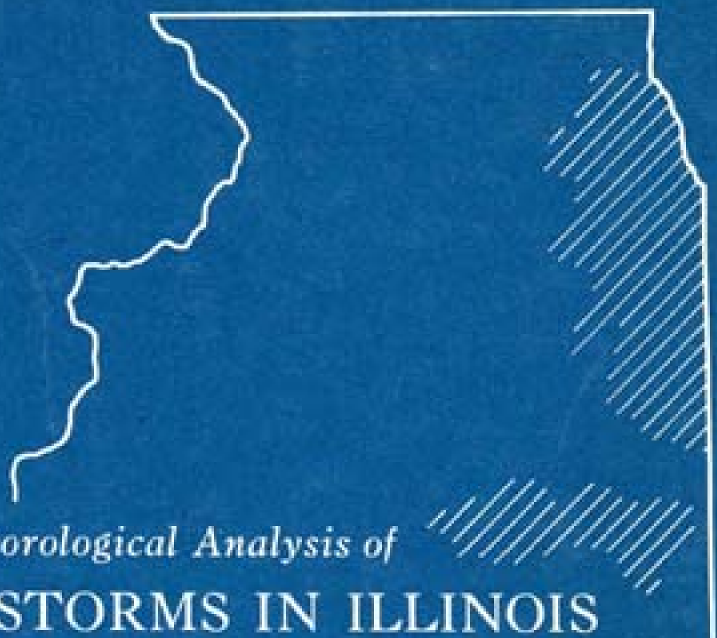
CHANGNON

ORT OF INVESTIGATION 35

OF ILLINOIS
AM G. STRATTON, Governor

DEPARTMENT OF REGISTRATION AND EDUCATION
VERA M. BINKS, Director



Hydrometeorological Analysis of

SEVERE RAINSTORMS IN ILLINOIS

1956-1957 with summary of Previous Storms

by

F. A. Huff, R. G. Semonin,
S. A. Changnon Jr. and D. M. A. Jones

ILLINOIS STATE WATER SURVEY
WILLIAM C. ACKERMANN, Chief

URBANA
1958

REPORT OF INVESTIGATION 35

STATE OF ILLINOIS
WILLIAM G. STRATTON, Governor

DEPARTMENT OF REGISTRATION AND EDUCATION
VERA M. BINKS, Director

HYDROMETEOROLOGICAL ANALYSIS OF SEVERE RAINSTORMS IN ILLINOIS 1956-1957 WITH SUMMARY OF PREVIOUS STORMS

by F. A. Huff, R. G. Semonin,
S. A. Changnon Jr. and D. M. A. Jones

STATE WATER SURVEY DIVISION
WILLIAM C. ACKERMANN, Chief

URBANA

1958

Printed by authority of the State of Illinois

114

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF ILLUSTRATIONS

TABLE OF CONTENTS (continued)

LIST OF ILLUSTRATIONS

TABLE OF CONTENTS (continued)

TABLES

INTRODUCTION

Data to define adequately the magnitude and extent of severe rainstorms are usually unavailable owing to the lack of funds to establish a nation-wide dense network of official weather stations. In 1948, the State Water Survey initiated studies to determine the requirements for the collection of accurate rainfall data on small areas and to ascertain rainfall relations for such areas. Several concentrated raingage networks have been established for this purpose. State Water Survey Bulletin 44, entitled "Rainfall Relations on Small Areas in Illinois", summarizes results of this program through 1956. Routine data collection using concentrated raingage networks on areas exceeding 400 square miles has not been accomplished in Illinois due to excessive operational costs. Since 1948, however, the State Water Survey has conducted field surveys following most of the major flood-producing rainstorms in Illinois to supplement the climatological network observations and, thus, provide greater detail and accuracy in defining the rainfall distribution in these storms. Depth-duration-area relations and other characteristics of severe rainstorms provide pertinent information to engineers concerned with the efficient design of hydraulic structures, such as dams, urban storm sewers, highway culverts, water-supply facilities, and many other engineering installations.

During the late spring and early summer of 1957, an unusual number of severe rainstorms occurred in Illinois and surrounding states. In Illinois, outstanding storms occurred on May 21-23 in the southern part of the state, on June 14-15 in the southwestern portion of the state, on June 27-28 in east central Illinois, and on July 12-13 in the northeastern region of the state. The locations of these storms are shown in Figure 1. The numbers in the centers of the storms indicate the locations of the higher point rainfall amounts, while the areas enclosed by the 7-inch and 4-inch isohyets are shown by the stippling. Extensive field surveys to obtain rainfall data for detailed analyses were conducted by Illinois State Water Survey personnel on all except the May 21-23 storm in southern Illinois. Information on the magnitude of this storm was received too late to conduct a satisfactory field survey. However, the Water Survey in cooperation with Southern Illinois University was operating a concentrated network of 60 raingages near the center of this storm which furnished some detailed data.

The four 1957 storms are among the heaviest on record for the state of Illinois. Records of maximum rainfall were exceeded in a number of communities including Chicago, Kankakee, and Paris. In the June 14-15 storm, a reliable measurement of 16.54 inches from a standard U. S. Weather Bureau non-recording gage, located near Millstadt in St. Clair County (Point A, Fig. 2), exceeded the 24-hour rainfall record for Illinois. The official maximum recorded at U. S. Weather Bureau stations in Illinois prior to 1957 was 10.48 inches at Aurora on October 1, 1954.[(1)] Other high values listed by the Weather Bureau are 10.25 inches at LaHarpe on June 10, 1905 and 9.15 inches at Galva on August 20, 1924. The record rainfall near Millstadt occurred within a 12-hour period.

The 16.54 inches near Millstadt also exceeded all values obtained by the State Water Survey in previous field surveys since initiation of such investigations in 1948. However, published Weather Bureau records for 24-hour periods have been exceeded in several of these storms by measurements obtained by the State Water Survey. These include: 12.5 inches in the north central Illinois storm of July 8, 1951;[(2)] 12.5 inches in the Rockford storm of July 18-19, 1952;[(3)] and, 11.4 inches in the northern Illinois storm of October 9-10, 1954.[(1)] High values obtained in the other 1957 storms were 13.1 inches in the June 27-28 storm and 11.1 inches in the July 12-13 storm. Area-depth relations in the 1957 storms, especially for the southwestern Illinois storm of June 14-15, are among the highest on record in Illinois for areas ranging from a point to 10,000 square miles.

As indicated previously, data obtained from severe rainstorms provide pertinent information used in hydrologic analyses, design, and planning. To further our knowledge of severe rainstorms in Illinois, a detailed analysis of the four 1957 storms was undertaken. The central Illinois storm of May 26-27, 1956, is included in this report, since it has not been described elsewhere.

In the analysis of each storm period, isohyetal maps for the total storm period and for incremental periods of peak rainfall within the total storm period have been prepared. From the isohyetal maps, area-depth relations have been established for the total storm period and for peak periods of rainfall within the overall storm. In conjunction with the area-depth studies, the time distribution of rainfall in each storm was also determined. Other analyses include the construction of mass rainfall curves for stations near the major axis of each storm, evaluation of the synoptic weather conditions associated with the storms, radar analyses of the storm characteristics, and a description of antecedent rainfall conditions.

A summary of severe rainstorm analyses during 1948-57 is presented in the final section of the report. Depth-duration-area relations in the major flood-producing storms during this period are shown. A comparison is made of area-depth envelope values in the 1948-57 storms with those obtained by the Corps of Engineers, based upon data for 1910-46 from climatological networks. Differences between area-depth values computed from field survey and climatological network data during 1948-57 are shown. Analytical results indicating the total area within the state and the percent of the state experiencing exceptionally heavy rainfall during 1948-57 are presented.

ACKNOWLEDGMENTS

This report was prepared under the direction of William C. Ackermann, Chief of the Illinois State Water Survey, and the general guidance of Glenn E. Stout, Head of the Meterology Section.

Credit is due various personnel in the following organizations for providing rainfall data pertinent to the study: U. S. Weather Bureau offices at Chicago, Kansas City, Mo., Asheville, North Carolina, and Champaign, Illinois; Illinois Division of Waterways; U. S. Geological Survey; U. S. Army Corps of Engineers; and, the East Side Levee and Sanitary District of East St. Louis, Illinois. Appreciation is also due numerous individuals who took time to supply our field meterologists with data or mailed information to the U. S. Weather Bureau or the State Water Survey in answer to newspaper and radio requests for rainfall data.

The radar data were collected with a CPS-9 radar which was supplied by the U. S. Army Signal Engineering Laboratories under Contract DA-36039 SC-64723.

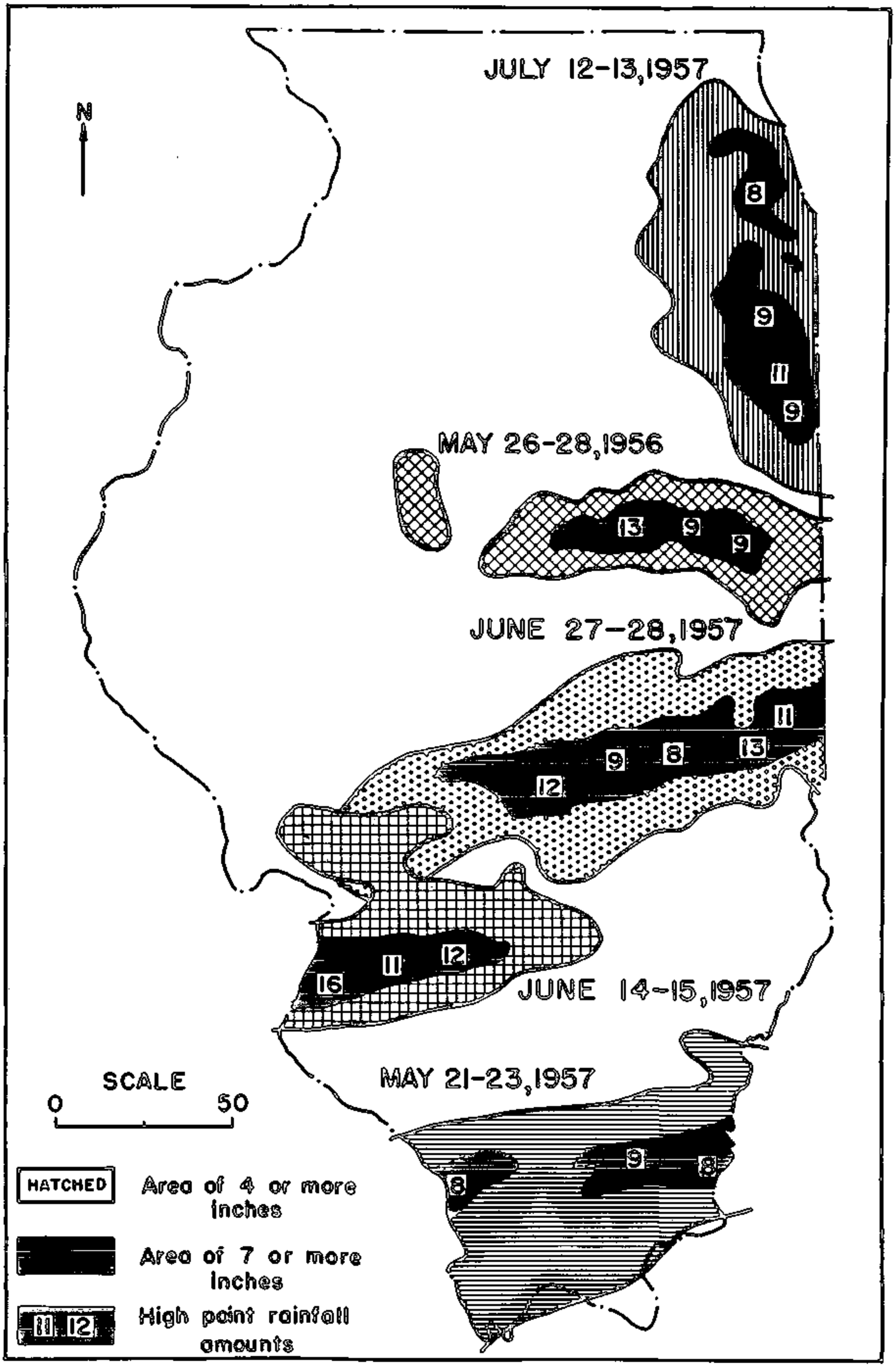


FIGURE 1 MAJOR RAINSTORMS IN ILLINOIS DURING 1956 AND 1957

STORM OF JUNE 14-15, 1957

Introduction

On June 14-15, 1957, one of the more severe rainstorms of short duration on record in the Midwest occurred in southwestern Illinois and eastern Missouri (Fig. 1). Rainfall amounts exceeding 16 inches occurred in the center of this storm. Rainfall in excess of five inches fell over 3000 square miles, while over one inch of rain blanketed an area of 22,000 square miles. Within the core of the storm all rainfall occurred during a 15-hour period. Near Millstadt, Illinois, 16.54 inches fell within less than 12 hours (Point A, Fig.2).

An extensive field survey was conducted by the Illinois State Water Survey to obtain a detailed isohyetal pattern of this storm. This survey was restricted mainly to Illinois, although some field investigation was done in eastern Missouri. Emphasis was placed upon obtaining observations within and near the core of the storm. A total of 189 observations was obtained by the State Water Survey. A total of 302 observations was available for defining the isohyetal patterns, the remaining observations being recorded by the U. S. Weather Bureau, Corps of Engineers, Illinois Division of Waterways, and other organizations having rain gages in the storm area. The distribution of the rainfall observations is shown in Figure 2.

Radar observations of the storm were made by the State Water Survey with a CPS-9 radar. This is a high-powered, 3-cm set, specifically designed for the detecting and tracking and the general meteorological analyses of storms. The set is located at the University of Illinois Airport at Savoy in east central Illinois. The main center of the storm was located approximately 125 miles from the radar set. The CPS-9 has an effective observation range of about 250 miles, although on occasions this range may vary considerably, depending upon storm characteristics, precipitation attenuation, and other atmospheric conditions.

Isohyetal Patterns

An isohyetal map for the entire storm period is presented in Figure 3. All of the storm rainfall occurred within a 24-hour period beginning in the late forenoon of June 14. All of the rainfall in the storm core south of St. Louis fell within the 15-hour period beginning at 1700 CST on June 14. Reference to Figure 3 shows the maximum rainfall occurring in extreme southwestern Illinois, with secondary peaks near Pacific in eastern Missouri and in Illinois east of the main center. The extremely tight rainfall gradient near the storm core and the east-northeast to west-southwest orientation of the storm can be seen in this figure. Investigation of other severe rainstorms in this region indicates that storm patterns similar to this storm frequently occur.

Fortunately, the June 14-15 storm was centered in an area where the recording gage density is considerably above average and sufficient to permit reliable approximations of the time distribution of the storm rainfall. Approximations of the isohyetal pattern during various peak periods of the storm were obtained by drawing maps for each peak period on which lines connecting points of equal percentage of total storm rainfall were indicated. These isopercentile maps were then used as overlays on the total storm isohyetal map to obtain rainfall values for each peak period.

An isopercentile map for the maximum 6-hour period of rainfall is shown in Figure 4. To obtain the maximum 6-hour rainfall, this isopercentile map was used as an overlay on the total storm map of Figure 3 and rainfall values calculated at intersections between the total storm isohyets and the isopercentile lines of Figure 4. The 6-hour maximum rainfall isohyetal map (Fig. 6) was then drawn from values obtained at the many intersection points. Other peak period maps for 3, 9, and 12 hours were constructed in the same manner. The 3-hour and 12-hour maps are presented in Figures 5 and 7. The several peak period maps were used to obtain area-depth relations for maximum periods within the over-all storm. These will be discussed later.

Characteristics of Rainfall Distribution

Figure 8 shows mass curves of rainfall constructed from recording rain gage records for stations near the major axis of the storm. The locations of these stations are shown on Figure 2. Belleville and Trenton are very close to the main storm center in southwestern Illinois. Reference to the mass curves for these stations shows that rain did not begin until early evening of the 14th and ended by 0800 of the 15th, the largest portion having fallen by 0400 of the 15th. The curve for St. Louis Airport a few miles north of the storm axis shows rainfall commencing somewhat earlier, in conjunction with a squall zone which moved in from the northwest and became quasi-stationary south of St. Louis. The mass curves of Figure 8 illustrate the typical characteristics of such storms, consisting of a number of bursts or individual showers during the over-all storm period. The curves indicate that the storm consisted of six to eight bursts at various locations along the core of the storm. The rainfall distribution along and near the axis of a storm, as portrayed by the recording rain gage charts and radar observations, indicates that the peak periods for 3, 6, 9 and 12 hours for the storm ended on June 15 at 0230, 0200, 0400, and 0730 EST, respectively. These maximum periods varied at individual stations within the core, of course, but the periods listed appeared to be the maxima for average rainfall within the storm.

Depth-Duration-Area Relations

Area-depth relations for the total storm period and for peak periods of 3, 6, 9 and 12 hours are shown in Table 1. Area-depth relations within this storm were found to be closely approximated by a relation of the form:

$$\text{Log } Y = a + b X^{0.4}$$

where Y is rainfall depth in inches, X is area in square miles and a and b are regression constants. Table 2 shows the time distribution of rainfall within the core of the storm. In this table, the percent of the total storm rainfall is given for selected areas within the storm core for peak rainfall periods of 3, 6, 9 and 12 hours. The values in Table 2 are for the area within the 6-inch isohyet as shown in the total storm rainfall map in Figure 3. The areas are comparable to those in Table 1. Thus, within the 100 square miles having the heaviest rainfall during the total storm period, 50 percent of the total storm rainfall occurred within the maximum 3-hour period, 72 percent within the maximum 6-hour period, and 97 percent within the maximum 12-hour period. Referring to Table 1, these correspond to amounts of 7.5, 10.9, and 14.7 inches within 3, 6, and 12 hours, respectively.

TABLE 1

DEPTH-DURATION-AREA DATA, JUNE 14-15

Duration	Depth (in.) for given area (sq. mi.) 25	50	100	200	500	1000	2000	5000	10,000
Entire Storm	16.5	16.0	15.1	14.2	12.5	11.0	9.3	6.7	5.0
Max. 12 hrs.	16.3	15.7	14.7	13.8	12.0	10.4	8.6	6.1	4.3
Max. 9 hrs.	13.8	13.2	12.3	11.4	9.7	8.2	6.6	4.5	3.0
Max. 6 hrs.	12.6	11.8	10.9	9.8	8.1	6.6	5.0	3.1	-
Max. 3 hrs.	8.7	8.2	7.5	6.7	5.5	4.4	3.4	2.0	-

TABLE 2

TIME DISTRIBUTION OF AREAL MEAN RAINFALL, JUNE 14-15

Period	Percent of total storm rainfall for given areas (sq. mi.) 25	50	100	200	500	1000	2000
Max. 3 hrs.	53	51	50	47	44	40	37
Max. 6 hrs.	76	74	72	69	65	60	54
Max. 9 hrs.	84	83	81	80	78	75	71
Max. 12 hrs.	99	98	97	97	96	95	93

Antecedent Rainfall

Total rainfall for 5-day and 10-day periods preceding the June 14-15 storm is shown for Illinois in the isohyetal maps of Figures 9 and 10. Heavy antecedent rainfall would, of course, accentuate the flood-producing capabilities of the June 14-15 storm. For the 5-day period, June 9-13, rainfall averaged about one inch at the center of the storm. For the 10-day antecedent period, June 4-13, amounts ranged from 1.5 to 3.0 inches in the storm core. Normal 5-day and 10-day rainfall amounts during this period in the region of the storm center are approximately 0.65 and 1.3 inches, respectively. Thus, rainfall during the antecedent periods was above average, but not exceptionally heavy. Figures 9 and 10 show some scattered heavy amounts north of the storm axis in the Kaskaskia and Little Wabash watersheds.

Synoptic Weather

The surface synoptic map for midnight on June 11, indicated a low pressure system of moderate intensity in the Hudson Bay area of northern Canada. A well-defined cold front extended southwestward from the center of the low across north central Illinois to a weak trough in the region of the Texas Panhandle.

Viewing this system as an entity, it is evident that the northern extremities of the system were moving rapidly eastward, while the position of the Bermuda high pressure cell was preventing rapid southerly advance of the front. The Bermuda high extended well inland over the south central states supplying moisture in the lower levels in the vicinity of the front.

During the next 24 hours, the Hudson Bay low continued its easterly movement; at the same time, the trough in Texas developed into a closed system with formation of a wave on the front which began moving northward. The relative motions of these systems produced a rotation of the cold front through Illinois, so that by midnight of June 12 the front was oriented east-west across northern Illinois. The Burmuda high continued to advect moisture from the Gulf of Mexico to the front, producing showers and thunderstorms.

Developments were rapid during the next 24 hours. By midnight on June 13, the wave that developed to the southwest was centered on the cold front due west of Illinois, with the cold front extending southward. Instability zones were forming and moving away from the cold front. The low pressure system continued to intensify while moving northward, and by noon on June 14 was located in upper Minnesota. The cold front extended southward into Wisconsin curving gently westward to central Missouri and into Texas. The surface synoptic pattern at noon is shown in Figure 11. The area enclosed by the 6-inch isohyet of Figure 3 is shown on this and subsequent surface maps for comparison of the rain core with synoptic conditions.

The low pressure system then began to move rapidly eastward while the southern extremities showed little movement. This type of relative motion forced the formation of a wave on the front in the vicinity of Moline, Illinois, which was the pivotal point of the relative motions along the front (Fig. 11, 1800 CST). A line of thunderstorms and rainshowers formed parallel to and in advance of the front in early afternoon of the 14th, but did not move away relative to the frontal position. The instability area maintained a separation of about 140 miles from the front and reflected the movements of the front. Hail reports [4] indicate widespread hail in Illinois with this instability zone. A tornado occurred at Springfield, Illinois in the afternoon.

The low continued its rapid eastward progress bringing the cold front slowly southward across Illinois. The instability zone drifted southward pivoting at a point in the St. Louis area. Heavy rain was occurring by early evening of June 14 and the instability zone remained stationary for about 12 hours. The surface synoptic pattern at midnight is shown in the upper portion of Figure 12, along with the radar portrayal of the squall zone at that time. Location of the 6-inch rainfall isohyet is also illustrated.

During the period of heavy rainfall, the upper winds in the storm zone veered gradually from the southwest at 5000 feet to west at 20,000 feet. The average speed decreased from 30 mph at 5000 feet to 20 mph at 20,000 feet. However, at 20,000 feet there was a jet maximum of about 65 mph associated with the cold front to the north of the heavy rainfall zone.

During the early morning on June 15, the extreme southern extension of the front in Texas began moving northward, causing the front in Illinois and Missouri to lose its wave-type characteristic and become an east-west, quasi-stationary front. The instability area weakened in intensity and began moving eastward bringing an end to the downpour in the southwestern Illinois area. The synoptic pattern at 0600 CST is shown in the lower portion of Figure 12.

Radar Analysis

The radar portrayal of the orientation, movement, and extent of the storm are shown in Figures 13 and 14. The radar station (CMI) is located at the center of the illustrations. The concentric circles represent ranges of 50, 100, and 150 nautical miles. The top illustration of Figure 13 shows the squall zone in advance of the approaching cold front at 1400 CST on June 14. At that time, the squall zone was oriented from northeast to southwest, approximately parallel to the front (Fig. 11).

The lower illustration of Figure 13 shows the radar portrayal six hours later at 2000 CST, about the time heavy rain started falling in the core of the storm in southwestern Illinois. Rain was occurring in the vicinity of the radar station at 2000 CST so that precipitation attenuation was distorting the presentation somewhat.

At wavelengths less than about seven centimeters, absorption and scattering by rain results in a decrease in the strength of the signal reflected from a storm to the radar. [4] That is, the ratio of received to transmitted power falls below normal. The loss in radar received power is proportional to the depth of the storm and the rainfall intensity within the storm. This precipitation attenuation masks certain characteristics of the rainstorms discussed in this report, and this factor is frequently referred to in ensuing sections.

Figure 13 shows that the orientation of the squall zone had changed considerably in the six hours from 1400 to 2000 CST. At 2000 CST, the most intense portion of the squall zone was oriented ENE-WSW on a line from south of St. Louis to south of Indianapolis. The large mass of storm echo to the east and south of the radar station in Figure 13 represents relatively light rain which would not be visible at greater range. Attenuation is undoubtedly masking the extent of the main squall zone somewhat in this case. The strength of the individual storms in the squall zone is indicated by the fact that storm echoes were visible at ranges of 150 miles and greater despite the attenuating effects of rain at and near the radar station. The reorientation of the squall zone, as portrayed by the radar, appears similar to that shown by the cold front on the synoptic weather maps, indicating that the northern part of the front moved rapidly eastward while the southern portion became quasi-stationary.

The upper illustration of Figure 14 shows the radar presentation of the storm at 0200 CST on the 15th. At that time, rain was not occurring at the radar station so that portrayal of the extent and shape of the squall zone is more realistic. The squall zone had an orientation similar to that six hours earlier in Figure 13. Radar photographs taken continuously throughout the night show that the squall zone remained quasi-stationary in the area south of St. Louis where the core of the storm was located (Fig. 3). The lower part of Figure 14 shows the radar presentation six hours later at 0800 CST on the 15th, when rainfall had ceased in the area of the storm core and the squall zone was dissipating throughout its length as viewed on radar.

Radar tracking of the movement of individual thunderstorms within the storm area indicated the presence of a wind maximum parallel to the major axis of the squall zone. This wind maximum was located approximately 50 miles north of the rainstorm core and in advance of the cold front. Individual storms within the squall zone were moving from WSW to ENE. Strong convergence of moist air into the squall zone to sustain the heavy rainfall was indicated by the radar. Individual storms south of the squall zone were observed by radar to move northward and merge with other storms moving from the WSW within the squall zone.

In summary, it may be said that the radar indicated the presence of a stationary squall zone along the axis of the rainfall core as shown by the isohyetal map of Figure 3. The squall zone remained approximately stationary from early evening to early forenoon, when relatively rapid dissipation took place. The orientation of the squall zone throughout agreed well with the reorientation taking place in the accompanying cold front located to the north of the heavy rainfall zone. Radar analysis also indicated that there was continued generation and movement of individual storms from WSW to ENE in the storm core and convergence of storms moving from the south into the squall zone to sustain the heavy rainfall throughout the night.

