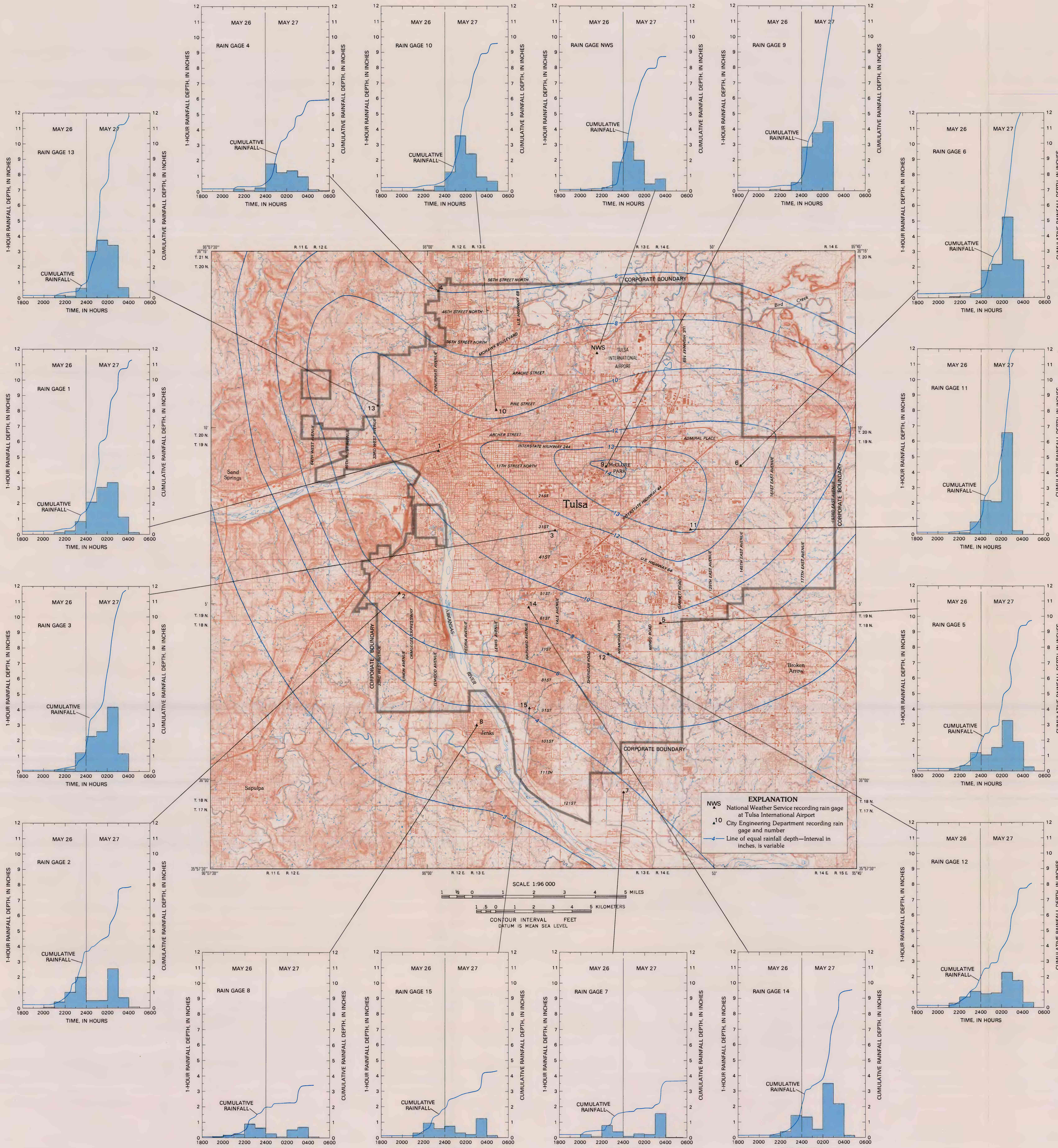

Map *A*.—Showing location of recording rain gages with corresponding rainfall histograms and mass curves, and lines of equal rainfall depths for the storm of May 26–27, 1984.

