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	STANDARD PROJECT FLOOD DETERMINATION	
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STANDARD PROJECT FLOOD DETERMINATIONS

I. INTRODUCTION

1-01. REFERENCES.

a. Circular Letter No. 4262 (Civil Works No. 65), dated 20 November 1946, subject, Standard Project Flood Estimates, wherein original instructions concerning the preparation of standard project flood estimates were issued.

b. Orders & Regulations, paragraph 4208.11 (Revised Mar. 1951) wherein the preparation of standard project flood estimates for certain classes of projects is directed, and instructions are presented regarding the submission of certain estimates for approval of the Chief of Engineers prior to incorporation in project reports. (See quotation in para 4-02 herein).

c. Engineering Manual, Civil Works, Part CXIV, Chapter 5, subject, Flood-Hydrograph Analyses and Computations.

1-02. PURPOSE AND SCOPE OF THIS BULLETIN.

a. This bulletin reviews briefly principal classes of flood analyses and estimates involved in the planning and design of flood control and multiple-purpose projects, with the primary objective of indicating the general application and purposes of Standard Project Flood Estimates.

b. Generalized rainfall criteria and recommended procedures for the computation of standard project storm rainfall and rainfall-excess quantities for small drainage basins (classified herein as approximately 1,000 square miles and less) located east of 105° longitude, are presented, with a concise explanation of their derivation.

c. Procedures for derivation of SPS and SPF estimates for large drainage basins (exceeding approximately 1000 sq.mi.) are discussed and illustrated.

d. This bulletin is sub-divided into four Sections, as follows:

I. Introduction
II. Generalized SPS Estimates for Small Drainage Basins
III. SPS Estimates for Large Drainage Basins
IV. Projects for which SPF Estimates are Required.

1-03. SPECIFICATIONS OF A STANDARD PROJECT STORM (Abbrev. "SPS).

a. The "standard project storm" estimate for a particular drainage area and season of year in which snow-melt is not a major consideration should represent the most severe flood-producing rainfall depth-area-duration relationship and isohyetal pattern of any storm that is considered reasonably characteristic of the region in which the drainage basin is located, giving consideration to the runoff characteristics and existence of water regulation structures in the basin. In deriving standard project storm rainfall estimates applicable to seasons and areas in which melting snow may contribute a substantial volume of runoff to the standard project flood hydrograph, appropriate allowances for snow melt are included with and considered as a part of the standard project storm rainfall quantities in computing the SPF hydrograph. Where floods are predominatly the result of melting snow, the SPF estimate is based on estimates of the most critical combinations of snow, temperature and water losses considered reasonably characteristic of the region.

b. The term "storm" is used in a broad sense to mean any period or sequence of rainfall events that may contribute to critical flood events in the particular drainage basin under study.

c. The term "region" as used above is construed to include the area surrounding the given basin in which storm producing factors are substantially comparable; i.e., the general area within which meteorological influences and topography are sufficiently alike to permit adjustment of storm data to a common basis of comparison with practical degree of reliability. Such a "region" includes a very large area in the eastern half of the United States where relief is generally moderate, and relatively small areas in certain sections of the western United States where extreme topography is encountered.

d. A general comparison of maximum storms of record in the region, supplemented my meteorological investigations, serve as a basis in selecting rainfall criteria to represent the most severe storm that is considered "reasonably characteristic" of a region. Certain storms of extraordinary severity may be eliminated as too unusual and extreme to warrant adoption as the standard project storm.

1-04. STANDARD PROJECT FLOOD (Abbrev. "SPF")

a. In general terms, the standard project flood may be defined as a hydrograph representing runoff from the standard project storm (and/or snow melt) as defined in paragraph 1-03 a. The SPF may have more than a single peak if these are the result of runoff from the SPS.

b. Infiltration losses assumed in computing runoff from the SPS should correspond to those considered reasonably likely to occur during storms of such magnitude, estimated on the basis of data obtained from the analys s of rainfall-runoff relations in major floods of record.

c. The same principles referred to above should be followed in the selection of unit hydrographs, in flood routing computations, and in other calculations related to the development of the SPF hydrographs.

d. Appropriate allowances should be made for variations in the areal distribution and sequence of rainfall over the basin during the SPS. The SPS rainfall estimate should be prepared in suitable form to permit significant variations in areal distribution, sequence, and intensities to be taken into consideration in computing runoff hydrographs.

e. In some cases, particularly with respect to very large drainage basins, the Standard Project Flood hydrograph estimate may, of necessity, be based on a study of actual hydrographs or stages of record, or on other procedures not involving directly a SPS estimate. In such cases, the general principles and objectives presented for the development of SPF estimates from rainfall and run-off criteria should serve as a guide.

f. It is apparent from a study of depth-area-duration data for major storms, and general consideration of the relative opportunities for drainage basins of various sizes, shapes and locations to be subjected to rainfall occurrences of SPS category, that the statistical probability of SPF occurrence would vary with size of drainage area and other hydrometeorological factors. For these, and a number of other reasons that might be listed, it is not considered feasible to assign specific frequency estimates to SPF determinations in general.

g. Where only the highest peak discharge of a SPF hydrograph is pertinent to specific project studies, the SPF may be referred to by that peak discharge as a matter of convenience.

1-05. STANDARD PROJECT FLOOD SERIES

Practically all detailed studies of unusual storms completed to date have been limited to durations of 120 hours or less. In the development of standard project flood criteria for very large drainage basins or those in which reservoirs serve to modulate runoff rates to a substantial extent, it is necessary to consider runoff resulting from rainfall over a substantially longer period than 120 hours. In some cases, runoff for a period of weeks or months prior to the occurrence of an extraordinary 120-hour storm must be taken into account in studies related to specific projects. It is apparent that the computation of hypothetical hydrographs covering such an extended length of time, following procedures involving storm rainfall data and application of the unit hydrograph technique, would be very laborious and subject to many uncertainties as to proper basic assumptions and criteria. These difficulties can be circumvented satisfactorily in most cases by developing a "standard project flood series" in which hydrographs for periods antecedent to and subsequent to a standard project storm of 120-hours duration are represented by flows actually observed in the basin, with such adjustments as may be deemed appropriate after a general study of flood and storm characteristics in the region involved.

1-06. BASIC FLOOD ESTIMATES IN PLANNING AND DESIGN OF PROJECTS.

a. General. Flood magnitudes in a particular drainage basin are governed by combinations of many variable factors, the most important being the quantity, intensity, sequence and areal distribution of precipitation, the infiltration capacity of the soil, and natural and artificial storage effects during floods. Compensating variations in these several factors usually serve to reduce flood runoff rates and volumes to values far below those that would result from critical combinations of such factors. Where relatively long-period records of stream flow are available, statistical analyses of the record provide a valuable means of estimating the magnitude of flood flows that may be expected with frequencies bearing a reasonable relationship to the period of observation. Statistical studies involving consideration of flow records of numerous streams in a region of reasonably comparable hydrologic and meteorological influences provide more reliable estimates of maximum flood potentialities and average frequencies of commonly observed flood magnitudes than can be obtained from studies of individual station records. However, because of the number and range of variation in independent variables involved and the wide range between flood magnitudes that would result from optimum combinations of critical flood-producing factors as compared with combinations generally observed, statistical analyses of actual stream flow records seldom, if ever, provide a reliable indication of extraordinary flood potentialities of a specific drainage basin. Accordingly, in the planning and design of major engineering projects for the regulation of stream flow, statistical analyses of stream flow records must be supplemented by hypothetical flood estimates based on scientific studies of principal flood-producing factors individually and in various combinations.

b. In accordance with the preceding discussion, three classes of basic flood estimates are required in general flood control planning and design investigations:

(1) Statistical Analyses of Stream Flow Records, including flood-frequency estimates (preferably on a regionalized basis) and various correlations of flood characteristics and hydrologic features of the drainage basin.

(2) Standard Project Flood (Abbrev. SPF) Estimates representing flood discharges that may be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the geographical region involved, excluding extremely rare combinations.

(3) <u>Maximum Probable (or "Maximum Possible)" Flood Estimates</u> representing flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

c. Statistical Flood Studies of several types have proven useful in engineering investigations, the most prevalent consisting of flood-frequency estimates. Flood-frequency determinations are used primarily as a basis for estimating the mean annual benefits that may be expected from the control or reduction of floods of relatively common occurrence.

d. Standard Project Flood estimate serves the following primary purposes:

(1) Represents a "standard" against which the degree of protection finally selected for a project may be judged and compared with protection provided at similar projects in other localities. The SPF estimate must reflect a generalized analysis of flood potentialities in a region, as contrasted to an analysis of flood records at the specific locality that may be misleading because of the inadequacies of records or abnormal sequences of hydrologic events during the period of stream flow observation.

(2) Represent the flood discharge that should be selected as the design flood for the project, or approached as nearly as practicable in consideration of economic or other governing limitations, where some small degree of risk can be accepted but an unusually high degree of protection is justified by hazards to life and high property values within the area to be protected. Estimates completed to date indicate that SPF flood discharges are generally equal to 40 to 60 percent of "maximum probable" floods for the same basins.

e. <u>Maximum Probable (or Maximum Possible) Flood</u> estimates are applicable to projects where consideration is to be given to virtually complete security against potential floods. Applications of such estimates are usually confined to the determination of spillway requirements for high dams, but in unusual cases may constitute the design flood for local protection works where an exceptionally high degree of protection is advisable and economically obtainable.

1-07. DESIGN FLOOD

a. The term "design flood" refers to the flood hydrograph or peak discharge value finally adopted as the basis for design of a particular project or section thereof after full consideration has been given to flood characteristics, frequencies, and potentialities, and the economic and other practical considerations entering into selection of the design discharge criteria. The term "design flood" is synonymous with "project design flood", although use of the latter term has been generally discontinued in order to avoid possible confusion with the term "standard project flood". For convenience in reference, such terms as "spillway design flood", "levee design flood", "channel design flood", etc., are used where appropriate.

b. The term "design flood" or "reservoir design flood" may be applied to the most severe flood that a particular reservoir may be capable of controlling under an adopted plan of operation but such usage has little value except where the reservoir is provided primarily for protection of damage centers near the dam. Usually selection of the flood control allocation in a reservoir is governed by consideration of flood control effects at several locations downstream, involving the analysis of a number of flood situations. Accordingly, application of the term "design flood" or "reservoir design flood" should be limited to those cases in which the term is actually indicative of the basis for a flood control storage allocation, more detailed criteria being specified for other cases.

1-08. RELATION OF SPF TO DESIGN FLOOD

a. In the design of flood control projects it would of course be desirable to provide protection against the maximum probable flood, if this were feasible within acceptable limits of cost. However, it is seldom practicable to provide absolute flood protection by means of local protection projects or reservoirs: - usually the costs are too high, and in many cases the acquisition of adequate rights-of-way for the purpose would involve unreasonably destruction or modifications of properties along the floodway. As a rule, some risk must be accepted in the selection of design flood discharges. A decision as to how much risk should be accepted in each case is of utmost importance and should be based on careful consideration of flood characteristics and potentialities in the basin, the class of area to be protected, and economic limitations.

b. The "design flood" for a particular project may be either greater or less than the standard project flood, depending to an important extent upon economic factors and other practical considerations governing the selection of design capacity in a specific case. However, selections should not be governed by estimates of average annual benefits of a tangible nature alone, nor should construction difficulties that may prove troublesome but not insurmountable be allowed to dictate the design flood selection, particularly where protection of high class urban or agricultural areas is involved. Intangible benefits, resulting from provision of a high degree of security against floods of a disastrous magnitude, including the protection of human life, must be considered in addition to tangible benefits that may be estimated in monetary terms.

c. The Standard Project Flood is intended as a practicable expression of the degree of protection that should be sought as a general rule in the design of flood control works for communities where protection of human life and unusually high-valued property is involved. Inasmuch as SPF estimates are to be based on generalized studies of meteorologic and hydrologic conditions in a region, the SPF estimates provides a basis for comparing the degree of protection provided by flood control projects in different localities, thus promoting a more consistent policy with respect to selection of design flood giving a comparable degree of protection for similar classes of property.

II. GENERALIZED SPS ESTIMATES FOR SMALL DRAINAGE BASINS

2-01. GENERAL

a. The criteria presented in this section apply specifically to drainage areas east of 105° longitude and primarily to basins less than approximately 1000 square miles in area. The rainfall criteria are basined primarily on analysis of major storms of record that have occurred in the spring, summer and fall seasons, during which convective activity is prominent. The criteria are not generally applicable to snow seasons without special adjustments. Inasmuch as records indicate that the most severe (but not necessarily the most frequent) floods in drainage areas of less than a few thousand square miles, within the area covered by the generalized charts, usually result from intense rainfall during the non-snow season, the criteria presented hereinafter are considered applicable in the computation of SPF estimates for most basins. Where this conclusion is not considered applicable by the reporting engineer, development of the SPS estimate should be based on a special study of flood producing factors affecting the particular basin. It is anticipated that such exceptions will apply only where runoff from snow melt, with or without coincident rainfall, is a major factor in the production of unusual floods.

b. Various approaches to the standardization of methods and criteria related to the computation of SPS and SPF estimates have been studied during the past two years. Because of the variability of factors involved, limitations in basic data, and th nature of the problem, certain arbitrary assumptions and simplifications of criteria have been necessary to obtain results suitable for practical use. Although any standardization of criteria must involve certain approximations, it has been concluded that adoption of generalized rainfall criteria substantially as presented herein is advisable for the purpose of assuring consistency between SPF estimates prepared by various offices, as well as to minimize work required in the preparation of estimates.

c. The development of generalized SPS rainfall criteria for drainage areas less than approximately 1000 square miles, located east of 105° longitude, is revealed generally by the explanation of plates in the following paragraph.

