# DROUGHT IN IOWA
## PATTERN, FREQUENCY, INTENSITY

IWARDS
Iowa Water Resources Data System

**REPORT SERIES**

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# DROUGHT IN IOWA

# THE PATTERN, FREQUENCY, AND INTENSITY


BY

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# INTRODUCTION

Droughts are a recurrent phenomenon and an inevitable part of the existing climate. Over a period of years, precipitation will vary around the average (or normal), so these year-to-year variations can not be ignored when activities depend on optimum levels of rainfall. The impact of below average precipitation can range from inconvenience to serious economic loss. The extent and seriousness of the impact depends on social and economic factors and in part on the intensity, duration, and frequency of precipitation deficit. Historical rainfall records can be analyzed to characterize precipitation deficits -- the average amount of deficit (intensity), the time periods over which they prevail (duration), and the chance that such events will reoccur (frequency).

## Purpose and Scope

This study is based on the evaluation of monthly precipitation totals for 62 Iowa weather stations. A 30-year record period was used, October 1947 through September 1977. The names and locations of the stations are shown in Figure 1. Data were grouped and analyzed for five duration periods:

1. 3 spring months (April - June)
2. 3 summer months (July - September)
3. 6 crop season months (April - September)
4. 12 water year months (October - September)
5. 24 months (2 consecutive water years)

The average and deficit amounts were calculated for each duration period for each station. The 30 year average is a middle value of all recorded amounts and represents the amount that can be expected in any year. The amounts of precipitation below the average occurring for frequencies

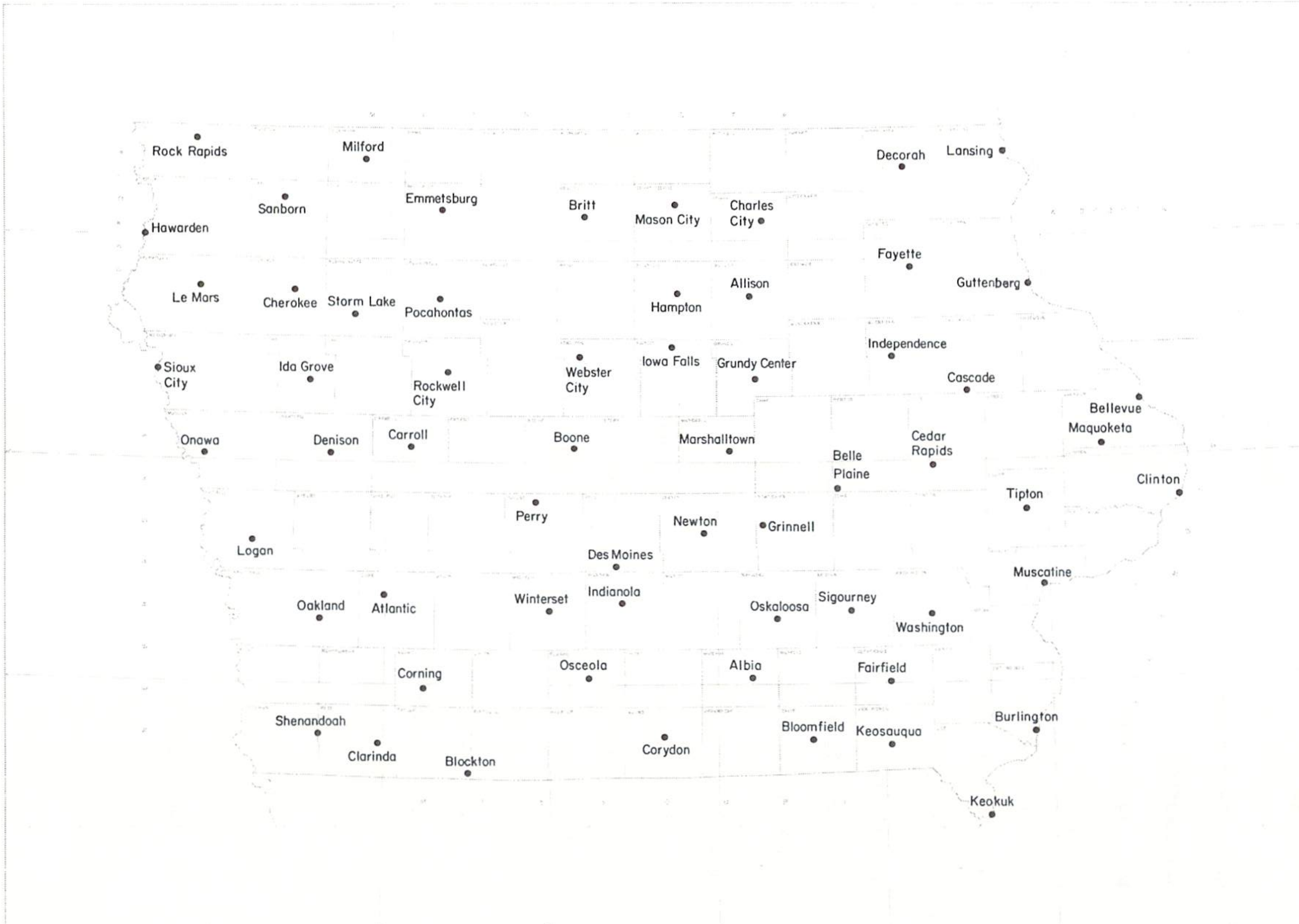



Figure 1. Network of precipitation stations studied.

(recurrence intervals) of once in 2, 5, 10, and 20 years represent the relative severity of precipitation deficits that can be expected.

## Report Objective

The principal objective of this report is to present a series of state isohyetal (precipitation) maps showing the average and expected below average precipitation for the five duration periods. The first section provides general information about the climate of Iowa and addresses the role of variability and below average precipitation in the state's climatic regime. This is followed by the map series, beginning with the 3-month spring period. For each series the spatial rainfall distribution is shown on frequency maps and the significance of each is discussed. The methods used to calculate and map precipitation amounts are described in Appendix A. The average and deficit amounts for each station are tabulated in Appendix B.

## Acknowledgements

This report was prepared through the efforts of the Water Resources Division, Technical Services Group of the Iowa Geological Survey, and the State Climatologist. The project was designed to demonstrate the service capabilities of the Iowa Water Resources Data System (IWARDS) and the cooperative research opportunity it offers state agencies.

We wish to acknowledge Mr. Richard Talcott (IWARDS manager), Mr. Pete Kollasch, and Mrs. Sue Daut, all of the IGS Technical Services Group for their technical and programming support, and for making data available from the Iowa precipitation data tapes.

Special acknowledgement is made to Mrs. Marie Klugman, University of Iowa Geography Department, for her role in preparing the master data set, coordinating the statistical treatment of the data, and verifying processed results.

Acknowledgement is also extended to Ms. Char Shreve and Mr. John Knecht, of the IGS Technical Services Group, who prepared the illustrations, and to Mrs. Barbara Miller who typed the manuscript. Our thanks go to Mr. Donald Koch, Assistant State Geologist, and Mr. Donivan Gordon, Chief of the IGS Water Resources Division, for their work in editing the report. Finally, we wish to acknowledge all those who supported this project and offered their encouragement during the preparation of this report.

# IOWA'S CLIMATIC SETTING

Iowa's climate is the most important of all the variables affecting the state's agricultural economy. It is the primary factor regulating the growth of food and fiber. Climate also influences energy consumption, usable water supplies, and their distribution. To some degree climate also regulates recreation, our health, and transportation systems. Even Iowa's fertile soils are, in part, a product of past climates.

The humid, continental climate of Iowa is characterized by warm to hot, humid summers and cold, dry winters. Of all the climatic elements precipitation is the most measured. About 90% of Iowa's precipitation occurs as rain and 10% as snow. The long-term average for the state totals nearly 32 inches a year, and ranges from about 25 inches in the northwest to around 35 inches in the east central and southeast.

In summer the prevailing southerly flow of warm, moist air from the Gulf of Mexico normally supplies over 70% of the annual precipitation. This is received during the warm half year from April through September (Fig. 2). From early spring, rainfall increases to a peak of over 5 inches during June, then diminishes somewhat in July and August and normally dwindles further to a moderately dry autumn.

In winter, cold, dry polar air masses move southeasterly across Iowa to block the inflow of Gulf moisture and greatly reduce winter precipitation. Yet, winter precipitation is of consequence. Some thirty inches of snow falls during an average winter. Historically, statewide average snowfall amounts have varied from little more than a third to nearly twice the normal. Snow is important as an insulator to soils and overwintering plants, and a regulator of air temperatures. Snow is also a source of meltwater which during spring replaces soil moisture, recharges the state's underground

IOWA NORMAL MONTHLY PRECIPITATION

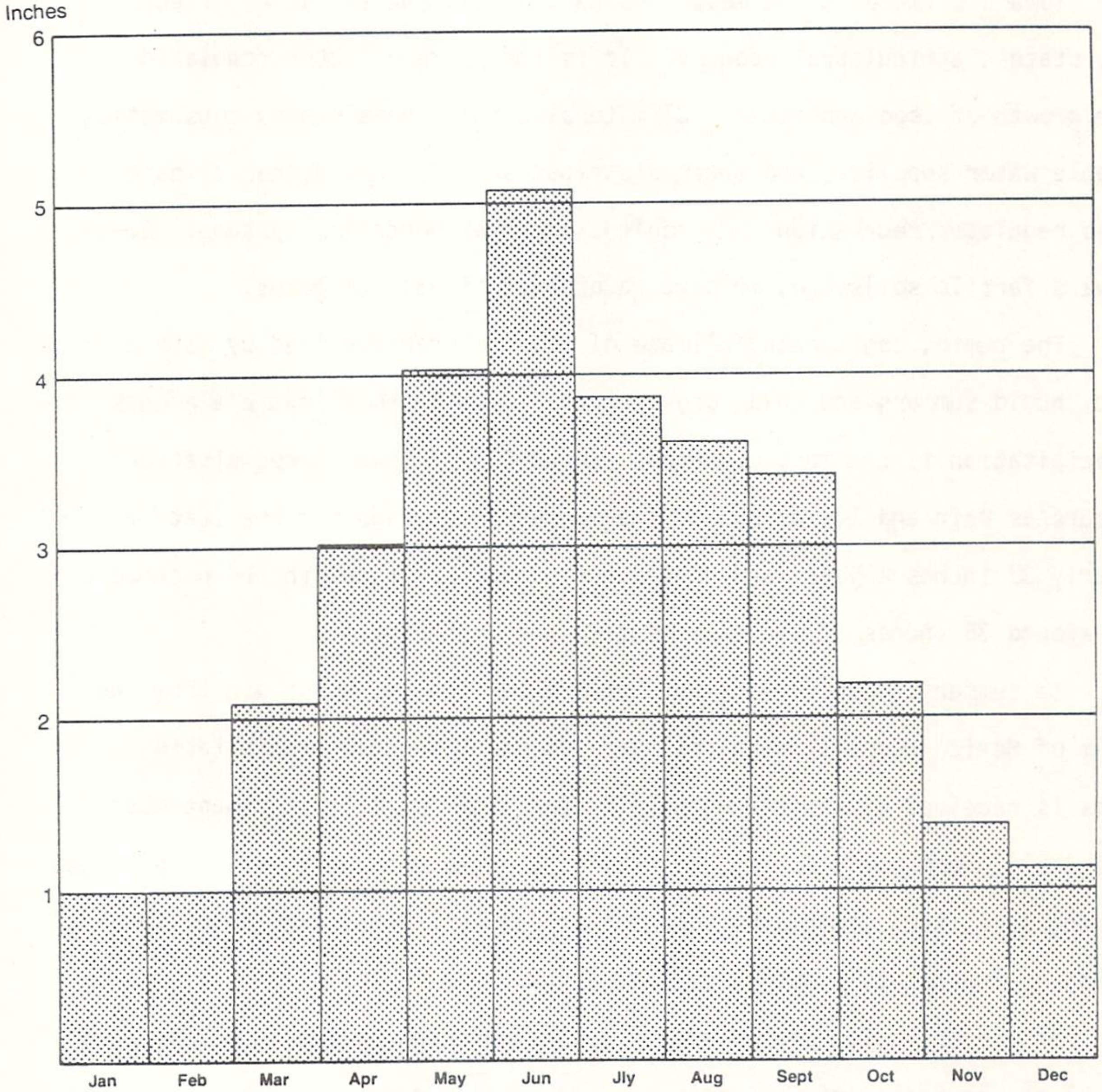



Figure 2. Iowa normal monthly precipitation (1941-1970 areally weighted data from 117 sites).

aquifers and increases surface water supplies in streams, lakes and ponds. Too, the economic and physical hardships due to severe snow storms and blizzards are substantial.

Average climatic conditions in Iowa nearly approach the optimum to produce bumper crops and provide adequate water supplies. Yet the average conditions are rarely experienced. Instead, Iowa's climate (including the daily weather) is characteristically variable both in time and space. Although the long-term state average precipitation is about 32 inches annual averages have varied greatly from one year to another, ranging from about 20 inches in 1910 to over 44 inches in 1881 (Fig. 3). The variation in total annual precipitation at specific locations is even greater than the state average, ranging from 12.11 inches at Clear Lake (1910) to 74.50 inches at Muscatine (1851). Within limits this variability is tolerable, but pronounced climatic anomalies can cause hardship and severe economic losses.

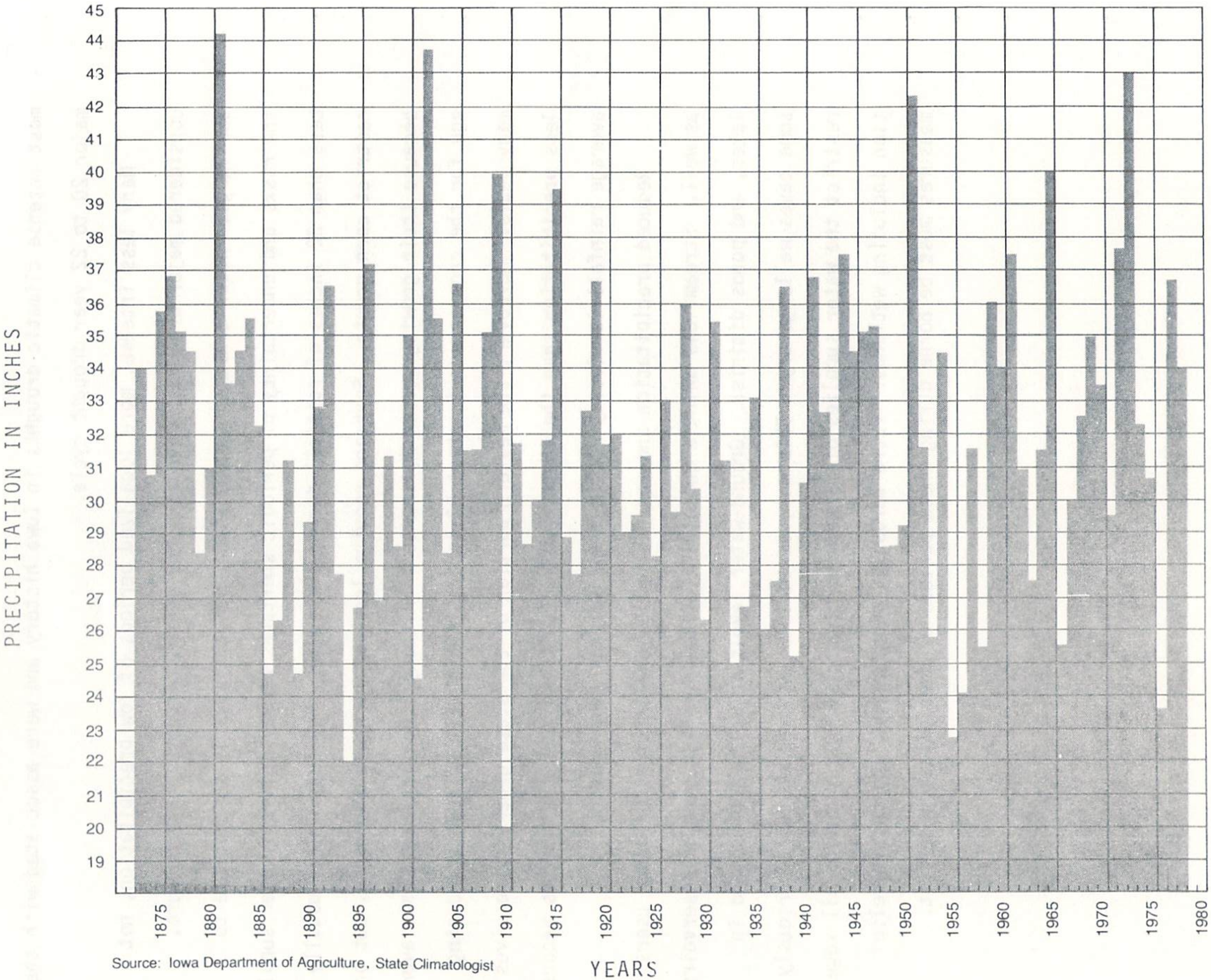
Precipitation anomalies, including drought, are the most destructive of all climatic events to agriculture (Table 1). For each $10 of Iowa crop loss, drought accounts for $3, excessive rain nearly $2, and hail another $1 or $2. Furthermore, losses accrue due to winds frequently associated with thunderstorms and to the excessive heat with drought. Actually, over 90% of all agricultural weather losses are attributable to precipitation and associated phenomena.

Table 1. Iowa's Average Annual Estimated Weather-Related Crop Yield Losses. *

| Weather Element | Corn | | Soybeans | |
|---|---|---|---|---|
| | Bushels per Acre | % of Total Loss | Bushels per Acre | % of Total Loss |
| Drought | 6.35 | 28 | 2.70 | 29 |
| Excessive Moisture | 3.80 | 17 | 2.10 | 22 |
| Hail | 2.69 | 12 | 1.87 | 20 |
| Wind | 3.78 | 17 | 0.98 | 10 |
| Excessive Heat | 3.90 | 17 | 0.99 | 10 |
| Excessive Coolness | 0.89 | 4 | 0.35 | 4 |
| Freeze or Frost | 1.02 | 5 | 0.48 | 5 |
| Total Losses | 22.43 | 100 | 9.47 | 100 |

*Adapted from Changnon (1974)

Because of the great variability of precipitation, periods of deficiency occur intermittently. Low precipitation accompanied by intense summer heat has produced the most serious drought. The most severe droughts in Iowa appear to coincide with a major 20 to 22-year cycle. According to a study by Waite (1978), Iowa's precipitation has fluctuated by 10-15% between the wet and dry periods of the cycles. The decades, 1900-09, 1920s, 1940s and 1960s were characterized by more reliable rainfalls while the intervening decades, the 1890s, 1910s, 1930s and 1950s were associated with moderate to severe extended drought periods and greater precipitation variations. The 1970s exhibited the same large precipitation variations and extended droughtiness (1974-77), but the decade became one of Iowa's wetter due to Iowa's record wettest two years during 1972-73 and another exceptionally moist period beginning with August 1977 and lasting through 1979. It is rare that two or more consecutive years of extremely low precipitation are




Source: Iowa Department of Agriculture, State Climatologist

Figure 3. Average annual precipitation for Iowa (1873-1978).

experienced as in 1955-56, 1933-1934, and 1893-1894-1895. These were the most intense climatic droughts in Iowa history and were associated with the major 20 to 22 year drought cycle.

Many less intense, more localized periods of low precipitation, not considered major droughts, have also had serious effects. Agriculture, the largest water consumer in the state, is particularly susceptible to the risks and uncertainty of periodic shortages of rainfall and water supplies. Less than 22 inches of rainfall during the summer crop season will usually restrict corn growth. Soybeans require less water, about 19 inches, but only because their growing season is shorter. Although the long-term state average for the crop season is about 22 inches, there will be deficits during many years. Moreover, the western portion of the state generally receives less precipitation than the eastern and deficits may be more serious because average rainfall is already marginal for optimal crop growth.

Reduced precipitation and water supplies are critical to other users as well. Streamflows dwindle and other surface supplies such as reservoirs, lakes, and ponds diminish. Ground-water levels in wells decline and in some cases wells go dry. This may, as in 1976 and part of 1977, seriously restrict the water supplies of farmers and municipalities, and to all vegetation including wetlands. Extra hardship, deprivation, and costly relief measures must be borne during these periods of precipitation deficit.

## MAGNITUDE AND FREQUENCY OF BELOW NORMAL PRECIPITATION

The 30-year records of precipitation during the 12-, 6-, and two 3-month periods are shown in Figures 4 and 5 for two stations, LeMars and Washington. Comparison of the two graphs shows variation in amounts of precipitation received at different stations and particularly the lower precipitation received in the west opposed to the more humid east. For instance, the 12-month average for LeMars is 7.5 inches lower than for Washington. The graphs also show the year-to-year variability between all duration periods.

The below average amounts with recurrence intervals of 2, 5, 10, and 20 years are tabulated above the graphs. An example for the LeMars station illustrates how to interpret the study's results. The value of 12.0 inches for the 6-month period (the April-September crop season) and 10-year recurrence interval (R.I. 10) means that over a long period of time there will be only 12 inches or less rainfall during 1 out of 10 crop seasons. The value for the 10-year recurrence interval is based on long-term probability and during the short record of 30 years, this amount may not occur only once, or in every, 10 years. Although the regularity and exact year of occurrence can not be predicted, the recurrence values indicate the severity of low precipitation periods. For example, the 6-month precipitation in 1956 was only 10.4 inches, about the amount expected only once in 20 years.

Summary data for the state is presented in Table 2. The deficits expected with a recurrence interval of 2 years are relatively small compared to those with lower frequencies. As indicated by the percent-of-period-average data, the greatest deficits across the state occur during the three summer months July through September. Most rainfall during this season is delivered by local, short-duration thunderstorms and the chance

## LE MARS

| Period | Recurrence Interval, (year) | | | | |
|---|---|---|---|---|---|
| | Ave. | RI2 | RI5 | RI10 | RI20 |
| 3 Month (Spring) | 10.2 | 10.2 | 7.5 | 6.0 | 5.0 |
| 3 Month (Summer) | 9.2 | 8.9 | 6.0 | 4.8 | 4.0 |
| 6 Month | 19.4 | 19.5 | 14.4 | 12.0 | 10.2 |
| 12 Month | 26.0 | 25.7 | 20.0 | 17.4 | 15.5 |

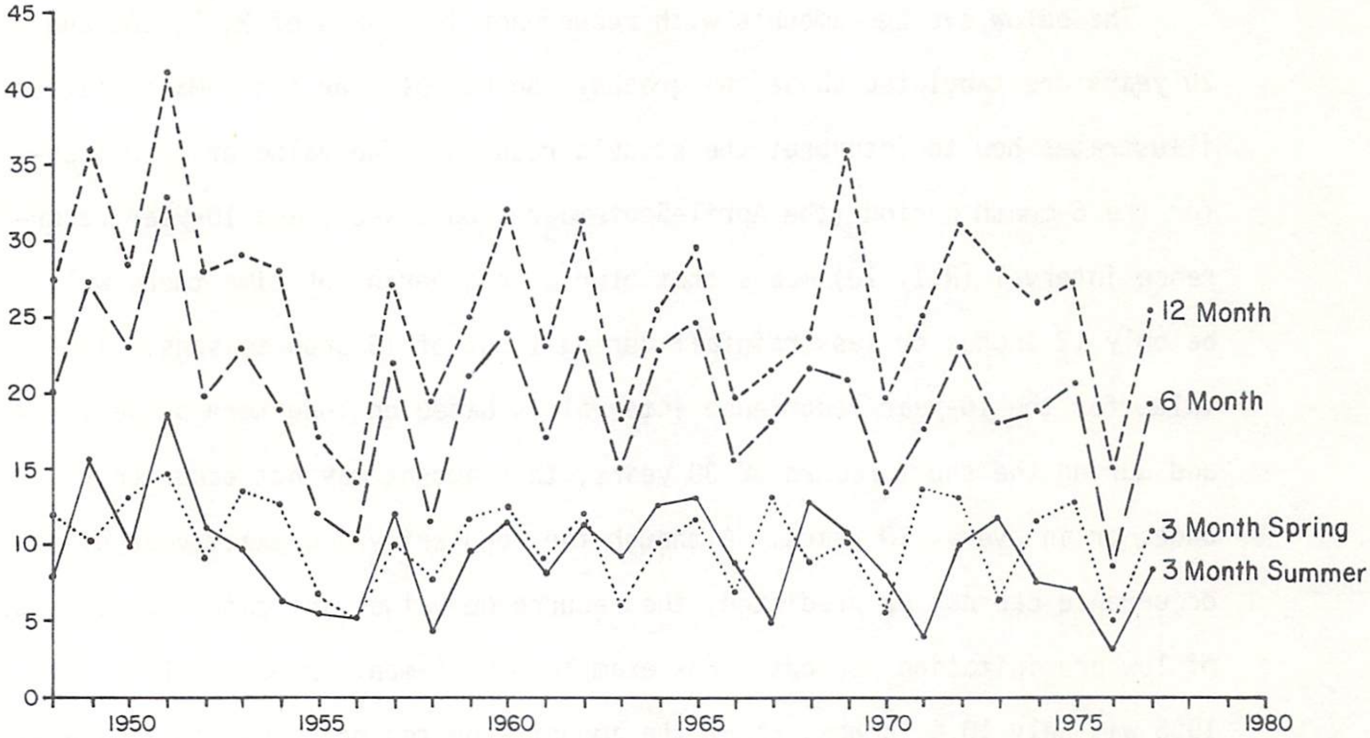



Figure 4. LeMars, Iowa 30 year (1947-77) precipitation record of spring, summer, six month and annual totals and table of recurrence interval values.

