Prepared in Cooperation with the Oklahoma Department of Transportation

DEPTH-DURATION FREQUENCY OF PRECIPITATION FOR OKLAHOMA

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in)	2.54	centimeter
inch (in)	25.4	millimeter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	259.0	hectare
square mile (mi^2)	2.590	square kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Depth-Duration Frequency of Precipitation for Oklahoma

By Robert L. Tortorelli, Alan Rea, and William H. Asquith

Abstract

A regional frequency analysis was conducted to estimate the depth-duration frequency of precipitation for 12 durations in Oklahoma (15, 30, and 60 minutes; 1, 2, 3, 6, 12, and 24 hours; and 1, 3, and 7 days). Seven selected frequencies, expressed as recurrence intervals, were investigated (2, 5, 10, 25, 50, 100, and 500 years). L-moment statistics were used to summarize depth-duration data and to determine the appropriate statistical distributions. Three different rain-gage networks provided the data (15-minute, 1-hour, and 1-day). The 60-minute, and 1-hour; and the 24-hour, and 1-day durations were analyzed separately.

Data were used from rain-gage stations with at least 10-years of record and within Oklahoma or about 50 kilometers into bordering states. Precipitation annual maxima (depths) were determined from the data for 110 15-minute, 141 hourly, and 413 daily stations.

The L-moment statistics for depths for all durations were calculated for each station using unbiased L-mo-ment estimators for the mean, L-scale, L-coefficient of variation, L-skew, and L-kurtosis. The relation between L-skew and L-kurtosis (L-moment ratio diagram) and goodness-of-fit measures were used to select the frequency distributions. The three-parameter generalized logistic distribution was selected to model the frequencies of 15-, 30-, and 60-minute annual maxima; and the three-parameter generalized extreme-value distribution was selected to model the frequencies of 1-hour to 7-day annual maxima.

The mean for each station and duration was corrected for the bias associated with fixed interval recording of precipitation amounts. The L-scale and spatially averaged L-skew statistics were used to compute the location, scale, and shape parameters of the selected distribution for each station and duration. The three parameters were used to calculate the depth-duration-frequency relations for each station. The precipitation depths for selected frequencies were contoured from weighted depth surfaces to produce maps from which the precipitation depth-duration-frequency curve for selected storm durations can be determined for any site in Oklahoma.

Introduction

Precipitation depths for various durations and frequencies, referred to as depth-duration frequency of precipitation in this report, have many uses. A common use of depth-duration frequency of precipitation is for the design of drainage structures that control and route localized runoff—such as parking lots, storm drains, and culverts. Another use of depth-duration frequency of precipitation is for compilation of rainfall-runoff models, which incorporate precipitation characteristics. Accurate depth-duration frequency of precipitation estimates are important for economical and safe structural designs at stream crossings and for developing reliable flood prediction models.

This report updates depth-duration frequency of precipitation from previous studies for Oklahoma. The U.S. Geological Survey, in cooperation with the Oklahoma Department of Transportation, conducted the study to define updated precipitation characteristics for Oklahoma.

Purpose and Scope

The purpose of this report is to update estimates of depth-duration frequency of precipitation for any location in Oklahoma. The precipitation durations investigated were: 15, 30, and 60 minutes; 1, 2, 3, 6, 12, and 24 hours; and 1, 3, and 7 days. The seven selected frequencies investigated, expressed as recurrence intervals, were: 2, 5, 10, 25 50, 100, and 500 years.

Generally, the accuracy of depth-duration frequency of precipitation estimates decreases as recurrence interval increases. An upper recurrence interval of 500 years was selected because most hydraulic design criteria for engineered structures incorporating depth-duration frequency of precipitation require recurrence intervals equal to or less than 500 years. The reciprocal of a recurrence interval is an annual exceedance probability. For example, a precipitation depth having an annual exceedance probability of 0.01 has a recurrence interval of 100 years. This does not imply that the 100-year precipitation depth for a given duration will be exceeded each 100 years, but that it will be exceeded on the *average* of once every 100 years. In fact, it might be exceeded in consecutive years or more than once in the same year. The probability of these last two facts happening is called risk. The procedures for making risk estimates are given by the Interagency Advisory Committee on Water Data (1982) and Kite (1988).

Accurate depth-duration frequency-of-precipitation analysis using data from any single station is difficult because the data for that station represent a poor spatial and (or) temporal sampling of precipitation. For example, when storms occur over a given area, there may or may not be a station to record the precipitation; and generally, only short length of record is available at a single station. Additionally, the distribution of precipitation associated with any one station tends to be nonuniform. More accurate depth-duration frequency of precipitation estimates can be developed by regionalizing data from many nearby stations (Stedinger and others, 1993, p. 18.33). The regionalization techniques used in this report are presented in the “Regionalization of Precipitation Annual Maxima” section. The techniques were conducted using a data base of annual maxima of precipitation (depths) from 110 15-minute, 141 hourly, and 413 daily National Weather Service stations, each with at least 10 years of record, within and near Oklahoma. In total, about 2,162 cumulative years of record are available for the 15-minute stations, 5,382 years for the hourly stations, and 19,233 years for the daily stations.

Previous Studies

Depth-duration frequency-of-precipitation information for the United States east of the Rocky Mountains, including Oklahoma, is available from three principal sources. The first source, commonly known as TP–40 (Hershfield, 1961), presents depth-duration frequency of precipitation for durations of 30 minutes to 24 hours and recurrence intervals of 2 to 100 years. The second source, commonly known as TP-49 (Miller, 1964), presents depth-duration frequency of precipitation for durations of 2 to 10 days and recurrence intervals of 2 to 100 years. The third source, commonly known as HYDRO–35 (Frederick and others, 1977), presents depth-duration frequency of precipitation for durations of 5 to 60 minutes and recurrence intervals of 2 to 100 years.

Several other investigations of precipitation frequency have been conducted in recent years in scattered efforts to update TP–40, TP-49, and/or HYDRO–35. Asquith (1998) conducted an investigation of depth-duration frequency of precipitation in Texas. He found that precipitation depths for durations of 15 minutes to 24 hours were best described by the generalized logistic distribution and depths for durations of 1 day to 7 days were best described by the generalized extreme-value distribution. Studies in Washington State (Schaefer, 1990) and Montana (Parrett, 1997) found that depth-duration of precipitation was best described by the generalized extreme-value distribution. The generalized extreme-value distribution also was selected by Huff and Angel (1992) to model the frequency of annual precipitation maxima for durations of 5 minutes to 10 days for the midwestern United States (Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). The generalized Pareto distribution was selected to model the frequency of annual precipitation maxima for durations of 1 hour to 7 days for the western United States (Arizona, Nevada, New Mexico, Utah, and parts of California, Colorado, Idaho, Oregon, Texas, and Wyoming) (L.T. Julian, National Weather Service, written commun., 1997). Wilks and Cember (1993) selected the Beta-P distribution to model the frequency of annual precipitation maxima for durations of 1 to 10 days for northeastern United States and southeastern Canada.

Climate of Oklahoma

The Oklahoma climate is influenced by the geographic location of the State on the leeward side of the Rocky Mountains. Average annual precipitation increases from west to east and ranges from about 15 inches in the extreme western panhandle to 55 inches in the southeastern corner of the State (Johnson and Duchon, 1995).

The precipitation distribution generally has two peaks during the year. The larger peak is in late spring, and the secondary peak is in early fall (Eddy, 1982). The primary source of moisture for precipitation is the Gulf of Mexico. The Pacific Ocean off the coast of Mexico is a source of moisture under certain weather patterns.

Oklahoma lies in the southern range of the polar jet stream and the northern range of the subtropical jet stream in winter, which causes extreme variations of temperature and precipitation. January temperatures have ranged from daytime highs of 70 degrees Fahrenheit to nighttime lows well below zero. Winter precipitation commonly consists of a combination of rain, ice, and snow. At times, strong winds and large snowfalls cause severe drifting and blizzard conditions (National Oceanic and Atmospheric Administration, 1977).

Much of the spring precipitation results from large thunderstorms, many of which produce tornadoes and large hail. These severe storms occur as surface low-pressure and frontal systems develop when a transient upper-air trough approaching from the west interacts with warm, moist air from the Gulf of Mexico. These convective storms, which generally move individually from southwest to northeast, move eastward as complexes across the State and provide most spring and early summer rainfall. A typical storm system is about 10 miles wide by 25 miles long (Eddy, 1982). Flooding caused by convective storms tends to be localized. If intense thunderstorms repeatedly develop over the same terrain for several hours or days, localized flooding can be severe.

A second large-scale feature in the Oklahoma precipitation delivery system is the Bermuda High. The Bermuda High is a semipermanent subtropical high-pressure cell in the North Atlantic Ocean whose circulation pattern is largely responsible for the warm and humid conditions that prevail in Texas and Oklahoma in summer (Bomar, 1983). Clockwise circulation around this air mass controls most of the surface-moisture supply received by Oklahoma from the Gulf of Mexico.

The location of the Bermuda high-pressure system substantially affects late summer and fall rainfall. If the system is south of its normal location, polar air masses can move southward into Oklahoma. Moisture from the Gulf of Mexico, and occasionally from decaying tropical cyclones, combines with southward-moving polar air to cause large-scale rainstorms. Tropical cyclones, which include hurricanes, can originate either in the Gulf of Mexico or the Atlantic or Pacific Oceans. Widespread floods can result from storms produced by these conditions.

If the Bermuda High occurs north and west of its normal location, drought can occur. The air is hot and humid, but the upper-air trough, along with disturbances necessary for the development of intense thunderstorms, stays north of Oklahoma. Without this triggering mechanism, thunderstorms can occur anywhere in the State, but none are large enough to produce intense rains and substantial runoff. Climatological data indicate that the absence of fall rains may result in prolonged less-than-average streamflow. Droughts also are characterized by a disproportionate lack of weekly rainfall that measures more than 0.5 inch (Eddy, 1982).

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Data Base of Precipitation Annual Maxima

Data Sources

Precipitation data for 15-minute, hourly, and daily National Weather Service stations is available through the National Climatic Data Center in Asheville, N.C. (National Climatic Data Center, 1999). The precipitation annual maxima (depths) of the selected durations for the National Weather Service stations were compiled by Hydrosphere Data Products, Inc. (1997). The stations in this investigation included those within and near Oklahoma (within 50 kilometers), to avoid discrepancies across state lines (a “state-line fault”), and to ensure reasonable results in the contouring process. The 15-minute precipitation data are available for 1971–96. Hourly precipitation data are available for 1940–96. Daily precipitation data are available from about 1893 to 1996.

The 15-, 30-, and 60-minute annual maxima were compiled from the 15-minute data. The 1-, 2-, 3-, 6-, 12-, and 24-hour annual maxima were compiled from the hourly data; and the 1-, 3-, and 7-day annual maxima were compiled from the daily data. The term “60-minute” duration is associated with the aggregation of four consecutive 15-minute data values, whereas the 1-hour duration is a single value from 1-hour data values. The term “24-hour” duration is associated with the aggregation of 24 consecutive 1-hour data values, whereas the 1-day duration is a single value from 1-day data values.

The 15-minute, hourly, and daily National Weather Service stations used in this study are listed in tables 1, 2, and 3 (at the back of report). The locations of the 15-minute, hourly, and daily stations are shown on figures 1, 2, and 3 (at the back of report).

The data base of annual values was reviewed for questionable data, such as (1) very small values that usually indicate an incomplete year (commonly the first or last year of record), or (2) very large values that could not be verified. All of the data from the questionable year were removed from the data base for these cases. Another data base problem was discovered in the 15-minute data for which four stations had identical values in the 15-, 30-, and 60-minute durations that matched the 1-hour value for all years of record. Records from those stations were removed from the data base. Removal of data from some years or stations did not greatly reduce the amount of precipitation data available from within and near Oklahoma.

Station data were combined when two stations were within two minutes of longitude and/or latitude (about 2 miles). For example, occasionally an existing station is relocated to a nearby site, and new stations might be established near an existing station. If the distance between two stations is small, then the data were assumed equivalent and combined into a single data set (similar to Asquith, 1998). Data sets were combined to increase the length of record of some nearby stations and to avoid potential problems in the analysis phase, which used 2-kilometer grid cells to produce contour maps. Combined station records accounted for three stations having 15-minute data (table 1), 10 stations having hourly data (table 2) and 18 stations having daily data (table 3).

Only those stations that had at least 10 years of data were selected for this study to ensure that data were representative of long-term precipitation characteristics. Droughts or periods of abundant rainfall in Oklahoma characteristically extend for 3 to 5 years (Johnson and Duchon, 1995). The use of data with at least 10 years of record reduces the chance that data are unduly biased by climatic episodes. One station (site 2, fig. 1, table 1) with eight years of 15-minute data was used for the analysis in an area where there was a sparsity of data.

The three types of precipitation stations generally are uniformly distributed statewide. However, the daily precipitation stations are the most densely-spaced network (figs. 1, 2, and 3). The areal densities of stations for the entire data base, expressed as stations per 1,000 square miles, for each station type are 0.948 for the 15-minute, 1.21 for the hourly, and 3.56 for the daily stations. The areal densities within Oklahoma, expressed as stations per 1,000 square miles, for each station type are 0.973 for the 15-minute, 1.27 for the hourly, and 3.60 for the daily stations. The distribution of record length is shown in table 4 for 15-minute stations, table 5 for hourly stations, and table 6 for daily stations. The tables indicate the record lengths are about the same among the states for each station type. However, there are substantial differences in the average record length between station types. Generally, daily stations have the longest lengths of record; the 15-minute stations have the shortest lengths of record.

Figure 4 illustrates the variability of a series of 1-day precipitation annual maxima among precipitation stations from four long-term stations in Oklahoma, which are located along generally the same longitude, but range from north to south. Similar variability occurs in data from the 15-minute and hourly stations.

Correction of Precipitation Annual Maxima for Fixed-Interval Recording

The ratios of 60-minute to 1-hour maxima and 24-hour to 1-day maxima were analyzed. The 1-hour and 1-day maxima generally are less than the 60-minute and 24-hour maxima. The difference is due to the 1-hour and 1-day maxima being collected on a fixed-interval basis (from beginning to end of each hour for hourly data, and from 7 am to 7 am for most daily data stations). However, the 60-minute and 24-hour maxima are determined with four consecutive or moving 15-minute windows or 24 consecutive 1-hour windows. One hundred ten stations have concurrent 60-minute and hourly maxima, which comprise 2,159 values; and 71 stations have concurrent 24-hour and daily maxima, which comprise 2,633 values. A 60-minute to 1-hour weighted-mean ratio of 1.12 (weighted standard deviation = 0.045) and a 24-hour to 1-day weighted-mean ratio of 1.12 (weighted standard deviation = 0.063) were determined for all stations. The weighting is based on the length of record for each station.

Weiss (1964) considered the ratio of true to fixed-interval maxima on the basis of probability theory and determined a theoretical correction factor of 1.143 for the true 60-minute to hourly maxima and for the true 24-hour to daily maxima. Miller and others (1973) and Asquith (1998) reported an empirically derived factor of 1.13. These factors are reasonably close to those deter-

Table 4. Summary of 15-minute precipitation gage distribution by state and lengths of record

Length of record (years)	Number of stations								Length of record (years)	
		Border states								
	Oklahoma	Arkansas	Colorado	Kansas	Missouri	New Mexico	Texas	Total	Total	Average
less than 10	-	-	-	-	-	1	-	1	8	8.0
10 to 19	34	4	-	7	-	-	6	51	738	14.5
20 to 29	34	3	2	4	1	-	14	58	1,416	24.4
Total	68	7	2	11	1	1	20	110	2,162	19.7
Average length of record	19.5	18.0	23.0	18.2	26.0	8.0	21.4			

Table 5. Summary of hourly precipitation gage distribution by state and lengths of record

Length of record (years)	Number of stations								Length of record (years)	
		Border states								
	Oklahoma	Arkansas	Colorado	Kansas	Missouri	New Mexico	Texas	Total	Total	Average
10 to 19	10	1	-	-	-	1	2	14	204	14.6
20 to 29	22	3	1	2	-	-	4	32	777	24.3
30 t0 39	9	2	-	2	-	-	4	17	566	33.3
40 to 49	28	4	1	8	2	1	1	45	2,124	47.2
50 to 59	20	-	-	-	-	-	13	33	1,711	51.8
Total	89	10	2	12	2	2	24	141	5,382	38.2
Average length of record	36.9	34.5	37.0	41.9	46.5	30.0	42.6			

Table 6. Summary of daily precipitation gage distribution by state and lengths of record

Length of record (years)	Number of stations								Length of record (years)	
		Border states								
	Oklahoma	Arkansas	Colorado	Kansas	Missouri	New Mexico	Texas	Total	Total	Average
10 to 19	35	4	1	1	1	4	7	53	748	14.1
20 to 29	32	3	-	1	-	1	7	44	1,135	25.8
30 to 39	19	3	2	4	-	-	3	31	1,081	34.9
40 to 49	143	13	3	23	6	3	17	208	9,984	48.0
50 to 59	1	1	-	3	-	-	9	14	767	54.8
60 to 69	1	1	1	-	-	-	5	8	524	65.5
70 to 79	2	-	-	-	1	-	4	7	524	74.9
80 to 89	3	-	-	-	-	1	7	11	931	84.6
90 to 99	14	1	-	6	-	-	13	34	3,231	95.0
100 to 109	2	1	-	-	-	-	-	3	308	102.7
Total	252	27	7	38	8	9	72	413	19,233	46.6
Average length of record	43.4	43.7	40.3	53.2	47.8	33.9	57.3			

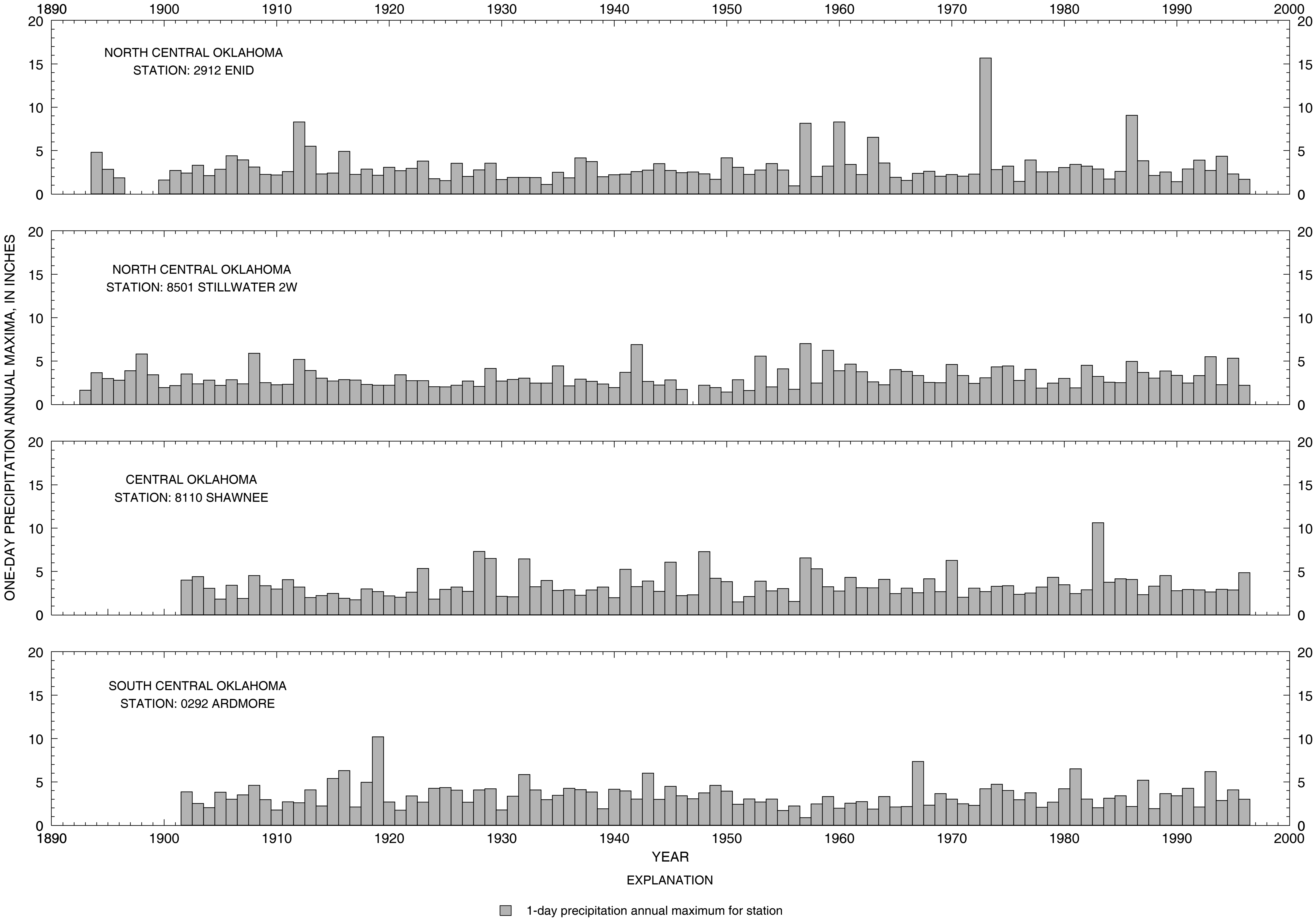

Figure 4. Time series of 1-day precipitation annual maxima for selected long-term stations (2912, 8501, 8110, and 0292) showing variability at each station.

Table 7. Correction factors for mean precipitation annual maxima

[Note: Weiss correction factors (Weiss, 1964) are from the equation {n/n-0.125}, where n is the number of subintervals for a given duration; min, minutes; n/a, empirical correction factor not determined for this report; hr, hours]

Duration (variable	Corresponding fixed intervals or time steps	Number of subintervals	Weiss correction factor (dimensionless)	Empirical correction factor within and near Oklahoma (dimensionless)
15 min	15 min	1	1.143	n/a
30 min	15 min	2	1.067	n/a
60 min	15 min	4	1.032	n/a
1 hr	1 hr	1	1.143	1.12
2 hr	1 hr	2	1.067	n/a
3 hr	1 hr	3	1.044	n/a
6 hr	1 hr	6	1.022	n/a
12 hr	1 hr	12	1.011	n/a
24 hr	1 hr	24	1.005	n/a
1 day	1 day	1	1.143	1.12
3 days	1 day	3	1.044	n/a
7 days	1 day	7	1.018	n/a

mined for this report. The empirical factors from this report are slightly less than the theoretical factor because both the 60-minute and 24-hour maxima were developed from finite samples (15-minute or 1-hour intervals) and are biased slightly downward.

The theoretical correction factors developed by Weiss were used for this study because (1) the small difference between Weiss' 1.143 and the empirical 1.12 for this study and (2) corrections were needed for the 15-, 30-, and 60-minute durations and for durations greater than 1 hour or 1 day. The correction factors are applicable only on the mean annual maxima for a given duration and are not applied to the individual data points (Weiss, 1964, p. 79). The theoretical correction factors used in this study from Weiss (1964) are listed in table 7. Schaefer (1990, p. 127) concluded that correction factors such as Weiss's or Miller's affect only the location (mean) and scale (standard deviation) measures of a given data set and do not affect higher measures of the data such as shape (skew). The adjustment to the scale measure of the annual maxima is discussed later in the "Spatial Averaging of L-coefficient of Variation and L-skew and Estimation of L-scale" section.

Regionalization of Precipitation Annual Maxima

Regionalization in a precipitation frequency analysis is the technique of combining the precipitation characteristics from more than one station to develop more accurate statistical summaries for each station. The primary goal of regionalization is to be able to estimate precipitation frequency for locations other than precipitation stations.

The regionalization approach used for Oklahoma is based on the following underlying assumptions: (1) a single probability distribution can be used to characterize the frequency of precipitation annual maxima (depth) for a given duration at all stations in the study area, and yields more accurate estimates, on average over all sites, than fitting separate distributions at each site (Asquith, 1998; Hosking and Wallis, 1997); (2) at-site station data for several nearby stations can be averaged to produce more reliable at-site parameters for the selected probability distribution; and (3) at-site values of depth-duration-frequency of annual precipitation maxima can be described as spatially continuous values throughout the study area and can be expressed by map contours. The map contours provide the means to estimate the depth-duration-frequency of annual precipitation maxima throughout the study area.

The steps of regionalization of precipitation annual maxima for this report include (1) computation of the L-moment statistics for each station and each duration using unbiased estimators; (2) determination of an appropriate probability distribution for modeling the frequency of annual maxima using L-moment ratio diagrams and goodness-of-fit measures; (3) improvement of the estimation of the L-coefficient of variation and L-skew by spatial averaging; (4) estimation of a corrected L-scale from the product of the corrected mean depth and the spatially averaged L-coefficient of variation; (5) computation of the appropriate distribution parameters with the corrected L-moment statistics at each precipitation station; (6) computation of depth-duration frequency of precipitation values with the appropriate distribution parameters at each precipitation station; (7) creation of depth surfaces in a 2-kilometer grid for each duration-frequency by smoothing the at-site values of precipitation depth using exponential-distance and length-of-record weighting; and (8) creation of depth-duration frequency of precipitation contour maps from the surfaces. The precipitation depth for selected frequencies and durations for any location in Oklahoma can be determined by the values on the contour maps.

The following sections present a brief introduction to the theory of L-moments and the technique for selecting an appropriate probability distribution using L-moment ratio diagrams and goodness-of-fit measures as presented by Asquith (1998). Greenwood and others (1979), Hosking (1986, 1990), Hosking and Wallis (1993, 1997), and Vogel and Fennessey (1993) provide comprehensive discussions of L-moments, probability distributions, and distribution selection.

L-Moments

Consider a random variable *X* (precipitation depth in this report) with a cumulative probability distribution function *F* (nonexceedance probability). The quantities

$$M_{ijk} = E[X^i F^j (1-F)^k] = \int_0^1 X^i F^j (1-F)^k dF \quad , \quad (1)$$

where E = the expectation operator, are known as probability-weighted moments as defined by Greenwood and others (1979). By letting $M_{ijk} = M_{1r0}$, the probability-weighted moment for moment r can be expressed as

$$\beta_r = E[XF^r] \quad . \quad (2)$$

An unbiased sample estimate of β_r (probability-weighted moments) for any distribution is computed from the following equation from Landwehr and others (1979):

$$b_r = \frac{1}{n}\sum_{j=1}^{n-r}\left[\frac{\binom{n-j}{r}}{\binom{n-1}{r}}\right]x_j , \quad (3)$$

where

b_r = unbiased sample estimate of β_r for moment number $r = 0, 1, 2, \ldots$ and

$x_{(j)}$ = ordered values of X where $x_{(1)}$ is the largest observation and $x_{(n)}$ is the smallest.

The probability-weighted moments are somewhat analogous to the more widely known product moments (mean, standard deviation, coefficient of variation, skew, kurtosis). For example, b_0 is equal to the mean; however, interpretation of the higher order probability-weighted moments is difficult. To facilitate probability-weighted moment interpretation, Hosking (1986, 1990) developed L-moments as specific linear combinations of the probability-weighted moments. Unbiased L-moment sample estimates are obtained by substituting the sample estimates of β_r into the following equation:

$$\lambda_{r+1} = \sum_{k=0}^{r} \beta_k (-1)^{r-k}\binom{r}{k}\binom{r+k}{k} \quad . \quad (4)$$

The L-moments can be formulated into values that are analogous, though not equal, to the product moments (Hosking, 1990). The mean, scale, coefficient of variation, skewness, and kurtosis of a distribution estimated using equation 4 are expressed by the following L-moments (λ_r) and L-moment (τ_r) ratios:

$$\lambda_1 \equiv \text{ mean, and } \lambda'_1 \equiv \text{ Weiss-corrected mean;} \quad (5)$$

$$\lambda_2 \equiv \text{ L-scale;} \quad (6)$$

$$\tau_2 = \frac{\lambda_2}{\lambda_1} \equiv \text{ L-coefficient of variation;} \quad (7)$$

$$\tau_3 = \frac{\lambda_3}{\lambda_2} \equiv \text{ L-skew; and} \qquad (8)$$

$$\tau_4 = \frac{\lambda_4}{\lambda_2} \equiv \text{ L-kurtosis.} \qquad (9)$$

The L-moment statistics of the precipitation annual maxima and the L-moment ratios in this investigation were calculated for each duration and for each station using unbiased estimators. The statistics calculated were the mean, L-scale, L-coefficient of variation, L-skew, and L-kurtosis. The use of the unbiased estimators decreases the chance of selecting an inappropriate distribution to fit a given data set (Hosking and Wallis, 1995, p. 2,024).

L-moment Ratio Diagrams and Goodness-of-fit Measures

L-moment ratio diagrams allow simple comparisons between the sample estimates of τ_3 and τ_4 and their theoretical counterparts from selected distributions. The diagrams provide a method to choose the appropriate distribution to represent a data set. Vogel and Fennessey (1993) demonstrated the significant differences between product-moment ratio diagrams (skew and kurtosis) and L-moment ratio diagrams; they concluded that L-moment ratio diagrams are preferable to product-moment ratio diagrams for distribution selection.

L-moment ratio diagrams for six selected durations are shown in figure 5. The diagrams show the relation between the station values of τ_2 and τ_4 and weighted-mean values of τ_3 and τ_4 for all stations in the study area to the theoretical τ_3 and τ_4 relations (Hosking, 1991b) from the generalized extreme-value, generalized logistic, log-normal, and Pearson III distributions. Reference to the term regional includes all stations within and near Oklahoma used in the investigation. The circles represent the τ_3 and τ_4 for each station. The scatter around the single regional (weighted) mean, in general, represents sampling variability—that is, stations with longer lengths of record are more likely to have τ_3 and τ_4 that plot closer to the single regional mean. The generalized Pareto and Pearson Type III distributions (Hosking, 1990; Stedinger and others, 1993) were evaluated, and the τ_3 and τ_4 relation from the data was determined to be different from the distributions. The generalized Pareto distribution is not shown in figure 5 for clarity. The weighted means of τ_3 and τ_4 generally plot between the generalized logistic and generalized extreme-value distributions. Data for 15-minute duration and the corresponding weighted values of τ_3 and τ_4 cluster around the generalized logistic distribution; and data for the other durations and the corresponding weighted values cluster around the generalized extreme-value distribution. The log-normal and Pearson III distributions can be dismissed on the basis of the poor fit to the data points.

Applying the results of the L-moment ratio diagrams for all durations, the generalized logistic distribution is selected as the appropriate probability distribution (or the best fit) for annual maxima for durations of 15 minutes to 60 minutes; while the generalized extreme-value distribution is selected as the appropriate probability distribution for annual maxima for durations of 1 hour to 7 days.

Goodness-of-fit measures (Z-statistics) of the generalized logistic and generalized extreme-value distributions were computed for each duration following the methods of Hosking and Wallis (1993) by considering all the stations in the study area as a single region. The Z-statistics of the generalized logistic and generalized extreme-value distributions of each duration are listed in table 8. The absolute values of the Z-statistics of the generalized logistic distribution are less than those of the generalized extreme-value distribution for 15-minute to 60-minute durations, and the absolute values of the Z-statistics of the generalized extreme-value distribution are smaller than those of the generalized logistic distribution for 1-hour to 7-day durations.

The goodness-of-fit measure can be interpreted in two ways. The first interpretation is that a distribution is considered appropriate if the absolute value of the Z-statistic is less than about 1.64; this interpretation is valid only if the region containing the data is homogeneous (Hosking and Wallis, 1993, 1997). Homogeneous is interpreted to mean that, except for a location-specific scaling factor, (1) the distribution form for the homogeneous region is known, and (2) the distribution is exactly defined (by specification of its parameters). The heterogeneity measures (H-statistic) for the entire region were computed for each duration following the methods of Hosking and Wallis (1993, 1997). The H-statistics (table 8) are generally larger than 2.0, which Hosking and Wallis (1993, p. 275; 1997, p. 63) conclude is indicative of a heterogeneous region; thus, strict interpretation of the goodness-of-fit measure is questionable.

The second interpretation of the goodness-of-fit is that the distribution with the smallest absolute value of the Z-statistic is considered appropriate, but the distribution parameters might require additional specification. Applying the second interpretation to the Z-statistics (table 8), the generalized logistic distribution is judged the appropriate probability distribution (or the best fit) for annual maxima for durations of 15 minutes to 60 minutes, and the generalized extreme-value distribution is judged the appropriate probability distribution for annual maxima for durations of 1 hour to 7 days.

Two previous studies, TP–40 (Hershfield, 1961) and HYDRO–35 (Frederick and others, 1977), each used the two-parameter Gumbel distribution, which is a special generalized extreme-value distribution, where τ_3 is equal to 0.1699 and τ_4 is equal to 0.1504 (Stedinger and others, 1993, p. 18.9). Either the generalized logistic or the generalized extreme-value distribution fits the study data better than the Gumbel distribution.

The investigation of precipitation frequency in Washington (Schaefer, 1990) determined that the generalized extreme-value distribution was appropriate for durations of 2, 6, and 24 hours; although Schaefer (1993) later adopted the four parameter Kappa distribution (Hosking, 1994). The investigations of precipitation frequency by Huff and Angel (1992) and Parrett (1997) determined that the generalized extreme-value distribution was appropriate for durations of 1 or more days for the midwestern United States and Montana. The investigation of Asquith (1998) for precipitation in Texas determined that the generalized logistic distribution was appropriate for durations of 15-minutes to 24 hours and the generalized extreme-value distribution was appropriate for durations of 1 day to 7 days.

Spatial Averaging of L-Coefficient of Variation and L-Skew and Estimation of L-Scale

The values for τ_2 and τ_3 were spatially averaged to (1) reduce the random component in the values, (2) improve the accuracy of the estimates, and (3) reduce the influence of any one station on the eventual contouring of the precipitation depths. Efficient investigation of discordant data (Hosking and Wallis, 1993, p. 272–273) within the entire data base was not feasible because of the large number of stations and durations—about 96,000 individual data values. The first L-moment, the mean, was not spatially averaged because (1) the mean depths exhibit very strong spatial dependence and (2) the estimates of the mean depth of each station are more accurate than estimates of the λ_2, τ_2, and τ_3 statistics.

The development of the spatial-averaging method (following Asquith, 1998) involves the following relation:

$$\Phi^S{}_i(x, y) = \Phi^T{}_i(x, y) + \Phi^N{}_i(r) \quad , \qquad (10)$$

where

$\Phi^S{}_i(x,y)$ = the value of τ_2 or τ_3 for station i at location (x,y);

$\Phi^T{}_i(x,y)$ = the true but always unknown value of τ_2 or τ_3 for station i; and

$\Phi^N{}_i(r)$ = the unknown random component of τ_2 or τ_3, which is a function of record length (r) at the station (with a model-error component included).

In equation 10, $\Phi^T{}_i(x,y)$ is a constant for the location (x,y), whereas both $\Phi^S{}_i(x,y)$ and $\Phi^N{}_i(r)$ are random variables. The references to spatial location and record length in equation 10 are dropped without a loss of generality, and $\Phi^T{}_i$ is computed as:

$$\Phi^T{}_i = \Phi^S{}_i - \Phi^N{}_i \quad . \qquad (11)$$

Assume that $\Phi^T{}_i$ is fixed within the area defined by n neighboring stations (call this the neighborhood). Specifically, the station of interest is $i = 1$, the first nearest station is $i = 2$, the farthest station is $i = n$; thus, the neighborhood contains n stations:

$$\Phi^T{}_1 = \Phi^T{}_2 = \Phi^T{}_3 = \Phi^T{}_4 = \ldots = \Phi^T{}_n . \qquad (12)$$

When $\Phi^T{}_i$ is assumed fixed, $\Phi^T{}_i$ becomes spatially constant on small geographic scales. On large geographic scales, this assumption is not true; however, if the neighborhood is small, then the gradient of $\Phi^T{}_i$ is close to zero, and $\Phi^T{}_i$ can be considered constant. Reformulating equation 11 for a neighborhood of five stations ($n = 5$) yields

$$5\Phi^T = \sum_{i=1}^{5} (\Phi^S{}_i - \Phi^N{}_i) . \qquad (13)$$

Next, expand the terms in the summation in equation 13:

$$\Phi^T = \frac{1}{5}\sum_{i=1}^{5} \Phi^S{}_i - \frac{1}{5}\sum_{i=1}^{5} \Phi^N{}_i \quad . \qquad (14)$$

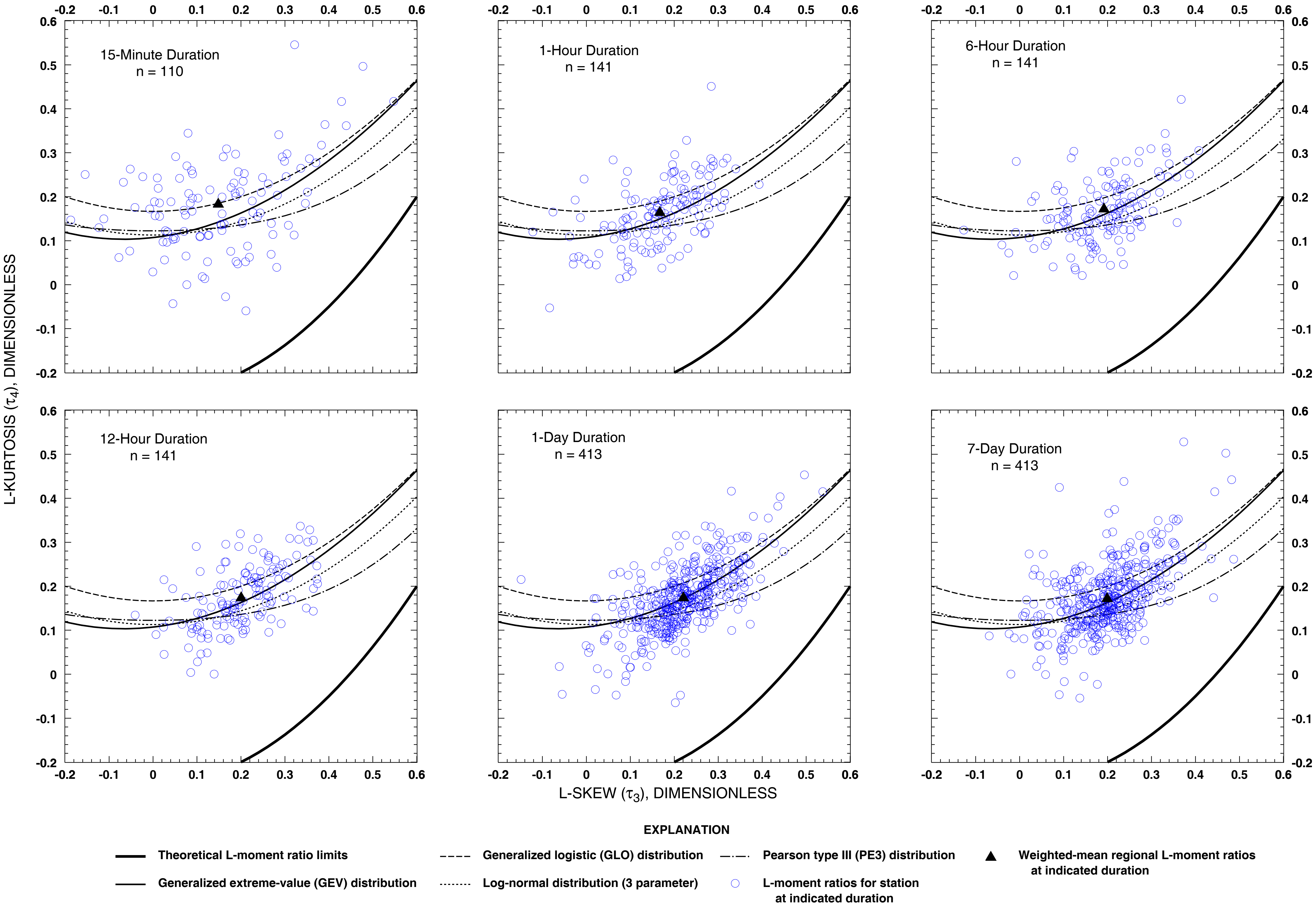

Figure 5. L-moment ratio diagrams for selected precipitation durations within and near Oklahoma.

Table 8. Summary of goodness-of-fit and heterogeneity measures within and near Oklahoma

[GLO, generalized logistic distribution; GEV, generalized extreme-value distribution; min, minutes; hr, hours]

Duration (variable)	Data base source	Number of stations	Goodness-of-fit measure (Z-statistic[1])		Heterogeneity measure (H-statistic[1])
			GLO	GEV	
15 min	15-min stations	110	-0.4*	-4.8	2.4
30 min			1.7*	-3.1	3.7
60 min			2.0*	-2.3	2.3
1 hr	Hourly stations	141	4.1	-2.9*	8.3
2 hr			3.5	-2.9*	6.1
3 hr			3.7	-2.5*	5.0
6 hr			3.1	-2.8*	3.2
12 hr			3.8	-2.2*	2.2
24 hr			4.8	-1.3*	0.3
1 day	Daily stations	413	9.5	-1.3*	2.7
3 days			7.9	-3.0*	-1.8
7 days			8.1	-3.8*	-1.4

[1] Hosking and Wallis, 1993, 1997

* Distribution chosen

If the expected value of Φ^N is zero, then the expected value of Φ^T becomes the mean of Φ^S_i. However, consider that the random components are time biased; that is, as record length (r) gets larger, Φ^N_i gets smaller and Φ^S_i approaches Φ^T_i. Therefore, it is practical to incorporate record length as a weighting factor on Φ^S_i:

$$\Phi^T = \frac{\sum_{i=1}^{n} r_i \Phi^S_i}{\sum_{i=1}^{n} r_i} \quad . \qquad (15)$$

The choice of the weights in equation 15 is somewhat arbitrary. Other weights could have been chosen, such as those based on separation distance from station $i = 1$ to station $i = n$ or those based on cross correlations in the data.

Equation 15 represents the spatial averaging method used on τ_2 and τ_3 where n represents the number of nearest (neighborhood) stations to average together. Equation 15 is equivalent to the regional moment estimation equation frequently seen in index-flood regional analyses (Hosking and Wallis, 1993, p. 271, eq. 2). Because equation 15 is applied to each duration and each station in the data base, the approach here may be considered a moving index-flood. The spatially averaged τ_2 and τ_3 are represented by the following:

$$\tau'_2 = \text{spatially averaged L-coefficient of variation, and} \qquad (16)$$

$$\tau'_3 = \text{spatially averaged L-skew.} \qquad (17)$$

If $n = 1$ in equation 15, then no averaging takes place and τ'_2 and τ'_3 are equal to the values for each station; likewise, if n equals the total number of stations ($n = 110$, 141, or 413), the computed values are weighted regional means. The assumption that Φ^T_i is constant becomes increasingly invalid as n gets larger. To determine an appropriate value for n, various values of n were tried, and the effects of different n values were evaluated on the basis of changes in the geographic distribution of τ_2 and τ_3 and the overall reduction in regional variance for τ_2 and τ_3. A value of $n = 5$, which corresponds to a neighborhood containing five stations, was selected as appropriate. Tests using values of n much greater than about 10 had the effect of severely reducing the regional variance of τ_2 and τ_3 and obscuring local variations.

A more accurate estimate of L-scale (λ'_2) can be determined because more accurate values of L-coefficient of variation (τ'_2) are available from the spatial averaging and because the mean (λ_1) has been corrected for fixed-time-interval bias (λ'_1) using the Weiss correction factor (table 7). Recalling that τ_2 is the ratio between L-scale and the mean (eq. 7), it follows that a more accurate estimate of L-scale can be derived from:

$$\lambda'_2 = \lambda'_1(\tau'_2) \quad . \qquad (18)$$

Contouring of Depth-Duration Frequency

The mean for each station and duration was corrected for the bias associated with fixed-interval recording of precipitation. A corrected L-scale subsequently was estimated using the corrected mean and the spatially averaged L-coefficient of variation for each duration and for each station. The values for λ'_1, λ'_2, and τ'_3 were used to compute the distribution parameters of the generalized logistic distribution (15-minute to 60-minute durations) and the generalized extreme-value distribution (1-hour to 24-hour, and 1-day to 7-day durations) for each station. Then, the resulting parameters were used to compute the precipitation depth for each station for seven selected frequencies (2, 5, 10, 25, 50, 100, and 500 year) at each of the 12 durations. These depth values then were used to create a gridded depth surface for each depth-duration frequency of precipitation using exponential-distance weighting and length-of-record weighting to interpolate and smooth the values.

The ARC/INFO GRID function, POINTINTERP (Environmental Systems Research Institute, Inc., 1997) was used to interpolate surface grids of each depth-duration frequency of precipitation on a 2-kilometer cell size. The exponential smoothing option was used for POINTINTERP, with a decay radius of 50 kilometers and a neighborhood radius of 100 kilometers. The POINTINTERP function calculates distance-weighted averages for each grid cell of all observed values within the neighborhood radius of 100 kilometers. The weight function is an exponential decay function having a value of 1 at the point and 0 at the neighborhood radius of 100 kilometers. The weighting function is shown graphically in figure 6 (smooth option ON).

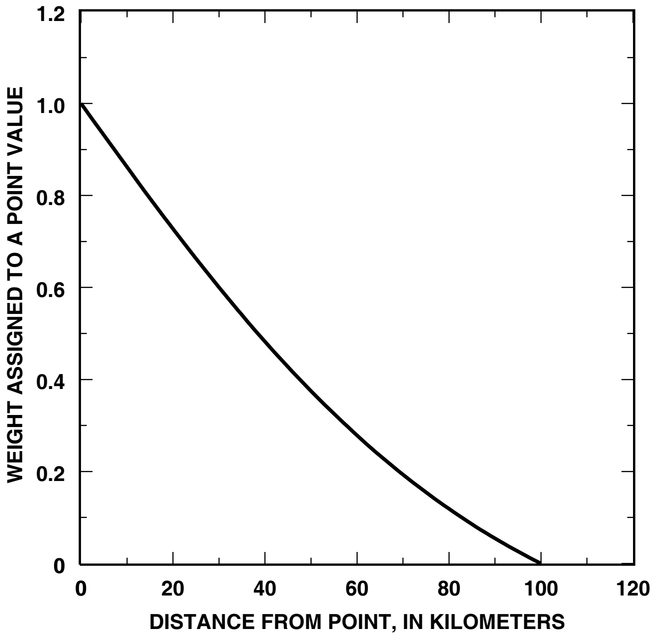

Figure 6. Relation of weight assigned to a point value as a function of distance using the smoothing option of ARC/INFO POINTINTERP.

Length-of-record weighting for the grid interpolation was accomplished by multiplying the depth-duration frequency of precipitation values by years of record for each station, then interpolating a surface of the resulting values using the POINTINTERP function. POINTINTERP also was used to interpolate a surface of the years of record. Then for each grid cell the values of the first surface were divided by the values of the second surface. This method weighted the final surface by distance and length of record. The result is that the final interpolated surface is closer to the observed values at stations having longer lengths of record than at stations with shorter lengths of record.

After interpolation, the depth-duration frequency of precipitation grids were masked to include just the area of Oklahoma plus a 20-kilometer buffer. Masking was done to (1) minimize the effects of poorer interpolations near the edges of the data (at 50 kilometers), and (2) assist in interpolating depth values at the state border. Contour lines were derived from each surface, choosing an appropriate contour interval, and placed on maps using a computer program ArcView (Environmental

Systems Research Institute, Inc., 1998). A few of the contours have minor anomalies that ordinarily would be removed for publication at this scale. The contours match the interpolated surfaces in Oklahoma because the precipitation station data, contours, and surfaces are published separately in digital form (Rea and Tortorelli, 1999). Therefore, it was decided to maintain consistency between the printed maps and the digital data sets. For this reason no editing such as smoothing, generalization, or removal of contours within Oklahoma has been applied to the contour maps. It is intended that the maps be used to estimate the precipitation depth values only within Oklahoma. The digital data sets may be accessed at: http://water.usgs.gov/lookup/get?ofr99-463.

The depth-duration frequency of precipitation grids were checked to ensure that the depth-duration frequency of precipitation values increase monotonically (are continuously increasing) with increasing recurrence interval and increasing duration. For example, (1) for the 12-hour duration, the 100-year depth of precipitation is larger than the 50-year depth of precipitation for all grid cells, and (2) for the 100-year recurrence interval, the 24-hour depth of precipitation is larger than the 12-hour depth of precipitation for all grid cells. The three data sets (15-minute, hourly, and daily) were treated as independent data sets. The few very small deviations from monotonically increasing depth-duration frequency of precipitation were near the edges of the grids at the 500-year frequency at durations of 6-hours and above and all were outside Oklahoma. Because all deviations were outside of Oklahoma no corrections were needed.

A neighborhood radius of 200 kilometers also was tested for selected depth-duration frequencies of precipitation. The resulting maps resembled traditional precipitation maps in which the contours were very smooth and had an even progression of contours increasing from west to east. Also, the differences between the surface and station values were much larger, due to a much greater degree of smoothing. A 100-kilometer radius was used to preserve some of the local variation.

Two other interpolation routines also were tested for selected depth-duration frequencies of precipitation: (1) inverse-distance weighting and (2) ARC/INFO TOPOGRID routine (Environmental Systems Research Institute, Inc., 1997). Exponential-distance weighting was used because the method produced the most consistent, smooth contour lines in the depth-duration frequency of precipitation maps.

In the following section, error analysis, suggested ways of using the final depth contours (fig. 7) and comparison to previous studies are presented (fig. 8).

Depth-Duration Frequency of Precipitation for Oklahoma

The depth-duration frequency of precipitation for any location in Oklahoma can be estimated from the precipitation depth maps (figs. 9–92 at end of report) and from procedures discussed in this section. Contour maps depicting the depth of precipitation for durations of 15 minutes to 60 minutes are shown in figures 9–29. Contour maps depicting the depth of precipitation for durations of 1 hour to 24 hours are shown in figures 30–71. Contour maps depicting the depth of precipitation for durations of 1 day to 7 days are shown in figures 72–92.

The contour lines are fairly dense on the depth-duration frequency of precipitation maps to make interpolation easy. The lower limit of 0.05 inch for the contour intervals is used since some annual precipitation maxima data in the data base (especially the 15-minute data set) were reported only to the nearest 0.1 inch. The contour intervals for the 15-minute to 60-minute durations range between 0.05 to 0.2 inch. The contour intervals for the 1-hour to 24-hour durations range from 0.05 to 0.5 inch. The contour intervals for the 1-day to 7-day durations range from 0.1 to 0.5 inch.

Error Analysis

The error associated with each map was analyzed using methods described by Asquith (1998). The analysis was only conducted for stations within Oklahoma (statewide). The error associated with a station is defined as

$$\in(p)_i = \Phi^S(p)_i - \Phi^C(p)_i\,, \qquad (19)$$

where

$\in(p)_i$ = error associated with precipitation depth for a duration frequency at station i;

$\Phi^S(p)_i$ = value of the estimated precipitation depth for a duration frequency at the station (control point); and

$\Phi^C(p)_i$ = value of the estimated precipitation depth for a duration frequency at the station from the surface (contours).

The error defined is only indicative of the true error because each station was used in the development of the contour maps. An independent means to measure error is not available.

The results of the map error analysis for precipitation depth are listed in table 9. For comparison purposes, the table lists the statewide mean for the control points, the standard deviation of differences between the statewide mean and each control point (station) value, and the coefficient of variation for the control points. The mean surface (contour) error, mean absolute surface (contour) error, maximum and minimum surface errors, root mean square error, and percent change from standard deviation to root mean square error for each depth-duration frequency also are listed. Each statistic is a weighted value, except for maximum and minimum surface errors, which means that the length of record of each station was considered in the computation. Maximum and minimum surface errors are listed to show the range of errors found in each depth-duration frequency of precipitation map.

The weighted mean surface error is the mean difference between values of the control points and values from the map. Mean surface errors near zero are desirable, because this is an indication of how well the interpolation routine worked. This error reflects if there is any potential bias in the map.

The root mean square error of a depth-duration frequency of precipitation surface was calculated by the following:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} r_i[\in(p)_i]^2}{\sum_{i=1}^{n} r_i}}\,, \qquad (20)$$

where

r_i = record length associated with station i; and

$\in(p)_i$ = error associated with the precipitation depth for a duration frequency at station i.

Root mean square error (RMSE) is analogous to the standard deviation (SD), and, therefore, the RMSE is comparable to the SD of the control points (differences between the statewide mean value and individual station values). The percent change from SD to RMSE, 100*[(RMSE – SD) / SD], is an indication of the improvement in precipitation depth estimation by using the map contours rather than simply using the corresponding statewide mean. If the percent decrease from the statewide standard deviation to the root mean square error is not at least 15 percent, then a contour map is not better than a single statewide mean (Asquith, 1998).

Percent changes from standard deviation to root mean square error for the (1) 15-minute to 60-minute durations ranged between -34.7 to -52.0 percent; (2) 1-hour to 24-hour durations ranged between -42.1 and -70.4 percent; and (3) 1-day to 7-day durations ranged between -45.8 and -70.3 percent. Therefore, the use of the contour maps results in more accurate estimates of the precipitation depth than by simply using a statewide mean.

Precipitation Intensity-Duration Frequency Curve

To reduce the potential errors in determining at-site depth-duration frequency of precipitation for different durations, the production of a log-log graph is suggested to show the relation between precipitation intensity (in inches per hour) and duration, and then a best-fit line manually plotted on the graph. The best-fit line or precipitation intensity-duration frequency curve represents the final precipitation depth for the selected location. The log-log transformation is used to (1) linearize the data, and (2) achieve equal variance about the line (Riggs, 1968). Representative intensity-duration frequency curves for Oklahoma City and other selected localities in Oklahoma are shown in figure 7. There is a relatively smooth transition of the intensity-duration frequency curve from short to long durations, in which the 15-minute, hourly, and daily data sources are used.

Potential discrepancies in using the contour maps to estimate at-site precipitation depths for different durations are most likely between the 60-minute and 1-hour duration estimates, and between the 24-hour and 1-day duration estimates. These discrepancies could occur partly because of the differences in record length among the 15-minute stations (mean 19.7 years), the hourly stations (mean 38.2 years) and the daily stations (mean 46.6 years) (tables 4-6). Additionally, the distribution and density of the stations vary between the 15-minute and hourly stations and between the hourly and daily stations. Finally, there is a change from the generalized logistic distribution for the 60-minute duration to the generalized extreme-value distribution for the 1-hour duration. Because both estimates at the 1-hour

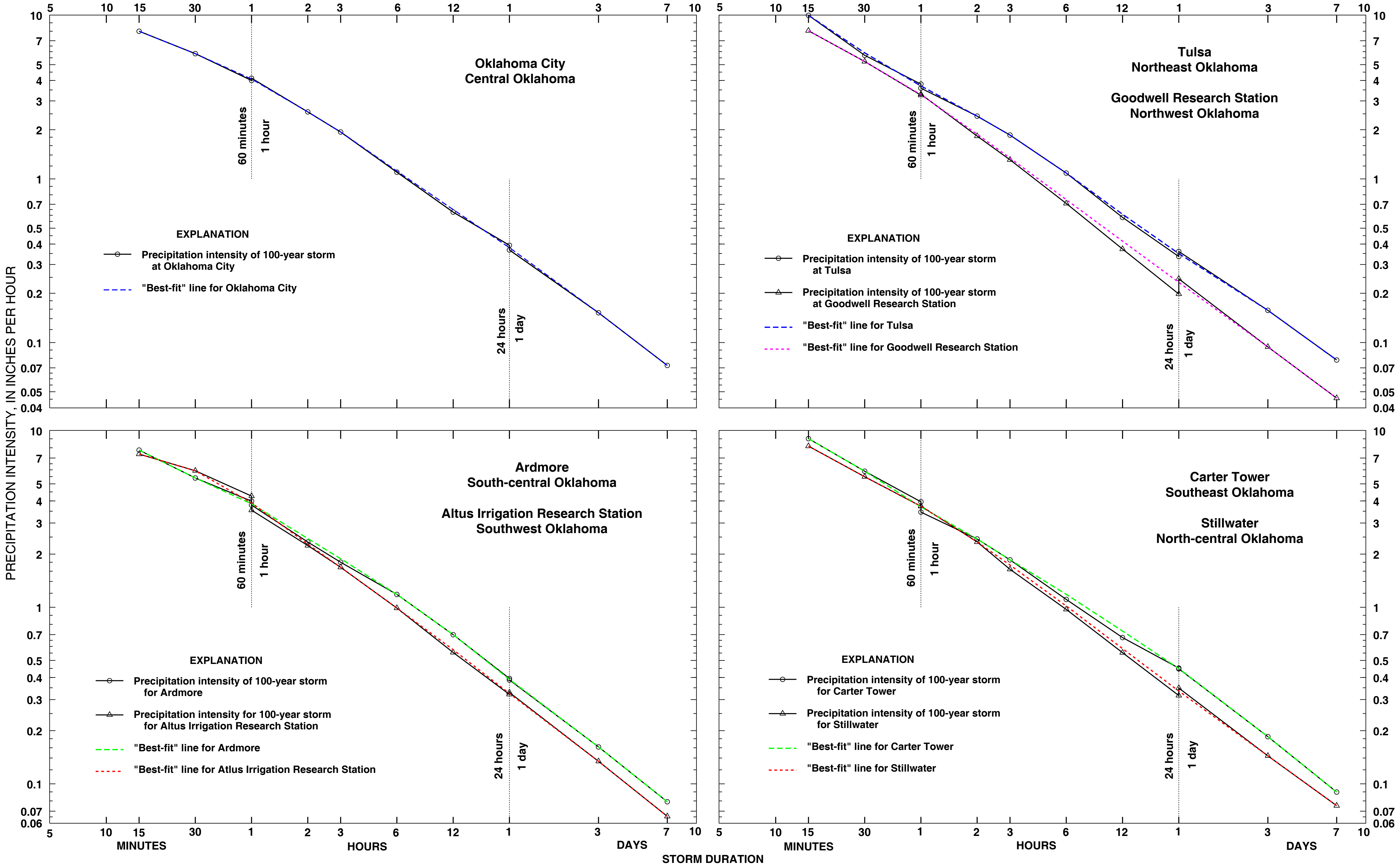

Figure 7. Precipitation intensity-duration curves for 100-year storm for selected localities in Oklahoma.