2-02. EXPLANATION OF PLATES

a. Plate 1. Generalized Estimates, Maximum Possible Precipitation. The isohyets on this chart represent the maximum probable 24-hour rainfall over 200 square miles area, as estimated by the Hydrometeorological Section of the U. S. Weather Bureau and explained in HMS Report No. 23.

b. Plate 2. SPS Index Rainfall. The isohyetes on Plate 2 represent the maximum average depth of rainfall in 24 hours over 200 square miles during the standard project storm, which is equal to approximately 40 to 60 percent of the maximum possible rainfall indicated on Plate 1, with a general average of about 50 percent. Plate 2 was prepared by reducing isohyets on Plate 1 to 50 percent of original values and reshaping the isohyets in certain regions by moderate amounts to conform with supplementary studies of rainfall characteristics in those regions During development studies similar charts were prepared for selected areas ranging from 10 to 20,000 square miles and storm durations from 6 to 96 hours. It was found that depth-area-duration values for these several charts bore a reasonably consistent relationship to values shown on Plate 2. Accordingly, Plate 2 was adopted as the "SPS Index Rainfall" chart, the use of which is explained hereinafter.

c. Plate 3. SPS Index Rainfall Isohyets vs Actual Storm Values. This chart shows graphically a comparison between the selected SPS Index Rainfall isohyets and rainfall values recorded during actual storms in various geographical locations for comparable durations and areas. Data from all storm studies completed to date (approx, 400) are shown on the chart.

d. Plate 4. Ratio of Actual Storm Values to SPS Index Rainfall. In Figure (a) of Plate 4 the rainfall values recorded in actual storms, as shown on Plate 3, are plotted against values indicated by SPS Index Rainfall isohyets for corresponding geographical locations. The number of actual storm values exceeding various percentages of the SPS Index Rainfall are shown graphically in Figure (a) and the percentages of actual storm values that equalled or exceeded various SPS Index Rainfall ratios are indicated in Figure (b). To demonstrate the relative consistency of relationships in different geographical areas, separate curves are plotted in Figure (b) for four areas, delineated by SPS Index Rainfall isohyets as indicated on Plate 4, as well as for the total area east of 105° longitude. It may be observed that on the average approximately 10 percent of the storms studied to date have equalled or exceeded the SPS Index Rainfall. This percentage will of course vary as additional storm studies are completed, but serves to illustrate that the standard project storm is not of unprecedented magnitude regionally, although it is definitely of a major category.

e. Plate 5. Tabulation, Precipitation During Major Storms of Record, Expressed in Percent of SPS Index Rainfall. In preparing this table the geographical location of maximum rainfall during each storm of record was determined by 2-degree latitude-longitude quadrangles, and the corresponding SPS Index Rainfall value was scaled from Plate 2; the average depths of rainfall over selected areas in various periods of time were obtained for the Corps of Engineers publications entitled "Storm Rainfall in the Eastern United States", and converted to percent of SPS Index Rainfall, as shown in Plate 5. For study purposes, the data were tabulated by geographical zones as delineated on Plate 2. Plate 5 includes 105 of the more outstanding storms of the 400 investigated in detail.

f. Plate 6. Generalized Depth-Area-Curves, 24-Hour Rainfall. Considering all storms tabulated in Plate 5, the 24-hour values of Index Rainfall Ratios (i.e. Percent of Index Rainfall) were arranged in order of diminishing magnitude for each of the areas designated in the column headings of Plate 5. The number of Index Rainfall Ratios exceeding various values was determined and converted to percent of the total number of storms studies (approx. 400). The curve on Plate 6 designated as "Maximum Observed" was obtained by plotting the highest value of Index Rainfall Ratio for each area and drawing a smooth curve to envelope the plotted points. The set of curves number 1E, 5E, and 10E was obtained by plotting for each selected area the values of Index Rainfall Ratio equalled or exceeded by 1 percent, 5 percent, and 10 percent, respectively, of the total number of values. For purpose of comparison, the set of curves designated as 1A, 5A, 10A, 25A and 50A were obtained by plotting the mean of the highest 1 percent, 5 percent, 10 percent, etc., of the Index Rainfall Ratios for the selected areas.

g. Plates 7 and 8. These Plates were prepared in the same manner as Plate 6, using data applicable to 48-hour and 96-hour storm periods, respectively.

h. Plates 9. SPS Depth-Area-Duration Relationships by 24-Hour Storm Increments. Following a general review of the problem and data analyzed, Curves Nos. 25A on Plates 6, 7, and 8 were selected as indices to the volume of precipitation that should be assumed as occuring in 24, 48, and 96-hour periods of Standard Project Storms. Plate 9 represents a replotting of Curves 25A from Plates 6, 7, and 8, with an interpolated curve for the 72-hour duration, for convenience in use. Applications of the cures in preparing SPS estimates for basins of various sizes are discussed hereinafter.

i. Plate 10. Time-Distribution of 24-Hour SPS Rainfall. In developing Plate 10, charts similar to Plate 2 were prepared from data recorded in actual storms to represent the maximum rainfall in 6 and 12 hours, respectively, over selected areas of less than 1000 sq.miles Correlations of maximum 6-hour and 12-hour rainfall values with the SPS Index Rainfall values for various geographical locations resulted in curves substantially as indicated in Fig (a) of Plate 10. Supplementary studies using different methods of approach substantiated the results obtained by the first method within acceptable limits of variation. A relatively extensive study of hydrographs of actual storms showed that the maximum 6-hour rainfall may occur near the beginning, middle or end of the maximum 24-hour rainfall period of a storm. Accordingly, the sequence of 6-hour rainfall increments indicated in Fig (b) of Plate 10 was selected for SPS estimates applicable to drainage areas of approximetely 1000 sq.mi. and less, on the basis that such a sequence would produce critical runoff from most basins. Procedures for estimating time-distribution of rainfall in SPS estimates for drainage basins larger than approximately 1000 sq.mi. are outlined hereinafter.

j. Plate 11. Time-Distribution of Maximum 6-Hour SPS Rainfall Analyses of major storms approaching SPS intensities over areas of a few hundred square miles or larger show that the rate of rainfall is usually fairly uniform during the maximum 6-hour period of the storm, with exception of intermittent short-period variations which usually produce only small variations in stream-flow rates at downstream points after valley storage has modulated local variations in surface runoff. Rainfall rates during less intense 6-hour periods of the storm are generally more erratic, and may follow many different sequences and rate changes in different storms. However, studies indicate that assumption of uniform rainfall intensities during successive 6-hour periods of the SPS, with exception of the maximum 6-hr. period of SPS estimates applicable to small drainage basins, would give satisfactory flood discharge estimates if reasonable conservatism is exercised in estimating infiltration losses and unit hydrographs. In order to assure safe estimates of peak discharges to be expected from SPS rainfall over drainage areas less than approximately 300 square miles on the average, the maximum 6-hour rainfall of the SPS should be broken down into shorter unit periods and higher intensities assumed for the shorter intervals according to criteria presented on Plate 11.

k. Plate 12, SPS Isohyetal Pattern. Studies of isohyetal patterns resulting from storms in which the maximum 6 or 12-hour rainfall is generally comparable to SPS values reveal that the patterns over a few thousand square miles or less are usually elliptical in shape and that the longer axis may be oriented in any direction, unless topographical influences are pronounced. Within these general limits, a wide variety of patterns might be selected with equal validity. To simplify SPS computations in which areal distribution of precipitation has an important influence on run-off rates and volumes, a typical isohyetal pattern is presented on Plate 12. The application of this isohyetal pattern is explained later.

l. Plates 13, 14 and 15. These relate to illustrative examples, as discussed hereinafter.

2-03. PREPARATION OF SPS ESTIMATES FOR SMALL DRAINAGE BASINS (LESS THAN 1000 SQ. MI.)

a. General. The preparation of a SPS estimate for a small drainage basin utilizing generalized criteria presented on Plates 2 and 9 to 12 involves the following steps:

(1) Interpolate from generalized isohyets on Plate 2 the SPS index rainfall corresponding to the location of the drainage basin under study (referred to hereinafter as "project basin").

(2) Enter Plate 9 with the SPS Index Rainfall value determined in step (1) to obtain the SPS Index Rainfall Ratios corresponding to 24, 48, 72 and 96-hour periods and an area equal to the total area of the project basin. Multiply these ratios by the SPS Index Rainfall to obtain average depths of rainfall within an isohyetal area equal to the drainage area of the project basin, and determine incremental 24-hour values by subtraction.

(3) Arrange the 24-hour SPS rainfall values determined in step (2) in a sequence favorable to production of critical runoff at project locations under consideration, based on a general appraisal of hydrologic conditions in the project basin.

(4) Prepare an overlay of the isohyetal map shown on Plate 12, converting the isohyet values to inches of 96-hour SPS rainfall by multiplying the percentage values on Plate 12 by the SPS index Rainfall value determined in step (1).

(5) Superimpose the project basin outline over the total-storm isohyetal map obtained in step (4), and planimeter to determine the average depth of total-storm rainfall over the basin and each sub-division thereof that is to be considered in estimating the SPS rainfall-excess and runoff rates.

(6) Subdivide the total-storm SPS rainfall values obtained in step (5) into 6-hour values in accordance with criteria presented on Plate 10. The same sequence and 6-hourly percentage distribution of rainfall is assumed for each day of the SPS.

(7) If the computed value of "t_p" for the drainage are under study, or important subdivisions thereof for which SPF discharges are desired, is less than 16 hours, subdivide the maximum 6-hour SPS rainfall value of the maximum 24-hour rainfall into shorter unit durations in accordance with criteria presented on Plate 11. (See p. 11 of reference cited in paragraph 1-01 for explanation of "t_p" and method of computation).

(8) Subtract estimated infiltration losses from SPS Rainfall values obtained in steps (6) and (7) to obtain rainfall-excess quantities to be used with unit hydrographs in computing SPF discharges.

b. Simplification of Procedure in Special Cases. If analyses of rainfall and runoff records in the project basin or comparable watersheds indicate that infiltration capacities over the basin are relatively uniform, and subdivision of the drainage basin for hydrologic reasons is not otherwise required for project study purposes, the general procedure outlined above may be simplified by omitting preparation of the isohyetal pattern referred to in step (4), simply using the depth-area curve values obtained in step (3), without correction for basin shape.

c. Illustrative Example: Computation of SPS rainfall for a sample drainage basin following the steps outlined in subparagraph a above is demonstrated on Plate 14. The drainage basin and isohyetal overlay (step 4) are shown on Plate 13. In this case, the existence of a flood-control reservoir in the area is assumed in order to demonstrate the centering of the storm over the uncontrolled area and the computation of rainfall for the controlled and uncontrolled areas separately. Explanation of the computation is as follows:

(1) Lines 1 to 5 establish the index rainfall and the magnitude and time arrangement of 24-hour rainfall amounts that would be obtained for the entire basin without reduction for the fact that the storm isohyets do not conform to the shape of the basin.

(2) Lines 6 to 12 incorporate the adjustment required for basin shape and the subdivision of rainfall among sub-basins. These lines can be eliminated where these refinements are not required. Values given in lines 6 to 8 were obtained by planimetering isohyets on Plate 13. Values of line 9 are those of line 5 divided by the total-storm rainfall (15.7 inches). Values of lines 10 to 12 are obtained by multiplying values of line 5 by those of lines 6 to 8 respectively.

(3) Lines 13 to 21 establish the hyetographs for each area. Six-hour percentage of maximum 24-hour rainfall obtained from Plate 10, are applied to each successive 24-hour period of rainfall. These are multiplied by respective values in lines 10-12 to obtain 6-hour rainfall amounts in lines 14 to 16. The tabulation on Plate 13 indicates that t_R is 3 hours in this case (see Plate 11). Appropriate percentages of maximum 6-hour rainfall in 3-hour intervals shown on Plate 11 are entered in line 18, Plate 14. These are multiplied by the respective values of the 66-hour column, lines 14 to 16, to obtain 3-hour amounts on lines 19 to 21.

(4) Lines 22 to 29 establish rainfall excess amounts. Infiltration losses (lines 22 and 23) are subtracted from rainfall amounts for the sub-areas A and B to obtain rainfall excess amounts for those sub-areas (lines 24 and 25). These are converted to volumes (lines 26 and 27, and are added to obtain rainfall-excess volumes for the total area (line 28). These volumes divided by the total area yield average rainfall-excess depths for the total area (line 29). Values of line 24 and 25 would be used in conjunction with unit hydrographs for the subareas in this case because of the existence of a flood-control reservoir at the lower end of area A. In cases where subdivision of the area is made only to account for areal differences in loss rates, values of line 29 can be used in conjunction with a unit hydrograph for the entire area.

2-04. APPROXIMATION OF SPF AS PERCENTAGE OF MAXIMUM PROBABLE FLOOD. As stated in sub-paragraph 1-06 d (2), estimates completed to date indicate that SPF discharges based on detailed studies usually equal 40 to 60 percent of the maximum probable (or "maximum possible") flood for the same basin; a ratio of 50 percent is considered representative of average conditions. Inasmuch as computation of maximum probable flood estimates are normally required as the basis of design of spillways for high dams, it is convenient to estimate the SPF for reservoir projects as equal to 50 percent of the maximum probable flood hydrograph to avoid the preparation of a separate SPF estimate (see paragraph 1-05 and 3-02 d regarding SPF series). Accordingly, this convention is acceptable for reservoir projects in general. The rule may also be applied in estimating SPF hydrographs for basins outside of the region and range of areas covered by generalized charts presented herein where maximum probable flood estimates based on detailed hydrometeorological investigations have been completed. Where snow melt or extreme ranges in topography are major factors to be taken into consideration, it is appropriate to estimate the maximum probable flood hydrograph for the basin by considering optimum combinations of critical flood-producing factors and assuming the SPF hydrographs is equal to 50 percent of the maximum probable discharges. This approximation is based on the conclusion that critical conditions can be determined from analyses of meteorological and topographic influences, whereas a substantial period of hydrometeorological records are required to determine appropriate combinations of flood producing factors meeting SPF specifications.

III. SPS ESTIMATES FOR LARGE DRAINAGE BASINS

3-01. GENERAL. The basic principles involved in the preparation of SPS and SPF estimates for large drainage basins are the same as those applicable to basins less than 1000 square miles in area, which have been discussed in Section II. However, generalizations of criteria become more difficult as the size of area increases. Whereas SPF discharge estimates for small areas are usually governed largely by the maximum 6 or 12-hour rainfall associated with a severe thunderstorm situation, floods of SPF category on large drainage basins are generally the result of a succession of relatively distinct rainfall events. Although the intensity and quantities of rainfall are important factors in the production of a flood in a large drainage basin, the location of successive increments of rainfall in the basin, and the syncronization of intense bursts of rainfall with progression of runoff, are of equal or greater importance in many cases than quantity of total precipitation. For example, the total rainfall over the Kansas River basin during the period 25-31 May 1903, which produced an estimated peak discharge of 260,000 cfs on the Kansas River at Kansas City, was almost identical with the total precipitation that occurred over the basin 9-12 July 1951 to produce a peak discharge of 510,000 cfs. Other examples of a similar nature might be cited. Accordingly, selection of a SPS for a large basin cannot be predicated on a statistical analysis of precepitation quantities alone, but must be based on a review of hydrometeorological data for several outstanding storms of record in the basin and adjacent regions in relation to hydrologic characteristics of the basin under study. Consideration of major floods of record and historical account should also play an important part in the selection of SPF criteria and final estimate.

3-02. EXAMPLE: SPS ESTIMATE FOR CUMBERLAND RIVER ABOVE OLD HICKORY DAM SITE (11,700 SQ. MI.).

a. Selection of Model Storm for SPS Estimate. Following is a chronological outline of the procedure used:

(1) Using the Corps of Engineers publication "Storm Rainfall in the United States, Depth-Area-Duration Data", approximately 30 storms of record within a few hundred miles of the Cumberland basin were tentatively listed for transposition. To limit the number, only those storms that produced rainfall exceeding an average of 6 inches over 5,000 sq. mi. were included. The average depth of rainfall over 5,000 and 10,000 sq. mi. was listed for purpose of comparison.

(2) Following a preliminary inspection of data referred to above, it was evident that winter-season storms were predominantly the most severe for the area involved, and that ground conditions would be most favorable for flood runoff during the winter. Accordingly, the list of storms cited in sub-paragraph a was reduced by eliminating the less important Summer and Fall Storms, and also certain winter storms that did not show isohyetal patters oriented favorably for transposition to the Cumberland basin. The final list of 19 storms considered for transposition is shown in table A of Plate 15.

(3) The list of 19 storms was referred to the Hydrometeorological Section of the Weather Bureau for an opinion regarding transposibility and for an estimate of adjustment required. Two transpositions of the 5,000 sq. mi. center area of each storm were considered, one transposition being made to the lower Cumberland basin (center at Clarksville, Tenn.) and the other to the Upper basin (center at Burnside, Ky.) The transposition adjustment factors furnished by the Weather Bureau are listed in the 5th and 6th columns of Table A, Plate 15.

(4) In order to facilitate a comparison of the relative magnitudes of rainfall quantities that might be expected over various size areas and in selected periods of time, the tabulation shown in Table A, Plate 15, was completed by multiplying the rainfall values observed in the respective storms by the average of the Clarksville and Burnside transposition factors.

