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RAINFALL FREQUENCY ATLAS OF THE MIDWEST

by Floyd A. Huff and James R. Angel

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Title: Rainfall Frequency Atlas of the Midwest.

Abstract: This report presents the results and methodology of an intense study of rainfall frequency relationships throughout the Midwest (Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). Using primarily 275 long-term daily reporting stations from the National Weather Service (NWS) cooperative network supplemented by 134 daily reporting stations with shatter records, rainfall amounts have been determined for recurrence intervals from 2 months to 100 years and for durations of 5 minutes to 10 days. The results are presented as maps and as climate division averages in tabular form. Several special raingage networks were used to develop relationships between amounts for 24 hours and less. This report also examines the time distributions of heavy rainfall over time, and other storm characteristics such as storm orientation and movement. The assumption of spatially independent observations between stations is also discussed.

Reference: Huff, Floyd A., and James R. Angel. Rainfall Frequency Atlas of the Midwest. Illinois State Water Survey, Champaign, Bulletin 71, 1992.

Indexing Terms: Climatology, heavy rainfall, hydroclimatology, hydrometeorology, Midwest, extreme value distributions, climate change.

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INTRODUCTION

Storms in the Midwest

The type of rainstorm that most frequently produces flash floods in the Midwest is very localized and produces a large amount of rainfall. According to Changnon and Vogel (198l), these storms usually last from 3 to 12 hours, significantly affect fewer than 400 square miles, and have 1- to 4-hour rainfall totals in excess of 3 inches. Changnon and Vogel's study indicates that approximately 40 of these storms occur in an average year in Illinois, or about one storm for very 1,500 square miles of territory. These storms cause serious local flooding problems on farmland (crop damage) and in urban areas, and interfere with small-reservoir operations.

A larger version of the storm described above is the most damaging flood-producing storm experienced in the Midwest and occurs on the average of about once in two years within the region (Huff, 1986). These "blockbuster" storms generally last from 12 to 24 hours, produce extremely heavy rainfall over a 2,000- to 5,000-square-mile area, and typically create 10- to 12-inch amounts of rain at the storm center. Rainfall amounts in excess of the 100-year recurrence-interval value of point rainfall commonly encompass areas of several hundred square miles about the storm's center.

A substantial portion of the maximum point rainfalls recorded in the precipitation data used in the present study occurred in storms of this type. Although they are rather rare occurrences, these storms may occur in clusters. For example, two of the three blockbuster storms that occurred in Illinois in 1957 took place within two weeks of each other. On the other hand, there have been times when no blockbuster storm was observed for several consecutive years.

Other flood-producing storms, affecting relatively large areas ranging from the size of a county to 20,000 or more square miles, result from a series of moderately intense showers and thunderstorms that occur intermittently for periods of 1 to 10 days. Many of these individual storms would produce little or no damage by themselves, but collectively they can cause urban drainage systems to overflow, and creeks and rivers to swell beyond capacity. This can result in both localized and widespread flooding.

The frequency distributions of heavy rainfall resulting from the storm systems described above are of importance to engineers and others involved in designing and operating structures, such as storm sewers and retention ponds, that can be affected by these events. To meet this need, our nine-state study has concentrated on determining rainfall frequency relations over a wide range of storm periods or partial storm periods (5 minutes to 10 days) and recurrence intervals (2 months to 100 years). The large-scale analysis program required was considered necessary to meet the diverse needs for rainfall frequency information, both now and in the foreseeable future.

Rationale for the Study

Some specific needs led to the undertaking of this study. First, frequency relations for the Midwest had not been updated since Hershfield's U.S. Weather Bureau Technical Paper 40 (TP40) in 1961. Second, further stimulation for the study resulted from recent findings (Huff and Changnon, 1987) that an apparent climatic trend operated on the frequency distributions of heavy rainstorms in Illinois from 1901-1980, which was confirmed by Huff and Angel (1990) for portions of the Midwest. Third, there was a need for more detailed spatial description of the variations in rainfall amounts for any given duration and recurrence interval than was provided in the TP40 study.

One of the problems with TP40 is that its 100-year, 24-hour values have been exceeded too frequently in certain regions of the Midwest. Table 1 summarizes the number of times that these values were exceeded for selected, long-term stations in each state. Assuming a binomial distribution, the probability of exceeding a 100-year event in a given year can be calculated for a particular station. For example, in Illinois the probability of exceeding a 100-year event is 0.583 with an average record length of 87 years. With 61 stations, one would expect a 100-year event to have been exceeded approximately 36 times during this period (column d in table 1) rather than the 69 times that were observed (column c in table 1). The results in Michigan are even more striking, with over three times the expected number of storms exceeding the 100-year value. But in Missouri the TP40 values were not exceeded nearly as often as expected, which suggests that these values are too high. For the entire Midwest, 246 storms exceeded the 100-year value against an expected number of 171 storms (a ratio of 1.43).

The present study has used a much larger, longer sample of precipitation data than was available for previous U.S. studies by Yarnell (1935), Hershfield (1961), and Miller et al. (1973), and an Illinois study by Huff and Neill (1959a). The present study has employed a comprehensive data sample from 409 stations in nine states across the Midwest (Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin). Records from 275 of these stations date back to the early 1900s. Thus we were able to provide greater spatial detail than was possible in the previous studies. Furthermore, the longer time sample should provide more accurate estimates of the various frequency distributions, particularly for relatively long recurrence intervals (25 years or more).

All the results in this report are expressed in the English system of units. It is anticipated that hydrologists and others who use the information will continue to use the English system in the foreseeable future. The following conversion table can be used in converting English units to metric units.

Table 1. Number of Times the 24-Hour, 100-Year Value from Technical Paper 40 Is Exceeded by State

	(a) Number of stations	*(b)* Average length of record	*(c)* Number of times exceeded	*(d)* Number of times expected	*Ratio (c)/(d)*
Illinois	61	87	69	36	1.92
Indiana	41	64	17	20	0.85
Iowa	43	80	20	24	0.83
Kentucky	25	67	11	12	0.92
Michigan*	46	60	71	21	3.38
Minnesota	25	67	14	12	1.17
Missouri	44	62	4	20	0.20
Ohio	41	60	27	19	1.42
Wisconsin	13	78	13	7	1.86
Midwest			246	171	1.43

*From Sorrell and Hamilton, 1990

Conversion Table

Multiply	*By*	*To obtain*
Inch (in.)	25.4	Millimeter (mm)
Mile (mi)	1.6	Kilometer (km)
Square mile (mi^2)	2.6	Square kilometer (km^2)

Organization of the Report

This report is divided into two main parts: Analyses, and Distribution Maps and Tables. Readers interested solely in obtaining rainfall amounts for particular durations and recurrence intervals should see chapter 3 and part 2. Chapter 10 provides a complete overview. Those interested in how the values were obtained should see the Introduction and chapters 1 and 2, which describe why the study was undertaken, the data sets used, and the statistical analyses that were applied.

Chapters 4, 5, and 7 provide auxiliary information about heavy storms in the Midwest, which may be useful for design and planning purposes. These chapters describe rainfall distribution within a storm, spatial characteristics of storms, and changes in the rainfall distribution through the seasons.

Chapter 6 addresses the issue of climate change and extreme rainfall, and documents significant changes with time over parts of the Midwest. Chapters 6 and 8 address two of the basic statistical assumptions of heavy rainfall events: a stationary time series and spatially independent rain events. Chapter 9 discusses the dispersion of point values around the climate section mean values found in the tables in part 2.

Basic Considerations

The basic philosophy applied in the nine-state study was that a combination of appropriate statistical techniques, guided by available meteorological and climatological knowledge of atmospheric processes, provides the best approach to the problem. In so doing, it is important to remember that the natural laws operating in the atmosphere are not controlled by any particular statistical distribution. Within the limits of the data sampled (for example, 25, 50, or 100 years), however, the application of appropriate statistical analysis provides a means of optimizing the information contained in that data.

The specific type(s) of statistical distribution that will provide the optimal rainfall frequency relations for a given location will vary depending on such factors as climate, land features (topography, large water bodies, etc.), and season of the year (if a seasonal analysis is being performed). Thus climatology would suggest it is doubtful whether the same statistical distribution that provides a good fit for Chicago data would also achieve the same degree of reliability if applied to data for Miami, Phoenix, or Seattle, where the precipitation climates have substantially different characteristics than at Chicago. For example, see Changnon's definition of the nation's rainfall climate zones based on analysis of hourly rainfall amounts and their distributions (Changnon and Changnon, 1989).

It is also important to remember that *any specific statistical distribution serves only as a means of optimizing information contained in the data sample.* One must be very cautious in extrapolating the derived frequency relations beyond the limits of the data. Thus if rainfall frequency relations have been derived from an 80-year data sample, it is reasonable to assume that the relations should be satisfactory for estimating the expected 100-year event, but certainly not the 500-year event. This is too far beyond the limits of the data. In fact, there is no assurance that the natural laws affecting the rainfall will continue to closely follow any particular statistical distribution for the next 500 years. If significant climate changes are occurring, as indicated by numerous investigators, then rainfall processes cannot be assumed to remain stationary in the future.

Before describing the specific procedures used in our nine-state study, it is necessary to mention another basic problem always encountered in rainfall frequency studies. There are two sources of potential variability contained in the data sample for a given location: natural and human-induced variability. The natural variability factor can cause significant differences to appear in the frequency distributions of two stations located within an area of apparent precipitation climate homogeneity. This variability can be caused by one or several storms of abnormal intensity occurring at one station and not the other, even over a long period. This is not an uncommon occurrence in regions such as the Midwest where thunderstorms are the primary producers of heavy rainstorms.

Unfortunately, this natural variability is very difficult, if not impossible, to separate from human-induced variability, which also often affects the data sample at a particular location. This variability is influenced by such factors as improper raingage exposure, the worst source of measurement error; recording errors; and mistakes in processing rainfall data. Vogel (1988) provides some good examples of problems created by improper raingage exposure, data processing inadequacies, and inadequate gage maintenance.

If isohyetal maps of rainfall frequency relations are to be the end product of a study, some scientific judgment must be used in assessing such data differences between stations. These variability errors cannot be completely eliminated by statistical treatment of the data. If areal mean frequency relations are derived for areas of similar precipitation climate, however, this problem can be reduced substantially.

Another important issue is the decision not to use hourly precipitation data to directly calculate rainfall frequency values. The hourly data were not used for three reasons: the period of record is typically shorter than for the daily reporting stations (35 years or less in most cases); there are fewer hourly stations in the region by a factor of 2; and, most importantly, the quality of the data is much poorer than that of the daily data. Sorrell and Hamilton (1990) came to the same conclusion about the drawbacks of the hourly data in their rainfall frequency analysis of Michigan. Developing an analysis based directly on the hourly data with the same accuracy and detail as the daily data would have been impossible. Therefore, the hourly data were only used to develop relationships between the daily data and durations less than daily (see chapter 1 for more discussion on the technique used).

Pilot Study

Initially, a very detailed study of Illinois rainfall frequency relations was made (Huff and Angel, 1989). In this study, the authors explored the use of those statistical distributions considered to have potential for application in Illinois based on (1) the observed characteristics of the data sample and (2) consideration of the precipitation climate and influences generated by certain topographical features and two large, urban areas (Chicago and St. Louis). An 83-year sample of data (1901-1983) for 61 cooperative stations and 34 recording gage stations in and near Illinois was available at the start of the pilot study.

It was assumed that the analytical techniques derived in the Illinois study were applicable to the other eight states in the Midwest, since there are no major changes in the general precipitation climate within this region. That is, there are no changes to a tropical, desert, or maritime climate within the region—the general climate type is humid continental. The above method of deriving analytical techniques from a detailed investigation of one climatically representative state (or area) in the region of interest is considered by the authors to be appropriate, time-saving, and cost-effective.

Information Accumulated for Each State

For each precipitation station in the pilot study, the frequency distribution of rainfall amounts was determined for storm durations of 5 minutes to 10 days and for recurrence intervals ranging from 2 months to 100 years to adequately meet the needs of users. Mean rainfall frequency relations were then calculated for each climatic section in the nine states. The climatic trend at each station was measured through use of the ratio of rainfall amounts in a 40 year-period (1947-1986) to those for the previous 40-year period (1907-1946) for selected recurrence intervals and rain durations.

From the point (station) data, frequency relations were developed in the form of isohyetal maps for selected rain periods and recurrence intervals (those most commonly used by hydrological engineers and others). Regional maps were derived for rain periods of 1, 2, 3, 6, 12, 24, 48, 72, 120, and 240 hours, and for recurrence intervals of 2, 5, 10, 25, 50, and 100 years. Methods have been provided for computing rainfall for the lesser used storm periods of 5 to 30 minutes, and for recurrence intervals of 2 to 12 months.

As indicated above, areal mean relations were also determined for each climatic section in each state. Section locations are shown in figure 1. Results, presented in tabular form, include the entire range of rain periods and recurrence intervals used in the point rainfall computations. Assuming approximate homogeneity of heavy rainfall climate within a section, the average relations are considered more reliable than point values. The mean section relationship helps minimize the effects of the natural variability and human-induced sampling errors, which sometimes distort the true distribution pattern of heavy rainfall at specific sampling points (stations).

Acknowledgments

This report is the culmination of rainfall frequency research originally begun in 1984 under the direction of Stanley A. Changnon. Jr., then Chief of the Illinois State Water Survey. Although the investigation was initially restricted to Illinois, it was expanded in 1988 to include the nine-state Midwest region of the Midwestern Climate Center

(MCC) with Stanley Changnon and Peter J. Lamb as the co-principal investigators. The work was continued and completed under the general direction of Kenneth Kunkel, present MCC Director.

Special appreciation goes to Stan Changnon for his foresight, guidance, and encouragement in establishing and accomplishing the program objectives. He and Ken Kunkel reviewed the report and made useful comments and suggestions. Special thanks go to Richard Katz, National Center for Atmospheric Research; Tibor Farago, Hungarian Meteorological Service; and J.R.M. Hosking, IBM Research Division, for providing software for some of the extreme rainfall analyses. Fred Nurnberger, Michigan State Climatologist, provided valuable long-term precipitation data for his state as well as comments on the manuscript. We also thank the following state climatologists for their review and comments on this project: Wayne Wendland, Illinois; Ken Scheeringa, Indiana; Harry Hillaker, Iowa; Glen Conner, Kentucky; Jim Zandlo, Minnesota; Wayne Decker, Missouri; Jeff Rogers, Ohio; and Pam Naber-Knox, Wisconsin.

John Brother and Linda Hascall supervised the extensive drafting work required for the report. Jean Dennison typed and assembled the report, which Eva Kingston edited and formatted.

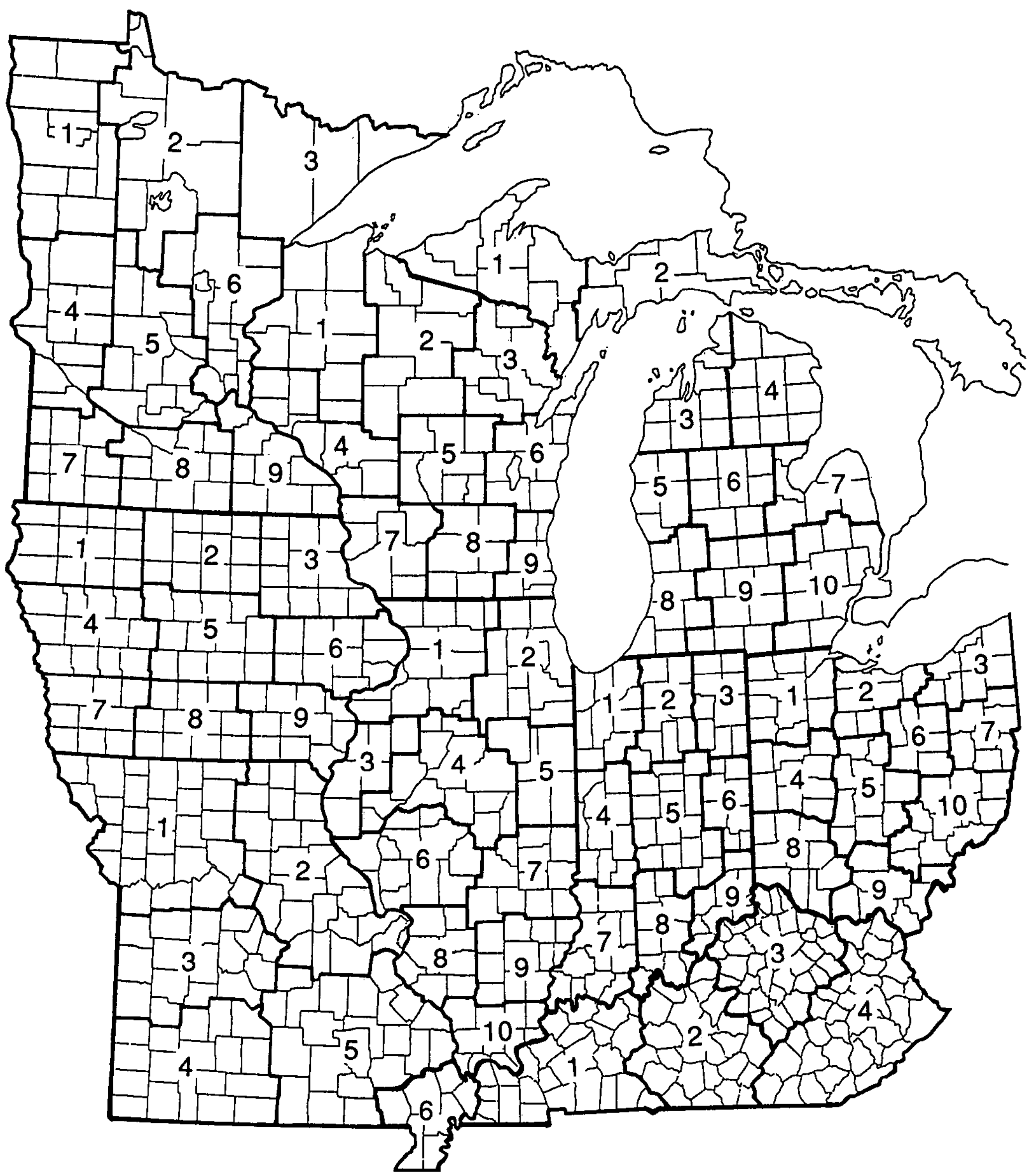

Figure 1. Climatic sections for the Midwest

PART 1. ANALYSES

1. DATA AND ANALYTICAL APPROACH

This study relied primarily on data from 275 daily reporting stations of the National Weather Service (NWS) cooperative network, which had records exceeding 50 years. These data were provided in digital form by the National Climatic Data Center and, in some cases, keypunched by the Midwestern Climate Center from written records. The coverage ranged from good in Illinois, Indiana, Iowa, Michigan, and Missouri to sparse in Minnesota, Wisconsin, Ohio, and Kentucky. These data were supplemented by daily data from 134 cooperative stations with shorter records (1948 to present), by first-order station data, and recording raingage data where available (1948 to present) (figure 2).

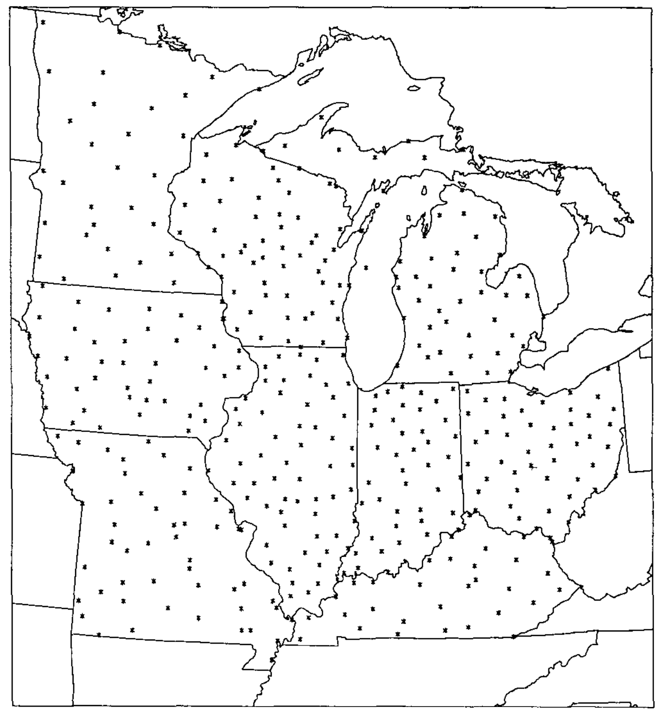

Figure 2. Stations used to derive the rainfall frequencies

Because the cooperative network provides only daily amounts of rainfall, an empirical factor of 1.13 was used to convert calendar-day rainfall to maximum 24-hour rainfall. This empirical factor was developed by NWS analysts (U.S. Weather Bureau, 1953) and confirmed by Hershfield (1961) and Huff and Neill (1959a). This factor was investigated further in the nine-state study by using all recording raingage data for the period 1948-1987 in Indiana and Illinois. Analysis verified the earlier findings that 1.13 represented the average ratio of maximum 24-hour to calendar-day rainfall in heavy rainstorms. Conversion factors of 1.05 and 1.02, respectively, were obtained for converting 2-day rainfall to maximum 48-hour rainfall and 3-day rainfall to maximum 72-hour rainfall in heavy storm events. The ratios decreased to 1.01 for 5-day and 10-day storms. These are average factors that may vary considerably between storms, but should result in only small errors when applied to a large sample of storms, such as used in this study. Table 2 shows the various conversion factors.

Recurrence-interval amounts for rain periods of less than 24 hours were obtained from average ratios of x-hour/24-hour rainfall. These ratios were determined primarily from recording raingage data for 1948-1983 at 34 Illinois stations and 21 stations in adjoining states (Huff and Angel, 1989). Results of a similar study, based on the Chicago urban network data for 1948-1974 (Huff and Vogel, 1976) and ratios developed by Hershfield (1961) were also considered when determining the empirical factors. All the information sources provided ratios that were in close agreement. Results are shown in table 3.

Frequency relations are usually developed for recurrence intervals of one year or longer. To meet some user needs, however, it was necessary to develop frequency relations for time periods shorter than 12 months. The data analysis showed that 2-month to 9-month frequency values are strongly related to the 2-year values. The x-month/24-month ratios were found to be spatially consistent for all recurrence intervals. These ratios are shown in table 4 for storm periods of 24 hours to 10 days. The 24-hour values are also applicable to storm periods of less than 24-hour duration.

For each station, the data were used to determine the annual maxima time series from the highest precipitation amount recorded in each year for a given storm duration. Station (point rainfall) frequency curves were then calculated for the various storm rainfall durations of interest. For this report, however, the annual maxima values were converted to partial duration values by using the transformation factors shown in table 5 (Huff and Neill, 1959a). The partial duration series includes all of the high values recorded during a sampling period without regard to their annual sequence. Thus all of the 50 highest values occurring in a 50-year period will be included in the partial duration series, but not necessarily in the annual maxima series. Although the annual maxima series is more adaptable to statistical testing, our experience indicates that the partial duration values are preferred by most users of heavy rainfall frequency relations, especially engineers involved in the design and operation of water control structures. The rainfall values are interchangeable through use of table 5.

Table 2. Ratio of Maximum Period to Calendar-Day Precipitation

Storm period (days)	*Ratio*
1	1.13
2	1.05
3	1.02
5	1.01
10	1.01

Table 3. Average Ratio of X-Hour/24-Hour Rainfall

Rain period (hours)	*Ratio (x-hour/24-hour)*
18	0.94
12	0.87
6	0.75
3	0.64
2	0.58
1	0.47
0.50 (30 min.)	0.37
0.25 (15 min.)	0.27
0.17 (10 min.)	0.21
0.08 (5 min.)	0.12

Table 4. Relationship Between 2-Year and Shorter Interval Frequency Values for Various Rainstorm Periods

	Mean ratio (x-month to 24-month rainfall) for given rainstorm period					
Storm period (hours)	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*12-month*
24	0.46	0.53	0.58	0.67	0.76	0.83
48	0.44	0.51	0.57	0.66	0.76	0.83
72	0.43	0.51	0.57	0.66	0.76	0.83
120	0.42	0.50	0.57	0.66	0.76	0.83
240	0.41	0.49	0.57	0.66	0.76	0.83

Table 5. Ratio of Partial Duration to Annual Maximum Frequencies

	Ratio for given recurrence interval		
Precipitation period (hours)	*2-year*	*5-year*	*10-year*
24	1.13	1.05	1.01
48	1.09	1.02	1.01
120	1.08	1.01	1.00
240	1.08	1.01	1.00

2. STATISTICAL METHODS

Background

In previous Illinois studies (Huff and Neill, 1959a; Huff and Angel, 1989), various statistical distributions were tested for their applicability in fitting extreme rainfall data in the Midwest. These distributions included log normal, Gumbel (1941). Frechet (Gumbel, 1956), Chow (1954), Jenkinson (1955), and log-Pearson (Reich, 1972). Log-log and semi-log fitting procedures were also investigated. Recently, as part of our nine-state study, an investigation was also made of the application of L-moments and maximum likelihood fitting methods to the generalized extreme value theory (Wallis, 1989; Hosking, 1990). Results were compared with those generated by the Huff-Angel method described below.

No single statistical distribution was found in the earlier Illinois studies (Huff and Neill, 1959b; Huff and Angel, 1989) that would consistently provide a satisfactory fit over the wide range of rain periods and recurrence intervals required to meet user needs. These studies generally showed that the Frechet, log-Pearson, and log-log methods provided the best fit for recurrence intervals exceeding 2 years. These methods, however, produced unsatisfactory estimates of rainfall values for recurrence intervals of 2 months to 2 years. For these shorter intervals, log-normal and semi-log fittings of the data often closely approximated the values indicated by plotting the ranked observational data.

These findings support those of Sevruk and Geiger (1980) who made an extensive appraisal of distribution types for extremes of precipitation for the World Meteorological Organization (WMO). But Sevruk and Geiger's worldwide appraisal did not reach a conclusion concerning the superiority of any particular distribution. They point out that "some distributions, however, may be superior to others under given seasonal and/or geographical conditions." This agrees with earlier Illinois findings, which indicated that the Frechet distribution was most applicable to annual, spring, summer, and fall data, but the log-normal distribution provided the best fit for winter data (Huff and Neill, 1959b).

Analytical Method Employed in the Nine-State Study

For our nine-state study, a log-log graphical analysis, hereafter referred to as the Huff-Angel method, was used for final derivation of the frequency relations. This method resulted in smooth curves, such as those illustrated in the Illinois example in figure 3. This figure shows the frequency distribution of 24-hour maximum rainfall amounts for recurrence intervals varying from 2 months to 100 years. A major change is reflected in the distribution characteristics for the two sectional curves near the 2-year recurrence interval.

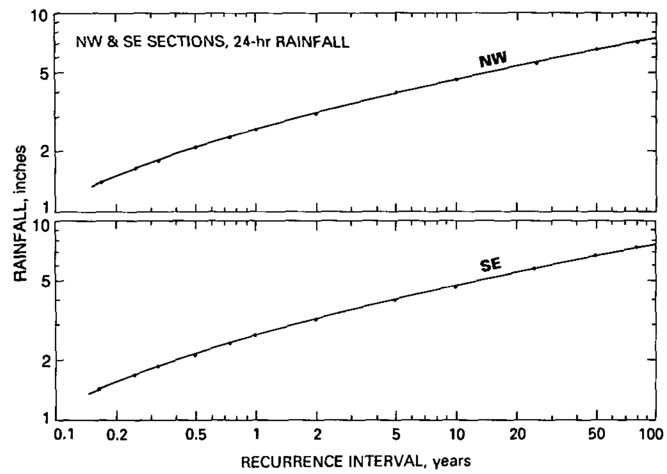

Figure 3. Typical sectional curves in Illinois for various recurrence intervals

Similar curves were obtained for the various sections and individual stations (sampling points) used in our nine-state study. The curve shape varied somewhat among stations, however. For example, at some stations, the change in curvature began closer to the 5-year than the 2-year recurrence interval. Changes in curve characteristics also occurred sometimes with increasing length of rain periods, but a smooth shape was preserved. For most stations, however, a linear fit was provided for return periods of 2 years or more. This method is more subjective than using specific statistical methods, such as L-moments or maximum likelihood, to fit a specific statistical distribution (such as log-normal, Gumbel, etc.). However, it does allow the analyst to incorporate meteorological-climatological knowledge and other pertinent findings from the various analysis procedures employed in the study. For example, human-made sampling errors were sometimes obvious in our nine-state study from comparison of station rainfall values within areas of approximately homogeneous precipitation climate. The integration of all available information is especially helpful in evaluating the rarer events (outliers) appearing in some station records.

The Huff-Angel method places acutoff on extrapolation at or near the 100-year frequency, since the data are not fitted to a specific mathematical distribution. For reasons cited earlier, however, extrapolation of any frequency relation much beyond the limits of the data sample (80+ years at most long-term stations) is not recommended. Furthermore, climatic and physiographic variations can cause the "best-fit" statistical distribution to vary within a single state as shown by Huff and Neill (1959a).

Comparison of Huff-Angel, L-moments, and Maximum Likelihood Methods' Fitting Procedures for Selected States

To evaluate the maximum likelihood and L-moments methods, the generalized extreme value (GEV) distribution was used because of (1) its versatility (the Gumbel and Frechet distributions, for example, are really special cases of the GEV) and (2) the need for a uniform distribution for comparison purposes. A literature search also indicated that the GEV distribution would be the most appropriate statistical distribution for computing point rainfall frequency relations.

Maximum Likelihood Method

The maximum likelihood method is a standard statistical procedure used in fitting a variety of hydrological data (e.g., Kite, 1977; Farago and Katz, 1990). For the stations used in this study, the sample size was always greater than 36 (64 on average). This method should thus yield relatively unbiased estimates of the parameters.

L-moments Method

Recently, another method for fitting distributions appeared in the literature, the L-moments method (Hosking, 1990). This method, analogous to the method of moments (L-mean, L-skewness, etc.), uses linear combinations of order statistics to develop estimates of the distribution. Theoretically, the advantages of this approach over the traditional method of moments are the smaller impact of outliers and the more accurate inferences derived from smaller samples. This method is being used by NWS in updating rainfall frequency relationships in the western United States (Vogel, personal communication, 1991).

In practice, the L-moments method is more involved than either the Huff-Angel or maximum likelihood methods, since it uses regional values to estimate some of the parameters. Thus care must be taken in grouping the stations into appropriate regions by plotting the L-skewness versus L-kurtosis to look for groupings, calculating a discordancy measure by station to indicate potential problems, and examining heterogeneity through Monte Carlo simulations. All this can easily be done using available software (Hosking. 1991). Once the stations are properly grouped, the precipitation amounts for various return periods can be calculated with the appropriate distribution, based on a goodness-of-fit measure.

L-moments Regions

The L-moments technique is relatively new and thus requires a more detailed discussion regarding its application. Because this method uses a regional approach to estimate the frequency distributionsat individual sites, its potential advantages are that it minimizes the sampling errors at individual sites and maximizes the number of available observations. Two crucial factors in this approach include the ability to identify homogeneous regions and the assumption that the individual sites are independent of each other. Hosking and Wallis (1991) describe the four steps to developing a regional frequency analysis.

1. Screening the data. The data are controlled to provide a valid analysis. Hosking and Wallis (1991) employ a discordancy measure based on the sample L-moments and the sample covariance matrix to identify stations that did not fit into the group due to data errors or to identify stations that belong in some other group.

2. Identifying homogeneous regions. Stations are grouped according to their statistical and geographical characteristics. The suggested method compares the L-covariance from the observed data with simulated data from a homogeneous region (using Monte Carlo techniques). The differences are divided by the standard deviation of the simulations to become the measure of heterogeneity (H). If H is less than 1, then the region is fairly homogeneous. Values greater than 2 are considered fairly heterogeneous.

3. Selecting the frequency distribution. Hosking and Wallis (1991) proposed a goodness-of-fit test to identify appropriate distributions from a family of distributions. The test statistics (Z) are the difference between the observed and fitted regional L-kurtosis divided by the standard deviation of the observed L-kurtosis. Values sufficiently close to zero indicate a "'good" fit.

4. Calculating the regional frequency distribution. The homogeneous regions are used to calculate the frequency distributions for the stations in each region.

The application of this methodology to the stations in Indiana and Minnesota proved somewhat difficult and required a number of subjective decisions. Initially, the stations were grouped by NWS climate division since these divisions are widely accepted as areas of reasonably homogeneous climate. Interestingly, several sites yielded high discordancy and heterogeneous indices indicating that they belonged in other regions. After several iterations, seven regions in Indiana (figure 4) and four regions in Minnesota (figure 5) were selected. As the maps show, the final regions are not always geographically coherent. Probably the worst case is the three stations in group 1 in Minnesota (figure 5): on Lake Superior, along the Minnesota-Wisconsin border, and in the southwest comer of the state. As Hosking and Wallis (1991) rightly point out, however, the physical evidence should take precedence over the statistical evidence. Therefore these three stations should be incorporated into the other groups. Since the L-moments method was not used for this report, however, a more sophisticated treatment of the regionalization was not developed.

The task of regional frequency analysis is further complicated by extreme rainfall events that may not be spatially independent (see Chapter 8). Spatial correlations between stations will cause problems with the test statistics, especially the heterogeneity and goodness-of-fit test. Hosking and Wallis (1991) therefore recommend that these statistics only be used as guidelines and not for hypothesis testing.

In general, assuming readily identifiable homogeneous precipitation regions with highly independent stations, one

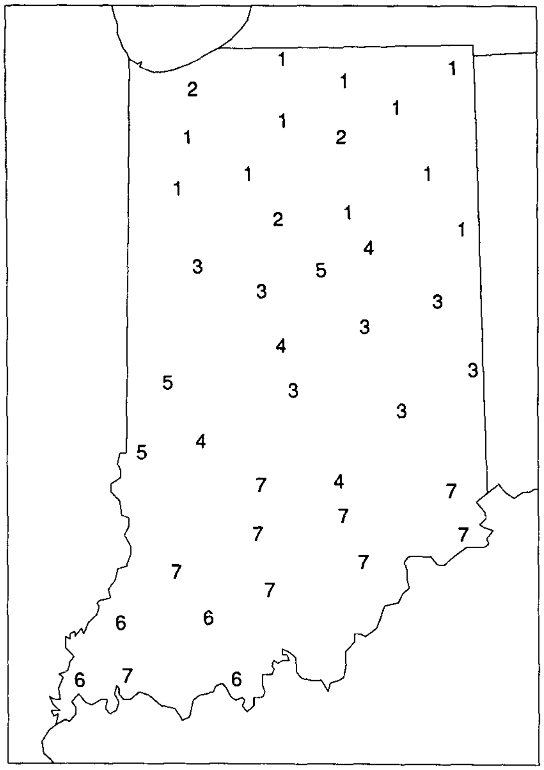

Figure 4. L-moments groups for Indiana

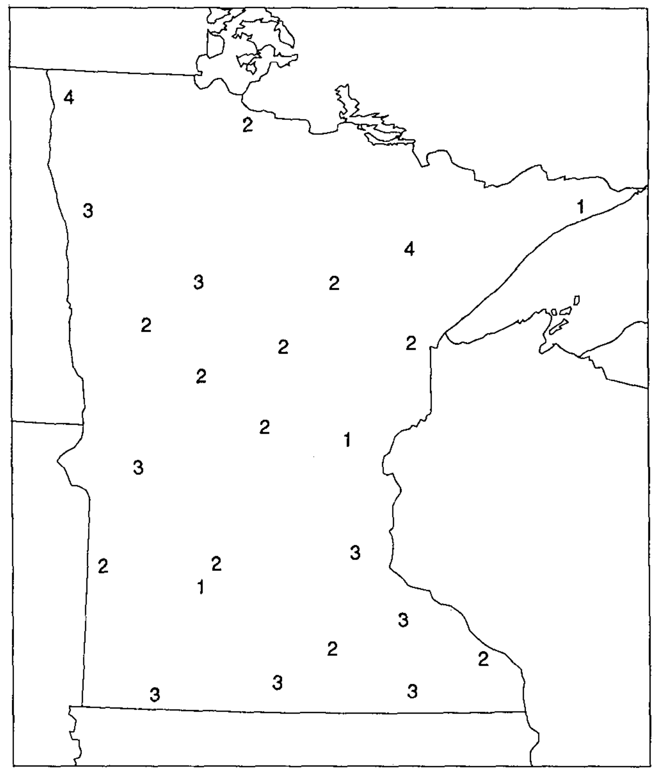

Figure 5. L-moments groups for Minnesota

can take full advantage of regional analysis to overcome sampling errors and short records. In the application here, however, the appropriateness of aregional analysis is not as clear-cut since identifying homogeneous regions is difficult and some spatial correlation exists among extreme rainfall events.

The standard method of moments technique was not used in the comparisons due to its relatively poor performance compared with the other techniques (based on preliminary data). This method has been generally applied to the Gumbel distribution.

Results

For comparison of the three methods, Indiana and Minnesota were selected for their relatively diverse climatic features in the Midwest region. The Huff-Angel values had been previously calculated and were not influenced by the results of the other two methods. The Huff-Angel and maximum likelihood methods were applied to individual stations. On the other hand, the L-moments method was applied to homogeneous groups of stations. The results are presented by state.

Indiana. Tables 6 and 7 summarize the differences found for 41 stations in Indiana from comparison of 24-hour, 100-year rainfall estimates. In general, the Huff-Angel method yielded slightly higher rainfall amounts than either the L-moments or maximum likelihood methods. The root mean square errors (RMSE) are about the same for all three methods. Analysis of the correlation between the L-moments and Huff-Angel methods shows good agreement throughout the 25-year recurrence interval (table 6 and figure 6). This relationship deteriorates somewhat at the longer intervals, as expected, because the methods extrapolate beyond the data, thus increasing the uncertainty in the values. No strong evidence of a bias is present until the 100-year amounts, which are being estimated with less than 100 years of data (35 to 85-year records), are reached, and any differences in the methods become more noticeable at the rarer recurrence intervals. Figure 7 shows examples of good (Albion, IN) and poor agreement (Bloomington, IN).

The 100-year values from the Huff-Angel and the L-moments methods were used in a worst-case comparison. Differences will usually be largest at this return period. The Huff-Angel method resulted in larger 100-year values at 21 stations (51 percent), compared with 19 stations (46 percent) with the L-moments method. One station (2 percent) had equal values with the two methods. The mean of the 100-year values was 6.4 inches for the L-moments method and 6.6 inches with the Huff-Angel method. The median difference (0.2 inch) is equivalent to a 3 percent difference. The median difference (0.3 inches) is equivalent to a 5 percent difference. These relatively small differences are insignificant from a meteorological standpoint. Differences much greater than those obtained from the two fitting methods could result from natural variability, human-induced variability, and extrapolation of the curves beyond the data to determine the 100-year values. For example, for the 100-year values, the spatial variance between the 41 stations was 1.04 inches while the variance of the differences between the Huff-Angel and L-moments methods was 0.54 inch.

Although the data do not strictly satisfy all the assumptions, a simple Analysis of Variance (ANOVA) model shows that there are no significant differences in the state-wide mean

Table 6. Comparison of Three Methods for Estimating 24-hour Maximum Amounts at Selected Return Periods for Indiana

	Huff-Angel vs. Maximum likelihood		*Huff-Angel vs. L-moments*		*Maximum likelihood vs. L-moments*	
Return period	*Mean difference (inches)*	*Corre-lation*	*Mean difference (inches)*	*Corre-lation*	*Mean difference (inches)*	*Corre-lation*
2	-0.03	0.98	-0.03	0.91	0.00	0.97
5	0.05	0.94	0.02	0.90	-0.03	0.98
10	0.07	0.96	0.03	0.92	-0.04	0.96
25	0.07	0.90	0.03	0.88	-0.04	0.89
50	0.06	0.81	0.04	0.79	-0.03	0.84
100	0.07	0.72	0.07	0.70	0.01	0.79

for the three methods. An examination of the data shows that some degree of skewness is present (figure 8). The estimates from the maximum likelihood method are least conservative (have a longer tail), and the L-moments estimates are most conservative with many more values lying in the middle of the distribution. The estimates by the Huff-Angel method rank between the other two methods.

To summarize, there are no meteorological or statistical differences in the methods used. By design, however, the L-moments method gives slightly more conservative values than the other two methods. Since wearedealing with samples from an unknown population, it is difficult to ascertain if more conservative values are better or not. The more conservative estimates may provide a relatively poor fit to the observational data in some cases. For example, in figure 7, the Huff-Angel curve appears to fit the observational data better than the L-moments curve.

The results of the L-moments study for Indiana were mapped, analyzed, and compared with the results of the Huff-Angel method for the 100-year, 24-hour values (figure 9). Although the patterns for both methods are generally similar, some of the spatial detail is lost in the L-moments pattern (figure 9b), especially in southern Indiana. Both maps show a ridge of relatively heavy rainfall extending south-southwest from north-central Indiana to its southwestern border. The L-moments map (figure 9b) indicates an increase in the rainfall gradient northward along theridge—that is, the highest values (8 inches) are indicated in north-central Indians—but the rainfall gradient increases from north to south on the Huff-Angel map (figure 9a). Interstate analyses showed that the ridge continues south-southwest from southwestern Indiana to a maximum in southeastern Illinois and western Kentucky: this agrees with the general climatic gradient of rainfall in these midwestern states. The L-moments high in north-central Indiana (figure 9b) was apparently produced by data from two short-term stations at Logansport and Warsaw. As shown on the Huff-Angel map (figure 9a), the north-central high is squeezed between lows to the west, east, and north, and is the northern extremity of the rainfall high.

In southern Indiana, the Huff-Angel pattern also indicates a low extending northeast from the southern border. This low appears to be an extension of relatively low 100-year rainfall amounts over eastern Indiana, western Ohio, and eastern Kentucky (as shown by interstate analyses). Thus there is relatively strong climatological support for this pattern anomaly. The Indiana low has been essentially eliminated by the L-moments fitting process.

A third region of some disagreement exists in extreme northwestern Indiana. Here, the Huff-Angel map indicates a more intense rainfall center (9 inches) than the L-moments pattern (8 inches). This high has strong climatological support with respect to location and intensity from Valparaiso and LaPorte in Indiana and from stations to the west and northwest in northeastern Illinois (Kankakee, Joliet, and Aurora). The L-moments process recognizes the pattem, but appears to reduce the magnitude more than is supported by the observational data responsible for establishment of the pattern anomaly.

The foregoing examples are presented to emphasize the necessity for integrating meteorological-climatological information and knowledge into rainfall frequency analyses, rather than placing complete dependency on a favored statistical distribution. The strictly statistical approach eliminates the subjectivity factor, but, in so doing, it ignores important scientific information pertinent to the problem. For the Huff-Angel and L-moments methods, the maps of the 100-year recurrence values showed the largest differences. All of the shorter recurrence-interval patterns, however, were in close agreement for the two methods.

Minnesota. In Minnesota, 25 long-term stations were used. Table 8 shows that the Huff-Angel method is in closer

Table 7. Performance of Huff-Angel and L-moments Methods at the 24-Hour, 100-Year Recurrence Interval by 41 Stations in Indiana

Site	*(a) Huff-Angel*	*(b) L-moments*	*Difference*	*Ratio (a):(b)*
Albion	5.3	5.0	0.3	1.1
Anderson	5.6	5.2	0.4	1.1
Angola	6.0	5.4	0.6	1.1
Berne	4.8	5.3	-0.5	0.9
Bloomington	7.9	6.4	1.5	1.2
Bowling Green	7.5	7.2	0.3	1.0
Collegeville	5.6	6.0	-0.4	0.9
Columbus	8.6	7.1	1.5	1.2
Evansville	5.8	6.4	-0.6	0.9
Farmland	5.4	5.5	-0.1	1.0
Ft. Wayne	5.5	4.9	0.6	1.1
Frankfort	5.9	6.0	-0.1	1.0
Goshen College	6.8	5.4	1.4	1.3
Indianapolis	5.4	5.8	-0.4	0.9
Jasper	6.7	7.5	-0.8	0.9
Kokomo	7.9	6.3	1.6	1.3
Logansport	7.1	8.4	-1.3	0.8
Marion	6.0	6.5	-0.5	0.9
Markland Dam	6.2	6.3	-0.1	1.0
Moors Hill	5.7	6.3	-0.6	0.9
Mt. Vernon	6.8	7.9	-1.1	0.9
Oolitic	5.4	6.4	-1.0	0.8
Paoli	6.0	6.3	-0.3	1.0
Plymouth	5.6	5.8	-0.2	1.0
Princeton	9.7	7.9	1.8	1.2
Richmond	6.6	5.5	1.1	1.2
Rockville	7.6	6.9	0.7	1.1
Rushville	5.5	5.7	-0.2	1.0
Scottsburg	7.0	6.4	0.6	1.1
Seymour	6.6	6.1	0.5	1.1

Table 7. Concluded

Site	*(a)* *Huff-Angel*	*(b)* *L-moments*	*Difference*	*Ratio (a):(b)*
South Bend	5.3	5.4	-0.1	1.0
Tell City	7.0	7.8	-0.8	0.9
Terre Haute	6.7	6.3	0.4	1.1
Valparaiso	9.0	7.9	1.1	1.1
Wabash	6.1	5.8	0.3	1.1
Warsaw	7.6	8.2	-0.6	0.9
Washington	7.7	6.4	1.3	1.2
West Lafayette	5.7	5.7	0.0	1.0
Wheatfield	6.2	5.9	0.3	1.1
Whitestown	8.8	7.1	1.7	1.2
Winamac	6.7	6.2	0.5	1.1
Mean	**6.6**	**6.4**	**0.2***	**1.0**
Median	**6.2**	**6.3**	**0.3**	**1.0**
Range	**4.8 to 9.7**	**4.9 to 8.4**	**-1.3 to 1.9**	**0.8 to 1.3**
L-moments < Huff-Angel		**21 (51%)**		
L-moments = Huff-Angel		**1 (2%)**		
L-moments > Huff-Angel		**19 (46%)**		

*This value does not match the one in table 6 because the amounts are to one decimal place in this table.

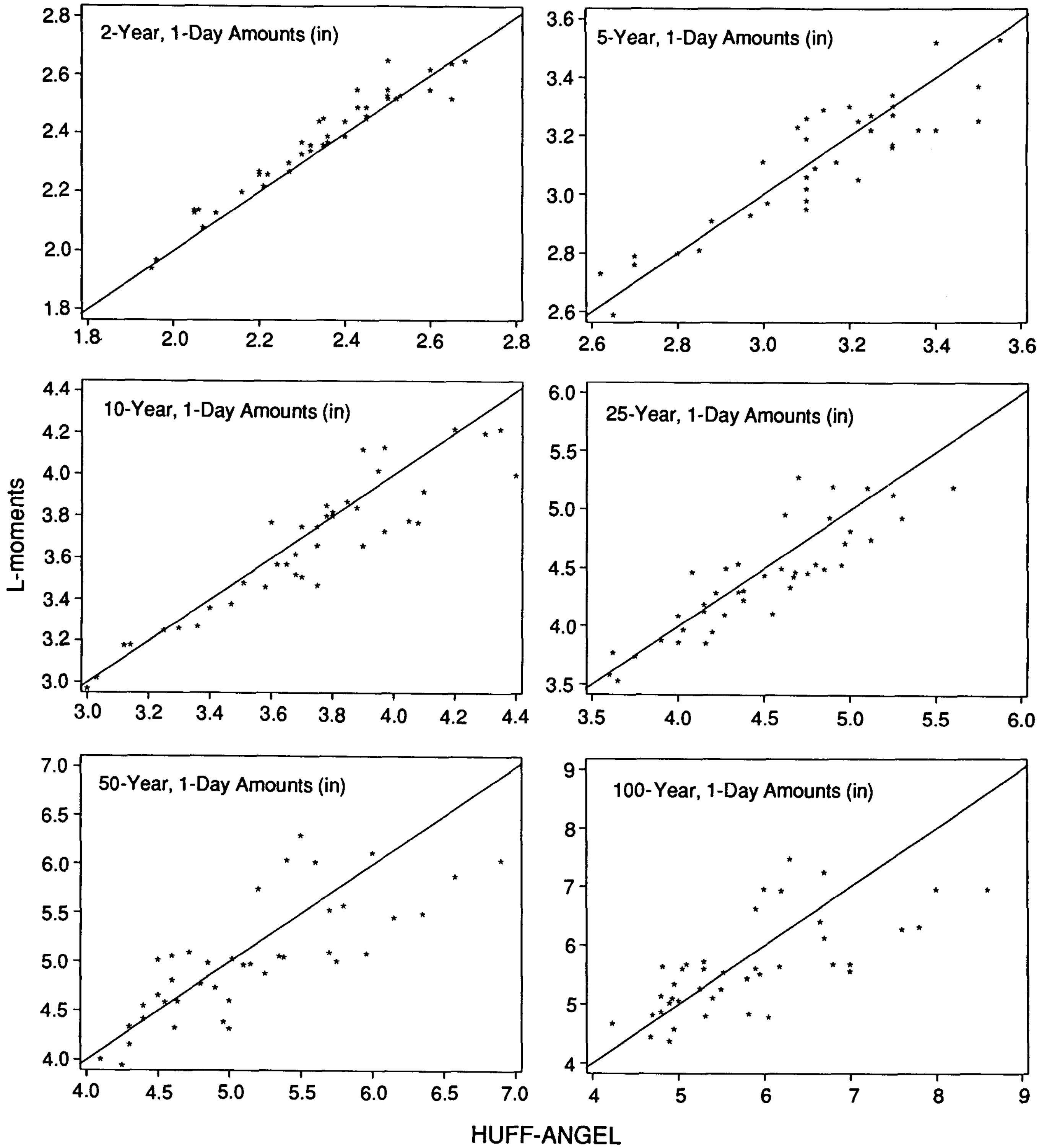

Figure 6. Correlation between L-moments and Huff-Angel methods
for 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals, and 24-hour rainfall amounts

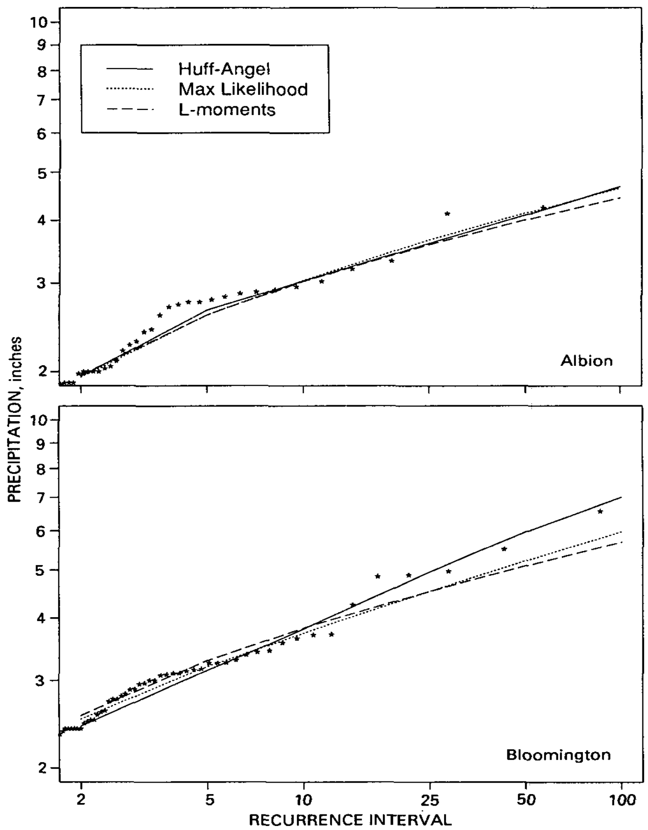

Figure 7. Curve-fitting comparisons for 1-day amounts

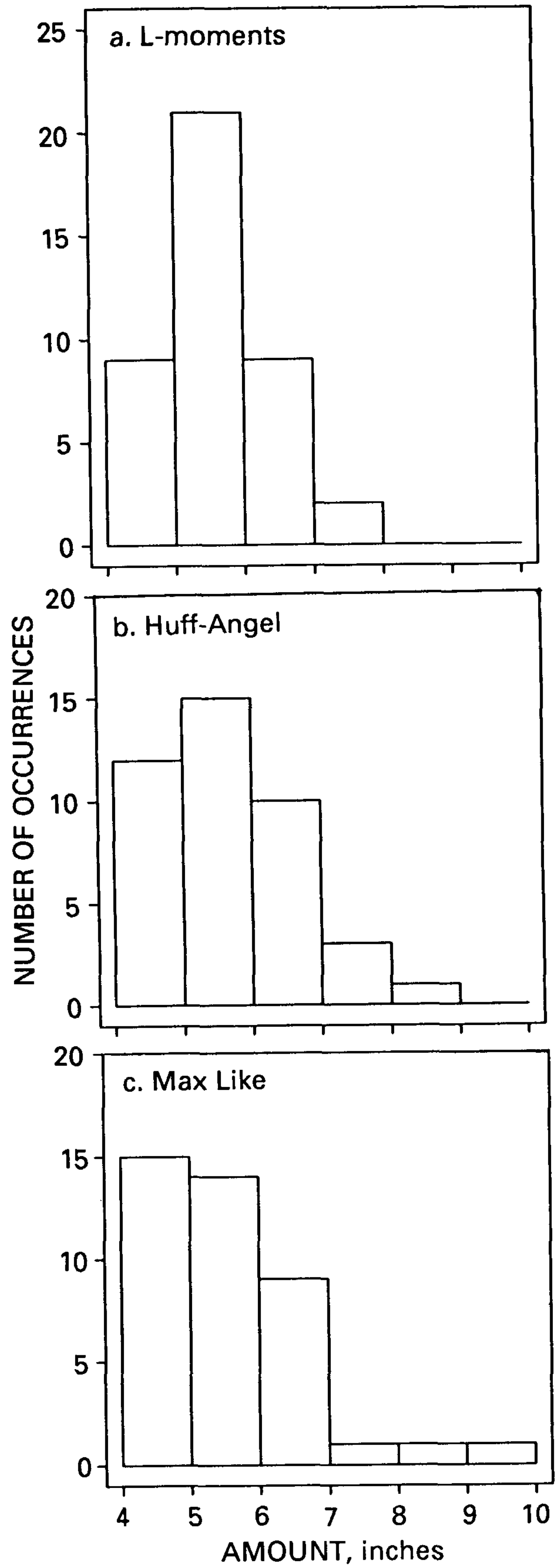

Figure 8. Histogram comparisons for 1-day rainfall amounts in Indiana

agreement with the L-moments method than with the maximum likelihood method. The correlations also remain higher for the 50- and 100-year recurrence intervals than those for Indiana, indicating a better agreement at the longer intervals.

The mean 24-hour, 100-year values for the Huff-Angel, L-moments, and maximum likelihood methods are 5.81, 5.80, and 5.70 inches, respectively. Using a simple Analysis of Variance (ANOVA) model, there are no significant differences in the three methods. The histograms of the 100-year values (figure 10) indicate that the Huff-Angel method more closely approximates a normal distribution than either of the other two methods. Overall, there is less skewness than in the Indiana data. The Huff-Angel method yielded larger values in 10 cases (40 percent), and smaller values in 12 cases (48 percent), compared to the L-moments method. The two methods agreed in 3 cases (12 percent), as shown in table 9.

The differences between the methods are generally neither statistically significant nor (more importantly) meteorologically significant. As in Indiana, there are no systematic biases between the methods except at the longest return period (100 years).

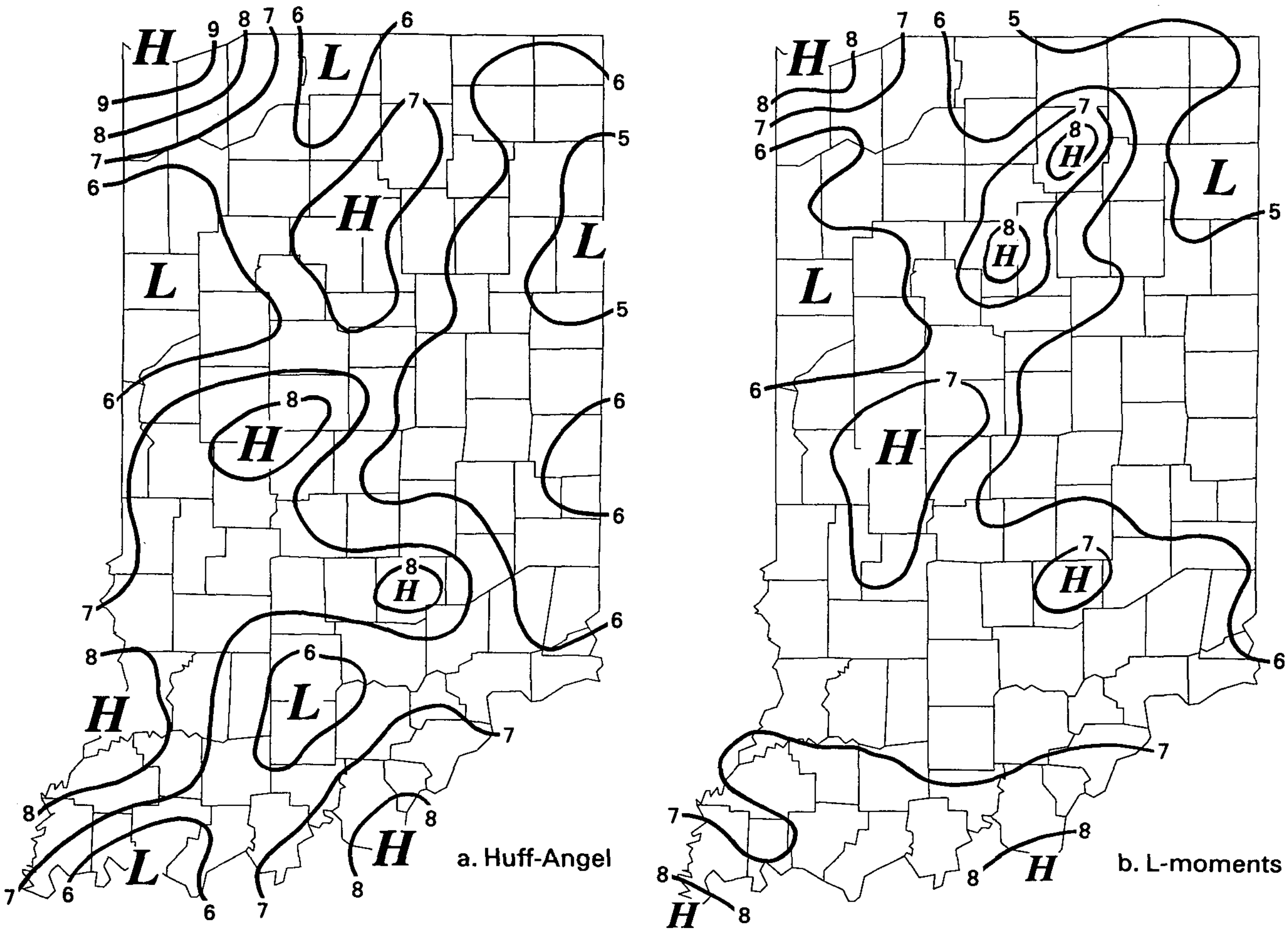

Figure 9. Comparison of Huff-Angel and L-moments methods for 100-year, 24-hour rainfall in Indiana

Table 8. Comparison of Three Methods for Estimating 24-Hour Maximum Amounts at Selected Return Periods for Minnesota

	Huff-Angel vs. Maximum likelihood		*Huff-Angel vs. L-moments*		*Maximum likelihood vs. L-moments*	
Return period	*Mean difference (inches)*	*Corre-lation*	*Mean difference (inches)*	*Corre-lation*	*Mean difference (in.)*	*Corre-lation*
2	0.00	0.94	0.01	0.94	0.01	0.99
5	0.05	0.97	0.05	0.95	0.00	0.98
10	0.11	0.97	0.09	0.92	-0.02	0.96
25	0.14	0.93	0.09	0.89	-0.05	0.93
50	0.15	0.89	0.07	0.85	-0.08	0.90
100	0.11	0.83	0.01	0.80	-0.10	0.87

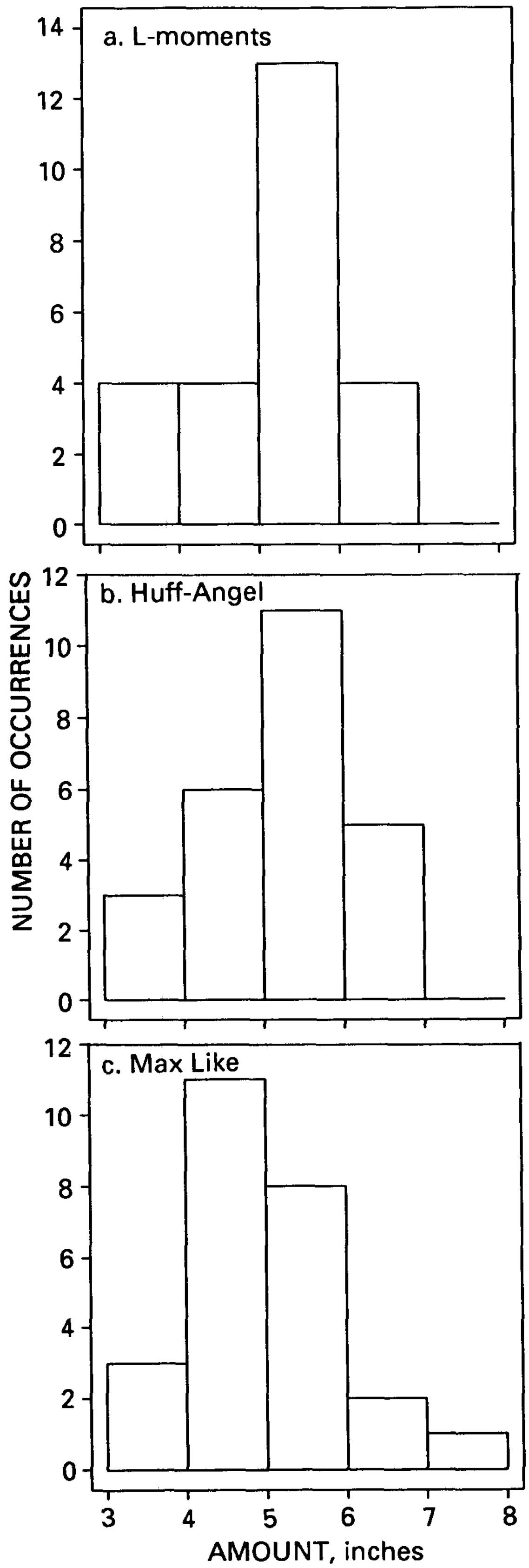

Figure 10. Histogram comparisons for 1-day rainfall in Minnesota

Table 9. Performance of Huff-Angel and L-moments Methods at the 24-Hour, 100-year Recurrence Interval for 25 Stations in Minnesota

Site	*(a) Huff-Angel*	*(b) L-moments*	*Difference*	*Ratio (a):(b)*
Baudette	5.9	4.8	1.1	1.2
Bird Island	5.4	5.4	0.0	1.0
Canby	4.2	5.5	-1.3	0.8
Cloquet	4.7	5.7	-1.0	0.8
Crookston	6.8	6.0	0.8	1.1
Detroit Lake	5.7	4.9	0.8	1.2
Grand Marais	4.2	3.7	0.5	1.1
Grand Meadow	7.0	7.1	-0.1	1.0
Grand Rapids	5.8	5.4	0.4	1.1
Hallock	6.4	5.8	0.6	1.1
Itasca	6.7	6.0	0.7	1.1
Little Falls	5.7	5.7	0.0	1.0
Minneapolis-St. Paul	7.1	6.5	0.6	1.1
Mora	3.9	4.4	-0.5	0.9
Morris	6.5	6.4	0.1	1.0
Pine River Dam	5.0	5.4	-0.4	0.9
Redwood Falls	4.0	4.0	0.0	1.0
Virginia	5.9	6.1	-0.2	1.0
Wadena	5.8	5.9	-0.1	1.0
Waseca	6.4	6.0	0.4	1.1
Willmar	6.2	7.2	-1.0	0.9
Winnebago	7.0	7.1	-0.1	1.0
Winona	5.3	6.0	-0.7	0.9
Worthington	7.0	7.1	-0.1	1.0
Zumbrota	6.7	7.1	-0.4	0.9
Mean	**5.8**	**5.8**	**0.0**	**1.0**
Median	**5.9**	**5.9**	**0.0**	**1.0**
Range	**3.9 to 7.1**	**3.7 to 7.2**	**-1.3 to 1.1**	**0.8 to 1.2**
L-moments < Huff-Angel		**10 (40%)**		
L-moments = Huff-Angel		**3 (12%)**		
L-moments > Huff-Angel		**12 (48%)**		

3. FREQUENCY DISTRIBUTIONS OF HEAVY RAINFALL EVENTS

In our nine-state study, we have used two methods of data analysis and presentation of results: isohytal maps and areal averages. Both methods have advantages and disadvantages, but together they provide adequate information for the varied needs of users. Descriptions of the two methods and the results obtained are presented in this section.

