precipitation depths for 5, 15, and 60 minute durations and returns periods of 2 and 100 years for the 37 eastern states are reproduced here as Figs. 11 and 12 for the convenience of the user. Other values are computed from those taken from the maps. Depths for 10 and 30 minute durations for a given return period are obtained using the 5, 15, and 60 minute values for the same return period as follows:

$$D_{10 \text{ min}} = 0.59D_{15 \text{ min}} + 0.41D_{5 \text{ min}} \quad (3.1)$$

$$D_{30 \text{ min}} = 0.49D_{60 \text{ min}} + 0.51D_{15 \text{ min}} \quad (3.2)$$

in which D is the rain depth. For return periods other than 2 and 100 years for a given duration the following equation can be used.

$$D_{T_r \text{ yr}} = aD_{100 \text{ yr}} + bD_{2 \text{ yr}} \quad (3-3)$$

Return Period, $T_r$ years	a	b
5	0.278	0.674
10	0.449	0.496
25	0.669	0.293
50	0.835	0.146

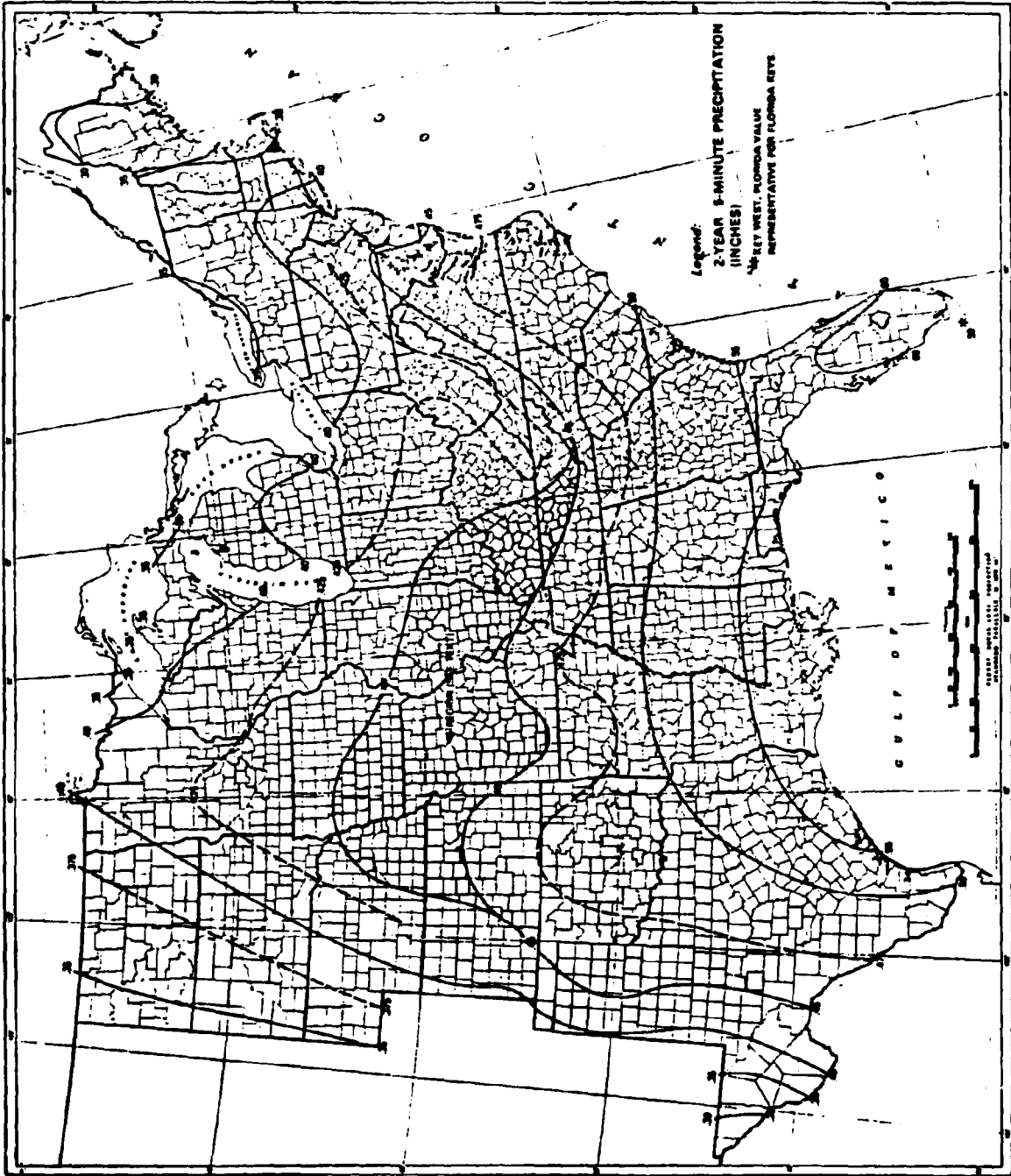


Fig. 11. Rainfall depth from HYDRO-35 for 2-year return period (a) 5-minute duration

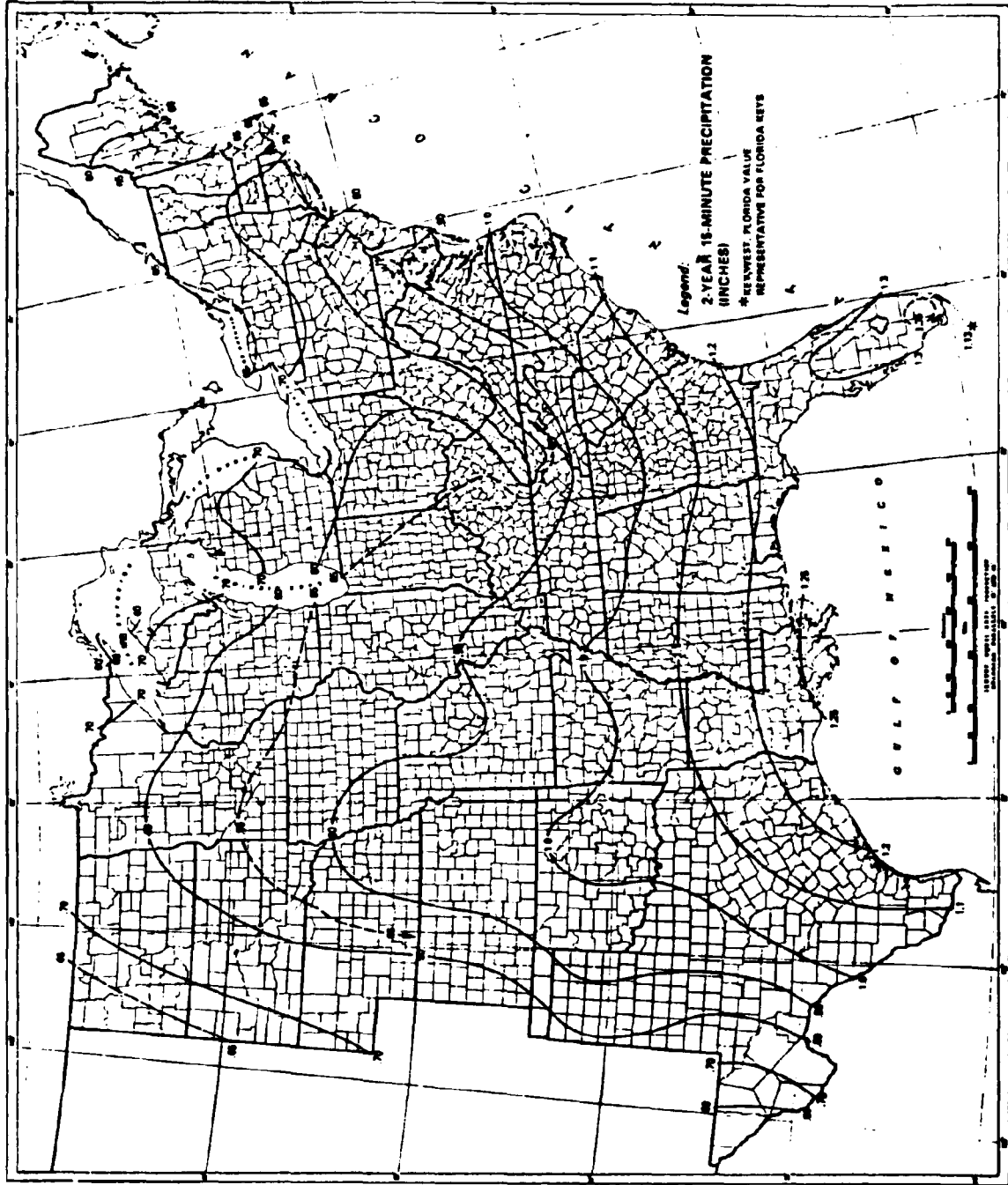


Fig. 11. Rainfall depth from HYDRO-35 for 2-year return period (b) 15-minute duration

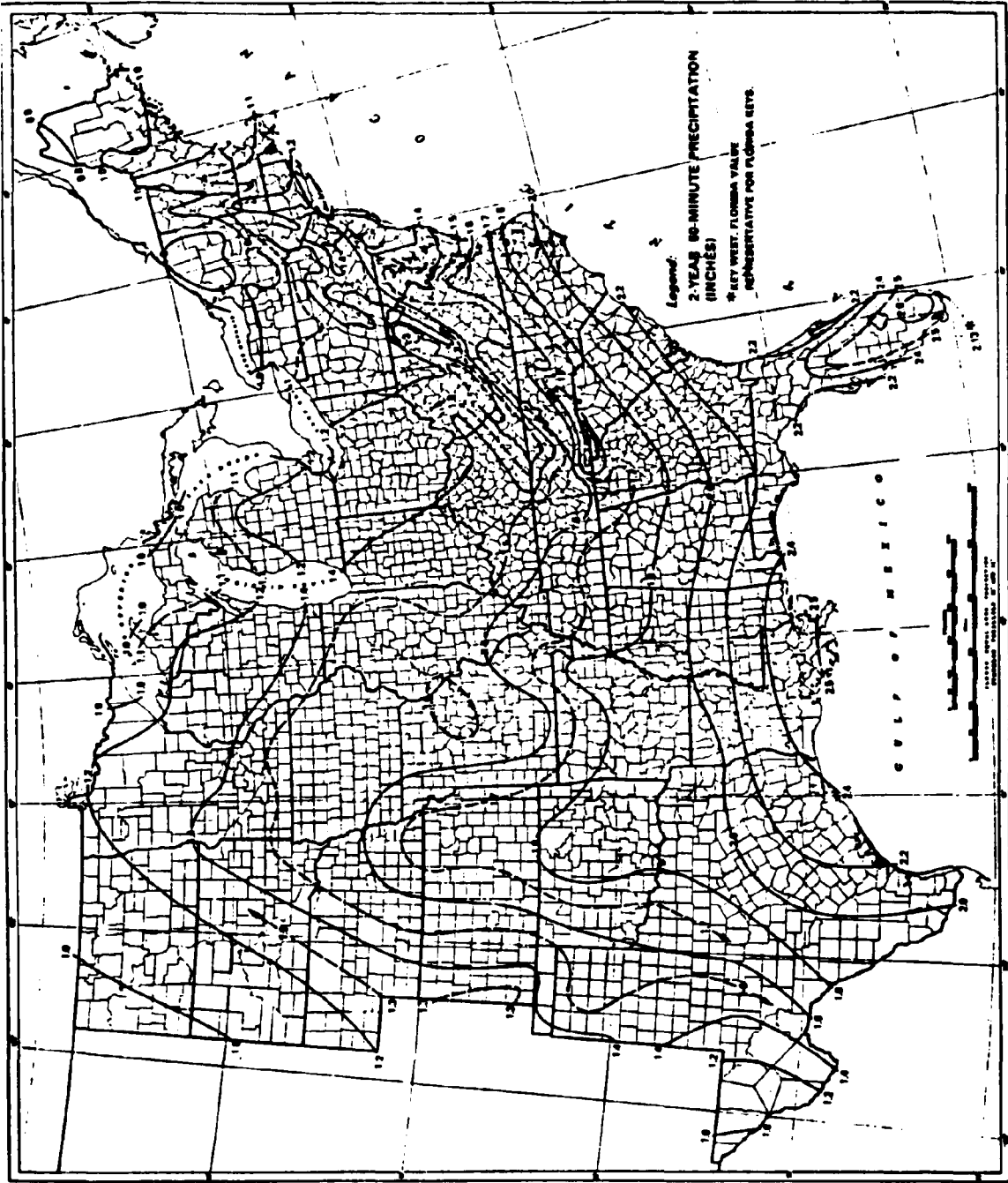


Fig. 11. Rainfall depth from HYDRO-35 for 2-year return period (c) 60-minute duration

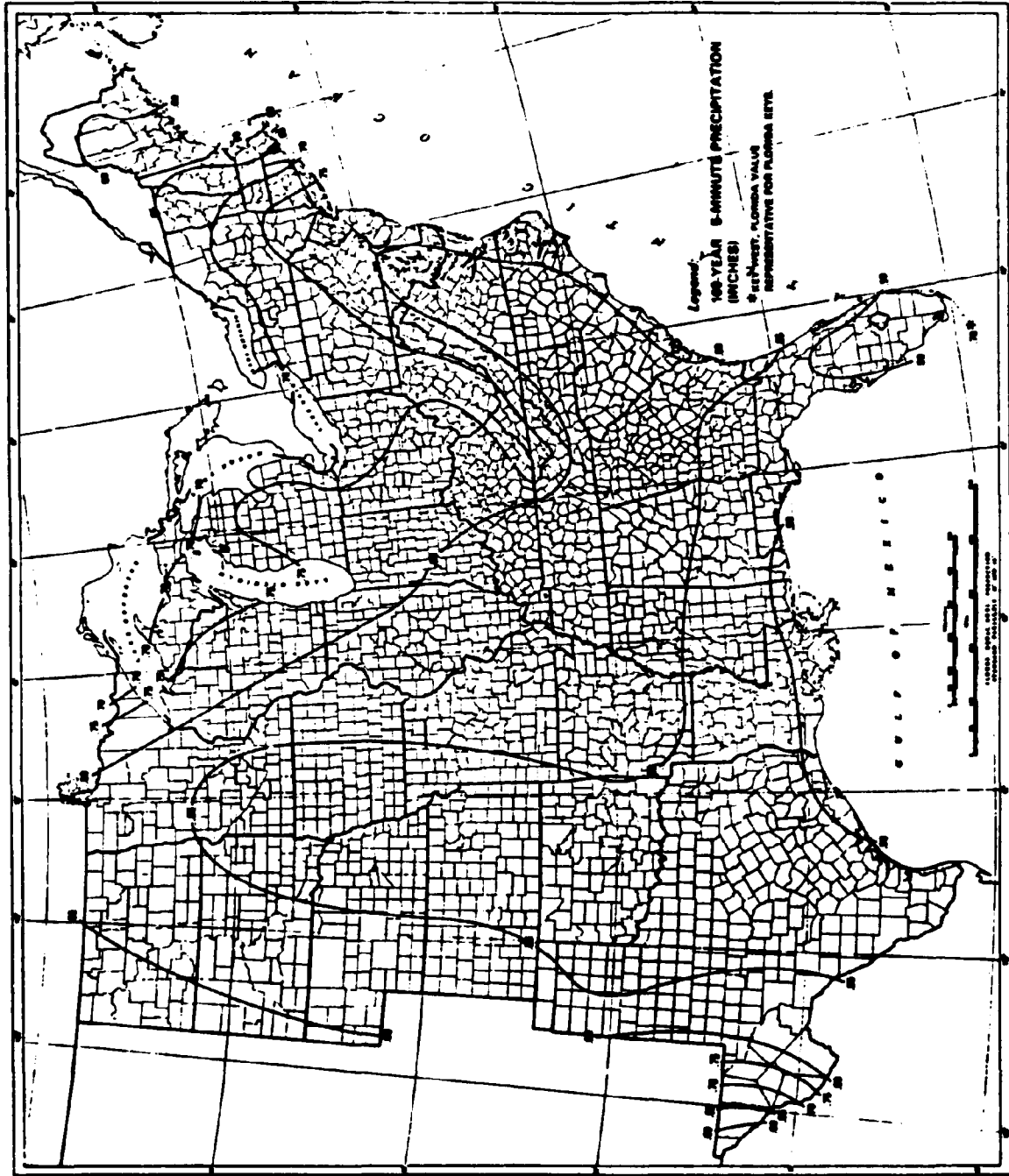


Fig. 12. Rainfall depth from HYDRO-35 for 100-year return period (a) 5-minute duration

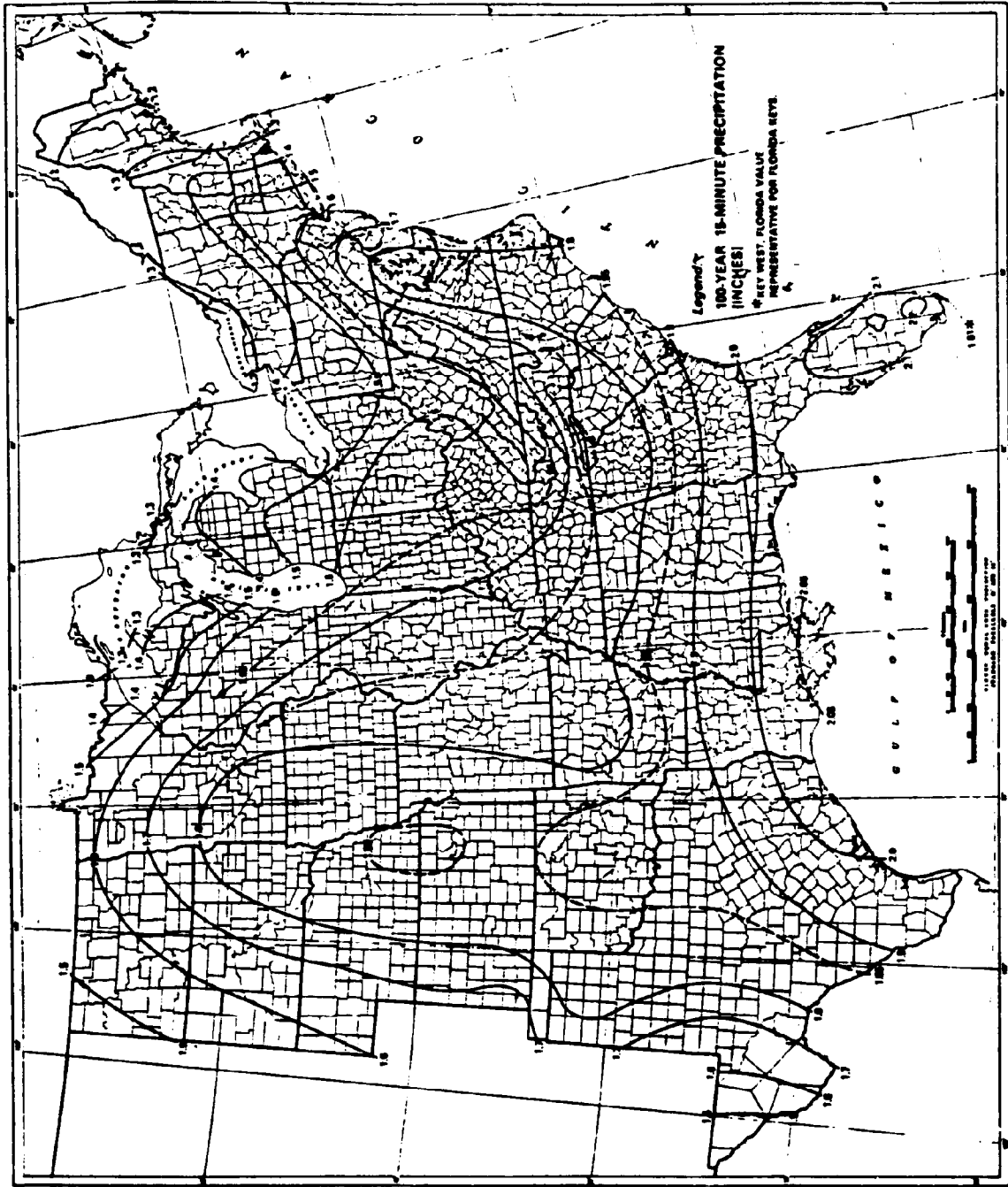


Fig. 12. Rainfall depth from HYDRO-35 for 100-year return period (b) 15-minute duration