(5) Inasmuch as rainfall values listed in Table A of Plate 15 represent average depths within isohyets that differ from the shape of the Cumberland watershed, adjustment for such differences is necessary to determine the quantity of rainfall that would fall on the watershed during the transposed storm. To minimize work, "basin shape" factors were computed only for the seven most important storms, as listed in Table B of Plate 15. The basin shape factor for each storm was determined by superimposing the basin outline over the total-storm isohyetal map prepared in the Part II Storm Study, planimetering to determine the average depth of rainfall within the basin outline, and dividing this value by the average rainfall depth for a corresponding size area as read from the maximum depth-area-curve for the storm. Results are listed in the 5th, 6th, and 7th columns of Table B, Plate 15.

(6) Depth-area-duration data for the seven most important storms included in the study, including adjustments for transposition and basin shape, are tabulated in Table B, Plate 15. Following a general comparison of data shown on Table B, consideration of seasonal characteristics of floods in the basin and the probable effects of reservoir operations on the regulation of runoff, the transposed and adjusted storm of 23-27 March 1913 (OR 1-15) was selected as the 120 hour SPS for the Cumberland basin above Old Hickory, Tenn.

(7) Average rainfall and rainfall-excess quantities for 7 sub-divisions of the drainage area were computed by 6-hour time intervals during the 120-hour SPS, as explained in paragraph 3-02 b.

(8) Criteria for the preparation of the SPF Series for the drainage area above Old Hickory, Tenn., were established in the manner explained in paragraph 3-02 d.

Footnote: Permissible rotation of isohyetal pattern was assumed as 20 degrees, but was less in the seven storms listed in Table B of Plate 15.

b. <u>Example: Computation of SPS Rainfall and Rainfall Excess for Cumberland River Basin above Old Hickory Dam Site.</u>

(1) The outline of the Cumberland basin was superimposed over the total-storm isohyetal map of the 23-27 March 1913 (OR 1-15 storm in the same position assumed in computing the "basin shape" factor referred to in sub-paragraph 3-02 a (5). Portions of the isohyetal map within each of seven sub-divisions of the basin were planimetered to determine the average depth of total-storm rainfall before adjustment for tranposition.

(2) The transposition adjustment factor for each of the seven sub-areas of the basin were interpolated on a straight line basis from values determined by the Hydrometeorological Section of the Weather Bureau, for Clarksville, Tenn., and Burnside, Ky. The total storm rainfall values computed for each of seven sub-areas were multiplied by the appropriate transposition factors to obtain the total-storm SPS precipitation for the area.

(3) Precipitation stations within the outline of the Cumberland basin as superimposed on the isohyetal map in step (1), and stations immediately adjacent thereto, were listed on Storm Study Form S-10, grouping the stations as they appeared in the sub-areas. The accumulative precipitation at each of these stations was then copied from the Form S-10 tabulations of the Part II Storm Study data.

(4) Average mass curves of unadjusted rainfall for the 23-27 March 1913 storm (OR 1-15) were computed by 6 hour intervals for each of the seven sub-areas of the basin, using data compiled in steps (1) and (3), following the same procedure used in computing average mass curves for "zones" in Part II Storm Studies (See Supplement C to Engineer Bulletin R&H No. 10, 1938 Form S-12). These average mass curve values were then adjusted to correspond to the SPS rainfall values for the respective sub-areas, and 6-hour increments of rainfall during the SPS were reduced from this curve.

(5) Rainfall-excess during successive 6-hour periods of the SPS were computed by subtracting losses corresponding to an infiltration index of 0.02 inch per hour, which conforms to values deduced from an analysis of a number of actual winter floods in the area.

c. <u>Variation in Procedure in Computing Rainfall-Excess.</u> In computing rainfall-excess values for the 120-hour SPS discussed in paragraph 3-02 b, 6-hour average losses over each sub-area were subtracted from 6-hour average rainfall values for the same composite area. Treatment of each sub-area as a unit was satisfactory in the particular study because of the very low infiltration index involved. However, in studies applicable to drainage basins of similar size in which infiltration losses are relatively high, rainfall-excess quantities should be computed for area sub-division corresponding to Thiessen polygons surrounding each precipitation station, in order that appropriate allowances may be made for areas not covered by rainfall exceeding losses during each period of the storm.

d. Example: SPF Series. The derivation of a "SPF Series" for the 11,700 sq. mi. drainage of the Cumberland River basin above Old Hickory, Tenn., covering a 4 ½ month period from 23 Dec to 7 May is outlined below:

(1) Flows for a three-month period antecedent to the SPF flood were assumed as equal to daily discharges recorded during the period from 23 Dec 1932 to 22 Mar 1933. The purpose of including the "antecedent" flows was to provide a concrete basis of determining the status in existing and anticipated reservoirs in the basin corresponding to runoff conditions considered reasonably likely to prevail prior to the SPF. Runoff during the three-month period selected was approximately 25 percent above the average observed for the months of January, February and March over a 29-year period of record from 1919 to 1947. The flows by months were also distributed fairly uniformly and variations were fairly representative of flood sequence observed during the period of record, excluding a few years of extraordinary flood occurrences. Although the general criteria adopted for selection of the "antecedent" flow data are in this case arbitrary and subject to appreciable variations on the basis of personal judgment, the procedure was adopted as an expedient in view of the necessity of taking into account the effects of antecedent conditions on routing of the SPF. It is apparent that the criteria followed will require variations in other circumstances, but it is believed that reasonable results may be obtained by exercise of judgment on the part of hydraulic engineers responsible for such studies.

(2) Flows for the 15-day period from 23 Mar to 7 Apr were computed from rainfall-excess estimates derived from the selected 120-hour standard project storm which was based on a transposition of the 23-27 Mar 1913 storm (OR 1-15) as discussed in paragraph 3-02 b.

(3) Flows for a 30-day period subsequent to the SPF were assumed as equal to daily discharge recorded during the period from 8 Apr to 7 May 1933. The 30-day period of flows "subsequent" to the SPF was included to permit a calculation of the time required to draw down the reservoirs if runoff should equal approximately the average observed for corresponding period over the period of record. In general, the derivation of a SPF Series is required only when runoff before or after the SPF is likely to influence conclusions reached by routing the SPF hydrograph thru storage.

3-03. USE OF SPS GENERALIZED DEPTH-AREA CURVES IN SELECTION OF STORMS FOR COMPARISON. The generalized curves and data shown on Plates 5 to 9, may be used in the selection of storms for detailed comparison in preparing SPS estimates for drainage basins up to 20,000 square miles, in lieu of the procedure outlined in sub-paragraph 3-02 a. In this manner the number of storms requiring detailed study to determine critical flood producing capabilities may be reduced to a small number. The remainder of the procedure should be substantially as outlined in paragraphs 3-02 b to 3-02 d.

IV. PROJECTS FOR WHICH SPF ESTIMATES ARE REQUIRED

4-01. GENERAL. The purpose to be served by SPF estimates are discussed briefly in paragraphs 1-06 and 1-08. In some cases the SPF estimate may have a major bearing on selection of the design flood for a particular project, whereas in other cases the estimate may serve only as an indication of the partial degree of protection proposed for the project. SPF estimates are useful in connection with practically all flood control investigations but to reduce the work required in project studies, preparation of SPF estimates is required only for those projects in which the proposed design flood is more than one of estimated 25-year frequency. To further reduce the work involved, approximate estimates are acceptable where it is apparent that the design flood is strictly limited by economic considerations and is substantially less than the SPF. The basis of SPF estimates should be clearly stated in each case.

4-02. ORDERS & REGULATIONS. For convenience in reference paragraph 4208.11 (Revised March 1951) is quoted below:

"Describe any "standard project flood" estimate established as a criterion in analyzing flood possibilities and flood control requirements, give the basis for its derivation and compare it with floods of record and the "design flood" finally selected as a basis for the project design. Standard project flood determinations will be prepared for local flood protection projects intended to protect against floods (greater than those) having an average frequency of exceedence in the order of once in 25 years, and such estimates will be submitted to the Chief of Engineers for approval prior to incorporation into the survey report. Standard project flood estimates will be prepared for flood control and multiple-purpose reservoirs, but such estimates need not be submitted to the Chief of Engineers for advance approval unless considered advisable by the reporting officer. Estimates will be prepared substantially in accordance with technical instructions issued by the Chief of Engineers".

4-03. MAJOR DRAINAGE PROJECTS. In accordance with the O&R cited above, SPF estimates will not be required for "major drainage" projects unless such projects serve also to provide protection against floods greater than those having average frequency of approximately once in 25 years.

4-04. LOCAL PROTECTION PROJECTS. SPF determinations are required for local protection projects included in survey reports that are intended to provide protection against floods greater than those having an average frequency of occurrence of approximately one in 25 years. SPF estimates should also be included in Definite Project Reports, design memoranda, and other special reports pertaining to the selection of design flood criteria for local protection projects; in the event estimates have been submitted to OCE in reports bearing specifically on SPF determinations, inclusion of appropriate references and summaries of results will suffice for report purposes, although inclusion of details pertaining to prior SPF estimates as a matter of record is desirable where this can be accomplished without undue expense.

4-05. RESERVOIR PROJECTS. In some instances SPF estimates serve as the primary basis for selecting the storage capacity of flood control reservoirs, and in such cases the estimate should be prepared with substantially the same care and detailed study observed in connection with determinations for local protection projects of comparable importance. However, in most cases selection of storage and outlet capacities for reservoirs are governed by considerations other than the SPF estimate, in which case the SPF estimate is of secondary importance and may be approximated satisfactorily by assuming that the SPF equals 50 percent of the spillway design flood for the project. (See para 2-04.).

4-06. SUBMISSION OF SPF ESTIMATES TO OCE FOR APPROVAL PRIOR TO INCORPORATION IN REPORTS.

a. All SPF estimates required for inclusion in survey reports under instructions discussed above should be submitted to OCE for approval prior to incorporation in the survey reports, with the following exceptions:

(1) SPF estimates for small drainage areas (less than approximately 1000 sq.miles) based on generalized rainfall criteria and procedures presented herein need not be submitted to OCE for advance approval unless the reporting officer considers advance approval advisable in specific cases.

(2) SPF estimates prepared for individual reservoirs need not be submitted to OCE for advance approval unless the estimate constitutes the primary basis for selection of the reservoir storage and outlet capacities.

b. With reference to SPF estimates related to Definite Project Reports and special studies, attention is invited to O&R, paragraph 4214.10 h, in which submission of appendices or portions of reports covering hydrologic features for advance approval by OCE is outlined. SPF estimates required under instructions presented above should be included in such advance submissions. In special cases, conferences should be arranged to permit review of SPF estimates and related hydrologic determinations that have a major bearing on the selection of design floods for important projects.

c. SPF estimates submitted for approval of OCE should be accompanied by supporting information, and a statement indicating the purpose of the particular estimate and the probable influence that the estimate will have on selection of the design flood for the project involved (See paragraph 4-01).

BY THE ORDER OF THE CHIEF OF ENGINEERS:

/s/ Stanley G. Reiff

/t/ STANLEY G. REIFF
Colonel, Corps of Engineers
Executive
Civil Works

2 Incls
1 List of Plates
2 Plates 1 - 15 incl.
Distribution: (C/L No. 4358)
F-1,2,3 and 5
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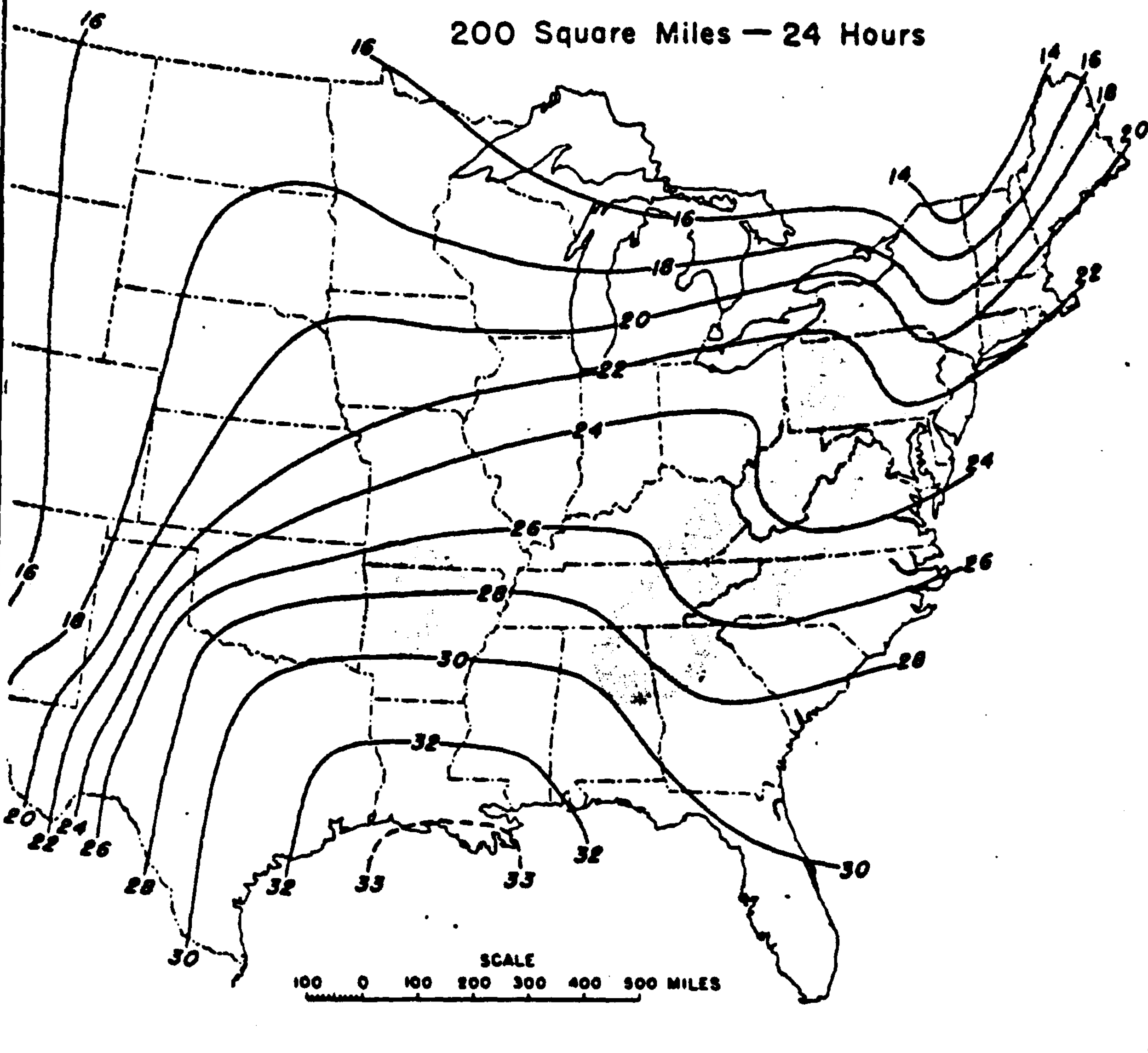
Civil Works Engineer Bulletin No. 52-8