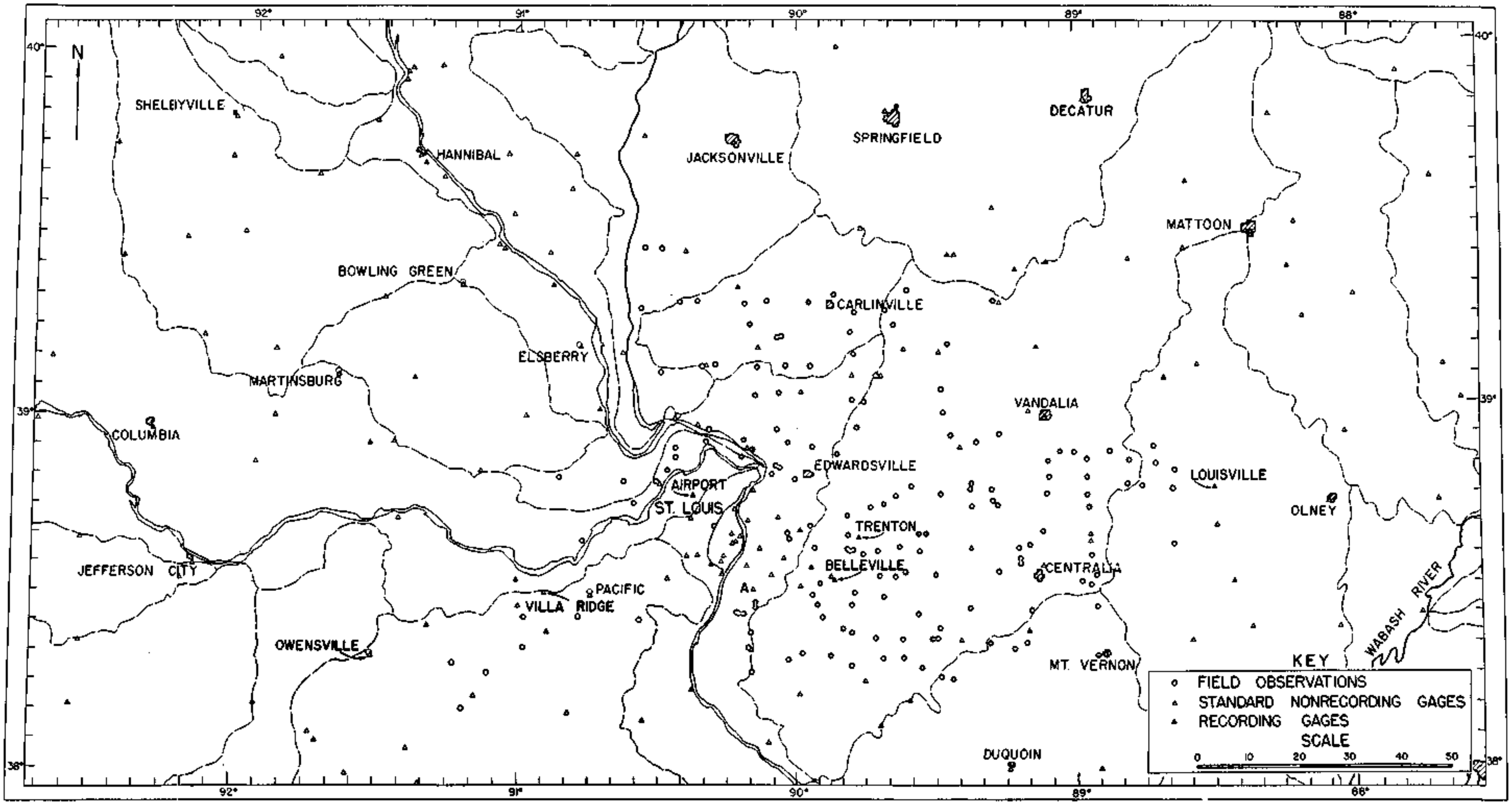


FIGURE 2 LOCATION OF POINT RAINFALL OBSERVATIONS, JUNE 14-15, 1957

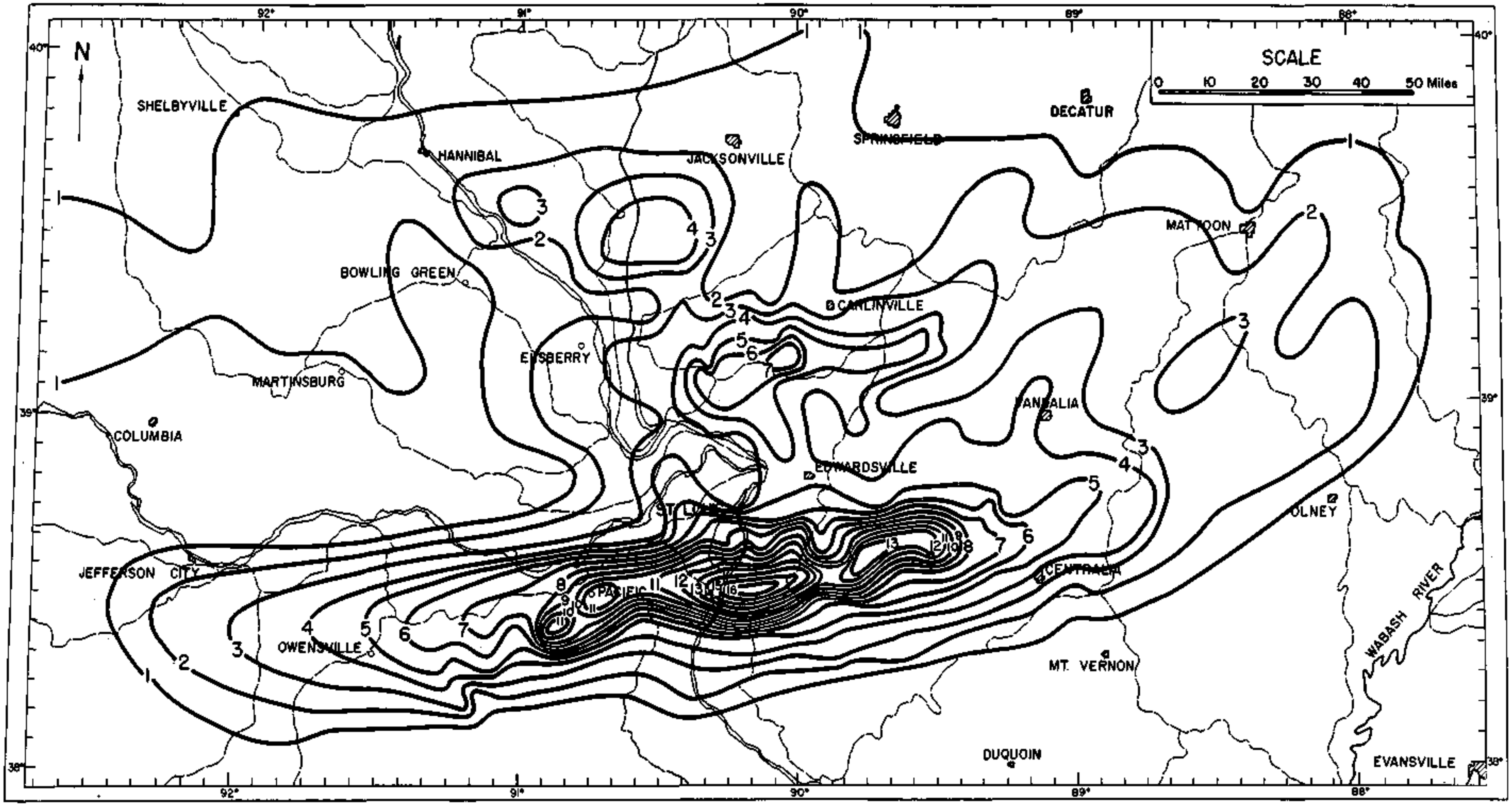


FIGURE 3 TOTAL STORM RAINFALL FOR JUNE 14-15, 1957

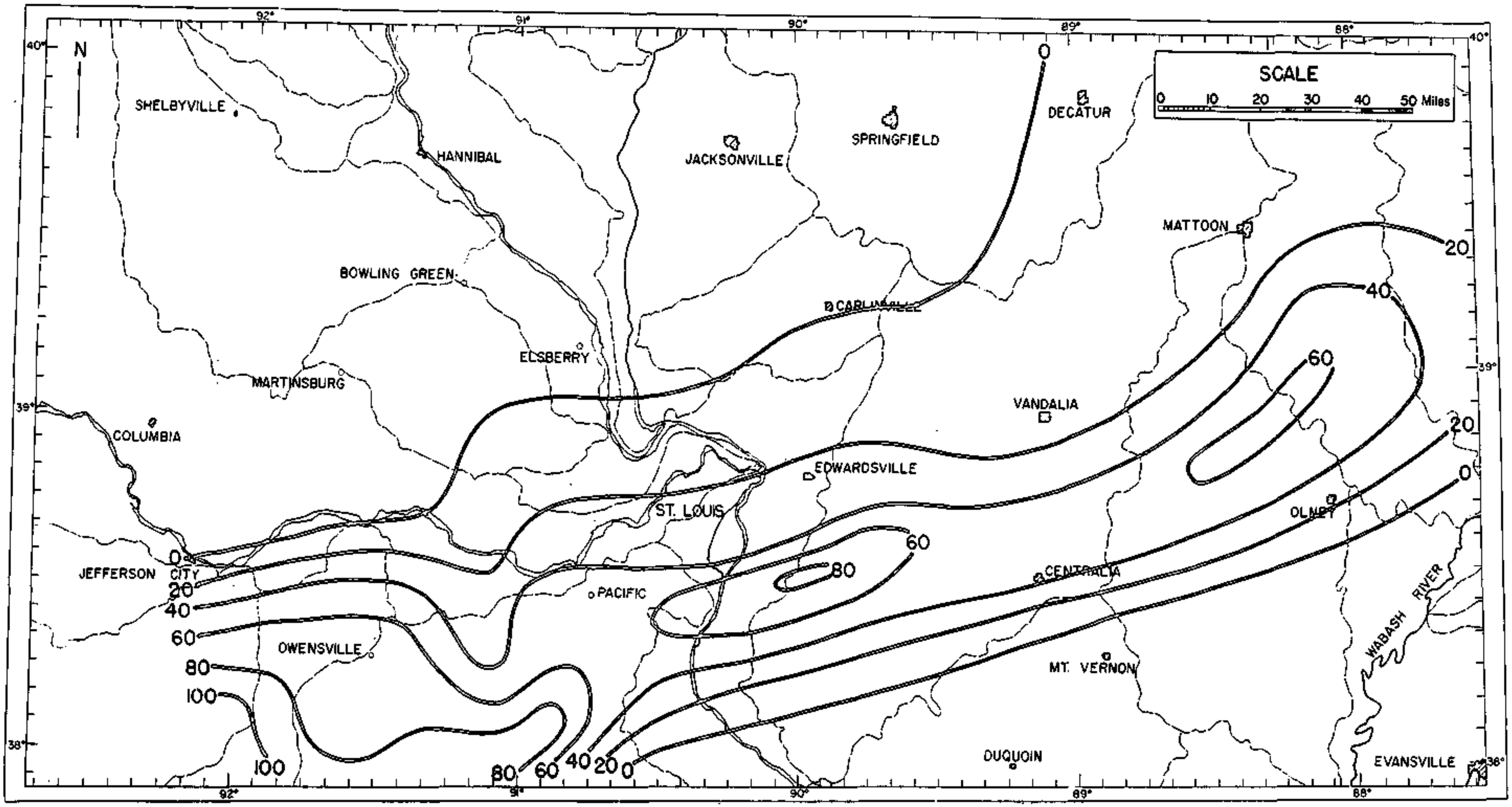


FIGURE 4 ISOPERCENTILE MAP FOR MAXIMUM 6-HOUR RAINFALL FOR JUNE 14-15. 1957

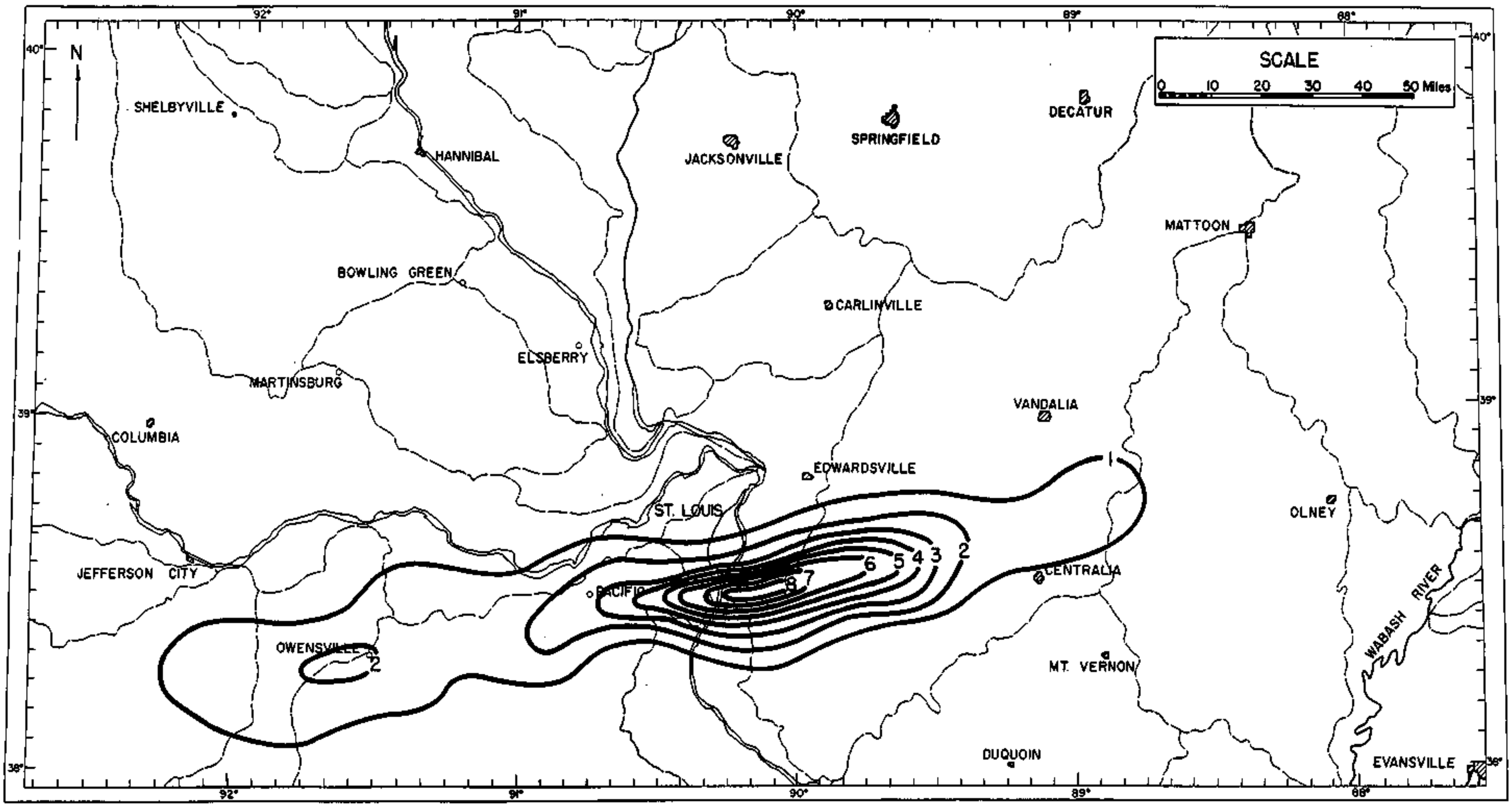


FIGURE 5 MAXIMUM 3-HOUR RAINFALL FOR JUNE 14-15, 1957

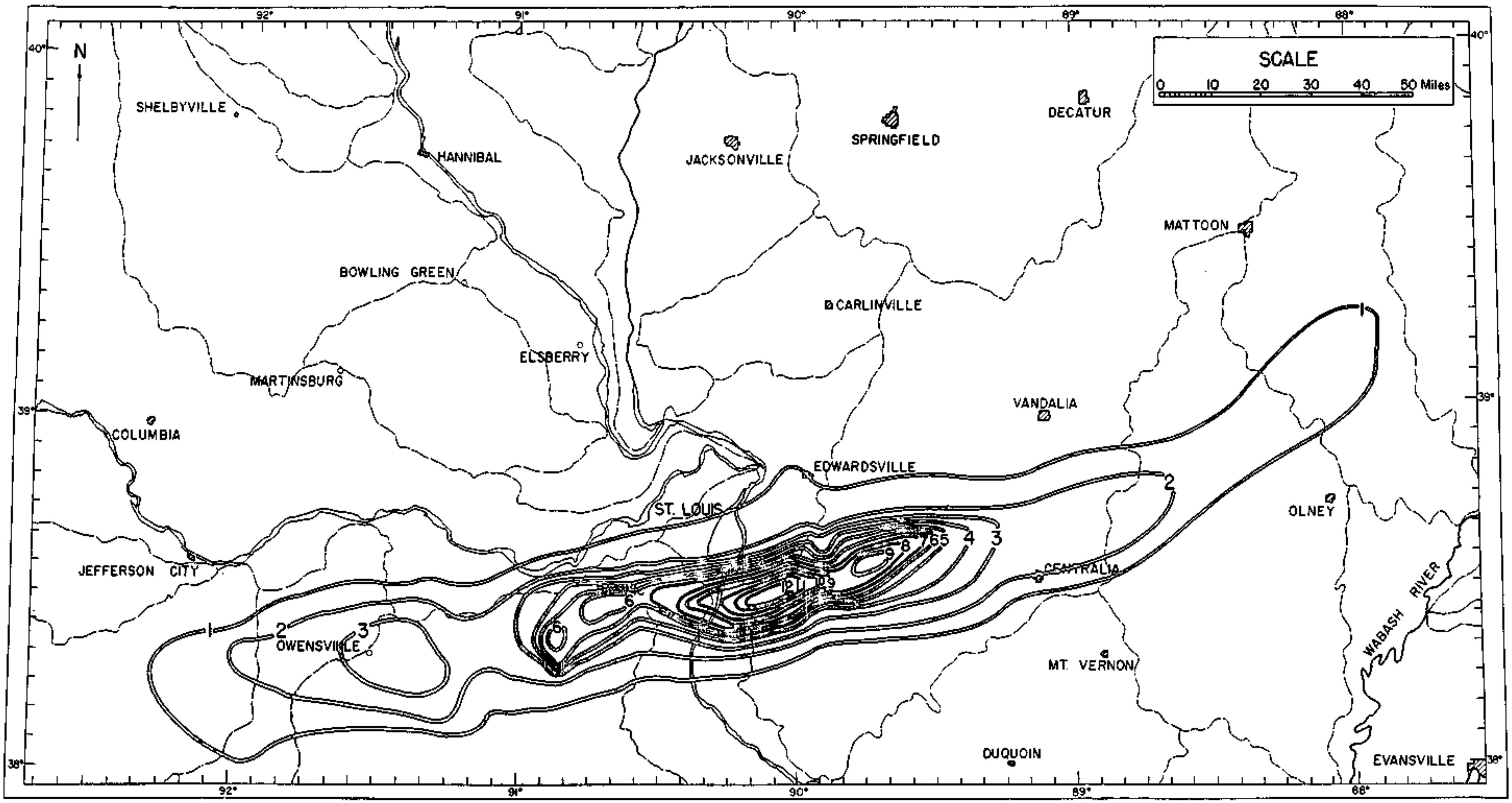


FIGURE 6 MAXIMUM 6-HOUR RAINFALL FOR JUNE 14-15, 1957

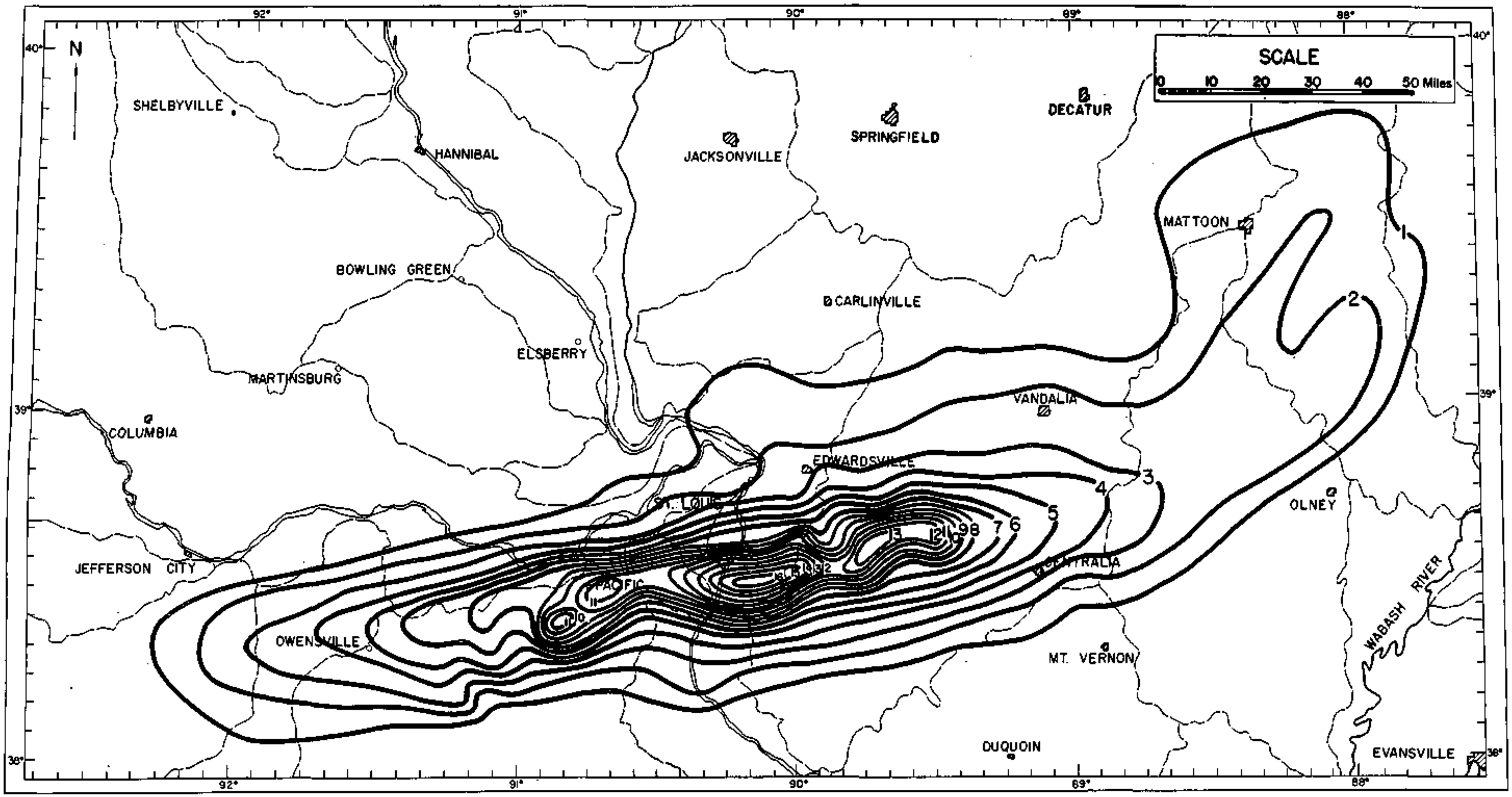


FIGURE 7 MAXIMUM 12-HOUR RAINFALL FOR JUNE 14-15, 1957

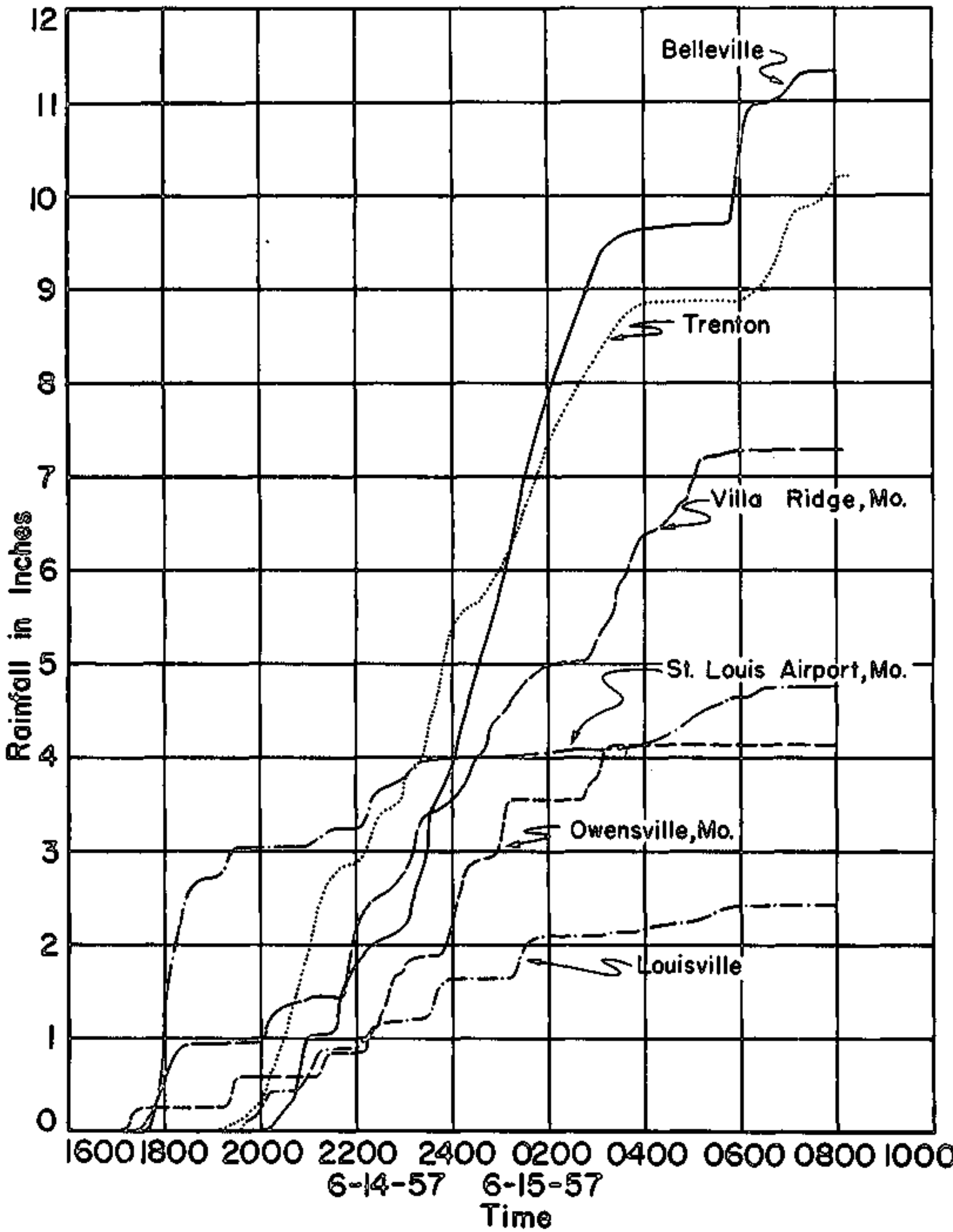


FIGURE 8 MASS CURVES OF RAINFALL FROM SELECTED STATIONS FOR JUNE 14-15, 1957

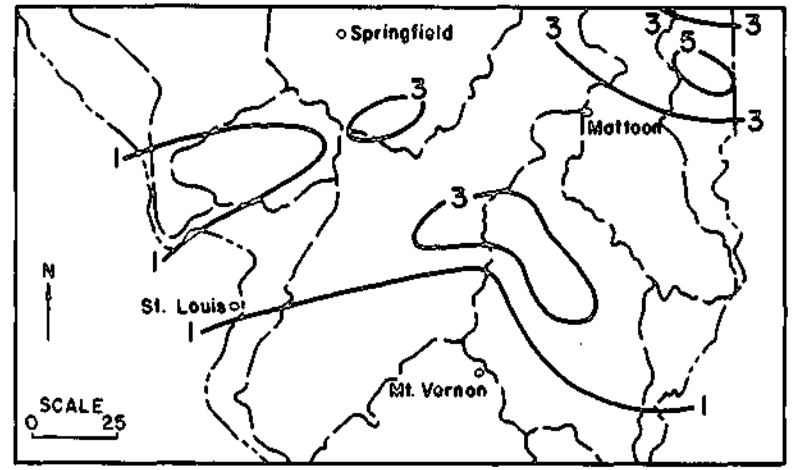


FIGURE 9 TOTAL RAINFALL JUNE 9-13, 1957

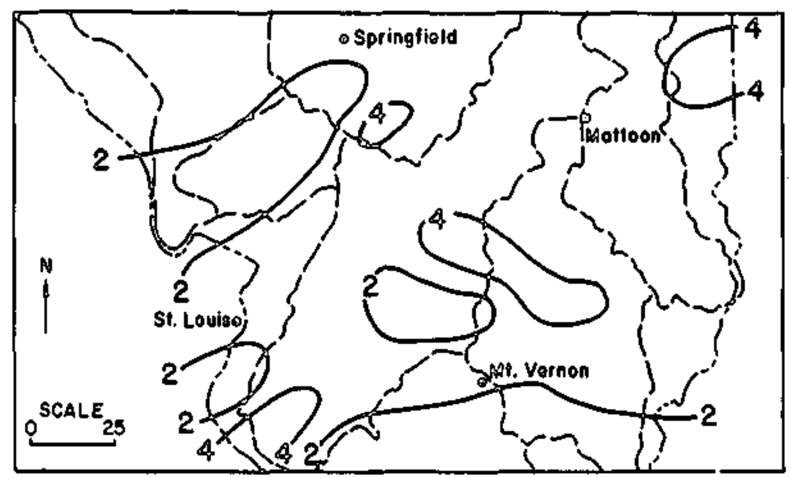


FIGURE 10 TOTAL RAINFALL JUNE 4-13, 1957

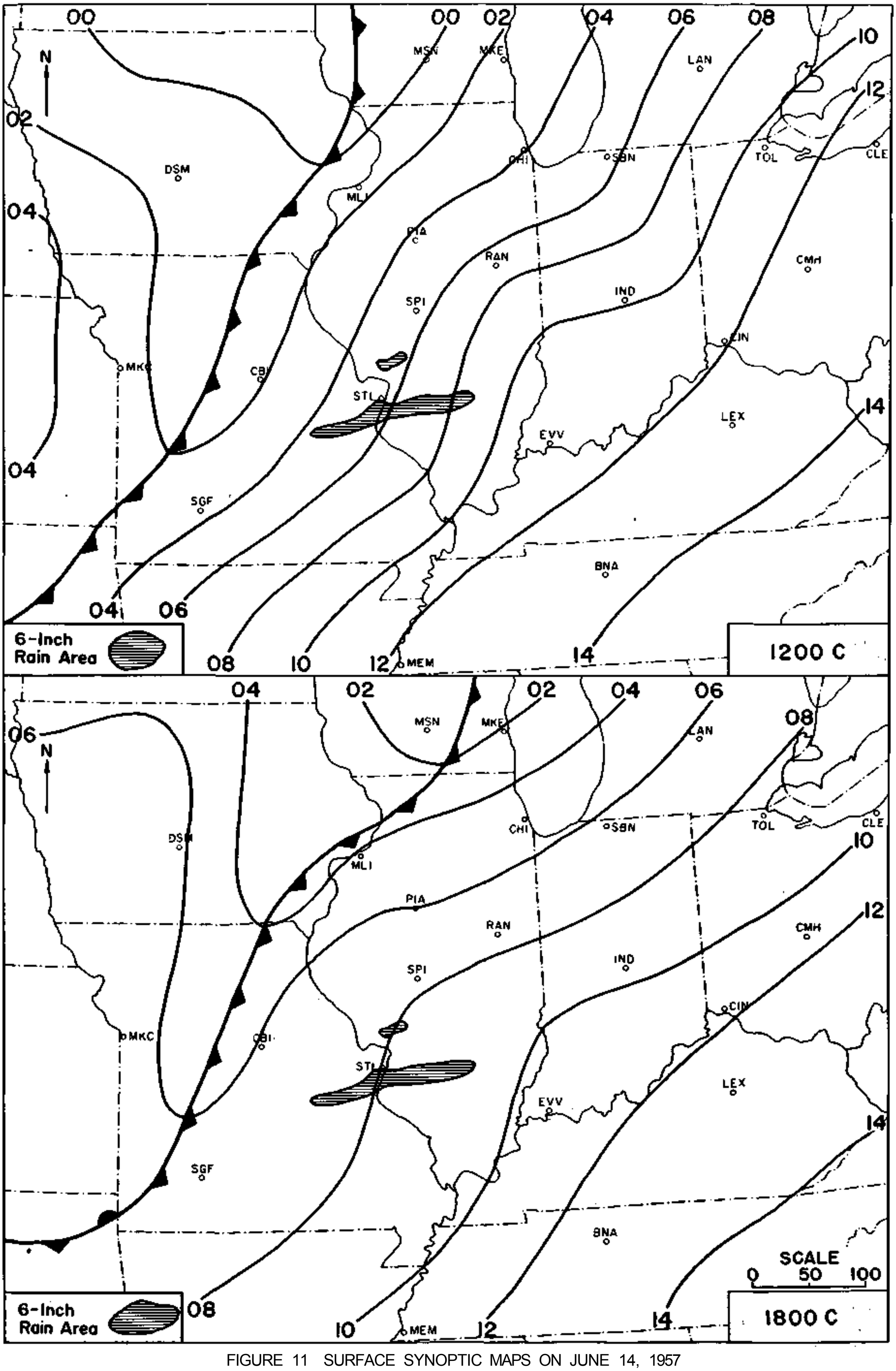


FIGURE 11 SURFACE SYNOPTIC MAPS ON JUNE 14, 1957

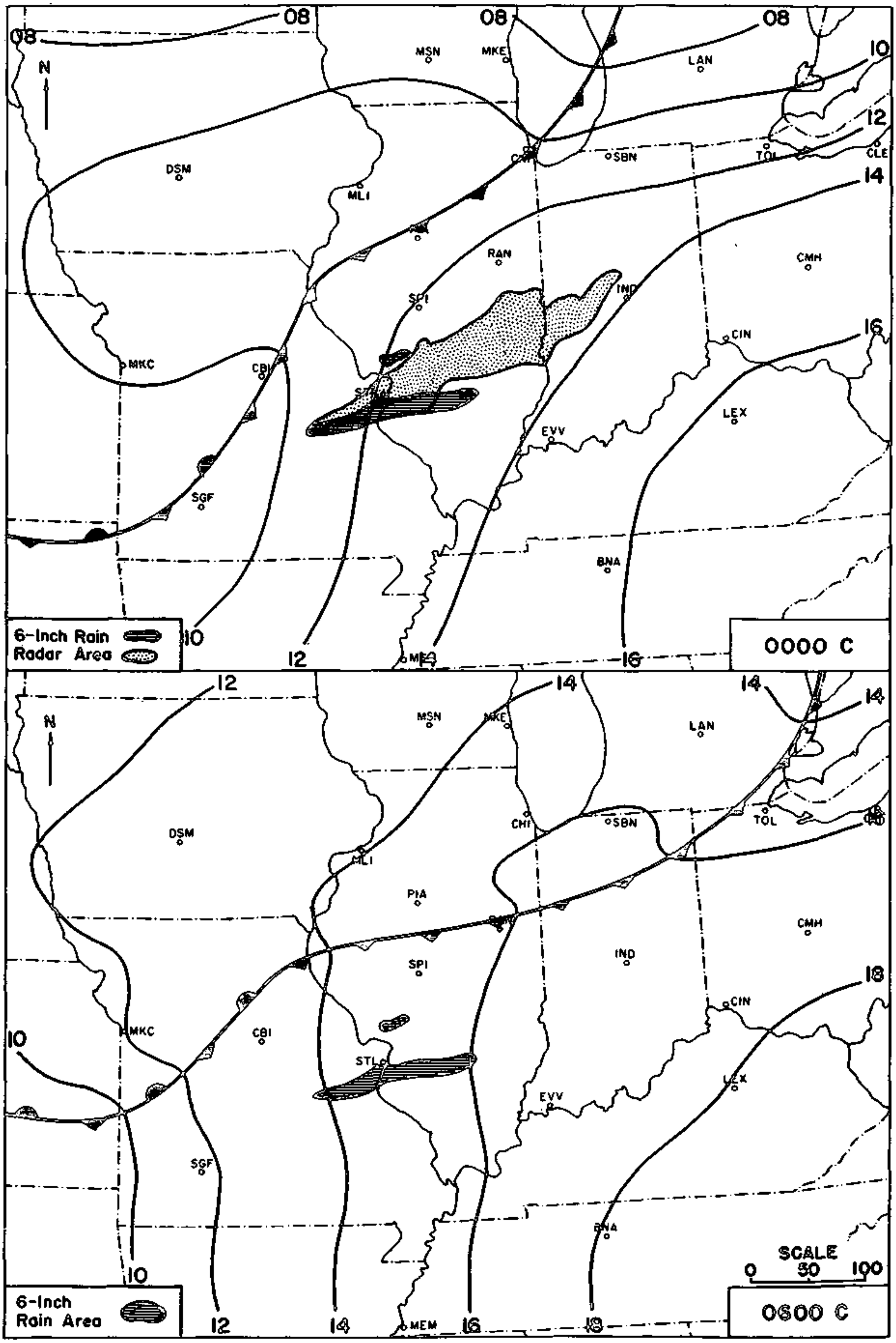


FIGURE 12 SURFACE SYNOPTIC MAPS ON JUNE 15, 1957

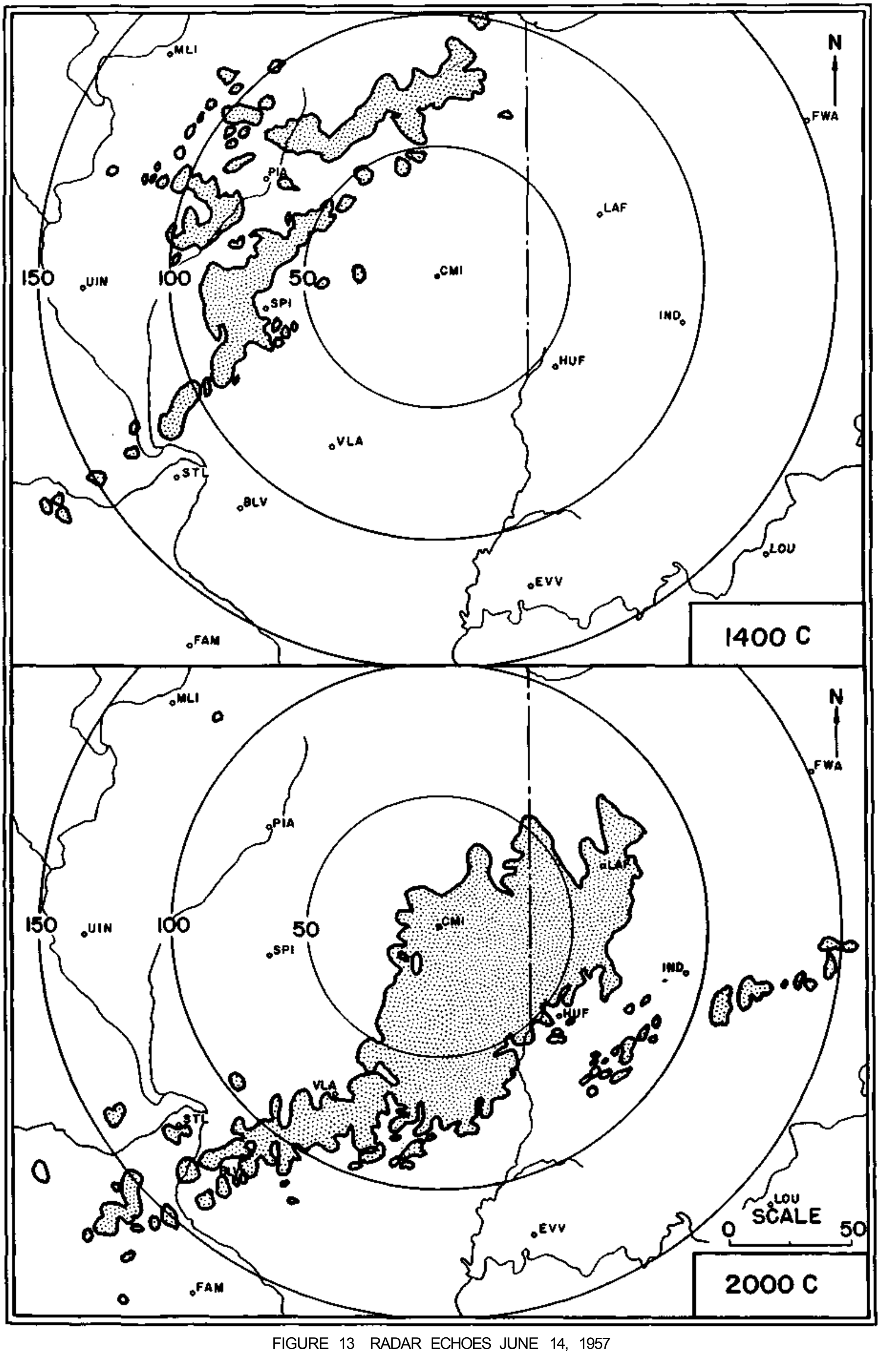


FIGURE 13 RADAR ECHOES JUNE 14, 1957

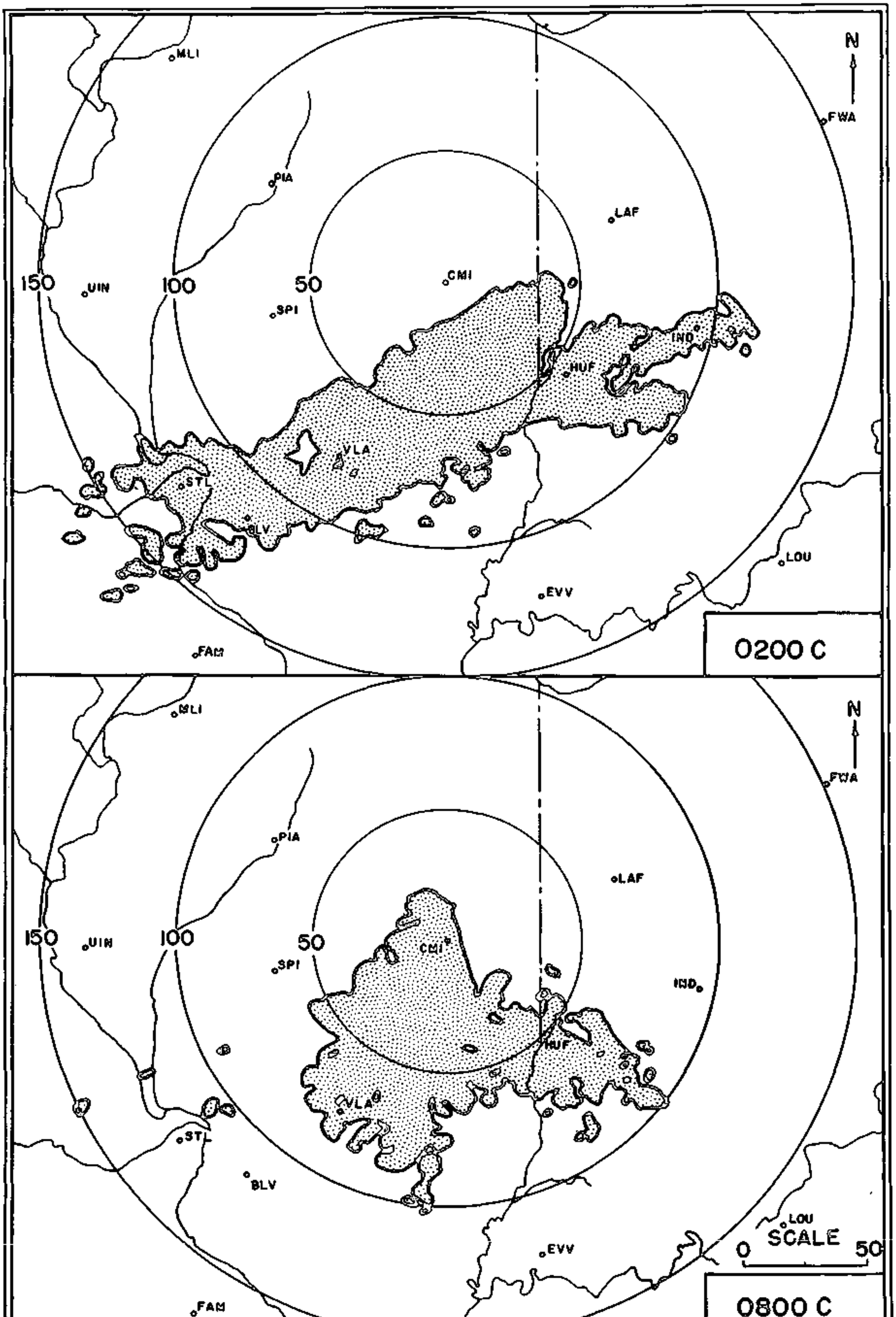


FIGURE 14 RADAR ECHOES JUNE 15, 1957

STORM OF JUNE 27-28, 1957

Introduction

On June 27-28, the third severe rainstorm of 1957 occurred in Illinois (Fig. 1). The major axis of this storm extended ENE from south central Illinois across Indiana into Ohio. The heaviest rainfall amounts in this storm were recorded in south central and extreme east central Illinois and in extreme west central Indiana. Amounts in excess of 12 inches were recorded southeast of Pana, at Point B on Figure 15, while over 13 inches was measured southwest of Paris, Point A on Figure 15. In western Indiana, amounts exceeding 10 inches were recorded. In Illinois and Indiana, rainfall in excess of five inches fell over 6600 square miles, while over two inches of rain covered an area of 40,000 square miles. Except for a few scattered showers during the early afternoon of June 27, all of the rain in the storm core in Illinois and western Indiana fell from late afternoon of the 27th to late forenoon of the 28th. All of the rain occurred within less than 24 hours and the majority of it within a 12-hour period beginning at 2230 CST on the 27th.

Portions of eastern Missouri also received heavy rainfall in the June 27-28 storm. The Missouri storm was centered southwest of St. Louis in the vicinity of Villa Ridge (Fig. 2). A storm total of 7.26 inches was recorded at Villa Ridge, 5.52 inches falling in a 2-hour period from midnight to 0200 CST on June 28. Crop hail insurance reports [4] for Illinois indicate scattered hail storms occurred within the storm zone.

A detailed field survey was conducted in Illinois by the State Water Survey with emphasis placed upon obtaining observations within and near the core of the storm. Results of the field survey, together with observations made by other organizations, provided over 400 observations within Illinois for establishing detailed isohyetal patterns (Fig. 15). The storm analysis for Indiana was accomplished using data furnished by the U. S. Weather Bureau. Verified field survey data for Indiana, as collected by the Corps of Engineers and Indiana Flood Control and Water Resources Commission, were not available at the time of the analysis and can be obtained in the offices of those agencies. Comparison of isohyetal patterns between those in this report and those subsequently developed by agencies in Indiana reveals that differences are of a minor nature.

Isohyetal Pattern

An isohyetal map for the total storm period is shown in Figure 16. As mentioned earlier, the heaviest storm rainfall occurred in south central Illinois, extreme east central Illinois, and west central Indiana. In Illinois, all of the rainfall fell within a 24-hour period beginning at noon on June 27. Within the total storm period, the maximum 12-hour rainfall occurred in the period beginning at 2230 CST on June 27. The isohyetal map for this period is shown in Figure 17. The technique described previously in conjunction with the June 14-15 storm was used to construct the peak period map.

Gage flooding and use of the singe traverse type of gage made delineation of the maximum 3-hour and 6-hour periods difficult at several key recording gage stations near the major axis of the storm during the latter part of the rainfall period. Estimates of hourly totals for these stations were made from hourly isohyetal maps constructed from other recording gage data within the storm region to aid in defining the peak 3-hour and 6-hour periods. Analysis indicated these two peak periods began at midnight of the 27th. Isohyetal maps were constructed for these peak periods (Figs. 18 and 19) and used for determining area-depth relations which will be discussed later.

Characteristics of Rainfall Distribution

Mass rainfall curves constructed from recording gage stations located along or near the core of the storm are shown in Figure 20. Station locations are shown in Figure 15. Again, these mass curves show the typical characteristics of the thunderstorm or flash flood rains, consisting of a number of bursts or individual showers during the total storm period. Note that Sullivan and Mattoon, which were located to the north of the major storm axis, received their heavy rainfall somewhat earlier than Paris, Morrisonville, and Waveland, which nearly coincide with the major axis of the storm. Greenfield, situated at the extreme western point of the major axis, did not receive its heaviest rainfall until the early morning hours of June 28. This was also typical of the distribution shown by a recording gage at Ohlman (Fig. 15), located a short distance northwest of the storm center in south central Illinois. Wide variability in the time and space distribution of rainfall in this type of storm is quite prevalent and makes definition of incremental peak periods within the total storm period difficult. The Paris and Waveland totals in Figure 20 were available and are so indicated, although the actual time distribution was not available after 0500 CST.

Depth-Duration-Area Relations

Area-depth relations for the total storm period and for maximum rainfall periods of 3, 6, and 12 hours are shown in Table 3. The area-depth data in this storm were fitted to an equation of the form:

$$\text{Log } Y = a + bX^{1/3}$$

where Y is rainfall depth in inches, X is area in square miles, and a and b are regression constants. Table 4 shows the time distribution of rainfall within the core of this storm for peak rainfall periods of 3, 6, and 12 hours. Values in Table 4 are for the area within the 7-inch isohyet shown in the total storm rainfall map of Figure 16. This table was obtained in the manner described in the previous section on the June 14-15 storm.

