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# Operation, Maintenance, and Upgrade of a 25-Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 2001

by

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# OPERATION, MAINTENANCE, AND UPGRADE OF A 25-RAINGAGE NETWORK FOR COLLECTION, REDUCTION, AND ANALYSIS OF PRECIPITATION DATA FOR LAKE MICHIGAN DIVERSION ACCOUNTING:
## WATER YEAR 2001

FINAL REPORT

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# ABSTRACT

A dense raingage network has operated in Cook County since the fall of 1989, to provide accurate precipitation for use in simulating runoff for Lake Michigan diversion accounting. This report describes the network design, the operations and maintenance procedures, the data reduction and quality control methodology, a comparison of rainfall amounts obtained via analog chart and data logger, and an analysis of precipitation for Water Year 2001 (October 2000 - September 2001). The data analyses include 1) monthly and Water Year 2001 amounts at all sites, 2) Water Year 2001 amounts in comparison to patterns from network Water Years 1990-2000, and 3) the 12-year network precipitation average for Water Years 1990-2001. Also included are raingage site descriptions, instructions for raingage technicians, documentation of raingage maintenance, and documentation of high storm totals.

# CONTENTS

# OPERATION, MAINTENANCE, AND UPGRADE OF A 25-RAINGAGE NETWORK FOR COLLECTION, REDUCTION, AND ANALYSIS OF PRECIPITATION DATA FOR LAKE MICHIGAN DIVERSION ACCOUNTING:
## WATER YEAR 2001

by

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## 1. INTRODUCTION

The volume of water diverted from Lake Michigan into the state of Illinois is monitored to ensure that the diversion does not exceed a long-term average of 3,200 cubic feet per second (cfs) as imposed by a 1967 U.S. Supreme Court Order, which was updated in 1980. This diversion has a long history, dating back to the mid-1800s with the completion of the Illinois and Michigan Canal. Over the years, it has been affected by such events as the reversal of the flow of the Chicago River and completion of the Chicago Sanitary and Ship Canal in 1901, and has weathered various legal proceedings that attempted to ensure that the diversion could be monitored and did not exceed certain limits. One of the key components of the monitoring procedure, administered by the U.S. Army Corps of Engineers (COE), Chicago District, is the accurate representation of the precipitation that falls over portions of Cook County, Illinois.

The primary components of Illinois' diversion from Lake Michigan are as follows: 1) water is pumped directly from Lake Michigan as the source of potable water supply and discharged into the river and canal system in the greater Chicago area as treated sewage; 2) storm runoff is discharged from the diverted watershed area of Lake Michigan, draining to the river and canal system; and 3) water enters the river and canal system directly from Lake Michigan.

The storm runoff from the Lake Michigan watershed basin enters the combined and separate sewer systems and watercourses. The combined sewers mix sanitary system flow with runoff, and this water then goes to the treatment plants or, during major flood events, becomes discharged into the water courses. When large storm events are predicted (and greater than normal storm runoff is anticipated), the canal system is drawn down prior to the event to prevent flooding. If the event fails to materialize, canal system levels are restored using a direct diversion from Lake Michigan through three facilities located along the shoreline: the Chicago River Controlling Works, O'Brien Lock and Dam, and the Wilmette Controlling Works.

The method for computing the diversion involves the direct measurement of diversion flow at Romeoville, Illinois, as measured by an acoustic velocity meter. Flow at Romeoville consists of both diversion and nondiversion flows (deductions). The theory behind diversion accounting is to use the flow at Romeoville and deduct from it flows not attributable to diversion. Diversion flows that bypass Romeoville are added to the resultant flow, yielding a net computed diversion of water from Lake Michigan. The deductions to the Romeoville record include runoff from 217 square miles of the Des Plaines River watershed that is discharged into the canal, the groundwater supply whose effluent is discharged into the canal, water used by federal facilities, and the Indiana water supply that is discharged into the canal via the Calumet River system and the Calumet Sag Channel.

