Natural Disaster Survey Report 77-2

Kansas City Flash Flood of September 12-13, 1977

A Report to the Administrator

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Rockville, Md.
December 1977

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U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Richard A. Frank, Administrator

FOREWORD

The primary goal of all of the NOAA National Weather Service warning programs is to save lives. Following every significant natural disaster, a NOAA NWS Survey Team is formed to evaluate the effectiveness of warning services by performing a detailed review of all related forecasting and warning actions. These actions are usually complicated interactions among human beings, sophisticated computers, communications systems, and observation systems. The "bottom line," however, is to get individuals in a threatened area to take some kind of protective action. It is on this basis that the effectiveness of the NWS warning programs is ultimately judged.

We are constantly striving to improve our performance and lessen the loss of life in weather-related disasters. This report presents the findings and recommendations of the team that surveyed the disastrous Kansas City flash flood.

Charles G. Knudsen
Director, Central Region
National Weather Service

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PREFACE

The NOAA National Weather Service (NWS) Survey Team that reviewed the Kansas City flash flood of September 12-13, 1977, had three members from the NWS Central Region Headquarters: Philip A. Calabrese, Team Leader and Chief, Meteorological Services Division; Russell G. Mann, Assistant Regional Hydrologist; and Lawrence A. Hughes, Chief, Scientific Services Division. Two members were from the NWS National Severe Storms Forecast Center in Kansas City: Guy H. Gray, Jr., Supervisor, Public Services and Radar Unit; and William C. Henry, Weather Service and Radar Specialist. Herbert S. Lieb, Chief, Disaster Preparedness Staff, NWS Headquarters, Silver Spring, Md., assisted the team.

Members of the team began their fact-finding survey in the Kansas City area on September 14 and concluded field reconnaissance on September 16. Three main areas were covered: broadcast media, Civil Defense/law-enforcement, and individual user reaction. The survey produced enough useful information to allow findings to be drawn and recommendations to be made.

The survey team wishes to thank all who kindly cooperated by consenting to interviews and who freely gave information. The success of the warning system is very dependent on the outstanding cooperation of the broadcast media and various local officials. Without this cooperation, NWS could not accomplish its weather warning function in the Kansas City area or anywhere else in the United States.

The cover photograph of the Country Club Plaza at the height of the flash flood is the courtesy of the Kansas City Star, Kansas City, Mo.

EXECUTIVE SUMMARY

Two record-setting rainstorms on Monday, September 12, 1977, inundated the Kansas City Metropolitan area with more than 16 inches (406 mm) of rain. The first rainstorm of very early Monday morning thoroughly soaked the local drainage basins and set the stage for the second devastating rainstorm Monday evening.

The resulting flash flood killed 25 people, all residents of the greater metropolitan area, and caused property losses estimated at $90 million in both the private and public sectors.

This report -- by the disaster survey team appointed by the Director of the NWS Central Region Headquarters -- describes the flash flood; the meteorological conditions that caused it; the data acquisition systems; the watches, warnings, and statements issued prior to the disastrous second burst of rainfall; and the reaction of local officials and the public.

For a flood of this magnitude, the survey team is convinced that the flash flood watch, and the subsequent warnings and statements saved lives. Prompt dissemination by the broadcast media also added substantially to the warning effort. Radio and TV stations followed their policy of interrupting normal programing with weather bulletins.

The weather radar was of inestimable value because the timely warnings were based largely on the information it provided. The interpretation of this information by the radar weather specialist and the meteorologist who was assigned the warning function was very professional and competent. Hydrologic data networks can provide much useful data; however, if the NOAA NWS personnel on duty had depended solely on obtaining rainfall measurements, the disaster, in all likelihood, would have occurred without adequate warning.

Satellite data, available from the Satellite Field Service Station (SFSS) collocated with the National Severe Storms Forecast Center (NSSFC), were used extensively in identifying the area of potential thunderstorm development and in observing ongoing thunderstorm movement.

It is all too apparent, though, from an analysis of storm fatalities that automobiles can become death vehicles in a flash flood, and there is a great need to publicize this fact in flash-flood literature and to emphasize this point in the flash-flood rules. The survey team's most pertinent findings and recommendations are summarized below:

Finding 1: There was timely issuance of a flash-flood watch about 10 hours before the Monday evening, September 12, 1977, rainfall. Follow-up warnings were very good.

A Special Weather Statement containing strong assertive language was released to attest to the urgency of the situation even though exact rainfall information was unavailable at the time.

Existing procedures were followed except for the inadvertent omission of the "call to action" sentence of the standard format.

Finding 2: The broadcast media did a timely, effective job in disseminating watches, warnings, and special statements.

Recommendation: Broadcast media should be commended for the role they played in the warning system.

Finding 3: Many people who experienced the flood showed they did not accept the reality of the situation with which they were confronted. Most noteworthy is the fact that 17 out of 25 deaths were associated with automobiles.

Recommendation: NOAA NWS should enlist the help of the mass media and school systems to educate the public to the danger of flash floods, expecially the danger associated with cars, and to the need for proper, live-preserving measures. NOAA NWS should institute procedures routinely to transmit flash-flood safety rules on NOAA Weather Wire (NWW) with flash-flood watches and/or warnings. Safety rules should also be broadcast on NOAA Weather Radio (NWR).

Finding 4: A demonstration flash-flood alarm system was installed in 1974 on Indian Creek at Holmes Road and turned over to Kansas City, Mo., in June 1976. The sensor did not operate during the flash flood because of a short in the sensor cable.

Recommendation: Each NOAA NWS office with county warning responsibility should work with local officials by providing, where appropriate and requested, local flash-flood warning programs or assist in setting up flash-flood alarms. Existing systems should be revisited at least yearly.

Finding 5: The severe ground clutter pattern associated with the Kansas City Radar hampered the ability of the radar operator to detect strong thunderstorm cells over the densely populated metropolitan area.

Recommendation: NOAA NWS should relocate the Kansas City WSR-57 Radar away from the metropolitan area. (Because the move of the radar to Kansas City International Airport is already planned for late 1978, every effort should be made to prevent delays in this schedule.)

Finding 6: Manually Digitized Radar Data (MDR) totals for the area most devastated by the flash floods did not reach an alert level (around 20) until the flash flooding had occurred.

Recommendation: NOAA NWS warning offices should be informed that MDR data should not be solely (or blindly) relied on as a major flash-flood alert or warning tool, especially for small, rapidly rising streams. In fact, dependence upon these data at times can be misleading. Emphasis should also be placed on antecedent meteorological and hydrological conditions, flash-flood guidance indices, and instantaneous rainfall rates as determined from Radar Video Integrator Processor data as they are available.

Finding 7: Despite extensive storm spotter and hydrological networks and communications systems for obtaining public or other reports, very few such reports were received at NSSFC in time to accelerate either the initial issuance of warnings or the extension of warnings to other counties. Also, too few reports were relayed to NSSFC to allow those on duty to assess fully the magnitude of the flooding event until after much of the damage had been done. Further, too few reports were received to allow for early identification of the worst flood areas and to tailor followup warnings or statements to highlight these.

Recommendation: NOAA NWS should see that:

(A) Further coordination with local officials and training of storm spotters emphasizes the critical importance of early reports of heavy rainfall as well as followup reports during such events. Rainfall gages should be provided to facilitate prompt observations and reporting of rainfall intensities.

(B) NSSFC establishes procedures for logging storm spotter or other reports, and for assuring that all such reports, regardless of their source, are consolidated and made available to the warning coordinator on duty.

Finding 8: The SFSS meteorologists maintained a close surveillance of precursory conditions as depicted in the satellite imagery and continuously provided NWS units with their current interpretation of the data.

Recommendation: Appropriate recognition for their coordination efforts should be given to the National Environmental Satellite Service meteorologists on duty.

Finding 9: Quantitative Precipitation Forecast (QPF) guidance products from the National Meteorological Center, while useful, are not adequate to the flash-flood task because they do not forecast the really unusual, smaller scale events and they are not in the best increments of time.

Recommendation: NOAA NWS should develop a method of forecasting very heavy rainfall in terms of 3-hour periods to match the 3-hour period used by the River Forecast Centers in their flash-flood guidance indices.

CHAPTER 1.

THE KANSAS CITY METROPOLITAN AREA FLASH FLOOD

Flash floods have become the Nation's deadliest natural disaster warning problem -- Rapid City (1972), 236 dead; Big Thompson Canyon (1976), 139 dead; Johnstown (1977), 76 dead; . . . and now Kansas City, 25 dead. The areas are different, the topographies are different, the causative weather systems are different, but the results are the same -- flash floods are devastating in terms of loss of life and property damage.

Kansas City is the hub of a large urban area, but it also is closely in tune with the agribusiness community of the surrounding region. Weather and its effects are reported by all the news media and followed closely by nearly everybody.

Tornadoes and severe thunderstorms are the main weather topics in the spring and summer. Generally speaking, these are relatively rare events, but flash floods are even rarer. Not that thunderstorms don't produce very heavy rains, many do in the Kansas City area. But they usually are associated with a rapidly moving squall line that traverses the area in an hour or so.

Beginning early on September 12, 1977, the Kansas City Metropolitan area was struck with its heaviest storm-total rainfall in history. This, in turn, generated the worst flood disaster since the major river flood of July 1951. The unprecedented rainfall turned normally placid creeks and streams into raging torrents. The killer flash flood claimed the lives of 25 people, all residents of the Kansas City area, and produced property damage estimated at $90 million to both the private and public sectors.

The excessive rainfall event was actually two record-breaking storms of about 6 to 8 hours' duration separated by an 8- to 12-hour period of no rain. The first burst of rain, maximizing at about 6 inches (152 mm), began shortly after midnight, September 12. Rainfall rates were extremely heavy. In North Kansas City, 2.20 inches (56 mm) of rain was observed in the ½-hour period ending at 1:50 A.M. Rainfall for this first burst totaled 5.50 inches (140 mm) in about 6 hours. Many of the local streams rose sharply. However, with the exception of Wolcott, Kans., in Wyandotte County, where 25 families were evacuated, the area had no serious flooding. The significant effect of this rainfall was that it thoroughly soaked the local drainage basins and set the stage for the second rainstorm, which began about 8 P.M.

The second burst of rainfall devastated the area. Amounts of 6 to 7 inches (152 to 178 mm) were recorded. Normally subsequent heavy rainfall occurs in an area downwind from the first event. In this case, the two storms occurred over nearly the same area. The map of total precipitation (fig. 1), shows the heaviest total amounts ranged from over 14 inches (356 mm) in the Brush Creek drainage to over 16 inches (406 mm) in

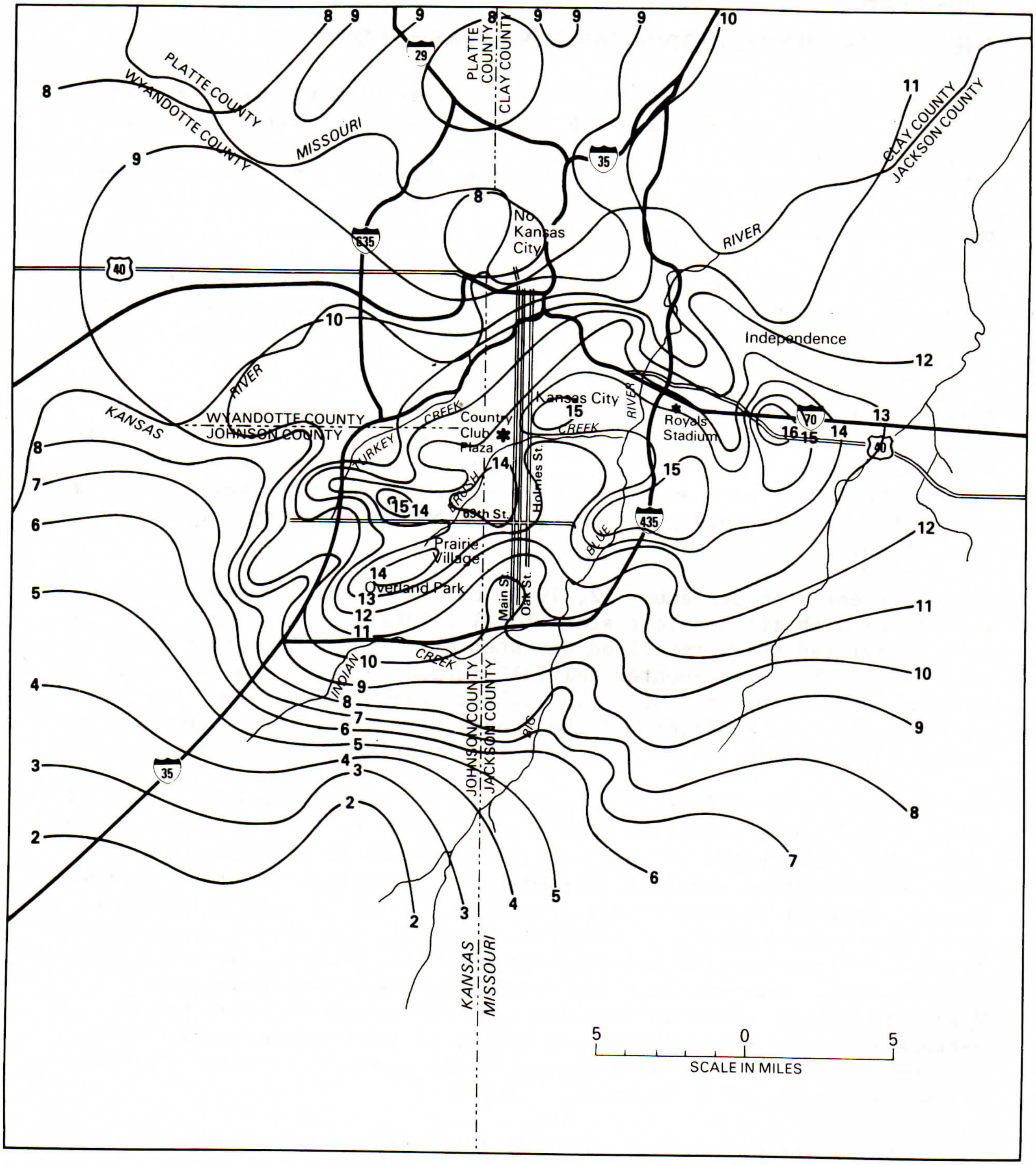

Figure 1. Total precipitation(inches) September 12-13, 1977, based on climatological network and by unofficial precipitation reports.

Independence. Figure 1(a) shows the primary stations in the Local Hydrologic network. An extensive bucket survey indicated a maximum rain gage observation of 16.22 inches (413 mm). All of the survey reports were from reliable rain gages. Figure 2 shows the hourly rainfall accumulation at the U.S. Geological Survey (USGS) recording rainfall gage in Independence.

The initial heavy rains reduced the flash-flood index (this is the amount of rain over a 3-hour period that is theoretically needed to produce minor flooding) for Zone 18, the Kansas City area, from 4.0 inches (102 mm) for September 11 to 1.6 inches (41 mm) for September 12. Based on this updated guidance prepared by the Kansas City River Forecast Center, and meteorological information, a flash-flood watch was issued at 10:30 A.M. for the afternoon and night of September 12. Additional updated watches, warnings, and statements were released during the afternoon and evening prior to the flood. (Details are given in chapter 4.)

When the second burst of torrential rains began about 8 P.M. over the previously saturated area, all creeks and streams in the area began to rise rapidly, almost simultaneously, with the rainfall. At 8:22 P.M. the Kansas City, Mo., police dispatcher began receiving reports from citizens throughout the city regarding water in basements and inundated streets. During the next few hours the dispatcher was swamped with continuous emergency calls from all parts of the city.

The Brush Creek area, which received the brunt of the disastrous flood waters, is a tributary of the Big Blue River. From its headwaters in the residential suburb of Prairie Village, Kans., it normally trickles peacefully northeastward to the Kansas-Missouri State line where its channel is paved with concrete as it passes through the Country Club Plaza shopping area. This area comprises numerous speciality shops, restaurants, recreational facilities, apartments, and hotels. Brush Creek then continues eastward 4 miles (6.5 km) through the heart of the city, and then it enters the heavy industrial manufacturing district of the lower Big Blue River north of Highway 50.

The Brush Creek drainage area above Main Street (Plaza area) of 14.8 square miles (38.3 square km) produces an average flow of only 8 cubic feet per second (0.2 cubic meters per second). The maximum previous discharge recorded at the USGS gage since records began in October 1970 was 4,300 cfs (120.4 cms) on June 28, 1976, and the highest previous gage height recorded was 9.20 feet (2.80 m) on September 11, 1975. High water marks during this disastrous flood indicate a crest of 22.2 feet (6.77 m) with an estimated discharge in the 35,000 to 40,000 cfs (980-1,120 cms) range, nearly 10 times the previous peak flow.

In other areas of the city, the heavy runoff flooded most low-lying streets and intersections. Turkey Creek in Johnson County, Kans., overflowed and blocked Interstate Highway I-35. Motorists were trapped inside cars on I-70 and U.S. 40. Innumerable cars stalled in high water; many were abandoned and quickly swept away.