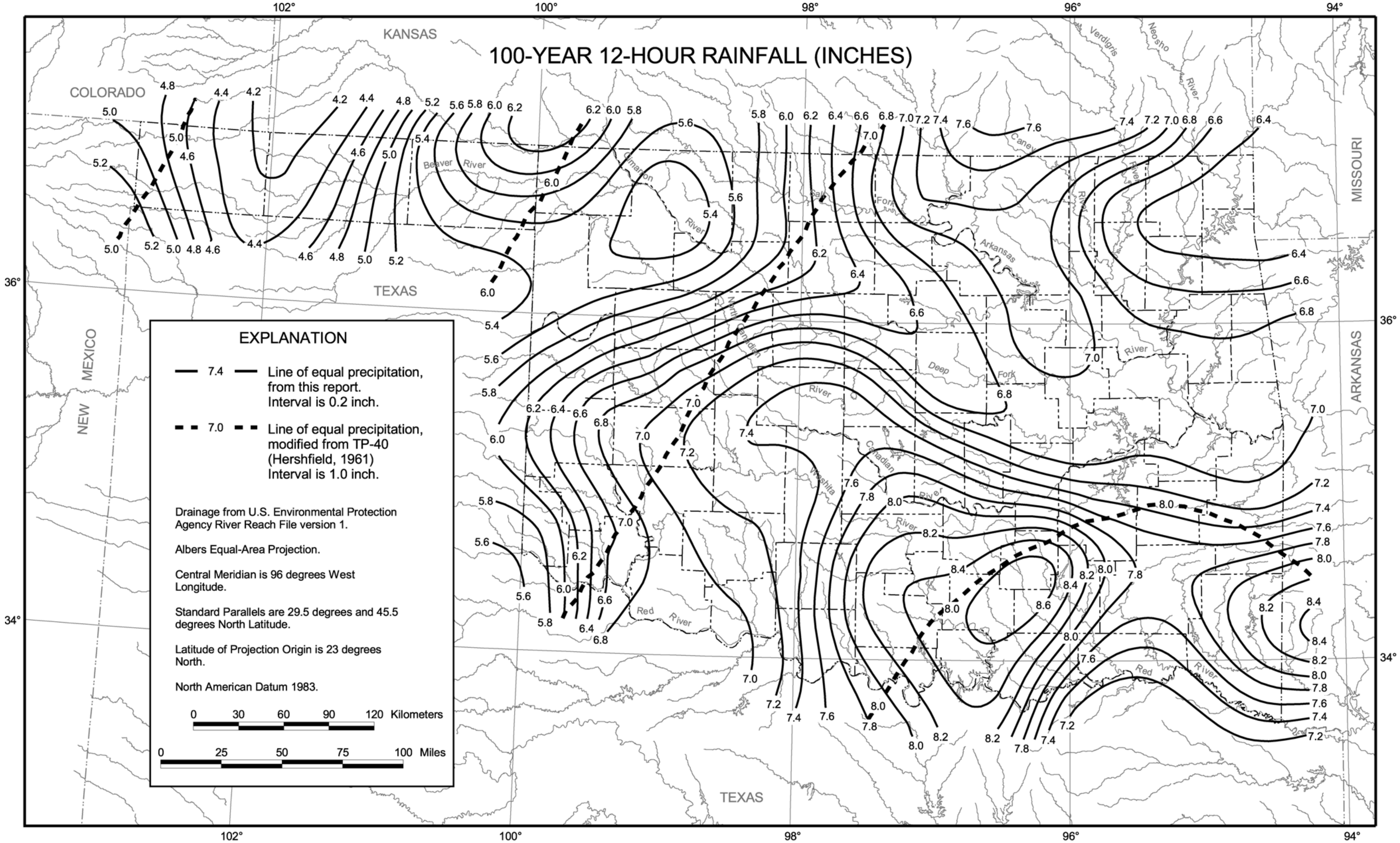

Figure 8. Comparison of depth of 100-year storm for 12-hour duration in Oklahoma between this report and Hershfield (1961).

Table 9. Summary statistics of depth-duration-frequency maps for each precipitation duration in Oklahoma

[Note: Surface error is defined as precipitation depth for control point minus value from depth surface used to create contour map; SD, standard deviation; RMSE, root mean square error; min, minutes; hr, hours; yr, years]

	Control points (stations)			Surface (contours)					
Duration/frequency	WT statewide mean of control points (in)	WT SD of statewide mean (in)	Coefficient of variation (Ratio of SD to mean)	WT mean surface error (in)	WT mean absolute surface error (in)	Maximum surface error (in)	Minimum surface error (in)	WT RMSE of surface (in)	Percent change from SD to RMSE
15-min									
2-yr	0.878	0.0946	0.108	-0.00315	0.0438	0.101	-0.168	0.0537	-43.2
5-yr	1.13	0.108	0.0951	-0.00380	0.0546	0.136	-0.206	0.0680	-36.7
10-yr	1.31	0.121	0.0925	-0.00446	0.0629	0.161	-0.234	0.0789	-34.7
25-yr	1.55	0.152	0.0976	-0.00561	0.0758	0.239	-0.277	0.0971	-35.9
50-yr	1.76	0.191	0.109	-0.00676	0.0885	0.323	-0.314	0.116	-39.0
100-yr	1.99	0.249	0.125	-0.00818	0.107	0.436	-0.358	0.143	-42.7
500-yr	2.64	0.486	0.184	-0.0129	0.179	0.861	-0.489	0.248	-48.9
30-min									
2-yr	1.22	0.137	0.113	-0.00242	0.0621	0.160	-0.188	0.0757	-44.6
5-yr	1.57	0.160	0.102	-0.00181	0.0774	0.210	-0.241	0.0958	-40.2
10-yr	1.82	0.181	0.0993	-0.00119	0.0881	0.256	-0.282	0.110	-39.0
25-yr	2.16	0.219	0.101	-0.0000610	0.104	0.332	-0.338	0.133	-39.3
50-yr	2.44	0.262	0.107	0.00111	0.122	0.405	-0.384	0.155	-40.9
100-yr	2.75	0.323	0.117	0.00265	0.145	0.495	-0.441	0.183	-43.2
500-yr	3.62	0.562	0.155	0.00819	0.227	0.789	-0.799	0.287	-49.0
60-min									
2-yr	1.56	0.188	0.120	-0.00221	0.0773	0.275	-0.241	0.103	-45.3
5-yr	2.05	0.240	0.117	-0.000626	0.104	0.370	-0.322	0.135	-43.8
10-yr	2.39	0.286	0.120	0.000885	0.123	0.445	-0.377	0.158	-44.6
25-yr	2.88	0.362	0.126	0.00351	0.151	0.561	-0.452	0.194	-46.4
50-yr	3.28	0.438	0.133	0.00615	0.175	0.694	-0.514	0.228	-48.0
100-yr	3.74	0.533	0.142	0.00949	0.206	0.900	-0.581	0.269	-49.5
500-yr	5.04	0.860	0.171	0.0210	0.309	1.62	-0.763	0.412	-52.0
1-hr									
2-yr	1.49	0.178	0.119	-0.00523	0.0598	0.252	-0.267	0.0820	-53.9
5-yr	2.02	0.202	0.100	-0.00637	0.0810	0.328	-0.344	0.110	-45.7
10-yr	2.38	0.224	0.0942	-0.00652	0.0967	0.381	-0.404	0.128	-42.7
25-yr	2.83	0.268	0.0947	-0.00606	0.121	0.472	-0.487	0.155	-42.1
50-yr	3.18	0.318	0.100	-0.00524	0.143	0.547	-0.552	0.180	-43.3
100-yr	3.52	0.384	0.109	-0.00405	0.169	0.628	-0.620	0.211	-45.1
500-yr	4.36	0.604	0.139	0.000141	0.252	0.941	-0.783	0.309	-48.8
2-hr									
2-yr	1.86	0.239	0.128	-0.00238	0.0757	0.293	-0.343	0.0994	-58.3
5-yr	2.52	0.287	0.114	-0.00239	0.103	0.407	-0.438	0.136	-52.6
10-yr	2.98	0.329	0.110	-0.00155	0.124	0.471	-0.507	0.162	-50.6

Table 9. Summary statistics of depth-duration-frequency maps for each precipitation duration in Oklahoma—Continued

[Note: Surface error is defined as precipitation depth for control point minus value from depth surface used to create contour map; SD, standard deviation; RMSE, root mean square error; min, minutes; hr, hours; yr, years]

	Control points (stations)			Surface (contours)					
Duration/frequency	WT statewide mean of control points (in)	WT SD of statewide mean (in)	Coefficient of variation (Ratio of SD to mean)	WT mean surface error (in)	WT mean absolute surface error (in)	Maximum surface error (in)	Minimum surface error (in)	WT RMSE of surface (in)	Percent change from SD to RMSE
25-yr	3.58	0.398	0.111	0.000453	0.155	0.567	-0.600	0.201	-49.6
50-yr	4.03	0.466	0.116	0.00259	0.181	0.711	-0.673	0.235	-49.6
100-yr	4.50	0.552	0.123	0.00527	0.212	0.885	-0.750	0.276	-49.9
500-yr	5.64	0.830	0.147	0.0135	0.305	1.40	-1.07	0.407	-51.0
3-hr									
2-yr	2.06	0.283	0.138	-0.00221	0.0848	0.324	-0.379	0.111	-60.9
5-yr	2.80	0.350	0.125	-0.00186	0.116	0.457	-0.476	0.151	-56.9
10-yr	3.31	0.401	0.121	-0.000774	0.139	0.538	-0.548	0.181	-55.0
25-yr	3.99	0.484	0.121	0.00155	0.174	0.631	-0.659	0.227	-53.2
50-yr	4.51	0.565	0.125	0.00398	0.205	0.718	-0.741	0.269	-52.3
100-yr	5.05	0.667	0.132	0.00697	0.242	0.947	-0.902	0.322	-51.8
500-yr	6.38	1.01	0.159	0.0162	0.362	1.67	-1.35	0.491	-51.5
6-hr									
2-yr	2.42	0.357	0.147	-0.00110	0.100	0.287	-0.426	0.130	-63.6
5-yr	3.30	0.448	0.136	-0.00128	0.137	0.406	-0.536	0.175	-61.0
10-yr	3.91	0.518	0.133	-0.00105	0.163	0.519	-0.640	0.207	-60.1
25-yr	4.72	0.628	0.133	-0.000357	0.202	0.708	-0.773	0.255	-59.4
50-yr	5.35	0.734	0.137	0.000435	0.237	0.888	-0.871	0.300	-59.1
100-yr	6.00	0.866	0.144	0.00146	0.277	1.10	-0.968	0.355	-59.0
500-yr	7.64	1.30	0.171	0.00478	0.410	1.79	-1.31	0.534	-59.1
12-hr									
2-yr	2.79	0.445	0.160	-0.00244	0.110	0.360	-0.411	0.139	-68.7
5-yr	3.79	0.571	0.150	-0.00284	0.148	0.464	-0.581	0.185	-67.5
10-yr	4.49	0.667	0.149	-0.00246	0.176	0.553	-0.695	0.220	-67.1
25-yr	5.41	0.813	0.150	-0.00122	0.216	0.676	-0.841	0.270	-66.8
50-yr	6.12	0.945	0.154	0.000286	0.251	0.777	-0.950	0.316	-66.6
100-yr	6.86	1.10	0.161	0.00230	0.294	0.940	-1.06	0.371	-66.3
500-yr	8.68	1.59	0.183	0.00904	0.433	1.69	-1.32	0.543	-65.8
24-hr									
2-yr	3.20	0.555	0.173	-0.00369	0.120	0.518	-0.572	0.167	-69.9
5-yr	4.38	0.742	0.170	-0.00502	0.160	0.684	-0.770	0.224	-69.9
10-yr	5.20	0.891	0.171	-0.00425	0.192	0.784	-0.916	0.266	-70.1
25-yr	6.30	1.12	0.178	-0.00107	0.243	0.896	-1.10	0.331	-70.4
50-yr	7.15	1.33	0.185	0.00309	0.292	0.973	-1.24	0.392	-70.4
100-yr	8.04	1.57	0.195	0.00893	0.351	1.12	-1.38	0.467	-70.2
500-yr	10.3	2.31	0.225	0.0301	0.537	1.79	-1.78	0.712	-69.1
1-day									

Table 9. Summary statistics of depth-duration-frequency maps for each precipitation duration in Oklahoma—Continued

[Note: Surface error is defined as precipitation depth for control point minus value from depth surface used to create contour map; SD, standard deviation; RMSE, root mean square error; min, minutes; hr, hours; yr, years]

Duration/frequency	Control points (stations)			Surface (contours)					Percent change from SD to RMSE
	WT statewide mean of control points (in)	WT SD of statewide mean (in)	Coefficient of variation (Ratio of SD to mean)	WT mean surface error (in)	WT mean absolute surface error (in)	Maximum surface error (in)	Minimum surface error (in)	WT RMSE of surface (in)	
2-yr	3.41	0.485	0.142	0.00802	0.128	0.778	-0.537	0.170	-65.0
5-yr	4.63	0.644	0.139	0.00793	0.184	1.11	-0.833	0.241	-62.6
10-yr	5.50	0.772	0.140	0.00516	0.233	1.36	-1.08	0.303	-60.8
25-yr	6.67	0.978	0.147	-0.00203	0.322	1.89	-1.45	0.414	-57.6
50-yr	7.60	1.17	0.155	-0.0105	0.417	2.36	-1.78	0.531	-54.8
100-yr	8.58	1.42	0.165	-0.0220	0.542	2.90	-2.15	0.683	-51.8
500-yr	11.1	2.21	0.200	-0.0628	0.952	4.61	-3.21	1.20	-45.8
3-day									
2-yr	4.20	0.630	0.150	0.00949	0.145	0.831	-0.581	0.187	-70.3
5-yr	5.69	0.846	0.149	0.00744	0.205	1.12	-0.719	0.265	-68.6
10-yr	6.75	1.02	0.151	0.00427	0.257	1.40	-0.861	0.333	-67.3
25-yr	8.19	1.29	0.157	-0.00196	0.349	1.85	-1.17	0.453	-64.8
50-yr	9.33	1.54	0.165	-0.00830	0.451	2.25	-1.43	0.579	-62.3
100-yr	10.5	1.84	0.175	-0.0161	0.584	2.82	-1.73	0.744	-59.6
500-yr	13.7	2.82	0.207	-0.0409	1.03	5.01	-2.83	1.31	-53.7
7-day									
2-yr	5.08	0.769	0.152	0.00554	0.178	1.16	-0.693	0.236	-69.4
5-yr	6.81	1.01	0.148	0.00327	0.247	1.65	-0.862	0.330	-67.3
10-yr	8.02	1.20	0.149	0.00195	0.303	1.96	-1.00	0.405	-66.1
25-yr	9.62	1.48	0.154	0.000447	0.403	2.32	-1.31	0.532	-64.2
50-yr	10.9	1.74	0.160	-0.000595	0.507	2.78	-1.74	0.660	-62.2
100-yr	12.2	2.05	0.169	-0.00161	0.640	3.33	-2.27	0.825	-59.9
500-yr	15.4	3.03	0.196	-0.00411	1.09	4.97	-3.90	1.39	-54.2

or 1-day duration are considered valid, the generation of an intensity-duration frequency curve as shown in figure 7 helps resolve discrepancies.

Figure 7 gives examples of these differences in the transition between the 60-minute and 1-hour durations, between the 24-hour and 1-day durations and how a best-fit line can help resolve these differences. These differences are not necessarily the same at all locations. The Oklahoma City plot has larger values at the 1-hour and 24-hour durations. The Tulsa, and Altus plots have larger values at the 60-minute and 1-day durations. The Ardmore plot has larger values at the 60-minute and 24-hour durations. The Goodwell and Stillwater plots have about the same value at the 60-minute and 1-hour durations and larger values at the 1-day duration. The Carter plot has a larger value at the 60-minute duration and about the same value at the at the 24-hour and 1-day durations.

Comparison to Previous Studies

Exact comparisons to previous studies [TP–40 (Hershfield, 1961), TP–49 (Miller, 1964), and HYDRO–35 (Frederick and others, 1977)] are not easy to document. The length of record and number of stations were much lower and maps were produced on the basis of computation of 2-year and 100-year analyses in the previous studies. Hershfield (1961) used data through 1958 from about 20 1-hour stations and 160 1-day stations. This report uses 38 more years of record and hundreds more stations. A comparison is shown in figure 8 between the depths for the 12-hour 100-year storm from TP–40 and the precipitation depths obtained from the appropriate contour map developed for this report (fig. 63). According to the figure, the depths calculated using the methods in this report are generally similar to those in TP–40. However, the contours of the depths using the methods in this report show much greater spatial detail than the depths available from TP–40.

The intensity-duration frequency curves derived from the methods of this report and the curves generated from TP–40, TP–49, and HYDRO–35 are not compared in this report. Some areas of the State could indicate larger or smaller values due to different data used to produce the contour maps.

Another difference between this study and past studies is seen in the depth-duration frequency of precipitation maps for the 15-minute and 30-minute durations (figs. 9–22). These depth-duration frequency of precipitation maps tend to be more random and do not show a definite pattern or progression of greater depths from west to east, as is the case with the other durations of 60 minutes to 7 day (figs. 23–92). For the short durations, depth-duration frequencies appear not to follow the west-to-east variations typical of other precipitation measures in Oklahoma (H.L. Johnson, Oklahoma Climatological Survey, written commun., 1999).

Depth-duration frequency of precipitation maps developed in this study are considered more accurate than maps from previous studies because of (1) the greater number of stations and longer lengths of record available, including the very wet period of 1986–1995; (2) the use of more powerful statistics (L-moments), which were not available at the time the previous studies were completed; (3) the use of more flexible and appropriate three-parameter distributions rather than the two-parameter Gumbel distribution used in previous studies; and (4) greater spatial detail of the depth-duration frequency of precipitation maps.

Oklahoma Mesonet

The Oklahoma Mesonet, a statewide network of environment monitoring stations, eventually will be able to provide additional data (Oklahoma Climatological Survey, 1999). The network was designed and implemented by scientists at the University of Oklahoma and Oklahoma State University. The Oklahoma Mesonet consists of 115 automated stations covering Oklahoma. There is at least one station in each of 77 Oklahoma counties.

Measurements from a set of instruments at each site are recorded every 5 minutes and the data are transmitted to a central location every 15 minutes. The core parameters measured at every Mesonet site are: (1) rainfall, (2) air temperature measured at 1.5 meters above the ground, (3) relative humidity measured at 1.5 meters above the ground, (4) wind speed and direction measured at 10 meters above the ground, (5) barometric pressure, (6) incoming solar radiation, and (7) soil temperatures at 10 centimeters below the ground under both natural sod and bare soil. The Oklahoma Climatological Survey at the University of Oklahoma receives the data, verifies the quality, and provides the data to Mesonet customers. The data are available from the Oklahoma Climatological Survey to customers as soon as 10 to 20 minutes after the measurements are acquired.

The first climate sites were installed in 1991, and 111 sites became operational in 1994. Because none of these stations yet have 10 years of record, these data were not used for this study.

Summary

Precipitation depths for various durations and frequencies have many uses. A common use of depth-duration frequency of precipitation is for the design of drainage structures that control and route localized runoff—such as parking lots, storm drains, and culverts. Another use of depth-duration frequency of precipitation is for compilation of rainfall-runoff river-flow models, which incorporate precipitation characteristics. Accurate depth-duration frequency of precipitation estimates are important for economical and safe structural designs at stream crossings and for developing reliable flood prediction models.

The durations investigated during a U.S. Geological Survey study of depth-duration frequency of precipitation for Oklahoma were 15, 30, and 60 minutes; 1, 2, 3, 6, 12, and 24 hours; and 1, 3, and 7 days. The seven selected frequencies investigated, expressed as recurrence intervals, were: 2, 5, 10, 25 50, 100, and 500 years. The basis for depth-duration frequency of precipitation is a data base of annual maxima of precipitation for each identified duration from 110 15-minute, 141 hourly, and 413 daily National Weather Service precipitation stations with at least 10 years of data within and near Oklahoma. About 2,162; 5,382; and 19,233 cumulative years of record are available for the 15-minute, hourly, and daily stations, respectively. The areal density of stations, in stations per 1,000 square miles, for each station type are 0.948 for the 15-minute, 1.21 for the hourly, and 3.56 for the daily stations.

The steps of regionalization of precipitation annual maxima for this report include (1) computation of the L-moment statistics for each station and each duration using unbiased estimators; (2) determination of an appropriate probability distribution for modeling the frequency of annual maxima using L-moment ratio diagrams and goodness-of-fit measures; (3) improvement of the estimation of the L-coefficient of variation and L-skew by spatial averaging; (4) estimation of a corrected L-scale from the product of the corrected mean depth and the spatially averaged L-coefficient of variation; (5) computation of the appropriate distribution parameters with the corrected L-moment statistics at each precipitation station; (6) computation of depth-duration frequency of precipitation values with the appropriate distribution parameters at each precipitation station; (7) creation of depth surfaces in a 2-kilometer grid for each duration-frequency by smoothing the at-site values of precipitation depth using exponential-distance and length-of-record weighting; and (8) creation of depth-duration frequency of precipitation contour maps from the surfaces. The precipitation depth for selected frequencies and durations for any location in Oklahoma can be determined by the values on the contour maps.

L-moment statistics of the precipitation annual maxima were calculated for each duration and for each station using unbiased L-moment estimators. The statistics calculated were the mean, L-scale, L-coefficient of variation, L-skew, and L-kurtosis. L-skew and L-kurtosis in L-moment ratio diagrams and goodness-of-fit measures were used to determine that the three-parameter generalized logistic distribution is an appropriate probability distribution for modeling the frequency of annual maxima for durations of 15, 30, and 60 minutes. The three-parameter generalized extreme-value distribution was determined as appropriate for durations of 1 hour to 7 days.

Spatial averaging of L-coefficient of variation and L-skew was used to (1) reduce the random component in the values, (2) improve the accuracy of the estimates, and (3) reduce the influence of any one station on the eventual contouring of the precipitation depths. The mean for each station and duration was corrected for the bias associated with fixed-interval recording of precipitation. A corrected L-scale subsequently was estimated using the corrected mean and the spatially averaged L-coefficient of variation for each duration and for each station. Finally, the corrected mean, the corrected L–scale, and the averaged L-skew for each station and duration were used to compute the location, scale, and shape parameters for the generalized logistic and generalized extreme-value distributions.

The resulting parameters were used to compute the precipitation depth for each station for seven selected frequencies (2, 5, 10, 25, 50, 100, and 500 year) at each of the 12 durations. These depth values then were used to create a gridded depth surface for each depth-duration frequency of precipitation using exponential distance weighting and length-of-record weighting to interpolate and smooth the values. After interpolation the depth-duration frequency of precipitation grids were masked to include just the area of Oklahoma plus a 20-kilometer buffer. This was done to (1) minimize the effects of poorer interpolations near the edges of the data (at 50 kilometers), and (2) assist in interpolating depth values at the State border. Contour lines were derived from each surface, choosing an appropriate contour interval. It is intended that the maps be used to estimate the precipitation depth values only within Oklahoma.

The depth-duration frequency of precipitation for any location in Oklahoma can be estimated using the appropriate precipitation depth maps. Percent changes from standard deviation to root mean square error for the (1) 15-minute to 60-minute durations ranged between -34.7 to -52.0 percent; (2) 1-hour to 24-hour durations ranged between -42.1 and -70.4 percent; and (3) 1-day to 7-day durations ranged between -45.8 and -70.3 percent. Therefore, the use of the contour maps results in more accurate estimates of the precipitation depth than by simply using a statewide mean.

To reduce the effects of potential errors associated with the maps, precipitation intensity-duration frequency curves should be developed on the basis of the relation between precipitation intensities (inches per hour) and duration. The intensity-duration frequency curves for selected localities in the State are presented. There is a relatively smooth transition of the intensity-duration frequency curve from short to long durations, in which the 15-minute, hourly, and daily data sources are used.

The contours of the depths using the methods in this report show much greater spatial detail than the depths available from previous studies. Another difference between this study and past studies is seen in the depth-duration frequency of precipitation maps for the 15-minute and 30-minute durations. These depth-duration frequency of precipitation maps tend to be more random and do not show a definite pattern or progression of greater depths from west to east, as is the case with the other durations of 60 minutes to 7 day. For the short durations, depth-duration frequencies appear not to follow the west-to-east variations typical of other precipitation measures in Oklahoma.

Depth-duration frequency of precipitation maps developed in this study are considered more accurate than maps from previous studies because of (1) the greater number of stations and longer lengths of record available, (2) the use of more powerful statistics (L-moments), which were not available at the time the previous studies were completed, (3) the use of more flexible and appropriate three-parameter distributions rather than the two-parameter Gumbel distribution used in previous studies, and (4) greater spatial detail of the depth-duration frequency of precipitation maps.

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Table 1. Fifteen-minute precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in the analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration]

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
1	453808	Kim 15 NNE	Colo.	3727	10319	25	1972	1996
2	188735	Clayton WSO Airport[1]	N.Mex.	3627	10309	8	1984	1995
3	786608	Springfield 7 WSW	Colo.	3723	10244	21	1976	1996
4	90840	Boise City 2 E	Okla.	3644	10229	13	1983	1996
5	300240	Eva 2 SSW	Okla.	3646	10155	13	1984	1996
6	876148	Sunray 4 SW	Tex.	3558	10152	14	1971	1984
7	243220	Elkhart 6 NNE	Kans.	3705	10151	12	1984	1996
8	80220	Big Bow 4 WSW	Kans.	3733	10138	15	1982	1996
9	362840	Goodwell Research Station	Okla.	3636	10137	19	1978	1996
10	864748	Stinnett	Tex.	3550	10127	18	1975	1992
12	741240	Range	Okla.	3633	10105	21	1976	1996
13	792220	Sublette	Kans.	3729	10051	25	1971	1996
14	565648	Matador 2	Tex.	3401	10050	26	1971	1996
15	577048	McLean	Tex.	3514	10036	26	1971	1996
16	766040	Riverside 4 W	Okla.	3647	10025	21	1976	1996
17	341048	Gageby 2 NW	Tex.	3538	10022	22	1971	1996
18	169848	Childress FAA Airport	Tex.	3426	10017	22	1975	1996
19	524748	Lipscomb	Tex.	3614	10016	26	1971	1996
20	956548	Wellington[2]	Tex.	3450	10013	23	1971	1996
21	256020	Englewood 1 NW	Kans.	3703	10000	13	1984	1996
22	810140	Shattuck 1 N	Okla.	3617	09952	21	1976	1996
23	564840	Mayfield	Okla.	3520	09952	26	1971	1996
24	546340	Mackie 4 NNW	Okla.	3545	09950	23	1974	1996
25	330440	Fort Supply Dam	Okla.	3633	09935	13	1984	1996
26	284940	Elk City	Okla.	3523	09924	21	1971	1996
27	17940	Altus Irrigation Research Station	Okla.	3435	09920	26	1971	1996
28	420240	Hobart	Okla.	3501	09905	26	1971	1996
29	796520	Sun City 2 NW	Kans.	3724	09858	15	1982	1996
30	870840	Taloga	Okla.	3602	09858	26	1971	1996
31	233440	Custer City	Okla.	3540	09853	24	1973	1996
32	940440	Waynoka	Okla.	3635	09852	13	1984	1996
33	962940	Wichita Mountain Wildlife Refuge	Okla.	3444	09843	18	1979	1996
34	434120	Kiowa	Kans.	3701	09829	24	1973	1996

Table 1. Fifteen-minute precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
35	328140	Fort Cobb	Okla.	3506	09826	20	1977	1996
36	349740	Geary	Okla.	3538	09819	26	1971	1996
37	21540	Ames	Okla.	3615	09811	12	1984	1995
38	374040	Great Salt Plains Dam	Okla.	3645	09808	13	1984	1996
39	662040	Okarche	Okla.	3543	09759	16	1981	1996
40	265440	Duncan Airport	Okla.	3429	09758	18	1979	1996
41	175040	Chickasha Experiment Station	Okla.	3503	09755	26	1971	1996
42	497840	Lake Overholser	Okla.	3529	09740	25	1971	1996
43	123320	Caldwell	Kans.	3703	09737	26	1971	1996
44	558940	Marshall	Okla.	3609	09737	22	1975	1996
45	92648	Bonita	Tex.	3346	09736	19	1978	1996
46	405240	Hennepin	Okla.	3431	09721	23	1974	1996
47	685940	Paoli 2 N	Okla.	3451	09715	25	1972	1996
48	29240	Ardmore[2]	Okla.	3412	09709	26	1971	1996
49	341548	Gainesville	Tex.	3338	09708	26	1971	1996
50	719640	Ponca City	Okla.	3644	09706	19	1978	1996
51	850140	Stillwater 2 W	Okla.	3607	09706	21	1972	1996
52	168440	Chandler 1	Okla.	3542	09653	26	1971	1996
53	770540	Roff 3 NW	Okla.	3439	09653	26	1971	1996
54	364248	Gordonville	Tex.	3348	09651	20	1977	1996
55	694440	Pawnee 5 N	Okla.	3624	09649	26	1971	1996
56	486540	Kingston	Okla.	3401	09645	13	1984	1996
57	974840	Wolf[2]	Okla.	3505	09641	26	1971	1996
58	661640	Oilton 2 SE	Okla.	3604	09634	26	1971	1996
59	239448	Denison Dam	Tex.	3349	09634	13	1984	1996
60	190240	Cleveland 5 WSW	Okla.	3617	09633	13	1984	1996
61	324820	Grenola 1 N	Kans.	3722	09627	26	1971	1996
62	693540	Pawhuska	Okla.	3640	09621	26	1971	1996
63	663840	Okemah	Okla.	3526	09618	17	1980	1996
64	409840	Heyburn Dam	Okla.	3557	09617	13	1984	1996
65	481240	Keystone Dam	Okla.	3609	09615	13	1984	1996
66	510840	Lehigh	Okla.	3428	09613	13	1984	1996
67	143740	Caney	Okla.	3414	09613	19	1978	1996
68	53540	Barnsdall	Okla.	3634	09610	13	1979	1996
69	439340	Hulah Dam	Okla.	3655	09606	18	1979	1996
70	497548	Lake Crockett	Tex.	3344	09555	24	1973	1996

Table 1. Fifteen-minute precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
71	425748	Honey Grove	Tex.	3335	09554	24	1971	1996
72	243020	Elk City Lake	Kans.	3717	09548	18	1979	1996
73	566440	McAlester FAA Airport	Okla.	3453	09547	17	1980	1996
74	672940	Oologah Dam	Okla.	3626	09541	13	1984	1996
75	648540	Nowata	Okla.	3642	09538	17	1980	1996
76	25640	Antlers	Okla.	3415	09538	26	1971	1996
77	450640	Inola 6 SSW	Okla.	3604	09533	13	1984	1996
78	438440	Hugo	Okla.	3400	09531	25	1972	1996
79	683448	Pat Mayse Dam	Tex.	3352	09531	26	1971	1996
80	553620	Mound Valley 3 WSW	Kans.	3711	09527	13	1984	1996
81	438640	Hugo Dam	Okla.	3400	09524	13	1984	1996
82	662740	Okay 3 W Lock 17	Okla.	3551	09522	15	1982	1996
83	497540	Lake Eufaula	Okla.	3518	09522	14	1983	1996
84	613040	Muskogee	Okla.	3546	09520	17	1980	1996
85	241548	Deport	Tex.	3331	09519	13	1984	1996
86	730940	Pryor 6 N	Okla.	3624	09518	23	1973	1996
87	902340	Tuskahoma	Okla.	3437	09517	13	1984	1996
88	328640	Fort Gibson Dam	Okla.	3552	09514	16	1981	1996
89	945040	Webbers Falls Dam	Okla.	3533	09510	26	1971	1996
90	849740	Stigler 1 SE	Okla.	3515	09507	24	1972	1996
91	67040	Bengal 2 NNW	Okla.	3451	09505	26	1971	1996
92	708040	Pine Creek Dam	Okla.	3414	09505	13	1984	1996
93	177348	Clarksville 1 W	Tex.	3337	09504	26	1971	1996
94	876940	Tenkiller Ferry Dam	Okla.	3536	09503	13	1984	1996
95	773940	Rose Tower	Okla.	3610	09501	23	1974	1996
96	174020	Columbus 1 SW	Kans.	3710	09451	13	1984	1996
97	767540	Robert S Kerr Dam	Okla.	3520	09447	26	1971	1996
98	154440	Carter Tower	Okla.	3415	09447	26	1971	1996
99	116840	Broken Bow Dam	Okla.	3408	09442	13	1984	1996
100	796729	Spring City	Mo.	3659	09432	26	1971	1996
101	627048	New Boston	Tex.	3327	09425	24	1973	1996
102	254405	Foreman	Ark.	3344	09424	13	1984	1996
103	195205	De Queen Dam	Ark.	3406	09423	13	1984	1996
104	475605	Mena	Ark.	3434	09416	13	1984	1996
105	281005	Gillham Dam	Ark.	3407	09414	26	1971	1996

Table 1. Fifteen-minute precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
106	244405	Fayetteville Experiment Station	Ark.	3606	09410	26	1971	1996
107	991648	Wright Patman Dam & Lake	Tex.	3318	09410	13	1984	1996
108	748805	Waldron	Ark.	3454	09406	22	1975	1996
109	202005	Dierks Dam	Ark.	3409	09406	13	1984	1996
110	894248	Texarkana	Tex.	3325	09405	24	1973	1996

[1] Exception to 10 years of record, station data were needed for map-contour smoothing analysis

[2] Station record was combined with record from station within 2 minutes latitude and/or longitude

Table 2. Hourly precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service Field Office]

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
1	661935	Pasamonte	N.Mex.	3618	10344	16	1948	1964
2	453808	Kim 15 NNE	Colo.	3727	10319	49	1948	1996
3	188735	Clayton WSO Airport	N.Mex.	3627	10309	44	1948	1995
4	786608	Springfield 7 WSW	Colo.	3723	10244	25	1972	1996
5	90840	Boise City 2 E[1]	Okla.	3644	10229	48	1947	1996
6	300240	Eva 2 SSW	Okla.	3646	10155	50	1947	1996
7	243720	Elkhart 3 N	Kans.	3703	10154	20	1948	1967
8	876148	Sunray 4 SW	Tex.	3558	10152	29	1955	1984
9	243220	Elkhart 6 NNE	Kans.	3705	10151	28	1968	1996
10	80220	Big Bow 4 WSW	Kans.	3733	10138	49	1948	1996
11	362840	Goodwell Research Station	Okla.	3636	10137	50	1947	1996
12	864748	Stinnett	Tex.	3550	10127	33	1959	1992
13	674040	Optima Lake	Okla.	3639	10108	21	1974	1994
14	741240	Range	Okla.	3633	10105	49	1947	1996
15	792220	Sublette	Kans.	3729	10051	39	1958	1996
16	565648	Matador 2[1]	Tex.	3401	10050	54	1942	1996
17	985848	Wolf Creek Dam	Tex.	3614	10040	34	1941	1974
18	577048	McLean	Tex.	3514	10036	57	1940	1996
19	766040	Riverside 4 W	Okla.	3647	10025	50	1947	1996
20	341048	Gageby 2 NW	Tex.	3538	10022	52	1941	1996
21	169848	Childress FAA Airport[1]	Tex.	3426	10017	56	1940	1996
22	524748	Lipscomb	Tex.	3614	10016	57	1940	1996
23	956548	Wellington[1]	Tex.	3450	10013	47	1949	1996
24	256020	Englewood 1 NW	Kans.	3703	10000	49	1948	1996
25	810140	Shattuck 1 N	Okla.	3617	09952	49	1948	1996
26	758840	Reydon 7 NNE	Okla.	3545	09952	19	1947	1965
27	564840	Mayfield	Okla.	3520	09952	48	1948	1996
28	546340	Mackie 4 NNW	Okla.	3545	09950	27	1970	1996
29	771440	Roll	Okla.	3547	09943	21	1948	1969
30	330440	Fort Supply Dam	Okla.	3633	09935	50	1947	1996
31	976240	Woodward Field Station	Okla.	3625	09924	31	1949	1979
32	284940	Elk City	Okla.	3523	09924	44	1947	1996
33	17940	Altus Irrigation Research Station	Okla.	3435	09920	26	1971	1996
34	18840	Altus 7 NE	Okla.	3443	09916	23	1947	1970
35	24240	Anthon 6 W	Okla.	3545	09906	27	1947	1973

Table 2. Hourly precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
36	420240	Hobart	Okla.	3501	09905	45	1952	1996
37	796520	Sun City 2 NW	Kans.	3724	09858	49	1948	1996
38	870840	Taloga	Okla.	3602	09858	28	1957	1996
39	802940	Seiling 3 N	Okla.	3611	09855	24	1947	1970
40	233440	Custer City	Okla.	3540	09853	24	1973	1996
41	940440	Waynoka	Okla.	3635	09852	49	1948	1996
42	962940	Wichita Mountain Wildlife Refuge	Okla.	3444	09843	49	1948	1996
43	434120	Kiowa	Kans.	3701	09829	49	1948	1996
44	972948	Wichita Falls WSO Airport	Tex.	3358	09829	57	1940	1996
45	328140	Fort Cobb	Okla.	3506	09826	45	1952	1996
46	349740	Geary	Okla.	3538	09819	50	1947	1996
47	21540	Ames	Okla.	3615	09811	49	1947	1995
48	374040	Great Salt Plains Dam	Okla.	3645	09808	50	1947	1996
49	662040	Okarche	Okla.	3543	09759	16	1981	1996
50	265440	Duncan Airport[1]	Okla.	3429	09758	50	1947	1996
51	632840	Ninnekah	Okla.	3457	09756	20	1947	1966
52	175040	Chickasha Experiment Station	Okla.	3503	09755	39	1958	1996
53	497840	Lake Overholser	Okla.	3529	09740	45	1952	1996
54	123320	Caldwell	Kans.	3703	09737	49	1948	1996
55	558940	Marshall	Okla.	3609	09737	22	1975	1996
56	666140	Oklahoma City WSFO Airport	Okla.	3524	09736	50	1947	1996
57	92648	Bonita	Tex.	3346	09736	57	1940	1996
58	676040	Orlando 1 NNE	Okla.	3610	09722	27	1948	1975
59	405240	Hennepin[1]	Okla.	3431	09721	49	1948	1996
60	685940	Paoli 2 N	Okla.	3451	09715	50	1947	1996
61	29240	Ardmore[1]	Okla.	3412	09709	38	1957	1996
62	341548	Gainesville	Tex.	3338	09708	56	1941	1996
63	719640	Ponca City	Okla.	3644	09706	44	1952	1996
64	850140	Stillwater 2 W	Okla.	3607	09706	45	1948	1996
65	29640	Ardmore FAA Airport	Okla.	3418	09701	11	1948	1958
66	168440	Chandler 1	Okla.	3542	09653	44	1953	1996
67	770540	Roff 3 NW	Okla.	3439	09653	50	1947	1996
68	364248	Gordonville	Tex.	3348	09651	54	1942	1996
69	694440	Pawnee 5 N	Okla.	3624	09649	50	1947	1996
70	486540	Kingston	Okla.	3401	09645	50	1947	1996
71	974840	Wolf[1]	Okla.	3505	09641	50	1947	1996
72	950340	West Branch	Okla.	3615	09639	10	1948	1957

Table 2. Hourly precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
73	661640	Oilton 2 SE	Okla.	3604	09634	49	1948	1996
74	239448	Denison Dam	Tex.	3349	09634	57	1940	1996
75	190240	Cleveland 5 WSW	Okla.	3617	09633	13	1984	1996
76	190040	Cleveland	Okla.	3618	09628	36	1947	1982
77	324820	Grenola 1 N	Kans.	3722	09627	49	1948	1996
78	693540	Pawhuska	Okla.	3640	09621	47	1950	1996
79	663840	Okemah	Okla.	3526	09618	46	1951	1996
80	409840	Heyburn Dam	Okla.	3557	09617	48	1949	1996
81	481240	Keystone Dam	Okla.	3609	09615	40	1957	1996
82	510840	Lehigh	Okla.	3428	09613	50	1947	1996
83	143740	Caney[1]	Okla.	3414	09613	50	1947	1996
84	53540	Barnsdall	Okla.	3634	09610	13	1979	1996
85	439340	Hulah Dam	Okla.	3655	09606	49	1947	1996
86	889848	Telephone	Tex.	3347	09601	14	1959	1972
87	497348	Lake Coffee Mill	Tex.	3344	09600	13	1946	1958
88	497548	Lake Crockett	Tex.	3344	09555	24	1973	1996
89	899240	Tulsa WSO Airport	Okla.	3611	09554	49	1948	1996
90	425748	Honey Grove	Tex.	3335	09554	50	1944	1996
91	566240	McAlester 4 W	Okla.	3457	09550	11	1947	1957
92	243020	Elk City Lake	Kans.	3717	09548	33	1964	1996
93	566440	McAlester FAA Airport	Okla.	3453	09547	17	1980	1996
94	672940	Oologah Dam	Okla.	3626	09541	41	1956	1996
95	648540	Nowata	Okla.	3642	09538	48	1949	1996
96	25640	Antlers	Okla.	3415	09538	50	1947	1996
97	450640	Inola 6 SSW	Okla.	3604	09533	29	1968	1996
98	438440	Hugo	Okla.	3400	09531	50	1947	1996
99	683448	Pat Mayse Dam	Tex.	3352	09531	31	1966	1996
100	553620	Mound Valley 3 WSW	Kans.	3711	09527	40	1957	1996
101	438640	Hugo Dam	Okla.	3400	09524	28	1969	1996
102	662740	Okay 3 W Lock 17	Okla.	3551	09522	25	1972	1996
103	497540	Lake Eufaula	Okla.	3518	09522	27	1970	1996
104	613040	Muskogee	Okla.	3546	09520	50	1947	1996
105	241548	Deport	Tex.	3331	09519	52	1944	1996
106	730940	Pryor 6 N	Okla.	3624	09518	23	1973	1996
107	902340	Tuskahoma	Okla.	3437	09517	49	1948	1996
108	2640	Adair 1 E	Okla.	3626	09515	21	1948	1968
109	328640	Fort Gibson Dam	Okla.	3552	09514	48	1949	1996

Table 2. Hourly precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
110	945040	Webbers Falls Dam	Okla.	3533	09510	31	1966	1996
111	849740	Stigler 1 SE	Okla.	3515	09507	49	1947	1996
112	67040	Bengal 2 NNW	Okla.	3451	09505	50	1947	1996
113	708040	Pine Creek Dam	Okla.	3414	09505	31	1966	1996
114	177348	Clarksville 1 W	Tex.	3337	09504	52	1940	1996
115	370040	Grand River Dam	Okla.	3628	09503	31	1947	1979
116	876940	Tenkiller Ferry Dam	Okla.	3536	09503	48	1949	1996
117	773240	Rose	Okla.	3613	09502	22	1951	1973
118	773940	Rose Tower	Okla.	3610	09501	21	1974	1996
119	174020	Columbus 1 SW	Kans.	3710	09451	49	1948	1996
120	735840	Quapaw	Okla.	3658	09447	16	1949	1965
121	767540	Robert S Kerr Dam	Okla.	3520	09447	31	1966	1996
122	154440	Carter Tower	Okla.	3415	09447	50	1947	1996
123	116840	Broken Bow Dam	Okla.	3408	09442	33	1964	1996
124	971940	Wister 3 NE	Okla.	5500	09441	22	1967	1988
125	765629	Seneca	Mo.	3651	09437	44	1948	1996
126	401040	Heavener Experiment Farm	Okla.	3455	09436	21	1947	1967
127	842040	Spiro 7 NE Lock & Dam 14	Okla.	3519	09433	16	1972	1987
128	796729	Spring City	Mo.	3659	09432	49	1948	1996
129	627048	New Boston	Tex.	3327	09425	24	1973	1996
130	254405	Foreman	Ark.	3344	09424	48	1948	1996
131	195205	De Queen Dam	Ark.	3406	09423	24	1973	1996
132	257405	Fort Smith WSO Airport	Ark.	3520	09422	49	1948	1996
133	475605	Mena	Ark.	3434	09416	49	1948	1996
134	281005	Gillham Dam	Ark.	3407	09414	31	1966	1996
135	769405	West Fork	Ark.	3555	09411	19	1948	1966
136	244405	Fayetteville Experiment Station	Ark.	3606	09410	31	1966	1996
137	991648	Wright Patman Dam & Lake[1]	Tex.	3318	09410	33	1955	1996
138	748805	Waldron	Ark.	3454	09406	49	1948	1996
139	202005	Dierks Dam	Ark.	3409	09406	24	1973	1996
140	894248	Texarkana	Tex.	3325	09405	29	1968	1996
141	704805	Texarkana FAA Airport	Ark.	3327	09400	21	1948	1968

[1] Station record was combined with record from station within 2 minutes latitude and/or longitude

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service Field Office; Natl, National; Dept, Department]

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
1	245335	Des Moines	N.Mex.	3645	10350	47	1948	1994
2	661935	Pasamonte	N.Mex.	3618	10344	49	1948	1996
3	126935	Bueyeros 4 NW	N.Mex.	3601	10344	20	1948	1967
4	507335	Long Canyon	N.Mex.	3700	10339	12	1948	1959
5	370635	Grenville	N.Mex.	3636	10337	49	1948	1996
6	672835	Pennington	N.Mex.	3619	10335	11	1949	1959
7	846808	Troy 1 SE	Colo.	3708	10318	38	1948	1987
8	387835	Hayden 6 NE	N.Mex.	3603	10313	18	1948	1965
9	188735	Clayton WSO Airport	N.Mex.	3627	10309	87	1896	1992
10	188135	Clayton 9 SSE	N.Mex.	3620	10306	12	1948	1959
11	476640	Kenton	Okla.	3654	10258	48	1948	1996
12	122448	Bunker Hill	Tex.	3609	10256	43	1948	1990
13	786608	Springfield 7 WSW	Colo.	3723	10244	40	1957	1996
14	753440	Regnier	Okla.	3656	10238	49	1948	1996
15	786208	Springfield	Colo.	3724	10237	64	1918	1985
16	126808	Campo 7 S	Colo.	3701	10234	42	1954	1996
17	187448	Coldwater	Tex.	3624	10234	41	1941	1983
18	224048	Dalhart FAA Airport[1]	Tex.	3601	10233	92	1905	1996
19	90840	Boise City 2 E	Okla.	3644	10229	49	1948	1996
20	398148	Hartley	Tex.	3553	10224	49	1948	1996
21	879308	Walsh 1 W	Colo.	3723	10215	31	1951	1996
22	194648	Conlen	Tex.	3614	10214	49	1948	1996
23	799208	Stonington	Colo.	3717	10211	48	1948	1996
24	869248	Stratford	Tex.	3621	10205	73	1911	1996
25	280308	Eversoll Ranch	Colo.	3702	10204	19	1948	1966
26	261748	Dumas	Tex.	3552	10158	59	1937	1996
27	681320	Richfield 10 WSW	Kans.	3714	10157	49	1948	1996
28	876148	Sunray 4 SW	Tex.	3558	10152	27	1933	1984
29	243220	Elkhart 6 NNE	Kans.	3705	10151	91	1900	1996
30	680820	Richfield 1 NE	Kans.	3716	10146	49	1948	1996
31	879840	Texhoma	Okla.	3630	10144	10	1948	1957
32	362840	Goodwell Research Station	Okla.	3636	10137	49	1948	1996
33	80020	Big Bow 2 S[1]	Kans.	3732	10134	44	1948	1991
34	607048	Morse	Tex.	3604	10129	55	1941	1996
35	383540	Guymon	Okla.	3642	10128	18	1948	1965

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service Field Office; Natl, National; Dept, Department]

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
36	383640	Guymon Lee Ranch	Okla.	3632	10124	11	1948	1958
37	378748	Gruver	Tex.	3615	10124	56	1941	1996
38	828720	Ulysses 1 SE	Kans.	3734	10121	58	1939	1996
39	385520	Hugoton	Kans.	3711	10121	49	1948	1996
40	419648	Hitchland 6 SSW	Tex.	3625	10121	25	1948	1972
41	429840	Hooker	Okla.	3652	10113	49	1948	1996
42	390240	Hardesty	Okla.	3637	10111	10	1948	1957
43	852348	Spearman	Tex.	3611	10111	77	1920	1996
44	695348	Perryton 11 WNW	Tex.	3627	10100	49	1948	1996
45	308548	Farnsworth 3 NNW	Tex.	3622	10059	17	1941	1957
46	469520	Liberal	Kans.	3703	10055	58	1939	1996
47	901740	Turpin 4 SSE	Okla.	3649	10052	15	1982	1996
48	792220	Sublette	Kans.	3729	10051	49	1948	1996
49	120348	Buler 4 NNW	Tex.	3611	10050	30	1948	1977
50	565848	Matador	Tex.	3401	10050	49	1948	1996
51	695248	Perryton 21 S	Tex.	3606	10049	19	1978	1996
52	883348	Tampico	Tex.	3428	10049	37	1948	1984
53	695048	Perryton 5 NNE	Tex.	3628	10047	86	1907	1996
54	587548	Miami	Tex.	3542	10038	92	1905	1996
55	642720	Plains	Kans.	3716	10036	26	1948	1974
56	647748	Notla 3 SE	Tex.	3606	10036	47	1950	1996
57	577048	McLean	Tex.	3514	10036	39	1948	1996
58	643348	Northfield	Tex.	3417	10036	49	1948	1996
59	59340	Beaver	Okla.	3649	10032	49	1948	1996
60	94448	Booker	Tex.	3627	10032	63	1922	1996
61	582148	Memphis	Tex.	3444	10032	91	1905	1996
62	598748	Mobeetie	Tex.	3532	10026	26	1947	1972
63	141248	Canadian 1 ENE	Tex.	3555	10022	91	1906	1996
64	517120	Meade	Kans.	3717	10020	49	1948	1996
65	228248	Darrouzett	Tex.	3626	10019	55	1942	1996
66	674048	Paducah[1]	Tex.	3401	10018	83	1913	1996
67	966248	Wheeler	Tex.	3526	10017	18	1979	1996
68	169848	Childress FAA Airport[1]	Tex.	3426	10017	93	1897	1996
69	524748	Lipscomb	Tex.	3614	10016	49	1948	1996
70	823648	Shamrock No 2[1]	Tex.	3513	10015	68	1929	1996
71	956548	Wellington	Tex.	3450	10013	56	1912	1996
72	285520	Fowler 3 NNE	Kans.	3725	10011	39	1948	1986

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

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Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
73	322548	Follett	Tex.	3626	10008	66	1930	1996
74	348940	Gate	Okla.	3651	10003	38	1959	1996
75	414048	Higgins	Tex.	3607	10002	50	1947	1996
76	757940	Reydon	Okla.	3539	09955	49	1948	1996
77	865240	Sweetwater	Okla.	3525	09955	15	1982	1996
78	921240	Vinson 3 WNW	Okla.	3455	09955	49	1948	1996
79	424940	Hollis	Okla.	3442	09955	73	1923	1996
80	504540	Laverne	Okla.	3642	09954	49	1948	1996
81	294440	Erick 4 E	Okla.	3512	09948	49	1948	1996
82	36520	Ashland	Kans.	3712	09946	97	1900	1996
83	340740	Gage FAA Airport	Okla.	3618	09946	49	1948	1996
84	33240	Arnett	Okla.	3608	09946	49	1948	1996
85	214248	Crowell	Tex.	3359	09943	81	1916	1996
86	733648	Quanah 5 SE	Tex.	3415	09941	92	1905	1996
87	173840	Cheyenne	Okla.	3536	09940	43	1948	1994
88	283640	Eldorado	Okla.	3428	09939	28	1948	1975
89	124340	Buffalo	Okla.	3650	09937	49	1948	1996
90	307040	Fargo	Okla.	3623	09937	49	1948	1996
91	795240	Sayre	Okla.	3518	09937	49	1948	1996
92	330440	Fort Supply Dam	Okla.	3633	09935	49	1948	1996
93	862740	Supply 1 E	Okla.	3634	09933	28	1948	1975
94	170148	Chillicothe	Tex.	3415	09931	69	1906	1974
95	603540	Moravia 2 NNE	Okla.	3508	09930	49	1948	1996
96	966840	Willow	Okla.	3503	09930	16	1981	1996
97	550940	Mangum Research Station	Okla.	3450	09926	49	1948	1996
98	976040	Woodward	Okla.	3626	09924	49	1948	1996
99	976240	Woodward Field Station	Okla.	3625	09924	32	1948	1979
100	284940	Elk City	Okla.	3523	09924	49	1948	1996
101	387140	Hammon 1 NNE	Okla.	3538	09922	49	1948	1996
102	756540	Retrop	Okla.	3510	09922	16	1981	1996
103	509040	Leedey	Okla.	3552	09921	49	1948	1996
104	170420	Coldwater	Kans.	3716	09920	49	1948	1996
105	17940	Altus Irrigation Research Station	Okla.	3435	09920	49	1948	1996
106	18440	Altus Dam	Okla.	3453	09918	49	1948	1996
107	934648	Vernon 4 S	Tex.	3405	09918	67	1904	1996
108	917240	Vici	Okla.	3609	09917	42	1955	1996
109	139640	Camargo	Okla.	3601	09917	28	1948	1975

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

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Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
110	613940	Mutual	Okla.	3614	09910	49	1948	1996
111	887940	Tipton 4 S	Okla.	3426	09908	41	1939	1979
112	335840	Freedom	Okla.	3646	09907	49	1948	1996
113	891420	Wilmore 16 SE	Kans.	3708	09904	11	1986	1996
114	420440	Hobart FAA Airport	Okla.	3500	09903	49	1948	1996
115	772740	Roosevelt	Okla.	3451	09901	49	1948	1996
116	335340	Frederick	Okla.	3424	09901	92	1905	1996
117	212540	Cordell	Okla.	3517	09859	49	1948	1996
118	6920	Aetna 2 S	Kans.	3704	09858	37	1948	1984
119	308840	Farry	Okla.	3648	09858	10	1948	1957
120	870840	Taloga	Okla.	3602	09858	49	1948	1996
121	190940	Clinton	Okla.	3531	09858	49	1948	1996
122	829940	Snyder	Okla.	3439	09857	48	1948	1996
123	263348	Dundee 6 NNW	Tex.	3349	09856	74	1923	1996
124	281848	Electra	Tex.	3402	09855	49	1948	1996
125	940440	Waynoka	Okla.	3635	09852	49	1948	1996
126	192740	Cloud Chief 2 SE	Okla.	3514	09849	28	1948	1975
127	656240	Oakwood 3 SW	Okla.	3554	09844	28	1948	1975
128	370940	Grandfield 4 NW	Okla.	3417	09844	47	1948	1994
129	962940	Wichita Mountain Wildlife Refuge	Okla.	3444	09843	49	1948	1996
130	942240	Weatherford	Okla.	3532	09842	49	1948	1996
131	19340	Alva	Okla.	3648	09841	43	1948	1996
132	203940	Colony	Okla.	3521	09841	14	1983	1996
133	447148	Iowa Park Experiment Station	Tex.	3355	09839	24	1940	1963
134	170640	Chattanooga 3 NE	Okla.	3427	09837	49	1948	1996
135	144540	Canton Dam	Okla.	3605	09836	49	1948	1996
136	517320	Medicine Lodge	Kans.	3717	09835	97	1900	1996
137	973048	Wichita Valley Farm 29	Tex.	3356	09835	29	1939	1972
138	150440	Carnegie 2 ENE	Okla.	3507	09834	49	1948	1996
139	234140	Dacoma 2 NE	Okla.	3641	09833	27	1949	1975
140	304740	Fairview	Okla.	3616	09829	29	1948	1976
141	972948	Wichita Falls WSO Airport	Tex.	3358	09829	96	1897	1996
142	675140	Orienta	Okla.	3621	09828	41	1956	1996
143	506340	Lawton	Okla.	3437	09827	49	1948	1996
144	328140	Fort Cobb	Okla.	3506	09826	28	1948	1975
145	936440	Watonga	Okla.	3551	09825	49	1948	1996
146	26040	Apache	Okla.	3454	09822	38	1948	1996

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service Field Office; Natl, National; Dept, Department]

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
147	172440	Cherokee	Okla.	3646	09821	49	1948	1996
148	532940	Lookeba 2 ENE	Okla.	3522	09820	57	1940	1996
149	740340	Randlett 8 E	Okla.	3411	09820	25	1948	1996
150	43120	Attica 6 WNW	Kans.	3716	09819	46	1948	1993
151	662940	Okeene	Okla.	3607	09819	49	1948	1996
152	349740	Geary	Okla.	3538	09819	49	1948	1996
153	927840	Walters	Okla.	3421	09818	49	1948	1996
154	401940	Helena 1 SSE	Okla.	3632	09816	49	1948	1996
155	22440	Anadarko 2 NNE	Okla.	3506	09814	49	1948	1996
156	409348	Henrietta	Tex.	3349	09812	96	1897	1996
157	266840	Duncan 12 W[1]	Okla.	3430	09810	45	1952	1996
158	374040	Great Salt Plains Dam	Okla.	3645	09808	49	1948	1996
159	939940	Waurika Dam	Okla.	3414	09803	10	1987	1996
160	26420	Anthony	Okla.	3709	09801	58	1939	1996
161	939540	Waurika	Okla.	3410	09800	87	1910	1996
162	558140	Marlow 1 WSW	Okla.	3439	09759	96	1901	1996
163	281840	El Reno 1 N	Okla.	3533	09758	76	1893	1996
164	266040	Duncan	Okla.	3430	09758	49	1948	1996
165	205440	Comanche	Okla.	3422	09758	45	1952	1996
166	174740	Chickasha	Okla.	3502	09757	65	1901	1966
167	908640	Union City 1 SE	Okla.	3523	09756	49	1948	1996
168	761448	Ringgold	Tex.	3349	09756	47	1948	1994
169	175040	Chickasha Experiment Station	Okla.	3503	09755	44	1953	1996
170	939140	Waukomis	Okla.	3617	09754	11	1948	1958
171	486140	Kingfisher 2 SE	Okla.	3551	09754	99	1897	1996
172	20040	Amber	Okla.	3510	09753	11	1986	1996
173	291240	Enid	Okla.	3625	09752	100	1894	1996
174	405540	Hennessey 2 SE	Okla.	3605	09752	49	1948	1996
175	98448	Bowie	Tex.	3334	09751	72	1897	1996
176	457340	Jefferson	Okla.	3643	09748	99	1897	1996
177	601448	Montague	Tex.	3340	09745	21	1943	1963
178	576840	Medford	Okla.	3648	09744	16	1981	1996
179	219640	Cox City 1 E	Okla.	3444	09743	16	1981	1996
180	497840	Lake Overholser	Okla.	3529	09740	32	1948	1979
181	83040	Blanchard 2 SSW	Okla.	3507	09740	45	1952	1996
182	179520	Conway Springs	Kans.	3723	09739	49	1948	1996
183	755640	Renfrow	Okla.	3656	09739	42	1949	1990