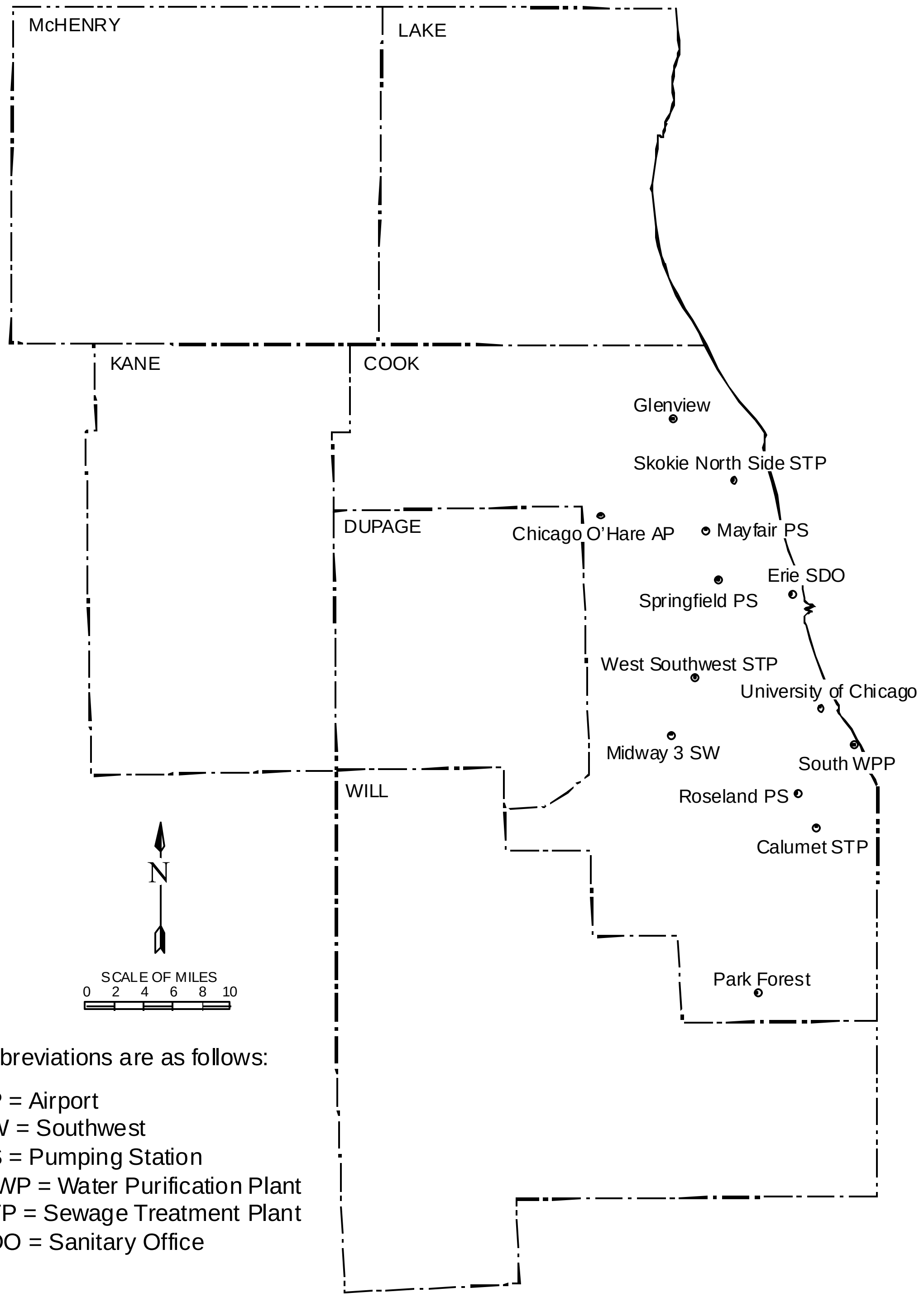
The diversion is approximated by adding the Lake Michigan water supply pumpage, direct diversions from Lake Michigan, and runoff from 673 square miles of diverted Lake Michigan watershed. This approximation is performed to cross-check the computed diversion.

In both of these procedures, it is necessary to estimate runoff from the Des Plaines River and the Lake Michigan watersheds. Hydrologic simulations of runoff perform two functions. One function is to model runoff. The second function is to aid in determining the runoff, groundwater, and sanitary proportions of treatment plant discharge. Inputs into the simulation model consist of land-use and climatological data. Of the latter, the most significant is precipitation data.