TABLE 3

DEPTH-DURATION-AREA DATA, JUNE 27-28

	Depth (in.) for given area (sq. mi.)									
Duration	25	50	100	200	500	1000	2000	5000	10,000	20,000
Entire storm	12.4	12.0	11.5	11.1	10.2	9.4	8.5	7.1	6.0	4.8
Max. 12 hrs.	12.0	11.5	10.9	10.3	9.3	8.4	7.4	5.9	4.7	-
Max. 6 hrs.	8.7	8.3	8.0	7.6	6.8	6.2	5.5	4.4	3.6	-
Max. 3 hrs.	4.5	4.3	4.2	4.0	3.7	3.4	3.1	2.6	2.2	-

TABLE 4

TIME DISTRIBUTION OF AREAL MEAN RAINFALL, JUNE 27-28

	Percent of total storm rainfall for given areas (sq. mi.)						
Period	25	50	100	200	500	1000	2000
Max. 3 hrs.	36	36	36	36	36	36	36
Max. 6 hrs.	70	69	69	68	67	66	65
Max. 12 hrs.	97	96	95	93	91	89	87

Antecedent Rainfall

Total rainfall for the 5-day and 10-day periods prior to the June 27-28 storm are indicated in the isohyetal maps of Figures 21 and 22. Normal 5-day and 10-day amounts in this region are approximately 0.7 inch and 1.4 inches, respectively. Figures 21 and 22 show below normal rainfall for the 5-day and 10-day antecedent periods, except for a small area south of the storm core where near normal amounts occurred.

Synoptic Weather

Unlike the June 14-15 storm in southwestern Illinois where a high pressure system acted as a pumping mechanism for atmospheric moisture, a low pressure system associated with a decaying hurricane provided a mechanism for moisture flow into Illinois in the June 27-28 storm. At 1800 CST on June 27, the hurricane was centered over central Louisiana, moving northeastward at about 20 mph, while a weak and dissipating frontal system was quasi-stationary in an east-west orientation across southern Illinois (Fig. 23). For comparison of the rain core with synoptic conditions the rain area within the 6-inch isohyet for the total storm period has been shown on the surface maps.

The frontal system exhibited a weak wave formation by midnight on June 27 and was moving eastward (Fig. 23). Meanwhile, the hurricane was decreasing in intensity during its movement to the northeast. The southerly winds on the east side of the hurricane were heavily laden with moisture and were directed into the weak warm front in the vicinity of the rainstorm. In addition to the rain core, the radar presentation of the storm at midnight is shown in the lower portion of Figure 23. The squall zone undoubtedly extended further south, but its true depth is masked by precipitation attenuation. Note the intersection of the squall zone and the front in the heavy rainfall area. The frontal system continued to weaken with the approach of the hurricane from the south. Mixing with the atmosphere associated with the hurricane made it difficult to distinguish a contrast in air mass characteristics across the front.

By 0600 CST on June 28 (Fig. 24), the wave had developed a small, closed, low pressure area in central Illinois with the associated cold front extending southwestward through central Missouri, while the warm front extended eastward through south central Indiana. The hurricane at that time had weakened significantly and had become an extra-tropical cyclone centered near Memphis, Tennessee. Circulation around the dying hurricane was such that the moisture source previously available during the night had been removed from south central Illinois. However, a squall zone associated with the cold front continued to move across Illinois. During the next six hours the low pressure area associated with the frontal system was observed to move to the northeast and the characteristics of a frontal system became nonexistent. At noon on June 28 (Fig. 24), the remains of the hurricane and the frontal system constituted one large trough of low pressure oriented north-south in eastern Indiana. By this time, rain had stopped in Illinois as the pressure slowly rose and the skies cleared.

U. S. Weather Bureau upper air maps for 1800 CST on June 27, prior to the start of the heavy rainfall, indicated SW winds at 25-30 mph at 5000 feet, increasing to 30-35 mph at 10,000 feet, and to 45-55 mph at 20,000 feet. The Showalter instability index ranged from -1 to +1 in the storm region. By midnight of the 27th, when heavy rainfall was occurring in Illinois, converging air was indicated by the winds in the lower 5000 feet. By 0600 CST on the 28th, near the end of the heavy rain period, winds had shifted to NW at 10-15 mph at 5000 feet near the storm core in Illinois with the passage of a weak trough. Over most of Indiana SW winds existed at this level. At 10,000 feet the winds were 35-45 mph from the WSW to SW, while at 20,000 feet they were about 35-40 mph from the SW.

Radar Analysis

The CPS-9 radar was in continuous operation throughout the storm period. However, detailed observations of the characteristics of the storm during the period of most intense rainfall were unsatisfactory due to precipitation attenuation effects. Nevertheless, considerable pertinent information pertaining to the orientation, movement, and development of the storm were obtained from analysis of the radar data.

The radar portrayal of storm conditions at 1300 CST on June 27 is shown in the upper illustration of Figure 25. At this time, individual storms were moving from the southwest.

During the afternoon of June 27, bands or lines of storms, oriented approximately east-west, were observed to move from the south. The band to the south of the station at 1300 CST in Figure 25 represents one of these observed bands. The storm zone to the northwest of the station appeared to develop about noon in the region where it is shown in Figure 25, and at that time, represented light showers. The band through the radar station at 1300 CST appeared to develop in the region shown. At 1300 CST, the quasi-stationary front discussed in the synoptic weather section was lying between the squall zone through the radar station and the one to the south of the station in Figure 25.

The radar presentation three hours later at 1600 CST is shown in the lower part of Figure 25. Precipitation attenuation was affecting the presentation at this time, due to rain surrounding the radar station. Attenuation may be responsible for the apparent dissipation of the storm zone to the northwest of the station. Also, the squall zone to the south and southeast of the station is probably not accurately represented. At this time, the study of extensive radar film records indicate that the most intense storms were oriented approximately ENE-WSW through the area which later became the center of the heavy rainfall zone.

The upper illustration of Figure 26 shows the radar portrayal of storm conditions at 2000 CST on June 27. It indicates that the storm zone northwest of the station was in approximately the same position as seven hours earlier, as shown in the upper portion of Figure 25. Any activity south of the main squall zone near the station was masked by attenuation at this time. Movement of individual storms indicated convergence into the main storm area. The main storm zone, centered a few miles south of the radar station, persisted throughout the afternoon and evening, similar to the one to the northwest. By 2000 CST, the storm zone to the northwest had become more intense. Radar analysis indicates that the squall zone which remained quasi-stationary to the south of the station was supported and sustained by squall lines or bands which moved into the zone from, the south. Although scattered, heavy rainfall amounts up to four inches were recorded in northeastern Illinois, the storm zone to the northwest of the radar station (2000 CST, Fig. 26) did not reach the proportions of the other storm zone, possibly because of the lack of the sustaining mechanism which appeared to be present with the more southerly squall zone. The movement of storms from the south into the zone south of the radar station and the presence of the weak warm front in close proximity to this area were undoubtedly associated with the maximizing of development in this zone.

The lower part of Figure 26 shows the radar portrayal at 2300 CST. Again, precipitation attenuation was masking certain of the storm characteristics. By this time, the squall zone to the northwest of the station had started moving slowly southeastward in the direction of the more intense squall zone. Again, it is noted that the zone to the south of the station had remained relatively stationary. The period of heaviest rainfall within the overall storm period began about the time of this illustration. With the initiation of heavier rainfall, attenuation became more severe. This is apparent by the range reduction to the northeast and southwest in comparison with the presentation at 2000 CST. Individual storms were converging into the area of maximum rainfall at this time.

Because of severe attenuation, the radar presentation was unsatisfactory during the early morning hours of June 28. By 0600 CST (Fig. 27), the intensity of rainfall in the storm zone had decreased somewhat and the radar presentation again became realistic. It is noted that by this time the squall zone was reoriented from ENE-WSW to NE-SW. Also, about this time the squall zone, which had been stationary, began moving to the east. The reorientation and movement appeared to be associated with the development and movement of the frontal wave shown at 0600 CST in Figure 24. As the wave developed and moved northward, the squall zone reoriented itself approximately parallel with the cold front portion of the weak frontal system and moved eastward ahead of the cold front (1000 CST, Fig. 27).

By comparing the radar analysis and synoptic weather analysis, it appears that a quasi-stationary squall zone developed near the region of maximum rainfall about noon of the 27th. At this time, the zone appeared to be slightly north of its eventual position. About the same time, another quasi-stationary zone developed to the northwest of the station in the region from Peoria to Chicago. These zones remained quasi-stationary throughout the day. The squall zone to the south of the station appeared to be supported and sustained through the presence of a weak warm front in its vicinity and the movement of squall lines from the south into it. These squall lines which moved from the south appeared to be associated with a decaying hurricane, which was moving northeastward and dissipating. Along the major axis of the rain storm, the heaviest rainfall occurred in south central and east central Illinois and in west central Indiana. These peak rainfall areas apparently occurred at or near the intersection of the quasi-stationary squall zone with the warm front. During the late evening, the quasi-stationary storm zone to the northwest started a slow southeastward movement, and it is believed that this zone merged with and supported the heavy rainfall in south central and east central Illinois in the early morning hours of the 28th. The most intense period of rainfall in south central Illinois appeared to coincide with the merging of this squall zone from the northwest with the main squall zone. Also, the second of two heavy burst periods in extreme east central Illinois appeared to be associated with the merging of this storm zone moving in from the northwest. The stationary squall zone reoriented itself and started moving eastward in the early forenoon. This reorientation and movement appeared to be associated with the development and northeastward movement of a wave on the frontal system. Also, by early forenoon, the movement of the hurricane was such that moisture flow into the maximum rainfall zone was reduced considerably. Thus, the combination of the movement and dissipation of the hurricane along with the development and northeastward movement of the wave on the frontal system appeared to be responsible for the ending of the torrential downpour in Illinois and western Indiana.