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

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Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
184	521640	Lindsay 2 W	Okla.	3449	09739	46	1948	1996
185	123320	Caldwell	Kans.	3703	09737	45	1948	1996
186	558940	Marshall	Okla.	3609	09737	46	1951	1996
187	224240	Crescent	Okla.	3557	09736	23	1948	1996
188	666140	Oklahoma City WSFO Airport	Okla.	3524	09736	49	1948	1996
189	524740	Loco 6 SE	Okla.	3416	09736	13	1984	1996
190	344840	Garber	Okla.	3626	09735	28	1948	1975
191	497640	Lake Hefner 2	Okla.	3535	09735	26	1949	1974
192	665640	Oklahoma City Penn Avenue	Okla.	3528	09733	27	1948	1974
193	400140	Healdton	Okla.	3414	09730	49	1948	1996
194	666440	Oklahoma City N Disposal	Okla.	3532	09728	28	1948	1975
195	666340	Oklahoma City East	Okla.	3528	09728	27	1948	1974
196	75540	Billings	Okla.	3632	09727	49	1948	1996
197	382140	Guthrie	Okla.	3553	09727	49	1948	1996
198	638640	Norman 3 S	Okla.	3511	09727	47	1948	1994
199	639140	Norman University of Okla.	Okla.	3513	09726	20	1937	1956
200	732740	Purcell 5 SW	Okla.	3458	09726	49	1948	1996
201	867020	Wellington 2 S	Kans.	3714	09724	49	1948	1996
202	613048	Muenster	Tex.	3339	09722	50	1947	1996
203	81440	Blackwell 1 W	Okla.	3648	09718	27	1948	1974
204	701240	Perry	Okla.	3617	09718	49	1948	1996
205	692640	Pauls Valley 4 WSW	Okla.	3444	09717	97	1900	1996
206	81840	Blackwell 2 E	Okla.	3649	09714	22	1975	1996
207	616920	Oxford	Kans.	3717	09710	48	1948	1996
208	750540	Redrock 1 NNE	Okla.	3628	09710	46	1951	1996
209	928648	Valley View	Tex.	3329	09710	50	1947	1996
210	29240	Ardmore	Okla.	3412	09709	95	1902	1996
211	341548	Gainesville	Tex.	3338	09708	88	1897	1986
212	556340	Marietta	Okla.	3356	09707	49	1948	1996
213	720140	Ponca City FAA Airport[1]	Okla.	3644	09706	49	1948	1996
214	850140	Stillwater 2 W	Okla.	3607	09706	103	1893	1996
215	342048	Gainesville 5 ENE	Tex.	3338	09704	10	1987	1996
216	627840	Newkirk	Okla.	3653	09703	99	1898	1996
217	895140	Tribbey 1 N	Okla.	3508	09703	17	1948	1964
218	31320	Arkansas City	Kans.	3704	09702	49	1948	1996
219	700340	Perkins	Okla.	3558	09702	49	1948	1996
220	29640	Ardmore FAA Airport	Okla.	3418	09701	22	1948	1969

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

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Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
221	896420	Winfield NO 1	Kans.	3714	09659	97	1900	1996
222	577940	Meeker 4 W	Okla.	3530	09659	49	1948	1996
223	174540	Chickasaw Natl Recreation Area[1]	Okla.	3430	09658	49	1948	1996
224	811040	Shawnee	Okla.	3521	09654	95	1902	1996
225	168440	Chandler 1	Okla.	3542	09653	95	1902	1996
226	694040	Pawnee	Okla.	3621	09648	49	1948	1996
227	231840	Cushing	Okla.	3559	09646	49	1948	1996
228	546840	Madill	Okla.	3405	09646	49	1948	1996
229	486540	Kingston	Okla.	3401	09645	49	1948	1996
230	491540	Konawa	Okla.	3458	09645	49	1948	1996
231	125640	Burbank	Okla.	3642	09644	49	1948	1996
232	739040	Ralston	Okla.	3630	09644	49	1948	1996
233	212620	Dexter	Kans.	3711	09643	35	1948	1982
234	726440	Prague	Okla.	3529	09642	49	1948	1996
235	554040	Maramec	Okla.	3615	09641	49	1948	1996
236	1740	Ada	Okla.	3447	09641	90	1907	1996
237	804240	Seminole	Okla.	3514	09640	49	1948	1996
238	950340	West Branch	Okla.	3615	09639	28	1948	1975
239	856340	Stroud 1 N	Okla.	3545	09639	17	1980	1996
240	888440	Tishomingo Natl Wildlife Refuge	Okla.	3411	09638	94	1903	1996
241	721440	Pontotoc	Okla.	3429	09637	49	1948	1996
242	827448	Sherman	Tex.	3338	09637	97	1897	1996
243	386240	Hallett 1 NW	Okla.	3615	09636	26	1948	1973
244	325040	Foraker	Okla.	3652	09634	49	1948	1996
245	239448	Denison Dam[1]	Tex.	3349	09634	88	1909	1996
246	190240	Cleveland 5 WSW	Okla.	3617	09633	13	1984	1996
247	957540	Wewoka 3 W	Okla.	3510	09633	49	1948	1996
248	139520	Cedar Vale	Kans.	3706	09630	42	1955	1996
249	190040	Cleveland	Okla.	3618	09628	35	1948	1982
250	324820	Grenola 1 N	Kans.	3722	09627	49	1948	1996
251	552240	Mannford 6 NW	Okla.	3610	09626	49	1948	1996
252	947940	Welty 1 SSE	Okla.	3537	09624	14	1983	1996
253	423540	Holdenville	Okla.	3505	09624	96	1901	1996
254	428940	Hominy	Okla.	3625	09623	48	1948	1996
255	114440	Bristow	Okla.	3550	09623	81	1916	1996
256	267840	Durant-US Dept of Agriculture	Okla.	3401	09623	95	1902	1996
257	693540	Pawhuska	Okla.	3640	09621	99	1898	1996

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

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Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
258	912548	Trenton	Tex.	3326	09620	50	1947	1996
259	663840	Okemah	Okla.	3526	09618	85	1912	1996
260	240920	Elgin	Kans.	3700	09617	49	1948	1996
261	409840	Heyburn Dam	Okla.	3557	09617	19	1949	1967
262	481240	Keystone Dam[1]	Okla.	3609	09615	49	1948	1996
263	139140	Calvin	Okla.	3458	09615	49	1948	1996
264	195440	Coalgate 1 WNW	Okla.	3433	09614	35	1948	1982
265	984140	Yuba 2 W	Okla.	3349	09614	28	1948	1975
266	957140	Wetumka 3 NE	Okla.	3516	09613	49	1948	1996
267	510840	Lehigh	Okla.	3428	09613	19	1948	1996
268	406440	Herd	Okla.	3652	09612	10	1948	1957
269	730520	Sedan	Kans.	3708	09611	49	1948	1996
270	92348	Bonham	Tex.	3336	09611	92	1903	1996
271	53540	Barnsdall	Okla.	3634	09610	49	1948	1996
272	39140	Atoka	Okla.	3424	09609	28	1948	1975
273	792140	Sapulpa 1 W	Okla.	3600	09608	28	1948	1975
274	439340	Hulah Dam	Okla.	3655	09606	49	1948	1996
275	481220	Longton	Kans.	3723	09605	46	1951	1996
276	63140	Beggs	Okla.	3545	09605	14	1983	1996
277	36440	Ashland	Okla.	3447	09604	12	1985	1996
278	39440	Atoka Dam	Okla.	3427	09604	34	1963	1996
279	667040	Okmulgee Water Works	Okla.	3537	09601	49	1948	1996
280	54840	Bartlesville 2 W	Okla.	3645	09600	49	1948	1996
281	825840	Skiatook	Okla.	3622	09600	49	1948	1996
282	898740	Tulsa	Okla.	3609	09600	12	1948	1959
283	739440	Ramona 4 N	Okla.	3636	09555	13	1983	1995
284	308340	Farris 3 WNW	Okla.	3416	09555	48	1948	1995
285	899240	Tulsa WSO Airport	Okla.	3611	09554	49	1948	1996
286	248540	Dewar 2 NE	Okla.	3529	09554	49	1948	1996
287	425748	Honey Grove	Tex.	3335	09554	82	1898	1996
288	78240	Bixby	Okla.	3558	09553	49	1948	1996
289	388440	Hanna	Okla.	3512	09553	48	1949	1996
290	98040	Boswell 4 NNW	Okla.	3405	09553	49	1948	1996
291	571340	McGee Creek Dam	Okla.	3419	09552	15	1982	1996
292	115740	Broken Arrow 2 SW	Okla.	3602	09549	28	1948	1975
293	243020	Elk City Lake	Kans.	3717	09548	33	1964	1996
294	566440	McAlester FAA Airport	Okla.	3453	09547	44	1953	1996

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

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Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
295	671340	Oneta 1 WNW	Okla.	3602	09544	11	1983	1993
296	395420	Independence	Kans.	3715	09542	97	1900	1996
297	672940	Oologah Dam	Okla.	3626	09541	23	1957	1979
298	395640	Haskell	Okla.	3549	09541	49	1948	1996
299	235440	Daisy 4 ENE	Okla.	3433	09541	49	1948	1996
300	197048	Cooper	Tex.	3322	09541	49	1948	1996
301	784440	Sageeyah	Okla.	3622	09540	10	1948	1957
302	648540	Nowata	Okla.	3642	09538	49	1948	1996
303	25640	Antlers	Okla.	3415	09538	47	1948	1994
304	182840	Claremore 2 ENE	Okla.	3619	09535	49	1948	1996
305	299340	Eufaula	Okla.	3518	09535	49	1948	1996
306	679448	Paris	Tex.	3340	09534	95	1897	1996
307	171140	Checotah	Okla.	3528	09531	49	1948	1996
308	185840	Clayton 11 WNW	Okla.	3441	09531	14	1981	1996
309	438440	Hugo	Okla.	3400	09531	49	1948	1996
310	587848	Mid City[1]	Tex.	3350	09531	98	1897	1996
311	667840	Oktaha 2 NE	Okla.	3536	09528	12	1985	1996
312	553620	Mound Valley 3 WSW	Kans.	3711	09527	46	1951	1996
313	171740	Chelsea 4 S	Okla.	3629	09525	14	1983	1996
314	924740	Wagoner	Okla.	3558	09522	49	1948	1996
315	497540	Lake Eufaula[1]	Okla.	3518	09522	36	1957	1996
316	737240	Quinton	Okla.	3508	09522	49	1948	1996
317	185540	Clayton	Okla.	3435	09521	22	1948	1969
318	613040	Muskogee	Okla.	3546	09520	49	1948	1996
319	241548	Deport	Tex.	3331	09519	17	1948	1996
320	730940	Pryor 6 N	Okla.	3624	09518	49	1948	1996
321	624220	Parsons 2 NW	Kans.	3722	09517	49	1948	1996
322	425840	Hollow	Okla.	3653	09517	49	1948	1996
323	902340	Tuskahoma	Okla.	3437	09517	32	1948	1996
324	193640	Cloudy Tower	Okla.	3423	09515	26	1948	1973
325	384648	Hagansport	Tex.	3321	09515	83	1910	1996
326	328640	Fort Gibson Dam	Okla.	3552	09514	32	1948	1979
327	961140	Whitefield 1 N	Okla.	3516	09514	19	1950	1968
328	830540	Sobol Tower	Okla.	3408	09514	39	1952	1990
329	106740	Braggs	Okla.	3540	09512	33	1948	1980
330	944540	Webbers Falls 5 WSW	Okla.	3529	09512	49	1948	1996
331	963440	Wilburton 9 ENE	Okla.	3457	09510	47	1948	1996

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service Field Office; Natl, National; Dept, Department]

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
332	911840	Valliant 3 W	Okla.	3400	09509	49	1948	1996
333	920340	Vinita 2 N	Okla.	3640	09508	49	1948	1996
334	512320	McCune 6 SW	Kans.	3718	09506	40	1953	1992
335	611520	Oswego 1 N	Kans.	3710	09506	49	1948	1996
336	370040	Grand River Dam	Okla.	3628	09503	32	1948	1979
337	838040	Spavinaw	Okla.	3623	09503	49	1948	1996
338	876940	Tenkiller Ferry Dam	Okla.	3536	09503	31	1949	1979
339	819740	Signal Mountain Tower	Okla.	3419	09503	24	1949	1972
340	624748	Negley 1 SE	Tex.	3344	09503	48	1949	1996
341	177248	Clarksville 2 NE	Tex.	3338	09502	92	1903	1996
342	318240	Flashman Tower	Okla.	3429	09500	35	1948	1984
343	867740	Tahlequah	Okla.	3556	09458	49	1948	1996
344	569340	McCurtain 1 SE	Okla.	3509	09458	49	1948	1996
345	58440	Bear Mountain Tower	Okla.	3408	09457	49	1948	1996
346	56740	Battiest 1 SSW	Okla.	3423	09456	12	1985	1996
347	306540	Fanshawe	Okla.	3457	09454	49	1948	1996
348	585540	Miami	Okla.	3653	09453	49	1948	1996
349	99148	Boxelder	Tex.	3329	09453	48	1949	1996
350	174020	Columbus 1 SW	Kans.	3710	09451	97	1900	1996
351	482040	Kiamichi Tower	Okla.	3438	09449	22	1948	1969
352	445140	Idabel	Okla.	3353	09449	49	1948	1996
353	456740	Jay Tower[1]	Okla.	3626	09448	49	1948	1996
354	735840	Quapaw	Okla.	3658	09447	41	1949	1989
355	379440	Grove	Okla.	3636	09447	28	1948	1975
356	467240	Kansas 1 ESE	Okla.	3612	09447	38	1959	1996
357	154440	Carter Tower	Okla.	3415	09447	49	1948	1996
358	786240	Sallisaw 2 NE	Okla.	3529	09446	49	1948	1996
359	543740	Lyons 2 N	Okla.	3546	09444	49	1948	1996
360	116240	Broken Bow 1 N	Okla.	3403	09444	49	1948	1996
361	977340	Wyandotte 1 N	Okla.	3649	09443	21	1948	1968
362	972440	Wister Dam	Okla.	3456	09443	32	1948	1979
363	116840	Broken Bow Dam	Okla.	3408	09442	33	1964	1996
364	828540	Smithville 1 W	Okla.	3428	09440	49	1948	1996
365	401740	Hee Mountain Tower	Okla.	3420	09439	46	1949	1995
366	641420	Pittsburg	Kans.	3721	09438	49	1948	1996
367	998540	Zoe 1 S	Okla.	3445	09438	37	1951	1987
368	149940	Carnasaw Tower	Okla.	3409	09438	49	1948	1996

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service Field Office; Natl, National; Dept, Department]

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
369	765629	Seneca	Mo.	3651	09437	13	1948	1996
370	850640	Stilwell 1 NE	Okla.	3550	09437	49	1948	1996
371	841640	Spiro	Okla.	3515	09437	49	1948	1996
372	725440	Poteau Water Works[1]	Okla.	3503	09437	49	1948	1996
373	235248	De Kalb	Tex.	3330	09436	49	1948	1996
374	400840	Heavener 1 SE	Okla.	3453	09435	45	1952	1996
375	866429	Waco 2 E	Mo.	3715	09434	49	1948	1996
376	833548	Simms 4 WNW	Tex.	3322	09434	15	1948	1973
377	662405	Siloam Springs	Ark.	3610	09432	40	1948	1987
378	431529	Joplin FAA Airport	Mo.	3710	09430	49	1948	1996
379	293005	Gravette	Ark.	3626	09427	49	1948	1996
380	16429	Anderson	Mo.	3639	09426	49	1948	1996
381	535405	Odell 2 N	Ark.	3547	09425	49	1948	1996
382	166605	Cove	Ark.	3426	09425	49	1948	1996
383	627048	New Boston	Tex.	3327	09425	17	1980	1996
384	254405	Foreman	Ark.	3344	09424	19	1948	1996
385	516005	Natural Dam	Ark.	3538	09423	34	1963	1996
386	597629	Neosho	Mo.	3652	09422	79	1918	1996
387	257405	Fort Smith WSO Airport	Ark.	3520	09422	97	1900	1996
388	344205	Horatio	Ark.	3356	09422	49	1948	1996
389	290805	Grannis	Ark.	3415	09420	28	1930	1957
390	194805	De Queen	Ark.	3402	09420	49	1948	1996
391	566748	Maud 1 S	Tex.	3319	09420	49	1947	1995
392	135629	Carthage	Mo.	3711	09419	45	1948	1996
393	224029	Diamond[1]	Mo.	3659	09419	49	1948	1996
394	411605	Lee Creek Guard Station	Ark.	3542	09419	15	1948	1962
395	117205	Camp Chaffee	Ark.	3518	09418	12	1948	1959
396	475605	Mena	Ark.	3434	09416	55	1942	1996
397	297605	Greenwood	Ark.	3513	09415	49	1948	1996
398	58605	Bentonville	Ark.	3621	09413	49	1948	1996
399	605	Abbott	Ark.	3504	09412	49	1948	1996
400	244405	Fayetteville Experiment Station[1]	Ark.	3606	09410	105	1892	1996
401	991648	Wright Patman Dam & Lake[1]	Tex.	3318	09410	41	1956	1996
402	501805	Mountainburg 2 NE[1]	Ark.	3539	09409	49	1948	1996
403	28605	Ashdown 2 S	Ark.	3338	09408	45	1948	1996
404	624805	Rogers	Ark.	3622	09406	28	1948	1975
405	748805	Waldron	Ark.	3454	09406	49	1948	1996

Table 3. Daily precipitation stations within and near Oklahoma with at least 10 years of annual maxima data through 1996—Continued

[Station number, National Weather Service station number and 2-digit Federal Information Processing Standards State Code; Years, years of record used in analysis, which may reflect editing of questionable data; WSO, Weather Service Office; FAA, Federal Aviation Administration; WSFO, Weather Service Field Office; Natl, National; Dept, Department]

Site number	Station number	Station name	State	Latitude	Longitude	Years		
						Total	Begin	End
406	894248	Texarkana	Tex.	3325	09405	28	1969	1996
407	781205	White Cliffs	Ark.	3348	09404	14	1948	1961
408	358405	Index	Ark.	3335	09403	22	1947	1968
409	507205	Mulberry 6 NNE	Ark.	3534	09401	37	1948	1984
410	201505	Dierks	Ark.	3407	09401	37	1959	1996
411	667829	Pierce City	Mo.	3657	09400	49	1948	1996
412	559105	Parks 2 W	Ark.	3448	09400	41	1956	1996
413	704805	Texarkana FAA Airport	Ark.	3327	09400	62	1930	1991

[1] Station record was combined with record from station within 2 minutes latitude and/or longitude

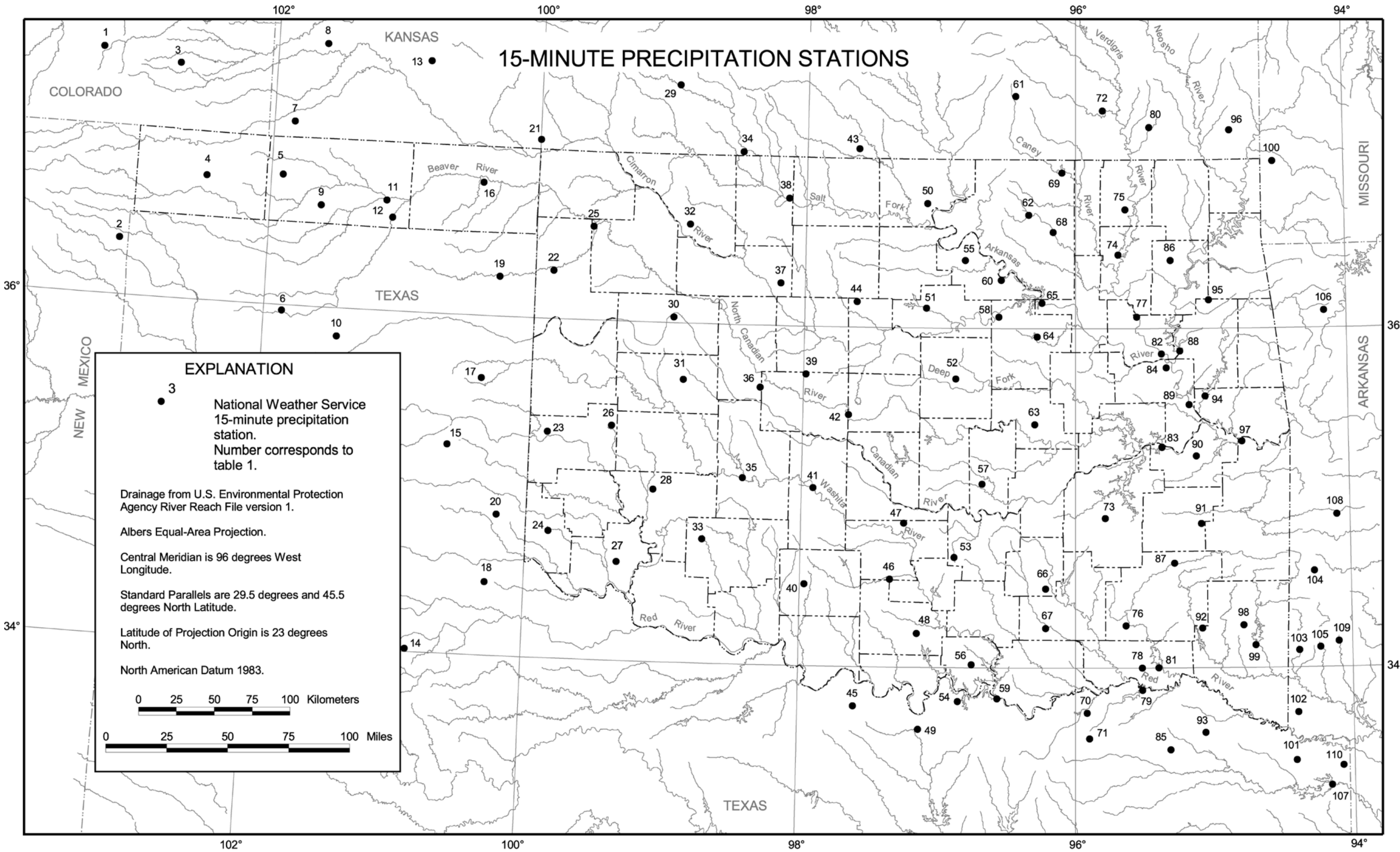


Figure 1. Location of National Weather Service 15-minute precipitaion stations used in study.

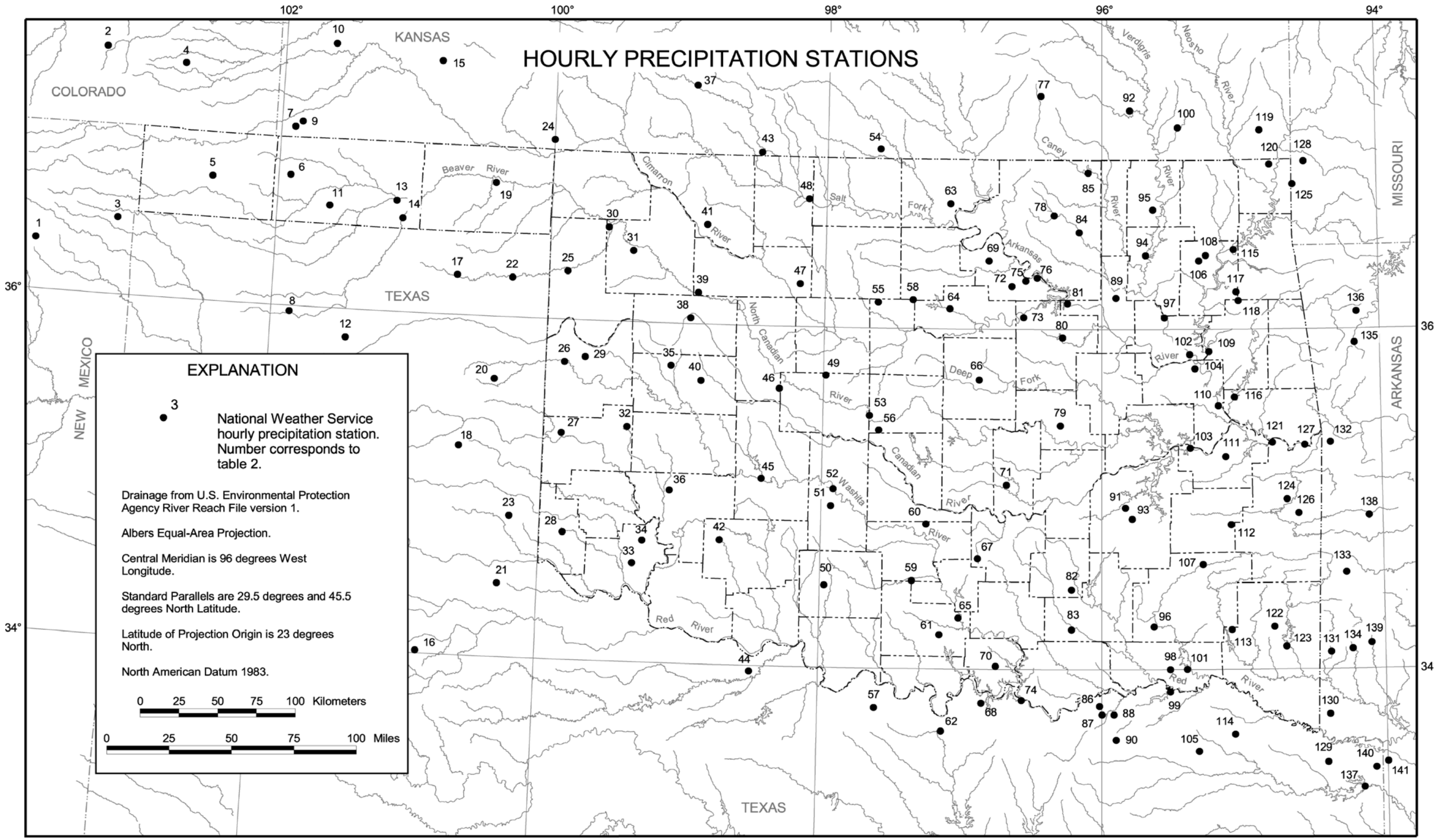
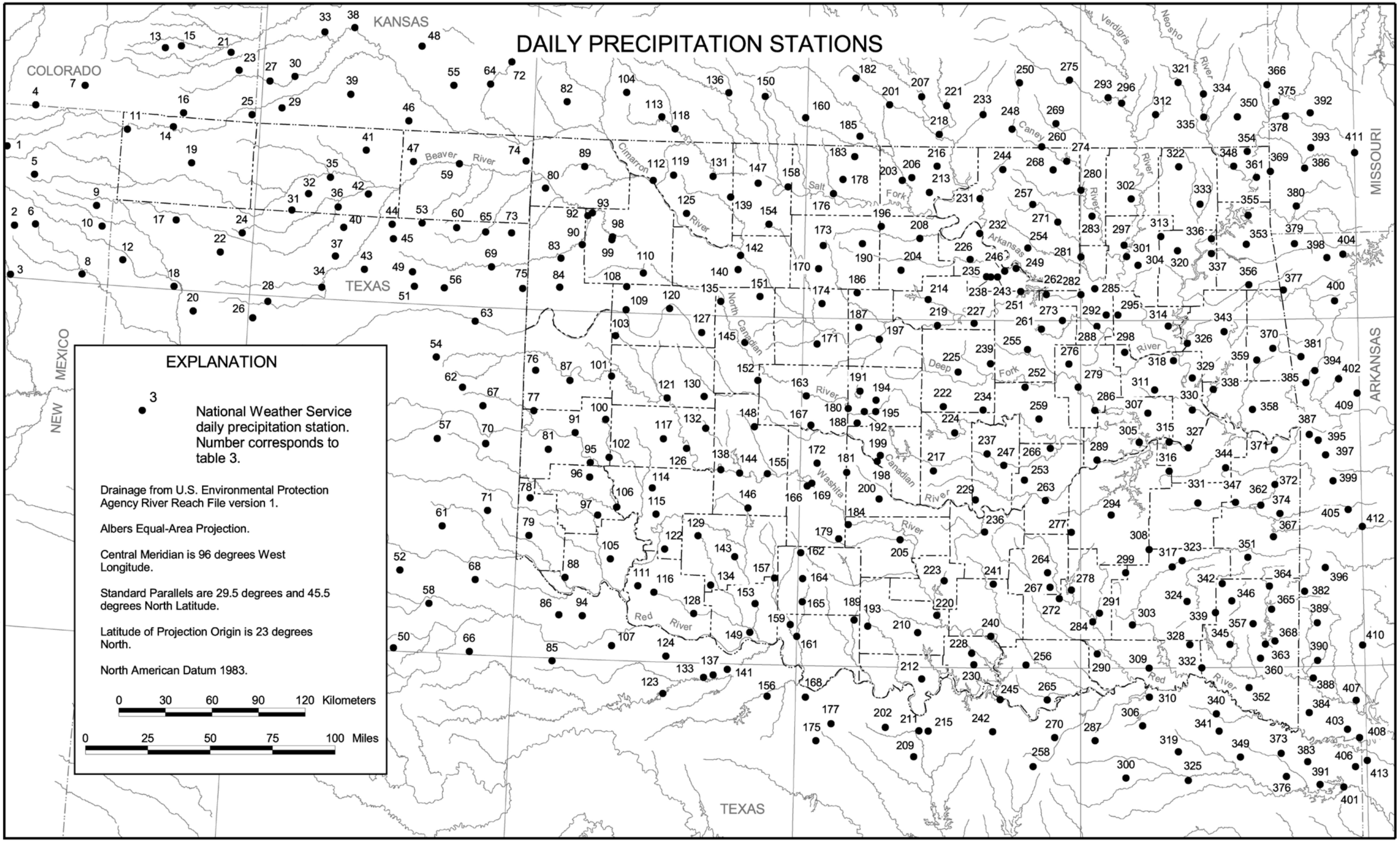


Figure 2. Location of National Weather Service hourly precipitation stations used in study.



National Weather Service daily precipitation station. Number corresponds to table 3.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 3. Location of National Weather Service daily precipitation stations used in study.

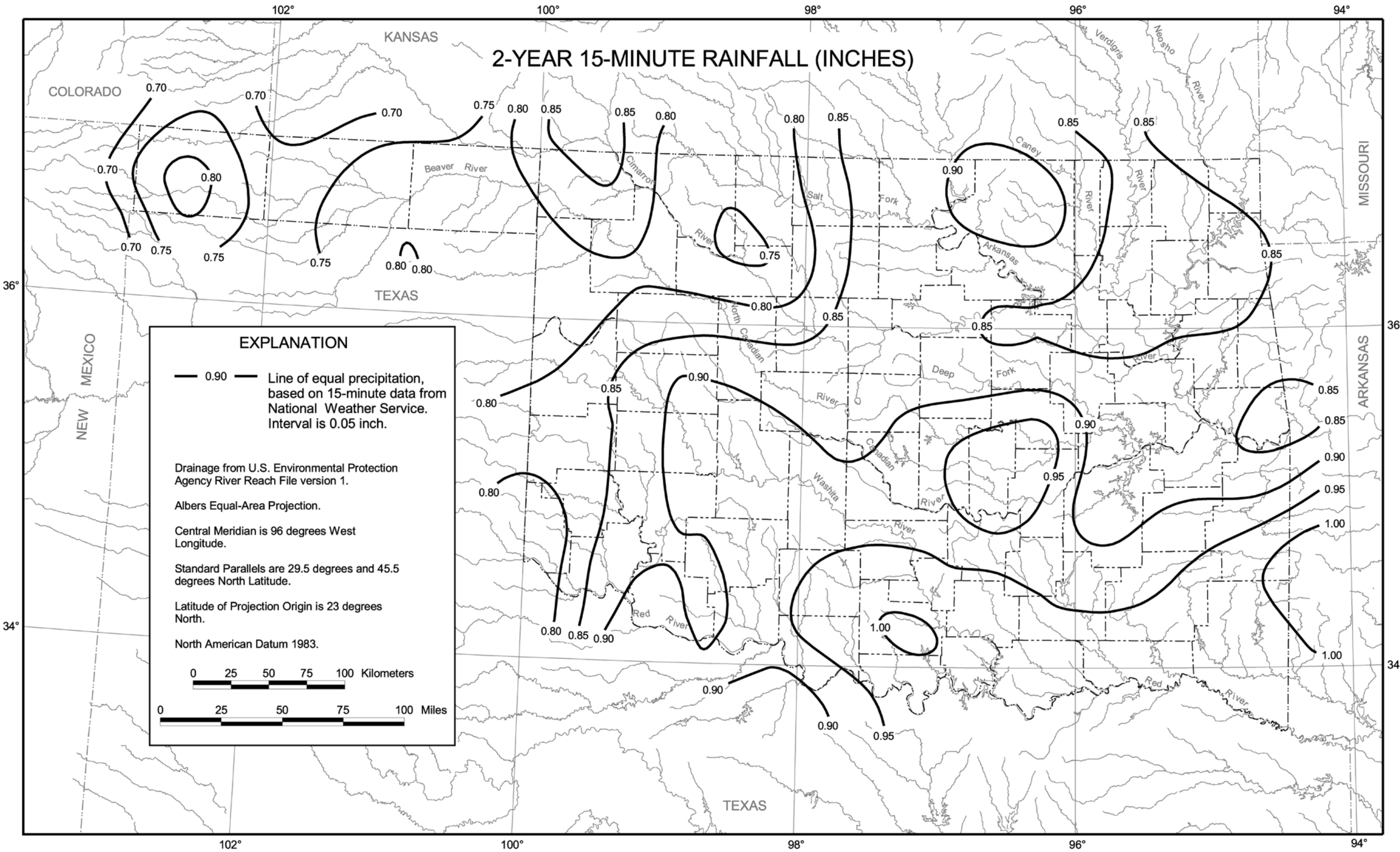
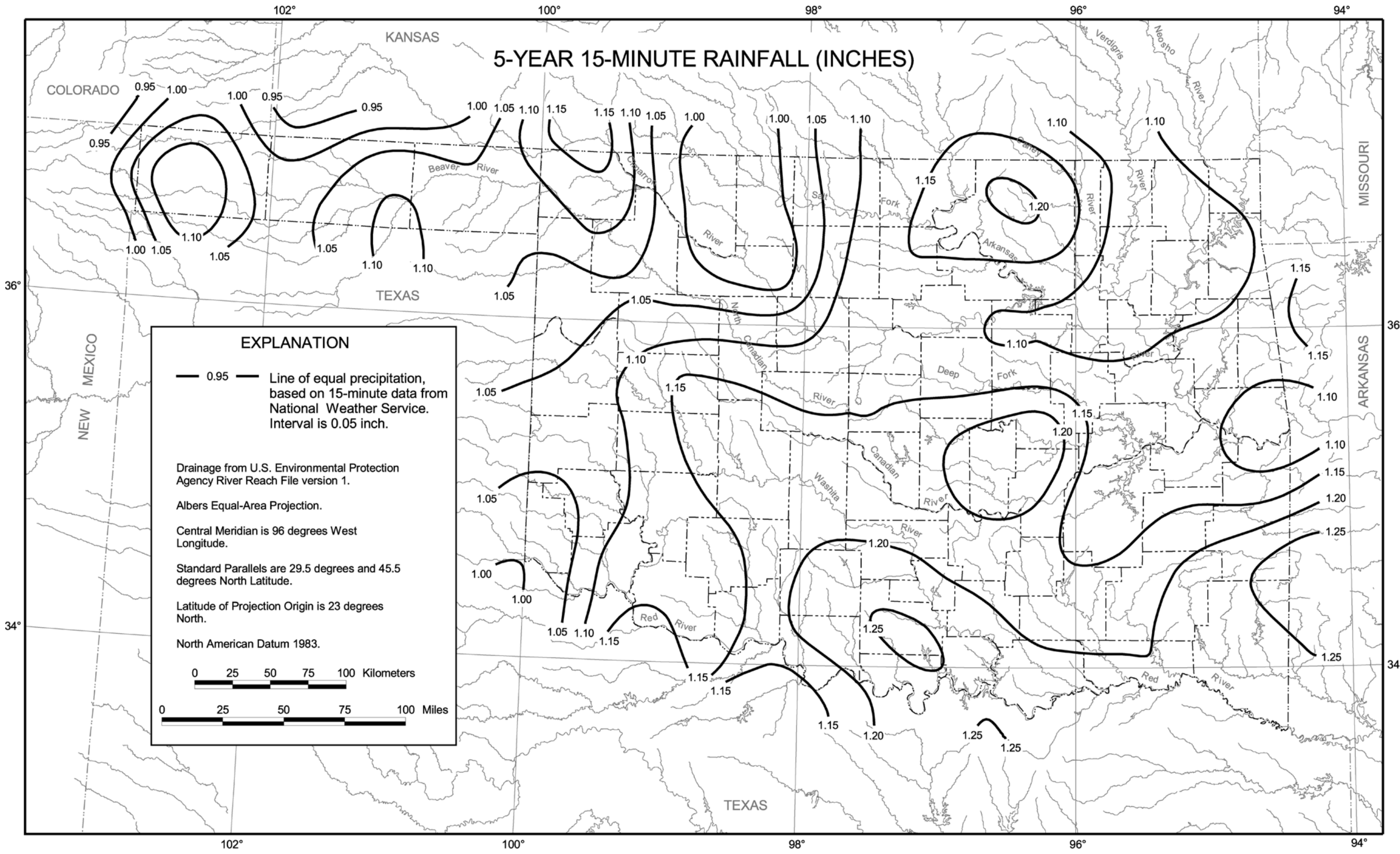


Figure 9. Depth of 2-year storm for 15-minute duration in Oklahoma.



Line of equal precipitation, based on 15-minute data from National Weather Service. Interval is 0.05 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

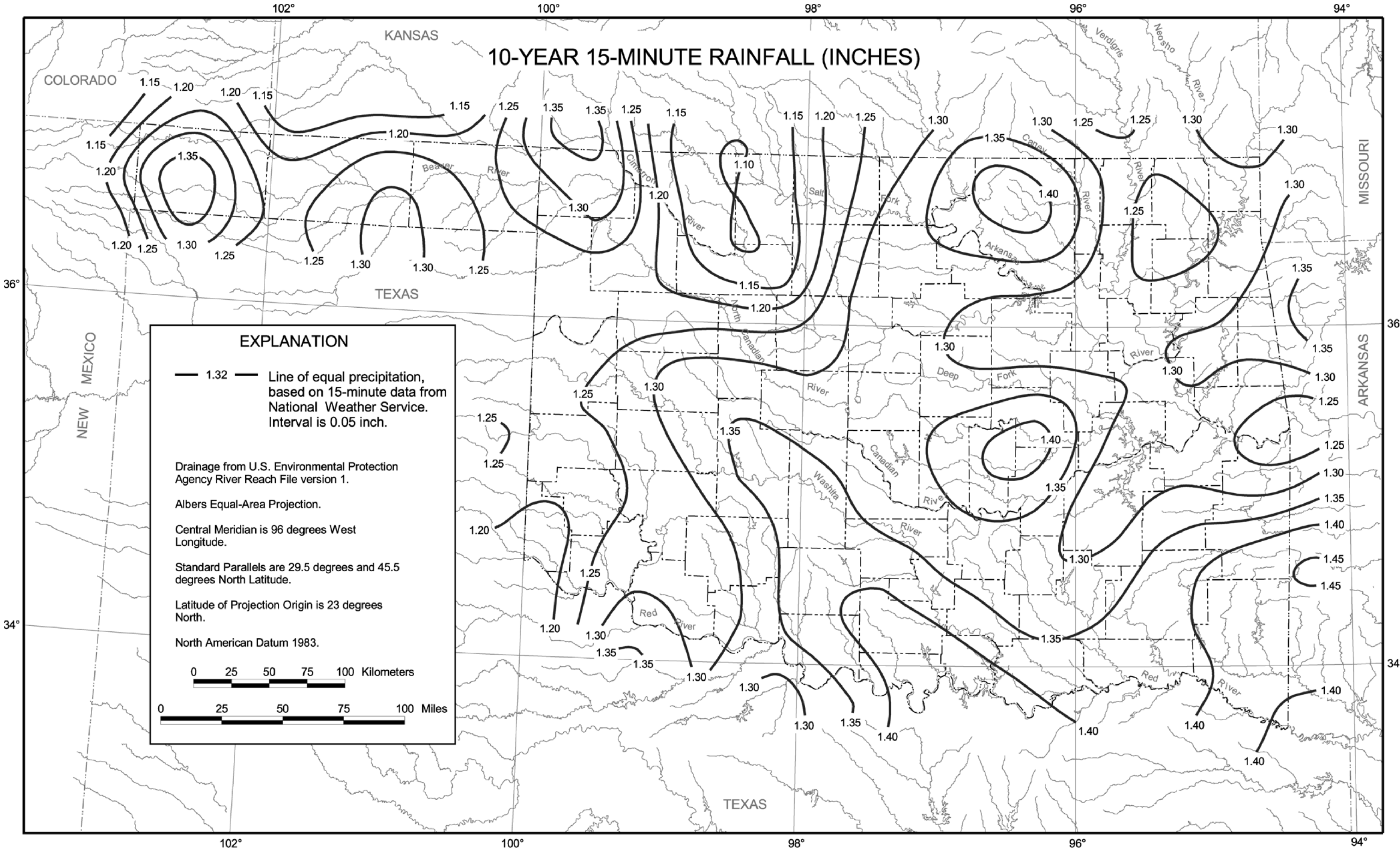
Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 10. Depth of 5-year storm for 15-minute duration in Oklahoma.



EXPLANATION

— 1.32 — Line of equal precipitation, based on 15-minute data from National Weather Service. Interval is 0.05 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

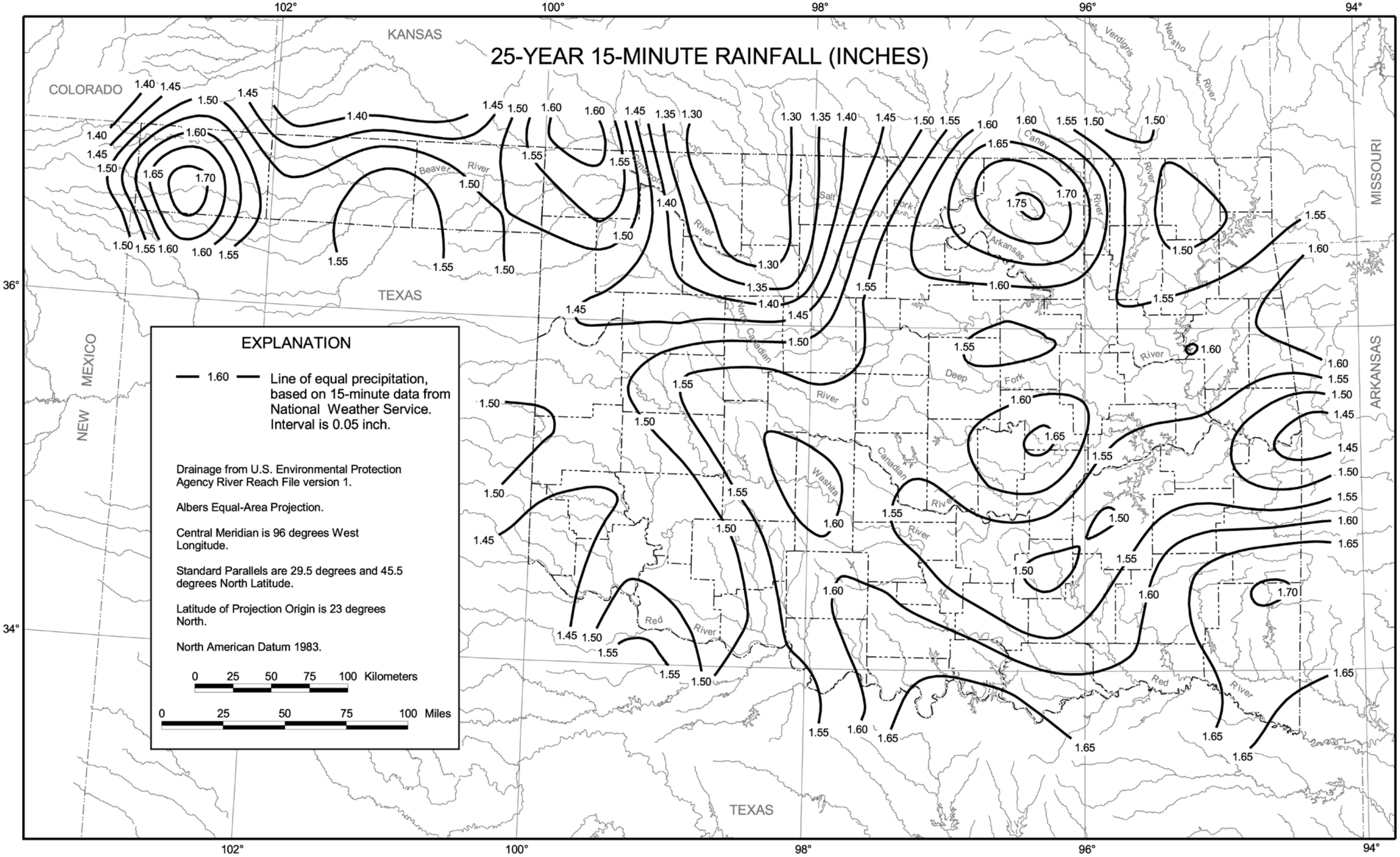
Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 11. Depth of 10-year torm for 15-minute duration in Oklahoma.



25-YEAR 15-MINUTE RAINFALL (INCHES)

EXPLANATION

— 1.60 — Line of equal precipitation, based on 15-minute data from National Weather Service. Interval is 0.05 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 12. Depth of 25 year-storm for 15-minute duration in Oklahoma.

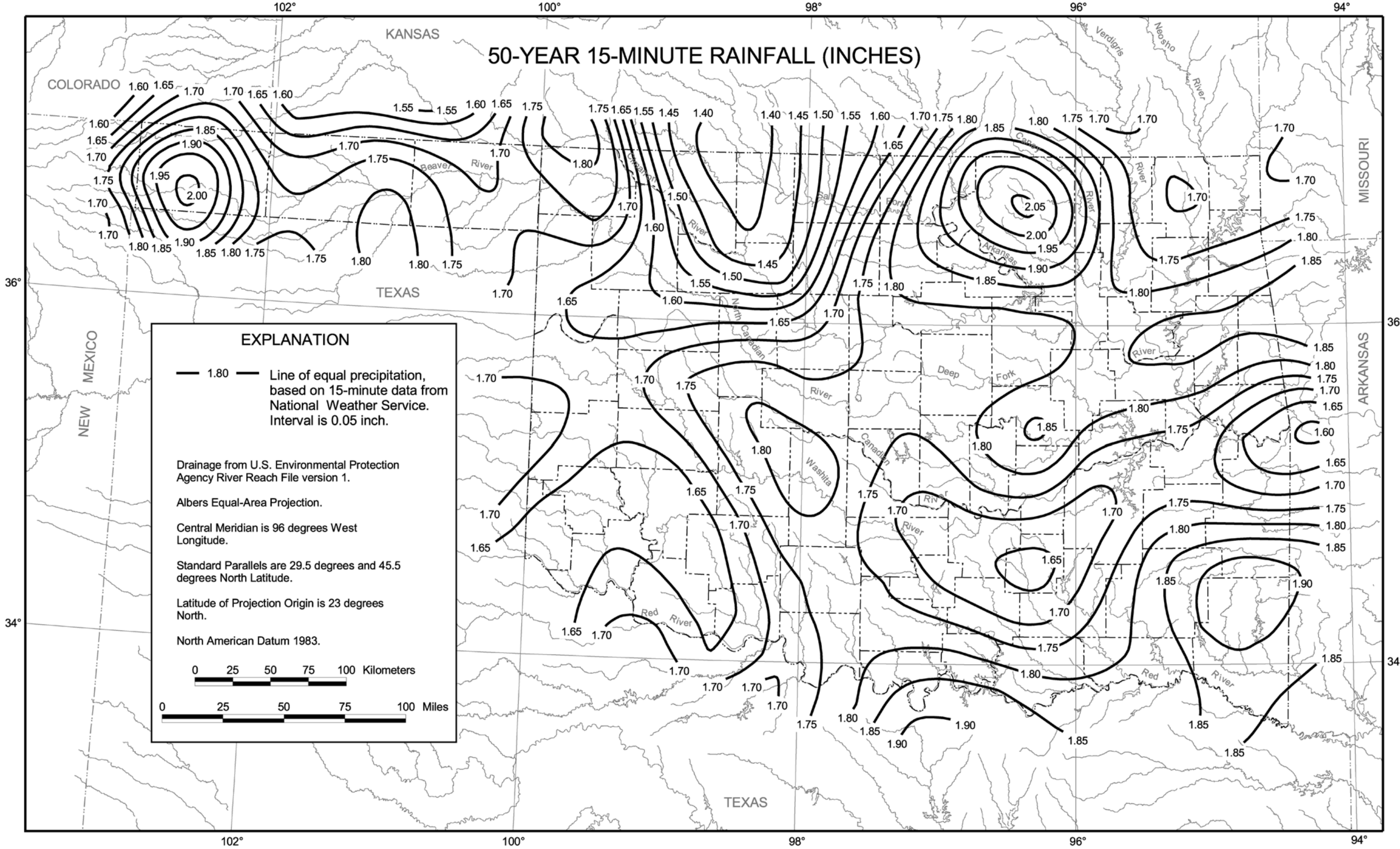


Figure 13. Depth of 50-year storm for 15-minute duration in Oklahoma.

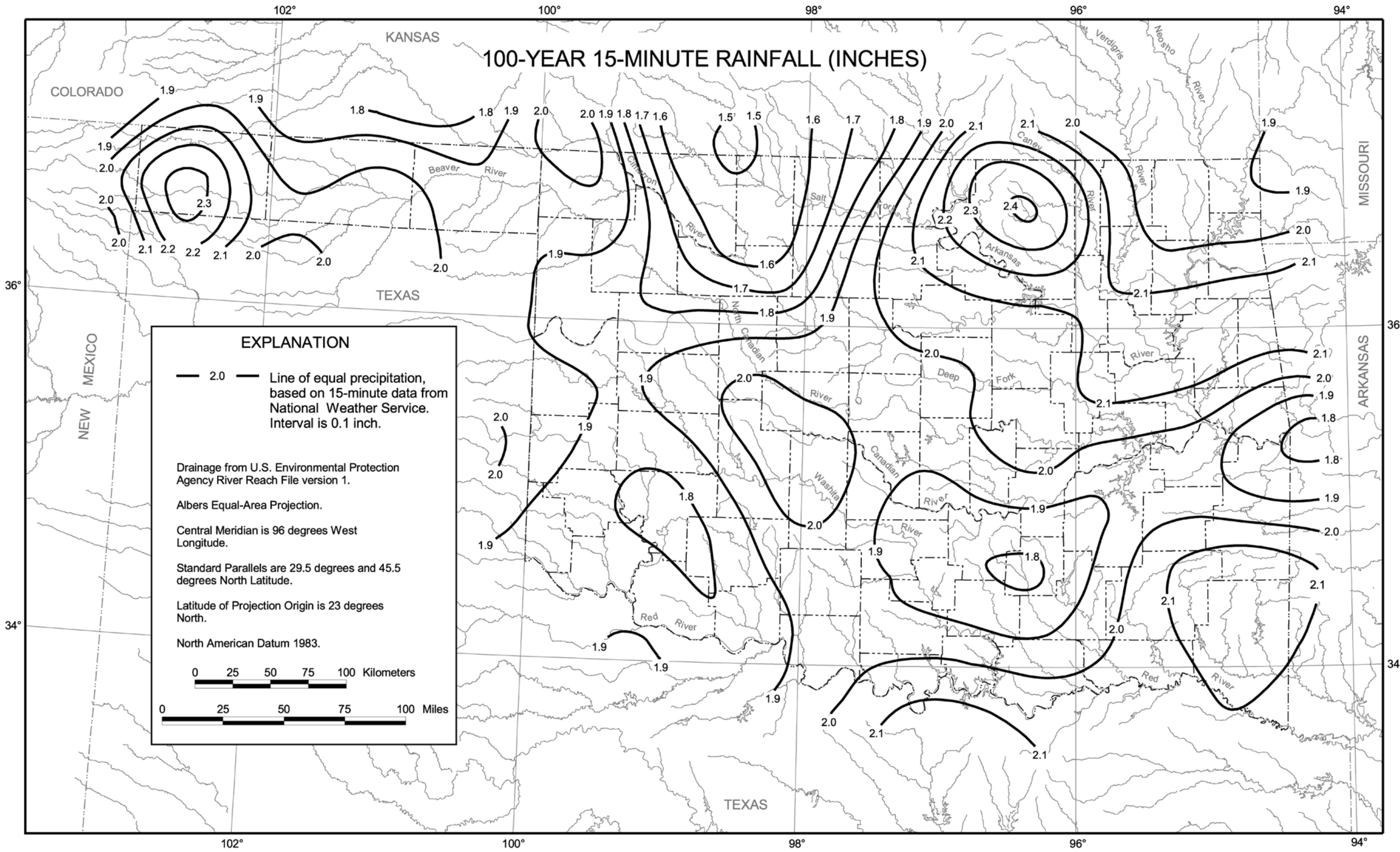
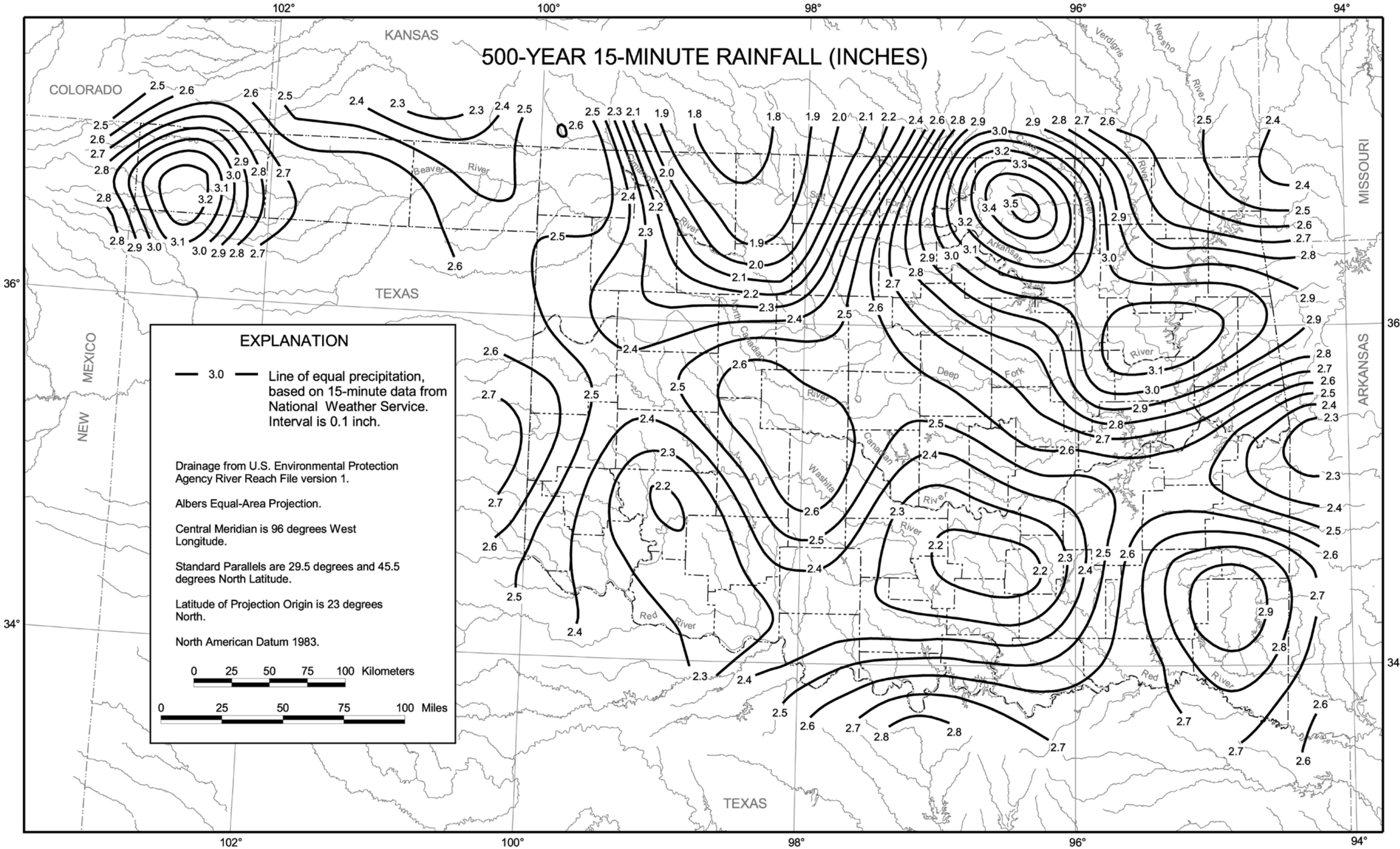


Figure 14. Depth of 100-year storm for 15-minute duration in Oklahoma.



EXPLANATION

— 3.0 — Line of equal precipitation, based on 15-minute data from National Weather Service. Interval is 0.1 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 15. Depth of 500-year storm for 15-minute duration in Oklahoma.

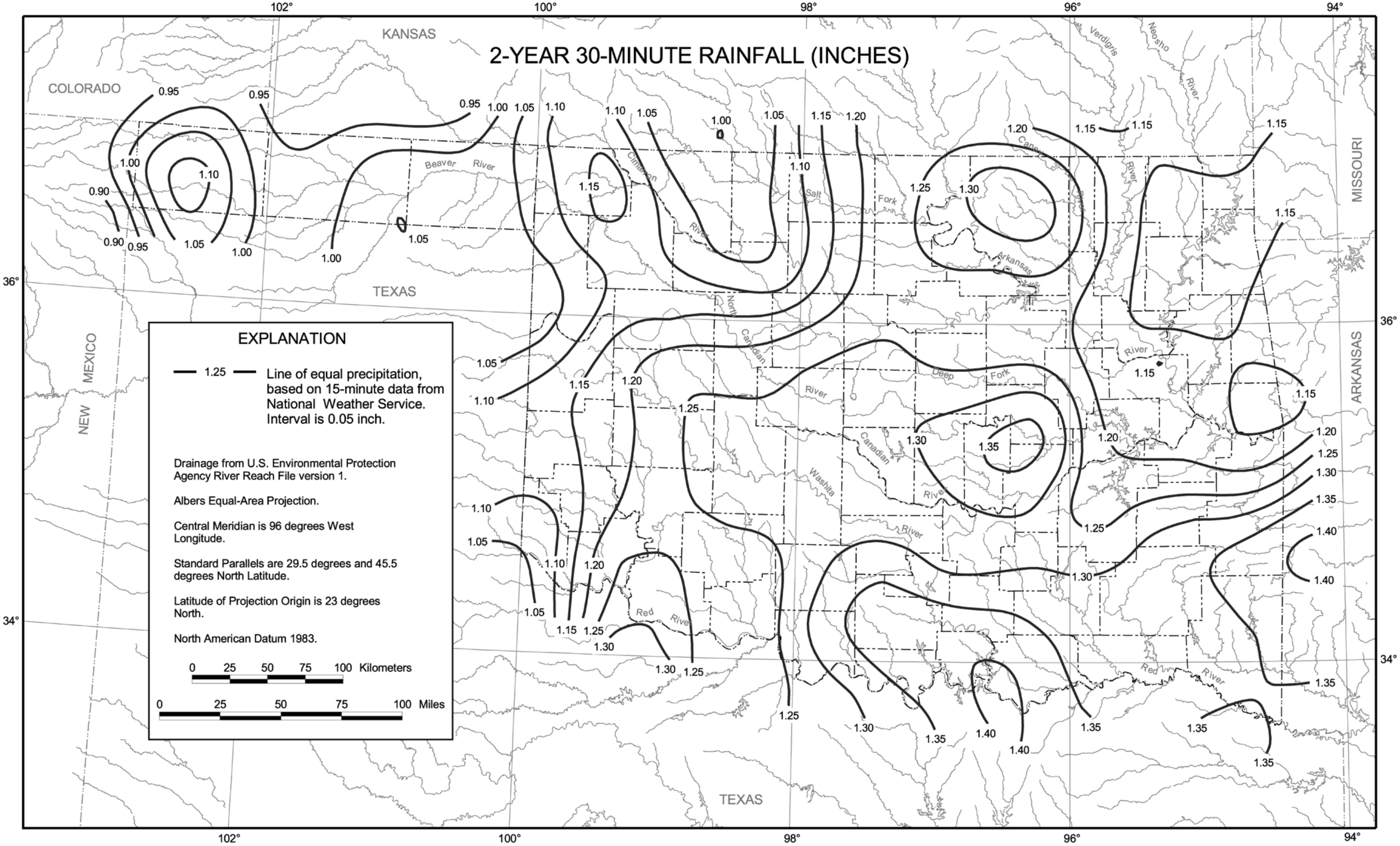


Figure 16. Depth of 2-year storm for 30-minute duration in Oklahoma.