Accurate precipitation data, thus, are essential to properly simulate the runoff process. Runoff can constitute a significant portion of the diversion. For example, from Water Year 1986 through Water Year 1989 (a water year extends from October 1 through September 30 of the following calendar year), runoff from the Des Plaines River watershed constituted a 142 cubic feet per second (cfs; 4 percent) deduction from the Romeoville measurement record in the diversion computations. In the cross-check approximations, the Lake Michigan watershed runoff constituted a 729 cfs (23 percent) share of the total diversion.

However, the precipitation data available for use by the accounting procedure prior to Water Year 1990 (particularly Water Years 1984-1989) displayed patterns inconsistent with known, long-term Chicago-area patterns (e.g., Changnon, 1961, 1968; Huff and Changnon, 1973; Vogel, 1988, 1989; Peppler, 1990, 1991a, 1993a). These patterns also diverge from the known urban effects found within the precipitation patterns for the Cook County region for heavier rainfall distributions from 1949-1974 (Huff and Vogel, 1976), particularly toward the south, and within patterns observed during the operation of a dense raingage network and radar system in the Chicago area during the late 1970s (Changnon, 1980, 1984).

The recent unusual patterns were caused by abnormally low precipitation totals at a select number of the 13 sites used by the accounting procedure (Figure 1). Inspection of these sites (Vogel, 1988), which are irregularly distributed over the region, revealed that the low precipitation totals were caused by 1) inadequate raingage exposure (e.g., gages situated on rooftops or too near natural or artificial, flow-



Abbreviations are as follows:

AP = Airport
SW = Southwest
PS = Pumping Station
WWP = Water Purification Plant
STP = Sewage Treatment Plant
SDO = Sanitary Office

Figure 1. Raingage locations used for diversion accounting purposes prior to Water Year 1990. These include National Weather Service gages located at Chicago O'Hare AP, Midway 3 SW, University of Chicago, and Park Forest; City of Chicago gages located at Mayfair PS, Springfield PS, South WPP, and Roseland PS; and Metropolitan Water Reclamation District of Greater Chicago gages located at Glenview, Skokie North Side STP, Erie SDO, West Southwest STP, and Calumet STP.

restricting obstructions) and 2) different observing, data reduction, and quality control practices used by the individual groups responsible for raingage operation and data collection (National Weather Service - NWS, Metropolitan Water Reclamation District of Greater Chicago - MWRDGC, and City of Chicago - CC). Vogel (1988) established that the unusual precipitation patterns began occurring in the late 1960s when some changes were made in data collection and reduction.

Vogel (1988) devised a procedure to adjust the questionable values, thus making the data suitable for use in the accounting procedure. This procedure, however, is tedious to implement, and the adjusted precipitation values may not completely capture the actual precipitation regime, although the data produced are much improved over the original values. This procedure also illuminated difficulties experienced when trying to merge data observations from different agencies and equipment into one data set. Vogel (1988) gave the following recommendation at the end of his report on the reduction and adjustment of the Water Year 1984 data and on field evaluations of the NWS, MWRDGC, and CC sites:

> "With these types of differences it will always be hard to maintain a consistent set of high-quality precipitation observations for the Chicago urban region. A precipitation network which must produce a set of high-quality observations should have a consistent set of gages; should be managed by one group with fixed quality control procedures, exposure criteria, and a set operating procedure. Management by one group would allow for consistent 1) observations, 2) quality control, and 3) spatial and temporal precipitation patterns.
>
> "To achieve this, it is recommended that a raingage network be established to monitor the precipitation over northeast Illinois relevant to the diversion of Lake Michigan waters. This network should consist of 10 to 15 weighing-bucket-recording raingages. The raingages should be reasonably spaced across the affected area. The network should be managed by one group to ensure that the best possible exposures are obtained initially, and that these exposures are inspected at least annually. The data from such a network should all be quality-controlled in a consistent manner.
>
> “Weighing-bucket raingages with daily charts would be capable of obtaining hourly or smaller time increments if daily charts are used. To reduce costs and to increase security, it is recommended that these raingages be located on private property, and that the observers be given a modest annual stipend. The charts from the observers should be mailed to a central location for data processing, quality control, and extraction of hourly precipitation totals. Raingages should be evenly spaced, as much as possible, and sites would be found after consulting with the agencies involved" (pp. 41-42).