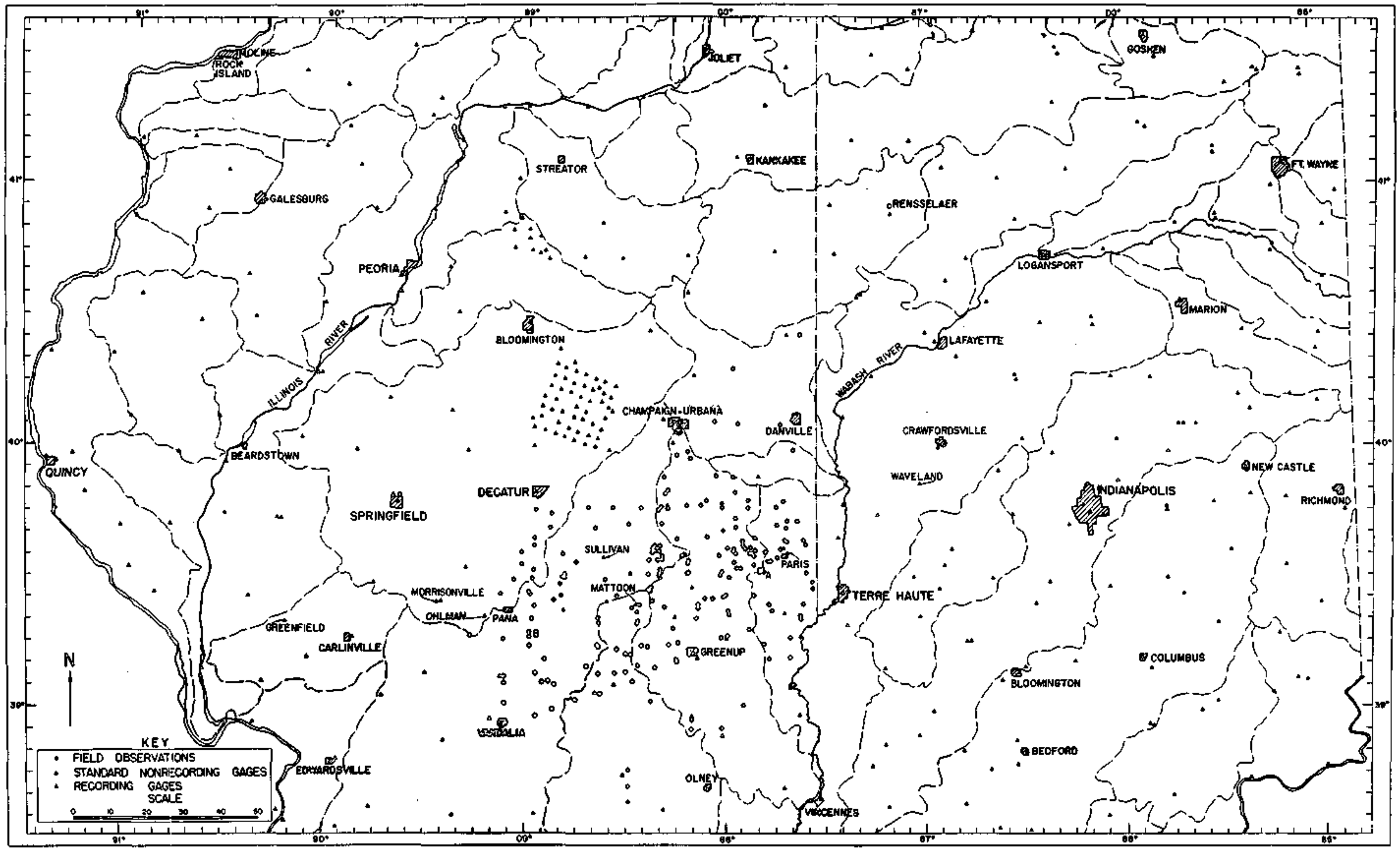


FIGURE 15 LOCATION OF POINT RAINFALL OBSERVATIONS, JUNE 27-28, 1957

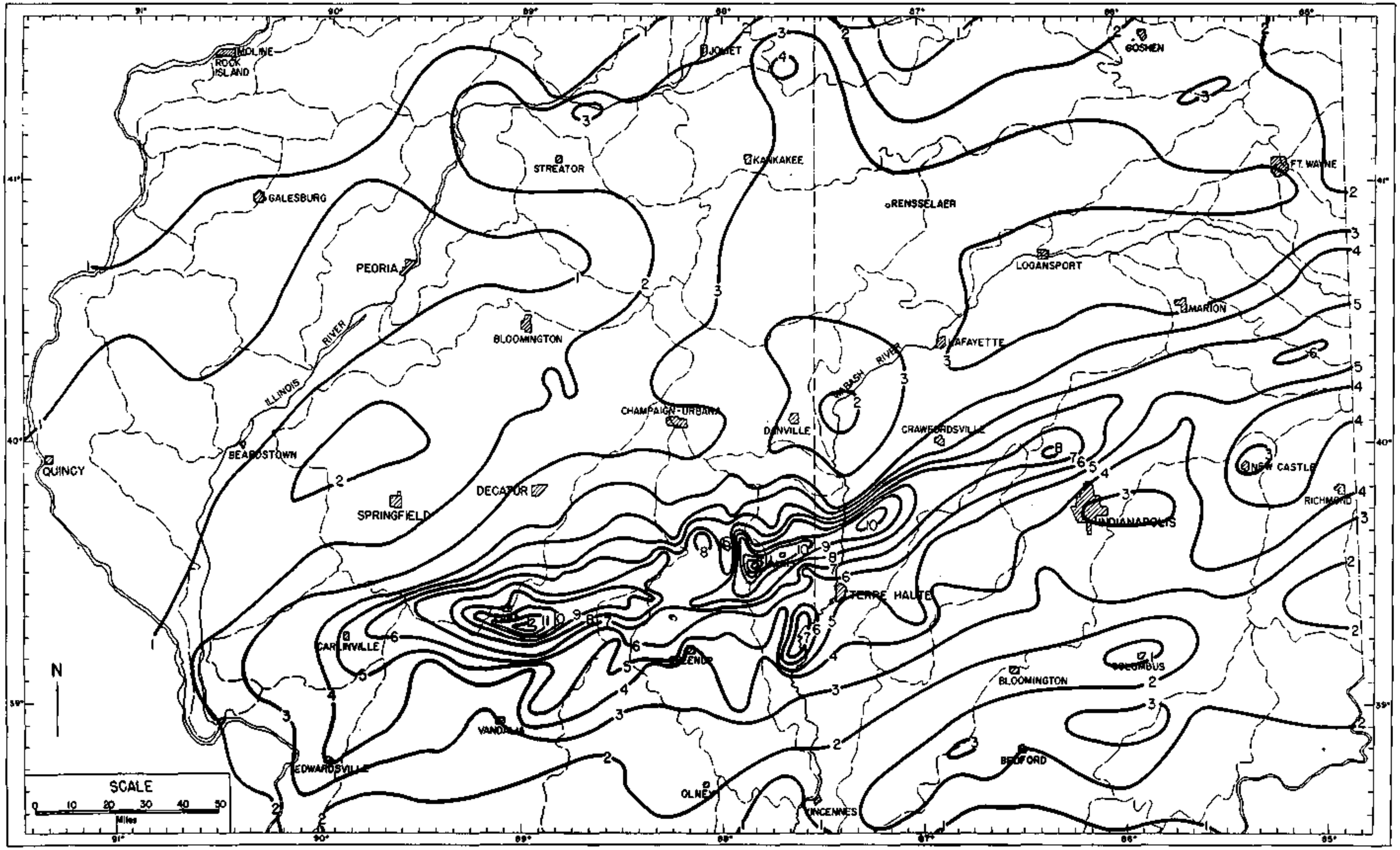


FIGURE 16 TOTAL STORM RAINFALL FOR JUNE 27-28, 1957

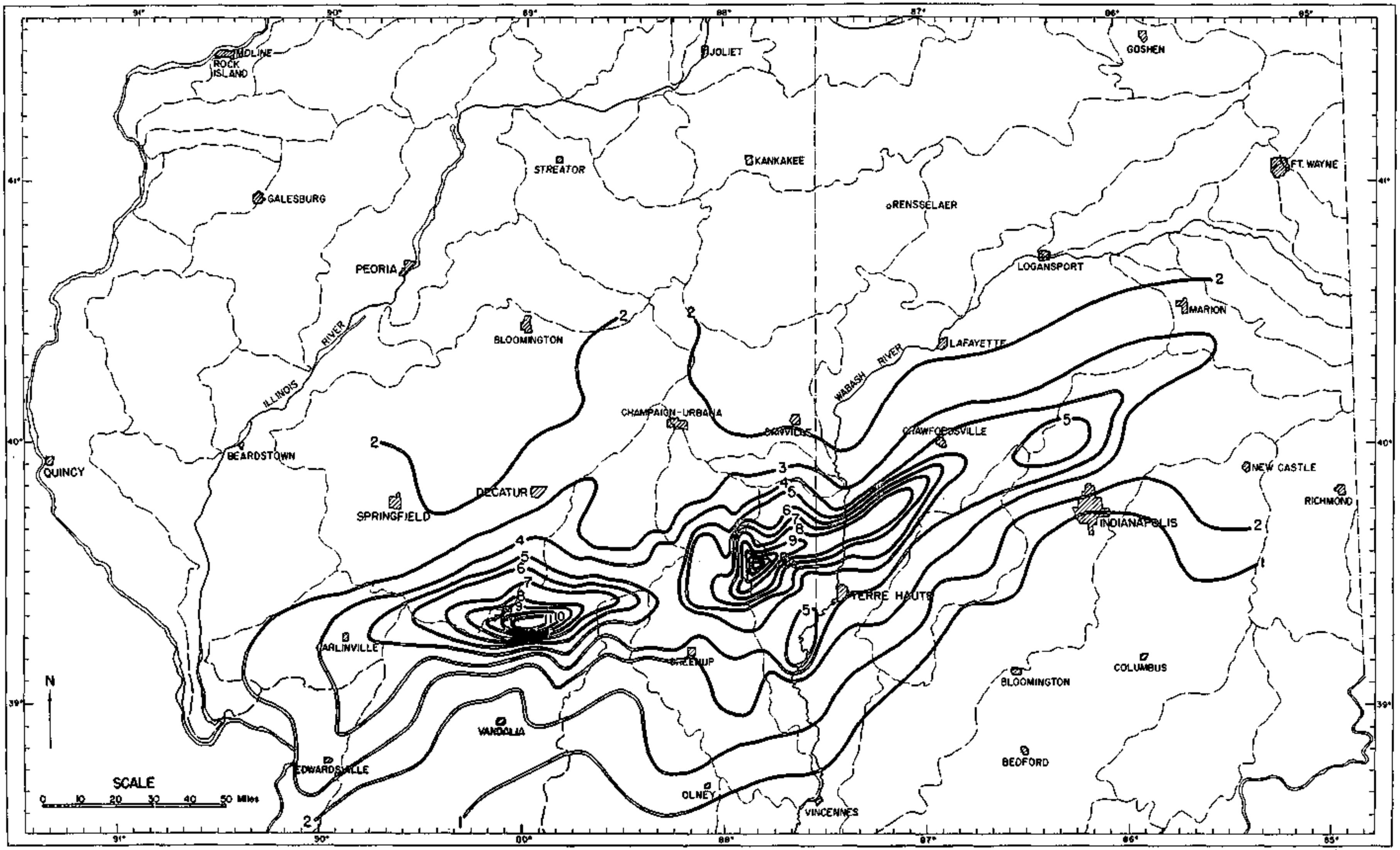


FIGURE 17 MAXIMUM 12-HOUR RAINFALL FOR JUNE 27-28, 1957

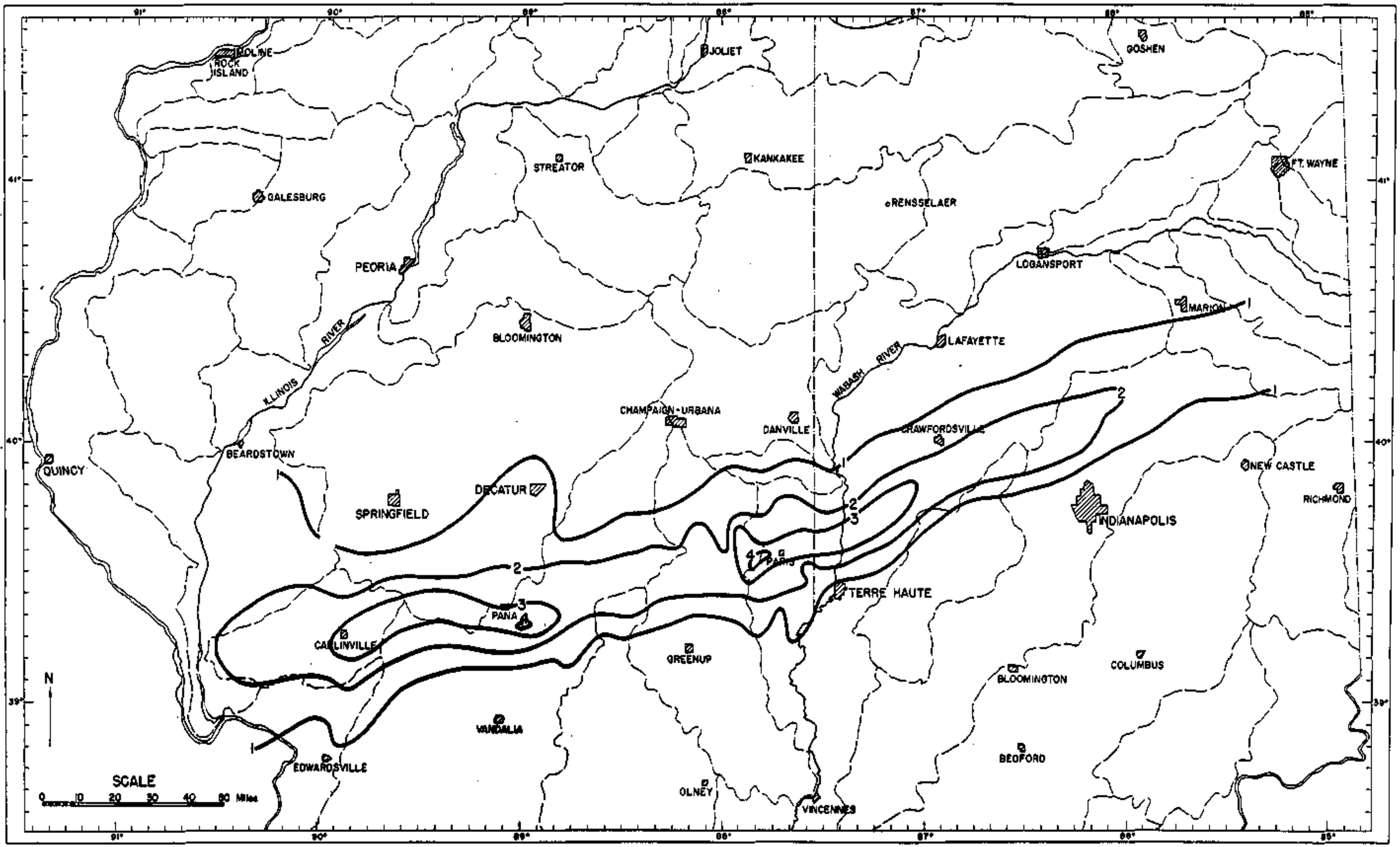


FIGURE 18 MAXIMUM 3-HOUR RAINFALL FOR JUNE 27-28, 1957

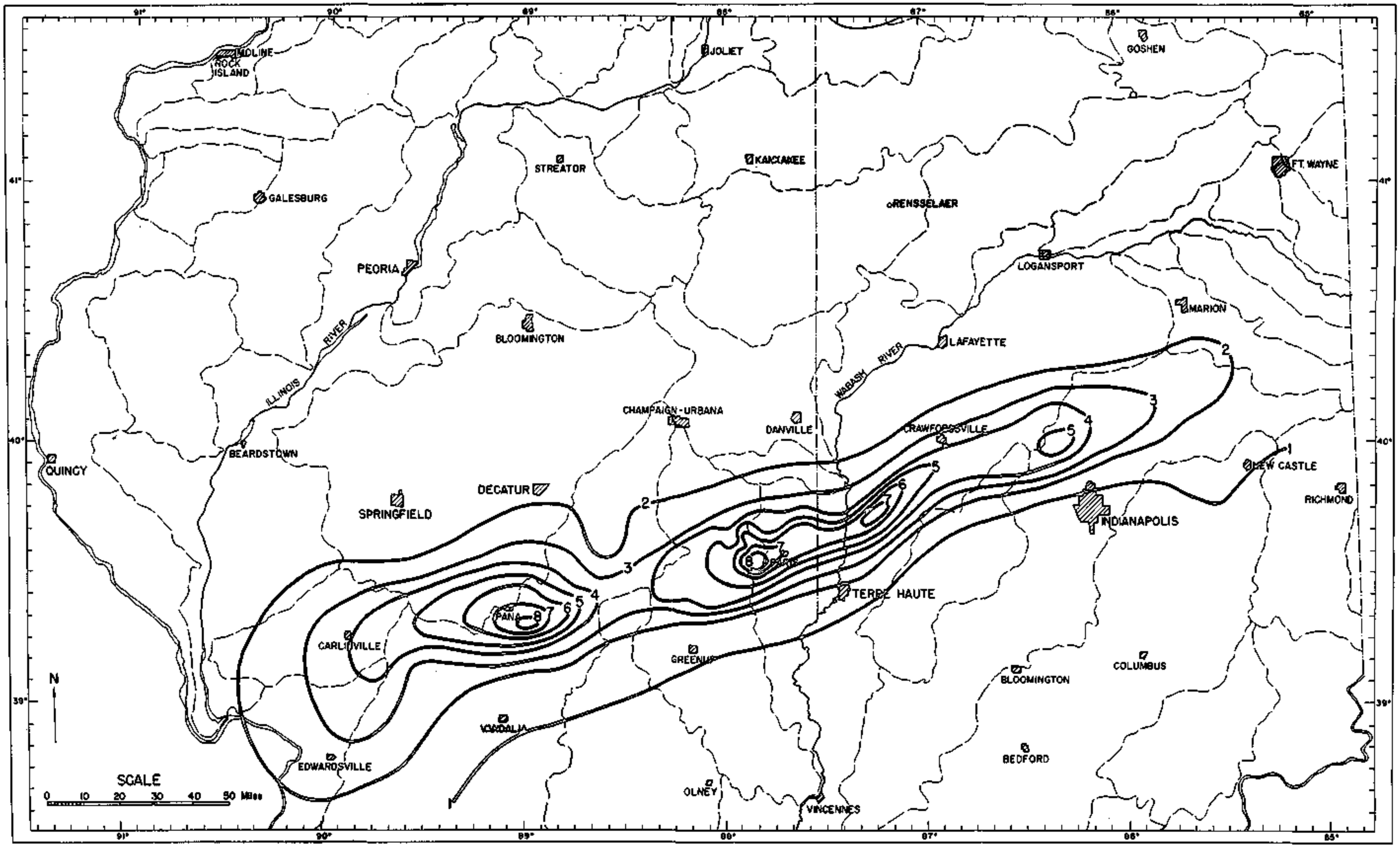


FIGURE 19 MAXIMUM 6-HOUR RAINFALL FOR JUNE 27-28, 1957

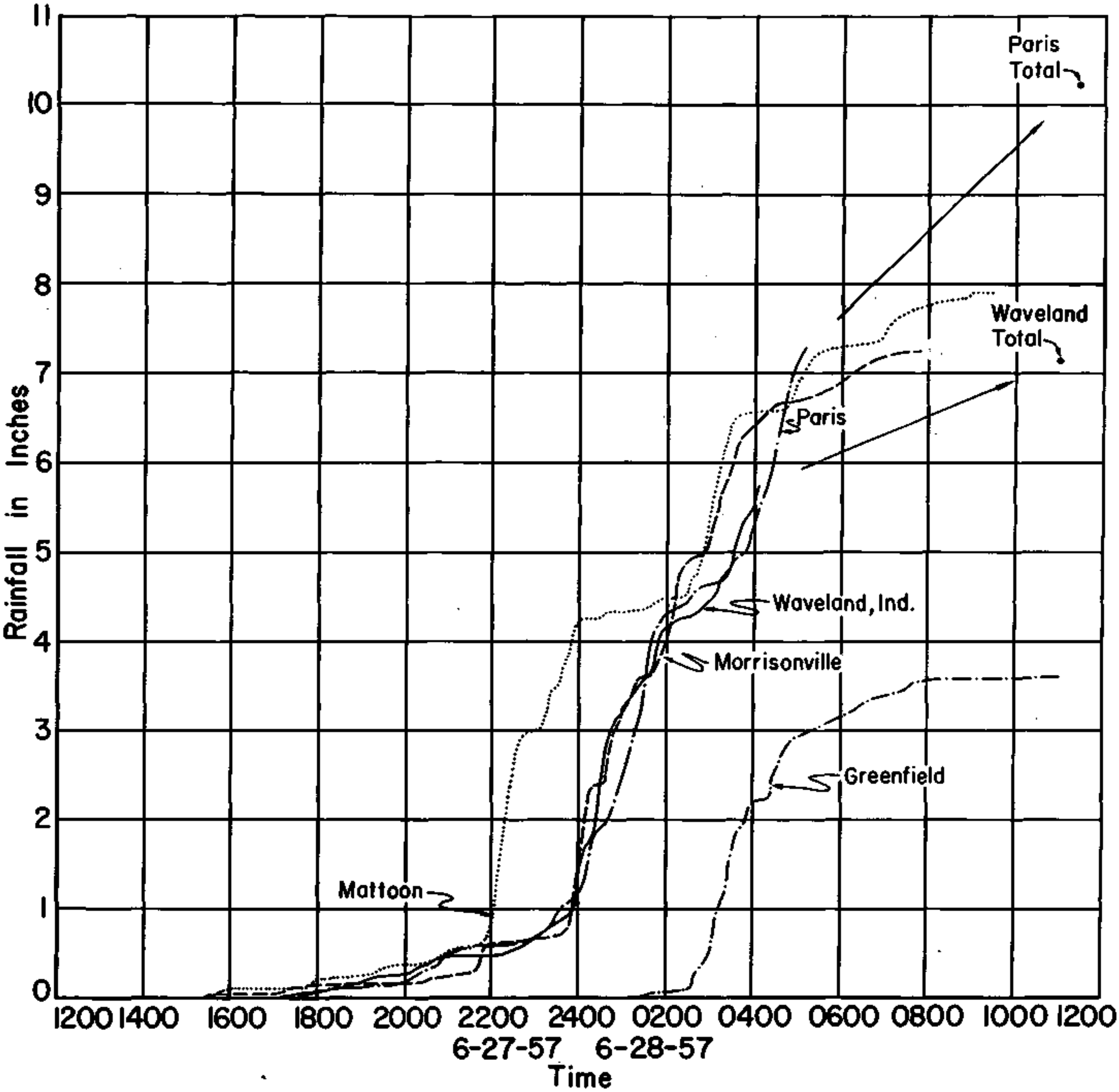


FIGURE 20 MASS CURVES OF RAINFALL FROM SELECTED STATIONS FOR JUNE 27-28, 1957

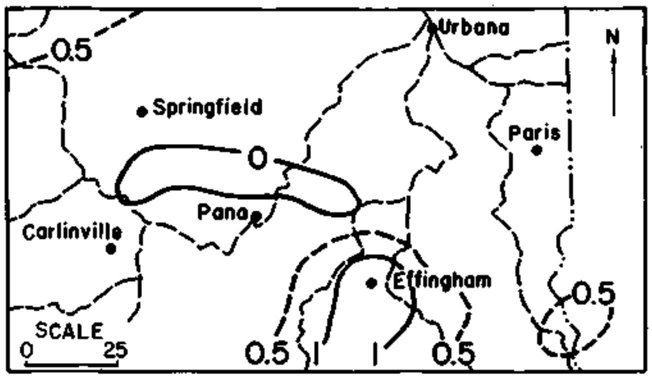


FIGURE 21 TOTAL RAINFALL JUNE 22-26, 1957

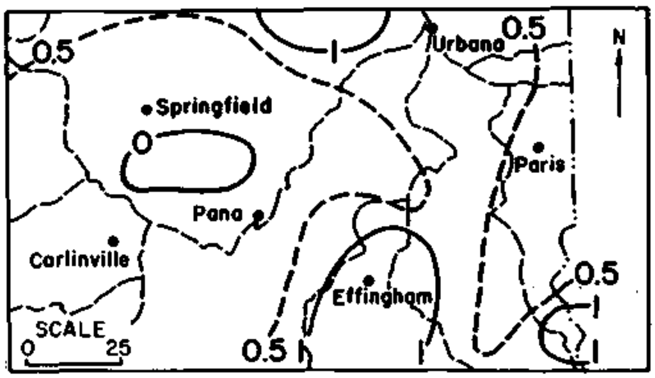


FIGURE 22 TOTAL RAINFALL JUNE 17-26, 1957

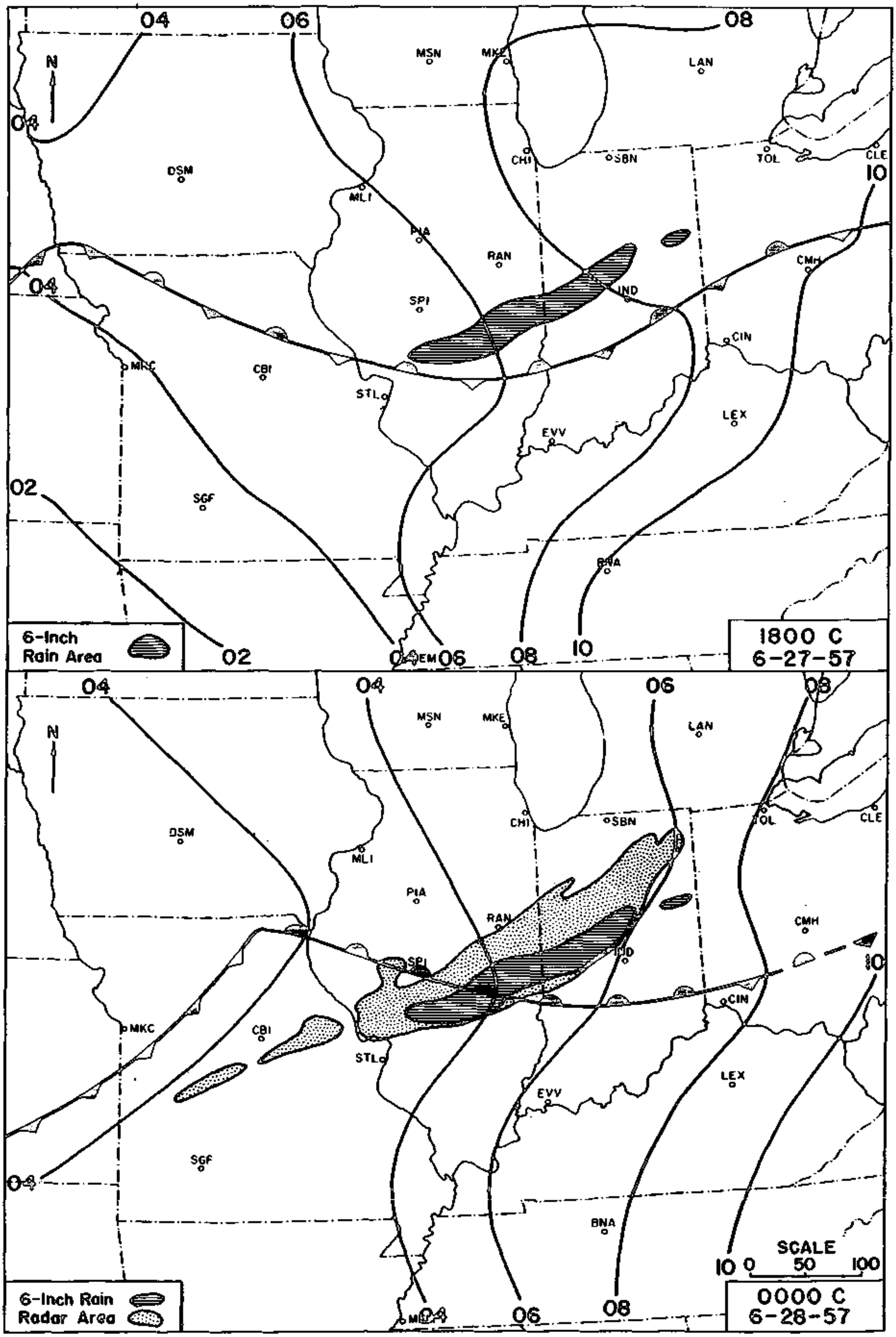


FIGURE 23 SURFACE SYNOPTIC MAPS ON JUNE 27-28, 1957

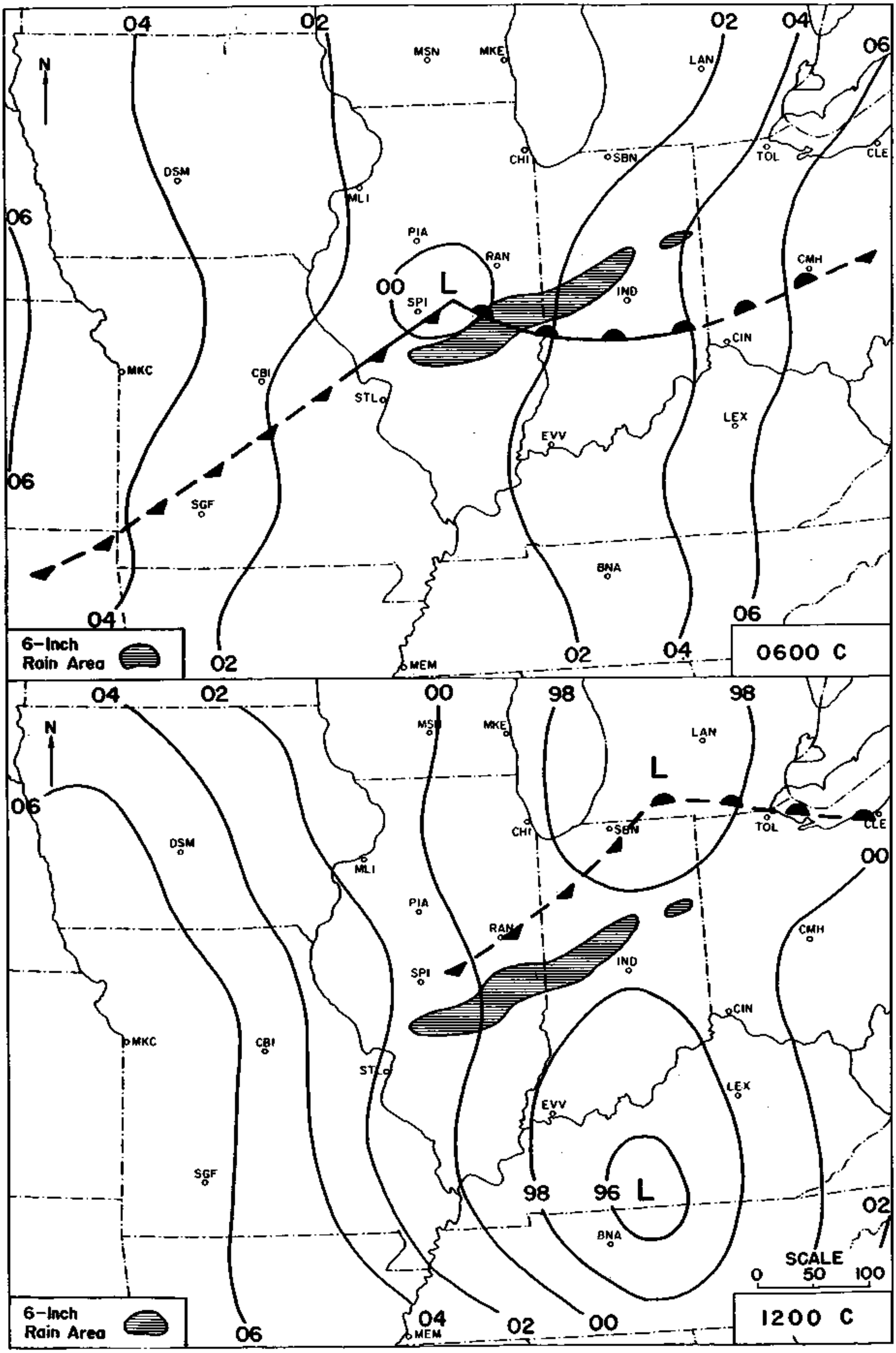


FIGURE 24 SURFACE SYNOPTIC MAPS ON JUNE 28, 1957

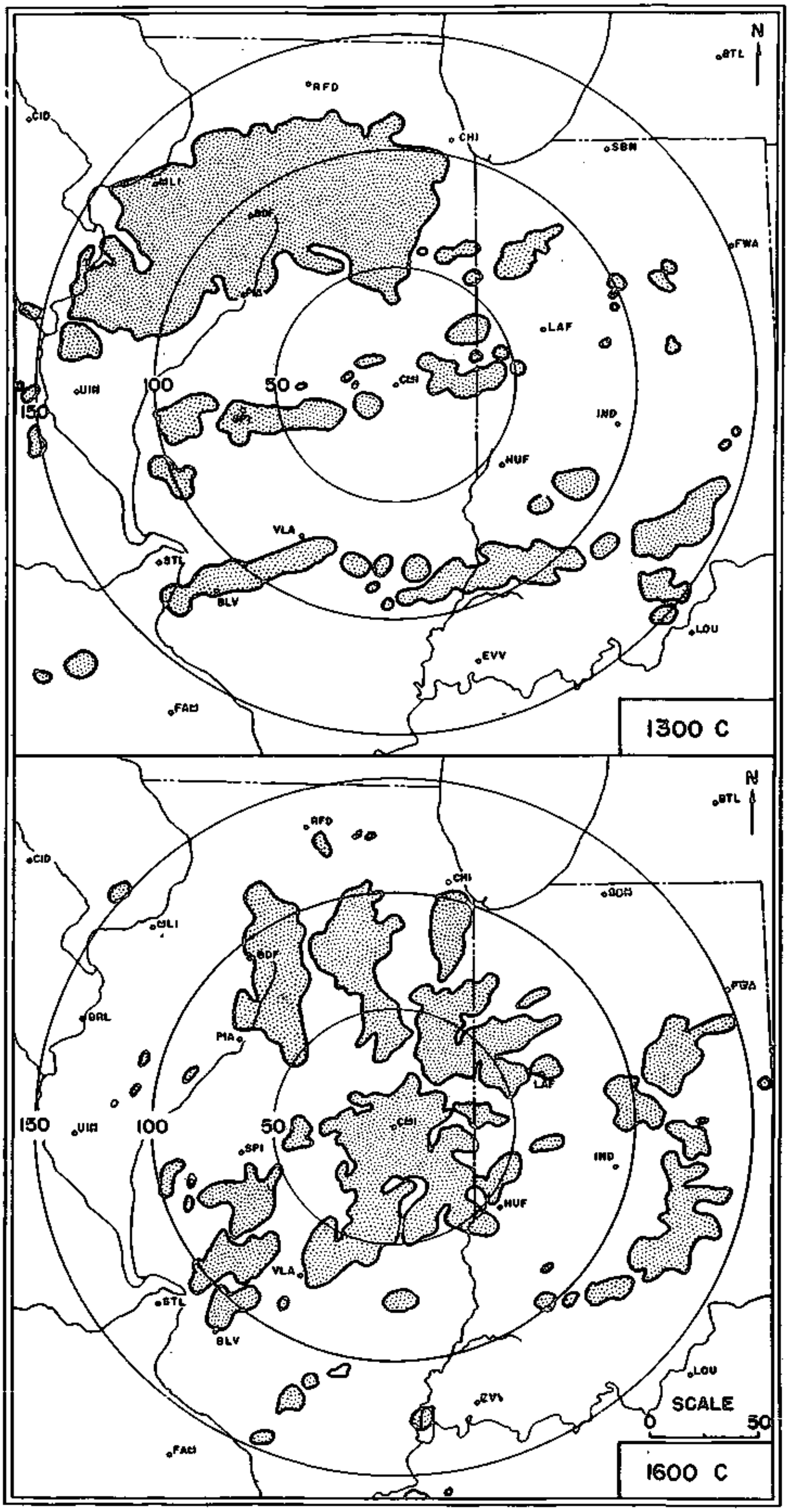


FIGURE 25 RADAR ECHOES JUNE 27, 1957

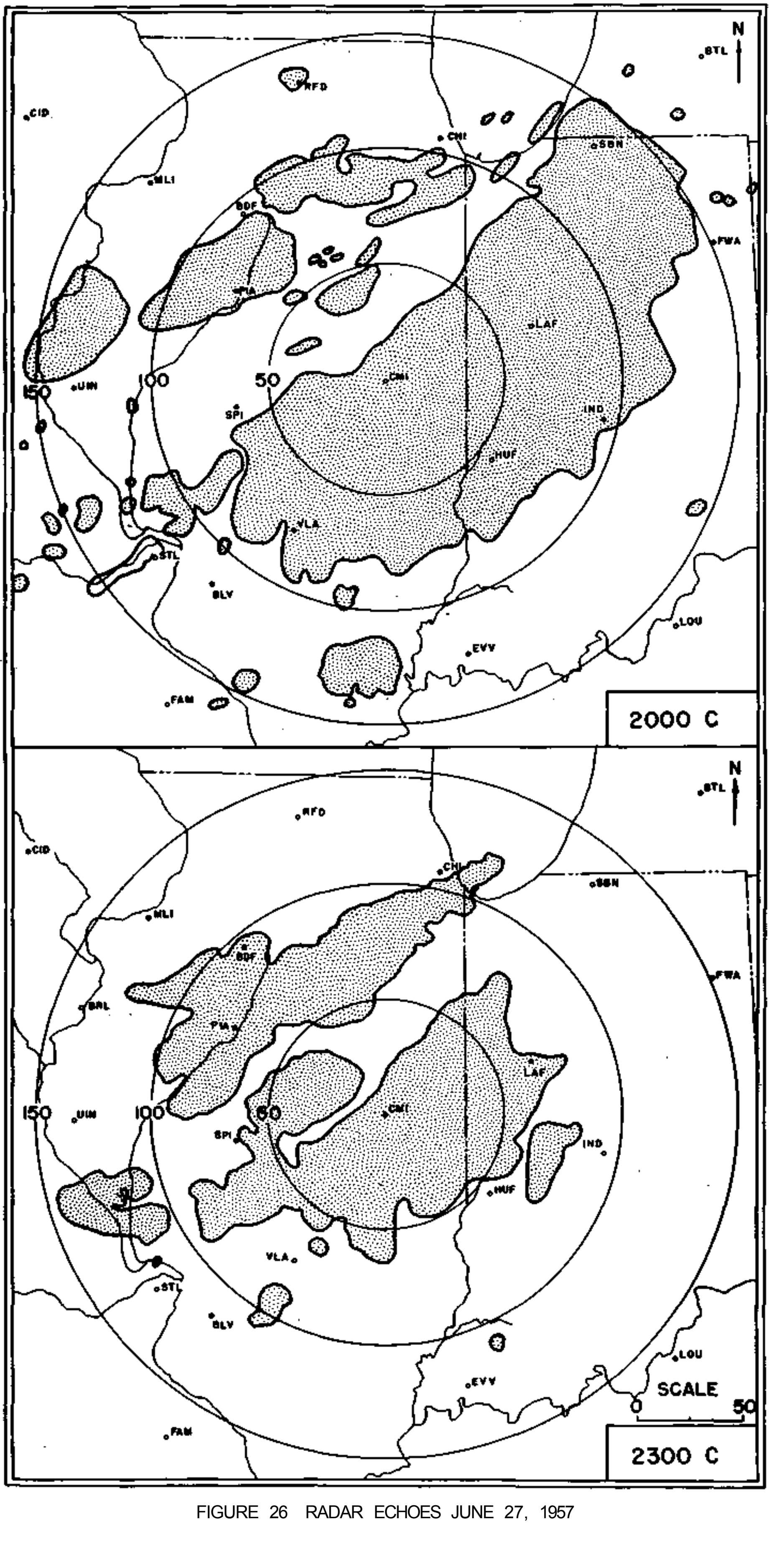


FIGURE 26 RADAR ECHOES JUNE 27, 1957

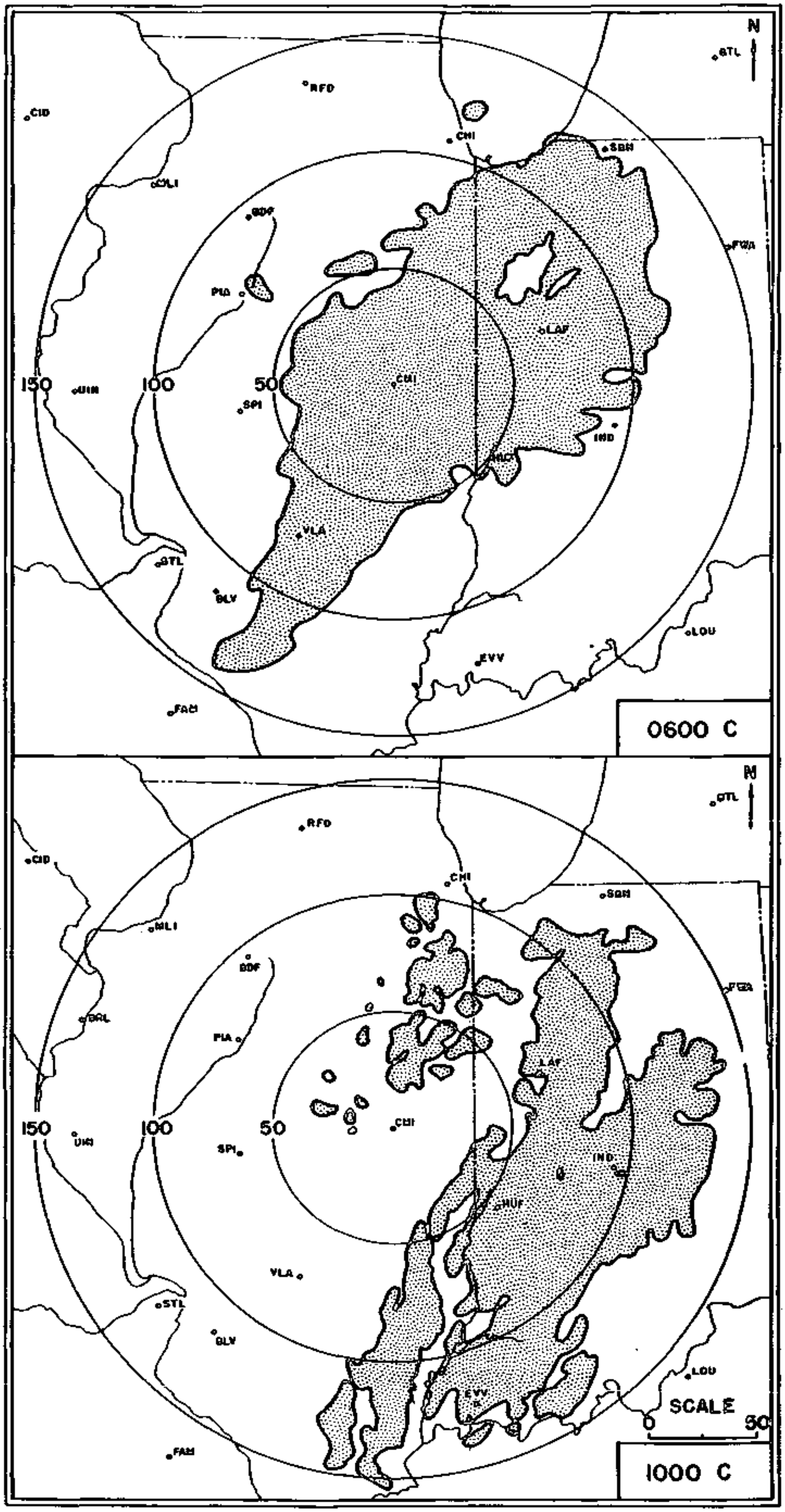


FIGURE 27 RADAR ECHOES JUNE 28, 1957

STORM OF JULY 12-13, 1957

Introduction

The third storm of 1957, in which rainfall amounts in excess of 10 inches were recorded in Illinois, occurred in the northeastern part of the state and extreme northwestern Indiana on July 12-13 (Fig.1). Again an extensive field survey was made to collect detailed data pertaining to the location, orientation, and intensity of the storm. Field survey data combined with that furnished by other organizations provided a total of 454 rainfall measurements upon which to base the storm analyses. The distribution of the rainfall observations is shown in Figure 28.

The maximum observed amount in this storm obtained from the field survey was 11.1 inches at Kankakee and near St. Anne, shown as Point A in Figure 28. Rainfall exceeding five inches covered an area of 3200 square miles in this storm, while more than two inches blanketed an area of 13,000 square miles in Illinois and Indiana.

Isohyetal Patterns

An isohyetal map for the entire storm period is shown in Figure 29. All of the storm rainfall occurred within a 21-hour period beginning at noon on July 12. The approximate north-south orientation of the major axis of the storm is different from that usually observed with severe rainstorms in Illinois. The most frequent orientations range from WNW-ESE through W-E to WSW-ENE.

An analysis of the peak periods of rainfall within the overall storm period was made. Figure 30 shows the isohyetal map for the 12-hour peak period within the storm, beginning at 1800 CST on July 12. Similar maps were constructed for 3-hour and 6 hour peak periods (Figs. 31 and 32) for the determination of area-depth relations.

Characteristics of Rainfall Distribution

Mass curves of rainfall constructed from recording rain gage charts for stations near the center of the storm are presented in Figure 33. The locations of these stations are shown on Figure 28. The mass curves show that there was considerable variability in the time distribution of heavy rainfall throughout the storm shown in Figure 29. This wide variability in the time distribution was due to the rainfall being associated with a series of squall lines with varying orientation and movement. These squall lines will be discussed in detail later in the sections on synoptic weather and radar. Reference to the mass curve for Kankakee, located near the core of the storm, shows that the heavy rainfall began about 1800 CST on July 12 and ended about 0640 CST on July 13. The rainfall resulted from a series of individual storms, the heaviest of which occurred between 1800 and 0200 CST. A series of 10 bursts can be seen on the mass curve for Kankakee in Figure 33. The rainfall distributions along and near the axis of the storm, as shown by the recording rain gage traces, indicate that the maximum 3-, 6-, and 12-hour rainfall periods began on the 12th at 2000, 2000, and 1800 CST, respectively. Again, these maximum periods varied considerably at individual stations within the storm core, but the selected periods appeared to provide the greatest average rainfall within the storm.

Depth-Duration Area Relations

Area-depth relations were determined for the total storm period and for peak periods of 3, 6, and 12 hours within the total storm period. The area-depth relations within this storm were found to be closely approximated by a relation of the form:

$$\text{Log } Y = a + bX^{0.5}$$

where Y is rainfall depth in inches, X is area in square miles, and a and b are regression constants. The derived area-depth relations are summarized in Table 5. Table 6 shows the time distribution of rainfall within the core of the storm for the peak rainfall periods of 3, 6, and 12 hours. Values in Table 6 are for the area within the 6-inch isohyet shown on the total storm rainfall map in Figure 29. The areas are comparable to those in Table 5. Thus, for the 100 square miles having the heaviest rainfall, 45 percent fell within a 3-hour period, 62 percent within a 6-hour period, and 87 percent within a 12-hour period. Referring to Table 5, these correspond to 4.8, 6.6, and 9.3 inches falling during the maximum 3-, 6-, and 12-hour periods, respectively. Comparison with similar results for the June 14-15 storm in southwestern Illinois shows that both the absolute and relative intensities for peak periods were greater for the earlier storm in the rainfall core.

TABLE 5

DEPTH-DURATION-AREA DATA, JULY 12-13

Duration	Depth (in.) for given area (sq. mi.) 25	50	100	200	500	1000	2000	5000	10,000
Entire storm	11.3	11.0	10.7	10.3	9.5	8.7	7.6	5.9	4.5
Max. 12 hrs.	9.8	9.6	9.3	8.9	8.2	7.3	6.5	4.9	-
Max. 6 hrs.	6.9	6.8	6.6	6.2	5.8	5.1	4.4	3.2	-
Max. 3 hrs.	5.1	5.0	4.8	4.5	4.0	3.6	3.0	2.1	-

TABLE 6

TIME DISTRIBUTION OF AREAL MEAN RAINFALL, JULY 12-13

Period	Percent of total storm rainfall for given areas (sq. mi.) 25	50	100	200	500	1000	2000
Max. 3 hrs.	45	45	45	44	42	41	39
Max. 6 hrs.	61	62	62	60	61	59	58
Max. 12 hrs.	87	87	87	86	86	85	85

Antecedent Rainfall

Total rainfall for the 5-day and 10-day periods preceding the July 12-13 storm is shown in the isohyetal maps of Figures 34 and 35. Normal rainfall for these 5-day and 10-day periods is approximately 0.5 and 1.0 inch, respectively. Figures 34 and 35 show below-average rainfall for both the 5-day and 10-day periods preceding the July 12-13 storm. Consequently, antecedent rainfall does not appear to have been a major factor in floods resulting from this storm.

Synoptic Weather

The surface synoptic map at noon on July 12 (Fig. 36) indicated a low pressure center located near Sioux Falls, South Dakota, with a trough extending east-southeastward to north central Ohio. The entire air mass covering the Great Plains and the Midwest was quite uniform and only weak fronts were evident in the troughs on the map. The stippled area in Figures 36-37 indicates the location of the region having rainfall in excess of six inches during the total storm period.

During the early morning hours of July 12, many scattered thunderstorms were observed throughout Wisconsin, north of the quasi-stationary front extending across northern Illinois (Fig. 36). However, by noon the storm activity appeared to be directly associated with the front in Illinois. The Water Survey's radar (Fig. 38) indicated that a squall zone had developed and was oriented NE-SW perpendicular to the front at this time. This squall zone moved eastward across Illinois and gave considerable shower activity in the Chicago area and extreme northeastern Illinois, as indicated by the mass rainfall curves for Chicago, Mt. Prospect, and McHenry in Figure 33.

By 1800 CST on July 12, the synoptic map (Fig. 36) had not changed much, although the low center appeared to be decreasing in intensity. In addition to the rainfall core, the radar portrayal of the storm at 2200 CST, during the height of the heavy rainfall period, has been indicated by stippling in Figure 36. The front across north central Illinois maintained a position and orientation similar to that six hours earlier as shown in the upper portion of Figure 36. The surface map at midnight on July 12th, indicated that the low center was moving eastward in western Iowa (Fig. 37). The front across Illinois had moved little from its previous position at this time and there was little change in the general synoptic situation. The lower portion of Figure 37 shows the surface synoptic pattern at 0600 CST on July 13. This map indicated some further movement eastward of the low center in Iowa, with the front remaining nearly stationary across northern Illinois. Note that the heavy rainfall zone is intersected by the front in Figures 36 and 37. The storm core in which more than 10 inches of rain fell, occurred in the immediate vicinity of the intersections shown in these figures. Crop hail loss reports [4] indicate that scattered hail storms also occurred throughout northern Illinois on July 12-13, with the heaviest concentration corresponding with the storm core in the area from Watseka to Chicago (Fig. 29).

During the early forenoon of July, 13, the front across northern Illinois began drifting southward and continued this southward movement throughout the day. This weak cold front became quasi-stationary across southern Illinois during the night of July 13-14, and was associated with heavy rainfall in that region. Approximately six inches of rain fell at Vandalia in conjunction with this storm in southern Illinois.

Upper air data for noon on July 12, prior to initiation of the storm, indicated winds of approximately 25 mph from the southwest at 5000 feet, veering to west at 10,000 feet with little change in speed. At 20,000 feet, winds were from the WNW at approximately 20 mph. By 1800 CST on July 12, the 5.000-ft winds in the storm area were from the southwest at 30 mph veering to west at 25 to 30 mph at 10,000 feet and to northwest at 30-35 mph at 20,000 feet. Twelve hours later (0600 CST, July 13), the winds had veered to the west and increased to 30-35 mph at 5,000 feet in the storm zone. At this time, the winds were still from the west at 10,000 feet but had increased to approximately 35 mph. At 20,000 feet, little change had taken place during the night and winds remained from the northwest at about 30 mph. Throughout the period of the storm, there was indication of a wind maximum at the 5000-ft and 10,000-ft levels in the storm zone. Also, strong instability was indicated by the Showalter stability index which was a -6 at 1800 CST on July 12, as computed from data collected at the Peoria radiosonde station.

Radar Analysis

Radar observations were made throughout the storm period with the CPS-9 radar. Again, precipitation attenuation distorted or masked portrayal of the storm at times. The radar presentation at 1330 CST on July 12 is shown in the upper part of Figure 38. As mentioned earlier in the synoptic weather discussion, the early afternoon squall zone was oriented from northeast to southwest and moved eastward. Rainfall observations indicate that light to moderate thundershower activity was associated with the squall zone shown at 1330 CST. Some hail was observed to have been associated with this storm area.

The lower portion of Figure 38 shows the radar portrayal at 1815 CST on July 12. By this time, a radical change had taken place in the orientation of the storm zone in northern Illinois. The first squall zone was orientated approximately perpendicular to the front shown on the synoptic map during the early afternoon. By late afternoon, the first squall zone had moved eastward out of Illinois and either dissipated or moved out of the range of the radar. Development of the second squall zone shown in the lower portion of Figure 38 then took place. This squall zone was orientated nearly parallel to the front through north central Illinois and moved southward almost perpendicular to the upper wind flow. As the second squall zone moved southward it decreased in intensity and reoriented to a more nearly west-east line. The center of activity in this squall zone was in the Kankakee area between Watseka and Chicago (Figs. 28-29).

The upper portion of Figure 39 shows the radar portrayal four hours later at 2200 CST on July 12. The second squall zone was orientated approximately west-east just north of the radar station at this time and was dissipating on its western side. Also, by this time a third squall zone had developed in approximately the same region as the second storm, being orientated approximately parallel to the front on the synoptic maps in Figures 36-37.

The lower part of Figure 39 shows the radar presentation four hours later at 0200 CST on July 13. By this time, the third squall zone shown in the Chicago area in the upper portion of this figure had moved southward and was lying a short distance north of the radar station.

Also, a fourth squall zone had developed on a line approximately parallel to the front through northern Illinois. The full extent of the fourth squall zone was masked in the radar portrayal at 0200 CST due to precipitation attenuation caused by squall zone no. 3. To show the presence of the storm at that time, hourly rainfall amounts for the period 0100 to 0200 CST have been plotted on the radar presentation. These rainfall amounts, in conjunction with the radar storm echoes shown in extreme northwestern Illinois, indicate the presence of the squall zone. Also, precipitation attenuation was masking the true extent of the third squall zone immediately north of the radar station, as evidenced by the rainfall amounts shown just to the rear of the radar portrayal of the storm. Also, note in Figure 39 that the remainder of the second squall zone can be seen approximately 50 miles south of the radar station.

Figure 40 shows the radar presentation in the early morning hours. The upper portion of this figure shows the radar presentation at 0600 CST on July 13. The fourth squall zone, which extended southeastward from northwestern Illinois at 0200 CST, had moved southward to within about 40 miles of the radar station by this time, while the third squall zone had moved to about 30 miles south of the station. Hourly rainfall amounts plotted on the map for 0600 CST indicate that rainfall had ended in the Chicago area and extreme northern Illinois. Again, precipitation attenuation was masking the true extent of the storm area to the north of the radar station as shown by the hourly rainfall amounts to the rear of the radar storm boundary.

The lower portion of Figure 40 shows the radar presentation at 0800 CST on July 13. By this time, rain had ceased in the region of the storm core south of Chicago. The squall zone shown to the south of and through the radar station appeared to dissipate rapidly as the forenoon progressed. Redevelopment took place during the afternoon over southern Illinois and was followed by heavy rainfall with recorded amounts up to six inches in some portions of southern Illinois during the night of July 13-14. The rainfall appeared to stop in the severe storm area in northeastern Illinois about the time the front shown on the synoptic maps started moving southward. The heavy rainfall in southern Illinois the following night appeared to be associated with the front as it again became quasi-stationary.