INTRODUCTION

The greatest flood disaster in the history of Tulsa, Oklahoma occurred during 8 hours from 2030 hours May 26 to 0430 hours May 27, 1984, as a result of intense rainfall centered over the metropolitan area. Storms of the magnitude that caused this flood are not uncommon to the southern great plains. Such storms are seldom documented in large urban areas. Total rainfall depth and rainfall distribution in the Tulsa metropolitan area during the May 26–27 storm were recorded by 16 recording rain gages. This report presents location of recording rain gages with corresponding rainfall histograms and mass curves, lines of equal rainfall depth (map ***A***), and flood magnitudes and inundated areas of selected streams within the city (map ***B***).

The limits of the study areas (fig. 1) are the corporate boundaries of Tulsa, an area of about 185 square miles. Streams draining the city are: Dirty Butter, Coal, and Mingo Creeks which drain northward into Bird Creek along the northern boundary of the city; and Cherry, Crow, Harlow, Joe, Haikey, Fry, Vensel, Fred, and Mooser Creeks which flow into the Arkansas River along the southern part of the city. Flooding along Haikey, Fry, Fred, Vensel, and Mooser Creeks was not documented for this report. The Arkansas River is regulated by Keystone Dam upstream from Tulsa (fig. 1). The Arkansas River remained below flood stage during the storm.

Flooded areas in Tulsa (map ***B***) were delineated on the topographic maps using flood profiles based on surveys of high-water marks identified immediately after the flood. The flood boundaries show the limits of stream flooding. Additional areas flooded because of overfilled storm drains or by sheet runoff are not shown in this report.

Data presented in this report, including rainfall duration and frequency, and flood discharges and elevations, provide city officials and consultants a technical basis for making flood-plain management decisions.

ACKNOWLEDGMENTS

Recording rain-gage charts, surveyed high-water marks and flood-boundary data were provided by Ruben Haye, Jr. of the City Engineering Department, City of Tulsa, Oklahoma. Additional rainfall information was provided by Eldon Beard of the Oklahoma City office of the National Weather Service. The lines of equal rainfall depths and flood-damage information were provided by the Tulsa office of the U.S. Army Corps of Engineers.

STORM RAINFALL

Rainfall data were recorded by the National Weather Service at the Tulsa International Airport and by the City Engineering Department at 15 recording rain gages located throughout the city.

About 2.51 inches of rain fell at the Tulsa International Airport during the evening of Saturday, May 26. From midnight May 26 until about 0430 hours on Sunday, May 27, an additional 6.23 inches of rain fell. The official recorded rainfall of 8.74 inches exceeded the previous record for 24 hours recorded at Tulsa in July 1963 (7.54 inches).

Rainfall depths recorded by the rain-gage network varied from 3.4 inches in the southwest section of the city to more than 12 inches at 3 locations in the east-central section of the city. Twelve inches or more were recorded at 3 locations within the Mingo Creek basin by catchments that filled, then overflowed. These catchments overflowed at about the same time (0300 hours on May 27). Rain-gage data from the surrounding recorders indicated that the storm continued until about 0430 hours with as much as 2.5 inches of additional rainfall. Thus, several unofficial reports of as much as 15 inches of rainfall appear plausible. These unofficial rainfall depths were considered during preparation of the map showing lines of equal rainfall depth. Total rainfall and maximum hourly accumulation for each recording rain gage are shown in table 1.

The unusually large total rainfall accumulations were the result of serial generation of large thunderstorm cells over the Tulsa metropolitan area for about 7 hours with little or no movement. It is estimated that about 89,000 acre-feet of rainfall fell within the city during the storm. In comparison, this volume exceeds the 79,567-acre-foot capacity of Lake Eucha, Tulsa's largest water-supply reservoir (fig. 1). Rainfall depths recorded during this storm have been exceeded in Oklahoma only by the 15.68 inches recorded at the National Weather Service rain gage at Enid, Oklahoma (fig. 1) in October 1973 (Bingham and others, 1974).