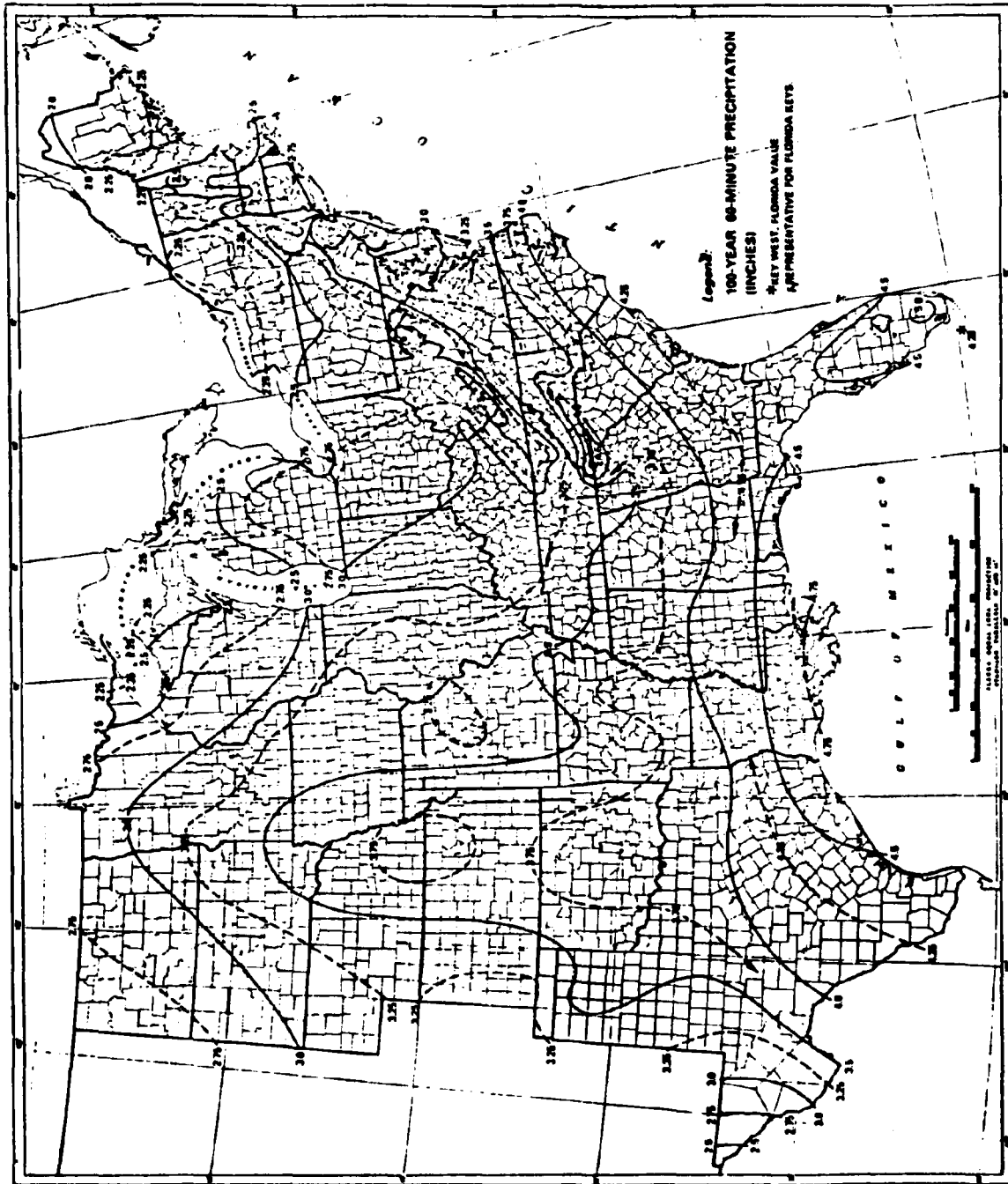


Fig. 12. Rainfall depth from HYDRO-35 for 100-year return period (c) 60-minute duration

For example, the longest flow time of the West Salem drainage basin shown in Fig. 4 is 0.8 hour. Taking this as the duration of the 25-year design storm, the depth is computed as follows.

For this location in southern Illinois, from Figs. 11 and 12 the following depths are read:

$$T_R = 2 \text{ years}, \quad D_{15 \text{ min}} = 0.88 \text{ in.}, \quad D_{60 \text{ min}} = 1.5 \text{ in.}$$

$$T_R = 100 \text{ years}, \quad D_{15 \text{ min}} = 1.71 \text{ in.}, \quad D_{60 \text{ min}} = 3.2 \text{ in.}$$

Thirty-minute rainfall depths are computed by using Eq. 3.2,

$$\text{For } T_R = 2 \text{ years}, \quad D_{30 \text{ min}} = 1.14 \text{ in.}$$

$$\text{For } T_R = 100 \text{ years}, \quad D_{30 \text{ min}} = 2.44 \text{ in.}$$

Plotting of these values as shown in Fig. 13 gives the depths for duration equal to 0.8 hour,

$$T_R = 2 \text{ years}, \quad D_{0.8 \text{ hr}} = 1.4 \text{ in.}$$

$$T_R = 100 \text{ years}, \quad D_{0.8 \text{ hr}} = 3.0 \text{ in.}$$

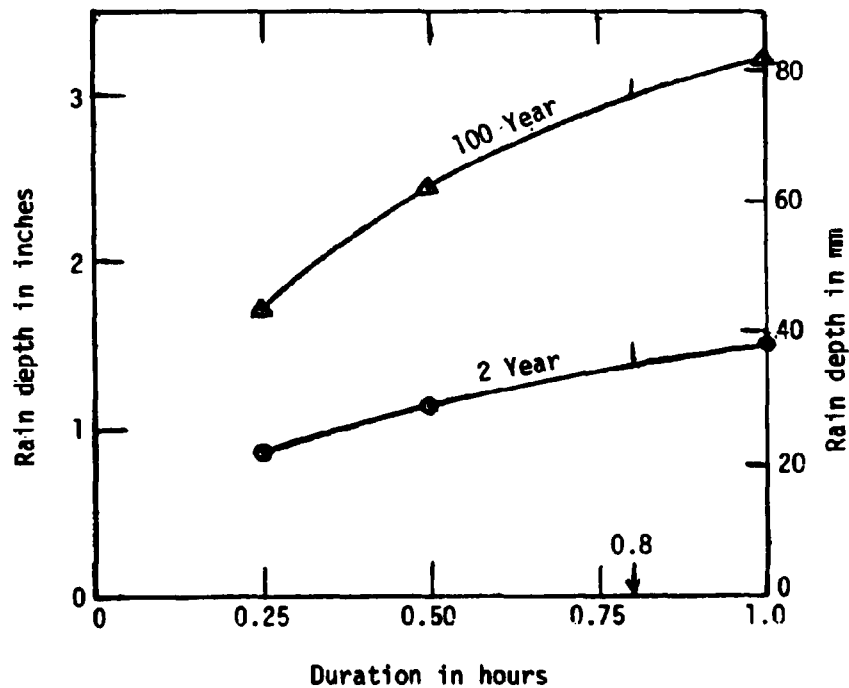


Fig. 13. Depth interpolation for HYDRO-35

Therefore, from Eq. 3.3, for 0.8-hour duration,

$$D_{.25} = 0.0669 D_{100 \text{ yr}} + 0.293 D_{2 \text{ yr}} = 2.42 \text{ in.}$$

The average intensity is  $i = D/t_d = 2.42/0.8 = 3.03 \text{ in./hr.}$

### C. Determination of Rainfall Depth Using Precipitation Record

Sometimes in highway drainage design the user may prefer to determine the design rainstorm depth from local rainfall record when such data are available, instead of using the generalized values from TP-40 or HYDRO-35. The procedure involves the following steps:

- (1) Selection from the data for each duration the annual maximum rainfall to establish the annual maximum series.
- (2) Compute the return period for each of the events in the annual maximum series.
- (3) Perform frequency analysis to establish the rainstorm depth(intensity) - duration - return period relationship.
- (4) Compute the depth for the design return period and duration.

The most likely precipitation data available to a highway engineer is probably the NWS hourly precipitation data which can be purchased from the NOAA Environmental Data Service, National Climatic Center (NCC), Asheville, North Carolina. The data are entered in NWS standard card image format Deck 488 (TD-9657) as shown in Fig. 14 and available in either card deck or in magnetic tapes of the following specifications:

- 9-track, 1600 bpi - EBCDIC - Odd parity - phase encoded
- 9-track, 800 bpi - EBCDIC - Odd parity - NRZ
- 7-track, 800 bpi - BCD - Even parity - NRZ
- 7-track, 556 bpi - BCD - Even parity - NRZ

If the NWS hourly data are used, the user may use the computer program FANHP described in Chapter V to perform the data selection, frequency analysis, and computation of the depth for the design return period. If the design duration is not an integer multiplier of an hour, the user should interpolate from integer-hour duration values.

CARD CONTENT

Col- umns	Item	Code	Remarks																																																																
1-2	State Number (See map, page 2)		<table border="0"> <tr> <td>01 Alabama</td> <td>17 Maine</td> <td>33 Ohio</td> <td>60 Alaska</td> </tr> <tr> <td>02 Arizona</td> <td>18 Maryland</td> <td>34 Oklahoma</td> <td>61 Kasal, Island Hawaiian</td> </tr> <tr> <td>03 Arkansas</td> <td>19 Massachusetts</td> <td>35 Oregon</td> <td>62 Oahu, " "</td> </tr> <tr> <td>04 California</td> <td>20 Michigan</td> <td>36 Pennsylvania</td> <td>63 Molokai, " "</td> </tr> <tr> <td>05 Colorado</td> <td>21 Minnesota</td> <td>37 Black Island</td> <td>64 Lanai, " "</td> </tr> <tr> <td>06 Connecticut</td> <td>22 Mississippi</td> <td>38 South Carolina</td> <td>65 Maui, " "</td> </tr> <tr> <td>07 Delaware</td> <td>23 Missouri</td> <td>39 South Dakota</td> <td>66 Hawaii, " "</td> </tr> <tr> <td>08 Florida</td> <td>24 Montana</td> <td>40 Tennessee</td> <td>67 Hahama Islands</td> </tr> <tr> <td>09 Georgia</td> <td>25 Nebraska</td> <td>41 Texas</td> <td>68 Puerto Rico</td> </tr> <tr> <td>10 Idaho</td> <td>26 Nevada</td> <td>42 Utah</td> <td>69 Virgin Islands</td> </tr> <tr> <td>11 Illinois</td> <td>27 New Hampshire</td> <td>43 Vermont</td> <td>70 Honduras</td> </tr> <tr> <td>12 Indiana</td> <td>28 New Jersey</td> <td>44 Virginia</td> <td>81 Nicaragua</td> </tr> <tr> <td>13 Iowa</td> <td>29 New Mexico</td> <td>45 Washington</td> <td>82 Mexico</td> </tr> <tr> <td>14 Kansas</td> <td>30 New York</td> <td>46 West Virginia</td> <td>83 Swan Island</td> </tr> <tr> <td>15 Kentucky</td> <td>31 North Carolina</td> <td>47 Wisconsin</td> <td>90 Canada</td> </tr> <tr> <td>16 Louisiana</td> <td>32 North Dakota</td> <td>48 Wyoming</td> <td>99 Misc. Stations</td> </tr> </table>	01 Alabama	17 Maine	33 Ohio	60 Alaska	02 Arizona	18 Maryland	34 Oklahoma	61 Kasal, Island Hawaiian	03 Arkansas	19 Massachusetts	35 Oregon	62 Oahu, " "	04 California	20 Michigan	36 Pennsylvania	63 Molokai, " "	05 Colorado	21 Minnesota	37 Black Island	64 Lanai, " "	06 Connecticut	22 Mississippi	38 South Carolina	65 Maui, " "	07 Delaware	23 Missouri	39 South Dakota	66 Hawaii, " "	08 Florida	24 Montana	40 Tennessee	67 Hahama Islands	09 Georgia	25 Nebraska	41 Texas	68 Puerto Rico	10 Idaho	26 Nevada	42 Utah	69 Virgin Islands	11 Illinois	27 New Hampshire	43 Vermont	70 Honduras	12 Indiana	28 New Jersey	44 Virginia	81 Nicaragua	13 Iowa	29 New Mexico	45 Washington	82 Mexico	14 Kansas	30 New York	46 West Virginia	83 Swan Island	15 Kentucky	31 North Carolina	47 Wisconsin	90 Canada	16 Louisiana	32 North Dakota	48 Wyoming	99 Misc. Stations
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3-6	Climatological Station No.		Station number list on record at National Weather Bureau Center. Number assigned alphabetically within state according to Rand McNally Atlas, 1948 Edition.																																																																
7-8	Year		Last two digits. 54 = 1954. Period of record generally August 1948 to present.																																																																
9-10	Month	01-12	January - December, respectively.																																																																
11-12	Day	01-31	Day of month.																																																																
13	Card Number		Card numbers 1 and 2 are the only cards used in this deck. Each hourly field is made up of three columns: whole inches, tenths and hundredths of inches. "X" overpunch in each column equals 10 inches; 12 overpunch in each column equals 20 inches. For example, 10.27 inches in the hourly column will be punched X/027; 21.77 punched 12/177. Amounts above the overpunch values are punched in the normal manner.																																																																
		Card No. 1 Hour Ending LST*	Card No. 2 Hour Ending LST*      * LST = Local Standard Time																																																																
14-16		01	13																																																																
17-19		02	14																																																																
20-22		03	15																																																																
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44-46		11	23																																																																
47-49		12	24																																																																
50-53		Blank	Daily Total																																																																
54-57		Blank	Monthly Total. When no precipitation occurred for the month, the value was punched 0000 on the first day of the current month.																																																																
58-78		Blank	Blank																																																																
79-80		Blank	Next day with precipitation, beginning or ending day of missing or accumulated data. Cols. 79-80 for last day of the month punched, should always be 01.																																																																
<b>Notes</b>																																																																			
<p>(1) The first day of the month is always punched for both No. 1 and No. 2 cards. When no precipitation occurs, the daily total is punched XBBB. If no precipitation occurred during the entire current month, the monthly total is punched 0000. This practice is used only on the first day of the month.</p> <p>(2) Missing data Blank all columns in appropriate field.</p> <p>(3) Trace is punched XBB, same as no precipitation.</p> <p>(4) Accumulative data (see Punching Practices) punched as OXB.</p> <p>(5) Hourly values of 0.01 and greater is punched; e.g., 0.01 is punched 001; .10 punched 010; 1.00 punched 100; 10.00 punched X/000; 12.36 punched X/236; 20.36 punched 12/036. (12 equals 12 overpunch of whole inch column.)</p> <p>(6) Daily and monthly values are punched as follows: Missing data - all columns BBBB, no precipitation or trace XBBB; accumulative data OXB.</p> <p>(7) Monthly total columns, 54-57, punched on No. 2 card only for last day of month with precipitation, or on the first day of the month when no precipitation occurred.</p>																																																																			

More detailed instructions are given in Punching Practices on pages 1 and 2. Blanks are indicated by "B".

Fig. 14. NWS hourly precipitation data card format

NWS WEATHER SERVICE, DATA CONTROL DIV  
WEATHER BUREAU, CLIMATOLOGICAL SERVICES DIV

REFERENCE MANUAL

Deck 488 - UWSA HOURLY PRECIPITATION

The user should be aware that all the hourly data tapes from NCC have problems. Three of the most common problems are:

- (1) For each date with rainfall there are two cards with the first 12 hours on the first card and the second 12 hours on the second card (Fig. 14). However, often these two cards are reversed in order.
- (2) The precipitation data are missing for one or more hours.
- (3) The precipitation data for one or more hours are not recorded in the proper hour(s), but the accumulated depth for several hours is known and recorded in the last of the accumulated hours.

The computer program FANHP can detect and handle these three data problems automatically.

Other NCC hourly data tape problems include the following.

- (4) One of the two cards of a raining date is missing.
- (5) Both cards of a raining date are missing. This case can only be detected if the "next rain date" information in the preceding card is correct.
- (6) The "next rain date" information (last two columns of the second card of a date) is missing, incorrect date entered, or incorrectly entered in wrong columns (e.g., in columns 78 and 79), or entered with incorrect symbols (e.g., @, !, #, <, 2., 3z).
- (7) First-day cards of a month are missing.

The user should be aware that even if there is no data format problem there is no assurance that the data entered are correct. For example, a not-so-uncommon case is the data being entered at incorrect time (1 hour off) during day-light savings time.

It should also be noted that the data measured by using Fischer & Porter raingages are unsuitable for the analysis of hyetograph because of the measurement accuracy of 0.1 inches (2.5 mm) instead of 0.01 inches (0.25 mm) for weighing or tipping-bucket raingages.

#### IV. USER'S GUIDE FOR COMPUTER PROGRAM

##### SATH

(Statistical Analysis of NWS Hourly Precipitation Data for Triangular Hyetograph)

##### A. Description of the Computer Program

This computer program, SATH, is designed to perform statistical analysis on hourly rainfall data to determine the parameters for triangular hyetographs. The program is specifically designed to accept the NOAA National Weather Service (NWS) hourly precipitation data magnetic tape or cards in standard NWS Deck 488 format, TD-9657, because this is the most commonly available rainfall data to highway engineers. The program automatically handles and corrects the following commonly occurred problems in the NWS hourly precipitation data:

- (1) Identify and correct reversed order of the two data cards of a date;
- (2) Identify and ignore missing data in the statistics computations;
- (3) Identify accumulated data and exclude them from the statistics computations because the duration of these rainstorms cannot be identified.

The program will not proceed if the NWS data tapes or cards contain other less commonly occurred data problems. For such cases the user should print out a listing of the data, examine the data errors and make proper corrections before re-running the computer program.