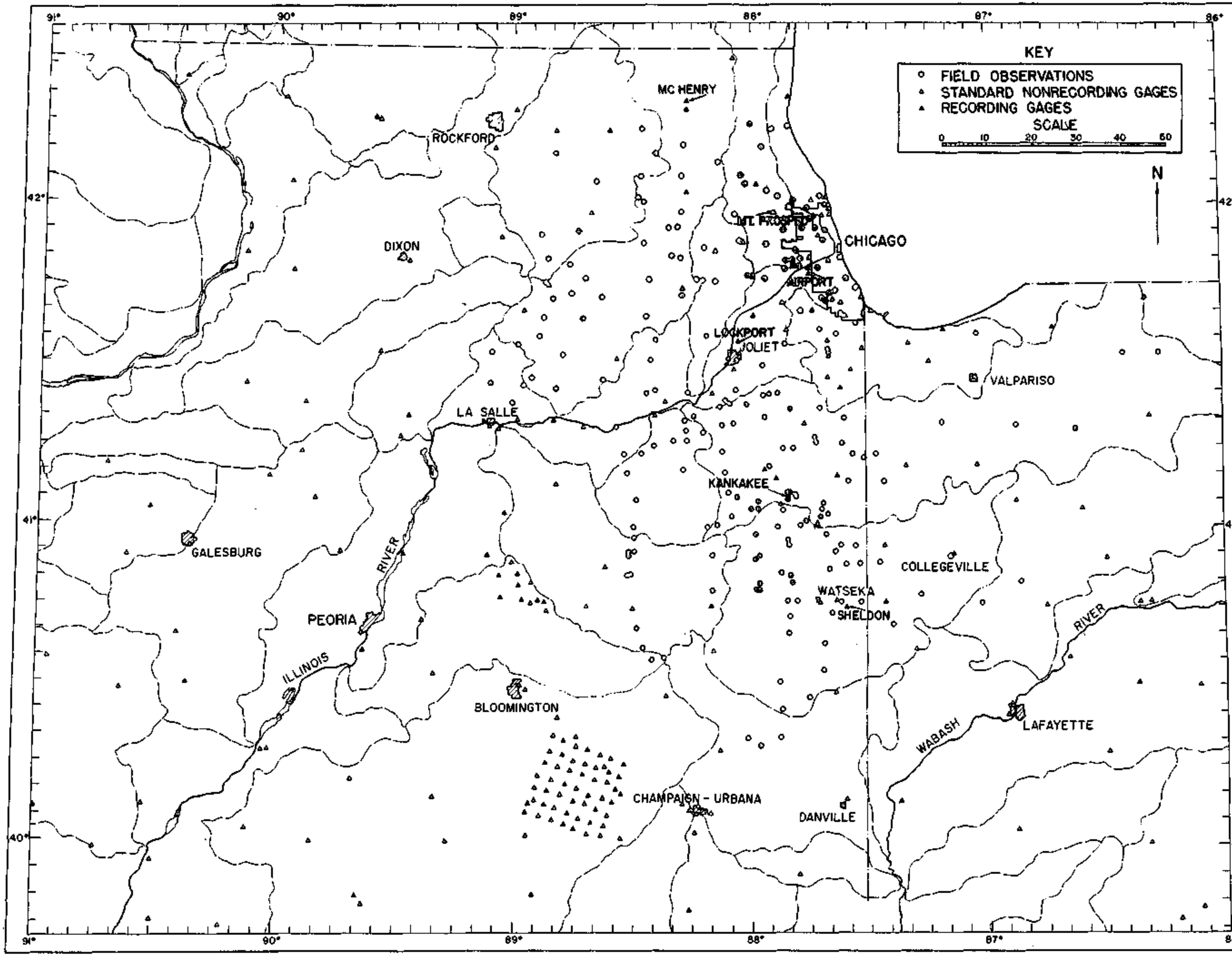


FIGURE 28 LOCATION OF POINT RAINFALL OBSERVATIONS, JULY 12-13, 1957

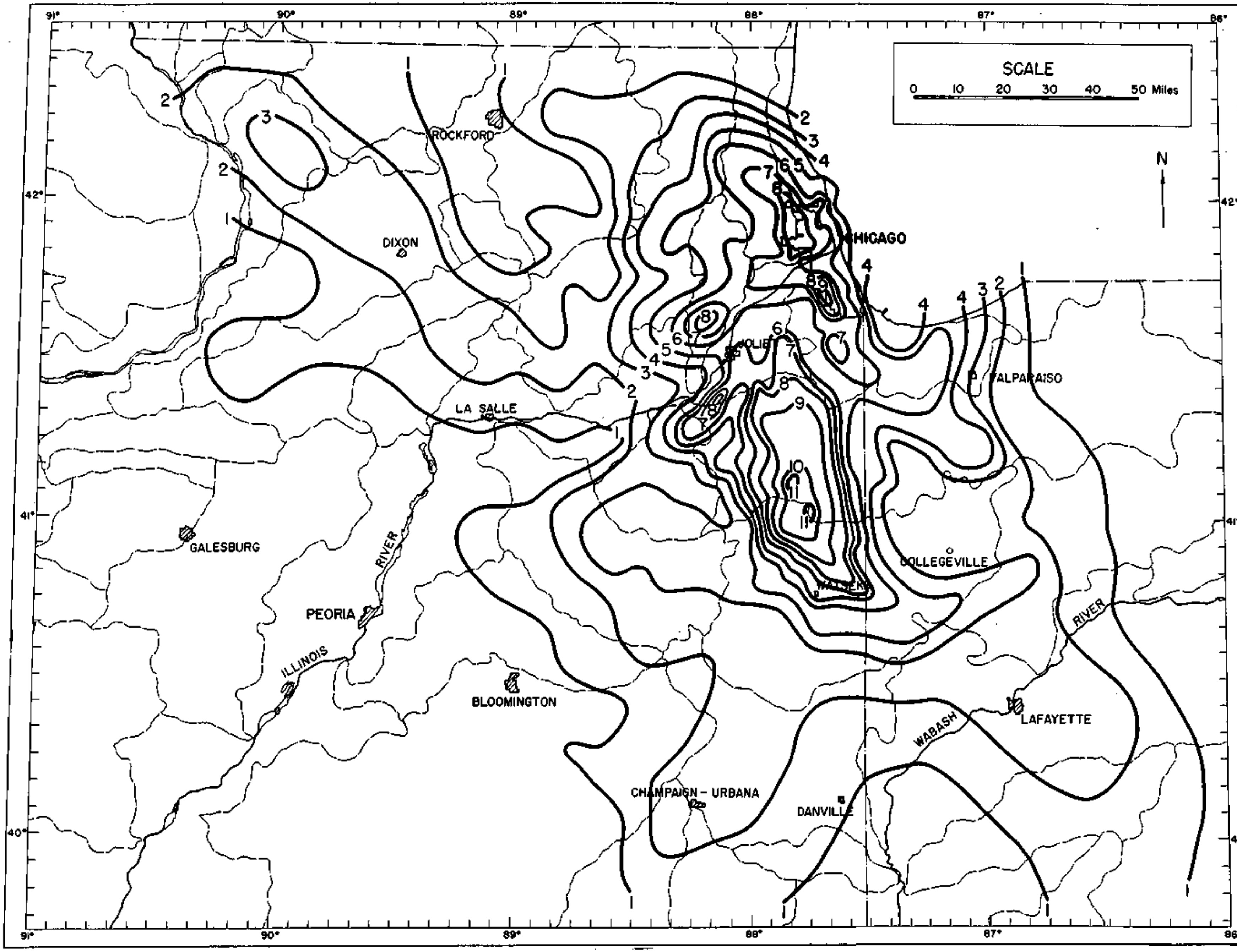


FIGURE 29 TOTAL STORM RAINFALL FOR JULY 12-13, 1957

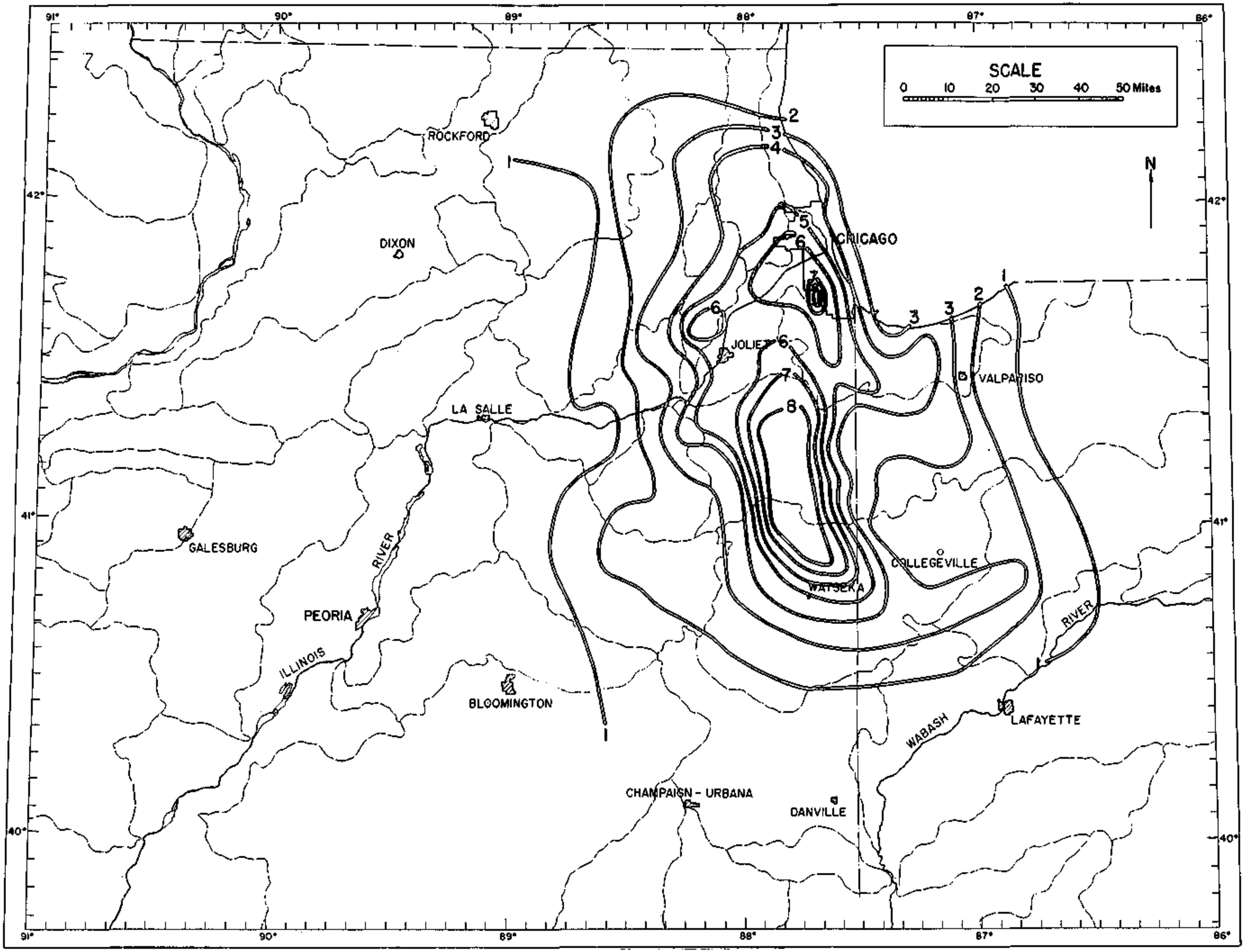


FIGURE 30 MAXIMUM 12-HOUR RAINFALL FOR JULY 12-13, 1957

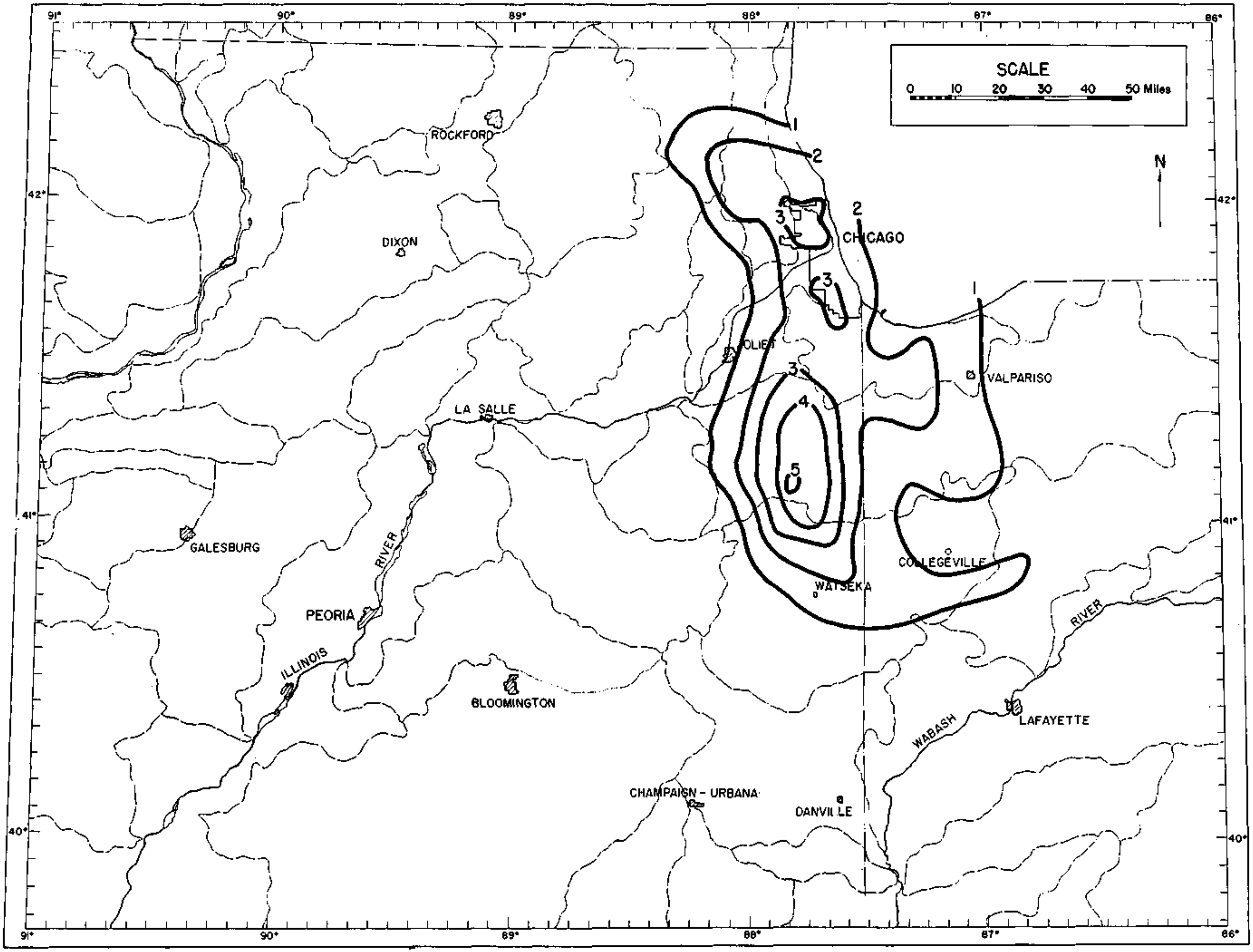


FIGURE 31 MAXIMUM 3-HOUR RAINFALL FOR JULY 12-13, 1957

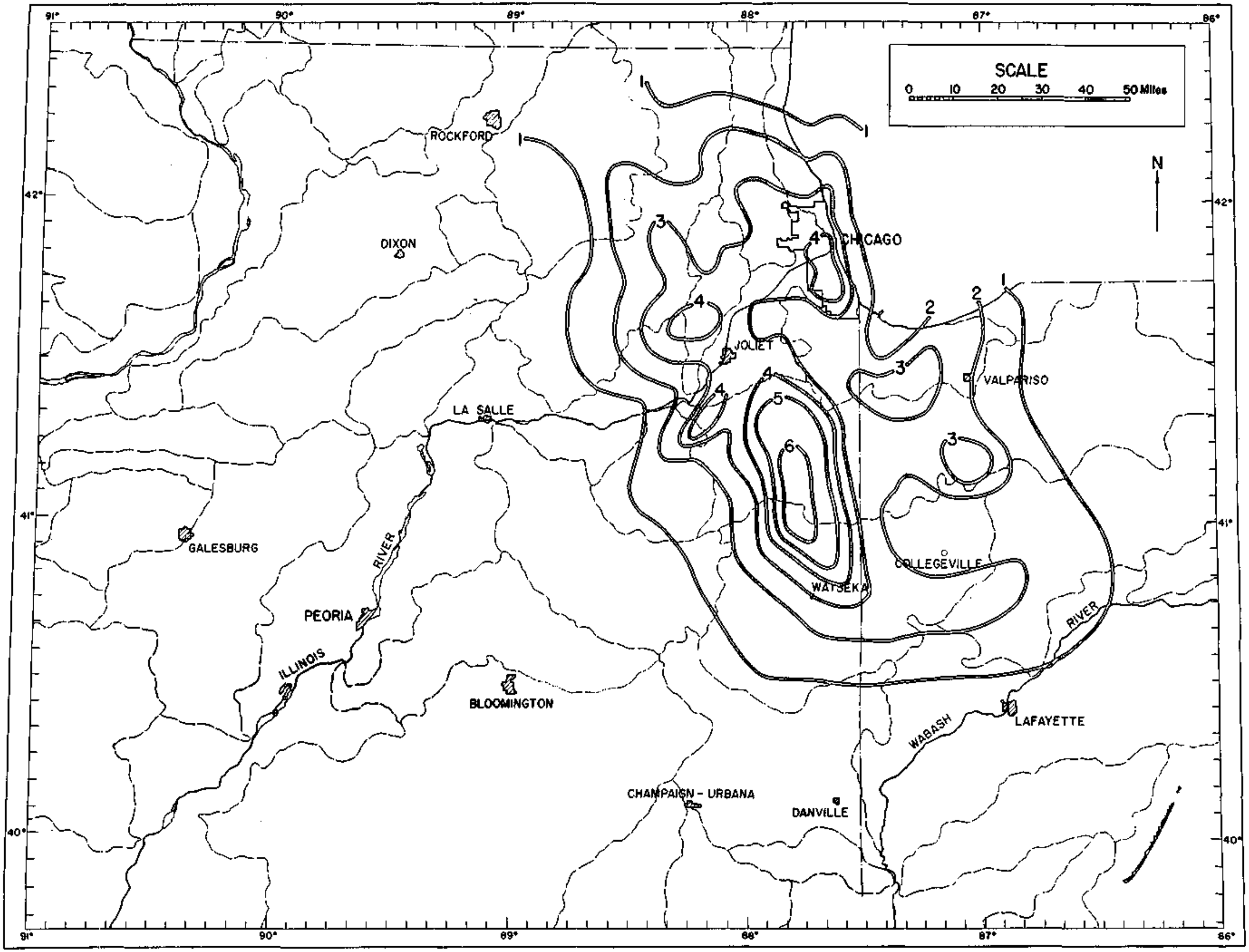


FIGURE 32 MAXIMUM 6-HOUR RAINFALL FOR JULY 12-13, 1957

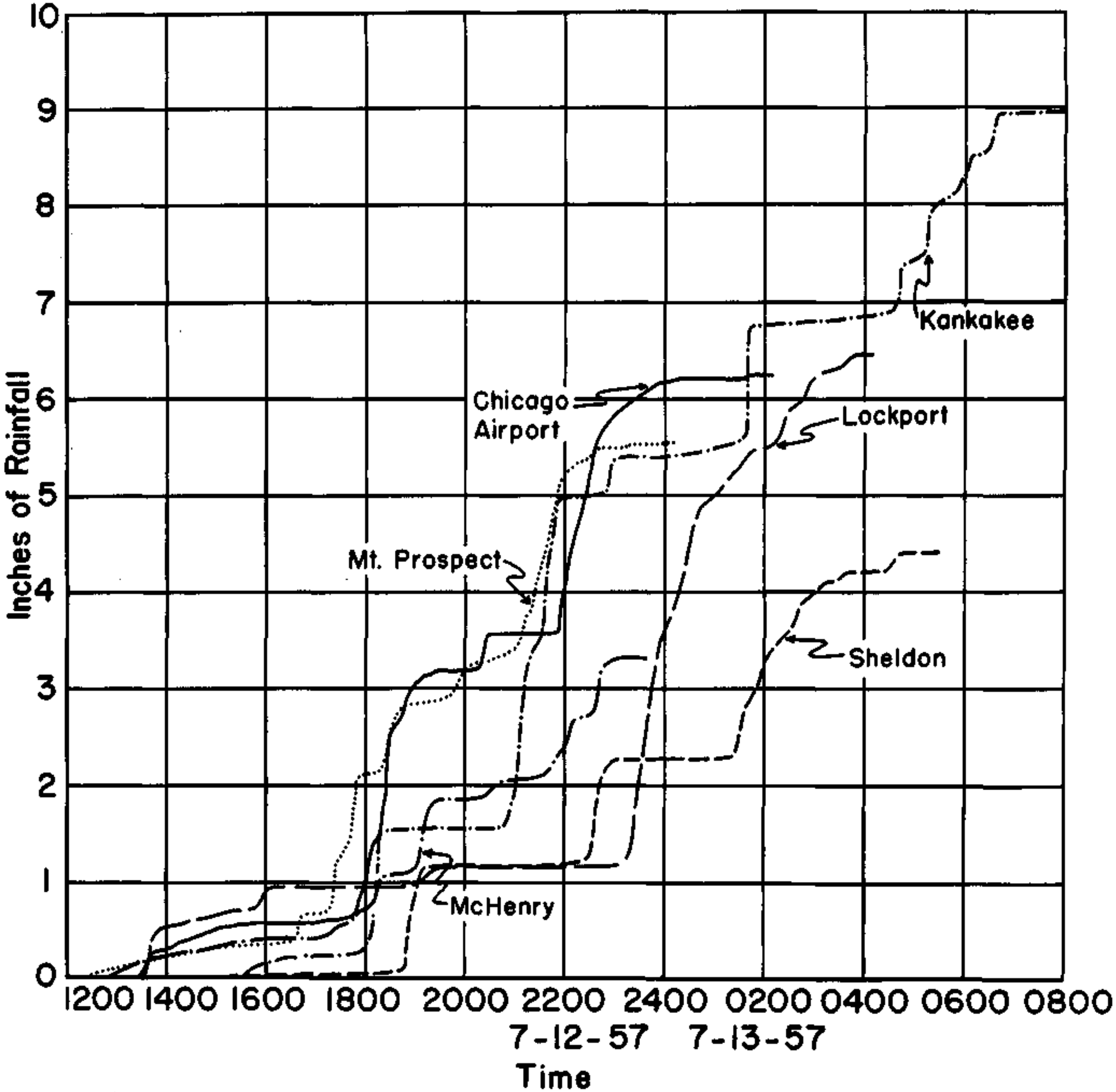


FIGURE 33 MASS CURVES OF RAINFALL FROM SELECTED STATIONS FOR JULY 12-13, 1957

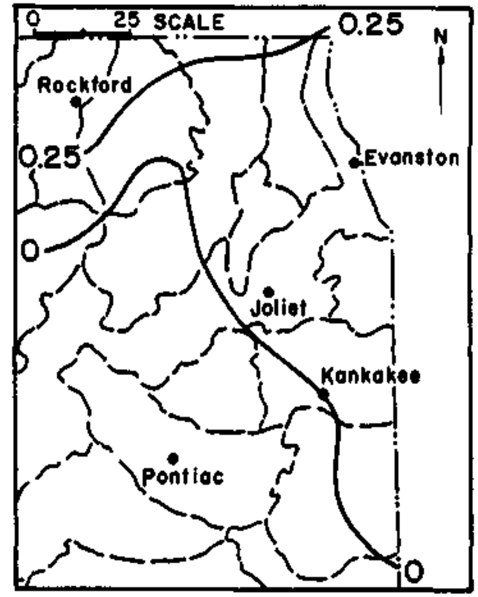


FIGURE 34 TOTAL RAINFALL JULY 7-11, 1957

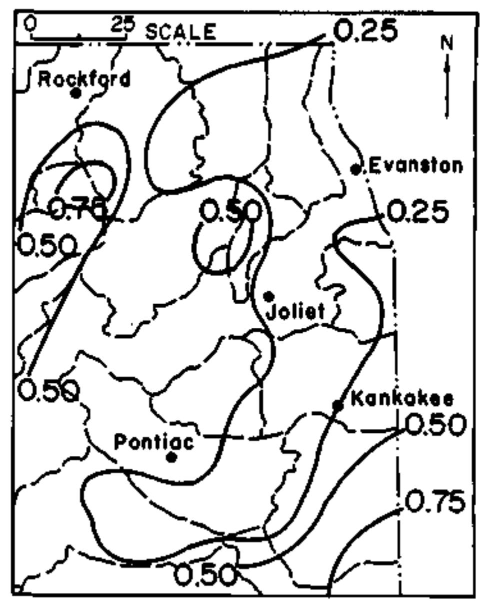


FIGURE 35 TOTAL RAINFALL JULY 2-11, 1957

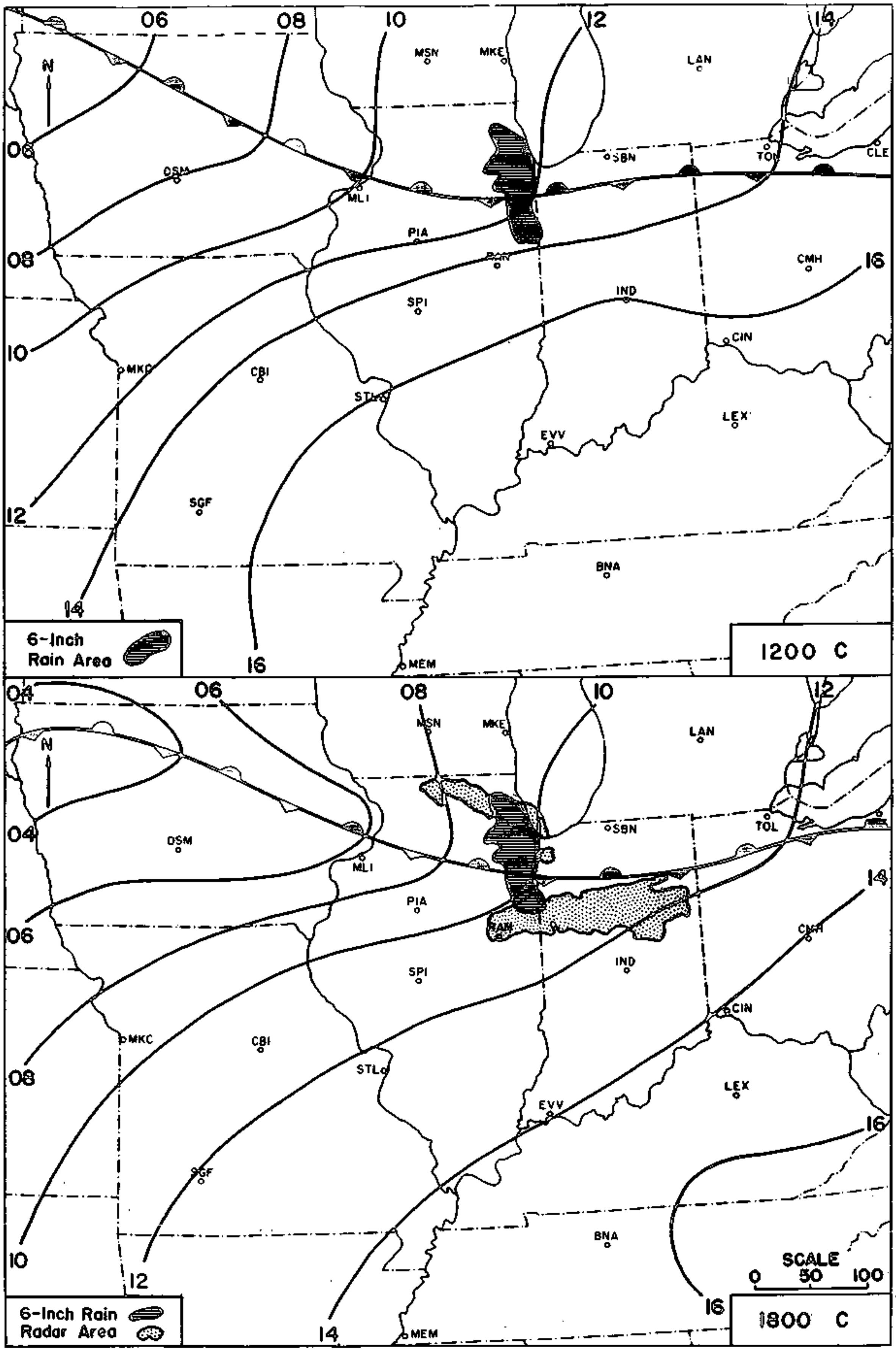


FIGURE 36 SURFACE SYNOPTIC MAPS ON JULY 12, 1957

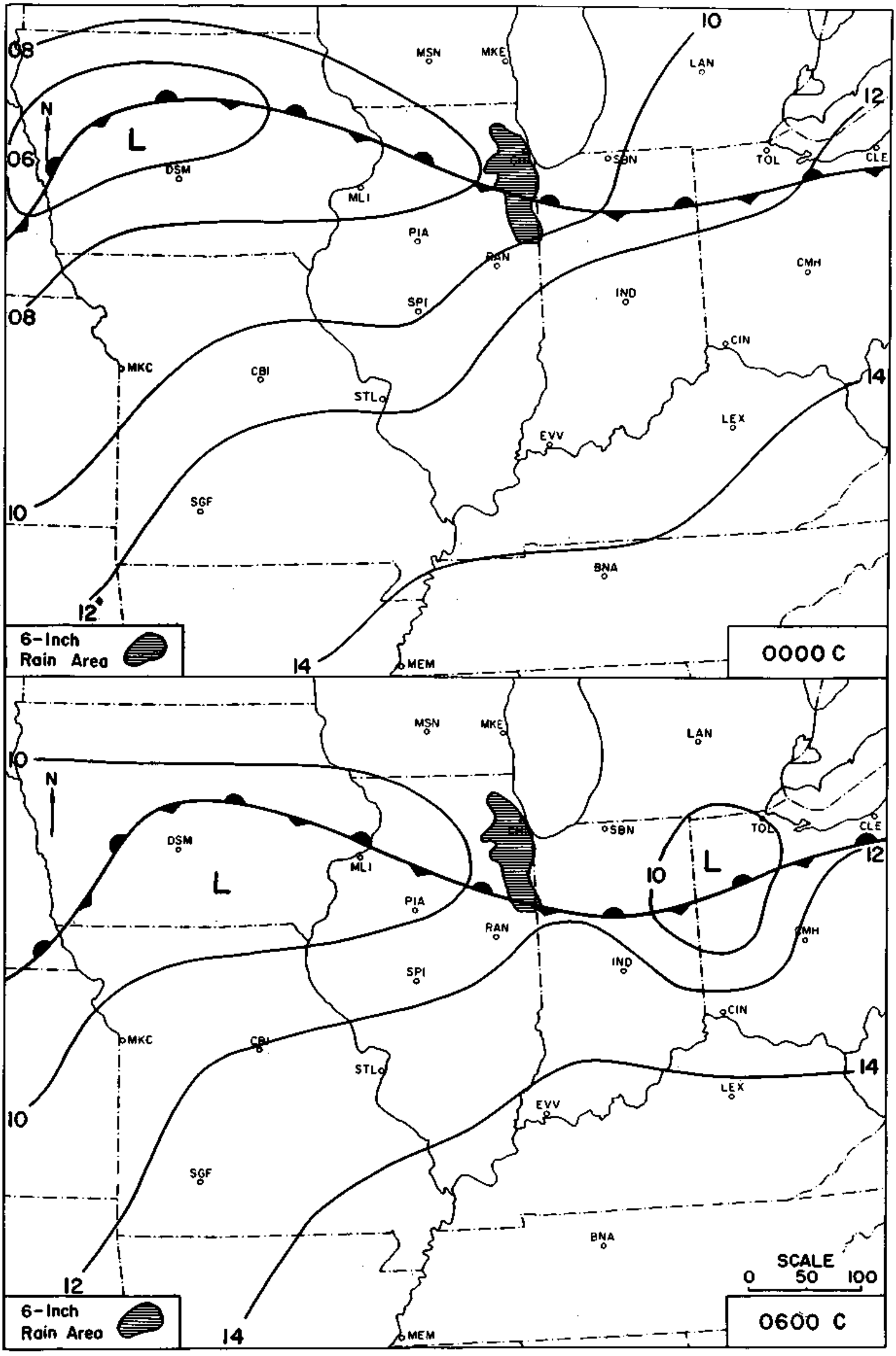


FIGURE 37 SURFACE SYNOPTIC MAPS ON JULY 13, 1957

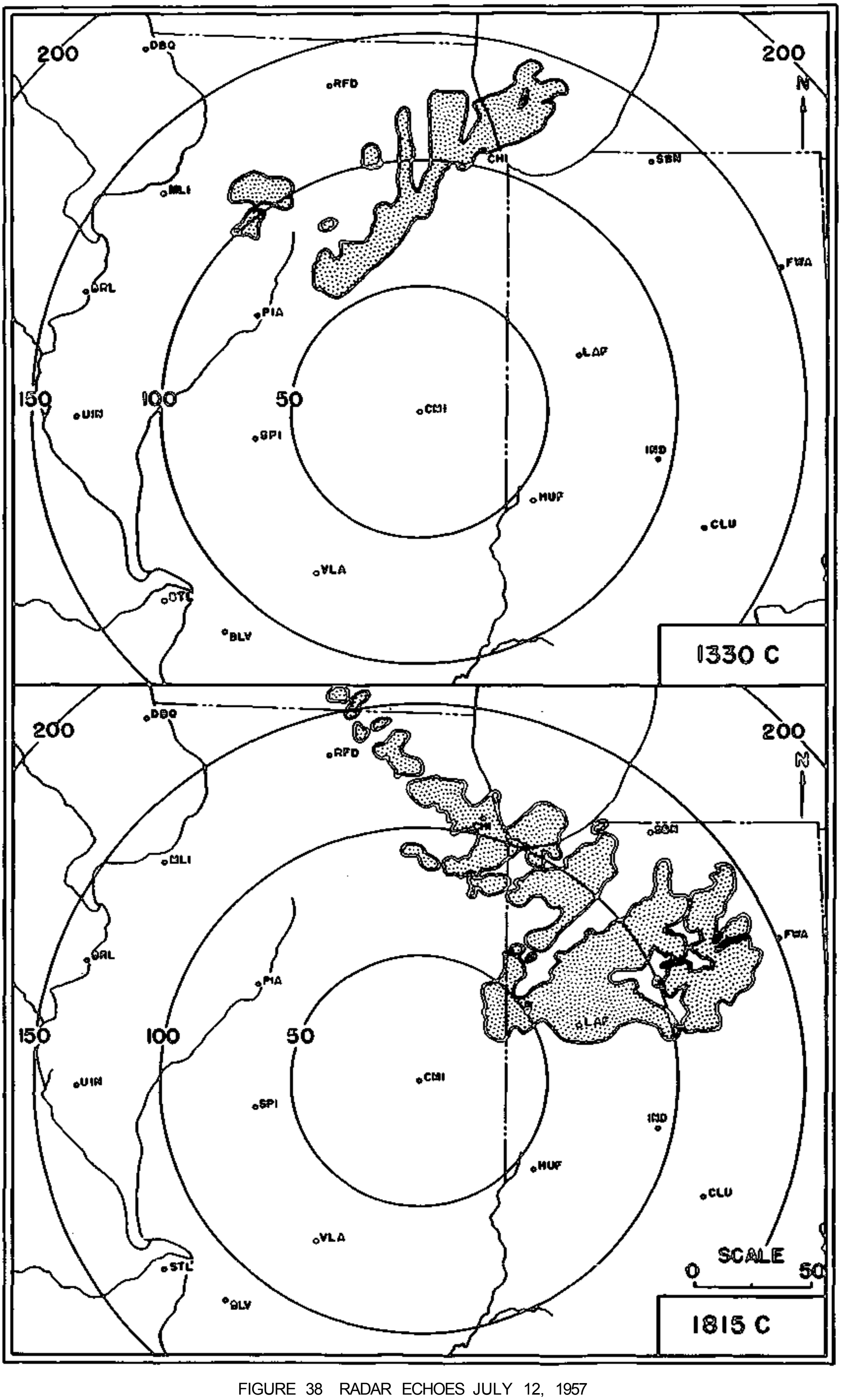


FIGURE 38 RADAR ECHOES JULY 12, 1957

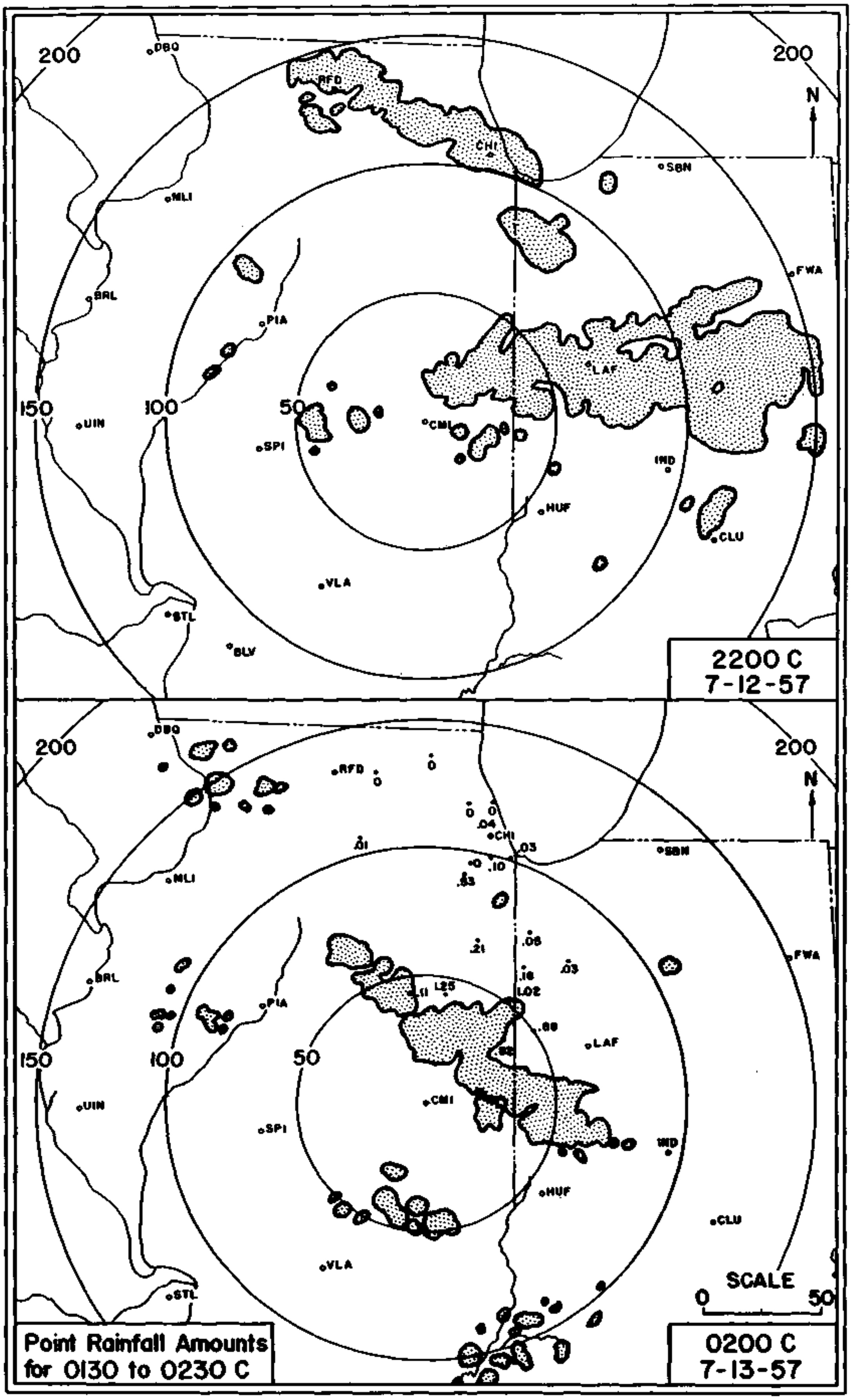


FIGURE 39 RADAR ECHOES JULY 12-13, 1957

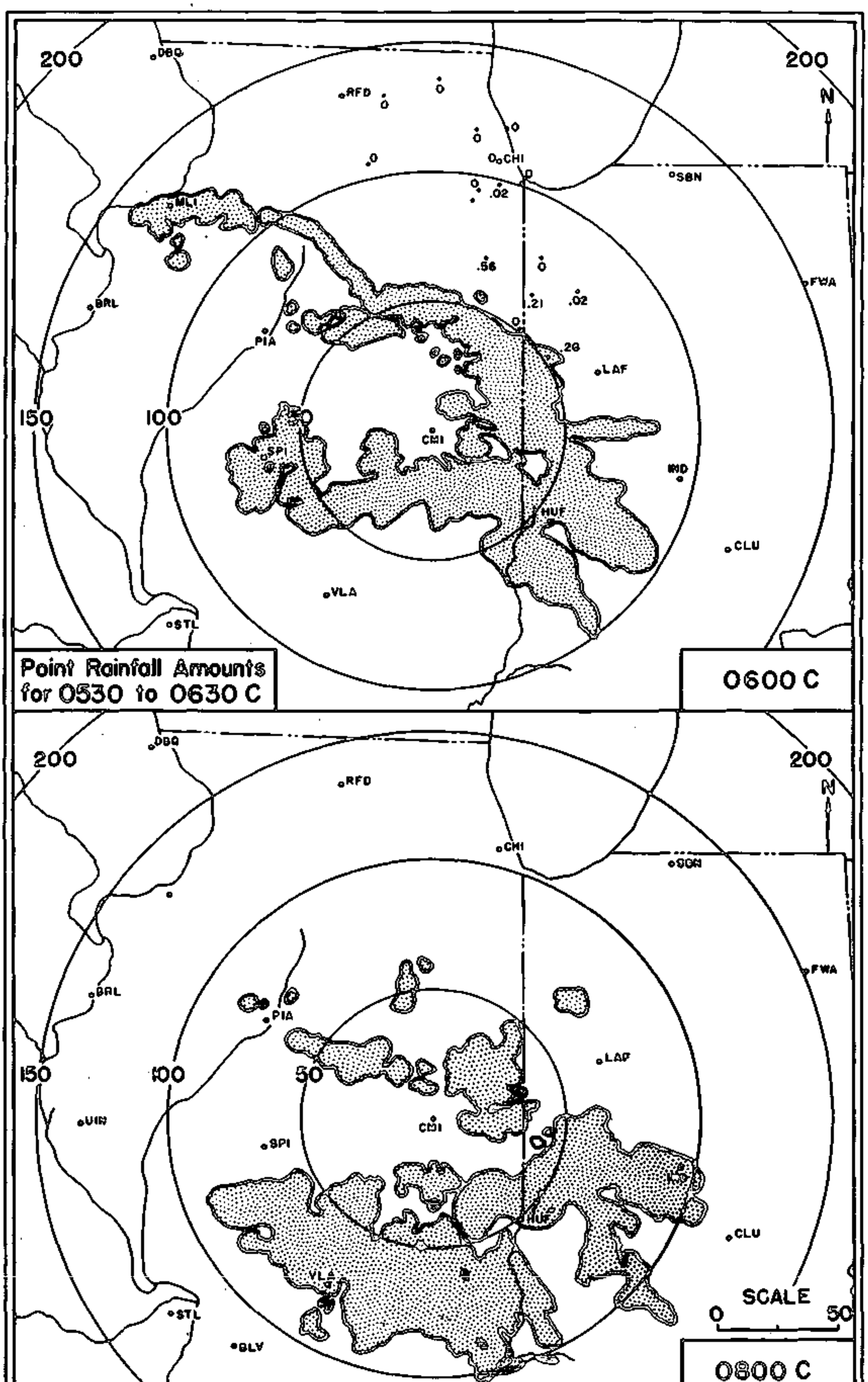


FIGURE 40 RADAR ECHOES JULY 13, 1957

STORM OF MAY 21-23, 1957

Introduction

The first of four severe rainstorms in Illinois during 1957 occurred over the southern part of the state May 21-23 (Fig. 1). The total storm consisted of three separate shower periods, beginning during the afternoon of May 21 and ending during the forenoon of May 23. The first and most severe of the three shower periods within Illinois began about 1600 CST on May 21 and ended in the early morning hours of May 22. The second shower period occurred during the afternoon of May 22, while the third and final storm occurred during the night of May 22-23. Hail insurance reports[4] indicate the occurrence of scattered hailstorms in conjunction with the heavy storm period on May 21.

As mentioned earlier in this report, information on the magnitude of this storm was not obtained soon enough to conduct a satisfactory field survey. However, data were available from a concentrated raingage network of 60 gages on an area which furnished some detailed data for analysis near the center of the storm. This network was maintained by the Water Survey in cooperation with Southern Illinois University at the time. The distribution of observations within the storm from U.S. Weather Bureau gages and the Water Survey network is shown in Figure 41.

Isohyetal Patterns

An isohyetal map for the total storm period is shown in Figure 42. The parallel dashed lines on this map enclose the area which was planimetered to determine area-depth relations. This was necessary to separate the Missouri-Illinois-Indiana storm from another storm to the south in Kentucky. Reference to Figure 42 shows that the core of this storm was in southern Illinois with amounts exceeding nine inches near Harrisburg (Point A Fig. 41). The heaviest rain in Illinois fell in conjunction with the first shower period during the six hours beginning at 1800 CST on May 21. Isohyetal maps for the maximum 6-hour, 12-hour, and 24-hour periods within the overall storm period are shown in Figures 43-45. All three periods began at 1800 CST on May 21. The 6-hour map in Figure-43 indicates that amounts in excess of six inches occurred within the core of the storm in southeastern Illinois.

Characteristics of Rainfall Distribution

Mass rainfall curves for recording gage stations near the major axis of the storm in Missouri, Illinois, and Indiana are shown in Figure 46. Locations of the recording gage stations of Figure 46 are shown in Figure 41. The area of greatest gage density in Figure 41 indicates the location of the Water Survey network discussed earlier. The concentration of the heavy rainfall in the first storm period on May 21 is shown by the mass curves for Carbondale, Murphysboro, and Glendale. Carbondale and Murphysboro are located near the storm center in southwestern Illinois in Figure 42, while Glendale is located southwest of Shawneetown near the 5-inch isohyet.

As mentioned previously, the stations in Figure 46 are near the center of the storm shown in Figure 42. Data from these and other recording gage stations within the storm area were used to draw isopercentile maps from which the peak-period isohyetal maps of Figures 43-45 were drawn.

Depth-Duration-Area Relations

Area-depth relations for the total storm and for peak periods within the total storm period are presented in Table 7. Area-depth relations within the storm were found to be closely approximated by an equation of the form:

$$\text{Log } Y = a + b X^{0.4}$$

where Y is rainfall depth in inches, X is area in square miles and a and b are regression constants. Table 8 shows the time distribution of rainfall within the core of the storm, and was determined in the same manner as similar tables presented for other storms in previous sections. Tables 7 and 8 show that the heaviest rainfall within the storm core in Illinois fell during the 6-hour period beginning at 1800 CST on May 21. In the center of the storm in southeastern Illinois over 70 percent of the total storm rainfall occurred within this 6-hour period.

TABLE 7

DEPTH-DURATION-AREA DATA, MAY 21-23

Duration	Depth (in.) for given area (sq. mi.)									
	25	50	100	200	500	1000	2000	5000	10,000	20,000
Entire storm	9.4	9.2	9.0	8.8	8.3	7.8	7.2	6.4	5.6	4.6
Max. 24 hrs.	7.9	7.8	7.6	7.3	6.8	6.3	5.7	4.8	-	-
Max. 12 hrs.	7.3	7.1	6.8	6.5	5.9	5.3	4.6	3.6	-	-
Max. 6 hrs.	7.0	6.7	6.4	6.1	5.5	4.8	4.2	3.2	-	-

TABLE 8

TIME DISTRIBUTION OF AREAL MEAN RAINFALL, MAY 21-23

Period	Percent of total storm rainfall for given areas (sq. mi.)						
	25	50	100	200	500	1000	2000
Max. 6 hrs.	73	73	71	70	66	62	58
Max. 12 hrs.	78	77	76	74	71	68	64
Max. 24 hrs.	84	85	85	83	82	81	79

Antecedent Rainfall

Rainfall within the storm area in southern Illinois for the 5-day and 10-day periods preceding the May 21-23 storm are shown in Figures 47 and 48. The normal 5-day and 10-day amounts for this area at this time of year are approximately 0.65 inch and 1.30 inches, respectively. The 5-day map in Figure 47 shows amounts generally within the range of two to four inches in the storm area. The 10-day map in Figure 48 shows amounts ranging from three to six inches. Thus, rainfall for the antecedent periods was considerably above normal and may have contributed appreciably to flood conditions associated with the May 21-23 storm.

Synoptic Weather

A deep low pressure system was located in south eastern North Dakota at noon on May 21 and was moving to the northeast about 10 mph. The frontal system associated with this low center was occluded from the center of the low, south-southeastward to north central Missouri, where a cold front extended southwestward to Texas and a warm front eastward across south central Illinois, (1230 CST, Fig. 49). During the next 12 hours, the occluded system continued to move northeastward and by midnight (Fig. 49) the low center was located in northern Minnesota. The point of intersection of the warm and cold fronts had moved north-northeastward, so that southern Illinois was in warm, moist, unstable air during the night of May 21 when heavy rains were occurring over southern Illinois and portions of Indiana and Missouri. The area enclosed by the 6-inch isohyet has again been outlined on the synoptic maps for comparison purposes.