RAINFALL INTENSITY AND FREQUENCY

The maximum 1-hour rainfall intensity was 6.55 inches between 0200 and 0300 hours on May 27 at rain gage 11. The 1-hour, 100-year rainfall (4.1 inches) reported in Herschfield (1961) was exceeded at five rain gages. The 8-hour, 100-year rainfall intensity (6.80 inches) also was exceeded at 12 rain gages. The 100-year frequency for various rainfall durations within the Tulsa area (Hershfield, 1961) are shown in figure 2. The approximate area within the corporate boundary of Tulsa that received rainfall in excess of the 8-hour, 100-year rainfall is shown in figure 3.

EXTENT OF FLOODING IN TULSA

The boundaries of flooding in Tulsa are delineated on the topographic map (map ***B***). Flood boundaries shown on the map were transferred from aerial photographs (scale: 1 inch to 400 feet) showing flood-inundation boundaries and high-water mark data from field surveys conducted by the City Engineering Department and the U.S. Army Corps of Engineers, Tulsa District. A majority of the topographic maps were published in 1974, thus urban development, new highways or streets, and other changes in the Tulsa area after 1974 are not shown on the map.

FLOOD PEAK DISCHARGE

The rate of discharge of a stream is the volume of water that passes a given location in a specific period of time. The discharge rates at selected locations for this flood are expressed in cubic feet per second (ft^3/s) and represent the discharge occurring at the time of maximum flood stage.

Flood peak discharges were determined for nine sites within the corporate boundaries of Tulsa. Discharges were determined by indirect methods using hydraulic formulas for flow in open channels, flow over road embankments, and flow through contracted openings at bridges and culverts. A transit-stadia survey of each site was made to determine: (1) The flood peak water-surface profile as represented by high-water marks, (2) cross-sectional properties of the stream channel and flood plain, and (3) geometry of any bridge, culvert, or roadway embankment.

Unit discharge, which generally is expressed in cubic feet per second per square mile [$(ft^3/s)/mi^2$], is an indication of runoff intensity. During the May 26–27 flood, the unit discharge during peak runoff at the indirect-measurement sites ranged from 823 $(ft^3/s)/mi^2$ for Mingo Creek at East 46th Street North (site 1) to 4,920 $(ft^3/s)/mi^2$ for Mill Creek in McClure Park (site 2). Flood discharges, with corresponding unit discharges for each of the nine sites in Tulsa, are summarized in table 2.

Crippen and Bue (1977) developed an envelope curve on the basis of maximum floods in the Oklahoma, Texas, Missouri, and Kansas region (Region 9, of Crippen and Bue, 1977, pg. 11). Unit peak discharges of the 1984 Tulsa flood and the outstanding floods that have occurred in Oklahoma, as measured at gaging stations, are compared to a modified envelope curve (fig. 4). Because of the similarity in magnitude of rainfall and runoff for urban areas, unit peak discharges from the Enid, Oklahoma flood (Bingham and others, 1974); the Great Bend, Kansas flood (Clement and Johnson, 1982); and the Kansas City, Missouri flood (Becker and others, 1983), also are shown in figure 4.

FLOOD FREQUENCY

As applied to floods, recurrence interval is the average interval of time within which a given flood magnitude will be equaled or exeeded once. For example, a flood with a 100-year recurrence interval has a 1 in 100 chance, on the average, of occurring in any given year, or a frequency of 1 in 100 years. The fact that a major flood occurs in one year does not decrease the probability of a flood as great or greater occurring within the same year. Peak discharges and flood profiles for the 100-year flood have been developed and published in the Flood Insurance Study for the City of Tulsa (Federal Emergency Management Agency, 1985).