A major problem encountered was how to develop the frequency relations to provide maximum accuracy and reliability for the user. As indicated previously, a major source of sampling error results from poor raingage exposure, inadequate gage maintenance, plus human-induced errors during data entry and data reduction. Nonrepresentative spatial variability may be introduced by rarely experienced severe rainstorms (outlier events), which do not properly reflect the average frequency distribution expected within the 100-year time frame covered by this study. While the time distribution analysis may eliminate outliers with respect to that station, it is much harder to remove systematic biases such as poor exposure or improperly maintained equipment. In both the isohyetal maps and the areal averages, every effort was made to minimize these types of errors.

Point Rainfall Frequency Distributions

Most frequency relations in the past have used isohyetal maps to present the frequency distributions (Yarnell, 1935; Hershfield, 1961). Although this approach can be susceptible to considerable subjectivity and sampling errors, it is useful and familiar to most users. It also facilitates accounting for smaller-scale features in water-control design processes. Examples of small-scale features are increased rainfall found downwind of large urban areas (Huff and Changnon, 1973) and changes associated with small-scale geographical features such as the hills of southern Illinois (Huff et al., 1975). *In the nine-state project, only observations supported by two or more stations have been incorporated into the analyses.*

For each state, isohyetal patterns of point rainfall were developed for the recurrence intervals and rainfall periods indicated earlier (2-year to 100-year; 1-hour to 240-hours). Several variables were used in establishing these patterns: 1) the frequency relations derived for each precipitation station from the recorded data at that station; 2) climatological-meteorological knowledge of the regional precipitation characteristics; and 3) known effects of physiographic features, inadvertent weather modification factors, or both within various regions of the state.

Initially, maps were plotted for each selected recurrence interval and rainfall duration from the individual station frequency distributions. Based strictly on the station data, isohyetal patterns were then lightly sketched to reveal areas where pattern distortions occur. These distortions are most often due to natural and/or human-induced variability (discussed earlier). At this point, consideration of variables (2) and (3) above becomes important in adjusting the isohyetal patterns to overcome unrealistic precipitation differences that may occur within areas of approximately homogeneous precipitation climate. But care must be taken not to overlook real spatial variations related to physiographic and inadvertent weather factors.

For example, in our Illinois pilot study, the isohyetal patterns downwind of the St. Louis metropolitan area showed an expected increase in the occurrence of heavy rainstorms. This was a *real* variation as opposed to a *variability distortion* (Changnon et al., 1977). An increase in the frequency distribution of heavy storm events in western Illinois was determined to be real and related to a well-recognized thunderstorm breeding area in the Missouri Ozarks located to the southwest (upwind of the high identified in the isohyetal analyses). Similarly, climatic variations produced substantial changes in the heavy rainstorm distribution characteristics from north to south in the state. There were also several areas, however, in which no real cause could be found for substantial differences in precipitation within relatively short distances. These differences were considered sampling vagaries *(unreal variation)* and the isohyetal pattern was adjusted to agree with the distributions indicated by other stations in the surrounding region. *In summary, we believe that careful attention to variables (1), (2), and (3) will produce logical, reliable isohyetal patterns that closely approximate the true distribution characteristics of heavy rainstorms within each state and for the nine-state region.* This analytical philosophy was followed throughout the study.

The adjusted isohyetal patterns resulting from the foregoing analytical procedures are shown in the maps in part 2 of this report for selected recurrence intervals ranging from 2 years to 100 years and rainfall periods varying from 1 hour to 10 days. To determine frequency values for rainfall periods of less than 1 hour, recurrence intervals of less than 2 years, or both, tables 3 and 4 in chapter 1 provide information for computing amounts for rain periods as small as 5 minutes and recurrence intervals as short as 2 months. Note that isohyets extending over the Great Lakes are for maintaining continuity and may not reflect actual conditions over the lakes.

The isohyetal gradient sometimes varies appreciably between consecutive maps in part 2. This was necessary to maintain proper display of the spatial pattern characteristics (highs, lows, troughs, ridges, etc.) indicated by the data. It was considered pertinent to show all features of the isohyetal patterns that persisted throughout all or most of the storm durations and recurrence intervals provided in the map series. These features reflect the combined effects of precipitation climate and other factors such as topography (hills, valleys, and large water bodies) and urban influences.

Areal Mean Frequency Distributions

Another approach to the spatial distribution problem is a method used by Huff and Neill (1959) in an earlier Illinois study to alleviate the consequences of spatial variability. The state was divided into regions of approximately homogeneous climate with respect to heavy rainstorm events. Average relations were then developed for each division. In our Midwest study, however, consideration of available climate information on the distribution of heavy rainfall and climatological-meteorological knowledge of storm system characteristics indicated that the well-established NWS climatic divisions could be used to divide the states. The only exception was Illinois, where a slight change was made in the established divisions to more accurately reflect a combined effect from the Ozarks and the Mississippi River valley in the western part of the state. While NWS climate division averages are recommended by the authors for most purposes, hydrologists often prefer to use isohyetal maps (when working with basins that cover two or more climate divisions for example).

The foregoing technique does not eliminate the potential sampling errors in the data samples, but it does moderate their effect in regions of similar precipitation climate, and should produce better estimates of the true distribution of heavy rainstorms across the nine-state region. Unless the divisions are properly selected, however, the averaging technique may mask real small-scale effects, such as those induced in the vicinity of the Great Lakes or the Missouri Ozarks. This problem would become more acute in regions incorporating major changes in topography, such as the Rocky Mountain and Appalachian regions.

Frequency relations for sectional mean rainfall for each state are shown in the sectional mean frequency distribution tables in part 2. Rainfall values are provided for recurrence intervals ranging from 5 minutes to 10 days, and for recurrence intervals varying from 2 months to 100 years in each section.

Use of the tables is indicated by the following example for Indiana (table 2 in part 2). Assume a user wishes to determine the 24-hour rainfall amount expected to occur, on the average, of once in 25 years at a given location in the Northwest Climate Section. Move down the duration column to 24 hours, which corresponds to 5.22 inches in the 25-year column. This is the *average* 25-year amount for the section. *In a specific 25-year period, however, this value may vary somewhat between individual points due to random spatial variability within the relatively homogeneous precipitation climate of the section.*

4. TIME DISTRIBUTIONS OF RAINFALL IN HEAVY STORMS

Modern runoff models used in the design of urban and small-basin water-control structures, necessitate defining the time distribution characteristics within heavy rainstorms. Such information is also pertinent to the use of the frequency distributions presented in this report. Huff (1990) used data from long-term operation of three recording raingage networks in Illinois to develop time distribution relationships. Although based upon Illinois data, these relationships should be applicable to our nine-state region and other locations of similar precipitation. The Illinois study was undertaken because earlier time distribution models, developed by the Soil Conservation Service (1972) and others, were not considered satisfactory for use in the Midwest's heavy rainstorms.

Method and Results of Analysis

The time distributions were expressed as cumulative percentages of storm rainfall and storm duration to enable valid comparisons between storms and to simplify analyses and presentation of data. Relations were developed for point rainfall and for areas of 10 to 400 square miles. Areal groupings showed only small changes in the time distributions with increasing sampling area. Therefore, average relations were determined for point rainfall and for areas of 10 to 50 and 50 to 400 square miles. Rainfall distributions were grouped according to whether the heaviest rainfall occurred in the first, second, third, or fourth quarter of a storm. For each quartile grouping, a family of curves was then derived to provide a quantitative measure of the interstorm variability expected to occur within that group. The interstorm variability was then expressed in probability terms for user application.

Tables 10-12 have been abstracted from the Huff report (1990). Table 10 shows the median time distribution of heavy storm rainfall at a point, table 11 for areas of 10 to 50 square miles, and table 12 for areas of 50 to 400 square miles. These tables show cumulative percent of rainfall expressed as a function of the cumulative percent of total storm time (storm duration) for first-, second-, third-, and fourth-quartile storms.

The median distributions are most commonly used by hydrologists and others. The reader is referred to Huff (1990) for additional information on time distributions for probability levels ranging from 10 to 90 percent. For example, table 13, assembled from the families of curves provided in the referenced report, shows time distributions at the 10, 50, and 90 percent probability levels in first-quartile storms for areas of 50 to 400 square miles. The 10 and 90 percent distributions are useful for estimating runoff relations in the more extreme types of time distributions.

Application of Results

For mean rainfall on *small basins* (≤ 400 square miles), the first- and second-quartile storms were found to be most prevalent (33 percent each), followedby third-quartile storms (23 percent), and fourth-quartile storms (11 percent). For *point rainfall,* first-quartile storms were most prevalent (37 percent), followed by second-quartile storms (27 percent), third-quartile storms (21 percent), and fourth-quartile storms (15 percent).

Storms with durations of 6 hours or less, 6.1 to 12 hours, 12.1 to 24 hours, and greater than 24 hours tended to be associated with first-, second-, third-, and fourth-quartile distributions, respectively.

For most structural design applications, use of the quartile type occurring most often is recommended for the design duration under consideration. For example, use the first-quartile curves for design durations of 6 hours and less, and use the second-quartile distributions for designs involving storm durations of 6.1 to 12 hours.

Using Results in Structural Design Problems: Case Studies

Case One

First, assume that a design based on a 5-inch rainstorm of 6-hour duration is being determined for a given point, based on a median or average time distribution. In this case, a first-quartile median curve would be appropriate. Then, from table 10, one can determine that 33 percent of the rainfall total (1.67 inches) would occur in the first 10 percent (36 minutes) of the storm. Similarly, 60 percent (3.00 inches) would be expected to occur in the first 25 percent (90 minutes) of the storm, and 82 percent (4.10 inches) in the first 50 percent (3 hours) of the rain period.

Case Two

Now, assume that the same design problem involves a 5-inch, 6-hour storm on a basin encompassing 100 square miles. Then, refer to table 12. In this case, the median values indicate that the areal average would be 17 percent of the rain (0.85 inch) in the first 10 percent (36 minutes) of a *first-quartile storm.* During the first 25 percent of the storm (90 minutes), 63 percent of the rain (3.15 inches) would fall, and during the first 50 percent (3 hours), 86 percent (4.30 inches) would fall.

Case Three

If a *second-quartile* instead of a *first-quartile storm* were used as the design basis for the 100-square-mile area, only 4 percent (0.20 inch) would occur in the first 10 percent of the storm. This would increase to 21 percent (1.05 inches) in the first 25 percent (90 minutes) of the storm period.

Then a rapid increase to 73 percent of the total rainfall (3.65 inches) would occur by the halfway point of the storm event.

Table 10. Median Time Distributions of Heavy Storm Rainfall at a Point

Cumulative storm time (percent)	*Cumulative storm rainfall (percent) for given storm type*			
	First-quartile	*Second-quartile*	*Third-quartile*	*Fourth-quartile*
5	16	3	3	2
10	33	8	6	5
15	43	12	9	8
20	52	16	12	10
25	60	22	15	13
30	66	29	19	16
35	71	39	23	19
40	75	51	27	22
45	79	62	32	25
50	82	70	38	28
55	84	76	45	32
60	86	81	57	35
65	88	85	70	39
70	90	88	79	45
75	92	91	85	51
80	94	93	89	59
85	96	95	92	72
90	97	97	95	84
95	98	98	97	92

Table 11. Median Time Distributions of Heavy Storm Rainfall on Areas of 10 to 50 Square Miles

	Cumulative storm rainfall (percent) for given storm type			
Cumulative storm time (percent)	*First-quartile*	*Second-quartile*	*Third-quartile*	*Fourth-quartile*
5	12	3	2	2
10	25	6	5	4
15	38	10	8	7
20	51	14	12	9
25	62	21	14	11
30	69	30	17	13
35	74	40	20	15
40	78	52	23	18
45	81	63	27	21
50	84	72	33	24
55	86	78	42	27
60	88	83	55	30
65	90	87	69	34
70	92	90	79	40
75	94	92	86	47
80	95	94	91	57
85	96	96	94	74
90	97	97	96	88
95	98	98	98	95

Table 12. Median Time Distributions of Heavy Storm Rainfall on Areas of 50 to 400 Square Miles

	Cumulative storm rainfall (percent) for given storm type			
Cumulative storm time (percent)	*First-quartile*	*Second-quartile*	*Third-quartile*	*Fourth-quartile*
5	8	2	2	2
10	17	4	4	3
15	34	8	7	5
20	50	12	10	7
25	63	21	12	9
30	71	31	14	10
35	76	42	16	12
40	80	53	19	14
45	83	64	22	16
50	86	73	29	19
55	88	80	39	21
60	90	86	54	25
65	92	89	68	29
70	93	92	79	35
75	95	94	87	43
80	96	96	92	54
85	97	97	95	75
90	98	98	97	92
95	99	99	99	97

Table 13. Time Distributions of Areal Mean Rainfall on 50 to 400 Square Miles in First-Quartile Storms at Probability Levels of 10, 50, and 90 Percent

	Cumulative storm rainfall for given storm probability		
Cumulative storm time (percent)	*10 percent*	*50 percent*	*90 percent*
5	24	8	2
10	50	17	4
15	71	34	13
20	84	50	28
25	89	63	39
30	92	71	46
35	94	76	49
40	95	80	52
45	96	83	55
50	97	86	57
55	98	88	60
60	98	90	63
65	98	92	67
70	99	93	72
75	99	95	76
80	99	96	82
85	99	97	89
90	99	98	94
95	99	99	97

5. SEASONAL DISTRIBUTIONS OF HEAVY RAINFALL

Background

In the design of some hydrological systems or structures, it is pertinent to know the seasonal characteristics of heavy rainstorms as well as the frequency distributions of maximum storm rainfall amounts for various storm durations. For example, when the soil is near saturation, a spring storm of intensity equivalent to a 5-year recurrence interval may have different consequences than had the same storm occurred in a drier summer month. Winter storms, while generally producing less precipitation than summer storms, can be devastating if they occur over frozen ground. With or without snow cover, these winter storms can cause rapid flooding. Heavy rainfall storms in the early spring and late fall may lead to higher rates of erosion due to tillage practices and a lack of vegetative cover.

Unfortunately, a lack of resources prohibited an extensive analysis of seasonal rainfall frequencies, comparable to the annual analysis. This report, however, presents three studies by the authors to provide some insight regarding the behavior of heavy rainstorms across the seasons in the Midwest.

Analysis and Results

The studies used the traditional four seasons: winter (December-February), spring (March-May), summer (June-August), and fall (September-November).

Seasonal Precipitation

Prior to a discussion of heavy rainstorms, it is helpful to understand the seasonal change in temperature and precipitation in the Midwest. In general, summer in the Midwest is not only the warmest season, but also the wettest one. Mean July precipitation ranges from 5.2 inches in Kentucky to 2.4 inches in Michigan. By contrast, mean January precipitation ranges from 4.0 inches in Kentucky to 0.6 inches in Minnesota. The largest differences in precipitation occur in winter, with the northern states (Minnesota, Wisconsin, and Michigan) receiving 50 to 80 percent less precipitation than in summer. Table 14 shows the annual precipitation and percent contribution by season. In general, Kentucky is the wettest state in the region with a nearly uniform distribution of precipitation throughout the four seasons. Minnesota is the driest state with 42 percent of its precipitation falling in summer and only 9 percent in winter. For all nine states combined, summer provides the largest contribution, followed by spring, fall, and winter with 32,27,25, and 16 percent, respectively.

In the Midwest, the temperatures for all four seasons and the annual mean temperature decrease northward (table 15). In general, Kentucky is the warmest state while Minnesota is the coldest state. In winter, Kentucky is the warmest state with much of its precipitation falling as rain rather than snow.

Seasonal Distribution of Heavy Rainstorms

The number of heavy storms in the Midwest changes from season to season as well as from state to state. Table 16 shows the seasonal contribution of the top-ranked, 1-day storms for 275 stations in the region. Three-fourths of such storms occur in the summer. The summertime maximum is most pronounced in Minnesota, Iowa, Illinois, Indiana, and Wisconsin. This is probably due to the shorter convective season in the northern latitudes. In Michigan, Missouri, and Ohio, the fall also contributes a significant number of storms. It is not known what physical process causes this effect in these three geographically diverse states. Missouri is also noteworthy in that 13 percent of its heavy storms occur in winter. Overall, the largest number of storms occur in June, July, August, and September.

Similar results were found for the top-ranked 2-, 3-, 5-, and 10-day totals. In each case, the largest percentage of storms occurred in the summer. A significant number of the storms in Kentucky, however, occurred in winter for these longer durations. Similar results were also obtained for all the annual maximum storms at each station. Summer continued to be the season of most frequent occurrences although the percentages were closer to 50 percent of the total (compared to 75 percent for the top-ranked storms). The contributions in spring and fall were from 20 to 25 percent of the total.

While summer is the dominant season for the Midwest for 1-day storms, an analysis of the top-ranked storms occurring in the warm season (April - September) compared with the cold season (October - March) indicates that the southernmost part of the region is more likely to experience its heaviest storms in the cold season at longer durations. This feature becomes most predominant in the 10-day storms. The top-ranked 10-day storms (figure 11) occur mostly in the cold season for the southern half of Missouri and for a large, coherent region along the Ohio River valley. These events are probably associated with the synoptic-scale cyclones that pass through those regions during those months. This pattern is not found for the 1-day storms, but becomes increasingly evident for the 2-, 3-, and 5-day storms. Because this pattern only occurs in the southern portions of Missouri, Indiana, and Ohio, it is not discernible in the state values in table 16.

In general, more of the heavier storms occurred in summer than in any other season, while the least number occurred in winter for shorter durations. In states with a shorter convective season (e.g., Minnesota), the peak in summer was more prominent than in regions where substantial convective activity may occur throughout the year (e.g., Kentucky).

Rainfall Frequencies by Season

The seasonal distribution of storms suggests that the magnitude of the seasonal rainfall frequency curves may change as one moves northward. For example, in the southern region where the number of storms is more evenly distributed

Table 14. Seasonal Rainfall Distribution (inches) for 1961-1990 by State

State	*Annual rainfall*	*Winter (percent)*	*Spring (percent)*	*Summer (percent)*	*Fall (percent)*
Illinois	38.69	16.7	29.1	29.8	24.3
Indiana	40.59	18.8	28.9	29.1	23.1
Iowa	33.08	9.2	28.2	38.1	24.6
Kentucky	48.15	23.6	28.6	25.9	22.0
Michigan	32.17	17.4	24.0	30.0	28.6
Minnesota	26.63	8.7	25.1	41.8	24.5
Missouri	41.15	15.8	29.4	28.5	26.2
Ohio	38.14	19.1	28.1	29.8	23.0
Wisconsin	31.68	11.1	25.4	36.6	26.9
Midwest	36.70	15.6	27.4	32.2	24.8

Table 15. Seasonal Temperature Distribution (°F) for 1961-1990 by State

State	*Annual*	*Winter*	*Spring*	*Summer*	*Fall*
Illinois	51.6	27.2	51.5	73.3	54.2
Indiana	51.4	28.3	51.0	72.2	53.9
Iowa	47.6	20.7	48.0	71.7	50.2
Kentucky	55.3	34.7	55.1	74.1	57.0
Michigan	44.2	20.7	42.3	66.0	47.6
Minnesota	40.8	11.0	41.3	66.9	43.9
Missouri	54.3	31.3	54.4	75.2	56.2
Ohio	50.3	28.3	49.6	70.6	53.0
Wisconsin	42.9	16.0	42.7	66.8	46.1
Midwest	48.7	24.2	48.4	70.8	51.4

Table 16. Seasonal Contribution of Top-Ranked 1-Day Storms

State	Winter (percent)	Spring (percent)	Summer (percent)	Fall (percent)	Most frequent month
Illinois	3.3	20.0	65.0	11.7	July
Indiana	2.4	17.1	63.4	17.1	July
Iowa	0.0	2.3	72.1	25.6	August
Kentucky	4.0	20.0	52.0	24.0	June
Michigan	2.3	14.0	39.5	44.2	September
Minnesota	0.0	7.7	80.8	11.5	August
Missouri	13.0	10.9	41.3	34.8	September
Ohio	4.9	14.6	48.8	31.7	July, September
Wisconsin	0.0	5.0	76.7	18.3	August
Midwest	3.4	12.2	60.3	24.2	July, August

across the seasons, one would expect similar seasonal rainfall frequency curves. In the northern region where there is a noticeable summer maximum in heavy storms, one would expect the summer rainfall frequency curves to be much higher than those for the other seasons. To examine this further, a transect was drawn from southeast Kentucky to northwest Minnesota, and 12 stations were chosen at approximately equal intervals (figure 12). Seasonal time series were developed for the period 1949-1990 (42 years) for all four seasons. The 1-day rainfall frequency amounts were calculated for 2-, 5, 10-, 25-, and 50-year recurrence intervals using the maximum likelihood method and the Generalized Extreme Value (GEV) distribution (Farago and Katz, 1990).

For each station, the four rainfall frequency curves are plotted for comparison (figure 13). The stations are arranged from north to south. It is readily apparent that the wintertime frequency curves are much lower than the other frequency curves in the northern states. At the same time, the summertime curves are nearly equal to the annual curves in the north. At the southern stations, the seasonal curves are closer together, and the summertime curves are not as close to the annual curves.

To generalize these findings, the ratio of the values of the seasonal curves to the annual curves was calculated for all recurrence intervals. Because the ratio did not change significantly from one recurrence interval to the next, an average for all recurrence intervals was calculated for each season at each station. These ratios are expressed as percentages in figure 14. Keeping in mind that a lower station number represents higher latitudes, the percentage of the winter values to annual values is very low in Minnesota, and increases dramatically to the south. A similar effect is noticeable, although not as pronounced, in the relationship for spring. On the other hand, the percentages of summer and fall values show little change with latitude. The summer percentages are all within 20 percent of the annual values.

In practice, the seasonal distribution of heavy rainfall may become important with respect to antecedent soil moisture conditions. For example, the USDA Soil Conservation Service (1968) discusses three categories of antecedent moisture conditions (AMC):

Type I. Soils are dry but not to the wilting point or when plowing or cultivation occurs (typical at times in spring, summer, and fall).

Type II. Average conditions precede previous annual maximum floods (the average case).

Type III. Heavy rainfall or light rainfall and low temperatures have occurred during the last five days prior to the given storm, and the soil is nearly saturated (particularly in late fall to early spring, especially in the southern third of the Midwest region).

Assuming a soil with a moderate infiltration rate (hydrological soil group B), the curve number for a row crop (straight row) can range from 61 to 90 (see table 17). This

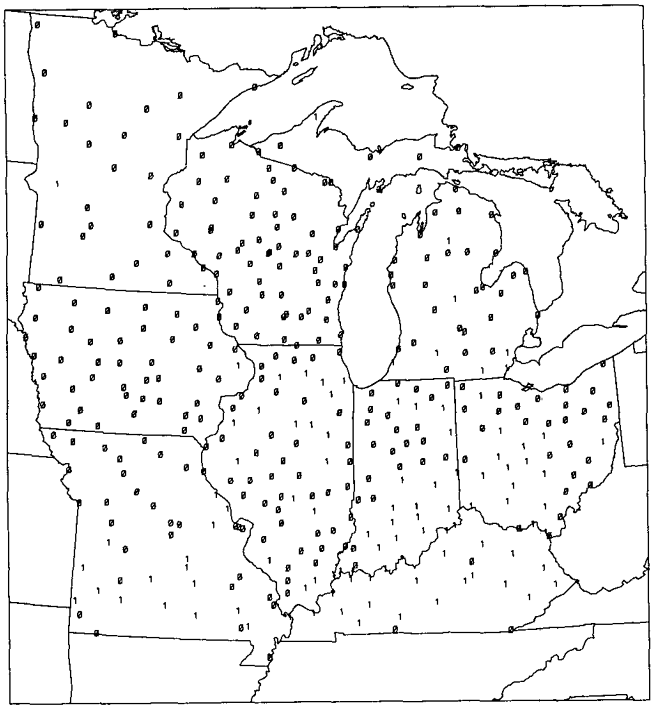

Figure 11. Top-ranked 10-day storms by season (1 = cold, 0 = warm)

Figure 12. Stations used in comparing seasonal variations in frequency curves

Table 17. Curve Number (CN) and Runoff(Q) Values from Three Antecedent Moisture Conditions (AMC) for Row Crops

AMC	*CN*	*Q (inches)*
I	61	2.0
II	78	3.8
III	90	5.4

wide range of curve numbers can lead to large differences in runoff. Assuming a 6-inch, 24-hour, 100-year rainfall, the calculated direct runoff can range from 2.0 to 5.4 inches, depending on the antecedent soil conditions (table 17). Therefore, in places with typically heavy winter precipitation (Kentucky), AMC type III can lead to much higher runoff values than by using the annual amounts and AMC type II.

Summary

Differences in the seasonal rainfall frequency values are evident due to differences in the seasonal contribution of heavy rainstorms. In the Midwest, these differences can be quite significant in the northern states where summer precipitation dominates. In the southern states, significant heavy storms occur in all seasons. For example, in southern Missouri, Indiana, and Ohio, the heaviest amounts for the longer duration storms (5-day and 10-day) are most likely to occur in the cold season. The impacts of all heavy rainstorm events will vary from season to season, depending on soil moisture, state of the soil (frozen or nonfrozen), and vegetative cover.

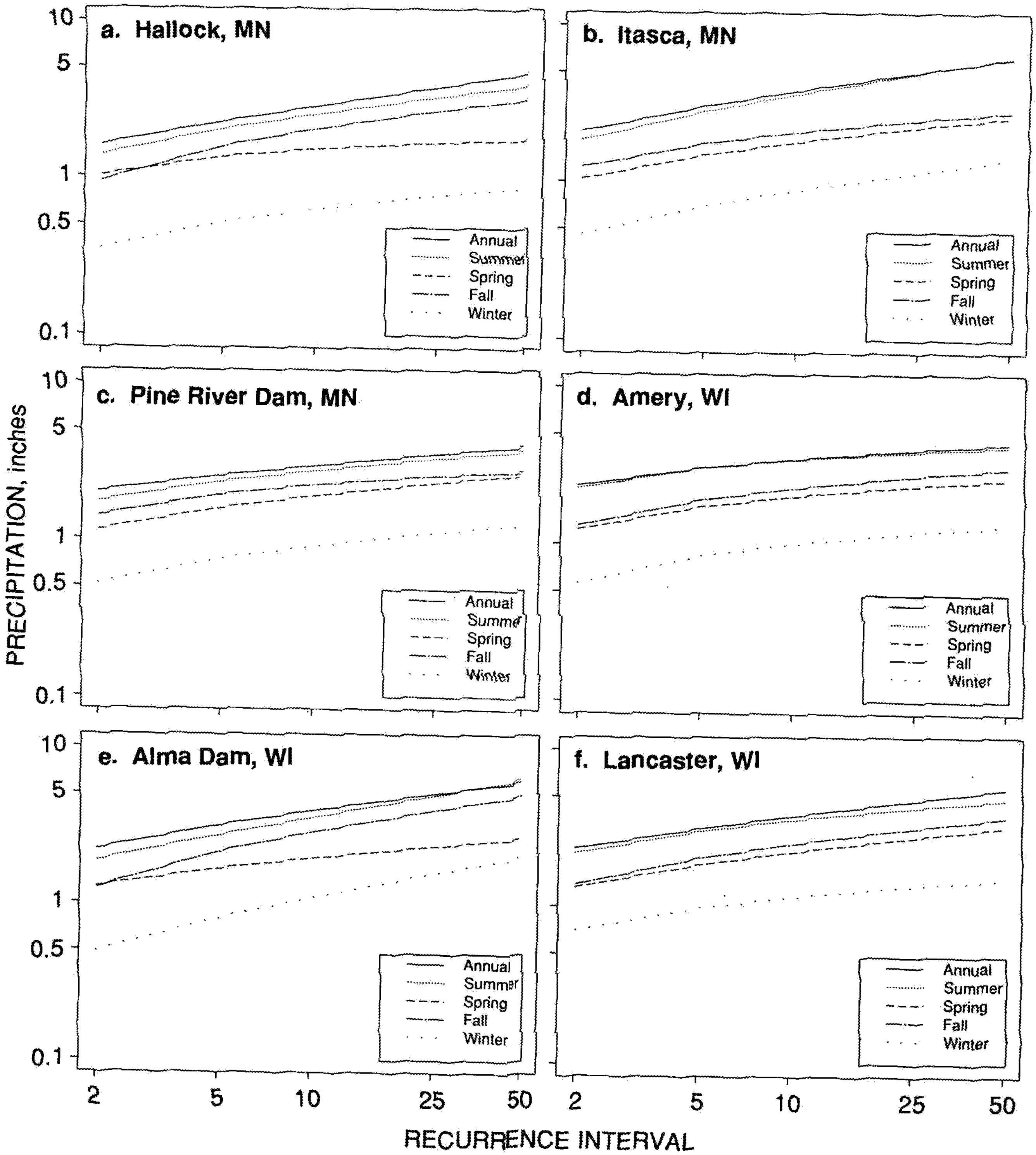

Figure 13. Seasonal rainfall frequency curves

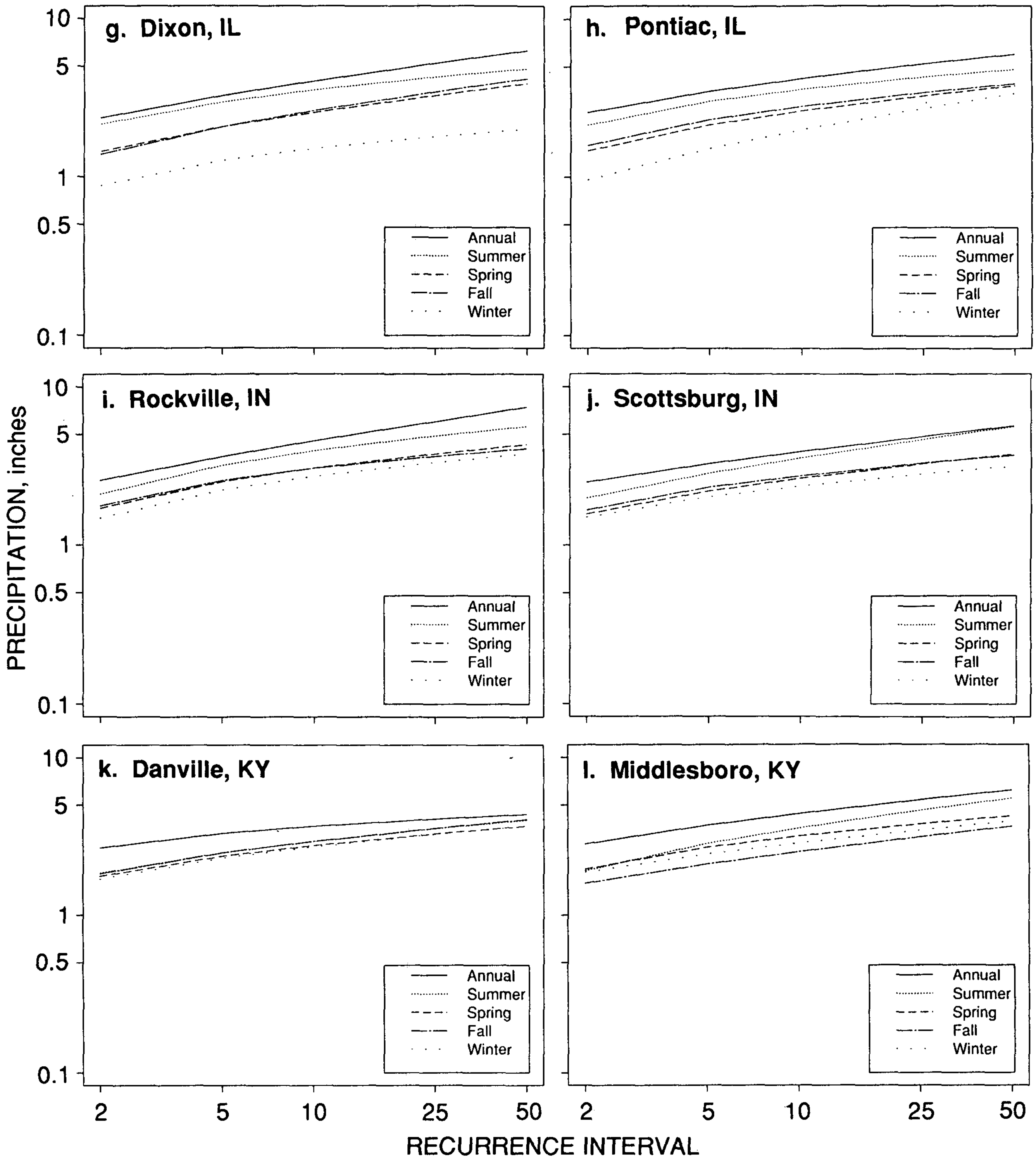

Figure 13. Concluded

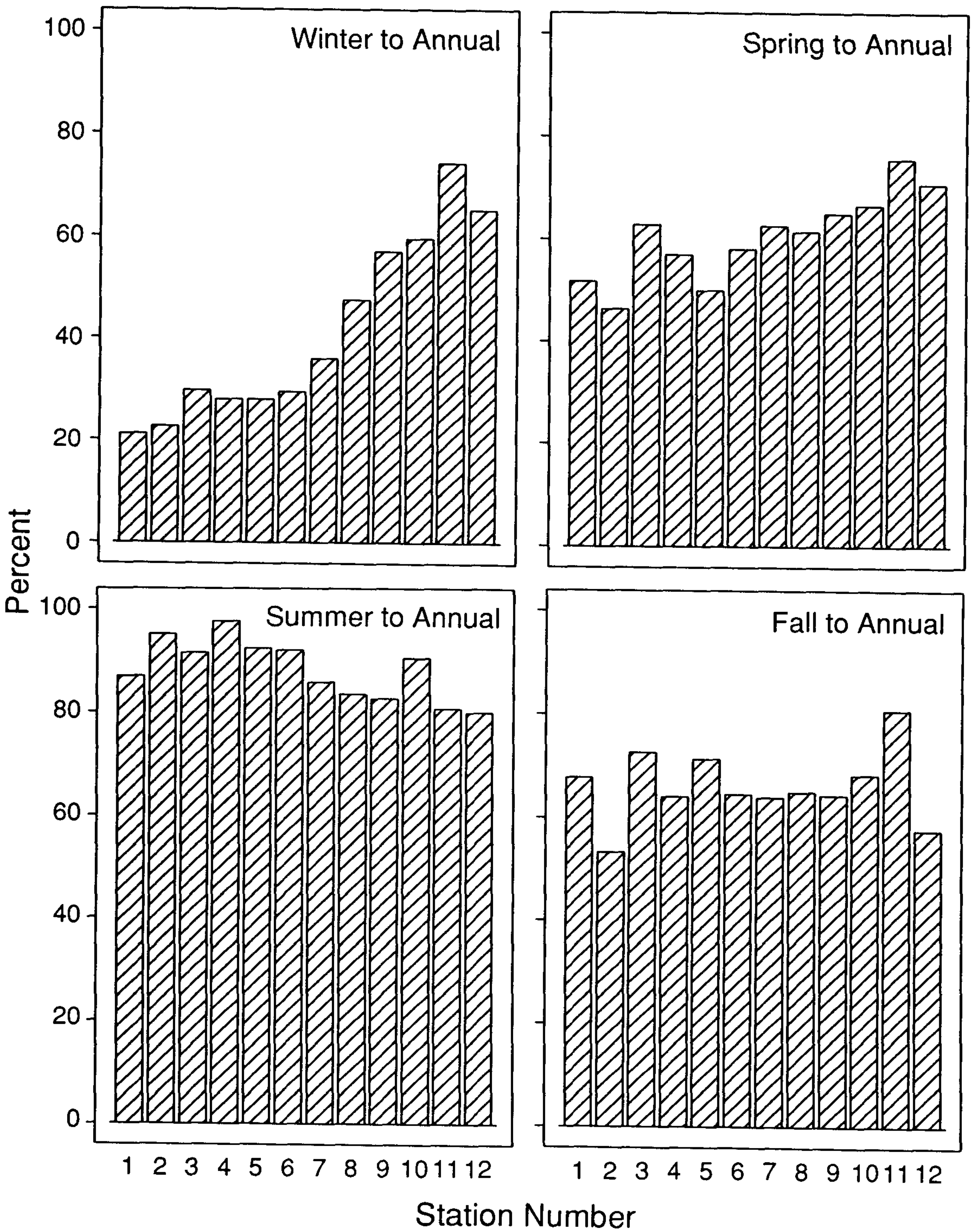

Figure 14. Ratio of seasonal curve to annual curve amounts expressed in percentages

6. FLUCTUATIONS IN FREQUENCY DISTRIBUTIONS OF HEAVY RAINSTORMS IN THE MIDWEST

Background

Heavy rainfall events are important in the design of water-related structures (e.g., storm sewer systems), in agriculture, in weather modification, and in monitoring climate change. Traditionally, hydrometeorologists have fit various statistical distributions to historical precipitation data to derive the recurrence intervals for selected storm durations. The assumption underlying the derivation of these values has been that there are year-to-year variations in the precipitation record, but the time series is stationary without major temporal fluctuations or long-term trends during the typical design life (50 to 100 years for most water-related structures). This assumption allows the use of all available historical data with equal weight. However, a preliminary study of Illinois by Huff and Changnon (1987) using 1901-1980 data for 22 stations investigated the possibility of a climatic trend in the distribution of heavy rainstorms in Illinois. A comparison of l-day and 2-day rainfall amounts for 2-year to 25-year recurrence intervals showed significant changes in the northern two-thirds of the state for two 40-year periods (1901-1940 and 194l-1980). This was supported by an earlier study of Illinois climate fluctuations (Changnon, 1984), which showed sizable shifts in total precipitation and thunderstorms for 1901-1980.

Analytical Approach and Results

Illinois

In Illinois, a 61-station sample was used to investigate the properties of the frequency distribution of maximum 24-hour and 48-hour storms derived from two 40-year periods (1901-1940 and 1941-1980). The frequency distributions were derived from the partial duration series of rainstorms for each station. The frequency values were obtained from log-log curves derived for each station. The l-day and 2-day values obtained were converted to maximum 24-hour and 48-hour amounts using the transformation factors 1.13 and 1.05, respectively, derived by Hershfield (1961) and Huff and Neill (1959).

The change between the two periods was expressed in terms of the ratio of values from the 1941-1980 period to those for the 1901-1940 period. A value > 1 indicates an increase in intensity, and a value < l indicates a decrease in intensity for a given storm duration and recurrence interval.

The results of the expanded study in Illinois supported the findings of Huff and Changnon (1987). For the two 40-year periods, there is a general increase in the northern two-thirds of the state and a slight decrease in the southern one-third. Figure 15 shows the pattern of ratios (1941-1980/1901-1940) calculated for 24-hour, 2-year rainfalls derived from station frequency curves based on data for each 40-year period. The pattern in the figure holds for the 5-year, 10-year, and 25-year recurrence intervals at the 24-hour and 48-hour storm durations (Huff and Angel, 1989). The ratio for the two 40-year periods had similar spatial behavior for the two storm durations. Within the state, 62 percent of the stations had ratios exceeding 1.00, and 36 percent exceeding 1.10 for 24-hour storms with a recurrence interval of 2 years. For a 2-year, 48-hour rainstorm, 68 percent of the stations had ratios exceeding 1.00,40 percent exceeding 1.10. The data were inadequate to derive 50-year and 100-year ratios from the station frequency curves.

The results for the two 40-year periods are supported by other studies in Illinois. In a study of the 1901-1980 period, Changnon (1985) found gradual changes to a wetter regime in Illinois that was most pronounced in the last 15 years (1965-1980). In an earlier study, Changnon (1983) noted increased flooding in recent years. especially in northeastern Illinois. This agrees with the 20 to 40 percent increase in the heavy rainfall distribution for northeastern Illinois found in our study.

Table 18 illustrates the effect of climatic variations between the two 40-year periods on heavy rainstorm frequency distributions (Huff and Angel, 1990). For 24-hour maximum rainfall at average recurrences of 2,5, and 10 years, six stations were selected to reflect different degrees of change during the 80-year sampling period. At Rockford in

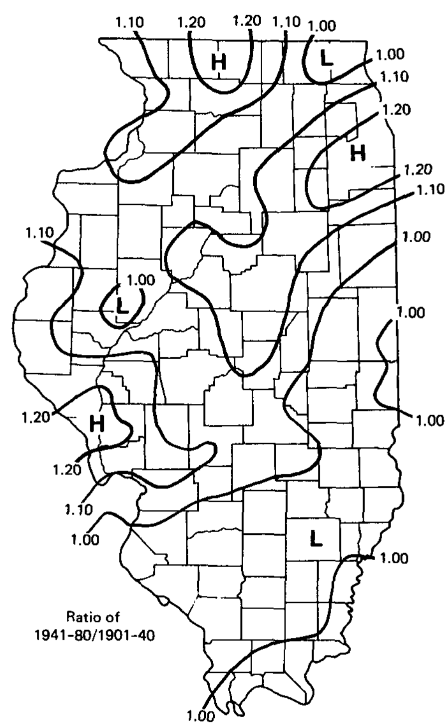

Figure 15. Ratio for two 40-year periods (1941-1980 and 1901-1940) for 2-year, 24-hour storms

Table 18. Examples of Variation in Recurrence Intervals Indicated for Maximum 24-Hour Rainfall Between Frequency Curves Derived from 1901-1940 and 1941-1980 Data in Illinois

Recurrence interval (1941-1980 curves)	*Equivalent Recurrence Interval for Selected Locations (1901-1940 curves)*					
	Rockford (NW)	*Kankakee (E)*	*Quincy (W)*	*Peoria (C)*	*Effingham (ESE)*	*Belleville (SW)*
2	5	5	5	3+	3+	2-
5	15	16	13	9	19	4
10	35	35	27	17	21	8

northern Illinois, the 2-year value on the frequency curve derived from 194l-1980 data corresponds to the 5-year value on the 1901-1940 curve. Similarly, the 5-year amount estimated by the 1941-1980 curve corresponds to the 15-year amount on the 1901-1940 curve, and the 10-year value corresponds to the 35-year value. If a structure with a 70-year lifetime was designed for rainstorms with a 35-year recurrence interval using the 1901-1940 data it would be implicitly expected to be exposed to only two such storms. The 1941-1980 data, however, suggests it might be exposed seven times to a storm of such magnitude over 70 years (on average). The underestimates would be most pronounced in northern and western Illinois (Rockford, Kankakee, and Quincy).

The Midwest

The next step was to extend the analyses to the neighboring states in the Midwest to determine if the pattern continued outside Illinois. For the other eight states (Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin), analyses similar to that employed in Illinois were used for comparisons between two 40-year periods (1907-1946 and 1947-1986). The Illinois values were also adjusted to this time frame. Comparisons were made for selected recurrence intervals for 24-hour storms. Unfortunately, the number of long-term stations with digital records is less in the other states than in Illinois. Whereas 61 stations were available for Illinois, records for only 24 stations were available on tape for Indiana, 35 for Iowa, 12 for Kentucky, 39 for Michigan, 24 for Minnesota, 27 for Missouri, 15 for Ohio, and 13 for Wisconsin. Thus the spatial detail and accuracy is diminished somewhat in these other states (especially Ohio and Wisconsin). Figure 16 shows the stations used in this section.

Figure 17 shows the 40-year ratios for 2-year, 24-hour storms. The shaded areas show regions with ratios > 1.00; that is, an increase in rainfall amounts for a given frequency and duration. There is a large area of increased values throughout the region. Decreased amounts are indicated in Missouri, Wisconsin, and along the Ohio River valley. There is some degree of spatial coherency in the area of increased values. That is, these are not just isolated, random pockets of high values. The areas with ratios > 1.10 (10 percent), a more significant threshold, show a narrow band starting near St. Louis and continuing to the northeast through Illinois, northwest Indiana, and into lower Michigan. Minnesota also has a larger area through the northwestern portion of the state with significantly higher ratios, There are other small pockets of high values in Iowa, Missouri, and Kentucky. These smaller regions may have been caused by smaller-scale effects, such as one exceptionally heavy rainstorm.

The map of 40-year ratios for a 5-year, 24-hour storm shows a pattern similar to the 2-year, 24-hour map for ratios > l.00 (figure 18). This coherence between return periods is consistent with the results found in Illinois. The areas of 5-year, 24-hour storm ratios > l.10 (10 percent) show the same band as before with an extension into northern Ohio as well as an area in northwest Missouri. The values within this band are also more intense. For example, the ratios near Chicago are 25 to 40 percent on the 5-year, 24-hour map, but only 20 percent on the 2-year, 24-hour map. The similar appearance between the 2- and 5-year, 24-hour maps suggests the changes are due to something other than sampling vagaries. The patterns of the 10-year, 24-hour analysis (not shown) were similar to those for the shorter intervals.

To investigate whether the patterns are indeed true and not due to random noise, correlations were calculated between the ratio maps and two random patterns, which were generated by randomly shuffling the station locations for the 2-year, 24-hour data. Thus the data values are the same although their locations are different. Table 19 shows the results of the correlation analysis. Although there is high correlation among the real patterns, no relationship was found for the random patterns.

Table 20 shows the percentage of stations having ratios ≥1.00 and ≥1.10. In general, two-thirds of the stations showed some increase while one-third showed increases > 10 percent between the two 40-year periods.

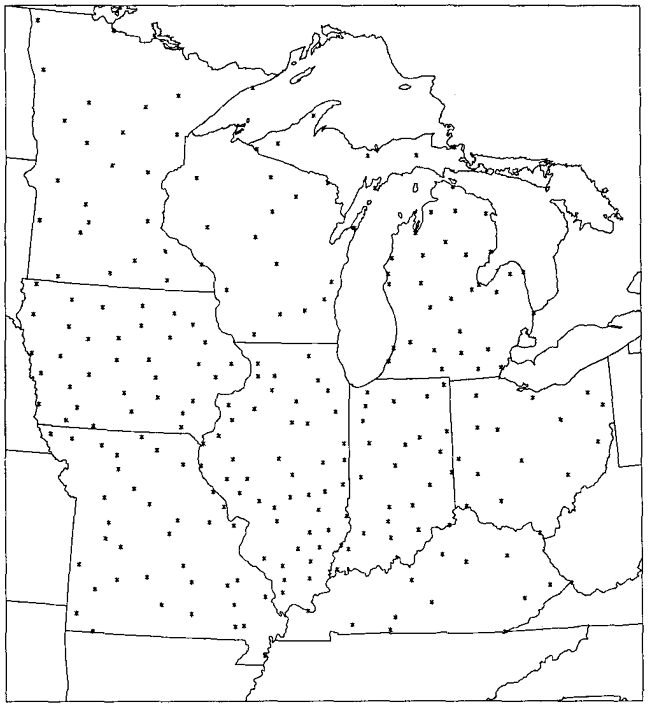

Figure 16. Stations used in temporal change study

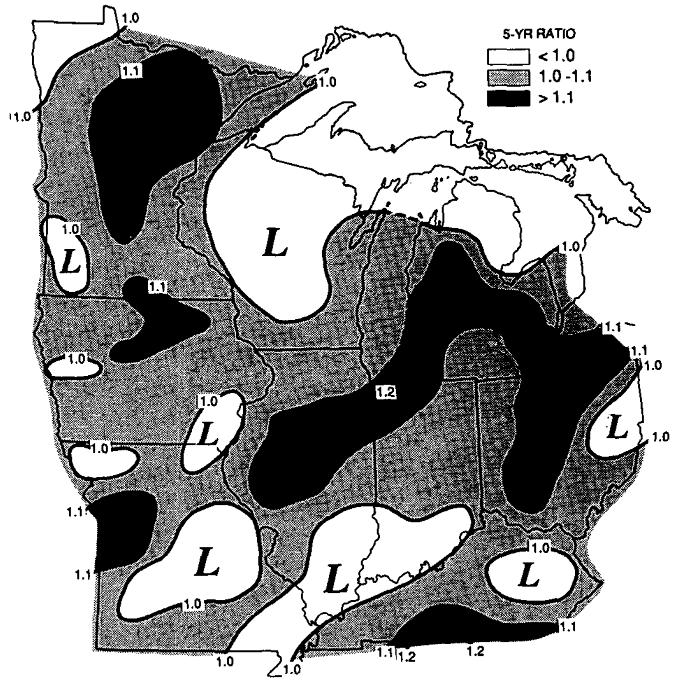

Figure 18. Ratio pattern for 5-year, 24-hour storms

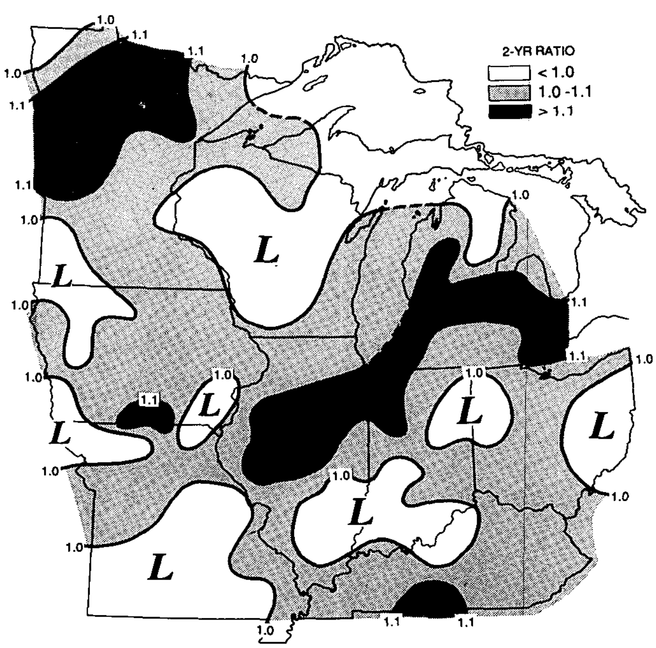

Figure 17. Ratio pattern for 2-year, 24-hour storms

Summary and Conclusions

This study has examined the change over time of the heavy rainfall distribution in the Midwest. A detailed study in Illinois suggests an increase in rainfall amounts for 2-, 5, and 10-year recurrence intervals during recent years. This is supported by other temporal studies of precipitation and related variables in Illinois. Preliminary results for other parts of the Midwest show a southwest to northeast axis of maximum change extending from Missouri to Michigan and northern Ohio. The increases appear to be greater than expected from natural climatic variability and are sufficiently large to have implications for water structure designs and other aspects of applied climatology. Furthermore, the findings suggest that the assumption of a stationary time series for fitting statistical distributions to historical precipitation data may be invalid. The results also suggest the need to update rainfall frequency relations more frequently. An update on the order of every 20 years would be appropriate to capture any substantial changes. It cannot be determined at this time what underlying physical processes may be involved with these changes.

Table 19. Correlation Analysis Between the Three Real Maps and Two Random Maps

	2-Year	*5-Year*	*10-Year*	*Random #1*	*Random #2*
2-Year	1.00	0.76	0.53	-0.03	0.00
5-Year	0.76	1.00	0.90	-0.02	-0.04
10-Year	0.53	0.90	1.00	-0.03	-0.03
Random #1	-0.03	-0.02	-0.03	1.00	0.05
Random #2	0.00	-0.04	-0.03	0.05	1.00

Table 20. Percentage of Stations Showing Increased Precipitation Amounts at Selected Return Periods for 24-Hour Storms Between Two 40-year Periods (1947-1986 and 1907-1946)

	Ratio >1.00	*Ratio >1.10*
2-year	63	24
5-year	63	31
10-year	60	34

7. SPATIAL CHARACTERISTICS OF HEAVY RAINSTORMS IN THE MIDWEST

Data from dense raingage networks operated by the Illinois State Water Survey have supported numerous studies of the spatial distribution characteristics of heavy rainstorms such as those in this report. Key results from several of these studies have been abstracted from published reports and technical papers and included here for the convenience of the user. They provide pertinent information for both hydrological designers and systems operators. Although based on Illinois data, the relationships are considered generally applicable to the Midwest.

Relation Between Point and Areal Mean Rainfall Frequency

Knowledge of the frequency distribution of areal mean rainfall is pertinent to the efficient design of hydraulic structures such as dams, urban storm sewers, highway culverts, and water-supply facilities. In the United States, a relatively large amount of data is available on the frequency distribution of point rainfall, but there is little information on the frequency distribution of areal mean rainfall. Consequently, there has been a need to determine how the mean rainfall frequency distributions for small areas about a point are related to the point frequency distributions.

Hershfield (1961) presented area-depth curves for estimating areal mean rainfall frequencies from point rainfall frequencies. Information was provided for areas ≤400 square miles and for storm durations of 0.5 to 24 hours. The relations were developed from limited raingage network data and apparently considered applicable throughout the United States. Huff (1970) used data from dense raingage networks in Illinois to provide similar relationships more applicable to the Midwest for storm durations of 0.5 to 48 hours. Results are summarized in table 21.

Storm Shape

Runoff characteristics in heavy storms are influenced by the shape and movement of the storms. Two studies have been made to determine the shape characteristics of heavy rainstorms in Illinois. In one study, data from 260 storms on a dense raingage network in central Illinois were used to investigate shapes on areas of 50 to 400 square miles (Huff, 1967). Storms were used in which areal mean rainfall exceeded 0.50 inch. In the other study, historical data for 350 heavy storms having durations up to 72 hours were used in a shape study of large-scale, flood-producing rain events. These were storms in which maximum l-day amounts exceeded 4 inches or in which 2-day and 3-day amounts exceeded 5 inches (StoutandHuff, 1962).Storms encompassed areas that ranged from 200 to 10,000 square miles.

The study of historical storms indicated that the rain intensity centers most frequently had an elliptical shape. The ratio of major to minor axis tended to increase with increasing area enclosed within a given isohyet; that is, the ellipse becomes more elongated. Within limits employed in the study, no significant difference in the shape factor occurred with increasing storm magnitude or with durations ranging from a few hours to 72 hours.

In the network study, elliptical patterns were found also to be the most prevalent type, but the heaviest storms tended to be made up of a series of rainfall bands. Intensity centers within these bands, however, were most frequently elliptical. From these two studies, a mean shape factor was determined that can be used as guidance in hydrologic problems in which storm shape is a significant design factor. The shape curve is shown in figure 19 for areas of 10 to 1,000 square miles. For those interested, the curve can be continued to 10,000 square miles because storms up to this size were included in the historical storm study.

Table 21. Relation Between Areal Mean and Point Rainfall Frequency Distributions

Storm period (hours)	*Ratio of areal to point rainfall for given area (square miles)*					
	10	*25*	*50*	*100*	*200*	*400*
0.5	0.88	0.80	0.74	0.68	0.62	0.56
1.0	0.92	0.87	0.83	0.78	0.74	0.70
2.0	0.95	0.91	0.88	0.84	0.81	0.78
3.0	0.96	0.93	0.90	0.87	0.84	0.81
6.0	0.97	0.94	0.92	0.89	0.87	0.84
12.0	0.98	0.96	0.94	0.92	0.90	0.88
24.0	0.99	0.97	0.95	0.94	0.93	0.91
48.0	0.99	0.98	0.97	0.96	0.95	0.94

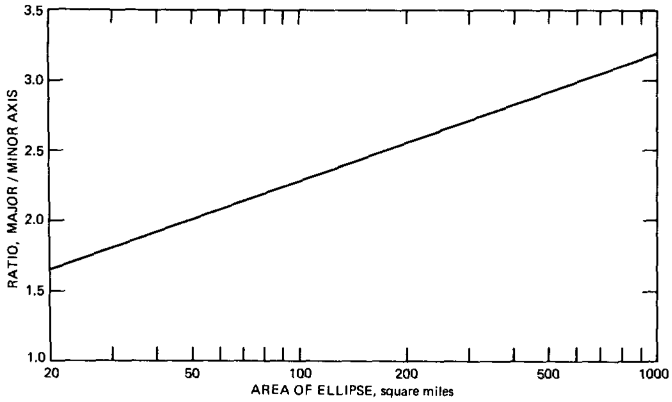

Figure 19. Mean shape factor for heavy storms

Storm Orientation

An important consideration in any region is the orientation of the major axis of heavy rainstorms. For example, if the axes of heavy rainstorms tend to be parallel to a river basin or other area of concern, then the total runoff in this region will be greater, on the average, than in a region perpendicular to most storm axes. The orientation of the storm axis also provides an indication of the movement of the major precipitation-producing entities embedded in any large-scale weather system. Because most individual storm elements have a component of motion from the west, an azimuth angle ranging from 180 to 360° was ascribed to each storm. Thus, if a storm had an orientation of 230°, the orientation was along a line from 230 to 050° (southwest to northeast).

No significant difference was found between the orientation of storms when they were stratified according to mean rainfall and areal extent. Table 22 shows the distribution in 260 heavy storms having mean rainfall exceeding one inch over a contiguous areas ≤10,000 square miles (Huff and Semonin, 1960). This distribution is considered typical for heavy storms in Illinois and the Midwest. Other studies have supported the results shown in table 22 (Huff and Vogel, 1976; Vogel and Huff, 1978).

Heavy rainstorms were found to be oriented most frequently from west-southwest to east-northeast through west to east or west-northwest to east-southeast (table 22). The median orientation of the 260 storms used in deriving table 22 was 265° (nearly west to east). In general, it has been found that the orientations of very heavy storms tend to be nearly west to east. Heavy, but less severe storms, are usually oriented west-southwest to east-northeast or west-northwest to east-southeast. Moderately heavy storms, especially those of short duration (1 to 3 hours), are frequently oriented west-southwest to east-northeast or southwest to northeast.

Table 22. Orientation of Heavy Rainstorms

Azimuth (degrees)	*Storms (percent)*	*Azimuth (degrees)*	*Storms (percent)*
180-215	4	276-295	20
216-235	6	296-315	12
236-255	30	316-335	6
256-275	21	336-360	1

Storm Movement

In the Midwest, heavy rainstorms are usually produced by one or more squall lines or squall areas traversing a basin or other area of interest. Each system (squall line or squall area) consists of a number of individual convective entities, usually thunderstorms, and these entities have a motion that is strongly related to the wind field in which they are embedded. These entities are often referred to as raincells. Network studies of the motion of heavy raincells (Huff, 1975) have provided the frequency distribution of cell movements shown in table 23. The most frequent raincell movements are from west-southwest through west to west-northwest (240-299°), which accounts for 42 percent of the total number analyzed in the Huff study. Of the total, 84 percent exhibited motion with a westerly component.

Table 23. Frequency Distribution of Heavy Raincell Movements

Azimuth (degrees)	*Storms (percent)*	*Azimuth (degrees)*	*Storms (percent)*
180-209	6	O-29	4
210-239	16	30-59	2
240-269	22	60-89	2
270-299	20	90-119	2
300-329	13	120-149	2
330-359	7	150-179	4

8. INDEPENDENCE OF EXTREME RAINFALL EVENTS

One of the problems involved in the development of rainfall frequency distributions is the *independence* (or lack thereof) of the observations. This is pertinent to selecting the method of analysis and grouping of the data in the analytical procedures.

One method of evaluating the magnitude of this problem is to examine the time distribution of the events incorporated into the frequency distributions for storm periods of varying duration. A pilot study was made using Indiana data for 1-, 2-, and 3-day storm periods to calculate 24-hour to 72-hour frequency relations. A total of 41 stations were used in deriving the Indiana relations.

First, the maximum recorded 1-day and 2-day amounts for each station were examined to determine whether both occurred in the same storm system. Among the 41 stations, 22 (54 percent) recorded both their 1-say and 2-day maxima in the same storm systems. Thus, 54 percent of the time the 1-day and 2-day events were not independent of each other, at least from a meteorological standpoint.

Next, the same type of examination was performed on 2-day and 3-day events. Results showed that 78 percent or 32 stations had their maximum amounts on days when both 2-day and 3-day records were established. Further examination showed that in 44 percent or 18 cases, the station maxima for all three storm periods (l-, 2-, and 3-day) occurred in single storm systems.

The conclusion suggested by this pilot study is that storm events that produce the data for deriving heavy rainfall frequency relations cannot be assumed to represent random occurrences with respect to storm periods of less than 72 hours. Unfortunately, these are the storm events of most concern to hydrologists involved in the design and operation of systems for the control of flood waters.

Next, comparisons were made between the top ten ranked storms for l-day and2-day events. Among the 25 long-term stations having records of 58 to 86 years, an average of 60 percent of the storm systems producing the ten largest l-day amounts also resulted in amounts ranked among the ten heaviest rain events for 2-day periods. The top ten storm events for these long-term stations exert a strong control over rainfall amounts derived for recurrence intervals of 10 years or longer. The median was also 60 percent, and the range varied from 40 to 80 percent (4 to 8 cases) among the 25 stations.

A similar analysis was made for the 16 short-term stations having records for 35-40 years. The mean and median were both 70 percent and the range varied from 60 to 90 percent at individual stations. Because of the shorter records, the top ten ranked storms exert a strong control on determining recurrence-interval amounts for intervals of 5 years or longer. The comparisons between the ten heaviest storms for l-day and 2-day rain periods strongly support the results from the analyses of maximum recorded values described previously.

The same comparative analysis was applied to the top ten ranked storms for 2- and 3-day periods. For the long-term stations, the average and median were both 80 percent, and the range was from 60 percent (6) to 100 percent (10). For the short-term stations, the average and median were 76 and 70 percent, respectively, and the range was from 50 to 90 percent. The above comparisons for 2 and 3 days are similar to those for 1 and 2 days, and also support the earlier conclusion relating to the independence of 24- to 72-hour frequency distributions of heavy rainfall.

Examples of Outstanding Storms

A determination was made of the number of occurrences of rainfall amounts that ranked among the ten heaviest in some of the most widespread storms in Indiana and Illinois. For this analysis, 2-day storm periods were selected, because many of the heaviest storms extend from late afternoon into evening and even later. Although these are single storms, they are split between two days at stations of the climate network that report once daily at approximately 1800 Central Standard Time.

One of the most outstanding storms occurred within a 24-hour period on October 5-6, 1910. Table 24 shows the stations at which a rank 1-10 amount occurred, the amount of rainfall, and its rank position among all storms at that station. Thus, 11 stations in Indiana qualified, and the storm ranked first among all storms at 4 stations. Similarly, Illinois had 12 stations with 1-10 ranks, and the storm ranked first among all storms at 5 stations. For the two states combined, there *were* 23 stations with rank 1-10 storms. Of these, nine experienced storms ranked first among 2-day storm periods. Thus 23 percent of all the 102 Indiana-Illinois stations had a rank 1-10 amount, and 9 percent had their heaviest 2-day storm on record.

Table 25 shows information on another outstanding 2-day event. On March 25-26, 1913, 15 Indiana stations recorded rank 1-10 storms. Among these, five stations recorded their heaviest 2-day storm on record. In Illinois, nine stations recorded rank 1-10 storms, but only one was ranked #l. Thus, for both states combined, 24 percent had rank 1-10 events, and 6 percent had their most severe 2-day storm on record. This particular storm was noted by the U.S. Weather Bureau (1913):

"In a period of 4 days, beginning on March 23 and ending on March 27, the average rainfall over the watershed of the WestFork of the WhiteRiver was 7.81 inches, and over the watershed of the East Fork, 8.41 inches. This extraordinary rainfall produced one of the greatest floods in the history of the state."