## WASHINGTON

| Period | Recurrence Interval, (year) | | | | |
|---|---|---|---|---|---|
| | Ave. | RI2 | RI5 | RI10 | RI20 |
| 3 Month (Spring) | 11.6 | 11.8 | 7.4 | 5.6 | 4.3 |
| 3 Month (Summer) | 11.0 | 10.0 | 6.5 | 5.1 | 4.3 |
| 6 Month | 22.6 | 21.9 | 17.0 | 14.8 | 13.2 |
| 12 Month | 33.5 | 33.1 | 26.9 | 24.0 | 21.9 |

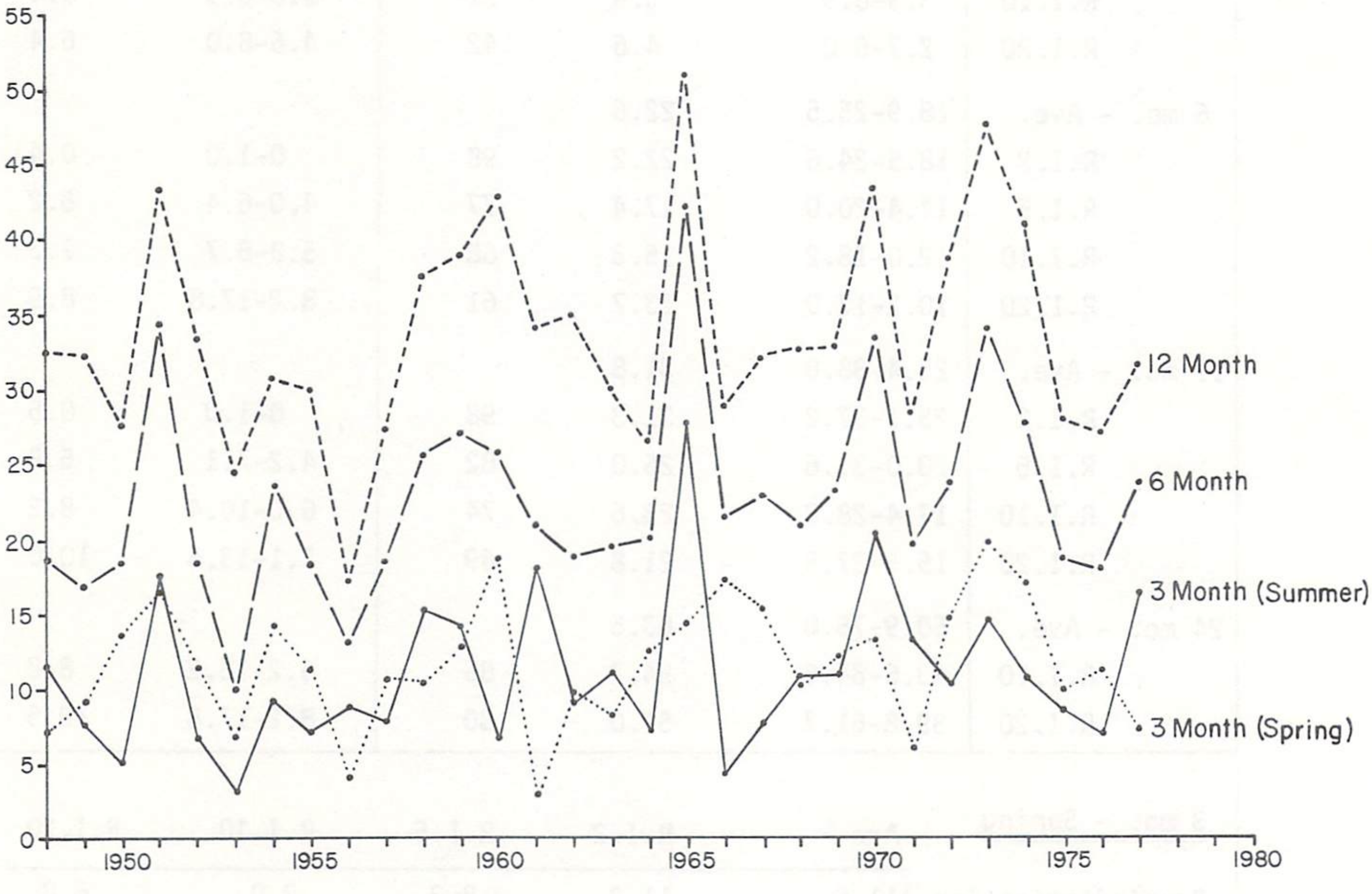



Figure 5. Washington, Iowa 30 year (1947-77) precipitation record of spring, summer, six month and annual totals and table of recurrence interval values.

TABLE 2

| Period | Precipitation (inches) Range | State Average | % of Period Average | Deficit (inches) Range | State Average |
|---|---|---|---|---|---|
| 3 mo. - Ave. | 9.7-13.3 | 11.6 | | | |
| Spring R.I.2 | 9.3-13.5 | 11.3 | 97 | 0-0.8 | 0.3 |
| R.I.5 | 6.6-10.2 | 8.3 | 72 | 2.6-4.4 | 3.3 |
| R.I.10 | 5.4-8.7 | 7.0 | 60 | 3.0-6.4 | 4.6 |
| R.I.20 | 4.3-7.8 | 6.0 | 52 | 3.6-7.6 | 5.6 |
| 3 mo. - Ave. | 9.1-12.7 | 11.0 | | | |
| Summer R.I.2 | 8.7-11.8 | 10.4 | 95 | 0-1.2 | 0.6 |
| R.I.5 | 5.4-8.1 | 7.0 | 64 | 2.7-5.4 | 4.0 |
| R.I.10 | 3.9-6.9 | 5.6 | 51 | 3.8-6.9 | 5.4 |
| R.I.20 | 2.7-6.0 | 4.6 | 42 | 4.6-8.0 | 6.4 |
| 6 mo. - Ave. | 18.9-25.5 | 22.6 | | | |
| R.I.2 | 18.6-24.6 | 22.2 | 98 | 0-1.0 | 0.4 |
| R.I.5 | 14.4-20.0 | 17.4 | 77 | 4.0-6.4 | 5.2 |
| R.I.10 | 12.0-18.2 | 15.3 | 68 | 5.8-8.7 | 7.3 |
| R.I.20 | 10.2-17.0 | 13.7 | 61 | 8.2-17.8 | 8.9 |
| 12 mo. - Ave. | 25.4-38.0 | 31.8 | | | |
| R.I.2 | 25.1-37.2 | 31.3 | 98 | 0-1.0 | 0.5 |
| R.I.5 | 20.0-31.6 | 26.0 | 82 | 4.2-7.1 | 5.8 |
| R.I.10 | 17.4-28.8 | 23.6 | 74 | 6.0-10.4 | 8.2 |
| R.I.20 | 15.5-27.5 | 21.8 | 69 | 7.1-13.4 | 10.0 |
| 24 mo. - Ave. | 50.9-76.0 | 63.5 | | | |
| R.I.10 | 43.6-64.6 | 54.7 | 86 | 6.2-13.2 | 8.8 |
| R.I.20 | 39.8-61.7 | 51.0 | 80 | 8.2-17.8 | 12.5 |

| 3 mo. - Spring | Ave | R.I.2 | R.I.5 | R.I.10 | R.I.20 |
|---|---|---|---|---|---|
| Precipitation (in.) | 11.6 | 11.3 | 8.3 | 7.0 | 6.0 |
| % of Period Ave. | | 97 | 72 | 60 | 52 |
| Deficit (in.) | | 0.3 | 3.3 | 4.6 | 5.6 |
| 3 mo. - Summer | | | | | |
| Precipitation (in.) | 11.0 | 10.4 | 7.0 | 5.6 | 4.6 |
| % of Period Ave. | | 95 | 64 | 51 | 42 |
| Deficit (in.) | | 0.6 | 4.0 | 5.4 | 6.4 |

of receiving adequate rainfall at any specific time or location is smaller. During summer, drought is likely to become most pronounced because of high crop demands for water, high evaporation rates, increased sunshine, high temperatures and diminishing soil moisture supplies. Too, summer rainfall becomes unreliable and spotty averaging less than that in spring and usually substantially less than crop requirements. By summer, the northward migration of the prevailing storm track into the northern United States or into southern Canada has removed the more general rains from Iowa and, instead, convective scattered thundershower activity produces a spotty rainfall pattern which often results in localized drought. The unreliability of summer rainfalls is documented by the large summer deficits in dryer years.

The six month period, a combination of spring and summer, exhibits a smaller percentage reduction of precipitation in dry years because about 40% of the dry springs are followed by wetter than normal summers. If spring rainfalls are depressed by as much or more than 15% the odds are five to three that the summer following will produce subnormal rainfalls. Average deficits for the six month period are smaller than those for the 12-month period by an inch or less. This is largely due to Iowa's pattern of rainfall. About 70% of the 12-month precipitation falls during the 6-month (October to March) crop season. The contributions of the 6-months (October-March) are relatively small, consequently the severity of below average precipitation for the 12-month period is similar to that of the crop season. Fortunately, about half of the winter precipitation falls on unfrozen ground during October, November and the latter part of March. This moisture is used to recharge Iowa soils while the other half of the cool half-year precipitation mostly runs off. Obviously, the beginning of the water year with substantial October and November precipitation is important to the next crop year, even though it can seriously hamper the current year crop harvest.

The expected 24-month precipitation for recurrence intervals of 10 and 20 years account for high percentages of the average 24-month total. For example, the 24-month precipitation for R.I. 10 is 86% of the average while for the summer period the 10-year below average precipitation is only 51% of the 3-month average. Two consecutive years of low precipitation is rare. Instead, the sequence of wet and dry periods tends to reduce the severity of below average precipitation over a 24-month period. Table 2 provides useful decision making information particularly for agricultural purposes. For example, a farmer may estimate the amount of soil water in the crop root zone at the beginning of winter and tentatively plan his crop distribution planting densities for the next year based upon the known probabilities of receiving selected rainfall amounts during the crop season and upon the amounts normally required for corn (22-23 inches), soybeans (19-20 inches) or oats (about 16 inches). The decision can, then, be periodically readjusted as the planting date approaches and the degree of soil moisture recharge is observed. Relating Table 2 data to the decision-making process can guide the farmers technology (e.g. tillage techniques, fertilizer and chemical applications or irrigation rates if available). In like manner can municipal water suppliers estimate their user requirements at each probability level.

The state average provides a general summary of the below average precipitation regime in Iowa, but as suggested by the ranges of precipitation amounts and deficits in Table 2, considerable variation in average and below average precipitation occurs in the state. To show the spatial pattern and intensity of recurring low precipitation, five series of state precipitation maps were prepared, one for each of the duration periods. Each series consists of precipitation contour maps (isohyetal maps) of the average and recurrence interval amounts for a duration period. The following sections include the map series and a discussion of below average precipitation patterns.

## Spring

The spring period, April through June, is the wetter half of the crop season. Soil moisture is usually at its most abundant level, evapotranspiration is relatively low, and streamflows and water tables are normally at the year's highest level. Late winter snowmelt and increasingly heavier showers from April to June normally cause streamflows to peak near the beginning of this period or in June. During this period an average of 11.6 inches of rain constitutes about 35% of the annual precipitation and more than half of the growing season precipitation.

The early part of the spring period is transitional between subfreezing temperatures and occasional late winter snow (average April snowfall is 1.3 inches) and the growing season. The growing season normally begins in late April in southern and in early May in northern Iowa. Usually by the end of May, about 65% of the state's agricultural crops have been planted. During this quarter of the year with soil preparation, crop planting, and early crop growth, soils are most vulnerable to water and wind erosion. Frequent spring wetness creates soil compaction problems, especially during cold, cloudy, wet spring periods. While warm dry springs are favored for crop planting, the probability for this condition is low. Crop moisture shortages are substantially higher in mid and late growing season.

Average Precipitation (Figure 6)

The precipitation gradient increases south and eastward from less than 10.0 inches in the northwestern to around 12.0 inches in the southern and eastern counties. The heaviest spring quarter precipitation is normally measured at Tipton (13.34 inches) and Cedar Rapids (13.31 inches) in east-central Iowa. From this hub of maximum precipitation there appears to be a three spoke extension of heavier spring rainfall; one extending southwest across Oskaloosa and Osceola to Clarinda, the second across Marshalltown, Boone, and Carroll, and a third extending north and west into an area between Decorah and Hampton. Since spring and summer precipitation is largely characterized by showers and thunderstorms, the variable rainfall intensities may account for part of the spoke-like isohyetal pattern. These isohyetal patterns are similarly developed on other recurrence intervals maps. Some of the relatively low precipitation measurements may be due to the open exposure and higher elevation (above ground level) locations of rain gages -- particularly at airport stations (e.g., Des Moines, Sioux City and Burlington).

2-year Recurrence Interval (Figure 7)

Precipitation for this interval is about 97% of the 30 year average. The isohyetal configuration is very similar to that of the average, except that the state receives about 0.5 inches less precipitation in most areas. Two areas are notable for their very small departure from the average: the driest area of the northwest and the wettest area in the east central parts of the state.

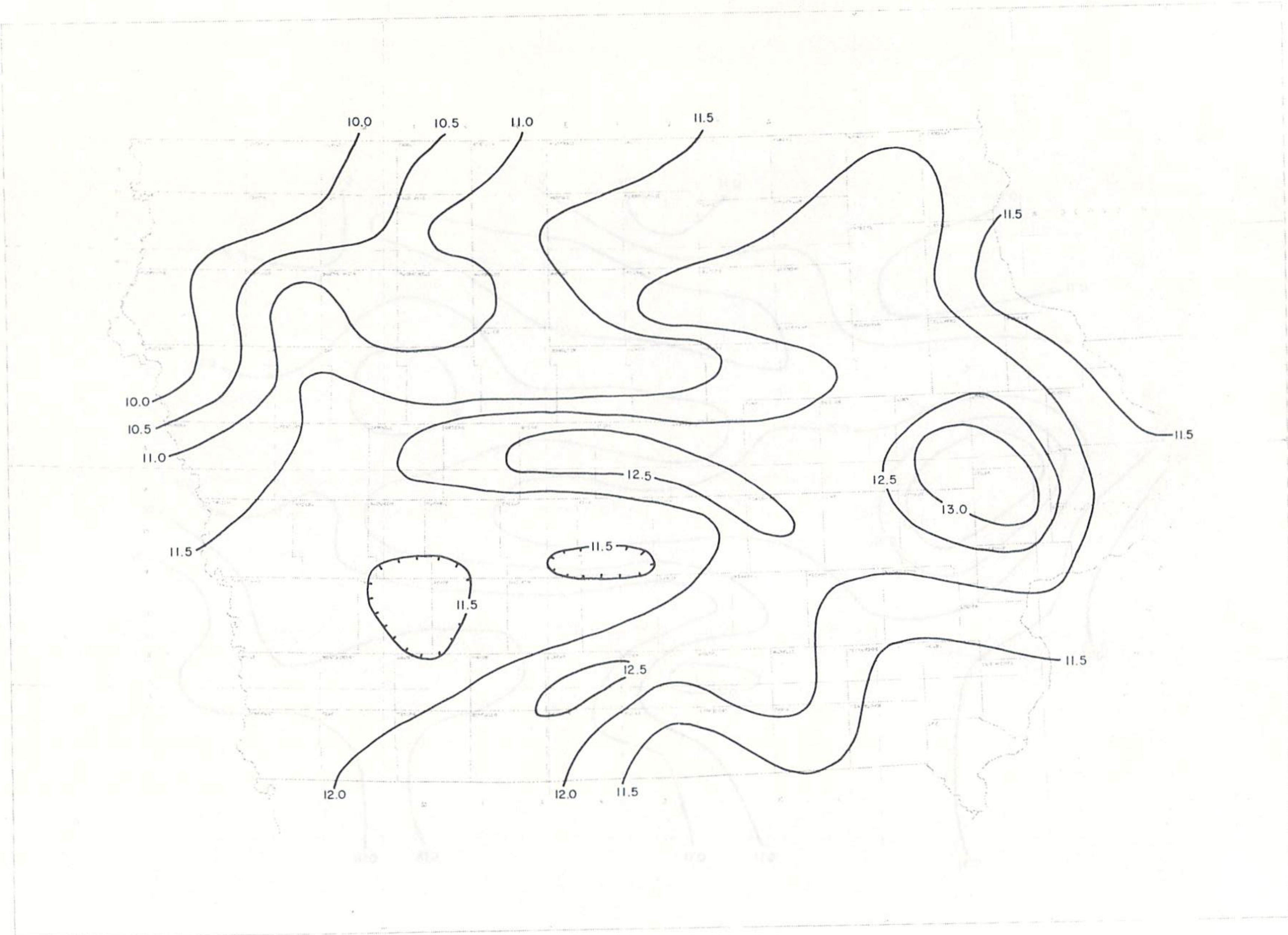



Figure 6. Average precipitation April-June, in inches.

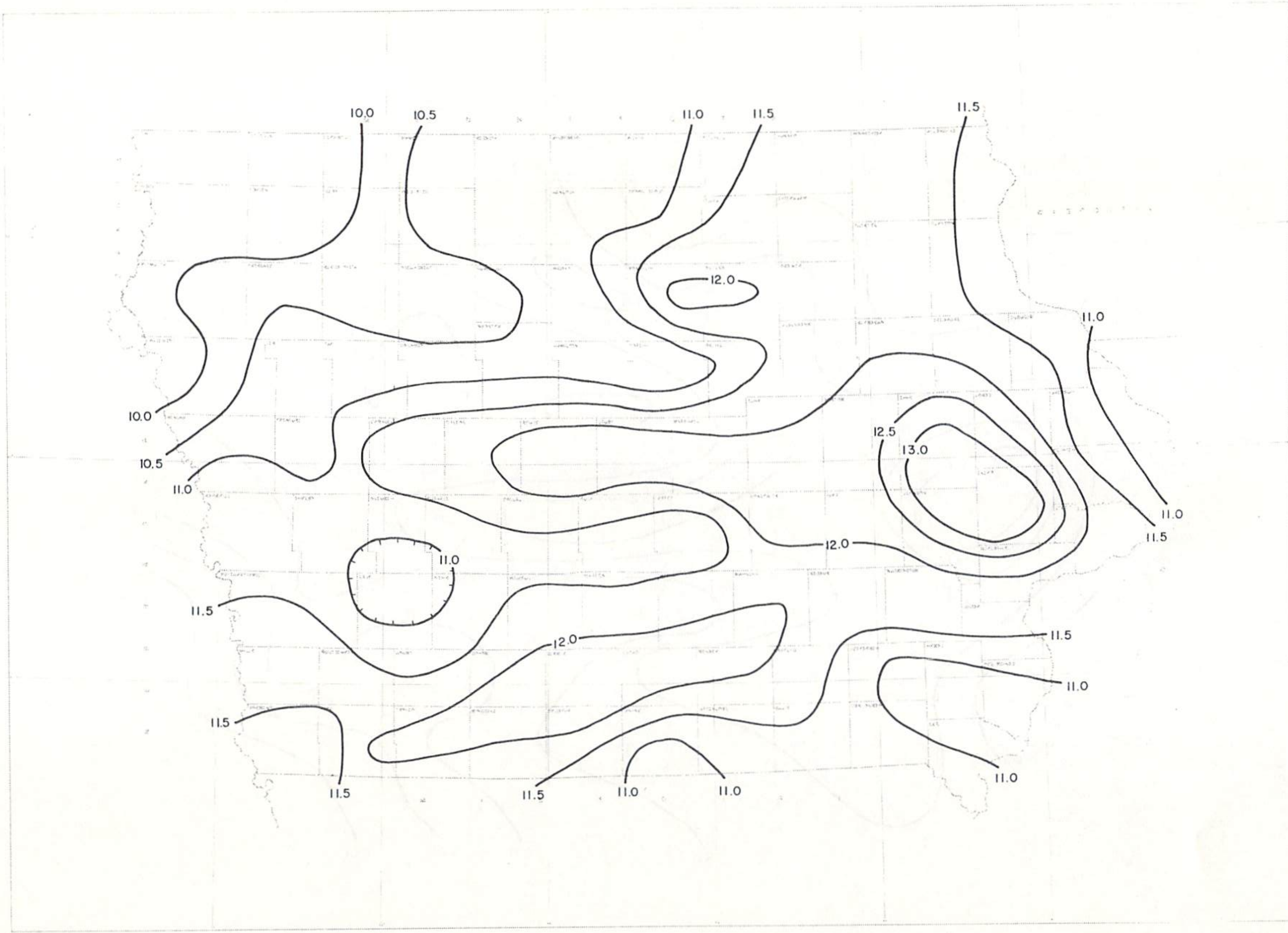



Figure 7. April-June below average precipitation in inches. Recurrence interval 2 years.

5-year Recurrence Interval (Figure 8)

Precipitation reductions to about 72% of the average can be expected to occur on the average of once per five years. This reduction is about 3.3 inches less than is normally expected and approximates the differing precipitation requirements of corn over soybeans. As shown on the map, precipitation varies from 6.6 inches in the northwest (Hawarden) to 10.2 inches in the east central (Tipton); an increase of 55% over the northwest and again at least the seasonal precipitation difference between soybeans and corn.

10-year Recurrence Interval (Figure 9)

Spring precipitation occurring in one year during any 10-year period will be equal to or less than the amounts shown on the map. The amount varies from 5.5 inches in the northwest to over 8.5 inches in the east central for a state average of about 7.0 inches, 60% of the average. Deficits are smaller in the northwest and increase toward the southeast. However, spring precipitation is lowest in the northwest and the impacts of small deficits where precipitation is already marginal can be just as great as where large deficits occur. The southeast shows a decrease of about 50% to around 6.0 inches which is of comparable intensity to some northwest counties.

The once in ten year spring recurrence interval of 6 to 8 inches rainfall provides approximately enough water to support the growing corn crop alone but precludes the usual addition of soil moisture necessary for the peak corn growing and maturation period during July and August.