Flood peak discharges computed for nine sites in Tulsa after the May 26–27 flood were compared by ratio to those discharges used to develop the 100-year flood profiles for Tulsa streams (Federal Emergency Management Agency, 1985). The 100-year flood peak discharge comparisons (table 2) ranged from 0.74 (site 7) to 2.48 (site 2). At 7 of the 9 sites, peak discharge exceeded that of the 100-year flood discharge.

High-water marks were surveyed along the main stem of Mingo Creek and are compared to the 100-year flood profile developed for the main stem of Mingo Creek by the Federal Emergency Management Agency (1985), in figure 5.

FLOOD DAMAGE

Fourteen people died from effects of the storm, and many more were injured. More than 5,500 single and multifamily homes, and 7,000 vehicles were damaged or destroyed. Flood damage to private and public property totaled more than 180 million dollars (U.S. Army Corps of Engineers, 1985).

President Ronald W. Reagan issued a disaster declaration under Public Law 93–288, Disaster Relief and Assistance Act of 1974, to provide public assistance for Tulsa, Rogers, and Wagoner Counties on May 31, 1984. The President issued a major-disaster declaration for public assistance for Tulsa, Rogers, Wagoner, and Osage Counties on June 8, 1984.

SUMMARY

Rainfall depths exceeded the 100-year recurrence interval for durations of 1 to 8 hours throughout much of the Tulsa metropolitan area during the May 26–27, 1984 storm. Recorded rainfall depths have been exceeded in Oklahoma only by the October 1973 storm in Enid, Oklahoma (Bingham and others, 1974).

Flood discharges were determined for selected urban basins after the storm. Flood peak discharges were determined to be greater than the 100-year peak discharge at 7 out of 9 sites measured. The peak unit discharge of 4,920 $(ft^3/s)/mi^2$ computed for Mill Creek in McClure Park, Tulsa, exceeds any known unit discharge in Oklahoma.

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CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units, conversion factors for terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer ($km/^2$)
acre-foot	1,233	cubic meter (m^3)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01094	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

Table 1.—*Rainfall recorded in rain-gage network during storm of May 26–27, 1984*

Rain-gage number	Location	Total accumulation (inches)	Maximum 1-hour rainfall: Accumulation (inches)	Time May 27 (hours)	Ratio to 1-hour, 100-year rainfall frequency[1]	Remarks
NWS	National Weather Service at Tulsa International Airport	8.74	3.30	0015–0115	0.80	
1	Archer Street and Boulder Avenue	11.26	3.85	0030–0130	0.94	
2	West 51st Street South and Yukon Avenue	7.84	2.53	0200–0300	0.62	
3	East 31st Street South and Urbana Avenue	11.66	4.67	0145–0245	1.14	
4	East 51st Street North and Cincinnati Avenue	5.90	2.30	0030–0130	0.56	
5	East 62nd Street South and 101st East Avenue	9.70	3.71	0230–0330	0.90	
6	East 11th Street South and 145th East Avenue	12.00	5.74	0215–0315	1.40	Gage filled at 0345 hours, rain stopped 0420 hours
7	East 117th Street South and Memorial Drive	3.67	1.58	0245–0345	0.39	
8	First and "B" Streets in Jenks	3.40	1.12	0245–0345	0.27	
9	East 7th Street South and 73rd East Avenue	12.00	5.05	0130–0230	1.23	Gage filled at 0300 hours
10	Oklahoma Street and Lewis Avenue	9.60	3.60	0100–0200	0.88	
11	East 31st Street South and 117th East Avenue	12.00	6.55	0200–0300	1.60	Gage filled at 0310 hours
12	East 71st Street South and 73rd East Avenue	8.01	2.80	0230–0330	0.68	
13	Newton Street and 25th West Avenue	11.80	4.98	0030–0130	1.21	
14	East 56th Street South and Harvard Avenue	9.55	3.48	0200–0300	0.85	
15	East 88th Street South and Harvard Avenue	4.30	1.20	0300–0400	0.29	

[1] 1-hour, 100-year rainfall frequency, 4.1 inches, from Hershfield (1961).