A third example of outstanding storms with respect to area enveloped and storm intensity is summarized inTable 26. This storm occurred in a 2-day period on August 14-16, 1946. It extended across central Missouri into southwestern and

Table 24. Distribution of Rank 1 to 10 Amounts in October 5-6, 1910, Storm in Indiana and Illinois

Station	*Rainfall (inches)*	*All-storm rank*
INDIANA		
Bloomington	7.68	1
Moore's Hill	8.23	1
Mt. Vernon	7.68	1
Scottsburg	7.86	1
Columbus	8.12	2
Richmond	5.60	2
Rushville	5.64	2
Paoli	6.32	3
Princeton	6.33	4
Washington	5.15	5
Markland Dam	5.55	7
ILLINOIS		
Cairo	9.24	1
Carbondale	8.67	1
Harrisburg	10.71	1
New Brunswick	10.72	1
Anna	9.70	1
DuQuoin	6.80	2
McLeansboro	6.42	3
Palestine	5.40	4
Fairfield	5.64	6
Flora	5.90	6
Mt. Carmel	5.16	9
Olney	5.09	10

Table 25. Distribution of Rank 1 to 10 Amounts in March 25-26, 1913, Storm in Indiana and Illinois

Station	*Amount (inches)*	*All-storm rank*
INDIANA		
Columbus	8.65	1
Rushville	7.84	1
Richmond	9.47	1
Farmland	7.39	1
Washington	7.91	1
Bloomington	7.68	2
Berne	4.90	2
Marion	5.13	3
Princeton	6.37	3
Whitestown	6.07	3
Markland Dam	5.65	4
Paoli	6.25	4
Scottsburg	6.10	5
Moore's Hill	4.88	5
Rockville	4.72	8
ILLINOIS		
Mt. Carmel	7.70	1
Fairfield	8.35	3
DuQuoin	6.12	4
Olney	5.59	4
Mt. Vernon	5.40	6
McLeansboro	5.95	8
Flora	5.68	8
Palestine	5.01	8
Paris	4.79	8

Table 26. Distribution of Rank 1 to 10 Amounts in August 14-16, 1946, Storm in Missouri and Illinois

Station	*Amount (inches)*	*All-storm rank*
MISSOURI		
St. Louis	11.71	1
Warsaw	8.70	1
St. Charles	8.48	1
Ellsberry	6.98	2
Salem	6.62	2
Boliver	6.85	3
Clinton	6.72	3
Lebanon	6.99	3
Rolla	5.25	8
Warrensburg	5.21	10
ILLINOIS		
Belleville	13.41	1
Mt. Vernon	10.43	1
Greenville	7.44	1
White Hall	5.15	8
Pana	5.04	8
New Burnside		9

southern Illinois. As indicated in the table, ten Missouri and six Illinois stations recorded rank 1-10 storms and six of these ranked #1 among 2-day storms on record.

Figure 20 further illustrates the areal extent and intensity of the storm of October 5-6, 1910. At each station, rainfall amounts (inches) and the rank of the storm in the station's history are shown. The northern boundary of the intense rainfall also is indicated by the dashed line. Only one reporting station in Illinois and none in Indiana south of the dashed line failed to report a rank 1-10 amount. It is likely that this storm also extended into Kentucky and southeastern Missouri, but records for these states were not available for 1910. This was undoubtedly one of the most severe rainstorms ever experienced in the nine-state area covered by this report.

Figure 21 shows the extent and intensity of the storm of March 25-26, 1913, and is similar in presentation to figure 20. This storm overlapped the area incorporated in the October 1910 storm. Rank 1-10 amounts were experienced at ten Indiana and seven Illinois stations in both storms. Only one reporting station within the dashed-line outline encompassing most of central and northern Indiana and southeastern Illinois did not record a rank 1-10 storm event. This is another illustration of the effect imposed on point rainfall frequency relations by a few very extreme rainfall events.

Additional Analyses

In view of the widespread nature of the three storms just discussed, further analyses were undertaken to ascertain the importance of such storm events in establishing the characteristics of rainfall frequency curves for 10-year to 100-year recurrence intervals. Data for Ohio, Indiana, Illinois, and Missouri were used to obtain an adequate sample of midwestern conditions. The storm data included 2-day amounts during the 1901-1987 period except for Missouri where records prior to 1912 were not available for all of the data set.

Two data stratifications included individual storms that produced five or more and ten or more qualifying amounts among the rank 1-10 values. The analyses were made separately for each state. Results are briefly summarized in

Figure 20. Areal extent and magnitude of storm of October 5-6, 1910

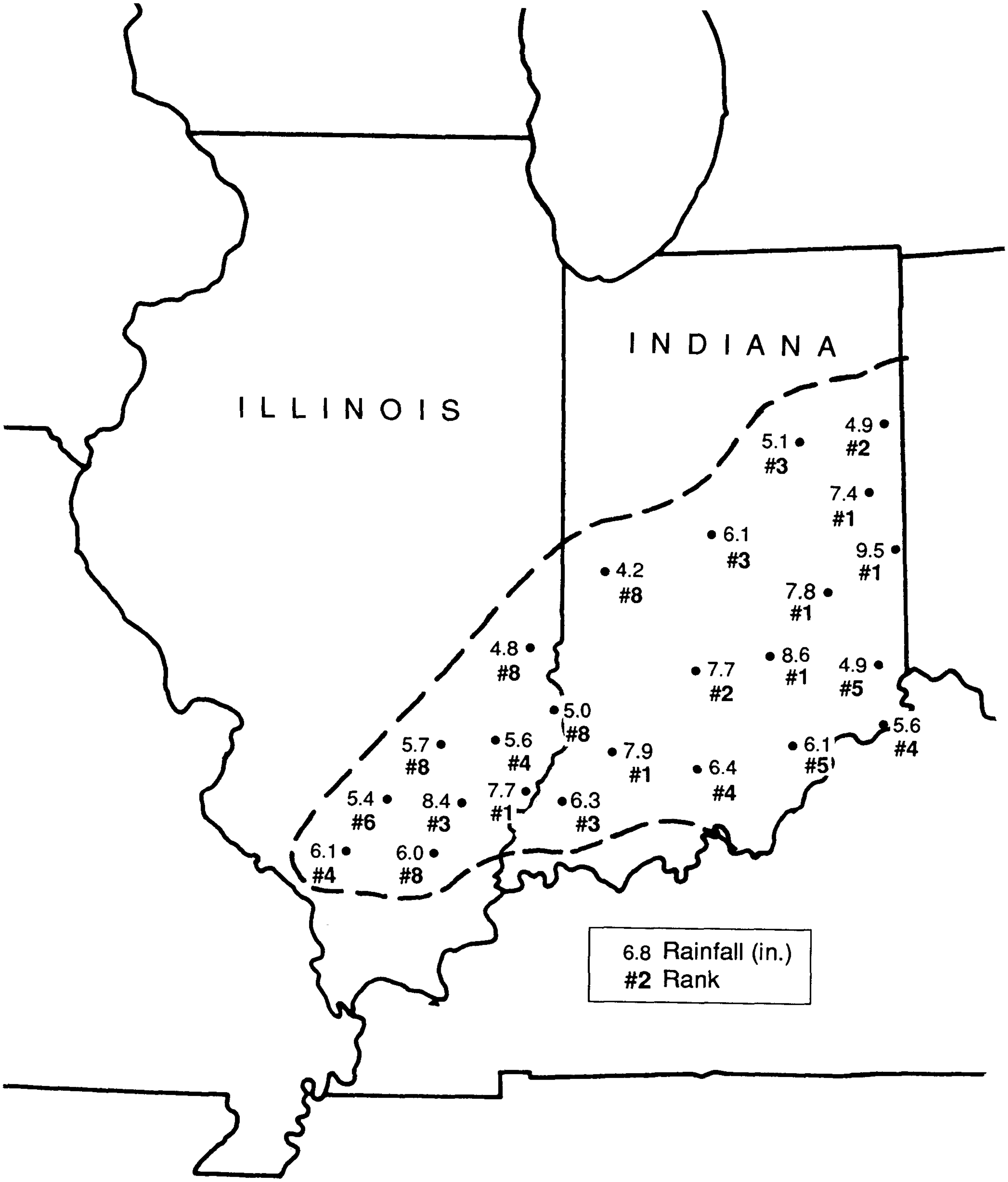

Figure 21. Areal extent and magnitude of storm of March 25-26, 1913

table 27, and provide further evidence of the relatively strong dependency of 10-year to 100-year recurrence interval values on a small portion of the heavy storm events used in establishing the frequency curves of point or areal mean rainfall.

In table 27, the first two columns show the total number of observational stations used in each state and the average precipitation gage density (mi²/gage). Gage density will influence the number of rank l-10 events observed in heavy storm systems. However, except for Missouri, the gage density differences among the four states are relatively small.

Following the first two columns, the number of storms (NS), the number of rank 1-10 qualifiers in these storms (NQ), and the percentage of the total number of rank l-10 values (Q%) are shown for each of the two data stratifications. The total number of qualifiers is the number of stations multiplied by 10.

Table 27 indicates that the percentage of total qualifiers accounted for by storms producing five or more qualifying amounts varied from a high of 34 percent in Indiana to a low of 25 percent in Ohio. The four-state average is 29 percent. The total number of qualifying storms (71) ranged from 24 in Illinois to 12 in Ohio. The summary for those storms having 10 or more qualifying amounts shows that these accounted for 10 to 16 percent of the total qualifiers, and these came from only three to six storm events among the states.

Summary

Results of this limited study indicate that the frequency distributions derived for 24- to 72-hour durations cannot be assumed to be independent. Frequently, qualifying amounts involve storm systems that dictate all three durations, especially among storms that determine the 10-year and longer recurrence-interval values. Examination of the heaviest IL-day storm events in Indiana and Illinois showed that the frequency distributions in the southern parts of these states were strongly influenced by two storms. Each of these storms produced amounts that ranked among the ten heaviest on record at over 20 percent of the 102 reporting stations in the two states. In one storm, 9 percent of all stations received their heaviest IL-day rainfall on record, and in the other, 6 percent of all stations recorded their heaviest amount.

Table 27. 2-Day Storms Producing 5 or More and 10 Or More Rank 1-10 Events

			≥ 5 Qualifiers			*≥ 10 Qualifiers*		
	N	G	NS	NQ	Q(%)	NS	NQ	Q(%)
Ohio	41	1000	12	101	25	3	46	11
Indiana	41	880	18	134	34	5	64	16
Illinois	61	915	24	192	31	6	69	11
Missouri	45	1530	17	120	27	4	46	10

Notes:
N = number of stations
G = gage density (mi²/gage)
NS = number of qualifying storms
NQ = total number of observations in qualifying storms
Q(%) = percent of all qualifiers accounted for by NQ

9. VARIABILITY WITHIN CLIMATIC SECTIONS

Frequency relations for climatic sections and individual points are presented in chapter 3 and part 2. The sectional relations provide estimates of the expected mean rainfall for various recurrence intervals and rain periods in areas of similar precipitation climate with respect to heavy rainfall occurrences. Naturalvariability, however, will produce variations for any given recurrence interval and storm period. This variability may be substantial even when long periods of record are used to develop frequency relations. Thus a measure of this variability is presented here for those who require such information.

The method employed involved comparing the variations in rainfall amounts between the frequency distributions derived for individual stations within a given climatic section and those indicated by the sectional mean distributions. The variability obtained by this methodresults primarily from random sampling variations due to the spatial distribution of heavy rainstorms in a particular climatic section during the sampling period. Variability due to other causes, such as observational and processing errors, has been minimized by using the individual frequency distributions, rather than the raw data observations, to measure the dispersion around the sectional mean frequency distributions.

The effects of "outliers" and "inliers", which are nonrepresentative of the expected rainfall for a given recurrence interval and storm duration, are also minimized but not completely eliminated by the methods used in our nine-state study. "Outliers" and "inliers" are rainfall amounts that are greater than or less than, respectively, any value expected to occur normally within the period of record undergoing analysis. For example, the 200-year storm event must occur in some year, and at some of the observational points this could have occurred during our observation period.

Table 28 shows the coefficient of variation, the standard deviation divided by the mean (expressed as a percentage), for each state for 24-hour to 10-day durations and 2-year to 100-year recurrence intervals. For a normal distribution, 68 percent of the observations are within one standard deviation of the mean, 95 percent are within two standard deviations, and 99 percent are within three standard deviations. The coefficient of variation is a measure of how well the individual station values fit the sectional mean values. For example, if the coefficient of variation is 4 percent, then 68 percent (one standard deviation) of the individual station values are expected be within 4 percent of the mean value. Larger coefficients of variation indicate wider scatter of station values above and below the sectional mean values. In practice, one may construct the 95 percent confidence band (two standard deviations) around the mean value. To do this, multiply the coefficient of variation by 2 to get two standard deviations (95 percent). So the 4 percent mentioned above now becomes 8 percent. One can then state that there is 95 percent confidence that any station value in that section will fall within 8 percent of the mean value.

Initial analyses of the individual climate sections showed that the coefficient of variation could be summarized on a state-by-state basis by averaging all climate section coefficients of variation for each state. This is advantageous since individual climate sections usually contained a small number of stations, which could lead to unreliable estimates of the coefficient of variation.

There are three general features of the coefficient of variation found in table 28. *It tends to increase with the longer recurrence intervals.* This is due to the fact that the uncertainty increases because of sampling inadequacies at the longer recurrence intervals. *It also tends to decrease at longer storm durations.* This is probably because longer duration values are associated with large-scale precipitation events, whereas the 24- and 48-hour values are more closely related to small-scale, convective activity. *Comparing the statesas a whole, one sees that at long recurrence intervals in Michigan, Minnesota, and Wisconsin, the coefficient of variation is generally higher than in the other states.* The authors speculate that this may be related to the relatively short convective season in these states limiting the number of stations exposed to the large rain-producing events in a given time period.

Use of the percentages in table 28 to compute the dispersion of point rainfall values about any sectional mean frequency distribution is illustrated in the following example. To determine the maximum positive and negative departures that will include 9.5 percent of the occurrences for a 50-year, 24-hour storm in northwestern Illinois, refer to the mean frequency distribution for 24-hour storms in northwestern Illinois (table 1 in part 2) or 6.53 inches.

Table 28 shows a coefficient of variation of 5 percent for a 50-year, 24-hour storm in Illinois. Multiply 5 percent by 2 to obtain the value encompassing 95 percent of the future point rainfall frequency distributions for northwestern Illinois. Then multiply this value (10 percent) by 6.53 inches to obtain the rainfall amount to be added or subtracted from the 6.53 inches to obtain the 95-percent confidence band. This calculation shows that 95 percent of the point rainfall estimates of the 50-year, 24-hour storm are expected to fall between 5.88 inches and 7.18 inches. The sectional frequency distributions (tables in part 2) and table 28 can be used to derive tables and curves for any climatic section and any storm duration to obtain a measure of that section's expected natural variability during a particular time period (5 years, 10 years, etc.).

Table 28. Dispersion of Point Rainfall Frequency Distributions about Section Mean Distributions for Various Recurrence Intervals and Rain Durations

	Coefficient of variation (percent)					
Duration	*2-Year*	*5-Year*	*10-Year*	*25-Year*	*50-Year*	*100-Year*
ILLINOIS						
24-Hour	3	4	4	5	5	7
48-Hour	3	4	4	4	5	6
72-Hour	3	4	4	4	5	6
5-Day	4	4	4	4	5	6
10-Day	3	4	4	4	5	6
INDIANA						
24-Hour	5	3	4	5	7	9
48 -Hour	4	4	4	6	7	9
72-Hour	4	3	4	6	7	8
5-Day	4	4	4	5	5	6
10-Day	4	4	5	5	5	6
IOWA						
24-Hour	4	4	5	7	8	9
48-Hour	4	4	5	7	8	9
72-Hour	3	4	5	6	7	8
5-Day	4	3	4	5	5	7
10-Day	3	4	4	4	4	5
KENTUCKY						
24-Hour	6	5	7	7	8	9
48 -Hour	6	5	6	7	8	9
72-Hour	5	5	6	7	7	8
5-Day	6	5	6	7	7	7
10-Day	6	5	6	5	5	5
MICHIGAN						
24-Hour	4	4	5	6	8	10
48-Hour	4	4	5	6	8	9
72-Hour	3	4	5	6	7	9
5-Day	4	5	5	6	7	8
10-Day	4	4	5	6	7	8
MINNESOTA						
24-Hour	4	5	6	9	10	12
48-Hour	4	5	6	8	10	13
72-Hour	4	5	6	8	8	11
5-Day	4	4	5	6	8	9
10-Day	5	4	5	6	6	7
MISSOURI						
24-Hour	4	5	6	7	8	8
48-Hour	4	5	5	6	7	7
72-Hour	4	5	5	6	6	7
5-Day	4	4	5	5	5	5
10-Day	4	4	4	4	5	6

Table 28. Concluded

Duration	*2-Year*	*5-Year*	*10-Year*	*25-Year*	*50-Year*	*100-Year*
OHIO						
24-Hour	4	5	6	6	7	7
48-Hour	4	4	5	5	6	7
72-Hour	4	4	5	6	6	7
5-Day	5	5	5	5	6	7
10-Day	4	5	5	6	7	8
WISCONSIN						
24-Hour	4	4	5	6	8	10
48-Hour	4	4	5	6	8	10
72-Hour	4	4	5	6	8	10
5-Day	4	4	5	6	8	9
10-Day	3	3	3	4	5	7

10. GENERAL SUMMARY AND CONCLUSIONS

The basic philosophy applied in our nine-state study is that a combination of appropriate statistical techniques, guided by available meteorological and climatological knowledge of heavy rainfall events, provides the best approach to developing reliable frequency distributions. It was recognized that the natural laws controlling the atmospheric processes are not governed by any specific statistical distribution. Within the limits of the data sampled, however, the application of appropriate statistical analysis provides a means of optimizing the information contained in that data.

Initially, a very detailed study of Illinois frequency relations was made. Methods and techniques developed in this study were then applied in the other eight midwestem states. Illinois is located near the center of this nine-state area, and there are no major changes in the general precipitation climate within this region.

Data and Analytical Approach

The study relied primarily upon data for 275 daily reporting stations within the NWS cooperative network. All of these stations had records exceeding 50 years. These data were supplemented by 134 cooperative stations with shorter records, by first-order station data, and by recording raingage data where available. Because the cooperative network provides only daily amounts of precipitation, well-established empirical factors were used to convert calendar-day rainfall to maximum 24-, 48-, and 72-hour amounts. Recurrence-interval amounts for rain periods of less than 24 hours were obtained from average ratios of x-hour/24-hour rainfall. These ratios were determined primarily from recording raingage data for 1948-1983 at 34 Illinois stations and 21 stations in adjoining states. Frequency relations for time periods shorter than 12 months were calculated from ratios relating x-month/24-month rainfall for various recurrence intervals.

For each station, the data were used to determine the annual maxima time series. Station frequency curves were then derived from the annual series values. For this report, however, the annual maxima values were converted to partial duration values. The annual maxima series is more adaptable to statistical testing, but the partial duration values are preferred by most users, especially engineers involved in the design and operation of water control structures.

Statistical Methods

As part of our nine-state research, an evaluation was made of various statistical methods and techniques considered to have potential for use in deriving the frequency distributions of heavy rainstorms. Major emphasis was placed on the applicability of (1) the L-moments method, which has received considerable attention in recent years; (2) the maximum likelihood methods; and (3) the Huff-Angel method used in the nine-state study. Except in a small percentage of the cases, the methods provided results that were not significantly different from either a statistical or meteorological standpoint, considering the inherent variability (real and human-induced) in the data samples. In general, the Huff-Angel estimates lie between those of the other two methods. From selected isohyetal maps comparing the L-moments and Huff-Angel distributions, it was concluded that the Huff-Angel spatial patterns conformed somewhat better with available climatological knowledge on the distribution of heavy storm rainfall in the Midwest. The largest differences occurred most frequently with the 100-year estimates, which represent an extension beyond the limits of all the data samples. Unfortunately, there is no reliable method of determining which estimate is “best” at predicting the most severe events.

Frequency Distribution of Heavy Rainfall Events

In our nine-state study, two methods of data analysis and presentation of results were used. For the first method, point rainfall frequencies were developed and presented in the form of isohyetal maps for various recurrence intervals and storm durations. This is the method most commonly used by past investigators. For the second method, areal mean rainfall frequency relations were developed in each state for regions of approximately homogeneous heavy rainfall climate. For both methods, frequency relations were developed for recurrence intervals ranging from 2 months to 100 years, and for rain periods varying from 5 minutes to 10 days. This wide range of frequency values was considered necessary to meet the needs of all potential users.

Point Rainfall Frequency Distributions

Isohyetal maps derived from individual station frequency relations were used to portray the spatial distribution of point rainfall for selected rain periods of 1 hour to 10 days, and recurrence intervals ranging from 2 to 100 years. Other rain durations and recurrence intervals can be calculated by transformation factors provided earlier in this report (tables 3 and 4). The isohyetal presentation is susceptible to considerable subjectivity and to natural and human-induced sampling errors undetected by statistical analyses. The method is useful and familiar to most users, however, and allows for incorporation of small-scale spatial differences resulting from localized influences if the sampling density is adequate.

Area1 Mean Rainfall Frequency Distributions

In the Midwest, consideration of available climate information on the distribution of heavy rainstorms, along with climatological-meteorological knowledge of storm system characteristics, indicated that the well-established NWS climate divisions could be used to divide the states into approximately homogeneous climate regions with respect to the frequency and intensity of extreme rainfall events. For each division, average frequency distributions were then developed using all stations within the division and those in neighboring divisions near its boundaries. The foregoing technique does not eliminate potential sampling errors in the data samples, but it does moderate their effects. Unless the divisions are properly selected, however, the averaging techniques may mask actual small-scale effects. This problem would be more acute in regions incorporating major changes in topography, such as the Appalachian and Rocky Mountain regions.

Time Distributions of Rainfall in Heavy Storms

Modem runoff models for urban and small-basin designs of water-control structures require definition of the time distribution characteristics within heavy rainstorms. Consequently, statistical time distributions developed for various types of storm systems in an Illinois study have been incorporated into this report. Although based on dense raingage network data in Illinois, the relationships should be applicable in the nine-state region and other areas of similar precipitation climate. These time distribution models can be used in conjunction with the frequency distributions presented in this report to accommodate hydrological needs.

Seasonal Distribution of Heavy Rainfall

The seasonal distribution of heavy rainstorms is pertinent in hydrology, agriculture, and other fields. In our nine-state study, available resources prohibited an extensive evaluation of seasonal rainfall frequencies. Three studies were pursued on a limited basis, however, and their results are included in this report to partially meet existing needs for seasonal information. These studies involved (1) the distribution of total precipitation in each of the four seasons (spring, summer, fall, and winter), (2) the seasonal distribution of heavy rainstorms, and (3) general characteristics and differences in seasonal frequency relations throughout the nine-state region. Results indicate that in the northern parts of the region, heavy rainstorms occur most often in the summer, followed by spring and fall, and are practically nonexistent in winter. In the southern parts of Missouri, Indiana, and Ohio, however, the heaviest amounts in long-duration storms (5 to 10 days) are most likely to occur in the cold season from mid-fall to early spring.

Temporal Fluctuations in Frequency Distribution of Heavy Rainstorms

Using the available data sample for 1901-1987, an investigation was made to determine whether climate trends or long-term fluctuations were indicated. For this purpose, the data were divided to provide two 40-year samples. Amounts for 2-, 5, and 10-year recurrence intervals were analyzed. The 87-year sample was not adequate to examine longer periods. Comparisons were then made between the various periods. In general, the results indicated an area of increasing frequency and/or intensity of heavy storms along an axis extending from Missouri north east ward through Illinois to southern Michigan and northern Ohio. The increases appear to be greater than expected from climate variability and sufficiently large to have an impact on water-control structural designs and other aspects of applied climatology.

Other Studies

Limited information has been presented that relates to the various spatial characteristics of heavy rainstorms in the Midwest. These have been abstracted from Illinois studies and include the relationship between point and areal mean rainfall frequency, storm shape, storm orientation, and storm movement.

Another limited study was concerned with the independence of extreme rainfall events. One of the numerous problems involved in the development of rainfall frequency relations is the independence of the observations. Results indicated that the 1-day to 3-day frequency distributions frequently involve storm systems that dictate all three events. This is especially evident in those storms that produce the long recurrence-interval values. For example, examination of the heaviest 2-day storm events in Indiana and Illinois showed that the frequency distributions in the southern parts of these states were strongly influenced by two storms. In the storm of October 5-6, 1910, 23 percent of all the long-period reporting stations in the two states had 2-day amounts that ranked among the ten heaviest on record, and 9 percent recorded their heaviest storm of the 1901-1987 period. In the storm of March 25-26, 1913, 24 percent of the stations in the two states reported amounts that rank among the first ten on record, and 6 percent had their heaviest storm ever observed.

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Part 2. Spatial Distribution Maps and Sectional Mean Frequency Distribution Tables

(The data for the sectional mean frequency tables are available on disk from the Midwestern Climate Center at the Illinois State Water Survey. Please call (217)244-8226 for further information.)

The user should consult the introduction and chapter 3 in part 1 before using the maps and tables in part 2 to understand their strengths and weaknesses.

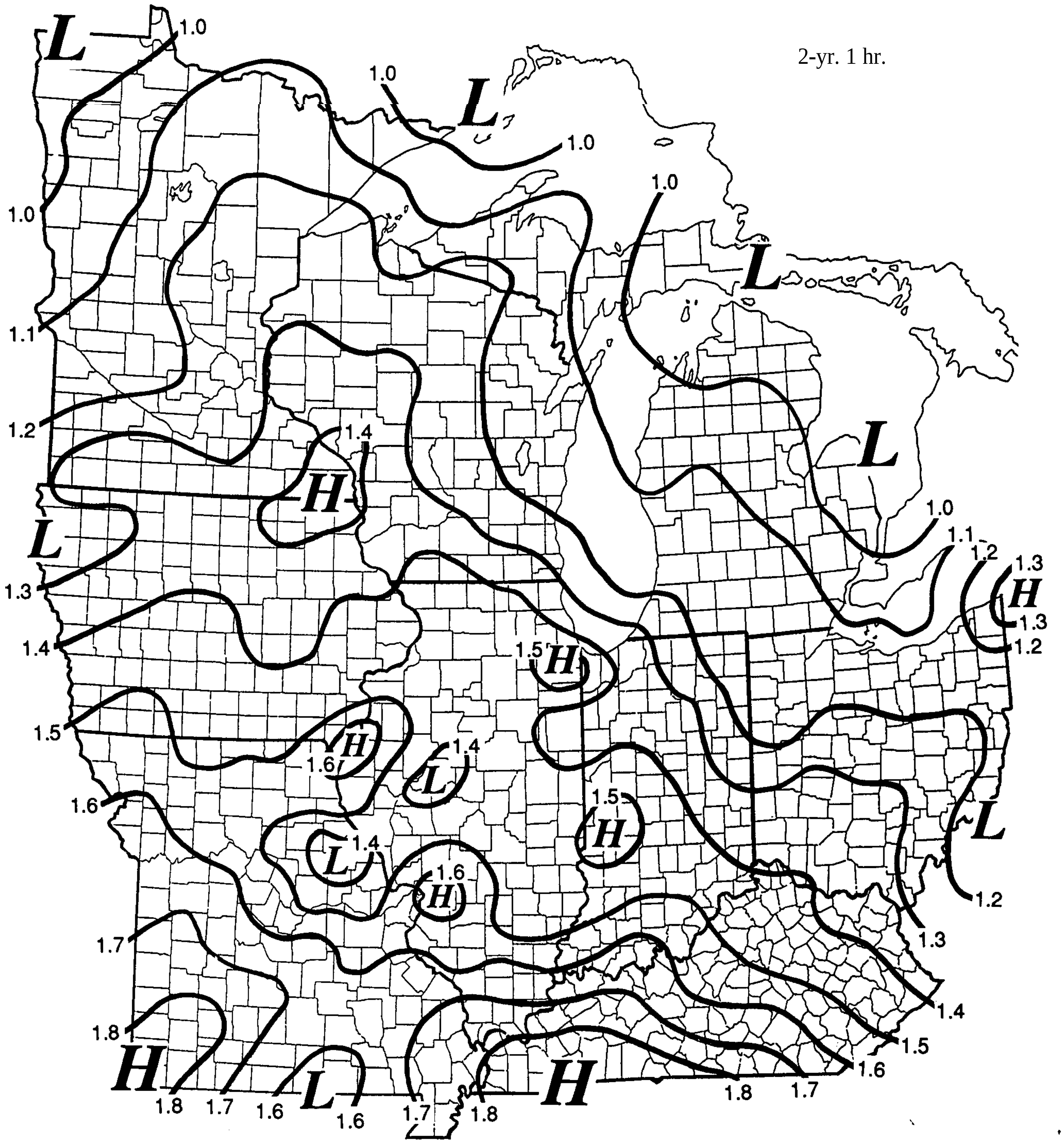


Figure 1. Spatial distribution of 1 -hour rainfall (inches)

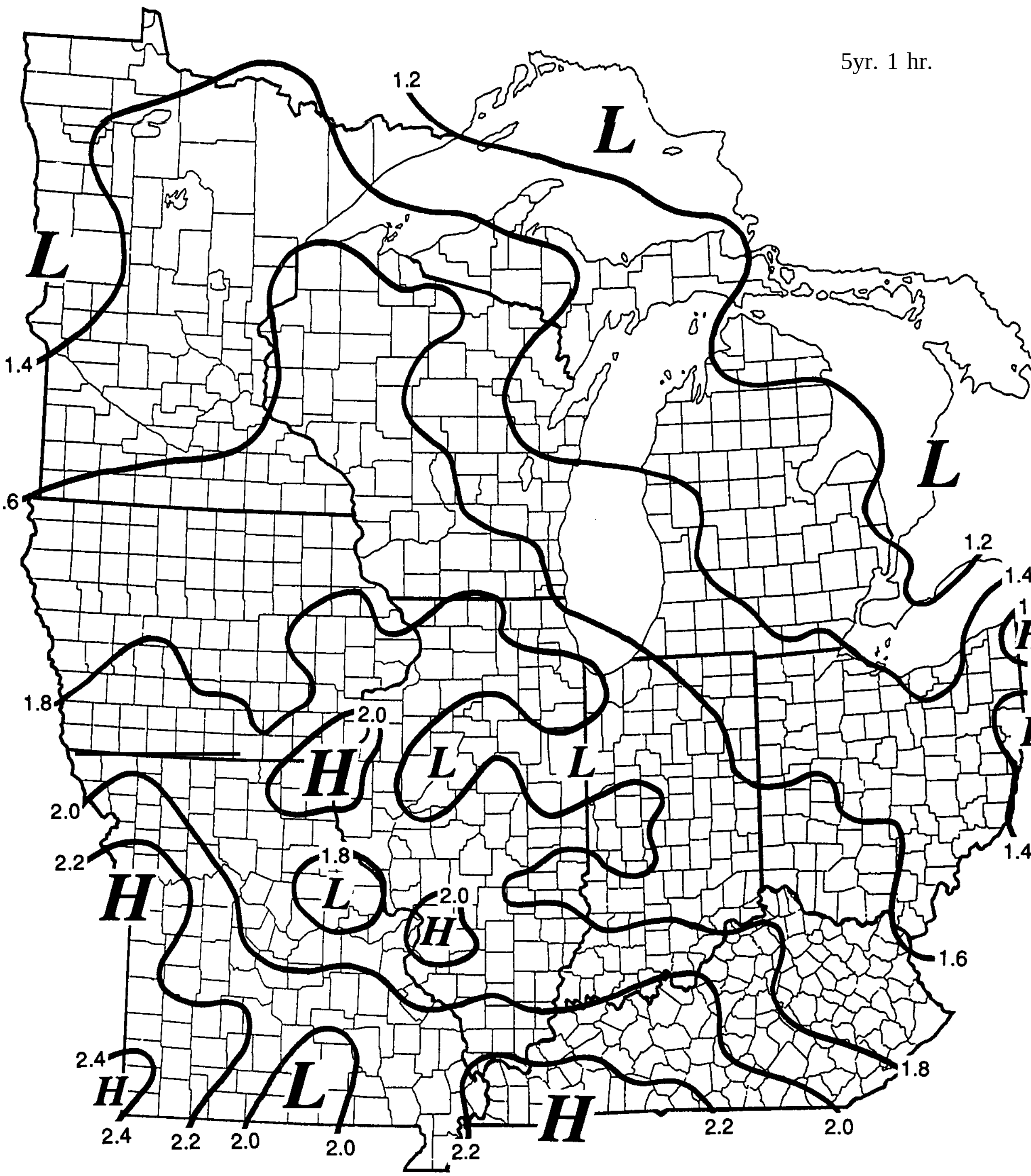
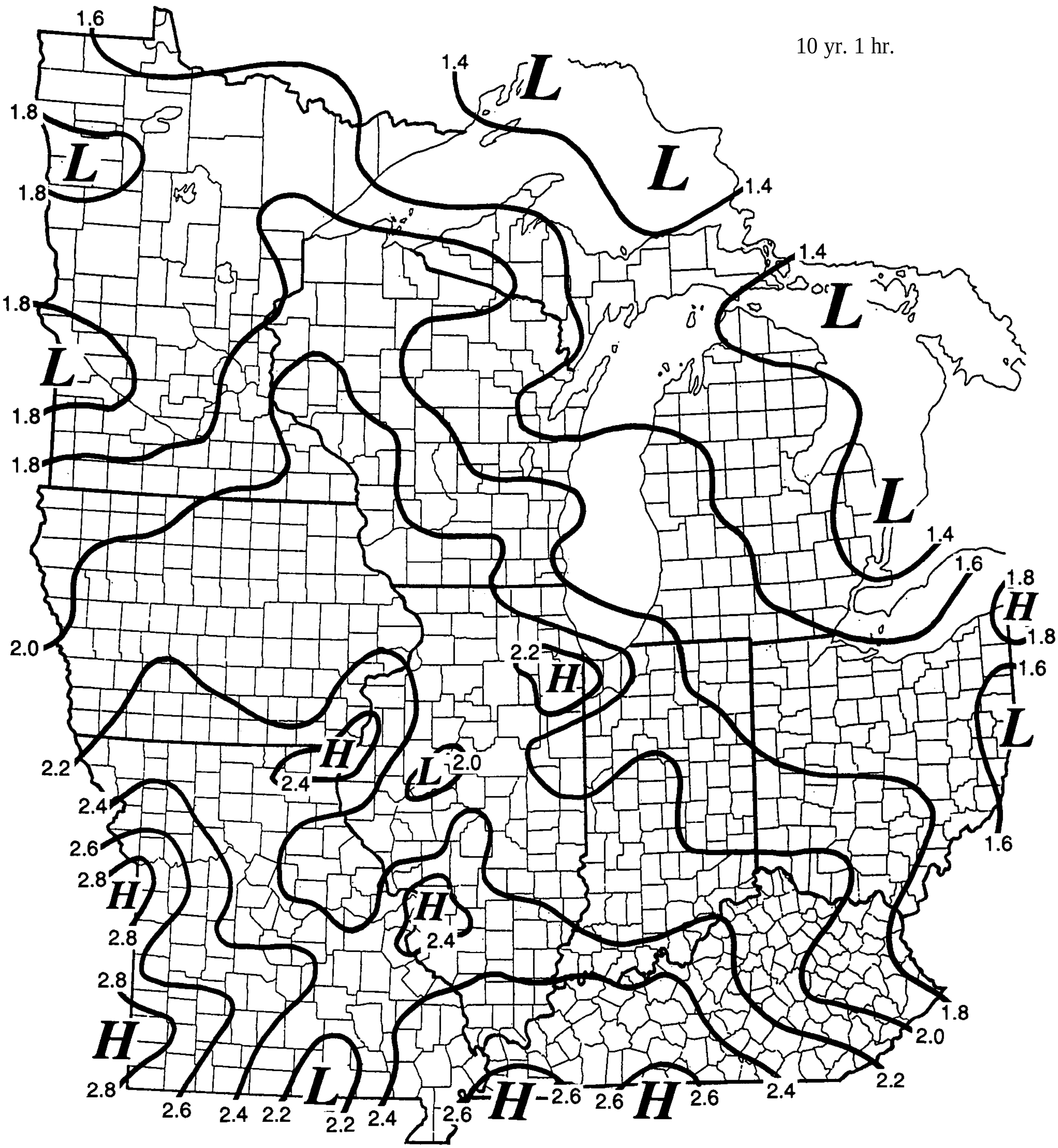


Figure 1. Continued



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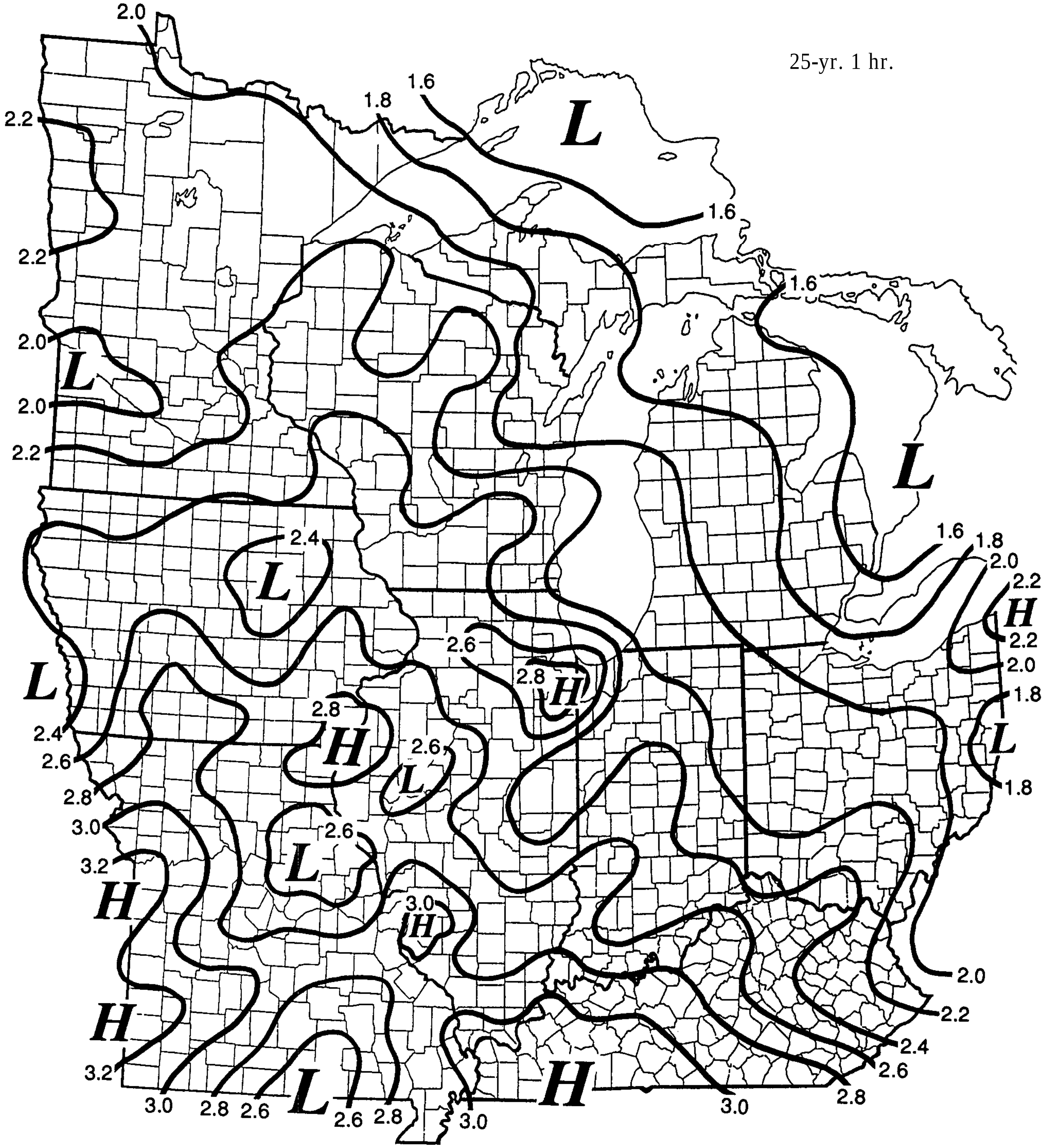

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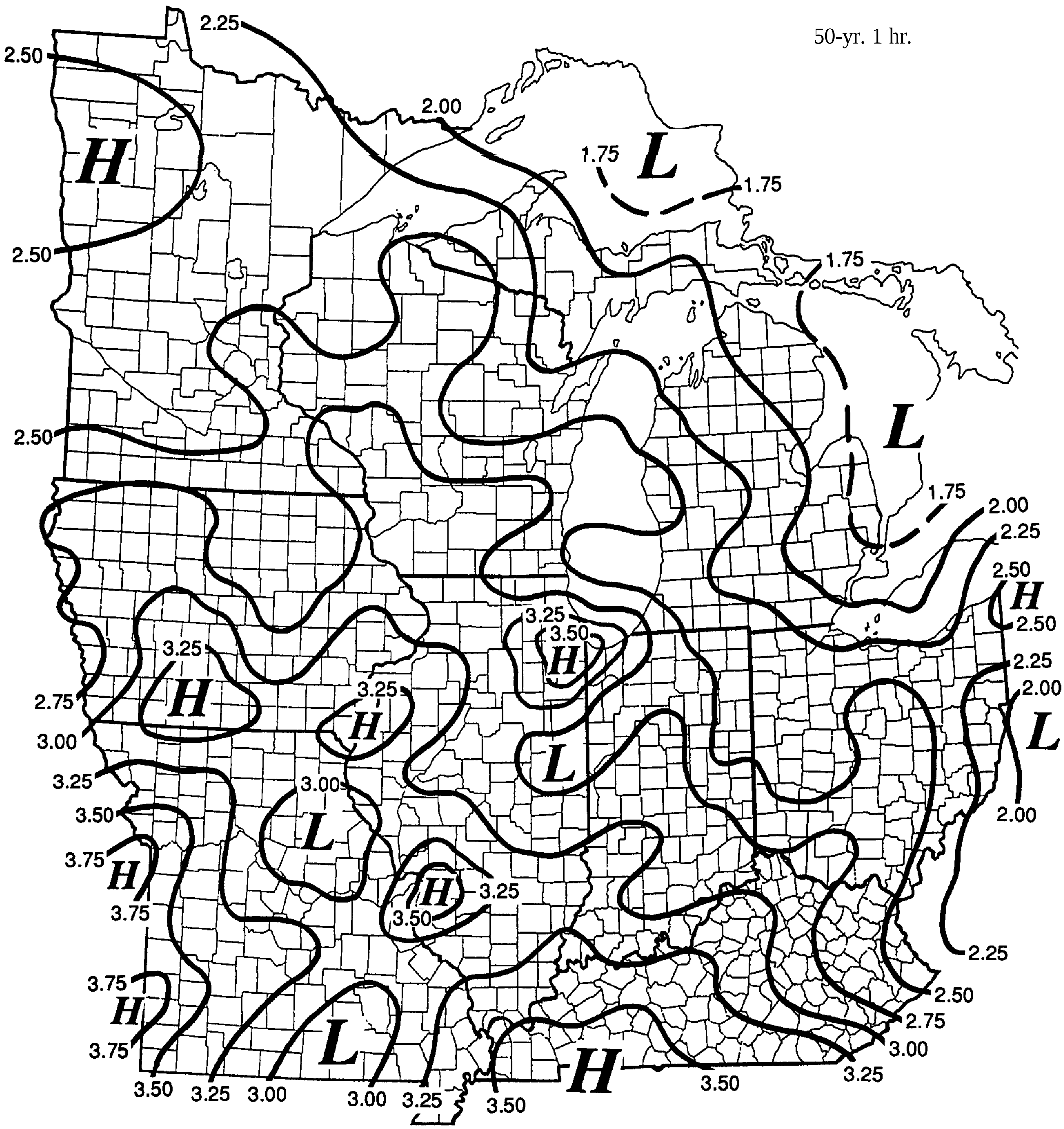
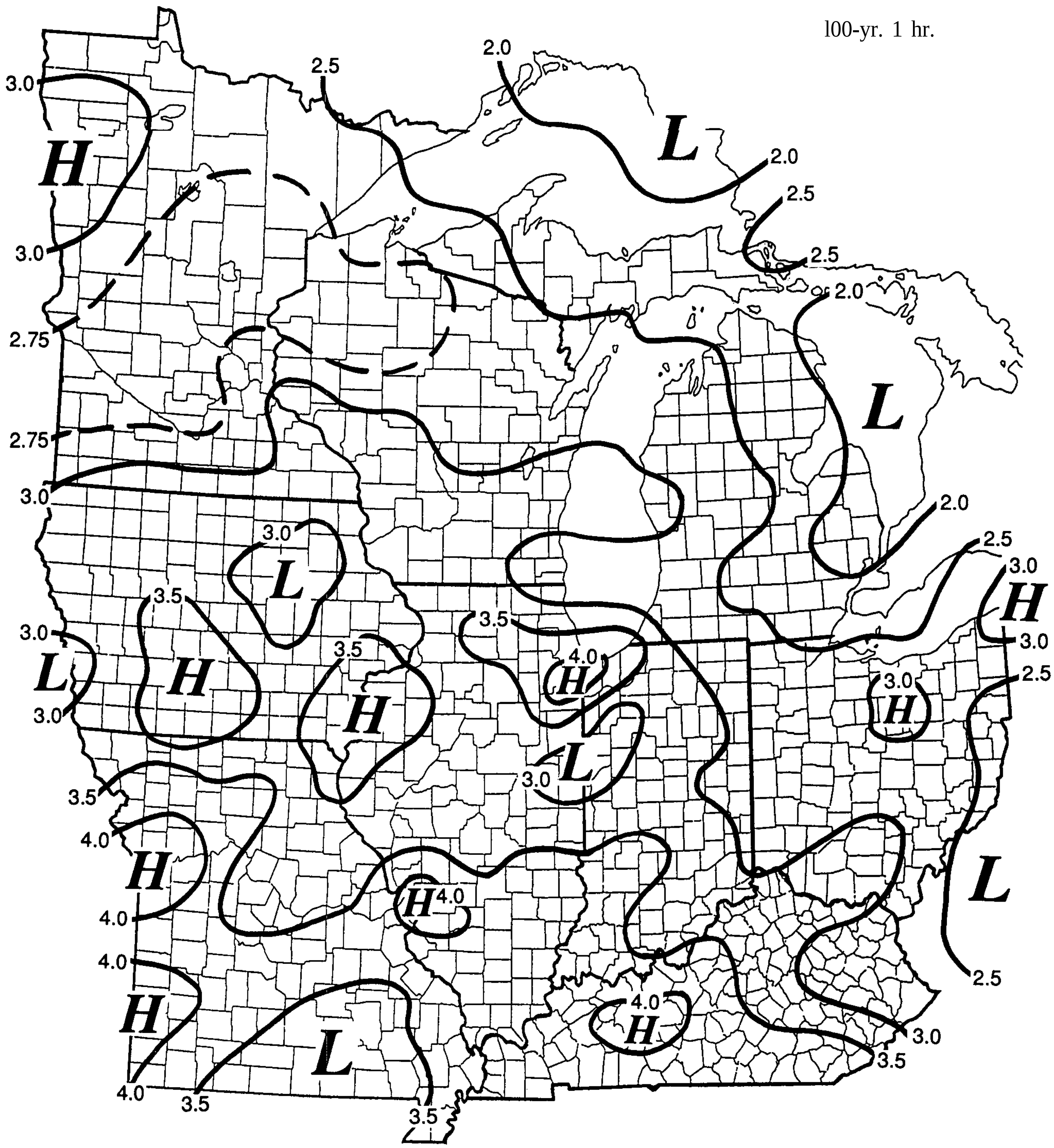


Figure 1. Continued

Correction: the 3.25 and 3.50 inch contours in northeastern Illinois should be 3.00 and 3.25 inches respectively.



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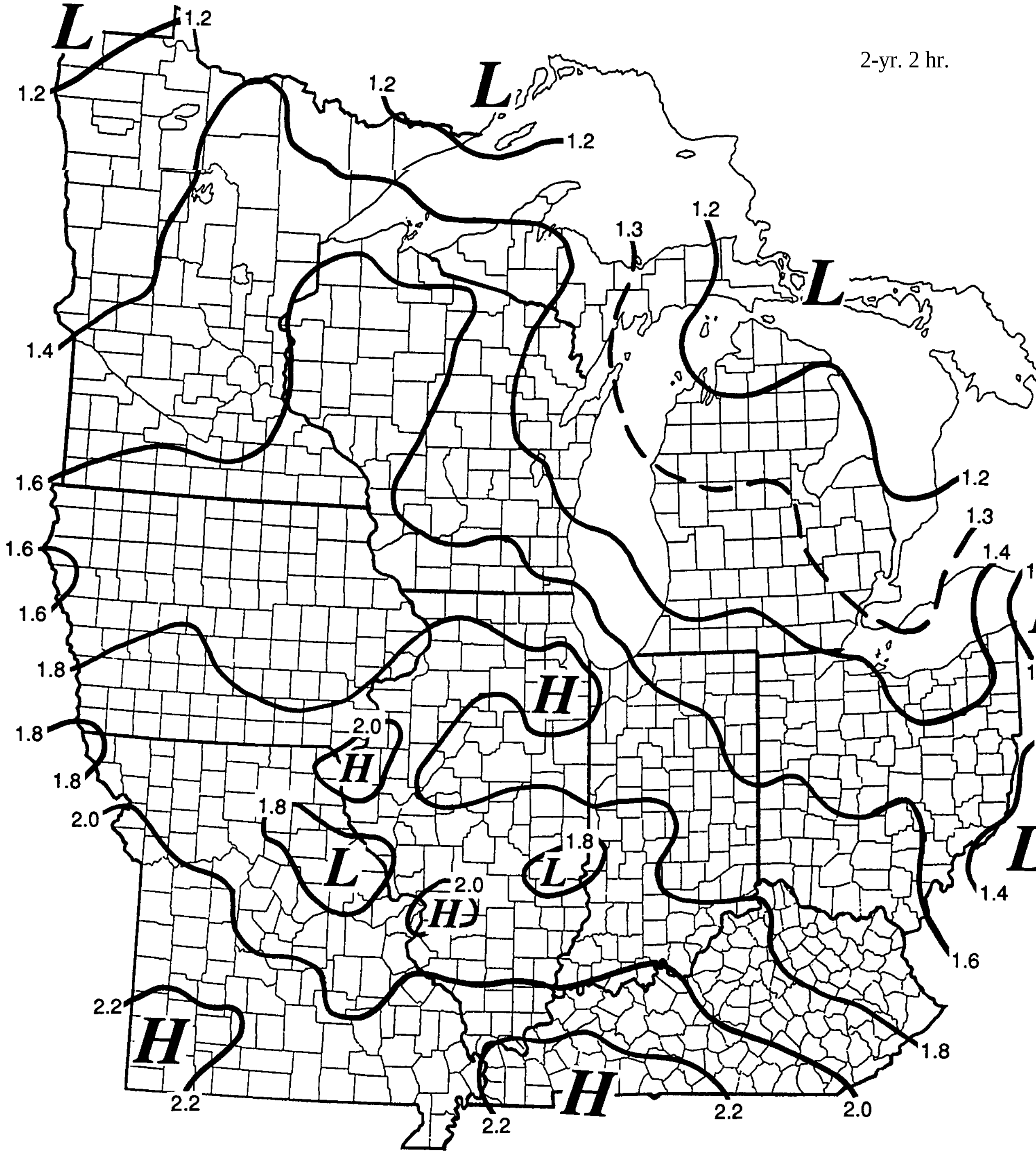
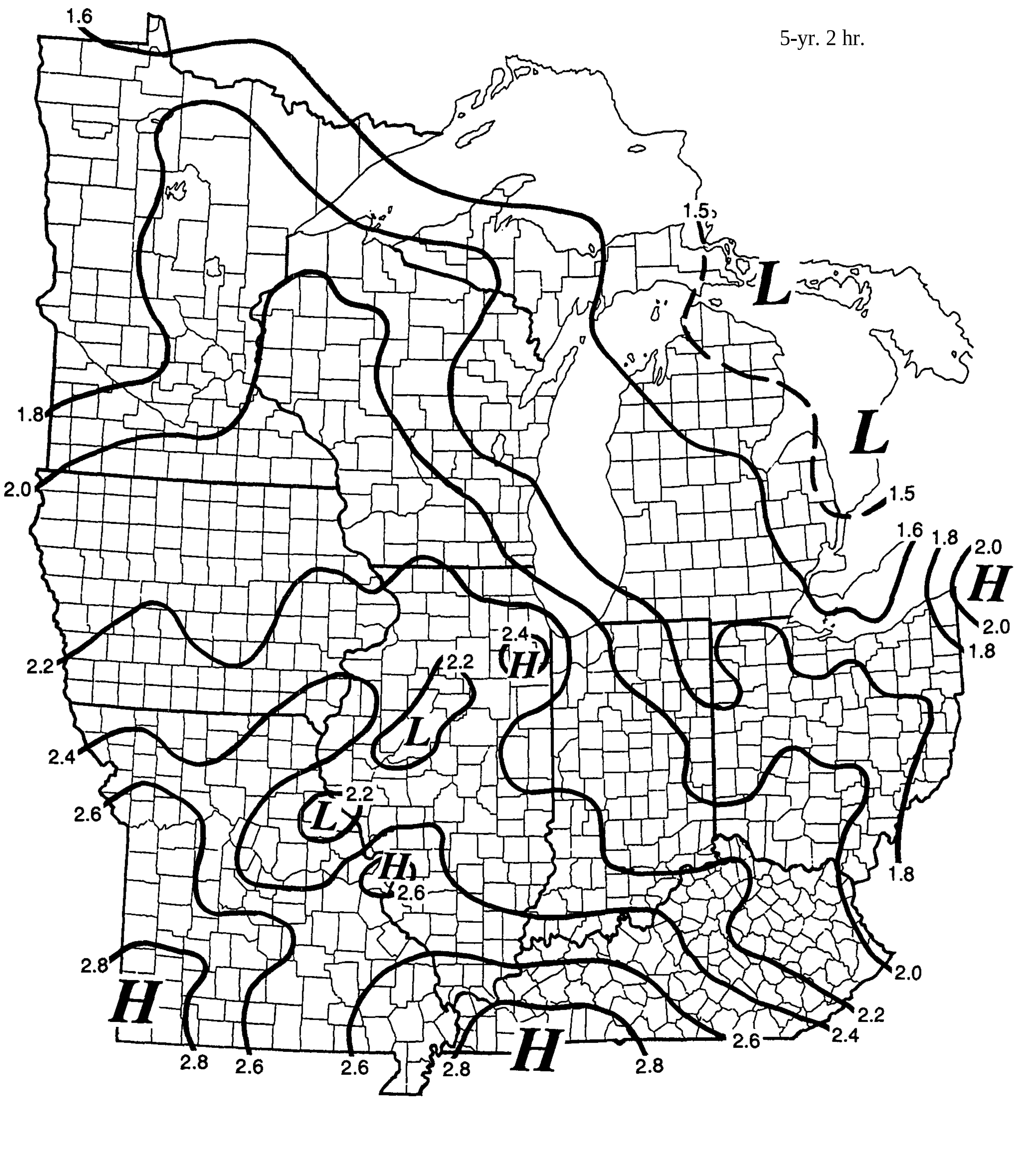


Figure 2. Spatial distribution of 2-hour rainfall (inches)



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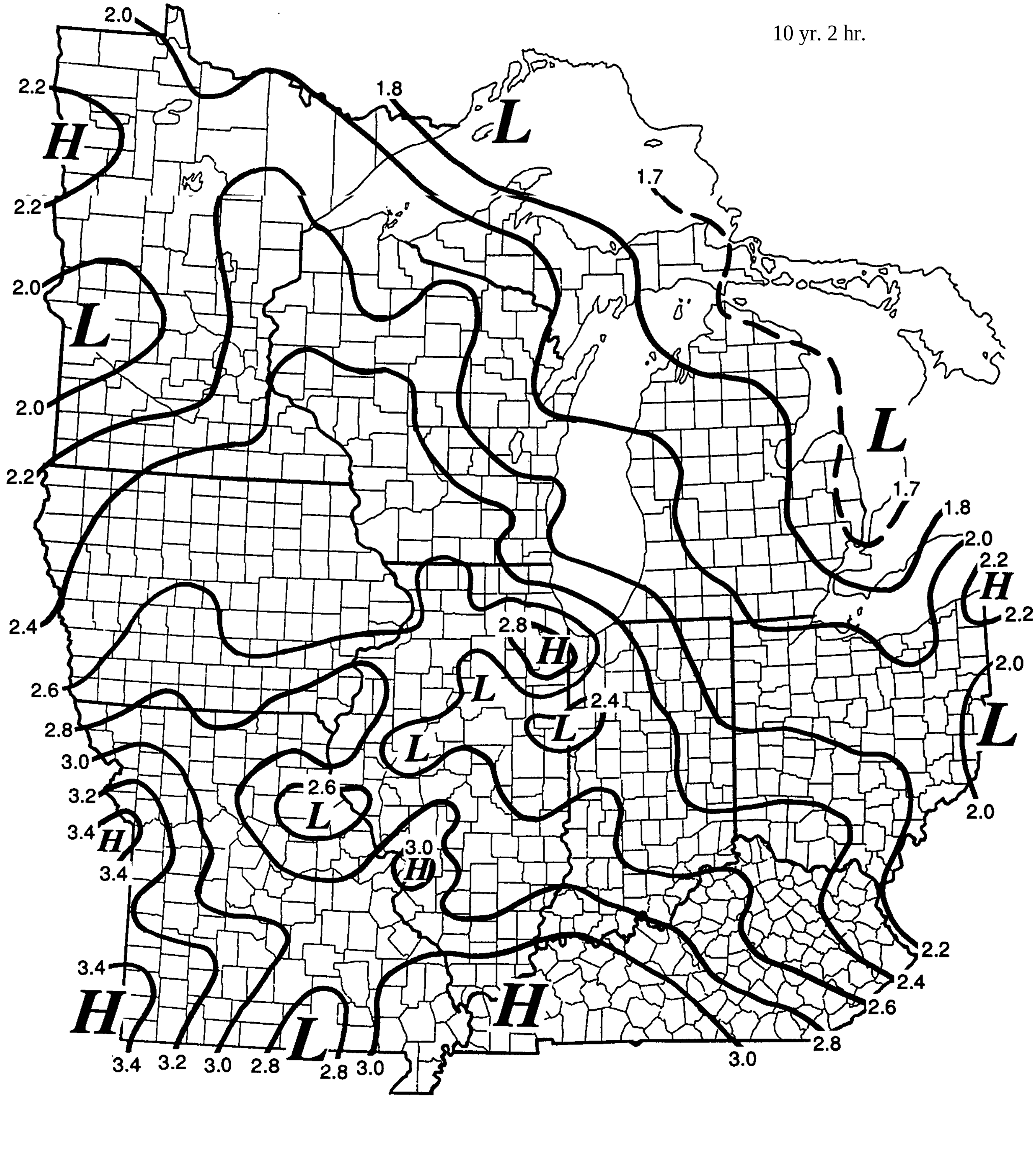

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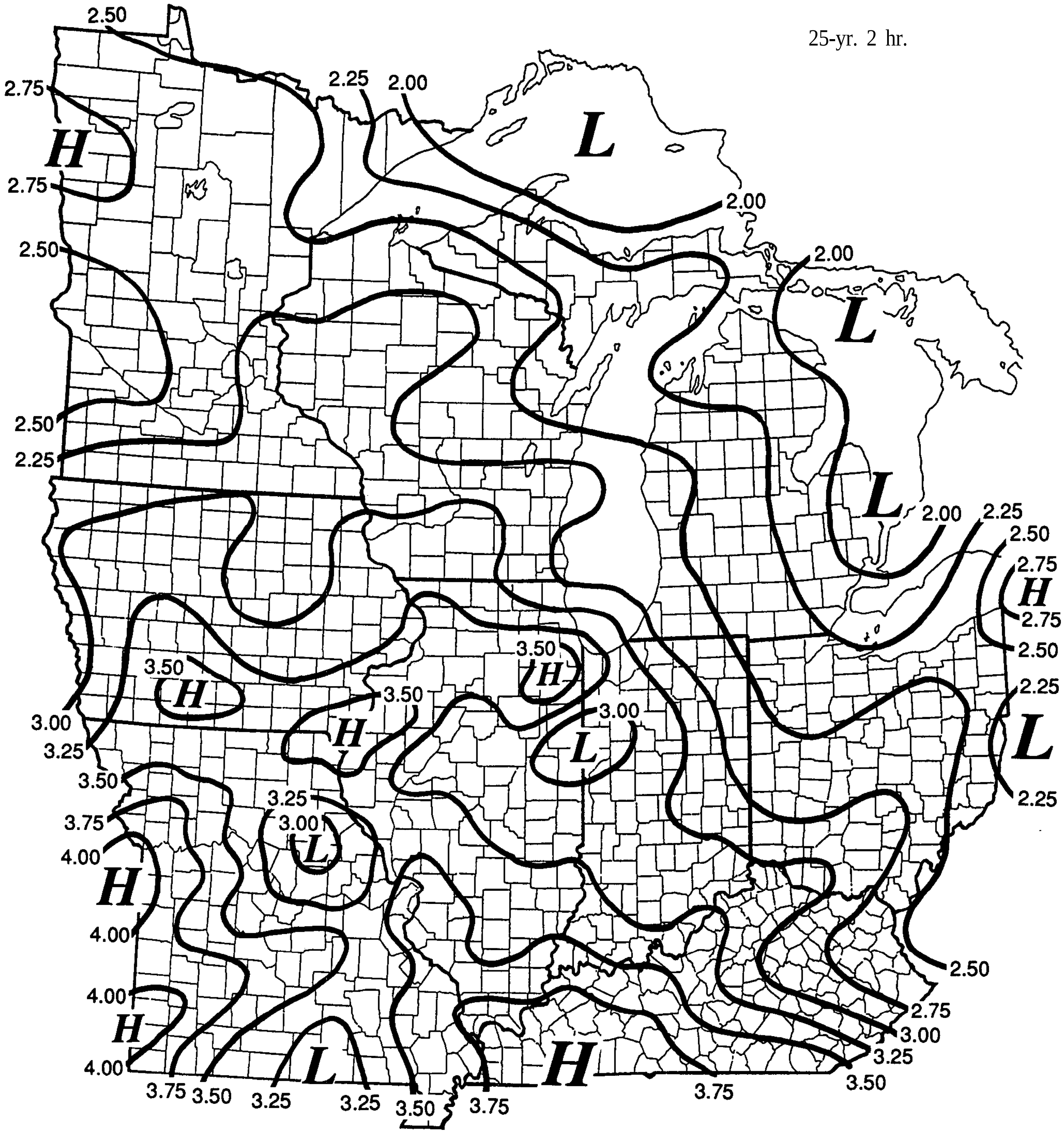

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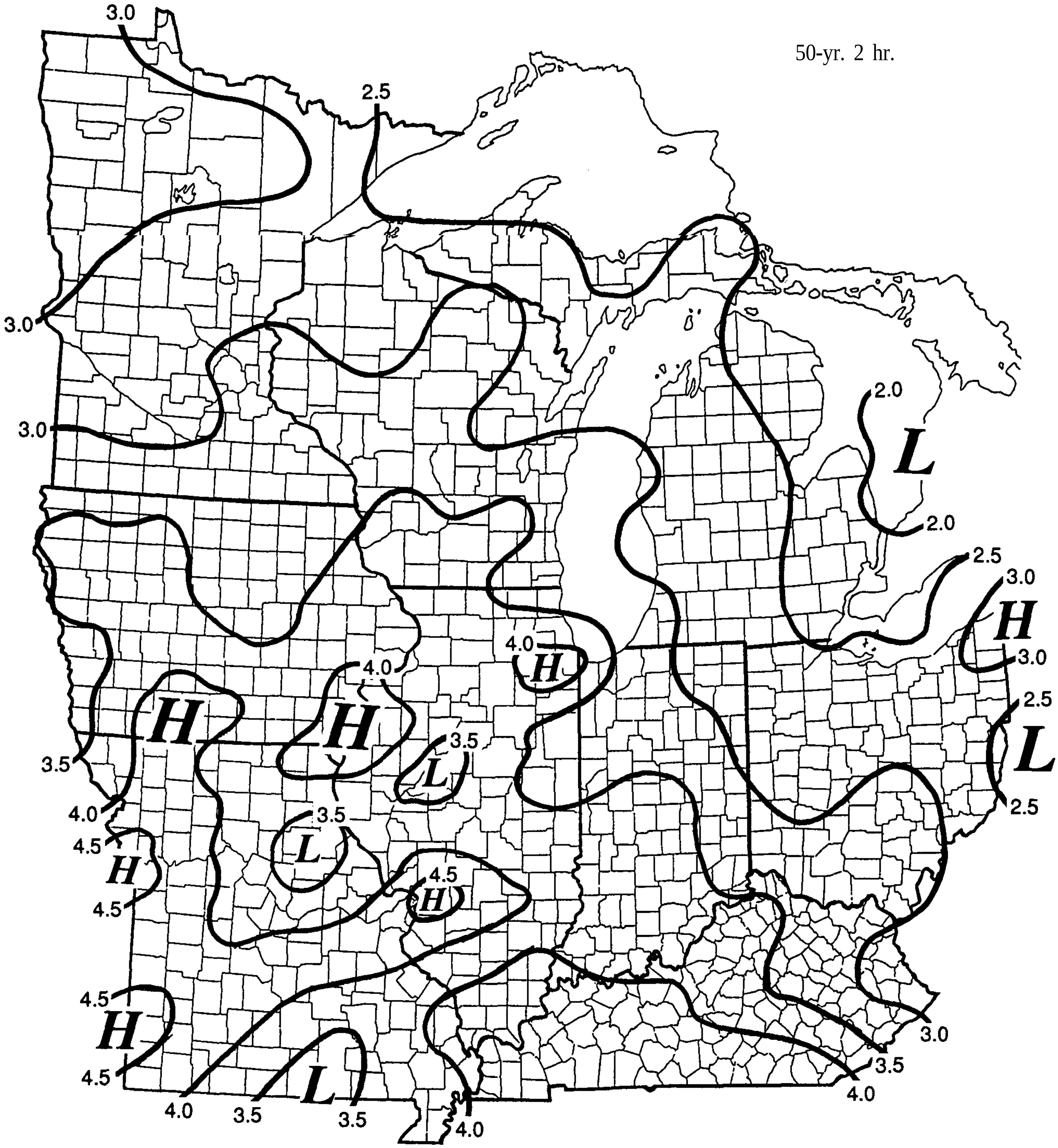

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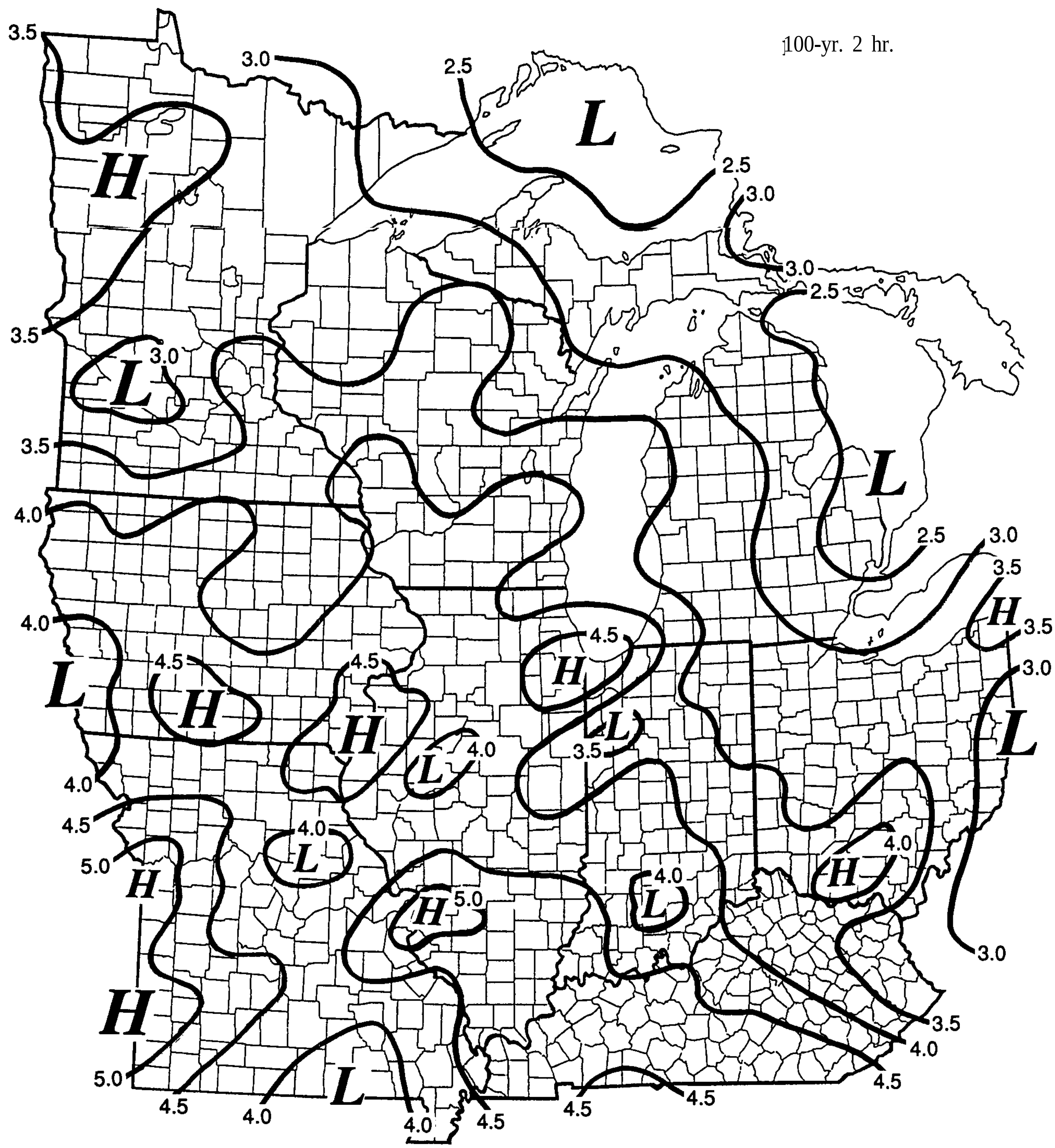

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2-yr. 3-hr.