Using Vogel's recommendation as a model, the State Water Survey (SWS) and the COE jointly decided in late 1988 to devise, install, and operate a new raingage network, funded by the COE. The purpose of the new network was to produce consistent, accurate data for the diversion accounting, which would require little or no adjustment. Implementation and operation of such a network would have to be justified on the grounds of both long-term cost savings and greater accuracy.

This report describes the maintenance and operation of the network, along with the data reduction and analysis techniques employed, and brief data analyses for Water Year 2001, year 12 of network operation.

## 2. NETWORK DESIGN

The SWS has operated dense raingage networks in the past (e.g., Huff, 1970, 1979), which tested gridded raingage spacing of 6 feet to 6 miles. Adequate sampling of convective precipitation (typical in spring and summer) was found to require nearly twice as many gages as required by more widespread, continuous precipitation (fall and winter). With that in mind, and opting for an optimum grid spacing, an initial attempt at creating a grid resulted in an array of 40 raingages located in the Cook County region within the Lake Michigan and Des Plaines River watersheds of the MWRDGC North, Central, South, and Lemont basins. Due to cost considerations, however, some spring/summer catchment ability was sacrificed, and a 25-site grid was devised using a 5- to 7-mile grid spacing between gages. Also due to cost considerations, raingages were not installed outside the watershed boundaries to better define isohyetal patterns at those boundaries. These 25 raingages, more than the 10 to 15 gages Vogel had originally envisioned, have provided adequate coverage for precipitation catchment during Water Years 1990-2001, the first 12 years of network operation (Peppler, 1991b, 1991c, 1993b, 1994, 1995; Westcott, 1996, 1997, 1998, 1999, 2000, 2001), and are consistent with the "best current engineering practice" as specified in the 1967 and 1980 Supreme Court decrees.

Topographic maps of the Cook County region were used to approximate the location of each of the 25 sites and fine-tune their placement to best position the sites with respect to residential areas, industrial facilities, or municipal grounds. Since terrain effects are fairly minimal in northeastern Illinois, gridding was possible. Gridding also allows the use of simple arithmetic averaging to compute areal depths instead of other labor-intensive methods such as the Thiessen polygonal method.

Once candidate locations were found, several preliminary field trips were made to the Cook County region, and letters were written by the SWS in summer 1989 seeking permission to use the selected locations as raingage sites. Due to the urbanization of the region, site selection was sometimes a frustrating venture, as it was difficult in many instances to identify good catchment areas free of barriers for ground-level placement. When selecting sites, highest priority was given to those at ground level in relatively open, secure areas, since obstructions and local wind eddies produced by flow barriers present the largest sources of error in collecting precipitation data. Placing the collector at ground level mitigates wind effects on catchment and represents the ideal exposure (Legates and Willmott, 1990), but it is not practical in wintertime when snow is measured. Thus, as has been standard SWS practice, each raingage was to be placed on stakes with its base approximately 8 inches above ground level and the top of its orifice at about 4 feet. When asked for permission to site a raingage on their property, most individuals, businesses, and municipalities were extremely receptive. As of September 30, 2001, only ten sites have been relocated to a different property since the network began collecting data in October 1989.

In late September and early October 1989, the entire 25-gage network was installed (Figure 2). Each universal weighing-bucket raingage used throughout the network was fitted with a battery-powered electric chart drive for more consistent and reliable operation. The SWS provided all raingages from its inventory. To improve the accuracy and reliability of the raingages, as of February 1, 2001, 25 raingages were deployed with linear potentiometers and data loggers, in addition to the battery-powered chart drive. Appendix I contains complete site descriptions for each network location, accurate as of September 30, 2001.