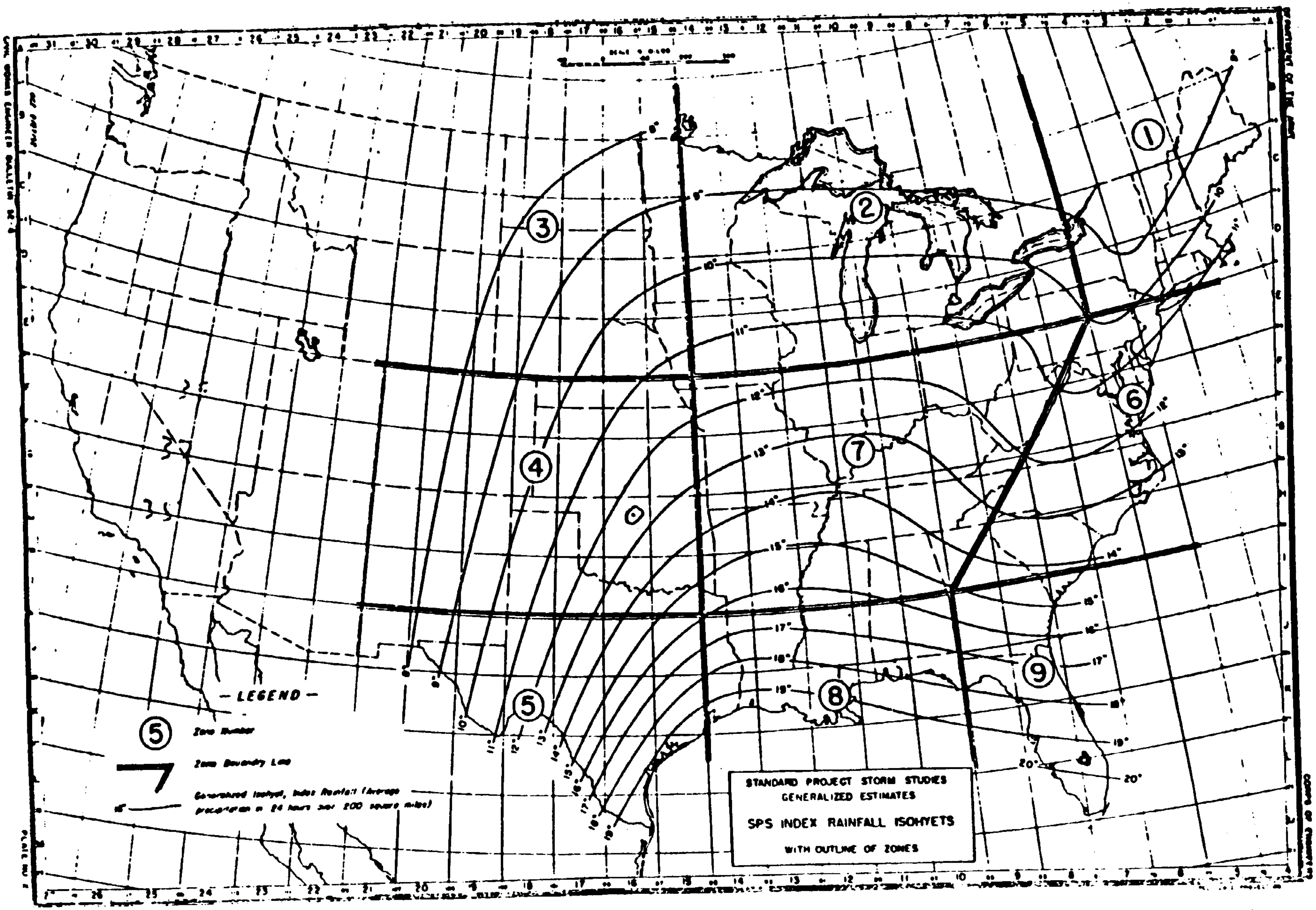
STANDARD PROJECT FLOOD DETERMINATIONS

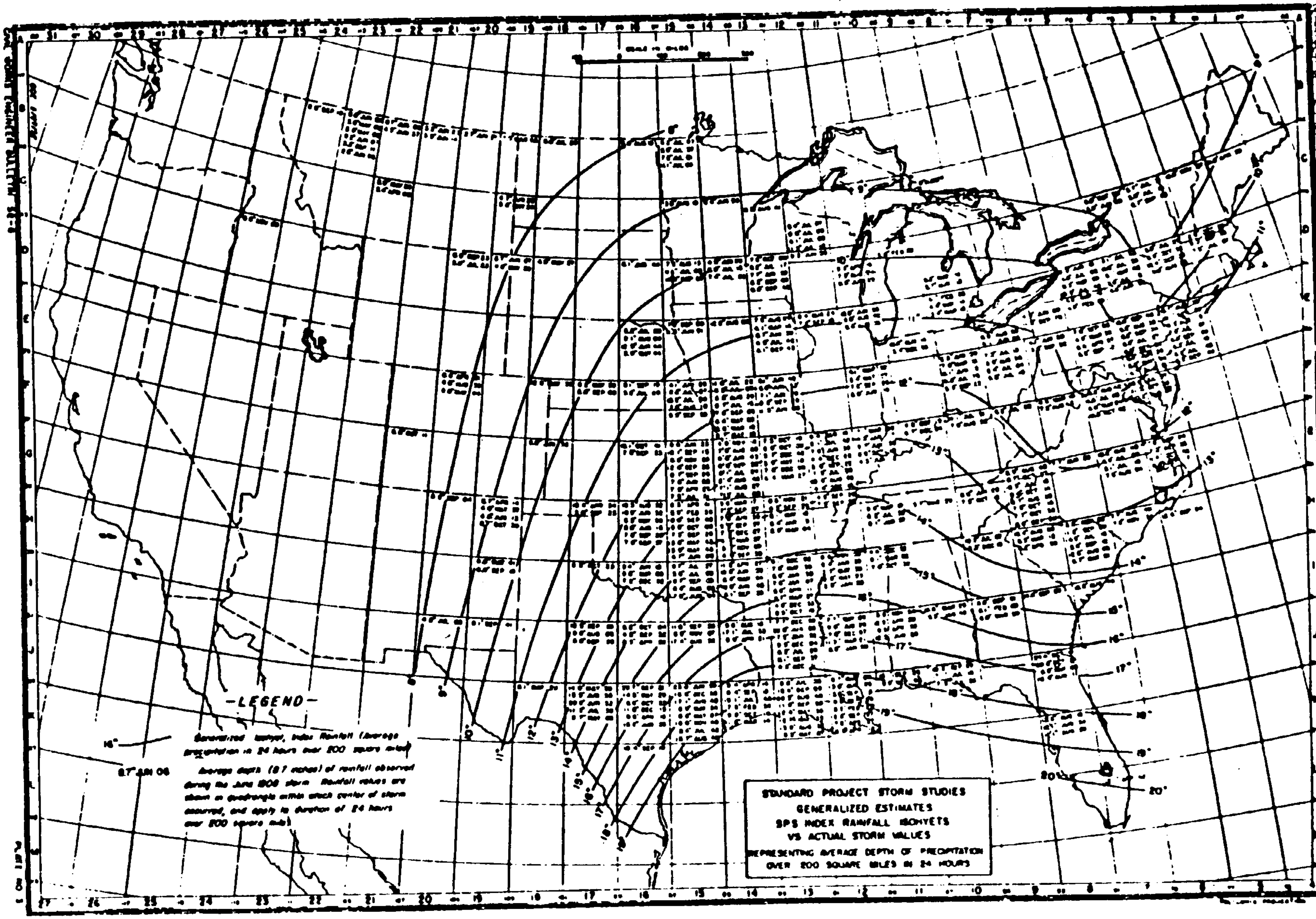
List of Plates

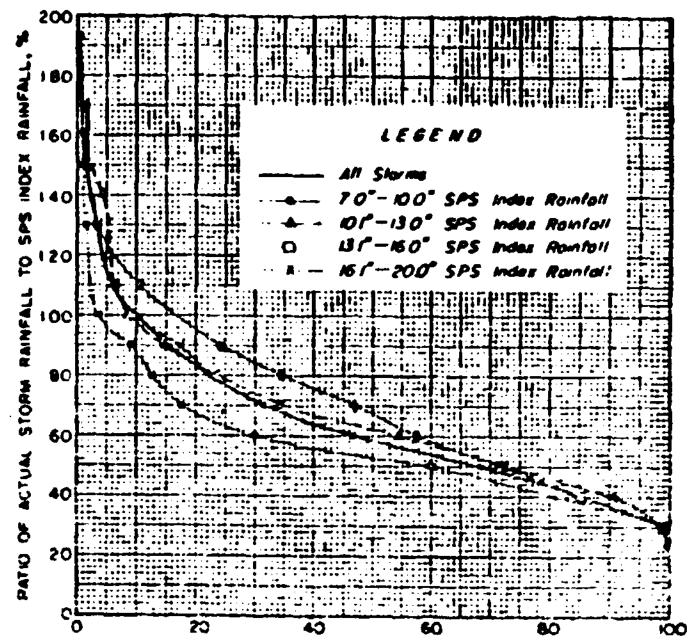
GENERALIZED ESTIMATES
MAXIMUM POSSIBLE PRECIPITATION



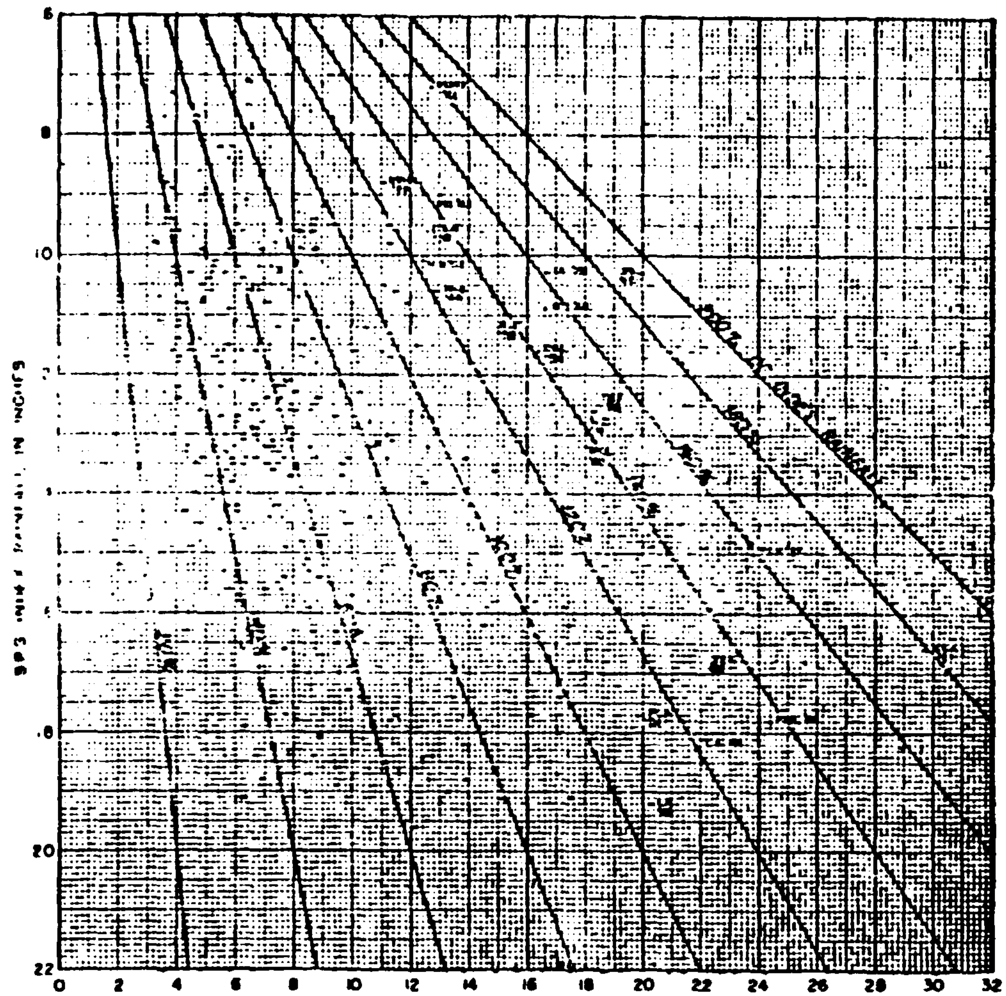
This plate is reproduced from H.M.S. Report No. 23 prepared by the Hydrometeorological Section of the U.S. Weather Bureau.


DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
STANDARD PROJECT STORM STUDIES
GENERALIZED ESTIMATES
SPS INDEX RAINFALL ISOHYETS
WITH OUTLINE OF ZONES
— LEGEND —
Zone Number
Zone Boundary Line
Generalized Isohyet, Index Rainfall (Average precipitation in 24 hours over 200 square miles)
CIVIL WORKS ENGINEER BULLETIN 52-8
PLATE NO. 2


STANDARD PROJECT STORM STUDIES
GENERALIZED ESTIMATES
SPS INDEX RAINFALL ISOHYETS
VS ACTUAL STORM VALUES
REPRESENTING AVERAGE DEPTH OF PRECIPITATION
OVER 200 SQUARE MILES IN 24 HOURS
—LEGEND—
Generalized isohyet, Index Rainfall (average precipitation in 24 hours over 200 square miles)
Average depth (8.7 inches) of rainfall observed during the June 1906 storm. Rainfall values are shown in quadrangle within which center of storm occurred, and apply to duration of 24 hours over 200 square miles
CIVIL WORKS ENGINEER BULLETIN 52-8
PLATE NO 3



(Fig b) PERCENT OF ACTUAL STORM OCCURRENCES



(Fig a) AVERAGE DEPTH OF RAINFALL IN ACTUAL STORMS, INCHES
(OVER 200 SQ. MI. IN 24 HOURS)