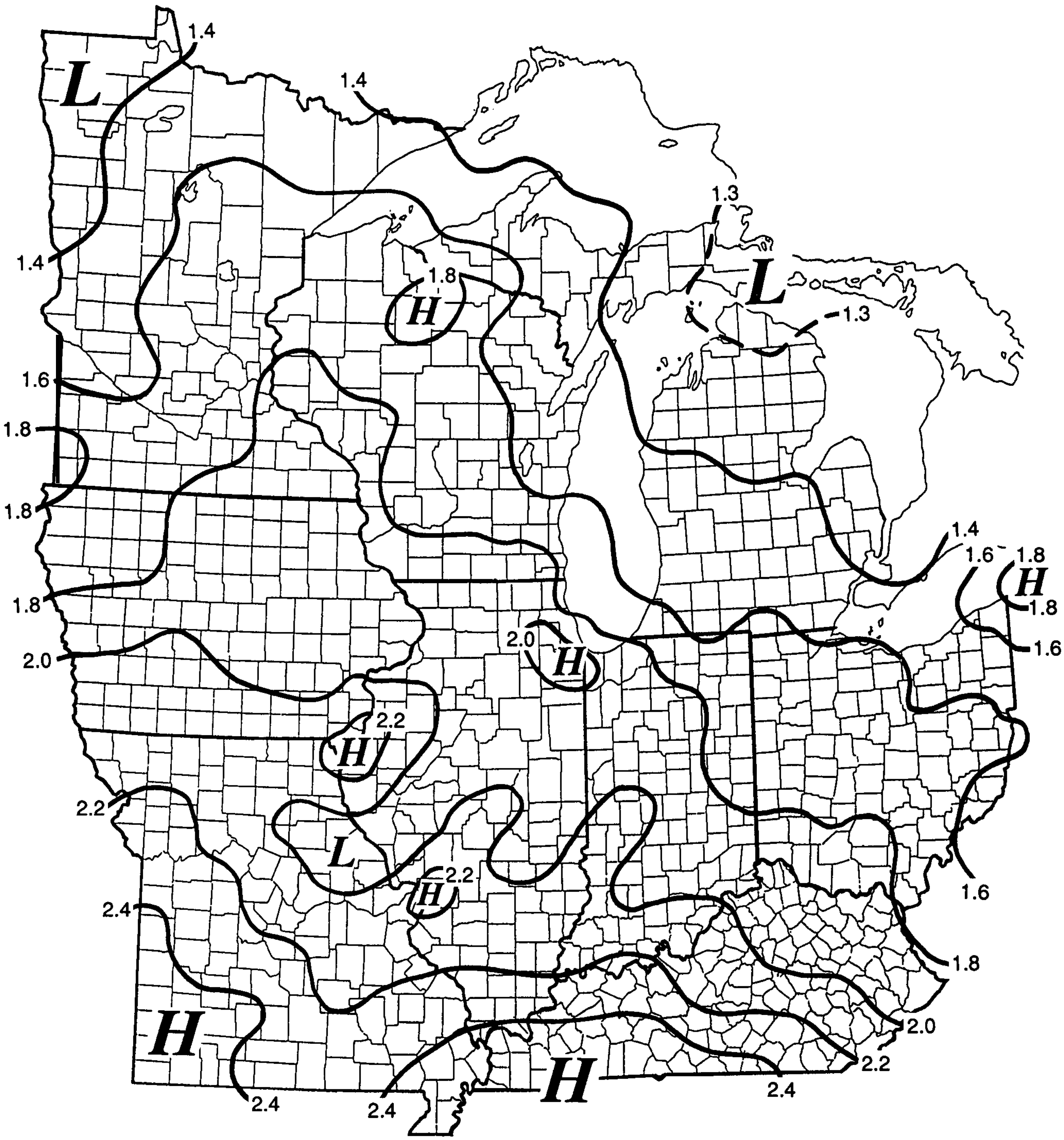


Figure 3. Spatial distribution of 3-hour rainfall (inches)

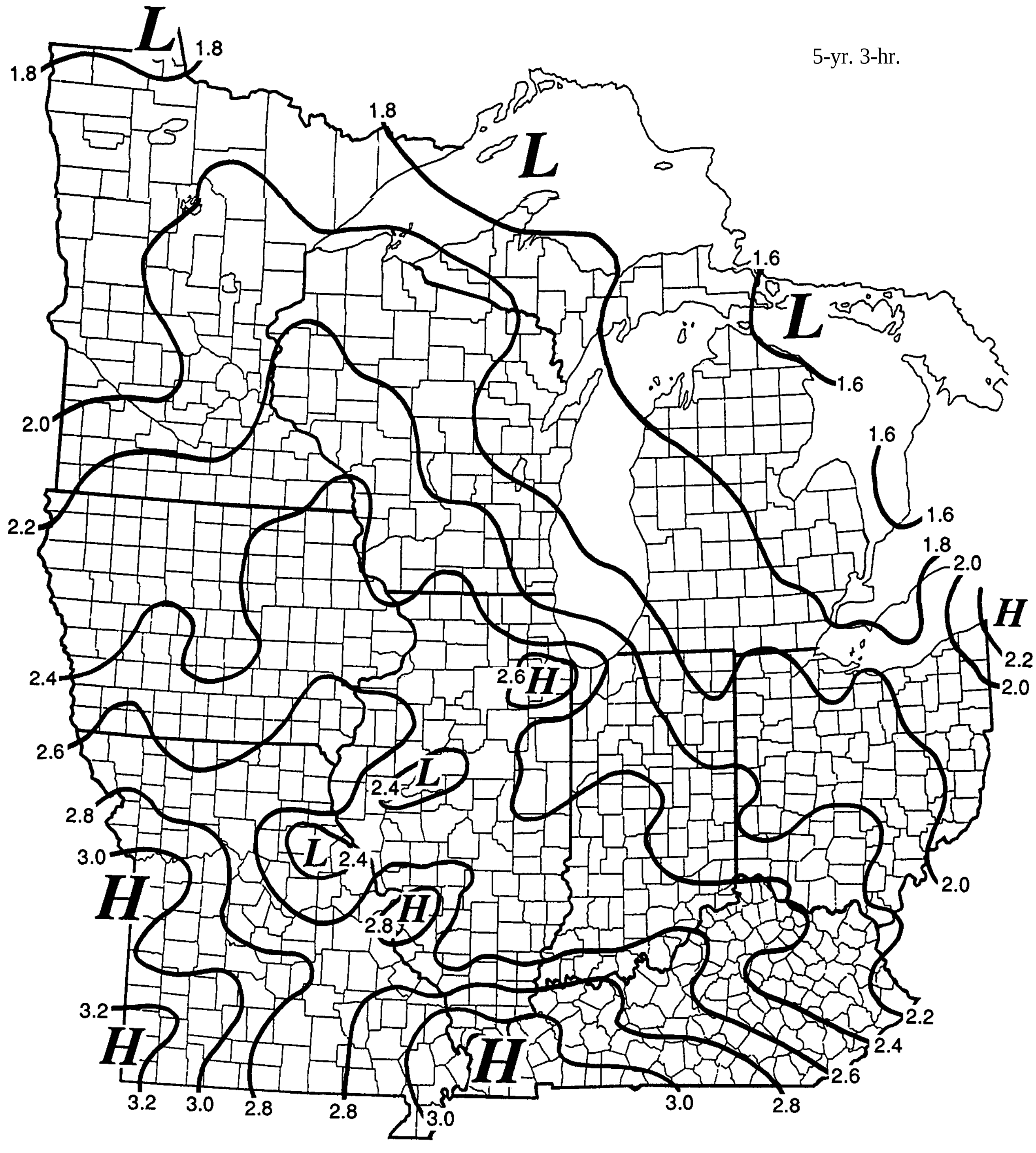
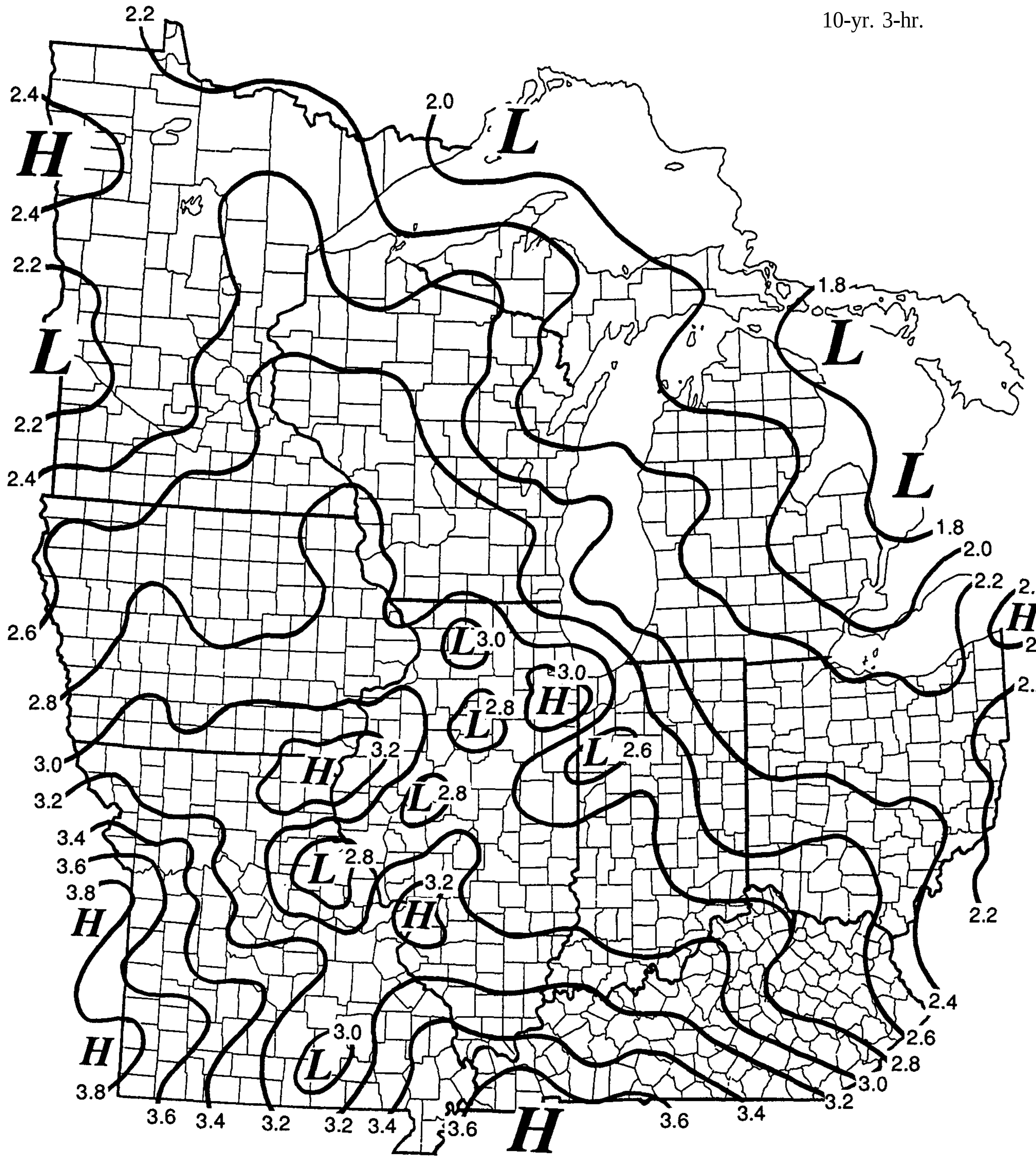


Figure 3. Continued

10-yr. 3-hr.



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25-Yr. 3-hr.

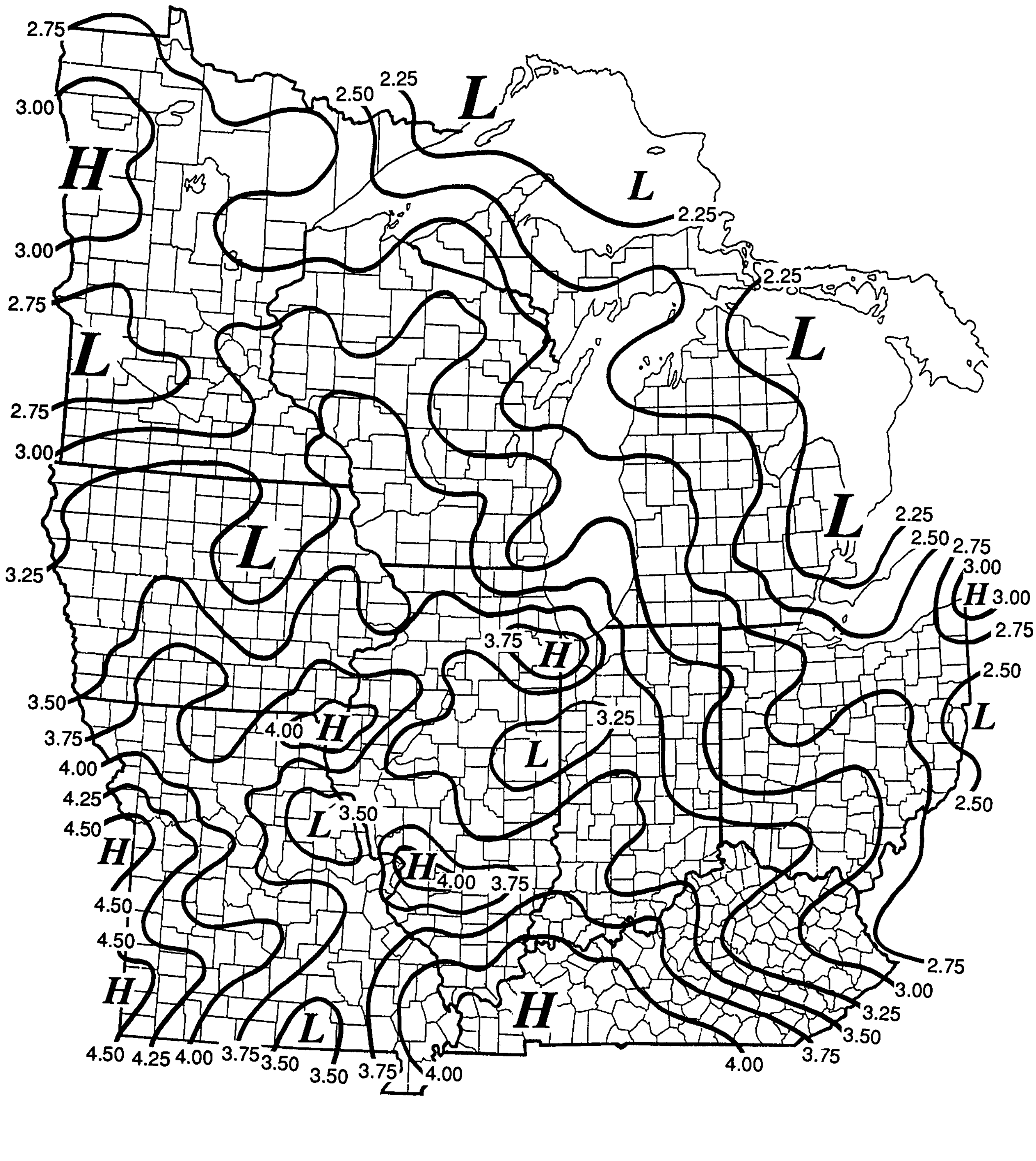
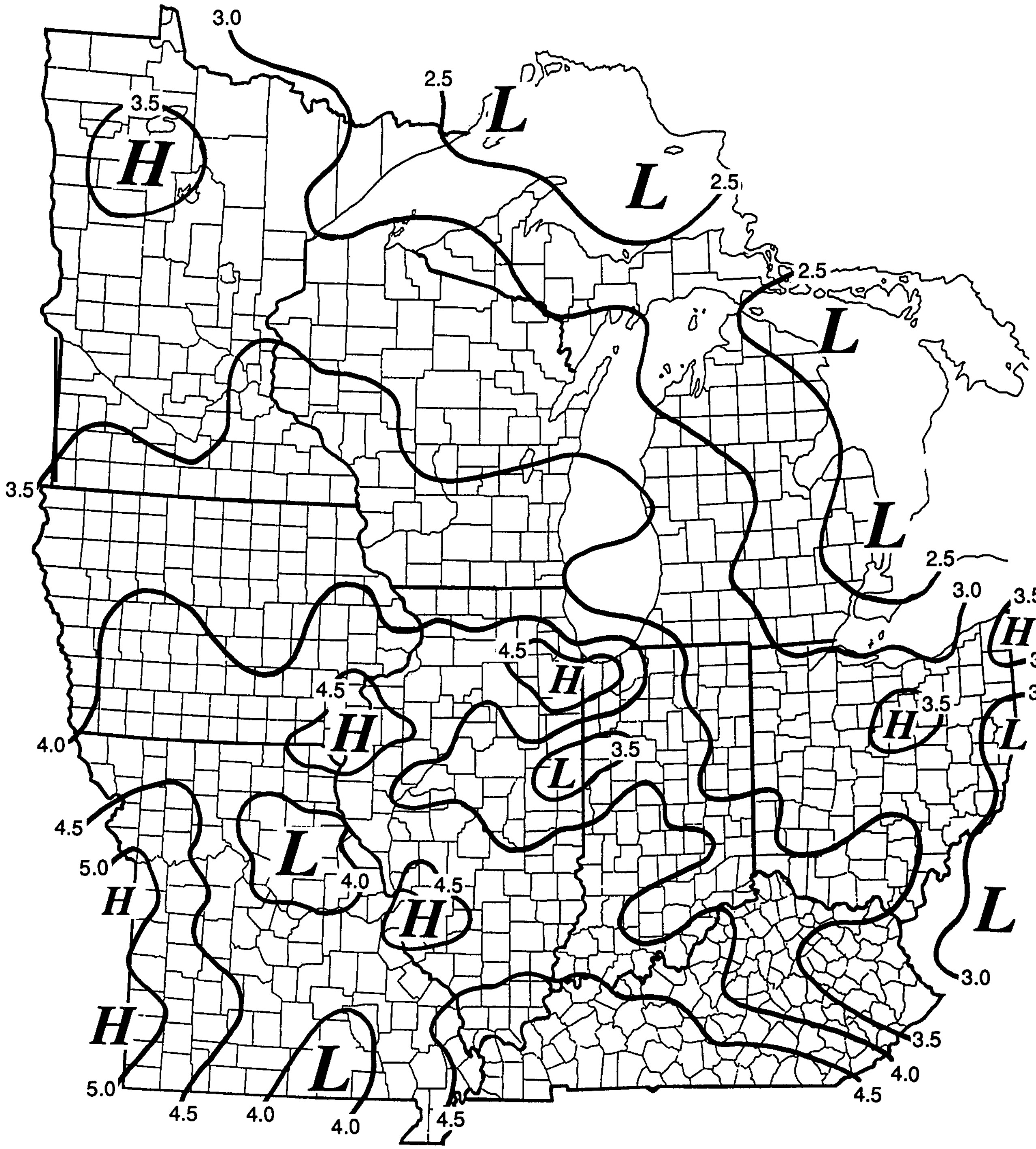


Figure 3. Continued

50-yr. 3-hr.



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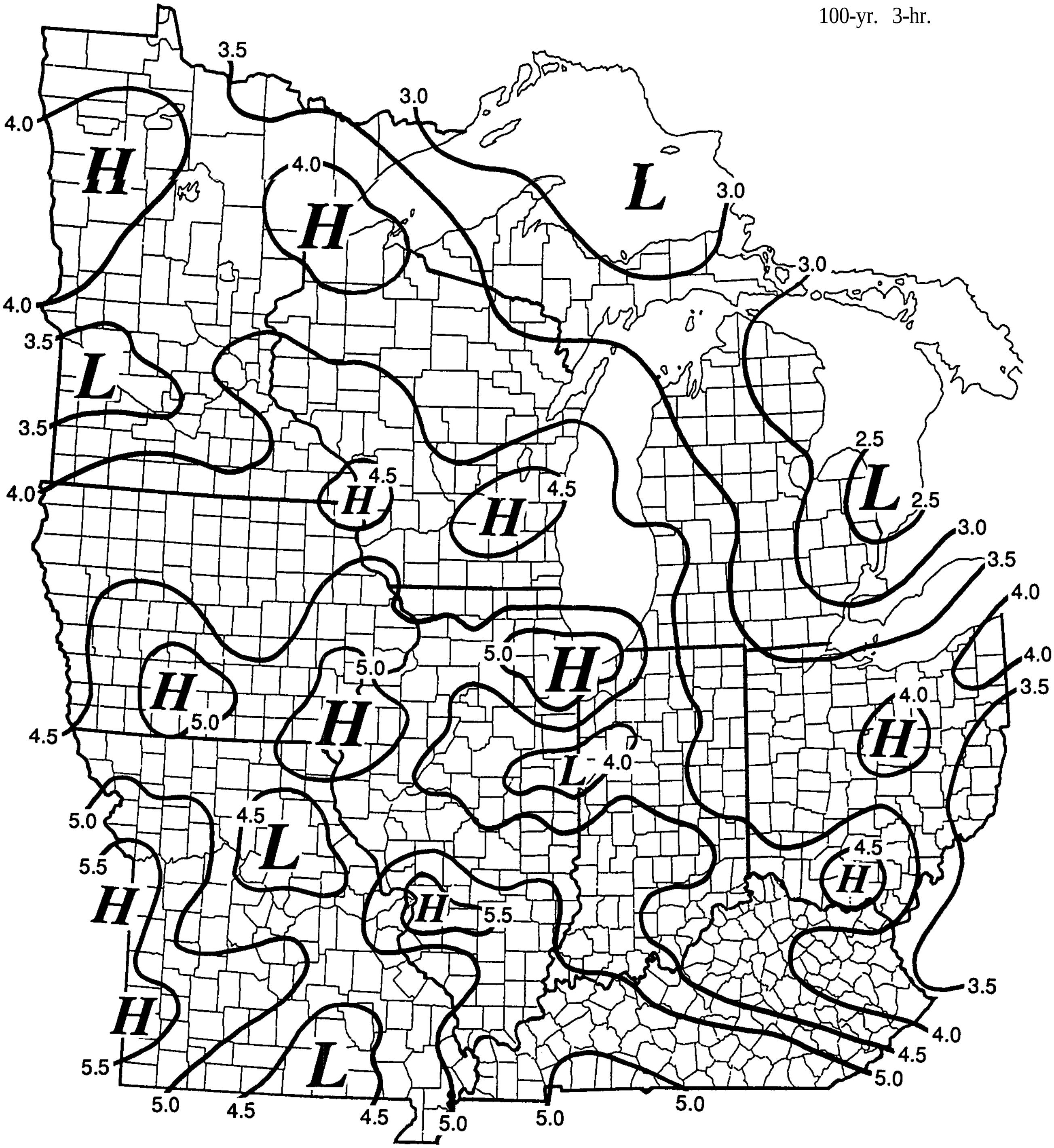


Figure 3. Concluded

2-yr. 6-hr.

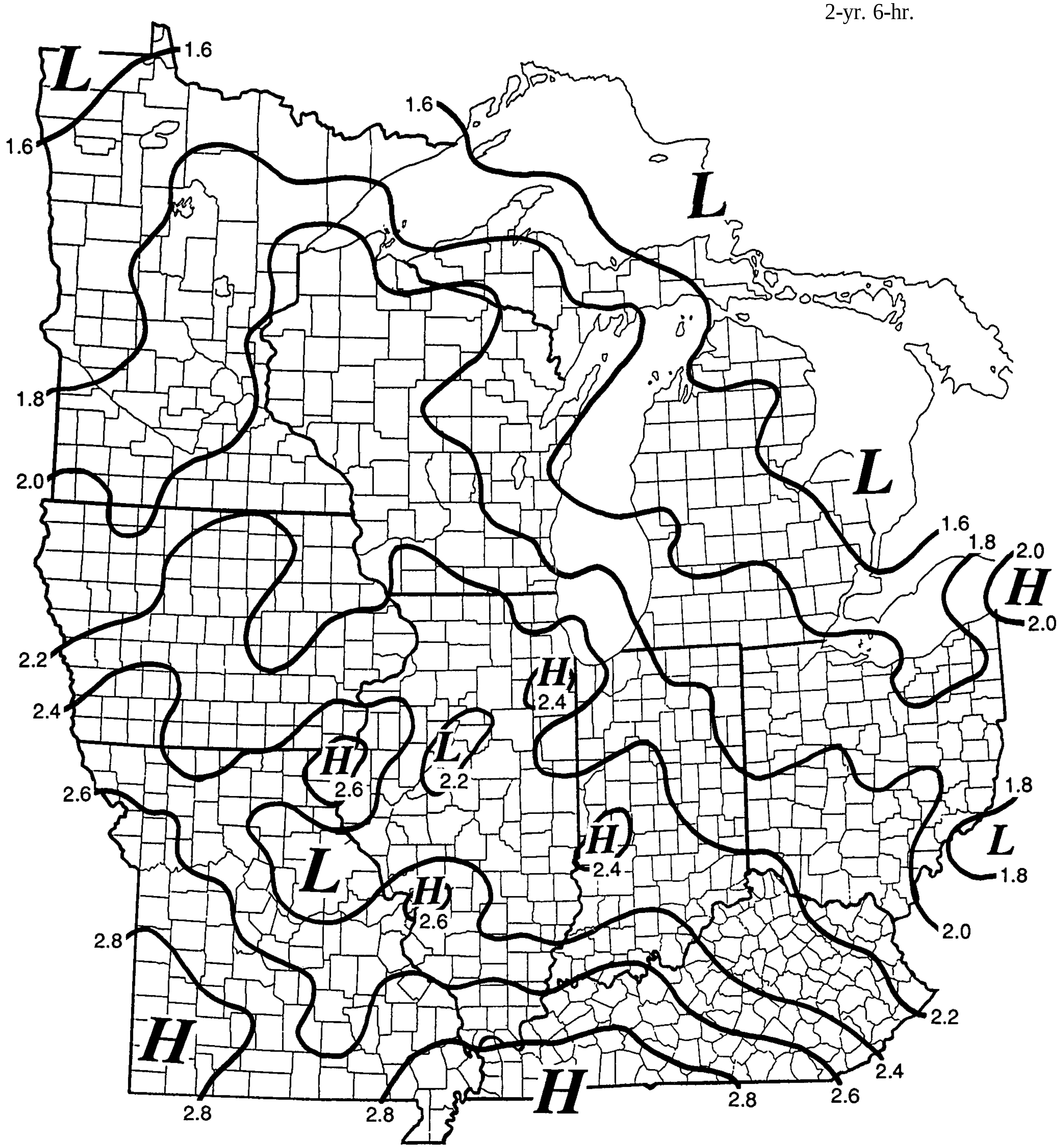
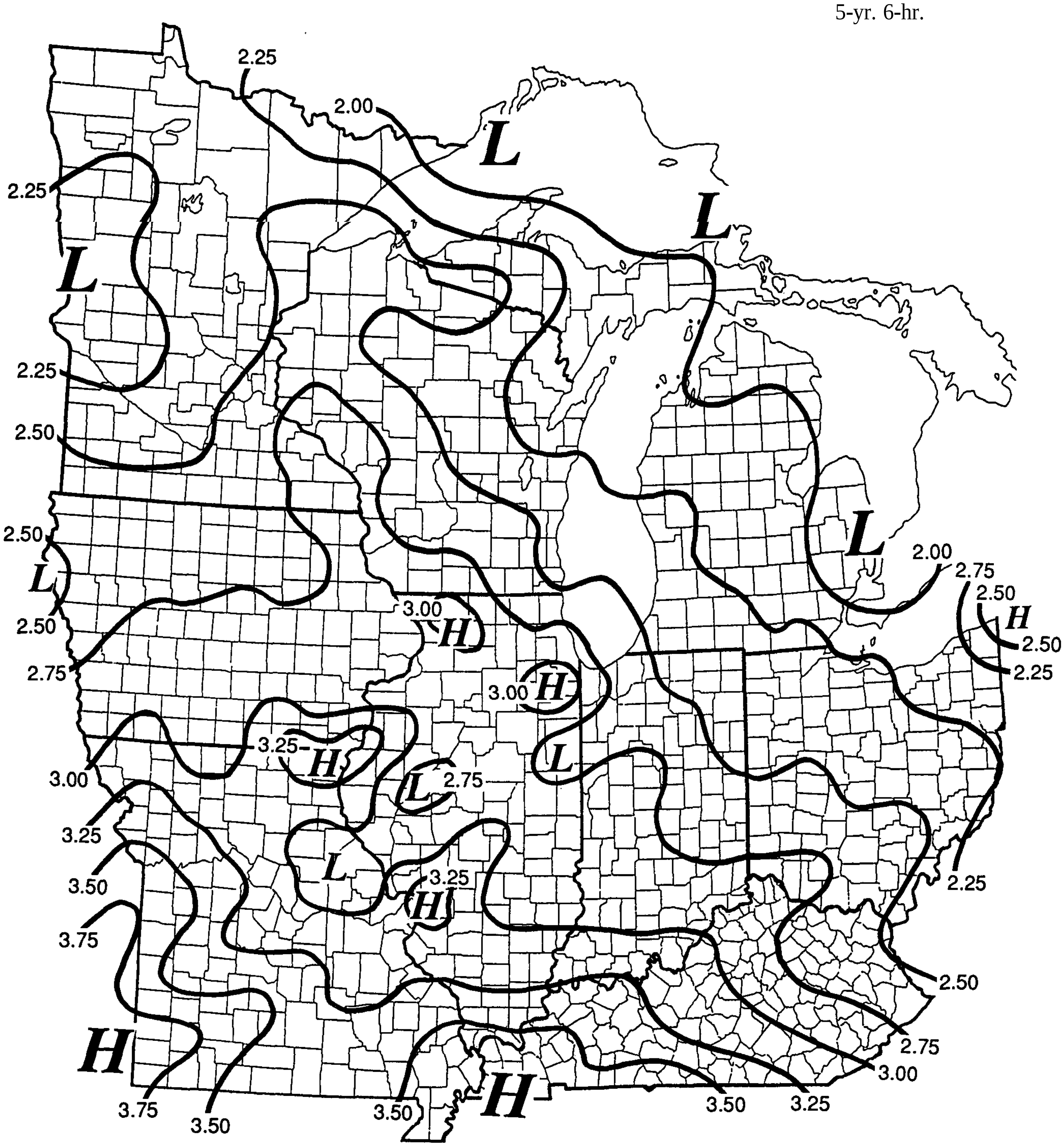


Figure 4. Spatial distribution of 6-hour rainfall (inches)

5-yr. 6-hr.



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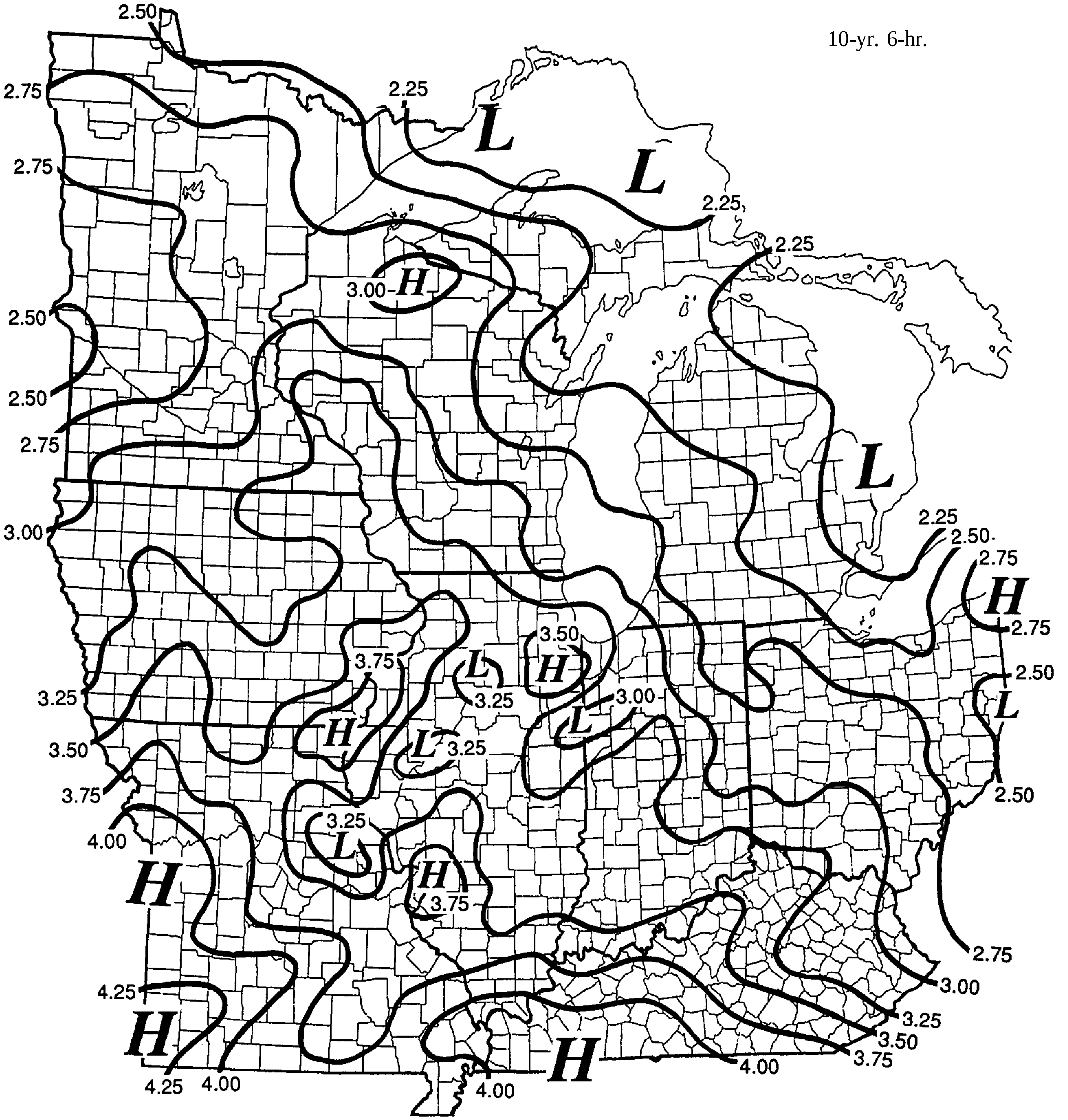

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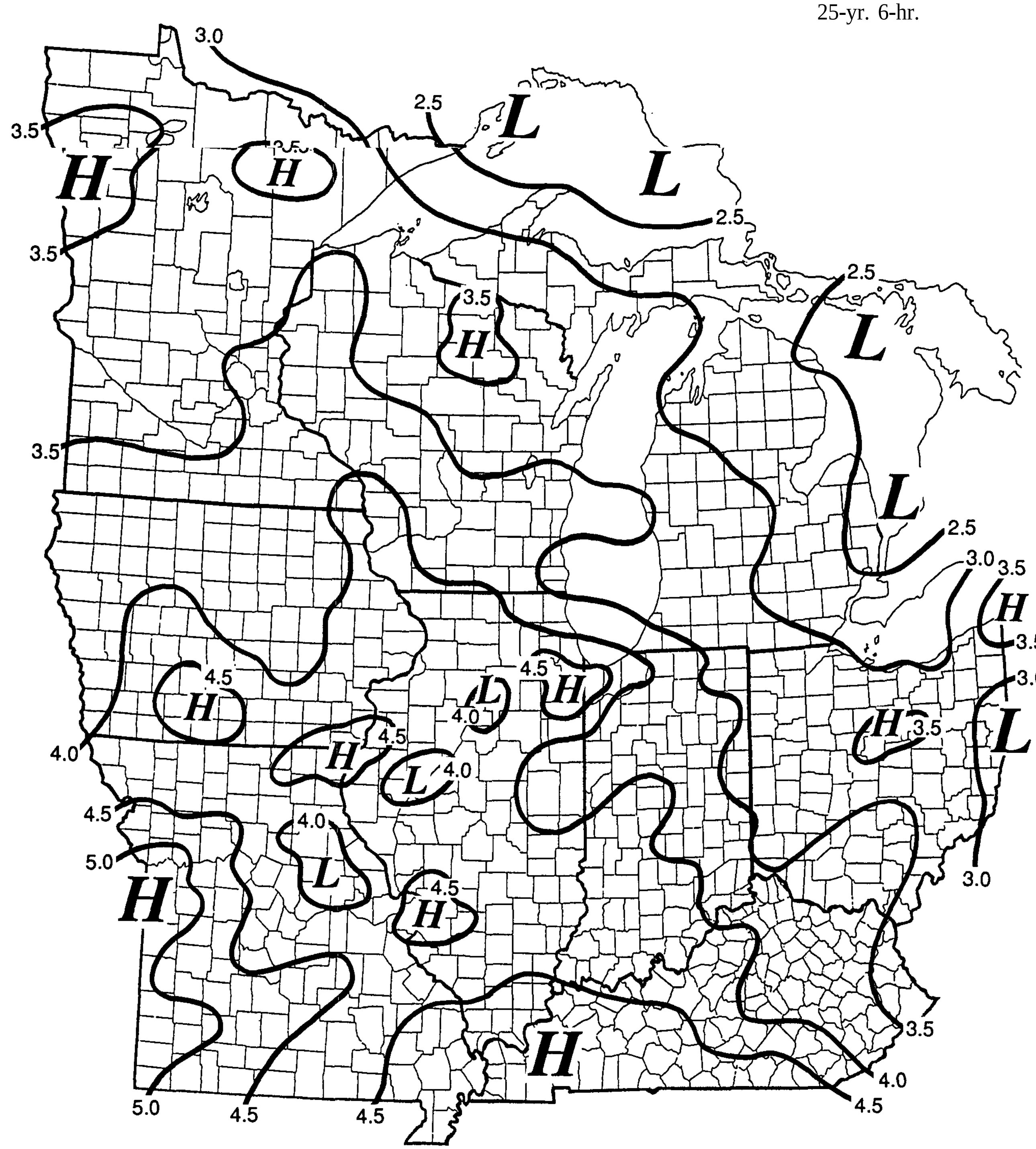
25-yr. 6-hr.



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50-yr. 6-hr.

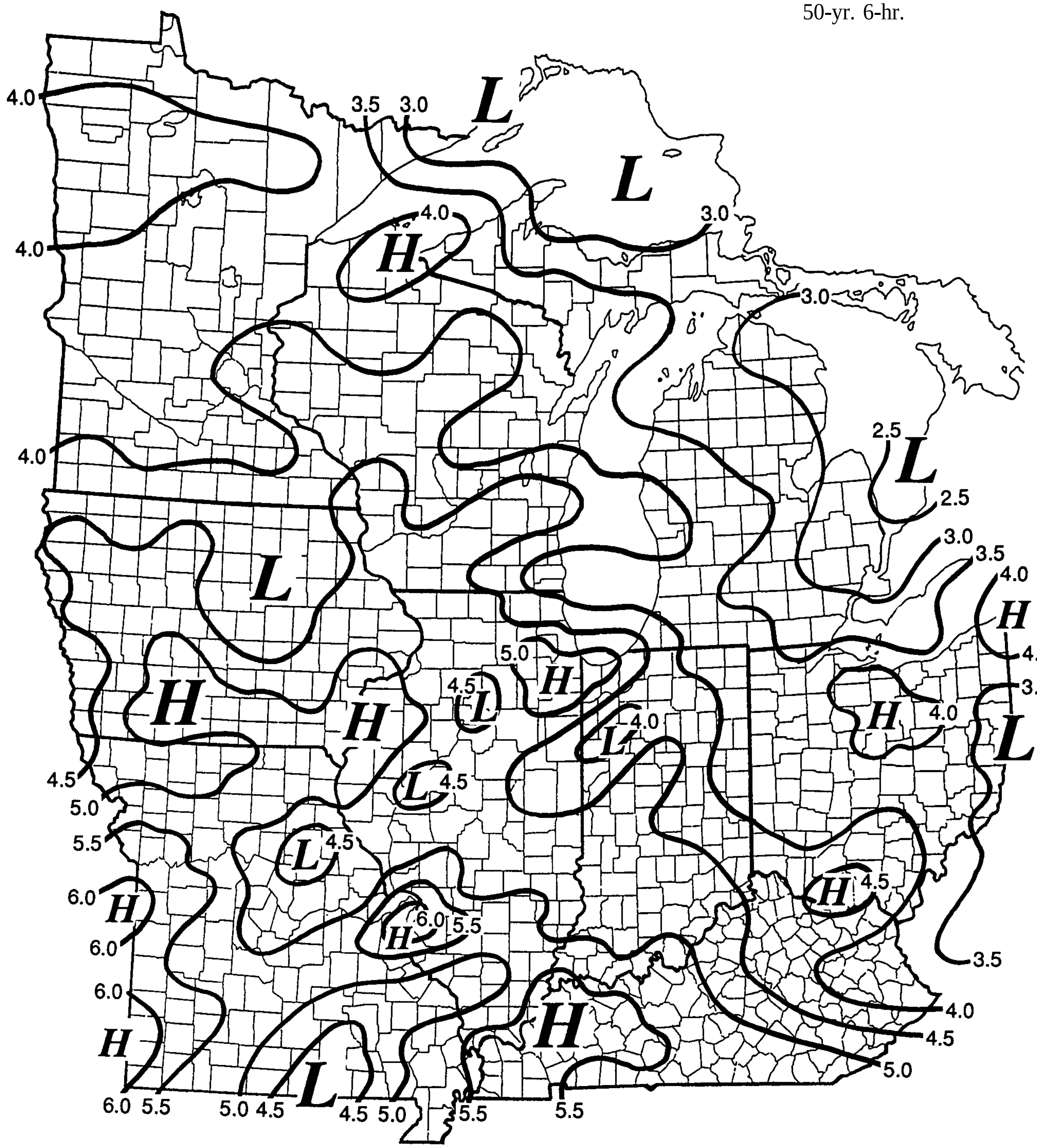


Figure 4. Continued

100-yr. 6-hr.

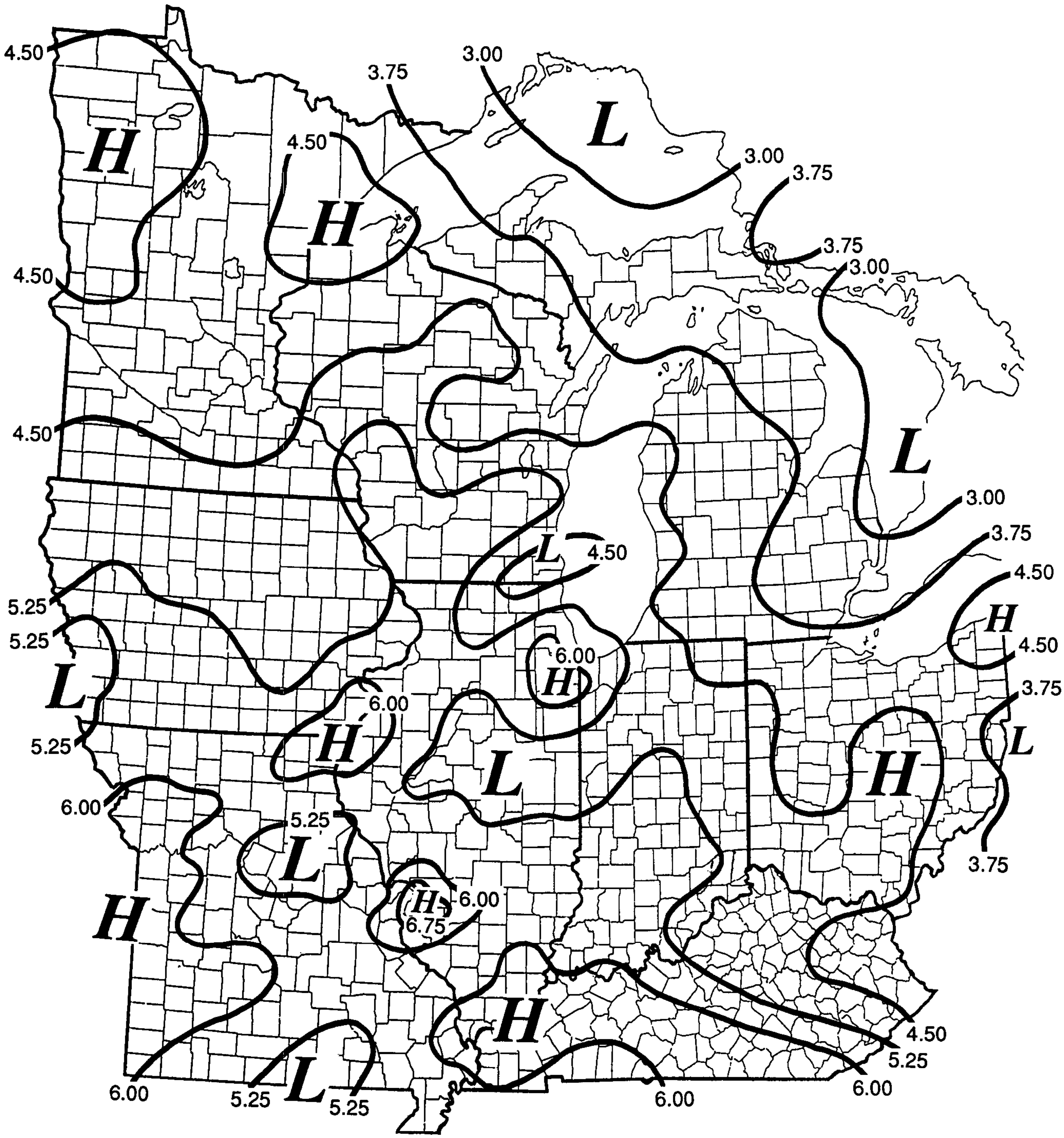


Figure 4. Concluded

2-yr. 12-hr.

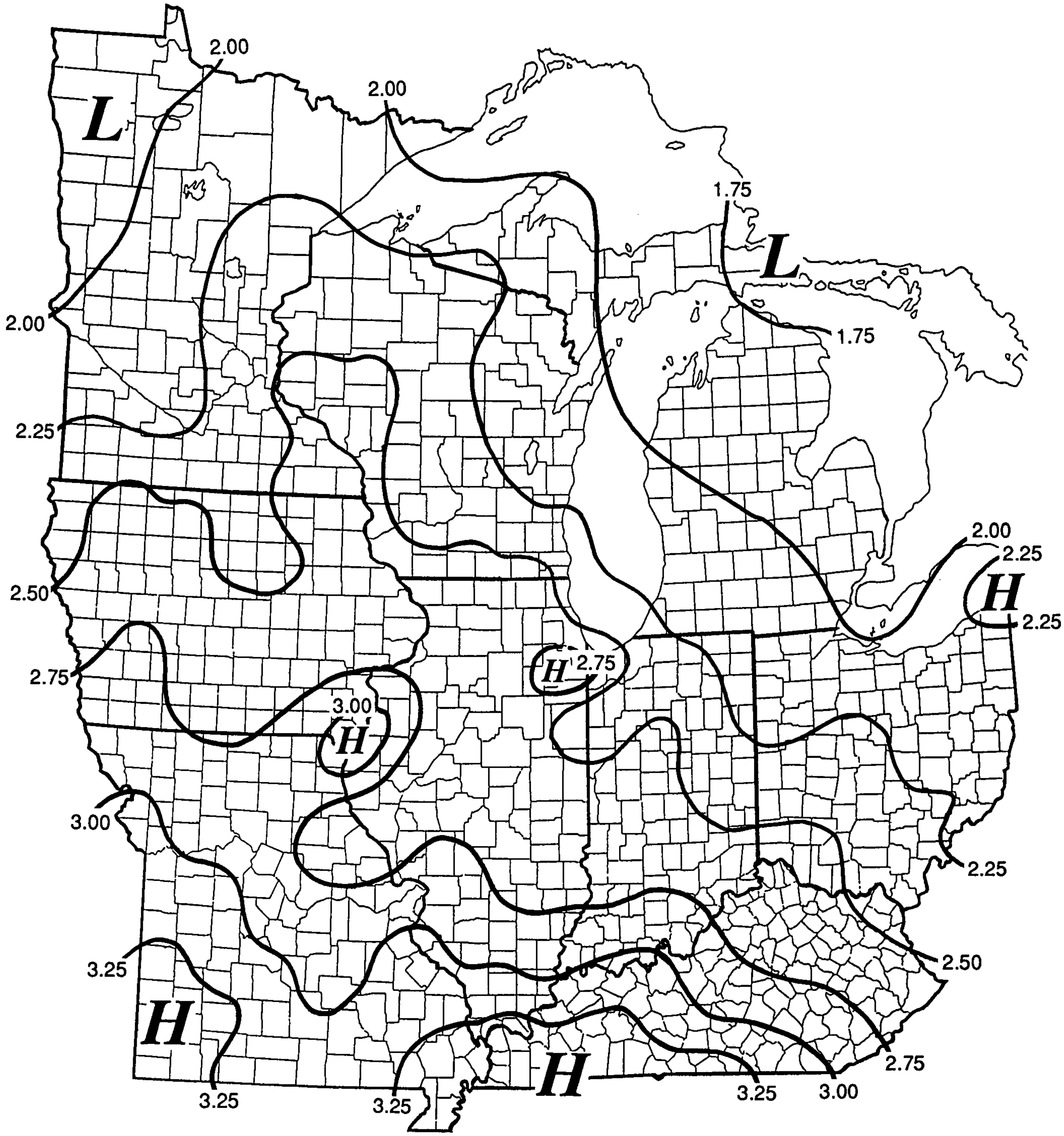
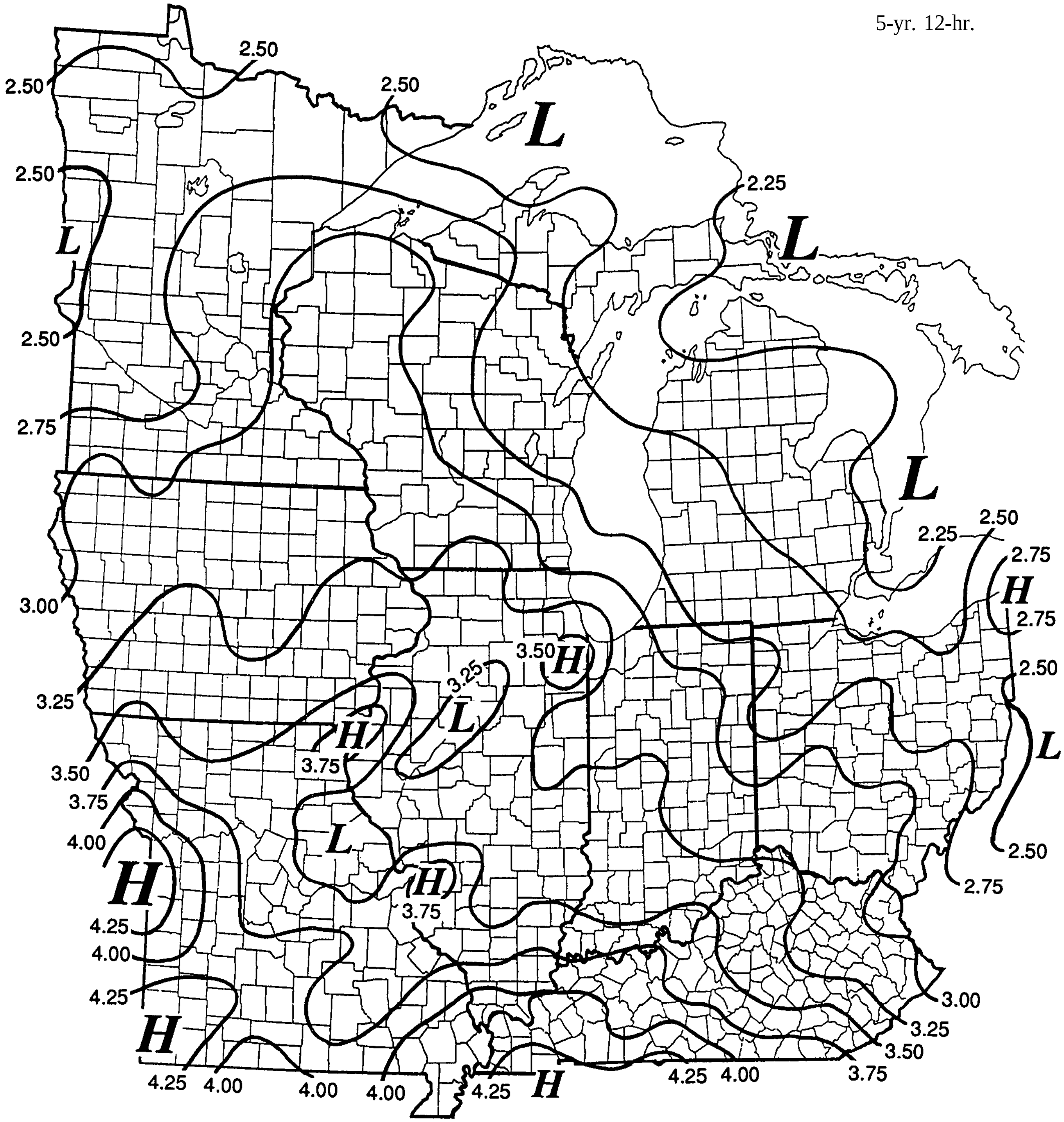


Figure 5. Spatial distribution of 12-hour rainfall (inches)



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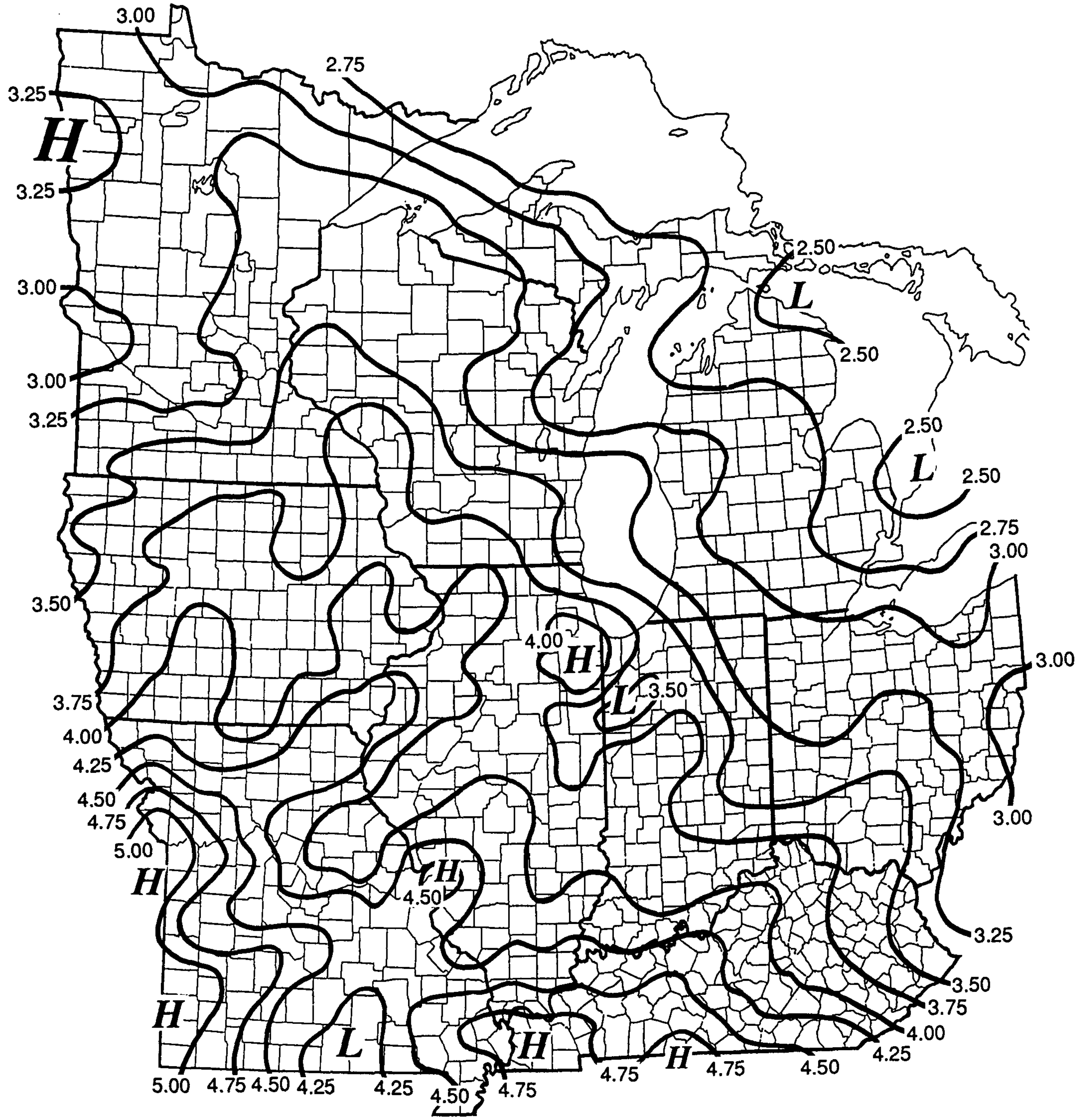

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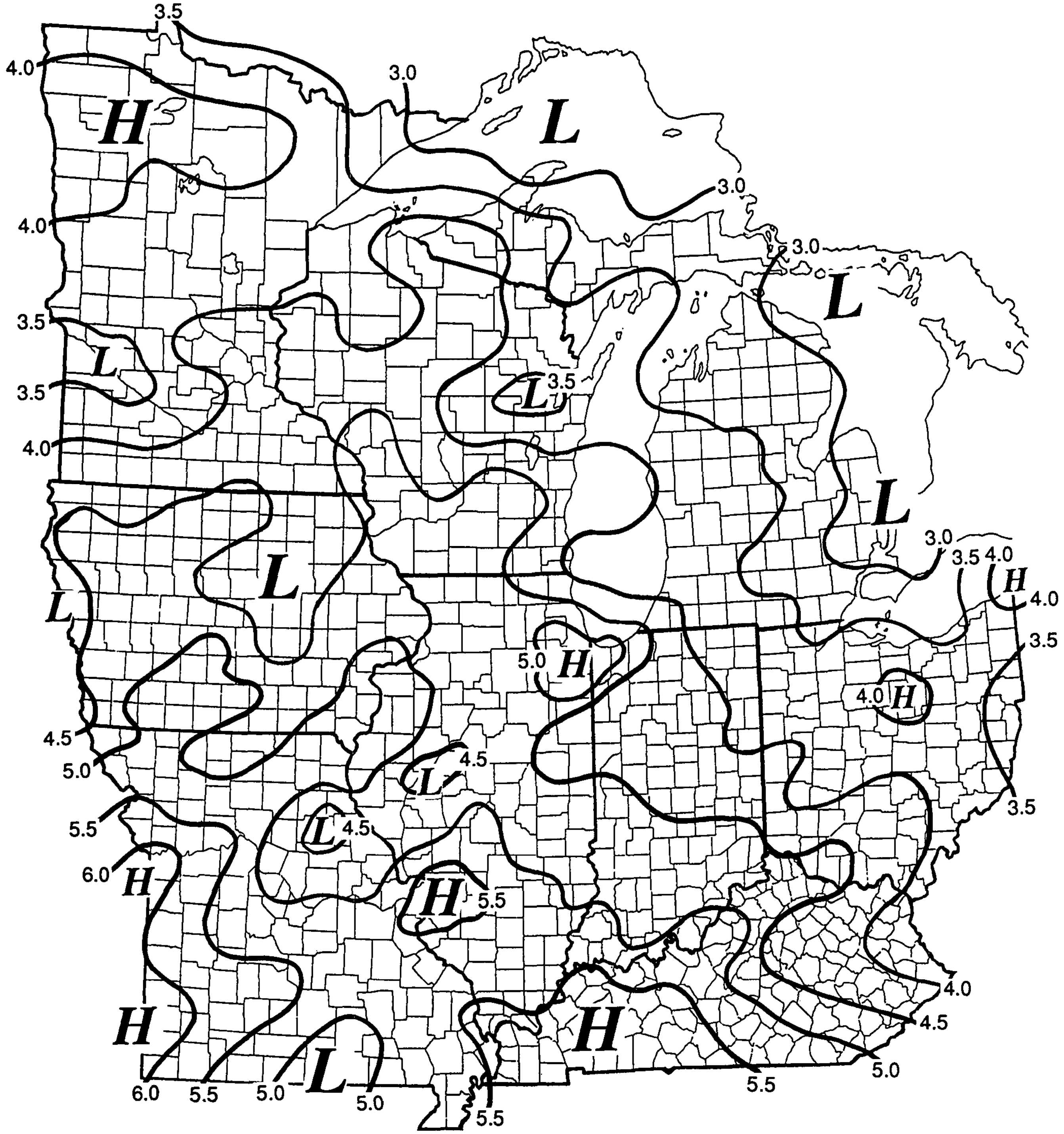
25-yr. 12-hr.