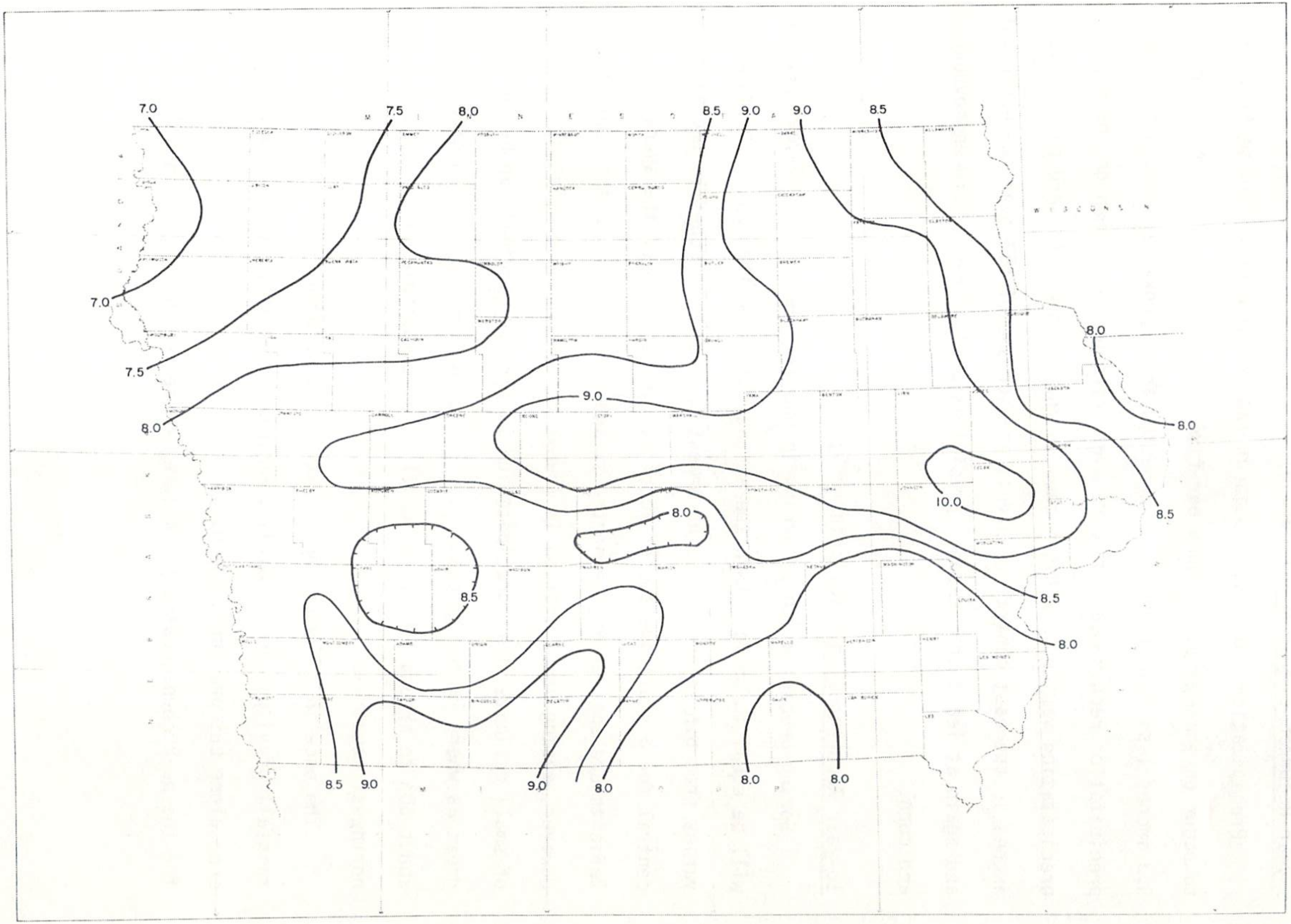



Figure 8. April-June below average precipitation in inches. Recurrence interval 5 years.

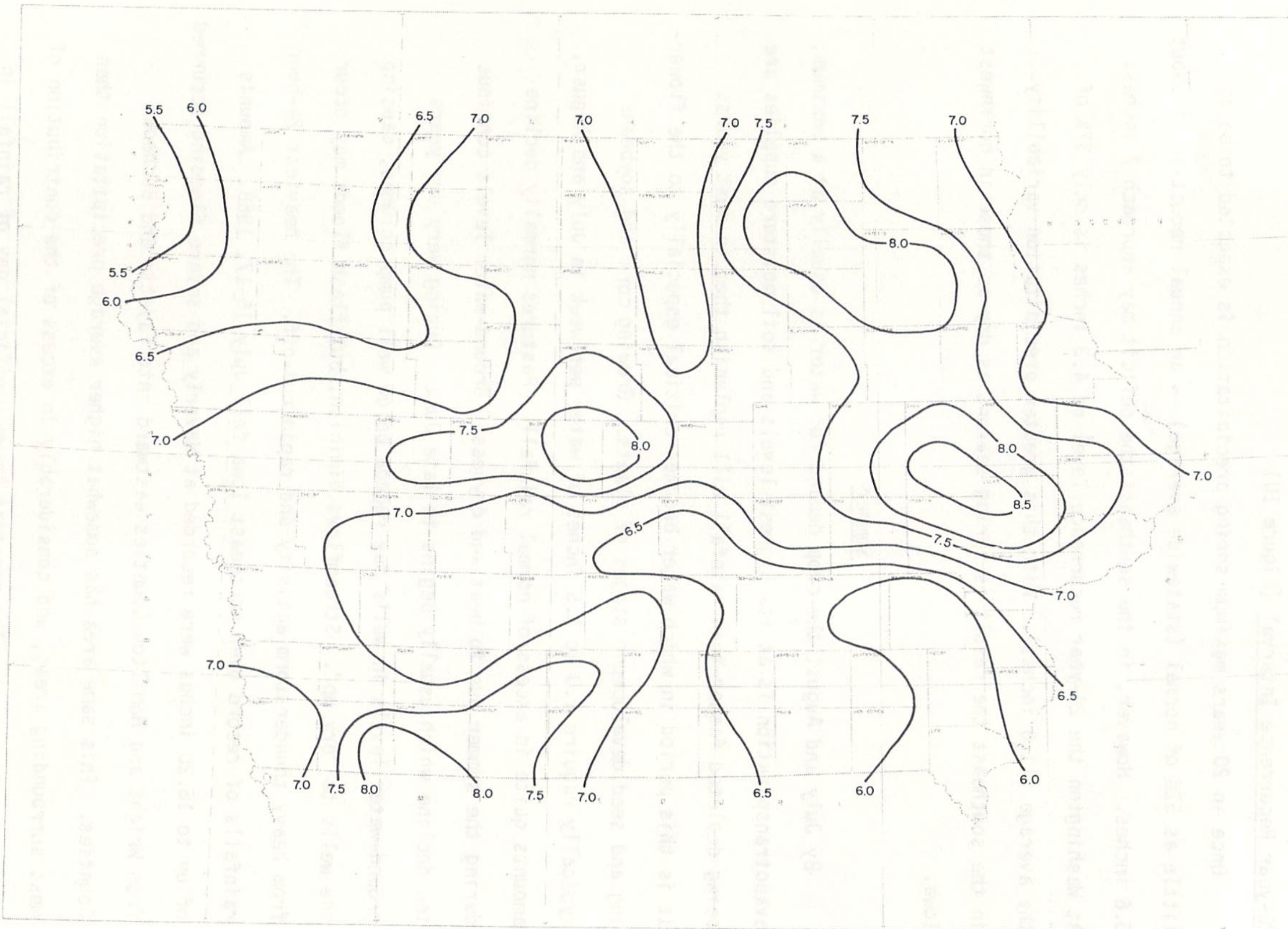



Figure 9. April-June below average precipitation in inches. Recurrence interval 10 years.

20-year Recurrence Interval (Figure 10)

Once in 20 years maximum spring precipitation is expected to be as little as 52% of normal (statewide average) -- an annual reduction of about 5.6 inches. However, in the southeast the deficit may approach 7 inches. At Washington the 20-year recurrence level of 4.3 inches is only 37% of the average (11.6 inches). With this greater precipitation variability in the southeast the result is spring seasons as dry as those in northwest Iowa.

## Summer

By July and August the crop demand for water is usually at a maximum; evapotranspiration is at its highest levels and soil moisture supplies are being depleted faster than rainfall will replenish them in most years. It is this period in which water becomes critical especially to the flowering and seed development stages of plants. Growing corn and soybeans typically require 1.0 to 1.5 inches of water per week in July and August, amounts quite in excess of normal rainfall. Pastures normally decline during the summer due to heat and dryness. Ground-water levels continue the decline which usually begins in late June. During very dry years ground-water levels in wells may recede below well pump columns, causing the wells to "dry up". Streamflows diminish, but flash floods may occur from heavy thunderstorm activity and rapid run-off. The heaviest 24-hour rainfalls of record over northeast Iowa fell July 16-17, 1968. Amounts of up to 16.20 inches were recorded at Waverly and severe flooding occurred from Wright and Hamilton Counties eastward into Fayette and Buchanan Counties. This same area has somewhat higher average precipitation than most surrounding areas, and considerably in excess of the contribution of this one major storm. The greatest known unofficial day of rainfall in

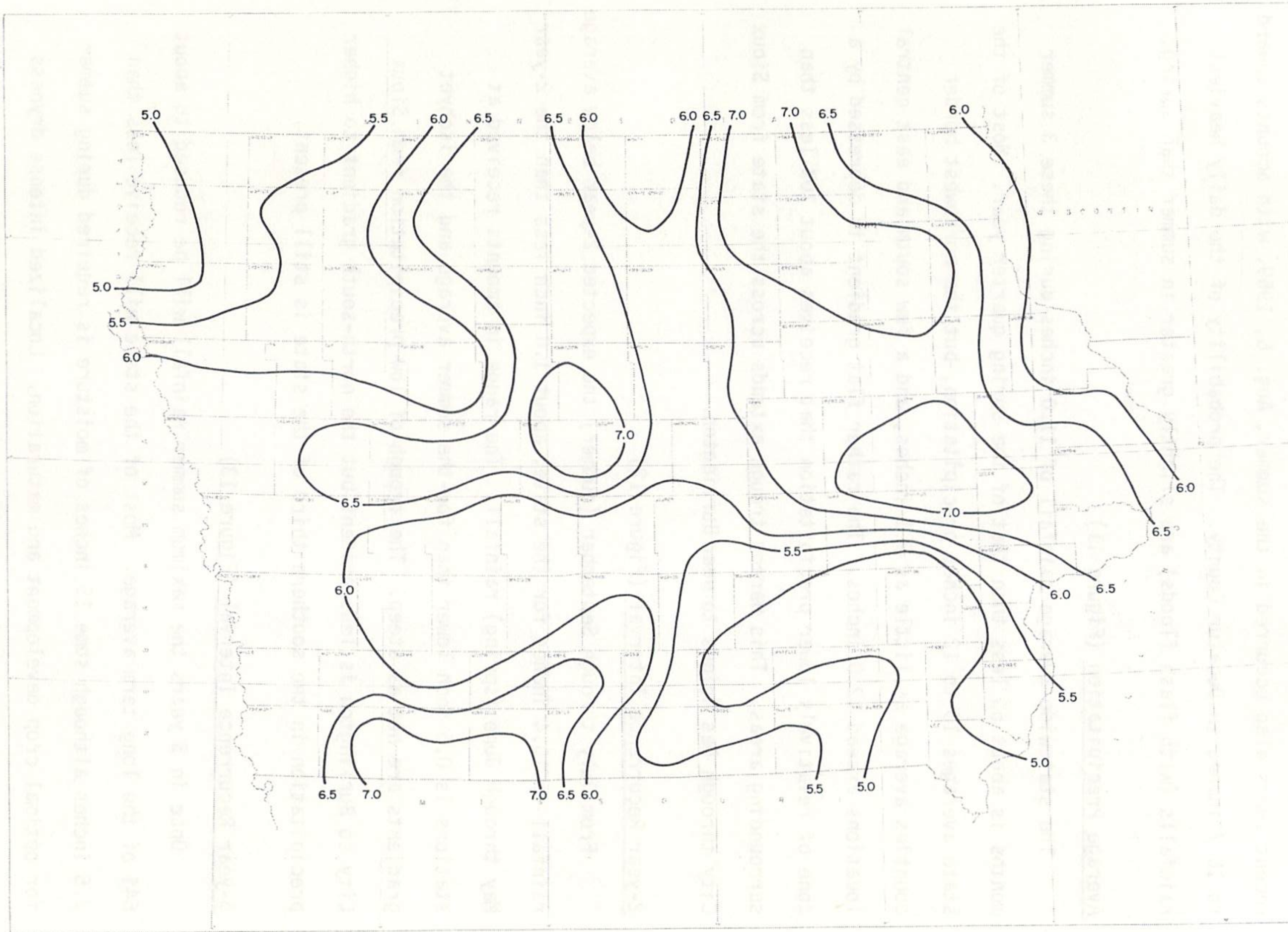



Figure 10. April-June below average precipitation in inches. Recurrence interval 20 years.

recent years also occurred in the summer, Aug. 6, 1959, with amounts upward to 16.7 inches in Decatur County. The probability of the daily heaviest rainfalls (with flash floods) are slightly greater in summer than spring.

Average Precipitation (Figure 11)

The statewide average rainfall of 11.0 inches during these 3 summer months is about 5% less than that of the spring quarter year. Most of the state averages 10 to 12 inches precipitation, but the northwest border counties average as little as 9.1 inches, and a few south and east central locations exceed 12.0 inches. The rather flat gradient is depressed by a zone of relatively lower precipitation that receives about 10% less than surrounding areas. This narrow trough extends across the state from Sioux City through Des Moines to near Burlington.

2-year Recurrence Interval (Figure 12)

From July through September (summer) the expected 2-year below average rainfall is 10.4 inches for the state, about 1.0 inch less than the 2-year May through June (spring) rainfall. The range in amounts received at stations is 0.5 inch lower than for the summer average and the isohyet gradients are not as steep. The trough of low precipitation from Sioux City to Burlington is less evident but the north-south gradient to higher precipitation in the southern third of the state is still present.

5-year Recurrence Interval (Figure 13)

Once in 5 years the maximum summer rainfall will be reduced to about 64% of the long term average. Most of the state will receive less than 7.5 inches although some 15 inches of moisture is required during summer for optimal crop development and maturation. Localized intense dryness in 1976 and other years, especially in the Boone-Marshalltown area,

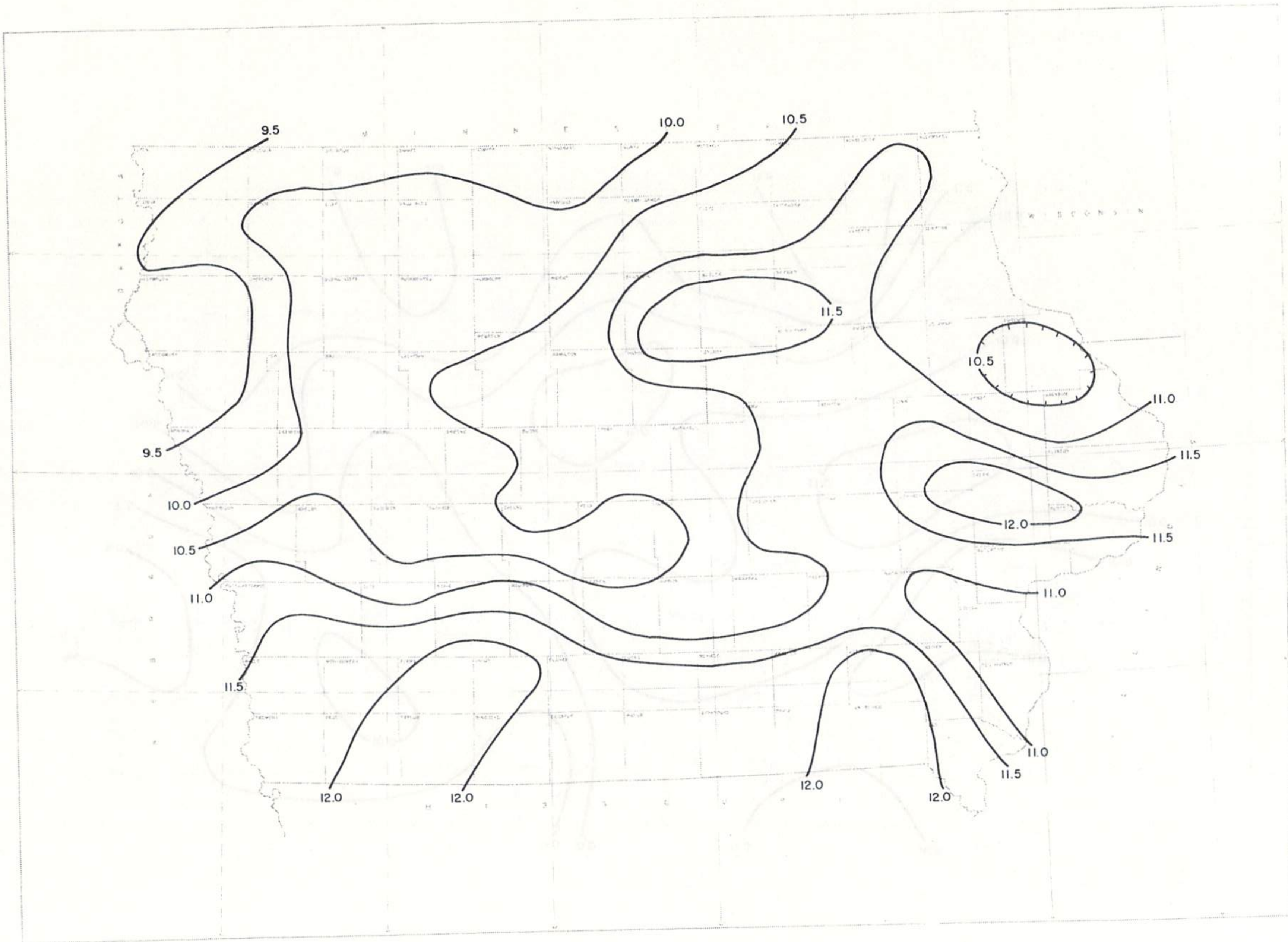



Figure 11. Average precipitation July-August, in inches.

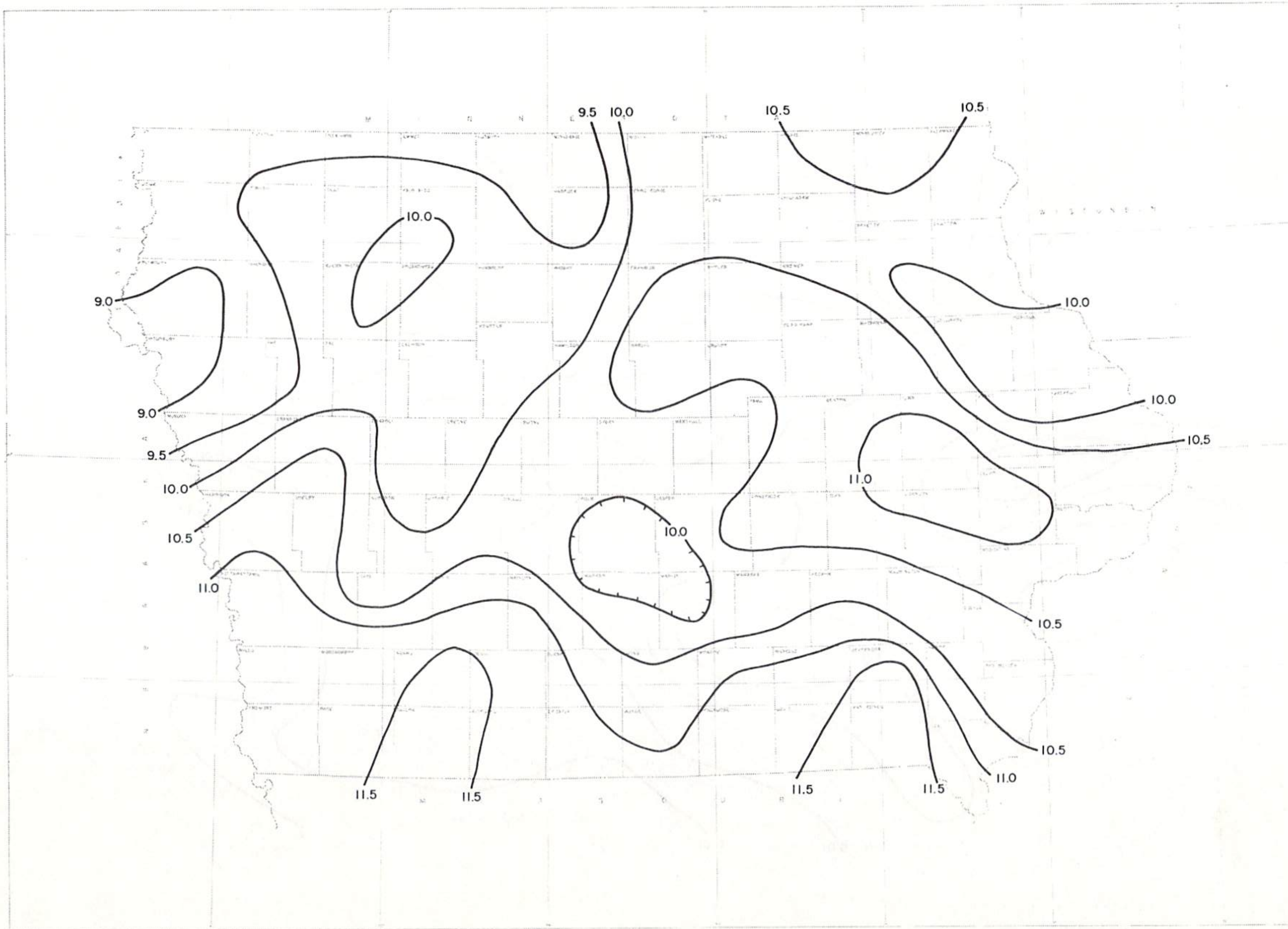



Figure 12. July-August below average precipitation in inches. Recurrence interval 2 years.

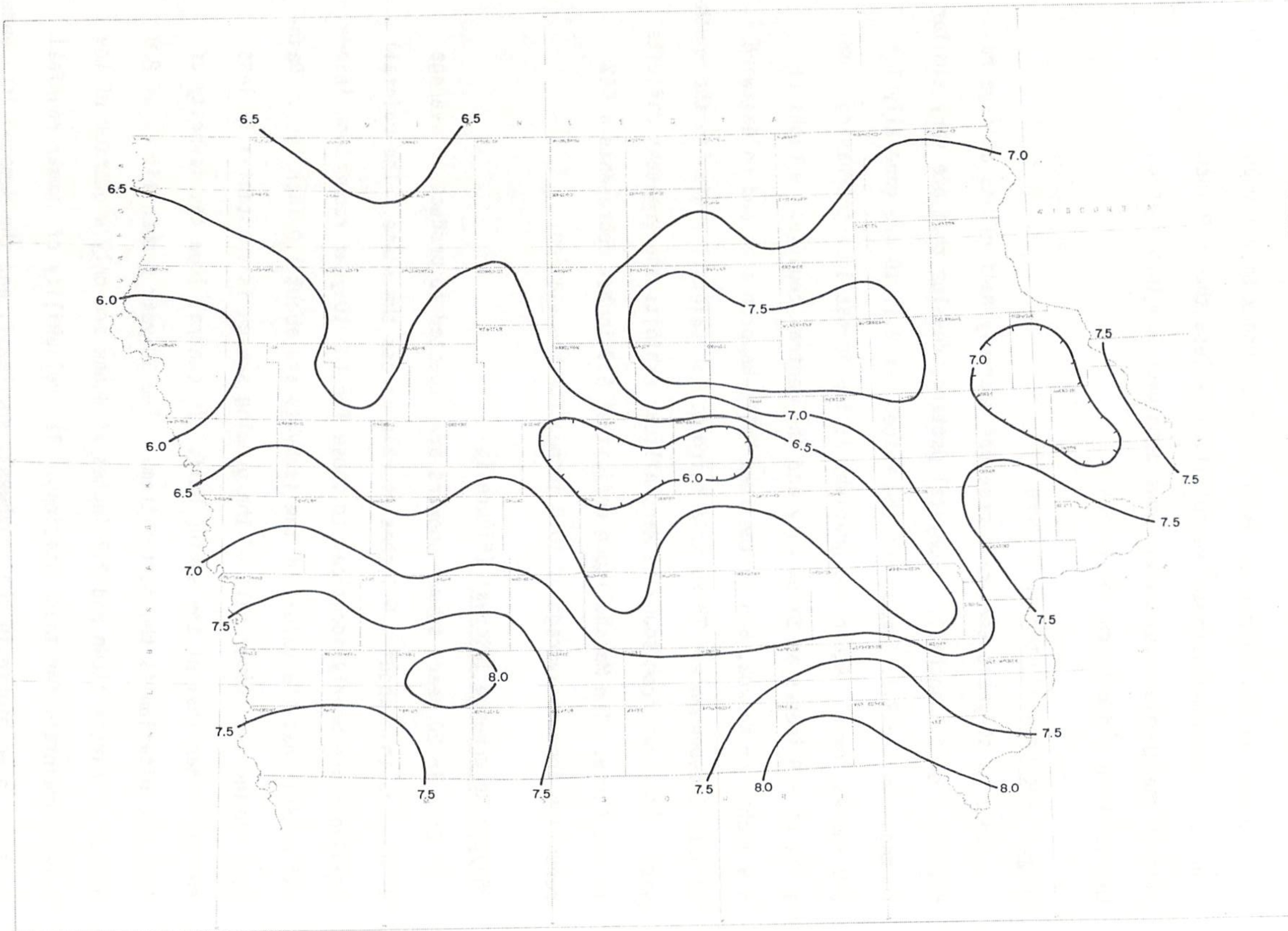


Figure 13. July-August below average precipitation in inches. Recurrence interval 5 years.

accentuated the low precipitation trough from Sioux City through the central counties. Expected maximum precipitation is less than 6.0 inches in this part of the gradient but ranges upward to over 7.0 inches across most of the southern and eastern localities.