From the length of the record of the available data (month and year, e.g., 06-1948 to 10-1978) the user chooses the continuous years (e.g., 1951-1970) and the "season" (consecutive months, e.g., June, July, and August) to be analyzed. The program will select from the data file the rainfall data for the season for each of the years specified for analysis. If the data of the entire year is desired, the "season" is January-December. The built-in (default) season contains five months from May through September. For a specified season, if the entire record length (years) of the data record is to be analyzed and the data of the first year and/or last year of the record contain only partial months of the season (e.g., the season is April-October whereas first year data starts in July and/or the last year record ends in August), the program will proceed to perform the statistical analysis with the partial season data for the first and/or last year and a message will be printed out warning of the partial season.

The program checks the appropriateness of the data set of the specified season and period from the NWS hourly precipitation data file, selects the data according to the specified durations of the rainfall, and computes the mean depth of all the rainstorms for each specified duration. The data of each given duration are further sorted according to the depth into the following four groups:

- (1) those rainstorms with depth greater than twice the mean depth,
- (2) those rainstorms with depth greater than the mean depth,
- (3) those rainstorms with depth greater than one-half of the mean depth,
- (4) all the rainstorms for the given duration.

Since hourly data is used, the duration must be multiple of hours. A maximum of six different durations, up to 9-hour duration, can be specified by the user. It has been observed that most NWS precipitation stations have one or more years for which no rainstorm lasted for 10 hours or longer. The built-in (default) durations considered are 2, 3, and 4 hours. Statistical analysis for the one-hour duration is not performed since it will give the trivial solution of  $a^\circ = 0.5$ .

For each depth group of each desired duration, the program computes the values of the following 12 parameters for each rainstorm:

- (a) duration of the rainstorm,  $t_d$ ,
- (b) depth of the rainfall,  $D$ ,
- (c) average intensity of the rainstorm,  $i = D/t_d$ ,
- (d) the first time moment arm of the hyetograph with respect to the beginning time of the rainstorm,  $\bar{t}$ ,
- (e) the second time moment arm of the hyetograph with respect to the beginning time of the rainstorm,  $G$ ,
- (f) standard deviation with respect to the centroid time of the hyetograph,  $\sigma_t$ ,
- (g) nondimensional first moment arm of the hyetograph with respect to the beginning time of the rainstorm,  $\bar{t}^\circ = \bar{t}/t_d$ ,
- (h) nondimensional second moment arm of the hyetograph with respect to the beginning time of the rainstorm,  $G_1^\circ = G/t_d^2$ ,
- (i) time to peak of the triangular hyetograph,  $a$ ,
- (j) time from peak to end of rain of the triangular hyetograph,  $b$ ,

- (k) nondimensional time to peak of the nondimensional triangular hyetograph,  $a^\circ = a/t_d = 3 \bar{t}^\circ - 1$ ,
- (l) nondimensional time from peak to end of rain of the nondimensional triangular hyetograph,  $b^\circ = b/t_d = 1 - a^\circ$ .

Subsequently, the program performs the statistical analysis of the data to compute the mean, standard deviation, and range (maximum and minimum) of the 12 parameters for the rainstorms of the desired depth group and duration.

The computer program essentially consists of two parts. The first part is the reading, verification, and sorting of the input hourly rainfall data. The second part is the statistical analysis. Most of the computer time is spent on the first part. The approximate execution time for an average NWS station of 30 years of record and a 5-month season is around 30 service units on a Cyber 175 computer system.

The program is written in FORTRAN IV language consisting of about 700 statements. It can be implemented on most Cyber and IBM 360, 370, and 4341 computer systems. It requires no external subroutines and normally requires a memory core of about 200K bytes (about 50K words) for compilation and execution. The memory capacity requirement varies with the length of record. Inquiry concerning the availability of the program should be addressed to Dr. B. C. Yen, Department of Civil Engineering, University of Illinois, Urbana, Illinois 61801 or to FWHA Office of Research & Development.

#### B. Input Data

The input data to run the computer program consists of two parts. One part contains four cards specifying the station identification, data form (tape or cards), length of record of the NWS data file, and information about the statistical analysis. Details of these four cards are described in the tabular listing of the input data card format presented in this section. An example input card set is given in Fig. 15.

Col. Card	ECHO OF DATA												
	1	2	3	4	5	6	7	8	9	10	11	12	
1	EXAMPLE OF PROGRAM SATH											URBANA, IL	118740
2	0	1	0	78	12								
3	18	60	77	3	6	2	0						
4	2.	4.											

Fig. 15. Example Input for SATH



In the following tabular description of the input data, for items having an I-format the number must be entered right justified, i.e., the last digit of the number must be placed in the last (most right-hand) space allotted to this item. For example, if the last year of the NWS precipitation record is 1978, the number "78" is entered in columns 19 and 20 of Card 2 since this item is allotted a space I5, from column 16 to column 20, of the card. A decimal point must not be used for a number having an I-format. For a number with an F-format, it is suggested that a decimal point be always specified and the number with the decimal point can be placed anywhere within the space allotted to this number. For instance, for a space of columns 21-25 allotted for F5.0, if the number is 12, one can enter this number as "12." or "12.0" anywhere between columns 21 and 25.

The other part of the input data is the NWS hourly precipitation data tape or card deck. This hourly data file is in the standard NWS Deck 488 card image format, TD-9657 as shown in Fig.14 . Unless hourly precipitation data modification is necessary, the user need not be familiar with this NWS hourly data format. The NWS precipitation data can be purchased from NOAA Environmental Data Service, National Climatic Center, Asheville, North Carolina 28801 in magnetic tape or card deck form. Theoretically, the NWS hourly data are directly applicable to this computer program because it is specifically written for such data. However, the user should be fully aware of the problems that commonly occur on NWS data file as described in Section III-C.

The NWS data are in English measurement units. However, the printout of the result of analysis can be in either English units only or in both English and SI units as the user desired and specified in column 35 of input Card 3. The program actually accepts SI unit input for which the printout will also be in SI units.

Figure 16 shows the input card deck arrangement.

Card Number	Card Column	Format	Description	Variable Name	Default Value
1	***		<i>Identification Card</i>	***	
	1-40	40A1	User defined title, up to 40 alphanumeric characters are allowed.	TITLE	(blank)
	41-60	20A1	Name of the station.	STATIO	(blank)
	61-70	I10	Identification number of the station.	NUMBER	(blank)
2	***		<i>Input Rainfall Data Information Card</i>	***	
	1-5	I5	Input data form Leave blank (or enter "0" in Column 5) if the input hydrologic data are on a magnetic tape. Enter "1" in Column 5 if the input data are on cards.	KIND	0
	6-10	I5	Measurements units of input data Enter "1" in Column 10 if English units are used. If SI units are used, enter "2" in Column 10.	MU	1
	11-15	I5	Data checking Enter "1" in Column 15 if the input data have been corrected for misplaced, missing and accumulated records. Enter "0" in Column 15 if the data have not been corrected.	MISS	0
	16-20	I5	The last two digits of the last year of the hydrologic record of the data file, e.g., "78" for 1978.	LYR	None
	21-25	I5	Two-digit representation of the last month of the last year of the hydrologic record, e.g., "07" = July.	LMR	None

Card Number	Card Column	Format	Description	Variable Name	Default Value
3	***		<i>Data Analysis Information Card</i>	***	
	1-5	I5	Number of years of the period to be analyzed, e.g., "20".	NYR	None
	6-10	I5	Last two digits of the first year of the period to be analyzed. It must not be earlier than the first year on the record file, e.g., "51" for 1951.	IFIRST	None
	11-15	I5	Last two digits of the last year of the period to be analyzed. It must be the same or earlier than the last year of the record file, e.g., "70" for 1970.	LASTYR	None
	16-20	I5	Number of months in the "season" to be analyzed. Minimum is one and maximum is 12. Default value is "5" for the 5-month season, May-September.	NMO	5
	21-25	I5	First month of the season, e.g., enter "4" in Column 25 for a season starting on April 1.	IMS	5
	26-30	I5	Number of precipitation durations for which statistical analysis will be performed, maximum is 6. Default value is "3" for durations of 2, 3, and 4 hours.	NXL	3
	31-35	I5	Printout measurement units. If the desired measurement units in the printout are the same as the input (i.e., English system input data and English system printout, or SI input and SI output) enter "0" in Column 35. If the input is in English units and the desired printout is in both English and SI units, place "1" in Column 35.	IPRSI	0

Card Number	Card Column	Format	Description	Variable Name	Default Name
4	***		<i>Durations of Precipitation</i>	***	
	1-5	F5.0	Enter the first precipitation duration, in hours, to be analyzed, e.g., "2." for 2-hour duration.	XLL1(1)	2.
	5-10	F5.0	Second precipitation duration, in hours, to be analyzed, e.g., "3."	XLL1(2)	3.
	11-15	F5.0	Enter successive durations to be analyzed, each in the 5 columns allotted, until all the durations are specified. The total number of durations must be the same as that specified in Column 25 of Card 3. Although not necessary, it is suggested to enter the durations in an ascending order. The default durations considered are 2, 3, and 4 hours.	XLL1( )	4.
	.	.		XLL1( )	None
	.	.		.	
	.	.		.	
	26-30	.		.	

### C. Printout

The computer printout after running the program contains three parts. The first part concerns with the input NWS hourly data, including the location and identification number of the raingage station, the period of record, and a listing of the missing and accumulated data in chronological order.

The second part of the printout contains statistical analysis results in tabular form, one table for each depth group of each duration, listing the mean, standard deviation, maximum and minimum for each of the 12 parameters described in Section A. The number of rainstorms used is also given for each table. The number of tables in this part is equal to four times the number of durations analyzed.

The last part of the printout is one table containing a summary of the results in terms of  $a^\circ$ ,  $\bar{t}^\circ$ ,  $G_1^\circ$  and the number of storms for each duration and depth group of rain storms analyzed.

An example of the printout is shown in Fig.17. This example printout corresponds to the example input shown in Fig. 15.

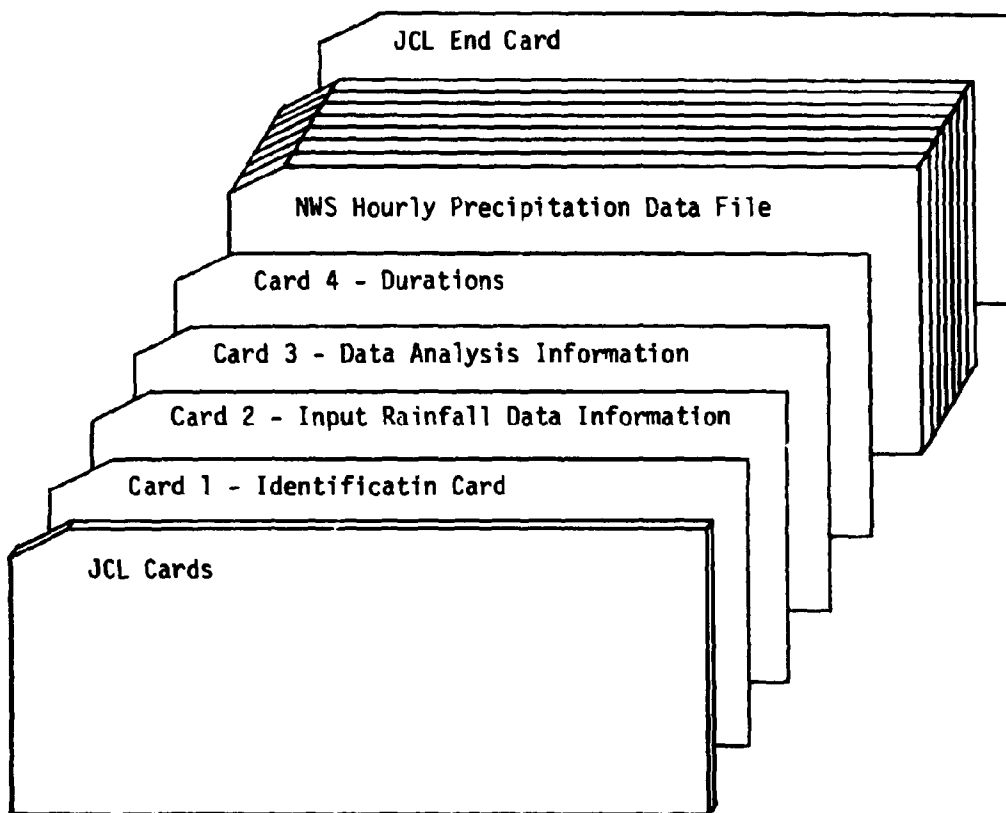


Fig. 16. Input data deck arrangement for execution of SATH



TABLE JUN-AUG RAINSTORM FROM HOURLY PRECIPITATION DATA AT STATION URBANA, IL  
 DURATION TD = 2.0 HR (1960-1977)

PARAMETER	UNIT	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
DURATION	(HR)	2.000	0.000	2.000	2.000
DEPTH	(IN.)	.273	.353	.020	2.090
INTENSITY	(IN./HR)	.137	.176	.010	1.045
FIRST TIME MOMENT	(HR)	.927	.278	.512	1.477
SECOND TIME MOMENT	(HR*HR)	1.188	.557	.358	2.287
TIME STANDARD DEVIATION	(HR)	.396	.106	.110	.500
NONDIM. 2ND TIME MOMENT	( )	.297	.139	.090	.572
NONDIM. 1ST TIME MOMENT	( )	.464	.139	.256	.738
A OF TRI. HYETOGRAPH	(HR)	.817	.718	0.000	2.000
B OF TRI. HYETOGRAPH	(HR)	1.183	.718	0.000	2.000
A OF NONDIM. HYETOGRAPH	( )	.409	.359	0.000	1.000
B OF NONDIM. HYETOGRAPH	( )	.591	.359	0.000	1.000

\*\*\*\*\* NUMBER OF RAINSTORMS = 175 \*\*\*\*\*

Fig. 17. Example computer printout of SATH (b) Computed results

TABLE JUN-AUG RAINSTORM FROM HOURLY PRECIPITATION DATA AT STATION URBANA, IL  
 DURATION TD = 2.0 HR  
 RAINFALL DEPTH RANGE .137 IN. (MEAN/2) < - DEPTH < 9999.0 IN.

PARAMETER	UNIT	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
DURATION	(HR)	2.000	0.000	2.000	2.000
DEPTH	(IN.)	.498	.396	.140	2.090
INTENSITY	(IN./HR)	.249	.198	.070	1.045
FIRST TIME MOMENT	(HR)	.902	.321	.512	1.477
SECOND TIME MOMENT	(HR <sup>2</sup> )	1.136	.643	.358	2.287
TIME STANDARD DEVIATION	(HR)	.352	.122	.110	.500
NONDIM. 2ND TIME MOMENT	( )	.284	.161	.090	.572
NONDIM. 1ST TIME MOMENT	( )	.451	.161	.256	.738
A OF TRI. HYETOGRAPH	(HR)	.755	.786	0.000	2.000
B OF TRI. HYETOGRAPH	(HR)	1.245	.786	0.000	2.000
A OF NONDIM. HYETOGRAPH	( )	.378	.393	0.000	1.000
B OF NONDIM. HYETOGRAPH	( )	.622	.393	0.000	1.000

\*\*\*\*\* NUMBER OF RAINSTORMS = 85 \*\*\*\*\*

Fig. 17. Example computer printout of SATH (b) Continued



TABLE JUN-AUG RAINSTORM FROM HOURLY PRECIPITATION DATA AT STATION URBANA, IL  
 DURATION ID = 2.0 HR  
 RAINFALL DEPTH RANGE .273 IN. (MEAN) < - DEPTH < 9999.0 IN.

PARAMETER	UNIT	STANDARD		
		MEAN	DEVIATION	MAXIMUM
DURATION	(HR)	2.000	0.000	2.000
DEPTH	(IN.)	.646	.400	2.090
INTENSITY	(IN./HR)	.323	.200	1.045
FIRST TIME MOMENT	(HR)	.912	.338	1.477
SECOND TIME MOMENT	(HR*HR)	1.157	.675	2.287
TIME STANDARD DEVIATION	(HR)	.338	.128	.500
NOVDIM. 2ND TIME MOMENT	( )	.289	.169	.572
NOVDIM. 1ST TIME MOMENT	( )	.456	.169	.738
A OF TRI. HYETOGRAPH	(HR)	.786	.815	2.000
B OF TRI. HYETOGRAPH	(HR)	1.214	.815	2.000
A OF NOVDIM. HYETOGRAPH	( )	.393	.408	1.000
B OF NOVDIM. HYETOGRAPH	( )	.607	.408	1.000

\*\*\*\* NUMBER OF RAINSTORMS = 58 \*\*\*\*

Fig. 17. Example computer printout of SATH (b) Continued

TABLE JUN-AUG RAINSTORM FROM HOURLY PRECIPITATION DATA AT STATION URBANA, IL  
 DURATION TD = 2.0 HR  
 RAINFALL DEPTH RANGE .546 IN. (MEAN\*2) < = DEPTH < 9999.0 IN.

PARAMETER	UNIT	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
DURATION	(HR)	2.000	0.000	2.000	2.000
DEPTH	(IN.)	.953	.425	.550	2.090
INTENSITY	(IN./HR)	.477	.212	.275	1.045
FIRST TIME MOMENT	(HR)	.904	.353	.512	1.452
SECOND TIME MOMENT	(HR*HR)	1.141	.705	.358	2.238
TIME STANDARD DEVIATION	(HR)	.325	.126	.110	.499
NONDIM. 2ND TIME MOMENT	( )	.285	.176	.090	.560
NONDIM. 1ST TIME MOMENT	( )	.452	.176	.256	.726
A OF TRI. HYETOGRAPH	(HR)	.779	.859	0.000	2.000
B OF TRI. HYETOGRAPH	(HR)	1.221	.859	0.000	2.000
A OF NONDIM. HYETOGRAPH	( )	.390	.429	0.000	1.000
B OF NONDIM. HYETOGRAPH	( )	.610	.429	0.000	1.000

\*\*\*\*\* NUMBER OF RAINSTORMS = 26 \*\*\*\*\*

Fig. 17. Example computer printout of SATH (b) Continued

TABLE JUN-AUG RAINSTORM FROM HOURLY PRECIPITATION DATA AT STATION URBANA, IL  
 DURATION TD = 4.0 HR (1960-1977)

PARAMETER	UNIT	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
DURATION	(HR)	4.000	0.000	4.000	4.000
DEPTH	(IN.)	.592	.560	.080	2.860
INTENSITY	(IN./HR)	.148	.140	.020	.715
FIRST TIME MOMENT	(HR)	1.780	.514	.659	3.100
SECOND TIME MOMENT	(HR <sup>2</sup> )	4.254	1.967	.748	10.400
TIME STANDARD DEVIATION	(HR)	.834	.221	.376	1.356
MONDIM. 2ND TIME MOMENT	( )	.266	.123	.047	.650
MONDIM. 1ST TIME MOMENT	( )	.445	.129	.165	.775
A OF TRI. HYETOGRAPH	(HR)	1.443	1.269	0.000	4.000
B OF TRI. HYETOGRAPH	(HR)	2.557	1.269	0.000	4.000
A OF MONDIM. HYETOGRAPH	( )	.361	.317	0.000	1.000
B OF MONDIM. HYETOGRAPH	( )	.639	.317	0.000	1.000

\*\*\*\*\* NUMBER OF RAINSTORMS = 50 \*\*\*\*\*

Fig. 17. Example computer printout of SATH (b) Continued

TABLE JUN-AUG RAINSTORM FROM HOURLY PRECIPITATION DATA AT STATION URBANA, IL  
 DURATION TD = 4.0 HR  
 RAINFALL DEPTH RANGE .296 IN. (MEAN/2) < = DEPTH < 9999.0 IN.