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50-yr. 12-hr.

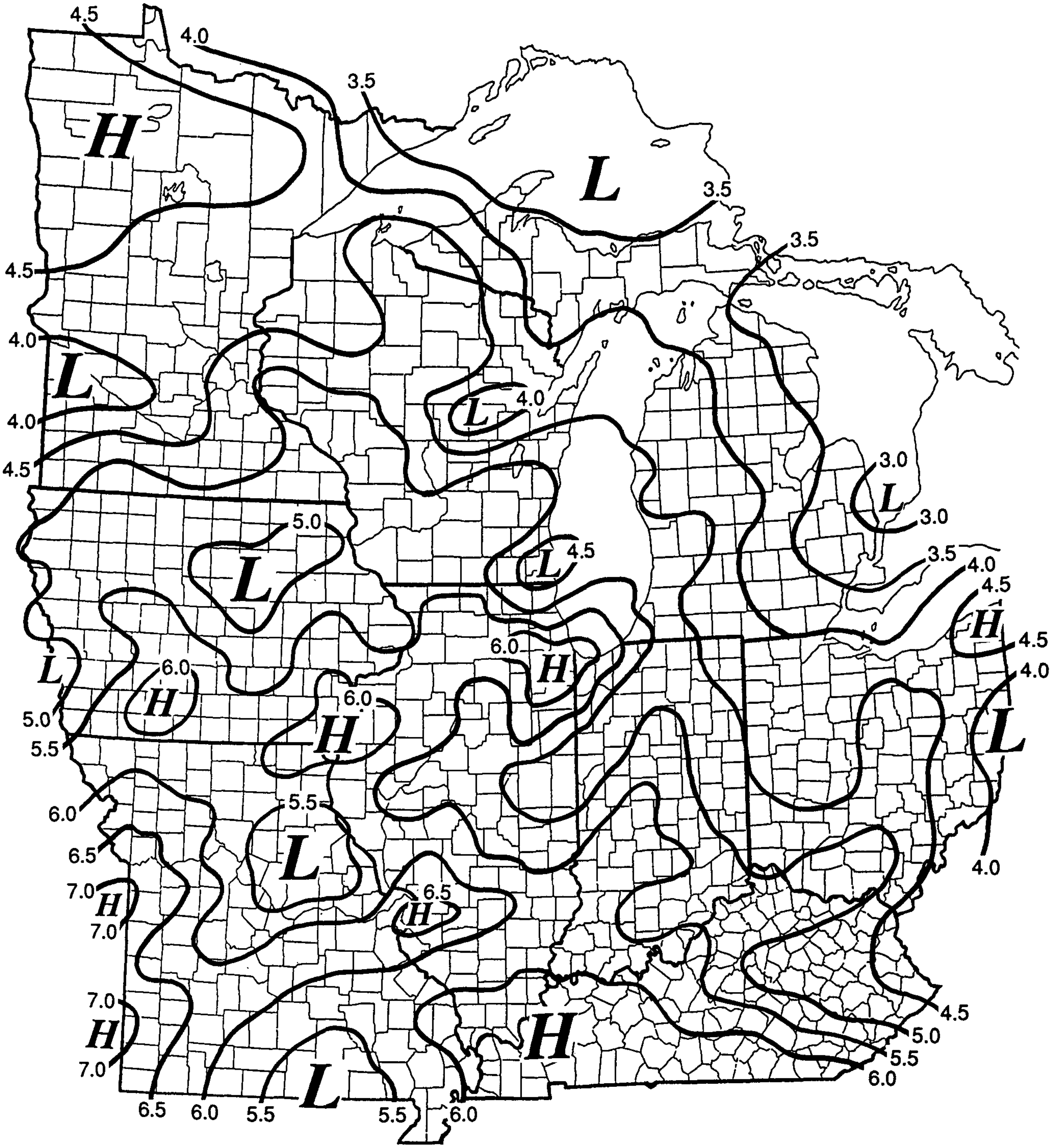
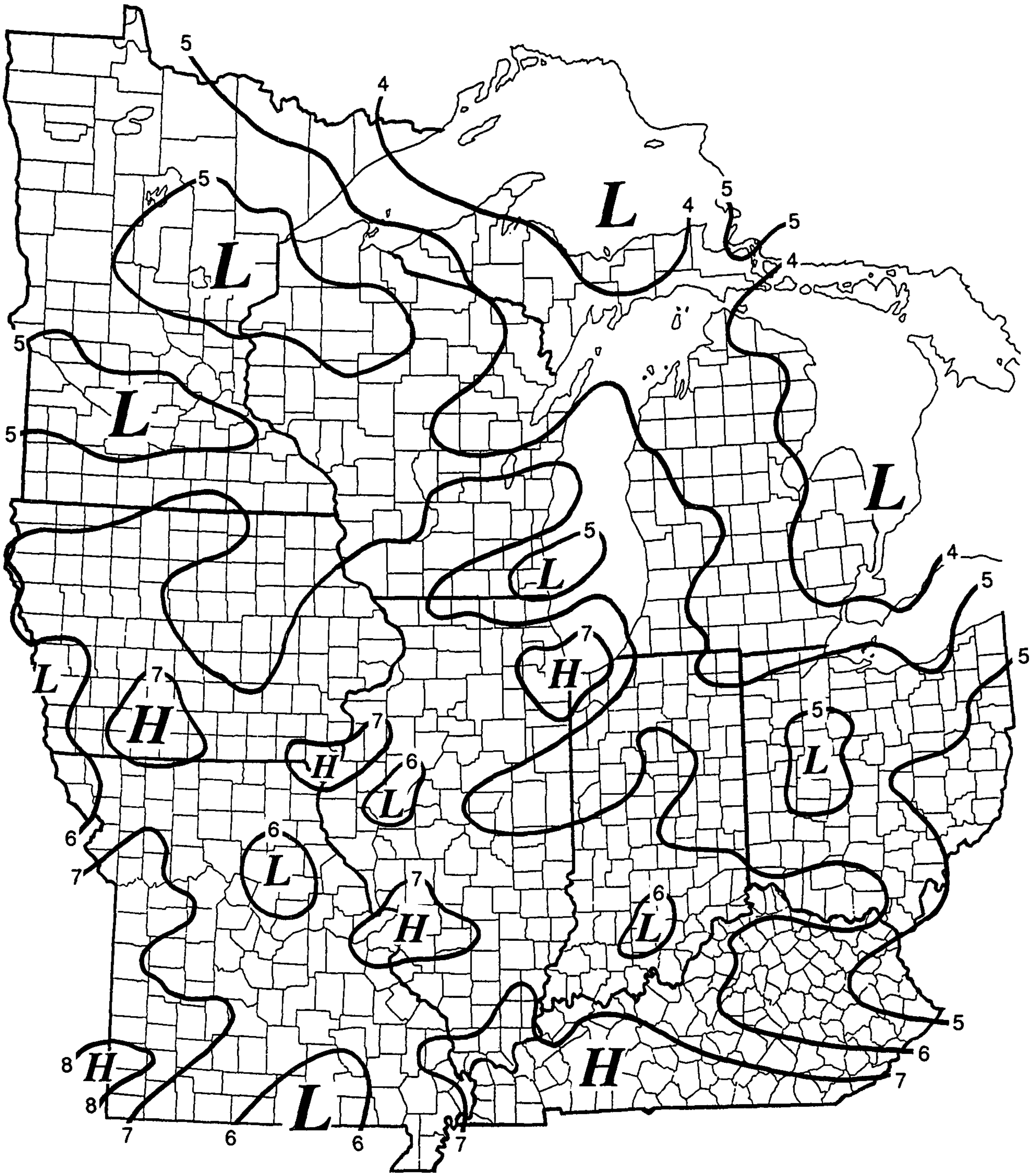


Figure 5. Continued

l00-yr. 12-hr.



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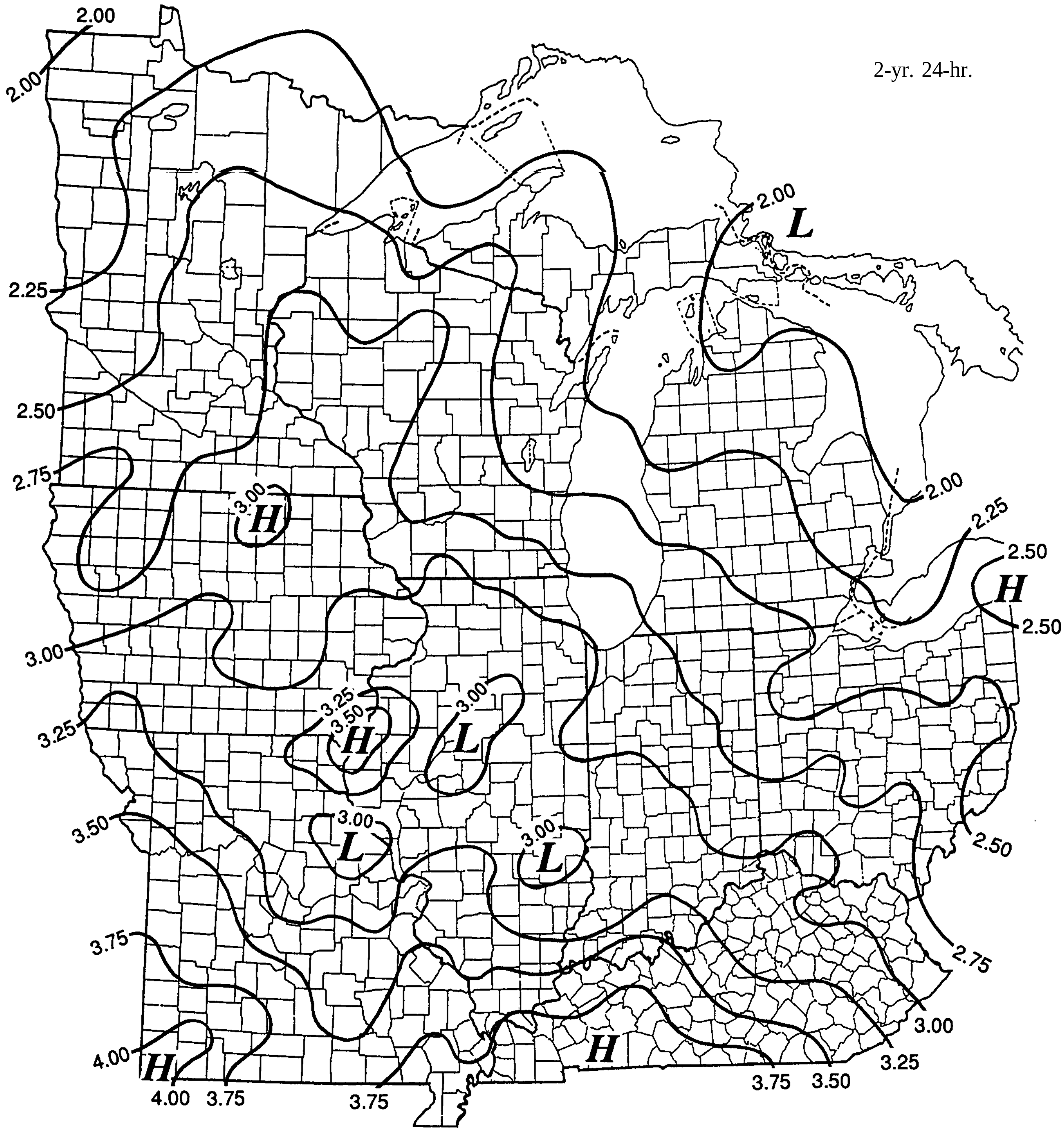
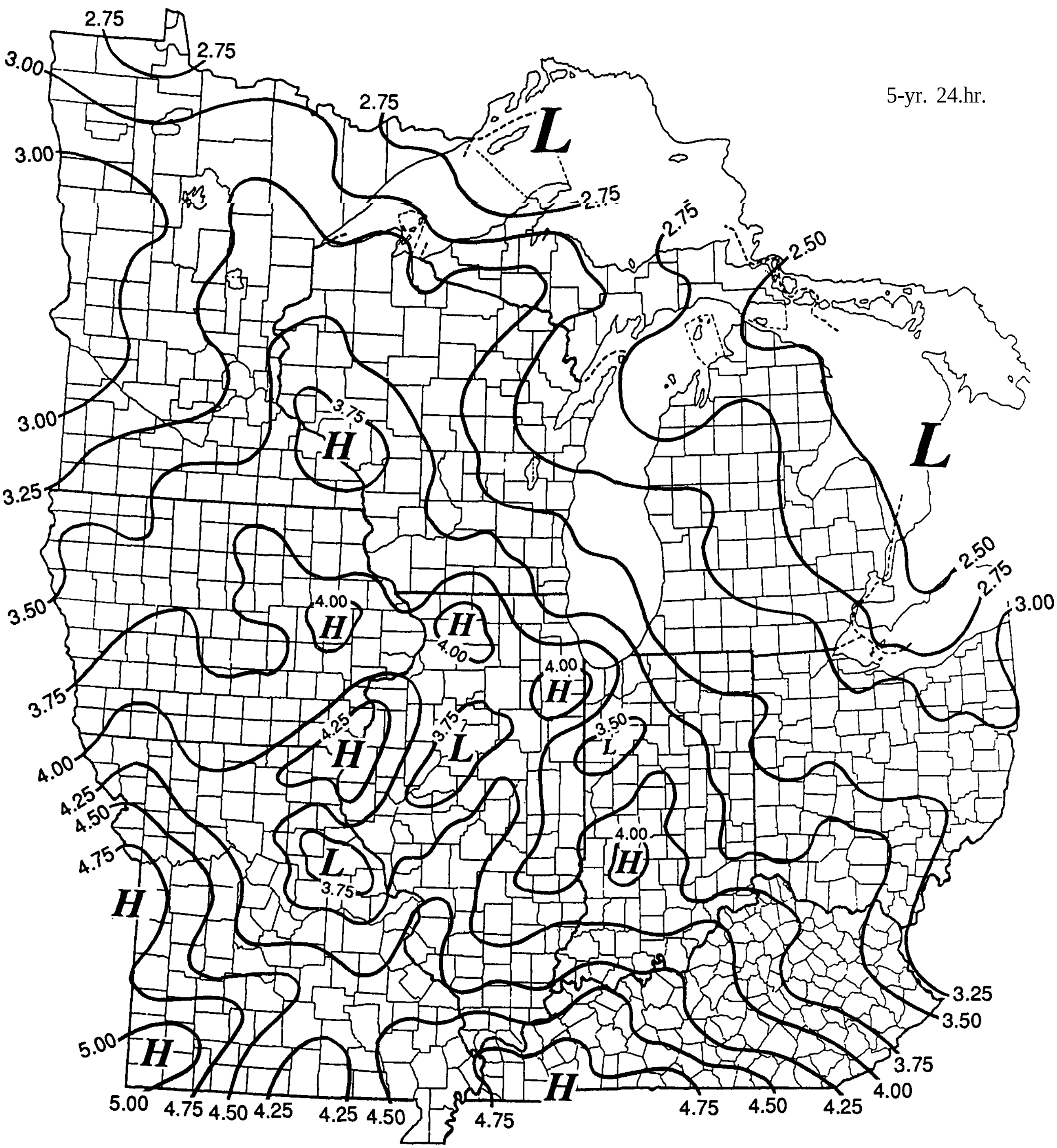


Figure 6. Spatial distribution of 24-hour rainfall (inches)



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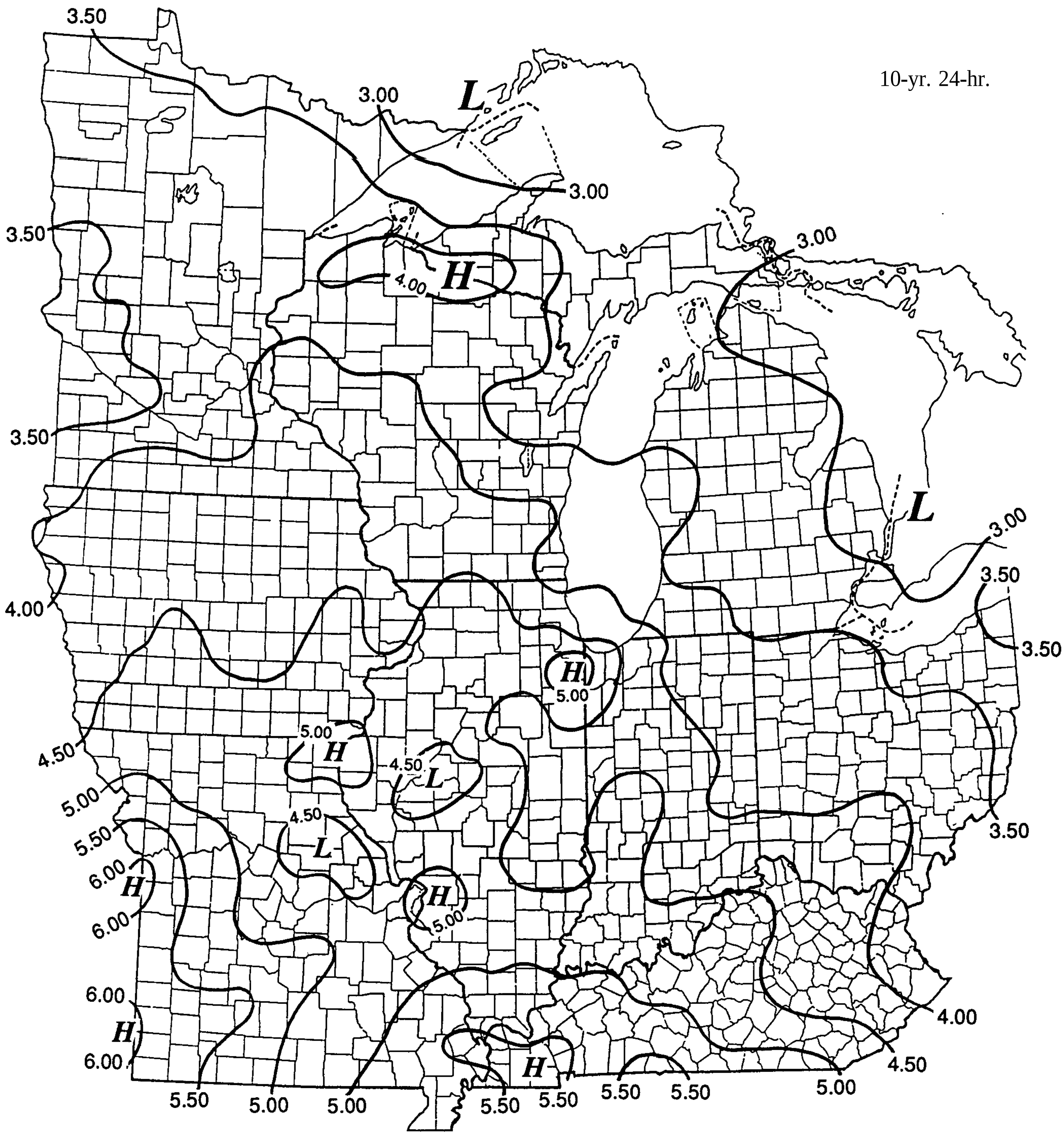

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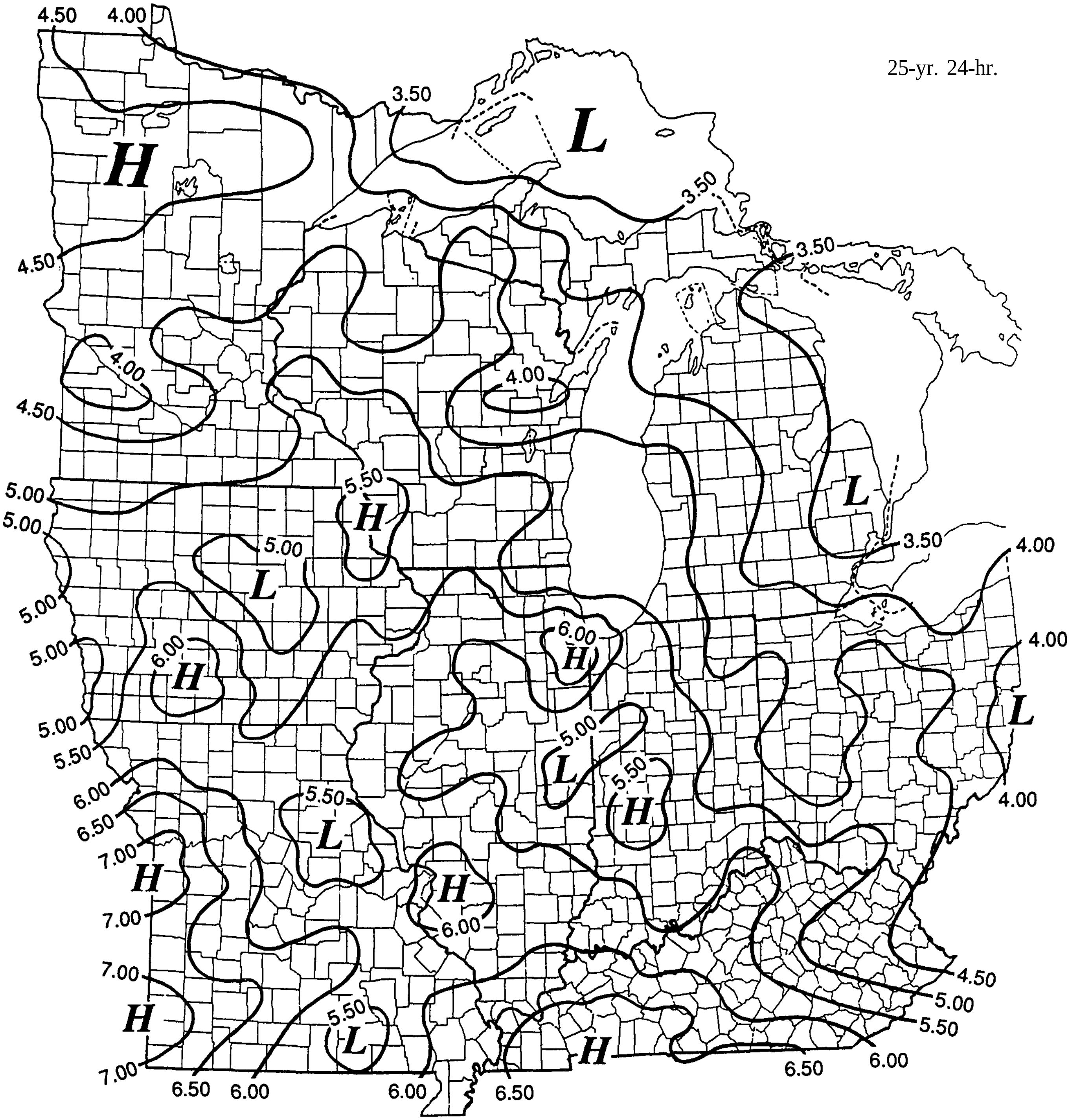

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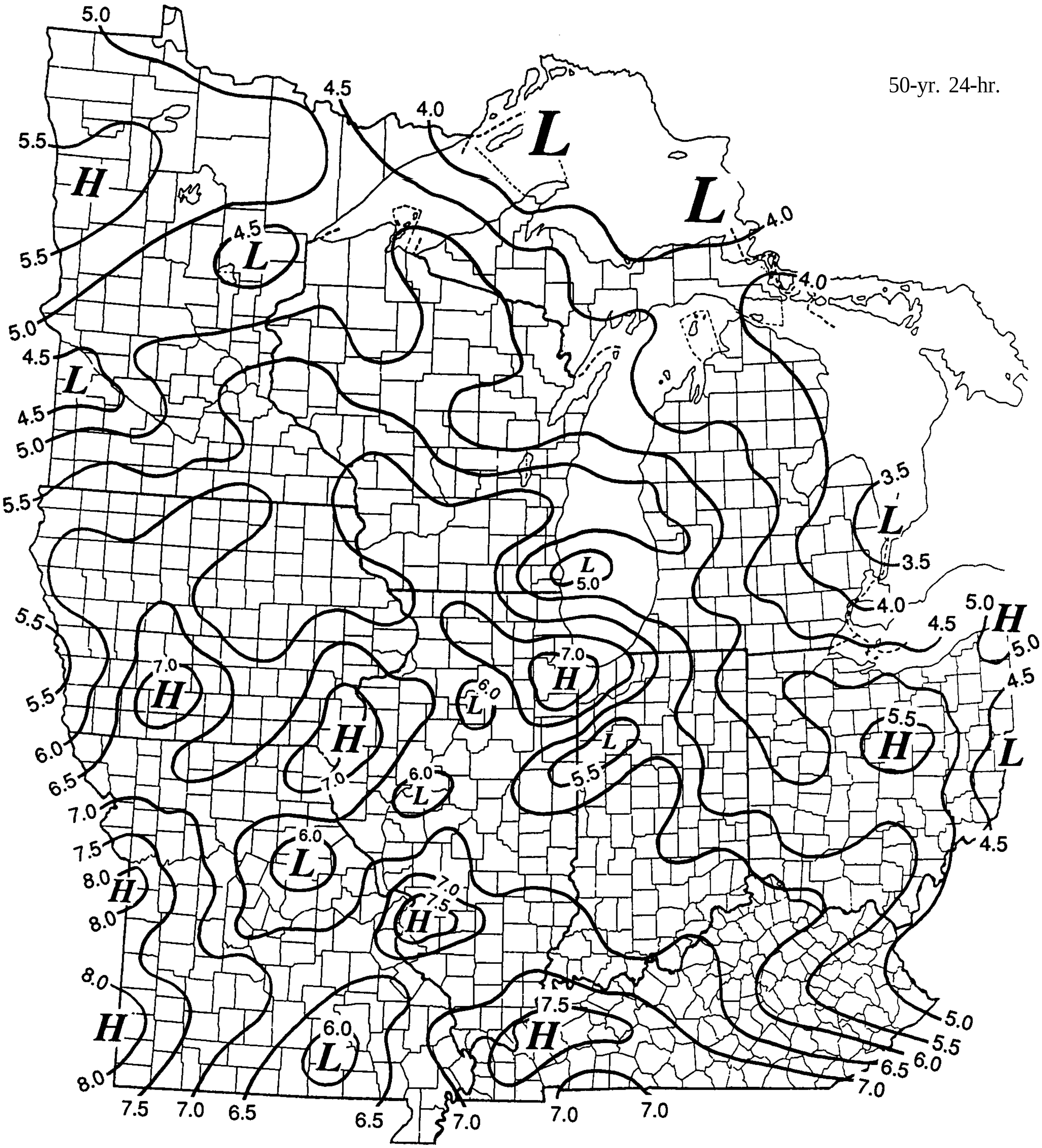

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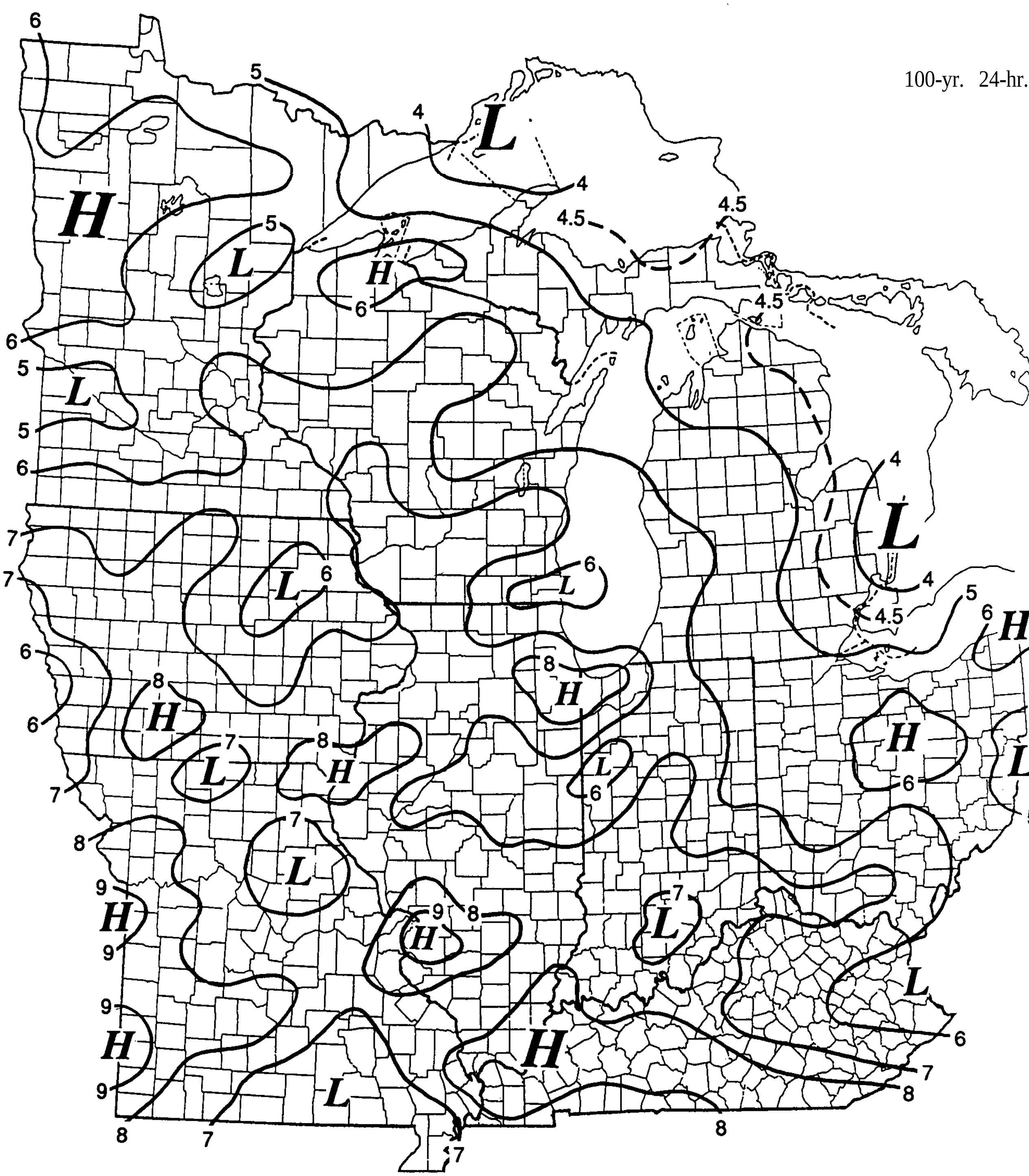

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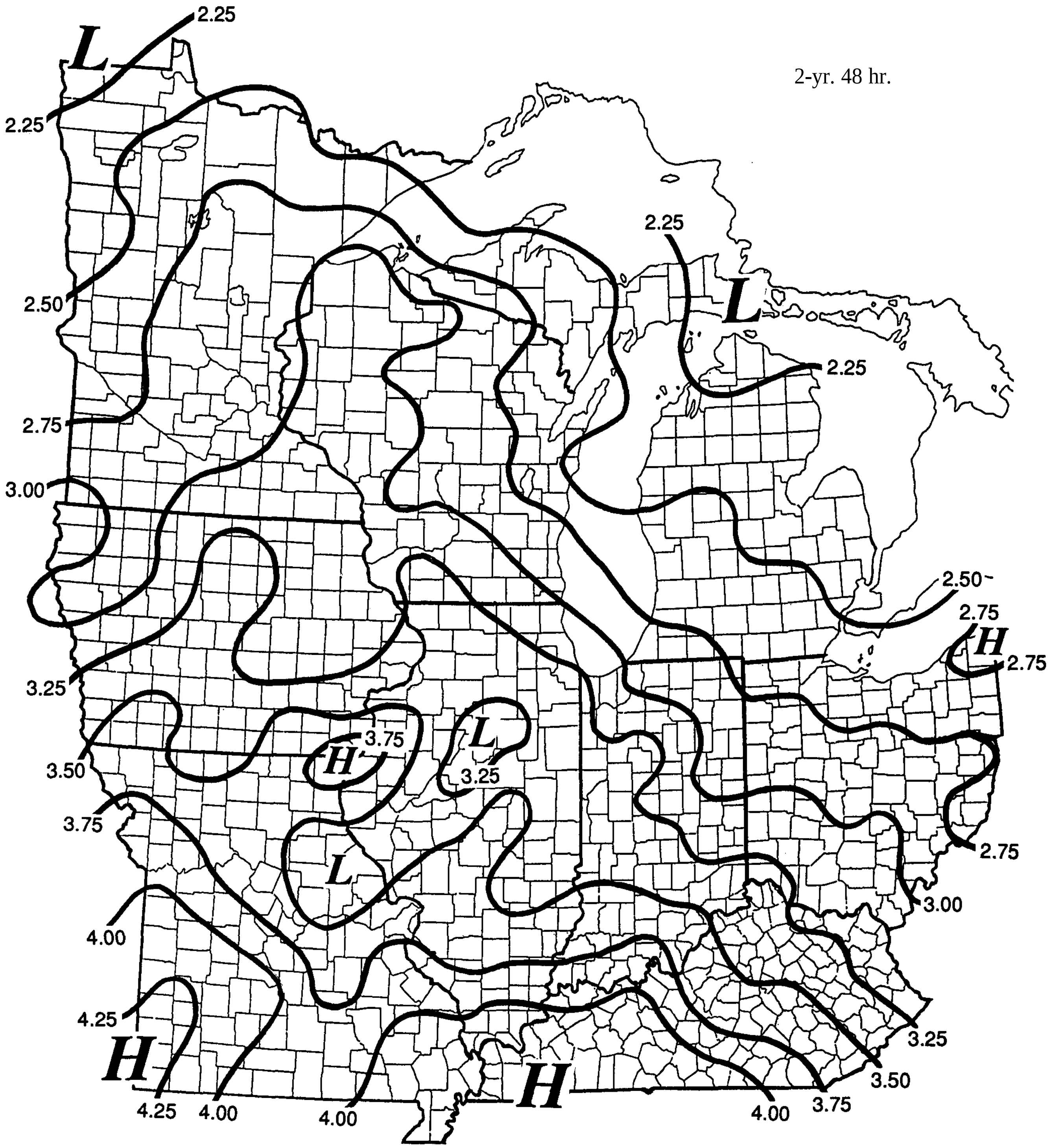
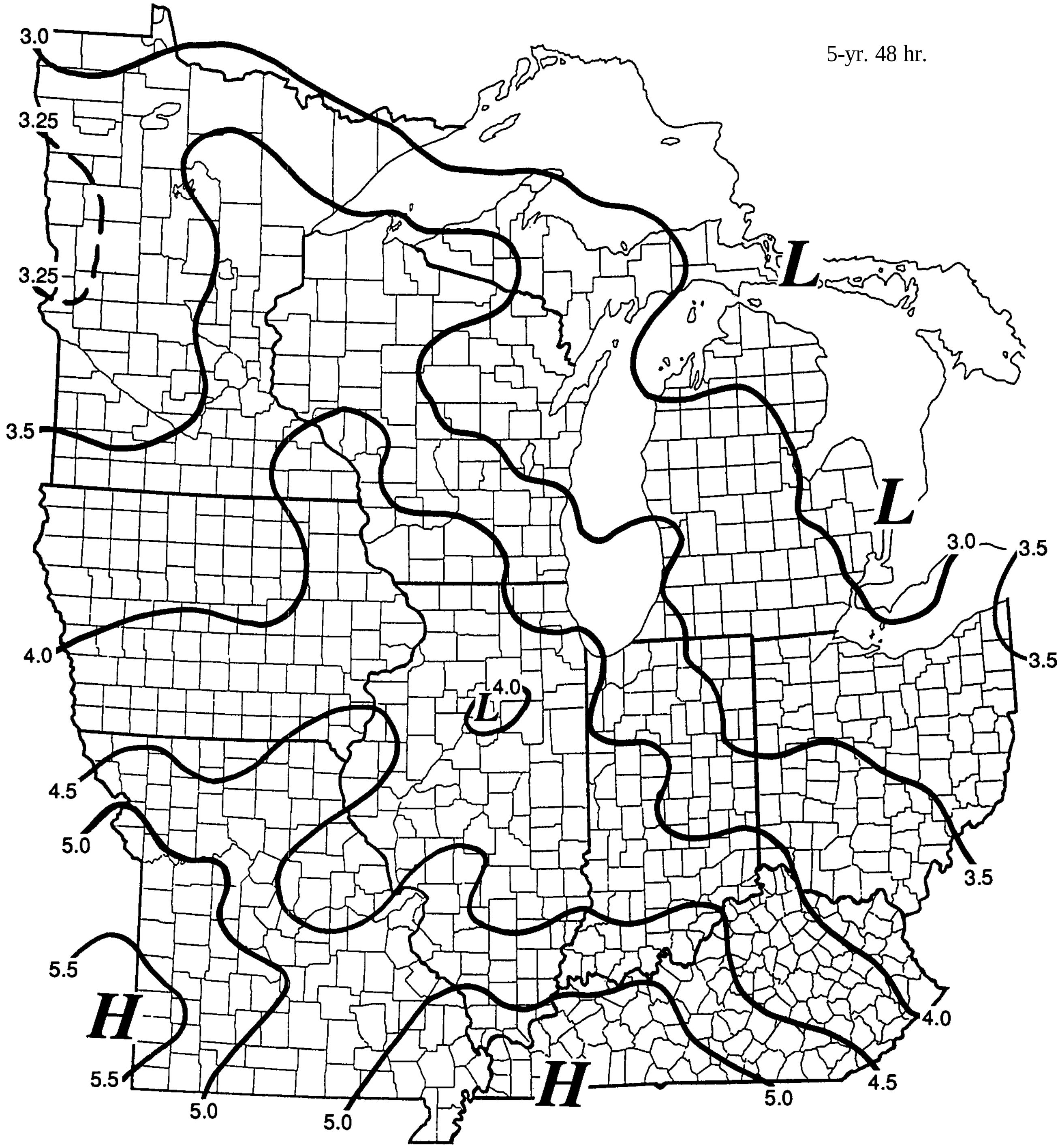


Figure 7. Spatial distribution of 48-hour rainfall (inches)



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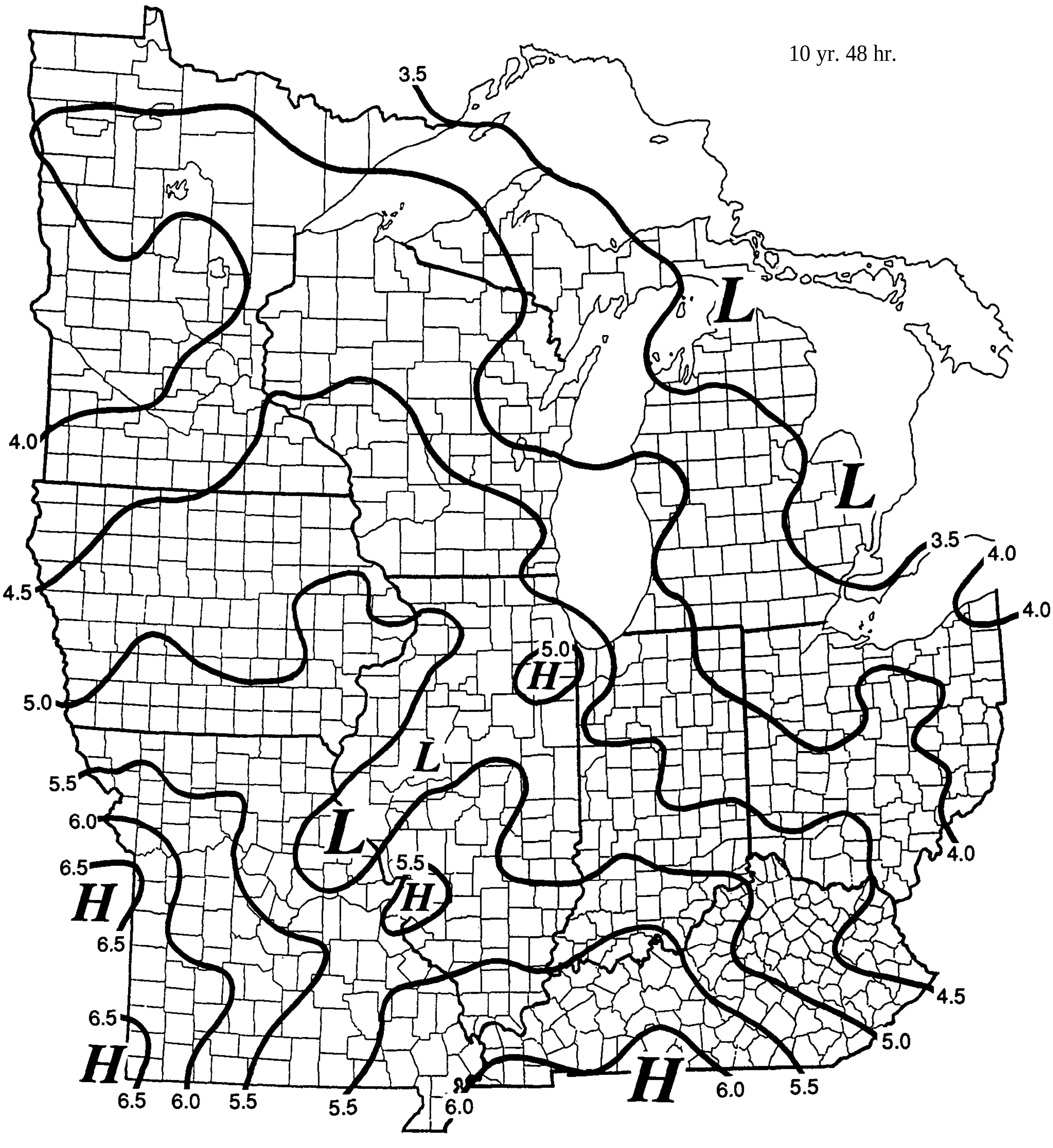

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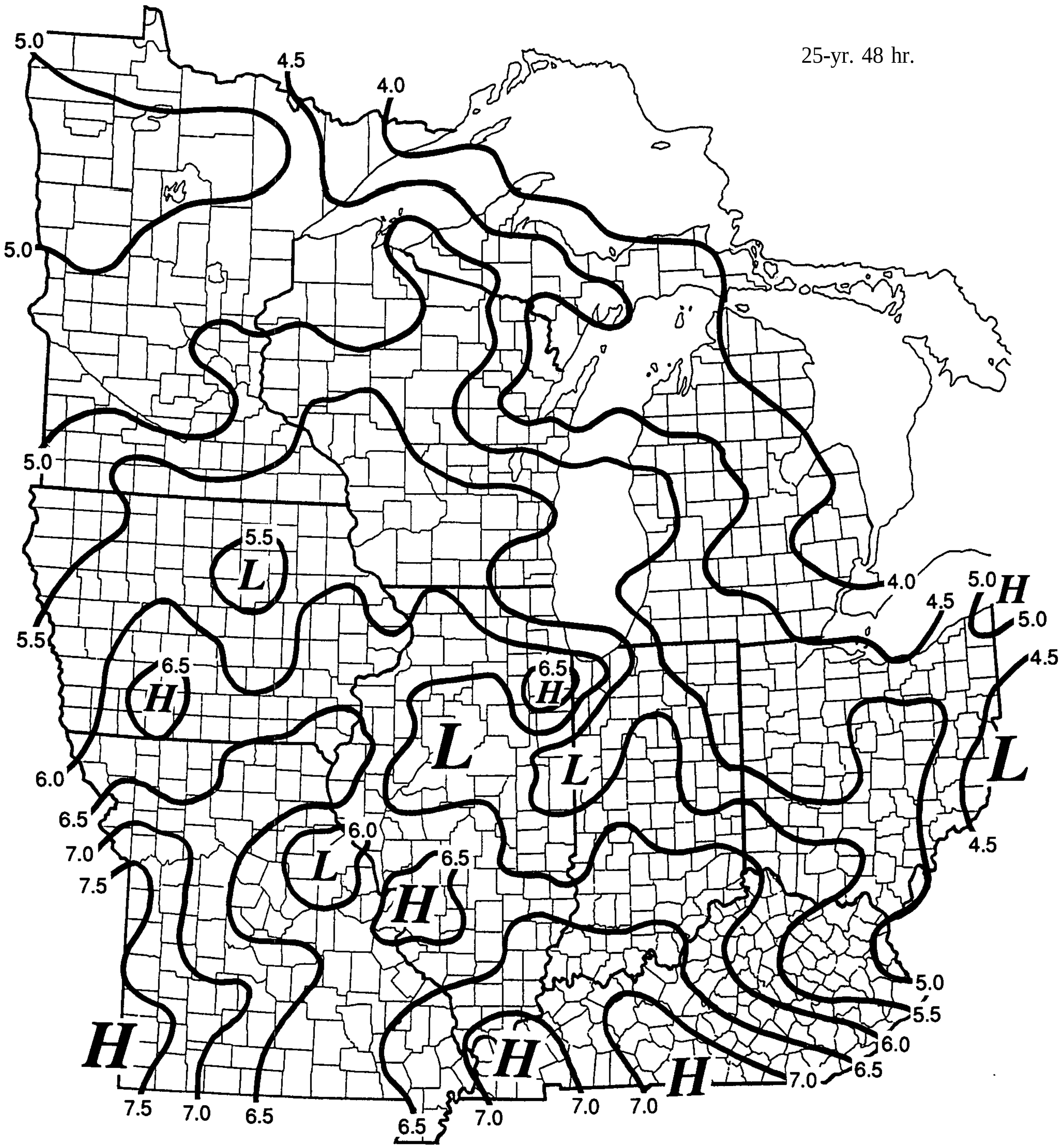

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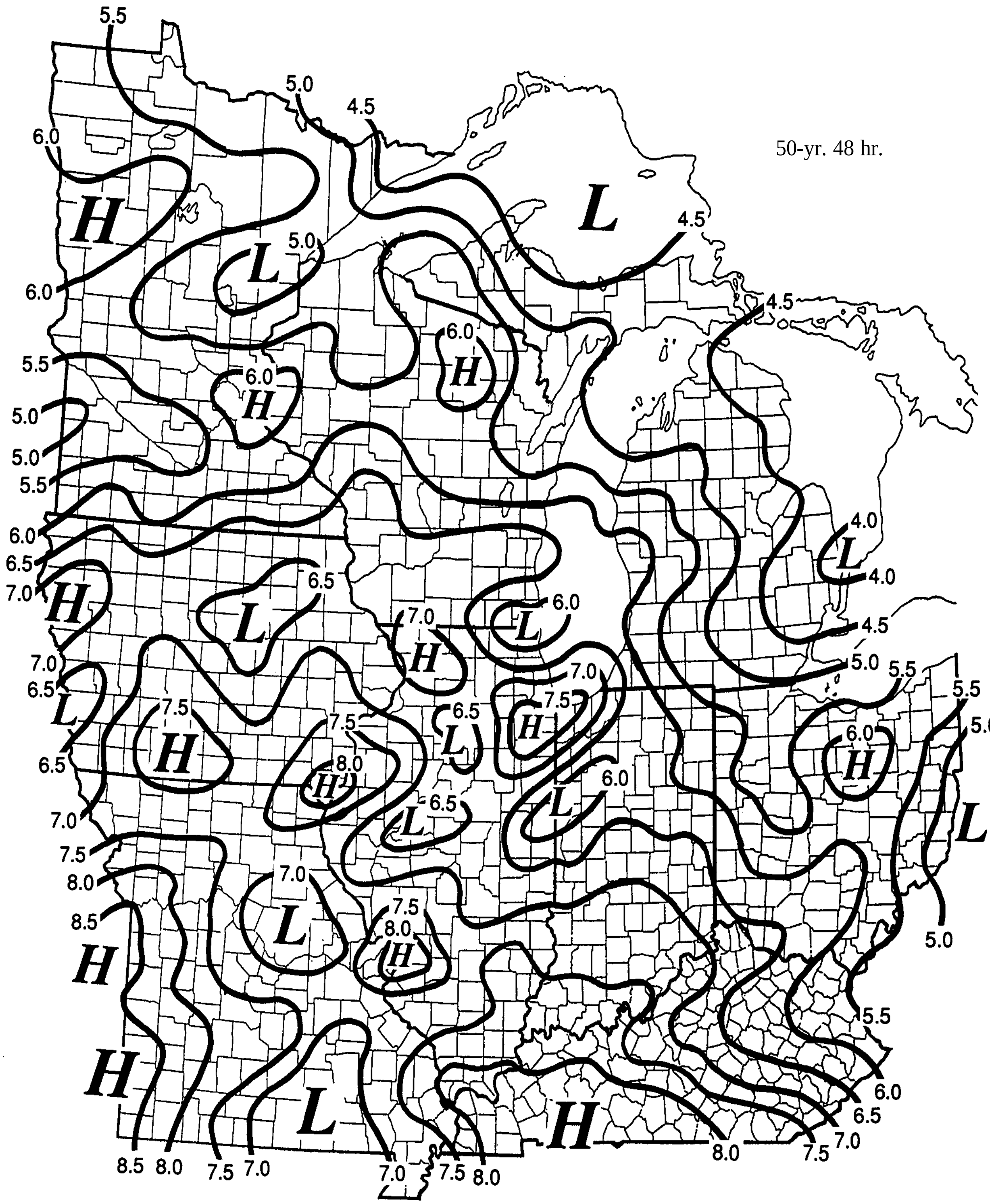

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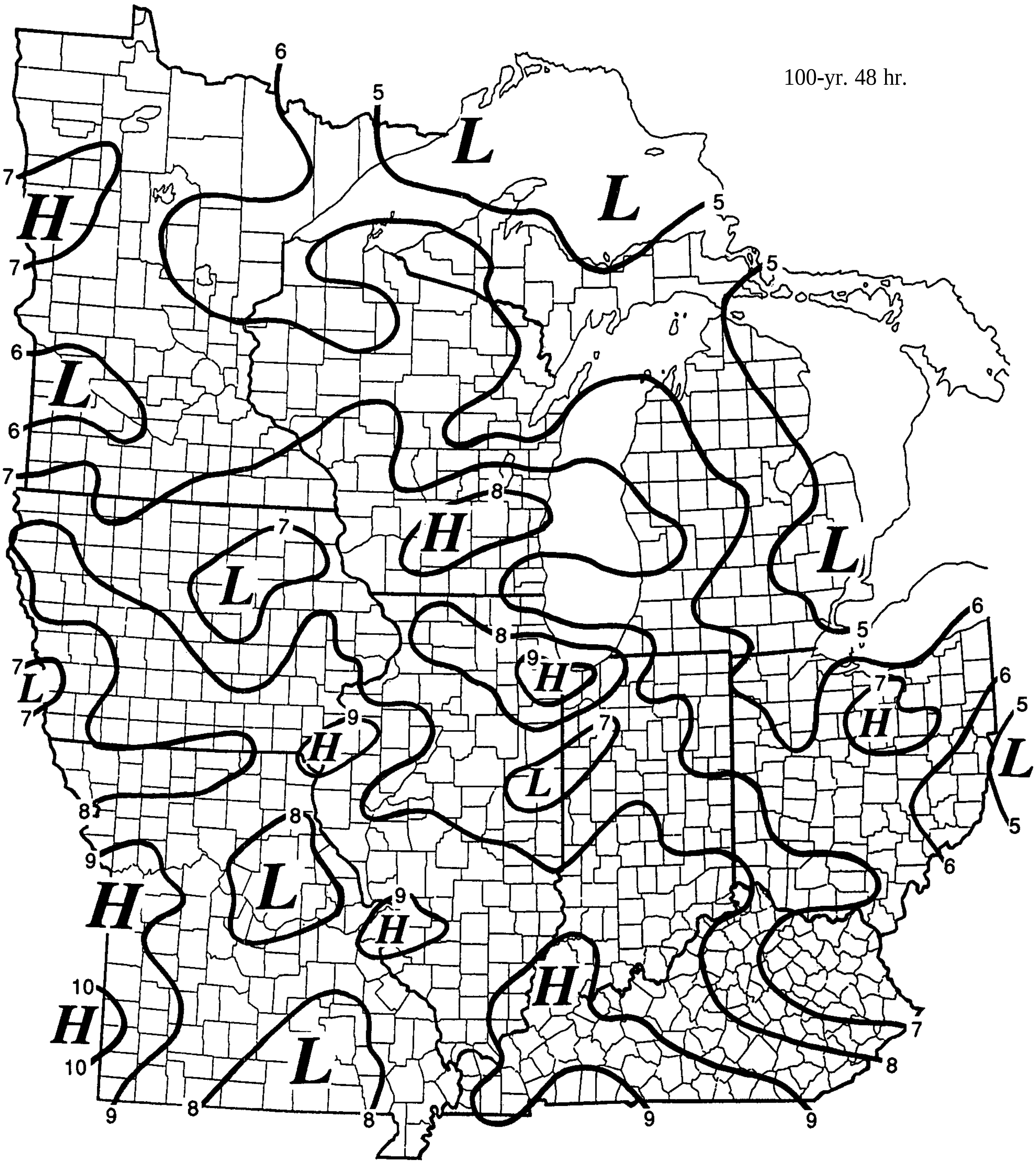

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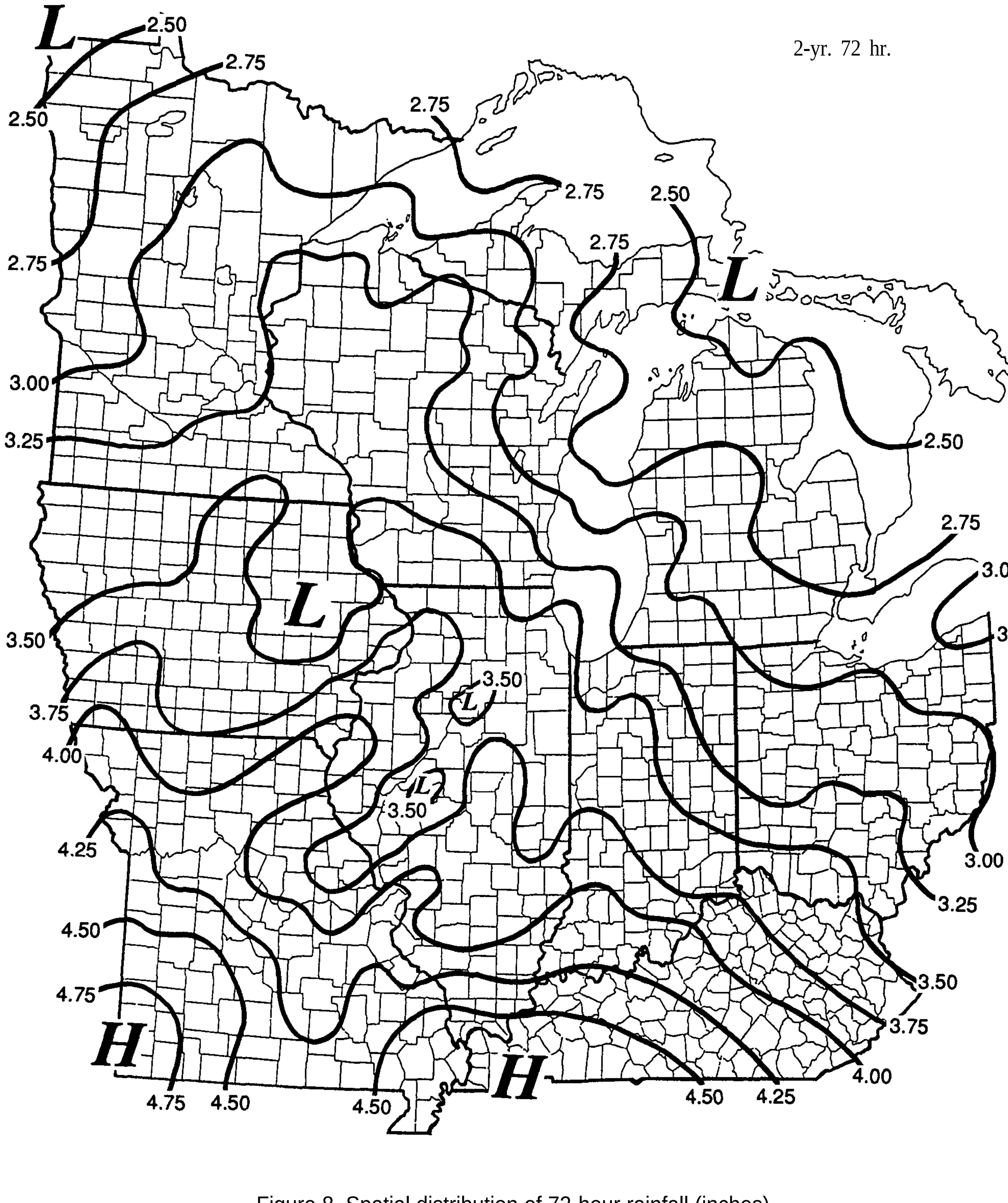
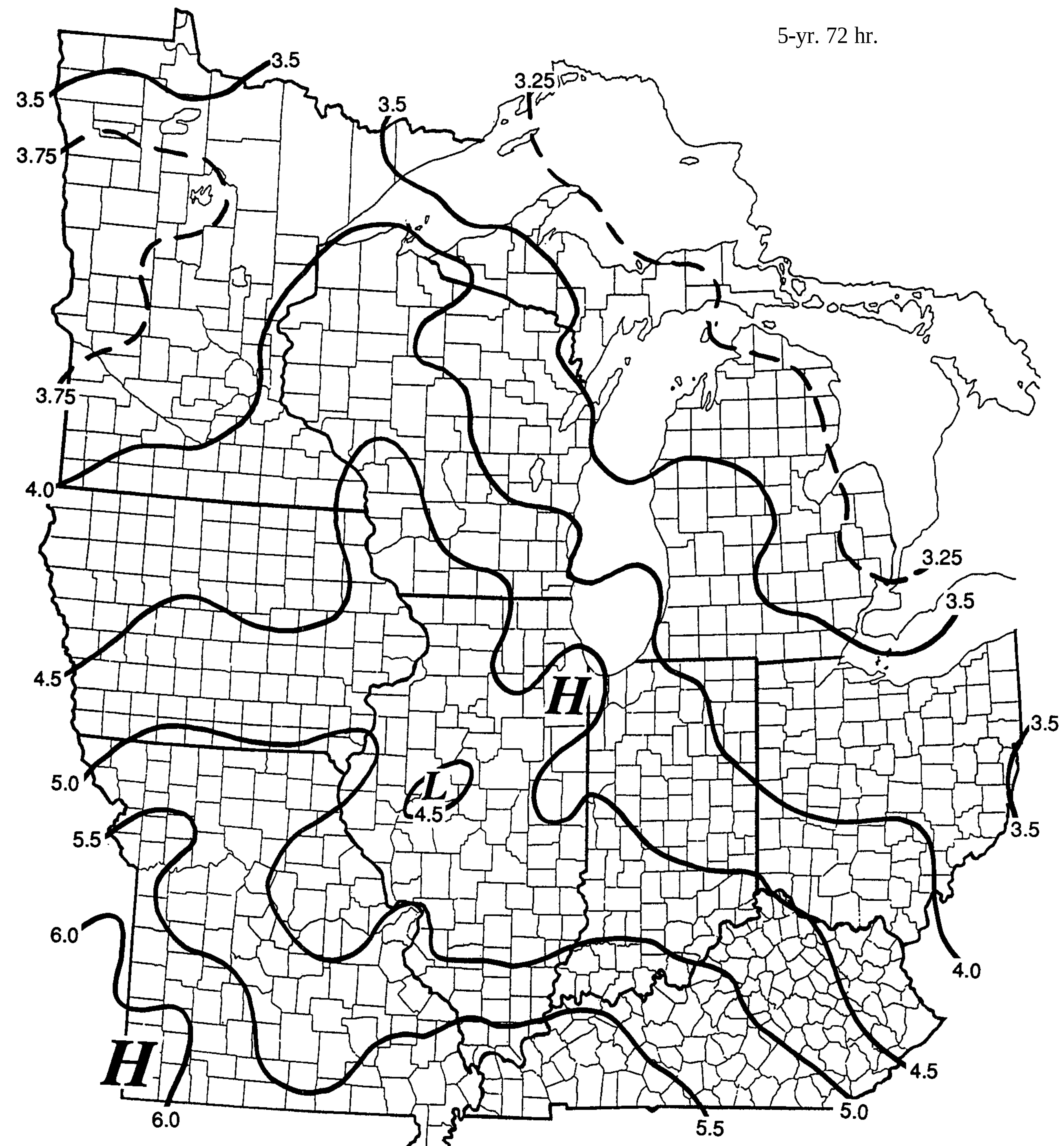


Figure 8. Spatial distribution of 72-hour rainfall (inches)