The weighing-bucket recording raingages used are as reliable as any others available (see Jones, 1969, for a complete description of tests of different raingages). All raingages are subject to catchment errors due to winds, wetting losses, evaporation, splashing into or out of the gage, and blowing snow (Legates and Willmott, 1990). Koschmieder (1934) noted that as wind speed increases, gage catch decreases. Legates and Willmott (1990) found that raingage errors "tend to be proportional to total precipitation and amount to nearly 11 percent of the catch." To prevent loss due to blowing snow during the winter, the Nipher shield and the shield used by Lindroth (1991) are helpful, but were not considered for the new network due to cost and vandalism considerations. In October 1997, an Alter shield was installed at site #13, a very windy lakefront location.

## 3. NETWORK OPERATION AND MAINTENANCE

Each raingage in the network was fitted with a linear potentiometer and a data logger, as of February 1, 2001, and also with an 8-day chart drive and chart cylinder gears that rotate the chart cylinder approximately once every week. The data logger records the date, time (Central Standard Time), and an accumulated precipitation total every 10 minutes. These data are downloaded to a laptop computer and 3-inch diskette, during the first week of each month, every 28-37 days. These data are brought to SWS for processing and quality control. The 8-day chart allows resolution down to 1-hour periods. Because a chart can measure up to 12 inches of precipitation, each gage is fitted with a galvanized bucket capable of holding 12 inches of