PARAMETER	UNIT	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
DURATION	(HR)	4.000	0.000	4.000	4.000
DEPTH	(IN.)	.864	.579	.300	2.860
INTENSITY	(IN./HR)	.216	.145	.075	.715
FIRST TIME MOMENT	(HR)	1.751	.560	.659	3.100
SECOND TIME MOMENT	(HR*HR)	4.116	2.263	.748	10.400
TIME STANDARD DEVIATION	(HR)	.779	.242	.376	1.356
NONDIM. 2ND TIME MOMENT	( )	.257	.141	.047	.650
NONDIM. 1ST TIME MOMENT	( )	.438	.140	.165	.775
A OF TRI. HYETOGRAPH	(HR)	1.360	1.344	0.000	4.000
B OF TRI. HYETOGRAPH	(HR)	2.640	1.344	0.000	4.000
A OF NONDIM. HYETOGRAPH	( )	.340	.336	0.000	1.000
B OF NONDIM. HYETOGRAPH	( )	.660	.336	0.000	1.000

\*\*\*\*\* NUMBER OF RAINSTORMS = 30 \*\*\*\*\*

Fig. 17. Example computer printout of SATH (b) Continued

TABLE JUN-AUG. RAINSTORM FROM HOURLY PRECIPITATION DATA AT STATION URBANA, IL  
 DURATION TD = 4.0 HR  
 RAINFALL DEPTH RANGE .592 IN. (MEAN) < = DEPTH < 9999.0 IN.

PARAMETER	UNIT	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
DURATION	(HR)	4.000	0.000	4.000	4.000
DEPTH	(IN.)	1.216	.547	.670	2.860
INTENSITY	(IN./HR)	.304	.137	.168	.715
FIRST TIME MOMENT	(HR)	1.640	.523	.659	2.608
SECOND TIME MOMENT	(HR <sup>2</sup> )	3.519	1.760	.748	7.410
TIME STANDARD DEVIATION	(HR)	.670	.203	.376	1.203
NONDIM. 2ND TIME MOMENT	( )	.220	.110	.047	.463
NONDIM. 1ST TIME MOMENT	( )	.410	.131	.165	.652
A OF TRI. HYETOGRAPH	(HR)	1.157	1.255	0.000	3.825
B OF TRI. HYETOGRAPH	(HR)	2.843	1.255	.175	4.000
A OF NONDIM. HYETOGRAPH	( )	.289	.314	0.000	.956
B OF NONDIM. HYETOGRAPH	( )	.711	.314	.044	1.000

\*\*\*\*\* NUMBER OF RAINSTORMS = 17 \*\*\*\*\*

Fig. 17. Example computer printout of SATH (b) Continued

TABLE JUN-AUG RAINSTORM FROM HOURLY PRECIPITATION DATA AT STATION URRANA, IL  
 DURATION ID = 4.0 HR  
 RAINFALL DEPTH RANGE 1.184 IN. (MEAN\*2) < = DEPTH < 9999.0 IN.

PARAMETER	UNIT	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
DURATION	(HR)	4.000	0.000	4.000	4.000
DEPTH	(IN.)	1.687	.568	1.240	2.860
INTENSITY	(IN./HR)	.422	.142	.310	.715
FIRST TIME MOMENT	(HR)	1.641	.472	1.190	2.608
SECOND TIME MOMENT	(HR*HR)	3.413	1.859	1.831	7.410
TIME STANDARD DEVIATION	(HR)	.658	.123	.499	.823
NONDIM. 2ND TIME MOMENT	( )	.213	.116	.114	.463
NONDIM. 1ST TIME MOMENT	( )	.410	.118	.297	.652
A OF TRI. HYETOGRAPH	(HR)	1.032	1.307	0.000	3.825
B OF TRI. HYETOGRAPH	(HR)	2.968	1.307	.175	4.000
A OF NONDIM. HYETOGRAPH	( )	.258	.327	0.000	.956
B OF NONDIM. HYETOGRAPH	( )	.742	.327	.044	1.000

\*\*\*\*\* NUMBER OF RAINSTORMS = 7 \*\*\*\*\*

Fig. 17. Example computer printout of SATH (b) Continued

JUN-AUG RAINSTORMS FROM HOURLY PRECIPITATION DATA AT STATION URRANA, IL (1960-1977)

PARAMETER	DEPTH GROUP		RAINSTORM DURATION (HR)	
	2.	4.	2.	4.
A OF NORDIM. HETOGGRAPH	ALL RAINSTORMS			
A OF NORDIM. HETOGGRAPH	.409	.361		
A OF NORDIM. HETOGGRAPH	.378	.340		
A OF NORDIM. HETOGGRAPH	.393	.289		
A OF NORDIM. HETOGGRAPH	.390	.258		
NORDIM. 1ST TIME MOMENT	ALL RAINSTORMS			
NORDIM. 1ST TIME MOMENT	.464	.445		
NORDIM. 1ST TIME MOMENT	.451	.438		
NORDIM. 1ST TIME MOMENT	.456	.410		
NORDIM. 1ST TIME MOMENT	.452	.410		
NORDIM. 2ND TIME MOMENT	ALL RAINSTORMS			
NORDIM. 2ND TIME MOMENT	.297	.266		
NORDIM. 2ND TIME MOMENT	.284	.257		
NORDIM. 2ND TIME MOMENT	.289	.220		
NORDIM. 2ND TIME MOMENT	.285	.213		
NUMBER OF RAINSTORMS	ALL RAINSTORMS			
NUMBER OF RAINSTORMS	175.000	50.000		
NUMBER OF RAINSTORMS	85.000	30.000		
NUMBER OF RAINSTORMS	58.000	17.000		
NUMBER OF RAINSTORMS	26.000	7.000		

Fig. 17. Example computer printout of SATH (c) Summary of results

D. Listing of the Computer Program

```

PROGRAM SATH(INP2,INPUT,OUT3,TEM,TAPE3=INF2,
1 TAPE5=INPUT,TAPE6=OUT3,TAPE10=TEM)
C*****
C
C   COMPUTER PROGRAM FOR STATISTICAL ANALYSIS OF NWS HOURLY
C   PRECIPITATION DATA FOR TRIANGULAR HYETOGRAPH
C
C   FOR ANY INFORMATION REGARDING THIS COMPUTER PROGRAM, THE USER
C   SHOULD REFER TO CHAPTER IV OF VOL. III (USER'S MANUAL)
C
C*****
C
C   DIMENSION X(9000),D(250),P(250,6),PA(2200,6),A(2200)
C   DIMENSION MONTH(12),IF(24),IP(24),XLL1(6)
C   DIMENSION STATS(5),NOV(2),DME(5),TSTATS(11,4)
C   DIMENSION SUF(18),ICARD(2),NCARD(2),R(4,4,4),JP(24)
C   INTEGER STATIO(20),TITLE(40)
C   COMMON/NAMONS/NAMON(12)
C   COMMON/NAPARS/NAPAR(6,12)
C   COMMON/NAUNTS/NAUNT1(2,12),NAUNT2(2,12)
C   COMMON/NAPLS/NAPL(6,4)
C   COMMON/NADGS/NADG(4,4)
C   IN1=5
C   IOU1=6
C
C *** INPUT 1
C   READ(IN1,1010) TITLE,STATIO,NUMBER
C ***
C
C *** INPUT 2
C   READ(IN1,1015) KIND,MU,MISS,LYR,LMR
C ***
C
C *** INPUT 3
C   READ(IN1,1020) NYR,IFIRST,LASTYR,NMO,IMS,NXL,IPRSI
C ***
C
C *** INPUT 4
C   READ(IN1,1025) (XLL1(I),I=1,NXL)
C
C   ECHO OF DATA
C
C   WRITE(IOU1,1005)
C   WRITE(IOU1,1006) TITLE,STATIO,NUMBER
C   WRITE(IOU1,1007) KIND,MU,MISS,LYR,LMR
C   WRITE(IOU1,1008) NYR,IFIRST,LASTYR,NMO,IMS,NXL,IPRSI
C   WRITE(IOU1,1009) (XLL1(I),I=1,NXL)
C   DO 101 I=1,NMO
101  MONTH(I)=IMS+I-1
C
C   DEFAULT VALUE
C
C   IF(NMO.LE.0) NMO=5
C   IF(MONTH(1).GT.0) GO TO 110
C   DO 105 I=1,5
105  MONTH(I)=4+I
110  IF(NXL.LE.0) NXL=3
C   IF(XLL1(1).GT.0.) GO TO 115
C   XLL1(1)=2.
C   XLL1(2)=3.
C   XLL1(3)=4.

```



```

C
C      PRINT INPUT DATA
C
115  D1=1.
      M1=MONTH(1)
      M2=MONTH(NMO)
      WRITE(IOUT,1060)
      WRITE(IOUT,1065) STATIO,NUMBER
      WRITE(IOUT,1070) IFIRST,LASTYR,NYR,D1,NAMON(M1),NAMON(M2)
      WRITE(IOUT,1060)
C
      NOL=0
      IZ=2
      IYR1=LASTYR+1
      IT1=24
      IN2=5
      OBLIMX=24*NMO*40
      IF(IBIMX.GT.9000) WRITE(IOUT,1011)
      XLLMIN=XLL1(1)
      XLLMAX=0.
      DO 120 I=1,NXL
      IF(XLL1(I).LT.XLLMIN) XLLMIN=XLL1(I)
      IF(XLL1(I).GT.XLLMAX) XLLMAX=XLL1(I)
120  CONTINUE
      IF(KIND.EQ.0) IN2=3
      IMR=0
125  DO 130 I=1,IBIMX
130  X(I)=0.0
      IZ=0
      I1=0
      IF(MISS.EQ.0) GO TO 230
      NN1=2
      IF(MU.EQ.2) GO TO 220
C
C *** INPUT HOURLY PRECIPITATION DATA
      NN1=1
205  DO 210 II=1,IZ
      READ(IN2,2005) NUM,IYR,IMO,IDY,(X(I+I2),I=1,12),INXBY
210  I2=I2+12
C ***
C
215  IF(NUM.NE.NUMBER.OR.IMR.NE.0) GO TO 216
      IMR=IMO
      IYR=IYR
216  IF(NUM.EQ.NUMBER.AND.IYR.GE.IFIRST.AND.IMO.GE.M1
      1.AND.IMO.LT.M2) GO TO 320
      IZ=0
      GO TO (205,220),NN1
C
C *** INPUT HOURLY PRECIPITATION DATA
220  DO 225 II=1,IZ
      READ(IN2,2010) NUM,IYR,IMO,IDY,(X(I+I2),I=1,12),INXBY
225  I2=I2+12
C ***
C
      GO TO 215

```

```

C *****
C
C THE STATEMENT IN THE FOLLOWING SIXTY LINES IS FOR THE PURPOSE TO
C CORRECT HOURLY PRECIPITATION DATA
C 1. CORRECT REVERSED DATA CARDS OF A DAY
C 2. IDENTIFY AND IGNORE MISSING DATA
C 3. IDENTIFY ACCUMULATED DATA AND SET THEM TO BE ZERO
C *****
230 K2=0
    IND=0
    IF(MC3.NE.0) GO TO 235
    DATA KKK /3H- /
    DATA NNN /3HO- /
    DATA NBB /3H /
235 IYY=KKK
C
C *** INPUT HOURLY PRECIPITATION DATA
    NNI=3
240 DO 245 II=1,12
    READ(IN2,2015) NUM,IYR,IMO,IDY,ICARD(II),(IT(I+K2),I=1,12),NOV(II)
245 K2=K2+12
C ***
C
    K2=0
    IF(NUM.NE.NUMBER.OR.IHR.NE.0) GO TO 248
    IHR=IMO
    IYR=IYR
248 IF(NUM.EQ.NUMBER.AND.IYR.GE.IFIRST.AND.IMO.GE.M1
    1.AND.IMO.LT.M2) GO TO 240
    GO TO 240
C *** INPUT HOURLY PRECIPITATION DATA
250 DO 255 II=1,12
    READ(IN2,2015) NUM,IYR,IMO,IDY,ICARD(II),(IT(I+K2),I=1,12),NOV(II)
255 K2=K2+12
C ***
C
    K2=0
260 IF(ICARD(1).EQ.1) GO TO 270
    WRITE(IOUT,3005) IYR,IMO,IDY
    DO 265 I=1,12
    IP(I)=IT(I+12)
265 IP(I+12)=IT(I)
    INXDY=NOV(1)
    NCARD(2)=ICARD(1)
    NCARD(1)=ICARD(2)
    GO TO 280
270 DO 275 I=1,24
275 IP(I)=IT(I)
    INXDY=NOV(2)
    NCARD(1)=ICARD(1)
    NCARD(2)=ICARD(2)
280 DO 281 I=1,24
    IF(IP(I).NE.NBB) GO TO 281
    WRITE(IOUT,3010) IYR,IMO,IDY,(IP(J),J=1,24),INXDY
    GO TO 282
281 CONTINUE
282 IF(IYY.EQ.NNN.AND.IP(1).NE.KKK.AND.IP(1).NE.NNN) GO TO 283
    GO TO 284
283 IP(1)=KKK
    INN=1
284 DO 285 I=1,23
    IF(IP(I).EQ.NNN.AND.IP(I+1).NE.NNN.AND.IP(I+1).NE.KKK) GO TO 286
    GO TO 285
286 IND=1

```

```

      DO 287 J=1,24
287  JF(J)=IP(J)
      IP(I+1)=KKK
285  CONTINUE
      IF (IND.EQ.1) WRITE(IOUT,3015) IYR,IMO,IDY,(JP(J),J=1,24),INXDY
      IYY=IP(24)
      IND=0
      REWIND 10
      WRITE(10,2020)(IP(I),I=1,24)
      REWIND 10
      IF (MU.EQ.2) GO TO 290
      READ(10,2025)(X(I+12),I=1,24)
      I2=I2+24
      GO TO 320
290  READ(10,2030) (X(I+12),I=1,24)
      I2=I2+24
      GO TO 320
C *****
C
295  I2=I1+I2-ITT
C
C      CHECK IF IT IS LAST DAY OF SPECIFIED SEASON
C
      IF (INXDY.EQ.1.AND.IMO.EQ.M2) GO TO 405
      IF (INXDY.EQ.1.AND.IMO.EQ.LMK.AND.IYR.EQ.LYR) GO TO 405
      GO TO (300,310,250),NN1
C
C *** INPUT HOURLY PRECIPITATION DATA
300  DO 305 I1=1,I2
      READ(IN2,2035)IYR,IMO,IDY,(X(I+12),I=1,12),INXDY
305  I2=I2+12
C ***
C
      GO TO 320
C
C *** INPUT HOURLY PRECIPITATION DATA
310  DO 315 I1=1,I2
      READ(IN2,2040)IYR,IMO,IDY,(X(I+12),I=1,12),INXDY
315  I2=I2+12
C ***
320  I1=ITT*(INXDY-IDY)
C
      IF (I1.GT.0) GO TO 295
      GO TO(325,335,325,330,325,330,325,325,330,325,330,325),IMO
325  NUMDY=31
      GO TO 340
330  NUMDY=30
      GO TO 340
335  X1=IYR
      X2=IYR/4
      X3=X1/4.
      IF (X2.EQ.X3) NUMDY=29
      IF (X2.NE.X3) NUMDY=28
340  I1=(NUMDY+1-IDY)*ITT
      GO TO 295
C
C      IDENTIFY EACH RAINSTORM AND COMPUTE ITS PARAMETERS
C
405  LC=0
      MC=1
      NC=1
      DO 475 I=1,I2
      IF (X(I).GT.0.) GO TO 410
      IF (NC.NE.MC) GO TO 420
      GO TO 475
410  IF (LC.GT.0) GO TO 415
      NC=MC+1
415  LC=LC+1
      D(LC)=X(I)

```

```

        IF(I.EQ.12) GO TO 420
        GO TO 475
420    IF(LC.GE.XLLMIN.AND.LC.LE.XLLMAX) GO TO 471
        GO TO 474
471    SUM1=0.
        DLC=LC
        DO 425 J=1,LC
425    SUM1=SUM1+D(J)
        P(MC,1)=SUM1
        P(MC,3)=SUM1/DLC
        SUM2=0.
        SUM3=0.
        DO 430 J=1,LC
        XJ=J
        SUM2=SUM2+D(J)*(XJ-0.5)
430    SUM3=SUM3+D(J)*(XJ-0.5)*(XJ-0.5)
        P(MC,2)=SUM2/SUM1
        IF(P(MC,2).LE.(DLC/3.0)) GO TO 435
        IF(P(MC,2).GE.(2.0*DLC/3.0)) GO TO 440
        GO TO 445
435    P(MC,5)=0.0
        GO TO 450
440    P(MC,5)=LC
        GO TO 450
445    P(MC,5)=3.0*P(MC,2)-LC
450    P(MC,3)=SUM3/SUM1+1./12.
        SKEW=SUM3/SUM1-P(MC,2)*P(MC,2)
        IF(SKEW<0.0)455,455,460
455    P(MC,4)=0.0
        GO TO 470
460    IF(DLC.NE.DT) GO TO 465
        P(MC,4)=0.0
        GO TO 470
465    P(MC,4)=SQRT(SKEW)
470    P(MC,6)=DLC
        MC=MC+1
474    LC=0
475    CONTINUE
C
        MC1=MC-1
        IF(MC1.EQ.0) GO TO 485
        DO 480 I=1,6
        DO 480 J=1,MC1
        MCJ3=MC3+J
480    PA(MC3+J,I)=P(J,I)
        MC3=MC3+MC1
C
        CHECK IF IT IS THE LAST YEAR OF THE PERIOD TO BE ANALYZED
C
485    IF(IYR.LT.LASTYR) GO TO 125
        NMT1=IMR
        NMT2=LMR
        WRITE(IOUT,4000) NAMON(NMT1),IYER,NAMON(NMT2),LYR
        NMT3=MONTH(1)
        NMT4=MONTH(NMD)
        WRITE(IOUT,4001) NAMON(NMT3),NAMON(NMT4),IFIRST,LASTYR
        IF(IMR.LE.MONTH(1)) GO TO 502
        IMR1=IMR-1
502    WRITE(IOUT,4002) NAMON(NMT3),NAMON(IMR1),IYER
        IF(LMR.GE.MONTH(NMD)) GO TO 503
        LMR1=LMR+1
        MNMD=MONTH(NMD)
        WRITE(IOUT,4003) NAMON(LMR1),NAMON(MNMD),LYR