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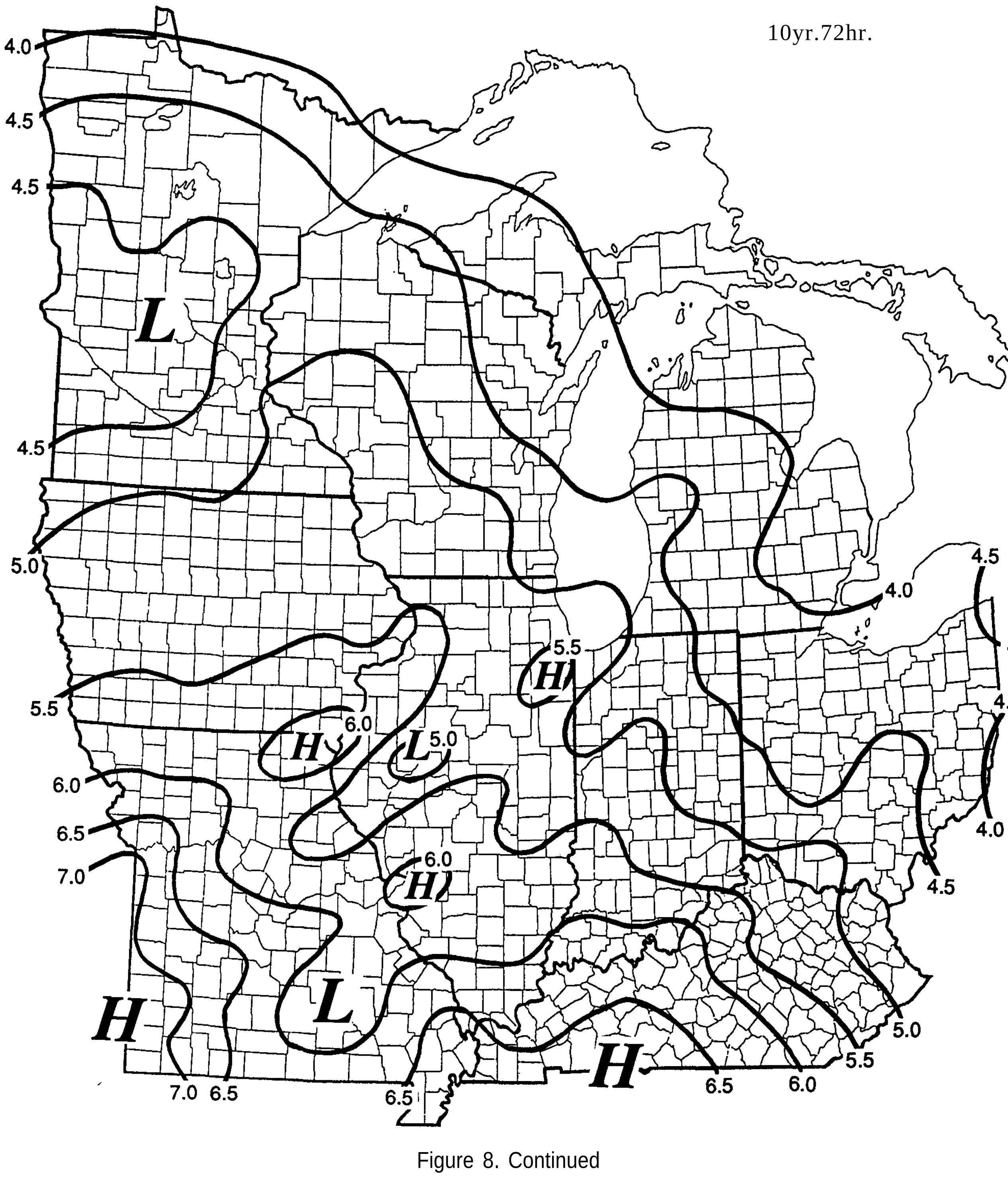

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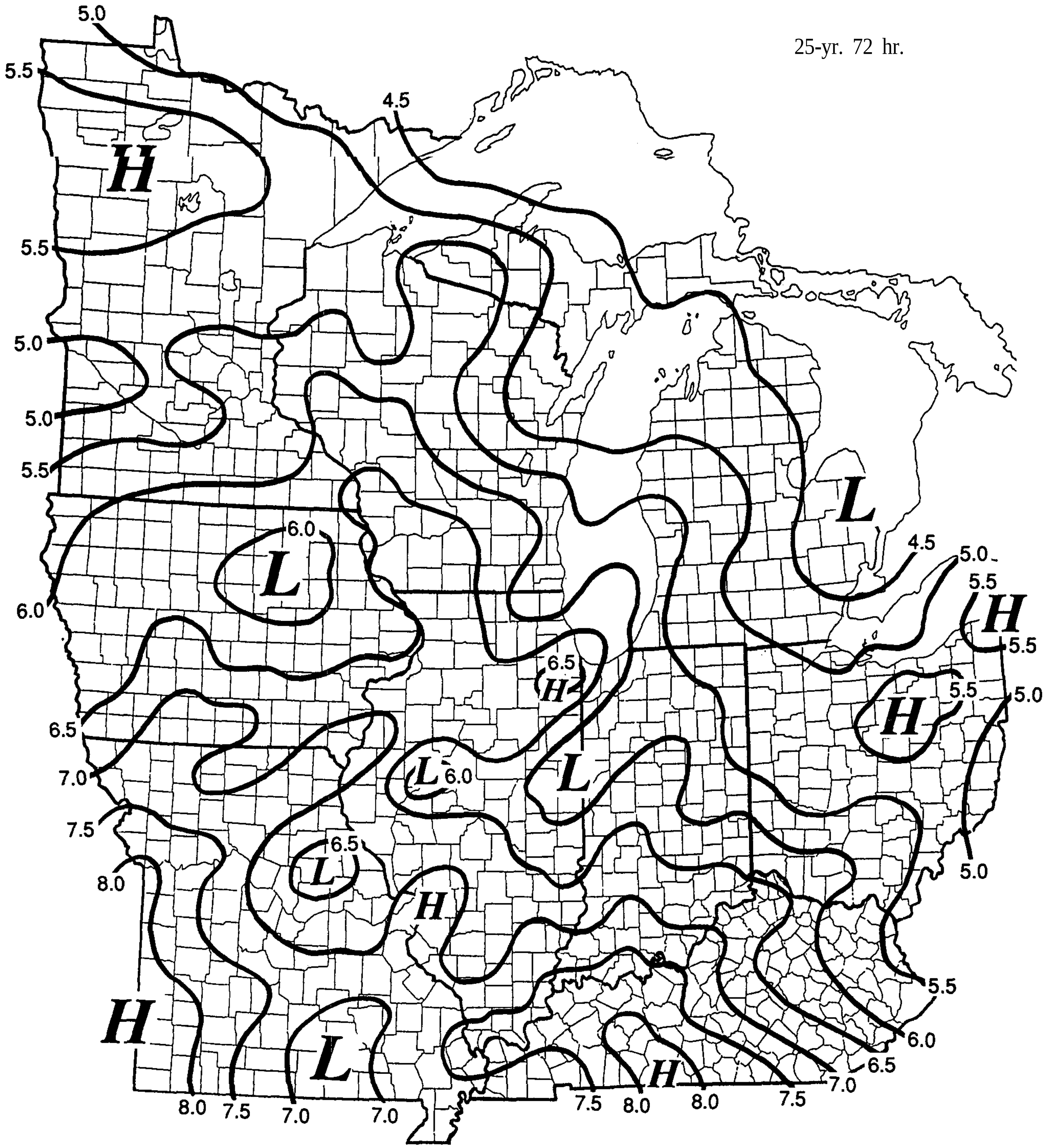

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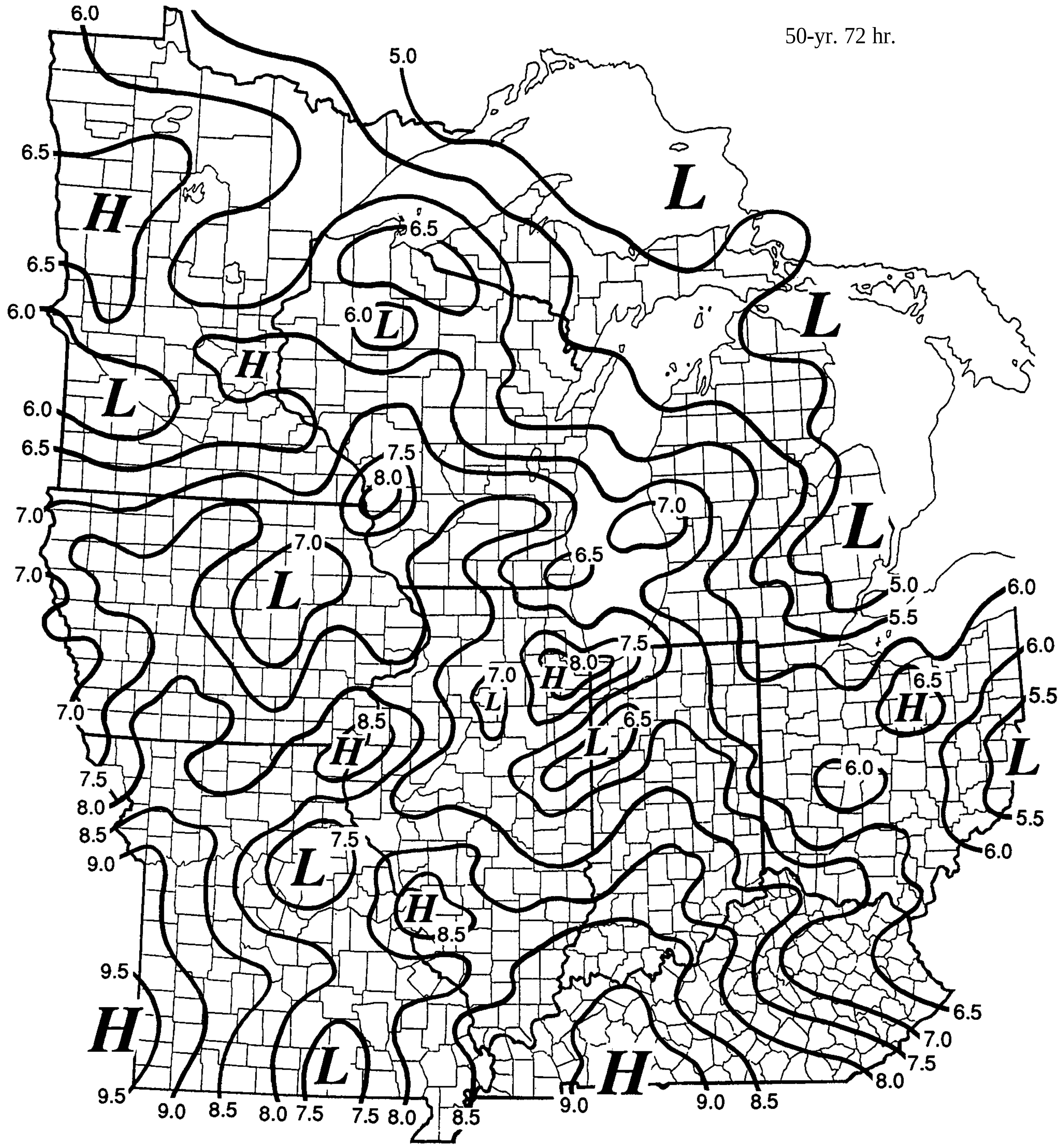
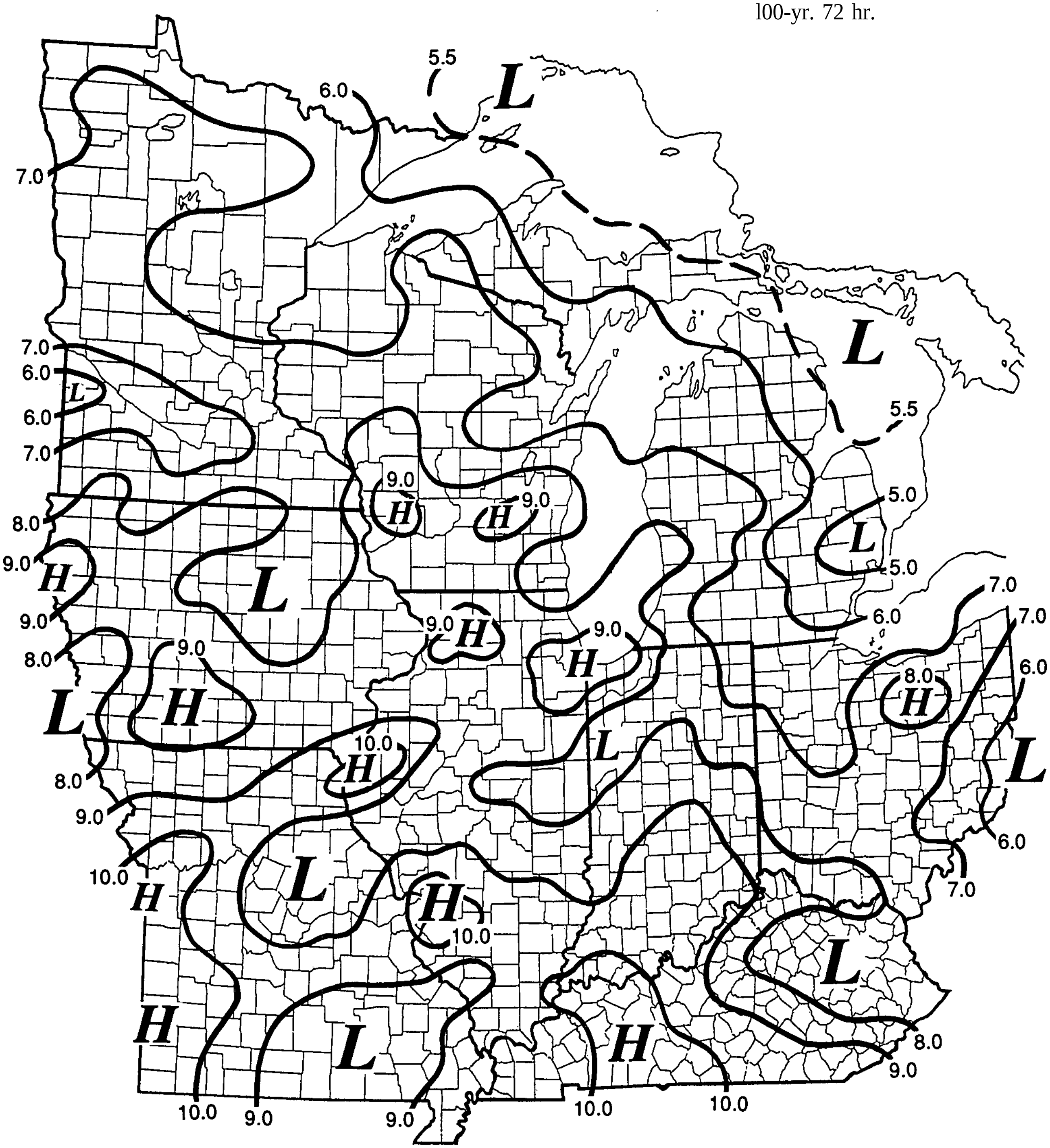


Figure 8. Continued

l00-yr. 72 hr.



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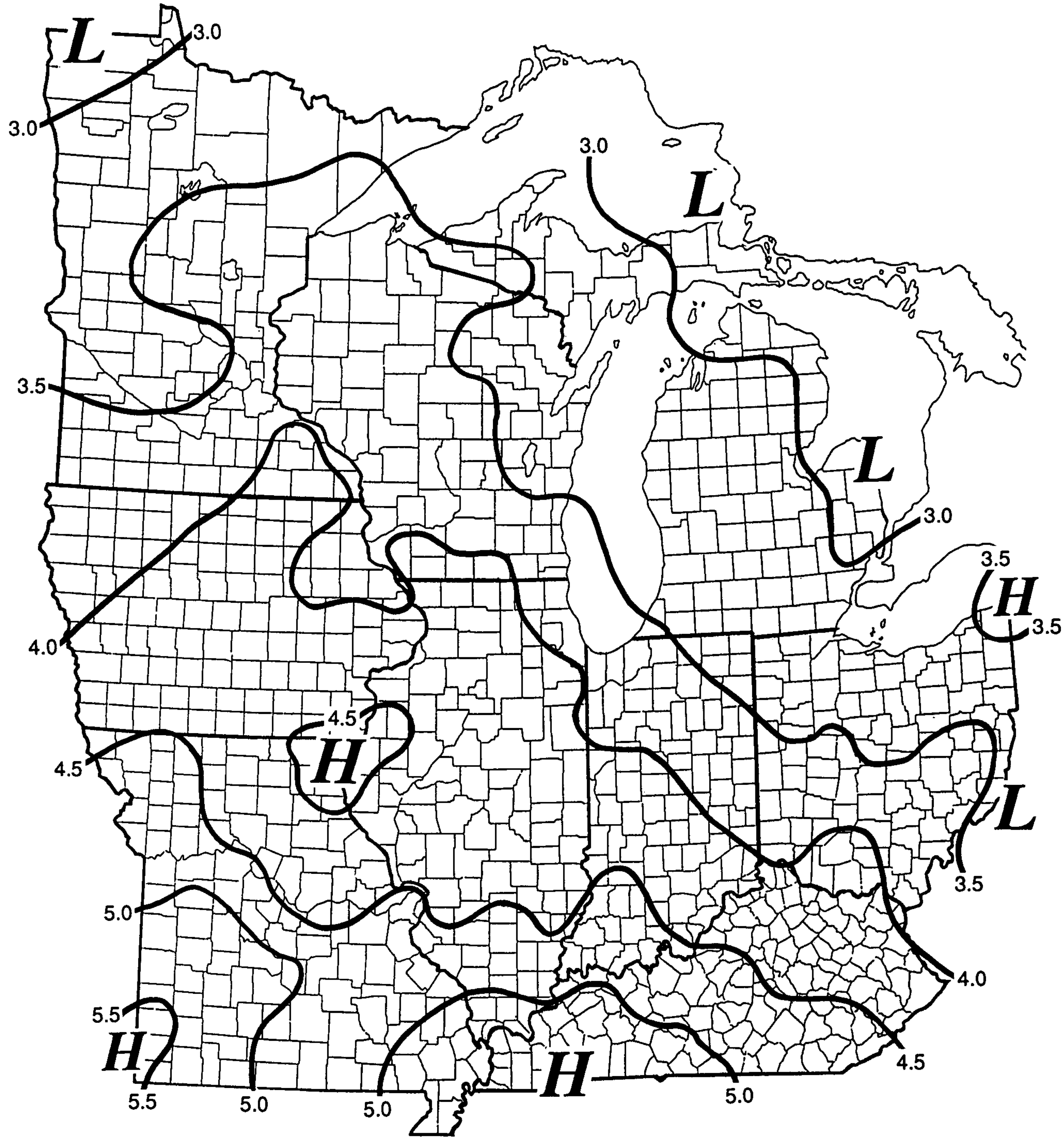

Figure 9. Spatial distribution of 5-day rainfall (inches)

5-yr. 5 day

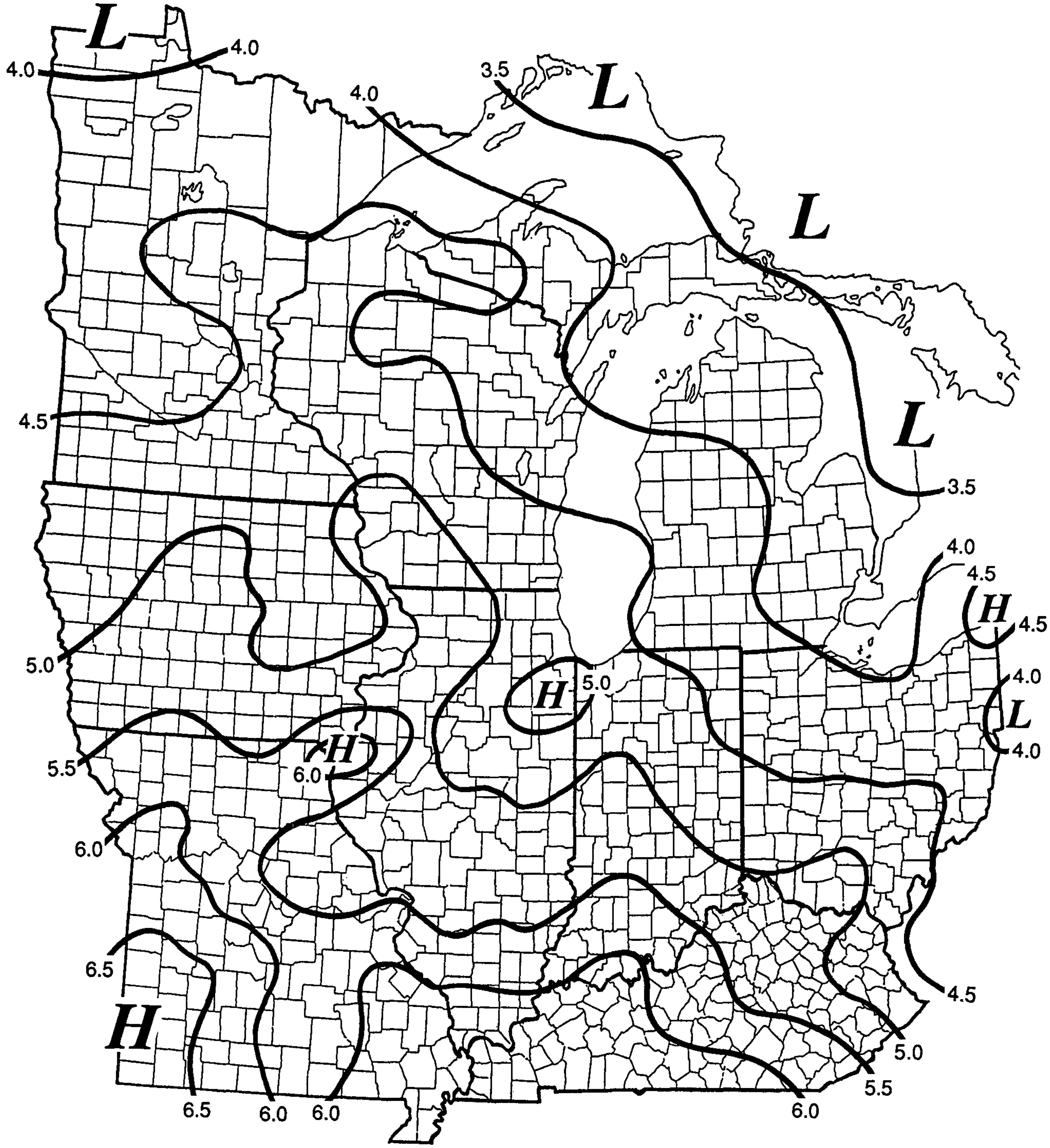

Figure 9. Continued

10-yr. 5 day

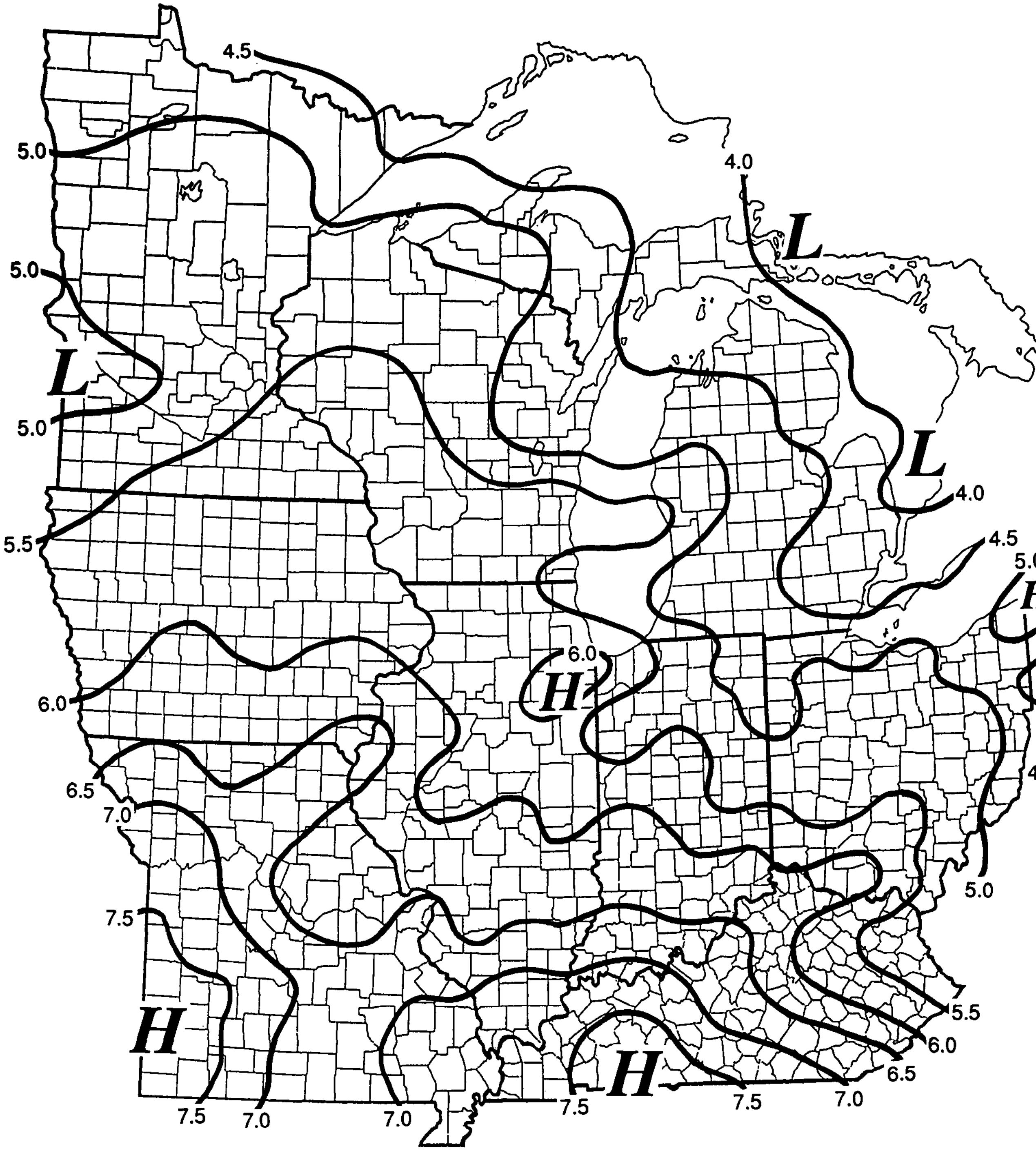

Figure 9. Continued

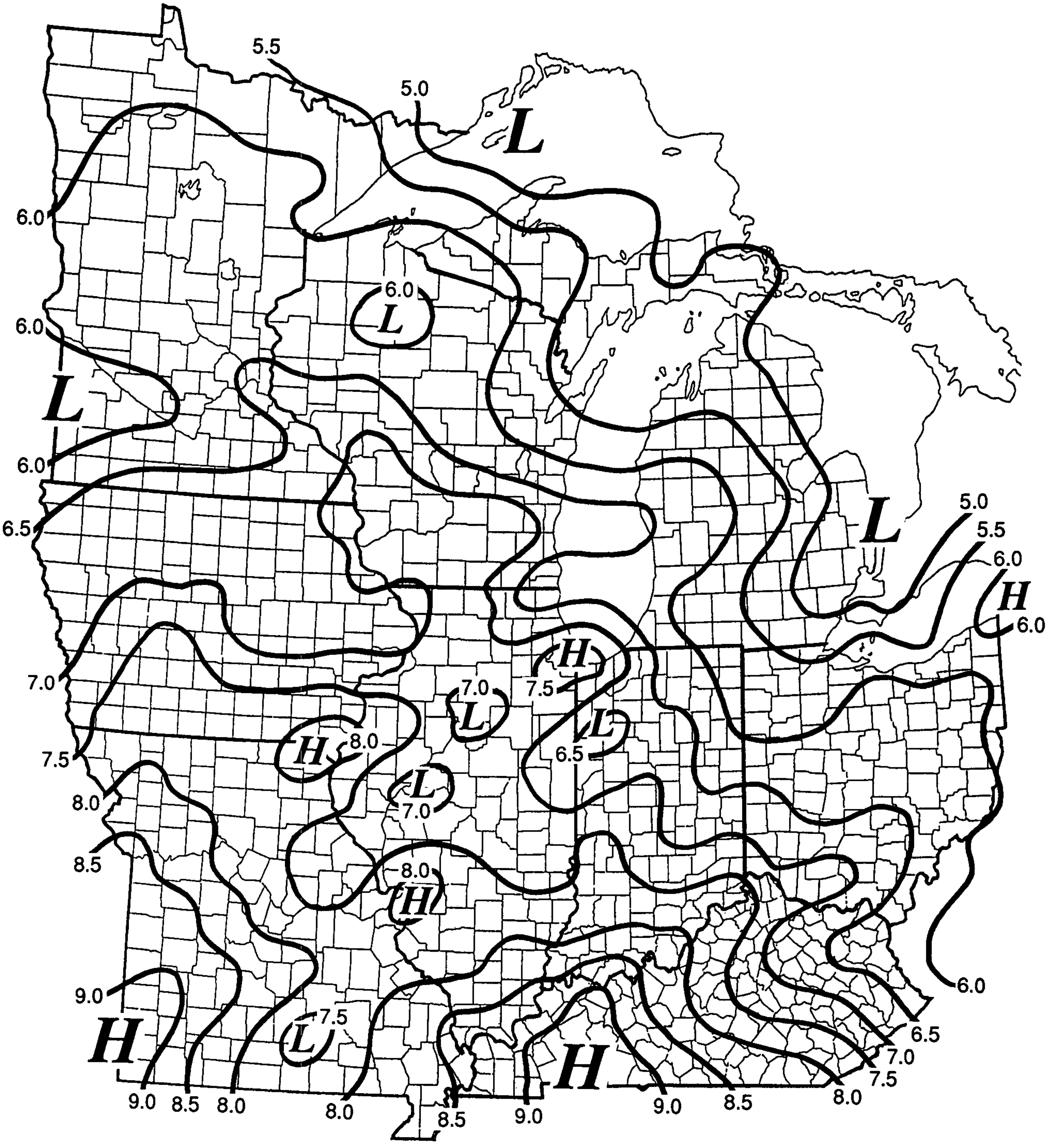

Figure 9. Continued

50-yr. 5 day

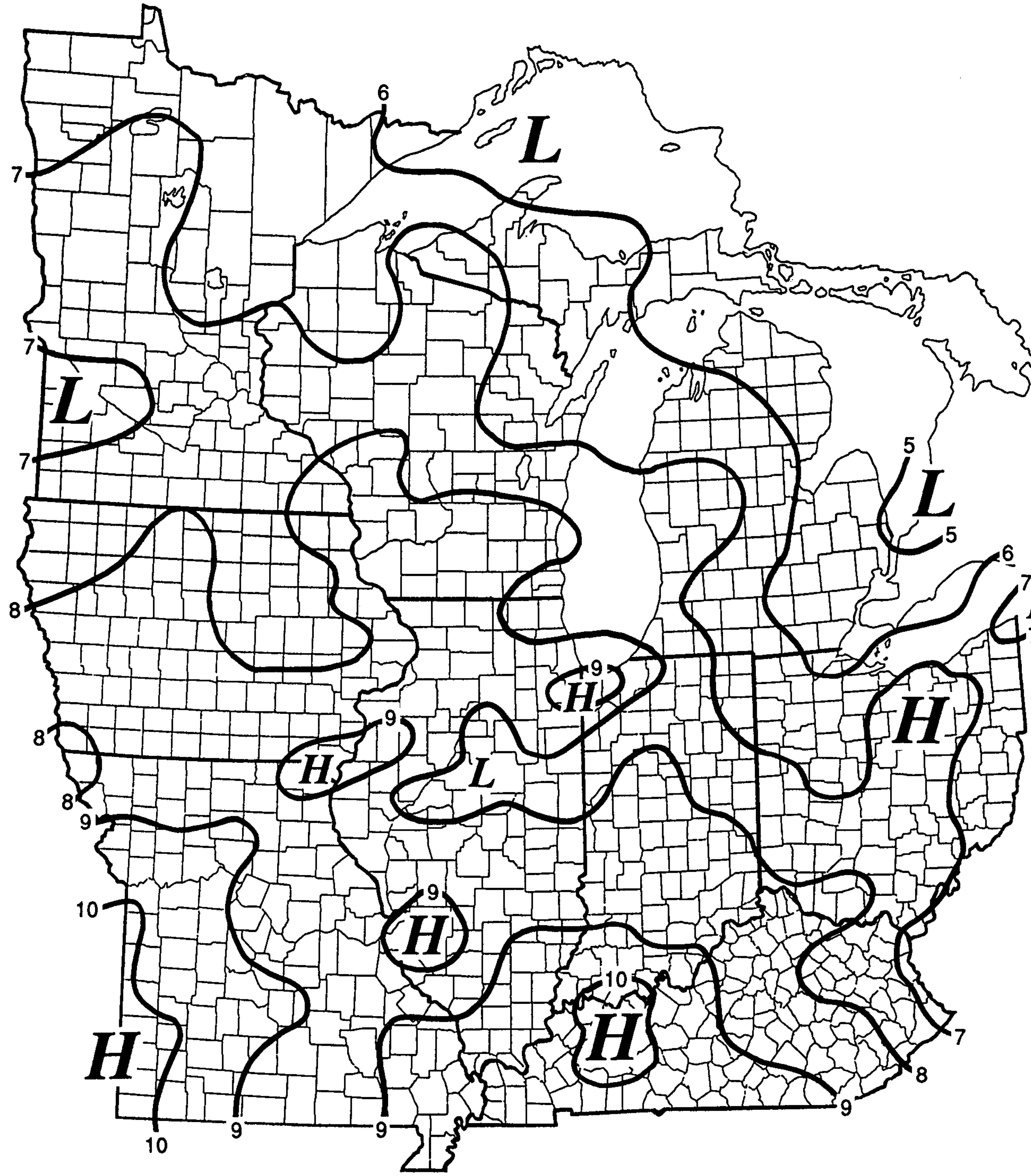

Figure 9. Continued

l00-yr. 5 day

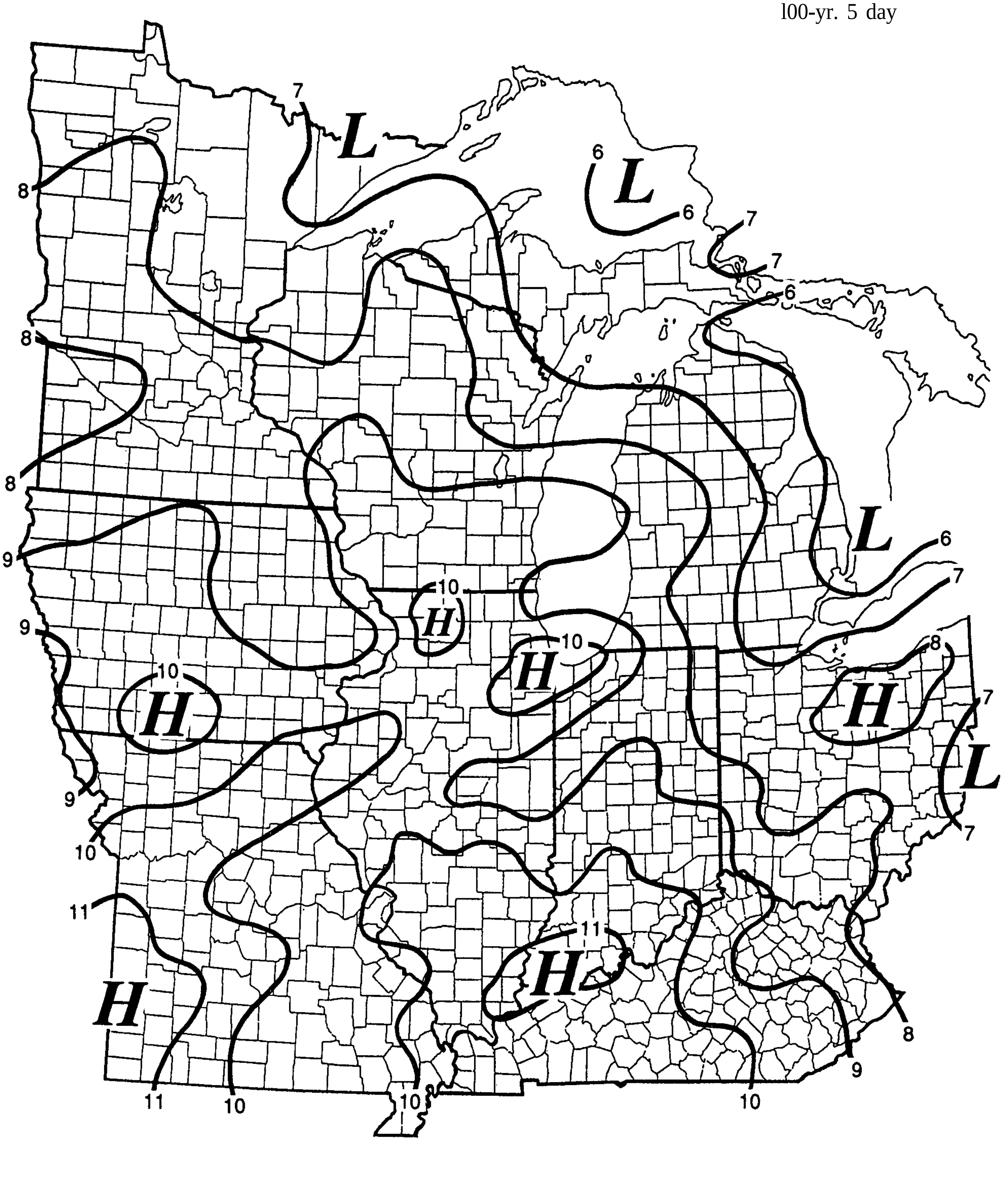

Figure 9. Concluded

2-yr. 10 day

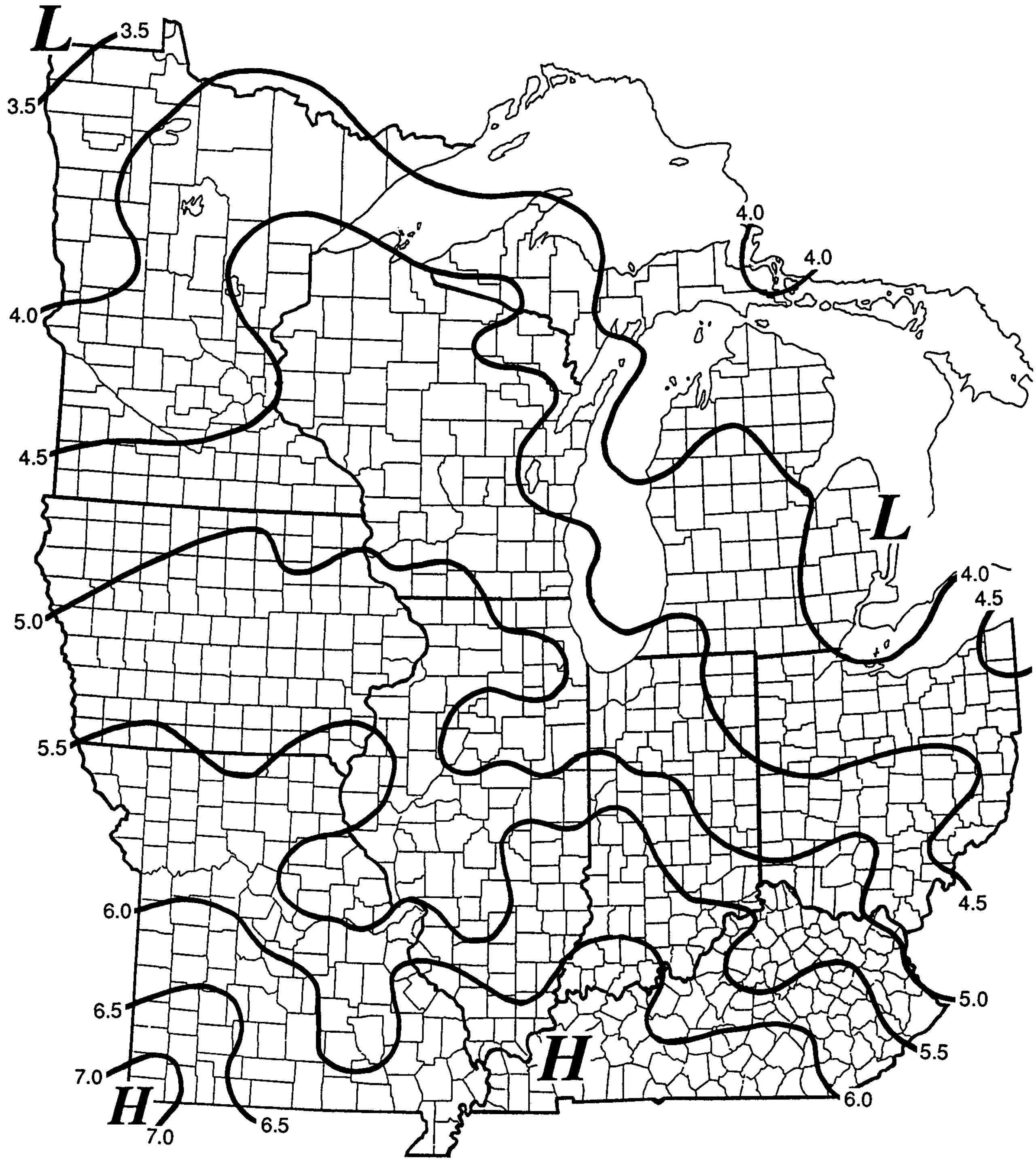

Figure 10. Spatial distribution of 10-day rainfall (inches)

5-yr. 10 day

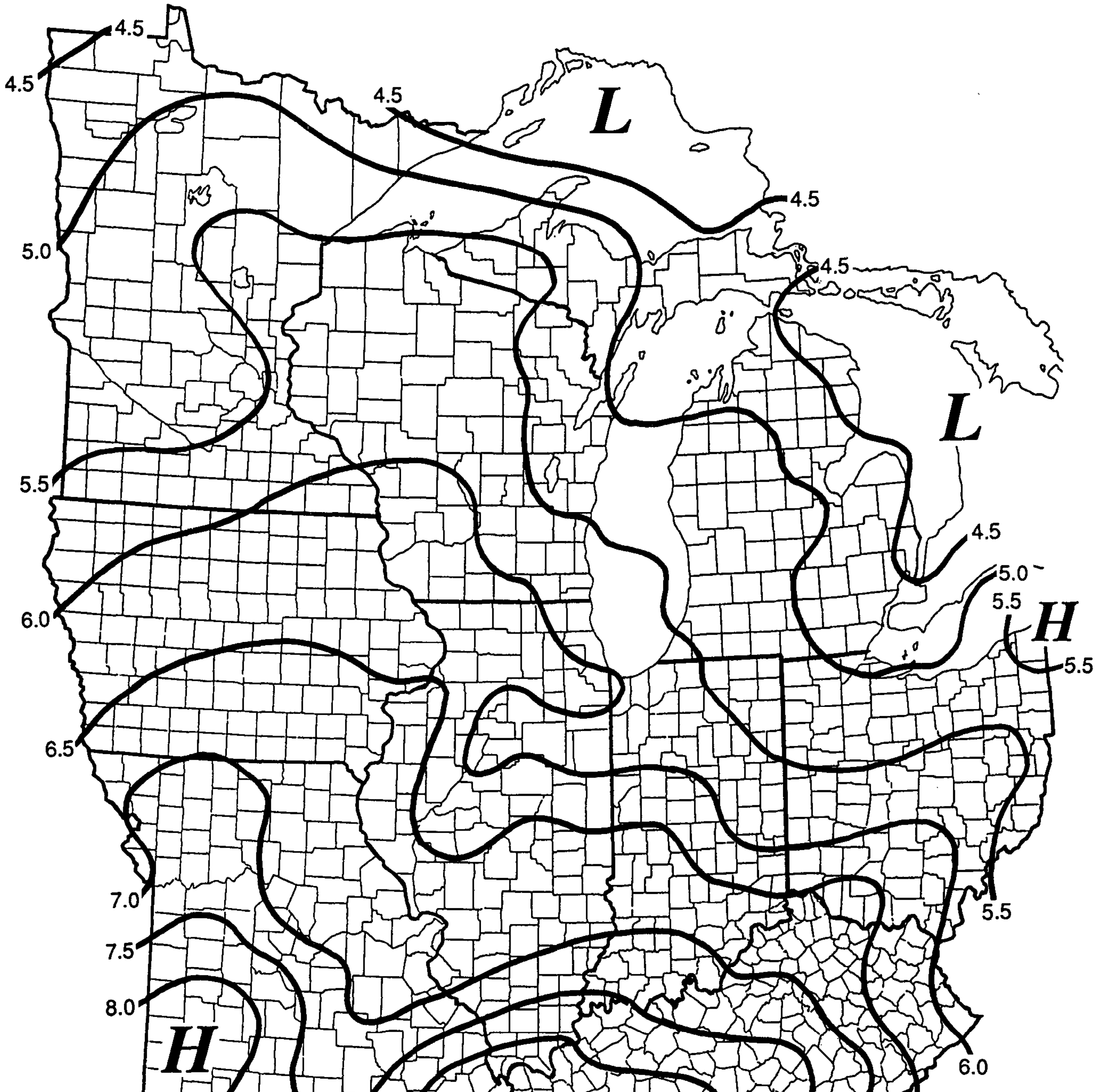

Figure 10. Continued

10-yr. 10 day

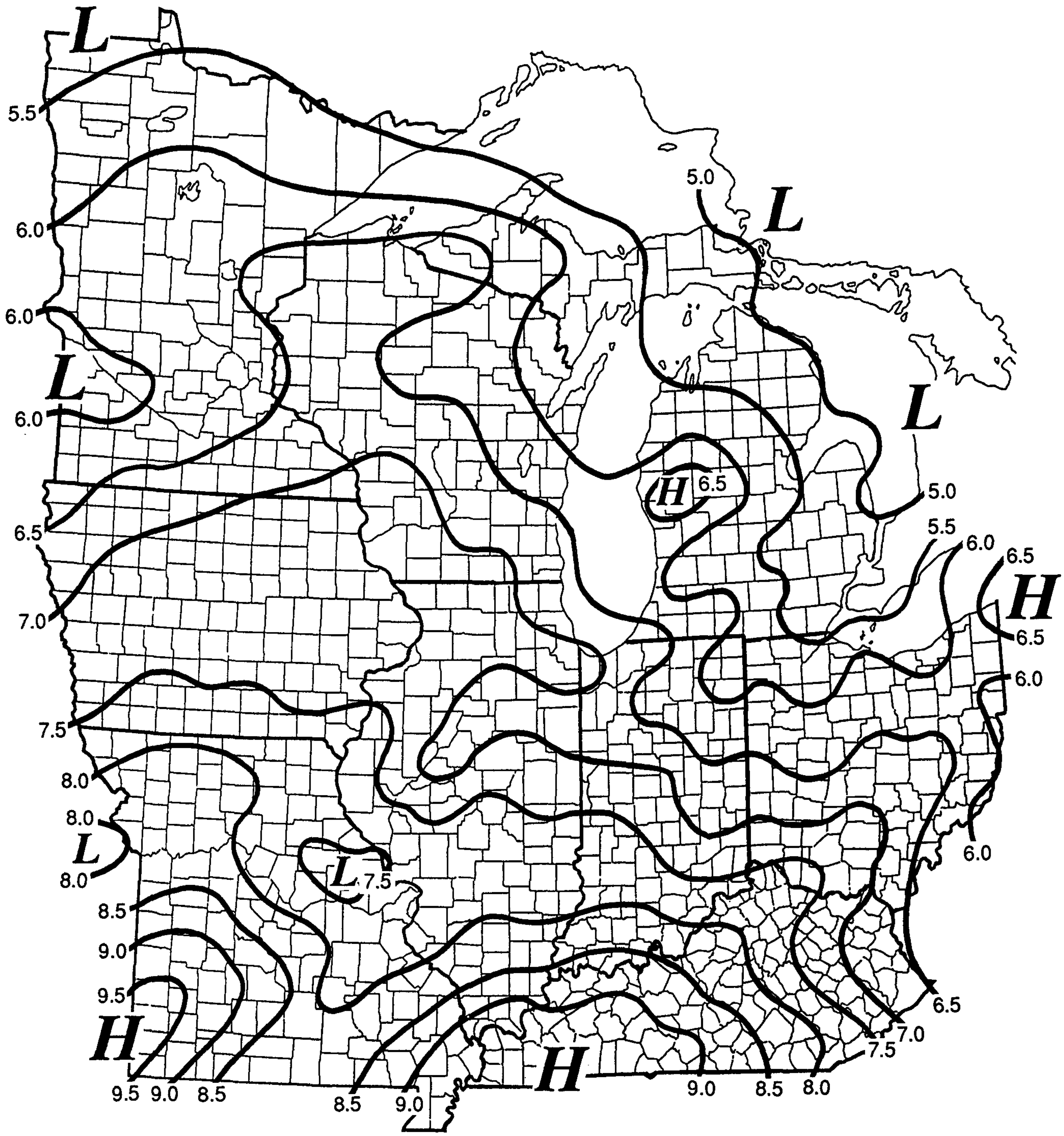

Figure 10. Continued

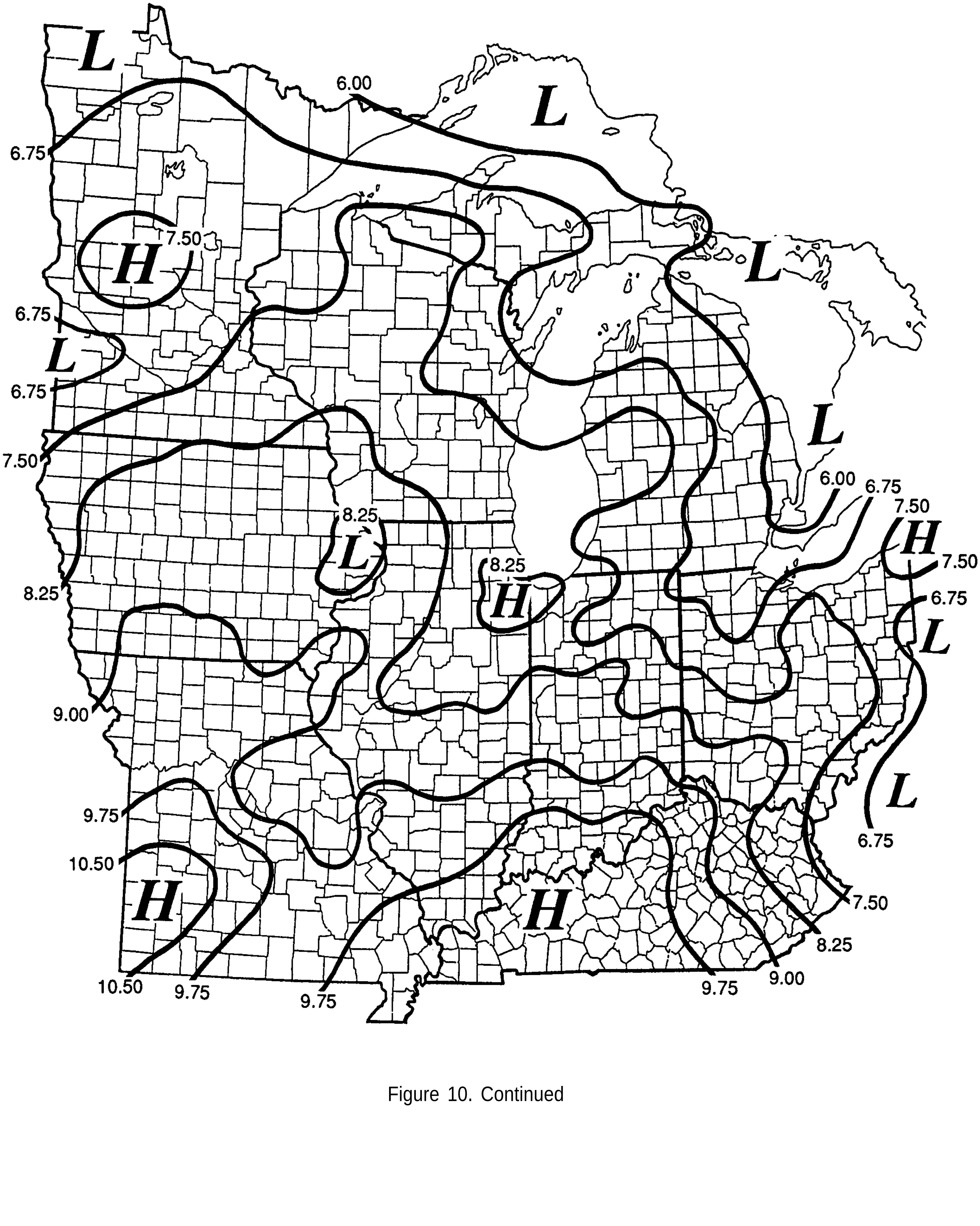

Figure 10. Continued

50-yr. 10 day

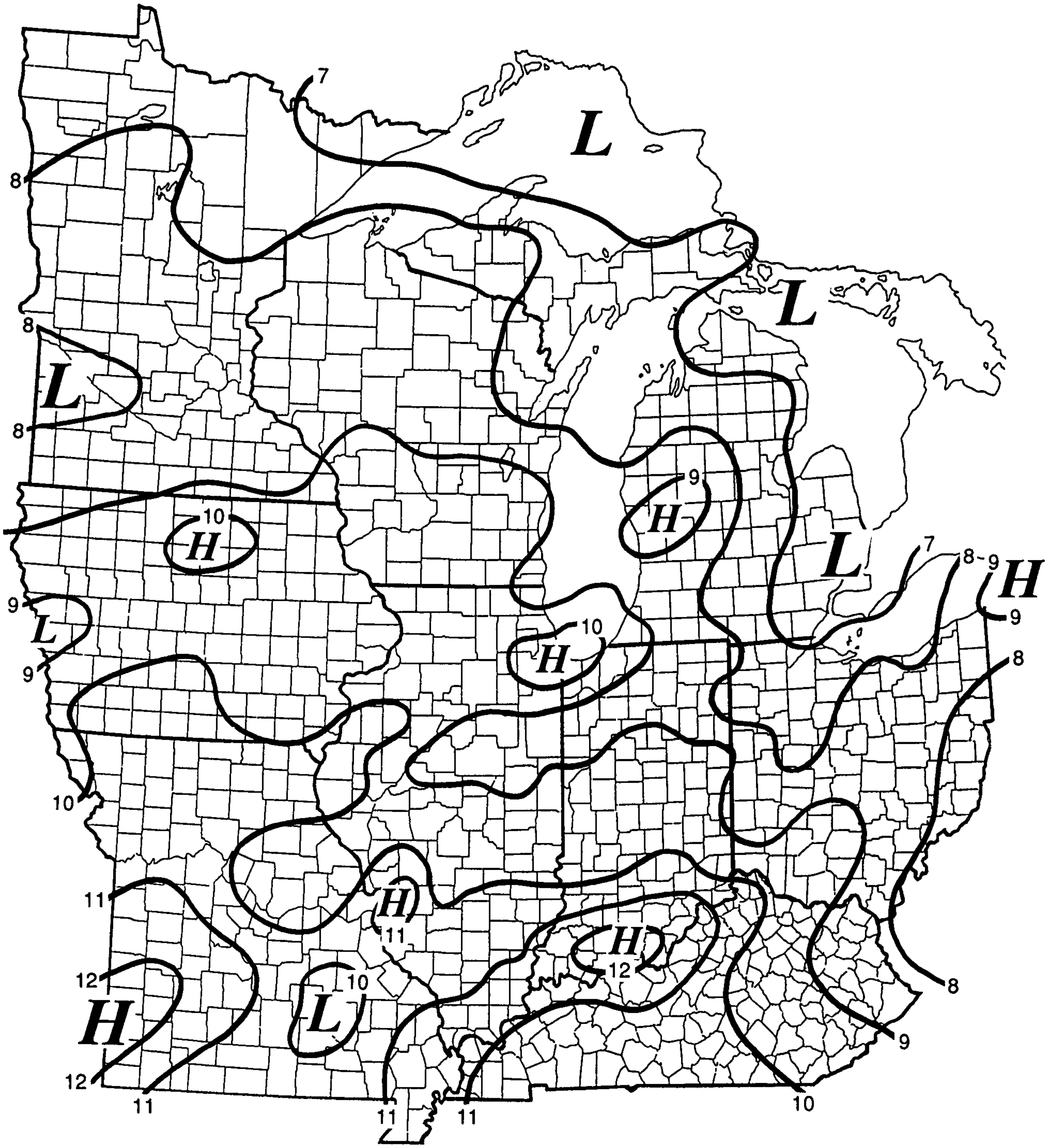

Figure 10. Continued

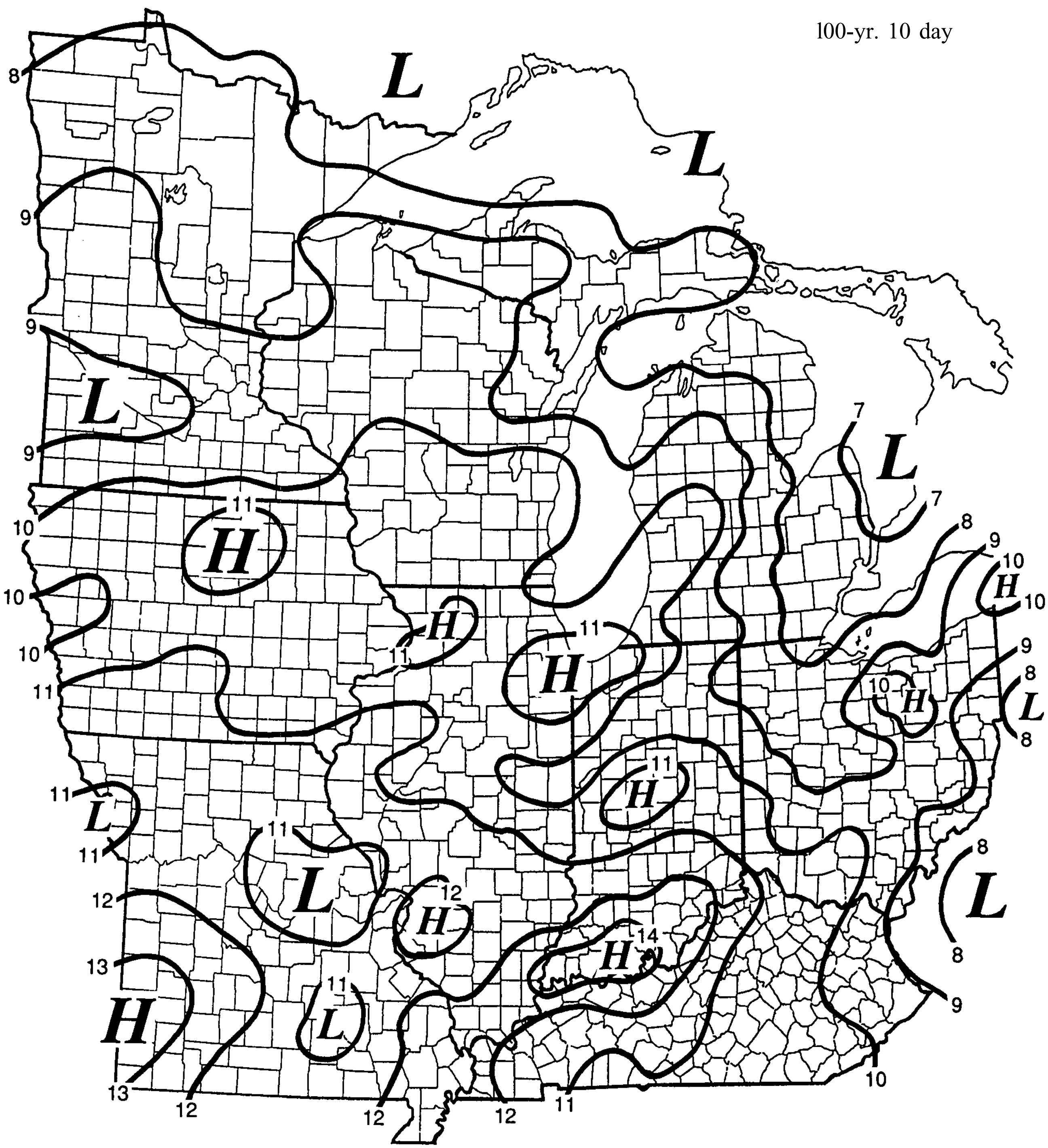

Figure 10. Concluded

Table 1. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Illinois

Sectional code (see figure 1 on page 4)

01 - Northwest	*06 - West Southwest*
02 - Northeast	*07 - East Southeast*
03 - West	*08 - Southwest*
04 - Central	*09 - Southeast*
05 - East	*10 – South*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	2.14	2.60	2.97	3.50	4.02	4.37	5.23	6.30	7.14	8.39	9.64	11.09
01	5-day	1.76	2.12	2.38	2.76	3.17	3.45	4.13	5.10	5.91	7.21	8.36	9.97
01	72-hr	1.58	1.90	2.11	2.45	2.82	3.06	3.73	4.67	5.42	6.59	7.64	8.87
01	48-hr	1.47	1.74	1.93	2.24	2.58	2.80	3.42	4.28	4.96	6.07	7.02	8.07
01	24-hr	1.40	1.64	1.80	2.08	2.36	2.57	3.11	3.95	4.63	5.60	6.53	7.36
01	18-hr	1.30	1.52	1.66	1.92	2.18	2.37	2.86	3.63	4.26	5.15	6.01	6.92
01	12-hr	1.23	1.43	1.57	1.81	2.06	2.24	2.71	3.43	4.03	4.88	5.66	6.51
01	6-hr	1.06	1.24	1.37	1.56	1.77	1.93	2.33	2.96	3.48	4.20	4.90	5.69
01	3-hr	0.91	1.06	1.16	1.33	1.52	1.65	1.99	2.53	2.97	3.59	4.18	4.90
01	2-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.83	2.33	2.74	3.31	3.86	4.47
01	1-hr	0.67	0.78	0.86	0.98	1.11	1.21	1.46	1.86	2.18	2.63	3.07	3.51
01	30-min	0.52	0.61	0.68	0.77	0.87	0.95	1.15	1.46	1.71	2.07	2.42	2.77
01	15-min	0.38	0.45	0.50	0.57	0.64	0.70	0.84	1.07	1.25	1.51	1.76	1.99
01	10-min	0.31	0.36	0.40	0.46	0.52	0.57	0.68	0.87	1.02	1.23	1.44	1.62
01	5-min	0.17	0.20	0.22	0.25	0.29	0.31	0.37	0.47	0.56	0.67	0.78	0.89
02	10-day	2.02	2.48	2.80	3.30	3.79	4.12	4.95	6.04	6.89	8.18	9.38	11.14
02	5-day	1.66	1.98	2.24	2.60	2.99	3.25	3.93	4.91	5.70	6.93	8.04	9.96
02	72-hr	1.53	1.83	2.02	2.34	2.70	2.93	3.55	4.44	5.18	6.32	7.41	8.78
02	48-hr	1.44	1.70	1.90	2.18	2.49	2.70	3.30	4.09	4.81	5.88	6.84	8.16
02	24-hr	1.38	1.61	1.76	2.03	2.31	2.51	3.04	3.80	4.47	5.51	6.46	7.58
02	18-hr	1.26	1.47	1.61	1.86	2.12	2.30	2.79	3.50	4.11	5.06	5.95	6.97
02	12-hr	1.20	1.40	1.53	1.77	2.01	2.18	2.64	3.31	3.89	4.79	5.62	6.59
02	6-hr	1.03	1.21	1.32	1.52	1.74	1.88	2.28	2.85	3.35	4.13	4.85	5.68
02	3-hr	0.88	1.02	1.13	1.30	1.47	1.60	1.94	2.43	2.86	3.53	4.14	4.85
02	2-hr	0.81	0.95	1.05	1.20	1.36	1.48	1.79	2.24	2.64	3.25	3.82	4.47
02	1-hr	0.65	0.76	0.84	0.96	1.09	1.18	1.43	1.79	2.10	2.59	3.04	3.56
02	30-min	0.51	0.60	0.65	0.75	0.86	0.93	1.12	1.41	1.65	2.04	2.39	2.80
02	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.82	1.03	1.21	1.49	1.75	2.05
02	10-min	0.30	0.35	0.39	0.45	0.51	0.55	0.67	0.84	0.98	1.21	1.42	1.67
02	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.36	0.46	0.54	0.66	0.78	0.91
03	10-day	2.27	2.78	3.13	3.68	4.23	4.60	5.60	6.91	7.89	9.24	10.36	11.90
03	5-day	1.92	2.30	2.56	2.97	3.41	3.71	4.57	5.80	6.65	7.90	8.95	10.50
03	72-hr	1.72	2.05	2.28	2.64	3.02	3.30	4.08	5.11	5.87	6.97	7.95	9.48
03	48-hr	1.61	1.88	2.09	2.42	2.76	3.01	3.68	4.56	5.50	6.45	7.56	8.80
03	24-hr	1.53	1.77	1.95	2.24	2.56	2.79	3.45	4.29	4.93	6.07	7.04	8.20
03	18-hr	1.41	1.64	1.80	2.07	2.36	2.57	3.18	3.95	4.53	5.59	6.47	7.55
03	12-hr	1.34	1.56	1.70	1.94	2.22	2.43	2.98	3.73	4.29	5.28	6.13	7.14
03	6-hr	1.15	1.34	1.47	1.67	1.91	2.10	2.58	3.22	3.70	4.55	5.28	6.15
03	3-hr	0.98	1.15	1.26	1.44	1.65	1.79	2.21	2.75	3.15	3.89	4.51	5.25
03	2-hr	0.91	1.06	1.17	1.32	1.50	1.65	2.02	2.53	2.91	3.58	4.15	4.84
03	1-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.60	2.02	2.32	2.86	3.31	3.85
03	30-min	0.57	0.66	0.73	0.83	0.95	1.03	1.27	1.59	1.82	2.25	2.61	3.03
03	15-min	0.41	0.48	0.53	0.61	0.69	0.75	0.91	1.16	1.33	1.64	1.90	2.21
03	10-min	0.34	0.39	0.43	0.49	0.56	0.61	0.74	0.94	1.08	1.33	1.55	1.81
03	5-min	0.18	0.21	0.23	0.26	0.30	0.33	0.40	0.51	0.59	0.73	0.84	0.98