The low pressure center weakened slightly during the next 12 hours while accelerating its northeastward movement. The surface map for 1230 noon on May 22 (Fig. 50) indicated the low center southwest of Hudson Bay. The occlusion had moved rapidly eastward while the cold front had moved a little to the southeast.

The surface map for 1830 CST on May 22 (Fig. 50) showed thunderstorms extending along the Ohio River Valley and west-southwestward to central Oklahoma. The front at that time exhibited several waves along it from the upper Great Lakes region to Texas. The pressure pattern had become greatly disturbed with the thunderstorms in the unstable warm air. However, with the eastward movement of the front followed by cooler and drier air, the rain and thunderstorms ended in southern Illinois.

The upper wind flow indicated a strong moisture flow from the Gulf of Mexico into the heavy rain area. During the heavy rain period, south-southwest to southwesterly winds existed from 5000 feet to 20,000 feet. Speeds ranged from approximately 30-35 mph at 5000 feet to 65-70 mph at 20,000 feet. During the forenoon of May 23 there was an abrupt change to westerly winds aloft with the passage of a trough. Rain ended with the passage of this trough.

Radar Analysis

The upper portion of Figure 51 shows the radar presentation at 2000 CST on May 21, during the period of heaviest rainfall in the storm core over southern Illinois. The rain was occurring in a squall zone which extended from northeastern Indiana southwestward and then westward through Illinois into Missouri. As the night progressed, the squall zone remained quasi-stationary over southern Illinois, while the portion of the squall zone over eastern Indiana moved southeastward. The lower portion of Figure 51 shows the radar portrayal at 0400 CST on May 22. The storm area over southeastern Indiana and western Ohio in the lower portion of Figure 51 resulted from a second storm zone which moved in from the northwest. Range restrictions and precipitation attenuation were affecting the radar portrayal during this storm period. Undoubtedly, the quasi-stationary squall zone over southern Illinois was being supported by strong moisture inflow and merging of storms moving from the south. The squall zone which became quasi-stationary over southern Illinois moved in from the northwest. The radar indicated that the quasi-stationary squall zone over southern Illinois decreased in intensity and moved southward during the early forenoon of May 22.

The upper portion of Figure 52 shows the radar presentation at 1400 CST on May 22. Scattered shower activity occurred over eastern Missouri, southern Illinois, and southwestern Indiana during the afternoon of May 22, the heaviest activity apparently occurring in eastern Missouri. The orientation of the squall zone differed considerably from the one of the previous night. The afternoon squall zone was oriented WNW-ESE, whereas the previous zone was oriented ENE-WSW through southern Illinois and eastern Missouri. The squall zone during the afternoon of May 22 was oriented approximately perpendicular to the upper air wind flow.

The lower portion of Figure 52 illustrates the radar portrayal at 2000 CST on May 22. The last of the three showers during the total storm period was in progress at that time. At 2000 CST, the squall zone appeared similar to the one of the previous evening which had produced the heavy rainfall in southern Illinois. However, this squall zone moved slowly southeastward during the night and additional storm development took place over eastern Missouri, southern Illinois and southwestern Indiana. Considerable shower activity was present during the early morning hours, but ceased during the early forenoon with the passage of the trough aloft and the shift of the upper winds from southwesterly to westerly, as pointed out in the previous section on synoptic weather.

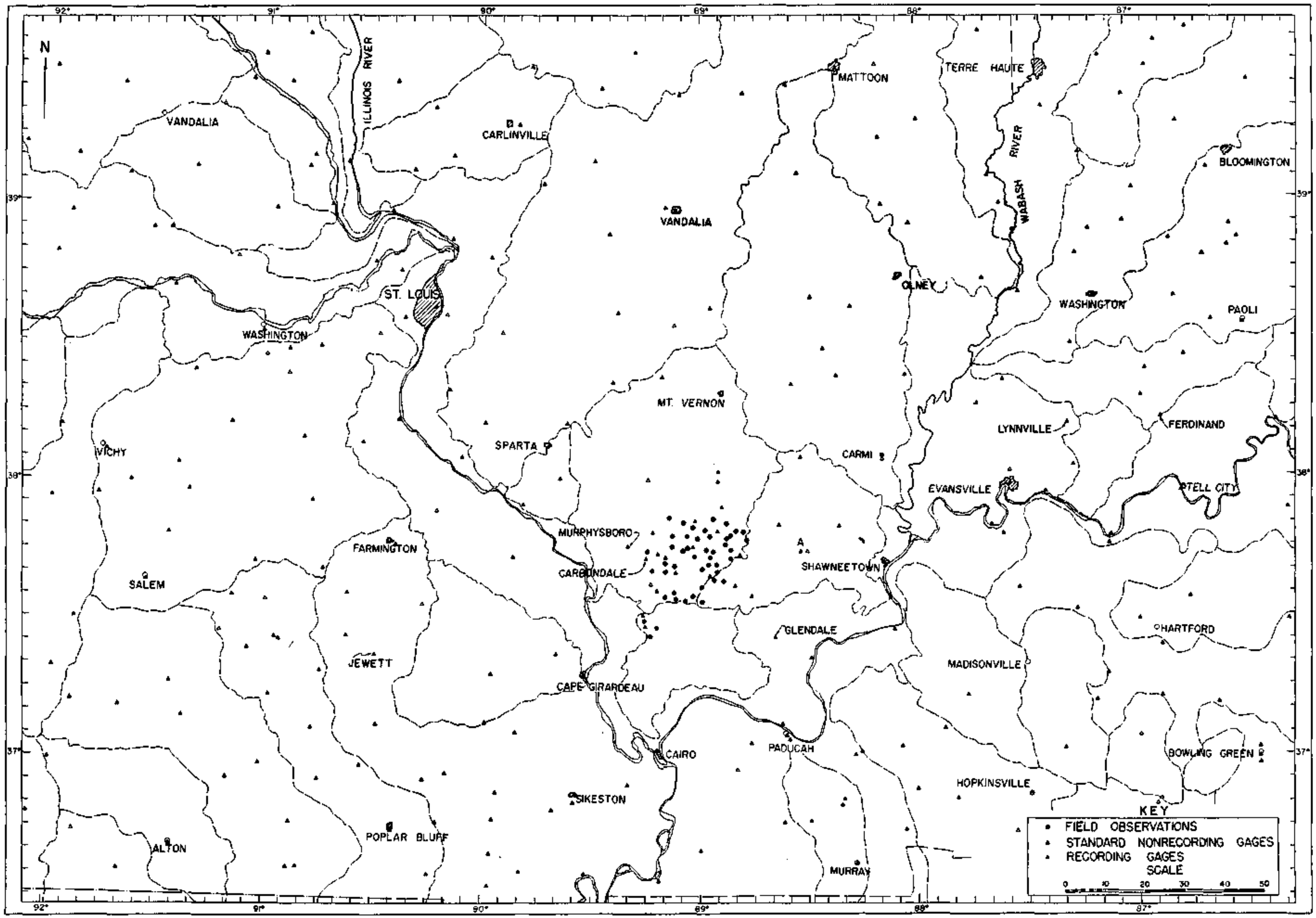


FIGURE 41 LOCATION OF POINT RAINFALL OBSERVATIONS, MAY 21-23, 1957

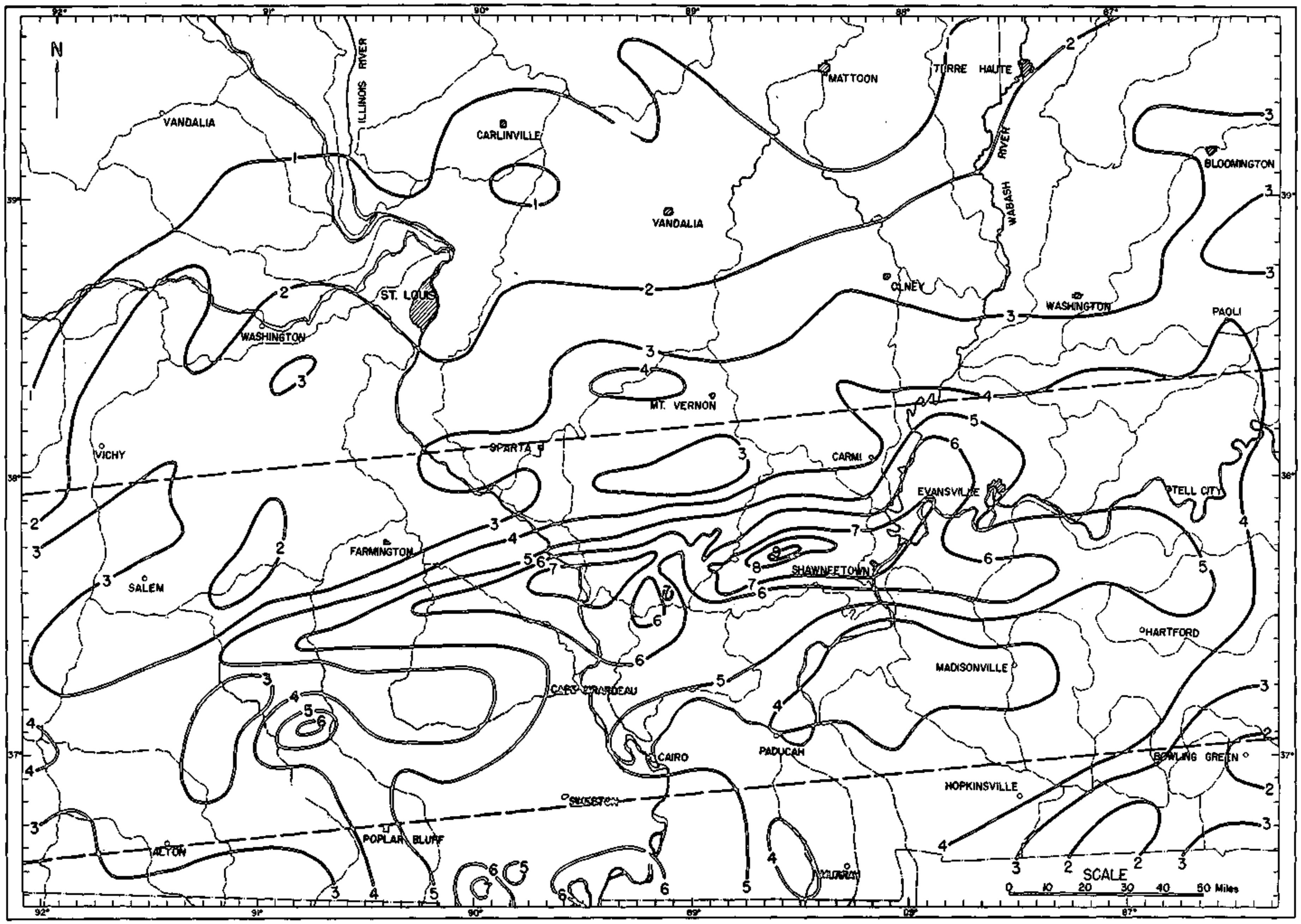


FIGURE 42 TOTAL STORM RAINFALL FOR MAY 21-23, 1957

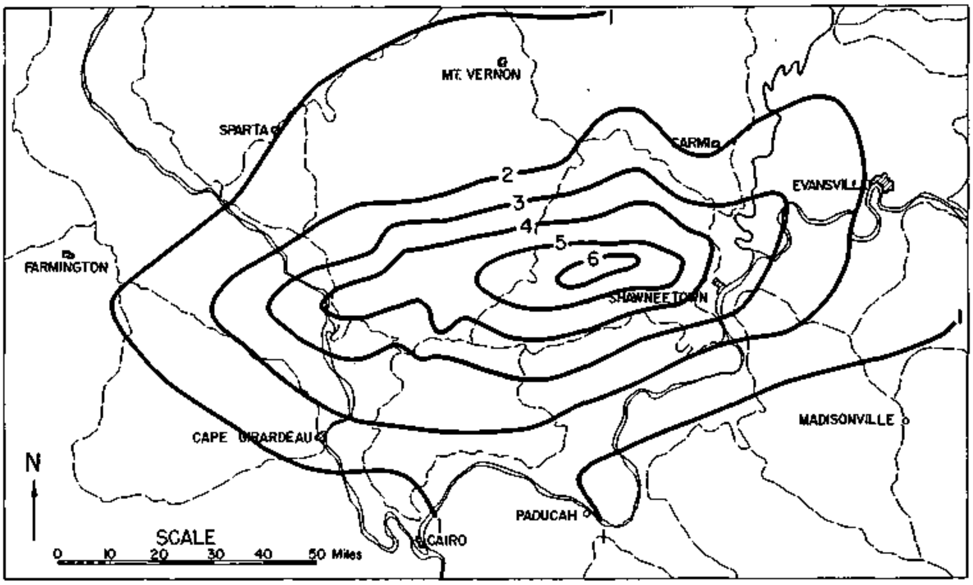


FIGURE 43 MAXIMUM 6-HOUR RAINFALL FOR MAY 21-23, 1957

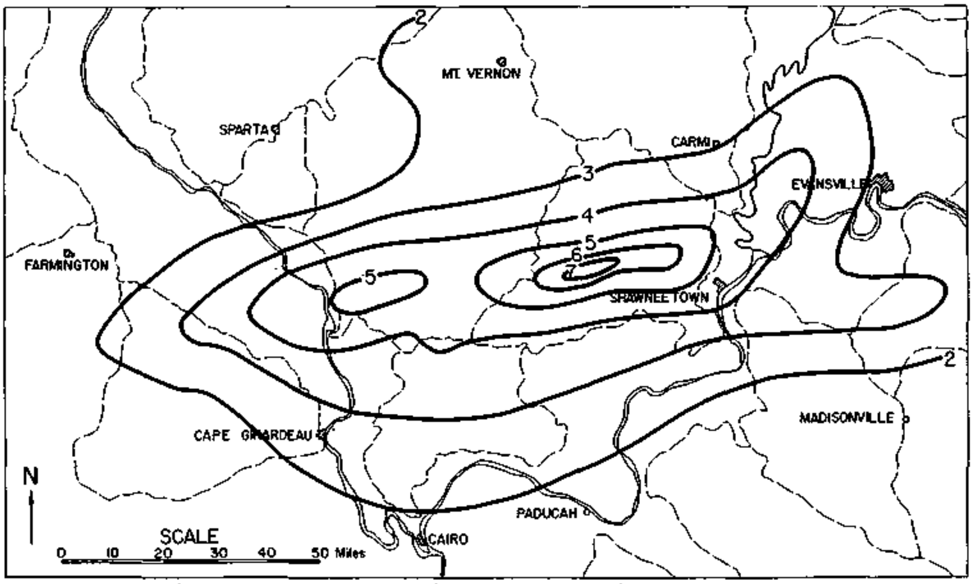


FIGURE 44 MAXIMUM 12-HOUR RAINFALL FOR MAY 21-23, 1957

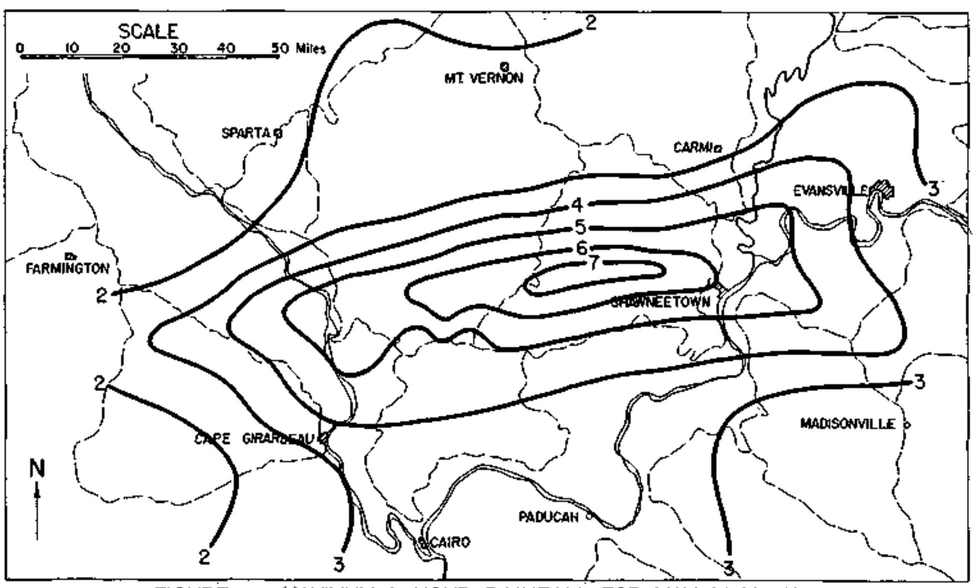


FIGURE 45 MAXIMUM 24-HOUR RAINFALL FOR MAY 21-23, 1957

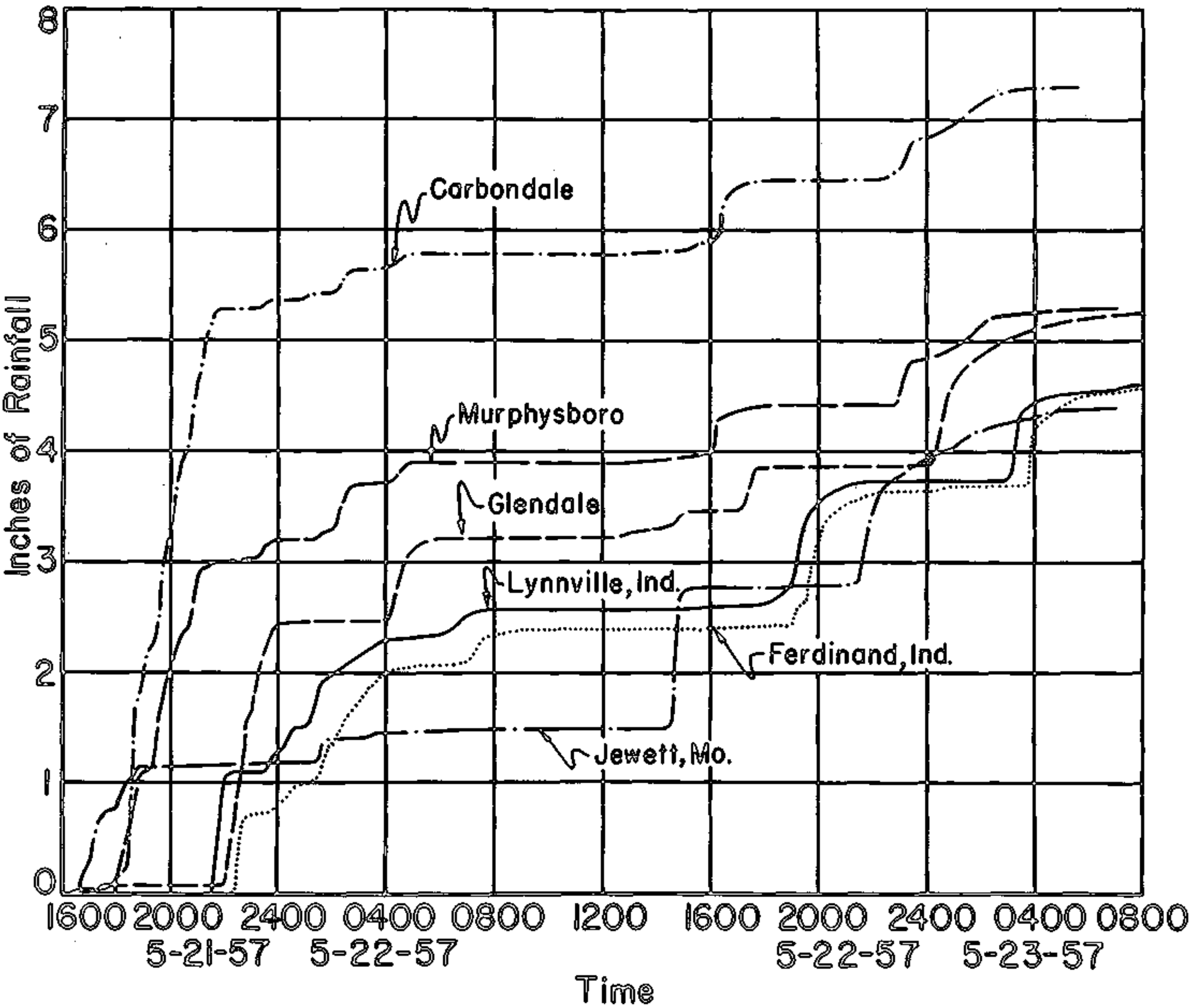


FIGURE 46 MASS CURVES OF RAINFALL FROM SELECTED STATIONS FOR MAY 21-23, 1957

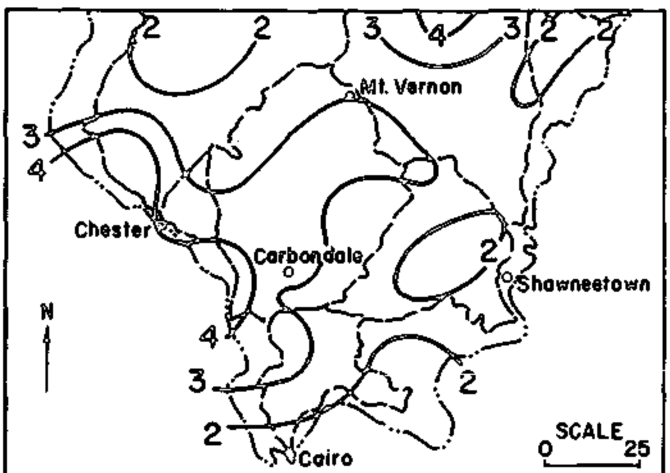


FIGURE 47 TOTAL RAINFALL MAY 16-20, 1957

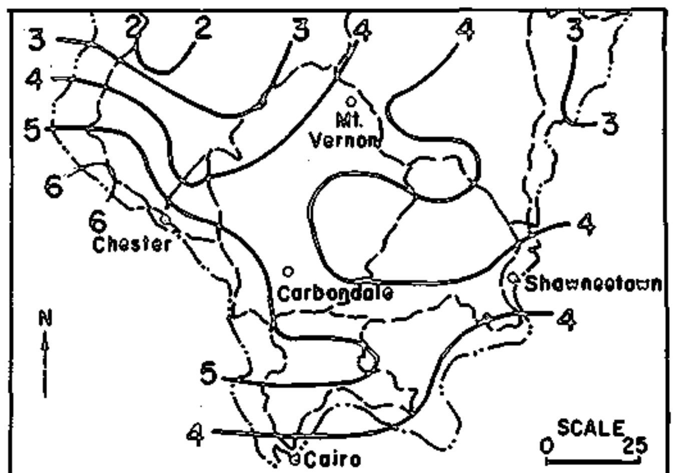


FIGURE 48 TOTAL RAINFALL MAY 11-20, 1957

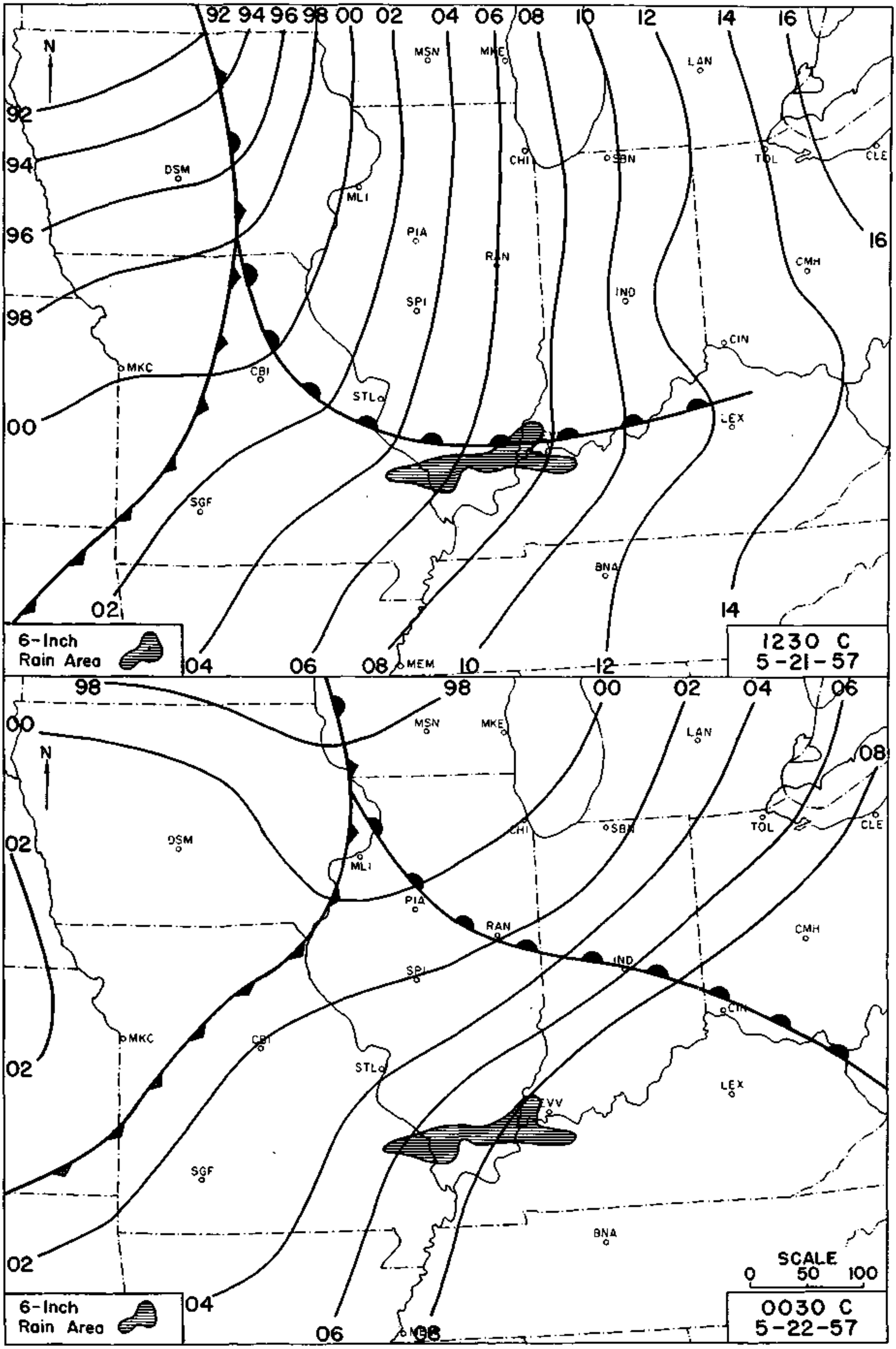


FIGURE 49 SURFACE SYNOPTIC MAPS ON MAY 21-22, 1957

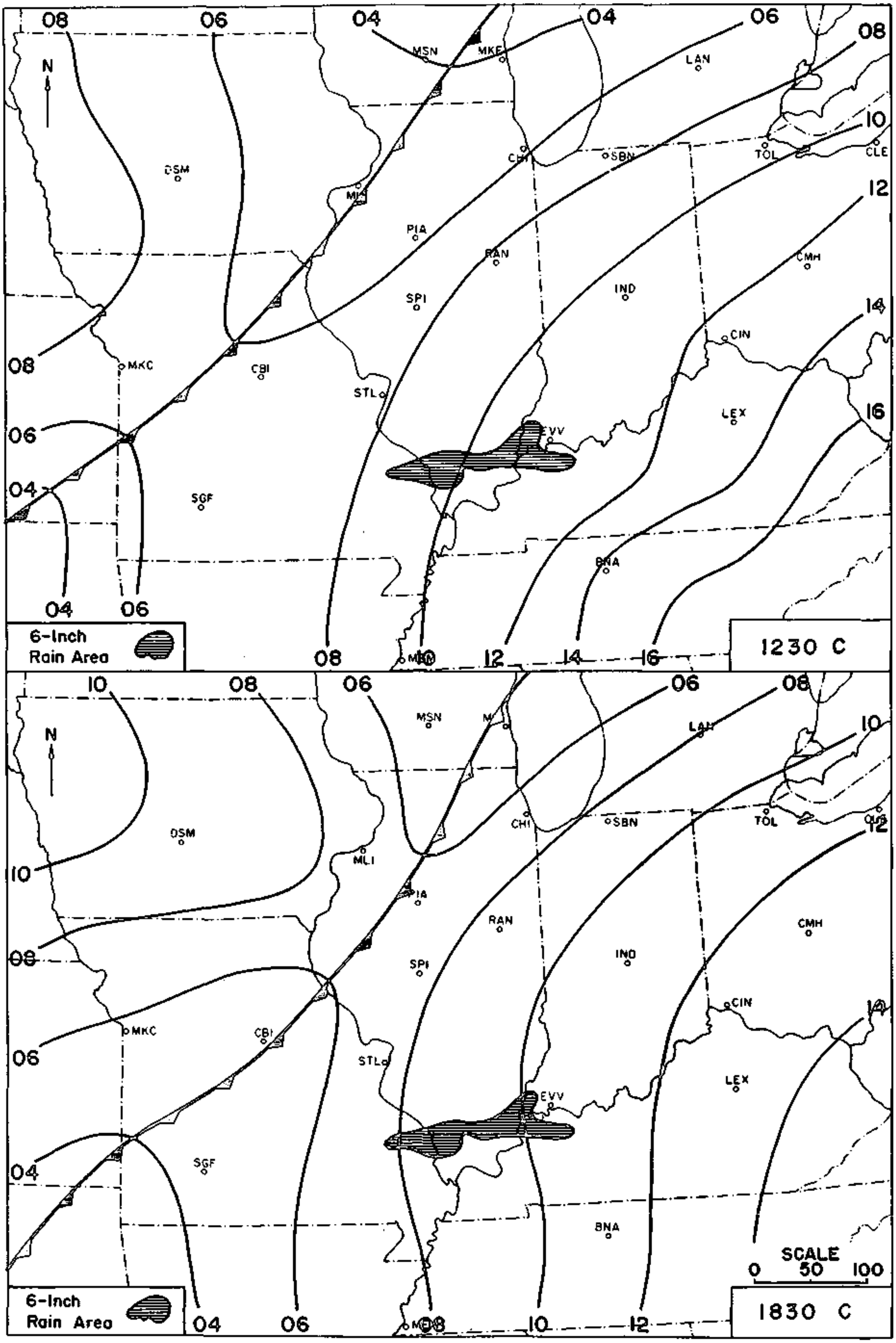


FIGURE 50 SURFACE SYNOPTIC MAPS ON MAY 22, 1957

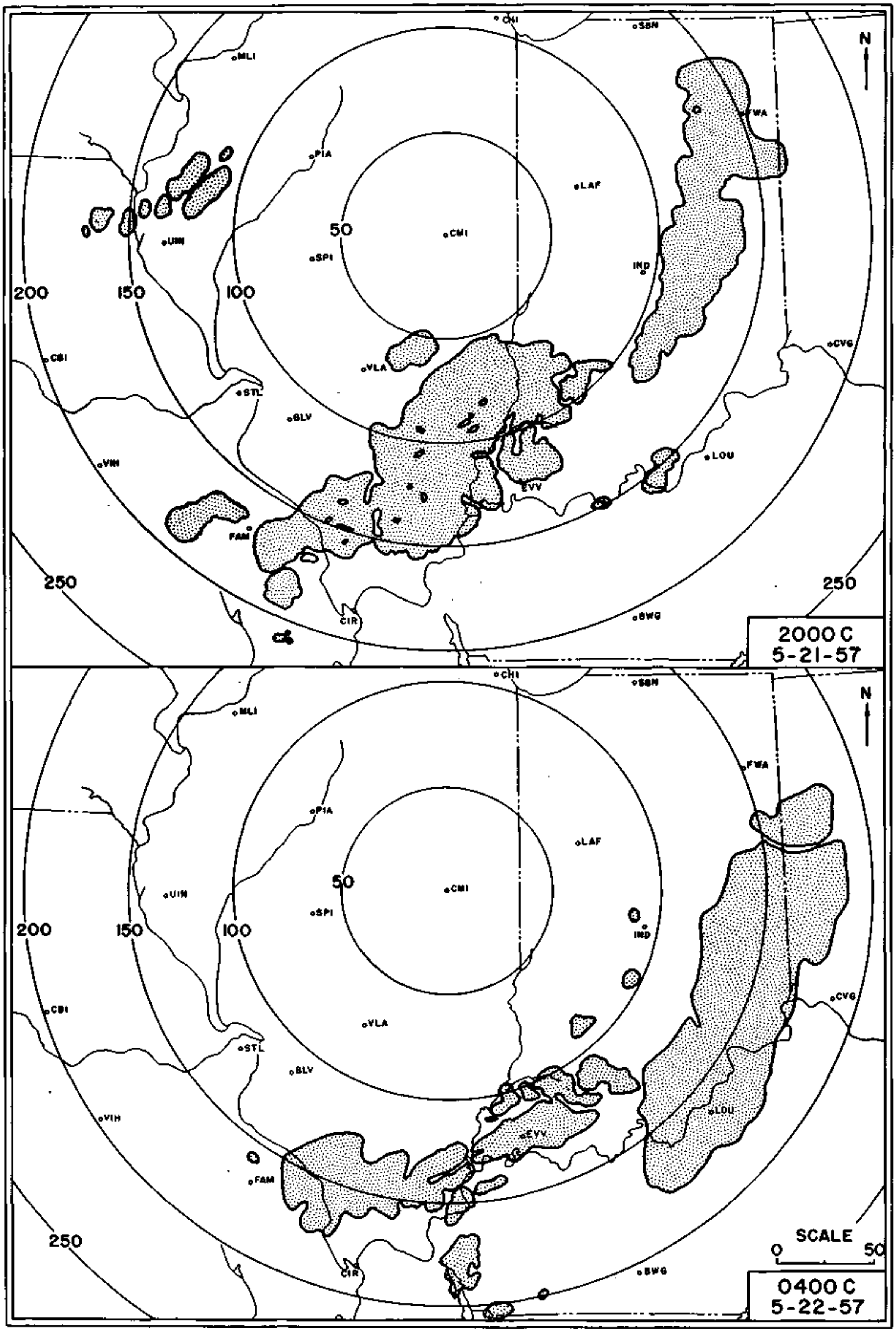


FIGURE 51 RADAR ECHOES MAY 21-22, 1957

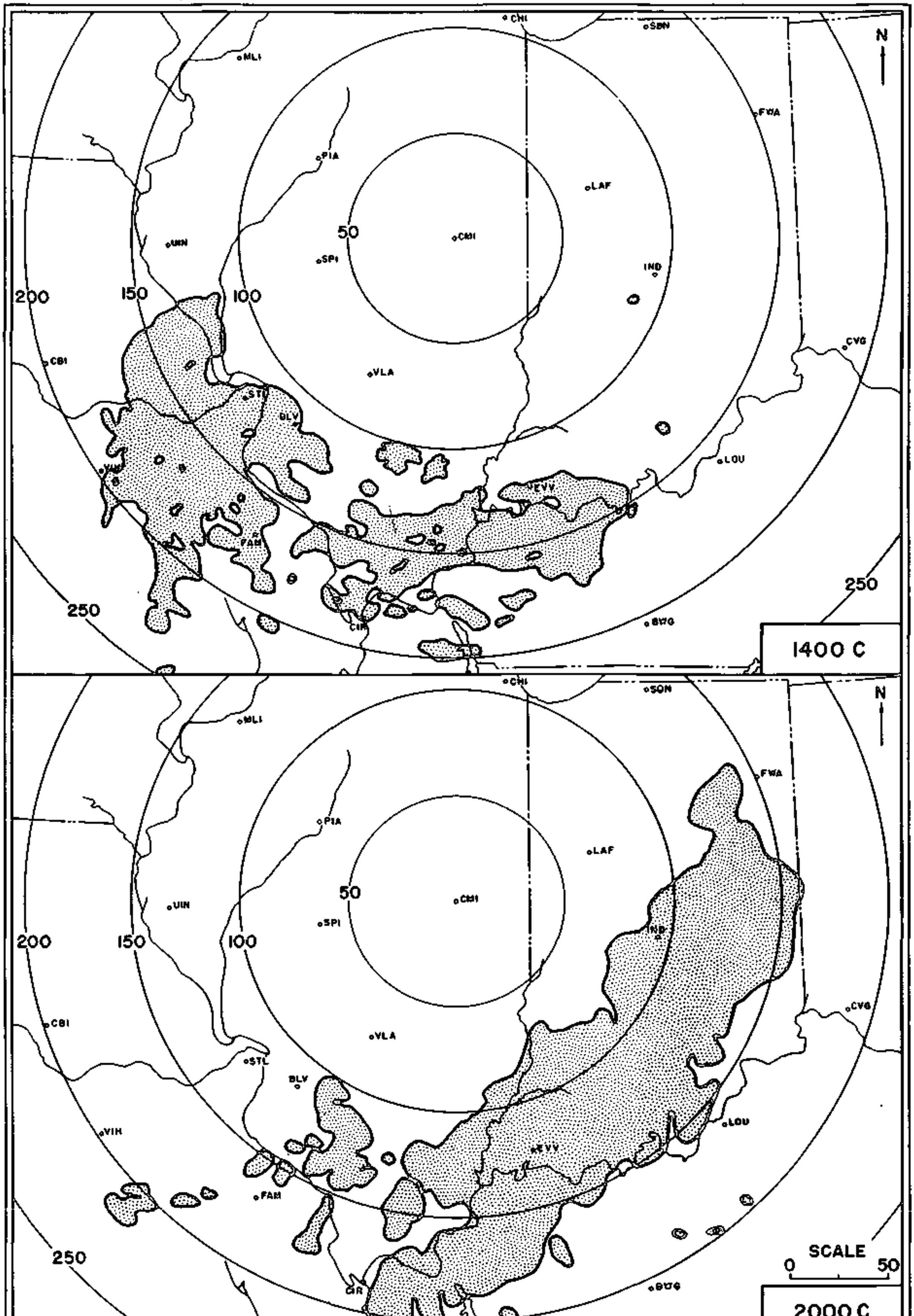


FIGURE 52 RADAR ECHOES MAY 22, 1957

STORM OF MAY 26-28, 1956

Introduction

On May 26-28, 1956, a severe rainstorm, centered in east central Illinois, produced rainfall amounts exceeding 13 inches (Fig. 1). Rainfall in Illinois extended over a period of approximately 63 hours beginning at 0300 CST on May 26. However, most of the rainfall in the core of the storm occurred during the night of May 26. In the storm center, 60 to 70 percent of the total storm rainfall occurred in a 6-hour period during the night of May 26, while 80 to 90 percent occurred within a 24-hour period starting during the evening of May 26. The major axis of the storm was oriented approximately WNW-ESE across east central Illinois, and west central and central Indiana. Hail insurance claims[4] for Illinois indicated considerable hail over central Illinois on May 27 and 28, but very little on May 26 when the heaviest rainfall was recorded. The distribution of rainfall observations obtained from a field survey and other sources is shown in Figure 53.