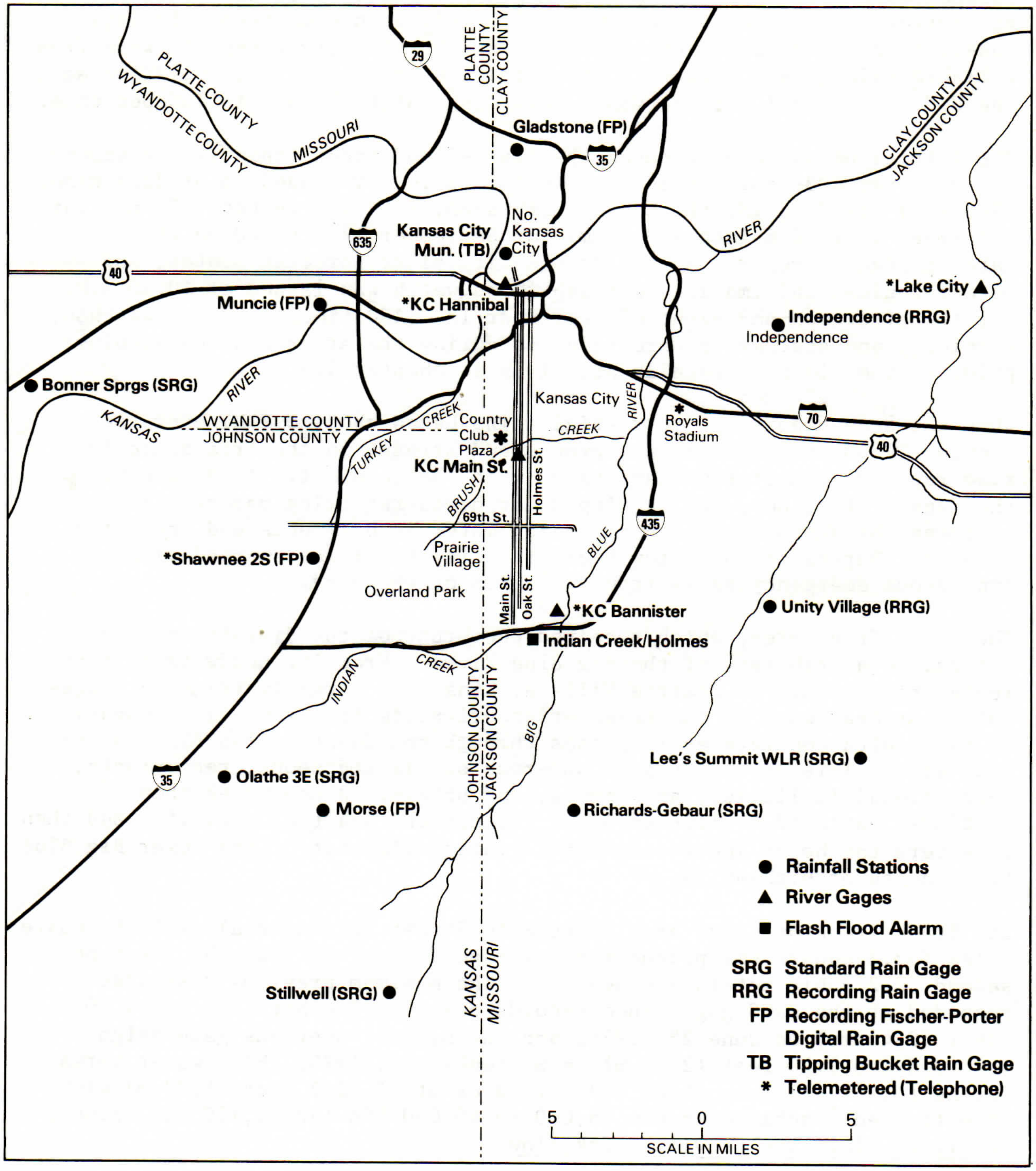

Figure 1a. Primary Hydrologic Network Stations.

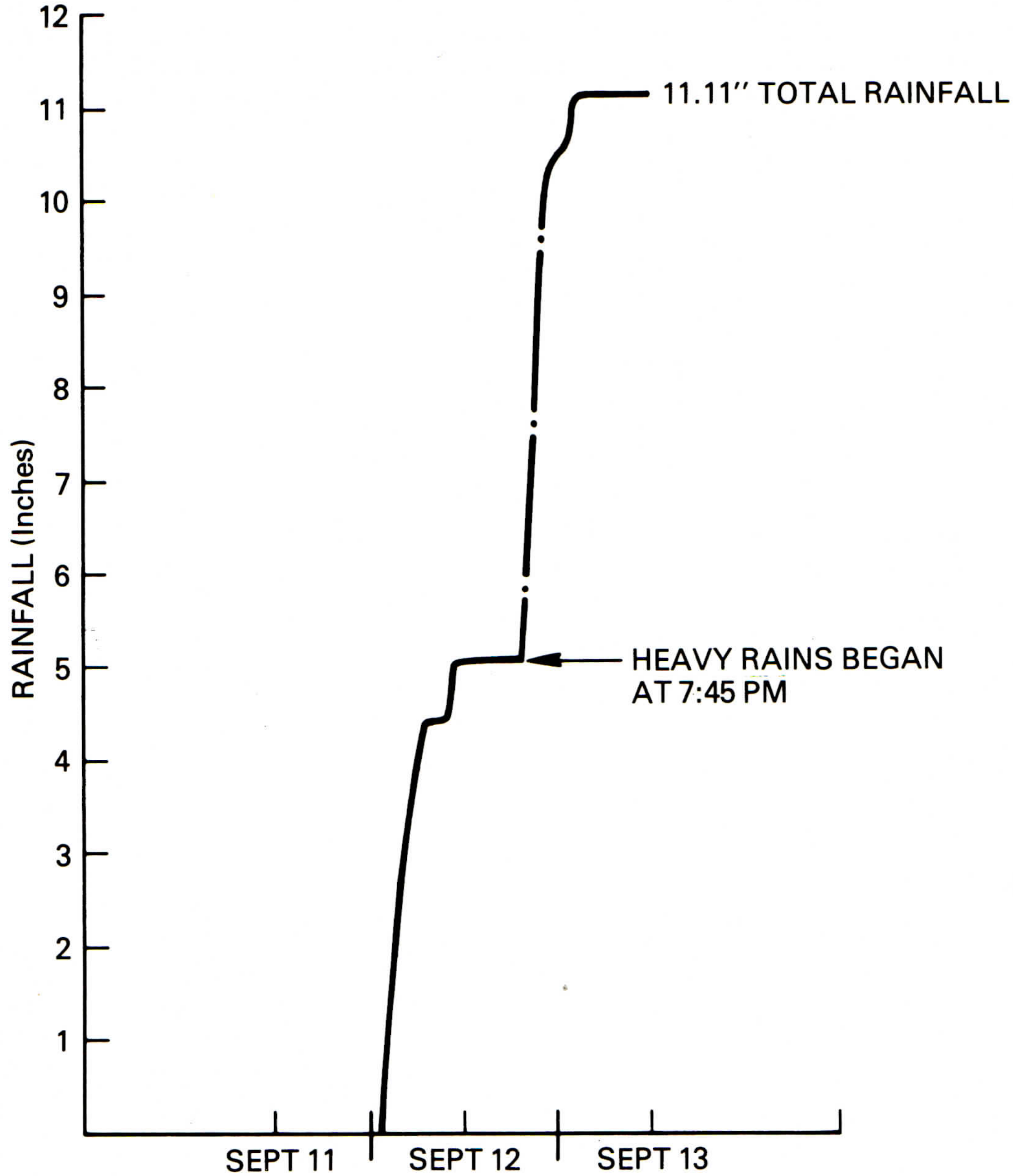

Figure 2. Graph of USGS Recording Raingage at Independence, Mo. Recording shows distinctive double rainfall events.

During the search for flood victims, the Police Department recovered 150 cars from the Brush Creek channel and on adjoining public property. Two commercial towing services reported logging over 2,000 tows during the week following the flood.

When compared to the death toll from recent flash floods, as stated earlier, the 25 fatalities in this flash flood are remarkably low considering its severity in this highly populated metropolitan area.

CHAPTER 2.

DATA ACQUISITION

Large amounts of surface, upper air, radar, and satellite meteorological data are routinely available to the National Severe Storms Forecast Center (NSSFC), which also serves as the local Kansas City Weather Service Office.

Weather Radar

Weather Radar coverage for the Kansas City area is provided by the Weather Surveillance Radar, 1957 (WSR-57) network radar in NSSFC. This radar is fully staffed around the clock. In addition, the Weather Surveillance Radar, 1974 C-Band (WSR-74C) Local Warning Radar at Topeka provides backup coverage to the network radar for the Kansas City area. A hotline phone system between the two offices provides the necessary communications link for backup and coordination.

Both radars were operating during the afternoon and evening of September 12 except for the Digitized Radar Experiment (D-RADEX) equipment with the WSR-57 Radar at NSSFC and the Video Integrator and Processor (VIP) portion of the Topeka Radar.

When operating properly, D-RADEX provides, among other things, estimates of accumulated rainfall in a given period of time for certain areas within a 125-nautical mile (230 km) radius of the radar. This does not include the area within a 10-nautical mile (18.5 km) radius of the radar, because the VIP (and thus, D-RADEX) is always blanked out within that range. In addition, the severe ground clutter pattern associated with the Kansas City Radar renders the D-RADEX values virtually worthless within a 40-nautical mile (74 km) radius of the radar. In fact, values from within this 40-nautical mile (74 km) radius are no longer available operationally on the local D-RADEX printout. Most of the heavy rains associated with the flooding fell within this 40-nautical mile (74 km) radius, and the heaviest rains were partially within the 10-nautical mile (18.5 km) radius of the radar. Therefore, it is unlikely that D-RADEX as it now operates at Kansas City could have provided any additional information in this particular situation that would have enhanced the warning effort.

The radar VIP provides automatic contouring of the various levels of radar echo intensity. This intensity, or reflectivity of weather radar echoes, is used operationally by NWS to estimate instantaneous rainfall rates. The accuracy of these estimates is affected by a number of factors including the structure of the precipitating cloud and its distance from the radar. However, for precipitation within the 125-nautical mile (230 km) range of the radar, the following table is used to estimate rainfall rates from convective clouds:

VIP level	Rainfall rate in inches per hour		
1		<	0.2 (5 mm)
2	0.20	to	1.1 (5 to 28 mm)
3	1.1	to	2.2 (28 to 56 mm)
4	2.2	to	4.5 (56 to 114 mm)
5	4.5	to	7.1 (114 to 180 mm)
6		>	7.1 (180 mm)

This rainfall rate vs. VIP level table was only recently developed and was issued to all NWS Central Region Offices in February 1977. The radar staff on duty that evening were familiar with these new rainfall rate relationships.

Figures 4 through 8 show the radar echo pattern and associated maximum VIP levels from 5:30 through 9:30 P.M. CDT, September 12. Numerous VIP level 5 echoes were indicated north and west of metropolitan Kansas City by 5:30 P.M. The precipitation area which contained the strongest cells continued to drift toward the metropolitan area during the next 2 hours until by 7:30 P.M. (fig. 6) the southern boundary had just reached the Kansas City downtown area. However, the strongest cells (VIP level 5) were still indicated to be about 25 miles (40 km) to the north at this time.

The initial two Flash-Flood Warnings (details on warnings are given in chapter 4) issued at 5:45 and 6:45 P.M. CDT, were based primarily on these radar observations. Those on duty the evening of September 12 indicated that very few reports of either flooding or heavy rains were received prior to the issuance of these two warnings. However, no running log was kept of reports coming in to the NSSFC offices; therefore, it is virtually impossible to determine exactly what reports were received and when. The Wyandotte County Kansas Civil Defense Operations Log for that night lists one report of heavy rain and marble-sized hail received at 5:30 P.M. from Platte County, Mo., via the Metropolitan Emergency Telephone System (METS). A second report of heavy rain and mothball-sized hail in Clay County, Mo., was entered on the same log at 5:50 P.M. (This was at the same time that the initial Flash-Flood Warning was transmitted on the METS system.) There is a METS drop, including a live speaker, in the radar room at NSSFC. Despite this, there is no indication that any NWS personnel actually heard either of these heavy rain reports or that there was any attempt to relay this information to the NWS Office. It should be noted that one report from Platte County of 1 inch (25 mm) of rain in a 30-minute period was included as part of the 5:45 P.M. warning. It is not known if this is the same report entered on the METS log; therefore, the overwhelming bulk of quantitative input to the initial two warnings was derived from radar data.

The 7:45 P.M. Flash-Flood Warning, which expanded the warning area to include Leavenworth, Wyandotte, and Johnson Counties in Kansas and Jackson County in Missouri was again based on radar-derived projections of cell movement into those areas. The first logged report of heavy rain or flooding in any of these four counties was at 8:06 P.M., "59th and Parallel -- cars in water." Fifty-Ninth and Parallel is in Wyandotte County.

A log of Manually Digitized Radar (MDR) values was maintained throughout the event. MDR values are estimates of accumulated rainfall within specified grid boxes which are about 40-nautical-mile (75 km) squares in the Kansas City area. The MDR grid for the Kansas City radar is shown in figure 9. Most of the severe flooding occurred in MDR Boxes 5 and 8. The heaviest rainfall occurred in Box 8, yet the MDR totals for Box 8, during the evening of the 12th, were not excessive and were less than for Box 5. The MDR totals for Box 8 did not reach the standard flash-flood alerting level (around 20) until 11:30 P.M., long after the severe flash flooding on Brush Creek had begun. As is often the case, the smaller streams reached flood level long before MDR values alone could indicate that sufficient rainfall to cause flooding had occurred.

On the evening of the 12th, MDR values for Box 8 may have been recorded lower than they should have been because they are based on radar VIP levels, and these could not be measured within 10 nautical miles (18.5 km) of the radar. VIP levels within this radius were interpolated. The Topeka radar could have provided the VIP levels within this area under normal operating circumstances; however, with the Topeka VIP out of service, no VIP values were available for an area in which the heaviest rain occurred. (The trouble with the Topeka VIP operation was eventually resolved on September 13th. A very minute piece of solder was discovered in a socket on a printed circuit board and was believed to have been the cause of the outage.)

The NWS Operations Manual takes cognizance of the problems created by radar ground clutter patterns by requiring that each radar office give special attention to significant echoes within 20 miles (32 km) of another radar. The Director of the NWS Central Region sent a letter to all radar offices in the Central Region on June 29, 1977, reminding them of this responsibility. As far as can be determined, the Kansas City radar office was not notified of strong cells in its area by any other radar office. However, the Kansas City radar operator on duty was aware that strong cells existed near the radar site and used various proven techniques (radar tilted to different elevations to reduce ground clutter, etc.) for obtaining information on their location, intensity, and movement. But, because of their proximity to the Kansas City radar and because of the Topeka VIP malfunction, VIP levels, and consequently rainfall rate estimates, could not be obtained for these cells. It is obvious, however, that this had no effect upon the initial issuance of the warning, because the warning was issued <u>before</u> the area of thunderstorms moved over the radar site. VIP data from Topeka could possibly have provided additional information for pinpointing the strongest cells and their movement or for estimating accumulated rainfall in the otherwise blind area of the Kansas City radar.

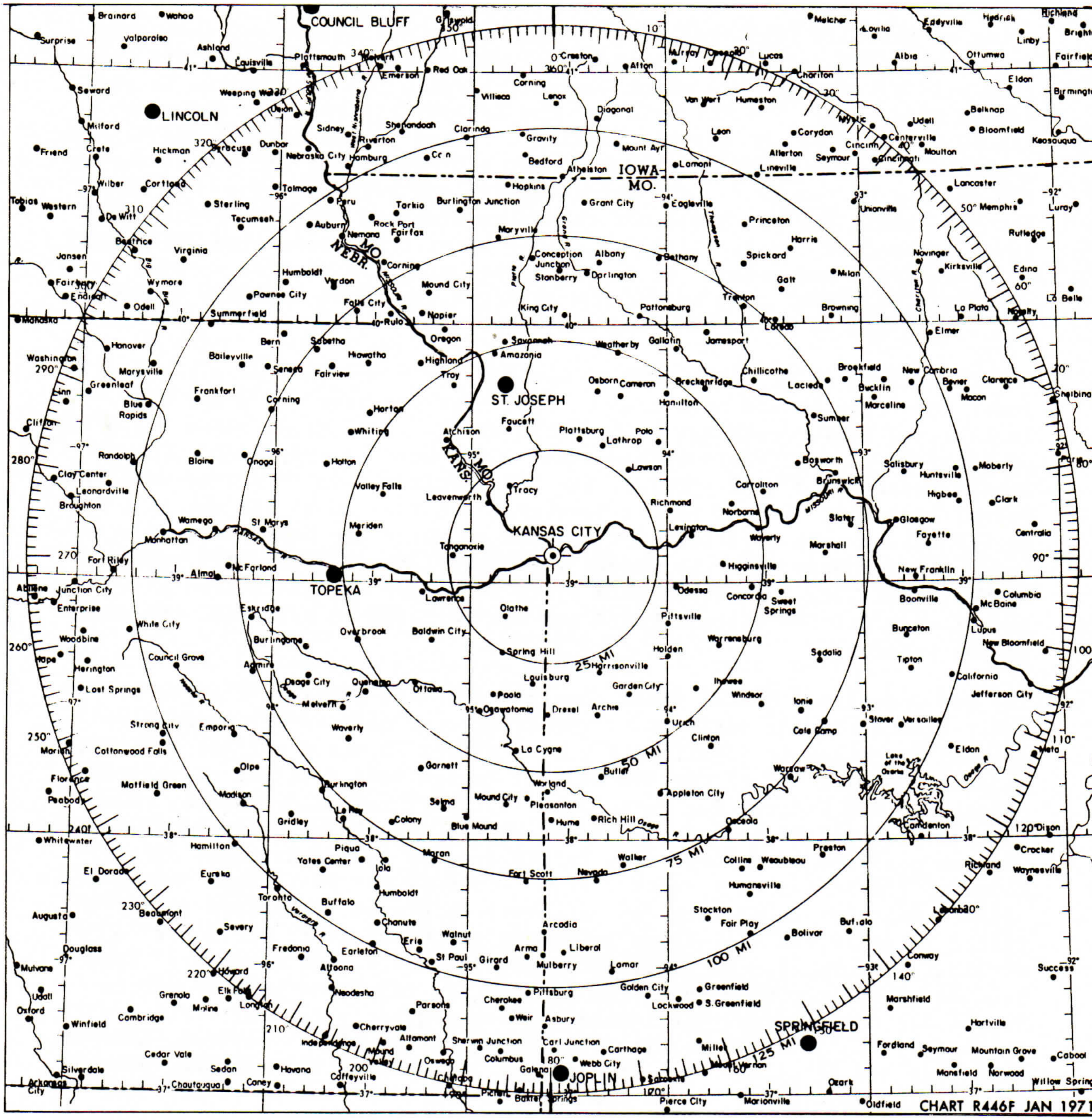

Figure 3. Copy of 125 Nautical Mile Overlay for the Kansas City Radar.