```

```

C
C   PERFORM ONE-WAY FREQUENCY ANALYSIS IN A SUBSET OF
C   SPECIFIED DURATION OR DEPTH GROUP
C
503  ICHECK=0
      DME(5)=1.0E20
      DME(1)=0.
      DUP=9999.
      IDIMPA=2200
      DO 505 I=1, IDIMPA
505  A(I)=0.0
      ZER=0.
      DO 570 NUMT1=1, NXL
510  CONTINUE
      XLL=XLL1(NUMT1)
      K1=0
      IF (ICHECK.NE.0) GO TO 520
      WRITE (IOUT,5005) NAMON(M1),NAMON(M2),STATIO,XLL,IFIRST,LASTYR
      DO 515 I=1,MC3
      IF (PA(I,6).NE.XLL) GO TO 515
      A(I)=1.0
      K1=K1+1
515  CONTINUE
      GO TO 540
520  DUL=DME(5)
      DLL=DME(ICHECK+1)
      IF (IPRSI.EQ.0.AND.MU.EQ.1) GO TO 525
      IF (IPRSI.EQ.0.AND.MU.EQ.2) GO TO 524
      IF (MU.EQ.1.AND.IPRSI.NE.0) GO TO 525
524  IF (ICHECK.EQ.1) WRITE (IOUT,5025) NAMON(M1),NAMON(M2),STATIO,XLL.
      1 DLL,DUP
      IF (ICHECK.EQ.2) WRITE (IOUT,5026) NAMON(M1),NAMON(M2),STATIO,XLL.
      1 DLL,DUP
      IF (ICHECK.LQ.3) WRITE (IOUT,5027) NAMON(M1),NAMON(M2),STATIO,XLL.
      1 DLL,DUP
      GO TO 530
525  IF (ICHECK.EQ.1) WRITE (IOUT,5020) NAMON(M1),NAMON(M2),STATIO,XLL.
      1 DLL,DUP
      IF (ICHECK.EQ.2) WRITE (IOUT,5021) NAMON(M1),NAMON(M2),STATIO,XLL.
      1 DLL,DUP
      IF (ICHECK.EQ.3) WRITE (IOUT,5022) NAMON(M1),NAMON(M2),STATIO,XLL.
      1 DLL,DUP
530  DO 535 I=1,MC3
      IF (PA(I,6).NE.XLL.OR.PA(I,1).LT.DLL.OR.PA(I,1).GE.DUL)
      1 GO TO 535
      A(I)=1.0
      K1=K1+1
535  CONTINUE
540  DO 550 NUMT=1,5
      NOPAR=NUMT
      CALL TAB1(PA,A,NOPAR,STATS,IDIMPA)
      IF (NOPAR.EQ.1) DMEAN=STATS(2)
      IF (IPRSI.EQ.0) GO TO 545
545  DO 539 J=2,5
      J1=J-1
539  TSTATS(NUMT,J1)=STATS(J)
550  CONTINUE
      IF (MU.EQ.1)
      1WRITE (IOUT,5010) (NAPAR(I,1),I=1,6),(NAUNT1(I,1),I1=1,2),
      2 XLL,ZER,XLL,XLL
      IF (MU.EQ.2)
      1WRITE (IOUT,5010) (NAPAR(I,1),I=1,6),(NAUNT2(I1,1),I1=1,2),
      2 XLL,ZER,XLL,XLL
      TSTATS(9,1)=XLL-TSTATS(5,1)
      TSTATS(9,2)=TSTATS(5,2)
      TSTATS(9,3)=XLL-TSTATS(5,4)
      TSTATS(9,4)=XLL-TSTATS(5,3)

```

```

DO 542 J=1,4
TSTATS(8,J)=TSTATS(5,J)
TSTATS(5,J)=TSTATS(4,J)
TSTATS(4,J)=TSTATS(3,J)
TSTATS(3,J)=TSTATS(2,J)
TSTATS(2,J)=TSTATS(1,J)/XLL
TSTATS(7,J)=TSTATS(3,J)/XLL
TSTATS(6,J)=TSTATS(4,J)/XLL/XLL
TSTATS(10,J)=TSTATS(8,J)/XLL
TSTATS(11,J)=TSTATS(9,J)/XLL
542 CONTINUE
DO 543 K=1,11
K4=K+1
IF (MU.EQ.1)
WRITE(IOUT,5010) (NAFAR(I5,K4),I5=1,6),(NAUNT1(K5,K4),K5=1,2),
2 (TSTATS(K,K3),K3=1,4)
IF (MU.EQ.2)
WRITE(IOUT,5010) (NAFAR(I5,K4),I5=1,6),(NAUNT2(K5,K4),K5=1,2),
2 (TSTATS(K,K3),K3=1,4)
543 CONTINUE
JCH=ICHECK+1
IF (K1.GT.0) GO TO 558
R(NUMT1,JCH,1)=-9.
R(NUMT1,JCH,2)=-9.
R(NUMT1,JCH,3)=-9.
R(NUMT1,JCH,4)=0.
GO TO 559
558 R(NUMT1,JCH,1)=TSTATS(10,1)
R(NUMT1,JCH,2)=TSTATS(7,1)
R(NUMT1,JCH,3)=TSTATS(6,1)
R(NUMT1,JCH,4)=K1
559 WRITE(IOUT,5015) K1
IF (MU.NE.1.OR.IPRSI.EQ.0) GO TO 544
IF (ICHECK.NE.0) DLL1=DLL*25.4
IF (ICHECK.NE.0) DUL1=DUL*25.4
DO 547 K5=1,2
DO 547 K6=1,4
547 TSTATS(K5,K6)=TSTATS(K5,K6)*25.4
IF (ICHECK.EQ.1) WRITE(IOUT,5025) NAMON(M1),NAMON(M2),STATIO,XLL,
1 DLL1,DUP
IF (ICHECK.EQ.2) WRITE(IOUT,5026) NAMON(M1),NAMON(M2),STATIO,XLL,
1 DLL1,DUP
IF (ICHECK.EQ.3) WRITE(IOUT,5027) NAMON(M1),NAMON(M2),STATIO,XLL,
1 DLL1,DUP
IF (ICHECK.EQ.0)
WRITE(IOUT,5005) NAMON(M1),NAMON(M2),STATIO,XLL,IFIRST,LASTYR
WRITE(IOUT,5010) (NAFAR(I,1),I=1,6),(NAUNT2(I1,1),I1=1,2),
1 XLL,ZER,XLL,XLL
DO 546 K=1,11
K4=K+1
WRITE(IOUT,5010) (NAFAR(I5,K4),I5=1,6),(NAUNT2(K5,K4),K5=1,2),
1 (TSTATS(K,K3),K3=1,4)
546 CONTINUE
WRITE(IOUT,5015) K1
544 DO 560 I=1,MC3
560 A(I)=0.0
IF (ICHECK.NE.0) GO TO 555
DME(2)=DMEAN*0.5
DME(3)=DMEAN
DME(4)=2.0*DMEAN
555 IF (ICHECK.EQ.3) GO TO 565
ICHECK=ICHECK+1
IF (ICHECK.LT.4) GO TO 510
565 ICHECK=0
570 CONTINUE
WRITE(IOUT,5040) NAMON(M1),NAMON(M2),STATIO,IFIRST,LASTYR
1 (XLL1(I),I=1,NXL)

```

```

WRITE(IOUT,5045)
DO 572 I3=1,4
DO 571 I2=1,4
WRITE(IOUT,5050) (NAPL(J3,I3),J3=1,4),(NABG(J2,I2),J2=1,4),
1 (R(I1,I2,I3),I1=1,NXL)
571 CONTINUE
WRITE(IOUT,5045)
572 CONTINUE
C
1005 FORMAT(40X,12HECHO OF DATA,/,10X,8(10H1234567890),/,10X,80
1(1H-),/)
1006 FORMAT(10X,40A1,20A1,I10)
1007 FORMAT(10X,5I5)
1008 FORMAT(10X,7I5)
1009 FORMAT(10X,6F5,0)
1010 FORMAT(40A1,20A1,I10)
1011 FORMAT(/,10X,35HDIMENSION OF ARRAY X EXCEEDS LIMITS,/)
1015 FORMAT(5I5)
1020 FORMAT(7I5)
1025 FORMAT(6F5,0)
1044 FORMAT(/,5(1H*),3X,3BHERROR---NUMBER OF MONTHS IN THE SEASON,
1 3X,5(1H*),/)
1050 FORMAT(/,5(1H*),3X,4BHERROR---NUMBER OF TIMES ONE-WAY FREQUENCY IS
1 ,16H TO BE PERFORMED,3X,5(1H*),/)
1055 FORMAT(/,5(1H*),3X,3BHERROR---NUMBER OF RAINSTORM PARAMETERS,
1 3X,5(1H*),/)
1060 FORMAT(1H1)
1065 FORMAT(28(/),29X,42HSTATISTICAL ANALYSIS OF PRECIPITATION DATA/
1//29X,20A1,I10)
1070 FORMAT(///26X,2H19,I2,6H TO 19,I2,2H, ,I2,19H YEARS OF RECORD OF,
1F5.2,10H HOUR DATA///42X,6HMONTHS,3X,A3,1H-,A3/)
2005 FORMAT(16,3I2,1X,12F3.2,29X,I2)
2010 FORMAT(16,3I2,1X,12F3.1,29X,I2)
2015 FORMAT(16,3I2,I1,12A3,29X,I2)
2020 FORMAT(24A3)
2025 FORMAT(24F3.2)
2030 FORMAT(24F3.1)
2035 FORMAT(6X,3I2,1X,12F3.2,29X,I2)
2040 FORMAT(6X,3I2,1X,12F3.1,29X,I2)
3005 FORMAT(23H ** REVERSED DATA ** 19,I2,2I4)
3010 FORMAT(22H ** MISSING DATA ** 19,I2,2I4,5X,24A3,10X,I2)
3015 FORMAT(26H ** ACCUMULATED DATA ** 19,I2,2I4,5X,24A3,10X,I2)
4000 FORMAT(/,10X,16HLENGTH OF RECORD,3X,A3,3H 19,I2,3H - ,
1 A3,3H 19,I2,/)
4001 FORMAT(/,10X,15HPERIOD ANALYZED,3X, A3,3H - ,A3,1H,,3H 19,
1 I2,3H - ,2H19,I2,/)
4002 FORMAT(/,10X,29HPARTIAL SEASON : NO DATA FOR ,
1 A3,3H - ,A3,3H 19,I2/)
4003 FORMAT(/,10X,29HPARTIAL SEASON : NO DATA FOR ,
1 A3,3H - ,A3,3H 19,I2/)
4007 FORMAT(/,5X,5(1H*),36HWARNING: DIMENSION OF ARRAY PA AND A,
1 15H EXCEEDS LIMIT ,/)
5005 FORMAT(/,6X,5HTABLE,4X,A3,1H-,A3,53H RAINSTORM FROM HOURLY PRECIP
1ITATION DATA AT STATION ,4X,20A1,/,17X,13HDURATION TD =,F5.1,3H HR
2,/,20X,3H(19,I2,3H-19,I2,1H),/,1X,100(1H-),/,63X,8HSTANDARD,/,1X,
39HPARAMETER,19X,4HUNIT,19X,4HMEAN,6X,9HDEVIATION,8X,7HMINIMUM,8X,
4 7HMAXIMUM,/,1X,100(1H-),/)
5010 FORMAT(1X,6A4,4X,2A4,4X,4F15,3)
5015 FORMAT(100(1H-),/,28X,5(1H*),3X,22HNUMBER OF RAINSTORMS =,
1 16,3X,5(1H*),4(/))
5020 FORMAT(/,6X,5HTABLE,4X,A3,1H-,A3,53H RAINSTORM FROM HOURLY PRECIP
1ITATION DATA AT STATION ,4X,20A1,/,17X,13HDURATION TD =,F5.1,3H HR
2,/,17X,20HRAINFALL DEPTH RANGE,F7.3,4H IN.,10H (MEAN/2) ,
313H < = DEPTH < ,F7.1,4H IN.,/,1X,100(1H-),/,43X,8HSTANDARD,/,1X,
49HPARAMETER,19X,4HUNIT,19X,4HMEAN,6X,9HDEVIATION,8X,7HMINIMUM,8X,
57HMAXIMUM,/,1X,100(1H-),/)
5021 FORMAT(/,6X,5HTABLE,4X,A3,1H-,A3,53H RAINSTORM FROM HOURLY PRECIP
1ITATION DATA AT STATION ,4X,20A1,/,17X,13HDURATION TD =,F5.1,3H HR
2,/,17X,20HRAINFALL DEPTH RANGE,F7.3,4H IN.,8H (MEAN) ,
313H < = DEPTH < ,F7.1,4H IN.,/,1X,100(1H-),/,43X,8HSTANDARD,/,1X,
49HPARAMETER,19X,4HUNIT,19X,4HMEAN,6X,9HDEVIATION,8X,7HMINIMUM,8X,
57HMAXIMUM,/,1X,100(1H-),/)

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5022 FORMAT(/,6X,5HTABLE,4X,A3,1H-,A3,53H RAINSTORM FROM HOURLY PRECIP
ITATION DATA AT STATION ,4X,20A1,/,17X,13HDURATION TD =,F5.1,3H HR
2,/,17X,20HRRAINFALL DEPTH RANGE,F7.3,4H IN.,10H (MEAN&2) ,
313H < = DEPTH < ,F7.1,4H IN.,/,1X,100(1H-),/,63X,8HSTANDARD,/,1X,
49HPARAMETER,19X,4HUNIT,19X,4HMEAN,6X,9HDEVIATION,8X,7HMINIMUM,8X,
57HMAXIMUM,/,1X,100(1H-),/)
5025 FORMAT(/,6X,5HTABLE,4X,A3,1H-,A3,53H RAINSTORM FROM HOURLY PRECIP
ITATION DATA AT STATION ,4X,20A1,/,17X,13HDURATION TD =,F5.1,3H HR
2,/,17X,20HRRAINFALL DEPTH RANGE,F7.3,4H MM.,10H (MEAN/2) ,
313H < = DEPTH < ,F7.1,4H MM.,/,1X,100(1H-),/,63X,8HSTANDARD,/,1X,
49HPARAMETER,19X,4HUNIT,19X,4HMEAN,6X,9HDEVIATION,8X,7HMINIMUM,8X,
57HMAXIMUM,/,1X,100(1H-),/)
5026 FORMAT(/,6X,5HTABLE,4X,A3,1H-,A3,53H RAINSTORM FROM HOURLY PRECIP
ITATION DATA AT STATION ,4X,20A1,/,17X,13HDURATION TD =,F5.1,3H HR
2,/,17X,20HRRAINFALL DEPTH RANGE,F7.3,4H MM.,8H (MEAN) ,
313H < = DEPTH < ,F7.1,4H MM.,/,1X,100(1H-),/,63X,8HSTANDARD,/,1X,
49HPARAMETER,19X,4HUNIT,19X,4HMEAN,6X,9HDEVIATION,8X,7HMINIMUM,8X,
57HMAXIMUM,/,1X,100(1H-),/)
5027 FORMAT(/,6X,5HTABLE,4X,A3,1H-,A3,53H RAINSTORM FROM HOURLY PRECIP
ITATION DATA AT STATION ,4X,20A1,/,17X,13HDURATION TD =,F5.1,3H HR
2,/,17X,20HRRAINFALL DEPTH RANGE,F7.3,4H MM.,10H (MEAN&2) ,
313H < = DEPTH < ,F7.1,4H MM.,/,1X,100(1H-),/,63X,8HSTANDARD,/,1X,
49HPARAMETER,19X,4HUNIT,19X,4HMEAN,6X,9HDEVIATION,8X,7HMINIMUM,8X,
57HMAXIMUM,/,1X,100(1H-),/)
5040 FORMAT(/,12X,A3,1H-,A3,23H RAINSTORMS FROM HOURLY,
1 32H PRECIPITATION DATA AT STATION ,20A1,5X,3H(19,12,
2 3H-19,12,1H),/,10X,103(1H-),/,10X,9HPARAMETER,20X,11HDEPTH GROUP
3 ,22X,23HRAINSTORM DURATION (HR),/,66X,4(F3.0,12X))
5045 FORMAT(10X,103(1H-),/)
5050 FORMAT(10X,10A4,4X,4(F15.3))

```

```

C
C STOP
C END
C *****
C
C SURROUTINE TAB1
C
C PURPOSE
C TO CALCULATE TOTAL, MEAN, STANDARD DEVIATION, MINIMUM, AND
C MAXIMUM FOR A GIVEN VARIABLE.
C
C USAGE
C CALL TAB1(A,S,NOVAR,STATS,NO)
C
C DESCRIPTION OF PARAMETERS
C A - INPUT MATRIX OF OBSERVATIONS
C S - INPUT VECTOR SPECIFYING OBSERVATIONS TO BE CONSIDERED.
C ONLY THOSE OBSERVATIONS WITH A CORRESPONDING NON-ZERO
C S(I) ARE CONSIDERED. VECTOR LENGTH IS NO
C
C NOVAR - THE VARIABLE TO BE TABULATED.
C STATS - OUTPUT VECTOR OF SUMMARY STATISTICS. VECTOR LENGTH IS 5
C
C STATS(1)= TOTAL
C STATS(2)= MEAN
C STATS(3)= STANDARD DEVIATION
C STATS(4)= MINIMUM
C STATS(5)= MAXIMUM
C
C NO - NUMBER OF OBSERVATIONS.
C
C REMARKS
C THE DIVISOR FOR STANDARD DEVIATION IS ONE LESS THAN THE NUMBER
C OF OBSERVATIONS USED.
C IF S IS A NULL VECTOR, THEN TOTAL, MEAN, AND STANDARD
C DEVIATION = 0, MIN=1.E75 AND MAX=-1.E75
C
C *****
C
C SURROUTINE TAB1(A,S,NOVAR,STATS,NO)
C DIMENSION A(1),S(1),STATS(1)

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TAB1 560
TAB1 570

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```

      DO 5 I=1,3
5  STATS(I)=0.0
C
C      CALCULATE MIN , MAX , AND TOTAL
C
      SCNT=0.0
      VMIN=1.0E75
      VMAX=-1.0E75
      IJ=NO*(NOVAR-1)
      DO 30 J=1,NO
      IJ=IJ+1
      IF(S(J)) 10,30,10
10  SCNT=SCNT+1.0
      STATS(1)=STATS(1)+A(IJ)
      STATS(3)=STATS(3)+A(IJ)*A(IJ)
      IF(A(IJ)-VMIN) 15,20,20
15  VMIN=A(IJ)
20  IF(A(IJ)-VMAX) 30,30,25
25  VMAX=A(IJ)
30  CONTINUE
      STATS(4)=VMIN
      STATS(5)=VMAX
      IF (SCNT) 35,50,35
C
C      CALCULATE MEAN AND STANDARD DEVIATION
C
35  IF(SCNT-1.0) 40,40,45
40  STATS(2)=STATS(1)
      STATS(3)=0.0
      GO TO 50
45  STATS(2)=STATS(1)/SCNT
      STATS(3)=SQRT(ABS((STATS(3)-STATS(1)*STATS(1)/SCNT)/(SCNT-1.0)))
50  RETURN
      END
      BLOCK DATA
      COMMON/NAMONS/NAMON(12)
      COMMON/NAFARS/NAFAR(6,12)
      COMMON/NAUNTS/NAUNTI(2,12),NAUNT2(2,12)
      COMMON/NAPLS/NAPL(6,4)
      COMMON/NADGS/NADG(4,4)
      DATA NAMON/3HJAN,3HFEB,3HMAR,3HAPR,3HMAY,3HJUN,
*      3HJUL,3HAUG,3HSEP,3HOCT,3HNOV,3HDEC/
      DATA NAFAR/4HDURA,4HTION,4H ,4H ,4H ,4H ,
*      4HDEFT,4HM ,4H ,4H ,4H ,4H ,
*      4HINTE,4HNSIT,4HY ,4H ,4H ,4H ,
*      4HFIRS,4HT TI,4HME M,4HOMEN,4HT ,4H ,
*      4HSECO,4HND T,4HIME ,4HHOME,4HNT ,4H ,
*      4HTIME,4H STA,4HNDAR,4HD DE,4HVIAT,4HION ,
*      4HNOND,4HIM. ,4H2ND ,4HTIME,4H MOM,4HENT ,
*      4HNOND,4HIM. ,4H1ST ,4HTIME,4H MOM,4HENT ,
*      4HA OF,4H TRI,4H. HY,4HETOG,4HRAPH,4H ,
*      4HB OF,4H TRI,4H. HY,4HETOG,4HRAPH,4H ,
*      4HA OF,4H NON,4HDIM.,4H HYE,4HTOGR,4HAPH ,
*      4HB OF,4H NON,4HDIM.,4H HYE,4HTOGR,4HAPH /
      DATA NAUNTI/4H(HR),4H ,4H(IN.,4H) ,4H(IN.,4H/HR),
*      4H(HR),4H ,4H(HR*,4HHR) ,4H(HR),4H ,
*      4H( ),4H ,4H( ),4H ,4H(HR),4H ,
*      4H(HR),4H ,4H( ),4H ,4H( ),4H /
      DATA NAUNT2/4H(HR),4H ,4H(MM.,4H) ,4H(MM.,4H/HR),
*      4H(HR),4H ,4H(HR*,4HHR) ,4H(HR),4H ,
*      4H( ),4H ,4H( ),4H ,4H(HR),4H ,
*      4H(HR),4H ,4H( ),4H ,4H( ),4H /
      DATA NAPL/4HA OF,4H NON,4HDIM.,4H HYE,4HTOGR,4HAPH ,
*      4HNOND,4HIM. ,4H1ST ,4HTIME,4H MOM,4HENT ,
*      4HNOND,4HIM. ,4H2ND ,4HTIME,4H MOM,4HENT ,
*      4HNUMB,4HER O,4HF RA,4HINST,4HORMS,4H /
      DATA NADG/4H AL,4HL RA,4HINST,4HORMS,
*      4H D ,4H >= ,4H0.5 ,4HMEAN,
*      4H D ,4H >= ,4H ,4HMEAN,
*      4H D ,4H >= ,4H 2 ,4HMEAN/
      END