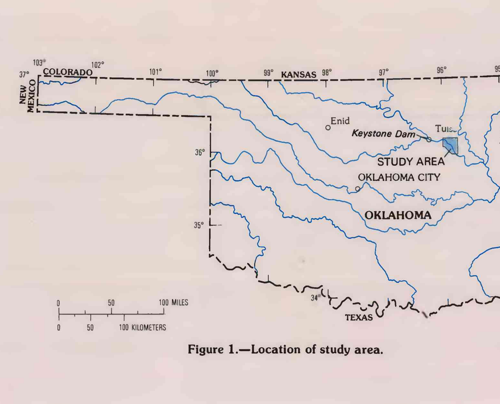


Figure 1.—Location of study area.

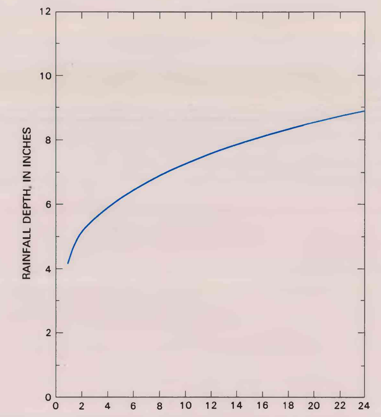


Figure 2.—Relation between rainfall depths and durations of the 100-year rainfall frequency for the Tulsa area (Interpolated from Hershfield, 1961).