10-year Recurrence Interval (Figure 14)

Once in 10-years the state receives scarcely half of its average rainfall (51% or 5.6 inches). Isohyetal patterns develop that are very similar to those on the R.I. 5 map, but the values for R.I. 10 are generally 1.5-2.0 inches lower. Again the gradient is low across Iowa increasing from a low of 3.9 inches at Sioux City and the central counties to highs of 6.9 inches at Keokuk, 6.5 in the Iowa Falls-Hampton area and on eastward to near Independence. There is a third higher rainfall region in the southwest. The area from Boone to Marshalltown exhibits the greatest deficits in the state. The Marshalltown deficit of 6.9 inches represents a 64% reduction from an average of 10.8 inches for the station.

20-year Recurrence Interval (Figure 15)

Once in 20 years summer showers are expected to produce an average of no more than about 4.6 inches of rain across the state. The rainfall gradients are nearly identical to those for the 10-year recurrence interval except that the values of the isohyets are about 1.0 inch less. Rainfall during the summer half of the growing season is substantially less reliable than that of the spring half. In central Iowa the severity of low precipitation is the most extreme. The 20-year probabilities of 2.8 inches at Marshalltown and 2.7 inches at Boone are only a quarter of the average rainfall for these stations. The reliability of summer rainfall appears to be higher in the southwest, southeast, and the Hampton-Independence

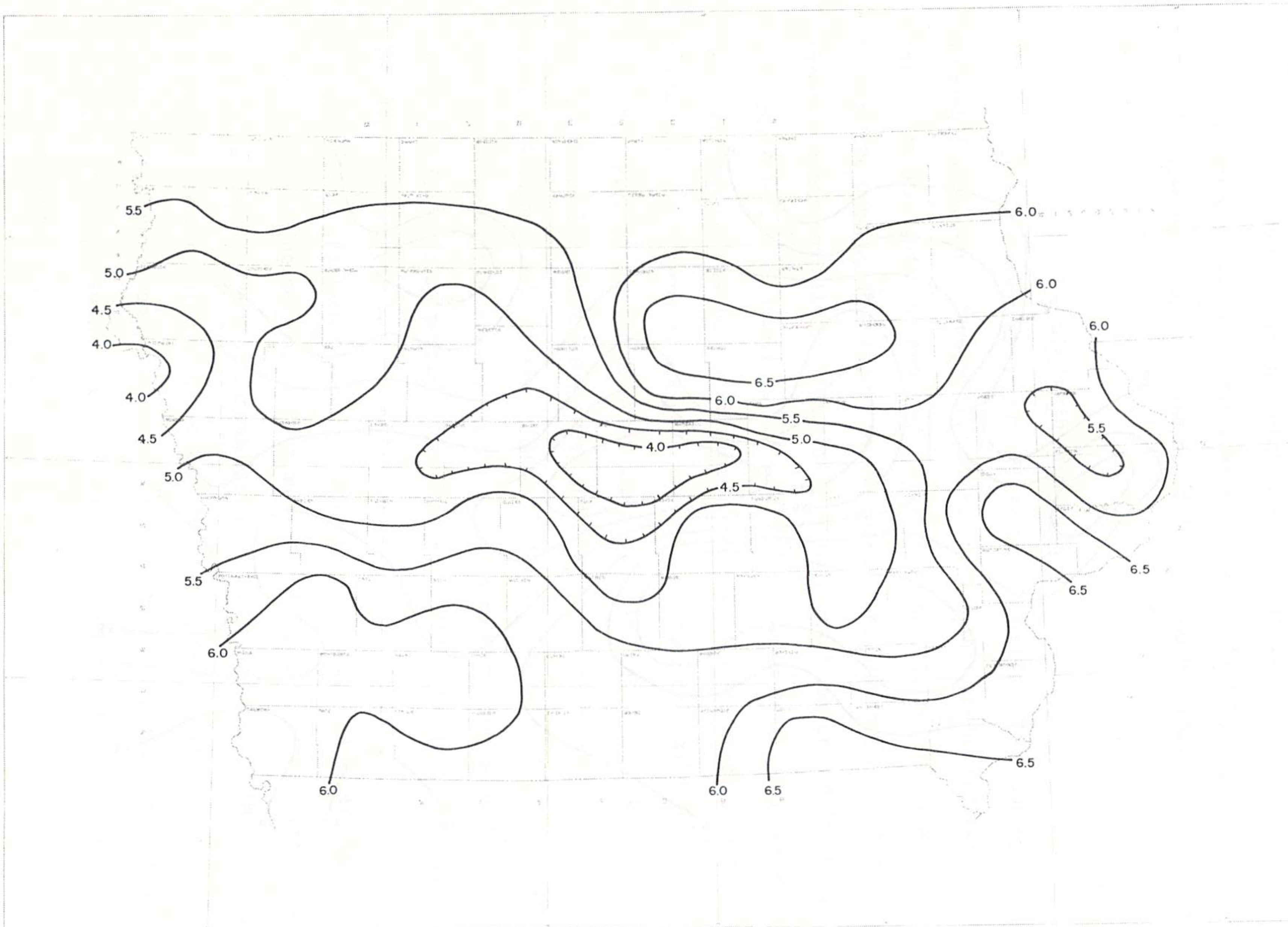



Figure 14. July-August below average precipitation in inches. Recurrence interval 10 years.

Recurring seasons of below average precipitation have stimulated interest in irrigation as a supplement during periods of water deficit, and as a mechanism to improve crop yields. The Iowa Natural Resources Council reports that before 1975 the number of requests remained relatively constant or increased slowly from year to year. Their records show that the number of irrigation permits in force by the end of the water year 1965 was 546; in 1970, 616; and in 1974, 726. However, during the drier mid-1970s, the number of permits increased dramatically, from 788 in 1975 to 1,534 in 1978. By early 1979, 341,000 acre feet of water was authorized for the irrigation of 276,000 acres. This is 13-14 inches per acre to supplement crop water needs not satisfied by rainfall or soil moisture. Although not all authorized water may be used during a particular growing season, the figures do indicate the impact of below normal rainfall on agriculture. The trend in irrigation also illustrates how the impacts vary with social conditions. Namely, the drought of the mid 1950s was more intense climatically, but irrigation then was not as technically and economically feasible. By the 1970s suitable irrigation equipment, particularly center pivot systems, adaptable to the hilly Iowa terrain became available. And, with these technical advances and more attractive economics, irrigation has enjoyed a greater role as an accepted agricultural practice.

Yet irrigation, at the above rates, in dry years constitutes the "mining" of ground water supplies and will become relatively more expensive as water levels drop and energy prices rise. This situation may hasten the use of rainfall enhancement techniques -- cloud seeding. Even though Great Plains results have been mixed, once perfected, this technique for supplying additional moisture during the crop growing season promises to be the more economical water production source for crops.

Average Precipitation (Figure 16)

Statewide precipitation during the growing season averages 22.6 inches, but ranges from less than 20 inches in the northwest to over 24 inches over part of the south and the east. Two relatively drier areas extend from Pottawattamie County through the center of the state to southeast counties along the Mississippi River and from Grundy to Pocahontas County. These probably result from the variability of shower intensities and, in part, to the siting of some rain gages.

The 6-month average precipitation values represent the average of both the spring and summer periods. Seldom, in a given year, are both periods notably dry; instead one relatively wet or dry period during the growing season is more common (see Figures 4 and 5), and tends to modulate the severity of average precipitation deficits shown for the 6-month period. By comparison, the individual 3-month periods appear more severe. This is evident in the state summary data in Table 2. The expected minimum precipitation at all recurrence intervals is larger for the growing season.

2-year Recurrence Interval (Figure 17)

Precipitation deficits at the 2-year recurrence interval are negligible and maximum deficits do not exceed one inch at any station. The statewide average deficit is only 0.4 inch and is lower than the average deficit for the three summer months (July - September). Statewide, precipitation for this frequency is 98% of the period average and the general trends of the isohyetal gradients are similar to those for average precipitation.

5-year Recurrence Interval (Figure 18)

In one of five years, the precipitation during the growing season can range down to about 14 inches in the far northwest to 19.0 inches in portions of the southwest and east-central Iowa. The average across the


Figure 16. Average precipitation April-September in inches.

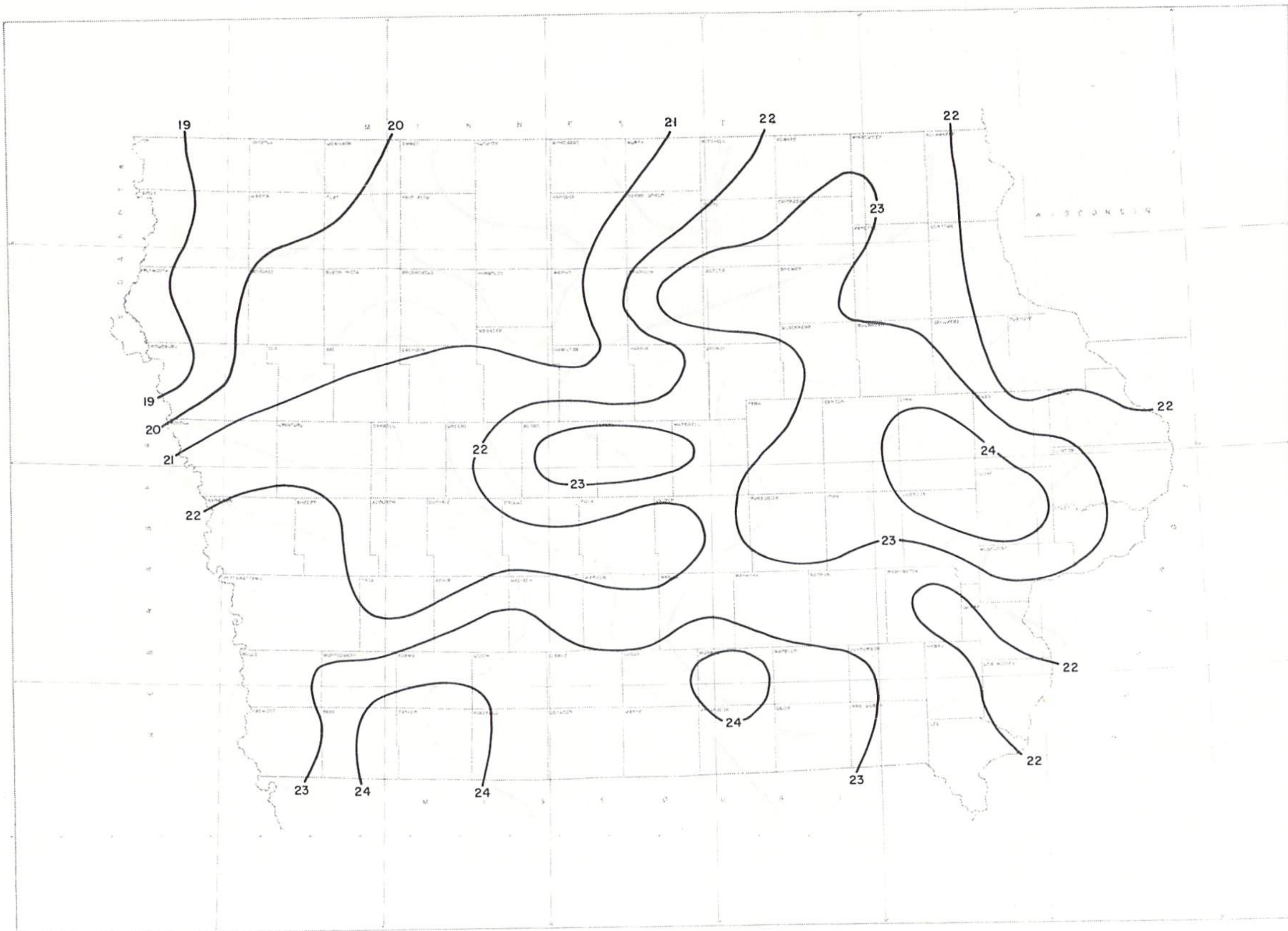



Figure 17. April-September below average precipitation in inches. Recurrence interval 2 years.

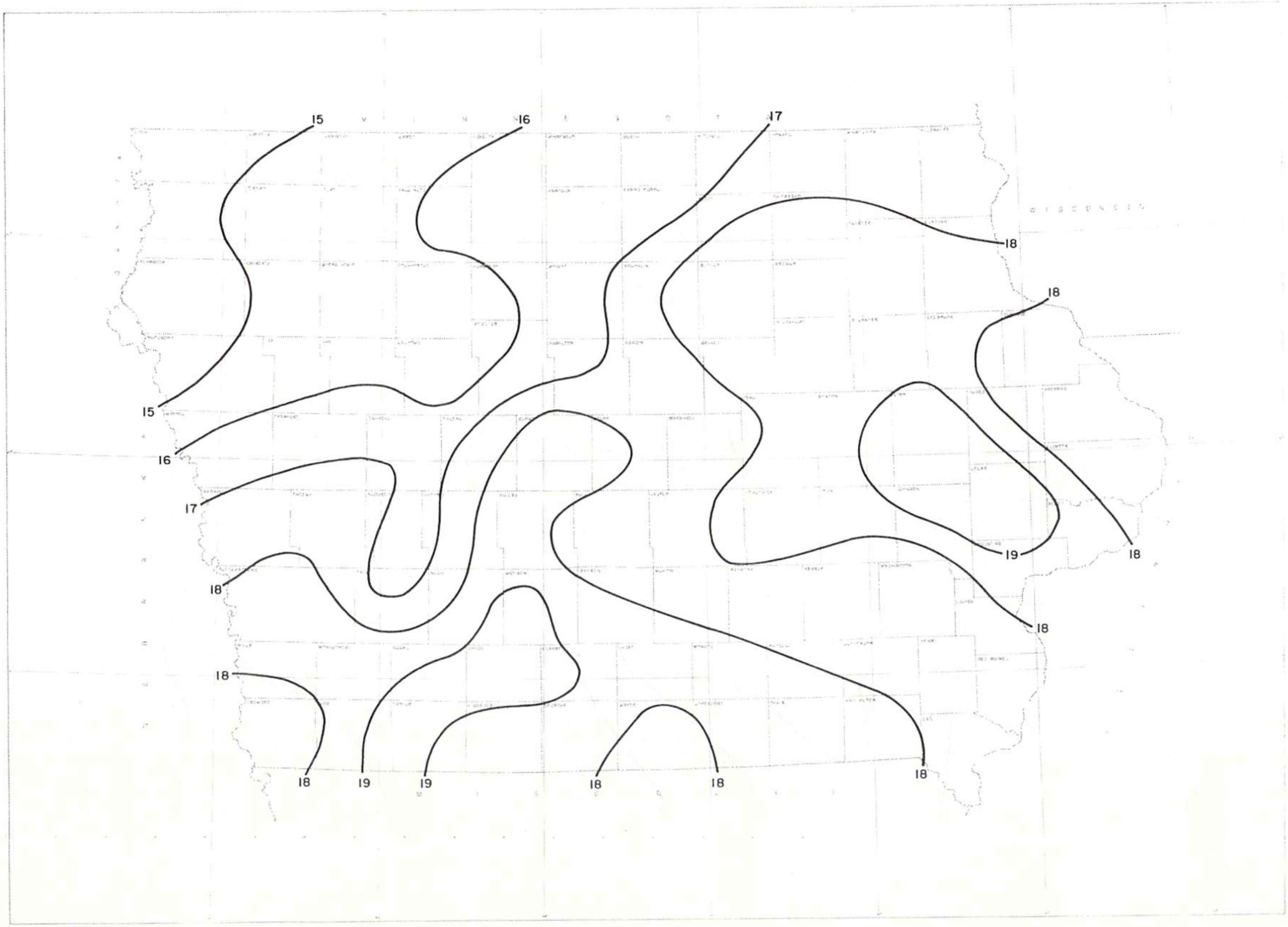



Figure 18. April-September below average precipitation in inches. Recurrence interval 5 years.

state can diminish to about 17.0 inches. Since 20-23 inches of water is required for optimal crop production, most areas of the state once in five years can experience crop moisture deficits, unless the season is begun with ample soil moisture reserves.

<u>10-year Recurrence Interval</u> (Figure 19)

The minimum 10-year growing season precipitation averages 15.3 inches (68% of the normal average or a deficit of 7.3 inches) but dried conditions are noted in the northwest 13.0 inches, ranging to 18 inches at Tipton across most of the east and south where precipitation is 25% to 40% greater than in the northwest. Rarely are pre-growing season soil moisture, ground water levels, reservoir storage, and streamflows so adequate that a deficiency of this magnitude does not cause serious crop stress and generally impacted water supplies. Under these conditions irrigation of general field crops and pastures is attractive and beneficial.

<u>20-year Recurrence Interval</u> (Figure 20)

In one out of 20 growing seasons the state receives only about 60% of the average precipitation. This means 6 month totals of less than 12 inches in northwest Iowa and few localitites in the state with as much as 16.0 inches. This normally leads to serious drought, particularly if accompanied by hot dry winds. Such conditions prevailed over much of the growing season in 1936 with the month of July being the most severe. During this month the state's average precipitation was only 0.51 inches, the average temperature was 83.4°F (8.8°F above average), the relative humidity was 31% (22% below 12:00 noon average), and skies were relatively cloudless (91% possible sunshine, 15% above average). Late season rains in 1936 marked the end of the drought, when in September an average of 7.22 inches of rain fell. This accounted for 41% of the season's total, but occurred too late to reconcile the most severe

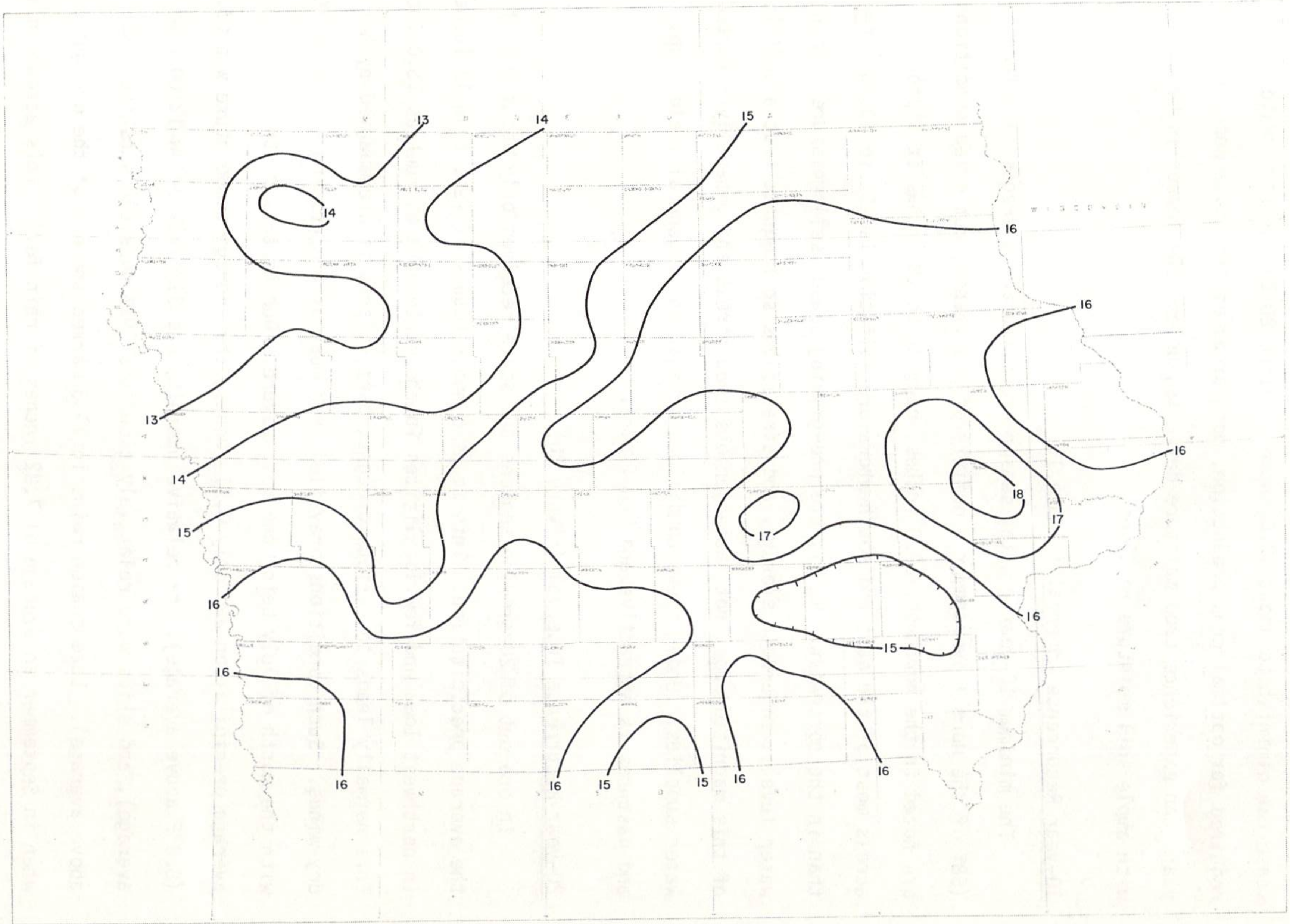



Figure 19. April-September below average precipitation in inches. Recurrence interval 10 years.