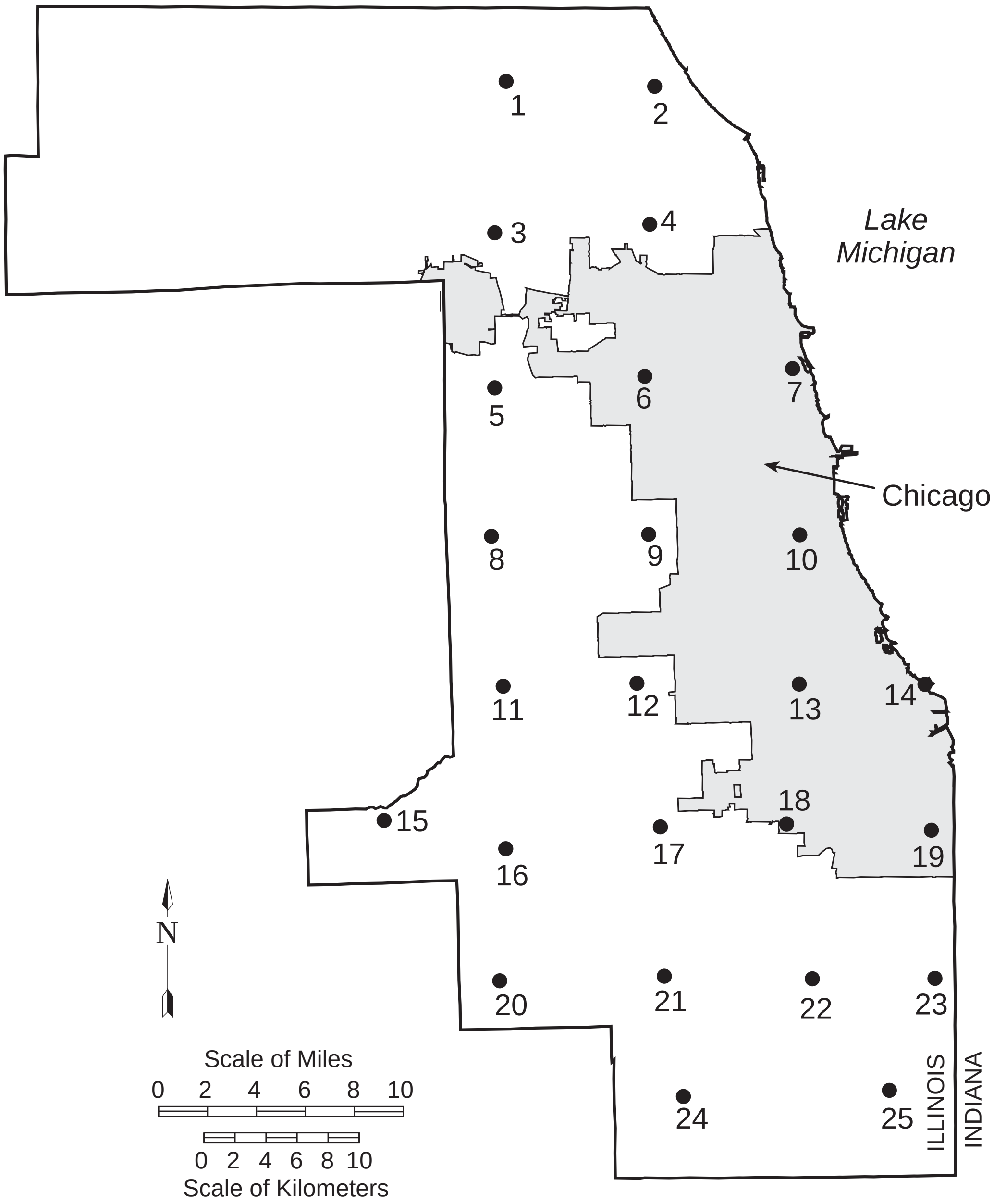


Figure 2. The Cook County 25-site raingage network used during Water Years 1990 to 2001.

precipitation in calibration with the 8-inch orifice opening used on the raingage collector. The data logger is also calibrated to 12 inches. An upward pen traverse on a chart measures the first 6 inches the bucket catches, and a reversed, downward pen traverse measures inches 7-12. The latter traverse, though often unnecessary, is vital whenever more than 6 inches of precipitation occurs between chart periods, or during winter when the antifreeze-charged buckets are allowed to accumulate precipitation without dumping for long periods of time.

A raingage technician residing in Champaign, Illinois, travels to Cook County and services each gage during the first week of each month, which means that 4-5 traces are drawn on each chart. Servicing includes downloading data from data loggers, removing and replacing the current chart, checking the pen point, dumping the bucket from April-October (the warm season of the year), and noting any problems, including chart-drive malfunction, gage imbalance or instability, vandalism, unauthorized movement of the gage, etc. During the warm season, evaporation shields are fitted into the collection orifice above the bucket to mitigate evaporation. During the cool season (November-March), these shields are removed and a 1-quart charge of antifreeze is added to each bucket. This allows frozen precipitation to melt in the bucket as it is caught, allowing the weighing mechanism to give a proper reading. Appendix II contains a complete set of servicing instructions followed by the raingage technician.

Each month the technician collects a complete set of 25 charts and makes a log entry regarding problems encountered at each site. The following section, describing the data reduction and quality control procedures, explains what happens to the data collected by the data loggers and on the analog charts.

Most problems encountered by the raingage technician pertain to either the data loggers or the chart drives and pens. Often, the solution is to replace the data logger or the chart drive or their batteries or the pen tips. If replaced, both the data loggers and the chart drives are cleaned and readied for reuse at the SWS. Two spare data loggers and chart drives allow for flexibility here. Some problems, however, cannot be solved during the routine monthly servicing. If necessary, a second one-day trip is made mid-month to resolve problems that could not be handled during the routine monthly visit. Appendix III provides a complete maintenance history, including site relocations, for the raingage network, and more fully describes the kinds of maintenance and repairs conducted. This information is accurate through September 30, 2001.

## 4. DATA REDUCTION

### Analog Charts

The data from these charts are used to assist in the quality control of the data logger precipitation and as backup if a data logger fails. The monthly set of charts is edited to identify the various traces on the charts and to number sequentially by date those traces showing precipitation. A running inventory of "on" and "off" chart times is maintained to ensure that the on-times on the newly received charts match the off-times on the last set of charts analyzed. Occasionally, the technician will make inadvertent errors in the on-time/off-time designations, particularly when time zones change in October and April (charts are always kept on Central Standard Time). The on- and off-times are marked on the charts, with the on-time revolution designated as "1", and the last revolution designated as appropriate. Then, the various precipitation periods (storms) are identified and numbered based on their sequence in relation to the first and last revolutions. This editing procedure also acts as a trouble-shooting exercise to identify chart-drive problems (running slow, fast, or not at all). Raingage instability also can be identified from a shaky pen trace. Skipping or unusually heavy traces indicate problems with the pen tip. Calibration problems can be noted if a trace reverses before the 6-inch line is reached. Finally, the editing stage permits the identification of missing periods of data on the charts, and these are appropriately marked.