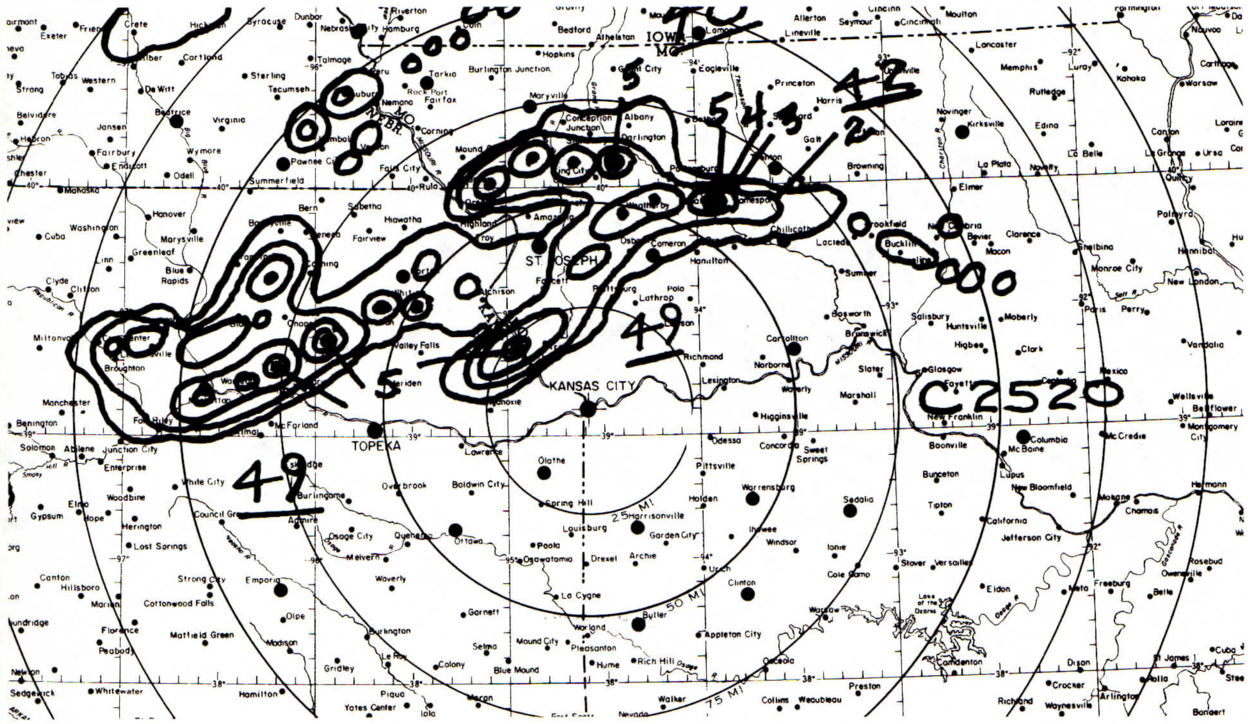

Figure 4. Kansas City radar scope tracings indicating VIP levels and maximum echo tops(thousands of feet) on September 12, 1977, at 5:30P.M. CDT.

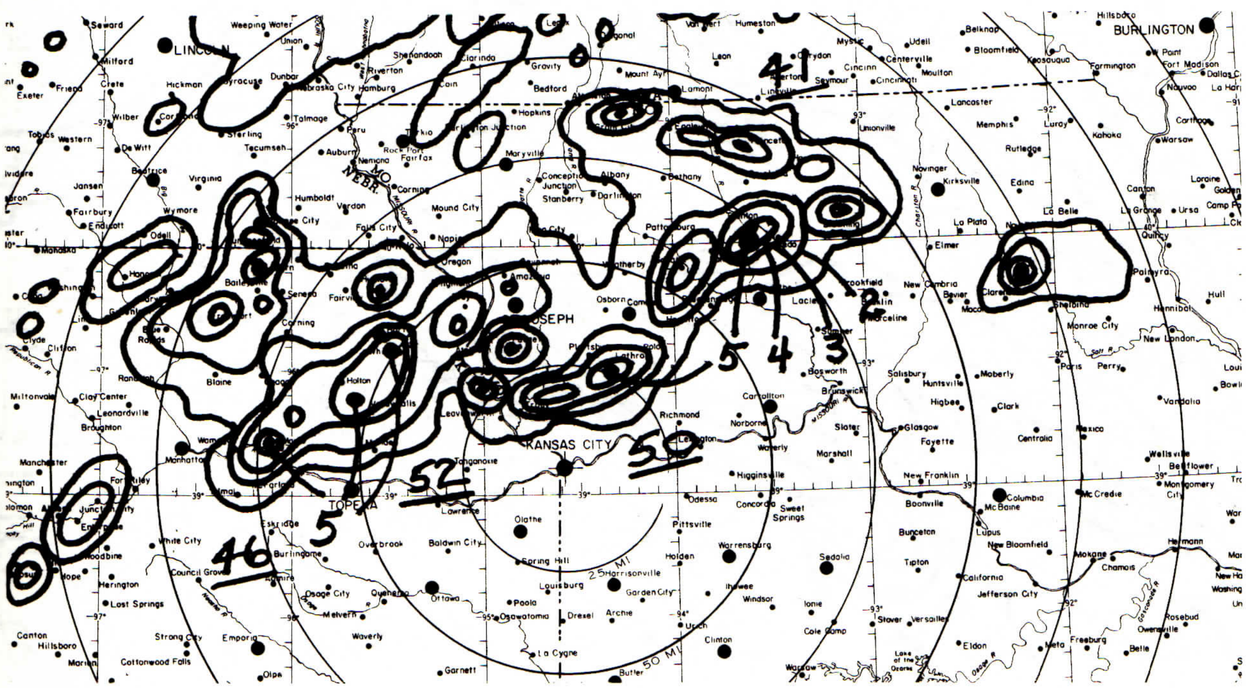

Figure 5. Kansas City radar scope tracings indicating VIP levels and maximum echo tops(thousands of feet) on September 12, 1977, at 6:30P.M. CDT.

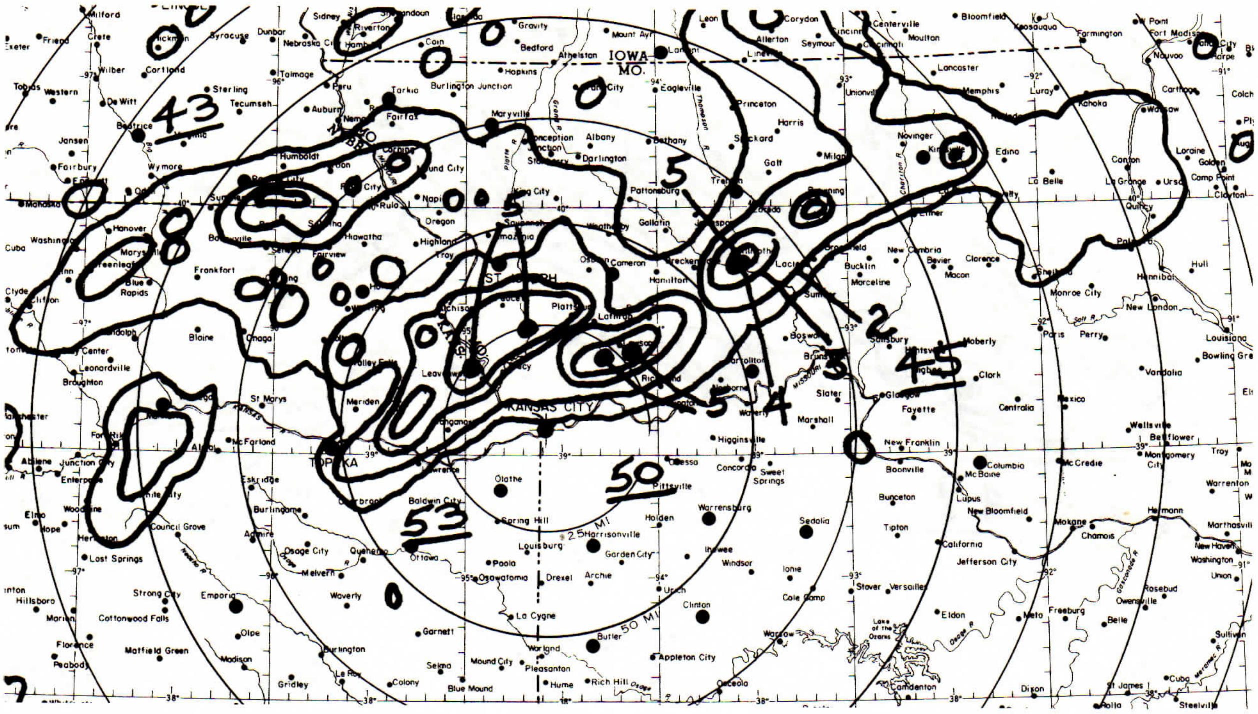

Figure 6. Kansas City radar scope tracings indicating VIP levels and maximum echo tops(thousands of feet) on September 12, 1977, at 7:30P.M. CDT.

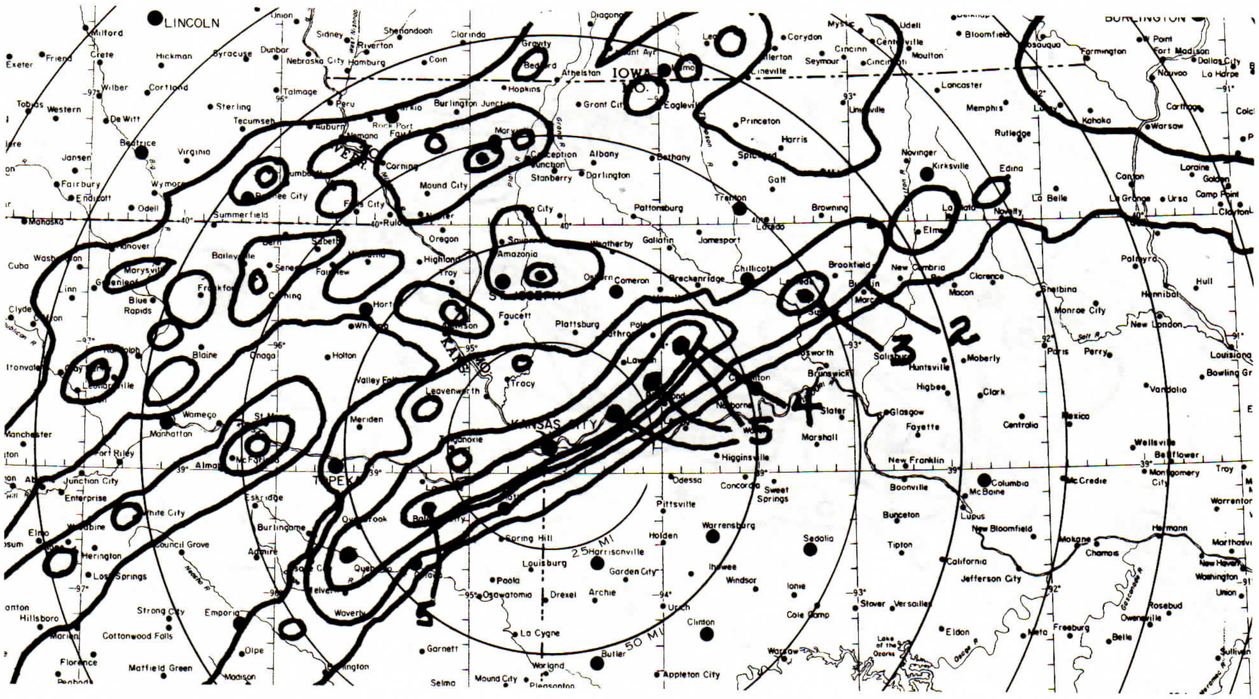

Figure 7. Kansas City radar scope tracings indicating VIP levels and maximum echo tops(thousands of feet) on September 12, 1977, at 8:30P.M. CDT.

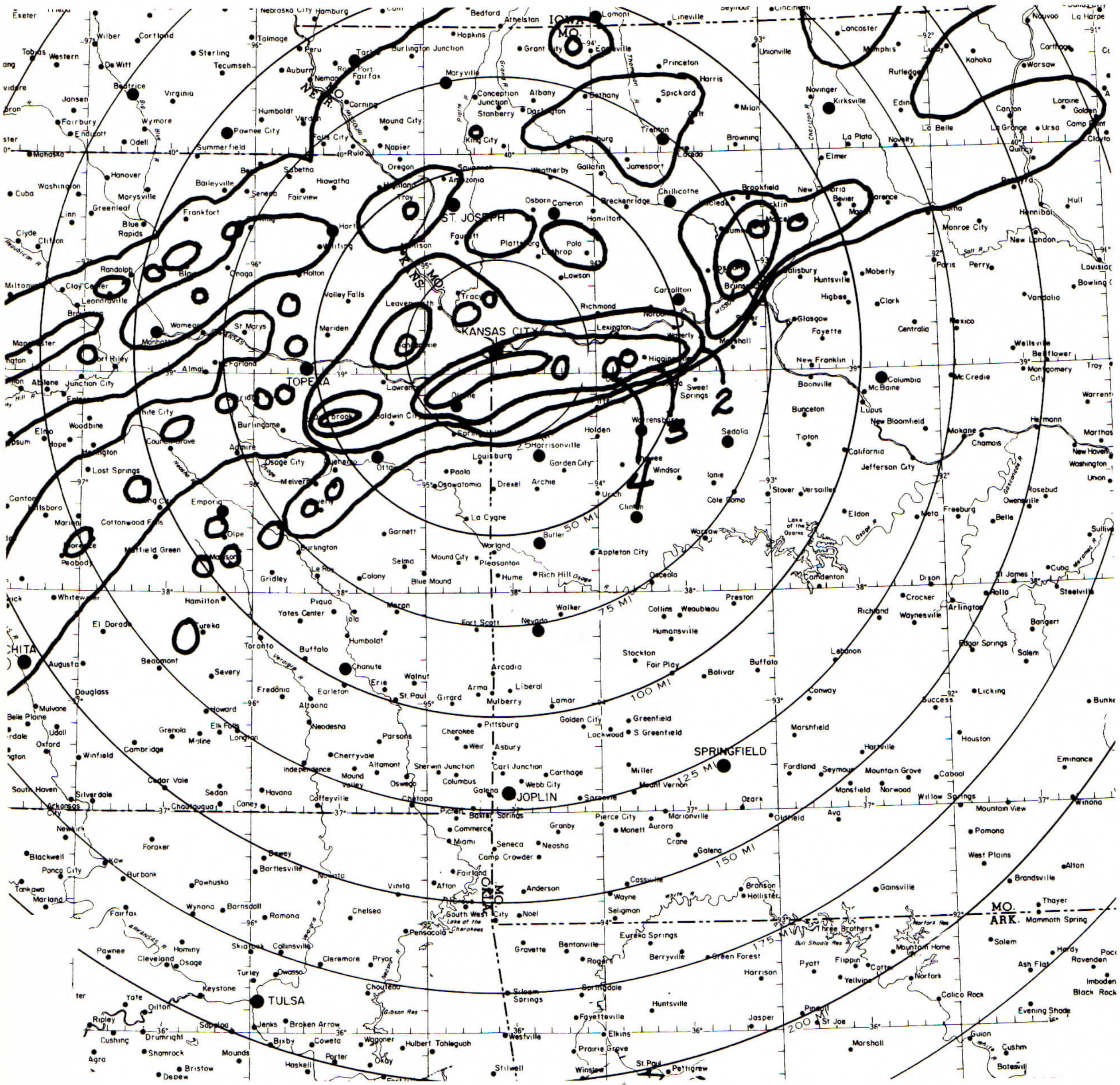

Figure 8. Kansas City radar scope tracings indicating VIP levels and maximum echo tops(thousands of feet) on September 12, 1977, at 9:30P.M. CDT.