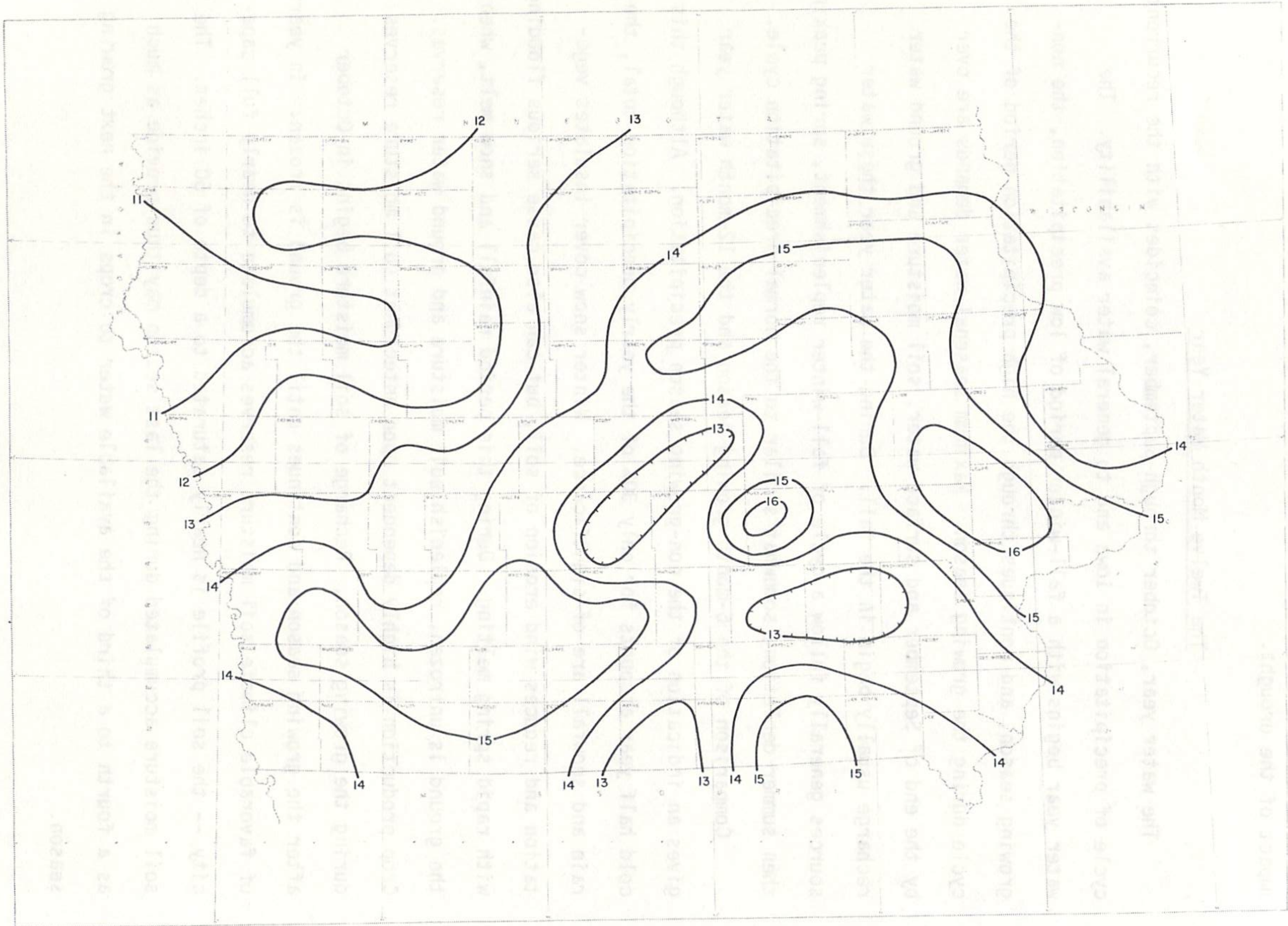



Figure 20. April-September below average precipitation in inches. Recurrence interval 20 years.

impact of the drought.

## The Twelve Month Water Year

The water year, October through September, coincides with the recurrent cycle of precipitation in Iowa and to general water availability. The water year begins with a fall-winter period of low precipitation, the non-growing season, and continues through the high precipitation period of the cycle during the growing season. Maximum seasonal water demands are over by the end of September and surface water, soil moisture and ground water recharge usually begin in the fall. During the water year these water sources generally follow a cycle of fall-winter replenishment, spring peaking, then summer depletion, somewhat similar to the normal precipitation cycle.

Comparison of the 6-month growing season and the 12-month water year gives an indication of the non-growing season precipitation. Although this cold half year accounts for only 30% of the yearly precipitation total, the rain and snowfall are of significance. Winter snow cover insulates vegetation and reduces wind erosion of soil, but can also cause serious flooding with rapid spring melting. During this period rainfall and snow melt, when the ground is unfrozen, replenish soil moisture and ground water reserves. Crop production is highly dependent upon antecedent soil moisture reserves during the growing season. Recharge of soil moisture begins in October after the growing season and continues until the ground is frozen. In years of favorable climate soil moisture reserves accumulate to nearly full capacity -- the soil profile is nearly saturated to a depth of 60 inches. The soil moisture accumulated during the last season may thus provide as much as a fourth to a third of the available water to crops in the next growing season.

Average Precipitation (Figure 21)

The average 12-month precipitation in most of the state provides sufficient water for most uses. The state average is nearly 32 inches, but varies northwest to southeast from 25 inches at Rock Rapids to 38 inches at Tipton. A variable gradient is apparent with heavier rainfall across most of the south, from Tipton-Cedar Rapids, and from the Hampton-Allison area west-northwest through Emmetsburg. Lower rainfall in the Des Moines-Sigourney-Burlington areas is quite apparent. This reflects the strong influence of the pattern during the growing season. Another light precipitation path is observed from Cherokee through Hamilton and Grundy counties.

2-year Recurrence Interval (Figure 22)

The 2-year, 12-month precipitation reflects only a 2% (0.5 inch) average deficit across the state but with greater variation in the mid-state. Otherwise, the general isohyetal pattern differs little from that of the 30-year average. The 2-year interval suggests that precipitation variations at that level may be less significant than other factors on crop production - e.g. temporal rainfall patterns or heavy rains with large run-offs.

5-year Recurrence Interval (Figure 23)

Once in five years the 12-month precipitation total for the state can be reduced by as much as 18% (5.2 inches) to a state average of 26.0 inches. Such deficits can cause serious concerns. Yet with good antecedent water conditions (e.g., high ground-water and reservoir levels, and adequate soil moisture reserves) water supplies for most purposes can be available. Crops may fare very well as they did in 1966 when the state average was only 26 inches. But, in 1966 antecedent moisture conditions were adequate and summer temperatures, fortunately, were moderate. By

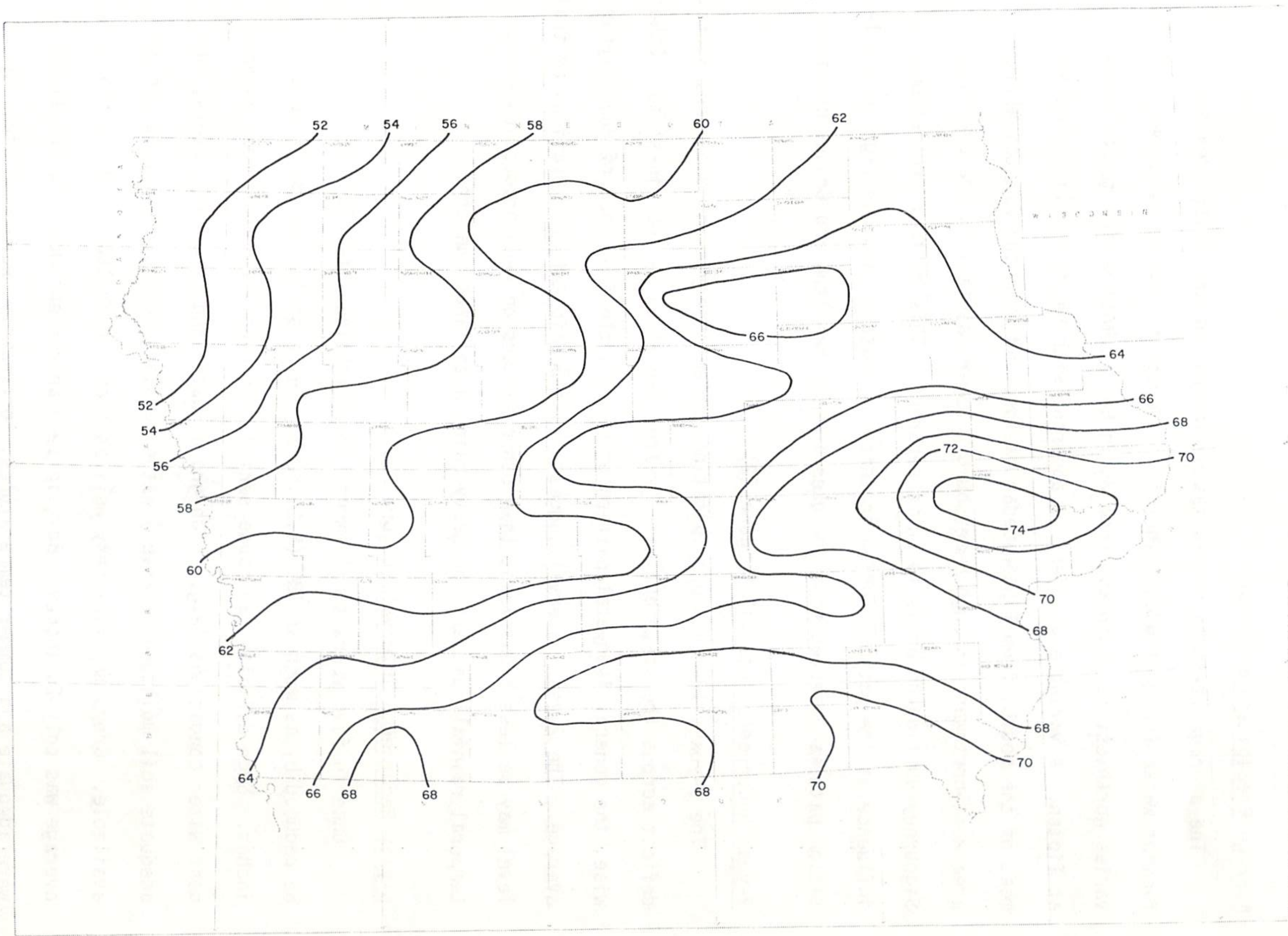



Figure 21. Average annual precipitation in inches.

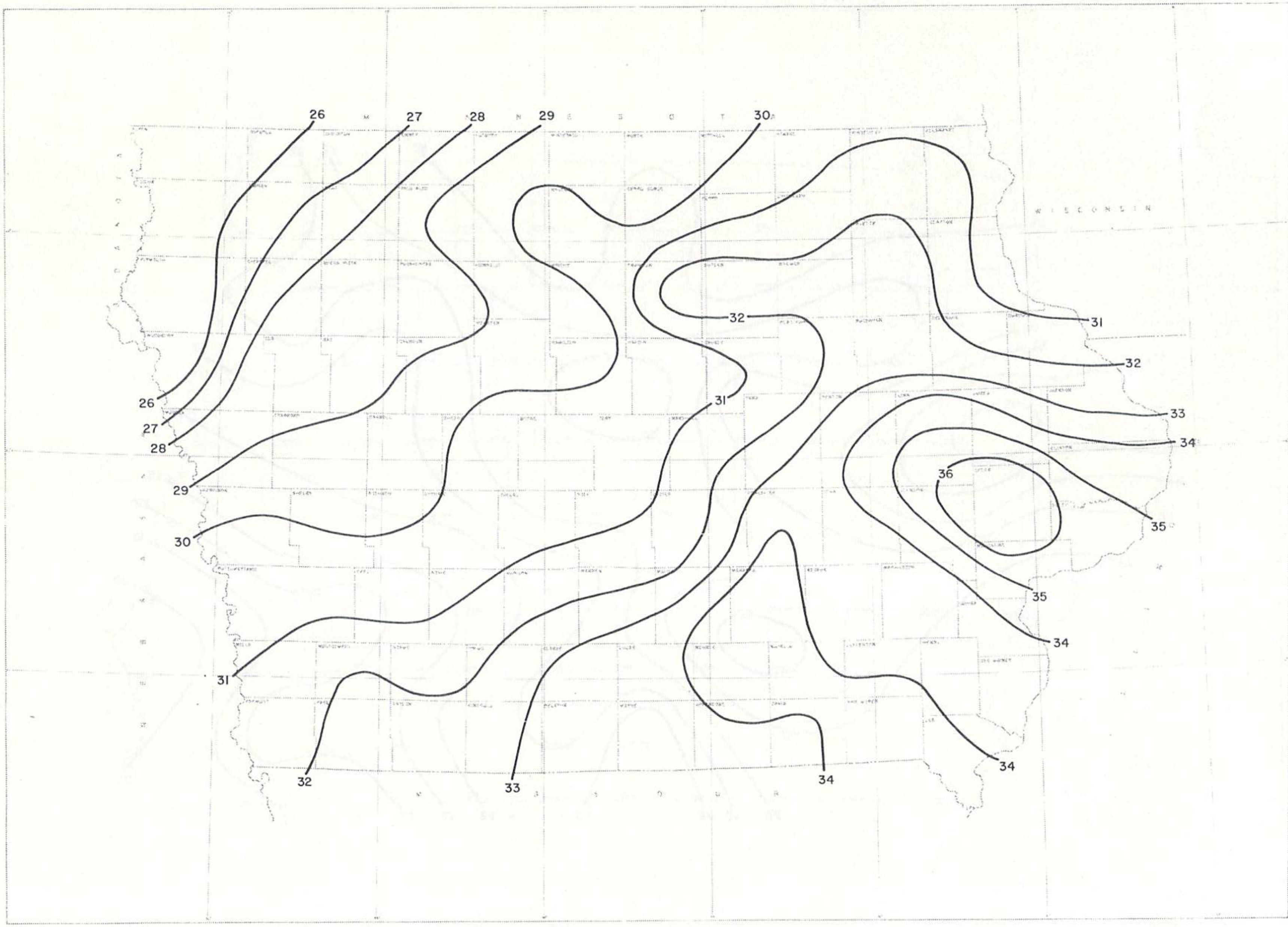



Figure 22. 12 month below average precipitation in inches. Recurrence interval 2 years.

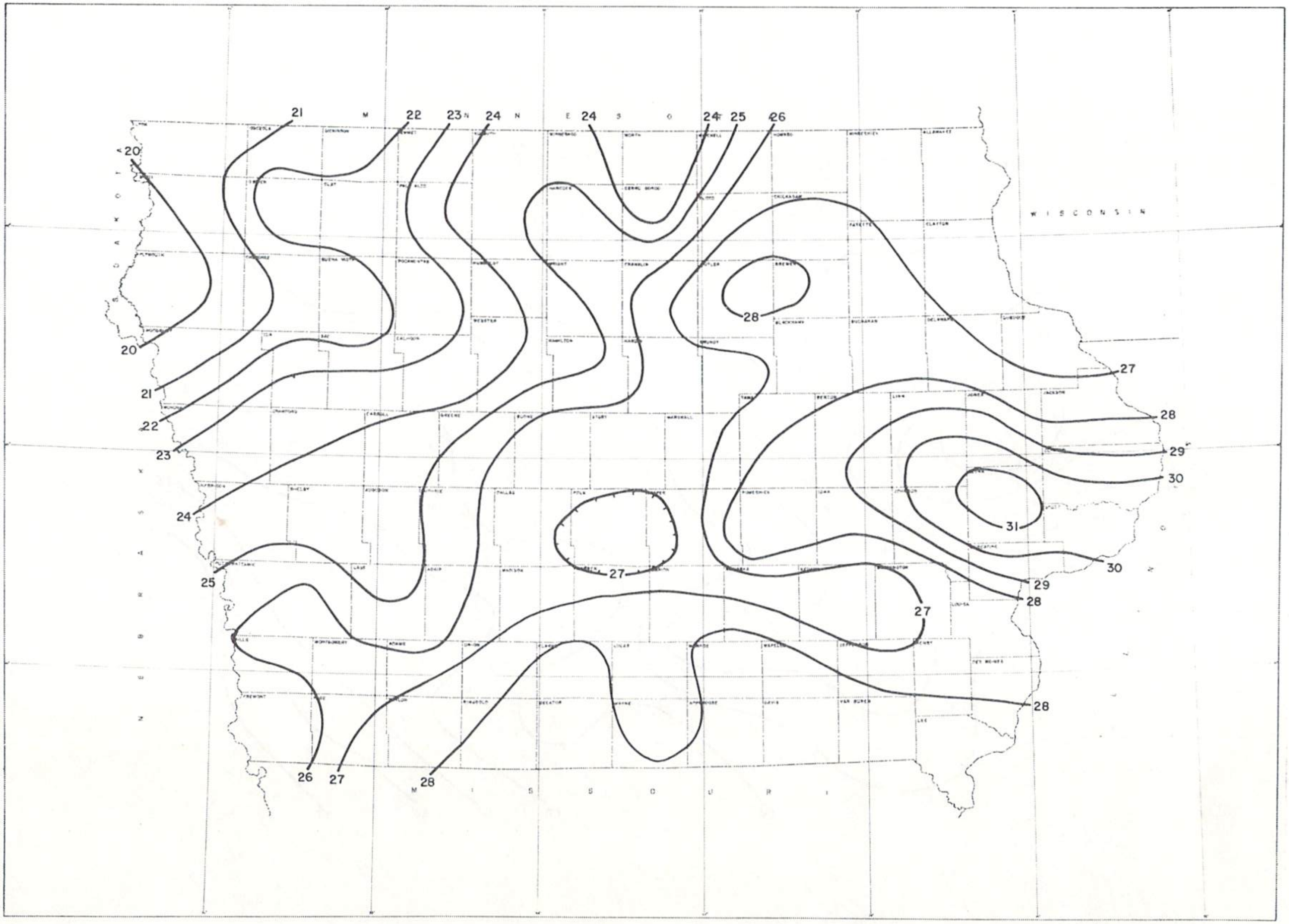



Figure 23. 12 month below average precipitation in inches. Recurrence interval 5 years.

contrast, the October 1975-1976 water year also averaged 26.0 inches of precipitation and serious drought conditions prevailed, substantially reducing crop production, drying up pastures by late summer, and reducing streamflows to a fraction of normal. The difference being that much warmer than average temperatures were experienced in 1976, and the growing season was approached with less than ideal antecedent water conditions.

10-year Recurrence Interval (Figure 24)

The 10-year frequency map shows a precipitation gradient from less than 19 inches in the northwest to over 28 inches in east-central Iowa. On a statewide basis the average is depressed by 26% to 23.6 inches, an amount associated with relatively severe dryness. The 1956 water year average of 22.9 inches is slightly less than the 10-year recurrence value but is an example approximating this level of dryness with water supply shortages, crop reductions, and economic pressures on Iowa's farm economy.

20-year Recurrence Interval (Figure 25)

The 20-year precipitation pattern is typical of the worst drought years that have affected Iowa. Somewhat cyclically, about once in each 20 to 22 years, Iowa can anticipate major precipitation deficits that are, on the average, about 10 inches less than normal. The effects of these occurrences are disastrous for agriculture in that they are usually accompanied by above normal temperatures and searing winds. During these periods the precipitation gradient ranges from under 16 inches in northwestern Iowa to a high of only 22 to 27 inches at the eastern boundary of the state.

The once in 20 year reduction of yearly precipitation by about ten inches provides Iowa a climate more nearly approximating that of Nebraska, and with it the same needs for supplemental water sources. From past experience we are aware of the cyclical nature of Iowa's major droughts

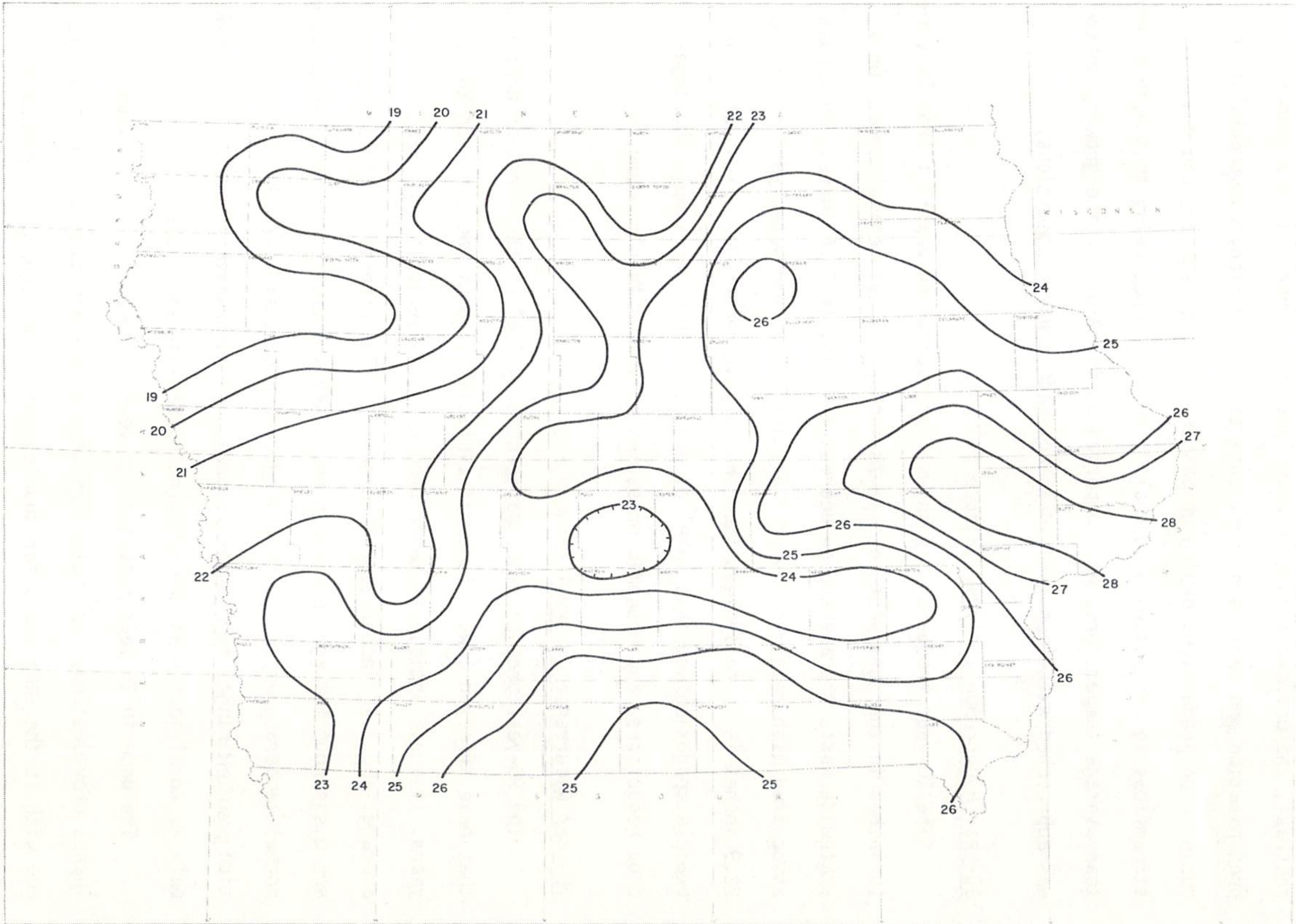



Figure 24. 12 month below average precipitation in inches. Recurrence interval 10 years.

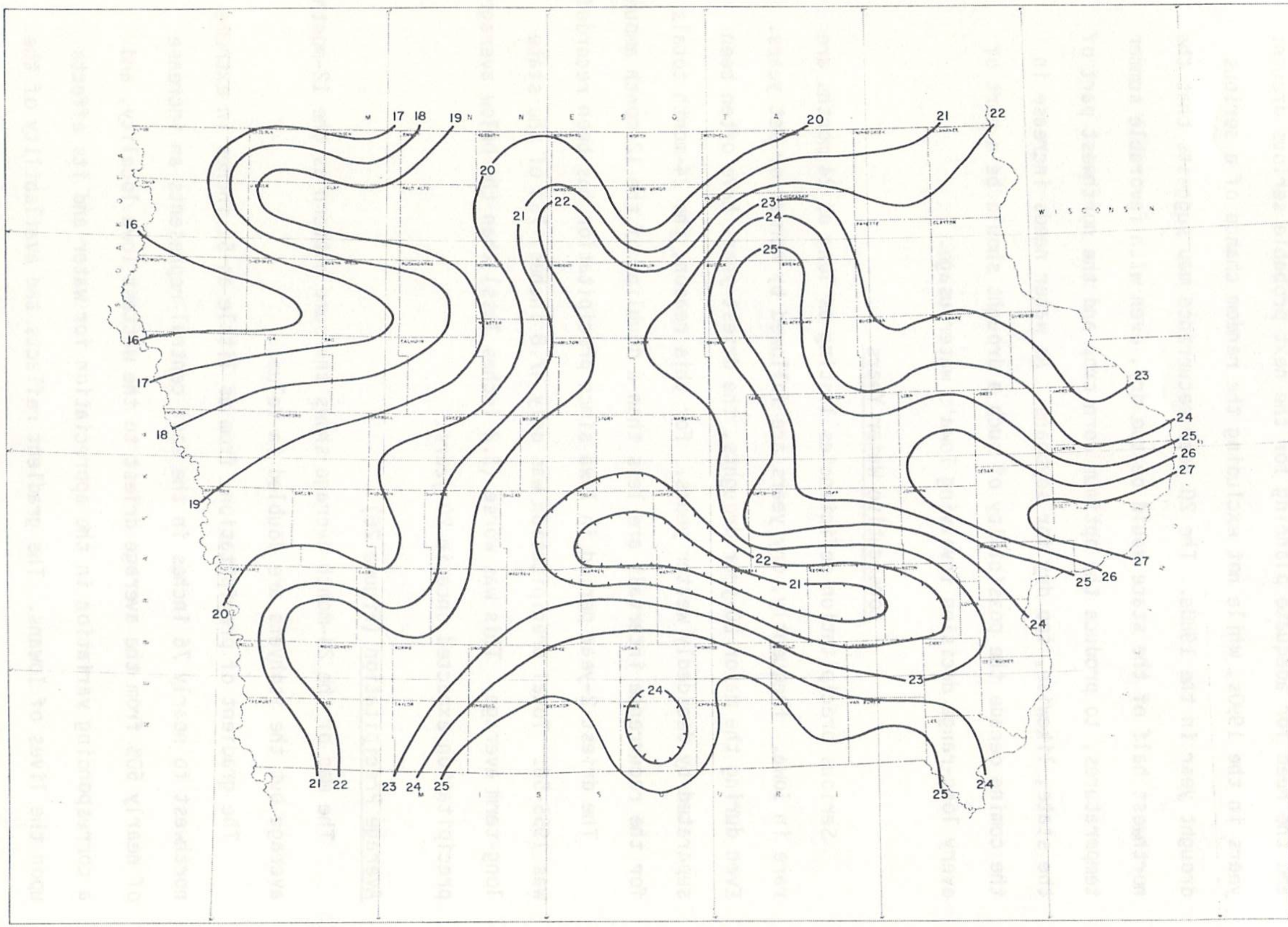



Figure 25. 12 month below average precipitation in inches. Recurrence interval 20 years.

and the need for adequate planning for the next probable serious drought years in the 1990s, while not excluding the random chance of a serious drought year in the 1980s. The 20 year recurrence map suggests that the northwest half of the state would be too dry, even with favorable summer temperatures, to produce the optimum corn crop and the northwest part of the state, likewise, too dry for soybeans. As water needs increase in the coming decade the possibility of such a drought should be a part of every long-range decision involving Iowa's water usage.