STANDARD PROJECT STORM STUDIES
GENERALIZED ESTIMATES

RATIO ACTUAL STORM VALUES TO SPS INDEX RAINFALL

OCE 3/9/52

STANDARD PROJECT STORM STUDIES

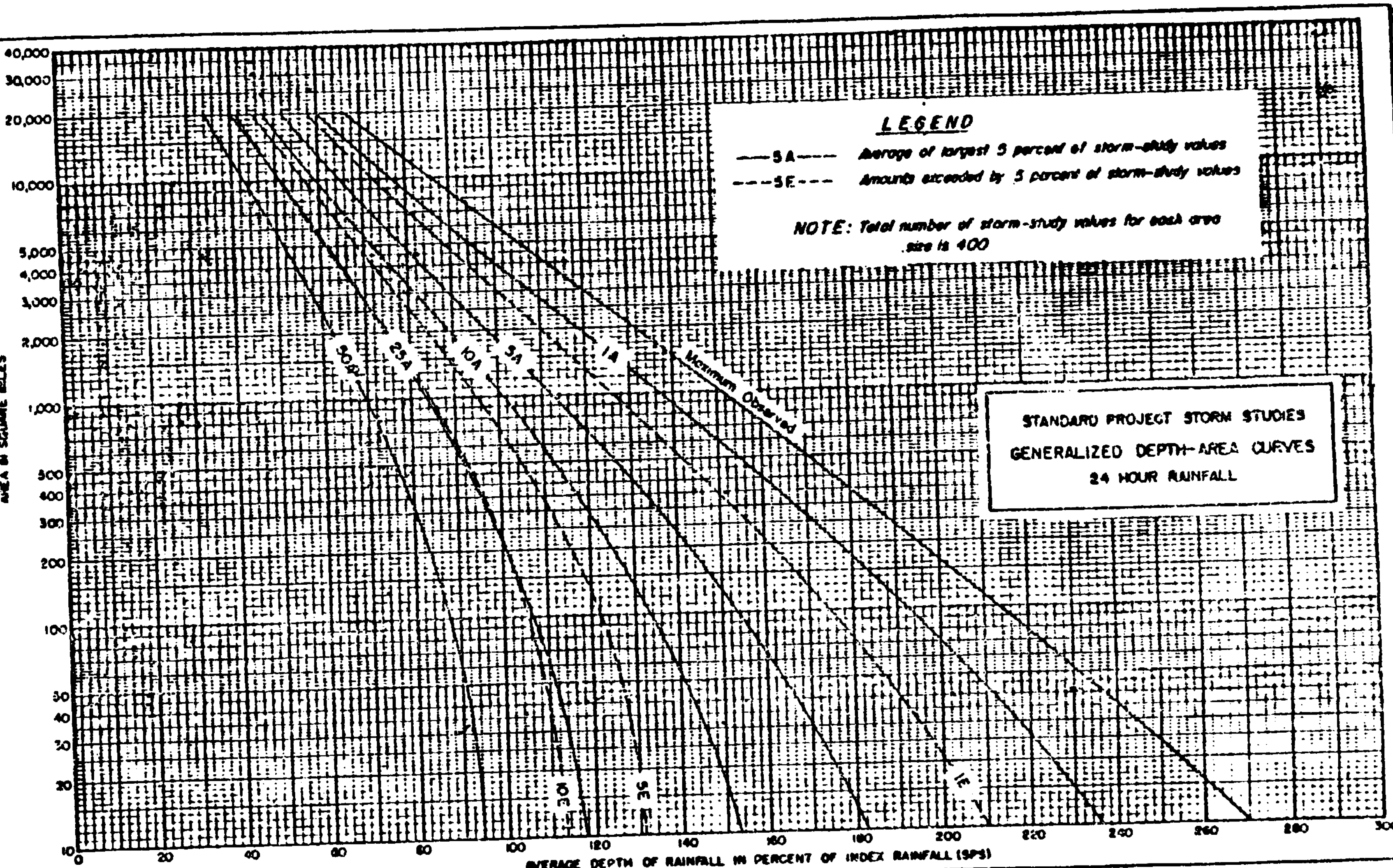
PRECIPITATION DURING MAJOR STORMS OF RECORD IN PERCENT OF SPS INDEX RAINFALL

LINE	LOCATION	BASIN ASSIGNMENT NO.	QUAD	DATE OF STORM	INDEX RAIN-FALL	PERCENT OF INDEX RAINFALL: 10 SQUARE MILES 6 hr	10 SQ. MI. 12 hr	10 SQ. MI. 24 hr	200 SQUARE MILES 6 hr	200 SQ. MI. 12 hr	200 SQ. MI. 24 hr	200 SQ. MI. 48 hr	1,000 SQUARE MILES 6 hr	1,000 SQ. MI. 12 hr	1,000 SQ. MI. 24 hr	1,000 SQ. MI. 48 hr	5,000 SQ. MILES 12 hr	5,000 SQ. MI. 24 hr	5,000 SQ. MI. 96 hr	20,000 SQ. MI. 24 hr	20,000 SQ. MI. 96 hr
				ZONE 1																	
1	Mass.	NA 1-4	D-5	12-14 July 1897	10.9"	42	70	77	36	60	70	93	31	53	44	88	42	58	71	36	95
2	N.E. Vt. NH	NA 1-17	C-3	2-4 Nov 1927	9.0"	87	120	139	49	91	98	113	53	81	87	99	53	74	86	59	71
3	N.Y.	NA 1-21	D-4	4-6 Oct 1932	9.4"	48	77	104	40	63	94	100	34	55	79	89	44	44	73	51	61
4	N.Y. & Pa.	NA 1-24	D-4	20-24 Aug 1933	9.4"	—	—	—	53	80	90	111	48	66	—	90	—	—	—	54	90
5	N.Y.	NA 1-24 (a)	D-4	20-24 Aug. 1933	9.6"	71	97	117	—	—	90	—	—	57	70	81	40	50	76	—	—
6	N.Y. & Pa.	NA 1-27	D-5	6-10 July 1935	9.7"	54	105	122	48	82	103	129	41	60	89	109	40	68	90	38	64
7	Mass.	NA 2-8	D-3	17-22 Sept 1938	10.5"	61	70	108	44	68	86	118	35	40	73	105	37	60	118	47	95
8	N.J. N.Y. Pa.	GL 4-9	D-4	7-11 Oct 1903	10.1"	93	79	136	47	70	123	134	37	63	108	120	46	89	[illegible]	68	71
				ZONE 2																	
8	N.J.N.Y.Pa.	GL 4-9	D-14	7-11 Oct 1903	10.1"	53	72	136	67	70	123	134	37	63	108	120	46	87	101	69	71
9	Pa.	NA 1-1	D-6	30 May-1 June 1889	10.0"	76	86	98	71	82	88	94	67	77	83	88	40	68	81	47	70
10	Mich.-Minn.	UMV 1-11	D-12	18-23 July 1909	8.8"	—	—	—	—	—	—	—	—	—	—	—	—	—	101	51	77
11	Mich.	UMV 1-11(b)	D-12	18-23 July 1909	9.2"	57	69	104	50	65	98	125	95	54	75	106	59	54	87	—	—
12	Wisc.	UMV 1-22	D-13	28-31 Aug 1941	9.5"	90	121	131	82	112	119	141	59	86	96	121	55	66	100	40	77
13	Minn.	UMV 2-3	C-13	11-15 Sept 1903	10.2"	55	58	63	36	48	51	59	31	42	45	53	39	41	48	32	58
14	Wisc.	GL 2-12	C-12	3-8 June 1905	9.9"	75	85	90	67	79	83	100	55	63	71	88	45	56	79	43	64
15	N.Y.	GL 2-16	D-10	31 Aug-1 Sept 1914	10.8"	117	117	117	93	93	93	93	53	53	53	53	—	—	—	—	—
16	Wisc.	GL 2-29	D-12	19-24 July 1912	9.8"	56	66	127	53	64	115	115	48	61	94	95	43	67	76	48	58
17	Wisc.	GL 4-5	D-12	25-27 July 1877	9.5"	94	67	105	33	69	99	103	30	58	91	94	48	71	76	—	—
18	Ohio	OH 9-19	D-7	10-13 Sept 1878	10.8"	55	104	115	54	100	110	129	48	94	102	119	74	85	105	62	78
19	Pa.	OH 9-23	D-6	17-18 July 1942	10.3"	180	259	284	127	165	193	193	82	100	129	129	—	—	—	—	—
20	Iowa	MR 1-20	D-14	24-28 Aug 1903	11.9"	60	100	120	95	86	106	115	46	76	90	97	56	67	80	46	57
				ZONE 3																	
21	Minn. S.D.	UMV 1-2	A-15	18-22 July 1897	8.4"	50	62	77	36	55	74	80	32	50	69	75	40	54	76	44	63
22	S.D.	UMV 1-6	D-15	7-11 Sept 1900	10.5"	58	64	76	33	59	67	68	30	50	58	59	40	48	58	39	51
23	Minn.	UMV 1-14(a)	A-15	18-23 July 1909	8.8"	119	122	151	115	118	176	131	104	109	114	121	67	69	—	—	—
24	Ia. Mo.	MR 1-5	C-15	14-17 July 1900	10.5"	64	90	117	58	78	106	113	43	54	87	96	42	65	84	40	57
25	Iowa	MR 4-2	D-15	23-27 June 1891	10.6"	85	105	121	66	90	108	109	50	73	88	90	47	61	60	54	44
26	Mont.	MR 4-21	A-20	17-21 June 1921	7.2"	146	162	185	145	150	176	191	103	133	157	168	86	107	136	54	83
27	Wyo.	MR 4-23	C-20	27 Sep-1 Oct 1923	7.6"	79	130	145	65	109	113	200	48	82	87	152	47	53	106	33	79
28	Iowa	MR 4-24	C-15	17-19 Sept 1926	10.5"	147	201	210	114	153	161	161	73	98	103	103	61	44	44	43	48
29	Nebr.	MR 6-15	D-16	10-13 June 1944	10.6"	186	144	144	105	122	122	133	74	89	88	95	38	43	55	—	—
				ZONE 4																	
30	Ia. Neb.	MR 1-24	E-15	6-7 July 1898	11.6"	60	104	104	47	85	88	88	34	40	72	72	35	43	44	—	—
31	Okla.	MR 2-12	G-16	4-6 June 1916	12.8"	39	64	70	37	61	66	66	34	53	58	60	43	50	58	39	42
32	Nebr.	MR 2-23	E-16	16-19 Sept 1919	11.1"	54	68	78	47	62	75	77	40	55	67	70	41	57	65	41	52
33	Kans.	MR 3-20	F-15	15-17 Nov 1928	12.4"	40	55	80	35	48	71	84	31	43	65	80	36	57	73	44	58
34	Colo.	MR 3-28A	E-18	30-31 May 1935	9.6"	214	232	232	117	131	131	131	60	75	75	75	37	42	42	—	—
35	Okla.	SW 1-5	H-15	1-5 June 1904	14.2"	44	50	55	42	47	53	82	40	46	51	76	40	46	70	34	56
36	N. Mex.	SW 1-6	G-20	26-30 Sept 1904	8.3"	46	51	80	35	46	75	85	29	40	65	77	34	53	82	40	65
37	Okla.	SW 1-10(a)	H-16	21-25 May 1908	12.9"	39	46	57	32	40	51	69	27	35	47	67	30	43	69	37	61
38	Okla.	SW 1-11	G-15	19-24 Oct 1908	13.4"	70	75	85	57	67	74	101	47	56	64	95	40	49	91	34	78
39	N. Mex.	SW 1-16	G-19	29 Apr-2 May 1914	9.6"	95	71	94	48	68	91	97	41	60	82	91	40	65	76	44	58
40	Kans.	SW 2-1	F-15	11-16 Sept 1906	12.8"	204	109	110	91	93	95	95	63	67	70	70	40	42	46	22	35
41	Okla.	SW 2-11	G-17	3-4 April 1934	11.6"	150	179	184	144	155	141	141	78	92	96	96	—	—	--	—	--
42	Okla. Kans.	SW 2-18	G-15	2-6 Sept 1940	13.8"	140	177	179	95	133	136	139	60	101	103	107	55	57	61	32	35
43	Okla.	SW 2-20	G-15	5-12 May 1943	14.1"	70	87	122	58	67	98	116	31	46	80	121	32	59	102	43	79
44	Okla. Kans.	SW 2-21	G-15	12-20 May 1943	13.4"	119	125	125	87	101	104	104	46	59	61	81	87	40	93	31	70
45	N.Mex. Tex.	GM 5-15(a)	H-19	15-17 Sept. 1919	9.2"	61	80	80	55	46	65	86	27	37	54	75	59	43	65	34	36
46	Kans.	MR 10-2	F-15	9-13 July 1951	10.8"	--	—	—	38	52	61	109	34	44	54	54	37	44	107	34	77
				ZONE 5																	
47	Tex.	GM 3-4	J-15	27 June-1 July 1899	16.9"	41	74	142	37	70	156	175	33	44	125	160	46	87	148	40	110
48	Tex.	GM 3-13	I-20	21-25 July 1905	8.6"	46	50	66	38	48	56	86	30	34	46	70	32	31	71	19	46
49	Tex.	GM 3-14	I-17	4-6 Aug 1906	12.6"	62	69	68	60	63	68	71	56	62	66	71	52	56	85	34	46
50	Tex.	GM 4-12	J-16	8-10 Sept 1921	16.6"	135	179	280	108	146	175	185	81	113	144	151	67	90	98	—	—
51	Tex.	GM 5-1	J-17	30 Jun-2 Jul 1932	15.0"	89	130	211	69	95	151	171	51	70	127	139	45	90	104	47	54
52	Tex.	GM 5-4	J-16	27 June-4 Jul 1936	17.3"	81	92	104	71	79	97	105	63	71	77	89	53	58	72	35	53
53	Tex.	GM 5-10	J-17	19-25 July 1938	15.0"	89	105	122	65	69	86	110	46	50	61	91	34	42	115	26	75
54	Tex.	GM 5-11	J-15	26-30 Jun 1940	18.1"	61	99	104	50	86	94	114	35	65	80	102	39	54	73	28	41
55	Tex.	GM 5-14A	I-15	30 Aug-5 Sep 1932	16.2"	42	85	115	47	[illegible]	107	112	39	48	91	94	40	54	67	28	43
56	N.Mex.	GM 5-19	I-19	20-23 Sept 1941	9.6"	105	117	126	54	76	84	112	40	57	66	86	41	50	81	39	65
57	Tex.	[illegible]	[illegible]	31 May 1935	15.2"	135	131	135	98	98	98	98	57	59	59	59	28	28	28	—	—