```

```

TAB1 580
TAB1 590
TAB1 600
TAB1 610
TAB1 620
TAB1 630
TAB1 640
TAB1 650
TAB1 660
TAB1 670
TAB1 680
TAB1 690
TAB1 700
TAB1 710
TAB1 720
TAB1 730
TAB1 740
TAB1 750
TAB1 760
TAB1 770
TAB1 780
TAB1 790
TAB1 800
TAB1 810
TAB1 820
TAB1 830
TAB1 840
TAB1 850
TAB1 860
TAB1 870
TAB1 880
TAB1 890
TAB1 900
TAB1 910

```

## V. USER'S GUIDE FOR COMPUTER PROGRAM

### FANHP

#### (Frequency Analysis for NWS Hourly Precipitation Data)

##### A. Description of the Computer Program

This computer program, FANHP, is designed to perform frequency analysis on hourly rainfall data to compute the depth of storm rainfall for different durations and return periods. This program is specifically designed to accept only the NOAA National Weather Service (NWS) hourly precipitation data magnetic tape or cards in standard NWS Deck 488 format, TD-9657. The program automatically handles and corrects the following commonly occurred problems in the NWS hourly precipitation data:

- (1) Identify and correct reversed order of the two data cards of a date;
- (2) Identify and ignore missing data in the statistics computation;
- (3) Identify accumulated data and exclude them from the statistics computations because the duration of these rainstorms cannot be identified.

The program will not proceed if the NWS data tapes or cards contain other less commonly occurred data problems. For such cases the user should print out a listing of the data, examine the data errors and make proper corrections before re-running the computer program.

From the length of the record of the available data (month and year, e.g., 06-1948 to 10-1978) the user chooses the continuous years (e.g., 1951-1970) and the "season" (consecutive months, e.g., April-October inclusive) to be analyzed. The program will select from the data file the rainfall data for the season for each of the years specified for analysis. If the data of entire year is desired, the "season" is January-December. The built-in (default) season is five months from May through September. For a specified season, if the entire record length (years) of the data record is to be analyzed and the data of the first year and/or last year of the record contain only partial months of the season (e.g., the season is April-October whereas first year data starts in July and/or the last year record ends in August), the program will proceed to select the maximum values from these partial seasons for the annual maximum series and a message will be printed out warning of the partial season.

The program verifies the appropriateness of the data set of the specified season and period from the NWS data file, and selects the data according to the specified durations of the rainfall to establish the annual maximum series for each duration. A maximum of six different durations, up to 12-hour duration, can be specified by the user. Since hourly data is used, the duration must be multiple of hours. The built-in (default) durations considered are 1, 2, 3, and 4 hours.

For each rainfall depth in the annual maximum series of each specified duration, the plotting position is computed by

$$T_r = (N + 1)/m$$

in which  $T_r$  = return period in years,  $N$  = number of years for the period of data considered, and  $m$  = rank. Annual exceedance series is not included here because of the commonly occurred problem of missing and accumulated rainfall data for the NWS hourly precipitation data file.

Each annual maximum series is analyzed for two different probability distributions, namely, Gumbel (extreme value type I) and log-Pearson III distributions. For Gumbel distribution two methods are used. They are the least-squares fitting method and the frequency factor method. For log-Pearson III distribution, only the frequency factor method following the procedure proposed by the U.S. Water Resources Council is used.

The dimension restrictions of the program are as follows:

- (1) Maximum number of years to be analyzed = 99
- (2) Maximum number of return periods to be computed and printing out for each duration = 10.

The computer program is written in FORTRAN IV language consisting of about 600 statements. It can be implemented on most Cyber and IBM 360, 370, and 4341 computer systems. It requires the use of two International Mathematical Subroutine Library (IMSL) subroutines DCADRE and VERTST if the log-Pearson III analysis is to be performed. Execution of the program requires a memory core of about 150K bytes (40K words) for compilation and execution. Most of the execution time is for the first part of data reading, filing and setting up the annual maximum series.

The input to run the program is essentially the same as that for the computer program SATH except Card 3 in which the last item is different, and Card 5 which is not required for SATH. Figure 18 shows an example input and Fig. 19 shows the input card deck arrangement.

The computer printout after running the program consists of two parts. The first part gives information on the NWS hourly precipitation data used, including the location and identification number of the gaging station, the periods of record and of analysis, and a listing of the missing and accumulated data in chronological order.

The second part of the printout contains the frequency analysis results for two versions of the Gumbel distribution and log-Pearson III distribution for each of the specified durations. An example of the printout corresponding to the input of Fig. 18 is shown in Fig 20. The average rainfall intensity for a given duration and return period, if desired, can be calculated by dividing the computed rain depth by the duration.

Inquiry concerning the availability of the computer program should be addressed to Dr. B. C. Yen, Department of Civil Engineering, University of Illinois, Urbana, Illinois 61801 or to FHWA Office of Research & Development.

Col. Card	ECHO OF DATA											
	123456789012345678901234567890123456789012345678901234567890											
1	EXAMPLE OF FANHP	URBANA, IL	118740									
2	0 1 0 78 12											
3	20 59 78 3 6 2 4											
4	1. 4.											
5	10. 25. 50. 100.											

Fig. 18. Example input for FANHP

Card Number	Card Column	Format	Description	Variable Name
1	***		<i>Identification Card</i>	***
	1-40	40A1	User defined title, up to 40 alphanumeric characters are allowed.	TITLE
	41-60	20A1	Name of the station.	STATIO
	61-70	I10	Identification number of the station.	NUMBER
2	***		<i>Input Data Information Card</i>	***
	1-5	I5	Input data form Leave blank (or enter "0" in Column 5) if the input hydrologic data are on a magnetic tape. Enter "1" in Column 5 if the input data are on cards.	KIND
	6-10	I5	Measurements units of input data Enter "1" in Column 10 if English units are used. If SI units are used, enter "2" in Column 10.	MU
	11-15	I5	Data checking Enter "1" in Column 15 if the input data have been corrected for misplaced, missing and accumulated records. Enter "0" in Column 15 if the data have not been corrected.	MISS
	16-20	I5	The last two digits of the last year of the hydrologic record of the data file, e.g., "78" for 1978.	LYR
	21-25	I5	Two-digit representation of the last month of the last year of the hydrologic record, e.g., "07" = July.	LMR

Card Number	Card Column	Format	Description	Variable Name
3	***	<i>Data Analysis Information Card</i>		***
	1-5	I5	Number of years of the period to be analyzed, maximum 99, e.g., "20".	NYR
	6-10	I5	Last two digits of the first year of the period to be analyzed. It must not be earlier than the first year on the record file, e.g., "51" for 1951.	IFIRST
	11-15	I5	Last two digits of the last year of the period to be analyzed. It must be the same or earlier than the last year on the record file, e.g., "70" for 1970.	LASTYR
	16-20	I5	Number of months in the "season" to be analyzed. Minimum is one and maximum is 12. Default value is "5" for the 5-month season, May-September.	NMO
	21-25	I5	First month of the season, e.g., enter "4" in Column 25 for a season starting on April 1.	IMS
	26-30	I5	Number of precipitation durations for which frequency analysis will be performed, maximum is 6. Default value is "4" for durations of 1, 2, 3, and 4 hours.	NXL
	31-35	I5	Number of return periods to be computed, e.g., "2", maximum 10.	M

Card Number	Card Column	Format	Description	Variable Name
4	***		<i>Durations of Precipitation</i>	***
	1-5	F5.0	Enter the first precipitation duration, in hours, to be analyzed, e.g., "2." for 2-hour duration.	XLL1(1)
	5-10	F5.0	Second precipitation duration, in hours, to be analyzed, e.g., "3."	XLL1(2)
	11-15	F5.0	Enter successive durations to be analyzed, each in the 5 columns allotted, until all the durations are specified. The total number of durations must be the same as that specified in Column 25 of Card 3. Although not necessary, it is suggested to enter the durations in an ascending order. The default durations considered are 1, 2, 3, and 4 hours.	XLL1( )
	.	.		.
	.	.		.
	.	.		.
	26-30			
5	***		<i>Return Periods to be Computed</i>	***
	1-5	F5.0	The first return period in years for which the value of the hydrologic event will be computed, e.g., "10." for 10 years.	T(1)
	6-10	F5.0	The second return period for which the value of the hydrologic event will be computed, e.g., "100."	T(2)
	11-15	F5.0	Repeat specifying the return periods in years until all of them are specified and leave the rest of the card blank. The total number of return periods must be the same as that entered in Columns 34-35 of Card 3. Although not necessary, it is suggested that the return periods be entered in an increasing order.	T( )
	.	.		.
	.	.		.
	.	.		.
	46-50			

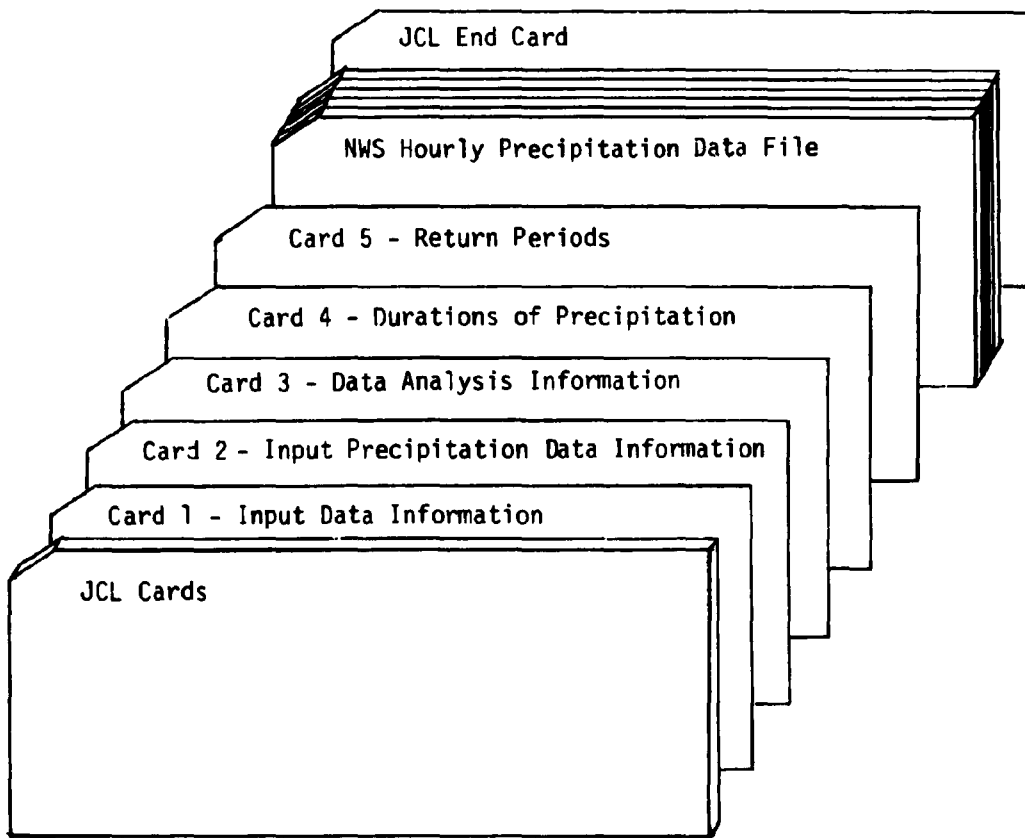


Fig. 19. Input data deck arrangement for execution of FANHP



FREQUENCY ANALYSIS OF PRECIPITATION DATA

URBANA, IL 118740

1959 TO 1978, 20 YEARS OF RECORD OF 1.00 HOUR DATA

		MONTHS		JUN-AUG			
		7	18	0-0-0-012-			
1	** ACCUMULATED DATA ** 1959	7	18				19
	** MISSING DATA ** 1969	6	1				2
	** MISSING DATA ** 1969	6	2				3
	** MISSING DATA ** 1969	6	3				4
	** MISSING DATA ** 1969	6	4				5
	** MISSING DATA ** 1969	6	5				6
	** MISSING DATA ** 1969	6	6				7
	** MISSING DATA ** 1969	6	7				8
	** MISSING DATA ** 1969	6	8				9
	** MISSING DATA ** 1969	6	9				10
	** MISSING DATA ** 1969	6	10				11
	** MISSING DATA ** 1969	6	11				12
	** MISSING DATA ** 1969	6	12				13
	** MISSING DATA ** 1969	6	13				14
	** MISSING DATA ** 1969	6	14				15
	** MISSING DATA ** 1969	6	15				16
	** MISSING DATA ** 1969	6	16				17
	** MISSING DATA ** 1969	6	17				18
	** MISSING DATA ** 1969	6	18				19
	** MISSING DATA ** 1969	6	19				20
	** MISSING DATA ** 1969	6	20				21
	** MISSING DATA ** 1969	6	21				22
	** MISSING DATA ** 1969	6	22				23
	** MISSING DATA ** 1969	6	23				24
	** MISSING DATA ** 1969	6	24				25
	** MISSING DATA ** 1969	6	25				26
	** MISSING DATA ** 1969	6	26				27
	** MISSING DATA ** 1969	6	27				28
	** MISSING DATA ** 1969	6	28				29
	** MISSING DATA ** 1969	6	29				30
	** MISSING DATA ** 1969	6	30				1
	** ACCUMULATED DATA ** 1970	7	3	0-0-098-	025-		8
	** ACCUMULATED DATA ** 1978	7	22				23
	** ACCUMULATED DATA ** 1978	7	23				24

LENGTH OF RECORD JAN 1959 - DEC 1978

PERIOD ANALYZED JUN - AUG, 1959 - 1978

Fig. 20. Example computer printout of FANHP (a) Information on NWS data

>>>>EXAMPLE OF FANHP

<<<<<

1.0 HOUR DURATION RAINFALL DATA

59	.770	60	.780	61	1.100	62	1.130
63	.940	64	1.030	65	2.300	66	1.090
67	.570	68	.940	69	1.480	70	1.260
71	1.120	72	1.790	73	1.390	74	.620
75	1.830	76	1.270	77	1.170	78	1.220

ANNUAL MAXIMUM SERIES - GUMBEL DISTRIBUTION

YEAR	RAINFALL(IN.)	RANK	PLOTING POSITIONS		
			RETURN PERIOD	NON-EXEC PROB	K
65	2.30	1	21.000	.9524	1.9048
75	1.83	2	10.500	.9048	1.3446
72	1.79	3	7.000	.8571	1.0078
69	1.48	4	5.250	.8095	.7619
73	1.39	5	4.200	.7619	.5653
76	1.27	6	3.500	.7143	.3992
70	1.26	7	3.000	.6667	.2538
78	1.22	8	2.625	.6190	.1229
77	1.17	9	2.333	.5714	.0026
62	1.13	10	2.100	.5238	-.1101
71	1.12	11	1.909	.4762	-.2173
61	1.10	12	1.750	.4286	-.3209
66	1.09	13	1.615	.3810	-.4223
64	1.03	14	1.500	.3333	-.5234
68	.94	15	1.400	.2857	-.6258
63	.94	16	1.313	.2381	-.7317
60	.78	17	1.235	.1905	-.8444
59	.77	18	1.167	.1429	-.9691
74	.62	19	1.105	.0952	-1.1167
67	.57	20	1.050	.0476	-1.3181

RESULTS USING LEAST SQUARES FIT

INTERCEPT OF LEAST SQUARES LINE = .10 IN.

SLOPE OF LEAST SQUARES LINE = .0011

STANDARD ERROR OF ESTIMATE = .078 IN.

CORRELATION COEFFICIENT = .9834

MAGNITUDE OF 10.YR. (K= 1.3046) RAINFALL = 1.846 IN.

MAGNITUDE OF 25.YR. (K= 2.0438) RAINFALL = 2.206 IN.

MAGNITUDE OF 50.YR. (K= 2.5923) RAINFALL = 2.473 IN.

MAGNITUDE OF 100.YR. (K= 3.1367) RAINFALL = 2.738 IN.

Fig. 20 . Example computer printout of FANHP (b) Computed results

RESULTS USING SAMPLE MEAN AND STANDARD DEVIATION

---

SAMPLE MEAN = 1.190 IN.  
 SAMPLE STANDARD DEVIATION = .421 IN.  
 STANDARD ERROR OF ESTIMATE = .099 IN.  
 CORRELATION COEFFICIENT = .8513  
 MAGNITUDE OF 10.YR. (K= 1.3046) RAINFALL = 1.739 IN.  
 MAGNITUDE OF 25.YR. (K= 2.0438) RAINFALL = 2.051 IN.  
 MAGNITUDE OF 50.YR. (K= 2.5923) RAINFALL = 2.282 IN.  
 MAGNITUDE OF 100.YR. (K= 3.1367) RAINFALL = 2.511 IN.