## Consecutive Water Years

Serious precipitation deficiencies lasting as long as 24 months are rare in Iowa. Frequently, dry years are followed by normal or wet years. Even during the major 20-year droughts, the driest years have often been separated by decidedly wetter years. For this reason, the 24-month totals for the recurrence intervals are less than a doubling of the 12-month amounts.

The driest 2-year period in Iowa since precipitation has been recorded was 1955-56. Total precipitation was only 47.8 inches, 75% of the state long-term average. This was worse (3.2 inches less) than the below average precipitation expected once in 20 years.

### Average Precipitation (Figure 26)

The map of the 24-month average shows the same pattern as the 12-month average but the isohyets are doubled in value.

The gradient of precipitation, from as little as 51 inches in extreme northwest to nearly 76 inches in the east central represents an increase of nearly 50% from the average driest to the wettest Iowa locality, and a corresponding variation in the appreciation for water and its effects upon the lives of Iowans. The gradient reflects the availability of the

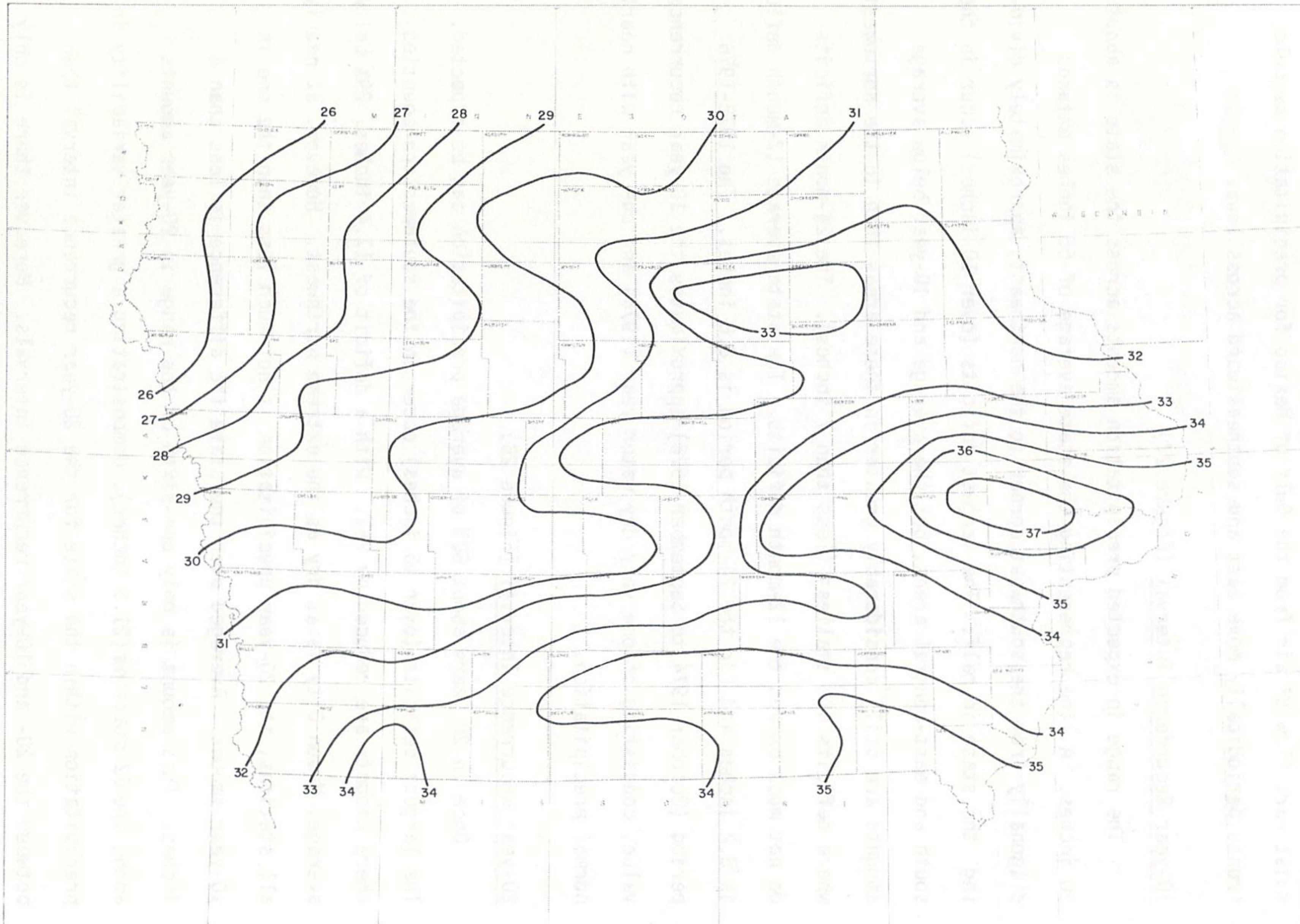



Figure 26. 24 month average precipitation in inches.

moist warm flow of air from the Gulf of Mexico for precipitation as cold fronts periodically move east and southeastward across Iowa.

10-year Recurrence Interval (Figure 27)

The range in expected precipitation amounts across the state is about 20 inches. A line representing the state average of 55 inches extends diagonally from the southwest corner to the northeast, approximately dividing the state in half. The largest deficits (over 10 inches) occur in the south and east-central areas, but the average and 10-year below average amounts are still considerably greater in these areas than in the northwest where deficits are smallest (less than 7 inches). The 24-month deficits do not much exceed the 12-month deficits. The state average 12-month deficit is 8.2 inches and for the 24-month period is 8.8 inches. The 1975-1976 period (October 1974 to September 1976) approximates the 10-year recurrence value, consisting of one very dry water year (1976) and one year with nearly normal precipitation.

20-year Recurrence Interval (Figure 28)

Once in 20 years about 80% of average precipitation can be expected. The largest deficits (over 16 inches) occur in the southwestern counties where amounts are reduced by 25%. With a deficit of 17.4 inches, 29% below average, Mason City is as dry as the extreme northwest. However, at nearly all stations, the 20-year precipitation is not much less than the one in 10-year amount. Averaged over the state the difference is less than 4 inches. This amount is only one-sixth of the range in 20-year amounts among the 62 stations (21.9 inches), demonstrating a greater variability in precipitation within the state for the 20-year recurrence interval than between the 20- and 10-year recurrence intervals. Moreover there is only

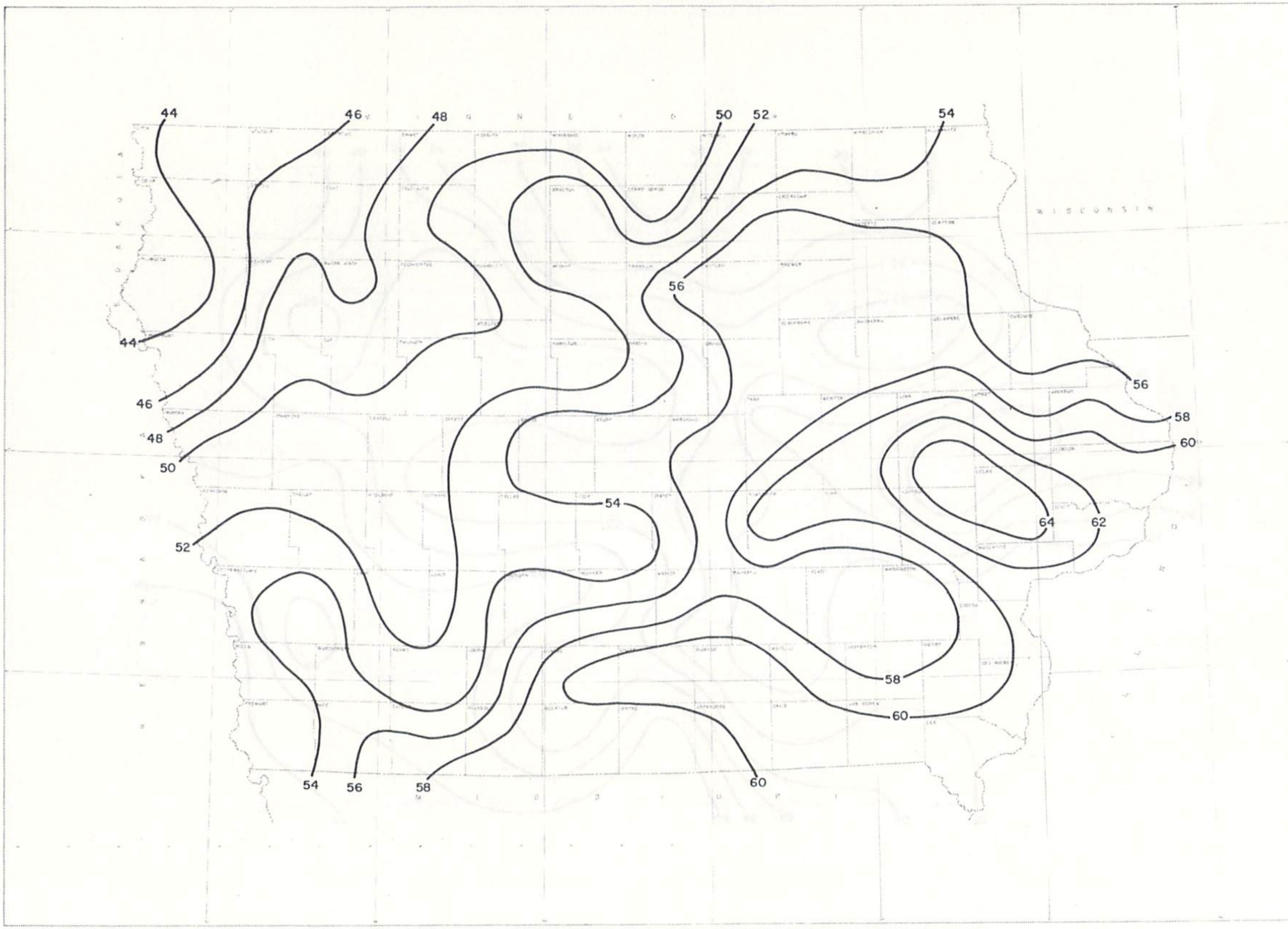



Figure 27. 24 month below average precipitation in inches. Recurrence interval 10 years.

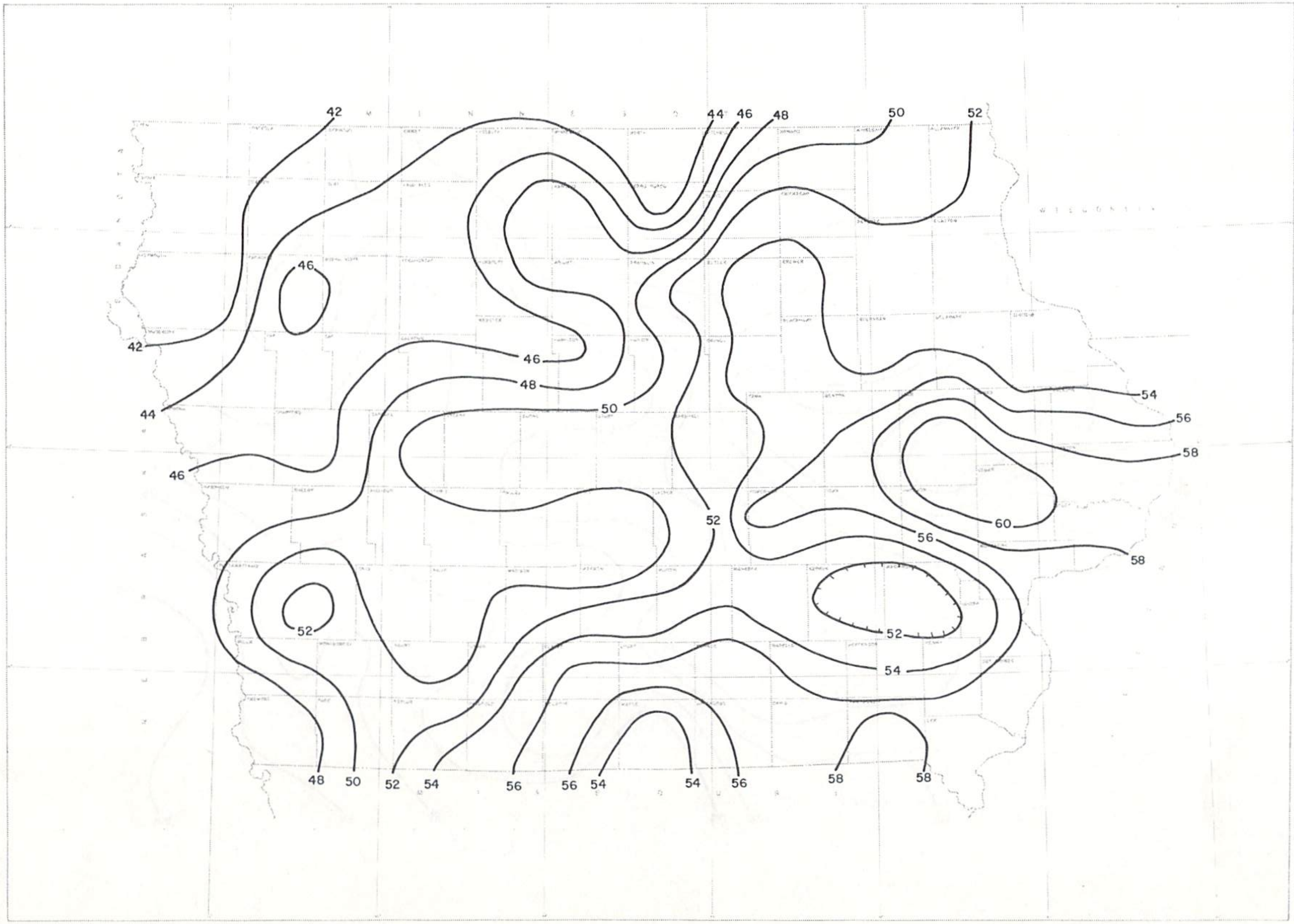



Figure 28. 24 month below average precipitation in inches. Recurrence interval 20 years.

a 2.5 inch difference between the 20-year precipitation for the 12-month period (10.0 inches) and the 24-month period (12.5 inches). Historically, the state experienced 20-year deficits in the 24-month period 1886-1887, 1910-1911, and 1933-1934. Those for 1955-1956 were worse than the 20-year deficits, as were the 1893-95 deficits.

Our water supplies and water quality are highly dependent upon our climate. In turn, the state economy hinges upon the availability of water. For the purpose of meaningful planning and management, the consideration of variations in precipitation availability, both in time and space, is a requirement. This information is needed to support agricultural engineering, cropping designs, farm and livestock management, watershed planning and the design of water management structures such as dams, reservoirs and channeling.

Precipitation fluctuations do significantly alter our environment including the attendant food production, energy use rates, water reserves, economy and even in more subtle ways affect our society by damaging or destroying the natural beauty of the land and waters. The significance of drought is, in part, measured by the deficiency of rainfall. But it is the interaction of the variable rainfalls and associated climatic factors with the natural resources and the socioeconomic factors which is the final measure of the impact of drought upon our society. The 1977 mid-Iowa drought cost Iowa's farmers one billion dollars in lost production and related expenses. This dollar impact reverberated through our economy, along with other uncounted losses and inconveniences experienced. Our social and economic strength lies in the adequacy, distribution and variety of our water resources and their ability to provide for our citizenry. The availability of water deeply affects the costs and conveniences of our living.

Iowa, at the center of the world's bread basket, will feel the pressure on its food producing capabilities as the world's population increases from four billion people in the mid-1970s to twice that number within one and a half decades into the 21st Century. As a leading export state, an all out effort to feed the world will require the best planning and use of our water resources possible. The pressure on our water resources will continue to increase. Our success will depend upon the effective management of our water resources, which in turn depends upon understanding our water limitations.

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APPENDIX A

Methodology

## Data

This study utilized monthly precipitation data for the 30-year period October, 1947, through September, 1977, for 62 Iowa climatic stations. The 62 stations are relatively evenly spaced over the state including stations near the borders to give as complete a coverage of the state as possible (Figure 1). Special care was given to choosing stations with reliable records and few or no missing values. A list of the 62 stations is given in Table 2. The monthly data for the period January, 1948 - December, 1974 are sums of daily precipitation values which were obtained from tapes from the National Climatic Center at Asheville, North Carolina. The data for the periods October - December, 1947 and January, 1975 - September, 1977 are monthly data taken from Climatological Data - Iowa Section publications.

Data for months with missing values were calculated as weighted averages of data from surrounding stations. The largest weight was assigned to the nearest station and the smallest to the station farthest from the station with the missing value; the sum of the weights as 1. In most cases the 3 nearest surrounding stations were averaged. If one station was very near the station with missing values, as 2 climatic stations in the same town, the second station's data were used to fill in missing values. A data tape containing the 30 years of monthly data for the period January, 1948 - December 1977 for the 62 stations was created and is available through IWARDS.

## Pearson Distribution

Hydrologists have long been interested in flood flow frequencies. Early studies showed that flood flow data are not normally distributed

TABLE 2

Stations

| | | | |
|---|---|---|---|
| 112 | Albia | 4052 | Independence 2 SW |
| 157 | Allison | 4063 | Indianola 2 SSW |
| 364 | Atlantic 1 NE | 4142 | Iowa Falls 1 E |
| 600 | Belle Plaine | 4381 | Keokuk L & D No. 19 |
| 608 | Bellevue L & D No. 12 | 4389 | Keosauqua |
| 745 | Blockton 2S | 4620 | Lansing |
| 753 | Bloomfield | 4735 | Le Mars |
| 807 | Boone | 4894 | Logan |
| 923 | Britt | 5131 | Maquoketa |
| 1060 | Burlington Radio KBUR | 5198 | Marshalltown |
| 1233 | Carroll 2 SSW | 5235 | Mason City FAA AP |
| 1257 | Cascade | 5493 | Milford 4 NW |
| 1319 | Cedar Rapids 1 | 5837 | Muscatine 4 ENE |
| 1402 | Charles City | 5992 | Newton |
| 1442 | Cherokee | 6151 | Oakland 2 E |
| 1533 | Clarinda | 6243 | Onawa |
| 1635 | Clinton 1 | 6316 | Osceola |
| 1833 | Corning | 6327 | Oskaloosa |
| 1848 | Corydon | 6566 | Perry |
| 2110 | Decorah 2 N | 6719 | Pocahontas |
| 2171 | Denison | 7147 | Rock Rapids |
| 2203 | Des Moines WSO AP | 7161 | Rockwell City |
| 2689 | Emmetsburg | 7386 | Sanborn |
| 2789 | Fairfield | 7613 | Shenandoah |
| 2864 | Fayette | 7678 | Sigourney |
| 3473 | Grinnell 3 SW | 7708 | Sioux City WSO AP |
| 3487 | Grundy Center | 7979 | Storm Lake |
| 3517 | Guttenberg L & D No. 10 | 8266 | Tipton |
| 3584 | Hampton 2 W | 8688 | Washington |
| 3718 | Hawarden | 8806 | Webster City |
| 4038 | Ida Grove | 9132 | Winterset |

but are instead positively skewed. Horton (1913) proposed that the normal distribution might fit the logs of the flow data better than the original flow data. Hazen (1914) fitted the lognormal distribution to flow data but found that it still did not provide a completely satisfactory fit. Hall (1921) and Foster (1924) fitted Pearson type III curves to flood flow data. Fitting the Pearson type III distribution to logs of the data is the current method used to analyze flood flow frequencies (Lara, 1973 and 1974). This method has been recommended by the U.S. Water Resources Council (1967). The log Pearson type III distribution has also been fitted to low flow stream flow data (Lara, 1979). The drought data used in this study are considered analogous to low flow data. The Pearson type III distribution was therefore fitted to the logs of the precipitation data. Precipitation amounts for various recurrence intervals can be estimated from the log Pearson type III distribution. The following is an example of this method using the 12-month precipitation totals for Albia, Iowa.

Example: 12-month period (October-September) Albia, Iowa

The drought data, 30 12-month precipitation totals, are ranked from the smallest amount (assigned rank 1) to the largest amount (assigned rank 30). Column 1 in Table 3 contains the ranks and column 2 contains the corresponding precipitation totals. Return periods (RP) are assigned to each total according to the formula $RP = \frac{N+1}{R}$, where N is the number of events and R is the rank of a particular event. The value associated with rank 1 is assigned a return period of $\frac{30+1}{1}$ or 31, the value associated with rank 2 is assigned a return period of $\frac{30+1}{2}$ or 15.5, and so on. These return periods can be interpreted in the following two ways: (1) a 12-month precipitation total (for October-September) of no more than 24.02 inches can be expected to occur once in 31 years; (2) that event has a (24.02" or less) 3.23% $(\frac{1}{31})$ chance of occurring in any particular October-September period; the event ranked 30, 55.33" or less, has a 96.77% $(\frac{30}{31})$ chance of occurring in any particular October-September period. Column 3 contains the values of the return periods and column 4 contains the percent chance of occurrence associated with a particular event.