Isohyetal Patterns

A total storm isohyetal map for Illinois and Indiana is shown in Figure 54. The storm pattern in Illinois was defined in detail from field survey data, while the analysis in Indiana was based upon data from U. S. Weather Bureau stations only. Figure 55 shows the total storm isohyetal map on a larger scale for the Illinois portion of the storm where detailed field survey data were available. Figures 56-58 show isohyetal maps for maximum rainfall periods of 6, 12, and 24 hours, respectively, for the Illinois portion of the storm. The largest measured amount, 13.1 inches, is shown at Point A on Figure 53.

Characteristics of Rainfall Distribution

Mass rainfall curves for recording gage stations near the axis of the storm in Illinois and Indiana are shown in Figure 59. The locations of these stations are shown in Figure 53. Downs is the recording station located nearest to the 13-inch core in Figure 55. In this core, the largest portion of the rainfall occurred from mid-evening of the 26th to early morning of the 27th. Rantoul, located near the axis of the storm but considerably east of the main core, received two heavy rainfall periods, one occurring on the night of the 26th and the other during the evening of the 27th. The mass curve for Lebanon, Indiana, also shows two major storm periods, one on the night of the 26th and the other on the night of the 27th. Crawfordsville, Indiana, received its major portion of rain during the night and early morning of May 26-27. Again, large variability in the time and space distribution of rainfall is evident. As pointed out in previous sections, this variability is a common characteristic of these warm season, flood-producing storms and makes delineation of peak rainfall periods difficult.

Depth-Duration-Area Relations

Area-depth relations for the total storm period and for incremental peak periods within the overall storm are presented in Table 9. The peak period relations are for the Illinois portion of the storm only. The area-depth data were fitted to an equation of the form:

$$\text{Log } Y = a + b X^{0.5}$$

where Y is rainfall depth in inches, X is area in square miles, and a and b are regression constants. Table 10 shows the time distribution of rainfall within the storm core for the peak rainfall periods of 6, 12, and 24 hours, all of which began at 2100 CST on May 26.

TABLE 9

DEPTH-DURATION-AREA DATA, MAY 26-28

Period	Depth (in.) for given area (sq. mi.) 25	50	100	200	500	1000	2000	5000	10,000
Entire storm (Ill. & Ind.)	11.9	11.3	10.6	9.6	8.1	6.9	5.6	4.8	4.2
Entire storm (Ill.)	11.9	11.3	10.6	9.6	7.5	6.2	-	-	-
Max. 24 hrs. (Ill.)	10.9	10.1	9.3	8.2	6.2	4.7	-	-	-
Max. 12 hrs. (Ill.)	9.2	8.5	7.6	6.5	4.8	3.5	-	-	-
Max. 6 hrs. (Ill.)	8.5	7.9	7.0	6.0	4.4	3.1	-	-	-

TABLE 10

TIME DISTRIBUTION OF AREAL MEAN RAINFALL, MAY 26-28

Period (Ill. only)	Percent of total storm rainfall for given areas (sq. mi.) 25	50	100	200	500	1000
Max. 6 hrs.	71	70	66	63	58	50
Max. 12 hrs.	77	75	72	68	62	57
Max. 24 hrs.	91	89	88	85	80	76

Antecedent Rainfall

Figures 60 and 61 show the total rainfall for periods of 5 and 10 days preceding the May 26-28 storm. At this time of the year, the normal 5-day and 10-day rainfall is approximately 0.65 inch and 1.30 inches, respectively, for the storm area in Illinois. Figures 60 and 61 show that below normal rainfall occurred in the storm area except in the region of Danville in extreme east central Illinois. Consequently, the antecedent rainfall should not have been an important factor in accentuating flood conditions in Illinois.

Synoptic Weather

The analysis of the surface chart for noon on May 26 revealed a trough oriented NW-SE from southern Nebraska to southern Illinois. This discontinuity was not sharply defined, although there were slight changes in winds, temperature, and stability in the low levels of the atmosphere. On the surface synoptic map for 1830 CST of May 26 (Fig. 62), this trough line remained oriented NW-SE on a line from northwestern Missouri through southern Illinois to western Kentucky. The trough was moving northeastward at about 15 mph at that time. A frontal system, not shown in Figure 62, was stationary in the upper Great Lakes region at 1830 CST. While the surface synoptic map did not indicate any appreciable difference in air mass characteristics across the trough, it was evident that a difference did exist in the stability of the lower layers. The air north of the trough was quite stable in the lower levels, as evidenced by widespread fog, while south of the trough scattered to broken clouds prevailed. The stippled area on the surface maps outlines the area within which the total storm rainfall exceeded six inches.

During the next 12 hours, the quasi-stationary front in the upper Great Lakes region began to move southward as a cold front, extending as far south as Milwaukee, Wisconsin, by early morning of May 27 (0630 CST, Fig. 62). The trough continued to move northeastward and by 0630 CST on the 27th was located on a line from Moline southeastward through Illinois to southwestern Indiana. At that time, the trough contained a pronounced bend resembling a frontal wave in the vicinity of Moline. The heaviest rain in the core of the storm in east central Illinois occurred in advance of this low level trough.

By the evening of May 27, the cold front had moved south of Chicago. It was oriented east-west from Ohio to central Illinois, where it curved to the northwest as shown at 1830 CST in Figure 63. By that time the trough line had merged with the frontal system. The cold front continued its southward movement, but became stationary by the end of the next 12-hour period. The lower portion of Figure 63 shows the situation at 0630 CST on May 28, when the cold front had reached its southernmost position. By this time the heavy rain had ended in central Illinois, but during the ensuing 12 hours the cold front retreated to the north as a warm front, bringing more showers and thunderstorms to Illinois and Indiana during the afternoon and evening of May 28. The rainfall during the night of May 27 was associated with the southward drifting cold front.

The upper winds indicated a strong flow of moisture off the Gulf of Mexico into the Midwest. Upper air maps indicated a convergence of westerly and southwesterly flow over Illinois prior to the heavy rainfall on May 26. During the storm period, the winds decreased with height from 30-35 mph at 5000 feet to 20-25 mph at 20,000 feet.

Radar and Hourly Rainfall Analysis

Analysis of hourly rainfall amounts from recording gages in Illinois and Indiana was made for the May 26-28 period. This analysis showed rather widespread light shower activity over southern and western Indiana beginning in the early morning hours of the 26th. This rainfall continued quite widespread throughout the forenoon, becoming more scattered in its distribution during the afternoon.

Radar photographs taken during the forenoon of May 26 showed several squall lines oriented NNW-SSE moving eastward across Illinois and Indiana, apparently developing over central and west central Illinois. By early afternoon, hourlv rainfall analysis showed only widely scattered showers occurring over Illinois, although rather widespread rain was occurring over Indiana associated with the eastward movement of the squall lines which passed through Illinois earlier. By 1900 CST only a very few stations in Illinois and western Indiana were recording rainfall.

Unfortunately, radar observations were limited during the period of the May 26-28 storm. At that time, a regular week-end observational schedule was not maintained with the radar because of lack of operating personnel. No radar data were available during the afternoon and night of May 26 and most of May 27. The upper portion of Figure 64 shows the radar presentation at 1300 CST on May 26, shortly before radar operations were terminated for that day.

The rainfall pattern, as determined from analysis of hourly rainfall amounts from recording gages, indicated a pronounced change in the orientation and movement of developing squall lines during the evening of May 26. The rainfall pattern starting about 2000 CST gave evidence of a developing and northward-moving squall Zone oriented WNW-ESE over southern Illinois. Its position correlated well with the position of the trough on the synoptic weather map mentioned earlier. The lower portion of Figure 64 shows the rainfall distribution for the hour ending at midnight on May 26, during the period of heavy rainfall in east central Illinois.

In the early morning hours on the 27th, the hourly rainfall pattern indicated the development of another squall zone oriented east-west in south central Illinois. This zone also appeared to move slowly northward into the area of heavy rainfall. The upper portion of Figure 65 shows the hourly rainfall pattern for the hour ending at 0400 CST, and illustrates the presence of the two storm zones oriented approximately east-west. The squall zone appearing at 2300-2400 CST in Figure 64 was apparently still in the area of heavy rainfall in east central Illinois and the second zone was moving into this area from the south and merging with the original squall zone in the storm area.

The lower portion of Figure 65 shows the radar portrayal at 1000 CST on May 27. The radar presentation at that time indicated two squall zones, one lying north of the area of heavy rainfall and the other approaching that area. It appears that the squall zone shown north of the storm area at 1000 CST in Figure 65 represents the remainder of the system which contributed heavy rainfall during the previous evening, while the southern zone through the radar station represents light shower activity occurring at that time. The hourly rainfall analyses indicated that individual rainstorm cells traveled eastward along the axis of the heavy rainfall zone during the night of May 26.

At 1600 CST on May 27, the radar indicated three bands of storms oriented roughly in a WNW-ESE position. At the same time, there was a line of storms oriented NW-SE through east central Illinois, producing intersecting squall lines. The upper portion of Figure 66 shows the radar presentation at 1700 CST on May 27, shortly before radar operations were concluded for the day. Note the presence of the squall zone from Peoria (PIA) through the radar station to Terre Haute (HUF) oriented approximately WNW-ESE. It is believed that this zone moved northward and was the source of heavy precipitation in the early evening in the vicinity of the storm axis in east central Illinois.

Analysis of hourly rainfall data indicates the redevelopment of heavy rainfall during the evening of May 27 in approximately the same area and with the squall zone oriented similar to the previous night. However, in east central Illinois the rainfall was more scattered and less intense than on the previous night. The lower portion of Figure 66 shows the rainfall pattern for the hour ending at 2000 CST. During late evening, the rainfall zone appeared to undergo a change in orientation from WNW-ESE to NW-SE. At the same time, rainfall records indicated a decrease in the intensity and areal extent of the storm, indicating that dissipation had begun.

Between midnight and 0200 on May 28, the main precipitation zone decreased in areal extent and intensity. However, a resurgence appeared to take place about 0400 CST, based upon analyses of hourly rainfall values. Later, there appeared to be a slow movement of the main rainfall zone northward and a gradual decrease in intensity. Radar operations started at 0800 CST on May 28 and verified the slow northward movement of the NW-SE squall zone. The radar presentation at 0820 CST on May 28 is shown in the upper portion of Figure 67. From the hourly rainfall analysis, it appears that this squall zone had remained stagnant in the Peoria-Rantoul-Indianapolis area for several hours during the night when the heaviest rainfall in this band occurred. As mentioned previously, it appears quite possible that the squall zone over the radar station at 1700 CST on May 27 (Fig. 66) moved into the instability zone during the evening with consequent intensification and stagnation.

The radar indicated the development of a north-south squall zone along the Mississippi River during the late forenoon of the 28th. This squall zone moved eastward and produced heavy rainfall in the Peoria area during mid-afternoon (Fig. 59). After reaching the Peoria region, the squall zone drifted very slowly eastward and appeared to be dissipating at 2040 CST when the radar was turned off for the day. A radar portrayal of the afternoon squall zone is shown in the lower portion of Figure 67.

In summary, the hourly rainfall records and radar data indicate that a very slow-moving or stagnant squall zone was present during the night of May 26 in the storm area. This zone reappeared in the same general area and with the same general orientation on the evening of May 27, but was not as strong as on May 26. On the night of May 26, a possible initiating mechanism appearing in the synoptic analysis was the northward-moving trough. On the evening of May 27, the southward drifting cold front was apparently associated with the rain.