STANDARD PROJECT STORM STUDIES

PRECIPITATION DURING MAJOR STORMS OF RECORD IN PERCENT OF SPS INDEX RAINFALL

ITEM	LOCATION	BASIC ASSIGNMENT NO.	QUAD	DATE OF STORM	INDEX RAIN-FALL	PERCENT OF INDEX RAINFALL															
						10 SQUARE MILES			200 SQUARE MILES				1,000 SQUARE MILES				5,000 SQ. MILES			20,000 SQ.MI.	
						6 hr	12 hr	24 hr	6 hr	12 hr	24 hr	48 hr	6 hr	12 hr	24 hr	48 hr	12 hr	24 hr	96 hr	24 hr	96 hr
										ZONE 6											
58	N.J.,Pa.	BA 1-3	D-4	20-24 Sept. 1882	10.5"	55	95	112	48	81	99	142	35	66	77	100	44	55	97	38	78
59	Md.	BA 1-7(b)	F-5	26-29 July 1897	11.1"	117	130	138	85	94	95	104	30	94	96	69	34	88	33	—	—
60	N.J.	BA 1-12	D-4	13-14 Aug 1919	11.8"	68	79	84	58	73	88	88	48	66	79	79	48	61	61	—	—
61	Md. Va.	BA 1-18	F-5	10-13 Aug 1928	11.8"	54	77	101	44	60	91	110	37	60	79	98	46	68	85	44	68
62	Pa.Del.Md.	BA 1-24(b)	D-5	20-24 Aug 1933	10.9"	55	81	101	43	70	—	98	36	—	80	—	54	66	77	—	—
63	N.J.	BA 2-7	D-4	19 Aug 1939	11.1"	87	154	140	78	137	111	111	65	128	110	110	54	64	64	—	—
64	N.J.	BA 2-4	D-5	31 Aug-1 Sept 1940	10.9"	175	208	200	126	158	152	158	78	96	96	96	—	—	—	—	—
65	N.Va.	BA 1-19	D-6	27-30 Sept 1896	10.8"	38	55	67	36	58	65	65	34	48	65	64	44	57	58	46	48
66	Md.	BA 1-26	F-5	2-6 Sept 1935	11.3"	53	86	111	37	61	100	156	34	56	95	125	51	67	119	44	89
67	Va.	BA 1-28 (A)	F-6	11-17 Oct 1942	11.8"	54	75	120	35	50	94	144	88	44	81	103	34	64	100	35	70
68	N.C.	BA 2-1	H-7	26-28 Aug 1893	13.2"	61	85	95	48	76	90	91	38	68	80	81	49	61	62	43	43
69	N.C.Ga.	BA 2-6	H-8	25-28 Aug 1908	13.0"	62	70	82	46	60	80	105	36	48	73	97	36	57	94	48	75
70	N.C. S.C.	BA 2-9	G-8	13-17 July 1916	12.6"	64	100	176	95	93	116	166	47	88	119	144	99	86	111	47	60
71	S.C.	BA 2-9(a)	H-7	13-17 July 1916	15.6"	62	79	111	38	76	109	130	34	60	99	110	51	74	68	—	—
72	S.C. Ga.	BA 2-15	H-7	16-19 Sept 1928	13.4"	52	76	84	43	69	84	98	34	65	80	89	53	70	82	54	72
73	Ga.	BA 3-1	K-9	27-31 July 1887	14.0"	50	70	78	43	63	73	106	35	53	64	94	59	65	90	63	69
74	S.C.Fla.Ga.	BA 3-16	H-5	13-17 Sept 1924	13.2"	73	89	100	54	83	95	102	48	78	67	94	40	71	89	46	74
75	Va.	BA 5-19(a)	G-6	10-17 Aug 1940	11.8"	37	72	97	33	64	86	130	30	55	77	116	48	64	109	48	95
76	N.C.	BA 5-19(b)	H-8	10-17 Aug 1940	12.4"	45	70	89	30	53	72	103	24	44	64	95	—	—	—	—	—
										ZONE 7											
77	Miss. Tenn.	LMV 1-4	H-12	17-21 Nov 1906	15.4"	38	46	63	30	38	50	62	25	33	53	57	28	46	64	38	40
78	Tenn. Miss.	LMV 1-12	G-11	15-17 Mar. 1919	14.5"	44	59	69	37	54	67	71	33	50	64	68	43	36	61	46	48
79	Ia. Ill.	UMV 2-5	E-13	9-10 June 1905	11.7"	86	105	103	76	97	97	97	68	85	85	85	42	68	60	33	33
80	Ohio, Tenn.	LR 1-15	E-9	25-29 Mar. 1913	11.7"	39	51	68	28	46	60	75	26	48	56	74	35	50	86	48	78
81	Ill. Ark.	OR 4-8	F-11	3-6 Oct 1910	13.4"	31	47	67	21	46	66	77	27	38	55	79	30	48	93	46	80
82	Tenn.	LR 7-15	G-10	21-23 Mar 1929	13.7"	52	64	76	42	56	71	73	35	48	65	65	36	55	61	—	48
83	Ohio	OR 9-11	E-8	6-7 Aug 1935	11.5"	84	101	103	61	83	86	86	47	68	70	70	46	50	50	—	—
84	Tenn.	LR 5-6	G-11	5-25 Jan 1937	14.2"	24	31	47	22	30	43	64	20	29	46	68	24	43	80	28	42
85	Mo.	MR 1-1	F-13	16-20 Dec 1895	13.2"	33	52	58	20	43	53	86	25	38	48	82	32	43	77	34	77
86	Mo. Kans.	MR 2-29	D-14	9-12 July 1922	11.6"	93	104	105	83	89	95	101	68	75	85	85	42	46	63	26	47
87	Mo.	MR 7-2(A)	F-14	18-15 Aug 1946	12.7"	85	87	118	65	72	98	137	43	52	65	108	37	48	80	35	57
88	Ill.	MR 7-2(B)	F-12	18-16 Aug. 1946	12.0"	57	77	94	42	65	83	127	38	55	70	115	38	47	90	38	40
89	Ga. Miss.	GM 1-22	H-9	4-10 Dec. 1919	13.9"	45	54	68	35	53	60	88	28	48	54	79	34	46	81	35	73
										ZONE 8											
90	Ala. Fla.	SA 4-25	J-11	17-21 Sept 1926	17.7"	46	68	97	44	68	91	99	36	54	77	87	48	68	78	43	38
91	Ala. Miss.	LMV 2-5	J-11	15-18 Apr 1900	16.8"	47	61	78	40	60	75	83	34	56	68	78	46	61	73	48	65
92	La.	LMV 2-13	J-12	20-30 Sept 1915	18.1"	56	74	80	50	70	75	75	43	64	68	68	46	55	56	39	42
93	Ala. Miss.	LMV 2-18	I-11	1-5 June 1928	16.7"	46	61	74	34	52	72	88	28	46	66	85	38	59	88	33	59
94	Ala.	LMV 2-20	I-10	11-16 Mar. 1929	17.0"	88	96	117	77	85	109	150	60	69	88	150	51	79	116	56	86
95	La.	LMV 2-26	I-14	24-27 July 1933	17.8"	34	60	105	32	55	99	111	29	55	95	103	18	63	99	38	77
96	La.	LMV 4-8	J-12	12-16 Apr 1927	19.1"	72	84	107	61	82	91	91	47	68	77	77	51	60	61	43	47
97	La.	LMV 4-24	J-13	6-9 Aug 1940	19.2"	44	82	110	41	78	100	166	31	57	98	150	33	64	119	39	66
98	Tex.	LMV 1-10	D-14	16-21 Aug 1915	17.5"	38	46	60	35	37	55	99	35	31	48	98	26	46	100	31	78
99	Fla. Miss.	GM 1-19	J-10	5-10 July 1916	17.4"	91	99	103	68	86	98	111	55	75	91	105	36	48	109	43	91
100	La.	LMV 1-7	I-13	15-17 June 1886	18.1"	69	97	125	65	94	121	155	56	87	111	142	54	68	92	—	—
101	Tex.	GM 5-21	J-14	27-29 July 1943	19.1"	56	66	95	40	52	79	114	31	45	78	105	32	54	88	38	80
										ZONE 9											
102	Ga.	SA 5-20	K-8	25-28 Sept 1929	15.4"	54	64	104	51	78	95	117	46	71	85	107	51	64	95	38	40
103	Fla.	SA 4-20	J-8	4-11 Oct 1924	17.8"	76	108	130	68	97	117	119	48	66	84	94	89	43	66	—	—
104	Fla.	SA 5-6	J-8	17-22 Oct 1941	17.8"	72	132	168	54	108	137	163	39	72	102	124	43	65	86	89	51
105	Ga.	SA 3-11	J-8	28-31 Aug. 1911	17.0"	88	101	112	75	88	96	101	56	70	79	88	36	47	63	86	43


LEGEND
——5A—— Average of largest 5 percent of storm-study values
- - -5E- - - Amounts exceeded by 5 percent of storm-study values
NOTE: Total number of storm-study values for each area size is 400
STANDARD PROJECT STORM STUDIES
GENERALIZED DEPTH-AREA CURVES
24 HOUR RAINFALL
50A
25A
10A
5A
1A
Maximum Observed
10E
5E
1E
AREA IN SQUARE MILES
40,000
30,000
20,000
10,000
5,000
4,000
3,000
2,000
1,000
500
400
300
200
100
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
AVERAGE DEPTH OF RAINFALL IN PERCENT OF INDEX RAINFALL (SPS)

CIVIL WORKS ENGINEER BULLETIN 52-8

DEPARTMENT OF THE ARMY

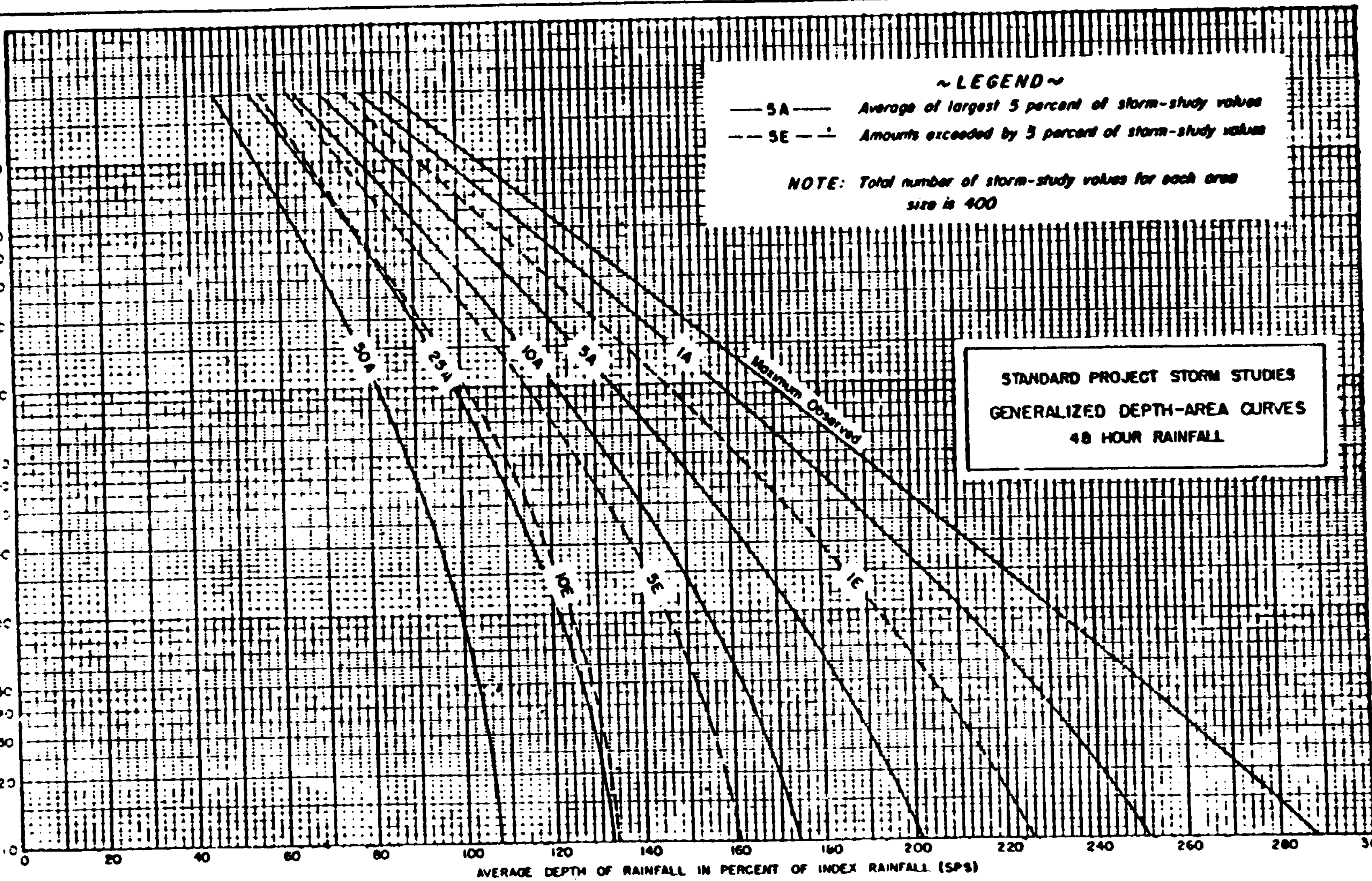
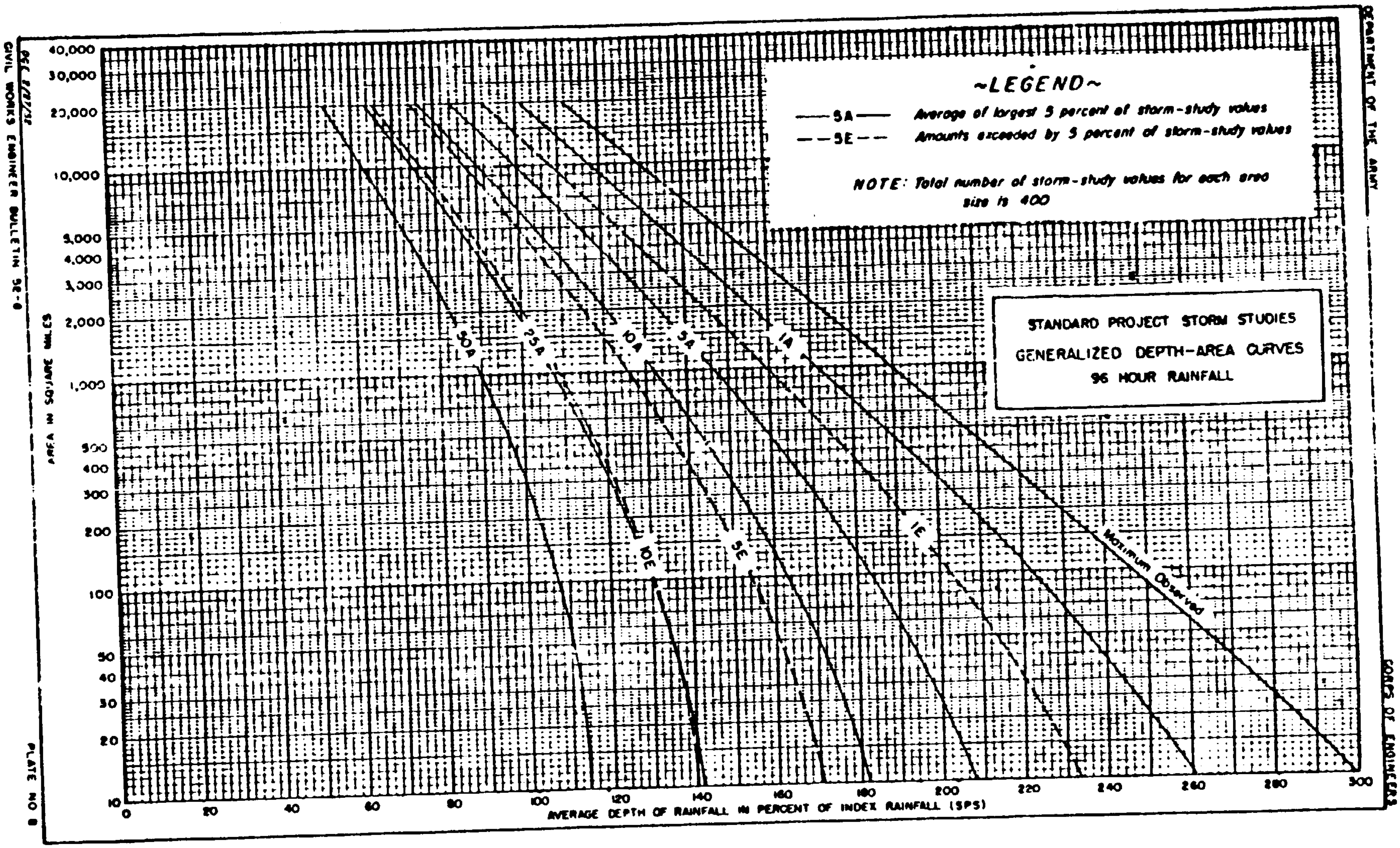
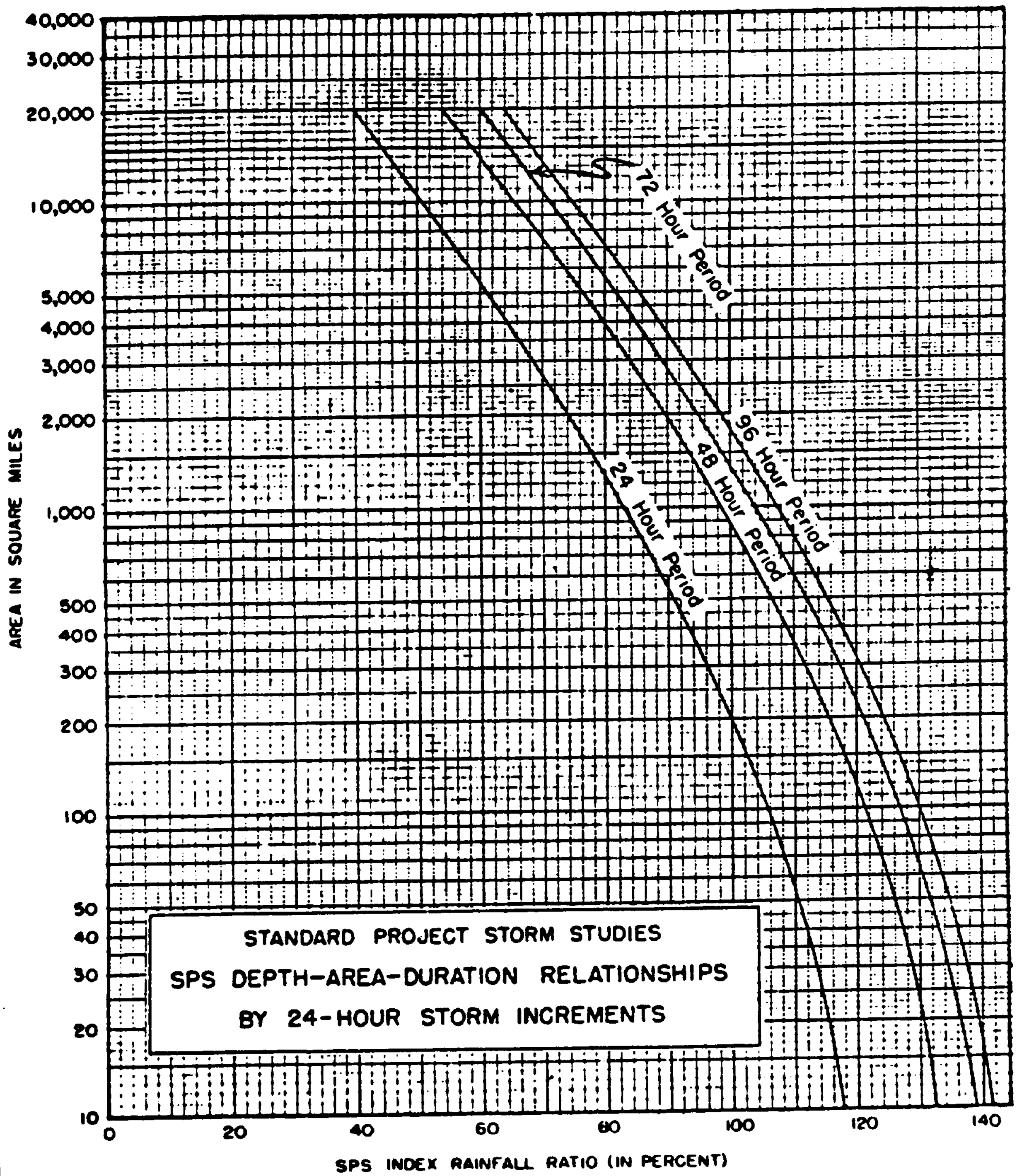