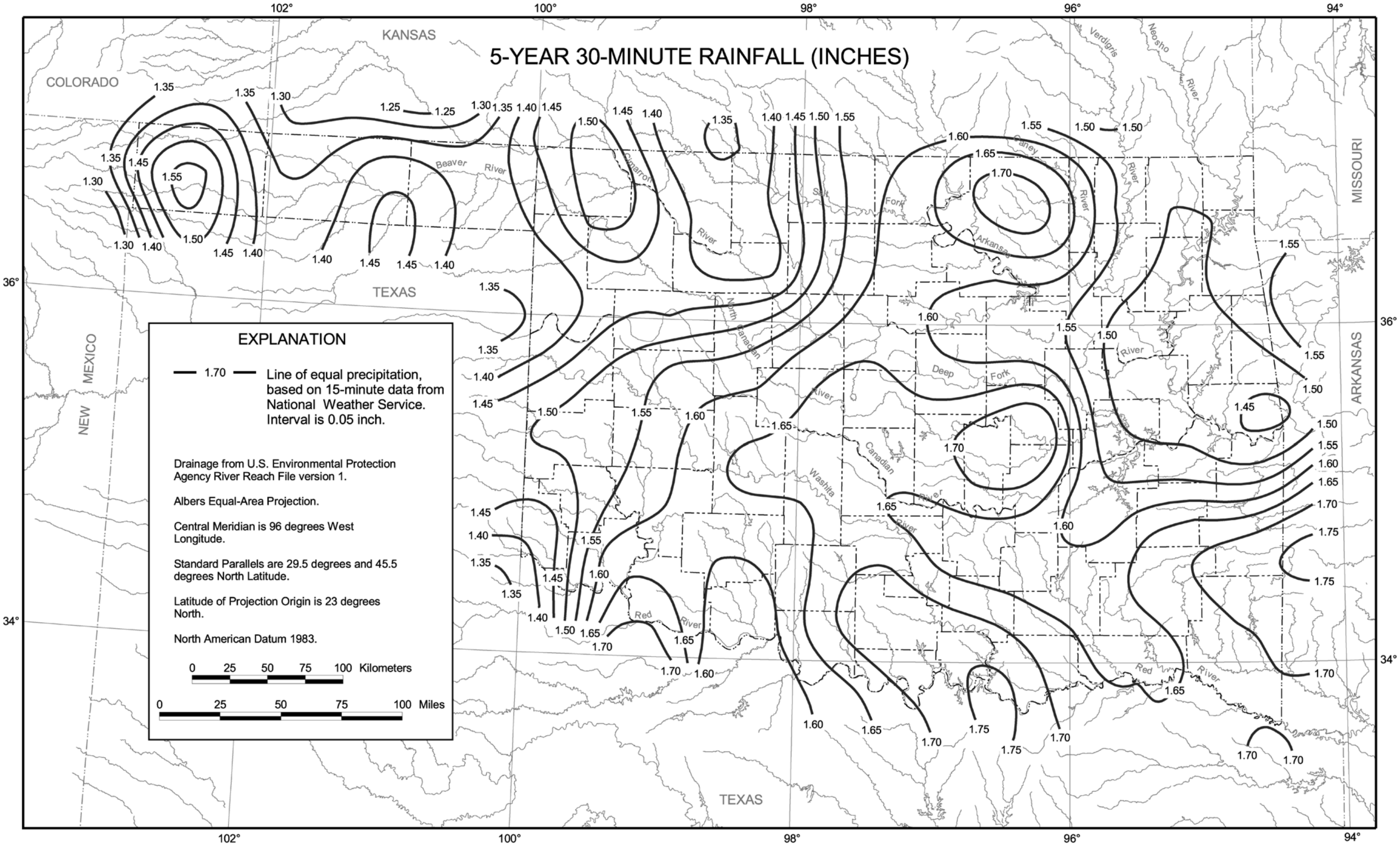


Figure 17. Depth of 5-year storm for 30-minute duration in Oklahoma.

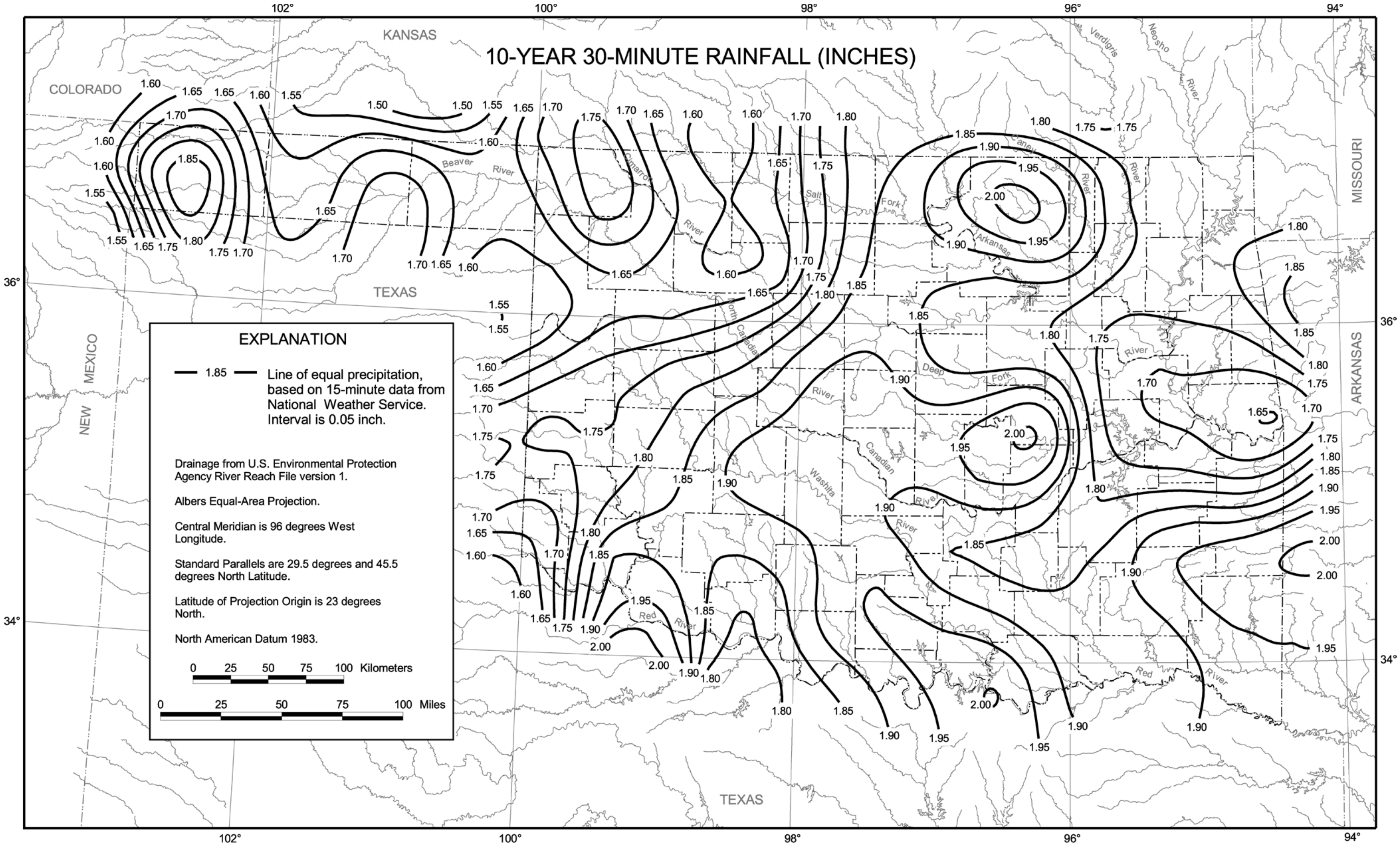
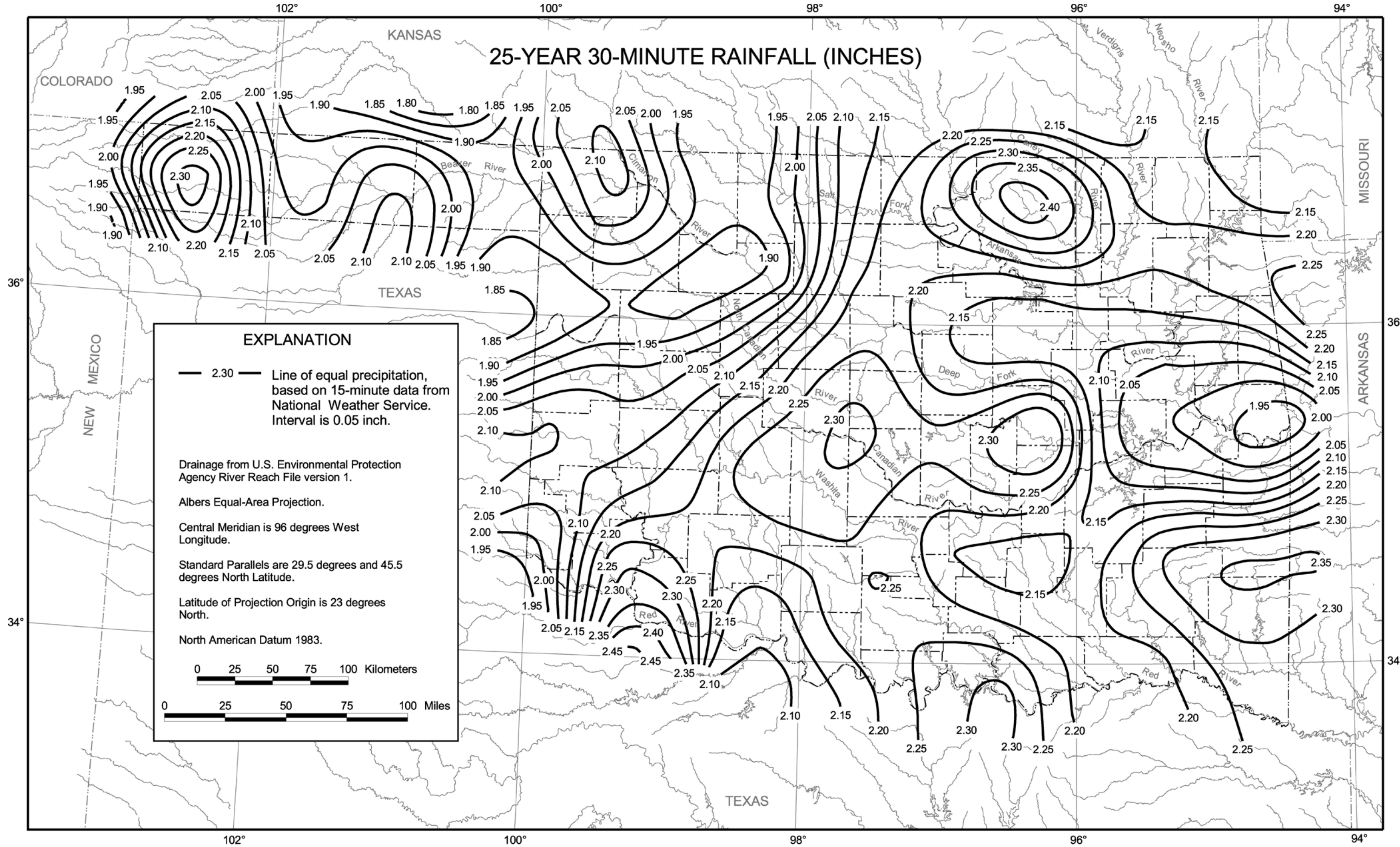


Figure 18. Depth of 10-year storm for 30-minute duration in Oklahoma.



Line of equal precipitation, based on 15-minute data from National Weather Service. Interval is 0.05 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 19. Depth of 25-year storm for 30-minute duration in Oklahoma.

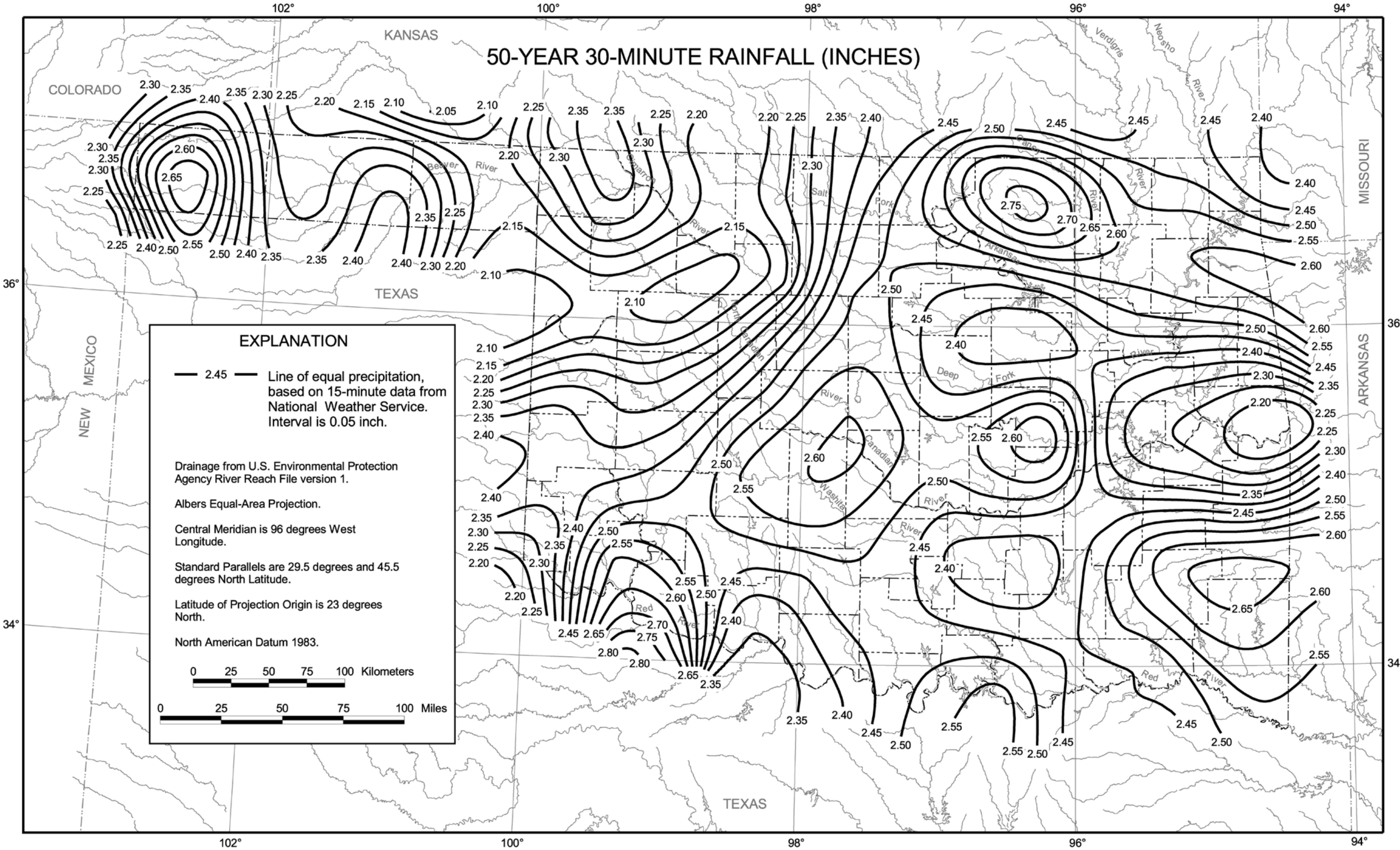


Figure 20. Depth of 50-year storm for 30-minute duration in Oklahoma.

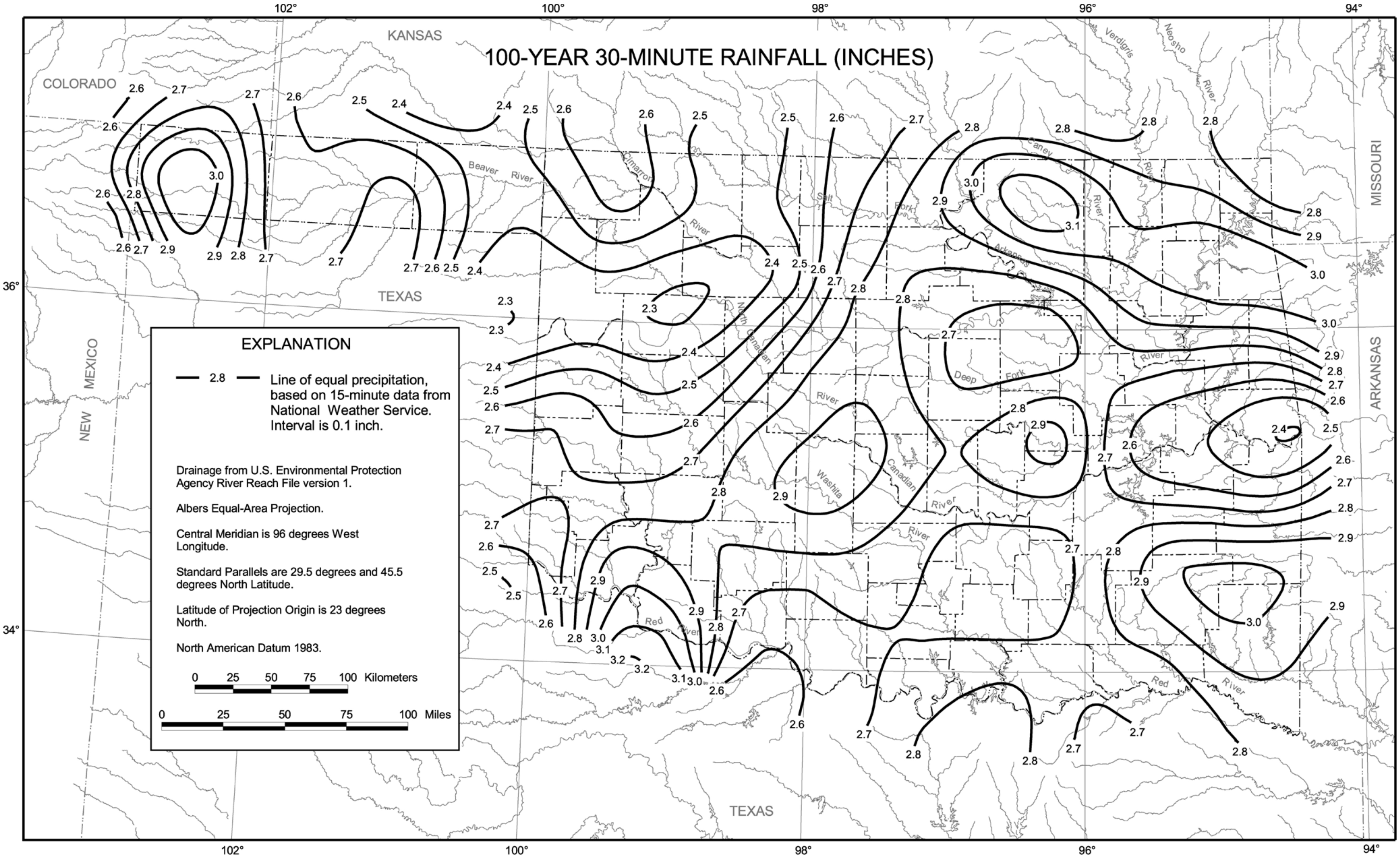


Figure 21. Depth of 100-year storm for 30-minute duration in Oklahoma.

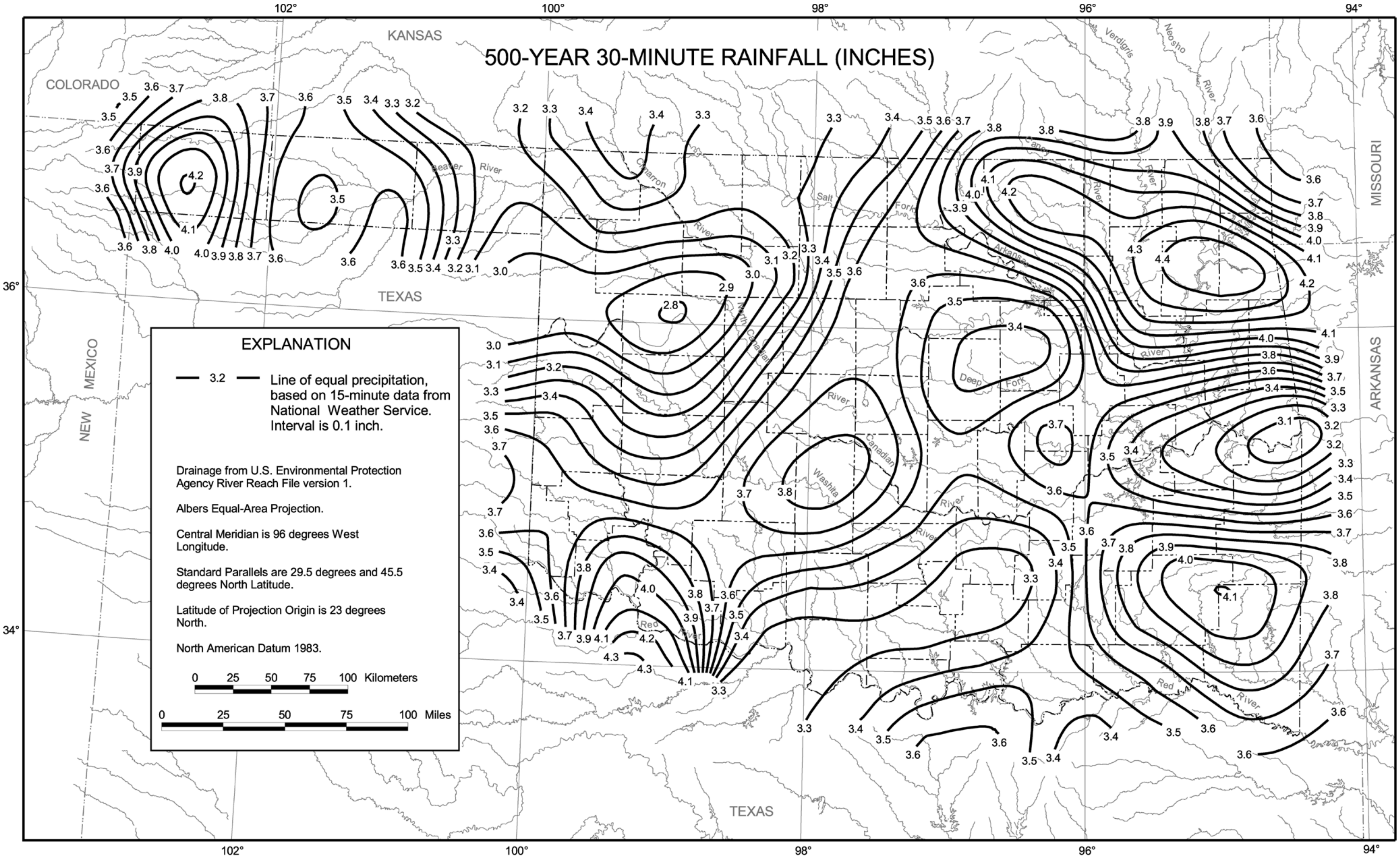


Figure 22. Depth of 500-year storm for 30-minute duration in Oklahoma.

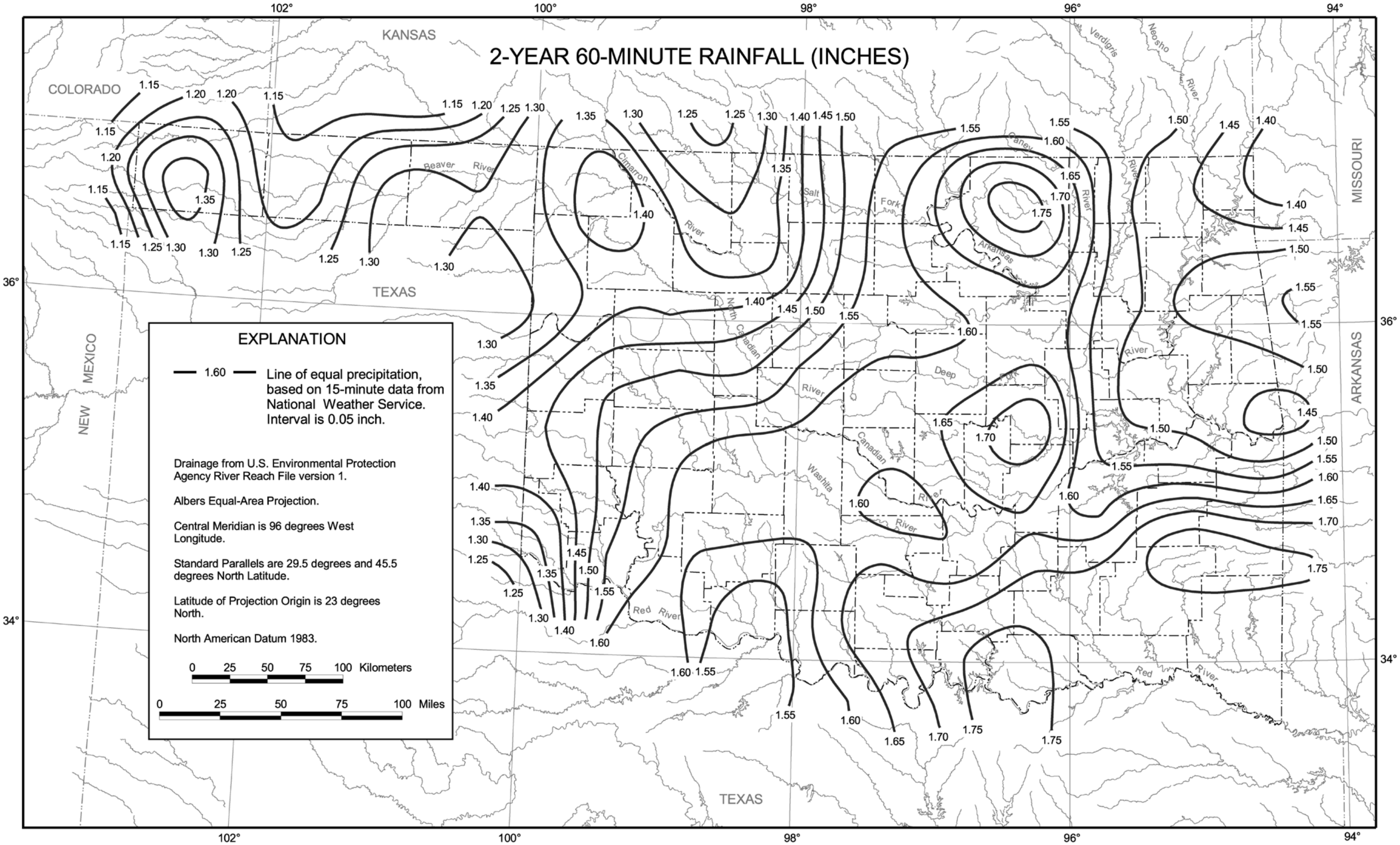
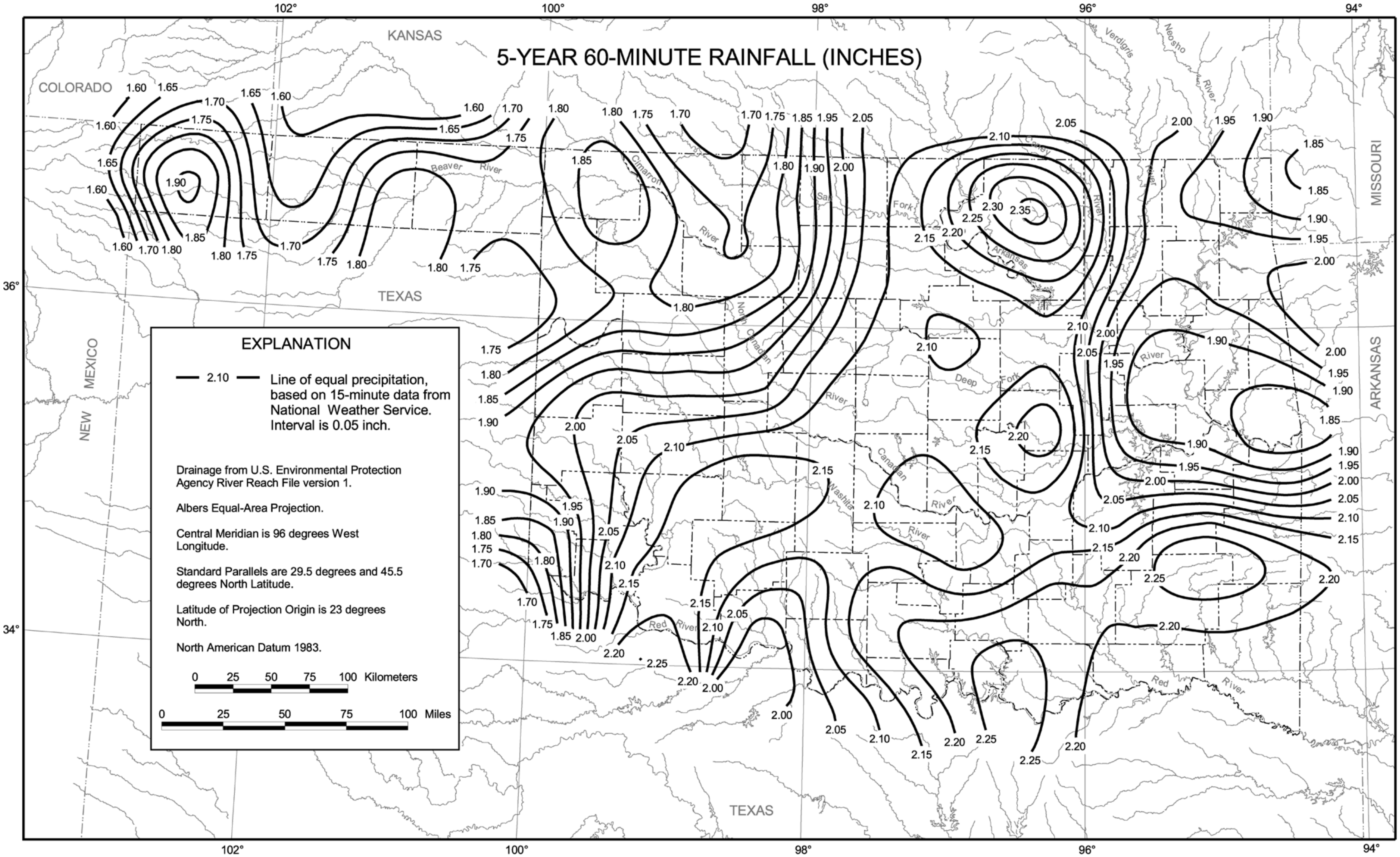


Figure 23. Depth of 2-year storm for 60-minute duration in Oklahoma.



EXPLANATION

— 2.10 — Line of equal precipitation, based on 15-minute data from National Weather Service. Interval is 0.05 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 24. Depth of 5-year storm for 60-minute duration in Oklahoma.

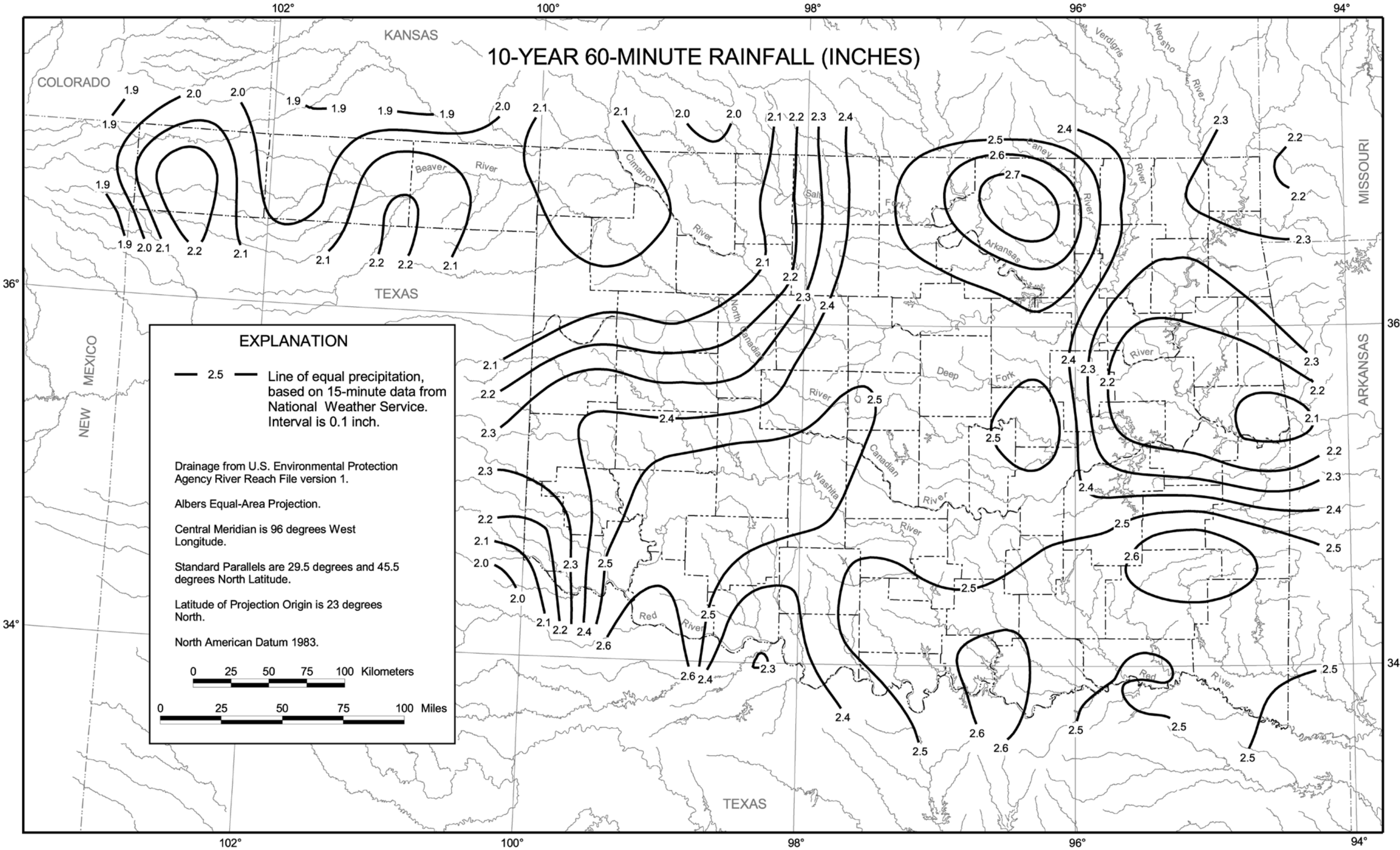


Figure 25. Depth of 10-year storm for 60-minute duration in Oklahoma.

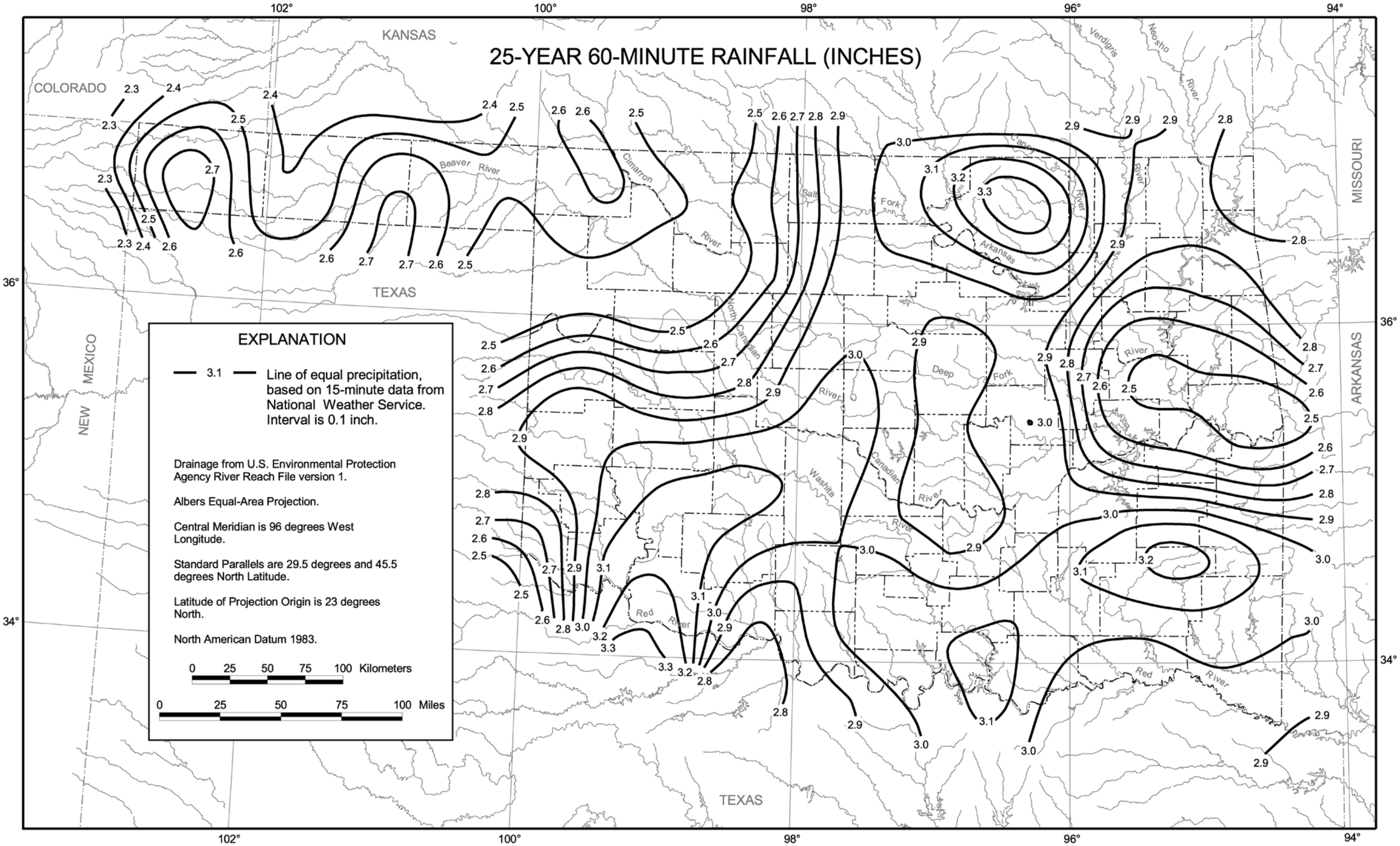
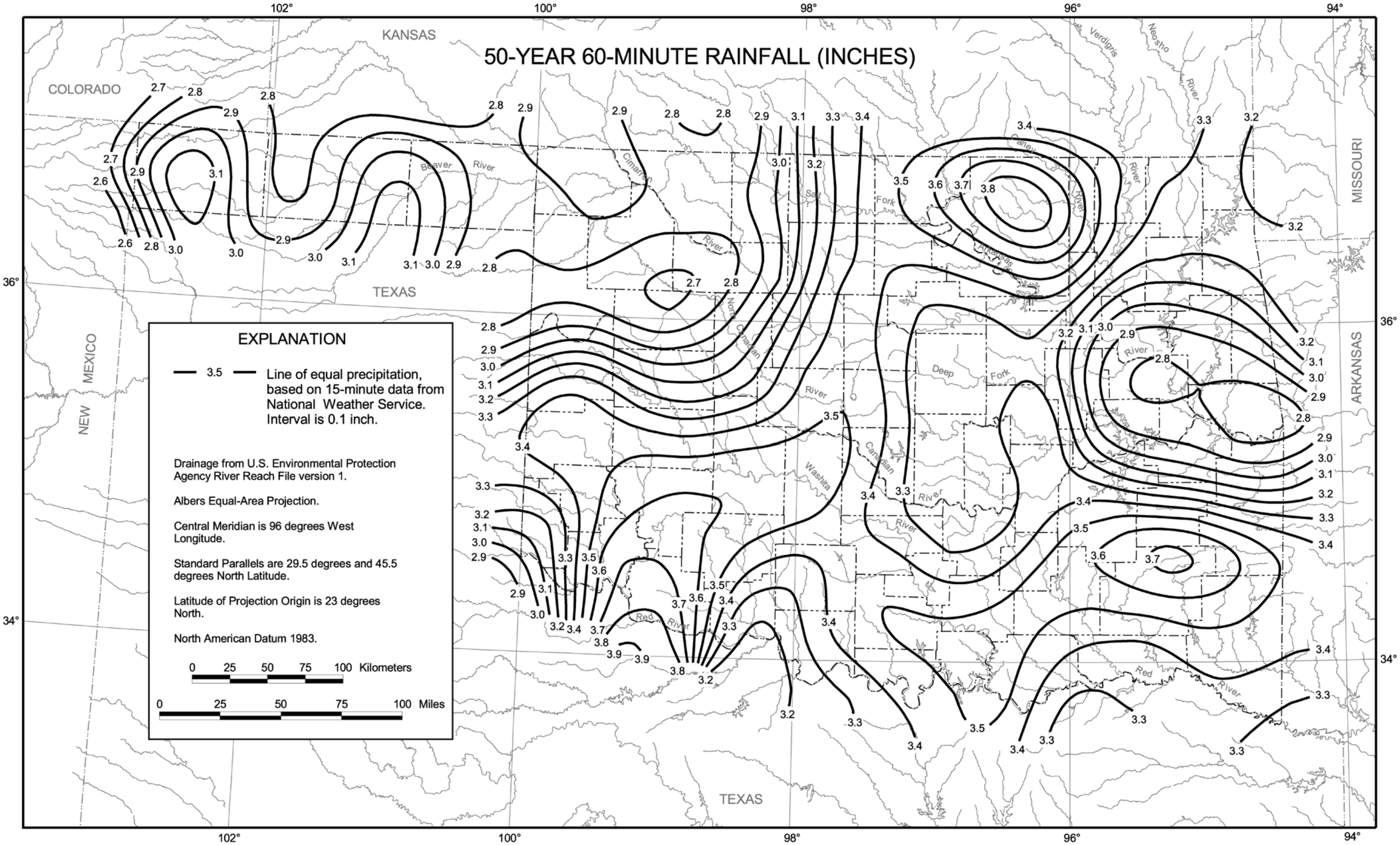


Figure 26. Depth of 25-year storm for 60-minute duration in Oklahoma.



EXPLANATION

— 3.5 — Line of equal precipitation, based on 15-minute data from National Weather Service. Interval is 0.1 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 27. Depth of 50-year storm for 60-minute duration in Oklahoma.

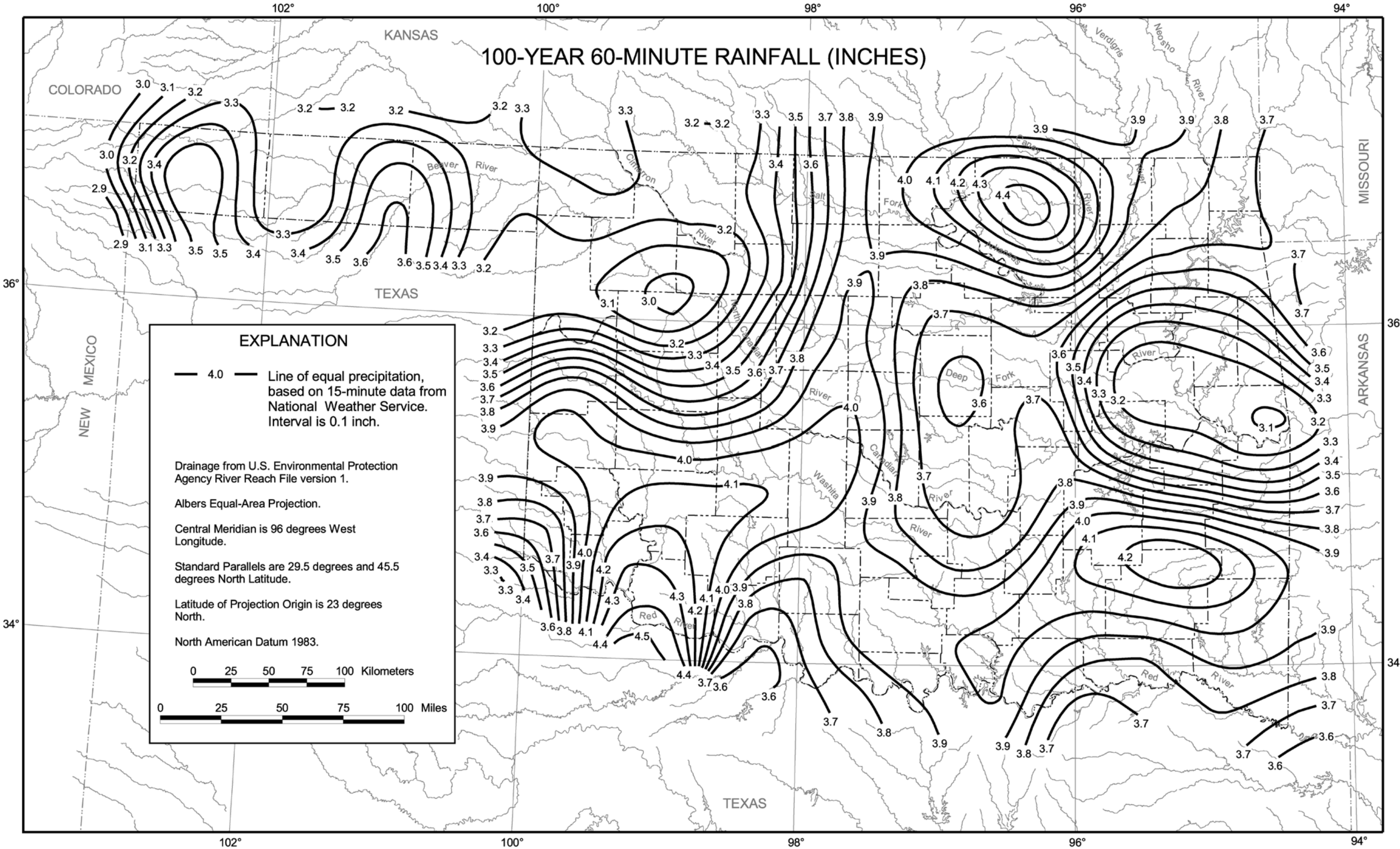


Figure 28. Depth of 100-year storm for 60-minute duration in Oklahoma.

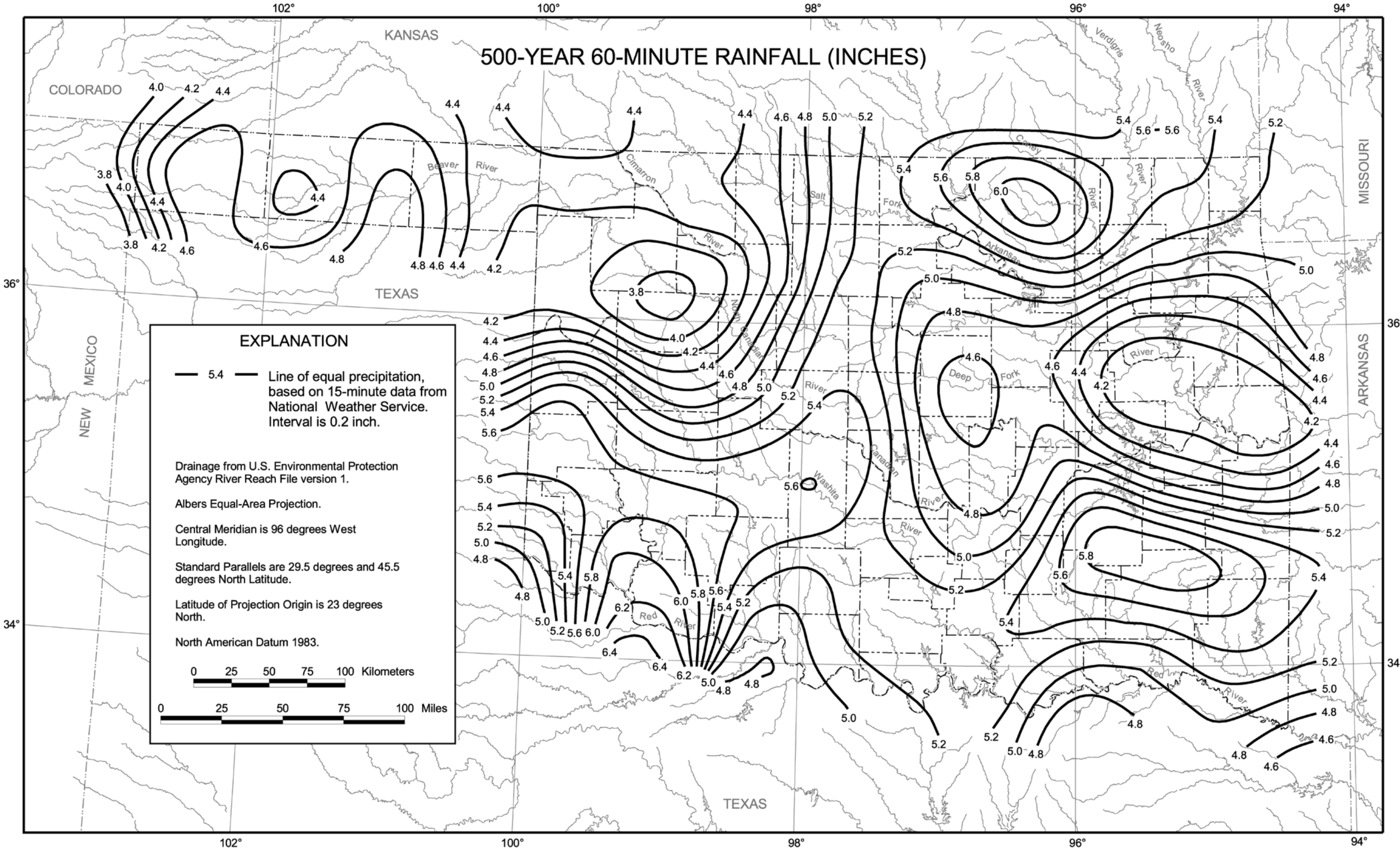


Figure 29. Depth of 500-year storm for 60-minute duration in Oklahoma.

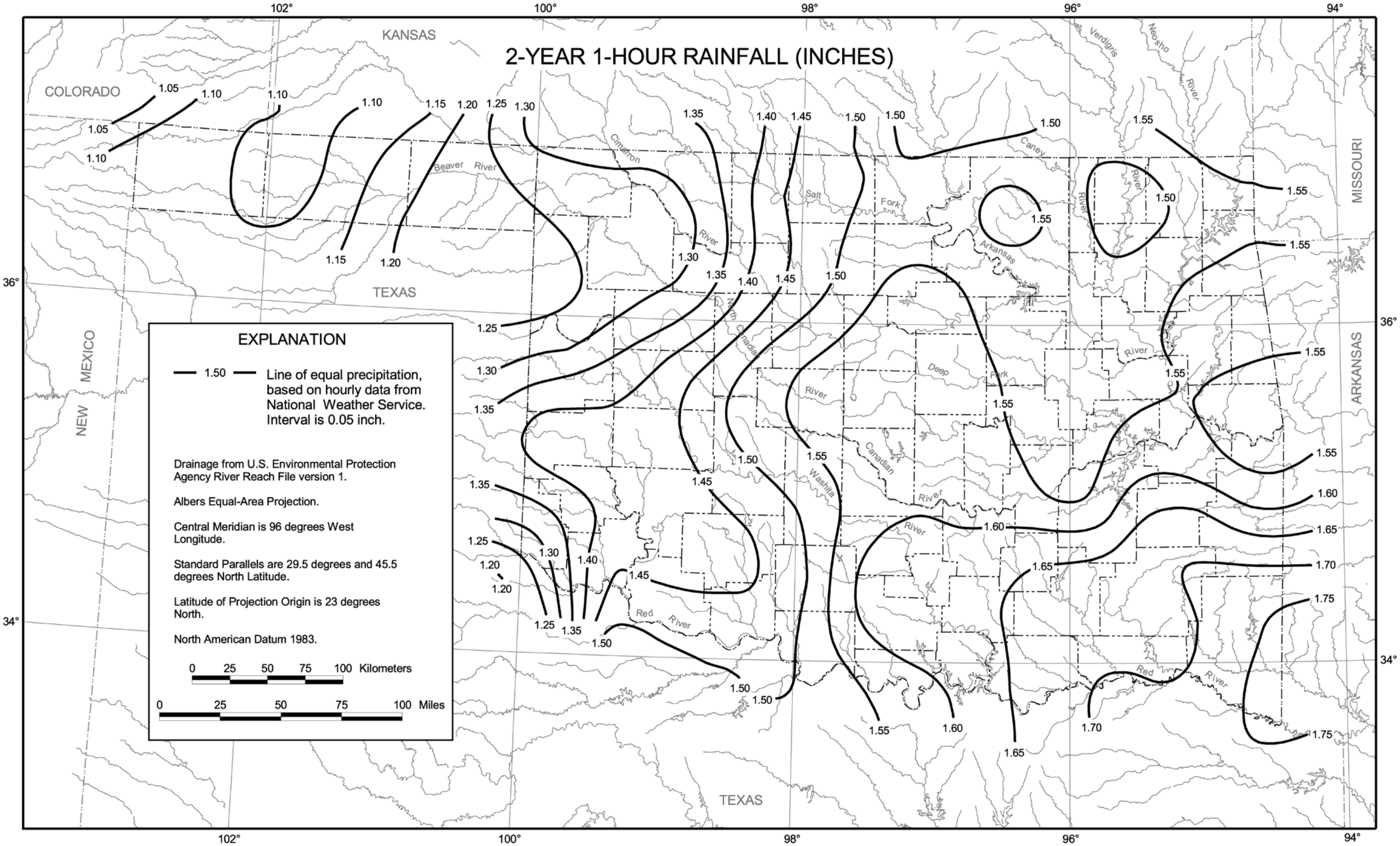
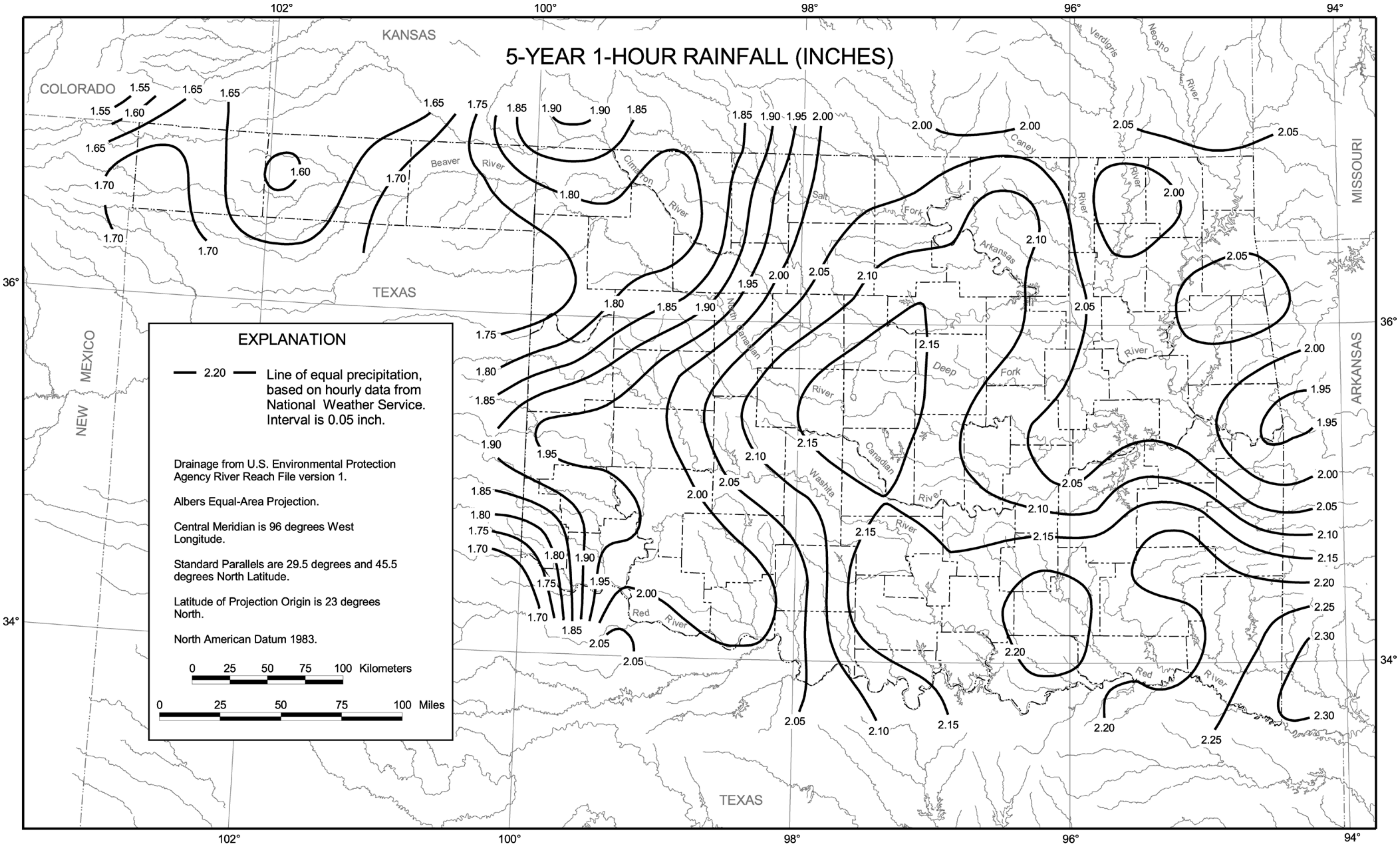


Figure 30. Depth of 2-year storm for 1-hour duration in Oklahoma.