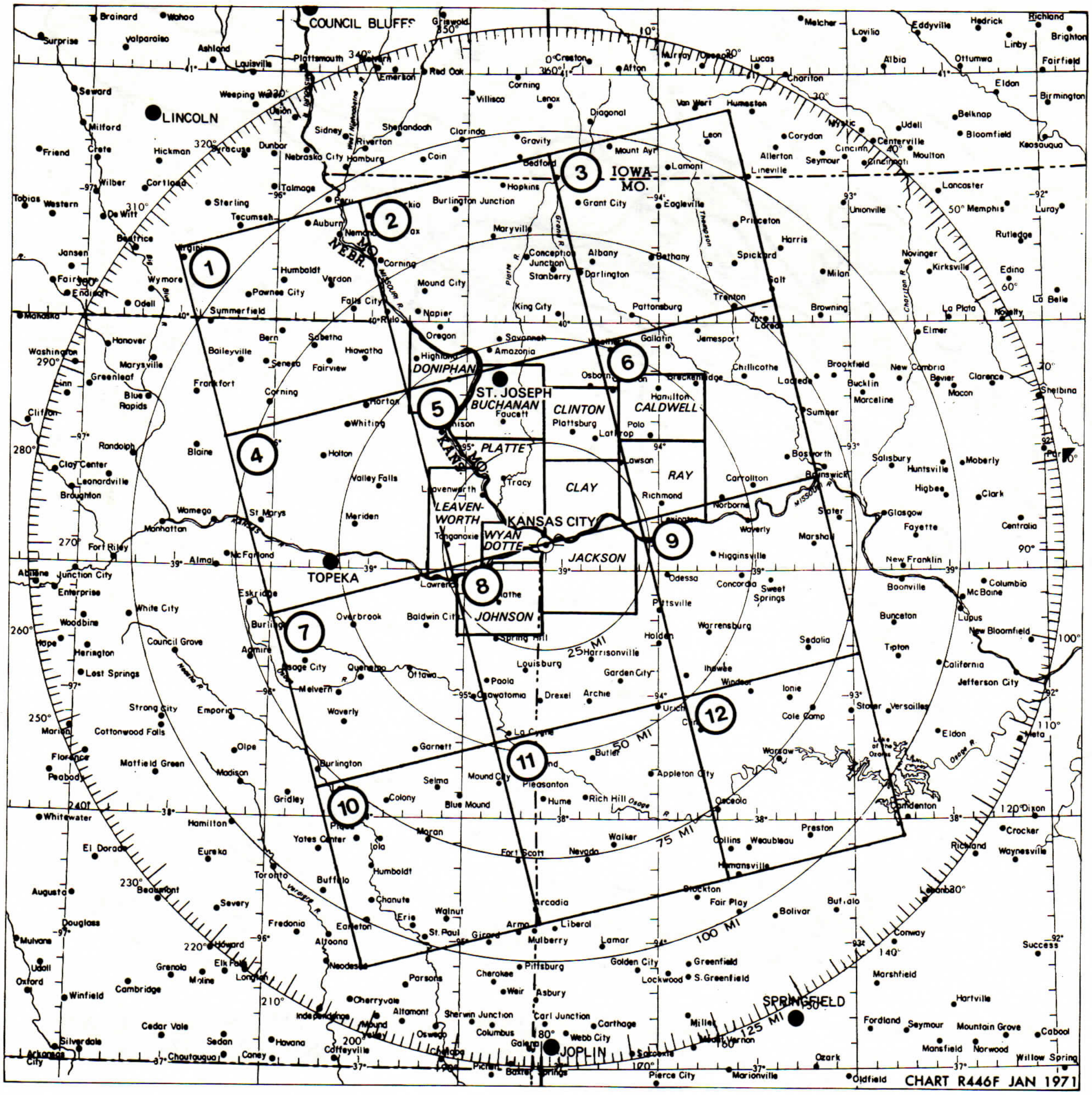

Figure 9. Manually Digitized Radar(MDR) Grid for Kansas City radar.

Satellite Data

During the daylight hours that preceded the onset of heavy rain, enhanced infrared and ½-mile (1 km) and 1-mile (2 km) resolution visible imagery were received at 30-minute intervals at the Kansas City National environmental Satellite Service's Satellite Field Service Station (NESS SFSS). This station is in the NSSFC complex and serves NSSFC and 23 other NWS Forecast Offices. Infrared data provide the ability to resolve features on the Earth's surface of about 5 miles (10 km) in diameter or larger. After sunset, only infrared data were received. State boundaries (grids) were manually superimposed on the satellite images to eliminate the possibility of error in computer grid location. All imagery was of high quality and available to the SFSS meteorologists in the form of hard-copy prints and in animated format displayed on a television monitor. One-half mile (1 km) resolution visible data were available for interpretation about 20 minutes after satellite acquisition time and the 1-mile (2 km) resolution data, infrared data, and the animated display were available about 10 to 15 minutes lager. The additional delay was due to photographic darkroom processing of the imagery and its ingestion into the Image Analyzer System. The ½-mile (1 km) resolution data were received on an internal processing display device which requires no darkroom support.

Maximum benefits from satellite data are realized when this information is effectively used to bridge the gap in time and space between conventional meteorological observations. A meld of all types of data (satellite, surface, upper-air, and radar) results in a more complete and accurate understanding of atmospheric processes and mechanisms.

During the day, the SFSS meteorologists identified a surface boundary in the imagery which had been established by the previous night's thunderstorm activity. This boundary is evident in figure 10 as a narrow line of clouds from near Topeka, Kans. (TOP), to Fort Leonard Wood, Mo. (TBN), to Salem, Ill. (SLO). At this time, the cloud line was not detected by radar because the clouds along the boundary were not precipitating. Boundaries of this type are known to represent narrow zones of energy that can initiate explosive convective development -- particularly at the point where the boundary intersects another boundary such as a cold front.

At 11:00 A.M., September 12, the SFSS meteorologist noted (photo not shown) the portion of the boundary in northeast Kansas was moving northward on a collision course with a cold front advancing eastward across Kansas. This suggested the boundary could initiate new thunderstorm development at its junction with the front in the vicinity of Topeka. The idea was further supported by surface and upper-air data that showed conditions to be ideal in that area for thunderstorm formation.

The SFSS meteorologist relayed this interpretation of the satellite imagery to those on duty in the operating units of NSSFC. After consultation between SFSS and the Severe Local Storms Unit, shortly after noon, a severe thunderstorm watch was issued at 1:00 P.M. to cover the area along and north of the boundary.

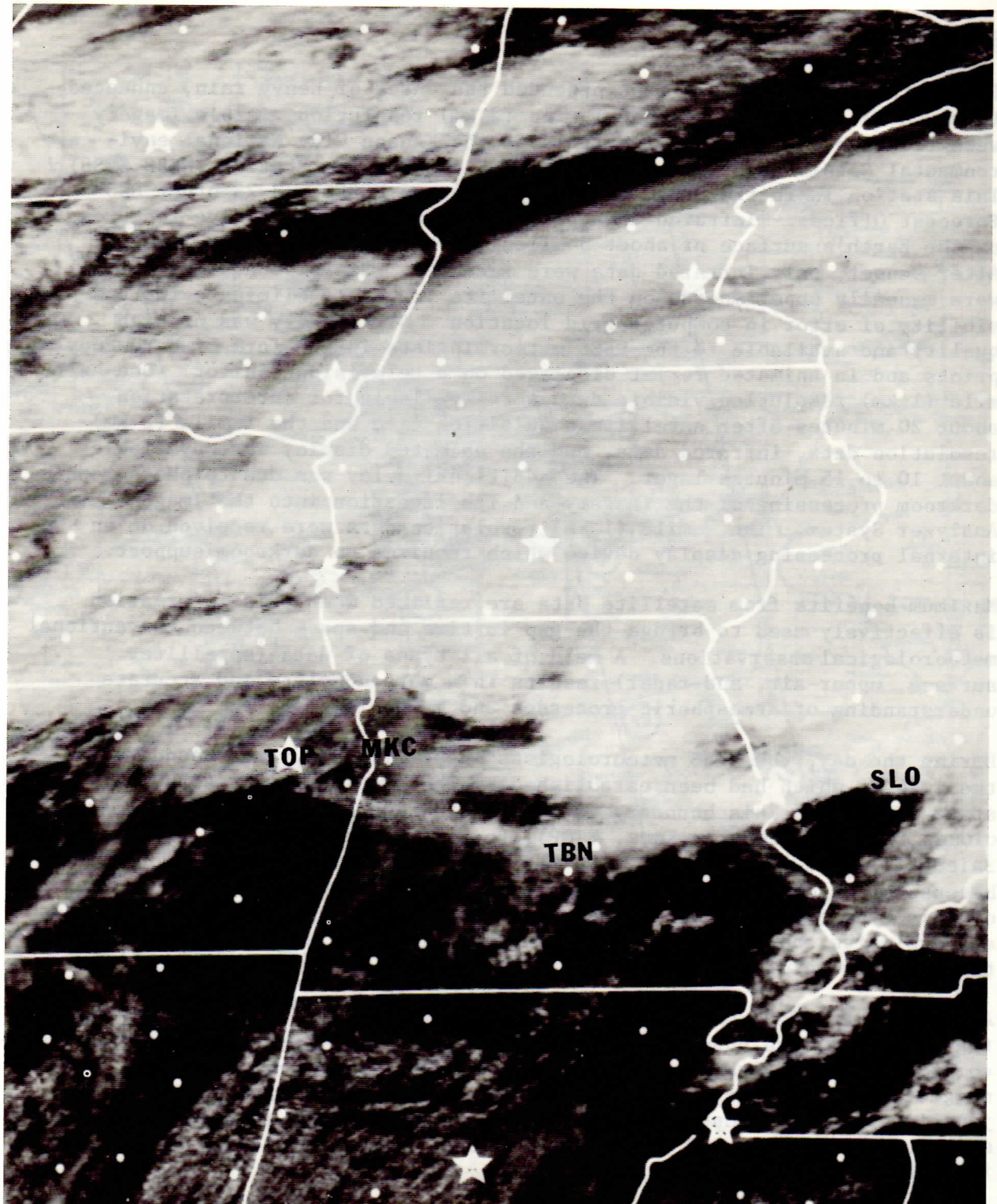

Figure 10. Enlargement of 1-mile resolution visible image acquired at 1:00P.M. CDT, September 12, 1977.

At 2:12 P.M., the first indication of thunderstorm development was received from a pilot who had spotted a rapidly building cell near Topeka. The picture acquired at 3:00 P.M. (fig. 11) showed this new development (A) to be at the intersection of the boundary with a narrow line of clouds along the surface front. This cell grew rapidly as noted in the satellite picture received 30 minutes later (fig. 12). Thunderstorms continued to develop southwestward along the front and by 6:00 P.M. (fig. 13), the first storm (A) had passed north of Kansas City (MKC) and a line of thunderstorms had formed along the front (B and C) from northeast Kansas to near the Oklahoma Panhandle. The enhanced infrared data indicated a significant change had taken place between 7:00 P.M. and 7:30 P.M. (figs. 14 and 15). The axis of the most intense thunderstorm development had been a few miles north of Kansas City (MKC), but the 7:30 P.M. picture showed this axis to be shifting south as evidenced by the new development (D) along the southern edge of the older storm. The collocated NWS units were advised of this recent change which placed an east-west zone of vigorous development across Kansas City. Thunderstorms continued to form and intensify over the Kansas City area; the heaviest rains fell along the southern edge of the thunderstorms where the enhanced infrared data indicated the maximum temperature gradient.

The pictures acquired at 10:00 P.M. and 11:00 P.M. (figs. 16 and 17) indicated the most active portion of the storm was decreasing in areal coverage and passing over Kansas City.

Upper Air

The closest upper-air (U/A) observing site to Kansas City is Topeka. However, because of the importance of U/A data to NSSFC, a large number of U/A charts and analyses, including many nonroutine U/A charts, are produced there. These charts were instrumental in providing much of the meteorological information pertinent to the early issuance of the flash-flood watch, and subsequent early issuance of the warnings.

Surface Observations

There are four types of surface observations available to the NSSFC:

(1) Aviation Observations from first- and second-order stations and Limited Aviation Weather Reporting Stations (LAWRS).

(2) Reports from Cooperative or Paid Observers in the Hydrologic or Public Service networks.

(3) Reports from Automated Reporting Equipment.

(4) Reports from the Public, Spotter Network, and Law-Enforcement agencies.

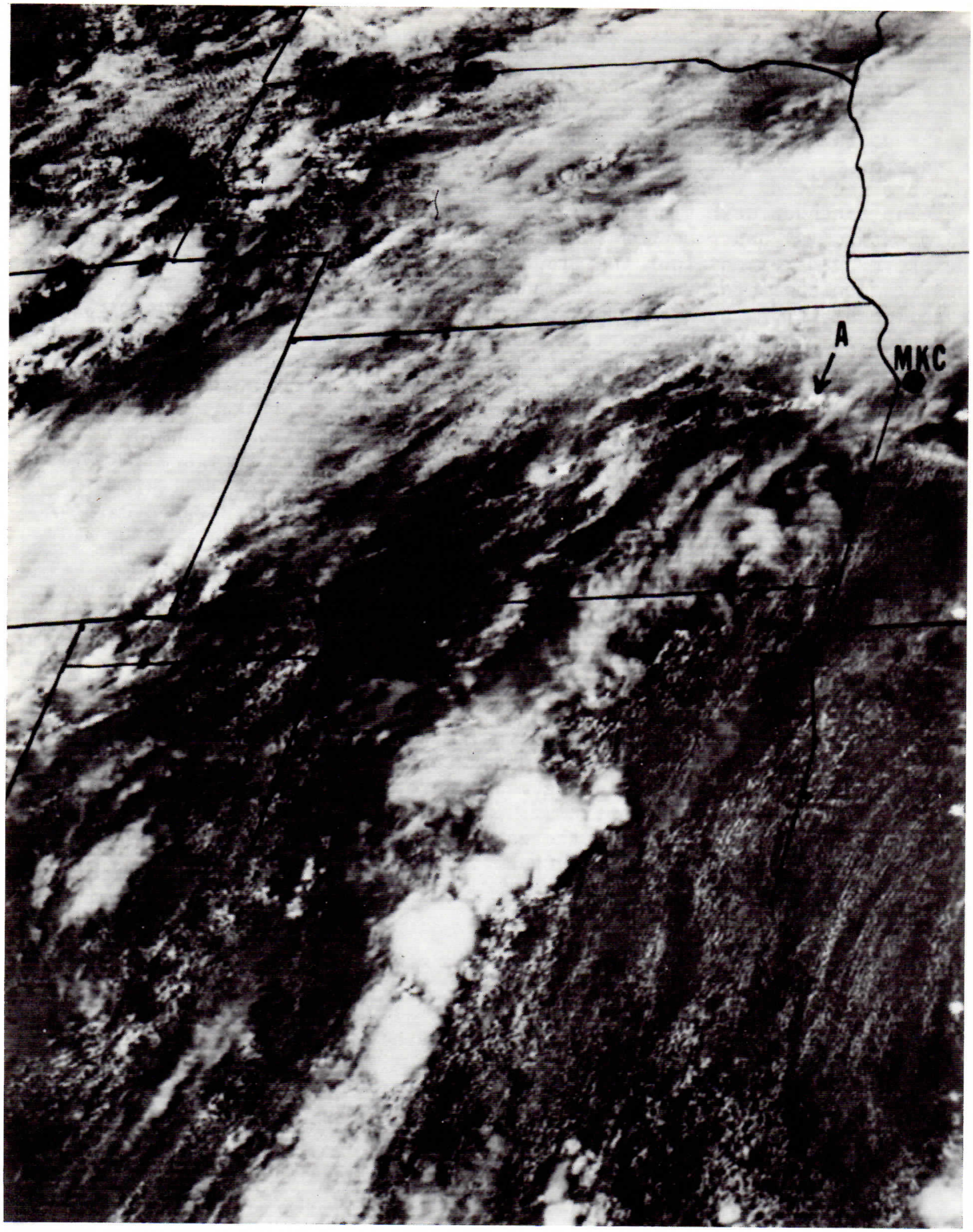

Figure 11. One-half-mile resolution visible image acquired at 3:00P.M. CDT, September 12, 1977, showing the initial stage of thunderstorm development.