After all charts have been edited, they are ready to be digitized with a Summagraphics Microgrid II digitizer. The chart values are fed into a personal computer with each chart processed separately. The four corners of a chart are digitized to set the grid, then on- and off-times are entered and their locations digitized. The number of revolutions on each chart is noted. Each trace indicating precipitation is digitized by "clicking on" each breakpoint along the respective trace. Once a chart is digitized, computer output gives details on the precipitation that was measured on the chart for each storm, with appropriate storm amounts and beginning and ending times. Also included is an analysis of whether the chart drive is running slow or fast, which helps assess whether the chart drive requires servicing. Errors made during the editing stage also can be caught during digitization. If a chart drive stops during a collection period, the beginning and ending points of the missing period are digitized and stored in the computer. The time required to edit and digitize the 8-day charts is minimal in comparison to that required for 24-hour charts, approximately 4 hours instead of 3 days. This is because there are fewer charts, 25 instead of 100, and also fewer traces per chart, 4-5 instead of 7-14.

Once a calendar month of data is logged into the computer, a C-language computer program, written at the SWS, calculates hourly precipitation values at all 25 sites for each hour of the month in question. These calculations are based on a linear interpolation between digitized breakpoints on the traces. The computed hourly values are compared to the digitized storm values during program execution to ensure consistent precipitation amounts. A printout of the entire monthly data array contains data for all 25 stations for all hours of the month. Monthly totals appear at the bottom of the printout. Missing values are denoted as 99.99.

### Data Loggers

The minimum rainfall amount recorded by the data logger is 0.01 inches every 10 minutes. Often electronic noise is present as evidenced by 10-minute values oscillating between –0.01- and 0.01-inch values. Noise can be caused by wind or other vibrations.

Computer software was developed to set 10-minute values to zero if within ±10 minutes of a - 0.01-inch value, or if within ±20 minutes of a value less than -0.01 inches. Further, if an isolated positive 10-minute value is found (no other precipitation for ±90 minutes), that value is also set to zero. These 10-minute accumulated precipitation amounts are then summed to hourly values and displayed in a format comparable to that already established for the analog chart data. Here, further elimination of noise is done. Values are usually considered part of a precipitation event if more than two adjacent gages detect precipitation during the same hour. However, it has been noted that there often are "events" in the hours just after sunrise. It is believed that these frequent events, not observed by the analog charts, are related to a rapid heating of the raingage. These "am" storms are deleted unless either the analog charts or the National Weather Service gages located in Cook County also report precipitation. The quality-control procedures for the data loggers outlined above have not eliminated any storm event delineated by the analog charts for the 8-month period of comparison.

### Final Data Array

The precipitation data array created from the data logger data is checked for time and space consistency, storm periods are delimited, and missing values are filled in with interpolated information. A storm is defined as a precipitation period separated from preceding and succeeding precipitation periods by approximately 6 hours at all stations in the network. This definition has been used by Huff (1967) for an area of similar dimensions in central Illinois, by Vogel (1986) to define extreme storm events in the Chicago area, and by Vogel (1988, 1989), Peppler (1990, 1991a-c, 1993a,b, 1994, 1995), and Westcott (1996, 1997, 1998, 1999, 2000, 2001) to delineate storms for Water Years 1984-2001. For each storm, values are summed, plotted on maps using all available data and stations, and isohyetal patterns are drawn. During Water Year 2001, 137 such storms were defined.

After a generalized precipitation pattern is obtained for each storm, storm total values also are obtained from the analog charts. A computer program using an objective analysis program is executed to objectively determine new values for hours designated as missing by the data loggers. The objective routine is also used to re-create values at gage sites for which questionable values were identified during the storm analysis stage. After execution of the program, the new values are compared to the analog chart values, and any unrealistic objective values are adjusted. Once everything has been verified, a final computer file of hourly precipitation values for the month being analyzed is archived.