Line of equal precipitation, based on hourly data from National Weather Service. Interval is 0.05 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 31. Depth of 5-year storm for 1-hour duration in Oklahoma.

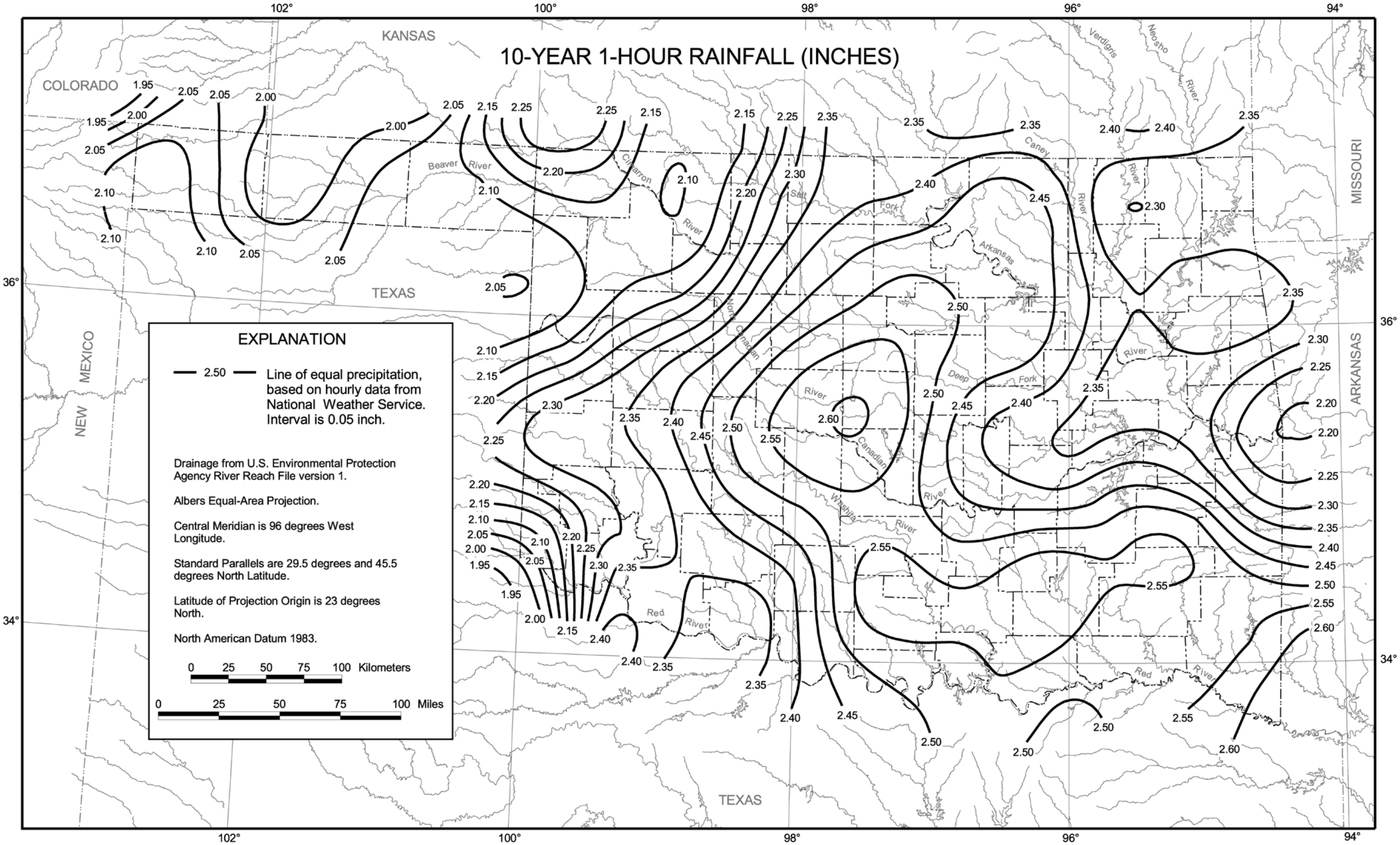


Figure 32. Depth of 10-year storm for 1-hour duration in Oklahoma.

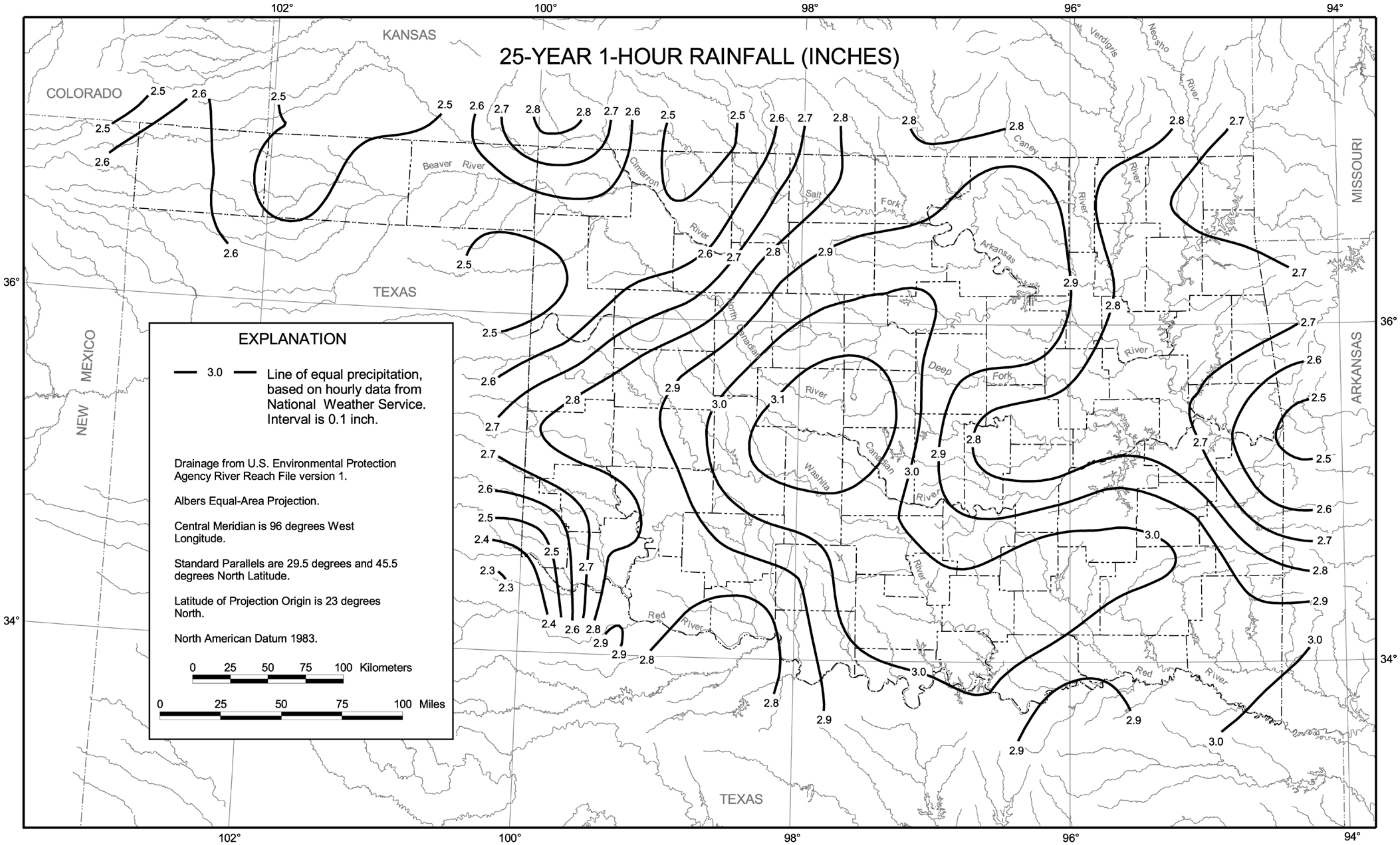


Figure 33. Depth of 25-year storm for 1-hour duration in Oklahoma.

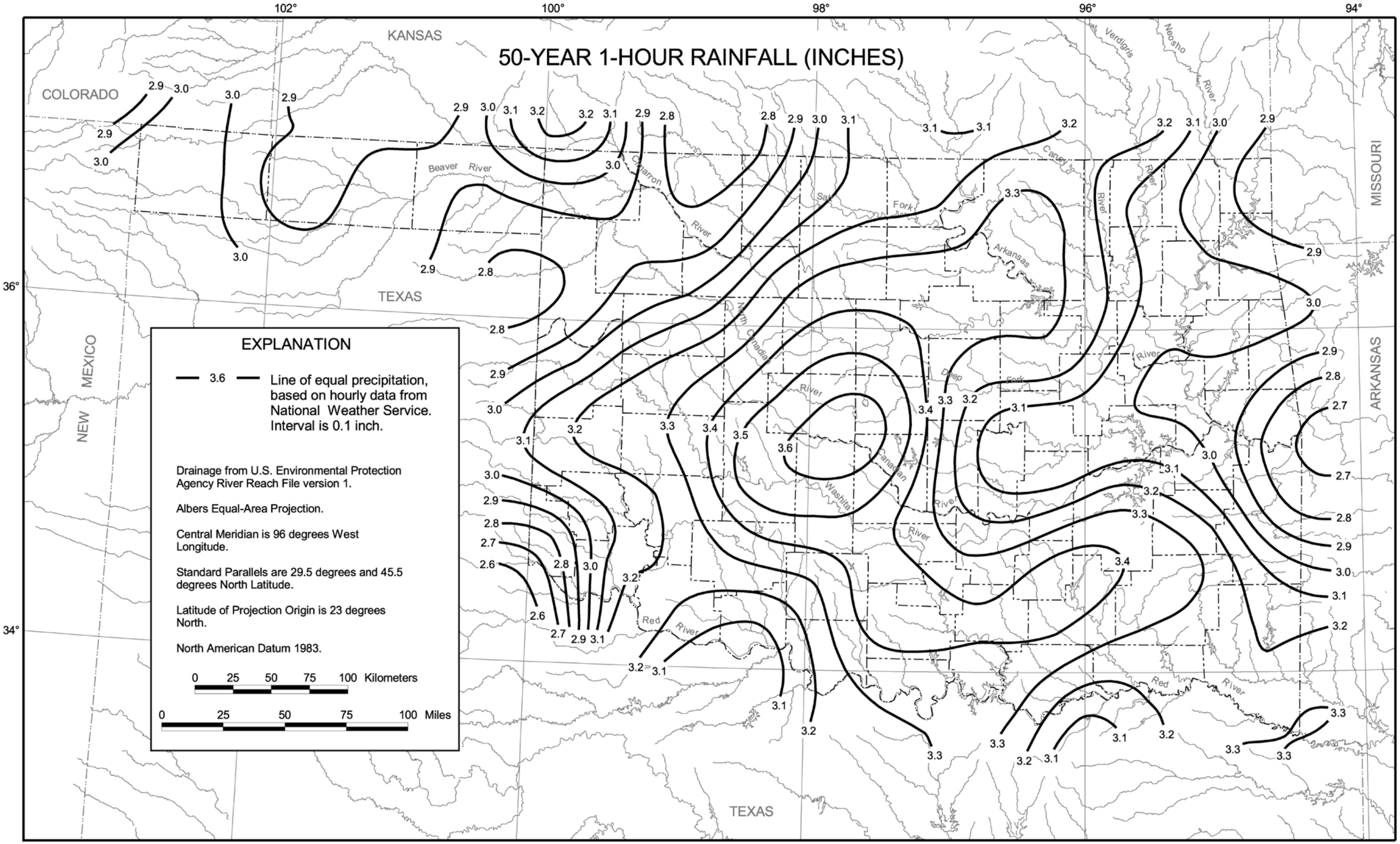


Figure 34. Depth of 50-year storm for 1-hour duration in Oklahoma.

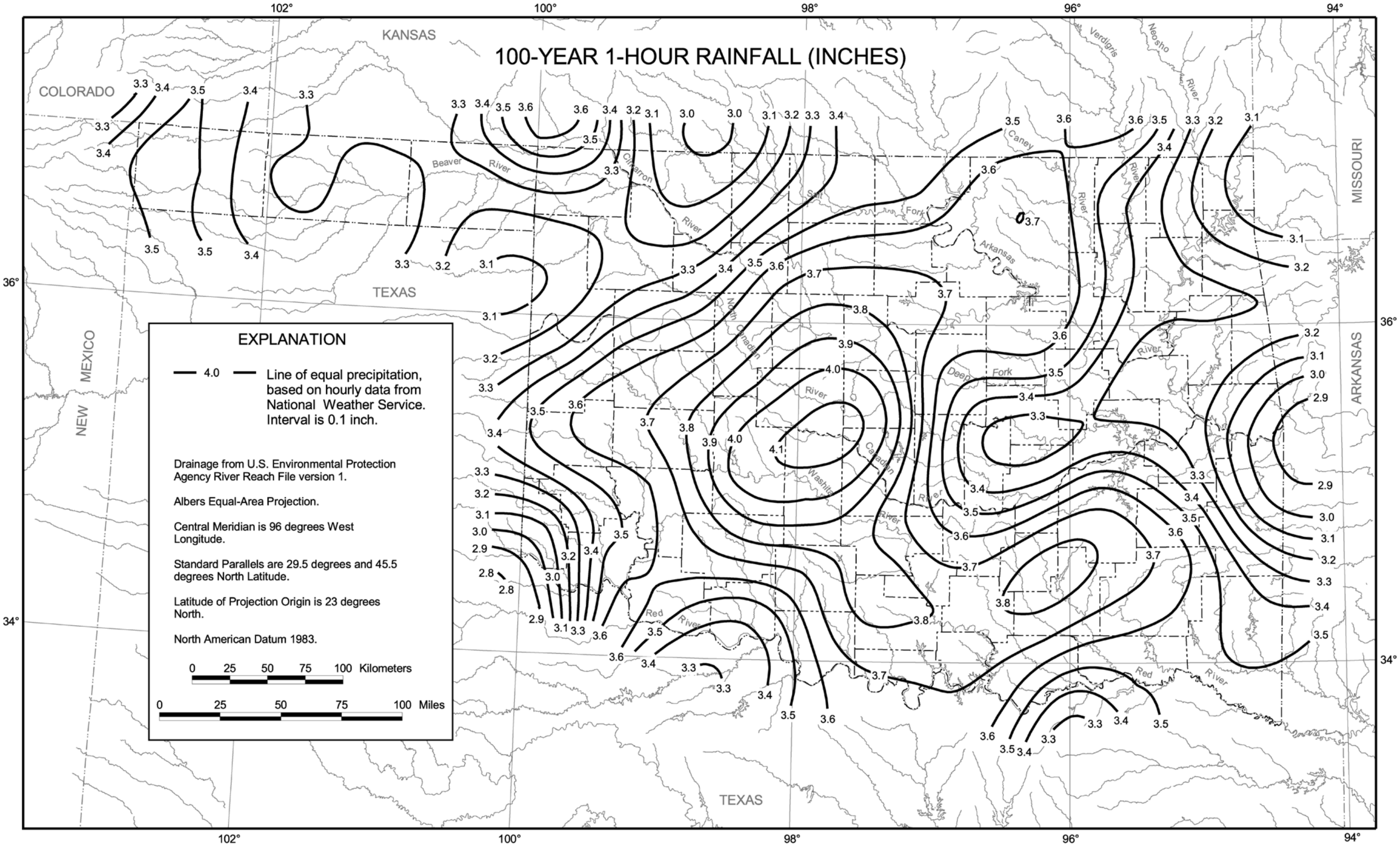


Figure 35. Depth of 100-year storm for 1-hour duration in Oklahoma.

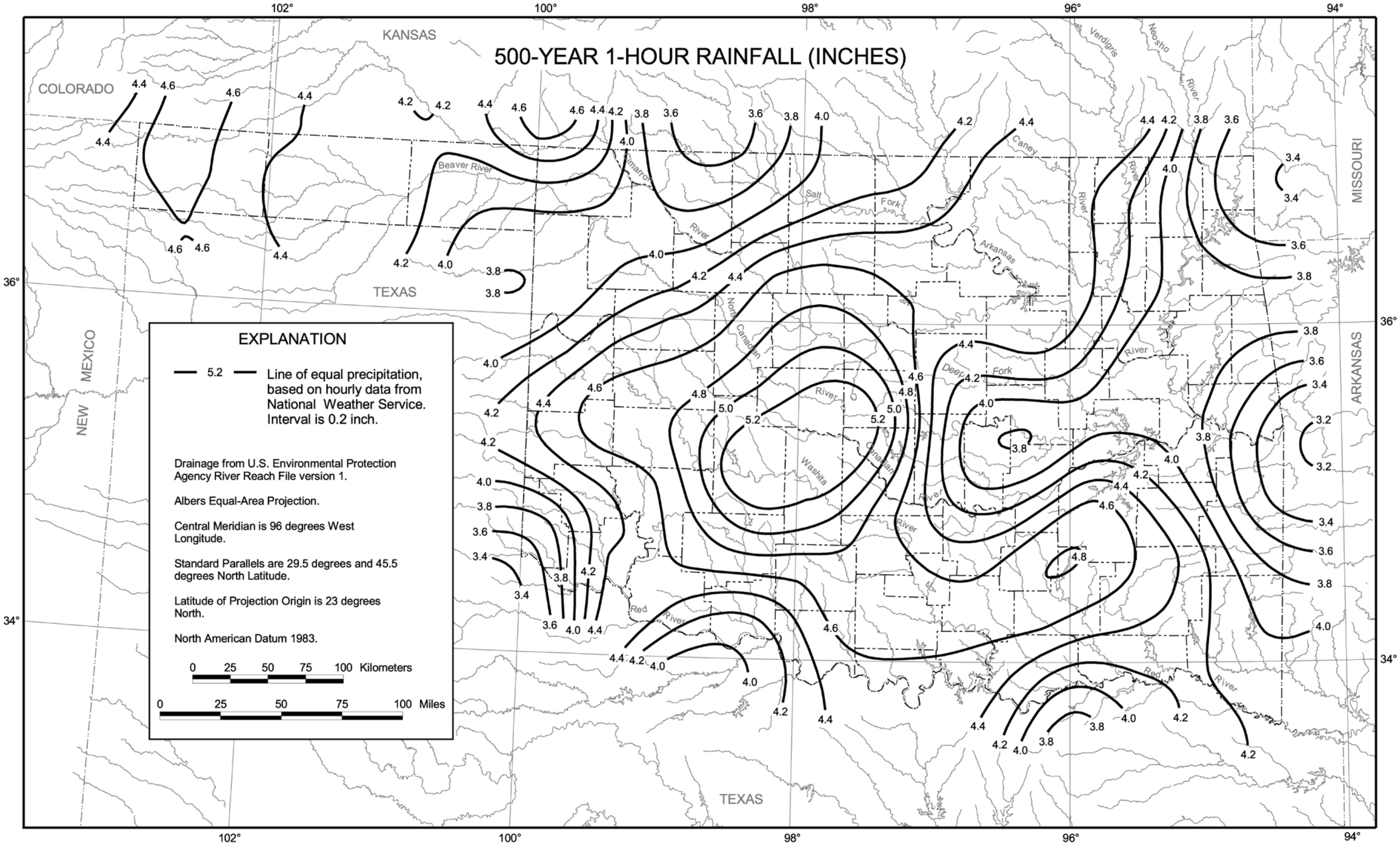


Figure 36. Depth of 500-year storm for 1-hour duration in Oklahoma.

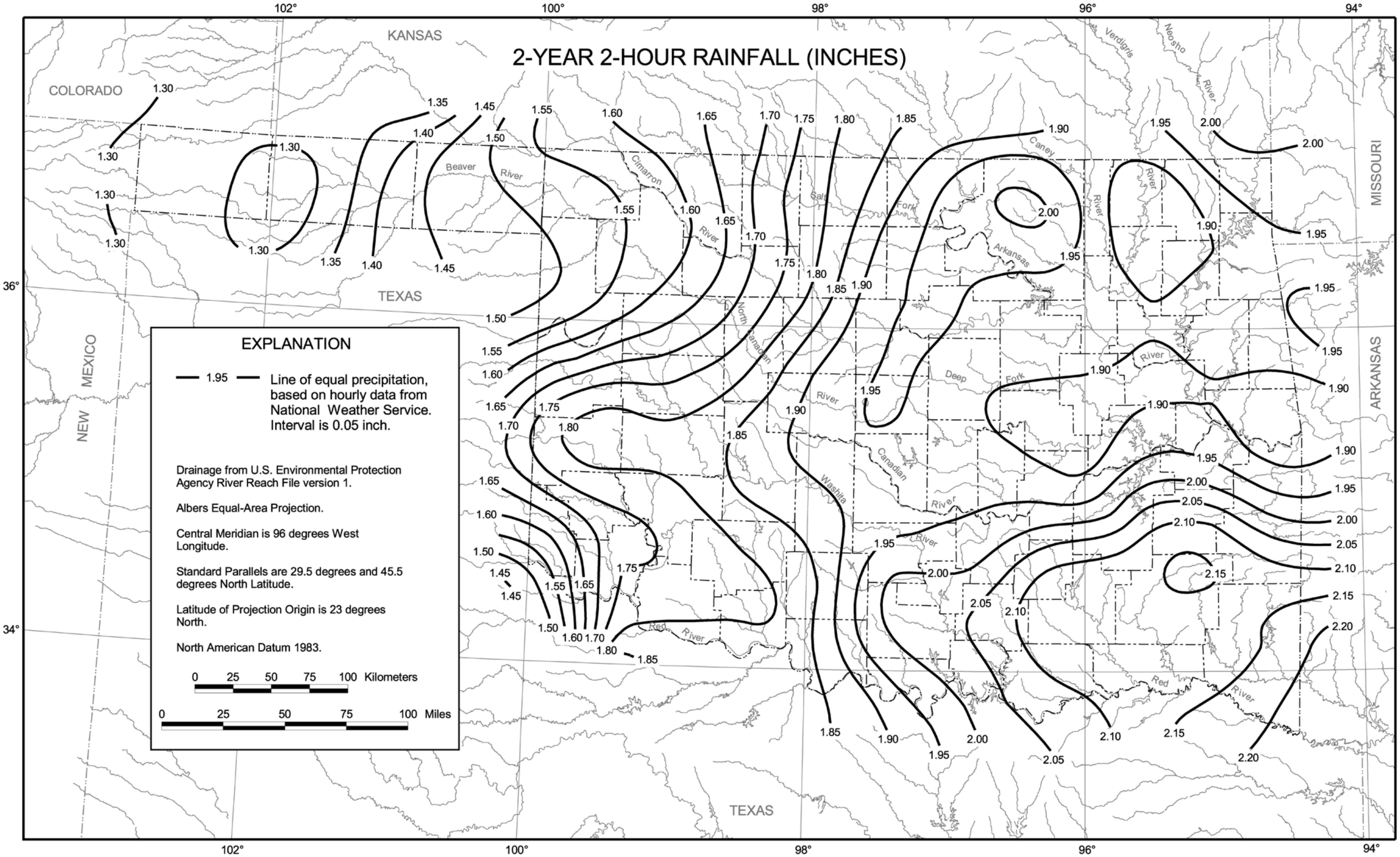
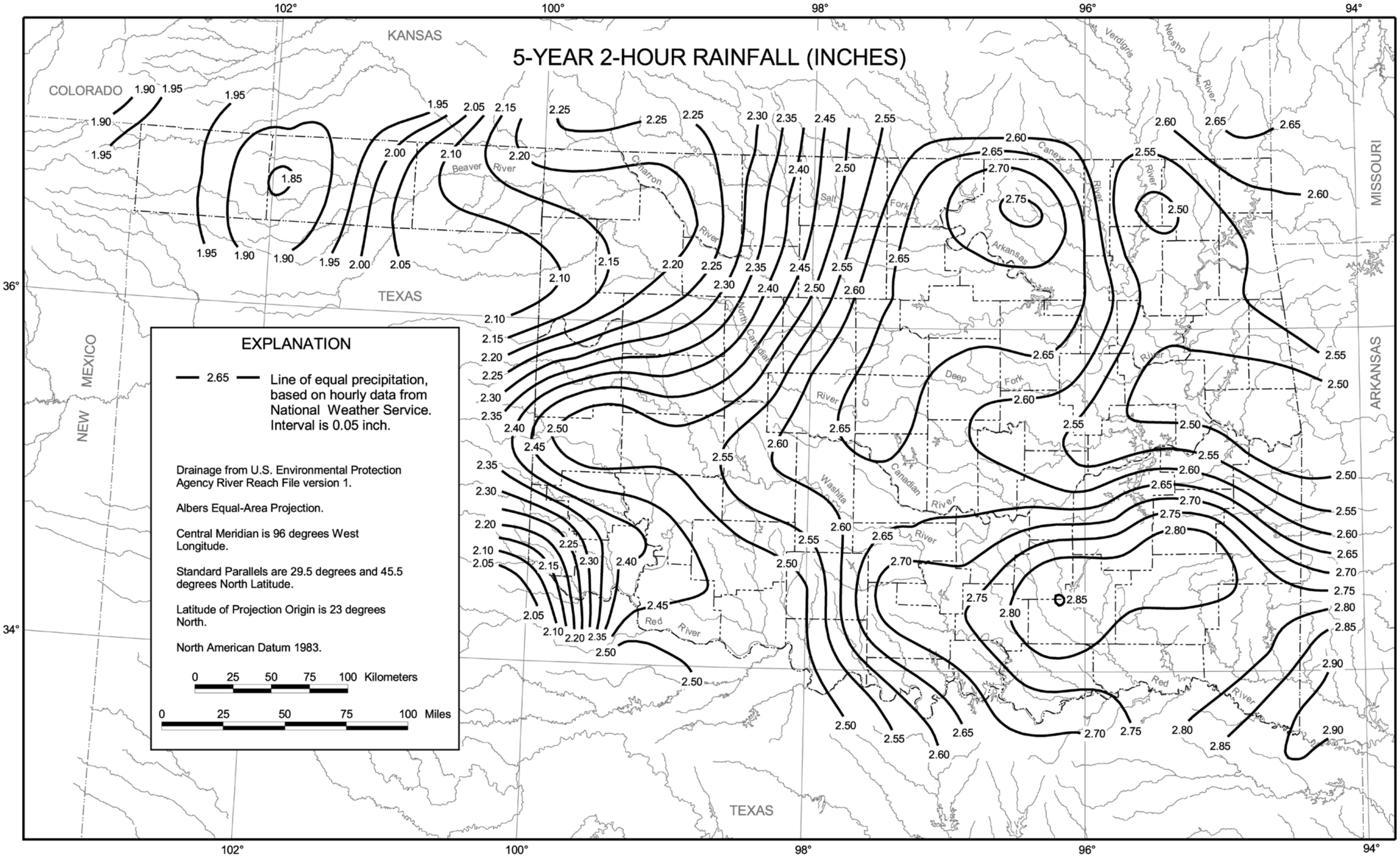


Figure 37. Depth of 2-year storm for 2-hour duration in Oklahoma.


5-YEAR 2-HOUR RAINFALL (INCHES)

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

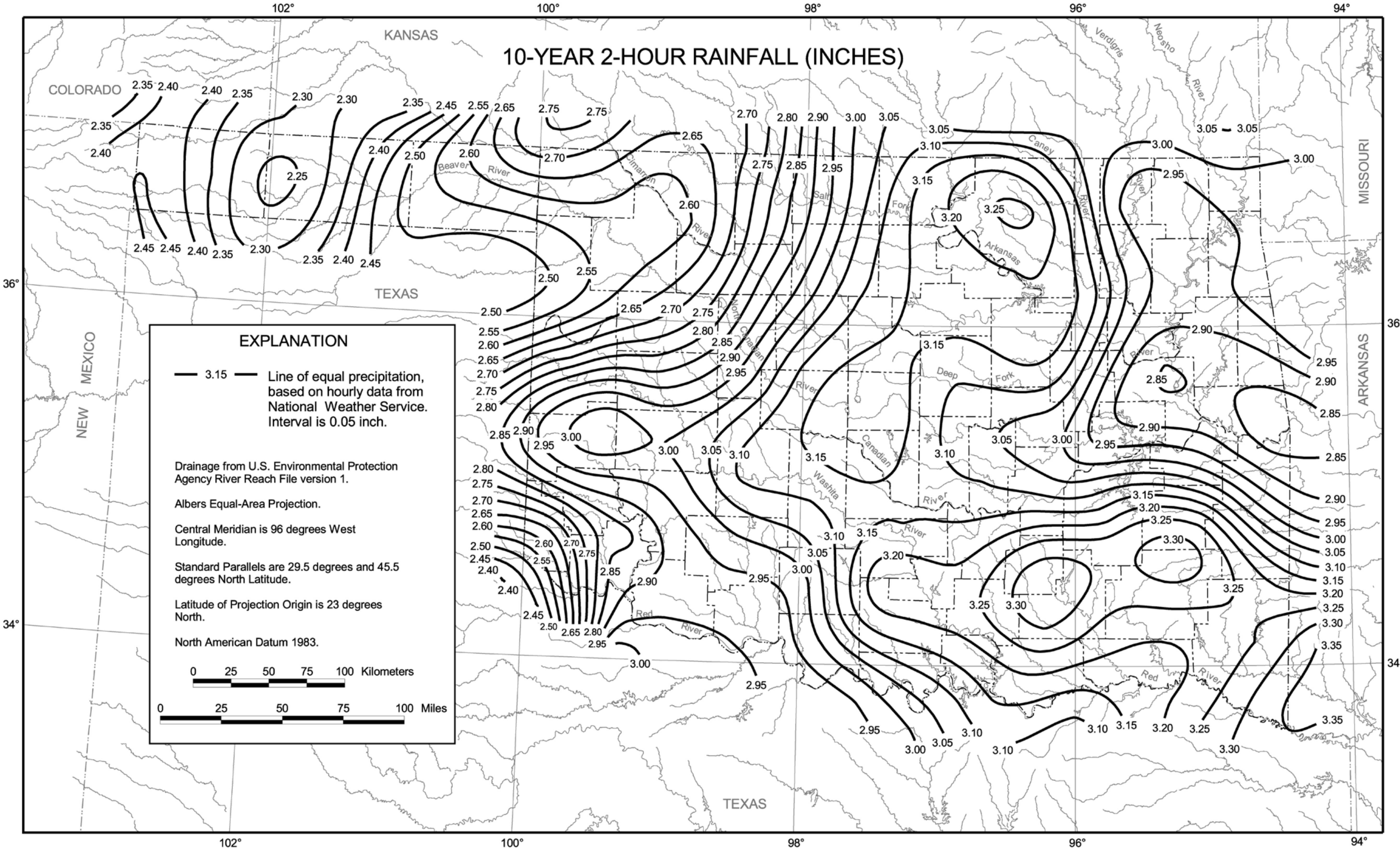
Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 38. Depth of 5-year storm for 2-hour duration in Oklahoma.



EXPLANATION

— 3.15 — Line of equal precipitation, based on hourly data from National Weather Service. Interval is 0.05 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 39. Depth of 10-year storm for 2-hour duration in Oklahoma.

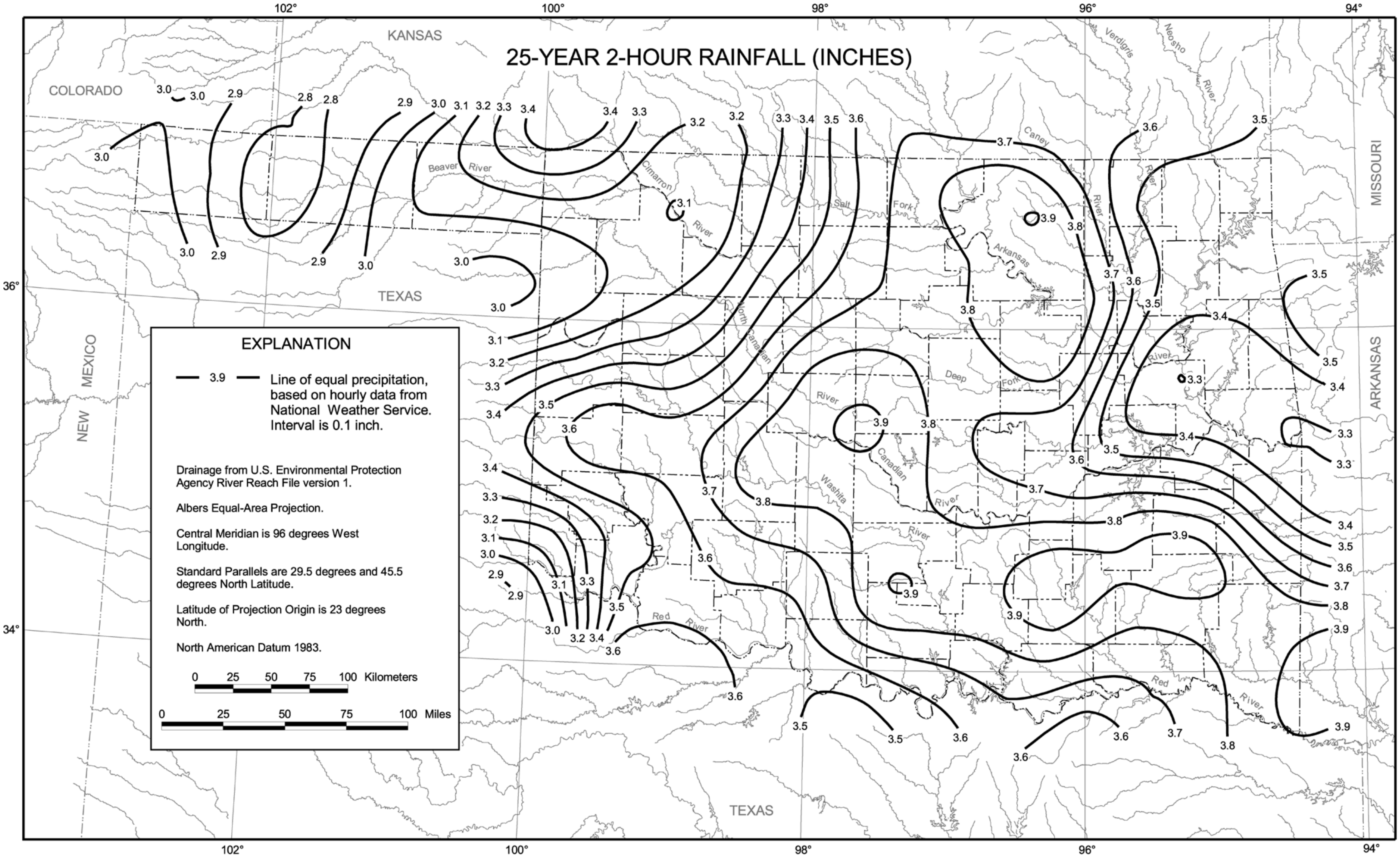


Figure 40. Depth of 25-year storm for 2-hour duration in Oklahoma.

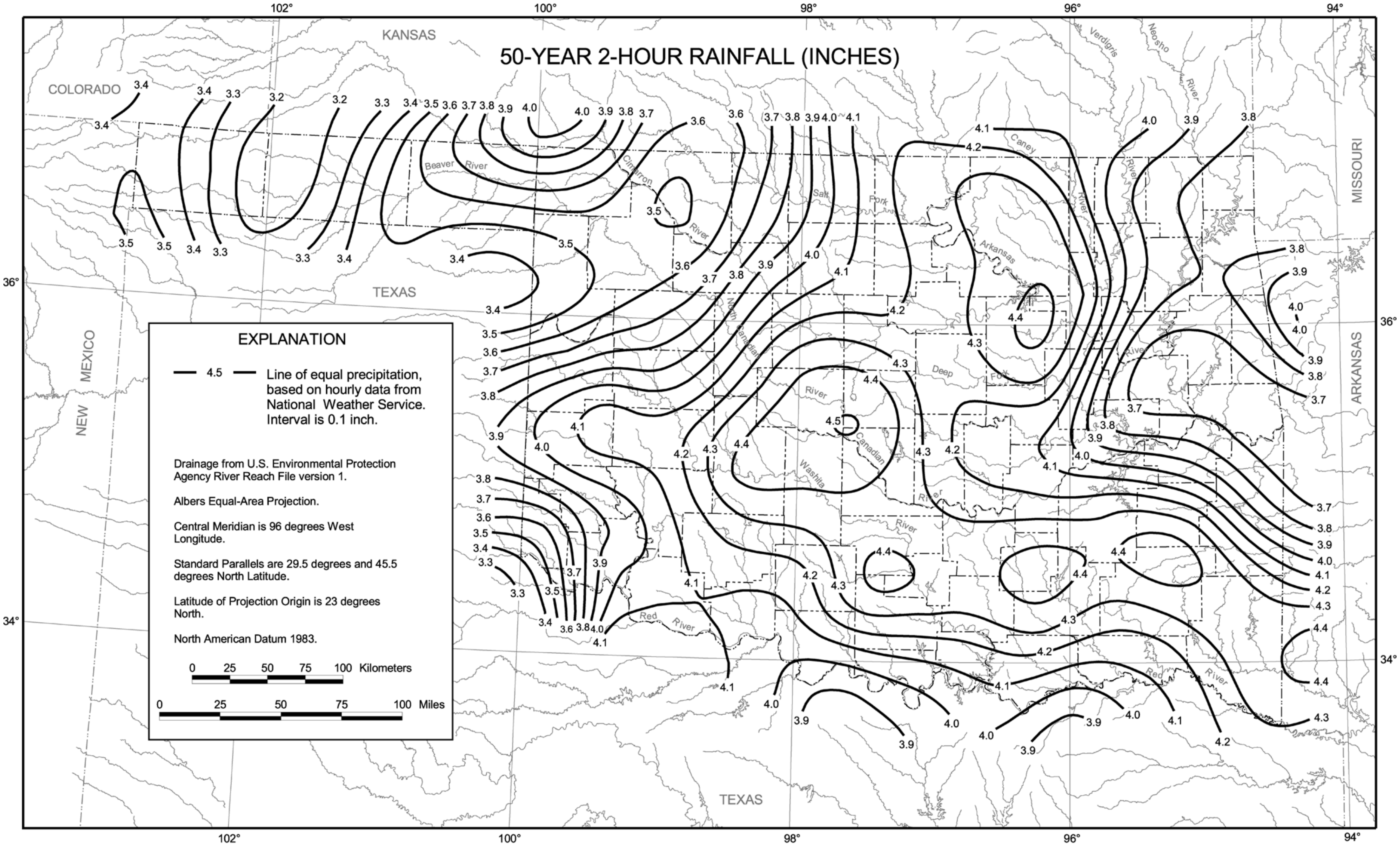
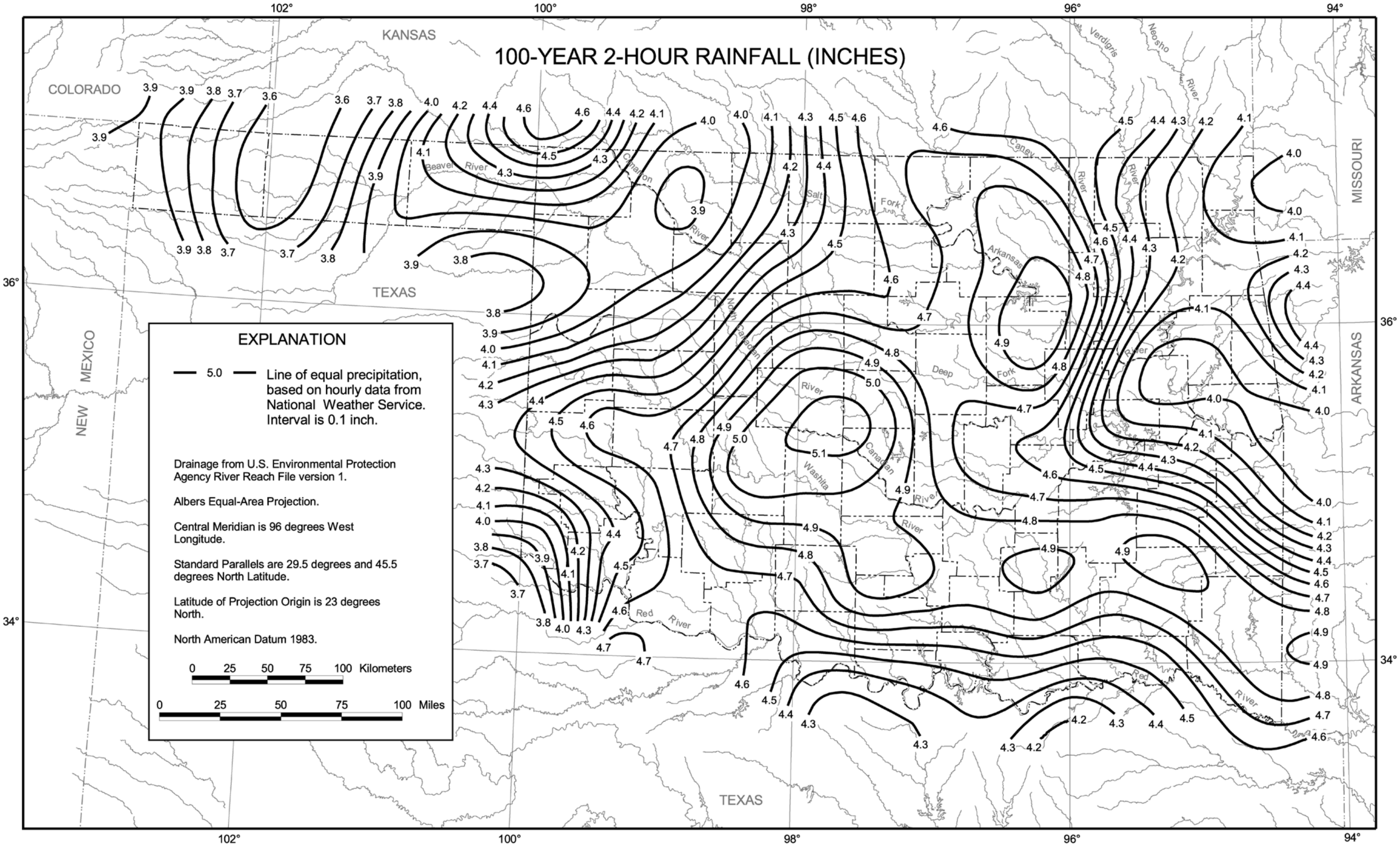


Figure 41. Depth of 50-year storm for 2-hour duration in Oklahoma.



EXPLANATION

— 5.0 — Line of equal precipitation, based on hourly data from National Weather Service. Interval is 0.1 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

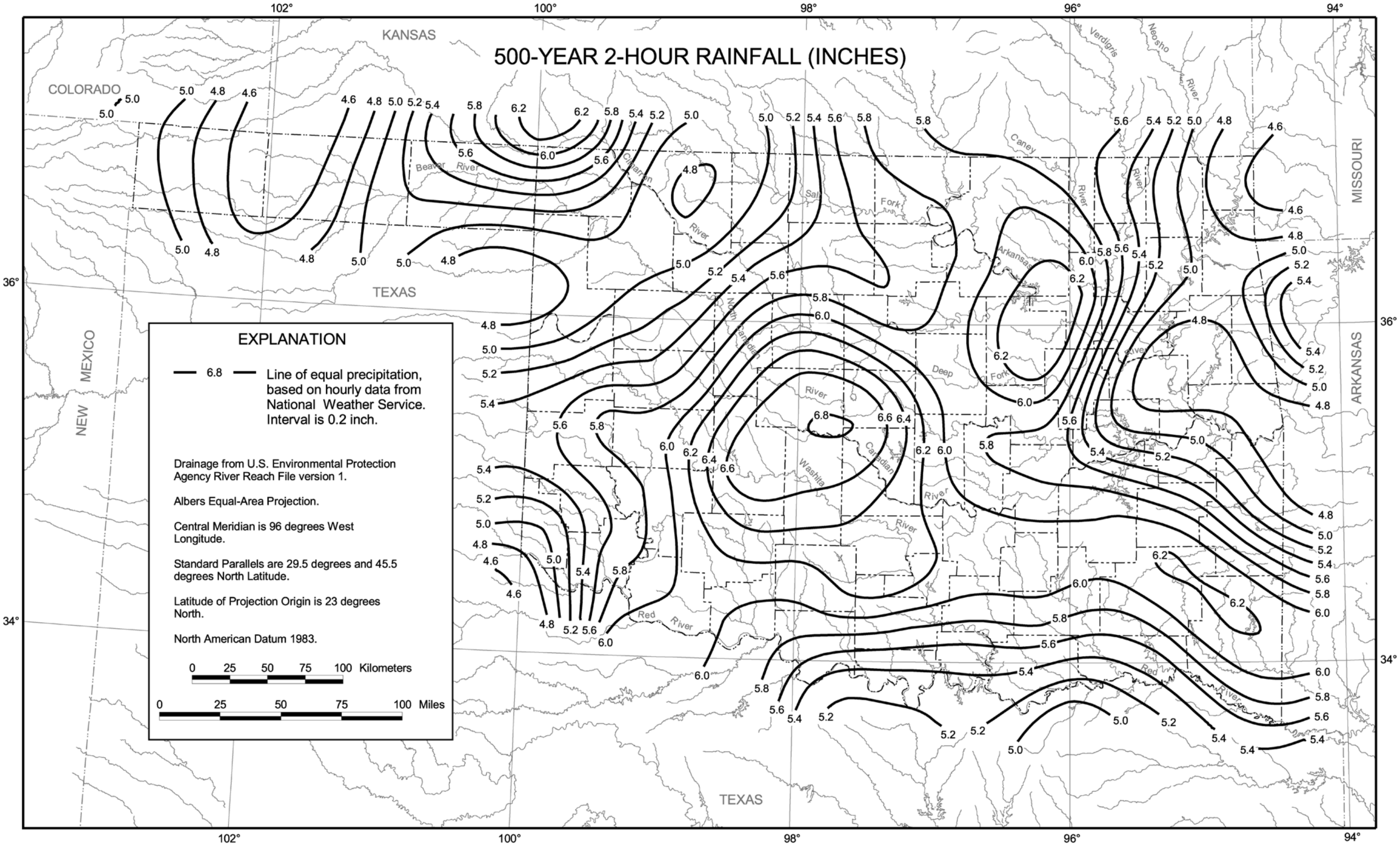
Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 42. Depth of 100-year storm for 2-hour duration in Oklahoma.



500-YEAR 2-HOUR RAINFALL (INCHES)

EXPLANATION

— 6.8 — Line of equal precipitation, based on hourly data from National Weather Service. Interval is 0.2 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

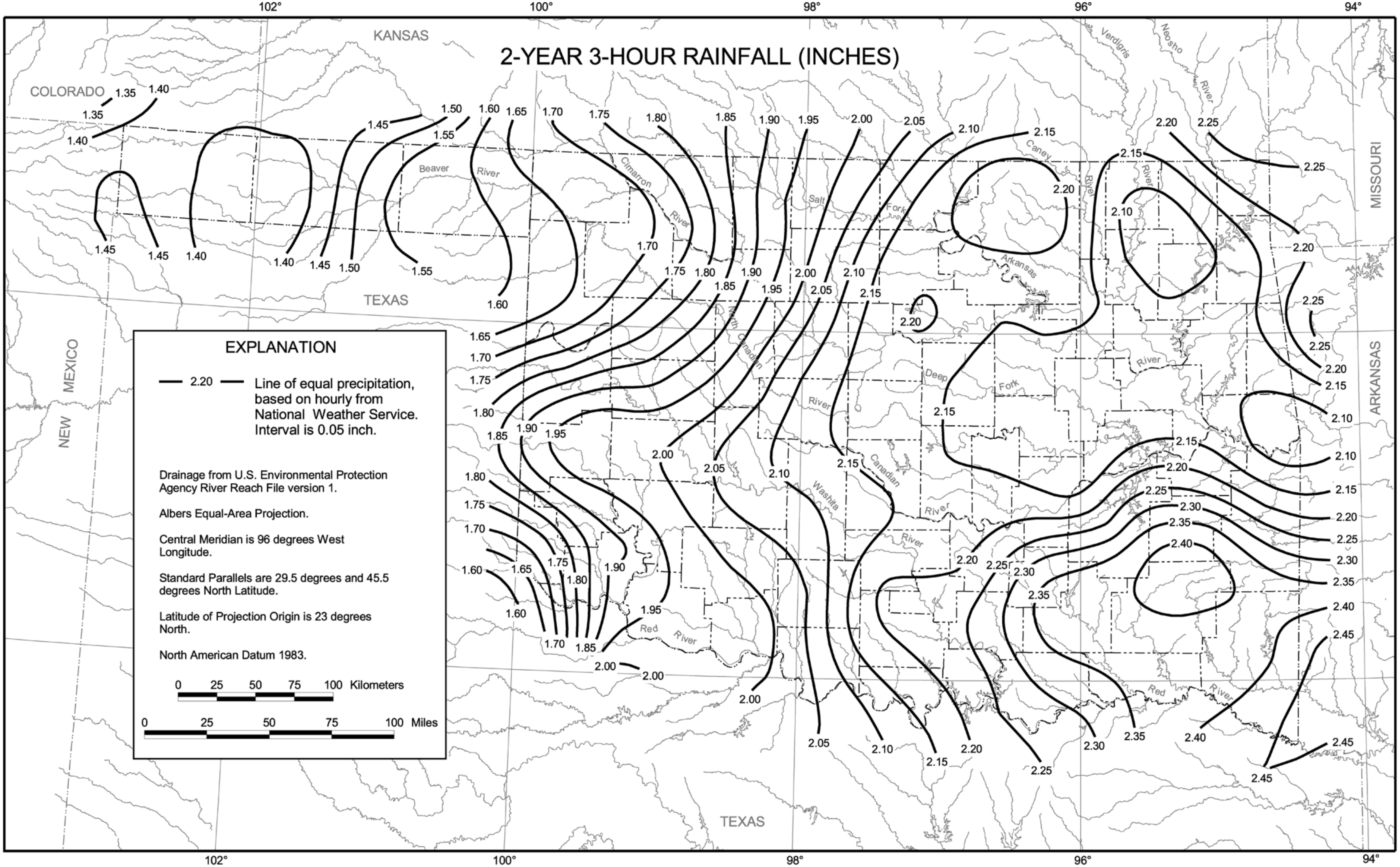
Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

0 25 50 75 100 Kilometers

0 25 50 75 100 Miles

Figure 43. Depth of 500-year storm for 2-hour duration in Oklahoma.



EXPLANATION

— 2.20 — Line of equal precipitation, based on hourly from National Weather Service. Interval is 0.05 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 44. Depth of 2-year storm for 3-hour duration in Oklahoma.

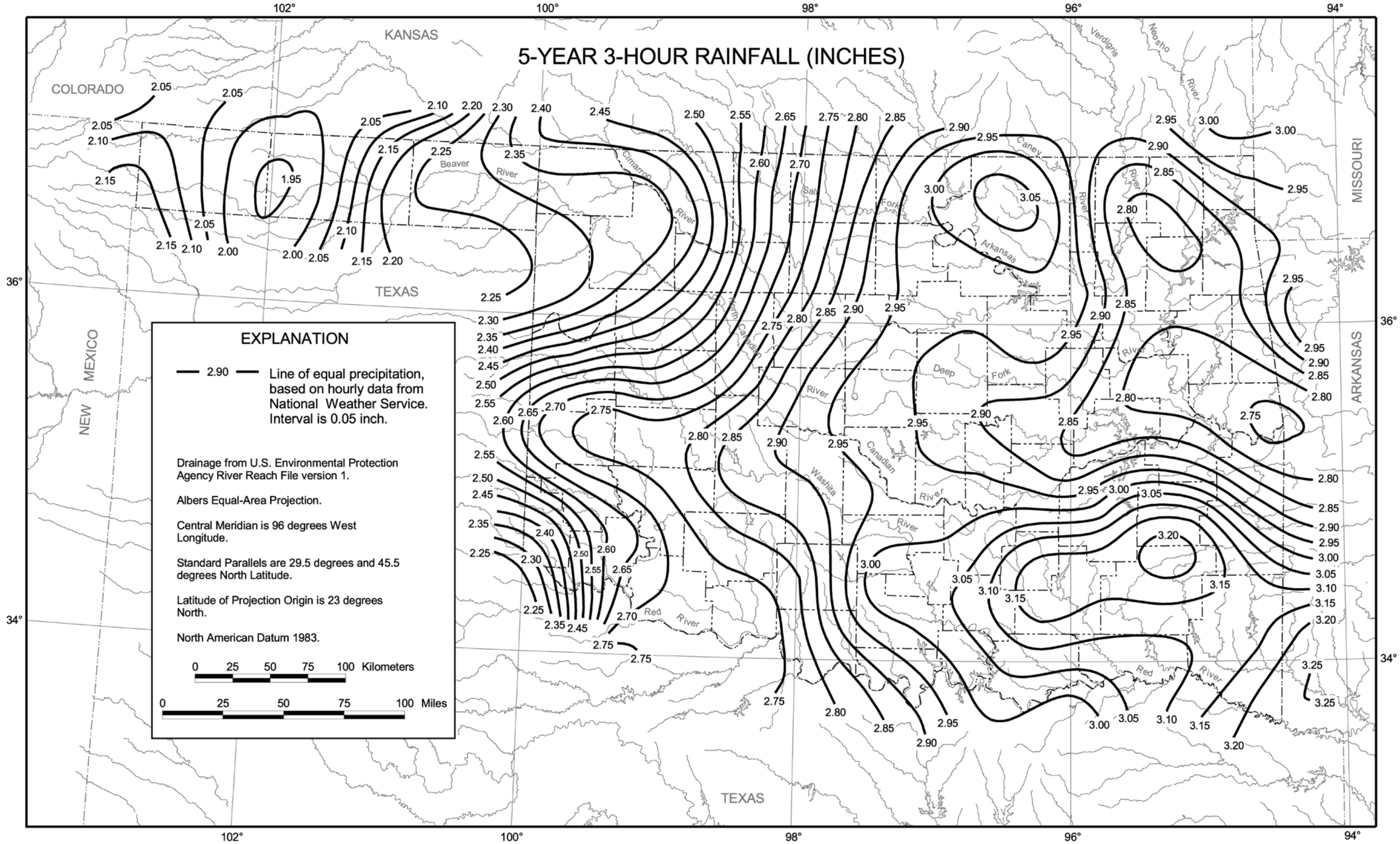
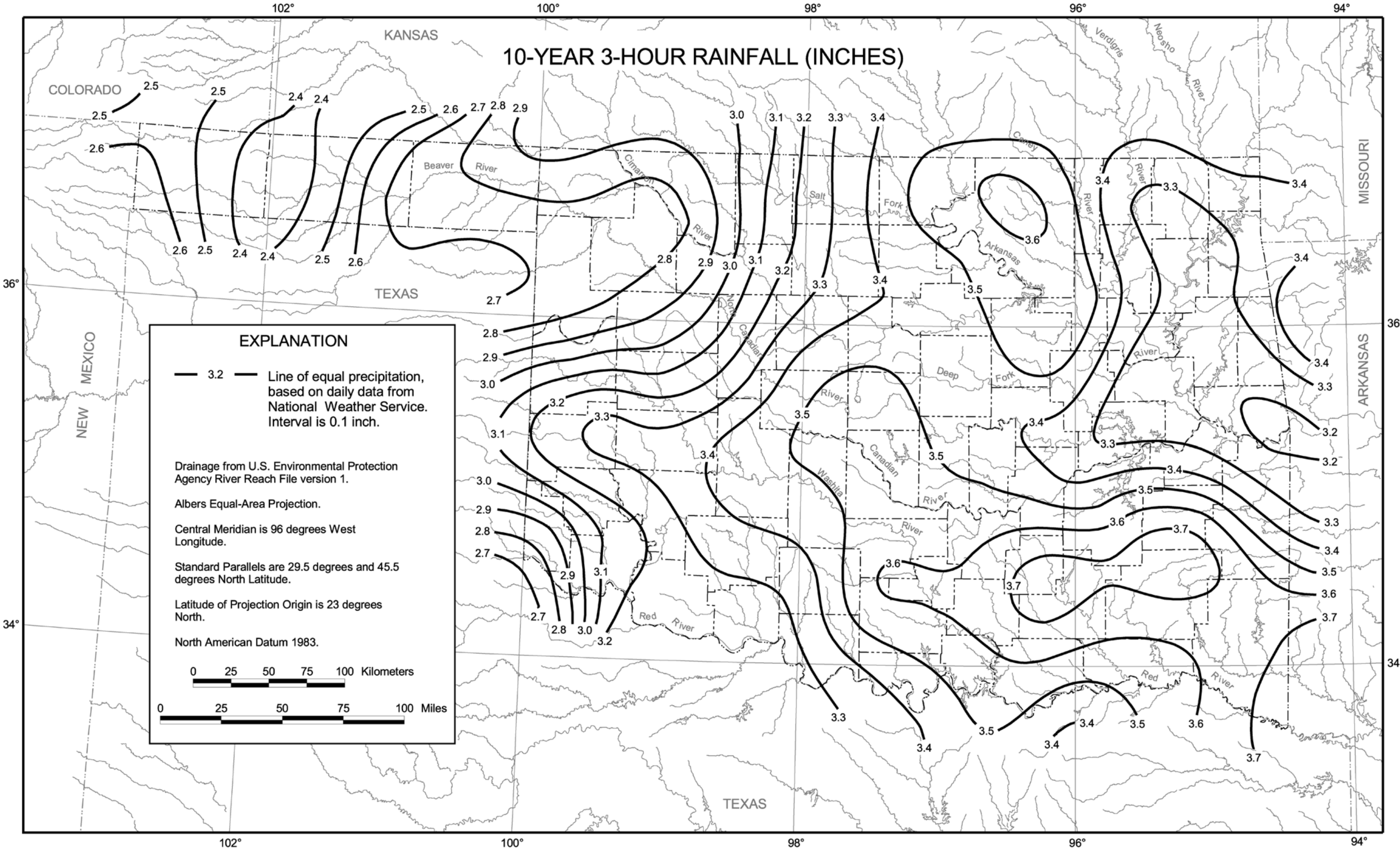


Figure 45. Depth of 5-year storm for 3-hour duration in Oklahoma.