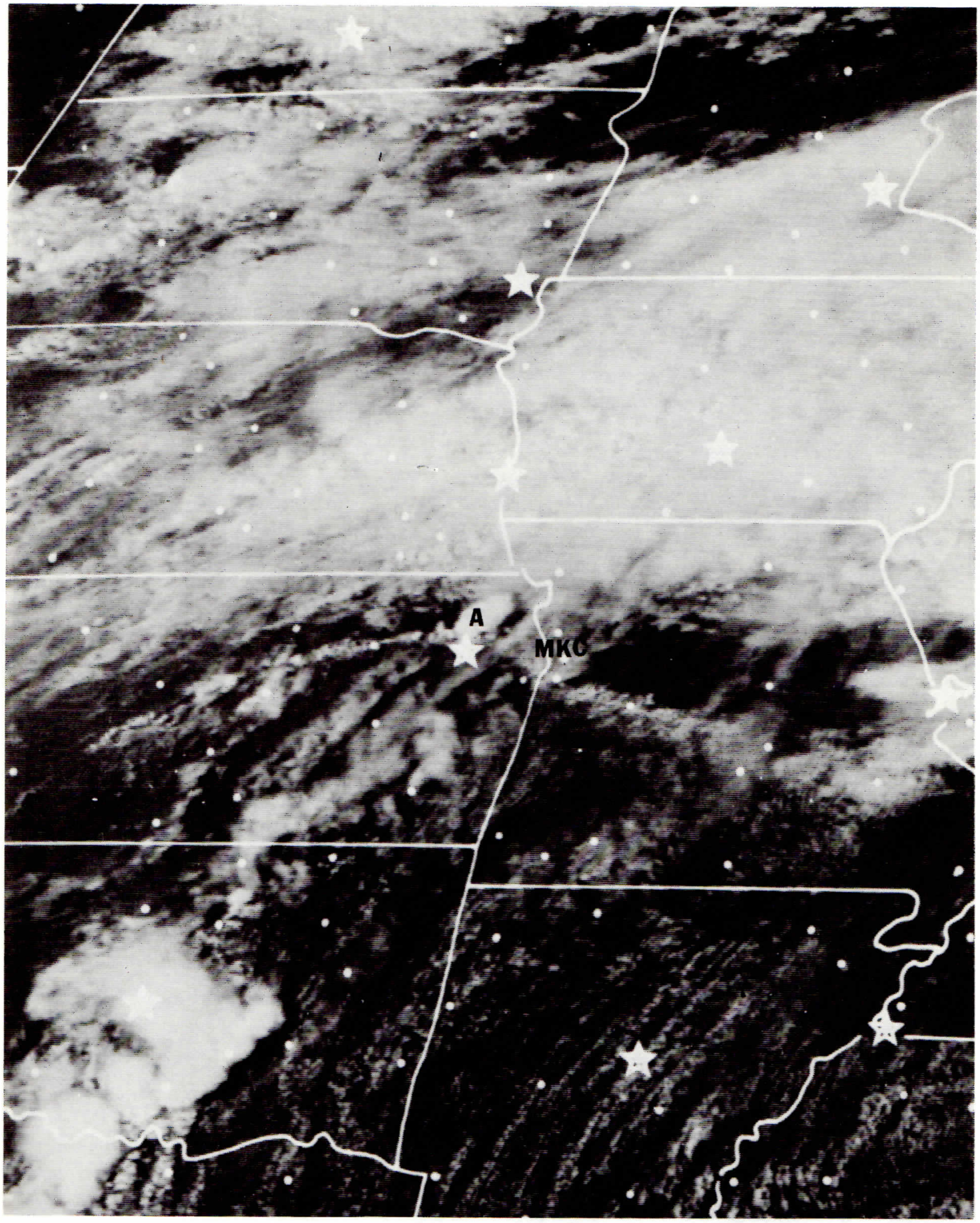

Figure 12. Enlargement of 1-mile resolution visible image acquired at 3:30P.M. CDT, September 12, 1977. Note rapid growth of thunderstorm in northeast Kansas(A).

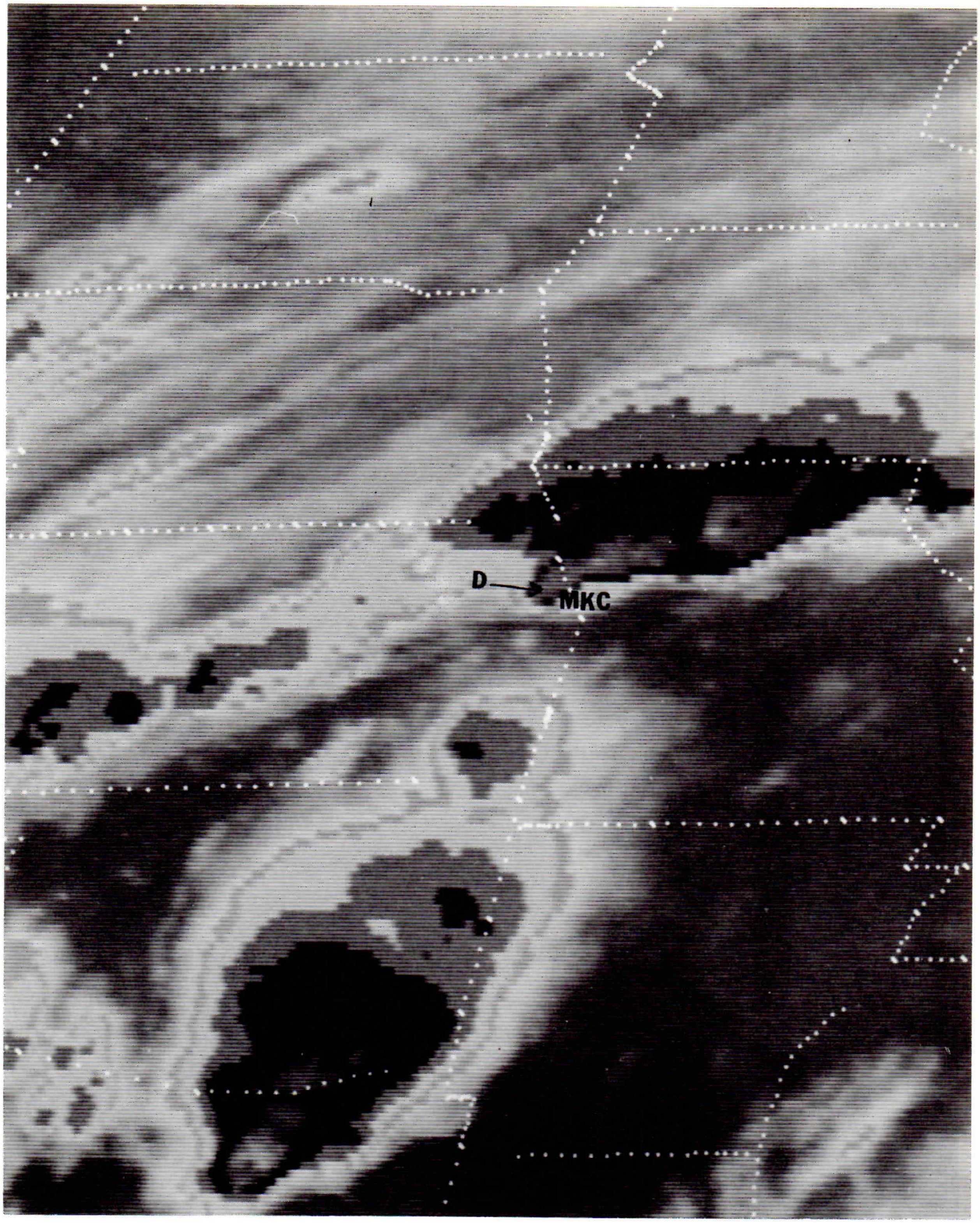

Figure 15. Enlargement of enhanced infrared image acquired at 7:30P.M. CDT, September 12, 1977. Note new cell development(D) just north and northwest of Kansas City(MKC).

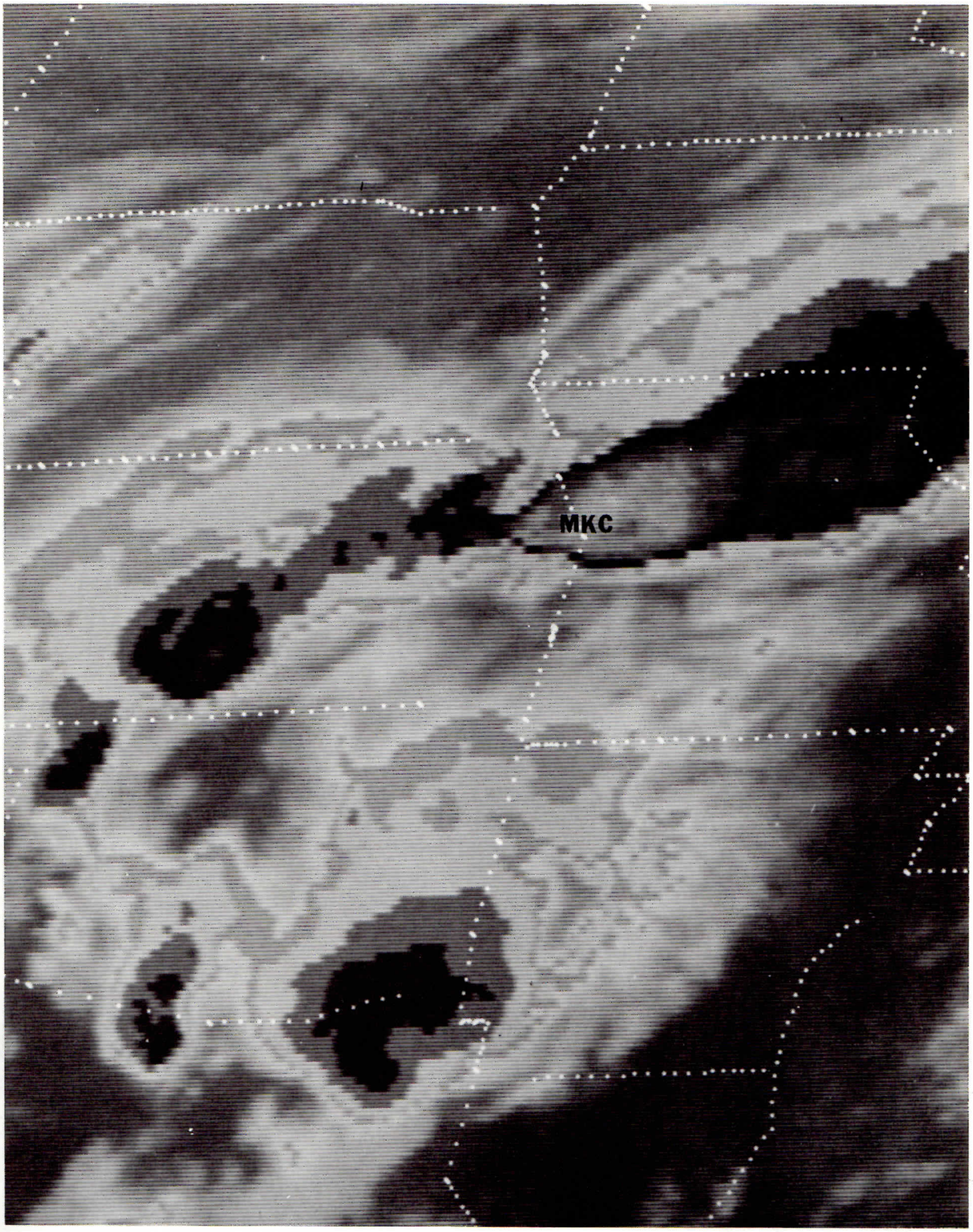

Figure 16. Enlargement of enhanced infrared image acquired at 10:00P.M. CDT, September 12, 1977.

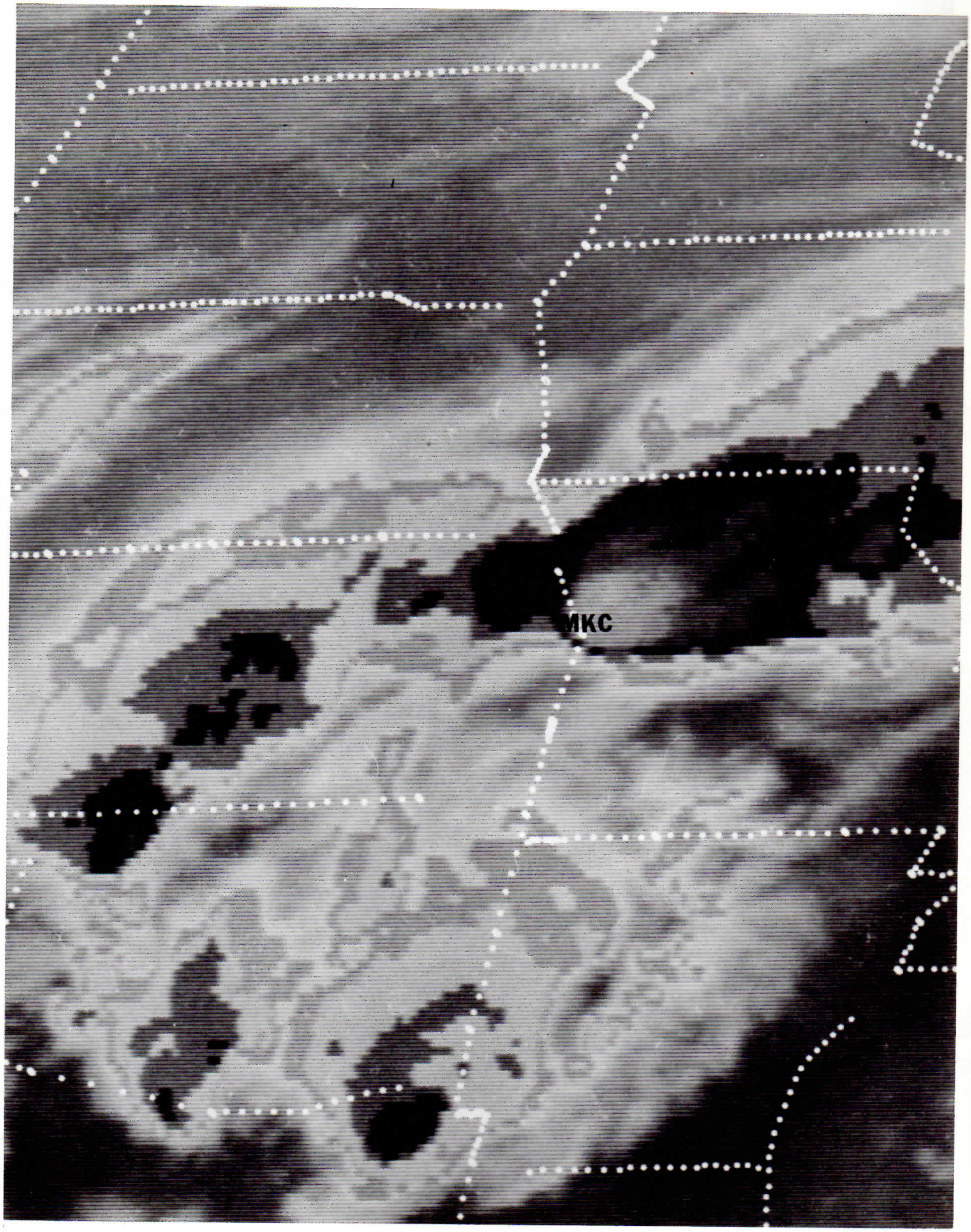

Figure 17. Enlargement of enhanced infrared image acquired at 11:00P.M. CDT, September 12, 1977.

Table 1 lists both the Aviation Reporting stations as well as the Automatic Reporting sites within about a 100-mile (160 km) radius of Kansas City.

Figure 18 shows the cooperative storm spotter network within a 50-mile (80 km) radius of Kansas City. A card index file containing the phone numbers and location of these spotters, arranged by azimuth and range, is kept in the radar room at NSSFC. Telephone reports are obtained either spontaneously from the network or by calls generated from NSSFC.

The area hydrologic network shown in figure 19 includes both cooperative and paid rainfall observers. The locations and phone numbers of observers in this network are listed in the River District Manual, which is readily available to NSSFC personnel. Two dedicated phone numbers, including a WATS number for nonlocal reports, are provided for this network. Despite instructions provided to the observers, very few rainfall reports were received from this network during the heavy rain period on the evening of September 12. Nearly all reports received by NSSFC during or immediately after the heaviest rains came from off-duty NWS personnel living in various parts of the city and suburbs.

Reports from the public can be made directly to NSSFC either via a recording/ring-through number, or through a publicly advertised severe weather reporting number generally known as the "Tornado Number." No known reports were received through either of these numbers.

Storm reports from local and State officials can also be relayed to the NSSFC via a hotline phone system called the Metropolitan Emergency Telephone System (METS). The NSSFC drop on METS is in the radar room where all transmissions are broadcast over a "live" speaker. Although no log was kept of incoming reports over METS at NSSFC, persons on duty recall hearing numerous "situation reports," nearly all of which were from areas already covered by warnings when the reports were received. The Wyandotte County Civil Defense log of the METS circuit confirms this. This circuit was undoubtedly the best source of actual reports available to NSSFC during the flash-flood.

Numerous county or community storm spotter networks exist throughout the eastern Kansas and western Missouri region. These are primarily for tornadoes and severe thunderstorms. Reports from these networks in the counties immediately surrounding Kansas City generally funnel in through the METS system, although some reports are occasionally phoned in to NSSFC. Direct contact between NWS personnel and the local county or community officials is an essential part of maintaining a successful spotter program. During 1977, direct NWS contact occurred with officials in every county of responsibility. Spotter training programs were conducted in Leavenworth, Wyandotte, and Johnson Counties in Kansas, and Platte, Clay, and Jackson Counties in Missouri. Spotter organizations in Caldwell, Ray, and Buchanan Counties were last visited in 1976.