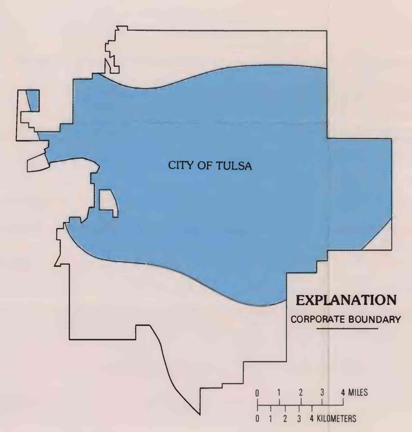
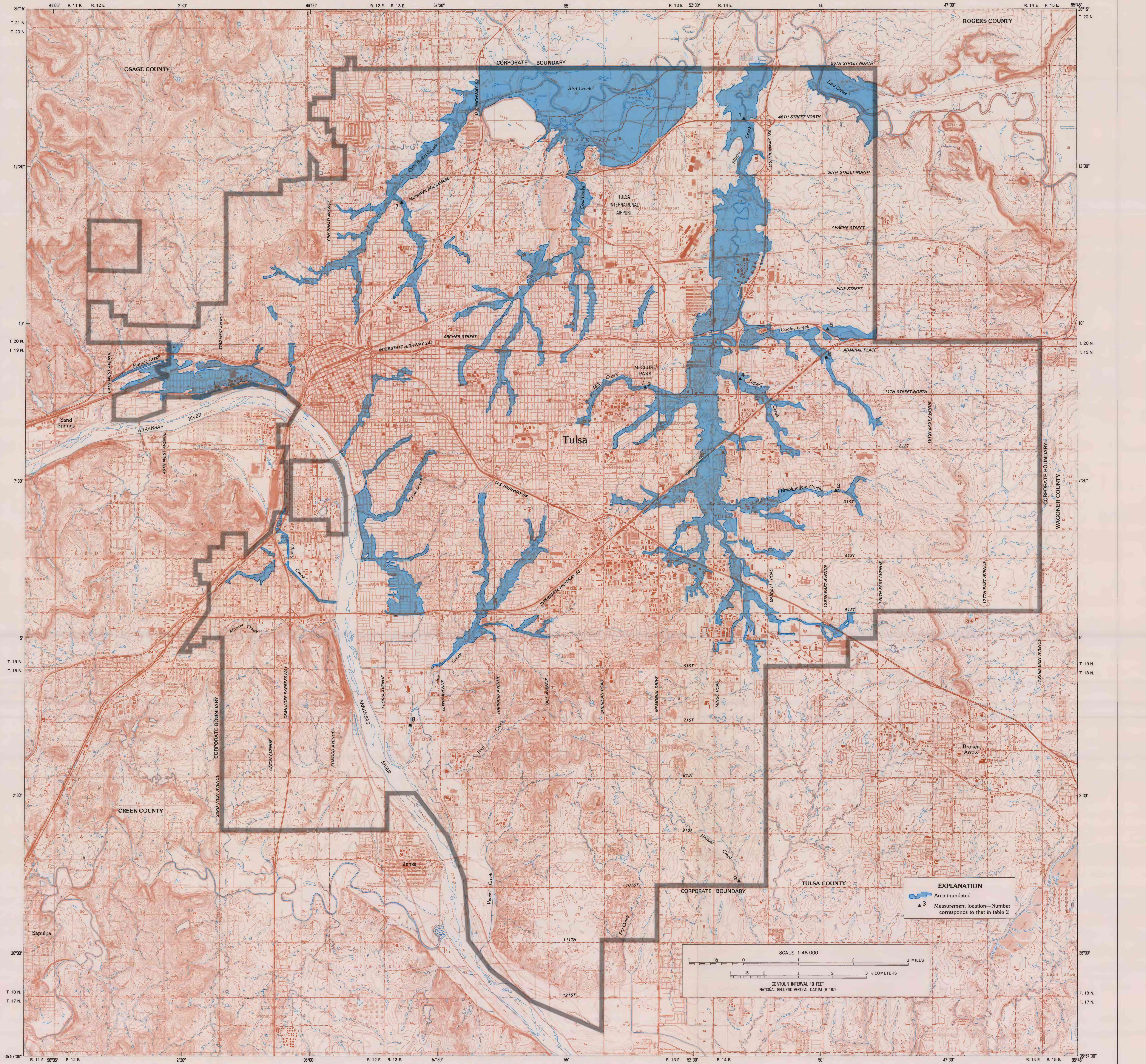


Figure 3.—Approximate area of Tulsa, Oklahoma (shaded), where rainfall depths exceeded the 8-hour, 100-year frequency relation.



Map *B*.—Showing peak discharge measurement locations and numbers and areas inundated by the flood of May 26–27, 1984.

Table 2.—*Summary of flood peak discharge for the flood of May 26–27, 1984*

[mi^2, square mile; ft^3/s, cubic feet per second; $(ft^3/s)/mi^2$, cubic feet per second per square mile]

Map number	Stream name and location	Indirect measurements: Drainage area (mi^2)	Flood peak discharge (ft^3/s)	Flood peak unit discharge [$(ft^3/s)/mi^2$]	Tulsa flood-insurance study 100-year flood peak[1]: Discharge (ft^3/s)	Unit discharge [$(ft^3/s)/mi^2$]	Ratio of flood peak discharge to 100-year flood-insurance study flood peak discharge
1	Mingo Creek at East 46th Street North	57.7	47,500	823	34,800	603	1.36
2	Mill Creek in McClure Park	2.50	12,300	4,920	4,950	1,980	2.48
3	Brookhollow Creek below 136th East Avenue Bridge	2.17	5,910	2,720	3,900	1,800	1.52
4	Tupelo Creek at US Highway 169	3.53	9,540	2,700	4,000	1,130	2.38
5	Cooley Creek at 129th East Avenue	2.14	4,160	1,940	4,170	1,950	1.00
6	Cooley Creek Tributary at Interstate I-44 and 129th East Avenue	2.26	5,040	2,230	3,300	1,460	1.53
7	Dirty Butter Creek Tributary at Mohawk Road	2.74	2,920	1,070	3,920	1,430	0.74
8	Joe Creek at East 71st Street South	14.6	23,000	1,580	14,000	959	1.64
9	Haikey Creek Tributary at East 101st Street South	5.45	6,040	1,110	5,890	1,080	1.03

[1] Federal Emergency Management Agency (1985).