PLATE NO 7

CORPS OF ENGINEERS


~LEGEND~
——5A—— Average of largest 5 percent of storm-study values
— — 5E — — Amounts exceeded by 5 percent of storm-study values
NOTE: Total number of storm-study values for each area size is 400
STANDARD PROJECT STORM STUDIES
GENERALIZED DEPTH-AREA CURVES
96 HOUR RAINFALL
50A
25A
10A
5A
1A
10E
5E
1E
Maximum Observed
AREA IN SQUARE MILES
AVERAGE DEPTH OF RAINFALL IN PERCENT OF INDEX RAINFALL (SPS)
CIVIL WORKS ENGINEER BULLETIN 52-8
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
PLATE NO 8



STANDARD PROJECT STORM STUDIES
SPS DEPTH-AREA-DURATION RELATIONSHIPS
BY 24-HOUR STORM INCREMENTS

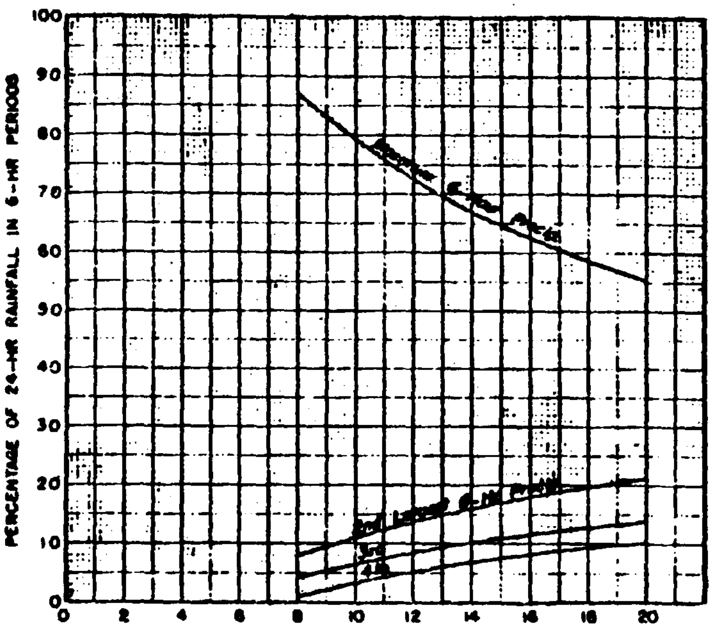


FIG. (a) SPS 24-HOUR PRECIPITATION OVER 200 SQ. MI. vs. PERCENT IN 6-HOUR PERIODS

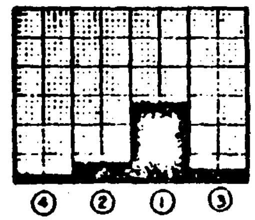


FIG. (b) TYPICAL ARRANGEMENT OF 6-HOUR RAINFALL QUANTITIES IN SPS

INDEX RAINFALL IN INCHES	PERCENTAGE OF 24-HOUR SPS RAINFALL IN DESIGNATED 6-HR PERIOD			
	④	②	①	③
1	2	3	4	5
8	1.0	8.0	87.0	4.0
9	2.1	9.5	83.0	5.4
10	3.2	11.0	79.2	6.6
11	4.3	12.5	75.9	7.5
12	5.3	13.8	72.5	8.4
13	6.1	14.9	69.6	9.4
14	7.0	16.0	66.9	10.1
15	7.6	17.0	64.5	10.9
16	8.1	17.9	62.4	11.6
17	8.8	18.9	60.3	12.0
18	9.1	19.7	58.5	12.7
19	9.8	20.3	56.8	13.1
20	10.1	21.0	55.1	13.8

FIG. (c) TABULATION OF DATA FROM FIG. (a)

STANDARD PROJECT STORM STUDIES
GENERALIZED ESTIMATES

TIME DISTRIBUTION OF 24-HOUR SPS RAINFALL

TIME DISTRIBUTION OF MAXIMUM 6-HOUR SPS RAINFALL

Rainfall Period (Sub-Division of 6-Hour Period)	Time Distribution of Maximum 6-Hour SPS Rainfall, Expressed in Percent of Total 6-Hour Rainfall			
	*Selected Unit Rainfall Duration, t_R			
	6-Hours	3-Hours	2-Hours	1-Hour
#1	#2	#3	#4	#5
1st	100	33	26	10
2nd		67	53	12
3rd			21	15
4th				38
5th				14
6th				11
TOTAL	100	100	100	100

*NOTE: The "selected unit rainfall duration," t_R is determined approximately from the synthetic unit hydrograph equation, $t_r = \frac{t_p}{5.5}$ in which "t_p" is the lag time from midpoint of unit rainfall duration, t_r, to peak of unit hydrograph, in hours, (See page 11, Engineering Manual for Civil Works, Part CXIV - Hydrologic and Hydraulic Analyses, Chapter 5 - Flood-Hydrograph Analyses and Computations). The following rounded-off values are to be used in the above table:

If t_p exceeds 16, use $t_R = 6$

If t_p is between 12 and 16, use $t_R = 3$

If t_p is between 6 and 12, use $t_R = 2$

If t_p is between 4 and 6, use $t_R = 1$

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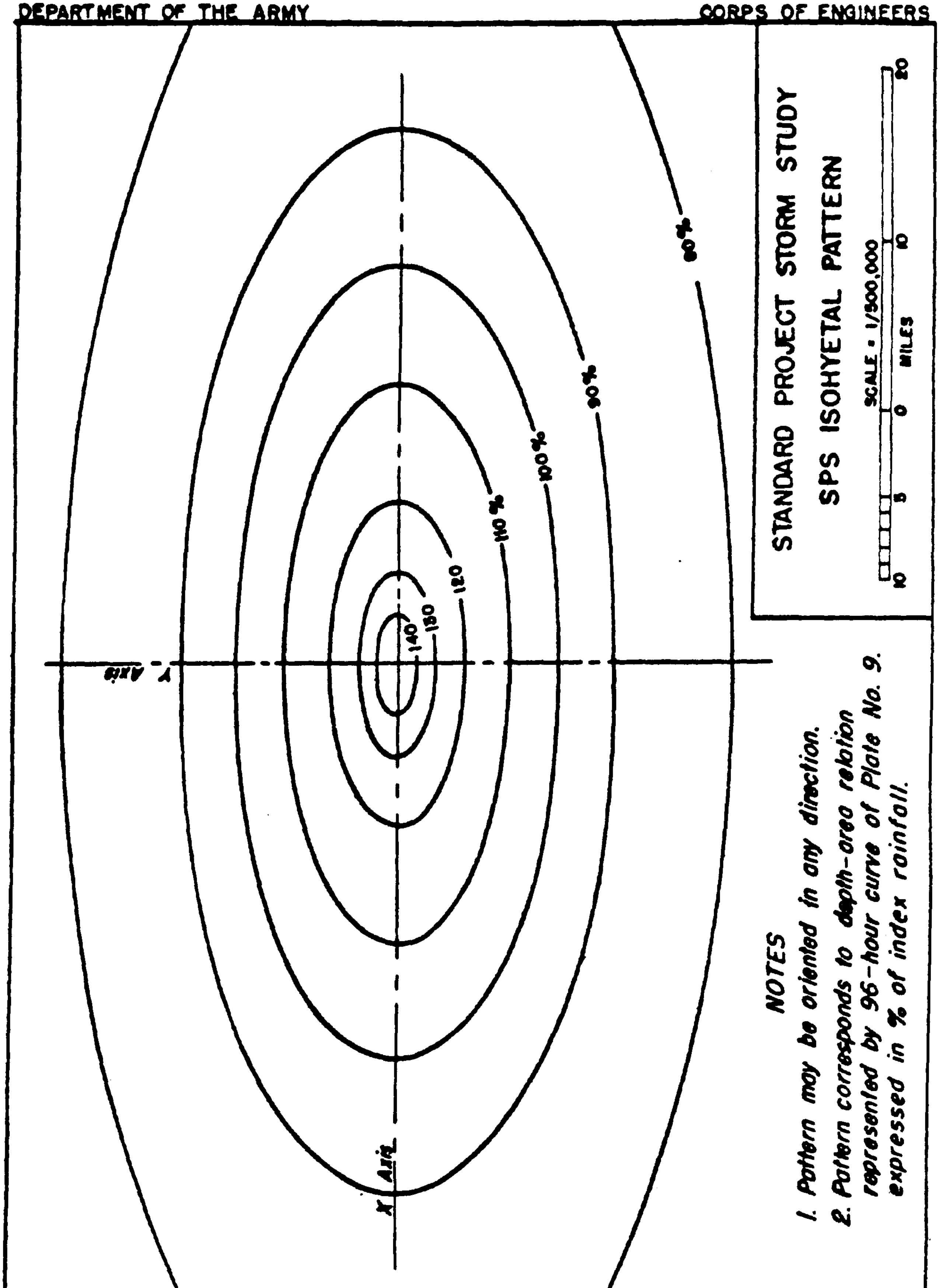
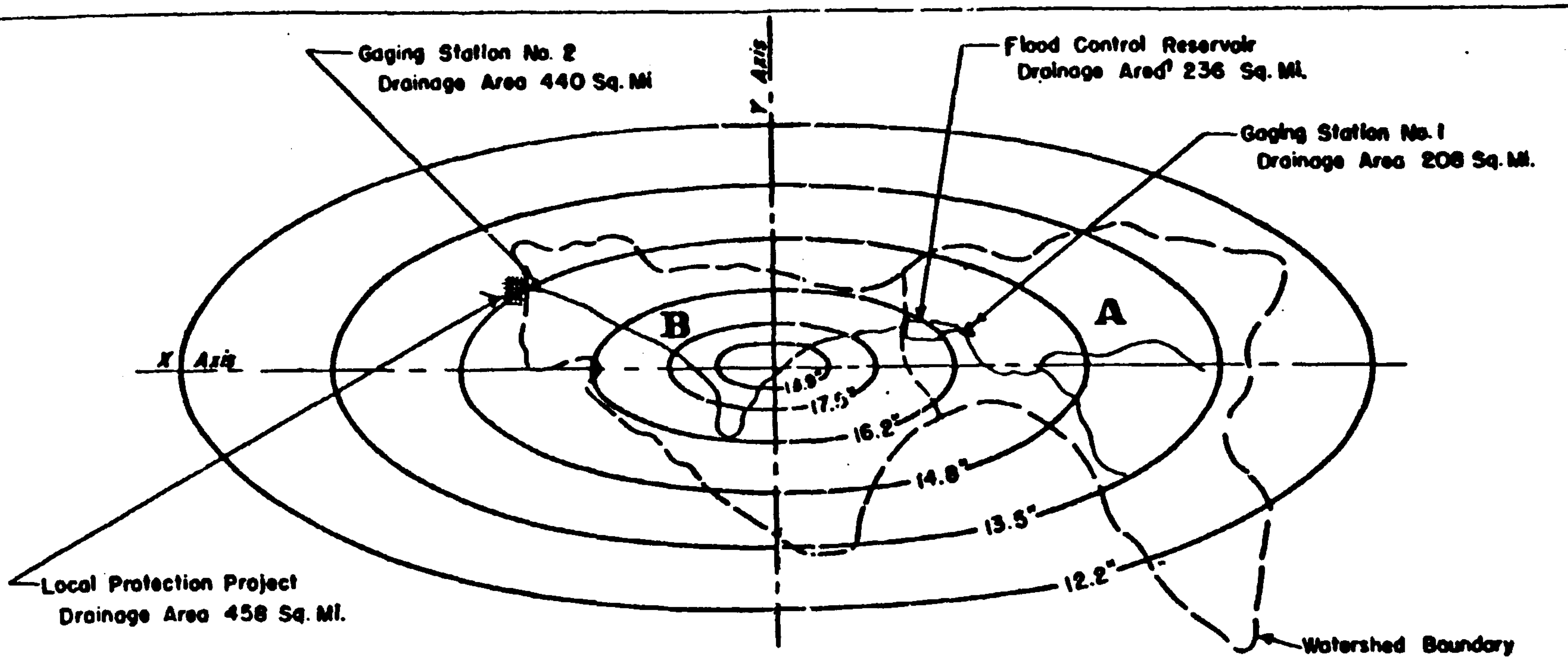

STANDARD PROJECT STORM STUDY
SPS ISOHYETAL PATTERN
SCALE = 1/500,000
10 5 0 10 20
MILES
80%
90%
100%
110%
120
130
140
X Axis
Y Axis
NOTES
1. Pattern may be oriented in any direction.
2. Pattern corresponds to depth-area relation represented by 96-hour curve of Plate No. 9. expressed in % of index rainfall.