Table 1.--Aviation and automatic reporting sites near Kansas City, Mo.

Station	Type	Frequenty of reports	How received at NSSFC
MCI	1st order	Hourly plus specials	Telewriter & Service A
MKC	FSS	Hourly plus specials	Telewriter & Service A
Topeka, Kans.	1st order	Hourly plus specials	Service A
Olathe, Kans.	LAWRS	Hourly plus specials	Telewriter
Manhattan, Kans.	FSS/SAWRS	Hourly plus specials (06-22 daily)	Service A
Emporia, Kans.	FSS	Hourly plus specials	Service A
Spikard	AMOS	3 times/hour	Service A
St. Joseph, Mo.	LAWRS	Hourly plus specials (07-22 daily)	Telewriter & Service A
Richards-Gebaur AFB	AF	Hourly plus specials (08-23 daily)	Service A
Valley Falls, Kans.	Fischer Porter Rain Gage	As requested	Telephone
Troy, Kans.	Fischer Porter Rain Gage	As requested	Telephone
Clinton, Kans.	Fischer Porter Rain Gage	As requested	Telephone
Blue Mound, Kans.	Fischer Porter Rain Gage	As requested	Telephone
Shawnee 2S, Kans.	Fischer Porter Rain Gage	As requested	Telephone
Kearney, Kans.	Fischer Porter Rain Gage	As requested	Telephone
Marshall, Mo.	Fischer Porter Rain Gage	As requested	Telephone
Drexel, Mo.	Fischer Porter Rain Gage	As requested	Telephone

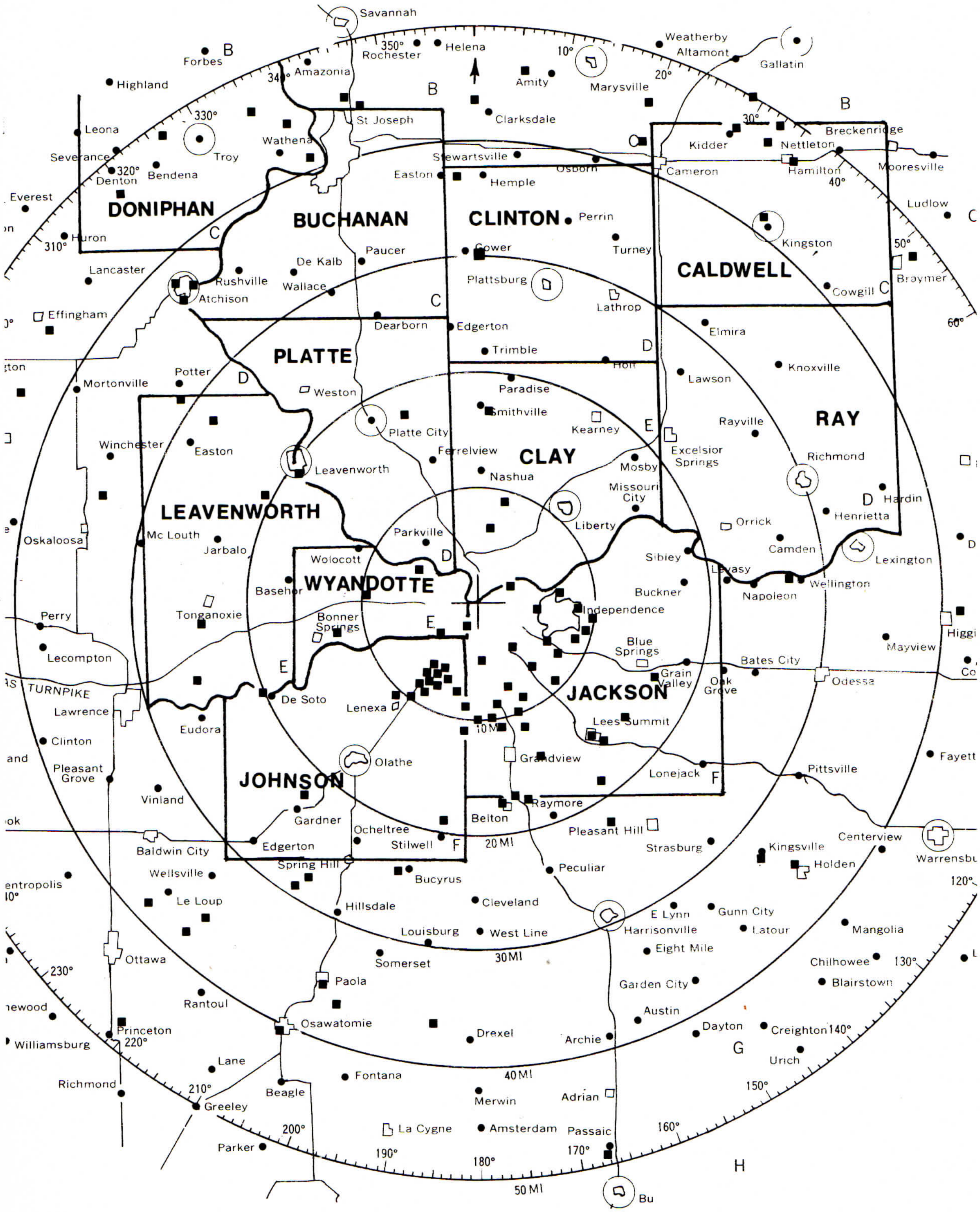

Figure 18. Cooperative Storm Spotter Network within 50-mile radius of Kansas City.

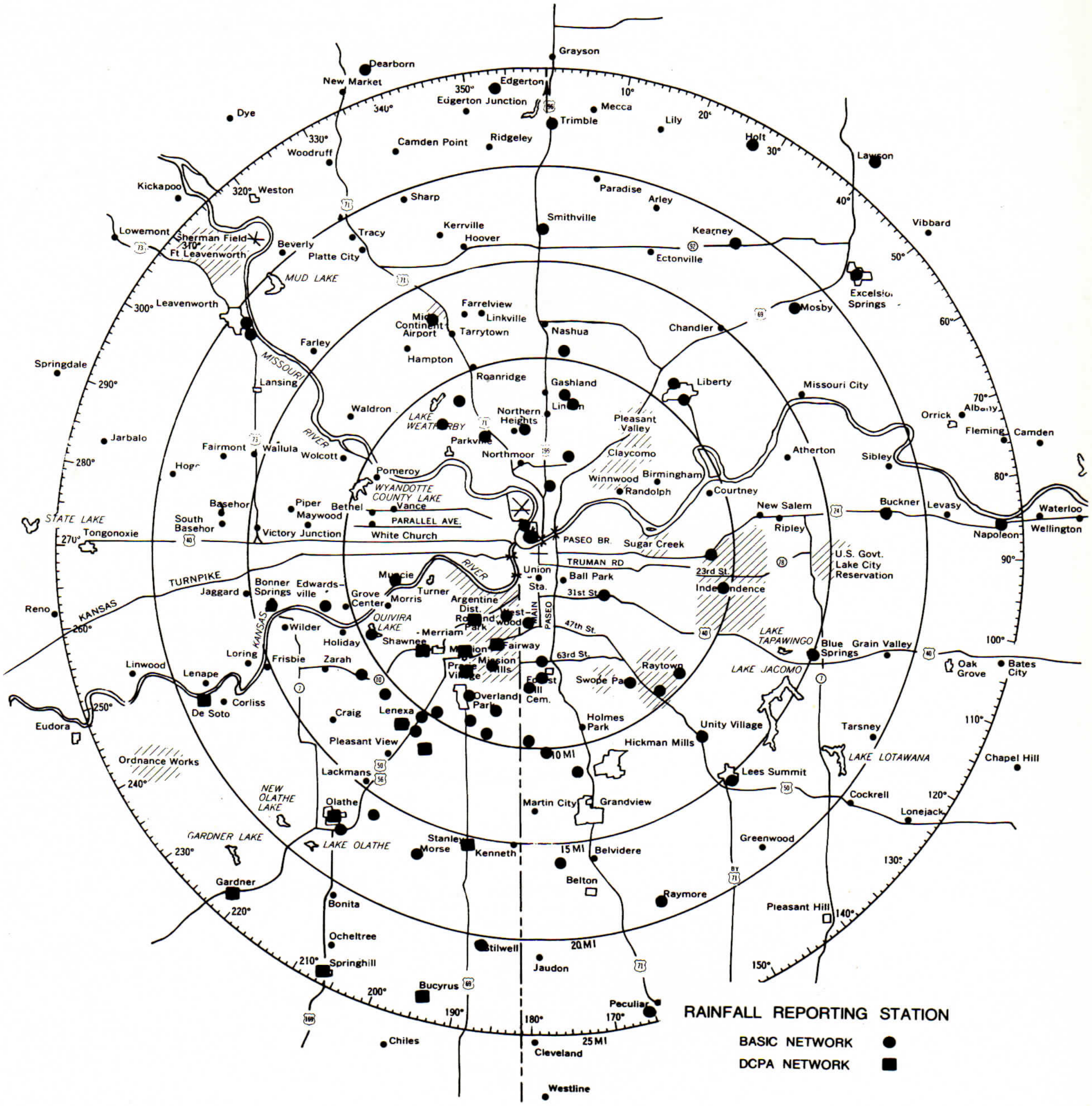

Figure 19. Hydrologic Reporting Network for the Greater Kansas City Area.

FINDINGS AND RECOMMENDATIONS

Finding 1: The Kansas City radar operator was not notified by any adjacent radar office of strong thunderstorm cells located within the ground clutter pattern of his radar, nor were they asked to do so.

Recommendation: NOAA NWS Radar offices should again be reminded of both the importance and written requirement for alerting adjacent radar sites of thunderstorm cells within their ground clutter pattern, and a radar office, suspecting such cells, should seek help if it is not forthcoming.

Finding 2: The Video Integrator and Processor with the Topeka Radar was not operating during the flash-flood event of September 12.

Recommendation: No recommendation can be made as established procedures were being followed to attempt to isolate and correct the problem. The VIP was returned to operational status about 2:00 P.M. on the 13th.

Finding 3: The severe ground clutter pattern associated with the Kansas City Radar impaired the ability of the radar operator to detect strong thunderstorm cells over the densely populated metropolitan area. It also greatly reduces the area of usable D-RADEX data, even when that equipment operates properly.

Recommendation: NOAA NWS should relocate the Kansas City WSR-57 Radar from the present site to a location at least 10 miles away from the metropolitan area. This would serve to both reduce the ground clutter pattern and remove the metropolitan area from the radar blind spot. (Because the move of the radar to Kansas City International Airport is already planned for late 1978, every effort should be made to prevent delays in this schedule.)

Finding 4: MDR totals for the area most devastated by the flash floods did not reach an alert level of around 20 until the flash flooding had occurred.

Recommendation: NOAA NWS warning offices should be informed that MDR data should not be solely (or blindly) relied on as a major flash-flood alert or warning tool; especially for small, fast-rising streams. In fact, dependence upon these data alone may be misleading. More emphasis should be placed on antecedent meteorological and hydrological conditions, flash-flood guidance values, and instantaneous rainfall rates as determined from VIP data as they are available.

Finding 5: In spite of extensive storm spotter and hydrologic networks and communications systems for obtaining public or other reports, very few such reports were received at NSSFC in time to accelerate either the initial issuance of warnings or the extension of warnings to other counties. Also, too few reports were relayed to NSSFC to allow those on duty to fully assess the magnitude of the flooding event until after much of the damage had been done. Further, too few reports were received to allow for early identification of the worst flood areas and to tailor followup warnings or statements to highlight these.

Recommendation: NOAA NWS should see that:

(A) Further coordination with local officials and training of storm spotters emphasize the critical importance of initial reports of heavy rainfall as well as status reports during events such as heavy rains. Rain gages should be provided to facilitate prompt observation and reporting or rainfall intensities.

(B) NSSFC establishes procedures for logging storm spotter or other reports to assure that all such reports, regardless of their source, are consolidated and made available to the warning coordinator on duty.

Finding 6: Information provided by SFSS to the collocated NWS Forecast units prior to and during the Kansas City flood was timely and accurate. The early recognition of the boundary that had been left by the previous night's thunderstorm activity in northern Missouri identified a mechanism which had potential for initiating new thunderstorm development over an area where the ground was already saturated. This information, when incorporated with other data, contributed to the NWS decision to issue a local forecast early in the day for possible heavy rain. Later satellite data provided information that was instrumental in the issuance of a severe thunderstorm watch which included the Kansas City Metropolitan area.

The evaluation of the 7:30 P.M. photograph that gave new information concerning the southward shift of the axis of thunderstorm development, coupled with supporting evidence from the radar operator, suggested the potential for heavy rain in the Kansas City area was increasing with time.

The SFSS meteorologists maintained a close surveillance of precursory conditions as depicted in the satellite imagery and continuously provided the NWS units with their current interpretation of the data.

Recommendation: The NESS SFSS meteorologists on duty should be given appropriate recognition for their supportive efforts.

CHAPTER 3.

METEOROLOGICAL CONDITIONS

As stated earlier, September 12, 1977, was very unusual in Kansas City, Mo., because on that day there were two separate, record-setting 6-hour rain events. While it is not rare in the Great Plains in the warm season for very heavy rain to fall on successive nights, it is extremely rare to have both events maximize at the same location as happened at Kansas City. Not only were these two events in the same metropolitan area, but both maximized at the same point in the area. This caused the second rain to fall on saturated soil, run off rapidly, and bring about the severe flooding.

Both events yielded about the same maximum rainfall observed at 6 to 7 inches 152 - 178 mm) in a 6-hour period. The first was midnight to 6:00 A.M. with the second from about 8:00 P.M. to shortly after midnight. The second event lasted less than 6 hours but gave the larger rain amounts. There was an observed maximum for the 30- to 36-hour storm period of over 16 inches (406 mm). There was sunshine in the afternoon between the two events, and there were sizable differences in the "cause" of the two events.

Both events were in air that was unstable and thus conducive to thunderstorms, and in air with a high moisture content and thus conducive to heavy rain from the thunderstorms. Figures 20 and 21 show the surface and 500-mb charts respectively for Monday morning (between the two events) as taken from the Daily Weather Map series. The main features are: (a) the weak surface warm front southwest of Kansas City; (b) the weak surface low and cold front in Kansas forecast to move slowly towards Kansas City; and (c) the weak short wave trough aloft over Colorado also forecast to move toward Kansas City to help lift the air over Kansas City.

The quantitative precipitation forecasts, both subjective and from numerical modeling, gave the general character of these heavy rains for both events by having sizable amounts of precipitation in the Kansas City area and having precipitation maxima near Kansas City in a large-scale sense. However, neither verified well enough in the smaller scale sense to truly indicate the magnitude of either event. The smaller scale events were the key to forecasting and warning of the flash flood.

In the first event, the low-level winds called the "low-level jet," which so characteristically reach a prominent maximum at night in the Great Plains, flowed up over the warm front southwest of Kansas City, and the rain amounts maximized north of the front where during the night the axis of the low-level jet (the strongest winds) impinged on the front.

The rain-cooled air of the first event (as described earlier in the section on Satellite Data) was a major factor in the second event later that day. This is because its southern boundary, which extended about from St. Louis to a bit south of Kansas City and into eastern Kansas, and was seen clearly in satellite pictures, either reinforced the warm front or became the

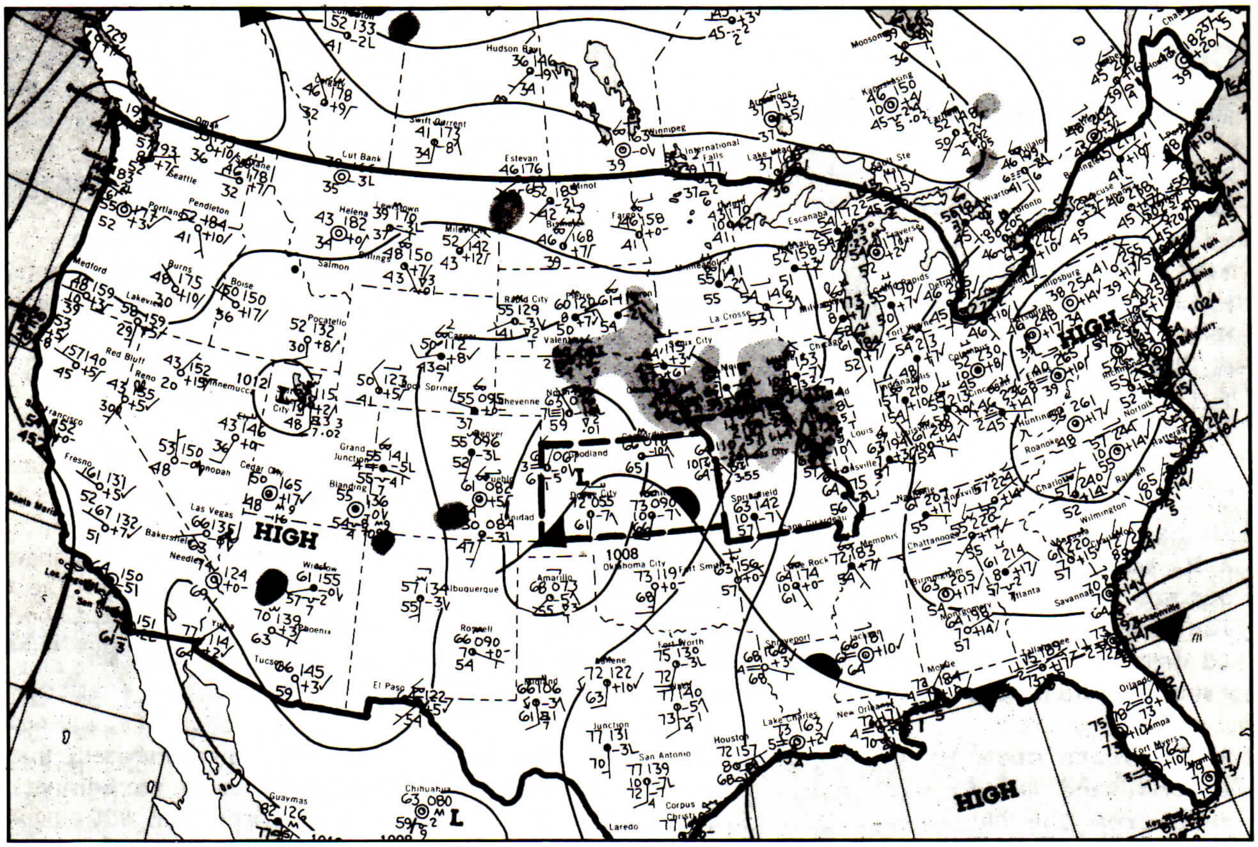

Figure 20. Surface Chart at 7:00A.M. CDT, September 12, 1977.