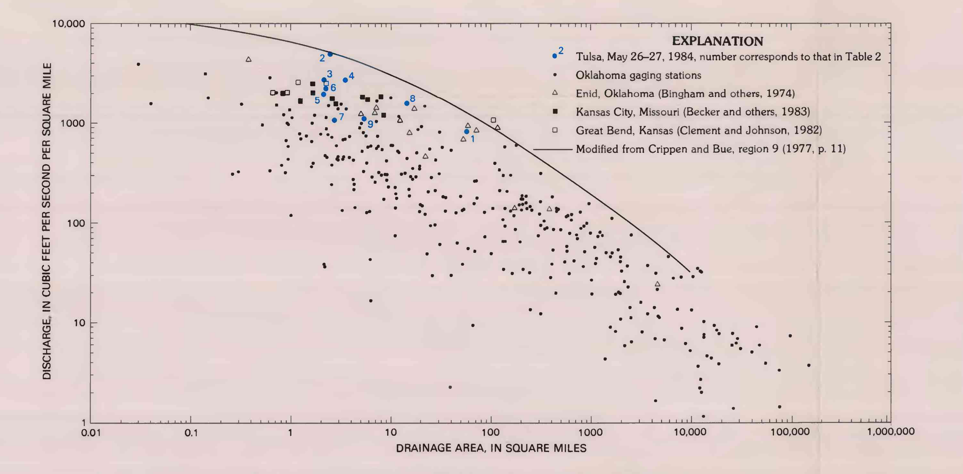


Figure 4.—Comparison of the May 26–27, 1984 unit discharges to upper limits of known floods in the Oklahoma, Texas, Missouri, and Kansas area.

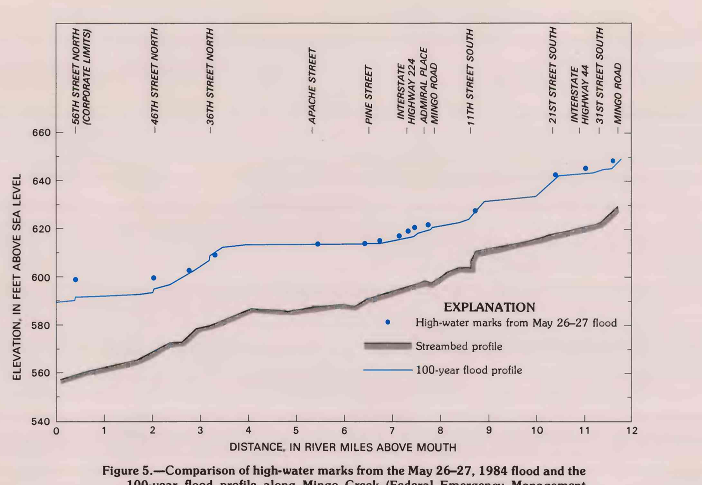


Figure 5.—Comparison of high-water marks from the May 26–27, 1984 flood and the 100-year flood profile along Mingo Creek (Federal Emergency Management Agency, 1985).

Base from U.S. Geological Survey 7½ minute quadrangles:
Bixby, 1967; Broken Arrow, 1974; Jenks, 1974; Leonard, 1973;
Sand Springs, 1974; Sapulpa North, 1974; Sapulpa South, 1983; Tulsa, 1974

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1988

FLOOD OF MAY 26–27, 1984 IN TULSA, OKLAHOMA

By
DeRoy L. Bergman and Robert L. Tortorelli
1988

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