Table 1. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	2.10	2.58	2.92	3.43	3.93	4.29	5.12	6.27	7.10	8.19	9.10	10.18
04	5-day	1.77	2.12	2.37	2.78	3.20	3.48	4.17	5.11	5.84	6.96	7.98	9.21
04	72-hr	1.59	1.91	2.12	2.44	2.80	3.05	3.70	4.55	5.26	6.15	7.25	8.16
04	48-hr	1.48	1.76	1.95	2.25	2.58	2.81	3.38	4.19	4.86	5.78	6.62	7.51
04	24-hr	1.39	1.63	1.80	2.04	2.32	2.52	3.02	3.76	4.45	5.32	6.08	6.92
04	18-hr	1.27	1.51	1.66	1.88	2.12	2.28	2.75	3.46	4.09	4.90	5.59	6.37
04	12-hr	1.19	1.40	1.53	1.77	2.01	2.17	2.62	3.27	3.87	4.63	5.29	6.02
04	6-hr	1.03	1.21	1.34	1.53	1.74	1.89	2.26	2.82	3.33	3.99	4.56	5.19
04	3-hr	0.89	1.03	1.13	1.30	1.47	1.61	1.93	2.41	2.85	3.41	3.89	4.43
04	2-hr	0.82	0.95	1.04	1.19	1.37	1.48	1.78	2.22	2.62	3.14	3.59	4.08
04	1-hr	0.65	0.76	0.83	0.95	1.09	1.18	1.42	1.77	2.09	2.50	2.86	3.25
04	30-min	0.52	0.60	0.66	0.75	0.86	0.93	1.12	1.39	1.64	1.97	2.25	2.56
04	15-min	0.37	0.44	0.49	0.56	0.63	0.68	0.81	1.02	1.20	1.44	1.64	1.87
04	10-min	0.30	0.35	0.39	0.45	0.50	0.55	0.66	0.83	0.98	1.17	1.34	1.52
04	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.36	0.45	0.53	0.64	0.73	0.83
05	10-day	2.13	2.62	2.96	3.48	4.00	4.35	5.15	6.21	6.97	8.04	8.90	9.92
05	5-day	1.75	2.10	2.37	2.75	3.15	3.42	4.12	4.96	5.67	6.76	7.65	8.78
05	72-hr	1.61	1.93	2.16	2.48	2.85	3.10	3.71	4.57	5.20	6.17	6.97	7.83
05	48-hr	1.51	1.77	1.95	2.26	2.57	2.82	3.40	4.16	4.77	5.66	6.40	7.16
05	24-hr	1.36	1.58	1.75	2.00	2.27	2.47	3.01	3.71	4.26	5.04	5.83	6.61
05	18-hr	1.25	1.47	1.62	1.84	2.09	2.27	2.77	3.41	3.92	4.63	5.37	6.08
05	12-hr	1.18	1.38	1.53	1.74	1.98	2.15	2.62	3.23	3.71	4.38	5.08	5.75
05	6-hr	1.00	1.18	1.32	1.49	1.70	1.85	2.26	2.78	3.20	3.78	4.38	4.96
05	3-hr	0.87	1.02	1.12	1.28	1.46	1.58	1.93	2.37	2.73	3.22	3.74	4.23
05	2-hr	0.79	0.93	1.03	1.17	1.34	1.46	1.78	2.19	2.52	2.97	3.44	3.90
05	1-hr	0.64	0.74	0.81	0.93	1.07	1.16	1.41	1.74	2.00	2.39	2.74	3.11
05	30-min	0.50	0.58	0.64	0.74	0.84	0.91	1.11	1.37	1.57	1.87	2.16	2.45
05	15-min	0.37	0.43	0.47	0.54	0.62	0.67	0.81	1.00	1.14	1.37	1.60	1.85
05	10-min	0.30	0.35	0.38	0.43	0.49	0.54	0.66	0.81	0.94	1.12	1.28	1.46
05	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.36	0.44	0.51	0.61	0.70	0.79
06	10-day	2.16	2.65	2.99	3.52	4.05	4.40	5.35	6.62	7.45	8.66	9.79	11.26
06	5-day	1.77	2.13	2.39	2.78	3.19	3.47	4.19	5.32	6.20	7.44	8.53	9.93
06	72-hr	1.63	1.95	2.16	2.50	2.88	3.13	3.81	4.85	5.68	6.84	7.76	8.92
06	48-hr	1.52	1.81	2.00	2.30	2.64	2.87	3.49	4.45	5.21	6.28	7.12	8.19
06	24-hr	1.42	1.66	1.84	2.10	2.38	2.59	3.11	3.93	4.65	5.57	6.46	7.45
06	18-hr	1.31	1.53	1.68	1.93	2.19	2.38	2.86	3.61	4.28	5.12	5.95	6.85
06	12-hr	1.24	1.44	1.57	1.82	2.07	2.25	2.71	3.39	3.97	4.84	5.62	6.48
06	6-hr	1.07	1.24	1.37	1.57	1.78	1.94	2.33	2.95	3.48	4.18	4.85	5.59
06	3-hr	0.91	1.07	1.18	1.34	1.52	1.66	1.99	2.51	2.98	3.56	4.14	4.77
06	2-hr	0.84	0.98	1.08	1.24	1.41	1.53	1.84	2.32	2.74	3.28	3.81	4.39
06	1-hr	0.67	0.79	0.87	0.99	1.12	1.21	1.46	1.85	2.19	2.62	3.04	3.50
06	30-min	0.53	0.61	0.68	0.78	0.88	0.96	1.15	1.46	1.72	2.06	2.39	2.75
06	15-min	0.38	0.45	0.49	0.57	0.64	0.70	0.84	1.06	1.26	1.52	1.75	2.01
06	10-min	0.31	0.36	0.40	0.46	0.52	0.57	0.68	0.87	1.02	1.22	1.42	1.64
06	5-min	0.17	0.20	0.22	0.25	0.29	0.31	0.37	0.47	0.56	0.67	0.78	0.89

Table 1. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	2.30	2.80	3.16	3.70	4.27	4.64	5.58	6.80	7.61	8.66	9.70	10.87
07	5-day	1.85	2.22	2.50	2.90	3.31	3.63	4.34	5.33	6.11	7.28	8.37	9.65
07	72-hr	1.62	1.90	2.15	2.50	2.87	3.12	3.73	4.64	5.32	6.39	7.35	8.54
07	48-hr	1.52	1.78	1.98	2.30	2.64	2.87	3.42	4.26	4.88	5.84	6.75	8.00
07	24-hr	1.40	1.63	1.78	2.07	2.35	2.55	3.03	3.80	4.44	5.37	6.23	7.41
07	18-hr	1.29	1.50	1.64	1.90	2.16	2.35	2.79	3.49	4.08	4.94	5.73	6.81
07	12-hr	1.21	1.42	1.55	1.80	2.04	2.22	2.63	3.30	3.86	4.67	5.42	6.45
07	6-hr	1.06	1.23	1.37	1.55	1.74	1.87	2.27	2.85	3.33	4.03	4.67	5.56
07	3-hr	0.89	1.05	1.15	1.32	1.50	1.63	1.94	2.43	2.84	3.44	3.99	4.74
07	2-hr	0.83	0.97	1.07	1.22	1.38	1.50	1.79	2.24	2.62	3.17	3.67	4.39
07	1-hr	0.66	0.77	0.85	0.97	1.10	1.20	1.42	1.78	2.09	2.52	2.93	3.48
07	30-min	0.52	0.60	0.66	0.76	0.86	0.93	1.12	1.41	1.64	1.99	2.31	2.74
07	15-min	0.38	0.44	0.49	0.56	0.63	0.69	0.82	1.03	1.20	1.45	1.68	2.00
07	10-min	0.31	0.36	0.40	0.45	0.51	0.56	0.66	0.83	0.98	1.18	1.37	1.63
07	5-min	0.17	0.20	0.22	0.25	0.29	0.31	0.36	0.46	0.54	0.64	0.75	0.89
08	10-day	2.22	2.74	3.09	3.63	4.18	4.54	5.54	6.80	7.80	9.20	10.44	11.81
08	5-day	1.85	2.21	2.49	2.90	3.31	3.62	4.40	5.46	6.34	7.68	8.88	10.68
08	72-hr	1.67	1.97	2.20	2.54	2.93	3.22	3.94	4.92	5.74	6.97	8.12	9.55
08	48-hr	1.57	1.85	2.06	2.38	2.75	2.97	3.59	4.52	5.26	6.43	7.36	8.81
08	24-hr	1.49	1.73	1.90	2.20	2.48	2.71	3.28	4.13	4.76	6.02	7.07	8.21
08	18-hr	1.35	1.59	1.74	2.00	2.29	2.49	3.02	3.80	4.38	5.54	6.51	7.55
08	12-hr	1.28	1.50	1.64	1.88	2.15	2.35	2.86	3.60	4.14	5.24	6.15	7.14
08	6-hr	1.12	1.30	1.44	1.64	1.87	2.03	2.45	3.10	3.57	4.52	5.30	6.16
08	3-hr	0.95	1.12	1.22	1.40	1.59	1.73	2.10	2.63	3.08	3.86	4.52	5.25
08	2-hr	0.88	1.02	1.13	1.28	1.47	1.60	1.94	2.44	2.87	3.55	4.20	4.84
08	1-hr	0.70	0.81	0.89	1.02	1.15	1.26	1.54	1.93	2.27	2.84	3.32	3.86
08	30-min	0.55	0.64	0.71	0.81	0.92	1.00	1.22	1.53	1.78	2.25	2.62	3.03
08	15-min	0.40	0.47	0.52	0.59	0.67	0.73	0.89	1.12	1.29	1.63	1.91	2.22
08	10-min	0.33	0.38	0.42	0.49	0.55	0.60	0.72	0.91	1.05	1.32	1.55	1.81
08	5-min	0.18	0.21	0.23	0.26	0.30	0.33	0.40	0.50	0.58	0.72	0.85	0.99
09	10-day	2.30	2.88	3.23	3.80	4.33	4.75	5.74	7.09	8.07	9.54	10.68	11.79
09	5-day	1.90	2.29	2.59	3.00	3.45	3.75	4.48	5.57	6.50	7.91	9.16	10.57
09	72-hr	1.73	2.02	2.25	2.62	3.00	3.27	3.92	4.92	5.75	7.05	8.23	9.40
09	48-hr	1.59	1.87	2.07	2.40	2.76	3.00	3.60	4.52	5.28	6.48	7.58	8.62
09	24-hr	1.44	1.68	1.85	2.12	2.41	2.62	3.16	4.00	4.62	5.79	6.71	7.73
09	18-hr	1.33	1.55	1.71	1.95	2.22	2.41	2.91	3.68	4.25	5.33	6.17	7.11
09	12-hr	1.25	1.46	1.60	1.85	2.10	2.28	2.75	3.48	4.02	5.04	5.84	6.72
09	6-hr	1.08	1.27	1.41	1.60	1.81	1.97	2.37	3.00	3.47	4.34	5.03	5.80
09	3-hr	0.92	1.08	1.21	1.37	1.55	1.68	2.02	2.56	2.96	3.71	4.29	4.95
09	2-hr	0.85	1.00	1.12	1.26	1.43	1.55	1.85	2.36	2.72	3.41	3.96	4.56
09	1-hr	0.68	0.79	0.88	1.00	1.13	1.23	1.49	1.88	2.20	2.72	3.15	3.63
09	30-min	0.53	0.62	0.68	0.78	0.89	0.97	1.17	1.47	1.73	2.14	2.48	2.86
09	15-min	0.39	0.46	0.50	0.58	0.65	0.71	0.85	1.08	1.25	1.56	1.81	2.09
09	10-min	0.32	0.37	0.41	0.47	0.53	0.58	0.70	0.88	1.02	1.27	1.48	1.70
09	5-min	0.18	0.20	0.22	0.26	0.29	0.32	0.38	0.48	0.55	0.69	0.81	0.93

Table 1. Continued

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
10	10-day	2.55	3.15	3.58	4.21	4.84	5.26	6.36	7.81	8.90	10.34	11.36	12.50
10	5-day	2.09	2.52	2.83	3.29	3.77	4.10	4.99	6.20	7.21	8.45	9.45	10.82
10	72-hr	1.88	2.25	2.49	2.87	3.30	3.59	4.36	5.48	6.34	7.53	8.54	9.52
10	48-hr	1.75	2.08	2.31	2.65	3.02	3.30	4.00	5.03	5.80	6.93	7.86	8.79
10	24-hr	1.63	1.91	2.10	2.41	2.74	2.97	3.62	4.51	5.21	6.23	7.11	8.27
10	18-hr	1.51	1.77	1.95	2.22	2.52	2.74	3.33	4.15	4.79	5.74	6.54	7.61
10	12-hr	1.42	1.66	1.83	2.10	2.38	2.59	3.15	3.93	4.53	5.42	6.19	7.20
10	6-hr	1.23	1.44	1.58	1.71	2.05	2.23	2.73	3.39	3.91	4.68	5.31	6.21
10	3-hr	1.06	1.23	1.35	1.54	1.75	1.90	2.32	2.89	3.33	3.99	4.55	5.29
10	2-hr	0.97	1.13	1.25	1.43	1.62	1.76	2.14	2.66	3.07	3.68	4.20	4.88
10	1-hr	0.77	0.90	0.99	1.13	1.29	1.40	1.70	2.12	2.45	2.93	3.34	3.89
10	30-min	0.61	0.70	0.77	0.89	1.01	1.10	1.34	1.66	1.93	2.31	2.63	3.06
10	15-min	0.43	0.51	0.56	0.65	0.74	0.80	0.98	1.22	1.41	1.68	1.92	2.23
10	10-min	0.36	0.42	0.46	0.53	0.60	0.65	0.80	0.99	1.14	1.37	1.56	1.82
10	5-min	0.20	0.23	0.25	0.29	0.33	0.36	0.43	0.54	0.62	0.75	0.85	0.99

Table 2. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Indiana

Sectional code (see figure 1 on page 4)

01- Northwes
02 - North Central
03 - Northeast
04 - West Central
05 - Central
06 - East Central
07 - Southwest
08 - South Central
09- Southeast

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	2.07	2.50	2.88	3.38	3.89	4.23	4.84	5.79	6.67	8.03	9.23	10.58
01	5-day	1.68	2.01	2.27	2.63	3.03	3.29	3.84	4.70	5.50	6.81	7.99	9.37
01	72-hr	1.53	1.80	2.04	2.36	2.71	2.95	3.46	4.24	4.97	6.10	7.17	8.38
01	48-hr	1.40	1.64	1.83	2.12	2.44	2.65	3.12	3.87	4.56	5.58	6.52	7.58
01	24-hr	1.33	1.55	1.69	1.96	2.23	2.42	2.89	3.61	4.22	5.22	6.10	7.12
01	18-hr	1.25	1.45	1.59	1.84	2.09	2.27	2.72	3.39	3.97	4.91	5.73	6.69
01	12-hr	1.16	1.35	1.48	1.71	1.94	2.11	2.51	3.14	3.67	4.54	5.31	6.19
01	6-hr	1.00	1.16	1.27	1.47	1.67	1.82	2.17	2.71	3.16	3.91	4.57	5.34
01	3-hr	0.85	0.99	1.08	1.26	1.43	1.55	1.85	2.31	2.70	3.34	3.90	4.56
01	2-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.68	2.09	2.45	3.03	3.54	4.13
01	1-hr	0.63	0.73	0.80	0.92	1.05	1.14	1.36	1.70	1.98	2.45	2.87	3.35
01	30-min	0.50	0.58	0.63	0.73	0.83	0.90	1.07	1.34	1.56	1.93	2.26	2.63
01	15-min	0.36	0.42	0.45	0.53	0.60	0.65	0.78	0.97	1.14	1.41	1.65	1.92
01	10-min	0.28	0.33	0.36	0.41	0.47	0.51	0.61	0.76	0.89	1.10	1.28	1.50
01	5-min	0.16	0.19	0.20	0.23	0.27	0.29	0.35	0.43	0.51	0.63	0.73	0.85
02	10-day	2.04	2.45	2.83	3.33	3.83	4.16	4.75	5.64	6.45	7.69	8.80	10.03
02	5-day	1.68	2.01	2.28	2.64	3.04	3.30	3.80	4.62	5.38	6.57	7.63	8.85
02	72-hr	1.48	1.74	1.97	2.28	2.62	2.85	3.33	4.10	4.79	5.88	6.86	8.00
02	48-hr	1.37	1.60	1.78	2.06	2.37	2.58	3.02	3.73	4.36	5.36	6.25	7.28
02	24-hr	1.30	1.51	1.65	1.91	2.17	2.36	2.78	3.43	4.00	4.90	5.67	6.54
02	18-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.61	3.22	3.76	4.61	5.33	6.15
02	12-hr	1.13	1.31	1.43	1.66	1.89	2.05	2.42	2.98	3.48	4.26	4.93	5.69
02	6-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.09	2.57	3.00	3.68	4.25	4.90
02	3-hr	0.83	0.97	1.06	1.22	1.39	1.51	1.78	2.20	2.56	3.14	3.63	4.19
02	2-hr	0.75	0.88	0.96	1.11	1.26	1.37	1.61	1.99	2.32	2.84	3.29	3.79
02	1-hr	0.61	0.71	0.78	0.90	1.02	1.11	1.31	1.61	1.88	2.30	2.66	3.07
02	30-min	0.48	0.56	0.61	0.70	0.80	0.87	1.03	1.27	1.48	1.81	2.10	2.42
02	15-min	0.35	0.41	0.45	0.52	0.59	0.64	0.75	0.93	1.08	1.32	1.53	1.77
02	10-min	0.28	0.32	0.35	0.41	0.46	0.50	0.58	0.72	0.84	1.03	1.19	1.37
02	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.33	0.41	0.48	0.59	0.68	0.78
03	10-day	1.81	2.18	2.52	2.96	3.40	3.70	4.25	5.12	5.84	6.96	8.01	9.16
03	5-day	1.52	1.82	2.06	2.38	2.74	2.98	3.46	4.18	4.81	5.83	6.76	7.80
03	72-hr	1.35	1.59	1.79	2.08	2.39	2.60	3.01	3.68	4.27	5.21	6.06	7.01
03	48-hr	1.27	1.48	1.65	1.91	2.20	2.39	2.77	3.38	3.92	4.78	5.57	6.45
03	24-hr	1.19	1.38	1.51	1.75	1.99	2.16	2.52	3.04	3.52	4.29	5.02	5.77
03	18-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.37	2.86	3.31	4.03	4.72	5.42
03	12-hr	1.03	1.20	1.32	1.52	1.73	1.68	2.19	2.64	3.06	3.73	4.37	5.02
03	6-hr	0.89	1.04	1.13	1.31	1.49	1.62	1.89	2.28	2.64	3.22	3.76	4.33
03	3-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.61	1.95	2.25	2.75	3.21	3.69
03	2-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.46	1.76	2.04	2.49	2.91	3.35
03	1-hr	0.56	0.65	0.71	0.83	0.94	1.02	1.18	1.43	1.65	2.02	2.36	2.71
03	30-min	0.44	0.51	0.56	0.65	0.74	0.80	0.93	1.12	1.30	1.59	1.86	2.13
03	15-min	0.32	0.37	0.41	0.47	0.53	0.58	0.68	0.82	0.95	1.16	1.36	1.56
03	10-min	0.25	0.29	0.31	0.36	0.41	0.45	0.53	0.64	0.74	0.90	1.05	1.21
03	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.30	0.36	0.42	0.51	0.60	0.69

Table 2. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	2.32	2.80	3.22	3.79	4.36	4.74	5.43	6.47	7.33	8.50	9.48	10.65
04	5-day	1.85	2.21	2.50	2.90	3.34	3.63	4.24	5.15	5.97	7.25	8.31	9.55
04	72-hr	1.64	1.93	2.18	2.53	2.91	3.16	3.76	4.53	5.34	6.43	7.45	8.55
04	48-hr	1.53	1.79	1.99	2.30	2.65	2.88	3.38	4.12	4.75	5.77	6.66	7.65
04	24-hr	1.45	1.68	1.84	2.13	2.42	2.63	3.12	3.83	4.47	5.39	6.17	7.01
04	18-hr	1.36	1.58	1.73	2.00	2.27	2.47	2.93	3.60	4.20	5.07	5.80	6.59
04	12-hr	1.26	1.47	1.60	1.85	2.11	2.29	2.71	3.33	3.89	4.69	5.37	6.10
04	6-hr	1.08	1.26	1.38	1.60	1.81	1.97	2.34	2.87	3.35	4.04	4.63	5.26
04	3-hr	0.92	1.08	1.18	1.36	1.55	1.68	2.00	2.45	2.86	3.45	3.95	4.49
04	2-hr	0.84	0.98	1.07	1.24	1.41	1.53	1.81	2.22	2.59	3.13	3.58	4.07
04	1-hr	0.68	0.79	0.87	1.00	1.14	1.24	1.47	1.80	2.10	2.53	2.90	3.29
04	30-min	0.53	0.62	0.68	0.79	0.89	0.97	1.15	1.42	1.65	1.99	2.28	2.59
04	15-min	0.39	0.45	0.50	0.58	0.65	0.71	0.84	1.03	1.21	1.46	1.67	1.89
04	10-min	0.30	0.35	0.38	0.45	0.51	0.55	0.66	0.80	0.94	1.13	1.30	1.47
04	5-min	0.18	0.20	0.22	0.26	0.29	0.32	0.37	0.46	0.54	0.65	0.74	0.84
05	10-day	2.13	2.56	2.95	3.47	3.99	4.34	5.06	6.07	6.96	8.36	9.57	10.86
05	5-day	1.73	2.07	2.34	2.71	3.12	3.39	3.97	4.86	5.66	6.91	8.07	9.44
05	72-hr	1.52	1.79	2.02	2.34	2.70	2.93	3.45	4.27	5.04	6.15	7.17	8.31
05	48-hr	1.42	1.66	1.85	2.14	2.47	2.68	3.18	3.94	4.63	5.65	6.56	7.55
05	24-hr	1.35	1.57	1.72	1.99	2.26	2.46	2.92	3.64	4.25	5.16	5.95	6.84
05	18-hr	1.27	1.48	1.62	1.87	2.13	2.31	2.74	3.42	3.99	4.85	5.59	6.43
05	12-hr	1.18	1.37	1.50	1.73	1.97	2.14	2.54	3.17	3.70	4.49	5.18	5.95
05	6-hr	1.02	1.18	1.29	1.50	1.70	1.85	2.19	2.73	3.19	3.87	4.46	5.13
05	3-hr	0.86	1.00	1.10	1.27	1.44	1.57	1.87	2.33	2.72	3.30	3.81	4.38
05	2-hr	0.79	0.92	1.00	1.16	1.32	1.43	1.69	2.11	2.46	2.99	3.45	3.97
05	1-hr	0.64	0.74	0.81	0.94	1.07	1.16	1.37	1.71	2.00	2.43	2.80	3.21
05	30-min	0.50	0.58	0.64	0.74	0.84	0.91	1.08	1.35	1.57	1.91	2.20	2.53
05	15-min	0.36	0.42	0.46	0.53	0.61	0.66	0.79	0.98	1.15	1.39	1.61	1.85
05	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.61	0.76	0.89	1.08	1.25	1.44
05	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.35	0.44	0.51	0.62	0.71	0.82
06	10-day	2.13	2.57	2.96	3.48	4.00	4.35	5.00	6.00	6.82	8.30	9.55	11.05
06	5-day	1.62	1.93	2.19	2.54	2.92	3.17	3.75	4.68	5.50	6.90	8.20	9.68
06	72-hr	1.45	1.70	1.92	2.22	2.56	2.78	3.30	4.15	4.98	6.06	7.25	8.55
06	48-hr	1.36	1.59	1.77	2.06	2.36	2.57	3.01	3.73	4.40	5.54	6.55	7.70
06	24-hr	1.26	1.47	1.61	1.66	2.12	2.30	2.76	3.37	3.89	4.65	5.29	6.05
06	18-hr	1.19	1.38	1.51	1.75	1.99	2.16	2.59	3.17	3.66	4.37	4.97	5.69
06	12-hr	1.10	1.28	1.40	1.62	1.84	2.00	2.40	2.93	3.38	4.05	4.60	5.26
06	6-hr	0.95	1.10	1.20	1.39	1.58	1.72	2.07	2.53	2.92	3.49	3.97	4.54
06	3-hr	0.81	0.94	1.03	1.19	1.35	1.47	1.77	2.16	2.49	2.98	3.39	3.87
06	2-hr	0.73	0.85	0.93	1.08	1.22	1.33	1.60	1.95	2.26	2.70	3.07	3.51
06	1-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.30	1.58	1.83	2.19	2.49	2.84
06	30-min	0.47	0.54	0.60	0.69	0.78	0.85	1.02	1.25	1.44	1.72	1.96	2.24
06	15-min	0.34	0.40	0.43	0.50	0.57	0.62	0.75	0.91	1.05	1.26	1.43	1.63
06	10-min	0.26	0.31	0.34	0.39	0.44	0.48	0.58	0.71	0.82	0.98	1.11	1.27
06	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.33	0.40	0.47	0.56	0.63	0.73

Table 2. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	2.53	3.05	3.52	4.14	4.76	5.17	5.99	7.29	8.46	10.28	11.91	13.74
07	5-day	1.96	2.35	2.66	3.08	3.54	3.85	4.54	5.64	6.66	8.25	9.72	11.32
07	72-hr	1.80	2.11	2.39	2.77	3.18	3.46	4.10	5.12	6.02	7.49	8.79	10.28
07	48-hr	1.65	1.93	2.15	2.50	2.87	3.12	3.68	4.56	5.35	6.62	7.77	9.08'
07	24-hr	1.52	1.77	1.93	2.24	2.54	2.76	3.27	4.00	4.65	5.66	6.52	7.47
07	18-hr	1.42	1.66	1.81	2.10	2.38	2.59	3.07	3.76	4.37	5.32	6.13	7.02
07	12-hr	1.32	1.54	1.68	1.94	2.21	2.40	2.84	3.48	4.05	4.92	5.67	6.50
07	6-hr	1.14	1.32	1.45	1.68	1.90	2.07	2.45	3.00	3.49	4.24	4.89	5.60
07	3-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.09	2.56	2.98	3.62	4.17	4.78
07	2-hr	0.88	1.02	1.12	1.30	1.47	1.60	1.90	2.32	2.70	3.28	3.78	4.33
07	1-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.54	1.88	2.19	2.66	3.06	3.51
07	30-min	0.56	0.65	0.71	0.83	0.94	1.02	1.21	1.48	1.72	2.09	2.41	2.76
07	15-min	0.41	0.48	0.52	0.61	0.69	0.75	0.88	1.08	1.26	1.53	1.76	2.02
07	10-min	0.32	0.37	0.41	0.47	0.53	0.58	0.69	0.84	0.98	1.19	1.37	1.57
07	5-min	0.18	0.21	0.23	0.27	0.30	0.33	0.39	0.48	0.56	0.68	0.78	0.90
08	10-day	2.39	2.88	3.32	3.90	4.49	4.88	5.74	6.95	7.99	9.60	11.04	12.64
08	5-day	1.90	2.27	2.57	2.98	3.42	3.72	4.50	5.54	6.43	7.71	8.88	10.18
08	72-hr	1.70	1.99	2.25	2.61	3.00	3.26	3.88	4.82	5.65	6.92	7.99	9.14
08	48-hr	1.61	1.88	2.10	2.43	2.80	3.04	3.61	4.41	5.13	6.18	7.14	8.13
08	24-hr	1.48	1.72	1.88	2.18	2.47	2.69	3.17	3.90	4.49	5.40	6.15	7.06
08	18-hr	1.39	1.62	1.77	2.05	2.33	2.53	2.98	3.67	4.22	5.08	5.78	6.64
08	12-hr	1.29	1.50	1.64	1.90	2.15	2.34	2.76	3.39	3.91	4.70	5.35	6.14
08	6-hr	1.11	1.29	1.41	1.64	1.66	2.02	2.38	2.93	3.37	4.05	4.61	5.30
08	3-hr	0.95	1.10	1.20	1.39	1.58	1.72	2.03	2.50	2.87	3.46	3.94	4.52
08	2-hr	0.86	1.00	1.09	1.26	1.44	1.56	1.84	2.26	2.60	3.13	3.57	4.09
08	1-hr	0.69	0.81	0.88	1.02	1.16	1.26	1.49	1.83	2.11	2.54	2.89	3.32
08	30-min	0.55	0.64	0.70	0.81	0.92	1.00	1.17	1.44	1.66	2.00	2.28	2.61
08	15-min	0.40	0.47	0.51	0.59	0.67	0.73	0.86	1.05	1.21	1.46	1.66	1.91
08	10-min	0.31	0.36	0.39	0.45	0.52	0.56	0.67	0.82	0.94	1.13	1.29	1.48
08	5-min	0.18	0.20	0.22	0.26	0.29	0.32	0.38	0.47	0.54	0.65	0.74	0.85
09	10-day	2.35	2.83	3.26	3.83	4.41	4.79	5.62	6.85	7.87	9.42	10.90	12.33
09	5-day	1.86	2.23	2.52	2.92	3.36	3.65	4.29	5.22	6.06	7.39	8.54	9.90
09	72-hr	1.67	1.96	2.22	2.58	2.96	3.22	3.87	4.77	5.53	6.75	7.80	8.95
09	48-hr	1.55	1.82	2.02	2.34	2.70	2.93	3.53	4.40	5.13	6.22	7.19	8.20
09	24-hr	1.36	1.58	1.73	2.00	2.27	2.47	3.03	3.81	4.42	5.39	6.20	7.12
09	18-hr	1.28	1.48	1.62	1.88	2.13	2.32	2.85	3.58	4.15	5.07	5.83	6.69
09	12-hr	1.18	1.38	1.50	1.74	1.98	2.15	2.64	3.31	3.85	4.69	5.39	6.19
09	6-hr	1.02	1.18	1.29	1.50	1.70	1.85	2.27	2.86	3.32	4.04	4.65	5.34
09	3-hr	0.87	1.01	1.11	1.28	1.45	1.58	1.94	2.44	2.83	3.45	3.97	4.56
09	2-hr	0.79	0.92	1.00	1.16	1.32	1.43	1.76	2.21	2.56	3.13	3.60	4.13
09	1-hr	0.64	0.74	0.81	0.94	1.07	1.16	1.42	1.79	2.08	2.53	2.91	3.35
09	30-min	0.50	0.58	0.64	0.74	0.84	0.91	1.12	1.41	1.64	1.99	2.29	2.63
09	15-min	0.37	0.43	0.47	0.54	0.62	0.67	0.82	1.03	1.19	1.46	1.67	1.92
09	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.64	0.80	0.93	1.13	1.30	1.50
09	5-min	0.17	0.19	0.21	0.24	0.26	0.30	0.36	0.46	0.53	0.65	0.74	0.85

Table 3. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Iowa

Sectional code (see figure 1 on page 4)

01 - Northwest | *06 - East Central*
02 - North Central | *07 - Southwest*
03 - Northeast | *08 - South Central*
04 - West Central | *09 - Southeast*
05 - Central

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.98	2.39	2.75	3.24	3.73	4.05	4.81	5.84	6.70	8.02	9.11	10.31
01	5-day	1.59	1.90	2.15	2.49	2.86	3.11	3.77	4.68	5.43	6.61	7.60	8.75
01	72-hr	1.41	1.66	1.88	2.18	2.50	2.72	3.33	4.21	4.99	6.07	7.12	8.23
01	48-hr	1.32	1.55	1.73	2.00	2.30	2.50	3.01	3.81	4.52	5.60	6.53	7.52
01	24-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.75	3.50	4.14	5.11	5.97	6.92
01	18-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.59	3.29	3.89	4.80	5.61	6.50
01	12-hr	1.06	1.24	1.35	1.56	1.78	1.93	2.39	3.05	3.60	4.45	5.19	6.02
01	6-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.06	2.62	3.11	3.83	4.48	5.19
01	3-hr	0.78	0.91	0.99	1.15	1.31	1.42	1.76	2.24	2.65	3.27	3.82	4.43
01	2-hr	0.71	0.83	0.90	1.04	1.19	1.29	1.59	2.03	2.40	2.96	3.46	4.01
01	1-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.29	1.64	1.95	2.40	2.81	3.25
01	30-min	0.45	0.52	0.57	0.66	0.75	0.82	1.02	1.30	1.53	1.89	2.21	2.56
01	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.74	0.95	1.12	1.38	1.61	1.87
01	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.73	0.87	1.07	1.25	1.45
01	6-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.42	0.50	0.61	0.72	0.83
02	10-day	1.96	2.37	2.73	3.21	3.69	4.01	5.04	6.26	7.32	8.93	10.37	11.40
02	5-day	1.75	2.10	2.37	2.75	3.16	3.44	4.13	5.05	5.80	7.00	8.03	9.28
02	72-hr	1.49	1.74	1.97	2.29	2.63	2.86	3.53	4.45	5.15	6.33	7.30	8.30
02	48-hr	1.42	1.66	1.84	2.14	2.46	2.67	3.30	4.11	4.78	5.80	6.67	7.67
02	24-hr	1.30	1.51	1.65	1.91	2.17	2.36	2.98	3.72	4.38	5.33	6.14	7.07
02	18-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.80	3.50	4.12	5.01	5.77	6.65
02	12-hr	1.13	1.31	1.43	1.66	1.89	2.05	2.59	3.24	3.81	4.64	5.34	6.15
02	6-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.24	2.79	3.29	4.00	4.61	5.30
02	3-hr	0.83	0.97	1.06	1.22	1.39	1.51	1.91	2.38	2.80	3.41	3.93	4.52
02	2-hr	0.75	0.88	0.96	1.11	1.26	1.37	1.73	2.16	2.54	3.09	3.56	4.10
02	1-hr	0.61	0.71	0.78	0.90	1.02	1.11	1.40	1.75	2.06	2.51	2.89	3.32
02	30-min	0.48	0.56	0.61	0.70	0.80	0.87	1.10	1.38	1.62	1.97	2.27	2.62
02	15-min	0.35	0.41	0.45	0.52	0.59	0.64	0.80	1.00	1.18	1.44	1.66	1.91
02	10-min	0.28	0.32	0.35	0.41	0.46	0.50	0.63	0.78	0.92	1.12	1.29	1.48
02	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.36	0.45	0.53	0.64	0.74	0.85
03	10-day	2.07	2.49	2.87	3.38	3.88	4.22	5.04	6.17	7.07	8.29	9.20	10.19
03	5-day	1.69	2.03	2.29	2.66	3.05	3.32	3.94	4.86	5.64	6.84	7.75	8.77
03	72-hr	1.49	1.74	1.97	2.29	2.63	2.86	3.44	4.33	5.14	6.19	7.00	7.84
03	48-hr	1.37	1.61	1.79	2.07	2.38	2.59	3.20	4.02	4.69	5.62	6.34	7.09
03	24-hr	1.28	1.48	1.62	1.88	2.13	2.32	2.91	3.67	4.31	5.11	5.73	6.36
03	18-hr	1.20	1.40	1.53	1.77	2.01	2.18	2.74	3.45	4.05	4.80	5.39	5.98
03	12-hr	1.11	1.29	1.41	1.64	1.86	2.02	2.53	3.19	3.75	4.45	4.99	5.53
03	6-hr	0.96	1.11	1.22	1.41	1.60	1.74	2.18	2.75	3.23	3.83	4.30	4.77
03	3-hr	0.81	0.95	1.04	1.20	1.36	1.48	1.86	2.35	2.76	3.27	3.67	4.07
03	2-hr	0.74	0.86	0.94	1.09	1.24	1.35	1.69	2.13	2.50	2.96	3.32	3.69
03	1-hr	0.60	0.70	0.76	0.88	1.00	1.09	1.37	1.72	2.03	2.40	2.69	2.99
03	30-min	0.47	0.55	0.60	0.70	0.79	0.86	1.08	1.36	1.59	1.89	2.12	2.35
03	15-min	0.35	0.40	0.44	0.51	0.58	0.63	0.79	0.99	1.16	1.38	1.55	1.72
03	10-min	0.27	0.31	0.34	0.40	0.45	0.49	0.61	0.77	0.91	1.07	1.20	1.34
03	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.35	0.44	0.52	0.61	0.69	0.76

Table 3. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	2.15	2.59	2.99	3.51	4.04	4.39	5.22	6.31	7.16	8.24	9.21	10.27
04	5-day	1.76	2.11	2.39	2.77	3.18	3.46	4.06	4.94	5.74	7.04	8.13	9.27
04	72-hr	1.52	1.79	2.02	2.34	2.70	2.93	3.51	4.37	5.13	6.28	7.26	8.46
04	48-hr	1.43	1.67	1.86	2.15	2.47	2.69	3.16	3.97	4.71	5.86	6.81	7.82
04	24-hr	1.36	1.59	1.74	2.01	2.28	2.48	2.94	3.64	4.30	5.27	6.08	7.00
04	18-hr	1.28	1.49	1.63	1.89	2.14	2.33	2.76	3.42	4.04	4.95	5.72	6.58
04	12-hr	1.19	1.38	1.51	1.75	1.99	2.16	2.56	3.17	3.74	4.58	5.29	6.09
04	6-hr	1.02	1.19	1.30	1.51	1.71	1.86	2.20	2.73	3.23	3.95	4.56	5.25
04	3-hr	0.87	1.02	1.11	1.29	1.46	1.59	1.88	2.33	2.75	3.37	3.89	4.48
04	2-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.71	2.11	2.49	3.06	3.53	4.06
04	1-hr	0.64	0.75	0.82	0.95	1.08	1.17	1.38	1.71	2.02	2.48	2.86	3.29
04	30-min	0.51	0.59	0.64	0.75	0.85	0.92	1.09	1.35	1.59	1.95	2.25	2.59
04	15-min	0.37	0.43	0.47	0.54	0.62	0.67	0.79	0.98	1.16	1.42	1.64	1.89
04	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.62	0.76	0.90	1.11	1.28	1.47
04	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.35	0.44	0.52	0.63	0.73	0.84
05	10-day	2.20	2.64	3.05	3.58	4.12	4.48	5.20	6.22	7.22	8.61	9.66	10.88
05	5-day	1.76	2.11	2.39	2.77	3.18	3.46	4.05	4.94	5.72	6.92	7.98	9.18
05	72-hr	1.51	1.77	2.00	2.32	2.67	2.90	3.47	4.41	5.16	6.22	7.06	8.12
05	48-hr	1.40	1.64	1.82	2.11	2.43	2.64	3.13	3.93	4.67	5.75	6.52	7.33
05	24-hr	1.31	1.52	1.67	1.93	2.19	2.38	2.91	3.64	4.27	5.15	5.87	6.61
05	18-hr	1.23	1.43	1.57	1.81	2.06	2.24	2.74	3.42	4.01	4.84	5.52	6.21
05	12-hr	1.14	1.32	1.45	1.68	1.90	2.07	2.53	3.17	3.71	4.48	5.11	5.75
05	6-hr	0.98	1.15	1.25	1.45	1.65	1.79	2.18	2.73	3.20	3.86	4.40	4.96
05	3-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.86	2.33	2.73	3.30	3.76	4.23
05	2-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.69	2.11	2.48	2.99	3.40	3.83
05	1-hr	0.62	0.72	0.78	0.91	1.03	1.12	1.37	1.71	2.01	2.42	2.76	3.11
05	30-min	0.48	0.56	0.62	0.71	0.81	0.88	1.08	1.35	1.58	1.91	2.17	2.45
05	15-min	0.35	0.41	0.45	0.52	0.59	0.64	0.79	0.98	1.15	1.39	1.58	1.78
05	10-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.76	0.90	1.08	1.23	1.39
05	5-min	0.16	0.19	0.20	0.23	0.27	0.29	0.35	0.44	0.51	0.62	0.70	0.79
06	10-day	2.14	2.57	2.96	3.49	4.01	4.36	5.21	6.27	7.12	8.25	9.27	10.35
06	5-day	1.84	2.20	2.48	2.88	3.31	3.60	4.12	4.89	5.61	6.70	7.75	9.00
06	72-hr	1.57	1.84	2.08	2.41	2.77	3.01	3.59	4.53	5.31	6.42	7.35	8.42
06	48-hr	1.38	1.61	1.79	2.08	2.39	2.60	3.21	4.15	5.05	6.02	6.87	7.83
06	24-hr	1.32	1.54	1.68	1.94	2.21	2.40	3.06	3.84	4.44	5.42	6.25	7.13
06	18-hr	1.24	1.45	1.58	1.83	2.08	2.26	2.88	3.61	4.17	5.09	5.88	6.70
06	12-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.66	3.34	3.86	4.72	5.44	6.20
06	6-hr	0.99	1.15	1.26	1.46	1.66	1.80	2.30	2.88	3.33	4.07	4.69	5.35
06	3-hr	0.85	0.99	1.08	1.25	1.42	1.54	1.96	2.46	2.84	3.47	4.00	4.56
06	2-hr	0.76	0.89	0.97	1.13	1.28	1.39	1.77	2.23	2.58	3.14	3.62	4.14
06	1-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.44	1.80	2.09	2.55	2.94	3.35
06	30-min	0.49	0.57	0.62	0.72	0.82	0.89	1.13	1.42	1.64	2.01	2.31	2.64
06	15-min	0.36	0.42	0.45	0.53	0.60	0.65	0.83	1.04	1.20	1.46	1.69	1.93
06	10-min	0.28	0.32	0.35	0.41	0.46	0.50	0.64	0.81	0.93	1.14	1.31	1.50
06	5-min	0.16	0.19	0.20	0.23	0.27	0.29	0.37	0.46	0.53	0.65	0.75	0.86

Table 3. Continued

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
07	10-day	2.29	2.76	3.18	3.74	4.30	4.67	5.47	6.54	7.53	9.00	10.25	11.66
07	5-day	1.81	2.17	2.45	2.84	3.27	3.55	4.26	5.30	6.20	7.59	8.71	9.86
07	72-hr	1.65	1.94	2.19	2.54	2.93	3.18	3.85	4.79	5.56	6.78	7.80	8.99
07	48-hr	1.57	1.84	2.05	2.38	2.73	2.97	3.53	4.38	5.11	6.19	7.09	8.04
07	24-hr	1.52	1.77	1.93	2.24	2.54	2.76	3.22	3.93	4.57	5.56	6.45	7.28
07	18-hr	1.42	1.66	1.81	2.10	2.38	2.59	3.03	3.69	4.30	5.23	6.06	6.84
07	12-hr	1.32	1.54	1.68	1.94	2.21	2.40	2.80	3.42	3.98	4.84	5.61	6.33
07	6-hr	1.14	1.32	1.45	1.68	1.90	2.07	2.41	2.95	3.43	4.17	4.84	5.46
07	3-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.06	2.52	2.92	3.56	4.13	4.66
07	2-hr	0.88	1.02	1.12	1.30	1.47	1.60	1.87	2.28	2.65	3.22	3.74	4.22
07	1-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.51	1.85	2.15	2.61	3.03	3.42
07	30-min	0.56	0.65	0.71	0.83	0.94	1.02	1.19	1.45	1.69	2.06	2.39	2.69
07	15-min	0.41	0.48	0.52	0.61	0.69	0.75	0.87	1.06	1.23	1.50	1.74	1.97
07	10-min	0.32	0.37	0.41	0.47	0.53	0.58	0.68	0.83	0.96	1.17	1.35	1.53
07	5-min	0.18	0.21	0.23	0.27	0.30	0.33	0.39	0.47	0.55	0.67	0.77	0.87
08	10-day	2.28	2.74	3.16	3.72	4.28	4.65	5.45	6.61	7.57	8.99	10.09	11.04
08	5-day	1.81	2.17	2.45	2.84	3.27	3.55	4.32	5.37	6.26	7.64	8.78	9.99
08	72-hr	1.60	1.88	2.13	2.46	2.83	3.08	3.67	4.68	5.64	6.90	7.96	9.24
08	48-hr	1.48	1.74	1.93	2.24	2.58	2.80	3.39	4.30	5.06	6.28	7.35	8.60
08	24-hr	1.38	1.60	1.75	2.03	2.30	2.50	3.11	3.87	4.65	5.78	6.73	7.74
08	18-hr	1.29	1.50	1.64	1.90	2.16	2.35	2.92	3.64	4.37	5.43	6.33	7.28
08	12-hr	1.19	1.39	1.52	1.76	2.00	2.17	2.71	3.37	4.05	5.03	5.86	6.73
08	6-hr	1.03	1.20	1.32	1.52	1.73	1.88	2.33	2.90	3.49	4.34	5.05	5.80
08	3-hr	0.88	1.02	1.12	1.30	1.47	1.60	1.99	2.48	2.98	3.70	4.31	4.95
08	2-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.80	2.24	2.70	3.35	3.90	4.49
08	1-hr	0.64	0.75	0.82	0.95	1.08	1.17	1.46	1.82	2.19	2.72	3.16	3.64
08	30-min	0.51	0.60	0.65	0.75	0.86	0.93	1.15	1.43	1.72	2.14	2.49	2.86
08	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.84	1.04	1.26	1.56	1.82	2.09
08	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.65	0.81	0.98	1.21	1.41	1.63
08	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.37	0.46	0.56	0.69	0.81	0.93
09	10-day	2.19	2.64	3.04	3.58	4.11	4.47	5.44	6.50	7.35	8.45	9.33	10.42
09	5-day	1.78	2.13	2.41	2.79	3.21	3.49	4.31	5.45	6.32	7.60	8.69	9.95
09	72-hr	1.55	1.82	2.06	2.38	2.74	2.98	3.79	4.87	5.74	6.95	7.88	8.98
09	48-hr	1.48	1.73	1.93	2.23	2.57	2.79	3.50	4.46	5.20	6.35	7.32	8.40
09	24-hr	1.38	1.60	1.75	2.03	2.30	2.50	3.14	4.03	4.67	5.67	6.58	7.59
09	18-hr	1.29	1.50	1.64	1.90	2.16	2.35	2.95	3.79	4.39	5.33	6.19	7.13
09	12-hr	1.19	1.39	1.52	1.76	2.00	2.17	2.73	3.51	4.06	4.93	5.72	6.60
09	6-hr	1.03	1.20	1.32	1.52	1.73	1.88	2.36	3.02	3.50	4.25	4.93	5.69
09	3-hr	0.88	1.02	1.12	1.30	1.47	1.60	2.01	2.58	2.99	3.63	4.21	4.86
09	2-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.82	2.34	2.71	3.29	3.82	4.40
09	1-hr	0.64	0.75	0.82	0.95	1.08	1.17	1.48	1.89	2.19	2.66	3.09	3.57
09	30-min	0.51	0.60	0.65	0.75	0.86	0.93	1.16	1.49	1.73	2.10	2.43	2.81
09	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.85	1.09	1.26	1.53	1.78	2.05
09	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.66	0.85	0.98	1.19	1.38	1.59
09	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.38	0.48	0.56	0.68	0.79	0.91

Table 4. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Kentucky

Sectional code (see figure 1 on page 4)

01 – Western   *03 - Bluegrass*
02 - Central   *04 - Eastern*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	2.57	3.09	3.56	4.19	4.82	5.24	6.27	7.74	8.94	9.99	10.60	11.12
01	5-day	2.18	2.61	2.95	3.42	3.94	4.28	5.09	6.35	7.42	8.90	9.82	10.53
01	72-hr	1.94	2.28	2.58	2.99	3.44	3.74	4.50	5.53	6.41	7.62	8.67	9.68
01	48-hr	1.80	2.11	2.35	2.72	3.13	3.40	4.09	5.10	5.90	6.92	7.84	8.74
01	24-hr	1.71	1.98	2.17	2.51	2.85	3.10	3.75	4.66	5.39	6.38	7.19	8.09
01	18-hr	1.60	1.86	2.04	2.36	2.68	2.91	3.53	4.38	5.07	6.00	6.76	7.60
01	12-hr	1.49	1.73	1.89	2.19	2.48	2.70	3.26	4.05	4.69	5.55	6.26	7.04
01	6-hr	1.28	1.48	1.62	1.88	2.13	2.32	2.81	3.49	4.04	4.78	5.39	6.07
01	3-hr	1.09	1.27	1.39	1.60	1.82	1.98	2.40	2.98	3.45	4.08	4.60	5.18
01	2-hr	0.99	1.15	1.26	1.46	1.66	1.80	2.17	2.70	3.13	3.70	4.17	4.69
01	1-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.76	2.19	2.53	3.00	3.38	3.80
01	30-min	0.63	0.74	0.80	0.93	1.06	1.15	1.39	1.72	1.99	2.36	2.66	2.99
01	15-min	0.46	0.54	0.59	0.68	0.77	0.84	1.01	1.26	1.46	1.72	1.94	2.18
01	10-min	0.36	0.42	0.45	0.53	0.60	0.65	0.79	0.98	1.13	1.34	1.51	1.70
01	5-min	0.20	0.24	0.26	0.30	0.34	0.37	0.45	0.56	0.65	0.77	0.86	0.97
02	10-day	2.52	3.03	3.50	4.11	4.73	5.14	6.03	7.45	8.68	9.86	10.57	11.05
02	5-day	2.03	2.43	2.75	3.19	3.67	3.99	4.78	6.00	7.04	8.39	9.35	10.22
02	72-hr	1.79	2.10	2.38	2.76	3.17	3.45	4.20	5.26	6.22	7.50	8.46	9.37
02	48-hr	1.67	1.96	2.18	2.53	2.91	3.16	3.88	4.82	5.65	6.82	7.75	8.75
02	24-hr	1.62	1.88	2.06	2.38	2.70	2.94	3.49	4.34	5.10	6.22	7.09	7.96
02	18-hr	1.52	1.77	1.93	2.24	2.54	2.76	3.28	4.08	4.79	5.85	6.66	7.48
02	12-hr	1.41	1.64	1.79	2.07	2.36	2.56	3.04	3.78	4.44	5.41	6.17	6.93
02	6-hr	1.21	1.41	1.54	1.78	2.02	2.20	2.62	3.26	3.82	4.66	5.32	5.97
02	3-hr	1.03	1.20	1.32	1.52	1.73	1.88	2.23	2.78	3.26	3.98	4.54	5.09
02	2-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.02	2.52	2.96	3.61	4.11	4.62
02	1-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.64	2.04	2.40	2.92	3.33	3.74
02	30-min	0.60	0.70	0.76	0.88	1.00	1.09	1.29	1.61	1.89	2.30	2.62	2.95
02	15-min	0.43	0.51	0.55	0.64	0.73	0.79	0.94	1.17	1.38	1.68	1.91	2.15
02	10-min	0.34	0.40	0.43	0.50	0.57	0.62	0.73	0.91	1.07	1.31	1.49	1.67
02	5-min	0.19	0.22	0.24	0.28	0.32	0.35	0.42	0.52	0.61	0.75	0.85	0.96
03	10-day	2.22	2.67	3.08	3.62	4.17	4.53	5.41	6.67	7.69	8.93	9.68	10.40
03	5-day	1.82	2.17	2.46	2.85	3.28	3.56	4.26	5.21	6.04	7.11	7.99	8.86
03	72-hr	1.60	1.88	2.13	2.46	2.83	3.08	3.68	4.61	5.41	6.36	7.15	7.99
03	48-hr	1.48	1.73	1.93	2.23	2.57	2.79	3.37	4.19	4.86	5.76	6.49	7.23
03	24-hr	1.41	1.64	1.79	2.07	2.36	2.56	3.05	3.76	4.36	5.15	5.78	6.44
03	18-hr	1.33	1.54	1.69	1.95	2.22	2.41	2.87	3.53	4.10	4.84	5.43	6.05
03	12-hr	1.23	1.43	1.56	1.81	2.05	2.23	2.65	3.27	3.79	4.48	5.03	5.60
03	6-hr	1.06	1.23	1.34	1.56	1.77	1.92	2.29	2.82	3.27	3.86	4.34	4.83
03	3-hr	0.90	1.05	1.15	1.33	1.51	1.64	1.95	2.41	2.79	3.30	3.70	4.12
03	2-hr	0.81	0.95	1.04	1.20	1.36	1.48	1.77	2.18	2.53	2.99	3.35	3.74
03	1-hr	0.66	0.77	0.84	0.97	1.10	1.20	1.43	1.77	2.05	2.42	2.72	3.03
03	30-min	0.52	0.61	0.66	0.77	0.87	0.95	1.13	1.39	1.61	1.91	2.14	2.38
03	15-min	0.38	0.44	0.48	0.56	0.63	0.69	0.82	1.02	1.18	1.39	1.56	1.74
03	10-min	0.30	0.35	0.38	0.44	0.50	0.54	0.64	0.79	0.92	1.08	1.21	1.35
03	5-min	0.17	0.20	0.22	0.25	0.29	0.31	0.37	0.45	0.52	0.62	0.69	0.77

Table 4. Concluded

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	2.31	2.78	3.21	3.78	4.34	4.72	5.53	6.48	7.27	8.31	9.06	9.79
04	5-day	1.83	2.18	2.47	2.86	3.29	3.58	4.25	5.15	5.93	6.95	7.84	8.77
04	72-hr	1.62	1.90	2.15	2.50	2.87	3.12	3.71	4.54	5.22	6.14	6.96	7.86
04	48-hr	1.54	1.80	2.00	2.32	2.67	2.90	3.42	4.13	4.73	5.60	6.38	7.23
04	24-hr	1.46	1.70	1.86	2.15	2.44	2.65	3.09	3.73	4.26	5.06	5.74	6.53
04	18-hr	1.37	1.59	1.74	2.02	2.29	2.49	2.90	3.51	4.00	4.76	5.40	6.14
04	12-hr	1.27	1.48	1.62	1.87	2.13	2.31	2.69	3.25	3.71	4.40	4.99	5.68
04	6-hr	1.09	1.27	1.39	1.61	1.83	1.99	2.32	2.80	3.20	3.80	4.30	4.90
04	3-hr	0.94	1.09	1.19	1.38	1.56	1.70	1.98	2.39	2.73	3.24	3.67	4.18
04	2-hr	0.85	0.99	1.08	1.25	1.42	1.54	1.79	2.16	2.47	2.93	3.33	3.79
04	1-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.45	1.75	2.00	2.38	2.70	3.07
04	30-min	0.54	0.63	0.69	0.79	0.90	0.98	1.14	1.38	1.58	1.87	2.12	2.42
04	15-min	0.40	0.46	0.50	0.58	0.66	0.72	0.83	1.01	1.15	1.37	1.55	1.76
04	10-min	0.31	0.36	0.39	0.45	0.52	0.56	0.65	0.78	0.89	1.06	1.21	1.37
04	5-min	0.18	0.20	0.22	0.26	0.29	0.32	0.37	0.45	0.51	0.61	0.69	0.78

Table 5. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Michigan

Sectional code (see figure 1 on page 4)

01 - West Upper — *06 - Central Lower*
02 - East Upper — *07 - East Central Lower*
03 - Northwest Lower — *08 - Southwest Lower*
04 - Northeast Lower — *09 - South Central Lower*
05 - West Central Lower — *10 - Southeast Lower*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.69	2.04	2.35	2.76	3.17	3.45	4.28	5.34	6.17	7.27	8.11	8.99
01	5-day	1.41	1.69	1.91	2.22	2.55	2.77	3.38	4.23	4.91	5.86	6.65	7.50
01	72-hr	1.24	1.46	1.65	1.91	2.20	2.39	2.96	3.69	4.29	5.11	5.79	6.49
01	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.64	3.31	3.84	4.59	5.20	5.86
01	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.39	3.00	3.48	4.17	4.73	5.32
01	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.25	2.82	3.27	3.92	4.45	5.00
01	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.08	2.61	3.03	3.63	4.12	4.63
01	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.79	2.25	2.61	3.13	3.55	3.99
01	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.53	1.92	2.23	2.67	3.03	3.40
01	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.39	1.74	2.02	2.42	2.74	3.09
01	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.12	1.41	1.64	1.96	2.22	2.50
01	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.29	1.54	1.75	1.97
01	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.65	0.81	0.94	1.13	1.28	1.44
01	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.73	0.88	0.99	1.12
01	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.29	0.36	0.42	0.50	0.57	0.64
02	10-day	1.61	1.94	2.23	2.62	3.02	3.28	3.93	4.78	5.44	6.43	7.22	7.98
02	5-day	1.25	1.50	1.70	1.97	2.26	2.46	3.00	3.71	4.25	5.11	5.81	6.55
02	72-hr	1.15	1.35	1.52	1.77	2.03	2.21	2.62	3.27	3.78	4.57	5.23	5.94
02	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.31	2.98	3.49	4.24	4.88	5.55
02	24-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.09	2.71	3.19	3.87	4.44	5.03
02	18-hr	0.86	1.00	1.09	1.26	1.44	1.56	1.96	2.55	3.00	3.64	4.17	4.73
02	12-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.82	2.36	2.78	3.37	3.86	4.38
02	6-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.57	2.03	2.39	2.90	3.33	3.77
02	3-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.34	1.73	2.04	2.48	2.84	3.22
02	2-hr	0.53	0.61	0.67	0.78	0.88	0.96	1.21	1.57	1.85	2.24	2.58	2.92
02	1-hr	0.43	0.50	0.55	0.63	0.72	0.78	0.98	1.27	1.50	1.82	2.09	2.36
02	30-min	0.34	0.39	0.43	0.49	0.56	0.61	0.77	1.00	1.18	1.43	1.64	1.86
02	15-min	0.25	0.29	0.31	0.36	0.41	0.45	0.56	0.73	0.86	1.04	1.20	1.36
02	10-min	0.19	0.22	0.24	0.28	0.32	0.35	0.44	0.57	0.67	0.81	0.93	1.06
02	5-min	0.11	0.13	0.14	0.16	0.18	0.20	0.25	0.33	0.38	0.46	0.53	0.60
03	10-day	1.63	1.96	2.26	2.66	3.06	3.33	3.99	4.92	5.65	6.66	7.50	8.35
03	5-day	1.29	1.54	1.75	2.02	2.33	2.53	3.10	3.91	4.57	5.46	6.23	7.04
03	72-hr	1.09	1.27	1.44	1.67	1.92	2.09	2.62	3.36	3.96	4.86	5.56	6.35
03	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.34	3.02	3.55	4.31	4.94	5.60
03	24-hr	0.89	1.04	1.13	1.31	1.49	1.62	2.09	2.70	3.21	3.89	4.47	5.08
03	18-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.96	2.54	3.02	3.66	4.20	4.78
03	12-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.82	2.35	2.79	3.38	3.89	4.42
03	6-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.57	2.03	2.41	2.92	3.35	3.81
03	3-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.34	1.73	2.05	2.49	2.86	3.25
03	2-hr	0.52	0.60	0.66	0.76	0.86	0.94	1.21	1.57	1.86	2.26	2.59	2.95
03	1-hr	0.42	0.49	0.53	0.62	0.70	0.76	0.98	1.27	1.51	1.83	2.10	2.39
03	30-min	0.33	0.38	0.42	0.49	0.55	0.60	0.77	1.00	1.19	1.44	1.65	1.88
03	15-min	0.24	0.28	0.31	0.36	0.40	0.44	0.56	0.73	0.87	1.05	1.21	1.37
03	10-min	0.19	0.22	0.24	0.28	0.31	0.34	0.44	0.57	0.67	0.82	0.94	1.07
03	5-min	0.10	0.12	0.13	0.15	0.17	0.19	0.25	0.32	0.39	0.47	0.54	0.61

Table 5. Continued

Rainfall inches for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.77	4.56	5.22	6.10	6.85	7.60
04	5-day	1.26	1.51	1.70	1.98	2.27	2.47	2.99	3.68	4.23	4.97	5.58	6.23
04	72-hr	1.12	1.31	1.48	1.72	1.98	2.15	2.63	3.27	3.75	4.45	5.00	5.60
04	48-hr	1.00	1.17	1.30	1.51	1.74	1.89	2.32	2.88	3.33	3.93	4.43	4.95
04	24-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.11	2.62	3.04	3.60	4.06	4.53
04	18-hr	0.89	1.03	1.13	1.30	1.48	1.61	1.98	2.46	2.86	3.38	3.82	4.26
04	12-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.84	2.28	2.64	3.13	3.53	3.94
04	6-hr	0.70	0.82	0.90	1.04	1.18	1.28	1.58	1.96	2.28	2.70	3.05	3.40
04	3-hr	0.60	0.70	0.76	0.88	1.00	1.09	1.35	1.68	1.95	2.30	2.60	2.90
04	2-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.22	1.52	1.76	2.09	2.35	2.63
04	1-hr	0.44	0.51	0.56	0.65	0.74	0.80	0.99	1.23	1.43	1.69	1.91	2.13
04	30-min	0.35	0.40	0.44	0.51	0.58	0.63	0.78	0.97	1.12	1.33	1.50	1.68
04	15-min	0.25	0.29	0.32	0.37	0.42	0.46	0.57	0.71	0.82	0.97	1.10	1.22
04	10-min	0.20	0.23	0.25	0.29	0.33	0.36	0.44	0.55	0.64	0.76	0.85	0.95
04	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.25	0.31	0.36	0.43	0.49	0.54
05	10-day	1.64	1.97	2.27	2.67	3.07	3.34	4.14	5.28	6.21	7.59	8.75	10.02
05	5-day	1.38	1.65	1.86	2.16	2.48	2.70	3.36	4.30	5.07	6.25	7.26	8.36
05	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.88	3.74	4.46	5.45	6.31	7.26
05	48-hr	1.04	1.22	1.36	1.58	1.81	1.97	2.53	3.34	4.01	4.97	5.81	6.73
05	24-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.28	3.00	3.60	4.48	5.24	6.07
05	18-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.14	2.82	3.38	4.21	4.93	5.71
05	12-hr	0.85	0.99	1.08	1.25	1.42	1.54	1.98	2.61	3.13	3.90	4.56	5.28
05	6-hr	0.73	0.85	0.93	1.08	1.22	1.33	1.71	2.25	2.70	3.36	3.93	4.55
05	3-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.46	1.92	2.30	2.87	3.35	3.88
05	2-hr	0.57	0.66	0.72	0.83	0.95	1.03	1.32	1.74	2.09	2.60	3.04	3.52
05	1-hr	0.46	0.53	0.58	0.67	0.76	0.83	1.07	1.41	1.69	2.11	2.46	2.85
05	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.84	1.11	1.33	1.66	1.94	2.25
05	15-min	0.26	0.31	0.34	0.39	0.44	0.48	0.62	0.81	0.97	1.21	1.41	1.64
05	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.48	0.63	0.76	0.94	1.10	1.27
05	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.27	0.36	0.43	0.54	0.63	0.73
06	10-day	1.76	2.12	2.44	2.87	3.30	3.59	4.31	5.36	6.21	7.46	8.51	9.54
06	5-day	1.44	1.72	1.95	2.26	2.59	2.82	3.40	4.22	4.89	6.11	7.17	8.31
06	72-hr	1.23	1.45	1.64	1.90	2.18	2.37	2.88	3.62	4.24	5.27	6.17	7.18
06	48-hr	1.09	1.28	1.42	1.65	1.90	2.06	2.51	3.17	3.71	4.59	5.35	6.20
06	24-hr	1.02	1.19	1.30	1.51	1.71	1.86	2.27	2.85	3.34	4.15	4.84	5.62
06	18-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.13	2.68	3.14	3.90	4.55	5.28
06	12-hr	0.89	1.04	1.13	1.31	1.49	1.62	1.97	2.48	2.91	3.61	4.21	4.89
06	6-hr	0.76	0.89	0.97	1.13	1.28	1.39	1.70	2.14	2.50	3.11	3.63	4.22
06	3-hr	0.65	0.76	0.83	0.96	1.09	1.19	1.45	1.82	2.14	2.66	3.10	3.60
06	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.32	1.65	1.94	2.41	2.81	3.26
06	1-hr	0.48	0.56	0.61	0.70	0.80	0.87	1.07	1.34	1.57	1.95	2.27	2.64
06	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.05	1.24	1.54	1.79	2.08
06	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.77	0.90	1.12	1.31	1.52
06	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.48	0.60	0.70	0.87	1.02	1.18
06	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.34	0.40	0.50	0.58	0.67