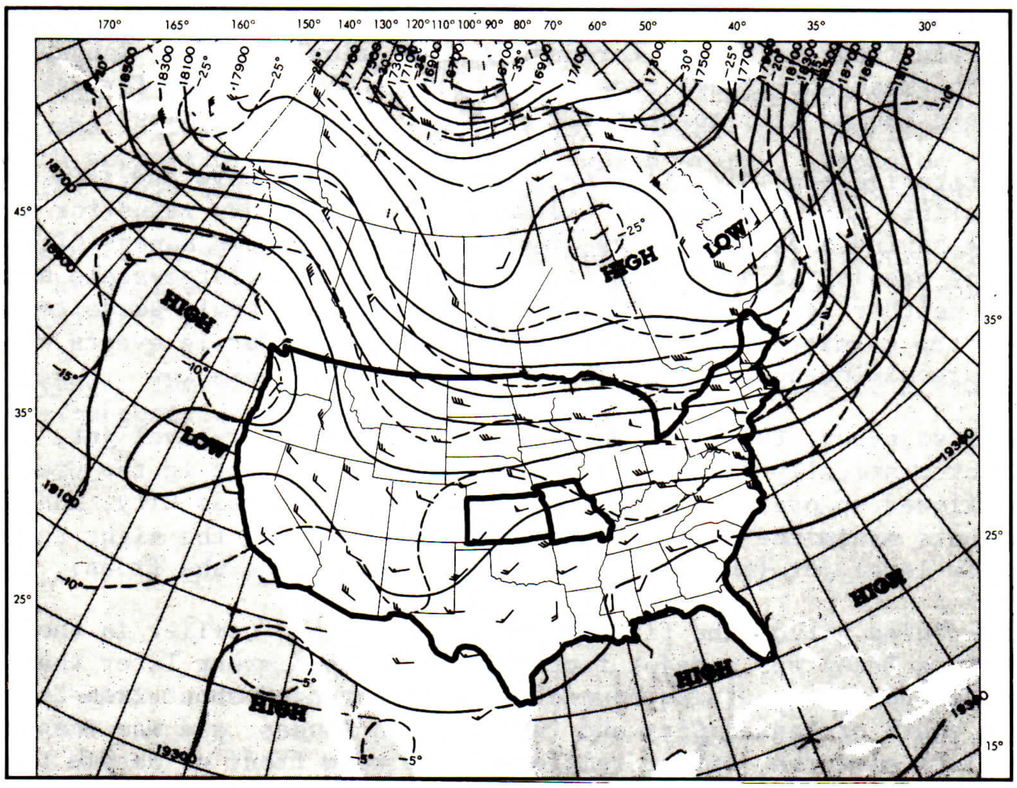

Figure 21. 500-mb Chart at 7:00A.M. CDT, September 12, 1977.

boundary of importance. The low-level jet was less important this time as it was blowing more parallel to this rain-cooled air boundary. Instead, the thunderstorms started about where the rain-induced boundary interacted with the cold front over Kansas which was advancing toward Kansas City during the sunny interval between these two rain events. The heaviest rainfall intensities were near the intersection of these two lines, and the precipitation maximized at Kansas City around the time the intersection got there.

In the Great Plains it is not uncommon for a flood in which the low-level winds are a prime factor to be brought about by rains on more than one night. The flood in July 1951 in Kansas and that on July 1, 1975, in North Dakota are examples. Both had at least three consecutive nights of heavy rain. However, the 1977 Kansas City flood was unusual even in that sense since the heaviest rains both nights were at almost exactly the same location, and this is the point that made it so devastating. With drainage basins as small as those involved, a shift of the heaviest rain of either event of only a few miles (so they weren't coincident) would have considerably alleviated or even prevented the flood. Another detail of significance is that the axis of heavy rain in the second event lay WSW-ENE which is along the line of Brush Creek and the other small basins in the Kansas City area, and along the line of radar echo movement. This allowed several thunderstorms to traverse the basins at speeds a bit higher than that generally associated with very large rainfall amounts as the line moved slowly across the basins. Thus the higher than usual winds aloft were not as critical as they would have been with a different orientation of the line. These details are on a scale that cannot yet be predicted with much lead time.

An examination of the publication "The Climate of Kansas" indicated that September is the month of maximum frequency of heavy rains of 5 inches (127 mm) or more in 24 hours from the start of record keeping through 1946. The next highest month is June.

FINDINGS AND RECOMMENDATIONS

Finding 1: Quantitative Precipitation Forecast (QPF) guidance products, while useful, are not adequate to the flash-flood task because they do not forecast the really unusual smaller scale events and they are not in the best increments of time.

Recommendation: NOAA NWS should produce forecasts in terms of 3-hour periods to match the 3-hour period used by the River Forecast Centers in their flash-flood guidance indices. (To alleviate some of the statistical problems in treating periods as short as 3 hours, the forecasts should be for the largest 3-hour amount in a 12-hour period; perhaps not even the standard 12-hour periods currently used, and possibly only one such period needs to be forecast because of the very short-term skill of such extreme forecasts. To maximize the size of the observed 3-hour amounts for use in an objective approach, hourly data should be used instead of reported 3-

hour amounts. This approach would let the National Meteorological Center guidance forecaster concentrate on the QPF potential, while letting the local offices concentrate on the timing.)

CHAPTER 4.

WATCH AND WARNING DISSEMINATION AND USER REACTION

The National Severe Storms Forecast Center in Kansas City is a unique forecast office in NWS. Not only does it have nationwide responsibility for forecasting severe local storms and producing the national weather summaries, but it also has some NWS Central Region aviation responsibilities, as well as serving the important function as the local Weather Service Office for the Kansas City area. In its local capacity it has forecast responsibility for Missouri Zones 17 and 18 and county warning responsibility for 31 counties in Missouri and 6 counties in Kansas. As part of its disaster preparedness responsibilities, every county was visited during the past year. The County CD Director and the Sheriff were contacted; if no county civil defense organization existed, then only the Sheriff was visited.

While the primary emphasis was on tornadoes and severe thunderstorms, the potential for flash floods and their effects were also discussed.

Watches, Warnings, and Statements

The aviation forecaster has the responsibility for making the Missouri Zone 17 and 18 forecasts. Based on consultation with the Severe Local Storms forecaster and the SFSS meteorologists, and a study of the objective and subjective progs supplied by the National Meteorological Center, he decided to issue the following forecast at 10:30 A.M., Monday, September 12, 1977.

MISSOURI ZONE 17 AND 18 FORECASTS
NATIONAL WEATHER SERVICE KANSAS CITY MO
1030AM CDT MON SEP 12 1977

MO17
KANSAS CITY METRO FORECAST

FLASH FLOOD WATCH THIS AFTERNOON AND TONIGHT.
MOSTLY CLOUDY THIS AFTERNOON WITH A GOOD CHANCE OF SHOWERS AND POSSIBLY HEAVY THUNDERSTORMS. HIGH IN THE MID TO UPPER 70S.

PERIODS OF SHOWERS AND LOCALLY HEAVY THUNDERSTORMS LIKELY TONIGHT. LOW IN THE LOW 60S.

BECOMING PARTLY CLOUDY TUESDAY WITH A CHANCE OF SHOWERS AND THUNDERSHOWERS DURING THE MORNING. HIGH IN THE LOW TO MID 70S.

WINDS . . . SOUTHEASTERLY 10 TO 20 MPH THIS AFTERNOON WITH HIGHER GUSTS NEAR THUNDERSTORMS. . . SHIFTING TO NORTHWESTERLY 10 TO 15 MPH LATE TONIGHT.

PROBABILITY OF RAIN . . . 50 PERCENT THIS AFTERNOON . . . 70 PERCENT TONIGHT AND 40 PERCENT TUESDAY.

This Watch was followed by a special weather statement that described the events of the previous rainfall and continued the flash-flood warning issued at 4:55 A.M. until 2:00 P.M.

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE KANSAS CITY MO
1200PM CDT MON SEP 12 1977

SHORTLY AFTER MIDNIGHT A LARGE AREA OF WARM . . . MOIST AND UNSTABLE AIR REACHED THE KANSAS CITY METROPOLITAN AREA DUMPING UNBELIEVABLE AMOUNTS OF RAIN . . . FLOODING THE STREETS AND HIGHWAYS. MOTORISTS EXPERIENCED FLOODED STREETS AND MAJOR SLOWDOWNS ON THEIR WAY TO A NEW WORK WEEK.

HIGH WATER HAS BEEN REPORTED THRUOUT THE METROPOLITAN AREA BY THE FIRE AND POLICE DEPTS.
INDEPENDENCE . . . STANDING WATER OF 1 TO 2 FEET IN SOME AREAS.
69TH AND NORTH OAK . . . 1 TO 2 FEET OF WATER.
LEAVENWORTH . . . WATER REACHING THE WINDOWS OF PARKED CARS.

A FLASH FLOOD WARNING IS IN EFFECT UNTIL 2 PM THIS AFTERNOON WITH THE POSSIBILITY OF EXTENDING THIS THRUOUT THE EVENING AS STORMS CONTINUE TO DEVELOP TO THE WEST OF THE KANSAS CITY AREA.

Continuing to observe the developing weather situation and the satellite photographs, the SELS forecaster issued a severe thunderstorm watch at 1:00 P.M. that included the Kansas City area. This watch and the flash flood watch were highlighted in the 4:30 P.M. forecasts.

MISSOURI ZONE 17 AND 18 FORECASTS
NATIONAL WEATHER SERVICE KANSAS CITY MO
430PM CDT MON SEP 12 1977

MO 17
KANSAS CITY METRO FORECAST

SEVERE THUNDERSTORM WATCH TIL 8 PM THIS EVENING. FLASH FLOOD WATCH TONIGHT. OTHERWISE . . . PERIODS OF SHOWERS AND THUNDERSTORMS WITH LOCALLY HEAVY RAIN TONIGHT. LOW IN THE LOWER 60S.

MOSTLY CLOUDY WITH A GOOD CHANCE OF SHOWERS AND THUNDERSHOWERS TUESDAY, HIGH IN THE LOWER 70S.

PARTLY CLOUDY WITH A CHANCE OF SHOWERS TUESDAY NIGHT. LOW IN THE UPPER 50S.

MOSTLY SUNNY WEDNESDAY, HIGH IN THE 70S.

WINDS . . . SOUTHERLY 10 TO 20 MPH WITH STRONGER GUSTS NEAR THUNDERSTORMS BECOMING NORTHERLY 10 TO 15 MPH LATE TONIGHT AND TUESDAY.

PROBABILITY OF RAIN . . . 80 PERCENT TONIGHT AND 50 PERCENT TUESDAY.

Thunderstorms began to increase in intensity and area of coverage in northeast Kansas after 4:30 P.M. and then they moved into northwest Missouri. Hail up to 1 inch (25 mm) in diameter was reported at 6:00 P.M. 12 miles (19 km) north of Kansas City.

After a report of 1 inch (25 mm) of rain in 30 minutes at Platte City, the following flash-flood warning was issued.

BULLETIN
FLASH FLOOD WARNING
IMMEDIATE BROADCAST REQUESTED
NATIONAL WEATHER SERVICE KANSAS CITY MO
545PM CDT MON SEP 12 1977

THE NATIONAL WEATHER SERVICE HAS ISSUED A FLASH FLOOD WARNING EFFECTIVE UNTIL 8 PM CDT FOR PERSONS IN PLATTE AND BUCHANAN COUNTIES IN MISSOURI AND DONIPHAN COUNTIES IN KANSAS. HEAVY RAIN WAS INDICATED BY RADAR TO BE MOVING INTO THESE COUNTIES AT 530 PM CDT.

PLATTE CITY MISSOURI . . . IN PLATTE COUNTY MISSOURI REPORTED 1 INCH RAIN IN 30 MINUTES. THESE RAINS WILL BE FALLING ON SOIL THAT IS ALREADY SATURATED AND IN AREAS WHERE STREAMS ARE ALREADY NEAR TO OR ABOVE BANKFUL.

As the thunderstorm activity moved slowly eastward and then southward, the following two warnings were issued:

BULLETIN
FLASH FLOOD WARNING
IMMEDIATE BROADCAST REQUESTED
NATIONAL WEATHER SERVICE KANSAS CITY MO
645PM CDT MON SEP 12 1977

THE NATIONAL WEATHER SERVICE HAS ISSUED A FLASH FLOOD WARNING EFFECTIVE UNTIL 9 PM CDT FOR PERSONS IN CLAY . . . CLINTON . . . CALDWELL . . . AND RAY COUNTIES IN MISSOURI.

HEAVY RAIN WAS INDICATED BY RADAR IN CLAY AND CLINTON COUNTIES IN MISSOURI AT 630 PM CDT.

VERY POOR VISIBILITY AND LOCAL FLOODING HAS BEEN EXPERIENCED WITH THESE STORMS.

BULLETIN
FLASH FLOOD WARNING
IMMEDIATE BROADCAST REQUESTED
NATIONAL WEATHER SERVICE KANSAS CITY MO
745PM CDT MON SEP 12 1977

THE NATIONAL WEATHER SERVICE HAS ISSUED A FLASH FLOOD WARNING EFFECTIVE UNTIL MIDNIGHT CDT FOR PERSONS IN DONIPHAN . . . LEAVENWORTH . . . WYANDOTTE AND JOHNSON COUNTIES IN KANSAS . . . AND BUCHANAN . . . PLATTE . . . CLINTON . . . CLAY . . . JACKSON . . . CALDWELL AND RAY COUNTIES IN MISSOURI.

HEAVY RAIN CONTINUES TO DEVELOP ACROSS EASTERN KANSAS AND WEST CENTRAL MISSOURI. INDIVIDUAL STORMS MOVE TO THE EAST WHILE THE AREA SINKS SLOWLY SOUTHWARD IN EASTERN KANSAS.

Throughout the developing situation the radar operator was concerned about the potential threat of serious flash flooding and all on duty agreed that strong, assertive language was needed.

The following special statement by the public service meteorologist fulfilled that need:

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE KANSAS CITY MO
845 CDT MON SEP 12 1977

VERY HEAVY RAINS HAVE CONTINUED TO DEVELOP ACROSS EASTERN KANSAS AND WESTERN MISSOURI DURING THE AFTERNOON AND EVENING HOURS AND HAVE MOVED INTO THE KANSAS CITY METROPOLITAN AREA.

THE HEAVY RAINS LAST NIGHT . . . OF 4 TO 6 INCHES . . . SATURATED THE SOIL . . . OVERLOADED THE STORM SEWERS AND RAISED SMALL STREAMS TO NEAR BANKFULL.

THESE LATEST RAINS ARE PRODUCING A VERY DANGEROUS PROBLEM TO MOTORISTS AND PERSONS IN LOW LYING AREAS. ANYONE ADJACENT TO SMALL STREAMS AND/OR DRAINAGE SYSTEMS SHOULD BE PREPARED TO MOVE OUT QUICKLY IF THE RAINS PERSIST AND THE STREAMS BEGIN TO OVERFLOW.

DO NOT TAKE THIS SITUATION LIGHTLY AS IT IS POTENTIALLY VERY DANGEROUS TO LIFE AND PROPERTY.

Dissemination

Because the flash-flood disaster occurred in the Kansas City Metropolitan area, the local dissemination methods were the most pertinent to survey. They are:

- NOAA Weather Radio (NWR)--The Kansas City Metropolitan area is served by Station KID-77, which operates on a frequency of 162.55 MHz with a power output of 1000 watts. From the transmitter located atop the Federal Building at 601 East 12th Street, the useful range is about 40 miles (64 km). (NSSFC also operates the NWR station serving the St. Joseph, Mo., area.) The NWR system is equipped with warning alarm capability.