A crude estimate of the precipitation value associated with a particular return period can be obtained by interpolation using the raw data and the return periods calculated as above. A better estimate can be derived from the Pearson type III distribution which has been fitted to the logs of the data (column 5 contains the logs of the data). The Pearson type III distribution is defined by three parameters: mean, u; standard deviation, $\sigma$; and skewness coefficient, $\gamma$. Values of these parameters are estimated from the data as follows:

TABLE 3

| Rank | Precip. Total | $\frac{(N+1)}{R}$ | % Chance | LP | K | $LP_{LS}$ |
|---|---|---|---|---|---|---|
| 1 | 24.02 | 31.00 | 3.23 | 1.38 | -1.822 | 1.38 |
| 2 | 24.72 | 15.50 | 6.45 | 1.39 | -1.501 | 1.41 |
| 3 | 25.94 | 10.33 | 9.68 | 1.41 | -1.294 | 1.43 |
| 4 | 27.49 | 7.75 | 12.90 | 1.44 | -1.131 | 1.44 |
| 5 | 29.06 | 6.20 | 16.13 | 1.46 | -0.994 | 1.45 |
| 6 | 29.45 | 5.17 | 19.35 | 1.47 | -0.871 | 1.46 |
| 7 | 29.48 | 4.43 | 22.58 | 1.47 | -0.759 | 1.47 |
| 8 | 29.59 | 3.88 | 25.81 | 1.47 | -0.655 | 1.48 |
| 9 | 29.79 | 3.44 | 29.03 | 1.47 | -0.557 | 1.49 |
| 10 | 30.42 | 3.10 | 32.26 | 1.48 | -0.465 | 1.50 |
| 11 | 31.26 | 2.82 | 35.48 | 1.49 | -0.376 | 1.50 |
| 12 | 32.40 | 2.58 | 38.71 | 1.51 | -0.291 | 1.51 |
| 13 | 33.67 | 2.38 | 41.94 | 1.53 | -0.209 | 1.52 |
| 14 | 36.05 | 2.21 | 45.16 | 1.56 | -0.129 | 1.52 |
| 15 | 36.55 | 2.07 | 48.39 | 1.56 | -0.052 | 1.53 |
| 16 | 36.68 | 1.94 | 51.61 | 1.56 | 0.031 | 1.54 |
| 17 | 36.84 | 1.82 | 54.84 | 1.57 | 0.109 | 1.54 |
| 18 | 36.85 | 1.72 | 58.06 | 1.57 | 0.189 | 1.55 |
| 19 | 36.86 | 1.63 | 61.29 | 1.57 | 0.272 | 1.56 |
| 20 | 37.29 | 1.55 | 64.52 | 1.57 | 0.358 | 1.57 |
| 21 | 37.41 | 1.48 | 67.74 | 1.57 | 0.448 | 1.57 |
| 22 | 37.77 | 1.41 | 70.97 | 1.58 | 0.543 | 1.58 |
| 23 | 38.32 | 1.35 | 74.19 | 1.58 | 0.643 | 1.59 |
| 24 | 38.47 | 1.29 | 77.42 | 1.59 | 0.750 | 1.60 |
| 25 | 39.69 | 1.24 | 80.65 | 1.60 | 0.866 | 1.61 |
| 26 | 39.77 | 1.19 | 83.87 | 1.60 | 0.994 | 1.62 |
| 27 | 41.52 | 1.15 | 87.10 | 1.62 | 1.138 | 1.63 |
| 28 | 41.61 | 1.11 | 90.32 | 1.62 | 1.309 | 1.65 |
| 29 | 42.46 | 1.07 | 93.55 | 1.63 | 1.530 | 1.66 |
| 30 | 55.33 | 1.03 | 96.77 | 1.74 | 1.872 | 1.69 |

$$\mu \text{ by } \overline{X} = \frac{\Sigma \; Xi}{N}$$

$X_i$ = log of data

N = number of events

$$\sigma \text{ by } S = \sqrt{\frac{\Sigma(Xi-\overline{X})^2}{N-1}}$$

$$\gamma \text{ by } g = \frac{N \; \Sigma(Xi-\overline{X})^3}{(N-1)(N-2)S^3}$$

In this example $\overline{X}$ = 1.54, S = 0.079, and g = 0.0635.

Associated with each return period or percent chance in the Pearson type III distribution are k values. These k values are dependent upon the skewness coefficient and are expressed as the number of standard deviations a certain percent chance or return period is from the mean. The k values are available in tabled form (Harter, 1969), column 6 contains those k values for the skewness coefficient $\gamma$ = 0.0635 and associated with return periods of 31, 15.5, etc. The number of standard deviations the return period of 31 is from the mean in this example is -1.822. That is, in the Pearson type III distribution with $\gamma$ = 0.0635, the value at which $\frac{1}{31}$ of the probability has been encountered is 1.822 standard deviations below the mean. The value at which $\frac{2}{31}$ of the probability has been encountered is 1.051 standard deviations below the mean.

Two methods which can be used to estimate the log of the precipitation amount for a specific return period are the method of moments and the method of least squares. The formula from which to compute the method of moments estimate is $LP_M = \overline{X} + kS$, where $LP_M$ is the log of the precipitation amount associated with a certain return period and determined by the method of moments, $\overline{X}$ is the mean of the logs of the data, k is the number of standard deviations a certain return period is from the mean, and S is the standard deviation of the logs of the data. In this example, $LP_M$ = 1.54 + k (0.079). Substituting the value of k for a particular return period into this formula and evaluating it gives an estimate of the log of the precipitation amount for the particular return period. In this study we have used the second method, namely the method of least squares, to determine the linear relationship between the logs of the precipitation data and the k values. For this example the relationship can be expressed as $LP_{LS} = 0.084k + 1.536$, where $LP_{LS}$ is the log of the precipitation amount associated with a particular return period and k is the number of standard deviations a particular return period is from the mean. Substituting the value of k for a 10-year (or 10-event) return period into $LP_{LS} = 0.084k + 1.536$ and evaluating it gives the log of the precipitation amount estimated for a 1 in 10-year recurrence interval (or return period). The least squares approach ensures us that the largest possible amount of variance in the relationship between the logs of the precipitation amounts and the k values has been accounted for given the specified form of the model (in this case we have specified a linear relationship between LP and k). The amount of precipitation that can be expected for a particular recurrence interval is found by taking the antilog of the $LP_{LS}$ values. These antilogs are the values plotted on the maps which have been discussed in this report.

A log Pearson type III program developed by the USGS and revised by IWARDS was used to compute the $LP_{LS}$ values. This program also produces estimates of precipitation amounts for certain return periods using the method of moments and, in addition, fits the log normal distribution to the data and computes estimates using both the method of moments and the method of least squares. (If the skewness coefficient $\gamma$ is equal to 0, the log Pearson type III distribution is equivalent to the lognormal distribution.

### Mapping the Estimates

The isoline maps presented in this report were created by a computer mapping routine called SYMAP and were revised slightly by Paul Waite around several stations whose records may have been faulty. The SYMAP procedure is entirely objective and therefore cannot distinguish between a station with a good record and a station with a faulty record. In all cases where revisions were made on the maps, these revisions were very small.

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## APPENDIX B

### Basic Data

On the following pages data is given for each station evaluated in this study. Values are given, in inches, for 30 year station average precipitation (period of record 1947-1977), and the station record averages and deficit averages for the periods, 3A (April-June), 3B (July-September), 6 months, 12 months, and 24 months at the recurrence intervals of 2, 5, 10 and 20 years.