Table 5. Continued

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
07	10-day	1.57	1.89	2.18	2.56	2.94	3.20	3.88	4.75	5.39	6.21	6.83	7.48
07	5-day	1.22	1.46	1.66	1.92	2.21	2.40	2.96	3.68	4.23	4.99	5.61	6.26
07	72-hr	1.11	1.30	1.47	1.70	1.96	2.13	2.62	3.28	3.78	4.49	5.05	5.66
07	48-hr	1.02	1.20	1.33	1.54	1.78	1.93	2.37	2.97	3.41	4.03	4.52	5.04
07	24-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.14	2.65	3.05	3.56	3.97	4.40
07	18-hr	0.90	1.05	1.15	1.33	1.51	1.64	2.01	2.49	2.87	3.35	3.73	4.14
07	12-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.86	2.31	2.65	3.10	3.45	3.83
07	6-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.61	1.99	2.29	2.67	2.98	3.30
07	3-hr	0.62	0.72	0.78	0.91	1.03	1.12	1.37	1.70	1.95	2.28	2.54	2.82
07	2-hr	0.56	0.65	0.71	0.82	0.93	1.01	1.24	1.54	1.77	2.06	2.30	2.55
07	1-hr	0.45	0.52	0.57	0.66	0.75	0.82	1.01	1.25	1.43	1.67	1.87	2.07
07	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.79	0.98	1.13	1.32	1.47	1.63
07	15-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.72	0.82	0.96	1.07	1.19
07	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.45	0.56	0.64	0.75	0.83	0.92
07	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.26	0.32	0.37	0.43	0.48	0.53
08	10-day	1.81	2.18	2.51	2.95	3.39	3.69	4.33	5.23	5.96	7.39	8.63	10.03
08	5-day	1.48	1.77	2.00	2.32	2.67	2.90	3.45	4.27	4.95	6.16	7.28	8.46
08	72-hr	1.29	1.52	1.72	1.99	2.29	2.49	3.00	3.75	4.41	5.50	6.45	7.51
08	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.63	3.32	3.91	4.93	5.83	6.82
08	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.37	3.00	3.52	4.45	5.27	6.15
08	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.23	2.82	3.31	4.18	4.95	5.78
08	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.06	2.61	3.06	3.87	4.58	5.35
08	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.78	2.25	2.64	3.34	3.95	4.61
08	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.52	1.92	2.25	2.85	3.37	3.94
08	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.37	1.74	2.04	2.58	3.06	3.57
08	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.11	1.41	1.65	2.09	2.48	2.89
08	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.30	1.65	1.95	2.28
08	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.64	0.81	0.95	1.20	1.42	1.66
08	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.74	0.93	1.11	1.29
08	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.28	0.36	0.42	0.53	0.63	0.74
09	10-day	1.77	2.13	2.45	2.89	3.32	3.61	4.26	5.15	5.83	6.81	7.60	8.40
09	5-day	1.43	1.71	1.93	2.24	2.58	2.80	3.36	4.10	4.71	5.57	6.27	6.99
09	72-hr	1.27	1.49	1.68	1.95	2.24	2.44	2.93	3.59	4.16	4.95	5.59	6.28
09	48-hr	1.17	1.37	1.52	1.77	2.03	2.21	2.66	3.28	3.79	4.50	5.10	5.73
09	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.42	2.98	3.43	4.09	4.63	5.20
09	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.27	2.80	3.22	3.84	4.35	4.89
09	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.11	2.59	2.98	3.56	4.03	4.52
09	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.82	2.24	2.57	3.07	3.47	3.90
09	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.55	1.91	2.20	2.62	2.96	3.33
09	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.40	1.73	1.99	2.37	2.69	3.02
09	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.14	1.40	1.61	1.92	2.18	2.44
09	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.90	1.10	1.27	1.51	1.71	1.92
09	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.65	0.80	0.93	1.10	1.25	1.40
09	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.51	0.63	0.72	0.86	0.97	1.09
09	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.36	0.41	0.49	0.56	0.62

Table 5. Concluded

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
10	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.82	4.64	5.27	6.11	6.79	7.51
10	5-day	1.28	1.53	1.73	2.01	2.31	2.51	3.05	3.68	4.16	4.78	5.26	5.74
10	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.74	3.34	3.76	4.31	4.74	5.16
10	48-hr	1.08	1.26	1.41	1.63	1.88	2.04	2.48	3.04	3.44	3.96	4.36	4.78
10	24-hr	1.03	1.20	1.31	1.51	1.72	1.87	2.26	2.75	3.13	3.60	3.98	4.36
10	18-hr	0.97	1.13	1.23	1.43	1.62	1.76	2.12	2.59	2.94	3.38	3.74	4.10
10	12-hr	0.90	1.04	1.14	1.32	1.50	1.63	1.97	2.39	2.72	3.13	3.46	3.79
10	6-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.69	2.06	2.35	2.70	2.99	3.27
10	3-hr	0.66	0.77	0.84	0.97	1.10	1.20	1.45	1.76	2.00	2.30	2.55	2.79
10	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.31	1.59	1.82	2.09	2.31	2.53
10	1-hr	0.48	0.56	0.62	0.71	0.81	0.88	1.06	1.29	1.47	1.69	1.87	2.05
10	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.02	1.16	1.33	1.47	1.61
10	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.74	0.85	0.97	1.07	1.18
10	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.47	0.58	0.66	0.76	0.84	0.92
10	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.33	0.38	0.43	0.48	0.52

Table 6. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Minnesota

Sectional code (see figure 1 on page 4)

01 - Northwest
02 - North Central
03 - Northeast
04 - West Central
05 - Central
06 - East Central
07 - Southwest
08 - South Central
09 - Southeast

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.53	1.84	2.12	2.50	2.87	3.12	3.83	4.89	5.80	6.97	7.88	8.75
01	5-day	1.27	1.53	1.73	2.00	2.30	2.50	3.11	4.11	5.01	6.12	7.05	7.94
01	72-hr	1.11	1.30	1.47	1.70	1.96	2.13	2.70	3.61	4.43	5.55	6.41	7.27
01	48-hr	1.03	1.20	1.34	1.55	1.78	1.94	2.42	3.25	4.05	5.13	5.91	6.70
01	24-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.16	2.94	3.69	4.57	5.41	6.11
01	18-hr	0.89	1.03	1.13	1.30	1.48	1.61	2.03	2.76	3.47	4.30	5.09	5.74
01	12-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.88	2.56	3.21	3.98	4.71	5.32
01	6-hr	0.70	0.82	0.90	1.04	1.18	1.28	1.62	2.20	2.77	3.43	4.06	4.58
01	3-hr	0.60	0.70	0.76	0.88	1.00	1.09	1.38	1.88	2.36	2.92	3.46	3.91
01	2-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.25	1.71	2.14	2.65	3.14	3.54
01	1-hr	0.44	0.51	0.56	0.65	0.74	0.80	1.02	1.38	1.73	2.15	2.54	2.87
01	30-min	0.35	0.40	0.44	0.51	0.58	0.63	0.80	1.09	1.37	1.69	2.00	2.26
01	15-mín	0.25	0.29	0.32	0.37	0.42	0.46	0.58	0.79	1.00	1.23	1.46	1.65
01	10-min	0.20	0.23	0.25	0.29	0.33	0.36	0.45	0.62	0.77	0.96	1.14	1.28
01	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.26	0.35	0.44	0.55	0.65	0.73
02	10-day	1.67	2.01	2.32	2.73	3.14	3.41	4.15	5.08	5.81	6.84	7.68	8.52
02	5-day	1.35	1.61	1.82	2.11	2.43	2.64	3.27	4.14	4.84	5.86	6.71	7.57
02	72-hr	1.24	1.45	1.64	1.90	2.19	2.38	2.90	3.64	4.31	5.28	6.10	6.96
02	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.68	3.38	3.97	4.86	5.62	6.45
02	24-hr	1.07	1.24	1.36	1.57	1.78	1.94	2.41	3.06	3.58	4.39	5.10	5.88
02	18-hr	1.00	1.16	1.27	1.47	1.67	1.82	2.27	2.88	3.37	4.13	4.79	5.53
02	12-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.10	2.66	3.11	3.82	4.44	5.12
02	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.81	2.30	2.68	3.29	3.82	4.41
02	3-hr	0.68	0.79	0.87	1.00	1.14	1.24	1.54	1.96	2.29	2.81	3.26	3.76
02	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.40	1.77	2.08	2.55	2.96	3.41
02	1-hr	0.50	0.58	0.64	0.74	0.84	0.91	1.13	1.44	1.68	2.06	2.40	2.76
02	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.89	1.13	1.32	1.62	1.89	2.18
02	15-min	0.29	0.33	0.36	0.42	0.48	0.52	0.65	0.83	0.97	1.19	1.38	1.59
02	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.51	0.64	0.75	0.92	1.07	1.23
02	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.29	0.37	0.43	0.53	0.61	0.71
03	10-day	1.66	1.99	2.30	2.70	3.11	3.38	4.04	4.82	5.41	6.28	6.96	7.58
03	5-day	1.36	1.62	1.84	2.13	2.45	2.66	3.24	4.05	4.69	5.54	6.16	6.57
03	72-hr	1.19	1.39	1.57	1.82	2.10	2.28	2.83	3.57	4.16	4.96	5.53	6.09
03	48-hr	1.09	1.28	1.42	1.65	1.90	2.06	2.54	3.21	3.74	4.49	5.06	5.63
03	24-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.31	2.88	3.36	4.08	4.64	5.20
03	18-hr	0.99	1.15	1.26	1.46	1.66	1.80	2.17	2.71	3.16	3.84	4.36	4.89
03	12-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.01	2.51	2.92	3.55	4.04	4.52
03	6-hr	0.79	0.92	1.00	1.16	1.32	1.43	1.73	2.16	2.52	3.06	3.48	3.90
03	3-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.48	1.84	2.15	2.61	2.97	3.33
03	2-hr	0.61	0.71	0.78	0.90	1.02	1.11	1.34	1.67	1.95	2.37	2.69	3.02
03	1-hr	0.50	0.58	0.63	0.73	0.83	0.90	1.09	1.35	1.58	1.92	2.18	2.44
03	30-min	0.39	0.45	0.50	0.58	0.65	0.71	0.85	1.07	1.24	1.51	1.72	1.92
03	15-min	0.29	0.33	0.36	0.42	0.48	0.52	0.62	0.78	0.91	1.10	1.25	1.40
03	10-min	0.22	0.26	0.28	0.32	0.37	0.40	0.49	0.60	0.71	0.86	0.97	1.09
03	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.28	0.35	0.40	0.49	0.56	0.62

Table 6. Continued

		Rainfall (inches) for given recurrence interval											
Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	1.70	2.04	2.35	2.77	3.18	3.46	4.18	5.21	6.08	7.25	8.17	9.07
04	5-day	1.45	1.73	1.96	2.27	2.61	2.84	3.38	4.20	4.92	6.03	7.05	8.20
04	72-hr	1.27	1.49	1.69	1.96	2.25	2.45	2.93	3.62	4.26	5.22	6.11	7.06
04	48-hr	1.18	1.38	1.53	1.78	2.04	2.22	2.65	3.28	3.83	4.64	5.38	6.23
04	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.40	2.95	3.42	4.19	4.83	5.57
04	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.26	2.77	3.21	3.94	4.54	5.24
04	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.09	2.57	2.98	3.65	4.20	4.85
04	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.80	2.21	2.57	3.14	3.62	4.18
04	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.54	1.89	2.19	2.68	3.09	3.56
04	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.39	1.71	1.98	2.43	2.80	3.23
04	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.13	1.39	1.61	1.97	2.27	2.62
04	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.89	1.09	1.27	1.55	1.79	2.06
04	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.65	0.80	0.92	1.13	1.30	1.50
04	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.50	0.62	0.72	0.88	1.01	1.17
04	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.35	0.41	0.50	0.58	0.67
05	10-day	1.76	2.12	2.44	2.87	3.30	3.59	4.19	5.43	6.24	7.34	8.25	9.23
05	5-day	1.45	1.74	1.97	2.28	2.62	2.85	3.51	4.43	5.18	6.21	7.09	8.02
05	72-hr	1.31	1.53	1.73	2.01	2.31	2.51	3.05	3.81	4.45	5.40	6.22	7.10
05	48-hr	1.22	1.43	1.59	1.84	2.12	2.30	2.78	3.48	4.05	4.88	5.59	6.37
05	24-hr	1.15	1.34	1.47	1.70	1.93	2.10	2.54	3.17	3.68	4.43	5.03	5.72
05	18-hr	1.08	1.26	1.38	1.60	1.81	1.97	2.39	2.98	3.46	4.16	4.73	5.38
05	12-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.21	2.76	3.20	3.85	4.38	4.98
05	6-hr	0.86	1.00	1.10	1.27	1.44	1.57	1.90	2.38	2.76	3.32	3.77	4.29
05	3-hr	0.74	0.86	0.94	1.09	1.23	1.34	1.63	2.03	2.36	2.84	3.22	3.66
05	2-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.47	1.84	2.13	2.57	2.92	3.32
05	1-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.19	1.49	1.73	2.08	2.36	2.69
05	30-min	0.43	0.50	0.55	0.63	0.72	0.78	0.94	1.17	1.36	1.64	1.86	2.12
05	15-min	0.31	0.36	0.40	0.46	0.52	0.57	0.69	0.86	0.99	1.20	1.36	1.54
05	10-min	0.24	0.28	0.31	0.36	0.40	0.44	0.53	0.67	0.77	0.93	1.06	1.20
05	5-min	0.14	0.16	0.17	0.20	0.23	0.25	0.30	0.38	0.44	0.53	0.60	0.69
06	10-day	1.83	2.21	2.54	2.99	3.44	3.74	4.53	5.51	6.23	7.16	7.90	8.68
06	5-day	1.55	1.85	2.09	2.42	2.79	3.03	3.66	4.50	5.15	6.11	6.86	7.69
06	72-hr	1.37	1.61	1.82	2.11	2.43	2.64	3.16	3.85	4.41	5.19	5.85	6.59
06	48-hr	1.28	1.50	1.67	1.94	2.23	2.42	2.89	3.53	4.03	4.74	5.36	6.02
06	24-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.65	3.23	3.69	4.35	4.88	5.46
06	18-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.49	3.04	3.47	4.09	4.59	5.13
06	12-hr	1.06	1.24	1.35	1.56	1.78	1.93	2.31	2.81	3.21	3.78	4.25	4.75
06	6-hr	0.91	1.06	1.16	1.34	1.53	1.66	1.99	2.42	2.77	3.26	3.66	4.10
06	3-hr	0.78	0.91	0.99	1.15	1.31	1.42	1.70	2.07	2.36	2.78	3.12	3.49
06	2-hr	0.71	0.83	0.90	1.04	1.19	1.29	1.54	1.87	2.14	2.52	2.83	3.17
06	1-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.25	1.52	1.73	2.04	2.29	2.57
06	30-min	0.45	0.52	0.57	0.66	0.75	0.82	0.98	1.20	1.37	1.61	1.81	2.02
06	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.72	0.87	1.00	1.17	1.32	1.47
06	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.56	0.68	0.77	0.91	1.02	1.15
06	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.32	0.39	0.44	0.52	0.59	0.66

Table 6. Continued

		Rainfall (inches) for given recurrence interval											
Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	1.88	2.27	2.61	3.07	3.53	3.84	4.51	5.45	6.16	7.25	8.20	9.13
07	5-day	1.59	1.90	2.15	2.49	2.86	3.11	3.72	4.53	5.18	6.17	7.03	8.02
07	72-hr	1.44	1.68	1.90	2.21	2.54	2.76	3.24	3.96	4.57	5.50	5.93	7.13
07	48-hr	1.30	1.52	1.69	1.96	2.25	2.45	2.92	3.60	4.18	5.04	5.74	6.48
07	24-hr	1.24	1.45	1.58	1.83	2.08	2.26	2.69	3.32	3.81	4.55	5.20	5.94
07	18-hr	1.17	1.36	1.48	1.72	1.95	2.12	2.53	3.12	3.58	4.28	4.89	5.58
07	12-hr	1.08	1.26	1.38	1.60	1.81	1.97	2.34	2.89	3.31	3.96	4.52	5.17
07	6-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.02	2.49	2.86	3.41	3.90	4.45
07	3-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.72	2.12	2.44	2.91	3.33	3.80
07	2-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.56	1.93	2.21	2.64	3.02	3.45
07	1-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.26	1.56	1.79	2.14	2.44	2.79
07	30-min	0.46	0.54	0.59	0.68	0.77	0.84	1.00	1.23	1.41	1.68	1.92	2.20
07	15-min	0.34	0.39	0.43	0.49	0.56	0.61	0.73	0.90	1.03	1.23	1.40	1.60
07	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.56	0.70	0.80	0.96	1.09	1.25
07	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.32	0.40	0.46	0.55	0.62	0.71
08	10-day	1.86	2.24	2.58	3.04	3.50	3.80	4.59	5.67	6.52	7.60	8.47	9.16
08	5-day	1.55	1.85	2.09	2.42	2.79	3.03	3.71	4.66	5.43	6.38	7.72	8.43
08	72-hr	1.37	1.60	1.81	2.10	2.42	2.63	3.22	4.06	4.77	5.67	6.43	7.08
08	48-hr	1.27	1.49	1.66	1.92	2.21	2.40	2.93	3.68	4.30	5.14	5.82	6.38
08	24-hr	1.20	1.40	1.53	1.77	2.01	2.19	2.68	3.38	3.95	4.66	5.28	5.85
08	18-hr	1.13	1.32	1.44	1.67	1.90	2.06	2.52	3.18	3.71	4.38	4.96	5.50
08	12-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.33	2.94	3.44	4.05	4.59	5.09
08	6-hr	0.90	1.05	1.15	1.33	1.51	1.64	2.01	2.54	2.96	3.49	3.96	4.39
08	3-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.72	2.16	2.53	2.98	3.38	3.74
08	2-hr	0.70	0.81	0.89	1.03	1.17	1.27	1.55	1.96	2.29	2.70	3.06	3.39
08	1-hr	0.57	0.66	0.72	0.83	0.95	1.03	1.26	1.59	1.86	2.19	2.48	2.75
08	30-min	0.45	0.52	0.57	0.66	0.75	0.81	0.99	1.25	1.46	1.72	1.95	2.16
08	15-min	0.32	0.38	0.41	0.48	0.54	0.59	0.72	0.91	1.07	1.26	1.43	1.58
08	10-min	0.25	0.29	0.32	0.37	0.42	0.46	0.56	0.71	0.83	0.98	1.11	1.23
08	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.41	0.47	0.56	0.63	0.70
09	10-day	1.89	2.28	2.62	3.09	3.55	3.86	4.81	5.93	6.72	7.70	8.42	9.10
09	5-day	1.63	1.95	2.20	2.55	2.93	3.19	3.95	4.89	5.55	6.38	7.01	7.63
09	72-hr	1.42	1.67	1.88	2.18	2.51	2.73	3.48	4.35	4.97	5.74	6.30	6.83
09	48-hr	1.33	1.56	1.73	2.01	2.31	2.51	3.15	3.94	4.52	5.24	5.81	6.43
09	24-hr	1.24	1.45	1.58	1.83	2.08	2.26	2.84	3.55	4.08	4.75	5.25	5.76
09	18-hr	1.17	1.36	1.48	1.72	1.95	2.12	2.67	3.34	3.84	4.47	4.93	5.41
09	12-hr	1.08	1.26	1.38	1.60	1.81	1.97	2.47	3.09	3.55	4.13	4.57	5.01
09	6-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.13	2.66	3.06	3.56	3.94	4.32
09	3-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.82	2.27	2.61	3.04	3.36	3.69
09	2-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.65	2.06	2.37	2.75	3.04	3.34
09	1-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.33	1.67	1.92	2.23	2.47	2.71
09	30-min	0.46	0.54	0.59	0.68	0.77	0.84	1.05	1.31	1.51	1.76	1.94	2.13
09	15-min	0.34	0.39	0.43	0.49	0.56	0.61	0.77	0.96	1.10	1.28	1.42	1.56
09	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.60	0.75	0.86	1.00	1.10	1.21
09	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.34	0.43	0.49	0.57	0.63	0.69

Table 7. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Missouri

Sectional code (see figure 1 on page 4)

01 - Northwest Prairie *04 - West Ozarks*
02 - Northeast Prairie *05 - East Ozarks*
03 - West Central Plains *06 - Bootheel*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	2.18	2.62	3.02	3.55	4.08	4.44	5.60	7.01	8.01	9.27	10.20	11.25
01	5-day	1.82	2.17	2.46	2.85	3.28	3.56	4.50	5.69	6.60	7.78	8.71	9.71
01	72-hr	1.62	1.90	2.15	2.50	2.87	3.12	3.99	5.11	5.98	7.07	7.92	8.82
01	48-hr	1.48	1.73	1.93	2.23	2.57	2.79	3.59	4.63	5.43	6.43	7.17	7.99
01	24-hr	1.39	1.62	1.77	2.05	2.33	2.53	3.27	4.25	4.98	5.89	6.58	7.30
01	18-hr	1.31	1.52	1.67	1.93	2.19	2.38	3.07	3.99	4.68	5.54	6.19	6.86
01	12-hr	1.21	1.41	1.54	1.78	2.02	2.20	2.84	3.70	4.33	5.12	5.72	6.35
01	6-hr	1.04	1.22	1.33	1.54	1.75	1.90	2.45	3.19	3.74	4.42	4.93	5.48
01	3-hr	0.89	1.04	1.13	1.31	1.49	1.62	2.09	2.72	3.19	3.77	4.21	4.67
01	2-hr	0.81	0.94	1.03	1.19	1.35	1.47	1.90	2.46	2.89	3.42	3.82	4.23
01	1-hr	0.65	0.76	0.83	0.96	1.09	1.19	1.54	2.00	2.34	2.77	3.09	3.43
01	30-min	0.52	0.60	0.66	0.76	0.86	0.94	1.21	1.57	1.84	2.18	2.43	2.70
01	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.88	1.15	1.34	1.59	1.78	1.97
01	10-min	0.29	0.34	0.37	0.43	0.49	0.53	0.69	0.89	1.05	1.24	1.38	1.53
01	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.39	0.51	0.60	0.71	0.79	0.88
02	10-day	2.21	2.66	3.07	3.61	4.15	4.51	5.41	6.64	7.62	8.90	9.92	11.02
02	5-day	1.79	2.14	2.42	2.81	3.23	3.51	4.27	5.37	6.27	7.53	8.51	9.57
02	72-hr	1.63	1.91	2.16	2.50	2.88	3.13	3.82	4.81	5.66	6.81	7.74	8.76
02	48-hr	1.48	1.74	1.93	2.24	2.58	2.80	3.44	4.33	5.09	6.14	6.99	7.91
02	24-hr	1.38	1.60	1.75	2.03	2.30	2.50	3.10	3.94	4.64	5.60	6.38	7.21
02	18-hr	1.29	1.50	1.64	1.90	2.16	2.35	2.91	3.70	4.36	5.26	6.00	6.78
02	12-hr	1.19	1.39	1.52	1.76	2.00	2.17	2.70	3.43	4.04	4.87	5.55	6.27
02	6-hr	1.03	1.20	1.32	1.52	1.73	1.88	2.32	2.95	3.48	4.20	4.78	5.41
02	3-hr	0.88	1.02	1.12	1.30	1.47	1.60	1.98	2.52	2.97	3.58	4.08	4.61
02	2-hr	0.80	0.93	1.01	1.17	1.33	1.45	1.80	2.29	2.69	3.25	3.70	4.18
02	1-hr	0.64	0.75	0.82	0.95	1.08	1.17	1.46	1.85	2.18	2.63	3.00	3.39
02	30-min	0.51	0.60	0.65	0.75	0.86	0.93	1.15	1.46	1.72	2.07	2.36	2.67
02	15-min	0.37	0.44	0.48	0.55	0.63	0.68	0.84	1.06	1.25	1.51	1.72	1.95
02	10-min	0.29	0.33	0.36	0.42	0.48	0.52	0.65	0.83	0.97	1.18	1.34	1.51
02	5-min	0.17	0.19	0.21	0.24	0.28	0.30	0.37	0.47	0.56	0.67	0.77	0.87
03	10-day	2.38	2.87	3.30	3.89	4.47	4.86	6.10	7.59	8.62	9.88	10.87	11.72
03	5-day	2.04	2.44	2.76	3.20	3.68	4.00	4.92	6.12	7.06	8.33	9.31	10.36
03	72-hr	1.79	2.10	2.38	2.76	3.17	3.45	4.25	5.33	6.20	7.39	8.32	9.30
03	48-hr	1.66	1.94	2.16	2.50	2.88	3.13	3.90	4.92	5.71	6.78	7.66	8.57
03	24-hr	1.55	1.80	1.97	2.28	2.59	2.81	3.50	4.41	5.16	6.16	6.93	7.74
03	18-hr	1.45	1.69	1.85	2.14	2.43	2.64	3.29	4.15	4.85	5.79	6.51	7.28
03	12-hr	1.34	1.56	1.71	1.98	2.24	2.44	3.05	3.84	4.49	5.36	6.03	6.73
03	6-hr	1.16	1.35	1.48	1.71	1.94	2.11	2.62	3.31	3.87	4.62	5.20	5.80
03	3-hr	0.99	1.15	1.26	1.46	1.66	1.80	2.24	2.82	3.30	3.94	4.44	4.95
03	2-hr	0.90	1.04	1.14	1.32	1.50	1.63	2.03	2.56	2.99	3.57	4.02	4.49
03	1-hr	0.73	0.84	0.92	1.07	1.21	1.32	1.64	2.07	2.43	2.90	3.26	3.64
03	30-min	0.57	0.67	0.73	0.84	0.96	1.04	1.30	1.63	1.91	2.28	2.56	2.86
03	15-min	0.42	0.49	0.53	0.62	0.70	0.76	0.95	1.19	1.39	1.66	1.87	2.09
03	10-min	0.32	0.38	0.41	0.48	0.54	0.59	0.73	0.93	1.08	1.29	1.46	1.63
03	5-min	0.19	0.22	0.24	0.28	0.31	0.34	0.42	0.53	0.62	0.74	0.83	0.93

Table 7. Concluded

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
04	10-day	2.63	3.17	3.65	4.30	4.94	5.37	6.59	8.05	9.13	10.49	11.52	12.61
04	5-day	2.12	2.54	2.87	3.33	3.83	4.16	5.21	6.50	7.45	8.70	9.68	10.77
04	72-hr	1.91	2.24	2.54	2.94	3.39	3.68	4.62	5.81	6.69	7.90	8.85	9.85
04	48-hr	1.75	2.05	2.28	2.64	3.04	3.30	4.14	5.25	6.07	7.17	8.05	8.97
04	24-hr	1.65	1.92	2.10	2.43	2.76	3.00	3.77	4.79	5.55	6.56	7.34	8.18
04	18-hr	1.55	1.80	1.97	2.28	2.59	2.82	3.54	4.50	5.22	6.17	6.90	7.69
04	12-hr	1.44	1.67	1.83	2.11	2.40	2.61	3.28	4.17	4.83	5.71	6.39	7.12
04	6-hr	1.24	1.44	1.57	1.82	2.07	2.25	2.83	3.59	4.16	4.92	5.51	6.14
04	3-hr	1.06	1.23	1.34	1.56	1.77	1.92	2.41	3.07	3.55	4.20	4.70	5.24
04	2-hr	0.96	1.11	1.22	1.41	1.60	1.74	2.19	2.78	3.22	3.80	4.26	4.74
04	1-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.77	2.25	2.61	3.08	3.45	3.84
04	30-min	0.61	0.71	0.78	0.90	1.02	1.11	1.39	1.77	2.05	2.43	2.72	3.03
04	15-min	0.45	0.52	0.57	0.66	0.75	0.81	1.02	1.29	1.50	1.77	1.98	2.21
04	10-min	0.35	0.40	0.44	0.51	0.58	0.63	0.79	1.01	1.17	1.38	1.54	1.72
04	5-min	0.20	0.23	0.25	0.29	0.33	0.36	0.45	0.57	0.67	0.79	0.88	0.98
05	10-day	2.30	2.77	3.20	3.76	4.32	4.70	5.96	7.36	8.29	9.48	10.34	11.31
05	5-day	1.92	2.30	2.60	3.02	3.47	3.77	4.78	5.99	6.86	8.02	8.97	9.93
05	72-hr	1.75	2.05	2.32	2.69	3.09	3.36	4.24	5.31	6.10	7.15	7.99	8.90
05	48-hr	1.61	1.88	2.09	2.42	2.79	3.03	3.82	4.78	5.50	6.47	7.24	8.06
05	24-hr	1.53	1.79	1.95	2.26	2.57	2.79	3.51	4.39	5.03	5.94	6.64	7.42
05	18-hr	1.44	1.68	1.83	2.12	2.41	2.62	3.30	4.13	4.73	5.58	6.24	6.97
05	12-hr	1.34	1.56	1.70	1.97	2.24	2.43	3.05	3.82	4.38	5.17	5.78	6.46
05	6-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.63	3.29	3.77	4.45	4.98	5.57
05	3-hr	0.98	1.15	1.25	1.45	1.65	1.79	2.25	2.81	3.22	3.80	4.25	4.75
05	2-hr	0.89	1.04	1.13	1.31	1.49	1.62	2.04	2.55	2.92	3.45	3.85	4.30
05	1-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.65	2.06	2.36	2.79	3.12	3.49
05	30-min	0.57	0.66	0.72	0.83	0.95	1.03	1.30	1.62	1.86	2.20	2.46	2.75
05	15-min	0.41	0.48	0.52	0.61	0.69	0.75	0.95	1.19	1.36	1.60	1.79	2.00
05	10-min	0.32	0.38	0.41	0.48	0.54	0.59	0.74	0.92	1.06	1.25	1.39	1.56
05	5-min	0.18	0.21	0.23	0.27	0.30	0.33	0.42	0.53	0.60	0.71	0.80	0.89
06	10-day	2.45	2.94	3.39	3.99	4.59	4.99	6.43	7.99	9.01	10.25	11.15	12.07
06	5-day	2.09	2.50	2.83	3.28	3.77	4.10	5.19	6.46	7.31	8.39	9.20	10.04
06	72-hr	1.91	2.24	2.53	2.94	3.38	3.67	4.67	5.81	6.60	7.58	8.35	9.12
06	48-hr	1.74	2.03	2.26	2.62	3.02	3.28	4.14	5.13	5.84	6.75	7.47	8.21
06	24-hr	1.64	1.91	2.09	2.42	2.75	2.99	3.74	4.65	5.29	6.16	6.83	7.51
06	18-hr	1.55	1.80	1.97	2.28	2.59	2.81	3.52	4.37	4.97	5.79	6.42	7.06
06	12-hr	1.43	1.66	1.82	2.11	2.39	2.60	3.25	4.05	4.60	5.36	5.94	6.53
06	6-hr	1.23	1.43	1.57	1.81	2.06	2.24	2.81	3.49	3.97	4.62	5.12	5.63
06	3-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.39	2.98	3.39	3.94	4.37	4.81
06	2-hr	0.95	1.11	1.21	1.40	1.59	1.73	2.17	2.70	3.07	3.57	3.96	4.36
06	1-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.76	2.19	2.49	2.90	3.21	3.53
06	30-min	0.61	0.71	0.78	0.90	1.02	1.11	1.38	1.72	1.96	2.28	2.53	2.78
06	15-min	0.45	0.52	0.57	0.66	0.75	0.81	1.01	1.26	1.43	1.66	1.84	2.03
06	10-min	0.35	0.40	0.44	0.51	0.58	0.63	0.79	0.98	1.11	1.29	1.43	1.58
06	5-min	0.20	0.23	0.25	0.29	0.33	0.36	0.45	0.56	0.63	0.74	0.82	0.90

Table 8. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Ohio

Sectional code (see figure 1 on page 4)

01 – Northwest	*06 -Central Hills*
02 - North Central	*07 - Northeast Hills*
03 – Northeast	*08 - Southwest*
04 - West Central	*09 - South Central*
05 – Central	*10 - Southeast*

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.69	2.04	2.35	2.76	3.17	3.45	4.22	5.17	5.89	6.83	7.56	8.31
01	5-day	1.42	1.70	1.93	2.23	2.57	2.79	3.43	4.29	4.92	5.81	6.51	7.26
01	72-hr	1.27	1.49	1.69	1.96	2.25	2.45	3.05	3.77	4.33	5.17	5.89	6.71
01	48-hr	1.17	1.36	1.52	1.76	2.02	2.20	2.74	3.43	3.96	4.74	5.40	6.14
01	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.52	3.18	3.70	4.43	5.05	5.73
01	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.37	2.99	3.48	4.16	4.75	5.39
01	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.19	2.77	3.22	3.85	4.39	4.99
01	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.89	2.38	2.78	3.32	3.79	4.30
01	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.61	2.04	2.37	2.84	3.23	3.67
01	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.46	1.84	2.15	2.57	2.93	3.32
01	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.18	1.49	1.74	2.08	2.37	2.69
01	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.93	1.18	1.37	1.64	1.87	2.12
01	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.68	0.86	1.00	1.20	1.36	1.55
01	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.53	0.67	0.78	0.93	1.06	1.20
01	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.30	0.38	0.44	0.53	0.61	0.69
02	10-day	1.63	1.96	2.26	2.66	3.05	3.32	4.19	5.31	6.19	7.40	8.35	9.35
02	5-day	1.35	1.61	1.82	2.11	2.43	2.64	3.33	4.32	5.10	6.21	7.14	8.14
02	72-hr	1.22	1.43	1.61	1.87	2.15	2.34	2.93	3.69	4.34	5.39	6.33	7.39
02	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.67	3.37	3.94	4.86	5.70	6.68
02	24-hr	1.09	1.27	1.39	1.60	1.82	1.98	2.44	3.06	3.55	4.35	5.08	5.92
02	18-hr	1.02	1.19	1.30	1.51	1.71	1.86	2.29	2.88	3.34	4.09	4.78	5.56
02	12-hr	0.95	1.10	1.20	1.39	1.58	1.72	2.12	2.66	3.09	3.78	4.42	5.15
02	6-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.83	2.30	2.66	3.26	3.81	4.44
02	3-hr	0.70	0.81	0.89	1.03	1.17	1.27	1.56	1.96	2.27	2.78	3.25	3.79
02	2-hr	0.63	0.74	0.80	0.93	1.06	1.15	1.42	1.77	2.06	2.52	2.95	3.43
02	1-hr	0.51	0.60	0.65	0.75	0.86	0.93	1.15	1.44	1.67	2.04	2.39	2.78
02	30-min	0.40	0.47	0.51	0.59	0.67	0.73	0.90	1.13	1.31	1.61	1.88	2.19
02	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.66	0.83	0.96	1.17	1.37	1.60
02	10-min	0.23	0.27	0.29	0.34	0.39	0.42	0.51	0.64	0.75	0.91	1.07	1.24
02	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.37	0.43	0.52	0.61	0.71
03	10-day	1.70	2.05	2.36	2.78	3.19	3.47	4.29	5.34	6.17	7.30	8.19	9.14
03	5-day	1.37	1.64	1.86	2.15	2.47	2.69	3.34	4.23	4.95	5.96	6.82	7.74
03	72-hr	1.26	1.48	1.67	1.94	2.23	2.42	2.99	3.72	4.34	5.31	6.15	7.09
03	48-hr	1.18	1.38	1.53	1.78	2.04	2.22	2.75	3.42	3.99	4.87	5.66	6.55
03	24-hr	1.12	1.31	1.43	1.65	1.88	2.04	2.50	3.10	3.60	4.39	5.11	5.89
03	18-hr	1.06	1.23	1.34	1.56	1.77	1.92	2.35	2.91	3.38	4.13	4.80	5.54
03	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.17	2.70	3.13	3.82	4.45	5.12
03	6-hr	0.84	0.98	1.07	1.24	1.41	1.53	1.88	2.32	2.70	3.29	3.83	4.42
03	3-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.60	1.98	2.30	2.81	3.27	3.77
03	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.45	1.80	2.09	2.55	2.96	3.42
03	1-hr	0.53	0.61	0.67	0.78	0.88	0.96	1.17	1.46	1.69	2.06	2.40	2.77
03	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.93	1.15	1.33	1.62	1.89	2.18
03	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.68	0.84	0.97	1.19	1.38	1.59
03	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.52	0.65	0.76	0.92	1.07	1.24
03	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.30	0.37	0.43	0.53	0.61	0.71

Table 8. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	1.85	2.23	2.57	3.02	3.48	3.78	4.59	5.63	6.43	7.48	8.30	9.19
04	5-day	1.54	1.84	2.08	2.41	2.77	3.01	3.65	4.54	5.22	6.17	6.92	7.74
04	72-hr	1.36	1.59	1.80	2.09	2.40	2.61	3.19	3.88	4.46	5.33	6.12	6.97
04	48-hr	1.25	1.46	1.62	1.88	2.16	2.35	2.91	3.58	4.09	4.88	5.56	6.35
04	24-hr	1.18	1.38	1.50	1.74	1.98	2.15	2.69	3.34	3.80	4.46	5.06	5.70
04	18-hr	1.11	1.29	1.41	1.64	1.86	2.02	2.53	3.14	3.57	4.19	4.76	5.36
04	12-hr	1.03	1.20	1.31	1.51	1.72	1.87	2.34	2.91	3.31	3.88	4.40	4.96
04	6-hr	0.89	1.03	1.13	1.30	1.48	1.61	2.02	2.50	2.85	3.35	3.80	4.27
04	3-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.72	2.14	2.43	2.85	3.24	3.65
04	2-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.56	1.94	2.20	2.59	2.93	3.31
04	1-hr	0.56	0.65	0.71	0.82	0.93	1.01	1.26	1.57	1.79	2.10	2.38	2.68
04	30-min	0.44	0.51	0.56	0.65	0.74	0.80	1.00	1.24	1.41	1.65	1.87	2.11
04	15-min	0.32	0.37	0.41	0.47	0.53	0.58	0.73	0.90	1.03	1.20	1.37	1.54
04	10-min	0.25	0.29	0.31	0.36	0.41	0.45	0.56	0.70	0.80	0.94	1.06	1.20
04	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.40	0.46	0.54	0.61	0.68
05	10-day	1.81	2.18	2.51	2.95	3.39	3.69	4.69	5.93	6.78	7.82	8.56	9.27
05	5-day	1.49	1.78	2.01	2.34	2.69	2.92	3.67	4.65	5.39	6.37	7.11	7.89
05	72-hr	1.36	1.59	1.80	2.09	2.40	2.61	3.23	3.99	4.54	5.36	6.09	6.92
05	48-hr	1.27	1.48	1.65	1.91	2.20	2.39	2.97	3.67	4.21	5.02	5.72	6.50
05	24-hr	1.19	1.39	1.52	1.76	2.00	2.17	2.70	3.35	3.86	4.64	5.33	6.06
05	18-hr	1.12	1.31	1.43	1.65	1.88	2.04	2.54	3.15	3.63	4.36	5.01	5.70
05	12-hr	1.04	1.21	1.32	1.53	1.74	1.89	2.35	2.91	3.36	4.04	4.64	5.27
05	6-hr	0.90	1.04	1.14	1.32	1.50	1.63	2.03	2.51	2.89	3.48	4.00	4.55
05	3-hr	0.76	0.89	0.97	1.13	1.28	1.39	1.73	2.14	2.47	2.97	3.41	3.88
05	2-hr	0.69	0.81	0.88	1.02	1.16	1.26	1.57	1.94	2.24	2.69	3.09	3.51
05	1-hr	0.56	0.65	0.71	0.83	0.94	1.02	1.27	1.57	1.81	2.18	2.51	2.85
05	30-min	0.44	0.51	0.56	0.65	0.74	0.80	1.00	1.24	1.43	1.72	1.97	2.24
05	15-min	0.32	0.38	0.41	0.48	0.54	0.59	0.73	0.90	1.04	1.25	1.44	1.64
05	10-min	0.25	0.29	0.32	0.37	0.42	0.46	0.57	0.70	0.81	0.97	1.12	1.27
05	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.40	0.46	0.56	0.64	0.73
06	10-day	1.72	2.08	2.39	2.82	3.24	3.52	4.35	5.47	6.38	7.61	8.66	9.74
06	5-day	1.41	1.68	1.90	2.21	2.54	2.76	3.33	4.24	4.98	6.15	7.12	8.21
06	72-hr	1.30	1.53	1.73	2.00	2.30	2.50	2.99	3.72	4.41	5.53	6.54	7.69
06	48-hr	1.22	1.43	1.59	1.85	2.13	2.31	2.78	3.44	4.09	5.12	6.06	7.17
06	24-hr	1.16	1.35	1.48	1.71	1.94	2.11	2.51	3.11	3.68	4.57	5.41	6.39
06	18-hr	1.09	1.27	1.39	1.60	1.82	1.98	2.36	2.92	3.46	4.30	5.09	6.01
06	12-hr	1.01	1.18	1.29	1.49	1.69	1.84	2.18	2.71	3.20	3.98	4.71	5.56
06	6-hr	0.87	1.01	1.11	1.28	1.45	1.58	1.88	2.33	2.76	3.43	4.06	4.79
06	3-hr	0.74	0.86	0.94	1.09	1.24	1.35	1.61	1.99	2.36	2.92	3.46	4.09
06	2-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.46	1.80	2.13	2.65	3.14	3.71
06	1-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.18	1.46	1.73	2.15	2.54	3.00
06	30-min	0.43	0.50	0.55	0.63	0.72	0.78	0.93	1.15	1.36	1.69	2.00	2.36
06	15-min	0.31	0.36	0.40	0.46	0.52	0.57	0.68	0.84	0.99	1.23	1.46	1.73
06	10-min	0.24	0.28	0.31	0.36	0.40	0.44	0.53	0.65	0.77	0.96	1.14	1.34
06	5-min	0.14	0.16	0.17	0.20	0.23	0.25	0.30	0.37	0.44	0.55	0.65	0.77

Table 8. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	1.71	2.06	2.37	2.79	3.21	3.49	4.33	5.37	6.10	7.03	7.77	8.48
07	5-day	1.40	1.67	1.89	2.19	2.52	2.74	3.32	4.11	4.72	5.55	6.26	6.99
07	72-hr	1.28	1.51	1.70	1.98	2.27	2.47	2.98	3.64	4.15	4.94	5.63	6.39
07	48-hr	1.19	1.39	1.55	1.79	2.06	2.24	2.73	3.33	3.81	4.53	5.15	5.81
07	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.50	3.02	3.42	3.94	4.41	4.92
07	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.35	2.84	3.21	3.70	4.15	4.62
07	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.17	2.63	2.98	3.43	3.84	4.28
07	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.88	2.26	2.57	2.95	3.31	3.69
07	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.60	1.93	2.19	2.52	2.82	3.15
07	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.45	1.75	1.98	2.29	2.56	2.85
07	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.17	1.42	1.61	1.85	2.07	2.31
07	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.93	1.12	1.27	1.46	1.63	1.82
07	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.68	0.82	0.92	1.06	1.19	1.33
07	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.52	0.63	0.72	0.83	0.93	1.03
07	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.30	0.36	0.41	0.47	0.53	0.59
08	10-day	1.96	2.35	2.71	3.19	3.67	3.99	4.97	6.15	7.02	8.09	8.89	9.71
08	5-day	1.59	1.90	2.15	2.49	2.86	3.11	3.92	4.94	5.66	6.58	7.32	8.05
08	72-hr	1.45	1.70	1.92	2.22	2.56	2.78	3.43	4.22	4.83	5.70	6.47	7.29
08	48-hr	1.35	1.58	1.76	2.04	2.35	2.55	3.15	3.87	4.44	5.26	5.98	6.77
08	24-hr	1.28	1.49	1.63	1.89	2.14	2.33	2.86	3.49	3.99	4.70	5.32	6.04
08	18-hr	1.20	1.40	1.53	1.77	2.01	2.19	2.69	3.28	3.75	4.42	5.00	5.68
08	12-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.49	3.04	3.47	4.09	4.63	5.25
08	6-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.14	2.62	2.99	3.52	3.99	4.53
08	3-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.83	2.23	2.55	3.01	3.40	3.87
08	2-hr	0.74	0.86	0.94	1.09	1.24	1.35	1.66	2.02	2.31	2.73	3.09	3.50
08	1-hr	0.61	0.70	0.77	0.89	1.01	1.10	1.34	1.64	1.88	2.21	2.50	2.84
08	30-min	0.47	0.55	0.60	0.70	0.79	0.86	1.06	1.29	1.48	1.74	1.97	2.23
08	15-min	0.35	0.40	0.44	0.51	0.58	0.63	0.77	0.94	1.08	1.27	1.44	1.63
08	10-min	0.27	0.31	0.34	0.40	0.45	0.49	0.60	0.73	0.84	0.99	1.12	1.27
08	5-min	0.15	0.18	0.20	0.23	0.26	0.28	0.34	0.42	0.48	0.56	0.64	0.72
09	10-day	1.91	2.30	2.65	3.12	3.59	3.90	4.91	6.09	6.92	7.92	8.62	9.35
09	5-day	1.61	1.92	2.17	2.52	2.90	3.15	3.92	4.92	5.66	6.65	7.43	8.24
09	72-hr	1.46	1.71	1.94	2.25	2.59	2.81	3.42	4.20	4.82	5.78	6.65	7.58
09	48-hr	1.35	1.58	1.76	2.04	2.35	2.55	3.10	3.79	4.39	5.31	6.14	7.08
09	24-hr	1.26	1.47	1.60	1.85	2.11	2.29	2.79	3.42	4.01	4.87	5.66	6.50
09	18-hr	1.18	1.38	1.50	1.74	1.98	2.15	2.62	3.21	3.77	4.58	5.32	6.11
09	12-hr	1.09	1.27	1.39	1.61	1.83	1.99	2.43	2.98	3.49	4.24	4.92	5.66
09	6-hr	0.95	1.10	1.20	1.39	1.58	1.72	2.09	2.57	3.01	3.65	4.24	4.88
09	3-hr	0.81	0.94	1.03	1.19	1.35	1.47	1.79	2.19	2.57	3.12	3.62	4.16
09	2-hr	0.73	0.85	0.93	1.08	1.22	1.33	1.62	1.98	2.33	2.82	3.28	3.77
09	1-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.31	1.61	1.88	2.29	2.66	3.06
09	30-min	0.47	0.54	0.60	0.69	0.78	0.85	1.03	1.27	1.48	1.80	2.09	2.40
09	15-min	0.34	0.40	0.43	0.50	0.57	0.62	0.75	0.92	1.08	1.31	1.53	1.76
09	10-min	0.26	0.31	0.34	0.39	0.44	0.48	0.59	0.72	0.84	1.02	1.19	1.37
09	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.41	0.48	0.58	0.68	0.78

Table 8. Concluded

		Rainfall (inches) for given recurrence interval											
Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
10	10-day	1.70	2.04	2.35	2.77	3.18	3.46	4.41	5.58	6.38	7.38	8.09	8.80
10	5-day	1.43	1.71	1.93	2.24	2.58	2.80	3.52	4.44	5.07	5.86	6.42	6.98
10	72-hr	1.28	1.51	1.70	1.98	2.27	2.47	3.07	3.78	4.32	5.08	5.69	6.33
10	48-hr	1.18	1.38	1.54	1.78	2.05	2.23	2.77	3.42	3.94	4.67	5.25	5.88
10	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.54	3.17	3.64	4.34	4.91	5.51
10	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.39	2.98	3.42	4.08	4.62	5.18
10	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.21	2.76	3.17	3.78	4.27	4.79
10	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.90	2.38	2.73	3.26	3.68	4.13
10	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.63	2.03	2.33	2.78	3.14	3.53
10	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.47	1.84	2.11	2.52	2.85	3.20
10	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.19	1.49	1.71	2.04	2.31	2.59
10	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.94	1.17	1.35	1.61	1.82	2.04
10	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.69	0.86	0.98	1.17	1.33	1.49
10	10-mín	0.24	0.28	0.30	0.35	0.40	0.43	0.53	0.67	0.76	0.91	1.03	1.16
10	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.30	0.38	0.44	0.52	0.59	0.66

Table 9. Sectional Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days and Recurrence Intervals of 2 Months to 100 Years in Wisconsin

Sectional code (see figure 1 on page 4)

01 – Northwest
02 - North Central
03 – Northeast
04 - West Central
05 – Central
06 - East Central
07 - Southwest
08 - South Central
09 - Southeast

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.90	2.29	2.64	3.10	3.57	3.88	4.78	5.83	6.58	7.63	8.47	9.37
01	5-day	1.55	1.85	2.09	2.42	2.79	3.03	3.75	4.66	5.35	6.27	7.05	7.90
01	72-hr	1.39	1.63	1.85	2.14	2.47	2.68	3.31	4.12	4.78	5.67	6.39	7.16
01	48-hr	1.30	1.53	1.70	1.97	2.26	2.46	3.05	3.82	4.41	5.23	5.88	6.56
01	24-hr	1.22	1.42	1.55	1.80	2.04	2.22	2.77	3.50	4.04	4.79	5.36	5.98
01	18-hr	1.15	1.34	1.46	1.69	1.92	2.09	2.60	3.29	3.80	4.50	5.04	5.62
01	12-hr	1.06	1.24	1.35	1.56	1.78	1.93	2.41	3.05	3.51	4.17	4.66	5.20
01	6-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.08	2.62	3.03	3.59	4.02	4.49
01	3-hr	0.78	0.91	0.99	1.15	1.31	1.42	1.77	2.24	2.59	3.07	3.43	3.83
01	2-hr	0.71	0.83	0.90	1.04	1.19	1.29	1.61	2.03	2.34	2.78	3.11	3.47
01	1-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.30	1.64	1.90	2.25	2.52	2.81
01	30-min	0.45	0.52	0.57	0.66	0.75	0.82	1.02	1.30	1.49	1.77	1.98	2.21
01	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.75	0.95	1.09	1.29	1.45	1.61
01	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.73	0.85	1.01	1.13	1.26
01	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.42	0.48	0.57	0.64	0.72
02	10-day	1.98	2.39	2.75	3.24	3.73	4.05	4.79	5.68	6.44	7.55	8.49	9.52
02	5-day	1.59	1.90	2.15	2.50	2.87	3.12	3.77	4.63	5.33	6.36	7.27	8.28
02	72-hr	1.40	1.65	1.86	2.16	2.48	2.70	3.30	4.08	4.72	5.69	6.50	7.41
02	48-hr	1.29	1.51	1.68	1.94	2.24	2.43	2.99	3.73	4.31	5.16	5.89	6.67
02	24-hr	1.22	1.41	1.55	1.79	2.03	2.21	2.74	3.39	3.90	4.66	5.29	6.01
02	18-hr	1.14	1.33	1.46	1.68	1.91	2.08	2.58	3.19	3.67	4.38	4.97	5.65
02	12-hr	1.06	1.23	1.34	1.56	1.77	1.92	2.38	2.95	3.39	4.05	4.60	5.23
02	6-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.06	2.54	2.93	3.49	3.97	4.51
02	3-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.75	2.17	2.50	2.98	3.39	3.85
02	2-hr	0.70	0.82	0.90	1.04	1.18	1.28	1.59	1.97	2.26	2.70	3.07	3.49
02	1-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.29	1.59	1.83	2.19	2.49	2.82
02	30-min	0.45	0.52	0.57	0.66	0.75	0.82	1.01	1.25	1.44	1.72	1.96	2.22
02	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.74	0.92	1.05	1.26	1.43	1.62
02	10-min	0.25	0.29	0.32	0.37	0.42	0.46	0.58	0.71	0.82	0.98	1.11	1.26
02	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.41	0.47	0.56	0.63	0.72
03	10-day	1.78	2.15	2.48	2.91	3.35	3.64	4.45	5.38	6.06	7.01	7.84	8.74
03	5-day	1.38	1.65	1.87	2.17	2.49	2.71	3.33	4.08	4.68	5.64	6.47	7.45
03	72-hr	1.21	1.42	1.60	1.86	2.13	2.32	2.87	3.59	4.18	5.07	5.84	6.74
03	48-hr	1.12	1.31	1.46	1.70	1.95	2.12	2.61	3.28	3.82	4.66	5.38	6.22
03	24-hr	1.04	1.22	1.33	1.54	1.75	1.90	2.34	2.94	3.46	4.24	4.94	5.77
03	18-hr	0.98	1.15	1.25	1.45	1.65	1.79	2.20	2.76	3.25	3.99	4.64	5.42
03	12-hr	0.91	1.06	1.15	1.34	1.52	1.65	2.04	2.56	3.01	3.69	4.30	5.02
03	6-hr	0.78	0.91	0.99	1.15	1.31	1.42	1.75	2.20	2.60	3.18	3.70	4.33
03	3-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.50	1.88	2.21	2.71	3.16	3.69
03	2-hr	0.61	0.70	0.77	0.89	1.01	1.10	1.36	1.71	2.01	2.46	2.87	3.35
03	1-hr	0.49	0.57	0.62	0.72	0.82	0.89	1.10	1.38	1.63	1.99	2.32	2.71
03	30-min	0.38	0.45	0.49	0.57	0.64	0.70	0.87	1.09	1.28	1.57	1.83	2.13
03	15-min	0.28	0.33	0.36	0.41	0.47	0.51	0.63	0.79	0.93	1.14	1.33	1.56
03	10-min	0.22	0.26	0.28	0.32	0.37	0.40	0.49	0.62	0.73	0.89	1.04	1.21
03	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.28	0.35	0.42	0.51	0.59	0.69

Table 9. Continued

Rainfall (inches) for given recurrence interval

Section	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
04	10-day	1.83	2.21	2.54	2.99	3.44	3.74	4.78	5.94	6.76	7.95	8.96	9.92
04	5-day	1.57	1.87	2.12	2.46	2.82	3.07	3.88	4.88	5.69	6.85	7.80	8.85
04	72-hr	1.40	1.64	1.86	2.15	2.47	2.69	3.43	4.36	5.17	6.24	7.07	8.06
04	48-hr	1.29	1.51	1.68	1.95	2.24	2.44	3.12	3.98	4.66	5.60	6.43	7.33
04	24-hr	1.23	1.43	1.56	1.81	2.05	2.23	2.92	3.72	4.40	5.28	6.02	6.88
04	18-hr	1.15	1.34	1.47	1.70	1.93	2.10	2.74	3.50	4.14	4.96	5.66	6.47
04	12-hr	1.07	1.24	1.36	1.57	1.78	1.94	2.54	3.24	3.83	4.59	5.24	5.99
04	6-hr	0.92	1.07	1.17	1.35	1.54	1.67	2.19	2.79	3.30	3.96	4.51	5.16
04	3-hr	0.79	0.92	1.00	1.16	1.32	1.43	1.87	2.38	2.82	3.38	3.85	4.40
04	2-hr	0.71	0.83	0.90	1.04	1.19	1.29	1.69	2.16	2.55	3.06	3.49	3.99
04	1-hr	0.58	0.67	0.73	0.85	0.97	1.05	1.37	1.75	2.07	2.48	2.83	3.23
04	30-min	0.46	0.53	0.58	0.67	0.76	0.83	1.08	1.38	1.63	1.95	2.23	2.55
04	15-min	0.33	0.38	0.42	0.49	0.55	0.60	0.79	1.00	1.19	1.43	1.63	1.86
04	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.61	0.78	0.92	1.11	1.26	1.44
04	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.35	0.45	0.53	0.63	0.72	0.83
05	10-day	1.90	2.29	2.64	3.10	3.57	3.88	4.77	5.81	6.53	7.59	8.50	9.52
05	5-day	1.54	1.84	2.08	2.41	2.77	3.01	3.69	4.49	5.14	6.09	6.94	7.87
05	72-hr	1.35	1.59	1.79	2.08	2.39	2.60	3.18	3.89	4.49	5.36	6.09	6.90
05	48-hr	1.25	1.46	1.63	1.89	2.17	2.36	2.90	3.58	4.11	4.87	5.48	6.17
05	24-hr	1.18	1.38	1.50	1.74	1.98	2.15	2.65	3.25	3.71	4.38	4.93	5.52
05	18-hr	1.11	1.29	1.41	1.64	1.86	2.02	2.49	3.06	3.49	4.12	4.63	5.19
05	12-hr	1.03	1.20	1.31	1.51	1.72	1.87	2.31	2.83	3.23	3.81	4.29	4.80
05	6-hr	0.89	1.03	1.13	1.30	1.48	1.61	1.99	2.44	2.78	3.29	3.70	4.14
05	3-hr	0.76	0.88	0.97	1.12	1.27	1.38	1.70	2.08	2.37	2.80	3.16	3.53
05	2-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.54	1.88	2.15	2.54	2.86	3.20
05	1-hr	0.56	0.65	0.71	0.82	0.93	1.01	1.25	1.53	1.74	2.06	2.32	2.59
05	30-min	0.44	0.51	0.56	0.65	0.74	0.80	0.98	1.20	1.37	1.62	1.82	2.04
05	15-min	0.32	0.37	0.41	0.47	0.53	0.58	0.72	0.88	1.00	1.18	1.33	1.49
05	10-min	0.25	0.29	0.31	0.36	0.41	0.45	0.56	0.68	0.78	0.92	1.04	1.16
05	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.39	0.45	0.53	0.59	0.66
06	10-day	1.70	2.05	2.36	2.78	3.19	3.47	4.28	5.29	6.11	7.36	8.51	9.85
06	5-day	1.34	1.60	1.81	2.10	2.42	2.63	3.22	4.01	4.74	5.91	6.98	8.28
06	72-hr	1.21	1.42	1.61	1.66	2.14	2.33	2.83	3.55	4.20	5.25	6.23	7.42
06	48-hr	1.13	1.32	1.47	1.70	1.96	2.13	2.61	3.26	3.87	4.86	5.77	6.88
06	24-hr	1.08	1.25	1.37	1.59	1.80	1.96	2.40	3.00	3.56	4.46	5.32	6.35
06	18-hr	1.01	1.18	1.29	1.49	1.69	1.84	2.26	2.82	3.35	4.19	5.00	5.97
06	12-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.09	2.61	3.10	3.88	4.63	5.52
06	6-hr	0.81	0.94	1.03	1.19	1.35	1.47	1.80	2.25	2.67	3.35	3.99	4.76
06	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.54	1.92	2.28	2.85	3.40	4.06
06	2-hr	0.63	0.73	0.80	0.92	1.05	1.14	1.39	1.74	2.06	2.59	3.09	3.68
06	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.13	1.41	1.67	2.10	2.50	2.98
06	30-min	0.40	0.47	0.51	0.59	0.67	0.73	0.89	1.11	1.32	1.65	1.97	2.35
06	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.65	0.81	0.96	1.20	1.44	1.71
06	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.75	0.94	1.12	1.33
06	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.36	0.43	0.54	0.64	0.76

Table 9. Concluded

Section	Duration	2-month	3-month	4-month	6-month	9-month	1-year	2-year	5-year	10-year	25-year	50-year	100-year
		Rainfall (inches) for given recurrence interval											
07	10-day	1.85	2.23	2.57	3.02	3.48	3.78	4.88	6.19	7.16	8.45	9.49	10.60
07	5-day	1.56	1.87	2.11	2.45	2.82	3.06	3.92	5.04	5.91	7.22	8.29	9.52
07	72-hr	1.40	1.65	1.86	2.16	2.48	2.70	3.42	4.43	5.23	6.43	7.49	8.68
07	48-hr	1.31	1.53	1.70	1.98	2.27	2.47	3.12	4.05	4.82	5.91	6.88	7.95
07	24-hr	1.24	1.44	1.57	1.82	2.07	2.25	2.82	3.60	4.31	5.29	6.17	7.15
07	18-hr	1.17	1.36	1.48	1.72	1.95	2.12	2.65	3.38	4.05	4.97	5.80	6.72
07	12-hr	1.08	1.25	1.37	1.59	1.80	1.96	2.45	3.13	3.75	4.60	5.37	6.22
07	6-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.12	2.70	3.23	3.97	4.63	5.36
07	3-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.80	2.30	2.76	3.39	3.95	4.58
07	2-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.64	2.09	2.50	3.07	3.58	4.15
07	1-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.33	1.69	2.03	2.49	2.90	3.36
07	30-min	0.46	0.53	0.58	0.67	0.76	0.83	1.04	1.33	1.59	1.96	2.28	2.65
07	15-min	0.34	0.39	0.43	0.49	0.56	0.61	0.76	0.97	1.16	1.43	1.67	1.93
07	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.59	0.76	0.91	1.11	1.30	1.50
07	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.34	0.43	0.52	0.63	0.74	0.86
08	10-day	1.82	2.19	2.52	2.97	3.41	3.71	4.72	5.93	6.86	8.21	9.33	10.60
08	5-day	1.52	1.82	2.06	2.39	2.75	2.99	3.78	4.86	5.73	7.03	8.14	9.36
08	72-hr	1.40	1.65	1.86	2.16	2.48	2.70	3.38	4.34	5.16	6.34	7.34	8.47
08	48-hr	1.30	1.53	1.70	1.97	2.26	2.46	3.07	3.96	4.68	5.79	6.75	7.82
08	24-hr	1.24	1.44	1.57	1.82	2.07	2.25	2.78	3.53	4.20	5.18	6.06	7.06
08	18-hr	1.17	1.36	1.48	1.72	1.95	2.12	2.61	3.32	3.95	4.87	5.70	6.64
08	12-hr	1.08	1.25	1.37	1.59	1.80	1.96	2.42	3.07	3.65	4.51	5.27	6.14
08	6-hr	0.93	1.08	1.18	1.37	1.55	1.69	2.09	2.65	3.15	3.88	4.55	5.30
08	3-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.78	2.26	2.69	3.32	3.88	4.52
08	2-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.61	2.05	2.44	3.00	3.51	4.09
08	1-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.31	1.66	1.97	2.43	2.85	3.32
08	30-min	0.46	0.53	0.58	0.67	0.76	0.83	1.03	1.31	1.55	1.92	2.24	2.61
08	15-min	0.34	0.39	0.43	0.49	0.56	0.61	0.75	0.95	1.13	1.40	1.64	1.91
08	10-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.74	0.88	1.09	1.27	1.48
08	5-min	0.15	0.17	0.19	0.22	0.25	0.27	0.33	0.42	0.50	0.62	0.73	0.85
09	10-day	1.81	2.18	2.52	2.96	3.40	3.70	4.55	5.65	6.58	7.89	9.09	10.49
09	5-day	1.50	1.79	2.03	2.35	2.70	2.94	3.66	4.66	5.50	6.72	7.85	9.14
09	72-hr	1.36	1.60	1.81	2.10	2.41	2.62	3.25	4.14	4.85	5.90	6.84	7.80
09	48-hr	1.27	1.49	1.66	1.92	2.21	2.40	2.98	3.78	4.43	5.36	6.22	7.14
09	24-hr	1.20	1.40	1.53	1.77	2.01	2.18	2.70	3.33	3.86	4.66	5.38	6.24
09	18-hr	1.13	1.31	1.43	1.66	1.89	2.05	2.54	3.13	3.63	4.38	5.06	5.87
09	12-hr	1.04	1.22	1.33	1.54	1.75	1.90	2.35	2.90	3.36	4.05	4.68	5.43
09	6-hr	0.90	1.04	1.14	1.32	1.50	1.63	2.03	2.50	2.89	3.49	4.03	4.68
09	3-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.73	2.13	2.47	2.98	3.44	3.99
09	2-hr	0.69	0.81	0.88	1.02	1.16	1.26	1.57	1.93	2.24	2.70	3.12	3.62
09	1-hr	0.56	0.65	0.71	0.83	0.94	1.02	1.27	1.57	1.81	2.19	2.53	2.93
09	30-min	0.45	0.52	0.57	0.66	0.75	0.81	1.00	1.23	1.43	1.72	1.99	2.31
09	15-min	0.32	0.38	0.41	0.48	0.54	0.59	0.73	0.90	1.04	1.26	1.45	1.68
09	10-min	0.25	0.29	0.32	0.37	0.42	0.46	0.57	0.70	0.81	0.98	1.13	1.31
09	5-min	0.14	0.17	0.18	0.21	0.24	0.26	0.32	0.40	0.46	0.56	0.65	0.75