- Metropolitan Emergency Telephone System (METS)--This is a telephone hotline system and links the local law-enforcement and Civil Defense offices. (See figure 22.) The user has the capability to talk to a certain location or to everyone simultaneously. Each station has a speaker and handset.

- Tornado Emergency Warning Network (TEWN)--This is a local radio- and TV-sponsored network. It provides a direct broadcast link between NWS and each broadcaster on the line. The control panels have buttons marked:

  Ready Position, CD Broadcast, All Clear, Tornado-KC, Tornado-100 Miles, Thunderstorm KC, General Information, Override Alarm

  The broacaster has the option of going "live" or taping the transmission.

  Current subscribers are:

  KCMO-TV, KCMO-AM, KCEZ-FM
  WDAF-TV, WDAF-AM, KYYS or KY 102-FM
  KPRS-AM/FM
  KCKN-AM/FM
  KMBA-TV
  WHB-AM
  KMBC-TV
  KMBZ-AM, KMBR-FM
  KCPT-TV

- NOAA Weather Wire (NWW)-Local Loop--This is a teletypewriter system and is the method used to disseminate written weather information to the news media for dissemination to the public. There are 16 local radio and TV subscribers.

- National Warning System (NAWAS)--This is an intrastate and interstate hotline telephone system operated by the Defense Civil Preparedness Agency (DCPA) and connects warning points in each State and between States. NSSFC has NAWAS drops on the Missouri, Kansas, and Iowa systems. The drop consists of a handset and a loudspeaker that constantly monitors the circuit.

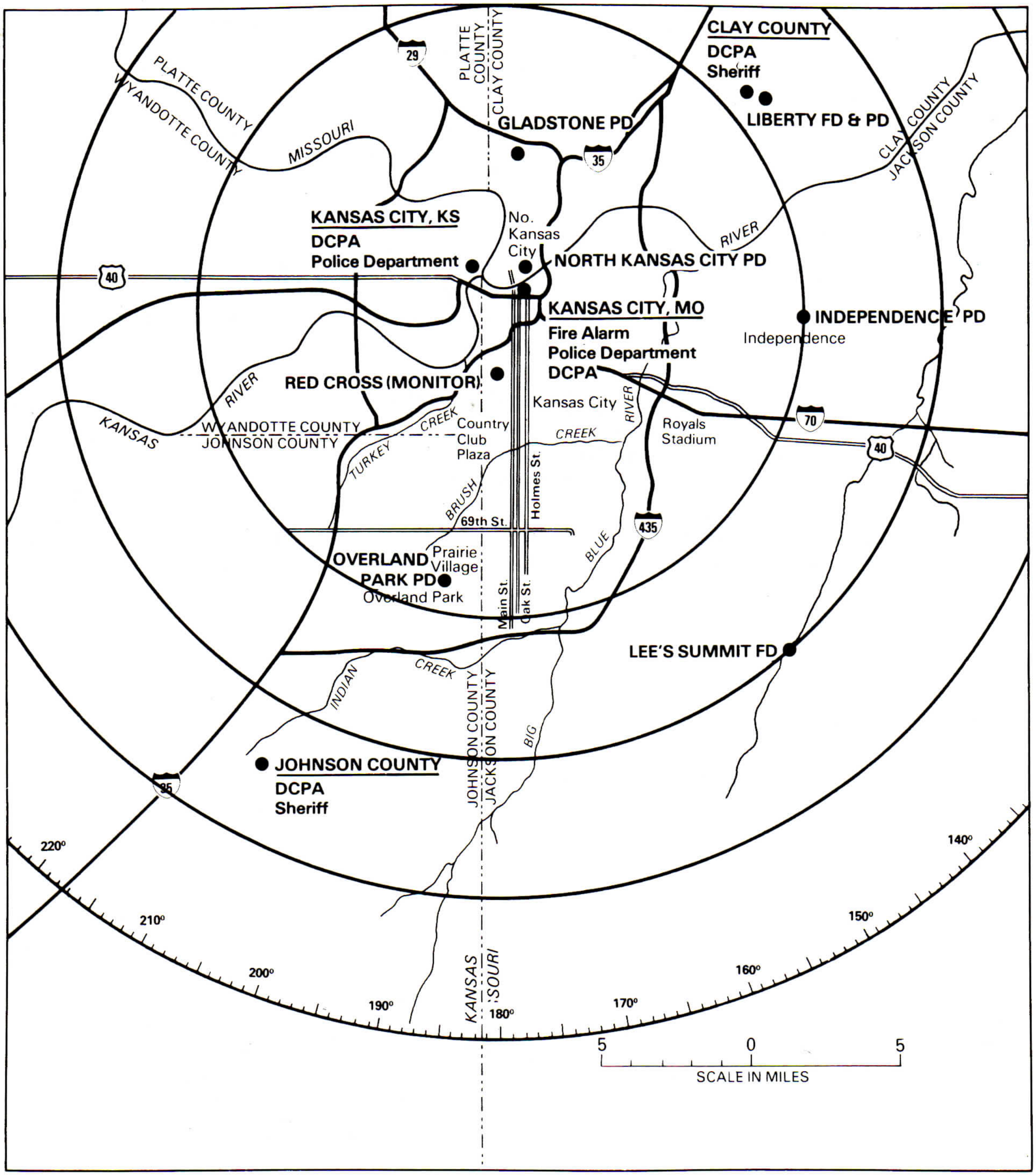

Figure 22. Kansas City Metropolitan Emergency Telephone System(METS).

All flash flood warnings were broadcast live and simultaneously over the NWR (with warning alarm), the METS (preceded by bells), and the TEWN line (Microphone and General Information buttons pressed), with 30-second lead time. The 8:45 P.M. Special Weather Statement was given the same dissemination. Table 2 shows the specific dissemination times of the key warnings and statements.

Local TV and radio dissemination of the flash-flood watches, warnings, and special statements was patterned after their excellent (immediate) dissemination procedures for tornadoes and severe thunderstorms. Most radio and TV stations are on either the TEWN line or the NWW. Two radio stations use transmissions from the Kansas City NWR KID-77 exclusively; one all-news radio station allows itself to be automatically interrupted when the NWR warning alarm is sounded.

The three TV stations visited use one of two methods to alert viewers: A slide denoting "Weather Bulletin" with a voice override or a visual "crawl" across the bottom of the screen. Their station policies are to interrupt regular programing any time they have weather bulletins.

One TV channel was knocked off the air by lightning from 9:32 P.M. to 10:45 P.M., but fortunately this was after broadcasting the important Special Weather Statement issued at 8:45 P.M.

Thousands of area residents and businesses were without power. Repair crews were still working to repair damage and restore power caused by the first burst of rainfall when the second deluge brought on a new series of power outages. At one time, Kansas City Power and Light officials estimated that 8,000 to 10,000 customers were without service. Southwestern Bell estimated 10,000 phones in Missouri and 6,000 phones in Kansas were knocked out of service.

User Reaction

A key link in the warning chain from NWS to individuals is the activation of the Emergency Operating Centers (EOC) of the various city and county governments. These centers can set in motion actions that save lives. One element making EOC's effective is that each maintains a centralized communications center. A list of EOC's showing their times of activation is given below:

Kansas City, Mo.--Because of the Flash Flood Watch issued September 12 at 10:30 A.M. and continued at 4:30 P.M., the Director of Emergency Preparedness alerted city department heads to be prepared to return, if needed. The recall was initiated at 11:00 P.M., and the Command Post was opened at 1:30 A.M., September 13.

Kansas City, Kans. (Wyandotte County)--EOC began operations at 5:30 A.M., September 12, and was manned until 4:00 A.M. the morning of September 13. City and County Commissioners were in the EOC.

Table 2.--Dissemination times of warnings and statements
(All times CDT September 12, Monday)

Product	NWR (Live)	NWR (Tape)	TEWN	METS	NWW (Local Loop)	NAWAS
Flash-Flood Warning for Platte, Buchanan (Mo.), and Doniphan (Kans.) Counties	5:48 PM	5:55 PM	5:48 PM	5:48 PM	5:52 PM*	5:55 PM
Flash-Flood Warning for Clay, Clinton, Caldwell, and Ray (Mo.) Counties	6:51 PM	6:45 PM	6:51 PM	6:51 PM	6:45 PM*	6:53 PM
Flash-Flood Warning for Doniphan, Leavenworth, Wyandotte, and Johnston (Kans.) Counties Buchanan, Platte, Clinton, Clay, Jackson, Caldwell, and Ray (Mo.) Counties	7:43 PM	7:55 PM	7:43 PM	7:43 PM	7:54 PM*	7:52 PM
Special Weather Statement ". . . do not take this situation lightly."	8:53 PM	8:50 PM*	8:53 PM	8:53 PM	8:48 PM*	8:54 PM

*Estimated times.

Independence, Mo.--The EOC recall was initiated at 6:30 P.M., September 12, with the recall of all off-duty police, firemen, and public works employees. This provided an army of about 650 people.

Johnson County, Kans.--EOC operated from the morning through 11:00 P.M. on September 12.

Clay County, Mo.--EOC operated from 3:00 A.M., September 12, until the evening of September 13.

Interviews with EOC operating officials indicated a need to disseminate the Flash Flood Watches and all Special Weather Statements over the METS systems. This would provide an additional means of alerting key officials to potential flooding problems.

The individual actions of police and firemen are credited with saving many lives. They worked valiantly to rescue persons trapped in cars and buildings.

In many instances citizens performed life-saving acts and also helped direct drivers away from flooded streets and low-lying intersections.

A crowd of about 15,000 at Royals Stadium had gathered to watch the Kansas City Royals baseball team play the Oakland A's. At 7:46 P.M. the game was halted in the bottom of the first inning. Veteran observers said it was the hardest rainfall ever to hit the stadium. The game was officially called off at 8:45 P.M.; those that remained struggled to their cars in the downpour and attempted to drive home.

Table 3 shows a breakdown of the casualties and the activity of each of these individuals as interpreted from press and police accounts.

Most (68%) of the deaths were car-related, clearly showing the need to emphasize the danger of driving when an area is under a flash-flood warning, and especially of driving into moving water. Many instances were reported where motorists attempted to cross flooded streets and intersections when vehicles ahead of them had already stalled. One woman attributed this phenomenon to a "macho desire to show others he could do (get through a flooded area) when others couldn't!" It also was obvious from press accounts of rescues that many individuals stayed in their stalled vehicles too long and were swept away. Commercial towing companies reported towing over 2,000 automobiles after the flood. Many vehicles, of course, were parked and floated away or were in underground garages as the flood engulfed them, but a substantial number were being driven before getting into trouble.

There are also clear and present dangers from walking and from a desire to view the flooded area. The dangers inherent in these activities also need to be publicized during flash-flood watches and especially when warnings are issued. These flash-flood rules need to be an integral part of the warning package on all dissemination channels.

Table 3--Flood-related casualties

Activity	Number of deaths	Percentage
Driving a car or a passenger	17	68%
Viewing flood waters	2	8%
Walking	2	8%
Other		
Heart Attack	1	4%
Electrocution	1	4%
Unknown	2	8%
TOTAL	25	100%

In limited discussions with private individuals, it is apparent that the severity of the flooding situation was difficult for some to comprehend. One resident who lives near Brush Creek was "aware" of the situation, but could remember hearing only the Severe Thunderstorm Watch issued during the afternoon. She said, "Most people are not alarmed about a rise in Brush Creek as it is not an unusual occurrence . . ."

Most people took action only when water reached them. At the restaurant near Brush Creek, the managers and customers watched the water rise. There were reports that some "toasted the flood," as did hurricane parties along coastal areas. They watched cars float away. When water reached the door of the restaurant, the door was closed. When the water got high enough to break the windows, the customers and restaurant personnel evacuated via the back door to a higher level. The heavy rain discouraged them from leaving even as the water from Brush Creek rose higher and higher.

There is some evidence that a portion of the public did hear the flash-flood watches and warnings, but paid no attention to them because they had heard so many watches and warnings of all types before without personally experiencing any disastrous consequences. This, of course, is a common problem all NWS offices face -- the "cry wolf" syndrome. It is a difficult problem to deal with, but efforts must be made to get individuals to understand the fact that the ability of meteorologists to predict severe weather of any type is limited. Therefore, overwarning has to be built into the watch and warning systems to ensure that virtually all disastrous weather situations are covered.

While NWR offers an excellent method to disseminate weather information instantaneous and continuously, it was evident from a very limited sampling that this system is still not widely known or used in the community. Much more needs to be done locally and nationally to bring the NWR program to its full potential.

One device with potential life-saving capability is a flash flood alarm system. One relatively inexpensive flash flood alarm system is a simple electromechanical device with three main elements: An automatic water level sensor at a point upstream from the flood-prone area, and intermediate station located where both commercial power and telephone services are available, and a community-alarm station from which warnings are distributed to users.

The upstream station has an enclosed float device, which, when lifted by the critical level or rising water, activates an electric current. This device may be mounted on an appropriate site such as a bridge support. When the rising water triggers the sensor, a signal is sent to the intermediate station which relays the signal to an alarm in a facility manned 24 hours a day, 7 days a week, such as a police or fire station. The alarm, a flashing light and buzzer, alerts those on duty to the upstream rise. It is then the responsibility of the local public officials to take the necessary action in accordance with their Local Preparedness Plan to protect lives and property.

As part of an NWS flash-flood demonstration project, a flash-flood alarm system was installed in 1974 on Indian Creek at Holmes Road, 1.53 miles (2.5 km) upstream from its confluence with the Big Blue River. The alarm signal is transmitted to the Fire Alarm Exchange at 414 East 22d Street. This demonstration system was turned over to Kansas City in June 1976.

The flash-flood alarm did not sound automatically on the night of September 12. A subsequent check revealed that the failure of the system to activate was caused by a short in the sensor cable.

FINDINGS AND RECOMMENDATIONS

Finding 1: There was timely issuance of a flash-flood watch about 10 hours before the Monday evening, September 12, 1977, rainfall. Followup warnings were very good.

A Special Weather Statement using strong, assertive language was released to attest to the urgency of the situation even though exact rainfall information was unavailable to the warning team at the time.

Existing procedures were followed except for the inadvertent omission of the "call to action" sentence of the format.

Finding 2: The Metropolitan Emergency Telephone System (METS) is an effective way to disseminate watch and warning information and in this case was used for dissemination of the flash-flood warnings.

Recommendation: NOAA NWS should instruct NSSFC to institute procedures to disseminate all flash-flood watches and special statements over METS.

Finding 3: The broadcast media did a timely, effective job of disseminating the flash-flood watches, warnings, and special statements.

Recommendation: NOAA NWS should congratulate the broadcast media on its performance and call attention to the important roll they play in warning dissemination.

Finding 4: The public knowledge of the NWR station in Kansas City needs to be strengthened.

Recommendation: NOAA NWS needs to be continually publicizing the NWR program, and a full-fledged public education program needs to be undertaken to fully realize the potential of the expanding system.

Finding 5: Many people who experienced the flood showed they did not accept the reality of the situation with which they were confronted.

They were unable to take rational actions under the dangerous conditions they faced. Drivers attempted to cross flood areas when others before them were unsuccessful and swept away. People tended to take action based on prior experience. If the experience was lacking, proper actions were not taken.

Recommendation: NOAA NWS should take a number of steps to increase the effectiveness of disaster preparedness activities in the flash-flood area:

(A) Each NWS office with county warning responsibility should work with local officials by providing, where appropriate and requested, a local flash-flood warning program or assist in setting up flash-flood alarms. Existing systems should be revisited and drills held at least yearly.

(B) Mass media and school systems should be enlisted to help educate the public to the danger of flash floods and proper, life-preserving measures.

(C) NWS should institute procedures routinely to transmit flash-flood safety rules on NWW with flash-flood watches and/or warnings. Appropriate safety rules should also be broadcast on NWR.

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AF	Air Force
AFB	Air Force Base
AMOS	Automatic Meteorological Observing Station
CD	Civil Defense
CDT	Central Daylight Time
cfs	cubic feet per second
cms	cubis meters per second
DCPA	Defense Civil Preparedness Agency
D-RADEX	Digitized Radar Experiment
EOC	Emergency Operating Center
FSS	Flight Service Station
km	kilometer
LAWRS	Limited Aviation Weather Reporting Station
m	meter
mb	millibar
MDR	Manually Digitized Radar
METS	Metropolitan Emergency Telephone System
mm	millimeter
NAWAS	National Warning System
NESS	National Environmental Satellite Service
NOAA	National Oceanic and Atmoshperic Administration
NSSFC	National Severe Storms Forecast Center
NWS	National Weather Service
NWR	NOAA Weather Radio
NWW	NOAA Weather Wire
progs	prognostic charts
QPF	Quantitative Precipitation Forecast
SAWRS	Supplementary Aviation Weather Reporting Station
SELS	Severe Local Storms
SFSS	Satellite Field Service Station
TEWN	Tornado Emergency Warning Network
U/A	Upper Air
USGS	United States Geological Survey

VIP	Video Integrator and Processor
WATS	Wide Area Telephone Service
WSR-57	Weather Surveillance Radar, 1957
WSR-74C	Weather Surveillance Radar, 1974 C-Band