1

ANNUAL MAXIMUM SERIES - LOG PEARSON TYPE III DISTRIBUTION

---

YEAR	RAINFALL(IN.)	LOG RAINFALL	RANK	PLOTTING POSITIONS		
				RETURN PERIOD	NON-EXEC	PROB K
65	2.30	.3617	1	21.000	.9524	1.6595
75	1.83	.2625	2	10.500	.9048	1.3056
72	1.79	.2529	3	7.000	.8571	1.0668
69	1.48	.1703	4	5.250	.8095	.8773
73	1.39	.1430	5	4.200	.7619	.7149
76	1.27	.1038	6	3.500	.7143	.5693
70	1.26	.1004	7	3.000	.6667	.4347
78	1.22	.0864	8	2.625	.6190	.3075
77	1.17	.0682	9	2.333	.5714	.1848
62	1.13	.0531	10	2.100	.5238	.0647
71	1.12	.0492	11	1.909	.4762	-.0548
61	1.10	.0414	12	1.750	.4286	-.1752
66	1.09	.0374	13	1.615	.3810	-.2985
64	1.03	.0128	14	1.500	.3333	-.4267
68	.94	-.0269	15	1.400	.2857	-.5626
63	.94	-.0269	16	1.313	.2381	-.7100
60	.78	-.1079	17	1.235	.1905	-.8750
59	.77	-.1135	18	1.167	.1429	-1.0682
74	.62	-.2076	19	1.105	.0952	-1.3127
67	.57	-.2441	20	1.050	.0476	-1.6772

RESULTS USING SAMPLE MEAN AND STANDARD DEVIATION

---

SAMPLE MEAN = .05080 = 1.124 IN.  
 SAMPLE STANDARD DEVIATION = .15072  
 STANDARD ERROR OF ESTIMATE = .03050  
 CORRELATION COEFFICIENT = .8912  
 SAMPLE SKEW COEF. = -.0298  
 MAGNITUDE OF 10.YR. (K= 1.2783) RAINFALL = 1.75 IN.  
 MAGNITUDE OF 25.YR. (K= 1.7404) RAINFALL = 2.06 IN.  
 MAGNITUDE OF 50 YR. (K= 2.0377) RAINFALL = 2.28 IN.  
 MAGNITUDE OF 100.YR. (K= 2.3044) RAINFALL = 2.50 IN.

Fig. 20 . Example computer printout of FANHP (b) Continued

1

>>>>EXAMPLE OF FANHP

<<<<<

4.0 HOUR DURATION RAINFALL DATA

59	.200	60	1.580	61	1.870	62	1.860
63	1.230	64	1.390	65	2.560	66	1.400
67	.830	68	2.380	69	2.860	70	2.260
71	2.130	72	1.090	73	1.460	74	1.320
75	2.700	76	1.140	77	1.070	78	1.420

ANNUAL MAXIMUM SERIES - GUMBEL DISTRIBUTION

YEAR	RAINFALL(IN.)	RANK	PLOTTING POSITIONS		
			RETURN PERIOD	NON-EXEC PROB	K
69	2.86	1	21.000	.9524	1.9048
75	2.70	2	10.500	.9048	1.3446
65	2.56	3	7.000	.8571	1.0078
68	2.38	4	5.250	.8095	.7619
70	2.26	5	4.200	.7619	.5653
71	2.13	6	3.500	.7143	.3992
61	1.87	7	3.000	.6667	.2538
62	1.86	8	2.625	.6190	.1229
60	1.58	9	2.333	.5714	.0026
73	1.46	10	2.100	.5238	-.1101
78	1.42	11	1.909	.4762	-.2173
66	1.40	12	1.750	.4286	-.3209
64	1.39	13	1.615	.3810	-.4223
74	1.32	14	1.500	.3333	-.5234
63	1.23	15	1.400	.2857	-.6258
76	1.14	16	1.313	.2381	-.7317
72	1.09	17	1.235	.1905	-.8444
77	1.07	18	1.167	.1429	-.9691
67	.83	19	1.105	.0952	-1.1167
59	.20	20	1.050	.0476	-1.3181

RESULTS USING LEAST SQUARES FIT

INTERCEPT OF LEAST SQUARES LINE = 1.670 IN.  
 SLOPE OF LEAST SQUARES LINE = .78 IN.  
 STANDARD ERROR OF ESTIMATE = .155 IN.  
 CORRELATION COEFFICIENT = .9752  
 MAGNITUDE OF 10.YR. (K= 1.3046) RAINFALL = 2.689 IN.  
 MAGNITUDE OF 25.YR. (K= 2.0438) RAINFALL = 3.267 IN.  
 MAGNITUDE OF 50.YR. (K= 2.5923) RAINFALL = 3.695 IN.  
 MAGNITUDE OF 100.YR. (K= 3.1367) RAINFALL = 4.121 IN.

Fig. 20. Example computer printout of FANHP (b) Continued

RESULTS USING SAMPLE MEAN AND STANDARD DEVIATION

SAMPLE MEAN = 1.638 IN.  
 SAMPLE STANDARD DEVIATION = .681 IN.  
 STANDARD ERROR OF ESTIMATE = .180 IN.  
 CORRELATION COEFFICIENT = .8513  
 MAGNITUDE OF 10.YR. (K= 1.3046) RAINFALL = 2.526 IN.  
 MAGNITUDE OF 25.YR. (K= 2.0438) RAINFALL = 3.030 IN.  
 MAGNITUDE OF 50.YR. (K= 2.5923) RAINFALL = 3.403 IN.  
 MAGNITUDE OF 100.YR. (K= 3.1367) RAINFALL = 3.774 IN.

1

ANNUAL MAXIMUM SERIES - LOG PEARSON TYPE III DISTRIBUTION

YEAR	RAINFALL(IN.)	LOG RAINFALL	RANK	PLOTTING POSITIONS		
				RETURN PERIOD	NON-EXEC	PROB K
69	2.86	.4564	1	21.000	.9524	.9145
75	2.70	.4314	2	10.500	.9048	.8723
65	2.56	.4082	3	7.000	.8571	.8256
68	2.38	.3766	4	5.250	.8095	.7747
70	2.26	.3541	5	4.200	.7619	.7196
71	2.13	.3284	6	3.500	.7143	.6599
61	1.87	.2718	7	3.000	.6667	.5953
62	1.86	.2695	8	2.625	.6190	.5251
60	1.58	.1987	9	2.333	.5714	.4485
73	1.46	.1644	10	2.100	.5238	.3646
78	1.42	.1523	11	1.909	.4762	.2719
66	1.40	.1461	12	1.750	.4286	.1688
64	1.39	.1430	13	1.615	.3810	.0528
74	1.32	.1206	14	1.500	.3333	-.0794
63	1.23	.0899	15	1.400	.2857	-.2329
76	1.14	.0569	16	1.313	.2381	-.4154
72	1.09	.0374	17	1.235	.1905	-.6399
77	1.07	.0294	18	1.167	.1429	-.9308
67	.83	-.0809	19	1.105	.0952	-1.3429
59	.20	-.6990	20	1.050	.0476	-2.0516

RESULTS USING SAMPLE MEAN AND STANDARD DEVIATION

SAMPLE MEAN = .16276 = 1.455 IN.  
 SAMPLE STANDARD DEVIATION = .25210  
 STANDARD ERROR OF ESTIMATE = .09872  
 CORRELATION COEFFICIENT = .8086  
 SAMPLE SKEW COEF. --2.1061  
 MAGNITUDE OF 10.YR. (K= .8678) RAINFALL = 2.41 IN.  
 MAGNITUDE OF 25.YR. (K= .9208) RAINFALL = 2.48 IN.  
 MAGNITUDE OF 50.YR. (K= .9363) RAINFALL = 2.50 IN.  
 MAGNITUDE OF 100.YR. (K= .9435) RAINFALL = 2.52 IN.

Fig. 20. Example computer printout of FANHP (b) Continued

## B. Listing of the Computer Program

```

PROGRAM FANHP(INP2,INPUT,OUT3,TEM,TAPE3=INP2,
1 TAPE5=INPUT,TAPE6=OUT3,TAPE10=TEM)
C*****
C
C
C   COMPUTER PROGRAM FOR FREQUENCY ANALYSIS OF NWS HOURLY
C   PRECIPITATION DATA
C
C   FOR ANY INFORMATION REGARDING THIS COMPUTER PROGRAM,
C   THE USER SHOULD REFER TO CHAPTER V OF VOL. III (USER'S MANUAL)
C
C*****
C*****
REAL KAMAX,INTCPT,MEAN,KPEAR,KDES
INTEGER YEAR,RNK,YMAX,STATIO(20)
DIMENSION QMAX(99),RNK(99),FLTP(99),NAMON(12)
1, KAMAX(99),YMAX(99),QLOG(99),KPEAR(99),T(10),PROB(
260),KDES(20),SYEAR(99),SQ(99),TITLE(40),UNIT(2)
DIMENSION MONTH(12),XLL1(6),YEAR(99),Q(99,12)
COMMON/PAKA/LASTYR,NUMBER,IFIRST,KIND,MISS,IDIMX,MU,M1,M2,IOUT
1
   ,LYR,LMR
DATA UNIT/3HIN.,3HMM./
DATA NAMON/3HJAN,3HFEB,3HMAR,3HAPR,3HMAY,3HJUN,
* 3HJUL,3HAUG,3HSEP,3HOCT,3HNOV,3HDEC/
IN1=5
IOUT=6
C
C *** INPUT 1
READ(IN1,1010) TITLE,STATIO,NUMBER
C
C *** INPUT 2
READ(IN1,1015) KIND,MU,MISS,LYR,LMR
C
C *** INPUT 3
READ(IN1,1020) NYR,IFIRST,LASTYR,NMO,IMS,NXL,M
C
C *** INPUT 4
READ(IN1,1025) (XLL1(I),I=1,NXL)
C
C *** INPUT 5
READ(IN1,1025) (T(I),I=1,M)
C
IDIMX=24*NMO*40
C
ECHO OF DATA
C
WRITE(IOUT,1005)
1005 FORMAT(40X,12HECHO OF DATA,/,10X,8(10H1234567890),/,10X,80
1 (1H-),/)
WRITE(IOUT,1006) TITLE,STATIO,NUMBER
WRITE(IOUT,1007) KIND,MU,MISS,LYR,LMR
WRITE(IOUT,1008) NYR,IFIRST,LASTYR,NMO,IMS,NXL,M
WRITE(IOUT,1009) (XLL1(I),I=1,NXL)
WRITE(IOUT,1009) (T(I),I=1,M)
1006 FORMAT(10X,40A1,20A1,I10)
1007 FORMAT(10X,5I5)
1008 FORMAT(10X,7I5)
1009 FORMAT(10X,6F5.0)
DO 101 I=1,NMO
101 MONTH(I)=IMS+I-1

```

```

C      DEFAULT VALUE
C
      IF(NMO.LE.0) NMO=5
      IF(MONTH(1).GT.0) GO TO 2
      DO 1 I=1,5
1     MONTH(I)=4+1
2     IF(NXL.LE.0) NXL=4
      IF(XLL1(1).GT.0.) GO TO 4
      DO 3 I=1,NXL
      A1 I
3     XLL1(I)=A1
C
C      PRINT INPUT DATA
C
4     DT=1.
      M1=MONTH(1)
      M2=MONTH(NMO)
      WRITE(IOUT,904)
      WRITE(IOUT,1065) STATID,NUMBER
      N=NYR
      WRITE(IOUT,1070) IFIRST, LASTYR,N,DT,NAMON(M1),NAMON(M2)
      WRITE(IOUT,904)
      CALL NUSDAT(YMAX,Q,KY)
      IF(KY.NE.N) WRITE(IOUT,950)
      DO 14 ICONT=1,NXL
      IJCONT=XLL1(ICONT)
      DO 5 JY=1,N
5     QMAX(IY)=Q(IY,IJCONT)
      WRITE(IOUT,904)
      WRITE(IOUT,938)
      WRITE(IOUT,931) (TITLE(KX),KX=1,40)
      WRITE(IOUT,938)
      WRITE(IOUT,905) XLL1(ICONT)
      WRITE(IOUT,986) (YMAX(I),QMAX(I),I=1,KY)
      IFG=0
      SMV=1.0E-10
      DO 16 I=1,KY
      IF(QMAX(I).GT.SMV) GO TO 16
      IFG=1
      WRITE(IOUT,987) IJCONT,YMAX(I)
16     CONTINUE
987    FORMAT(/,10X,5(1H*),26H WARNING: NO RAINSTORM OF,
1     I3,20H HR DURATION FOR 19,I2,2X,5(1H*),/)
      IF(IFG.EQ.1) GO TO 14
      WRITE(IOUT,932)
      CALL RANK(QMAX,N,RNK,N)
      A=1.
      DO 6 J=1,N
      PLTP(I)=(N+1)/A
      PROB(I)=1-1/PLTP(I)
      A=A+1.
      Z=ALOG(PLTP(I))-ALOG(PLTP(I)-1.)
6     KAMAX(I)=-((SQRT(6.)/3.14159)*(0.5772157+ALOG(Z)))
      WRITE(IOUT,907)
      WRITE(IOUT,908)
      WRITE(IOUT,933) UNIT(MU)
      DO 7 I=1,N
      NN=RNK(I)
7     WRITE(IOUT,910) YMAX(NN),QMAX(I),I,PLTP(I),PROB(I),KAMAX(I)
      CALL FIT(KAMAX,QMAX,SLOPE,INTCPT,SE,STDD,CORCOF,N,MEAN,1)
      CALL RESULT(SLOPE,INTCPT,SE,STDD,CORCOF,MEAN,1,1,MU,IOUT)
      DO 8 I=1,M
      TT=T(I)
8     CALL DESIGN(TT,SLOPE,INTCPT,1,MU,IOUT)

```

```

CALL FIT (KMAX,QMAX,SLOPE,INTCPT,SE,STDD,CORCOF,N,MEAN,2)
CALL RESULT (SLOPE,INTCPT,SE,STDD,CORCOF,MEAN,2,1,MU,IOUT)
DO 9 I=1,M
  TT=T(I)
9 CALL DESIGN (TT,STDD,MEAN,1,MU,IOUT)
  A=0.
  B=0.
  C=0.
  J=1
  K=N
  DO 10 J=J,N
    QLOG(I)=ALOG10(QMAX(I))
    B=B+QLOG(I)*QLOG(I)
10  A=A+QLOG(I)
  MEAN=A/K
  STDD=SURT((B-A*A/K)/(K-1))
  DO 11 T=J,N
11  C=C+((QLOG(J)-MEAN)/STDD)*((QLOG(I)-MEAN)/STDD)*((QLOG(I)-MEAN)/
1  STDD)
  G=CXC/((K-1)*(K-2))
  GG=G
  IF (ABS(G).LT.0.001)G=0.001
  WRITE (IOUT,911)
  CALL KP (KPEAR,N,PLTP,G)
  WRITE (IOUT,912)
  WRITE (IOUT,913)
  WRITE (IOUT,934) UNIT(MU)
  DO 12 I=1,N
    NN=KNK(I)
12  WRITE (IOUT,915) YMAX(NN),QMAX(I),QLOG(I),I,PLTP(I),PROB(I),
1  KPEAR(I)
  CALL KP(KDES,M,T,G)
  CALL FIT (KPEAR,QLOG,SLOPE,INTCPT,SE,STDD,CORCOF,N,MEAN,2)
  CALL RESULT (SLOPE,INTCPT,SE,STDD,CORCOF,MEAN,2,2,MU,IOUT)
  WRITE (IOUT,917) G
  DO 13 I=1,M
    R=STDD*KDES(I)+MEAN
    R=EXP(2.302585*R)
13  WRITE (IOUT,948) T(I),KDES(I),R,UNIT(MU)
14 CONTINUE
  STOP
C
903 FORMAT (I4,F10.0)
904 FORMAT (1H1)
905 FORMAT (/22X,F4.1,2X,27H HOUR DURATION RAINFALL DATA/23X,32(1H-)/)
906 FORMAT (4(5X,I4,1X,F10.1))
907 FORMAT (4(5X,I4,1X,F8.3))
907 FORMAT (20X,43H ANNUAL MAXIMUM SERIES - GUMBEL DISTRIBUTION,
1 /20X,43(1H-)/)
908 FORMAT (42X,18HPLOTTING POSITIONS)
933 FORMAT (1X,4HYEAR,5X,9HR RAINFALL(,A3,1H),5X,4HR RANK,4X,13H RETURN PER
1IOD,2X,13H NON-EXEC PROB,3X,1HK/)
910 FORMAT (1X,I4,F15.2,I11,F15.3,F12.4,F12.4)
911 FORMAT (1H1)
912 FORMAT (10X,57H ANNUAL MAXIMUM SERIES - LOG PEARSON TYPE III DISTRI
1BUTION,/,10X,57(1H-)/)
913 FORMAT (47X,18HPLOTTING POSITIONS)
934 FORMAT (1X,4HYEAR,2X,9HR RAINFALL(,A3,1H),2X,13H LOG RAINFALL ,3X,4HR
1RANK,2X,13H RETURN PERIOD,2X,13H NON-EXEC PROB,2X,1HK/)
915 FORMAT (1X,I4,F12.2,F13.4,I10,F13.3,F12.4,2X,F10.4)
917 FORMAT (1X,19H SAMPLE SKEW COEF. =,F7.4/)
948 FORMAT (1X,13H MAGNITUDE OF ,F4.0,7HYR. (K=,F7.4,12H) RAINFALL =,
1 F8.2,1X,A3/)
931 FORMAT (/,5H >>>>,40A1,5H <<<<,/)
942 FORMAT (/,80(1H=)/)
938 FORMAT (80(1H=))
950 FORMAT (/,10X,5(1H*),30H NUMBER OF YEARS DOES NOT MATCH,/)
1010 FORMAT (40A1,20A1,I10)
1015 FORMAT (515)
1020 FORMAT (715)