EXPLANATION

— 3.2 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.1 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

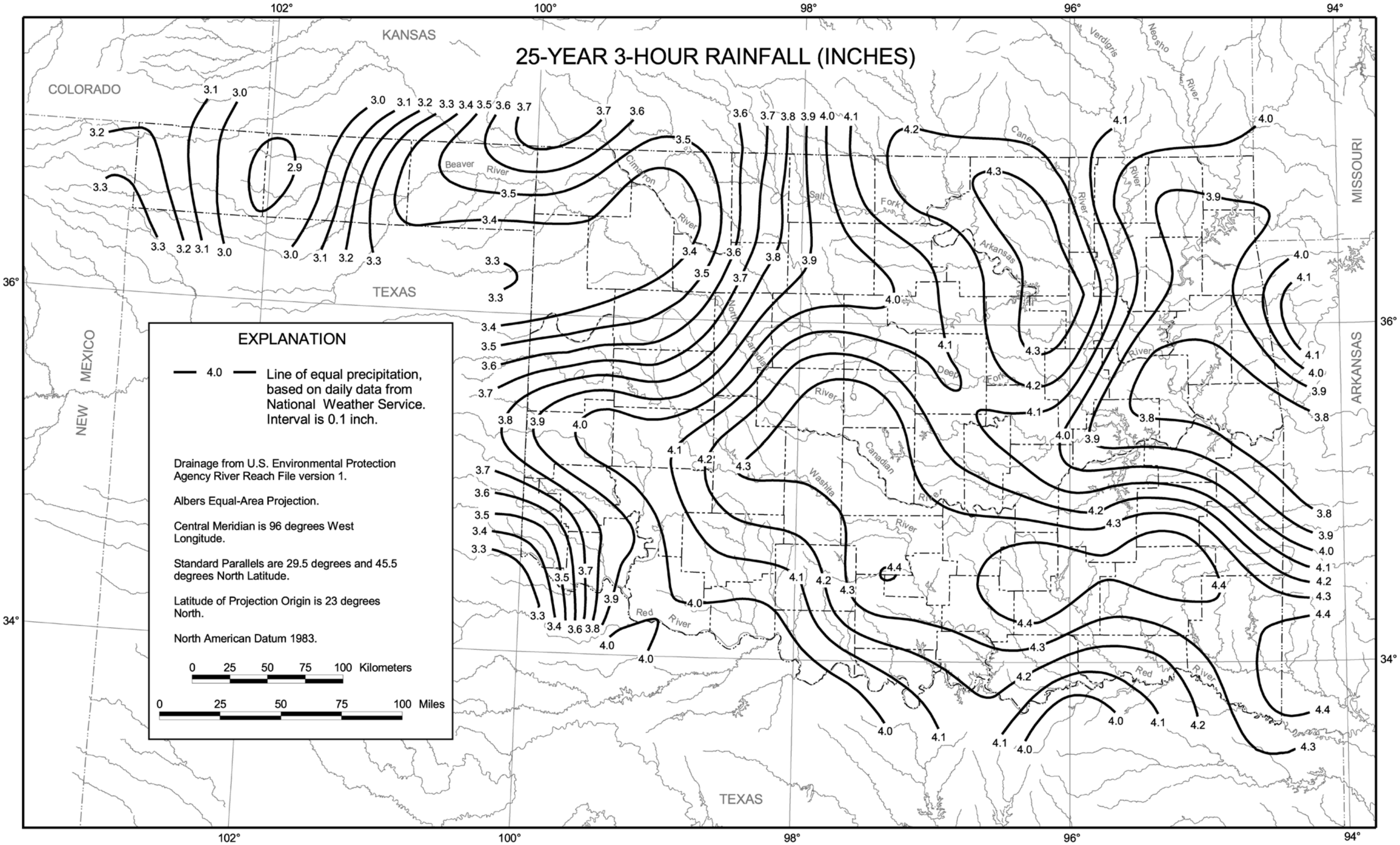
Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 46. Depth of 10-year storm for 3-hour duration in Oklahoma.



EXPLANATION

— 4.0 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.1 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 47. Depth of 25-year storm for 3-hour duration in Oklahoma.

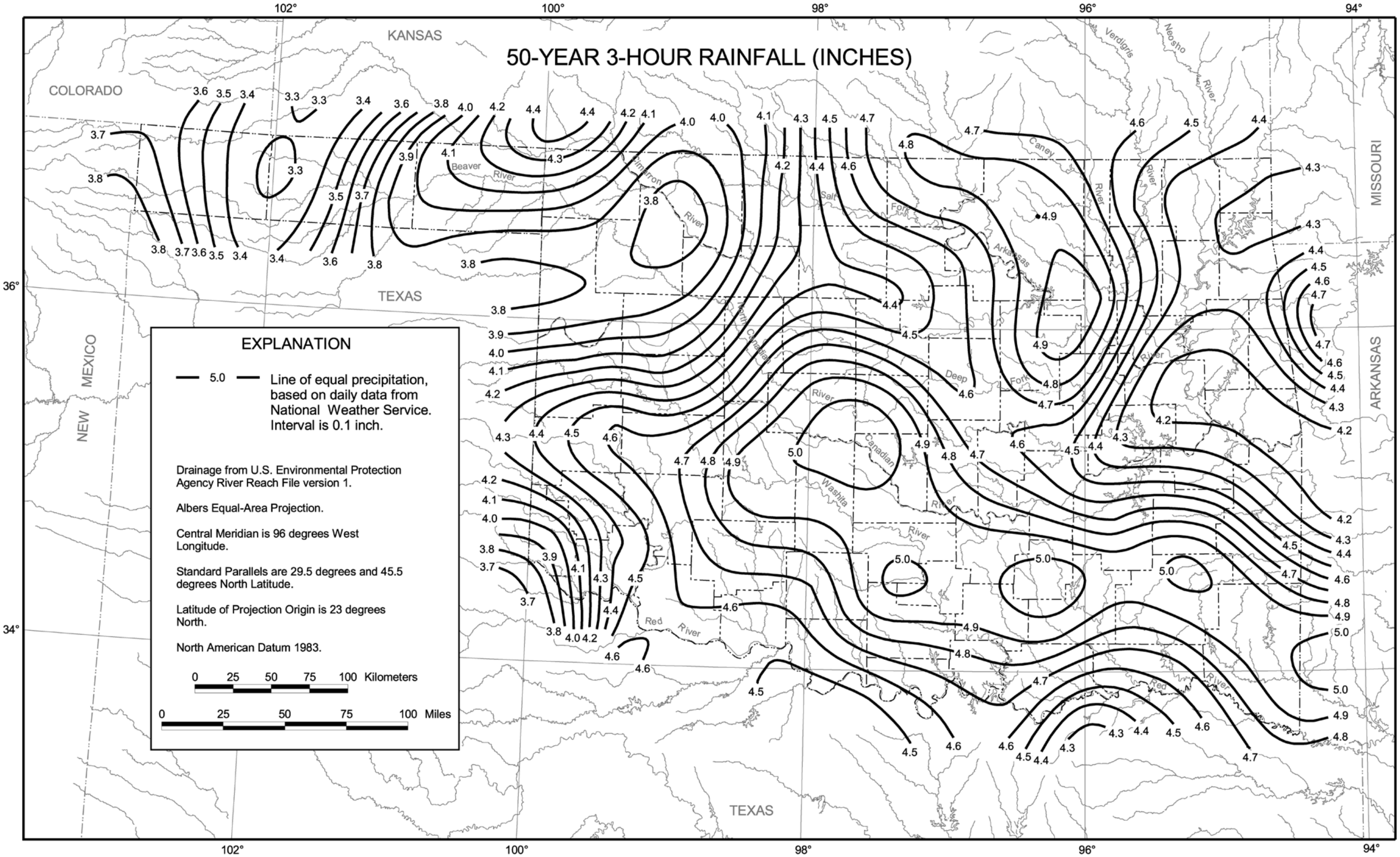


Figure 48. Depth of 50-year storm for 3-hour duration in Oklahoma.

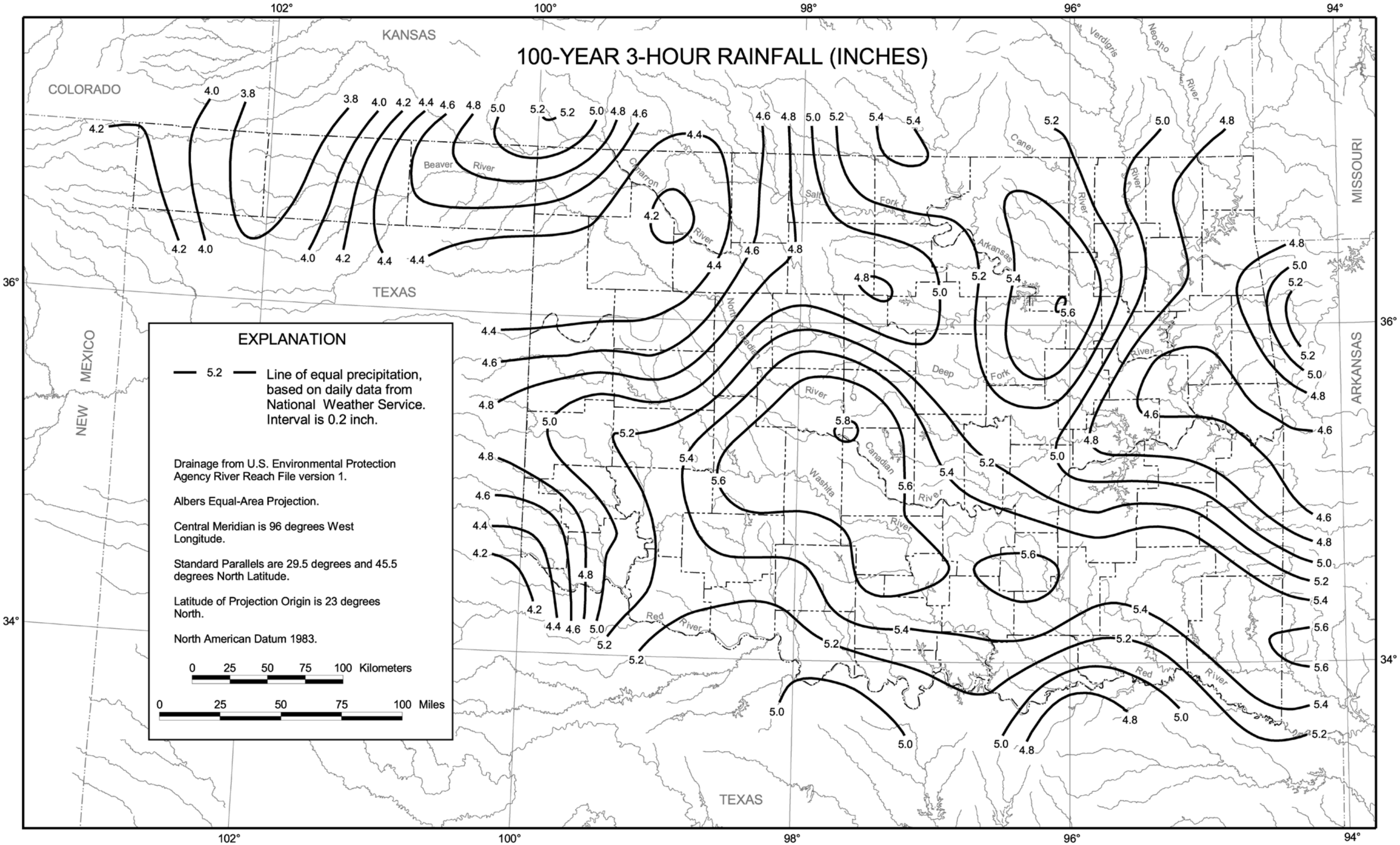


Figure 49. Depth of 100-year storm for 3-hour duration in Oklahoma.

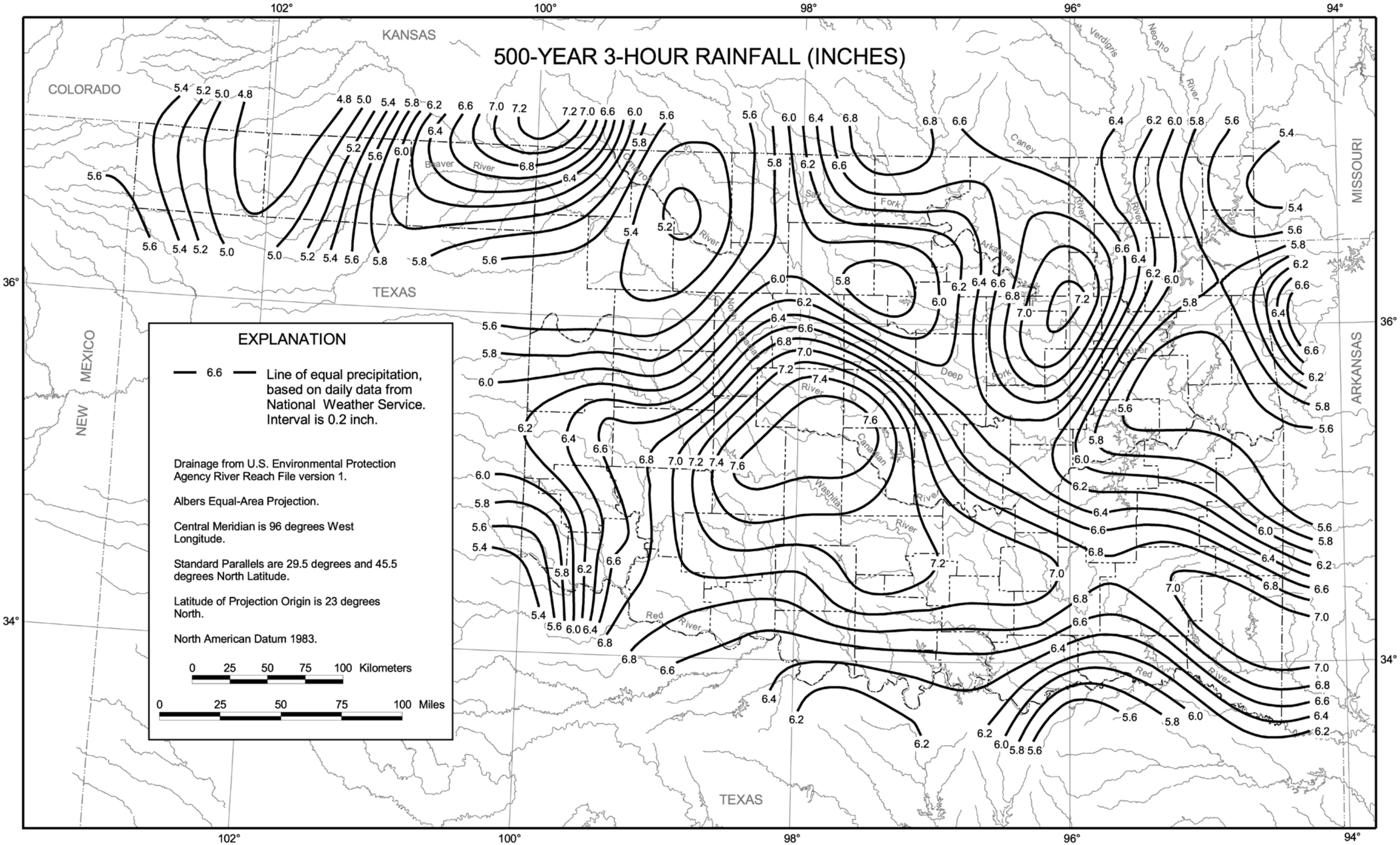


Figure 50. Depth of 500-year storm for 3-hour duration in Oklahoma.

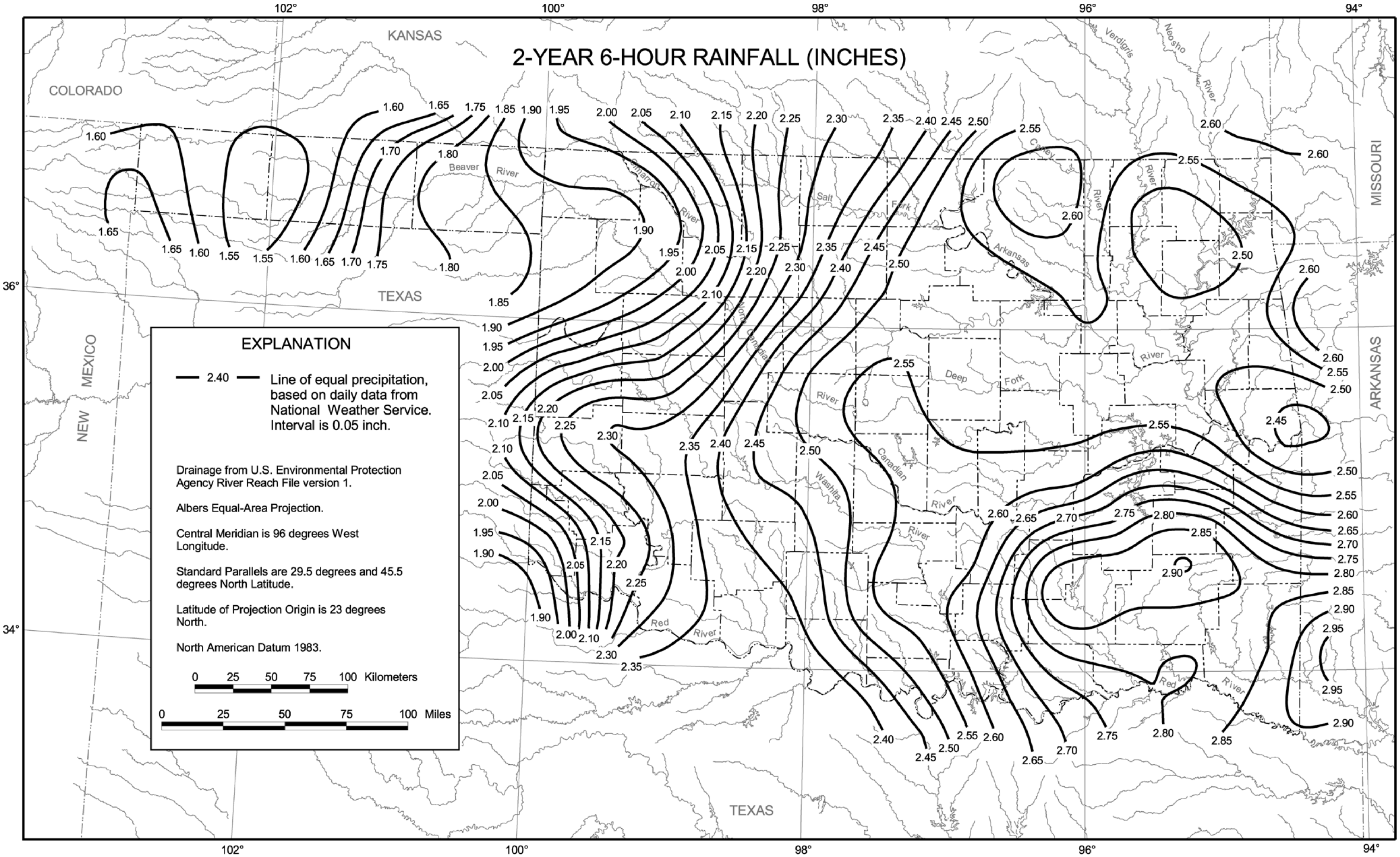


Figure 51. Depth of 2-year storm for 6-hour duration in Oklahoma.

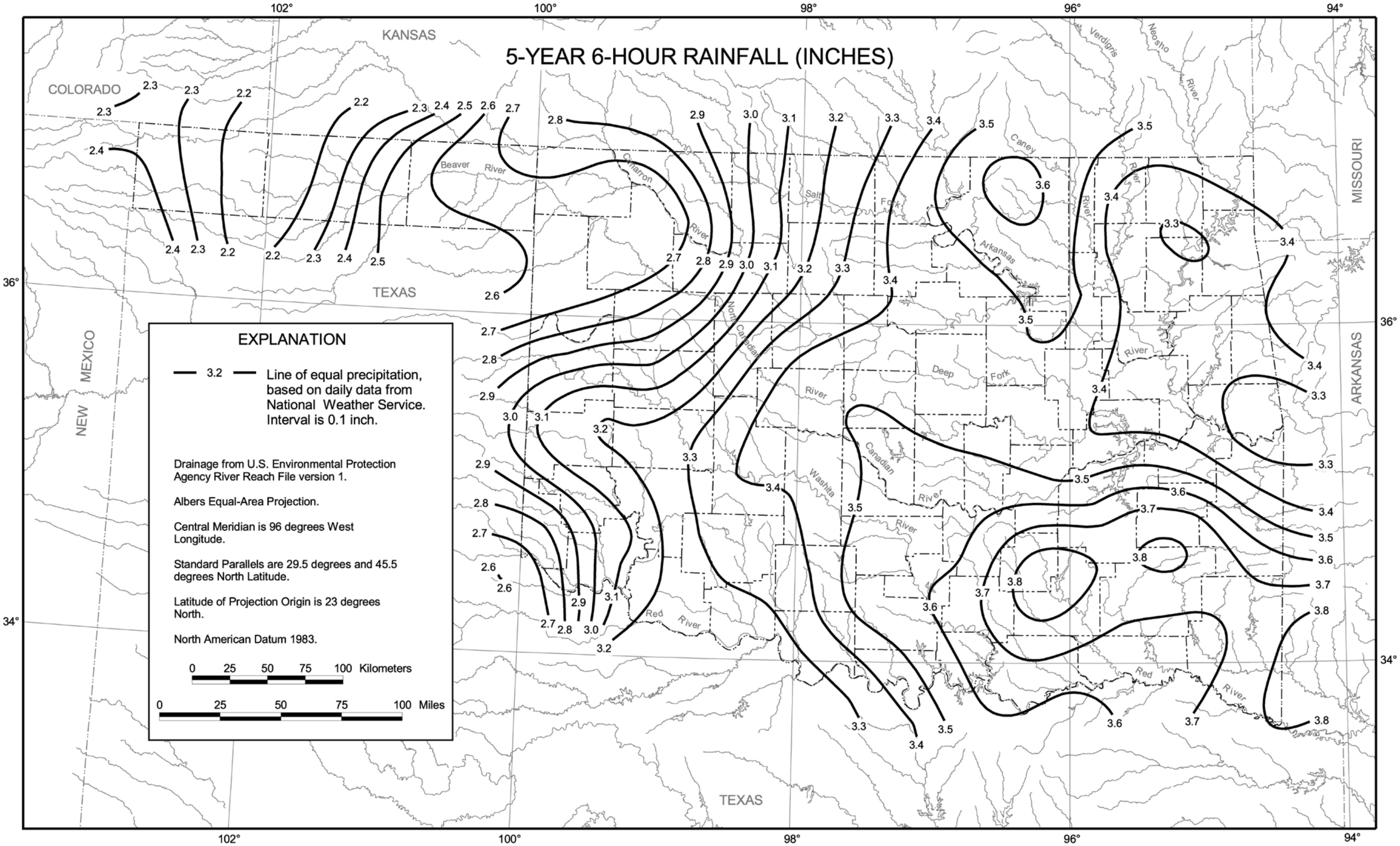
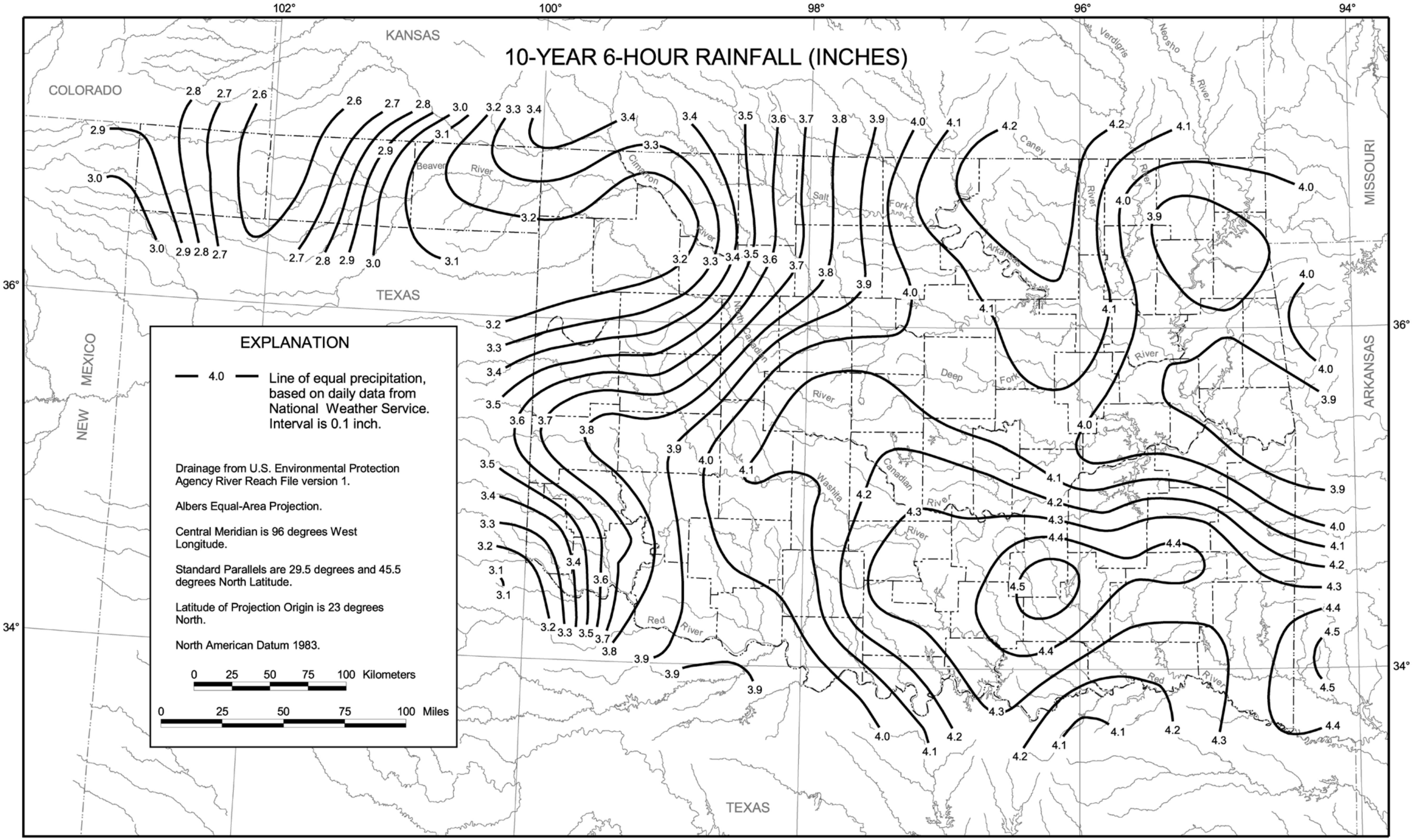


Figure 52. Depth of 5-year storm for 6-hour duration in Oklahoma.



10-YEAR 6-HOUR RAINFALL (INCHES)

EXPLANATION

— 4.0 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.1 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 53. Depth of 10-year storm for 6-hour duration in Oklahoma.

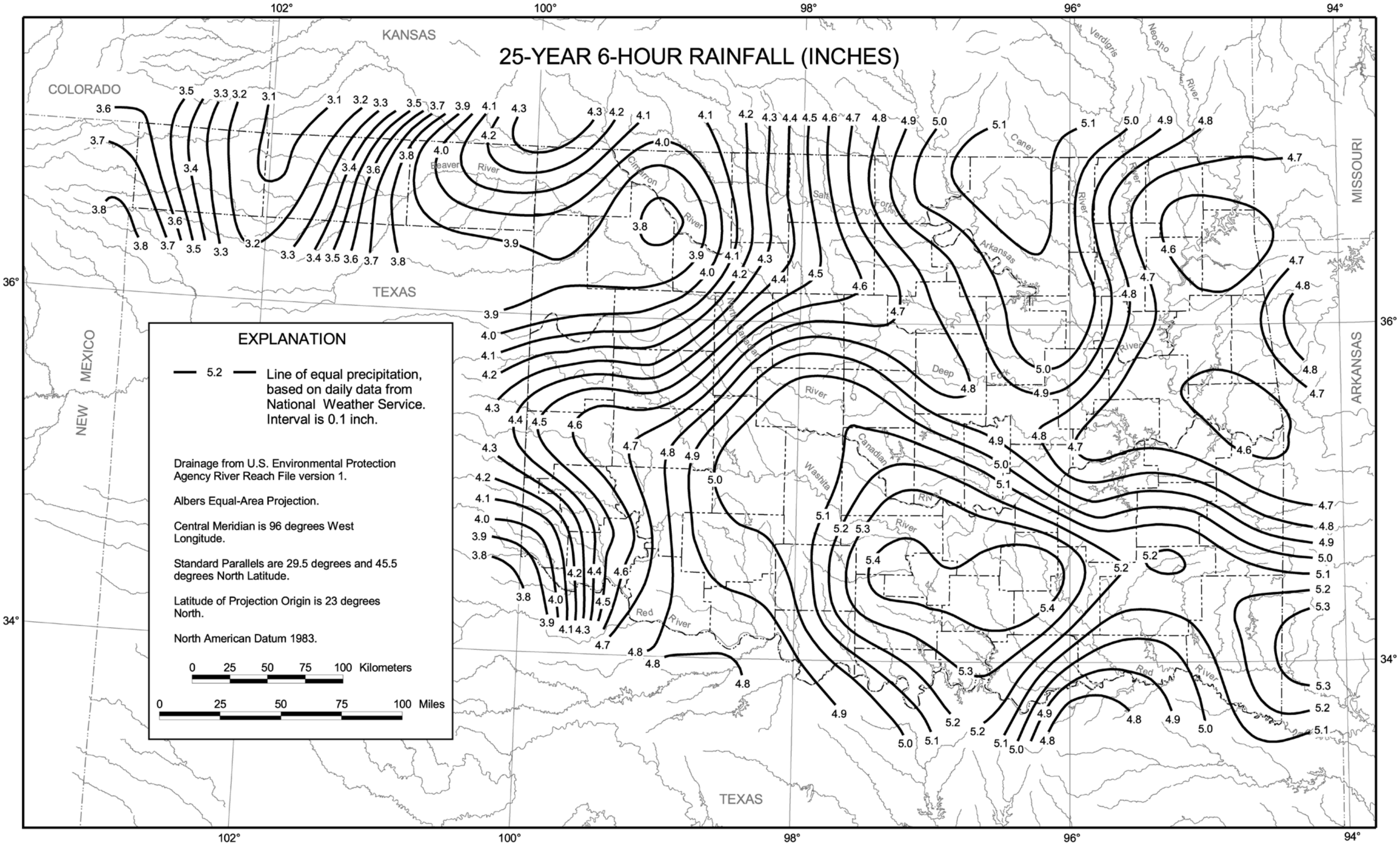


Figure 54. Depth of 25-year storm for 6-hour duration in Oklahoma.

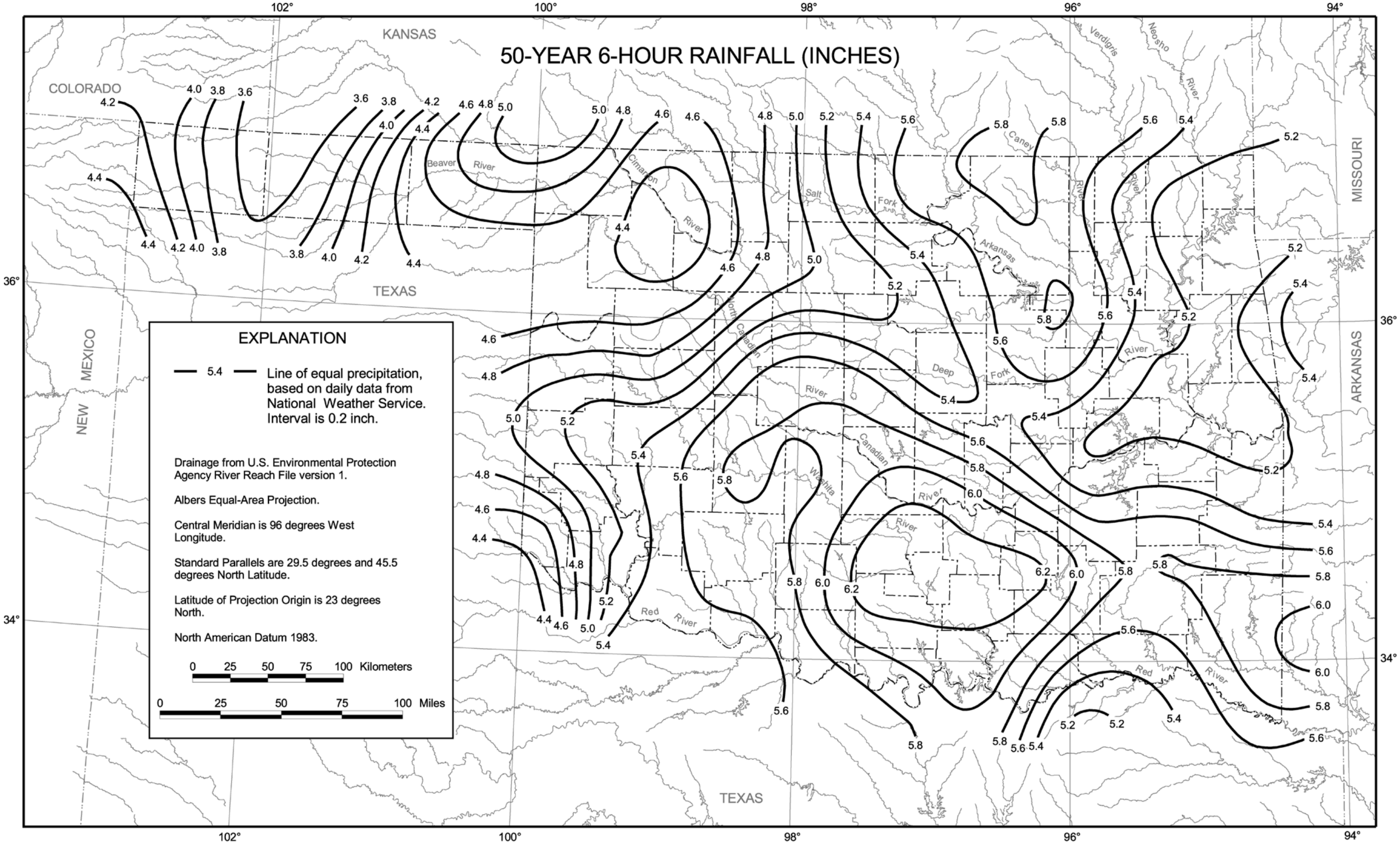
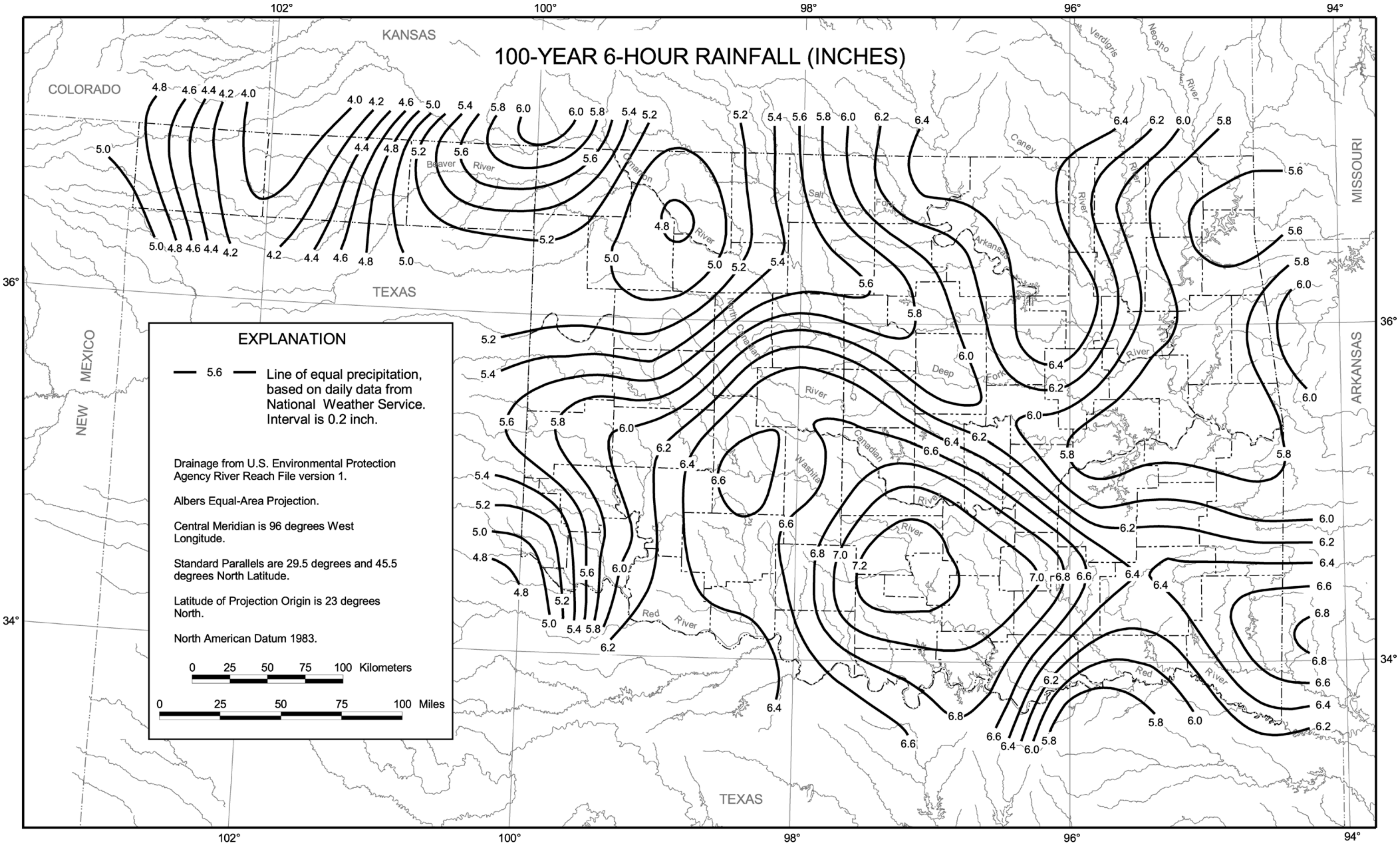


Figure 55. Depth of 50-year storm for 6-hour duration in Oklahoma.



EXPLANATION

— 5.6 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.2 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

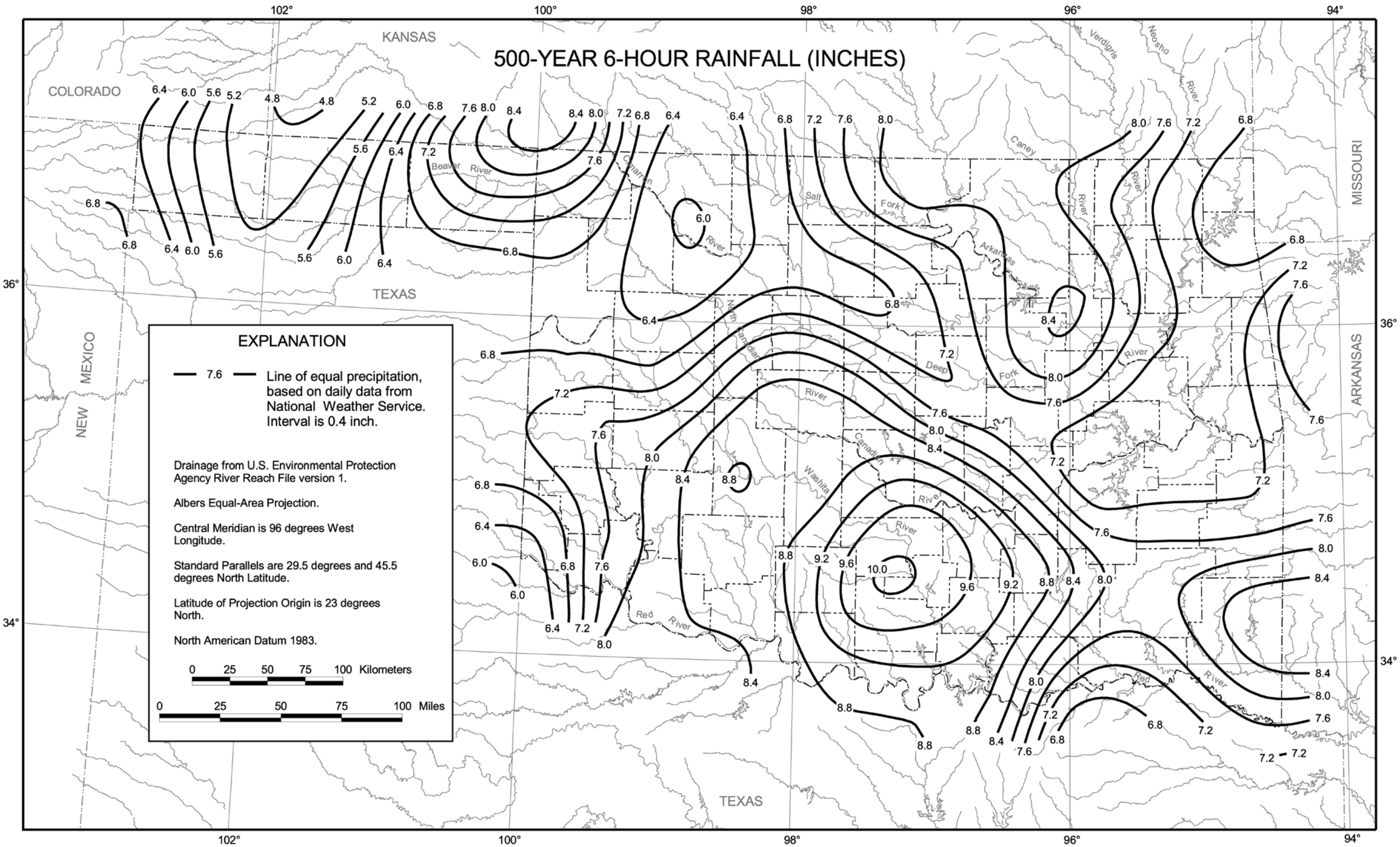
Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 56. Depth of 100-year storm for 6-hour duration in Oklahoma.



xx

Figure 57. Depth of 500-year storm for 6-hour duration in Oklahoma.

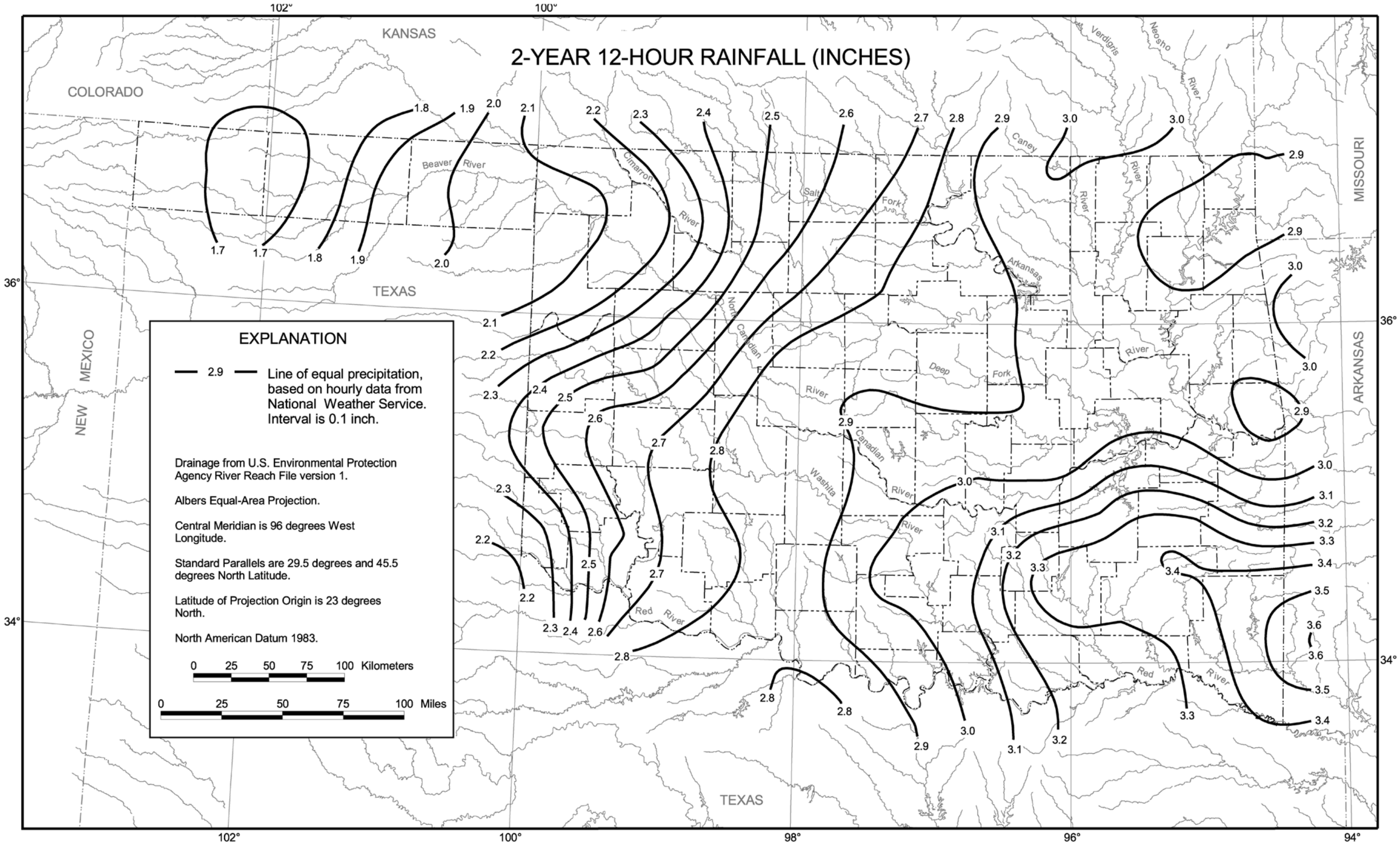


Figure 58. Depth of 2-year storm for 12-hour duration in Oklahoma.

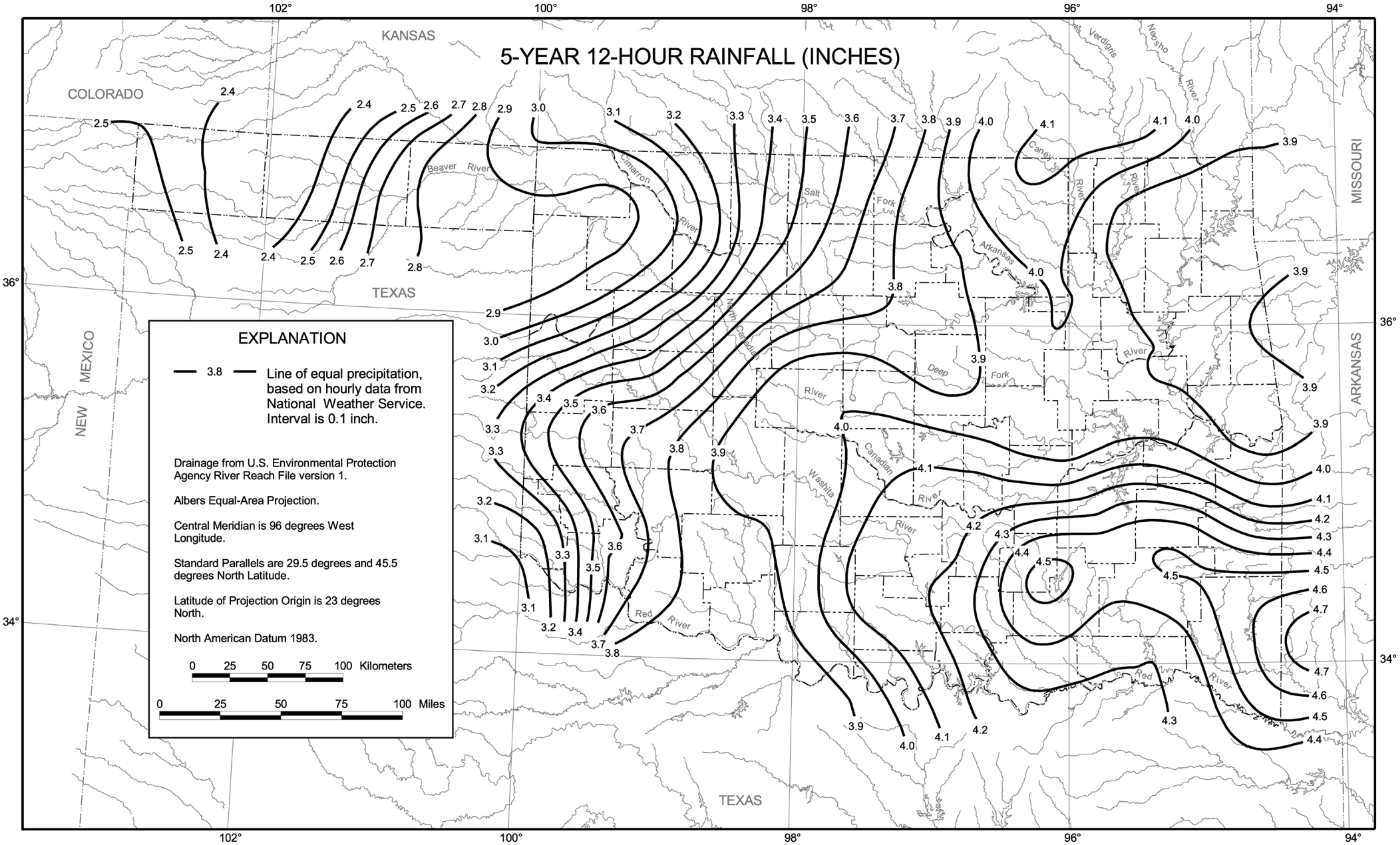


Figure 59. Depth of 5-year storm for 12-hour duration in Oklahoma.

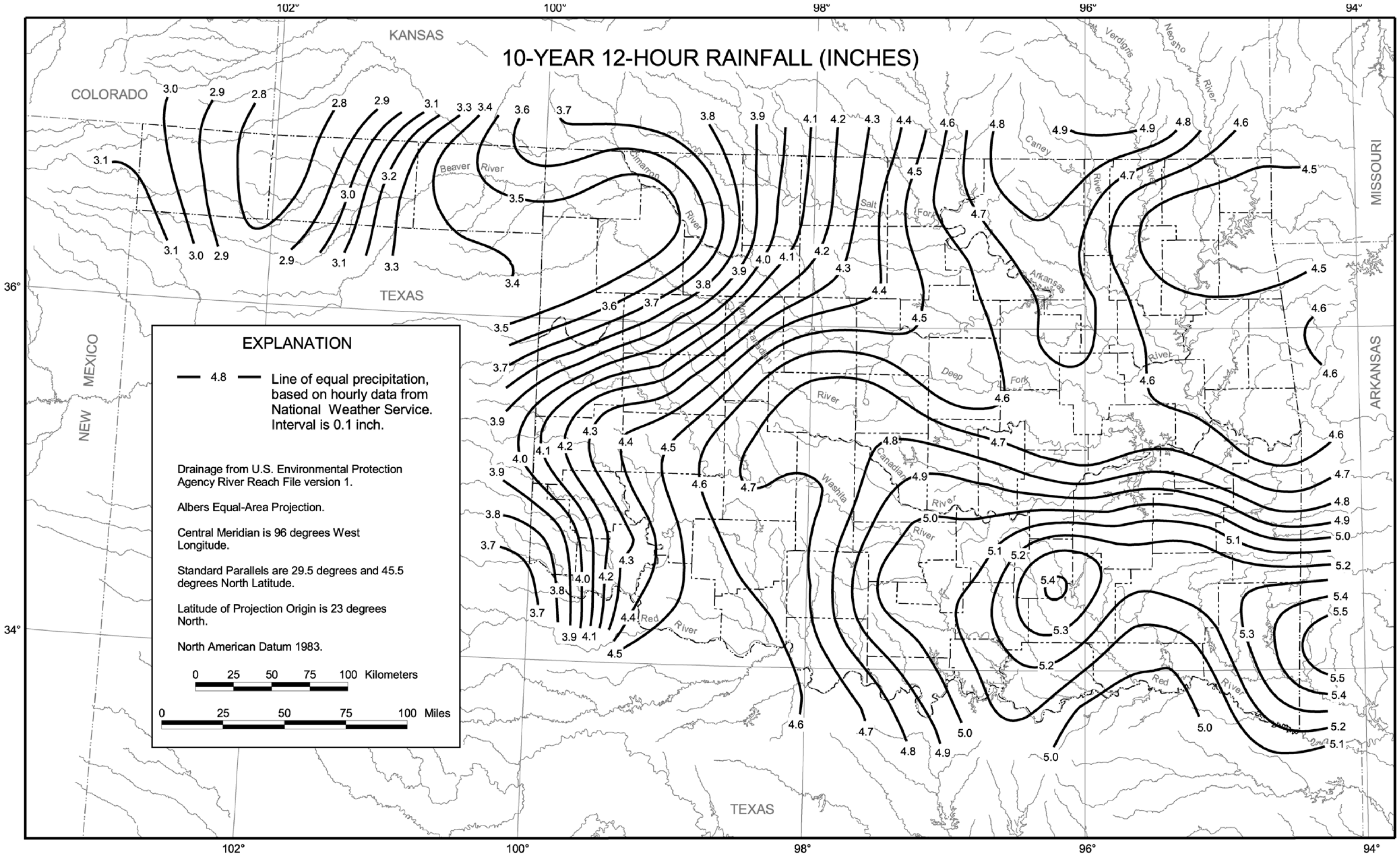


Figure 60. Depth of 10-year storm for 12-hour duration in Oklahoma.

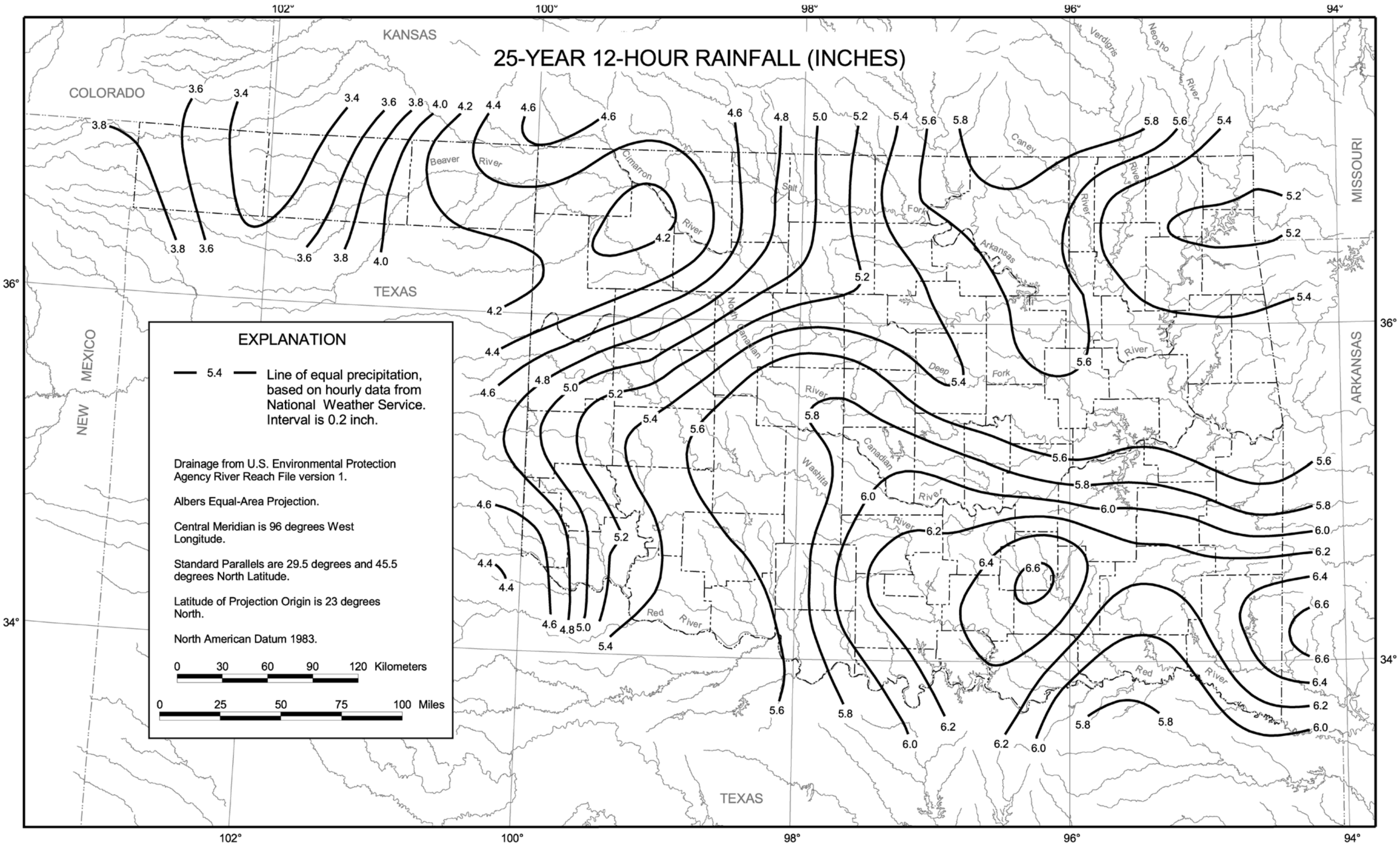
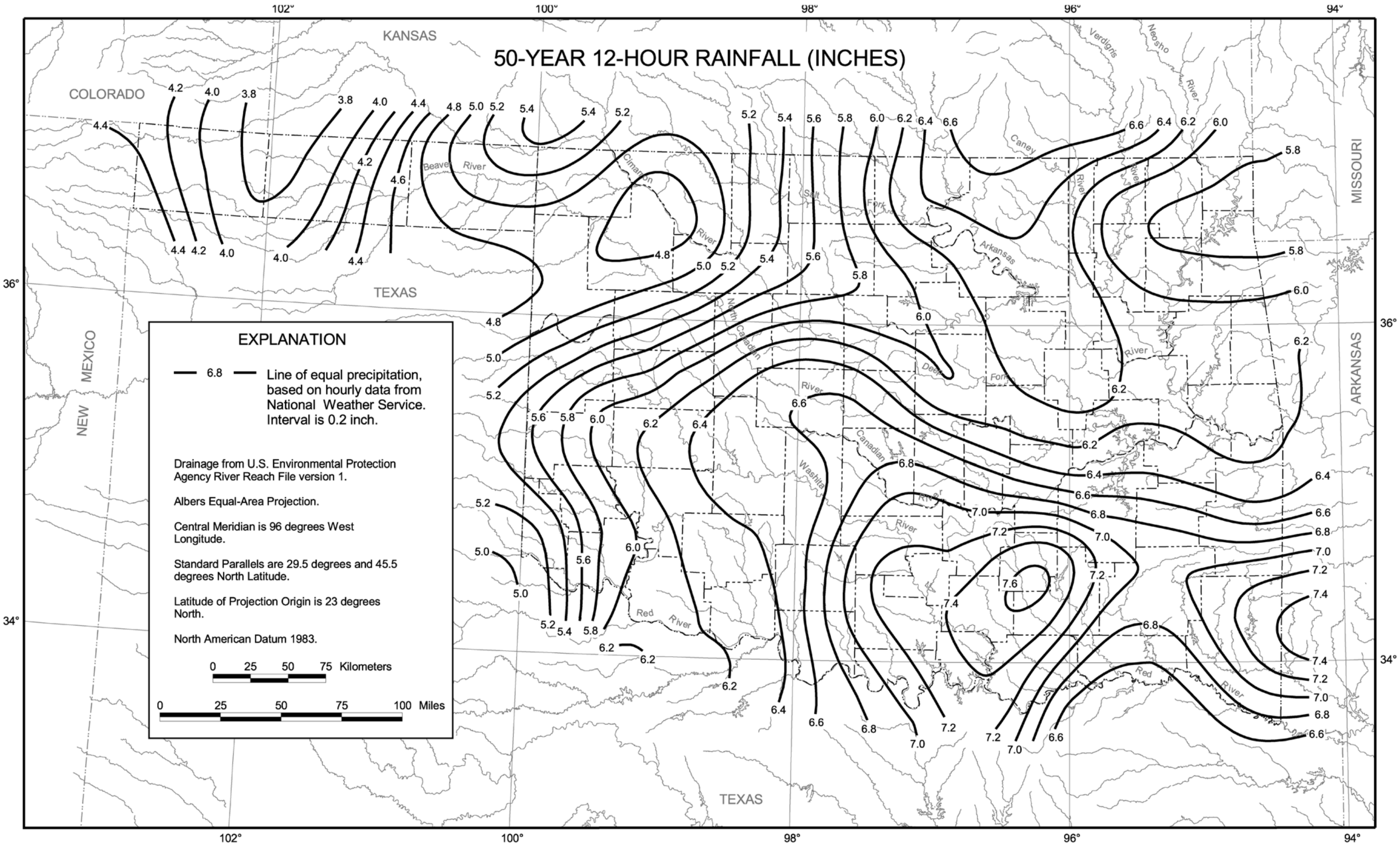


Figure 61. Depth of 25-year storm for 12-hour duration in Oklahoma.