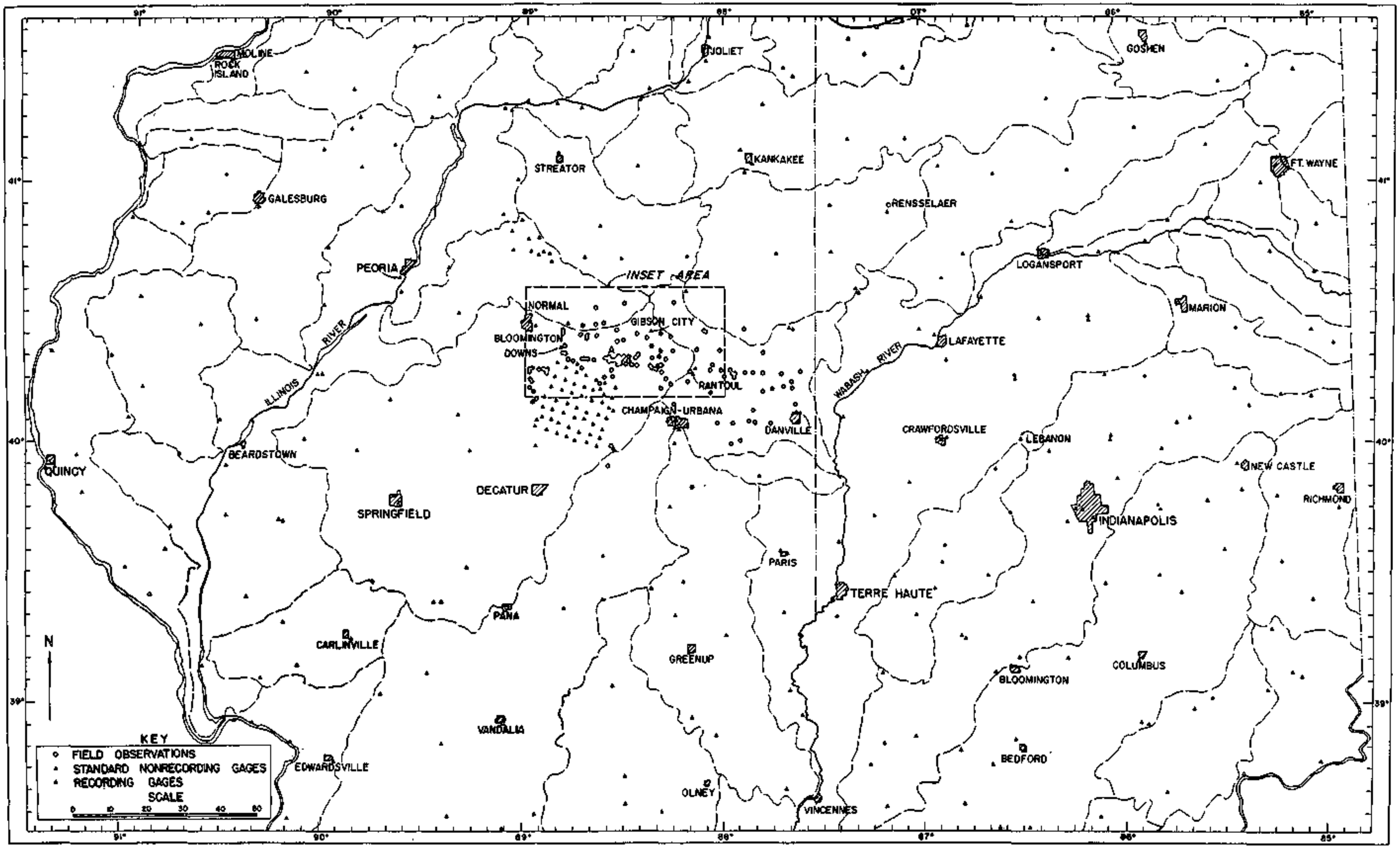


FIGURE 53 LOCATION OF POINT RAINFALL OBSERVATIONS, MAY 26-28, 1956

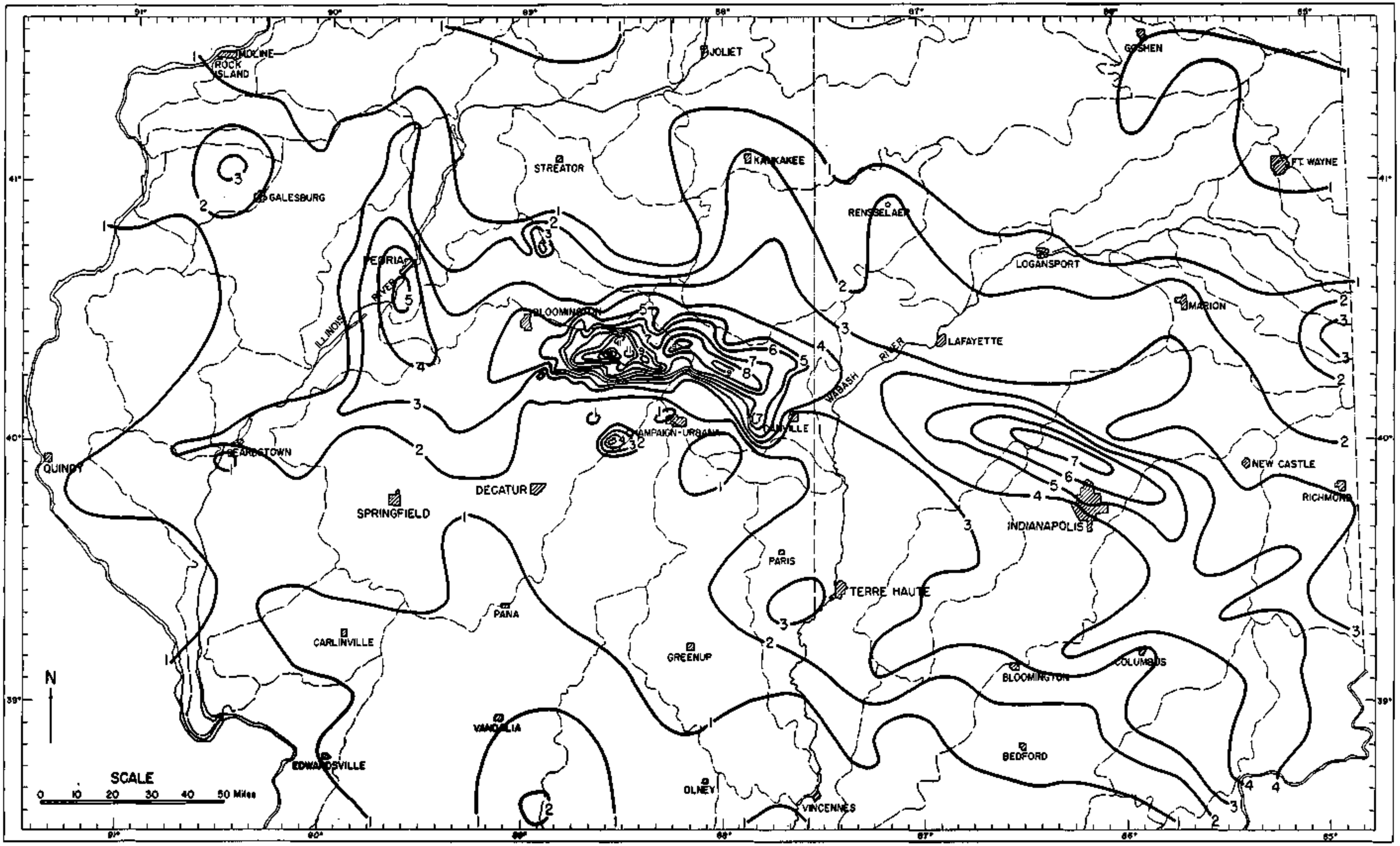


FIGURE 54 TOTAL STORM RAINFALL FOR MAY 26-28, 1956

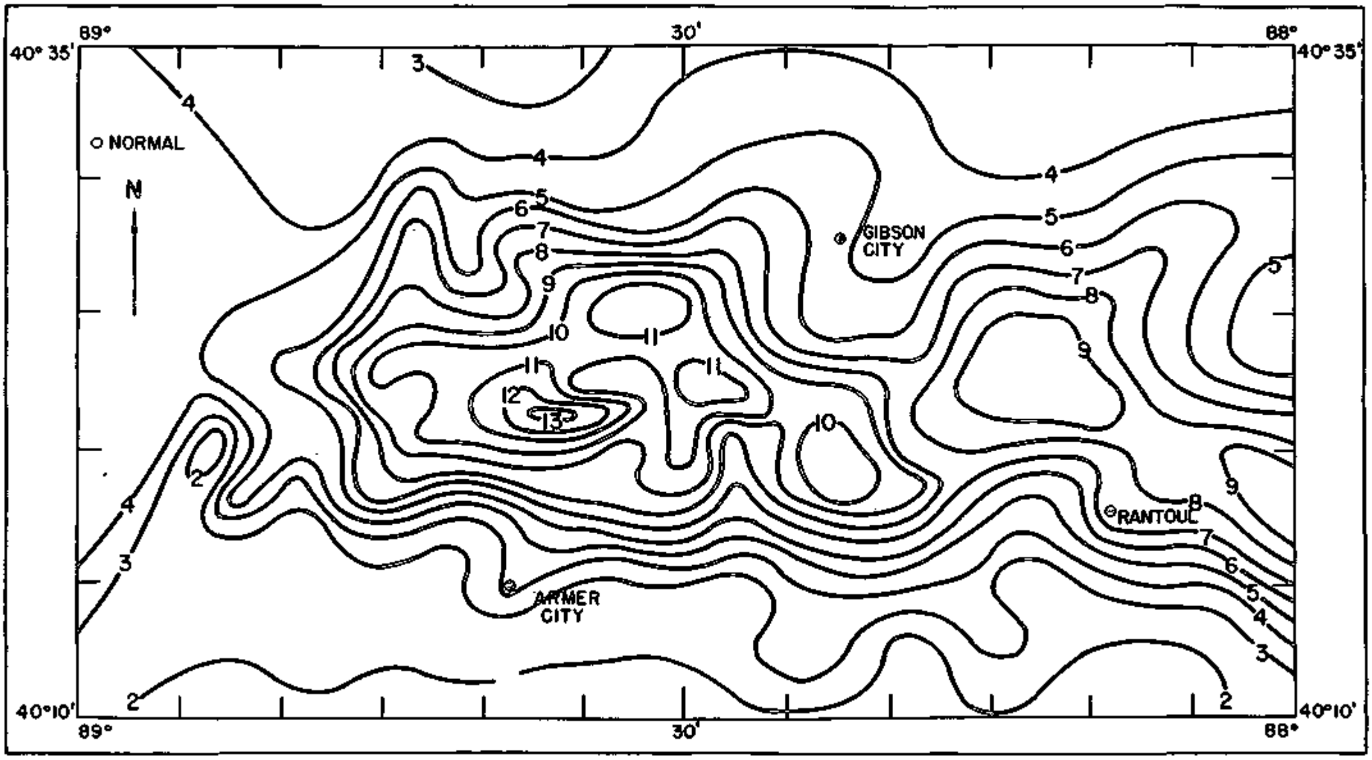


FIGURE 55 AREA OF LARGEST RAINFALL MAY 26-28, 1956

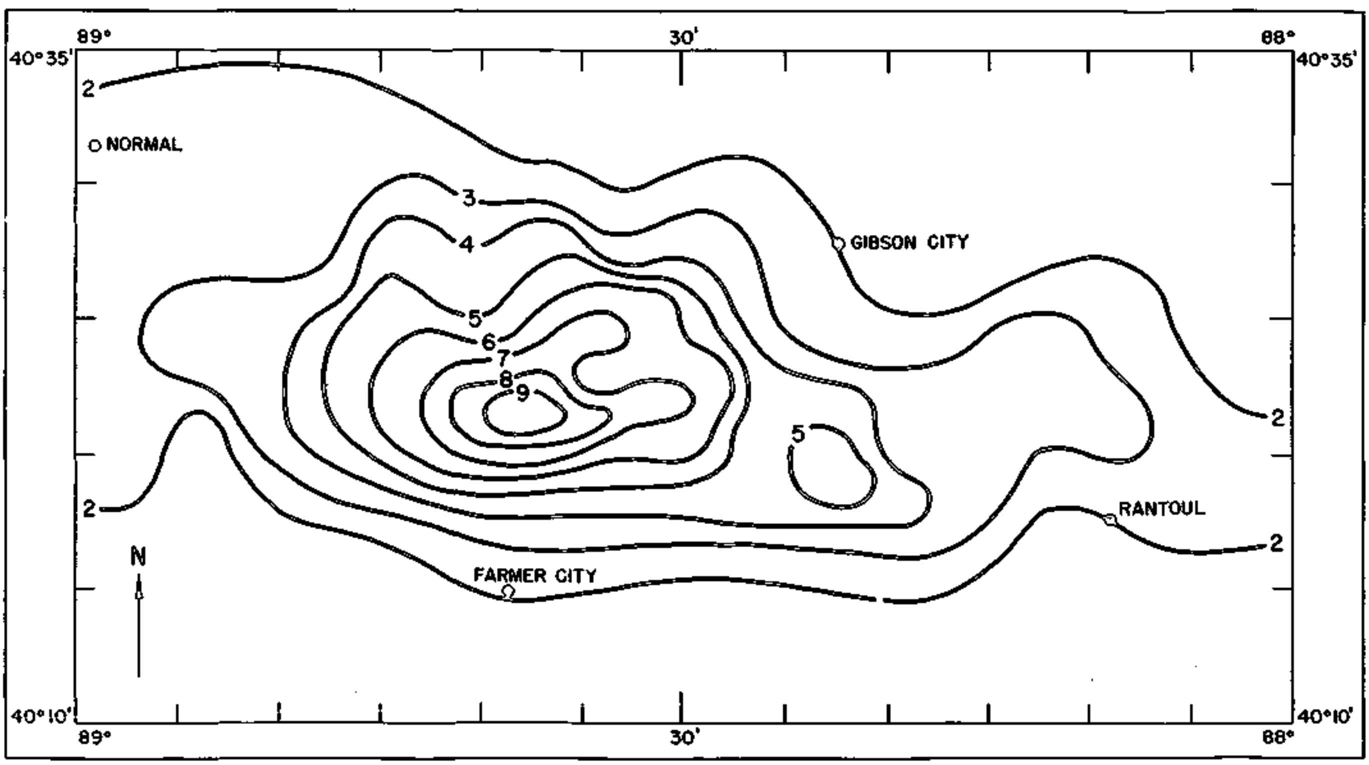


FIGURE 56 MAXIMUM 6-HOUR RAINFALL FOR MAY 26-28, 1956

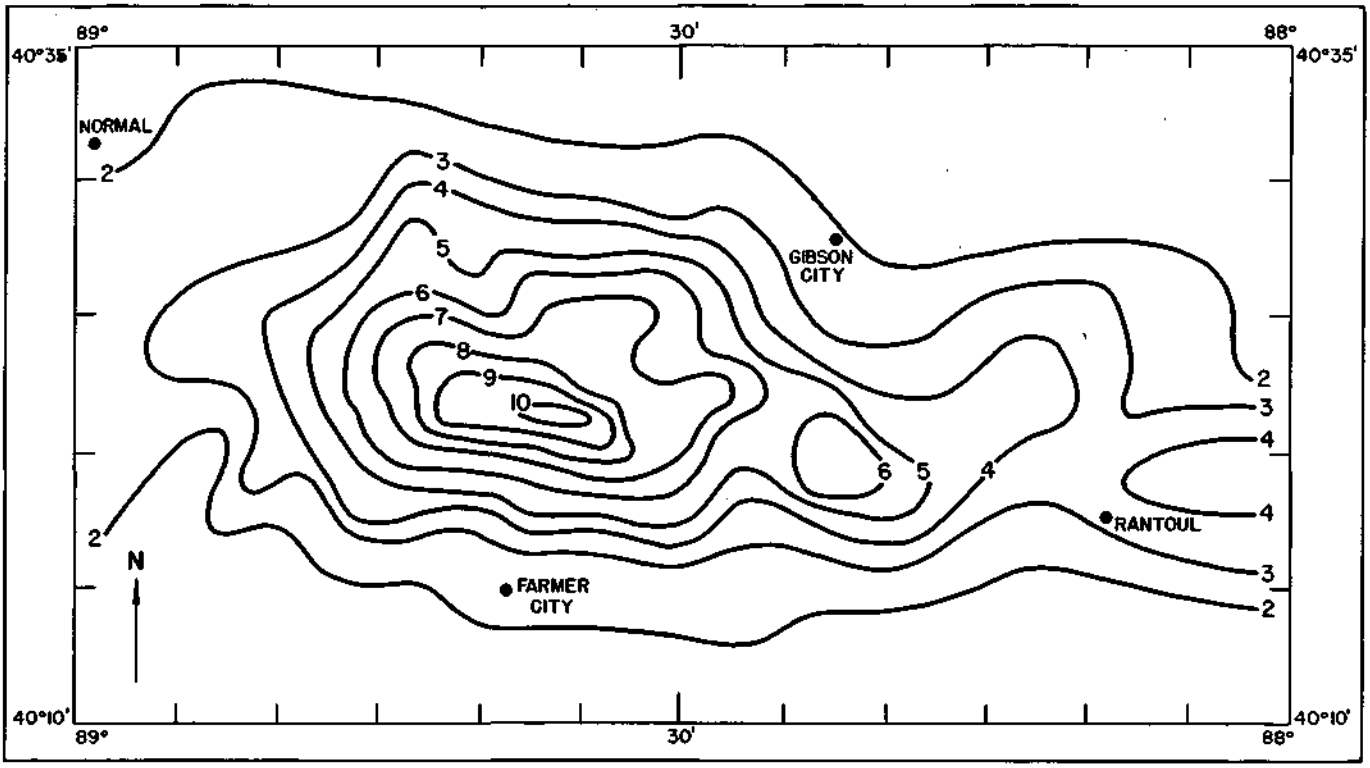


FIGURE 57 MAXIMUM 12-HOUR RAINFALL FOR MAY 26-28, 1956

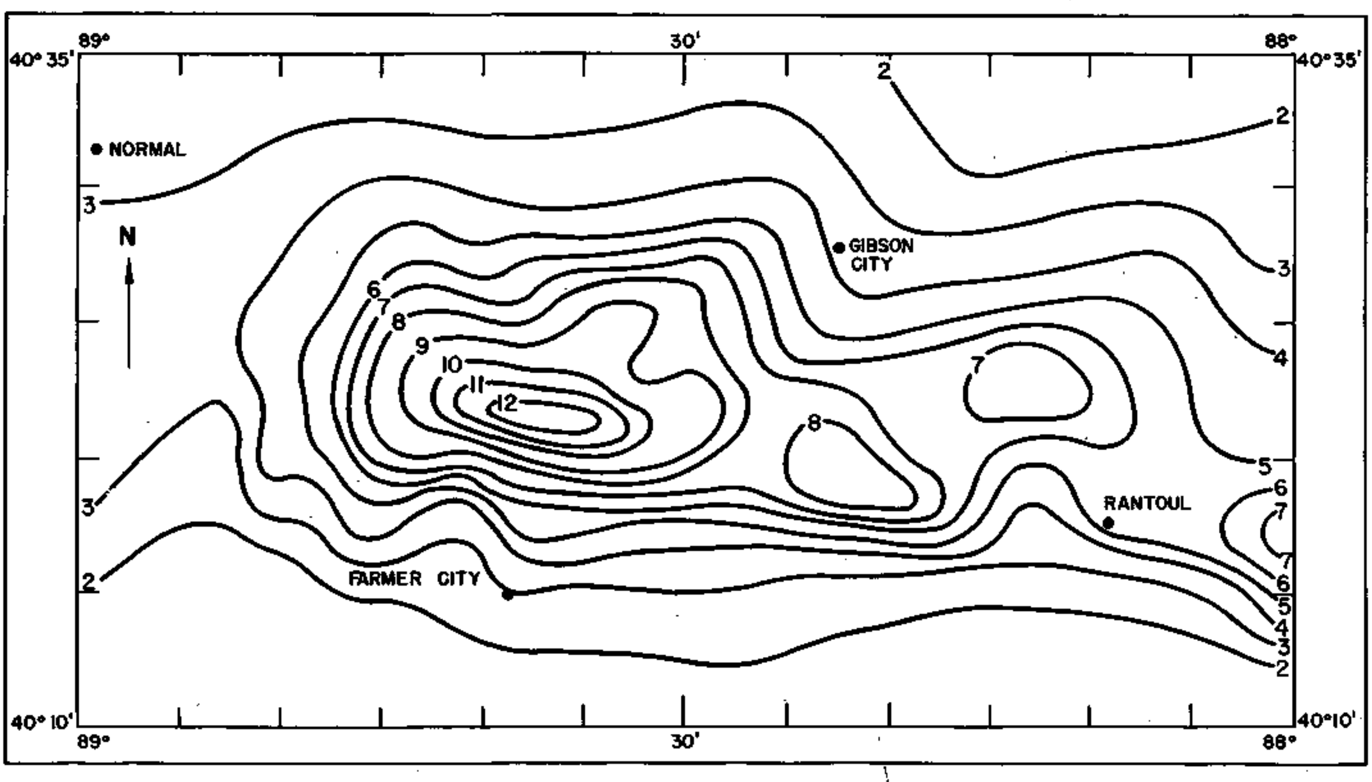


FIGURE 58 MAXIMUM 24-HOUR RAINFALL FOR MAY 26-28, 1956

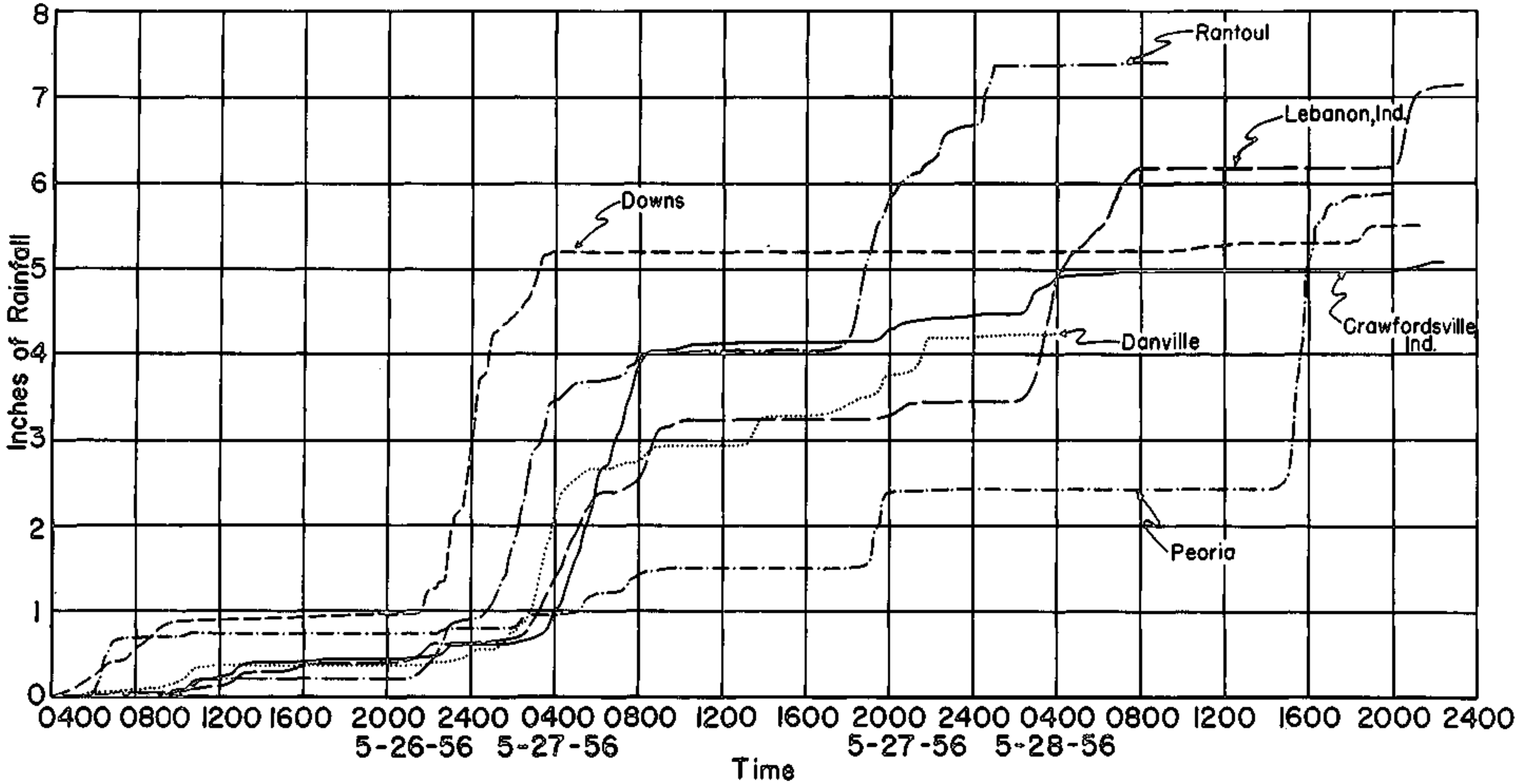


FIGURE 59 MASS CURVES OF RAINFALL FROM SELECTED STATIONS FOR MAY 26-28, 1956

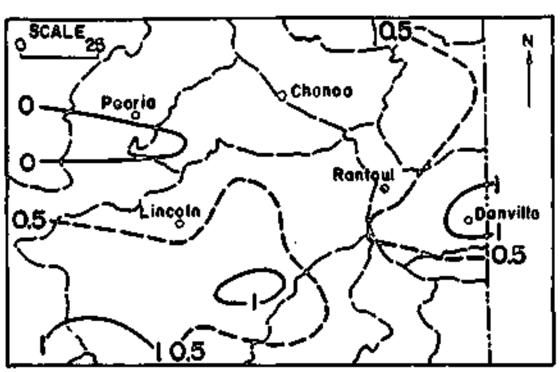


FIGURE 60 TOTAL RAINFALL MAY 21-25, 1956

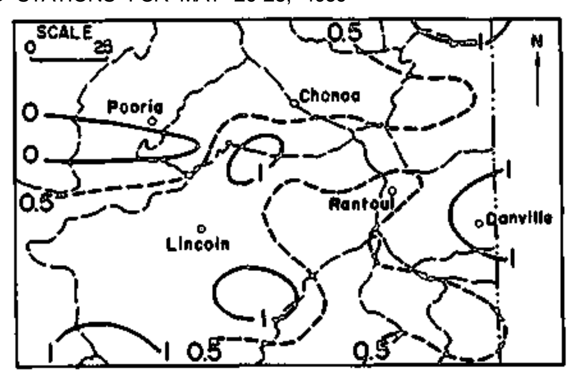


FIGURE 61 TOTAL RAINFALL MAY 16-25, 1956

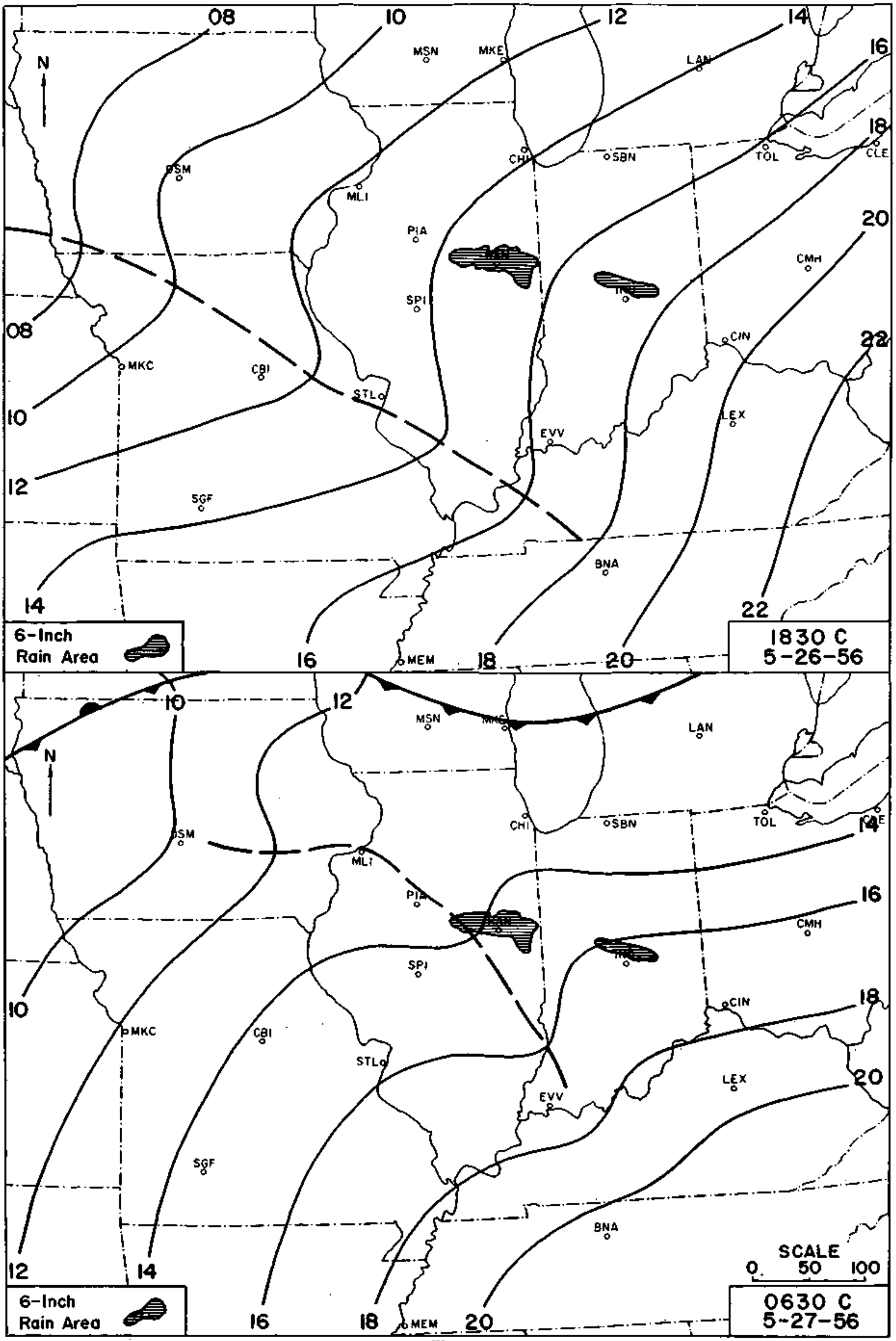


FIGURE 62 SURFACE SYNOPTIC MAPS ON MAY 26-27, 1956

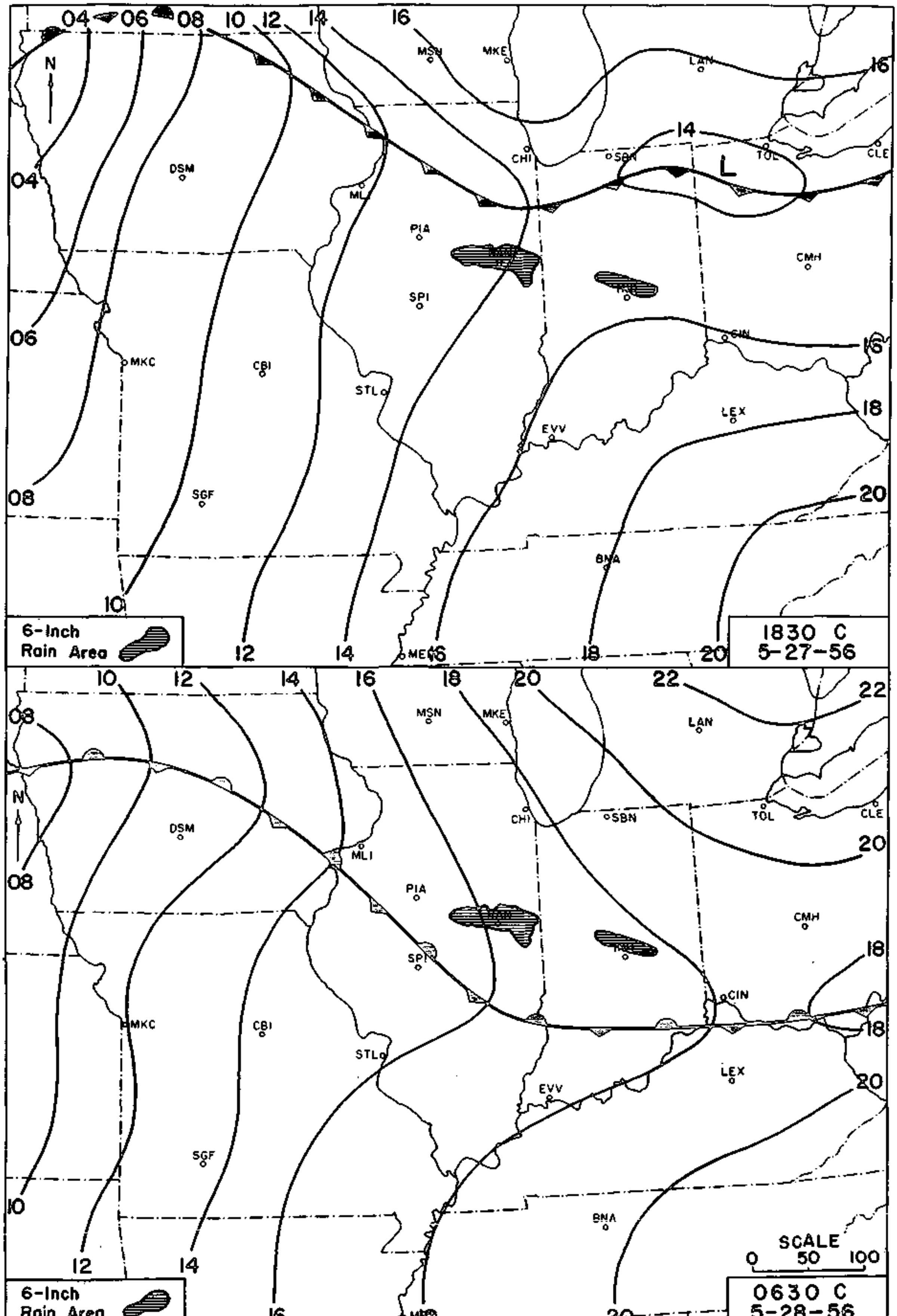


FIGURE 63 SURFACE SYNOPTIC MAPS ON MAY 27-28, 1956

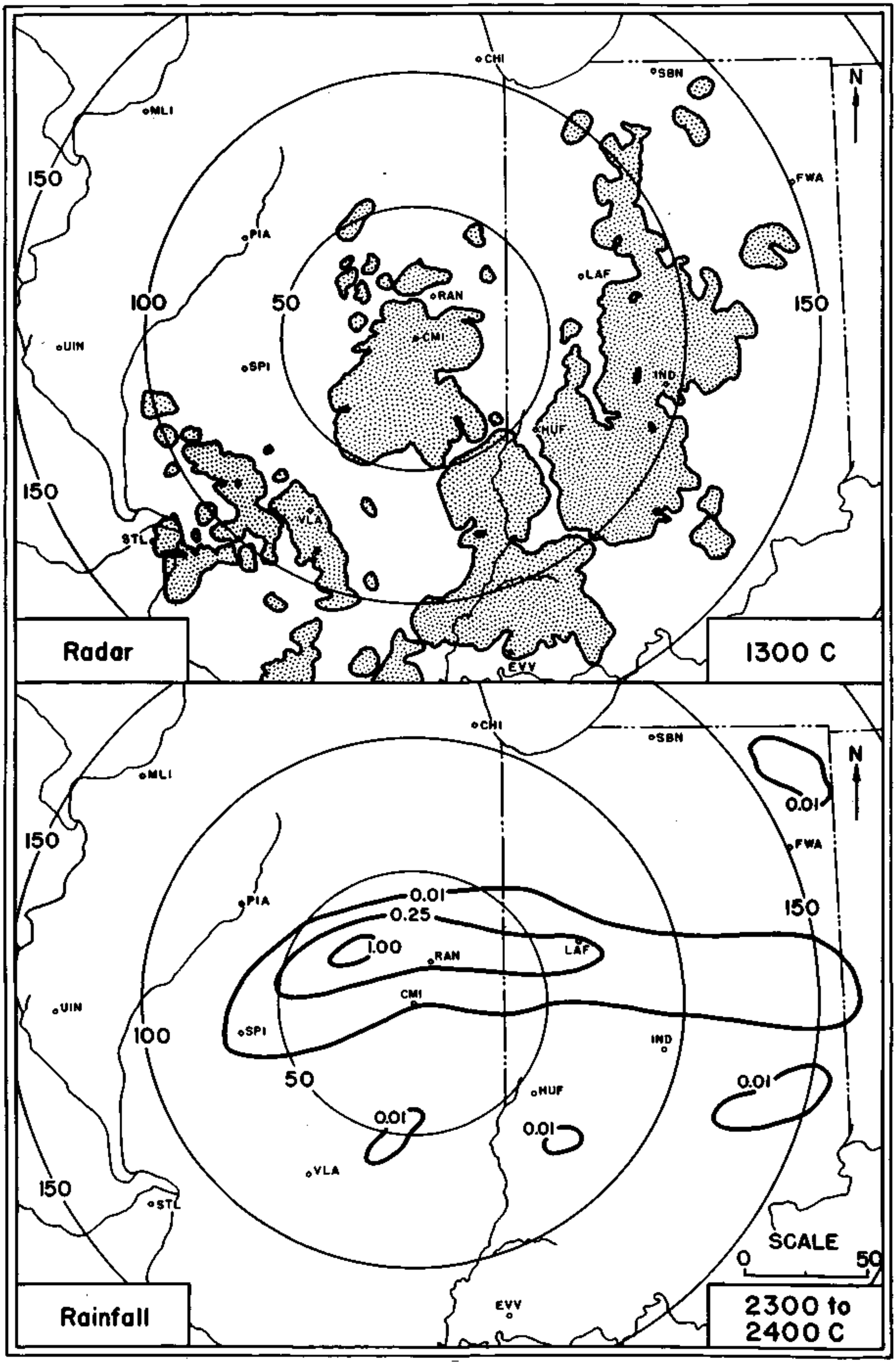


FIGURE 64 RADAR AND RAINFALL MAY 26, 1956

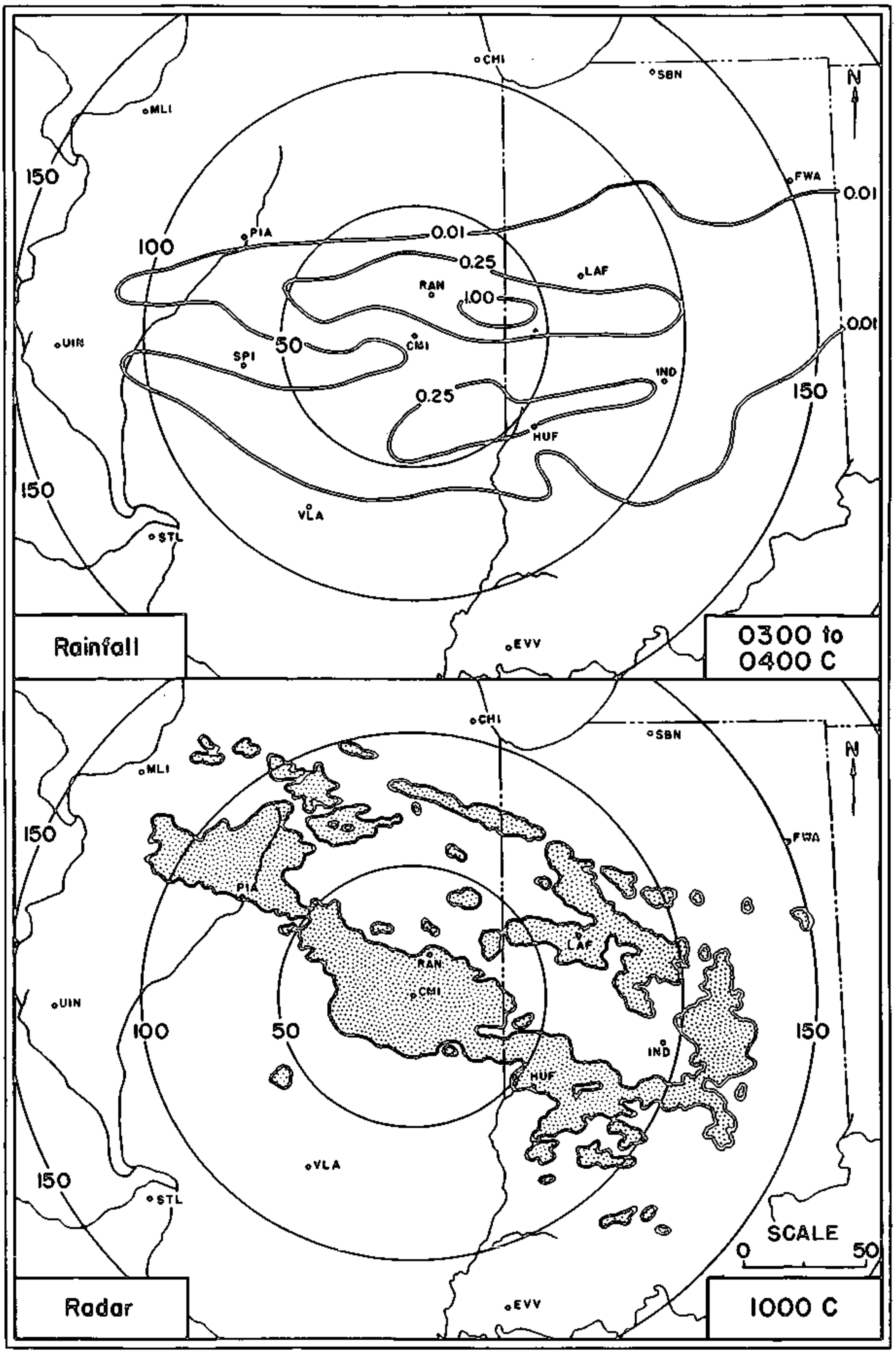


FIGURE 65 RADAR AND RAINFALL MAY 27, 1956

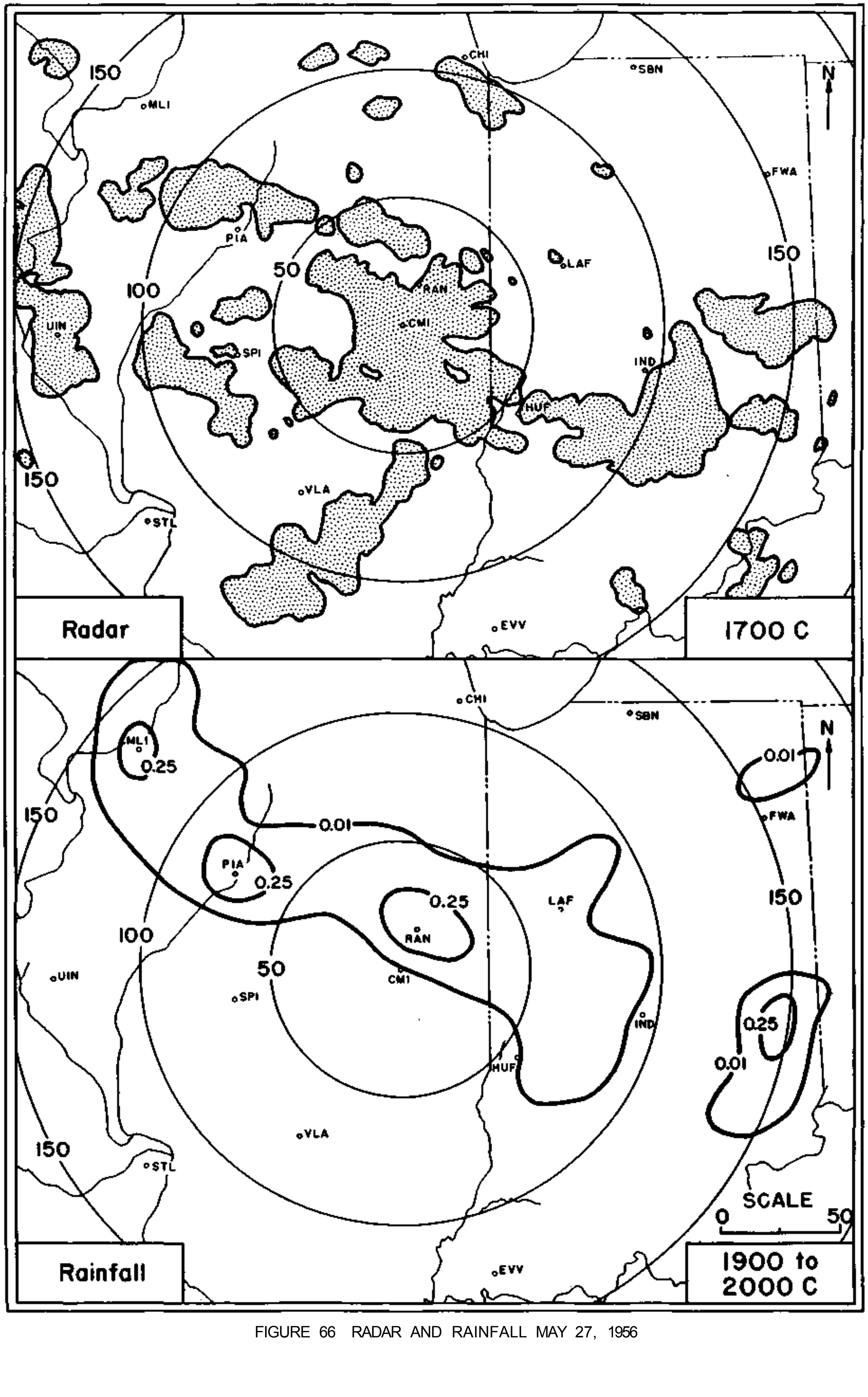


FIGURE 66 RADAR AND RAINFALL MAY 27, 1956

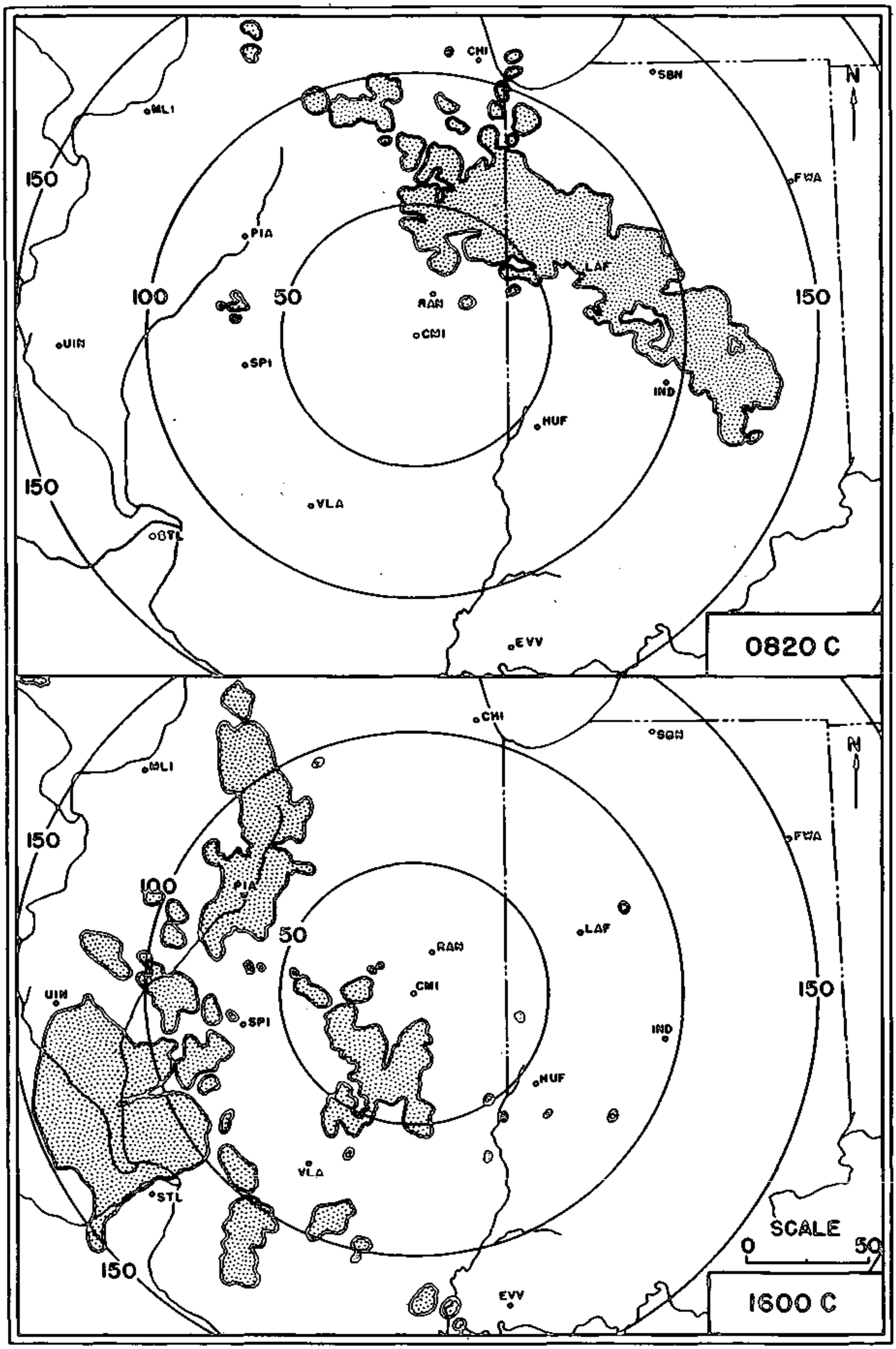


FIGURE 67 RADAR ECHOES MAY 28, 1956

SUMMARY OF SEVERE RAINSTORM ANALYSES, 1948-57

Field surveys of severe rainstorms have been an integral part of the Water Survey's meteorological program since 1948. Unusually heavy storms investigated prior to 1956 are listed in references 1, 2 and 3. The severe rainstorms of 1948-57 have been distributed over various regions of the state, indicating that such storms may occur anywhere in Illinois. Preliminary study of other unusually heavy storms during the period 1916-57, based upon data from the U. S. Weather Bureau climatological network,[7] also indicates that these heavy storms may occur throughout Illinois, but suggests that the southwestern portion of the state may experience them more frequently than other areas of the state. Further study of the frequency distribution of severe rainstorms is presently underway as part of the Water Survey meteorological program.

Severe storms studied to date appear generally to have an elongated core and a preferential orientation. In most cases, the major axis approaches a west to east orientation, varying from WNW-ESE through W-E to WSW-ENE. Radar analysis and investigation of synoptic weather conditions associated with the 1948-57 severe storms indicate that the observed shape and orientation are probably typical characteristics of these storms. Scattered hail throughout the storm area is usually associated with these storms, indicating the extreme instability of the atmosphere and extensive vertical development of cloud layers. Since the orientation and movement of storms with respect to the watersheds over which they lie materially affects the magnitude and characteristics of the basin runoff, further investigation of the orientations of severe rainstorms is desirable to aid the design engineer.

Area-depth relations for the 1948-57 storms have been combined in Table 11 for convenience of the user. Storms investigated during 1948-57 had durations tanging from 9 to 63 hours. Although most of these storms had rainfall occurring intermittently for one to three days, a large portion of the rainfall in the storm core always occurred within a 3-hour to 6-hour period. This can be readily seen by reference to Table 11 and the time distributions in Tables 2, 4, 6, 8 and 10. For example, the storm of May 26-28, 1956 extended over a period of 63 hours. However, within the core of the storm 50 to 70 per cent of the rain occurred within a 6-hour period during the night of May 26 (Table 10).

TABLE 11

DEPTH-DURATION-AREA DATA, 1948-57

Date	Depth (in.) for given area (sq. mi.) and duration								
	25	50	100	200	500	1000	2000	5000	10,000
				24 hours					
6/14-15/57	16.5	16.0	15.1	14.2	12.5	11.0	9.3	6.7	5.0
6/27-28/57	12.4	12.0	11.5	11.1	10.2	9.4	8.5	7.1	6.0
7/12-13/57	11.3	11.0	10.7	10.3	9.5	8.7	7.6	5.9	4.5
5/21-23/57	7.9	7.8	7.6	7.3	6.8	6.3	5.7	4.8	-
5/26-28/56	10.9	10.1	9.3	8.2	6.2	4.7	-	-	-
10/ 9-10/54	11.7	11.6	11.3	10.9	10.3	9.5	8.6	7.0	5.4
				12 hours					
6/14-15/57	16.3	15.7	14.7	13.8	12.0	10.4	8.6	6.1	4.3
6/27-28/57	12.0	11.5	10.9	10.3	9.3	8.4	7.4	5.9	4.7
7/12-13/57	9.8	9.6	9.3	8.9	8.2	7.3	6.5	4.9	-
5/21-23/57	7.3	7.1	6.8	6.5	5.9	5.3	4.6	3.6	-
5/26-28/56	9.2	8.5	7.6	6.5	4.8	3.5	-	-	-
10/ 9-10/54	7.3	7.2	7.0	6.8	6.3	5.9	5.3	4.2	3.3
7/ 8- 9/51 (9 hrs.)	12.0	11.3	10.6	9.8	8.8	7.8	6.7	5.6	4.5
				6 hours					
6/14-15/57	12.6	11.8	10.9	9.8	8.1	6.6	5.0	3.1	-
6/27-28/57	8.7	8.3	8.0	7.6	6.8	6.2	5.5	4.4	3.6
7/12-13/57	6.9	6.8	6.6	6.2	5.8	5.1	4.4	3.2	-
5/21-23/57	7.0	6.7	6.4	6.1	5.5	4.8	4.2	3.2	-
5/26-28/56	8.5	7.9	7.0	6.0	4.4	3.1	-	-	-
10/ 9-10/54	5.3	5.2	5.0	4.8	4.4	4.0	3.6	2.8	2.1
7/18-19/52	9.5	8.7	7.8	6.8	5.3	-	-	-	-
7/ 8- 9/51	11.9	11.0	10.3	9.5	8.5	7.5	6.5	5.3	4.2
				3 hours					
6/14-15/57	8.7	8.2	7.5	6.7	5.5	4.4	3.4	2.0	-
6/27-28/57	4.5	4.3	4.2	4.0	3.7	3.4	3.1	2.6	2.2
7/12-13/57	5.1	5.0	4.8	4.5	4.0	3.6	3.0	2.1	-
7/ 8- 9/51	7.6	7.2	6.8	6.3	5.3	4.5	3.7	2.5	-

Analysis of data for the severe storms of 1948-57 indicates that area-depth relations within the storm cores can be closely approximated by an empirical equation of the form:

$$\text{Log } Y = a + b X^n$$

Where Y is rainfall depth in inches, X is area in square miles, and a, b and n are regression constants. This equation differs somewhat from the earlier results of Huff and others,[8,9] based upon data from concentrated networks in Illinois encompassing areas from 5 to 300 square miles. In the previous studies, a close approximation was obtained from an equation of the form:

$$Y = a + b X^{0.5}$$

The difference in findings can be attributed to several factors. The network studies dealt with small areas fixed in space. Also, these results were based upon a large number of the several types of moderate to heavy storms characterizing warm season rainfall in the Midwest. The 1948-57 severe storm studies involved analysis of much larger storm areas and were restricted to storms of an unusual nature with very large rainfall gradients in the storm core.

Table 12 shows area-depth envelope values for selected areas and storm periods, based upon storms for which field surveys have been conducted since 1948. The envelope values for 24 hours, based upon Corps of Engineers studies [6] of storms centered in Illinois during 1910-46, are included for comparison purposes. The envelope relations are shown graphically in Figure 68. Individual storm values during 1948-57 are represented by the plotted points in this figure. In addition to the storms discussed previously in the present report, field surveys were conducted for storms occurring on October 9-10, 1954; July 18-19, 1952; and July 8-9, 1951. Most of the envelope values for the 1948-57 storms in Table 12 are from the southwestern Illinois storm of June 14-15, 1957. Most of the Corps of Engineers values are based upon the southwestern Illinois storm of August, 1946. The Corps of Engineers analysis, of course, was made primarily from climatological network observations. It is interesting to note that most of the maximum values in the 24-hour storm periods investigated by the Corps of Engineers occurred in a 1946 storm, when the gage density of the U. S. Weather Bureau climatological network in Illinois had increased greatly beyond that of earlier years. A review of Weather Bureau records [7] indicates that there were 87 gages in Illinois in 1916. By 1926 this number had risen only to 94 and by 1936 to 109- Late in the 1930-40 decade a considerable increase in density took place and by 1942 there were about 161 gages in Illinois. The number increased rapidly through the war years to 249 gages in 1948, and more slowly to 278 gages in 1956.

There were three storms during the 1948-57 period in which maximum 24-hour rainfall amounts for areas up to 5000 square miles exceeded the long-period envelope values of 24-hour storms compiled by the Corps of Engineers. These were the storms of June 14-15, 1957 in southwestern Illinois, June 27-28, 1957 in east central Illinois and October 9-10, 1954 in northern Illinois.

TABLE 12

AREA-DEPTH ENVELOPE FOR 1948-57 STORMS

Storm	Depth (in.) for given area (sq. mi.)								
Period	25	50	100	200	500	1000	2000	5000	10,000
3 hrs.	8.7	8.2	7.5	6.7	5.5	4.5	3.7	2.6	2.2
6 hrs.	12.6	11.8	10.9	9.8	8.5	7.5	6.5	5.3	4.2
12 hrs.	16.3	15.7	14.7	13.8	12.0	10.4	8.6	6.1	4.7
24 hrs.	16.5	16.0	15.1	14.2	12.5	11.0	9.3	7.1	6.0
24 hrs. (Corps of Engineers)			11.1	10.6	9.9	9.0	7.8	6.5	6.3

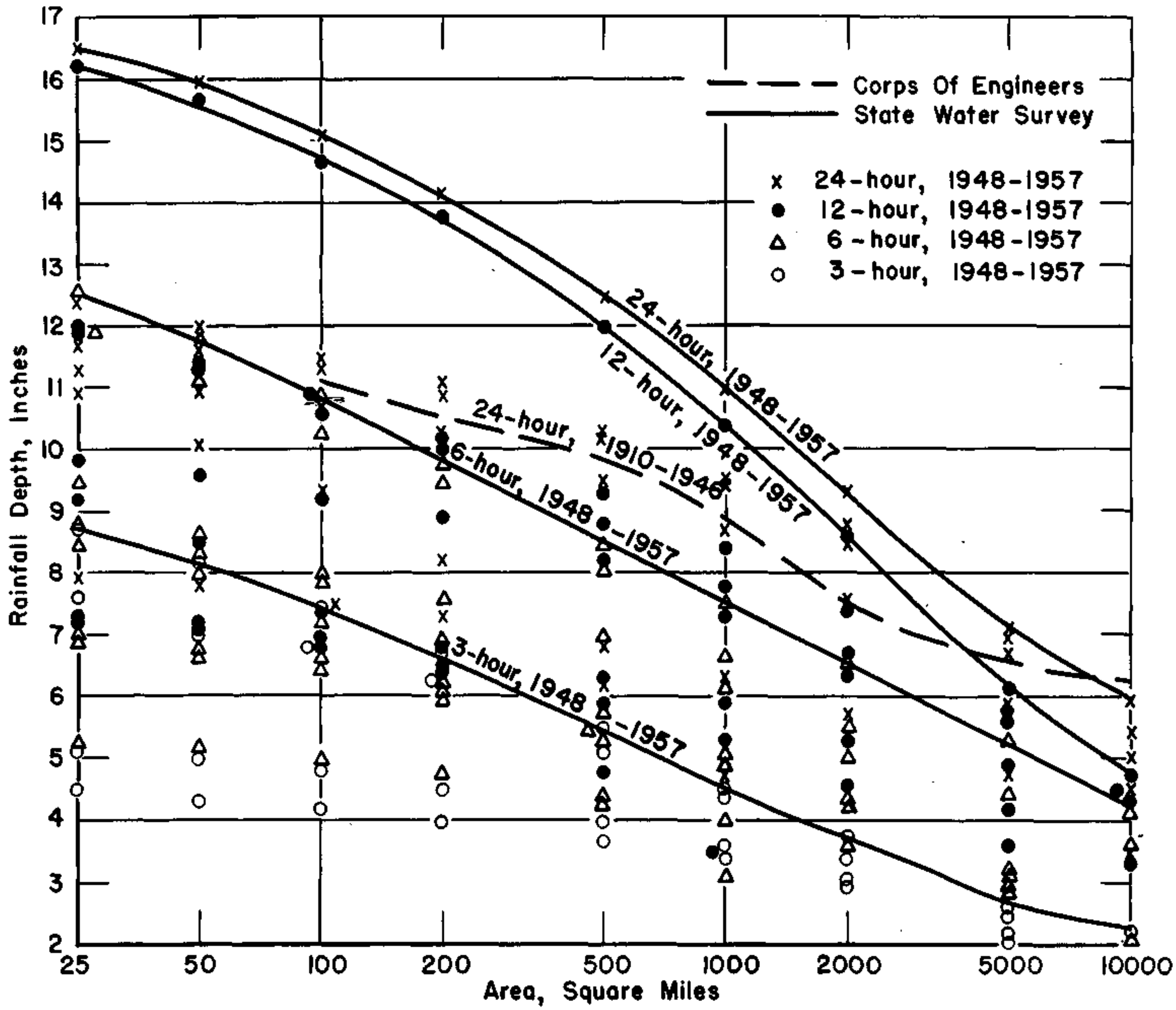


FIGURE 68 AREA-DEPTH ENVELOPES OF 3- TO 24-HOUR STORMS

Table 13 shows the ratio of field survey to climatological network area-depth values during the 1948-57 period. Both average and maximum ratios are shown. The maximum ratios are the highest observed in any single storm, while the average ratios are means combining all storms. Undoubtedly, the ratios would have been greater in the earlier years when the climatological network density was considerably less than it has been in the past ten years. Both Tables 12 and 13 emphasize the inadequacy of existing climatological networks for accurate definition of maximum area-depth relations in the center of severe rainstorms. The results indicate the desirability of continuing the present field survey program of the Water Survey in order to obtain a better definition of the rainfall distribution in severe rainstorms. Increasing the gage density of the climatological network should be given consideration.

TABLE 13

RATIO OF FIELD SURVEY TO CLIMATOLOGICAL NETWORK AREA-DEPTH VALUES

Area (sq. mi.)	Ratio		Area (sq. mi.)	Ratio	
	Avg.	Max.		Avg.	Max.
Point	1.28	1.62	200	1.13	1.19
10	1.20	1.36	500	1.10	1.14
50	1.17	1.26	1000	1.08	1.13
100	1.16	1.24	2000	1.05	1.12

Table 14 shows the total area within Illinois where 24-hour rainfall amounts have equalled or exceeded specified depths during the past 10 years (1948-57), based upon field survey data. The rainfall area has also been expressed as percent of the total state area in each case. Thus, Table 14 shows that approximately 1130 square miles or two percent of the entire state experienced a 24-hour rainfall of 10 inches during 1948-57.

TABLE 14

AREA HAVING 24-HOUR RAINFALL EQUALLING OR EXCEEDING SPECIFIED AMOUNTS

	Rainfall (in.) equalled or exceeded				
	12	11	10	9	8
Total Area (sq. mi.)	365	600	1130	2150	3980
Percent of State	0.7	1.1	2.0	3.8	7.1

REFERENCES

1. Huff, F. A., H. W. Hiser, and G. E. Stout, The October 1954 Storm in Northern Illinois, Report of Investigation 27, Illinois State Water Survey, Urbana, Illinois, p. 11, 1955.

2. The Storm of July 8, 1951 in North Central Illinois, Report of Investigation 14, Illinois State Water Survey, Urbana, Illinois, p. 43, 1952.

3. Larson, B. O., H. W. Hiser, and W. S. Daniels, The Storm of July 18-19, 1952, Rockford, Illinois and Vicinity, Report of Investigation 24, Illinois State Water Survey, Urbana, Illinois, p. 12, 1955.

4. Hail Loss Reports, Chicago States Hail Loss Clearing Bureau, Chicago, Illinois.

5. Huff, F. A., J. C. Neill, and M. Spock, Jr., Evaluation of a Low Powered 3-cm Radar for Quantitative Rainfall Measurements, Report of Investigation 29, Illinois State Water Survey, Urbana, Illinois, pp. 24-34, 1956.

6. Storm Rainfall in the United States, Corps of Engineers, U. S. Army, Washington, D. C, 1945 (with supplemental data to February 1954).

7. Climatological Data, Illinois, 1916-57, U. S. Dept. of Commerce, Weather Bureau, Washington, D. C.

8. Huff, F. A. and G. E. Stout, "Area-Depth Studies for Thunderstorm Rainfall in Illinois", Transactions, American Geophysical Union, 33(4), August, 1952.

9. Huff, F. A. and J. C. Neill, Rainfall Relations on Small Areas in Illinois, Bulletin 44, Illinois State Water Survey, Urbana, Illinois, pp. 23-30, 1957.