UNIT HYDROGRAPH DATA

LOCATION	DRAINAGE AREA	L	L_{ca}	$(L \cdot L_{ca})^{0.3}$	C_t	t_p	t_r	t_R	t_{pR}	$640C_p$	Q_p
Dam A	236	37	20	7.3	1.8	13.1	2.4	3.0	13.2	380	6,800
LPP B	222	35	18	6.9	2.3	15.9	2.9	3.0	15.9	420	5,900

NOTES

1. *Project location: Lat. 37°, Long. 94° (Index rainfall = 13.5").*
2. *Isohyets correspond to those of Plate No. 12 with percentages multiplied by index rainfall of 13.5 inches.*
3. *For definition and application of unit-hydrograph symbols see Engineering Manual for Civil Works, Part CXIV, Chapter 5.*
4. *C_t and C_p based on floods observed at gaging stations 1 & 2.*
5. *t_R based on criteria on Plate No. 11.*

STANDARD PROJECT STORM STUDIES
ILLUSTRATIVE EXAMPLE
APPLICATION OF ISOHYETAL PATTERN
(MAXIMUM 96-HOUR PERIOD OF SPS)

10 5 0 10 20
MILES

TABLE 14

COMPUTATION OF RAINFALL AND RAINFALL EXCESS DURING STANDARD PROJECT STORM OVER SAMPLE DRAINAGE BASIN

Line No.	*Step No.	Item	Data on Sub-Areas: Designation	Area Sq.Mi.	Initial Loss	Loss Rate	Time in Hours: 24	48	72	96	Rainfall, Loss and Excesses by Periods — Time from Beginning of Rainfall - Hours: 6	12	18	24	30	36	42	48	54	60	66	Subdivision of Max. 6-Hour Rainfall: 61	62	63	64	65	66	72	78	84	90	96	Total
1		Location of Basin (Lat. 37°, Long. 94°)		468																													
2	1	Index Rainfall in Inches (From Plate 2)		200			13.5																										
3	2	Index Rainfall Ratios in Percent (From Plate 9)		468			92	107	113	116																							
4	2	Maximum Rainfall in Inches for Duration		468			12.4	14.4	15.3	15.7																							
5	3	24-Hour Rainfall Increment in Inches		468			0.4	2.0	12.4	0.9																							
6	5	Average Rainfall for Total Storm in Inches (From Plate 13)	A							14.0																							
7	5	Average Rainfall for Total Storm in Inches	B							16.3																							
8	5	Average Rainfall for Total Storm in Inches	Total							15.1																							
9	6	24-Hour Rainfall Increment in Percent of Total (From Line 5)					2.6	12.7	79.0	5.7																							
10	6	24-Hour Rainfall Increment in Inches	A				0.3	1.8	11.1	0.8																							
11	6	24-Hour Rainfall Increment in Inches	B				0.4	2.1	12.9	0.9																							
12	6	24-Hour Rainfall Increment in Inches	Total				0.4	1.9	11.9	0.9																							
13	6	6-Hour Percentages of 24-Hour Rainfall (From Plate 10)									7	15	68	10	7	15	68	10	7	15	68**							10	7	15	68	10	
14	6	6-Hour Rainfall in Inches	A	236							0.0	0.1	0.2	0.0	0.1	0.3	1.2	0.2	0.8	1.7	7.5**							1.1	0.1	0.1	0.5	0.1	14.0
15	6	6-Hour Rainfall in Inches	B	232							0.0	0.1	0.3	0.0	0.2	0.3	1.4	0.2	0.9	1.9	8.8**							1.3	0.1	0.1	0.6	0.1	16.3
16	6	6-Hour Rainfall in Inches	Total	468							0.0	0.1	0.3	0.0	0.1	0.3	1.3	0.2	0.8	1.8	8.1**							1.2	0.1	0.1	0.6	0.1	15.1
17	7	Rainfall Interval in Hours																						3			3						
18	7	Percentage Subdivision of Max. 6-Hour Rainfall (From Plate 11)																			100**			20			80						
19	7	Subdivision of Maximum 6-Hour Rainfall in Inches	A	236																	7.5**			1.5			6.0						
20	7	Subdivision of Maximum 6-Hour Rainfall in Inches	B	232																	8.8**			1.8			7.0						
21	7	Subdivision of Maximum 6-Hour Rainfall in Inches	Total	468																	8.1**			1.6			6.5						
22	8	Infiltration Losses in Inches	A	236	0.5	0.15					0.0	0.1	0.2	0.0	0.1	0.3	0.9	0.2	0.8	0.9	0.9**			0.4			0.5	0.9	0.1	0.1	0.5	0.1	6.1
23	8	Infiltration Losses in Inches	B	232	0.5	0.10					0.0	0.1	0.3	0.0	0.2	0.3	0.6	0.2	0.6	0.6	0.6			0.3			0.3	0.6	0.1	0.1	0.6	0.1	5.0
24	8	Rainfall-Excess in Inches	A	236							0	0	0	0	0	0	0.3	0	0	0.8	6.6**			1.1			5.5	0.2	0	0	0	0	7.9
25	8	Rainfall-Excess in Inches	B	232							0	0	0	0	0	0	0.8	0	0.3	1.3	8.2**			1.5			6.7	0.7	0	0	0	0	11.3
26	8	Rainfall-Excess in Inch-Square Miles	A	236							0	0	0	0	0	0	71	0	0	189	1560**			260			1300	47	0	0	0	0	1867
27	8	Rainfall-Excess in Inch-Square Miles	B	232							0	0	0	0	0	0	178	0	67	289	1820**			333			1490	155	0	0	0	0	2512
28	8	Rainfall-Excess in Inch-Square Miles	Total	468							0	0	0	0	0	0	249	0	67	478	3380**			593			2790	202	0	0	0	0	4379
29	8	Rainfall-Excess in Inches	Total	468							0	0	0	0	0	0	0.5	0	0.1	1.0	7.2**			1.3			6.0	0.5	0	0	0	0	9.4

*See paragraph 2-05 a of Bulletin

**These values subdivided into 3-hour periods in accordance with procedures and criteria specified in paragraph 2-05 c and Plate 11.

PLATE No. 15

CUMBERLAND RIVER BASIN, STANDARD PROJECT STORM DETERMINATION

TABLE A

ADJUSTMENT OF RAINFALL VALUES FROM MAXIMUM DEPTH-AREA CURVES OF RECORD STORMS FOR TRANSPOSITION TO CUMBERLAND RIVER BASIN ABOVE OLD HICKORY, TENN.

Line Number	Storm Number	Date of Storm	Approximate Location of Storm Center considered (5000 sq. mi. area)	Transposition Factor For 5000 sq. mi. Area: Clarksville	Transposition Factor For 5000 sq. mi. Area: Burnside	Assumed Average for Basin	300 sq. mi.: 12 Hrs.	300 sq. mi.: 24 Hrs.	300 sq. mi.: 48 Hrs.	300 sq. mi.: 120 Hrs.	1,000 sq. mi.: 12 Hrs.	1,000 sq. mi.: 24 Hrs.	1,000 sq. mi.: 48 Hrs.	1,000 sq. mi.: 120 Hrs.	5,000 sq. mi.: 12 Hrs.	5,000 sq. mi.: 24 Hrs.	5,000 sq. mi.: 48 Hrs.	5,000 sq. mi.: 120 Hrs.	10,000 sq. mi.: 12 Hrs.	10,000 sq. mi.: 24 Hrs.	10,000 sq. mi.: 48 Hrs.	10,000 sq. mi.: 120 Hrs.
1	OR 9-19	10-15 Sep 1878	[illegible], Ohio	1.50	1.18	1.35	13.6	16.0	17.4	(18.1)	12.6	13.6	14.1	(16.0)	10.0	11.5	13.4	(15.1)	8.6	10.1	10.1	(10.5)
2	GM 7-18	21-25 Mar 1929	Crossville, Tenn.	1.10	0.97	1.04	8.7	10.1	10.4	-	8.0	9.3	9.8	-	6.8	7.8	8.4	-	5.6	6.0	7.6	-
3	UMV 1-4	27-31 Dec 1926	Austin, Miss.	0.88	0.80	0.84	4.9	7.6	8.1	(15.6)	4.3	6.9	7.4	(14.3)	3.7	6.0	6.6	(10.8)	3.4	5.8	6.3	(11.8)
4	OR 4-6	3-6 Oct 1910	Cairo, Ill.	1.02	.92	0.97	6.0	8.5	10.8	(14.9)	5.0	7.0	11.6	10.6	5.8	6.3	9.0	10.1	3.6	6.1	9.0	11.0
5	OR 1-1	16-20 Dec 1895	Springfield, Mo.	1.12	.90	1.06	6.0	7.4	11.1	(10.4)	5.3	6.9	11.4	(11.8)	4.8	6.0	10.1	(10.7)	4.0	5.6	5.2	(9.8)
6	OR 1-18	25-27 Mar 1913	Richmond, Ind.	1.06	1.31	1.19	6.4	8.3	11.0	13.2	5.0	7.0	10.3	10.0	4.0	4.9	9.4	10.1	4.0	4.4	8.0	11.0
7	OR 5-6	5-8 Jun 1937	Dover, Tenn.	1.00	.80	0.81	5.0	5.4	8.8	13.1	3.7	5.2	8.0	10.5	3.1	4.4	7.8	11.7	2.7	3.0	6.0	11.1
8	UMV 1-13A	28-[illegible] Oct 1919	Cuba, Mo.	1.11	1.01	1.06	5.7	7.1	10.0	(12.0)	4.0	7.2	10.6	(10.6)	3.6	4.4	9.3	(9.0)	3.4	5.0	8.6	(8.0)
9	UMV 1-22	15-17 Mar 1919	Henderson, Tenn.	0.85	0.85	0.80	7.1	8.0	(9.8)	-	6.6	8.4	(8.8)	-	5.7	7.4	(7.0)	-	5.1	6.2	(7.0)	-
10	UMV 1-19	10-[illegible] Jan 1935	Bolivar, Tenn.	.95	.85	0.80	4.8	7.4	10.4	(11.7)	4.8	7.0	10.0	(11.5)	3.8	5.6	8.8	(9.8)	3.0	3.8	7.6	(8.0)
11	OR 1-20	1-[illegible] Jan 1904	[illegible], Ky.	1.04	.95	0.89	5.6	6.6	8.8	9.4	4.0	6.1	7.6	6.7	3.4	5.4	6.6	7.6	3.0	3.1	6.2	7.0
12	UMV 1-12	9-13 May 1918	Anna, Ill.	1.06	.97	1.00	5.6	6.8	7.8	(7.4)	5.2	5.0	7.0	(7.3)	4.4	5.2	4.6	(6.0)	3.0	4.0	4.2	(6.4)
13	OR 2-15	25-[illegible] Jun 1936	Farmington, Mo.	1.11	1.00	1.06	5.0	6.0	7.6	9.0	5.3	6.3	7.2	9.5	4.2	5.0	4.3	8.7	3.0	4.4	3.1	4.0
14	UMV 1-9	10-[illegible] Jan 1918	Conway, Ark.	.80	.85	0.80	3.3	5.6	6.6	-	3.0	3.3	6.3	-	2.6	4.7	3.0	-	0.0	4.0	3.0	-
15	LMV 2-[illegible]	6-11 Jan 1930	Memphis, Tenn.	.95	.88	0.88	3.6	5.2	8.2	9.2	3.4	4.0	7.7	8.0	3.0	4.3	7.1	8.0	2.0	4.0	4.0	7.0
16	OR 4-1	31 Jul-5 Aug 1875	Delaware, Ind.	1.17	1.04	1.10	4.0	6.6	7.6	10.0	3.4	5.7	6.0	9.6	2.0	4.3	3.7	8.1	2.6	4.0	3.1	7.0
17	OR 5-0	20-31 Mar 1930	Paducah, Ky.	1.01	.90	0.96	4.6	6.6	7.0	(7.0)	3.7	5.0	6.0	(7.3)	2.6	4.1	4.7	(6.0)	0.1	3.4	4.0	(5.7)
18	OR 2-10	15-[illegible] Dec 1930	[illegible], Ark.	.97	.81	0.87	2.7	4.0	5.2	7.2	0.3	3.7	5.0	7.0	7.0	3.3	4.4	4.0	1.0	3.1	4.0	4.4
19	UMV 3-6	7-11 Dec 1919	Hot Springs, Ark.	.89	.85	0.89	4.8	7.6	7.7	8.6	3.6	6.4	6.6	8.3	2.0	3.0	4.8	7.4	2.4	3.0	3.0	4.6

TABLE B

ADJUSTMENT OF RAINFALL VALUES OF SEVEN HIGH-RANKING TRANSPOSED STORMS FOR SHAPE OF DRAINAGE BASIN ABOVE OLD HICKORY, TENN.

Line Number	Storm Number	Date of Storm	Approximate Location of Storm Center considered (5000 sq. mi. Area)	Total Storm Precip. from D-A Curve	Total Storm Precip. Within Basin Outline	Basin Shape Factor	300 sq. mi.: 12 Hrs.	300 sq. mi.: 24 Hrs.	300 sq. mi.: 48 Hrs.	300 sq. mi.: 120 Hrs.	1,000 sq. mi.: 12 Hrs.	1,000 sq. mi.: 24 Hrs.	1,000 sq. mi.: 48 Hrs.	1,000 sq. mi.: 120 Hrs.	5,000 sq. mi.: 12 Hrs.	5,000 sq. mi.: 24 Hrs.	5,000 sq. mi.: 48 Hrs.	5,000 sq. mi.: 120 Hrs.	10,000 sq. mi.: 12 Hrs.	10,000 sq. mi.: 24 Hrs.	10,000 sq. mi.: 48 Hrs.	10,000 sq. mi.: 120 Hrs.
1	OR 9-19	10-15 Sep 1878	[illegible], Ohio	9.6	6.7	.91	10.3	13.6	15.0	16.5	11.5	12.6	14.7	(15.4)	9.1	10.3	12.4	(13.9)	7.7	9.6	11.0	(13.4)
2	GM 7-18	21-25 Mar 1929	Crossville, Tenn.	7.4	6.4	.86	7.3	8.6	8.7	-	6.7	7.8	8.8	-	5.5	6.4	7.4	-	4.7	5.2	6.8	
3	UMV 1-4	27-31 Dec 1926	Austin, Miss.	13.0	11.8	.91	4.5	6.6	7.4	(14.2)	3.8	6.3	6.7	(13.0)	3.4	5.8	6.0	(11.1)	3.1	5.0	5.7	(10.1)
4	OR 4-6	3-6 Oct 1910	Cairo, Ill.	11.8	10.4	.90	5.4	7.7	11.5	13.0	4.5	6.6	10.3	12.8	3.5	5.7	8.9	10.9	3.2	5.5	8.3	10.1
5	OR 1-1	16-20 Dec 1895	Springfield, Mo.	9.1	8.2	.90	5.4	6.7	10.9	(11.8)	4.8	6.2	10.3	(10.6)	4.0	5.4	9.1	(9.6)	3.6	5.0	8.3	(8.9)
6	OR 1-18	25-27 Mar 1913	Richmond, Ind.	9.6	9.1	.95	6.1	7.0	10.5	12.5	5.5	7.5	9.0	12.3	4.7	6.6	8.0	11.8	4.3	6.1	8.3	10.0
7	OR 5-6	5-8 Jun 1937	Dover, Tenn.	20.3	18.6	.91	5.6	5.2	7.4	12.0	5.4	4.8	7.4	11.5	2.9	4.0	6.7	10.6	2.6	3.6	6.5	10.2

* Note: The total storm values correspond to those represented by isohyetal maps for durations somewhat longer than 120 hours in some cases.