50-YEAR 12-HOUR RAINFALL (INCHES)

EXPLANATION

6.8 Line of equal precipitation, based on hourly data from National Weather Service. Interval is 0.2 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 62. Depth of 50-year storm for 12-hour duration in Oklahoma.

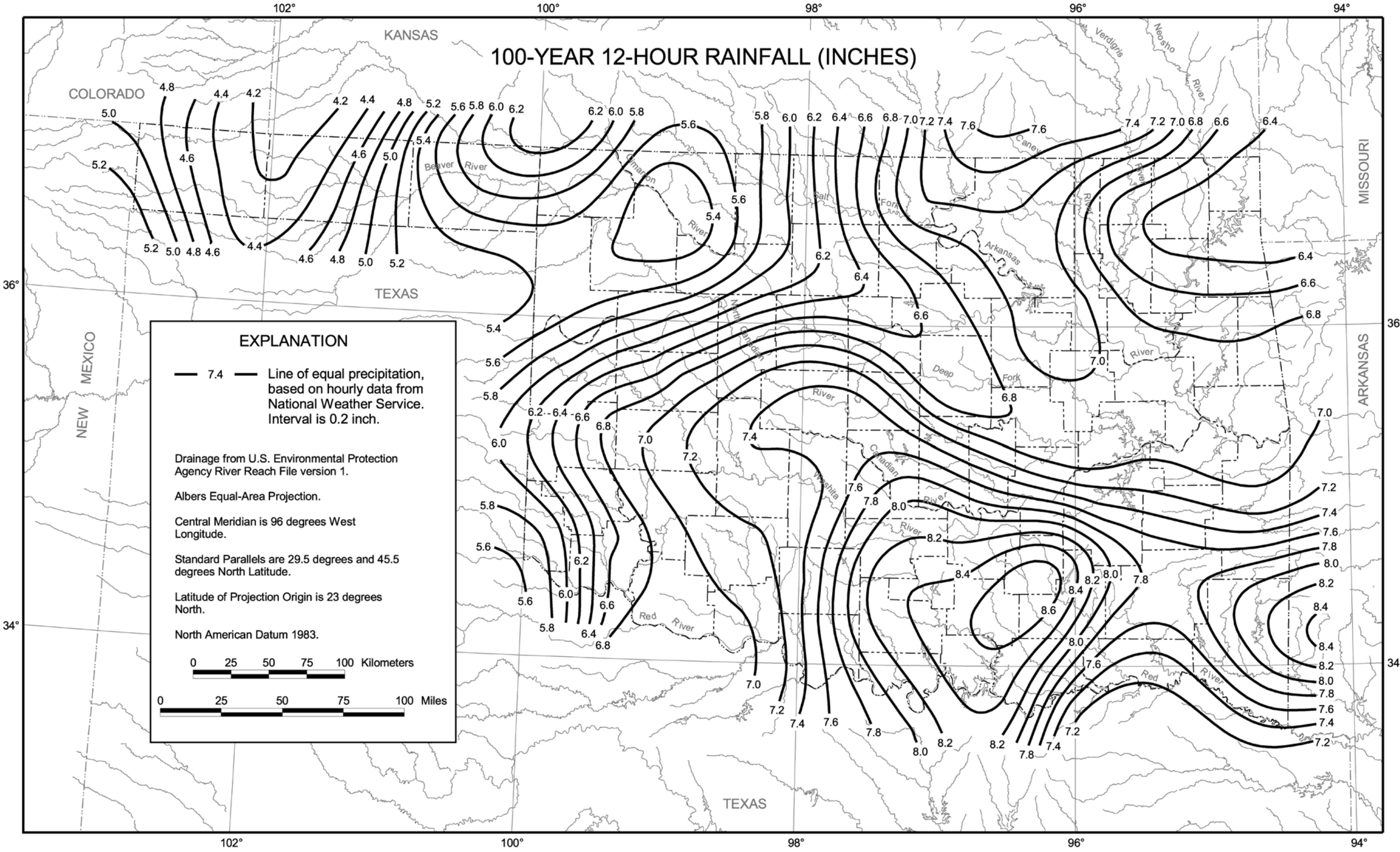


Figure 63. Depth of 100-year storm for 12-hour duration in Oklahoma.

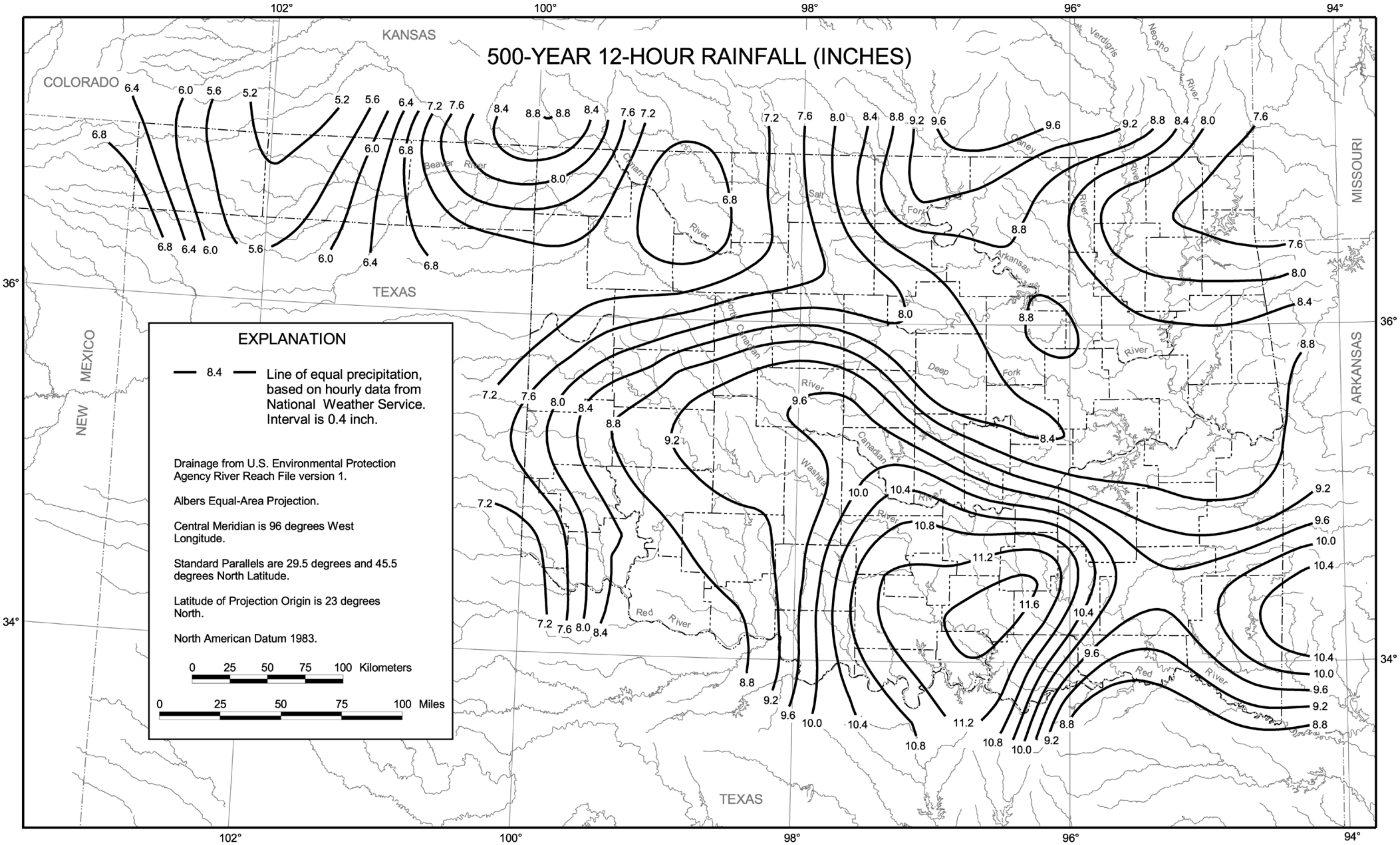


Figure 64. Depth of 500-year storm for 12-hour duration in Oklahoma.

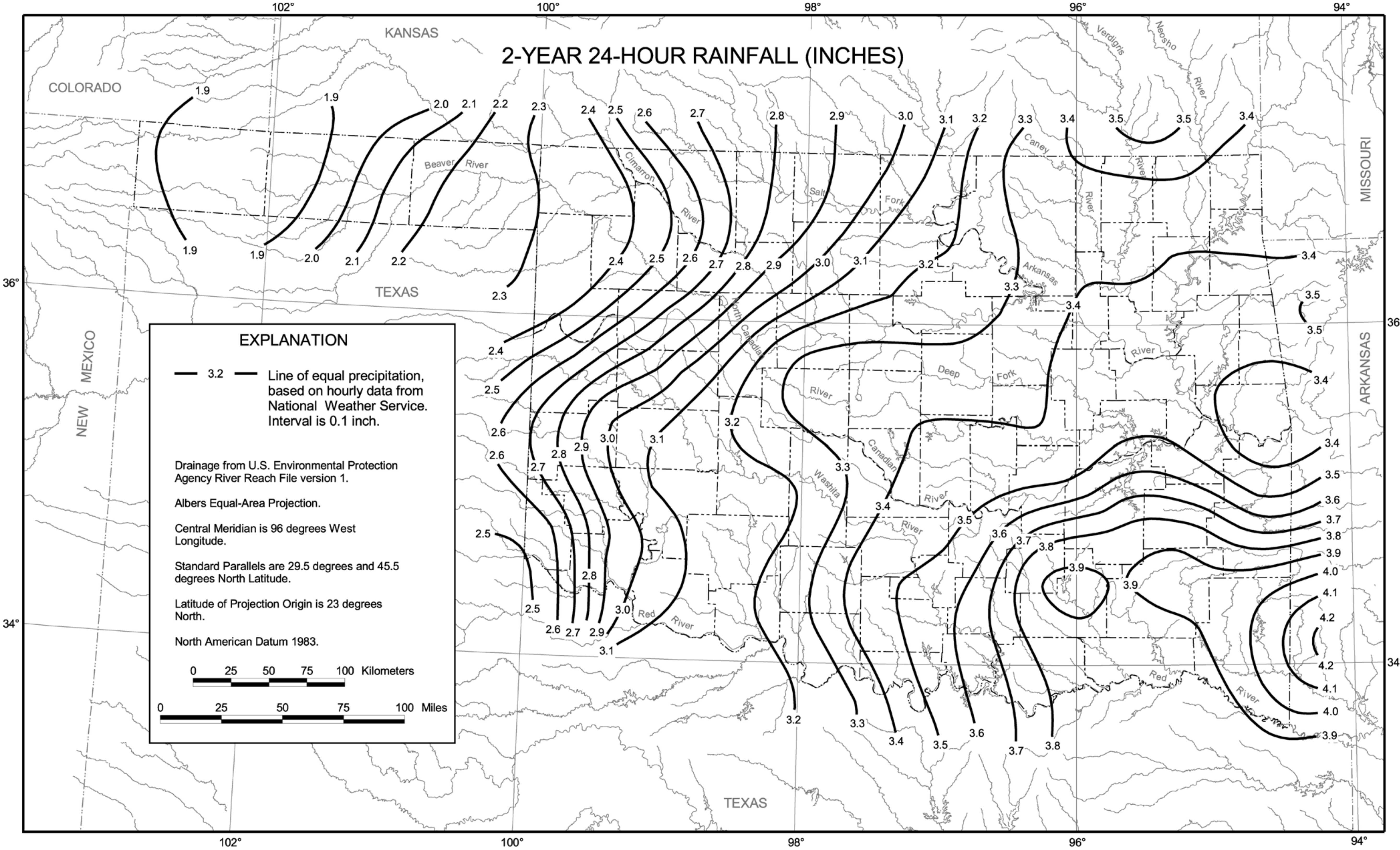


Figure 65. Depth of 2-year storm for 24-hour duration in Oklahoma.

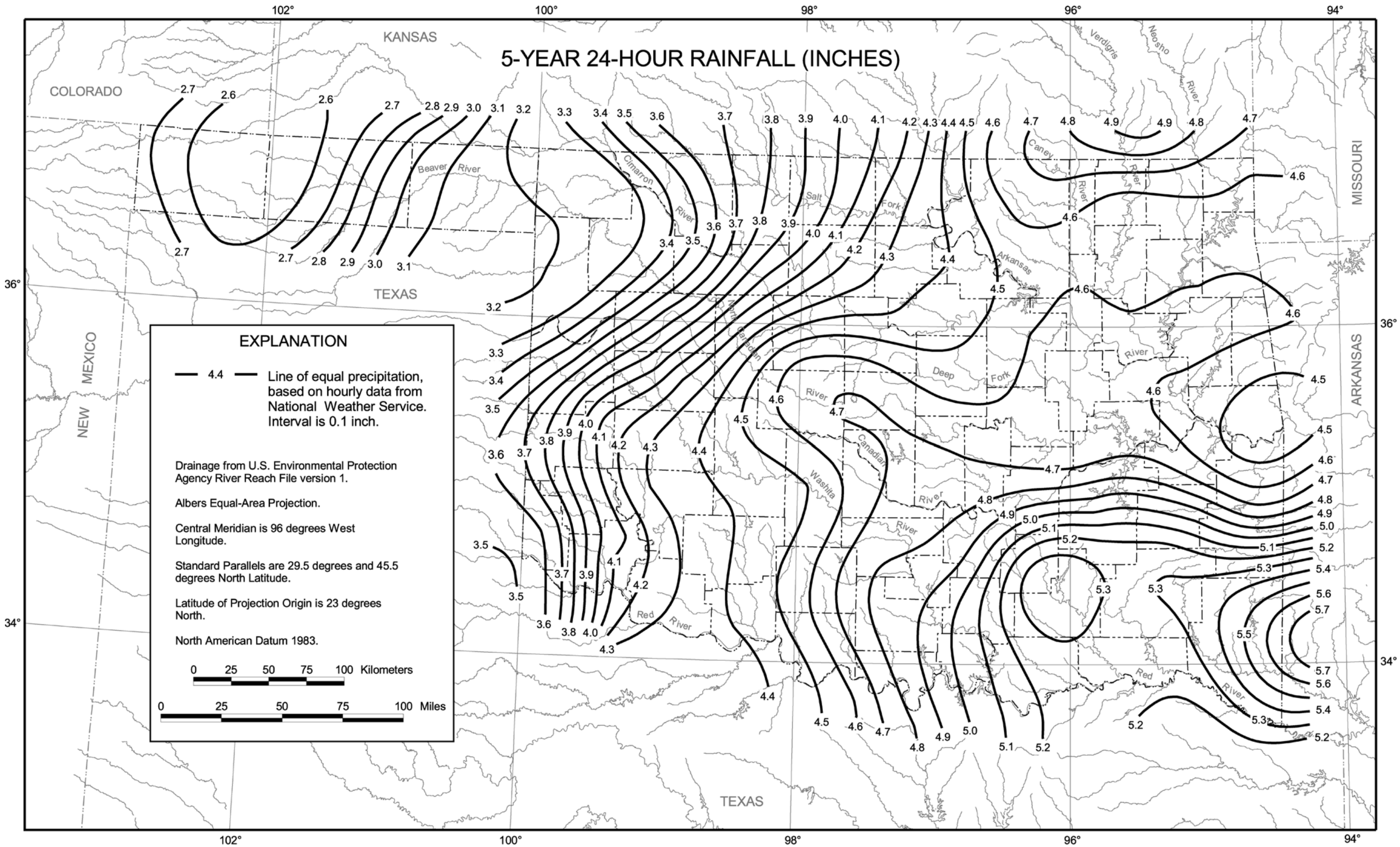


Figure 66. Depth of 5-year storm for 24-hour duration in Oklahoma.

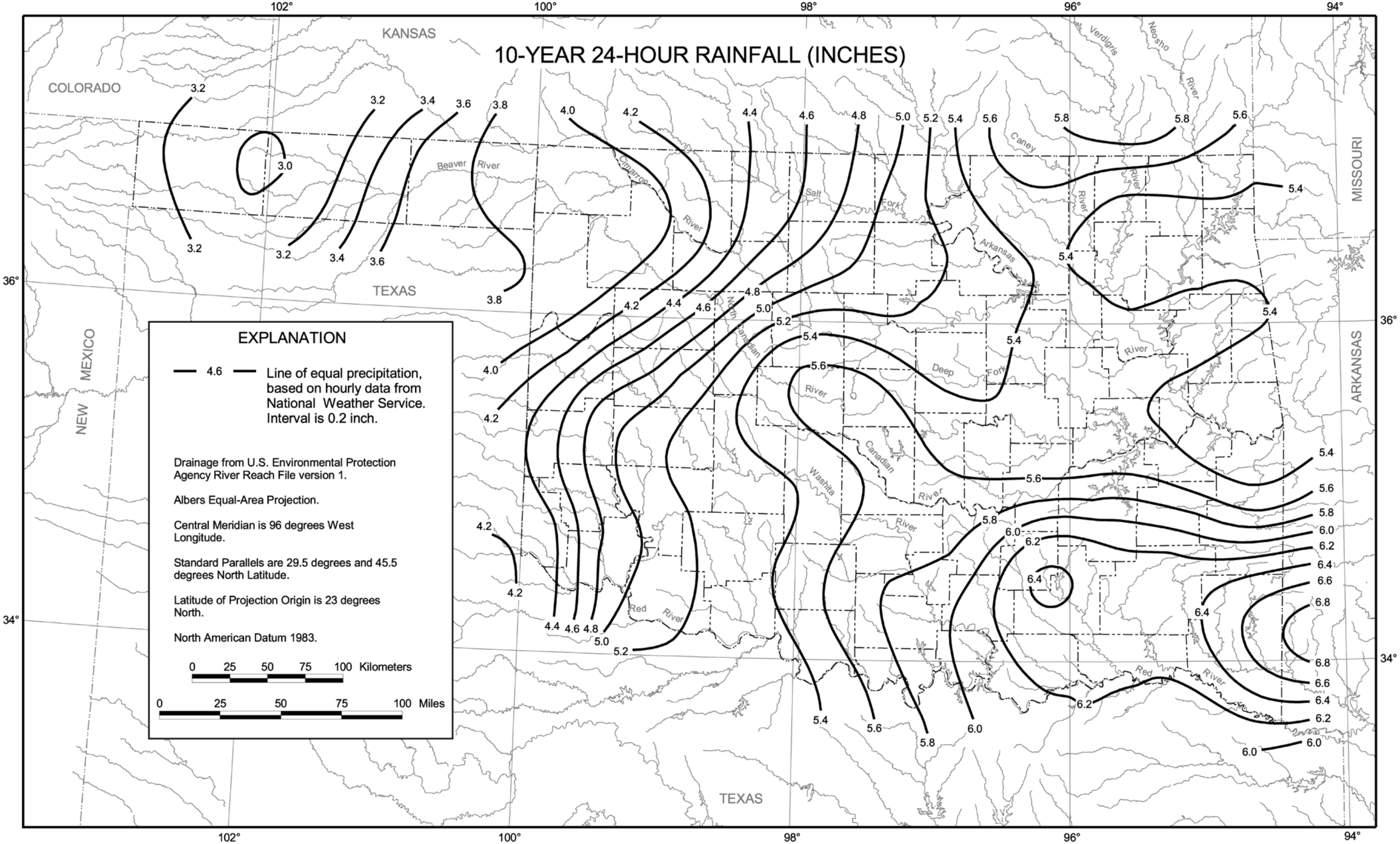


Figure 67. Depth of 10-year storm for 24-hour duration in Oklahoma.

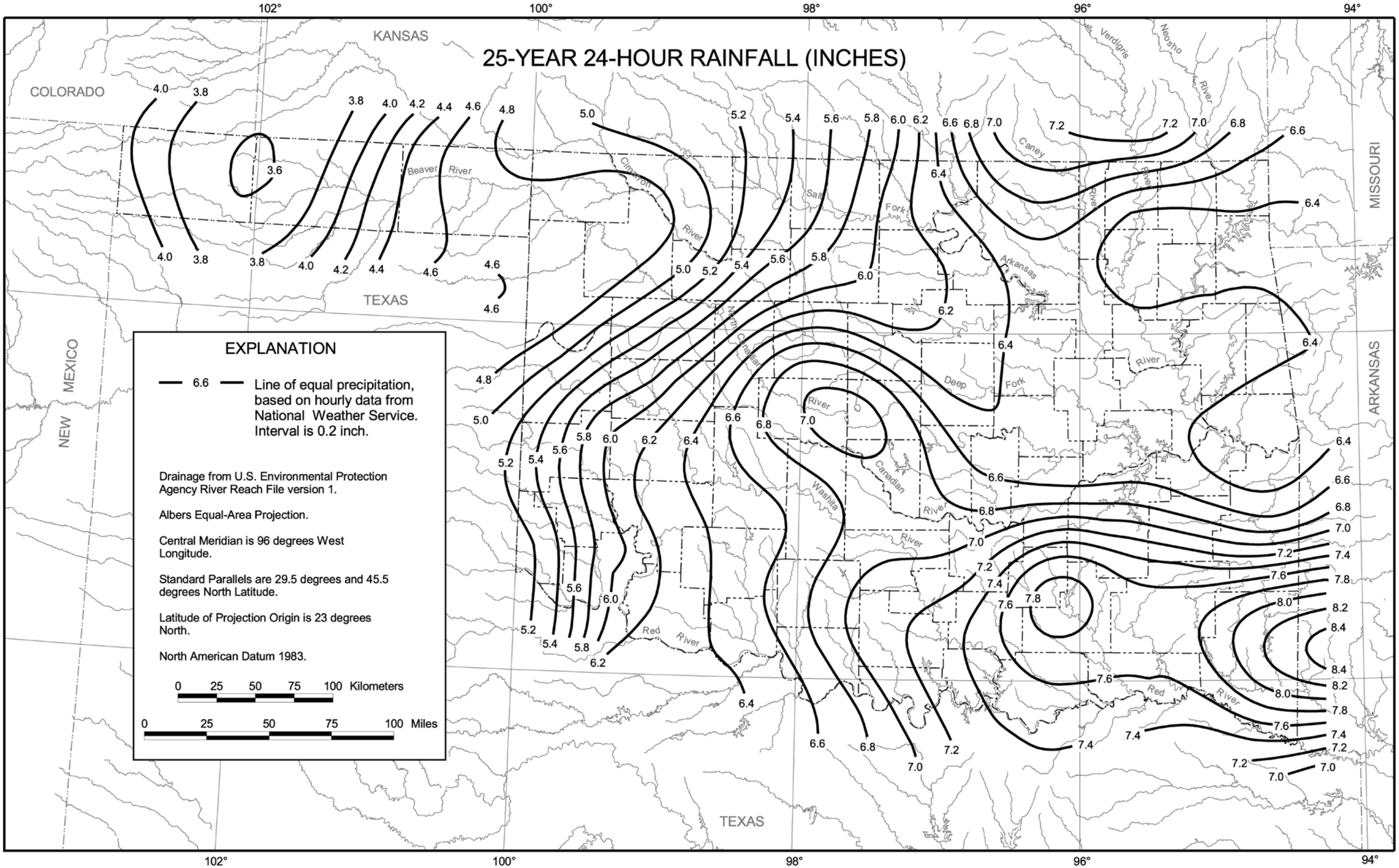


Figure 68. Depth of 25-year storm for 24-hour duration in Oklahoma.

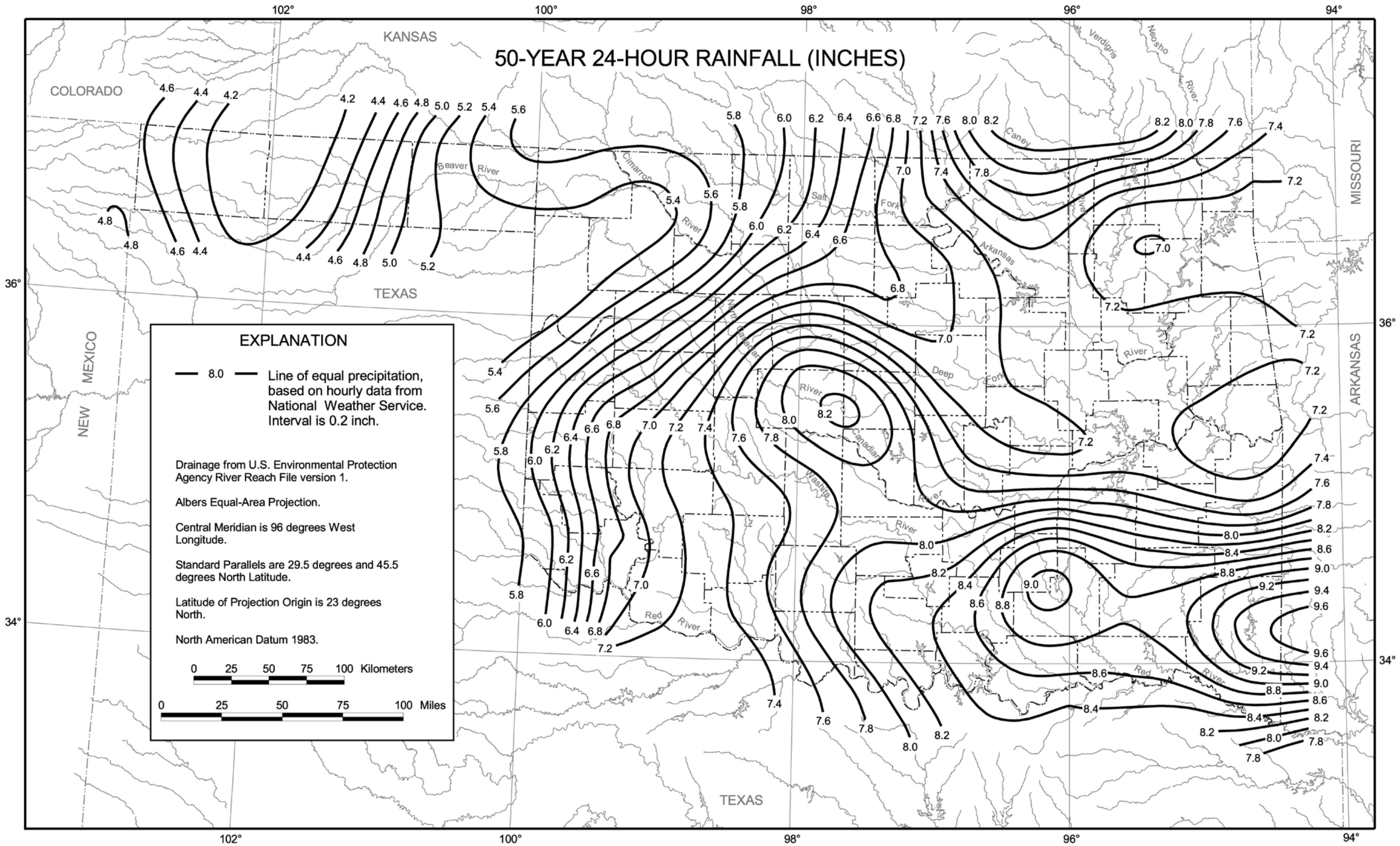


Figure 69. Depth of 50-year storm for 24-hour duration in Oklahoma.

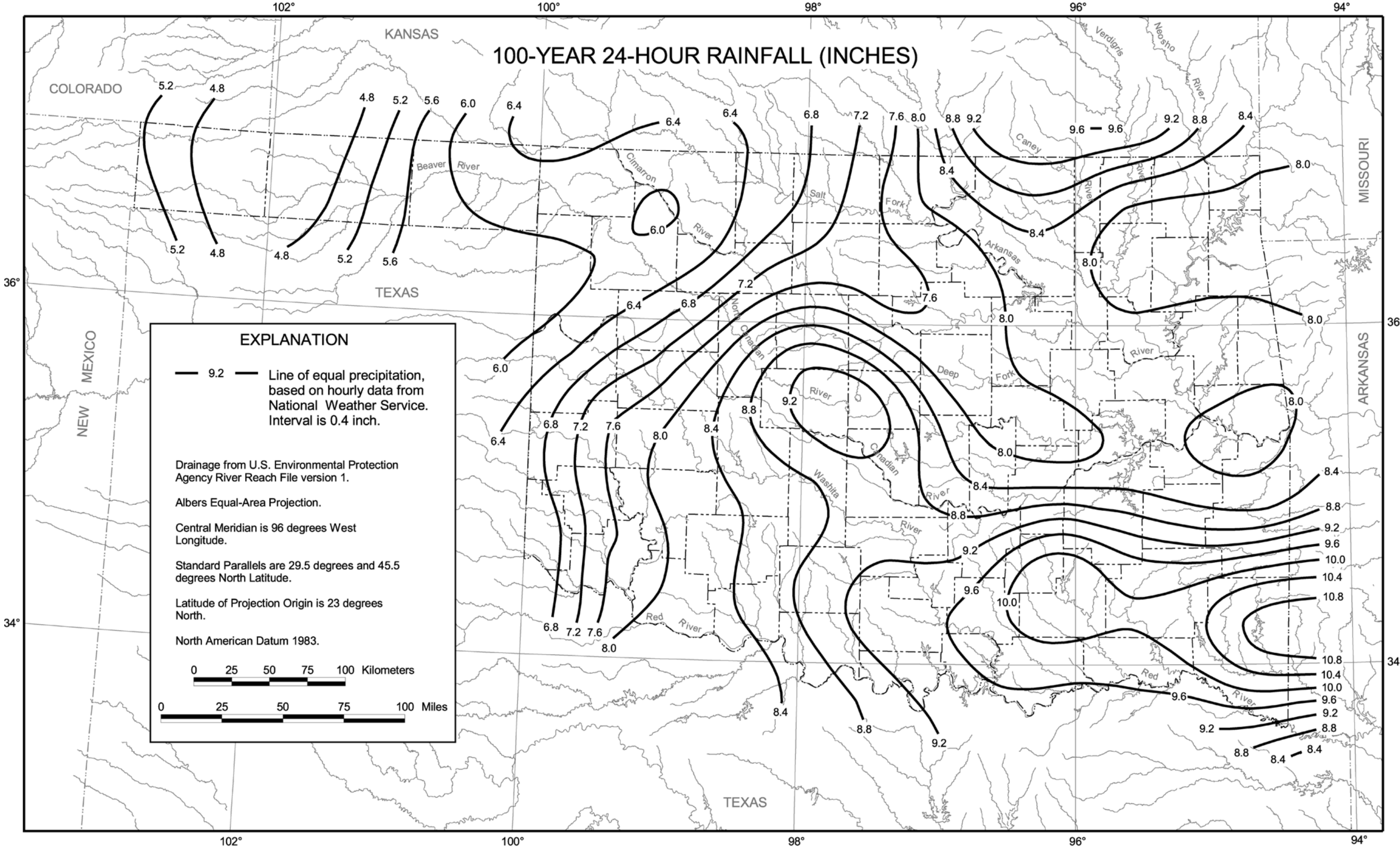
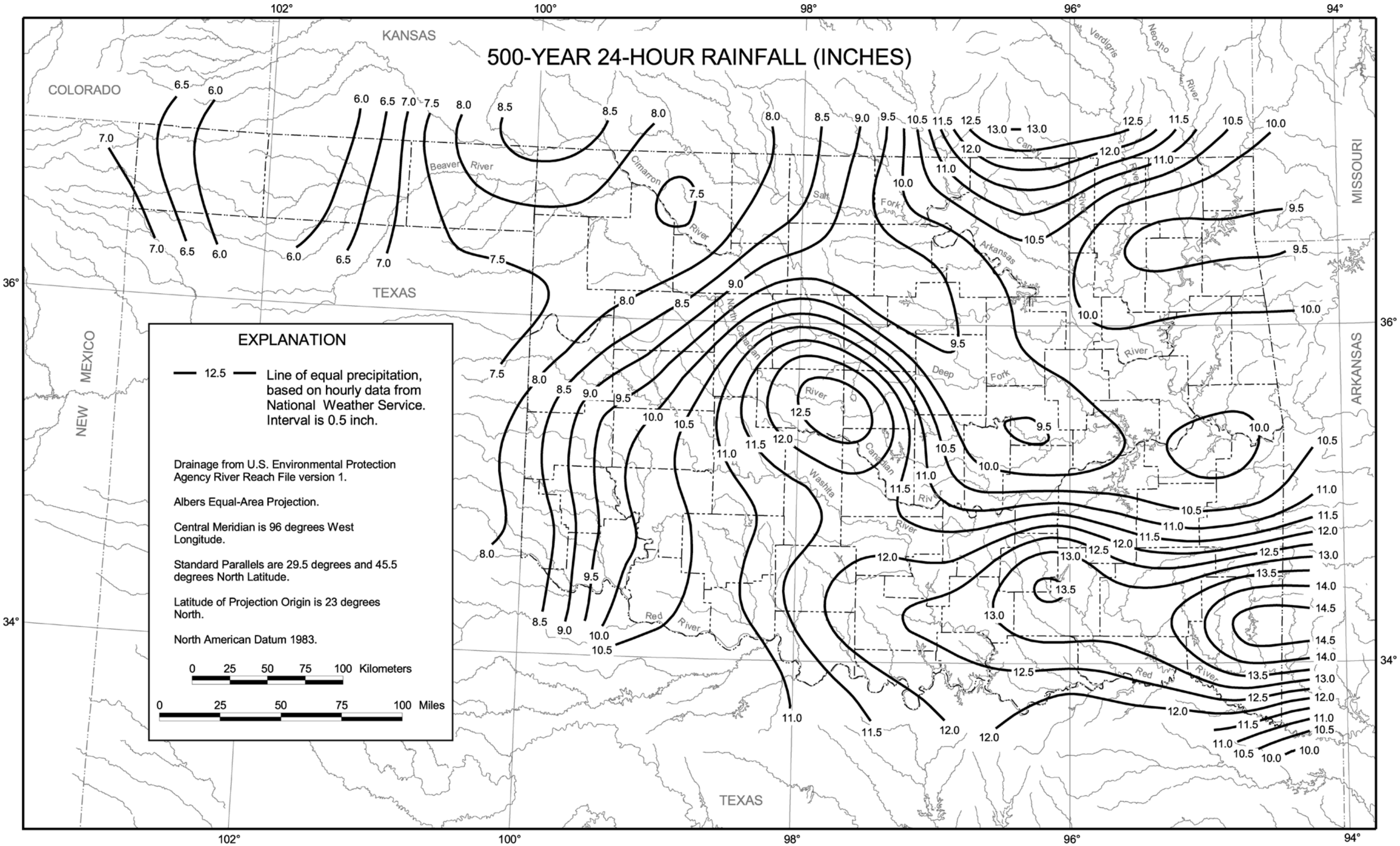


Figure 70. Depth of 100-year storm for 24-hour duration in Oklahoma.



Line of equal precipitation, based on hourly data from National Weather Service. Interval is 0.5 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 71. Depth of 500-year storm for 24-hour duration in Oklahoma.

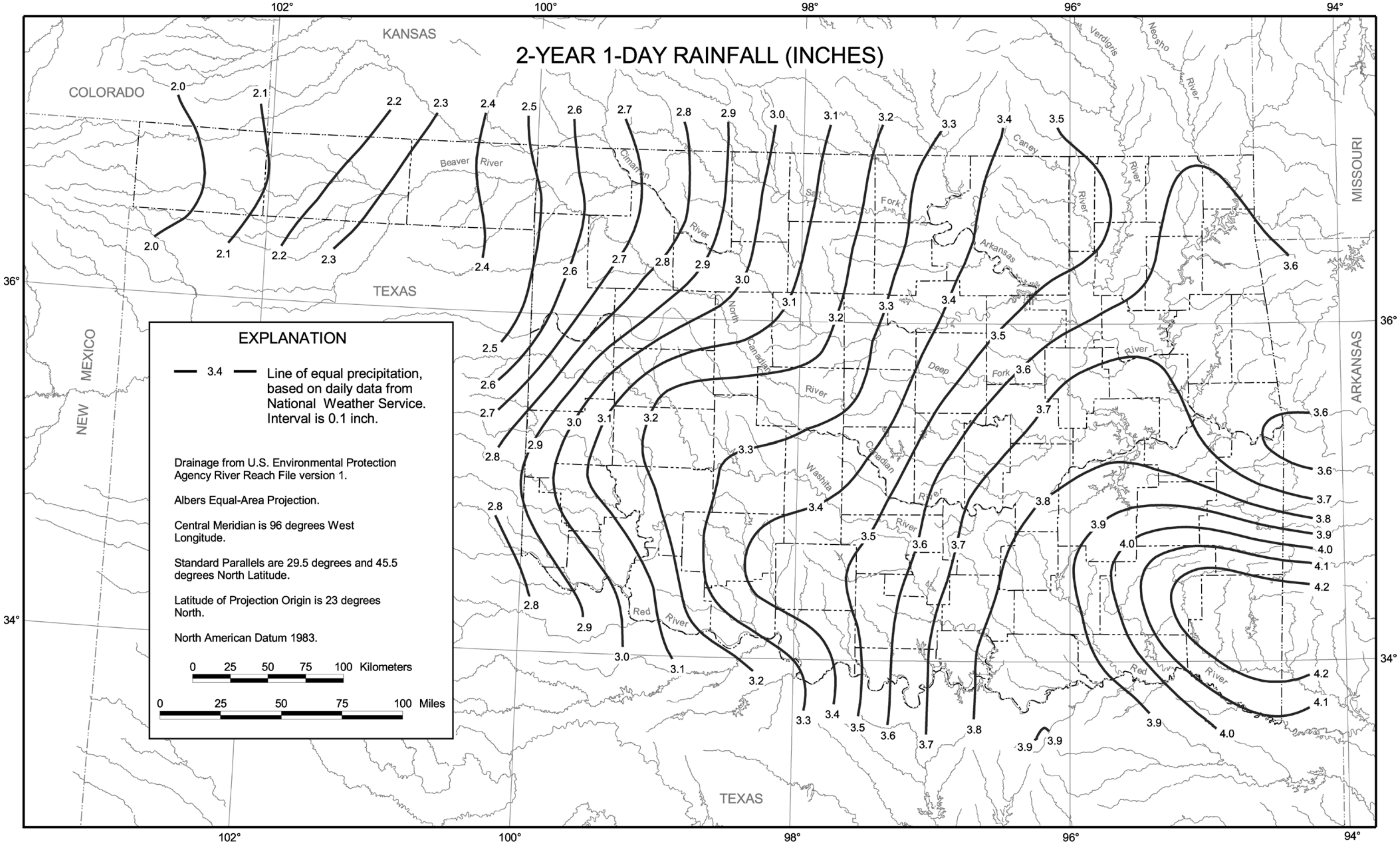


Figure 72. Depth of 2-year storm for 1-day duration in Oklahoma.

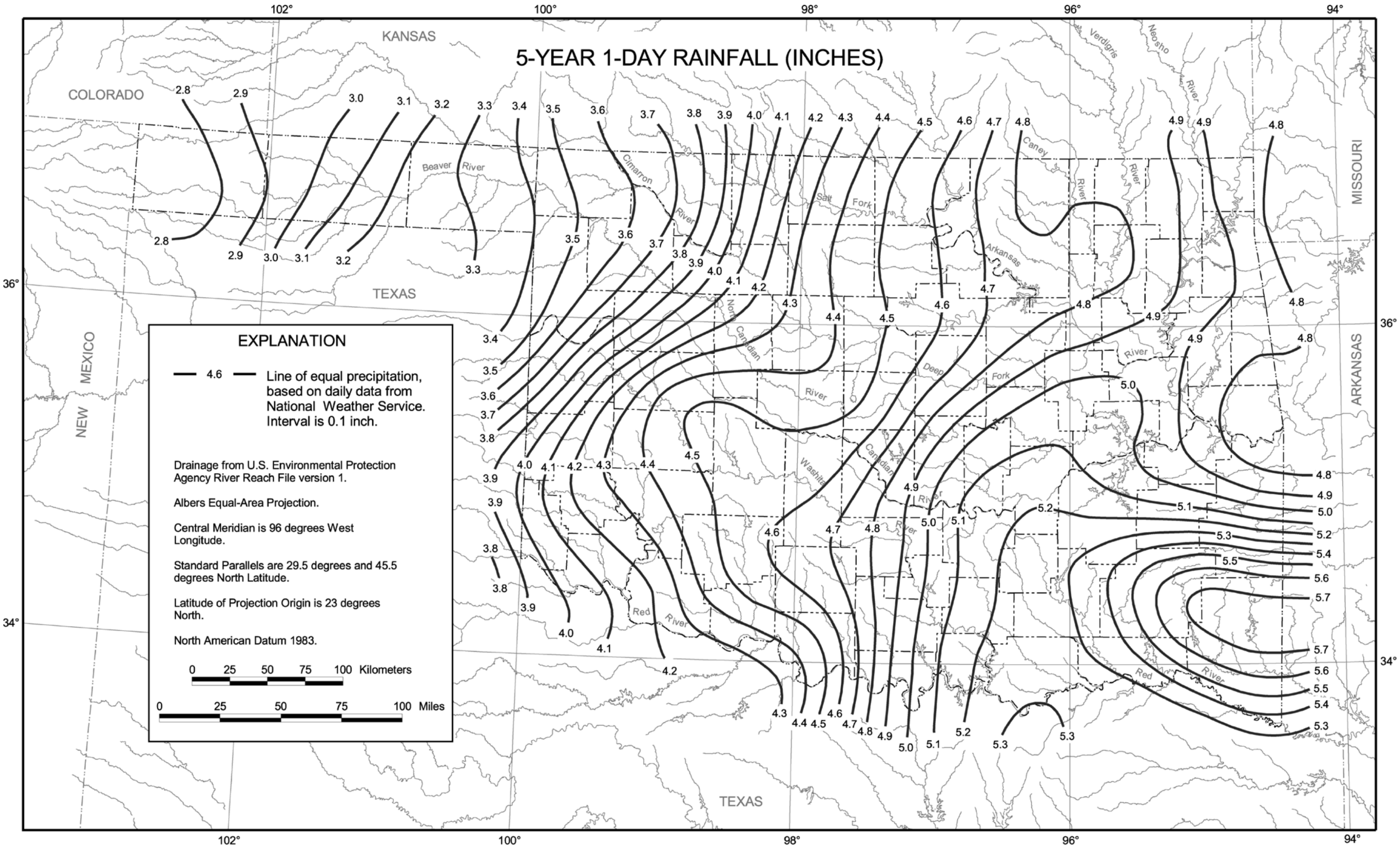
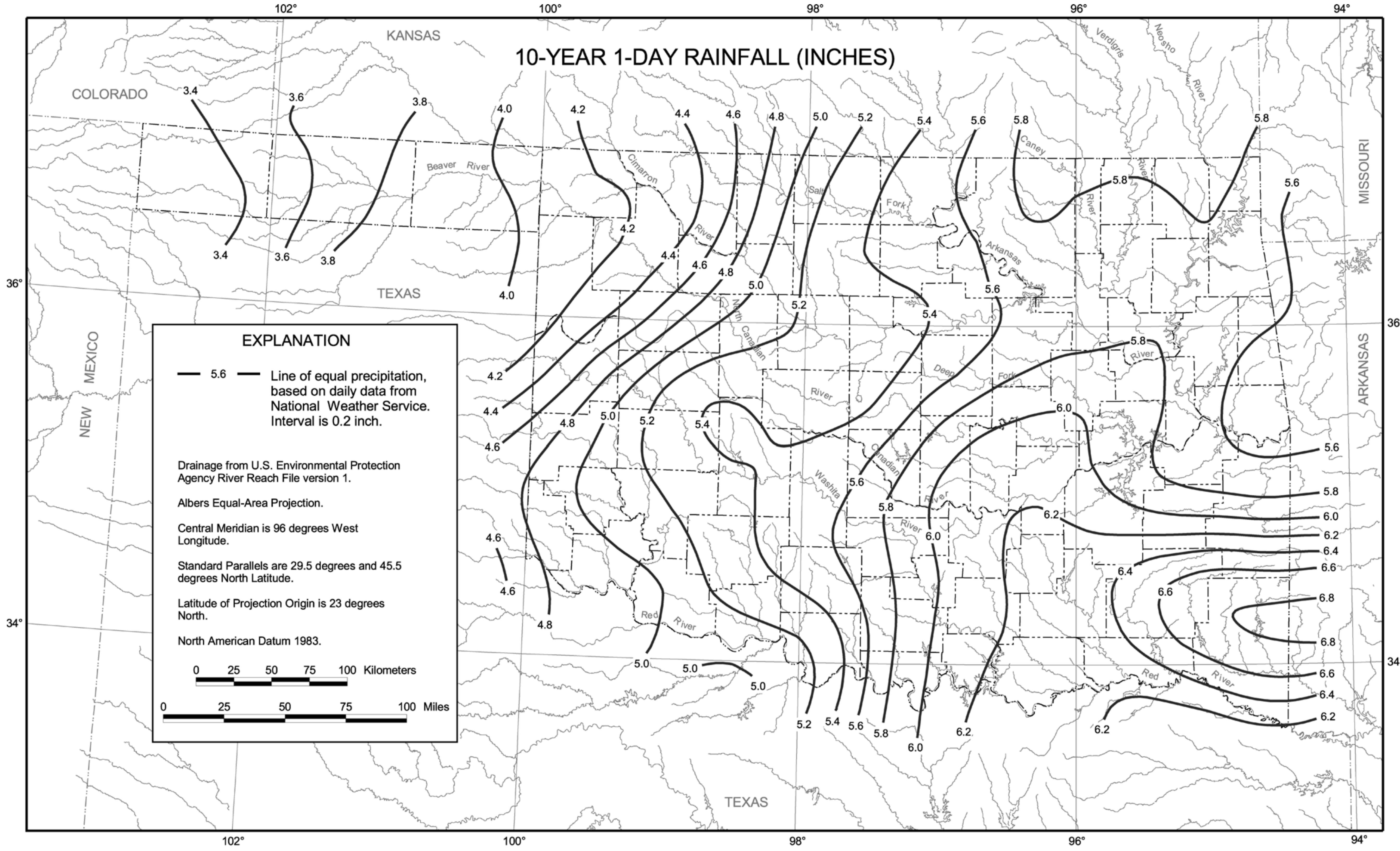


Figure 73. Depth of 5-year storm for 1-day duration in Oklahoma.



EXPLANATION

5.6 Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.2 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

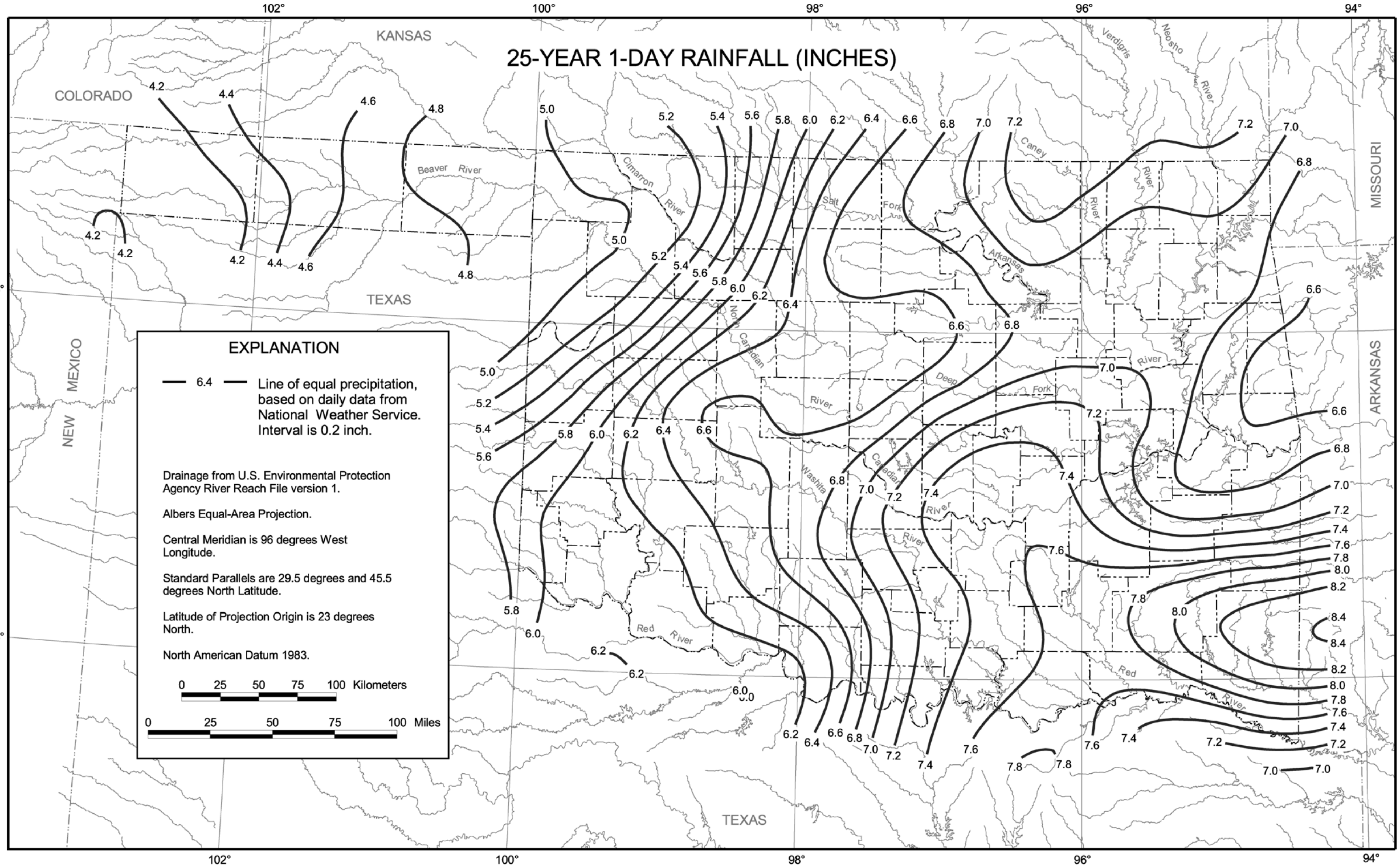
Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 74. Depth of 10-year storm for 1-day duration in Oklahoma.



25-YEAR 1-DAY RAINFALL (INCHES)

EXPLANATION

— 6.4 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.2 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 75. Depth of 25-year storm for 1-day duration in Oklahoma.

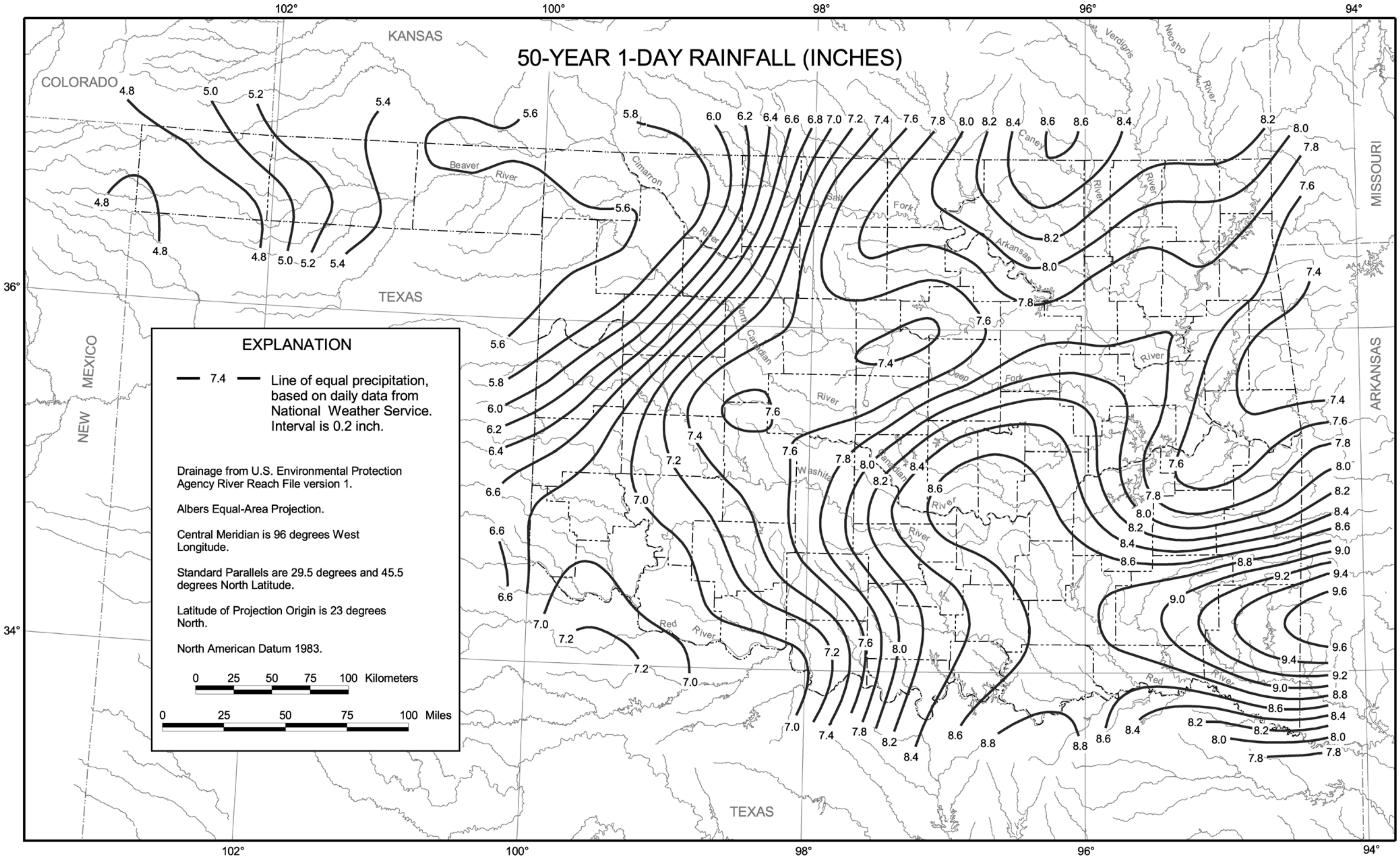
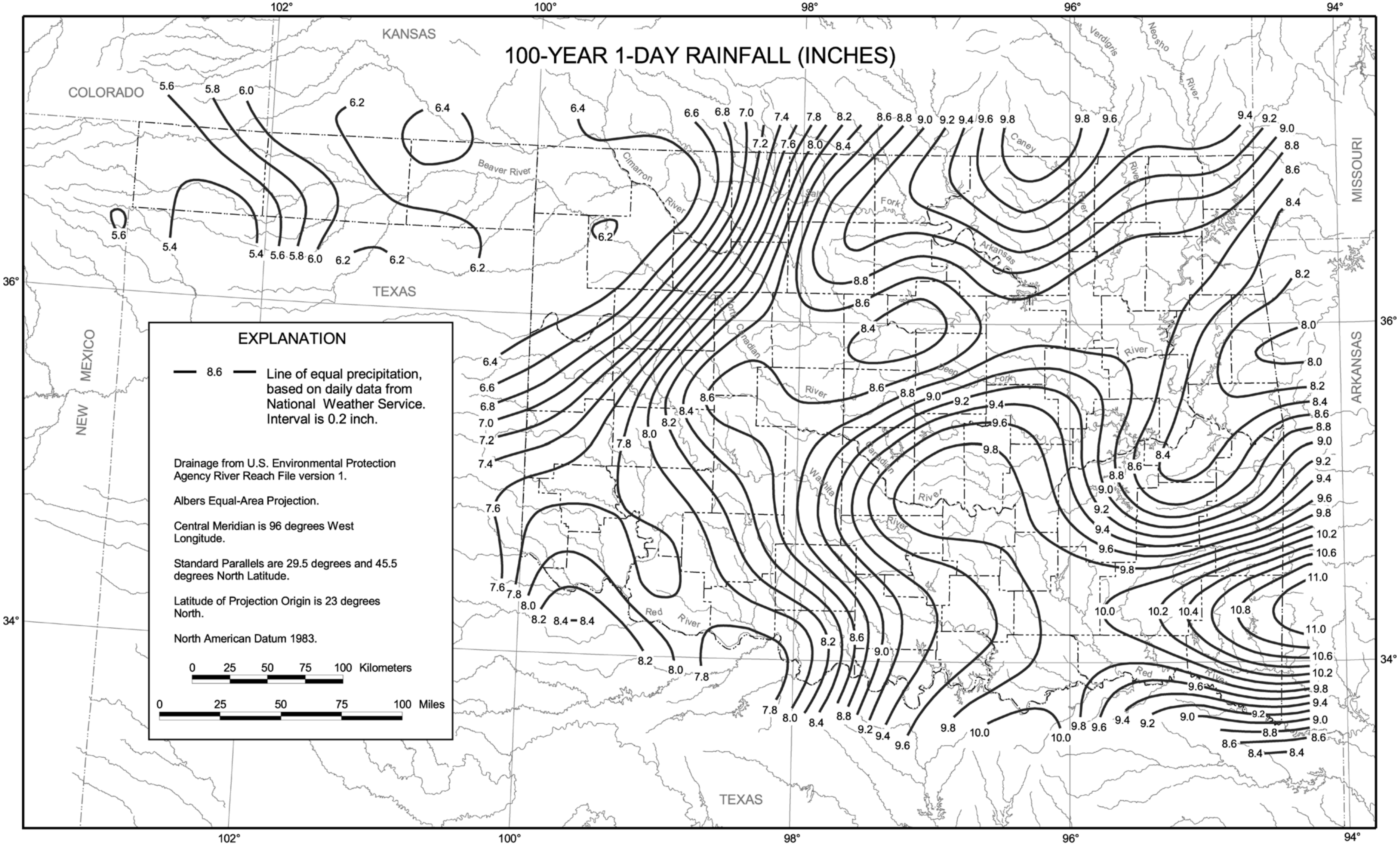


Figure 76. Depth of 50-year storm for 1-day duration in Oklahoma.