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Albia | 3A | 12.4 | 12.0 | .4 | 7.9 | 4.5 | 6.0 | 6.4 | 4.8 | 7.6 |
| | 3B | 11.7 | 11.2 | .5 | 7.4 | 4.3 | 5.8 | 5.9 | 4.6 | 7.1 |
| | 6 | 24.1 | 24.6 | .0 | 18.6 | 5.5 | 16.2 | 7.9 | 13.8 | 10.3 |
| | 12 | 34.9 | 34.7 | .2 | 28.8 | 6.1 | 26.9 | 8.0 | 25.1 | 9.8 |
| | 24 | 69.7 | | | | | 61.7 | 8.0 | 57.5 | 12.2 |
| Allison | 3A | 12.5 | 12.0 | .5 | 8.9 | 3.6 | 7.4 | 5.1 | 6.5 | 6.0 |
| | 3B | 11.6 | 10.7 | .9 | 7.4 | 4.2 | 6.2 | 5.4 | 5.2 | 6.4 |
| | 6 | 24.0 | 23.4 | .6 | 18.6 | 5.4 | 16.6 | 7.4 | 15.1 | 8.9 |
| | 12 | 33.4 | 32.4 | 1.0 | 28.2 | 5.2 | 26.3 | 7.1 | 25.1 | 8.3 |
| | 24 | 66.9 | | | | | 57.5 | 9.4 | 55.0 | 11.9 |
| Atlantic | 3A | 11.1 | 10.7 | .4 | 7.6 | 3.5 | 6.2 | 4.9 | 5.2 | 5.9 |
| | 3B | 11.0 | 10.2 | .8 | 7.1 | 3.9 | 5.8 | 5.2 | 4.9 | 6.1 |
| | 6 | 22.0 | 21.4 | .6 | 17.0 | 5.0 | 14.8 | 7.2 | 13.5 | 8.5 |
| | 12 | 30.4 | 30.2 | .2 | 24.6 | 5.8 | 21.9 | 8.5 | 20.0 | 10.4 |
| | 24 | 60.8 | | | | | 51.3 | 9.5 | 49.0 | 11.8 |
| Belle Plaine | 3A | 12.4 | 12.0 | .4 | 9.1 | 2.9 | 7.8 | 4.6 | 6.9 | 5.5 |
| | 3B | 11.3 | 11.0 | .3 | 6.5 | 4.5 | 4.6 | 6.7 | 3.4 | 7.9 |
| | 6 | 23.7 | 23.4 | .3 | 18.6 | 5.1 | 16.2 | 7.5 | 14.4 | 9.3 |
| | 12 | 34.4 | 33.9 | .5 | 28.8 | 5.6 | 26.9 | 7.5 | 25.1 | 9.3 |
| | 24 | 68.7 | | | | | 60.3 | 8.4 | 56.2 | 12.5 |
| Bellevue | 3A | 11.0 | 10.5 | .5 | 7.8 | 3.2 | 6.6 | 4.4 | 5.8 | 5.2 |
| | 3B | 11.0 | 10.2 | .8 | 7.6 | 3.4 | 6.3 | 4.7 | 5.6 | 5.4 |
| | 6 | 22.0 | 21.9 | .1 | 17.4 | 4.6 | 15.5 | 6.5 | 13.8 | 8.2 |
| | 12 | 33.0 | 32.4 | .6 | 27.5 | 5.5 | 25.1 | 7.9 | 23.4 | 8.6 |
| | 24 | 65.9 | | | | | 56.2 | 9.7 | 53.7 | 12.2 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Blockton | 3A | 12.1 | 11.8 | .3 | 8.9 | 3.2 | 7.9 | 4.2 | 7.1 | 5.0 |
| | 3B | 12.0 | 11.5 | .5 | 7.6 | 4.4 | 5.9 | 6.1 | 4.7 | 7.3 |
| | 6 | 24.1 | 24.0 | .1 | 18.6 | 5.5 | 16.6 | 7.5 | 15.0 | 9.1 |
| | 12 | 33.7 | 32.4 | 1.3 | 28.2 | 5.5 | 26.3 | 7.4 | 25.7 | 8.0 |
| | 24 | 67.3 | | | | | 57.5 | 9.8 | 55.0 | 12.3 |
| Bloomfield | 3A | 11.9 | 11.5 | .4 | 8.1 | 3.8 | 6.6 | 5.3 | 5.5 | 6.4 |
| | 3B | 12.0 | 11.5 | .5 | 8.1 | 3.9 | 6.8 | 5.2 | 5.8 | 6.2 |
| | 6 | 23.9 | 22.9 | 1.0 | 18.6 | 5.3 | 17.0 | 6.9 | 15.8 | 8.1 |
| | 12 | 34.8 | 33.9 | .9 | 28.8 | 6.0 | 26.3 | 8.5 | 24.6 | 10.2 |
| | 24 | 69.5 | | | | | 60.3 | 9.2 | 56.2 | 13.3 |
| Boone | 3A | 12.9 | 12.6 | .3 | 9.8 | 3.1 | 8.5 | 4.4 | 7.4 | 5.5 |
| | 3B | 10.5 | 10.5 | .0 | 5.8 | 4.7 | 3.9 | 6.6 | 2.7 | 7.8 |
| | 6 | 23.4 | 23.4 | .0 | 18.6 | 4.8 | 16.2 | 7.2 | 14.4 | 9.0 |
| | 12 | 32.8 | 32.4 | .4 | 26.9 | 5.9 | 24.6 | 8.2 | 22.9 | 9.9 |
| | 24 | 65.5 | | | | | 56.2 | 9.3 | 52.5 | 13.0 |
| Britt | 3A | 11.7 | 11.0 | .7 | 8.3 | 3.4 | 7.4 | 4.3 | 6.8 | 4.9 |
| | 3B | 10.1 | 9.3 | .8 | 6.6 | 3.5 | 5.5 | 4.6 | 4.7 | 5.4 |
| | 6 | 21.8 | 20.9 | .9 | 16.6 | 5.2 | 14.8 | 7.0 | 13.5 | 8.3 |
| | 12 | 30.8 | 30.2 | .6 | 25.7 | 5.1 | 23.4 | 7.4 | 22.4 | 8.4 |
| | 24 | 61.6 | | | | | 53.7 | 7.9 | 50.1 | 11.5 |
| Burlington | 3A | 11.2 | 11.0 | .2 | 7.8 | 3.4 | 6.3 | 4.9 | 5.2 | 6.0 |
| | 3B | 11.0 | 10.2 | .8 | 7.4 | 3.6 | 6.3 | 4.7 | 5.5 | 5.5 |
| | 6 | 22.2 | 21.9 | .3 | 17.4 | 4.8 | 15.1 | 7.1 | 13.8 | 8.4 |
| | 12 | 33.8 | 33.1 | .7 | 28.2 | 5.6 | 25.7 | 8.1 | 24.0 | 9.8 |
| | 24 | 67.7 | | | | | 60.3 | 7.4 | 57.5 | 10.2 |
| Carroll | 3A | 12.1 | 11.8 | .3 | 8.7 | 3.4 | 7.6 | 4.5 | 6.6 | 5.5 |
| | 3B | 10.1 | 9.8 | .3 | 6.0 | 4.1 | 4.6 | 5.5 | 3.6 | 6.5 |
| | 6 | 22.2 | 21.9 | .4 | 17.0 | 5.2 | 14.8 | 7.4 | 13.2 | 9.0 |
| | 12 | 30.4 | 29.5 | .9 | 24.6 | 5.8 | 21.9 | 8.5 | 20.4 | 10.0 |
| | 24 | 60.7 | | | | | 51.3 | 9.4 | 50.1 | 10.6 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Cascade | 3A | 12.1 | 11.8 | .3 | 8.3 | 3.8 | 6.9 | 5.2 | 6.0 | 6.1 |
| | 3B | 10.2 | 9.3 | .9 | 6.6 | 3.6 | 5.5 | 4.7 | 4.8 | 5.4 |
| | 6 | 22.4 | 21.9 | .5 | 17.4 | 5.0 | 15.5 | 6.9 | 13.8 | 8.6 |
| | 12 | 32.8 | 32.4 | .4 | 27.5 | 5.3 | 25.7 | 7.1 | 24.0 | 8.8 |
| | 24 | 65.6 | | | | | 56.2 | 9.4 | 53.7 | 11.9 |
| Cedar Rapids | 3A | 13.3 | 13.2 | .1 | 10.0 | 3.3 | 8.7 | 4.6 | 7.4 | 5.9 |
| | 3B | 11.8 | 11.2 | .6 | 7.2 | 4.6 | 5.6 | 6.2 | 4.6 | 7.2 |
| | 6 | 25.1 | 24.6 | .5 | 20.0 | 5.1 | 17.8 | 7.3 | 16.2 | 8.9 |
| | 12 | 36.0 | 35.5 | .5 | 30.2 | 5.8 | 28.2 | 7.8 | 26.3 | 9.7 |
| | 24 | 72.1 | | | | | 64.6 | 7.5 | 62.7 | 9.4 |
| Charles City | 3A | 12.0 | 11.8 | .2 | 9.3 | 2.7 | 8.3 | 3.7 | 7.6 | 4.4 |
| | 3B | 10.8 | 10.2 | .6 | 6.9 | 3.9 | 5.6 | 5.2 | 4.7 | 6.1 |
| | 6 | 22.8 | 22.9 | .0 | 18.2 | 4.6 | 16.2 | 6.6 | 14.8 | 8.0 |
| | 12 | 31.7 | 31.6 | .1 | 27.5 | 4.2 | 25.7 | 6.0 | 24.6 | 7.1 |
| | 24 | 63.4 | | | | | 56.2 | 7.2 | 53.7 | 9.7 |
| Cherokee | 3A | 11.2 | 10.5 | .7 | 7.6 | 3.6 | 6.5 | 4.7 | 5.6 | 5.6 |
| | 3B | 10.0 | 9.8 | .2 | 6.3 | 3.7 | 4.9 | 5.1 | 3.8 | 6.2 |
| | 6 | 21.2 | 20.9 | .3 | 15.5 | 5.7 | 12.9 | 8.3 | 11.0 | 10.2 |
| | 12 | 27.6 | 28.2 | .0 | 21.9 | 5.7 | 19.0 | 8.6 | 16.6 | 11.0 |
| | 24 | 55.3 | | | | | 49.0 | 6.3 | 46.8 | 8.5 |
| Clarinda | 3A | 12.4 | 12.0 | .4 | 9.3 | 3.1 | 8.1 | 4.3 | 7.2 | 5.2 |
| | 3B | 12.6 | 11.5 | 1.1 | 7.2 | 5.4 | 5.8 | 6.8 | 4.7 | 7.9 |
| | 6 | 25.1 | 24.6 | .5 | 19.0 | 6.1 | 16.6 | 8.5 | 14.4 | 10.7 |
| | 12 | 34.6 | 33.9 | .7 | 27.5 | 7.1 | 24.6 | 10.0 | 22.4 | 12.2 |
| | 24 | 69.1 | | | | | 56.2 | 12.9 | 51.3 | 17.8 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Clinton | 3A | 11.7 | 11.0 | .7 | 8.1 | 3.6 | 7.1 | 4.6 | 6.3 | 5.4 |
| | 3B | 11.5 | 10.7 | .8 | 7.4 | 4.1 | 6.0 | 5.5 | 5.1 | 6.4 |
| | 6 | 23.2 | 22.4 | .8 | 17.8 | 5.4 | 16.2 | 7.0 | 14.8 | 8.4 |
| | 12 | 35.7 | 34.7 | 1.0 | 30.2 | 5.5 | 28.2 | 7.5 | 27.5 | 8.2 |
| | 24 | 71.4 | | | | | 61.7 | 9.7 | 58.9 | 12.5 |
| Corning | 3A | 11.6 | 11.5 | .1 | 8.3 | .3 | 6.9 | 4.7 | 5.9 | 5.7 |
| | 3B | 12.7 | 11.8 | .9 | 8.1 | 4.6 | 6.6 | 6.1 | 5.6 | 7.1 |
| | 6 | 24.2 | 24.0 | .2 | 19.0 | 5.2 | 16.6 | 7.6 | 15.1 | 9.1 |
| | 12 | 32.8 | 31.6 | 1.2 | 26.3 | 6.5 | 24.0 | 8.8 | 22.4 | 10.4 |
| | 24 | 65.7 | | | | | 52.5 | 13.2 | 49.0 | 16.7 |
| Corydon | 3A | 11.2 | 11.0 | .2 | 7.8 | 3.4 | 6.3 | 4.9 | 5.4 | 5.8 |
| | 3B | 11.9 | 11.0 | .9 | 7.2 | 4.7 | 5.8 | 6.1 | 4.7 | 7.2 |
| | 6 | 23.2 | 23.4 | .0 | 17.8 | 5.4 | 14.8 | 8.4 | 12.6 | 10.6 |
| | 12 | 33.6 | 33.1 | .5 | 27.5 | 6.1 | 24.6 | 9.0 | 22.4 | 11.2 |
| | 24 | 67.1 | | | | | 57.5 | 9.6 | 53.7 | 13.4 |
| Decorah | 3A | 12.0 | 11.8 | .2 | 8.5 | 3.5 | 7.1 | 4.9 | 6.0 | 6.0 |
| | 3B | 11.5 | 10.7 | .8 | 7.2 | 4.3 | 5.8 | 5.7 | 4.8 | 6.7 |
| | 6 | 23.5 | 22.9 | .6 | 17.8 | 5.7 | 15.5 | 8.0 | 13.5 | 10.0 |
| | 12 | 31.8 | 31.6 | .5 | 26.3 | 5.5 | 23.4 | 8.4 | 21.4 | 10.4 |
| | 24 | 63.6 | | | | | 53.7 | 9.9 | 50.1 | 13.5 |
| Denison | 3A | 11.6 | 11.0 | .6 | 8.5 | 3.1 | 7.4 | 4.2 | 6.8 | 4.8 |
| | 3B | 10.5 | 10.7 | .0 | 6.5 | 4.0 | 4.7 | 5.8 | 3.4 | 7.1 |
| | 6 | 22.1 | 21.9 | .2 | 17.0 | 5.1 | 14.4 | 7.7 | 12.3 | 9.8 |
| | 12 | 29.7 | 28.8 | .9 | 24.0 | 5.7 | 21.4 | 8.3 | 19.5 | 10.2 |
| | 24 | 59.3 | | | | | 50.1 | 9.2 | 45.7 | 13.6 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Des Moines | 3A | 11.2 | 11.0 | .2 | 7.9 | 3.3 | 6.5 | 4.7 | 5.4 | 5.8 |
| | 3B | 10.1 | 9.3 | .8 | 6.0 | 4.1 | 4.7 | 5.4 | 3.8 | 6.3 |
| | 6 | 21.4 | 21.4 | .0 | 17.0 | 4.4 | 14.4 | 7.0 | 12.9 | 8.5 |
| | 12 | 30.5 | 30.9 | .0 | 25.1 | 5.4 | 21.4 | 9.1 | 18.6 | 11.9 |
| | 24 | 61.0 | | | | | 51.3 | 9.7 | 45.7 | 15.3 |
| Emmetsberg | 3A | 11.1 | 10.7 | .4 | 8.3 | 2.8 | 7.4 | 3.7 | 6.8 | 4.3 |
| | 3B | 10.4 | 10.0 | .4 | 6.6 | 3.8 | 5.2 | 5.2 | 4.3 | 6.1 |
| | 6 | 21.5 | 20.9 | .6 | 16.2 | 5.3 | 14.1 | 7.4 | 12.3 | 9.2 |
| | 12 | 29.9 | 29.5 | .4 | 24.0 | 5.9 | 21.4 | 8.5 | 19.5 | 10.4 |
| | 24 | 59.8 | | | | | 50.1 | 9.7 | 45.7 | 14.1 |
| Fairfield | 3A | 11.2 | 11.0 | .2 | 7.6 | 3.6 | 6.2 | 5.0 | 5.1 | 6.1 |
| | 3B | 12.2 | 11.8 | .4 | 7.6 | 4.6 | 5.8 | 6.4 | 4.6 | 7.6 |
| | 6 | 23.4 | 22.9 | .5 | 17.8 | 5.6 | 15.1 | 8.3 | 13.5 | 9.9 |
| | 12 | 34.0 | 33.9 | .1 | 27.5 | 6.5 | 24.6 | 9.4 | 22.4 | 11.6 |
| | 24 | 68.1 | | | | | 57.5 | 10.6 | 53.7 | 14.4 |
| Fayette | 3A | 12.1 | 11.8 | .3 | 9.3 | 2.8 | 8.5 | 3.6 | 7.8 | 4.3 |
| | 3B | 10.7 | 10.0 | .7 | 7.4 | 3.3 | 6.3 | 4.4 | 5.6 | 5.1 |
| | 6 | 22.8 | 22.4 | .4 | 18.6 | 4.2 | 17.0 | 5.8 | 15.5 | 7.3 |
| | 12 | 32.4 | 32.4 | .0 | 27.5 | 4.9 | 25.1 | 7.3 | 23.4 | 9.0 |
| | 24 | 64.9 | | | | | 57.5 | 7.4 | 53.7 | 11.2 |
| Grinnell | 3A | 12.6 | 12.0 | .6 | 8.7 | 3.9 | 7.1 | 5.5 | 6.0 | 6.6 |
| | 3B | 11.4 | 11.0 | .4 | 6.9 | 4.5 | 5.2 | 6.2 | 4.2 | 7.2 |
| | 6 | 24.0 | 23.4 | .6 | 19.0 | 5.0 | 17.4 | 6.6 | 16.2 | 7.8 |
| | 12 | 34.3 | 33.9 | .4 | 28.8 | 5.5 | 26.3 | 8.0 | 24.6 | 9.7 |
| | 24 | 68.6 | | | | | 60.3 | 8.3 | 56.2 | 12.4 |
| Grundy Center | 3A | 11.9 | 11.5 | .4 | 8.7 | 3.2 | 7.4 | 4.5 | 6.6 | 5.3 |
| | 3B | 11.0 | 10.5 | .5 | 7.8 | 3.2 | 6.5 | 4.5 | 5.6 | 6.4 |
| | 6 | 22.9 | 22.4 | .5 | 18.2 | 4.7 | 16.2 | 6.7 | 14.8 | 8.1 |
| | 12 | 31.6 | 30.9 | .7 | 26.9 | 4.7 | 25.1 | 6.5 | 24.0 | 7.6 |
| | 24 | 63.2 | | | | | 56.2 | 7.0 | 55.0 | 8.2 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Guttenberg | 3A | 11.3 | 11.2 | .1 | 8.5 | 2.8 | 7.2 | 4.1 | 6.3 | 5.0 |
| | 3B | 10.9 | 10.2 | .7 | 7.2 | 3.7 | 6.0 | 4.9 | 5.2 | 5.7 |
| | 6 | 22.2 | 21.9 | .3 | 18.2 | 4.0 | 16.2 | 6.0 | 14.8 | 7.4 |
| | 12 | 31.2 | 30.9 | .3 | 26.3 | 4.9 | 24.0 | 7.2 | 22.4 | 8.8 |
| | 24 | 62.5 | | | | | 55.0 | 7.5 | 52.5 | 10.0 |
| Hampton | 3A | 12.3 | 12.0 | .3 | 8.5 | 3.8 | 7.1 | 5.2 | 6.2 | 6.1 |
| | 3B | 11.8 | 11.0 | .8 | 7.8 | 4.0 | 6.6 | 5.2 | 5.8 | 6.0 |
| | 6 | 24.1 | 23.4 | .7 | 18.2 | 5.9 | 16.2 | 7.9 | 14.4 | 9.7 |
| | 12 | 33.2 | 32.4 | .0 | 26.9 | 6.3 | 24.6 | 8.6 | 22.9 | 10.3 |
| | 24 | 66.3 | | | | | 56.2 | 10.1 | 52.5 | 13.8 |
| Hawarden | 3A | 9.9 | 9.3 | .6 | 6.6 | 3.3 | 5.4 | 4.5 | 4.6 | 5.3 |
| | 3B | 9.5 | 9.3 | .2 | 6.3 | 3.2 | 5.1 | 4.4 | 4.2 | 5.3 |
| | 6 | 19.4 | 18.6 | .8 | 14.4 | 5.0 | 12.3 | 7.1 | 11.0 | 8.4 |
| | 12 | 25.7 | 25.1 | .6 | 20.0 | 5.7 | 17.8 | 7.9 | 16.2 | 9.5 |
| | 24 | 51.3 | | | | | 43.6 | 7.7 | 40.7 | 10.6 |
| Ida Grove | 3A | 11.7 | 11.0 | .7 | 8.1 | 3.6 | 7.1 | 4.6 | 6.2 | 5.5 |
| | 3B | 10.2 | 9.6 | .6 | 6.5 | 3.7 | 5.4 | 4.8 | 4.6 | 5.6 |
| | 6 | 21.9 | 20.9 | 1.0 | 15.8 | 6.1 | 13.8 | 8.1 | 12.3 | 9.6 |
| | 12 | 29.4 | 29.5 | .0 | 23.4 | 6.0 | 20.4 | 9.0 | 18.2 | 11.2 |
| | 24 | 58.9 | | | | | 50.1 | 8.8 | 45.7 | 13.2 |
| Independence | 3A | 12.1 | 12.0 | .1 | 9.1 | 3.0 | 7.6 | 4.5 | 6.6 | 5.5 |
| | 3B | 11.3 | 10.7 | .6 | 7.8 | 3.5 | 6.5 | 4.8 | 5.5 | 5.8 |
| | 6 | 23.4 | 23.4 | .0 | 18.6 | 4.8 | 16.2 | 7.2 | 14.4 | 9.0 |
| | 12 | 32.2 | 32.4 | .0 | 27.5 | 4.7 | 25.1 | 7.1 | 23.4 | 8.8 |
| | 24 | 64.4 | | | | | 56.2 | 8.2 | 53.7 | 10.7 |
| Indianola | 3A | 11.9 | 11.8 | .1 | 8.7 | 3.2 | 7.2 | 4.7 | 6.2 | 5.7 |
| | 3B | 10.7 | 10.2 | .5 | 6.5 | 4.2 | 5.0 | 5.7 | 4.1 | 6.6 |
| | 6 | 22.6 | 22.4 | .2 | 18.2 | 4.4 | 16.6 | 6.0 | 15.1 | 7.5 |
| | 12 | 32.5 | 32.4 | .1 | 26.9 | 5.6 | 24.6 | 7.9 | 22.9 | 9.6 |
| | 24 | 65.0 | | | | | 56.2 | 8.8 | 52.5 | 12.5 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Iowa Falls | 3A | 11.1 | 10.7 | .4 | 8.1 | 3.0 | 6.9 | 4.2 | 6.0 | 5.1 |
| | 3B | 11.6 | 11.0 | .6 | 7.9 | 3.7 | 6.8 | 4.8 | 5.9 | 5.7 |
| | 6 | 22.8 | 21.9 | .9 | 17.8 | 5.0 | 16.2 | 6.6 | 15.1 | 7.7 |
| | 12 | 31.5 | 30.9 | .6 | 26.3 | 5.2 | 24.6 | 6.9 | 23.4 | 8.1 |
| | 24 | 63.1 | | | | | 53.7 | 8.4 | 50.1 | 13.0 |
| Keokuk | 3A | 11.5 | 11.2 | .3 | 7.4 | 4.1 | 5.8 | 5.7 | 4.6 | 6.9 |
| | 3B | 11.9 | 11.2 | .7 | 8.1 | 3.8 | 6.9 | 5.0 | 6.0 | 5.9 |
| | 6 | 23.4 | 22.4 | 1.0 | 17.8 | 5.6 | 15.8 | 7.6 | 14.1 | 9.3 |
| | 12 | 35.6 | 34.7 | .9 | 28.8 | 6.8 | 25.7 | 9.9 | 24.0 | 11.6 |
| | 24 | 71.1 | | | | | 60.3 | 10.8 | 56.2 | 14.9 |
| Keosauqua | 3A | 11.5 | 11.2 | .3 | 7.8 | 3.7 | 6.0 | 5.5 | 4.9 | 6.6 |
| | 3B | 12.4 | 11.8 | .6 | 7.9 | 4.5 | 6.5 | 5.9 | 5.4 | 7.0 |
| | 6 | 23.9 | 22.9 | 1.0 | 18.2 | 5.7 | 15.8 | 8.1 | 14.4 | 9.5 |
| | 12 | 35.5 | 34.7 | .8 | 28.8 | 6.7 | 26.9 | 8.6 | 25.1 | 10.4 |
| | 24 | 71.1 | | | | | 61.7 | 9.4 | 58.9 | 12.2 |
| Lansing | 3A | 11.6 | 11.2 | .4 | 8.1 | 3.5 | 7.1 | 4.5 | 6.2 | 5.4 |
| | 3B | 10.6 | 10.2 | .4 | 7.1 | 3.5 | 5.8 | 4.8 | 4.8 | 5.8 |
| | 6 | 22.2 | 21.4 | .8 | 17.0 | 5.2 | 15.1 | 7.1 | 13.8 | 8.4 |
| | 12 | 31.6 | 30.9 | .7 | 26.3 | 5.3 | 24.0 | 7.6 | 22.4 | 9.2 |
| | 24 | 63.3 | | | | | 55.0 | 8.3 | 52.5 | 10.8 |
| LeMars | 3A | 10.2 | 10.2 | .0 | 7.4 | 2.8 | 6.0 | 4.2 | 5.0 | 5.2 |
| | 3B | 9.2 | 8.9 | .3 | 6.0 | 3.2 | 4.8 | 4.4 | 4.0 | 5.9 |
| | 6 | 19.4 | 19.5 | .0 | 14.4 | 5.0 | 12.0 | 7.4 | 10.2 | 9.2 |
| | 12 | 26.0 | 25.7 | .3 | 20.0 | 6.0 | 17.4 | 8.6 | 15.5 | 10.5 |
| | 24 | 51.9 | | | | | 43.6 | 8.3 | 39.8 | 12.1 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Logan | 3A | 11.6 | 11.2 | .4 | 8.3 | 3.3 | 7.1 | 4.5 | 6.2 | 5.4 |
| | 3B | 11.0 | 11.0 | .0 | 7.1 | 3.9 | 5.4 | 5.6 | 4.2 | 6.8 |
| | 6 | 22.6 | 22.4 | .2 | 17.8 | 4.8 | 15.5 | 7.1 | 13.8 | 8.8 |
| | 12 | 30.5 | 30.2 | .3 | 24.6 | 5.9 | 21.9 | 8.6 | 19.5 | 11.0 |
| | 24 | 61.0 | | | | | 52.5 | 8.5 | 47.9 | 13.1 |
| Maquoketa | 3A | 11.7 | 11.2 | .5 | 8.7 | 3.0 | 7.6 | 4.1 | 6.8 | 4.9 |
| | 3B | 11.0 | 10.5 | .5 | 6.8 | 4.2 | 5.2 | 5.8 | 4.2 | 6.8 |
| | 6 | 22.7 | 22.9 | .0 | 17.4 | 5.3 | 15.1 | 7.6 | 13.2 | 9.5 |
| | 12 | 34.1 | 33.9 | .2 | 28.2 | 5.9 | 25.1 | 9.0 | 22.9 | 11.2 |
| | 24 | 68.1 | | | | | 60.3 | 7.8 | 57.5 | 12.6 |
| Marshalltown | 3A | 12.3 | 12.0 | .3 | 8.9 | 3.4 | 7.4 | 4.9 | 6.3 | 6.0 |
| | 3B | 10.8 | 10.0 | .8 | 5.5 | 5.3 | 3.9 | 6.9 | 2.8 | 8.0 |
| | 6 | 23.0 | 22.9 | .1 | 17.4 | 5.6 | 14.8 | 8.2 | 12.9 | 10.1 |
| | 12 | 32.4 | 31.6 | .8 | 26.9 | 5.5 | 24.6 | 7.8 | 22.9 | 9.5 |
| | 24 | 64.8 | | | | | 56.2 | 8.6 | 52.5 | 10.3 |
| Mason City | 3A | 11.6 | 11.0 | .6 | 8.1 | 3.5 | 6.8 | 4.8 | 5.9 | 5.7 |
| | 3B | 10.6 | 10.2 | .4 | 6.9 | 3.7 | 5.6 | 5.0 | 4.6 | 6.0 |
| | 6 | 22.2 | 21.4 | .8 | 16.6 | 5.6 | 14.8 | 7.4 | 13.2 | 9.0 |
| | 12 | 30.1 | 29.5 | .6 | 23.4 | 6.7 | 20.9 | 9.2 | 18.6 | 11.5 |
| | 24 | 60.1 | | | | | 49.0 | 11.1 | 42.7 | 17.4 |
| Milford | 3A | 10.2 | 10.0 | .2 | 7.4 | 2.8 | 6.3 | 3.9 | 5.5 | 4.7 |
| | 3B | 9.9 | 9.6 | .3 | 6.2 | 3.7 | 4.9 | 5.0 | 3.9 | 6.0 |
| | 6 | 20.1 | 20.0 | .1 | 15.1 | 5.0 | 12.9 | 7.2 | 11.2 | 8.9 |
| | 12 | 26.9 | 26.3 | .6 | 21.4 | 5.5 | 19.0 | 7.9 | 17.4 | 9.5 |
| | 24 | 53.9 | | | | | 46.8 | 7.1 | 42.7 | 11.2 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Muscatine | 3A | 12.0 | 11.8 | .2 | 8.5 | 3.5 | 7.1 | 4.9 | 6.0 | 6.0 |
| | 3B | 11.4 | 10.7 | .7 | 7.8 | 3.6 | 6.5 | 4.9 | 5.6 | 5.8 |
| | 6 | 23.4 | 22.9 | .5 | 18.6 | 4.8 | 16.6 | 6.8 | 15.5 | 7.9 |
| | 12 | 35.2 | 35.5 | .0 | 29.5 | 5.7 | 26.9 | 8.3 | 24.6 | 10.6 |
| | 24 | 70.4 | | | | | 61.7 | 8.7 | 56.2 | 14.2 |
| Newton | 3A | 11.9 | 11.2 | .7 | 7.9 | 4.0 | 6.5 | 5.4 | 5.6 | 6.3 |
| | 3B | 10.5 | 10.2 | .3 | 6.6 | 3.9 | 5.1 | 5.4 | 4.1 | 6.4 |
| | 6 | 22.4 | 21.9 | .5 | 17.8 | 4.6 | 15.5 | 6.9 | 14.1 | 8.3 |
| | 12 | 31.8 | 31.6 | .2 | 26.3 | 5.5 | 23.4 | 8.4 | 21.9 | 9.9 |
| | 24 | 63.6 | | | | | 56.2 | 7.4 | 51.3 | 12.3 |
| Oakland | 3A | 11.8 | 11.5 | .3 | 8.5 | 3.3 | 7.2 | 4.6 | 6.3 | 5.5 |
| | 3B | 11.5 | 11.0 | .5 | 7.8 | 3.7 | 6.3 | 5.2 | 5.2 | 6.3 |
| | 6 | 23.3 | 22.9 | .4 | 18.6 | 4.7 | 17.0 | 6.3 | 15.5 | 7.8 |
| | 12 | 31.6 | 30.9 | .7 | 26.3 | 5.3 | 24.0 | 7.6 | 22.4 | 9.2 |
| | 24 | 63.3 | | | | | 55.0 | 8.3 | 52.5 | 10.8 |
| Onawa | 3A | 11.4 | 11.0 | .4 | 8.3 | 3.1 | 7.1 | 4.3 | 6.3 | 5.1 |
| | 3B | 9.7 | 9.8 | .0 | 6.5 | 3.2 | 5.0 | 2.7 | 4.0 | 5.7 |
| | 6 | 21.1 | 21.4 | .0 | 16.2 | 4.9 | 13.8 | 7.3 | 11.8 | 9.3 |
| | 12 | 28.8 | 28.8 | .0 | 23.4 | 5.4 | 20.9 | 7.9 | 18.6 | 10.2 |
| | 24 | 57.5 | | | | | 50.1 | 7.4 | 47.7 | 9.8 |
| Osceola | 3A | 12.5 | 12.3 | .2 | 9.1 | 3.4 | 7.6 | 4.9 | 6.6 | 5.9 |
| | 3B | 11.7 | 11.0 | .7 | 7.4 | 4.3 | 5.9 | 5.8 | 4.8 | 6.9 |
| | 6 | 24.2 | 23.4 | .8 | 19.0 | 5.2 | 16.6 | 7.6 | 15.1 | 9.1 |
| | 12 | 34.2 | 33.9 | .3 | 28.8 | 5.4 | 26.3 | 7.9 | 24.6 | 9.6 |
| | 24 | 68.5 | | | | | 60.3 | 8.2 | 56.2 | 12.3 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Oskaloosa | 3A | 12.2 | 12.0 | .2 | 8.1 | 4.1 | 6.3 | 5.9 | 5.0 | 7.2 |
| | 3B | 10.8 | 10.0 | .8 | 6.6 | 4.2 | 5.1 | 5.7 | 4.3 | 6.5 |
| | 6 | 23.1 | 22.4 | .7 | 17.0 | 6.1 | 14.8 | 8.3 | 12.9 | 10.2 |
| | 12 | 33.8 | 34.7 | .0 | 26.9 | 6.9 | 23.4 | 10.4 | 20.4 | 13.4 |
| | 24 | 67.5 | | | | | 57.5 | 10.0 | 52.5 | 15.0 |
| Perry | 3A | 11.9 | 11.8 | .1 | 8.5 | 3.4 | 6.9 | 5.0 | 5.9 | 6.0 |
| | 3B | 10.8 | 10.2 | .6 | 6.6 | 4.2 | 5.1 | 5.7 | 4.2 | 6.6 |
| | 6 | 22.7 | 22.4 | .3 | 18.2 | 4.5 | 15.8 | 6.9 | 14.1 | 8.6 |
| | 12 | 31.1 | 30.9 | .2 | 26.3 | 4.8 | 24.0 | 7.1 | 22.4 | 8.7 |
| | 24 | 62.3 | | | | | 53.7 | 8.6 | 50.1 | 12.2 |
| Pocahontas | 3A | 10.7 | 10.0 | .7 | 7.6 | 3.1 | 6.6 | 4.1 | 6.0 | 4.7 |
| | 3B | 10.1 | 9.8 | .3 | 6.3 | 3.8 | 4.9 | 5.2 | 3.9 | 6.2 |
| | 6 | 20.9 | 20.4 | .5 | 15.5 | 5.4 | 13.2 | 7.7 | 11.5 | 9.4 |
| | 12 | 28.4 | 28.2 | .2 | 22.4 | 6.0 | 19.5 | 8.9 | 17.8 | 10.6 |
| | 24 | 56.7 | | | | | 49.0 | 7.7 | 45.7 | 11.0 |
| Rock Rapids | 3A | 9.7 | 9.6 | .1 | 7.1 | 2.6 | 6.0 | 3.7 | 5.2 | 4.5 |
| | 3B | 9.5 | 9.1 | .4 | 6.8 | 2.7 | 5.6 | 3.9 | 4.9 | 4.6 |
| | 6 | 19.1 | 19.0 | .1 | 14.8 | 4.3 | 12.6 | 6.5 | 11.2 | 7.9 |
| | 12 | 25.4 | 25.1 | .3 | 20.4 | 5.0 | 18.6 | 6.8 | 16.6 | 8.8 |
| | 24 | 50.9 | | | | | 44.7 | 6.2 | 41.7 | 9.2 |
| Rockwell City | 3A | 11.3 | 11.0 | .3 | 8.1 | 3.2 | 6.8 | 4.5 | 5.8 | 5.5 |
| | 3B | 10.6 | 9.8 | .8 | 6.2 | 4.4 | 4.7 | 4.9 | 3.7 | 6.9 |
| | 6 | 21.9 | 21.4 | .5 | 15.5 | 6.4 | 13.2 | 8.7 | 11.5 | 10.4 |
| | 12 | 29.9 | 29.5 | .4 | 23.4 | 6.5 | 20.9 | 9.0 | 18.6 | 11.3 |
| | 24 | 59.7 | | | | | 51.3 | 8.4 | 47.9 | 11.8 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Sanborn | 3A | 9.9 | 9.3 | 0.6 | 7.2 | 2.7 | 6.5 | 3.4 | 5.8 | 4.1 |
| | 3B | 10.3 | 9.8 | 0.5 | 6.9 | 3.4 | 5.8 | 4.5 | 4.9 | 5.4 |
| | 6 | 20.2 | 19.5 | 0.7 | 15.8 | 4.4 | 14.1 | 6.1 | 13.2 | 7.0 |
| | 12 | 27.1 | 26.3 | 0.8 | 22.4 | 4.7 | 20.4 | 6.7 | 19.0 | 8.1 |
| | 24 | 54.2 | | | | | 46.8 | 7.4 | 42.7 | 11.5 |
| Shenandoah | 3A | 11.7 | 11.2 | .5 | 8.1 | 3.6 | 6.9 | 4.8 | 6.0 | 5.7 |
| | 3B | 11.7 | 11.0 | .7 | 7.4 | 4.3 | 6.2 | 5.5 | 5.2 | 6.5 |
| | 6 | 23.4 | 22.9 | .5 | 17.8 | 5.6 | 15.5 | 7.9 | 13.5 | 9.9 |
| | 12 | 32.3 | 31.6 | .7 | 25.7 | 6.6 | 22.4 | 9.9 | 20.4 | 11.9 |
| | 24 | 64.5 | | | | | 53.7 | 10.8 | 47.9 | 16.6 |
| Sigourney | 3A | 11.8 | 11.8 | .0 | 7.6 | 4.2 | 5.9 | 5.9 | 4.6 | 7.2 |
| | 3B | 11.3 | 10.7 | .6 | 6.6 | 4.7 | 4.9 | 6.4 | 3.8 | 7.5 |
| | 6 | 23.0 | 22.9 | .1 | 17.4 | 5.6 | 14.4 | 8.6 | 12.6 | 10.4 |
| | 12 | 32.7 | 33.1 | .0 | 26.3 | 6.4 | 23.4 | 9.3 | 20.9 | 11.8 |
| | 24 | 65.4 | | | | | 56.2 | 9.2 | 51.3 | 14.1 |
| Sioux City | 3A | 9.8 | 9.6 | .2 | 7.6 | 2.2 | 6.8 | 3.0 | 6.2 | 3.6 |
| | 3B | 9.1 | 8.7 | .4 | 5.4 | 3.7 | 4.0 | 5.1 | 3.0 | 6.1 |
| | 6 | 18.9 | 18.6 | .3 | 14.4 | 4.5 | 12.3 | 6.6 | 10.7 | 8.2 |
| | 12 | 25.6 | 25.1 | .5 | 20.4 | 5.2 | 18.6 | 7.0 | 17.0 | 8.6 |
| | 24 | 51.1 | | | | | 44.7 | 6.4 | 42.7 | 8.4 |
| Storm Lake | 3A | 10.9 | 10.5 | .4 | 7.6 | 3.3 | 6.5 | 4.4 | 5.6 | 5.3 |
| | 3B | 10.2 | 10.0 | .2 | 6.8 | 3.4 | 5.4 | 4.8 | 4.4 | 5.8 |
| | 6 | 21.2 | 20.9 | .3 | 15.5 | 5.7 | 12.9 | 8.3 | 11.0 | 10.2 |
| | 12 | 28.2 | 28.2 | .0 | 21.4 | 6.8 | 18.6 | 9.6 | 16.2 | 12.0 |
| | 24 | 56.5 | | | | | 47.9 | 8.6 | 44.7 | 11.8 |

| Station Name | Period | Average Precip. | R.I. 2 | | R.I. 5 | | R.I. 10 | | R.I. 20 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit | Precip. | Deficit |
| Tipton | 3A | 13.3 | 13.5 | .0 | 10.2 | 3.1 | 8.5 | 4.8 | 7.1 | 6.2 |
| | 3B | 12.2 | 11.2 | 1.0 | 8.1 | 4.1 | 6.8 | 5.4 | 5.9 | 6.3 |
| | 6 | 25.5 | 24.6 | .9 | 20.0 | 5.5 | 18.2 | 7.3 | 17.0 | 8.5 |
| | 12 | 38.0 | 37.2 | .8 | 31.6 | 6.4 | 28.8 | 9.2 | 26.9 | 11.1 |
| | 24 | 76.0 | | | | | 64.6 | 11.4 | 61.7 | 14.3 |
| Washington | 3A | 11.6 | 11.8 | .0 | 7.4 | 4.2 | 5.6 | 6.0 | 4.3 | 7.3 |
| | 3B | 11.0 | 10.0 | 1.0 | 6.5 | 4.5 | 5.1 | 5.9 | 4.3 | 6.7 |
| | 6 | 22.6 | 21.9 | .7 | 17.0 | 4.6 | 14.8 | 7.8 | 13.2 | 8.4 |
| | 12 | 33.5 | 33.1 | .4 | 26.9 | 6.6 | 24.0 | 9.5 | 21.9 | 11.6 |
| | 24 | 67.1 | | | | | 57.5 | 9.6 | 51.3 | 15.8 |
| Webster City | 3A | 11.2 | 10.7 | .5 | 8.5 | 2.7 | 7.6 | 3.6 | 6.9 | 4.3 |
| | 3B | 10.6 | 10.0 | .6 | 6.6 | 4.0 | 5.1 | 5.5 | 4.2 | 6.4 |
| | 6 | 21.8 | 20.9 | .9 | 16.6 | 5.2 | 14.8 | 7.0 | 13.5 | 8.3 |
| | 12 | 29.7 | 28.8 | .9 | 24.6 | 5.1 | 22.4 | 7.3 | 21.4 | 8.3 |
| | 24 | 59.4 | | | | | 50.1 | 9.3 | 45.7 | 13.7 |
| Winterset | 3A | 11.9 | 11.8 | .1 | 8.3 | 3.6 | 6.8 | 5.1 | 5.6 | 6.3 |
| | 3B | 11.3 | 11.0 | .3 | 7.2 | 4.1 | 5.8 | 5.5 | 4.8 | 6.5 |
| | 6 | 23.2 | 22.9 | .3 | 19.0 | 4.2 | 17.0 | 6.2 | 15.8 | 7.4 |
| | 12 | 32.3 | 31.6 | .7 | 26.9 | 5.4 | 24.6 | 7.7 | 22.9 | 9.4 |
| | 24 | 64.7 | | | | | 55.0 | 9.7 | 50.1 | 14.6 |