```



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1025 FORMAT(10F5.0)
1065 FORMAT(28(//),29X,40HFREQUENCY ANALYSIS OF PRECIPITATION DATA/
1//29X,20A1,110)
1070 FORMAT(///26X,2H19,I2,6H 10 19,I2,2M, ,I2,19H YEARS OF RECORD OF,
1F5.2,10H HOUR DATA///42X,6HMONTHS,3X,A3,1H-,A3/)
END
C
SUBROUTINE NWSDAT(YEAR,Q,KY)
C
INTEGER YEAR
DIMENSION YEAR(99),Q(99,12),AQ(12),X(9000),D(150),IT(24)
DIMENSION NOV(2),ICARD(2),IF(24),NCARD(2),JP(24),NAMON(12)
COMMON/PARA/LASTYR,NUMBER,IFIRST,KIND,MISS,IDIMX,HU,H1,H2,IOUT
1 ,LYR,LMP:
DATA NAMON/3HJAN,3HFEB,3HMAR,3HAPR,3HMAY,3HJUN,
* 3HJUL,3HAUG,3HSEP,3HOCT,3HNOV,3HDEC/
MC3=0
I2=2
LYR1=LASTYR+1
KY=0
ITT=24
IN2=5
IF(KIND.EQ.0) IN2=3
IMR=0
IF(IDIMX.GT.9000) WRITE(IOUT,1011)
1011 FORMAT(/,10X,35HDIMENSION OF ARRAY X EXCEEDS LIMITS,/)
125 DO 130 I=1, IDIMX
130 X(I)=0.0
I2=0
I1=0
IF(MISS.EQ.0) GO TO 230
NN1=2
IF(HU.EQ.2) GO TO 220
C
C *** INPUT HOURLY PRECIPITATION DATA
NN1=1
205 DO 210 I1=1,I2
READ(IN2,2005) NUM,IYR,IMO,IDY,(X(I+I2),I=1,12),INXDY
210 I2=I2+12
C ***
C
215 IF(NUM.NE.NUMBER.OR.IMR.NE.0) GO TO 216
IMR=IMO
IYR=IYR
216 IF(NUM.EQ.NUMBER.AND.IYR.GE.IFIRST.AND. IMO.GE.M1
1 .AND. IMO.LT.H2) GO TO 320
I2=0
GO TO (205,220),NN1
C
C *** INPUT HOURLY PRECIPITATION DATA
220 DO 225 I1=1,I2
READ(IN2,2010) NUM,IYR,IMO,IDY,(X(I+I2),I=1,12),INXDY
225 I2=I2+12
C ***
C
GO TO 215
C *****
C
C THE STATEMENT IN THE FOLLOWING SIXTY LINES IS FOR THE PURPOSE TO
C CORRECT HOURLY PRECIPITATION DATA
C 1. CORRECT REVERSED DATA CARDS OF A DAY
C 2. IDENTIFY AND IGNORE MISSING DATA
C 3. IDENTIFY ACCUMULATED DATA AND SET THEM TO BE ZERO
C
C *****
230 K2=0
IND=0

```

```

        IF(MC3.NE.0) GO TO 235
        DATA KKK /3H- /
        DATA NNN /3H0- /
        DATA NBB /3H /
235 IYY=KKK
C
C *** INPUT HOURLY PRECIPITATION DATA
      NN1=3
240 DO 245 I1=1,I2
      READ(IN2,2015) NUM,IYR,IMO,IDY,ICARD(I1),(IT(I+K2),I=1,12),NOV(I1)
245 K2=K2+12
C ***
C
      K2=0
      IF(NUM.NE.NUMBER.OR.IMR.NE.0) GO TO 248
      IMR=IMO
      IYR=IYR
248 IF(NUM.EQ.NUMBER.AND.IYR.GE.FIRST.AND.IMO.GE.M1
      1 .AND.IMO.LT.M2) GO TO 260
      GO TO 240
C *** INPUT HOURLY PRECIPITATION DATA
250 DO 255 I1=1,I2
      READ(IN2,2015) NUM,IYR,IMO,IDY,ICARD(I1),(IT(I+K2),I=1,12),NOV(I1)
255 K2=K2+12
C ***
C
      K2=0
260 IF(ICARD(1).EQ.1) GO TO 270
      WRITE(IOUT,3005) IYR,IMO,IDY
      DO 265 J=1,12
      IF(I)=IT(I+12)
265 IP(I+12)=IT(I)
      INXDY=NOV(1)
      NCARD(2)=ICARD(1)
      NCARD(1)=ICARD(2)
      GO TO 280
270 DO 275 I=1,24
275 IP(I)=IT(I)
      INXDY=NOV(2)
      NCARD(1)=ICARD(1)
      NCARD(2)=ICARD(2)
280 DO 281 I=1,24
      IF(IP(1).NE.NBB) GO TO 281
      WRITE(IOUT,3010) IYR,IMO,IDY,(IP(J),J=1,24),INXDY
      GO TO 282
281 CONTINUE
282 IF(IYY.EQ.NNN.AND.IP(1).NE.KKK.AND.IP(1).NE.NNN) GO TO 283
      GO TO 284
283 IP(1)=KKK
      IND=1
284 DO 285 I=1,23
      IF(IP(I).EQ.NNN.AND.IP(I+1).NE.NNN.AND.IP(I+1).NE.KKK) GO TO 286
      GO TO 285
286 IND=1
      DO 287 J=1,24
287 JP(J)=IP(J)
      IP(I+1)=KKK
285 CONTINUE
      IF(IND.EQ.1) WRITE(IOUT,3015) IYR,IMO,IDY,(JP(J),J=1,24),INXDY
      IYY=IP(24)
      IND=0
      REWIND 10
      WRITE(10,2020)(IP(I),I=1,24)
      REWIND 10
      IF(MU.EQ.2) GO TO 290
      READ(10,2025)(X(I+I2),I=1,24)
      I2=I2+24
      GO TO 320
290 READ(10,2030) (X(I+I2),I=1,24)
      I2=I2+24
      GO TO 320

```

```

C *****
C
C 295 I2=I1+I2-ITT
C
C CHECK IF IT IS LAST DAY OF SPECIFIED SEASON
C
C IF(INXDY.EQ.1.AND.IMO.EQ.M2) GO TO 405
C IF(INXDY.EQ.1.AND.IMO.EQ.LHR.AND.IYR.EQ.LYR) GO TO 405
C GO TO (300,310,250),NN1
C
C *** INPUT HOURLY PRECIPITATION DATA
C 300 DO 305 II=1,I2
C READ(IN2,2035)IYR,IMO,IDY,(X(I+I2),I=1,I2),INXDY
C 305 I2=I2+12
C ***
C
C GO TO 320
C
C *** INPUT HOURLY PRECIPITATION DATA
C 310 DO 315 II=1,I2
C READ(IN2,2040)IYR,IMO,IDY,(X(I+I2),I=1,I2),INXDY
C 315 I2=I2+12
C ***
C 320 I1=ITT*(INXDY-IDY)
C
C IF(I1.GT.0) GO TO 295
C GO TO(325,335,325,330,325,330,325,325,330,325,330,325),IMO
C 325 NUMDY=31
C GO TO 340
C 330 NUMDY=30
C GO TO 340
C 335 X1=IYR
C X2=)YR/4
C X3=X1/4.
C IF(X2.EQ.X3) NUMDY=29
C IF(X2.NE.X3) NUMDY=28
C 340 I1=(NUMDY+1-IDY)*ITT
C GO TO 295
C
C IDENTIFY EACH RAINSTORM AND COMPUTE ITS DURATION, TOTAL DEPTH
C
C 405 LC=0
C MC=1
C NC=1
C DO 430 JD=1,12
C 430 AQ(JD)=0.
C DO 475 I=1,I2
C IF(X(I).GT.0.) GO TO 410
C IF(NC.NE.MC) GO TO 420
C GO TO 475
C 410 IF(LC.GT.0) GO TO 415
C NC=MC+1
C 415 LC=LC+1
C D(LC)=X(I)
C IF(I.EQ.I2) GO TO 420
C GO TO 475
C 420 IF(LC.GE.1.AND.LC.LE.12) GO TO 500
C GO TO 474
C 500 DO 505 J=1,LC
C J1=LC-J+1
C DO 504 J2=1,J1
C J3=J2+J-1
C SUM=0.
C DO 503 J4=J2,J3
C 503 SUM=SUM+D(J4)
C IF(SUM.GT.AQ(J)) AQ(J)=SUM
C 504 CONTINUE
C 505 CONTINUE

```

```

MC=MC+1
474 LC=0
475 CONTINUE
KY=KY+1
OO 480 ID=1,12
480 Q(KY, ID)=A(I, ID)
YEAR(KY)=IYR
C CHECK IF IT IS THE LAST YEAR OF THE PERIOD TO BE ANALYZED
C
485 IF(IYR.LT.LASTYR) GO TO 125
WRITE(IOUT,4000) NAMON(IMR),IYER,NAMON(LMR),LYR
NMT3=M1
NMT4=M2
WRITE(IOUT,4001) NAMON(NMT3),NAMON(NMT4),IFIRST,LASTYR
IF(IMR.LE.M1) GO TO 502
IMR1=IMR-1
WRITE(IOUT,4002) NAMON(NMT3),NAMON(IMR1),IYER
502 IF(LMR.GE.M2) RETURN
LMR1=LMR+1
MNM0=MONTH(NM0)
WRITE(IOUT,4002) NAMON(LMR1),NAMON(MNM0),LYR
4000 FORMAT(/10X,16LENGTH OF RECORD,3X,A3,3H 19,I2,3H - ,
1 A3,3H 19,I2,/)
4001 FORMAT(/10X,15HPERIOD ANALYZED,3X,A3,3H - ,A3,1H,,3H 19,
1 I2,3H - ,2H19,I2,/)
4002 FORMAT(/10X,29HPARTIAL SEASON : NO DATA FOR ,
1 A3,3H - ,A3,3H 19,I2,/)
RETURN
2005 FORMAT(16,3I2,1X,12F3.2,29X,I2)
2010 FORMAT(16,3I2,1X,12F3.1,29X,I2)
2015 FORMAT(16,3I2,I1,12A3,29X,I2)
2020 FORMAT(24A3)
2025 FORMAT(24F3.2)
2030 FORMAT(24F3.1)
2035 FORMAT(6X,3I2,1X,12F3.2,29X,I2)
2040 FORMAT(6X,3I2,1X,12F3.1,29X,I2)
3005 FORMAT(22H** REVERSED DATA ** 19,I2,2I4)
3010 FORMAT(21H** MISSING DATA ** 19,I2,2I4,5X,24A3,10X,I2)
3015 FORMAT(25H** ACCUMULATED DATA ** 19,I2,2I4,5X,24A3,10X,I2)
END
C
SUBROUTINE RANK (QMAX,JJ,RNK,NN)
C
DIMENSION FLOW(99), RNK(99), QMAX(99)
INTEGER RNK
DO 1 I=1,JJ
1 FLOW(I)=QMAX(I)
N=1
DO 4 K=1,NN
DO 3 I=1,JJ
IF (FLOW(I).GE.FLOW(N)) GO TO 2
GO TO 3
2 RNK(K)=I
N=RNK(K)
3 CONTINUE
FLOW(N)=0.
4 CONTINUE
DO 5 I=1,NN
N=RNK(I)
5 FLOW(I)=QMAX(N)
DO 6 I=1,NN
6 QMAX(I)=FLOW(I)
RETURN
END

```

```

C
SUBROUTINE FIT (K,Q,SLOPE,INTCPT,SE,STDD,CORCOF,N,MEAN,NL)
C
DIMENSION K(99), Q(99)
REAL K,INTCPT,MEAN
J=1
M=N
IF (NL.EQ.2) GO TO 2
A=0.
B=0.
C=0.
D=0.
DO 1 I=J,N
  A=A+K(I)
  B=B+Q(I)
  C=C+K(I)*Q(I)
  D=D+K(I)*K(I)
1 E=A*A-M*D
  SLOPE=(A*B-M*C)/E
  INTCPT=(A*C-D*B)/E
2 CONTINUE
B=0.
C=0.
DO 3 I=J,N
  B=B+Q(I)
3 BB=B/M
  MEAN=BB
  DO 4 I=J,N
  C=C+(Q(I)-BB)*(Q(I)-BB)
  STDD=SQRT(C/(M-1))
  IF (NL.EQ.2) INTCPT=MEAN
  IF (NL.EQ.2) SLOPE=STDD
  A=0.
  B=0.
  DO 5 I=J,N
  A=A+(SLOPE*K(I)+INTCPT-Q(I))*(SLOPE*K(I)+INTCPT-Q(I))
  B=B+(SLOPE*K(I)+INTCPT-BB)*(SLOPE*K(I)+INTCPT-BB)
5 SE=SQRT(A/(M-2))
  CORCOF=SQRT(B/C)
  RETURN
  END
C
SUBROUTINE DESIGN (T,SLOPE,INTCPT,M,MU,IOUT)
C
REAL K,INTCPT
DIMENSION UNIT(2)
DATA UNIT/3HIN.,3MM./
IF (M.EQ.1) GO TO 1
K=(SQRT(6.)/3.14159)*(ALOG(10.)*ALOG10(T)-0.5772157)
Q=SLOPE*K+INTCPT
GO TO 2
1 Z=ALOG(T)-ALOG(T-1.)
  K=-(SQRT(6.)/3.14159)*(0.5772157+ALOG(Z))
  Q=SLOPE*K+INTCPT
2 CONTINUE
WRITE (IOUT,902) T,K,Q,UNIT(MU)
RETURN
902 FORMAT (1X,13HMAGNITUDE OF ,F4.0,7HYR. (K=,F7.4,12H) RAINFALL =,
1 F8.3,1X,A3/)
  END
C
SUBROUTINE RESULT (SLOPE,INTCPT,SE,STDD,CORCOF,MEAN,M,NM,MU,IOUT)
C
REAL INTCPT,MEAN
DIMENSION UNIT(2)
DATA UNIT/3HIN.,3MM./
IF (M.EQ.2) GO TO 6

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```

WRITE (IOUT,901)
WRITE (IOUT,903) INTCPT,UNIT(MU)
WRITE (IOUT,902) SLOPE,UNIT(MU)
WRITE (IOUT,904) SE,UNIT(MU)
WRITE (IOUT,906) CORCOF
RETURN
6 CONTINUE
WRITE (IOUT,910)
IF (MM.EQ.2)GO TO 8
WRITE (IOUT,911) MEAN,UNIT(MU)
WRITE (IOUT,912) STDD,UNIT(MU)
WRITE (IOUT,904) SE,UNIT(MU)
WRITE (IOUT,906) CORCOF
RETURN
8 CONTINUE
B=EXP(2.302585*MEAN)
WRITE (IOUT,914) MEAN,B,UNIT(MU)
WRITE (IOUT,915) STDD
WRITE (IOUT,916) SE
WRITE (IOUT,906) CORCOF
RETURN
901 FORMAT (//20X,31HRESULTS USING LEAST SQUARES FIT/20X,31(1H-))
902 FORMAT (1X,29HSLOPE OF LEAST SQUARES LINE =,F10.2,1X,A3/)
903 FORMAT (1X,33HINTERCEPT OF LEAST SQUARES LINE =,F10.3,1X,A3/)
904 FORMAT (1X,28HSTANDARD ERROR OF ESTIMATE =,F10.3,1X,A3/)
906 FORMAT (1X,25HCORRELATION COEFFICIENT =,F7.4/)
907 FORMAT (1X,29HSLOPE OF LEAST SQUARES LINE =,F10.5/)
908 FORMAT (1X,33HINTERCEPT OF LEAST SQUARES LINE =,F10.5,2X,1H=,F10.2
1,1X,A3/)
909 FORMAT (1X,28HSTANDARD ERROR OF ESTIMATE =,F10.5/)
910 FORMAT (//20X,48HRESULTS USING SAMPLE MEAN AND STANDARD DEVIATION/
120X,48(1H-))
911 FORMAT (1X,13HSAMPLE MEAN =,F10.3,1X,A3/)
912 FORMAT (1X,27HSAMPLE STANDARD DEVIATION =,F10.3,1X,A3/)
914 FORMAT (1X,13HSAMPLE MEAN =,F10.5,2X,1H=,F10.3,1X,A3/)
915 FORMAT (1X,27HSAMPLE STANDARD DEVIATION =,F10.5/)
916 FORMAT (1X,28HSTANDARD ERROR OF ESTIMATE =,F10.5/)
END
C
SUBROUTINE KP (K,N,PP,G)
C
DIMENSION K(99), PP(99)
COMMON BB,W,C,SQRTC,GG
REAL MEAN,K
EXTERNAL F
RERR=1.0E-6
GG=G
AERR=0.
C=4./(G*G)
RR=C-1.
SQRTC=SQRT(C)
IF (ABS(G).LE.0.5) W=ALGAMA(C)
IF (ABS(G).GT.0.5)W=GAMMA(C)
IF (IER.EQ.129.OR.IER.EQ.130) STOP
I=1
1 CONTINUE
P=1.-1./PP(I)
IF (G.LT.0.) P=1./PP(I)
K(I)=-.7797*(.5772+ALOG(ALOG(PP(I))-ALOG(PP(I)-1.)))
IF (G.LT.0) K(I)=-.7797*(.5772+ALOG(ALOG(PP(I)/(PP(I)-1))-ALOG(1/(
1PP(I)-1))))
A=-SQRTC+1E-13
IF (K(I).LE.A)K(I)=A
B=K(I)
S=NCADRE(F,A,B,AERR,RERR,ERROR,IER)
2 CONTINUE

```

```

      Y=F(B)
      DK=(P-S)/Y
      IF (ABS(DK).LT.1.)GO TO 350
      IF (DK.LT.0.)DK=-1.
      IF (DK.GE.0.)DK=1.0
350  CONTINUE
      DF=F-S
      IF (ABS(DF).LT.0.000001)GO TO 3
      A=B
199  IF ((B+DK).GT.-SQRTC)GO TO 200
      DK=DK/2.
      GO TO 199
200  CONTINUE
      B=B+DK
      DS=DCADRE(F,A,B,AEERR,RERR,ERROR,IER)
      S=S+DS
      K(1)=K(I)+DK
      GO TO 2
3  CONTINUE
      K(I)=K(I)+DK
      IF (G.LT.0.) K(I)=-K(I)
      IF (I.EQ.N) RETURN
      I=I+1
      GO TO 1
      END
      FUNCTION F (X)
      COMMON BB,W,C,SQRTC,GG
      XRCPC=X*SQRTC+C
      IF (ABS(GG).LE.0.5)ARGL=ALOG(SQRTC)-W+BB*ALOG(XRCPC)-XRCPC
      IF (ABS(GG).GT.0.5)ARGL=SQRTC*XRCPC**BB/(W*EXP(XRCPC))
      IF (ABS(ARGL).LT.500.) GO TO 1
      F=1.E-30
      RETURN
1  CONTINUE
      F=EXP(ARGL)
      IF (ABS(GG).GT.0.5)F=ARGL
      RETURN
      END
C
      SUBROUTINE UERTST (IER,JUNK,IOUT)
C
      IF (IER.LT.128) RETURN
      WRITE (IOUT,1) IER
      RETURN
1  FORMAT(27H POSSIBLE ERROR IN K VALUE ,I3)
      END
/

```

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## FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.\*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

### *FCP Category Descriptions*

#### **1. Improved Highway Design and Operation for Safety**

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

#### **2. Reduction of Traffic Congestion, and Improved Operational Efficiency**

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

#### **3. Environmental Considerations in Highway Design, Location, Construction, and Operation**

Environmental R&D is directed toward identifying and evaluating highway elements that affect

the quality of the human environment. The goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

#### **4. Improved Materials Utilization and Durability**

Materials R&D is concerned with expanding the knowledge and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

#### **5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety**

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

#### **6. Improved Technology for Highway Construction**

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

#### **7. Improved Technology for Highway Maintenance**

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

#### **0. Other New Studies**

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

\* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (NEED-3), Office of Research and Development, Federal Highway Administration, Washington, D.C. 20593.