EXPLANATION

— 8.6 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.2 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

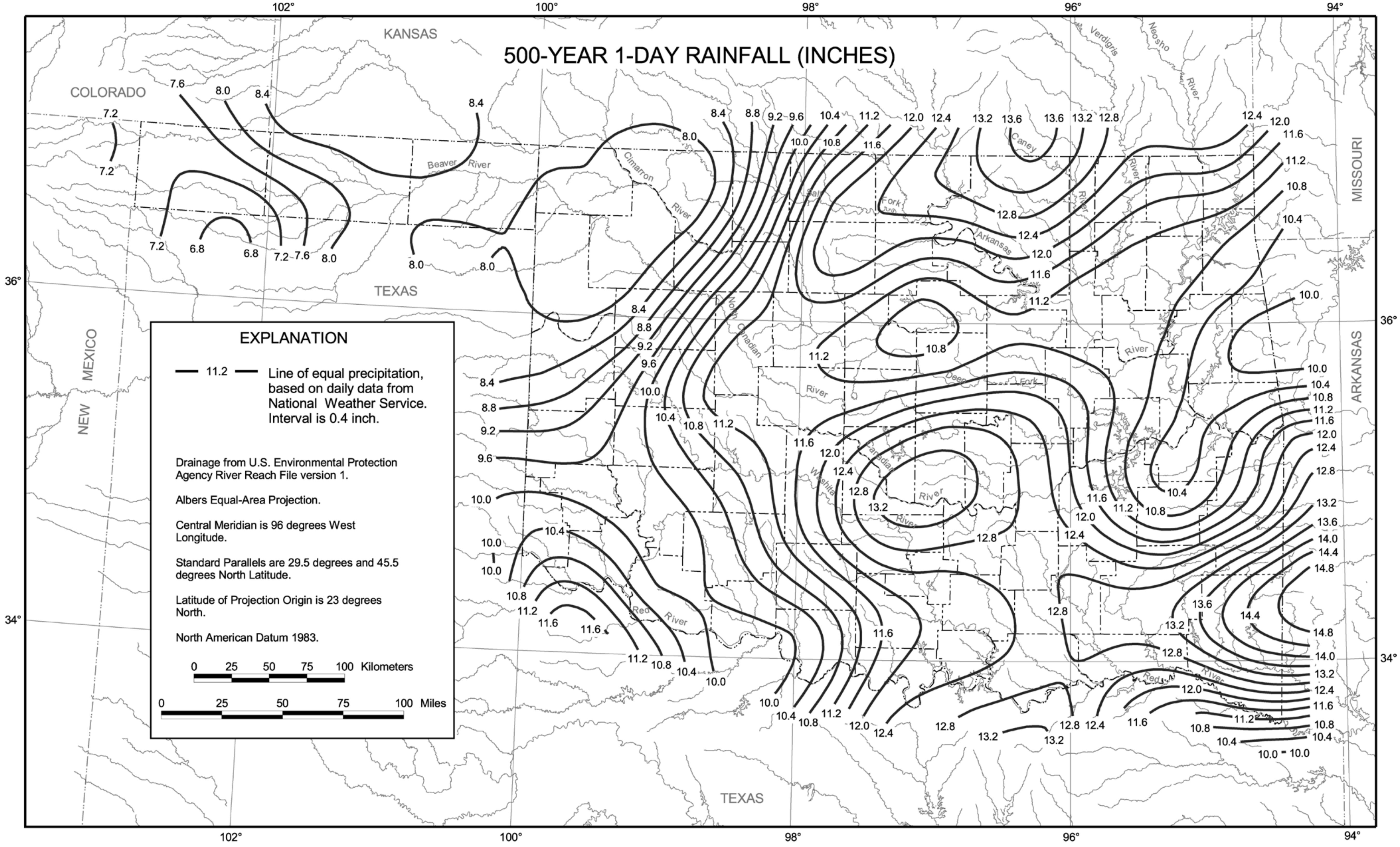
Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

0 25 50 75 100 Kilometers

0 25 50 75 100 Miles

Figure 77. Depth of 100-year storm for 1-day duration in Oklahoma.



EXPLANATION

— 11.2 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.4 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 78. Depth of 500-year storm for 1-day duration in Oklahoma.

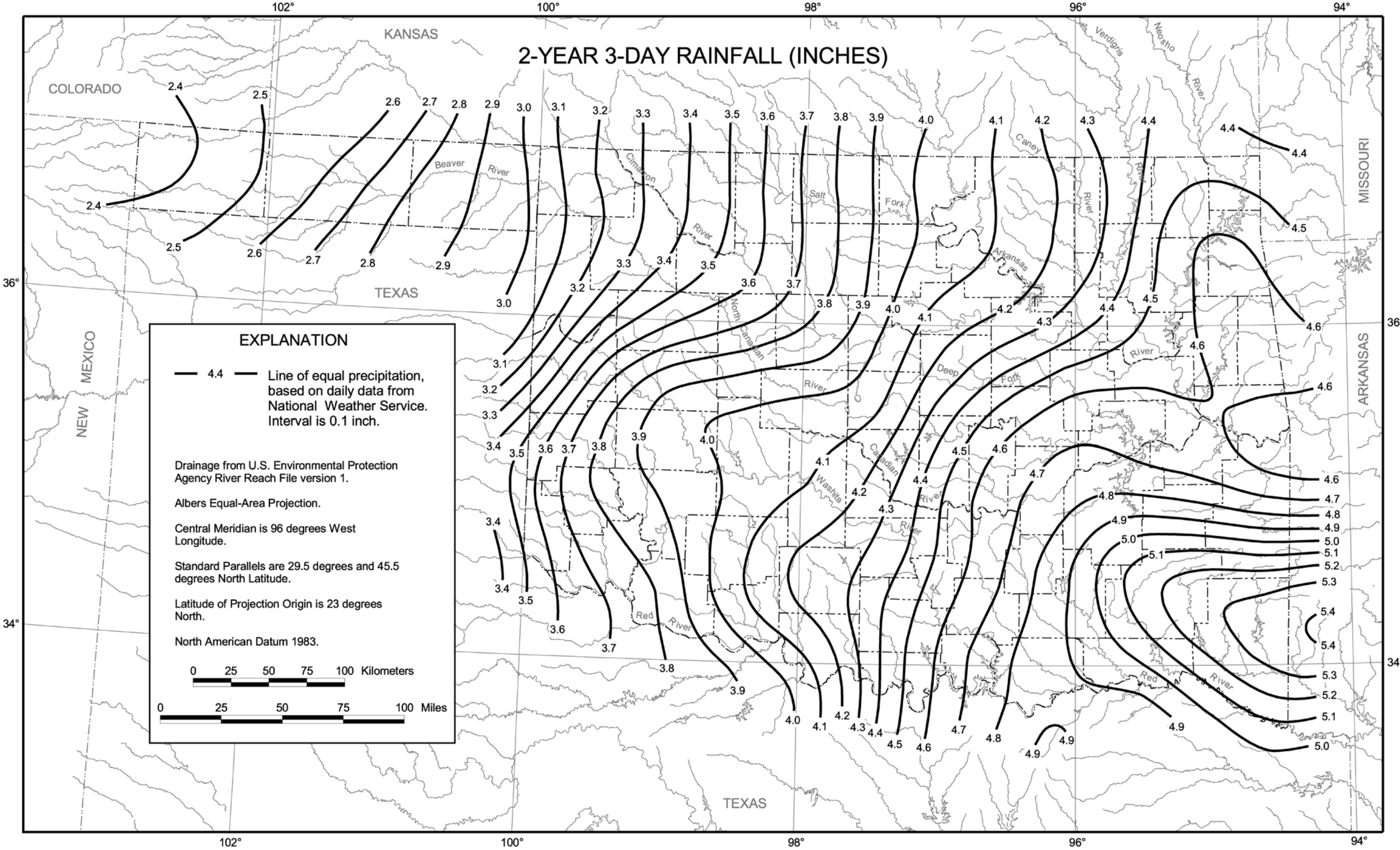


Figure 79. Depth of 2-year storm for 3-day duration in Oklahoma.

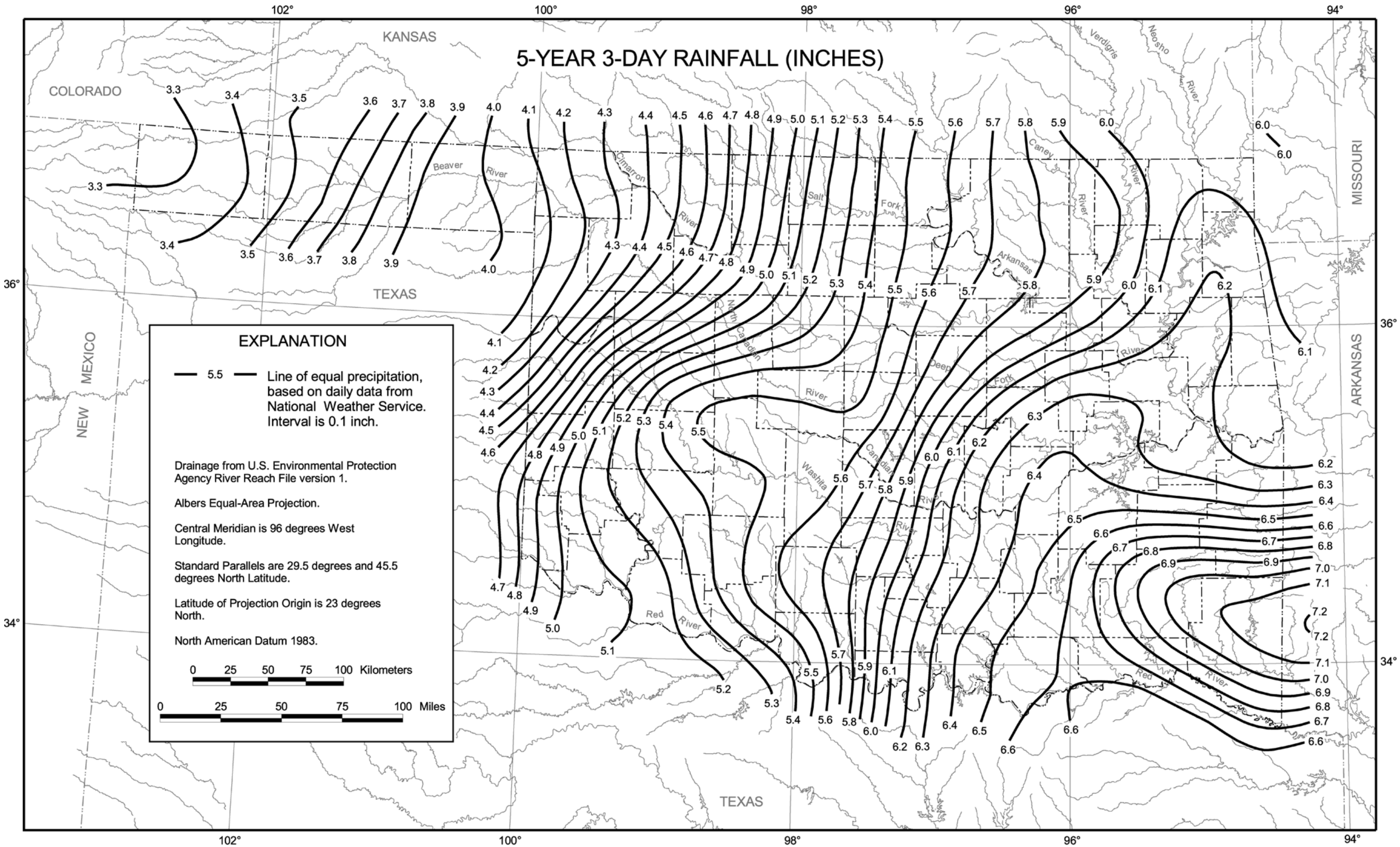


Figure 80. Depth of 5-year storm for 3-day duration in Oklahoma.

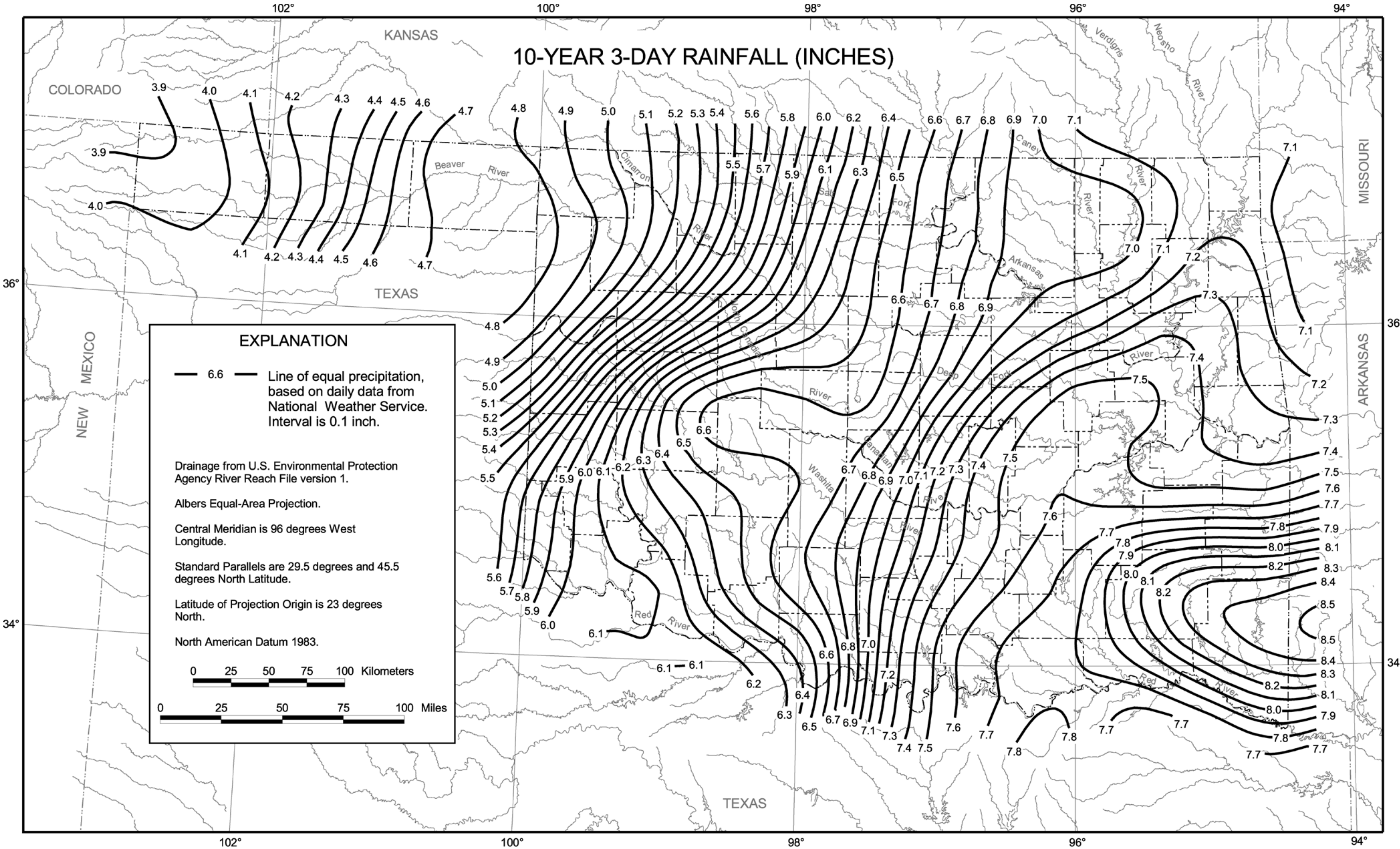
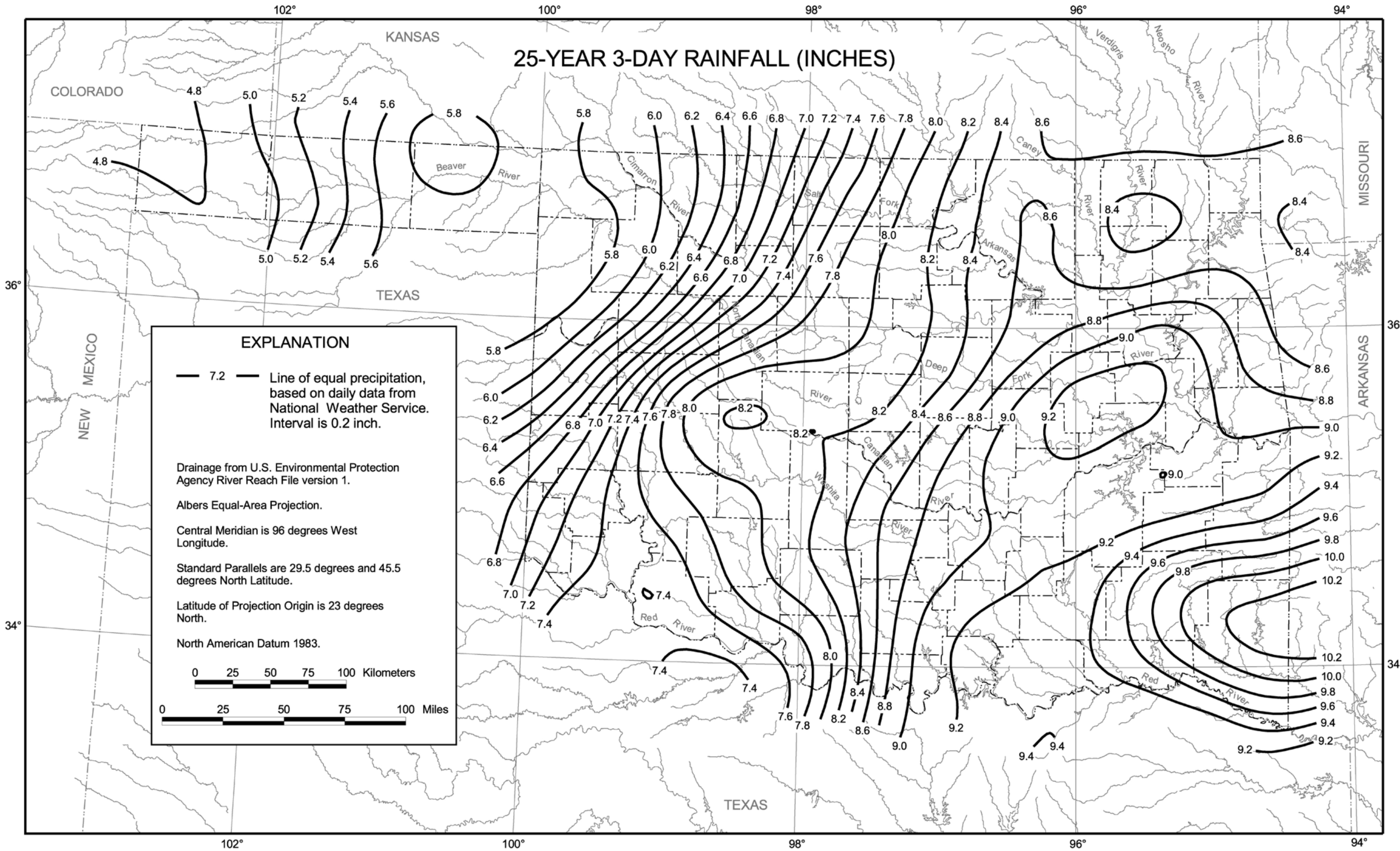


Figure 81. Depth of 10-year storm for 3-day duration in Oklahoma.



Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.2 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 82. Depth of 25-year storm for 3-day duration in Oklahoma.

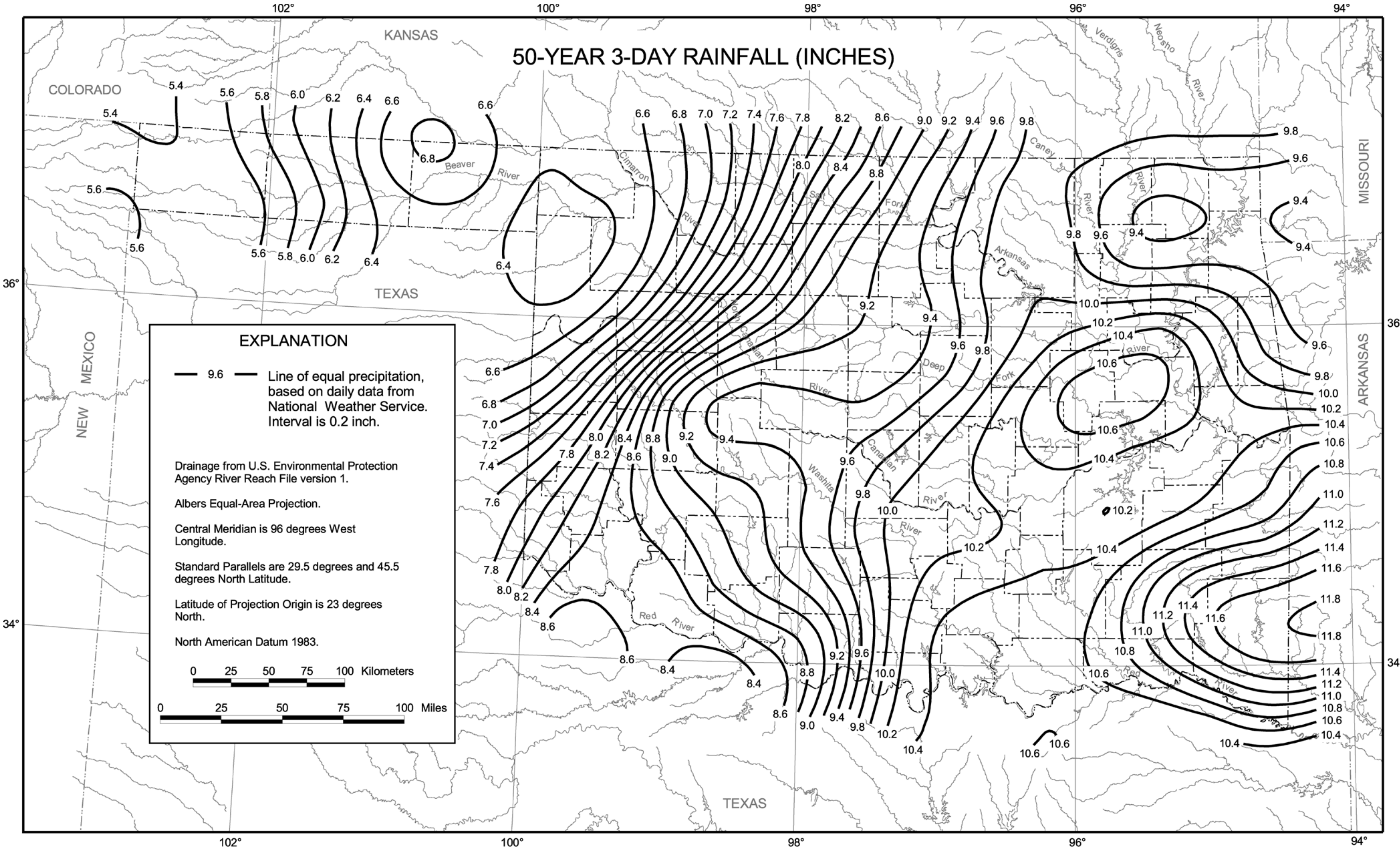


Figure 83. Depth of 50-year storm for 3-day duration in Oklahoma.

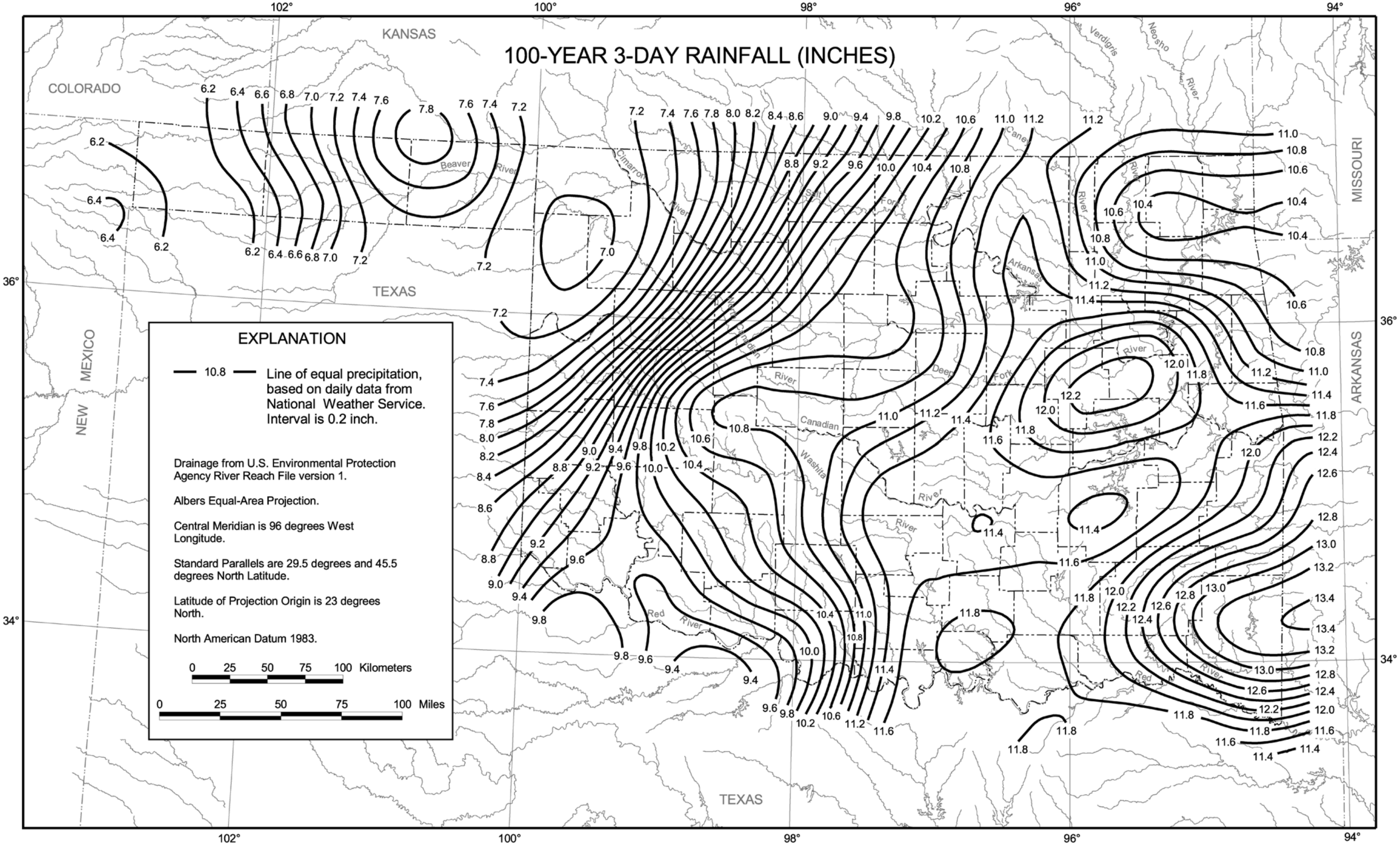
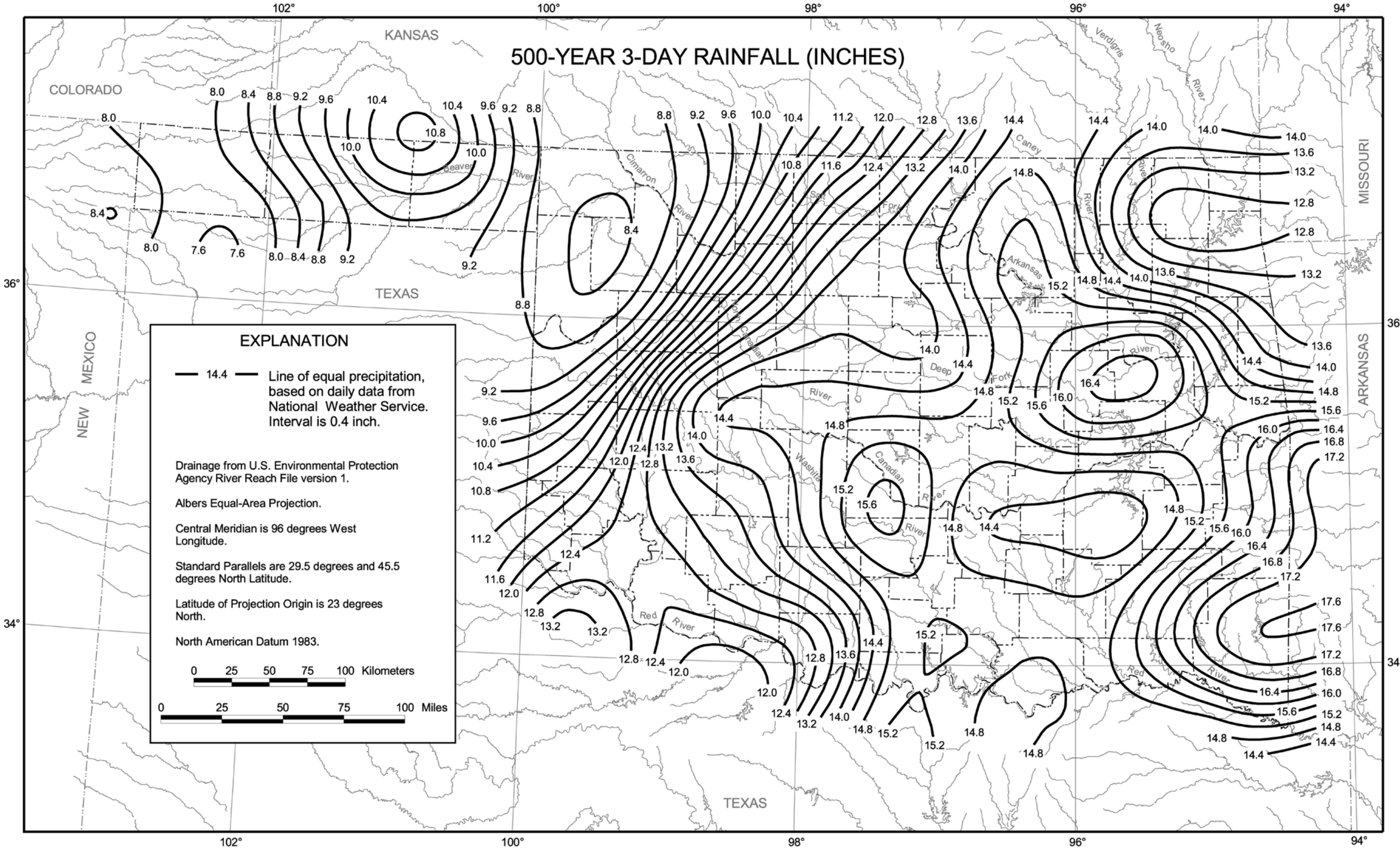


Figure 84. Depth of 100-year storm for 3-day duration in Oklahoma.



EXPLANATION

— 14.4 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.4 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

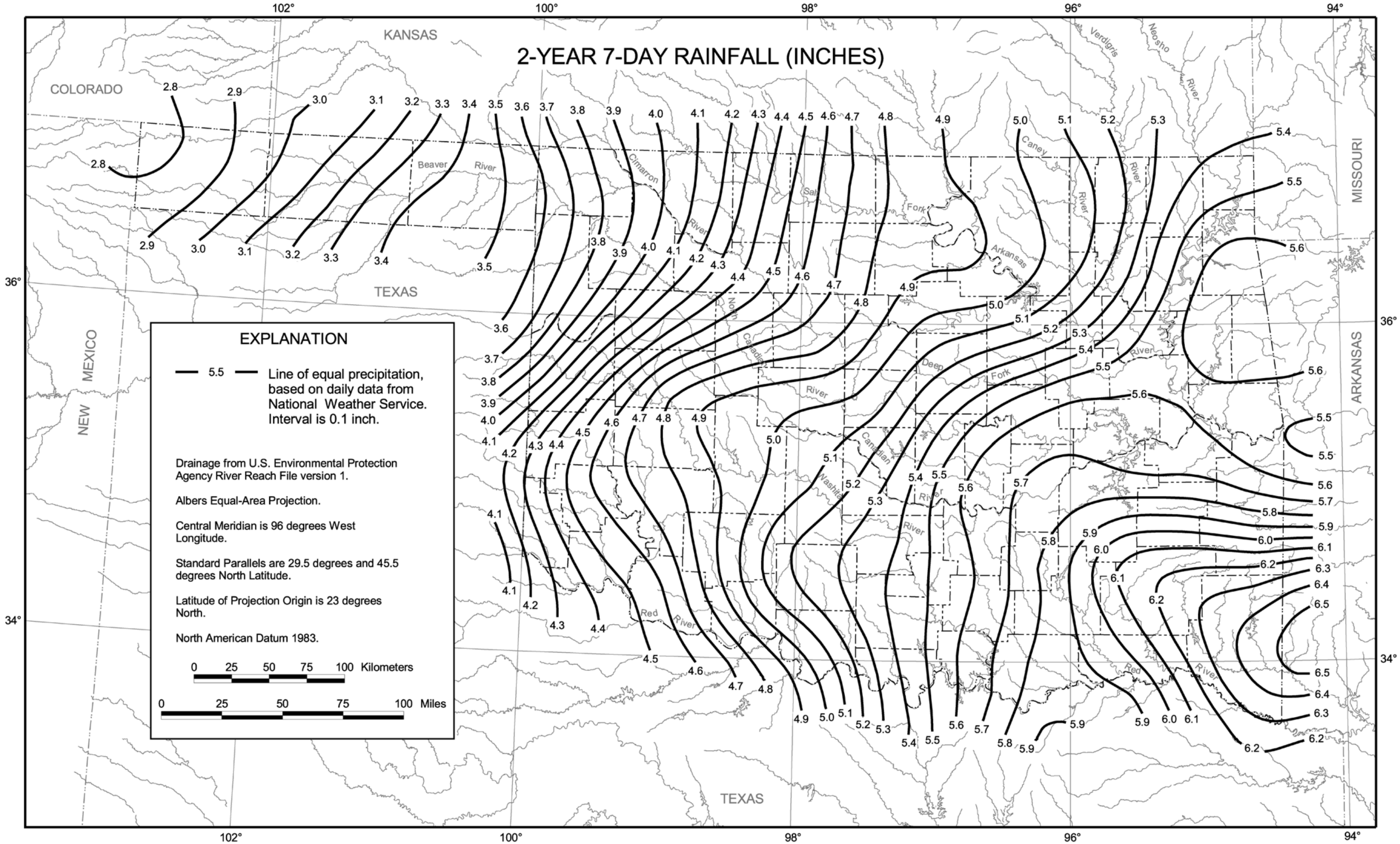
Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 85. Depth of 500-year storm for 3-day duration in Oklahoma.



EXPLANATION

— 5.5 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.1 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

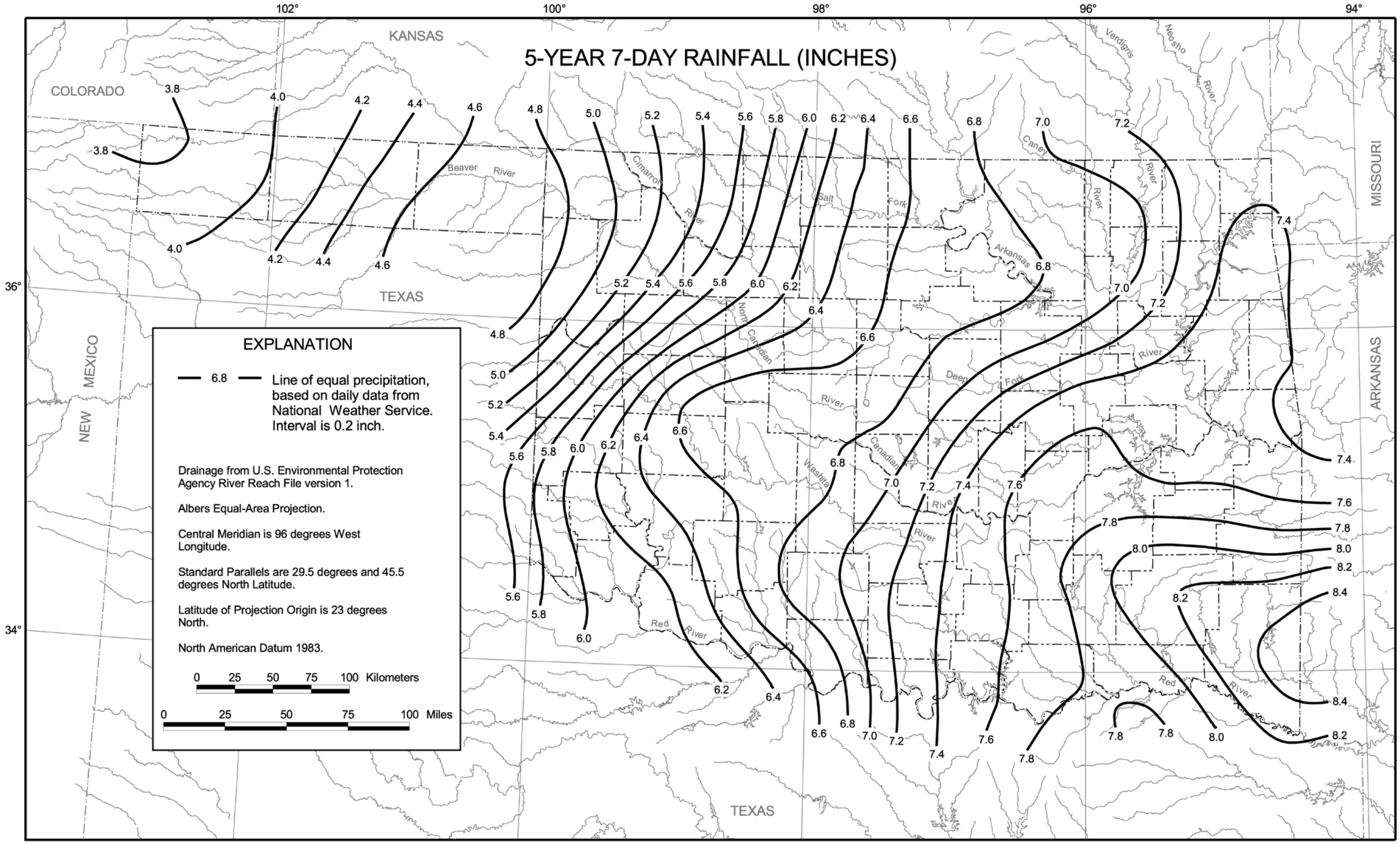
Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 86. Depth of 2-year storm for 7-day duration in Oklahoma.



EXPLANATION

— 6.8 — Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.2 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 87. Depth of 5-year storm for 7-day duration in Oklahoma.

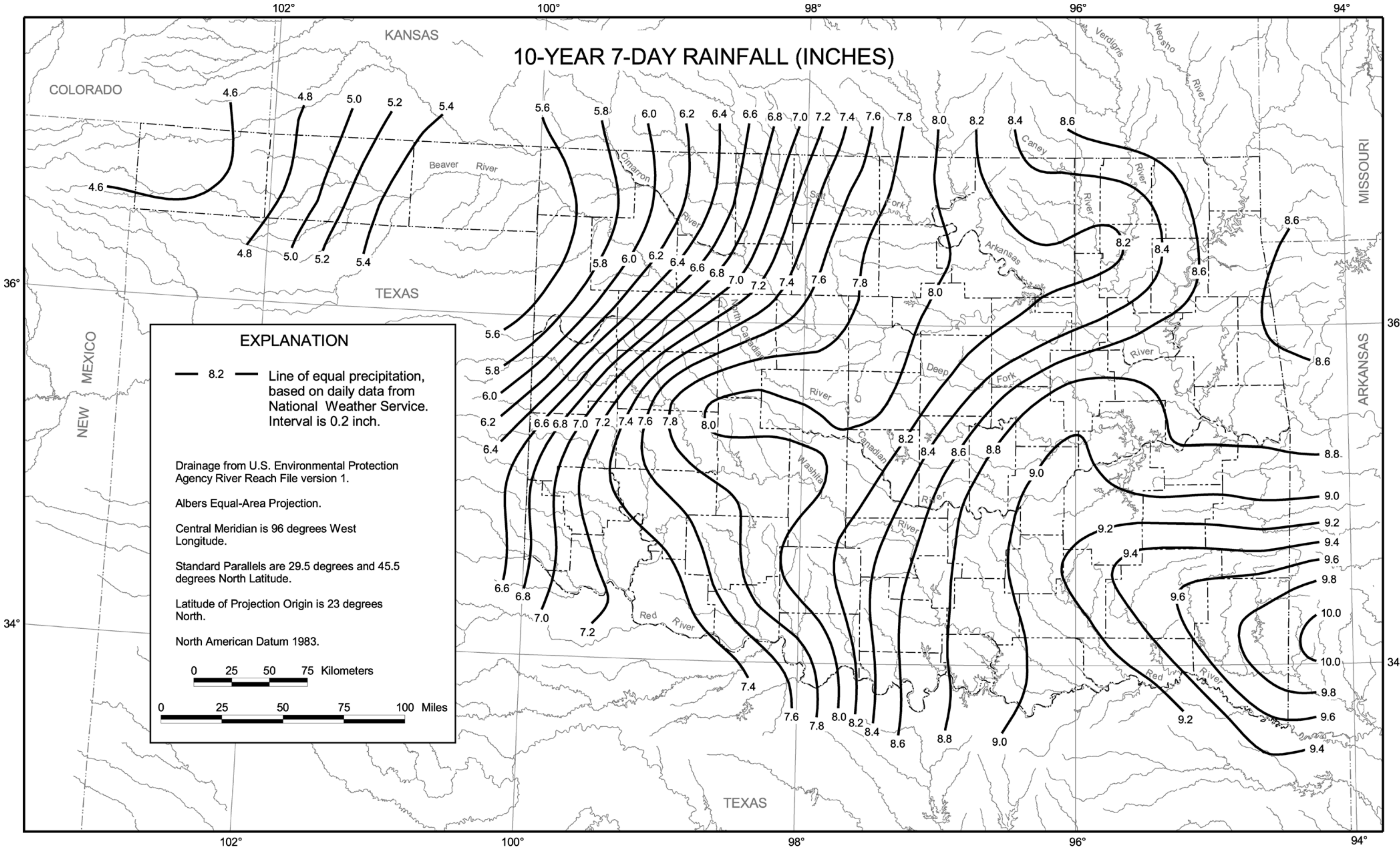


Figure 88. Depth of 10-year storm for 7-day duration in Oklahoma.

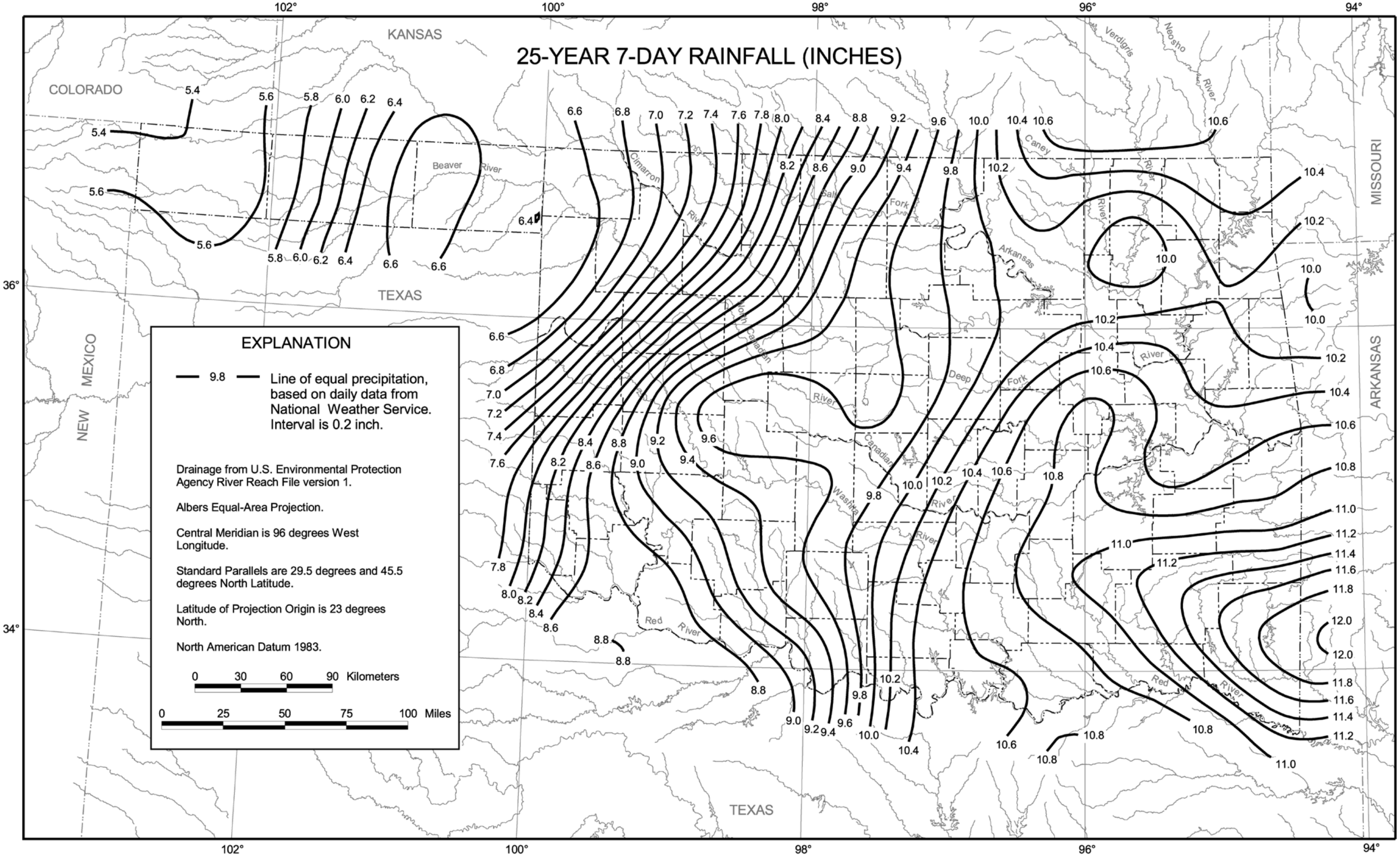
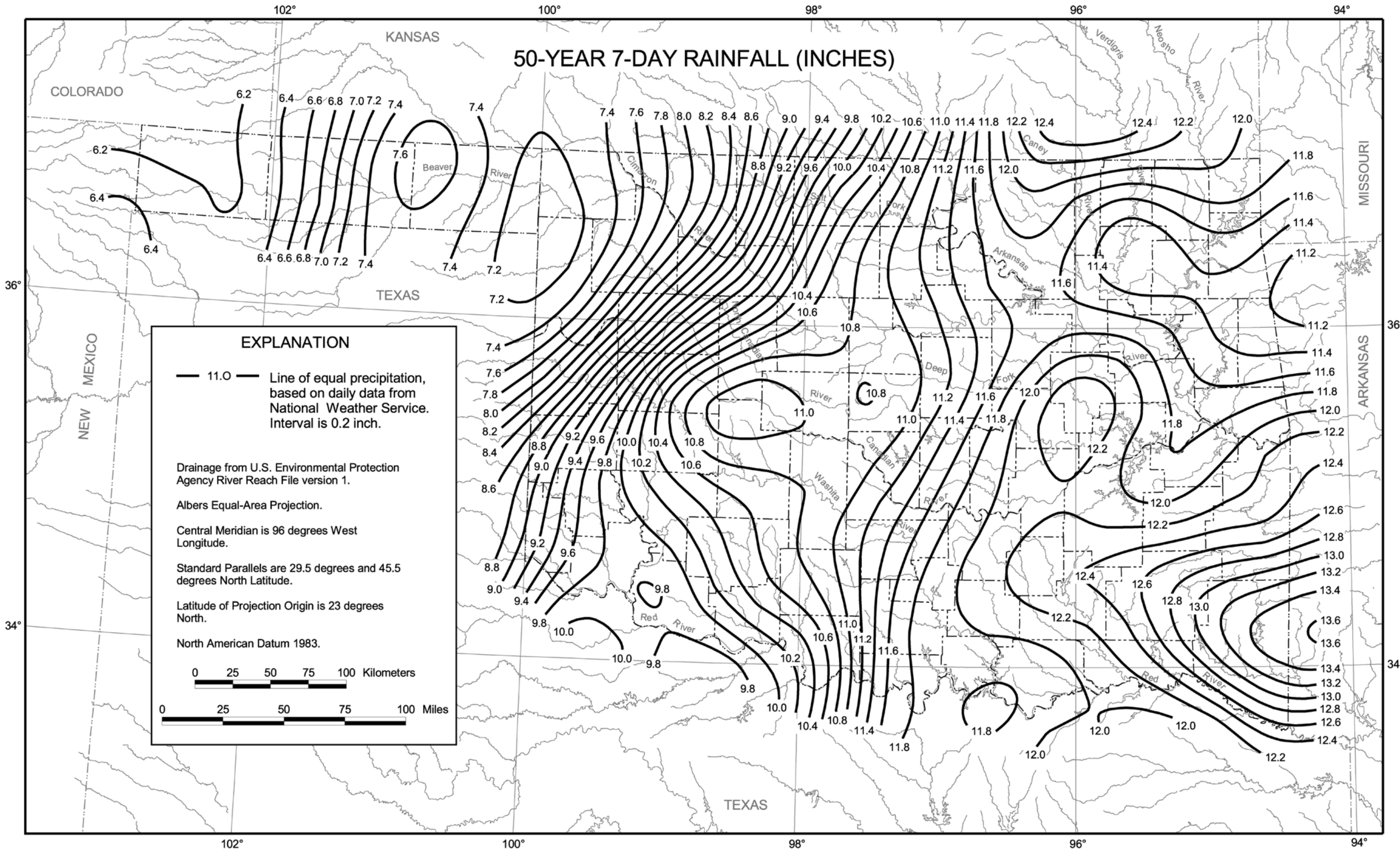


Figure 89. Depth of 25-year storm for 7-day duration in Oklahoma.



EXPLANATION

11.0 Line of equal precipitation, based on daily data from National Weather Service. Interval is 0.2 inch.

Drainage from U.S. Environmental Protection Agency River Reach File version 1.

Albers Equal-Area Projection.

Central Meridian is 96 degrees West Longitude.

Standard Parallels are 29.5 degrees and 45.5 degrees North Latitude.

Latitude of Projection Origin is 23 degrees North.

North American Datum 1983.

Figure 90. Depth of 50-year storm for 7-day duration in Oklahoma.

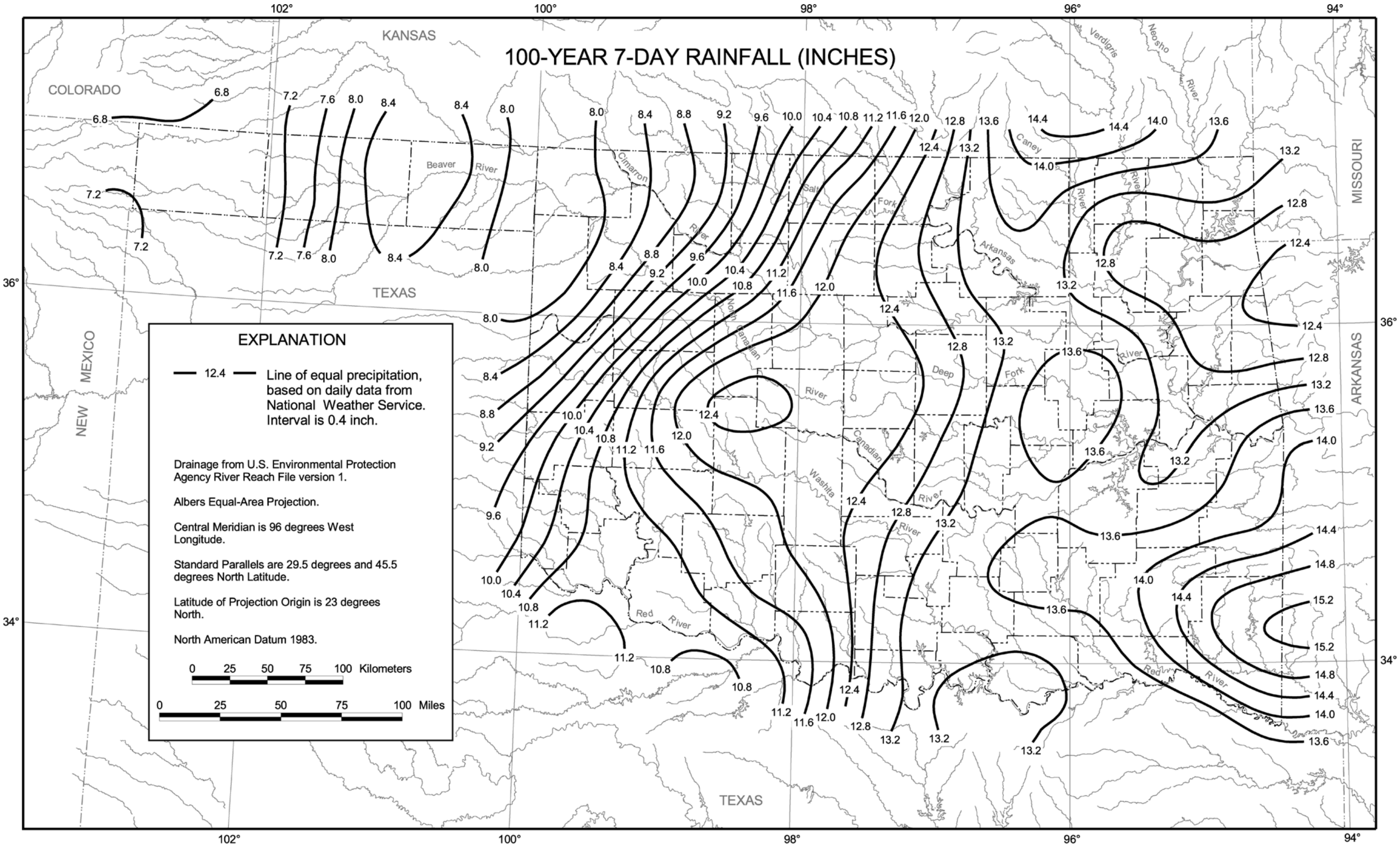


Figure 91. Depth of 100-year storm for 7-day duration in Oklahoma.

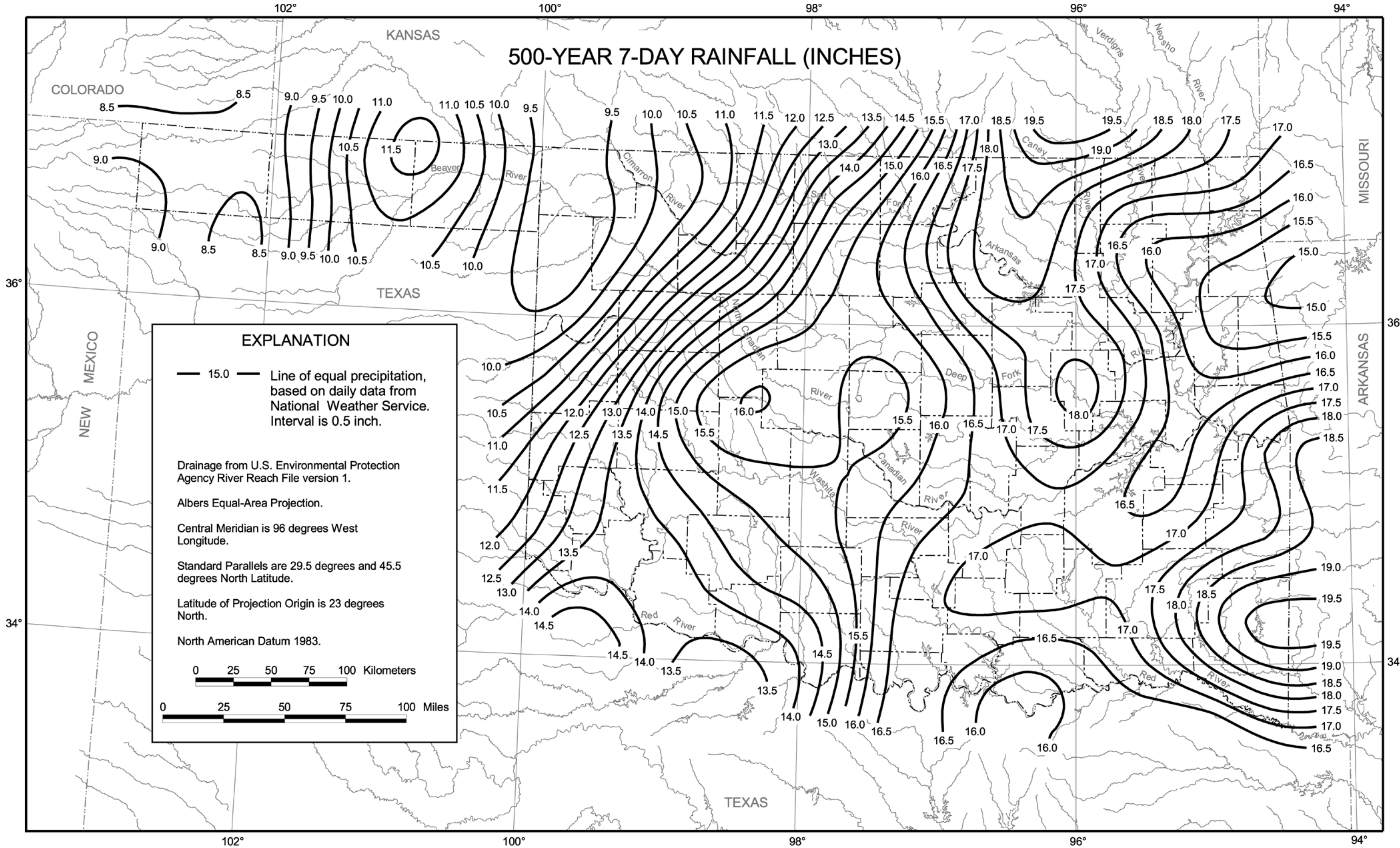


Figure 92. Depth of 500-year storm for 7-day duration in Oklahoma.