## 5. COMPARISON OF STORM RAINFALL FROM THREE COLLECTION METHODS

Data loggers were installed in all raingages between January 15 and February 2, 2001. At 10 sites, the original raingage was maintained through September 30, 2001. The 24-hour charts were maintained at the 10 co-located gages. Eight-day charts are employed at the 25 refurbished gages equipped with data loggers. Ideally, 24-hour charts should be read weekly and the 8-day charts extracted monthly for ease of reading the chart data. Due to personnel constraints, the 24-hour charts were pulled from the 10 co-located gages every two weeks.

The most prominent improvement in the precipitation data derived from the data loggers is the accuracy of the timing of storm events. The onset and end times of storms between gages are more consistent when employing data loggers. This in large part is due to the elimination of the chart drive and pen mechanism which are known to stick unless attended on a near-daily basis. Further, the data loggers evaluate precipitation accumulations at 10-minute intervals rather than at the standard hourly accumulations acquired from digitizing the analog charts.

The following figures compare storm total precipitation amounts for raingage pairs. The 8-day charts, though of poorer time resolution correlated slightly better with the data loggers (0.99) than did the amounts from the 24-hour charts (0.97). This is likely because of the recent cleaning and refurbishment of the gages using 8-day charts. The total storm precipitation pairs show rainfall values for the data loggers versus the 24-hour charts (Network 34; N34) in Figure 3, for the data loggers versus the 8-day charts (Network 35, N35) in Figure 4, and for the 24-hour versus the 8-day charts precipitation totals in Figure 5. Note that the pairs are centered on the 1:1 line, and the largest scatter is for precipitation amounts less than 1.5 inches.

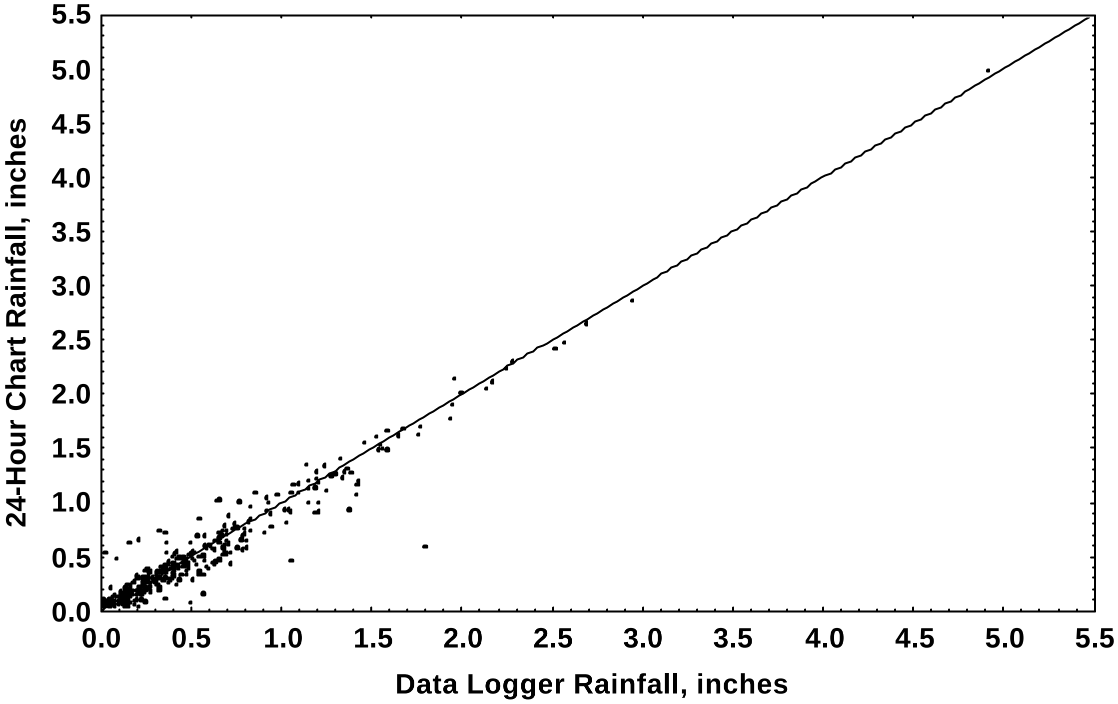


Figure 3. Storm total precipitation at individual gages for the data loggers and the 24-hour (N34) chart data, February 1 – September 30, 2001.

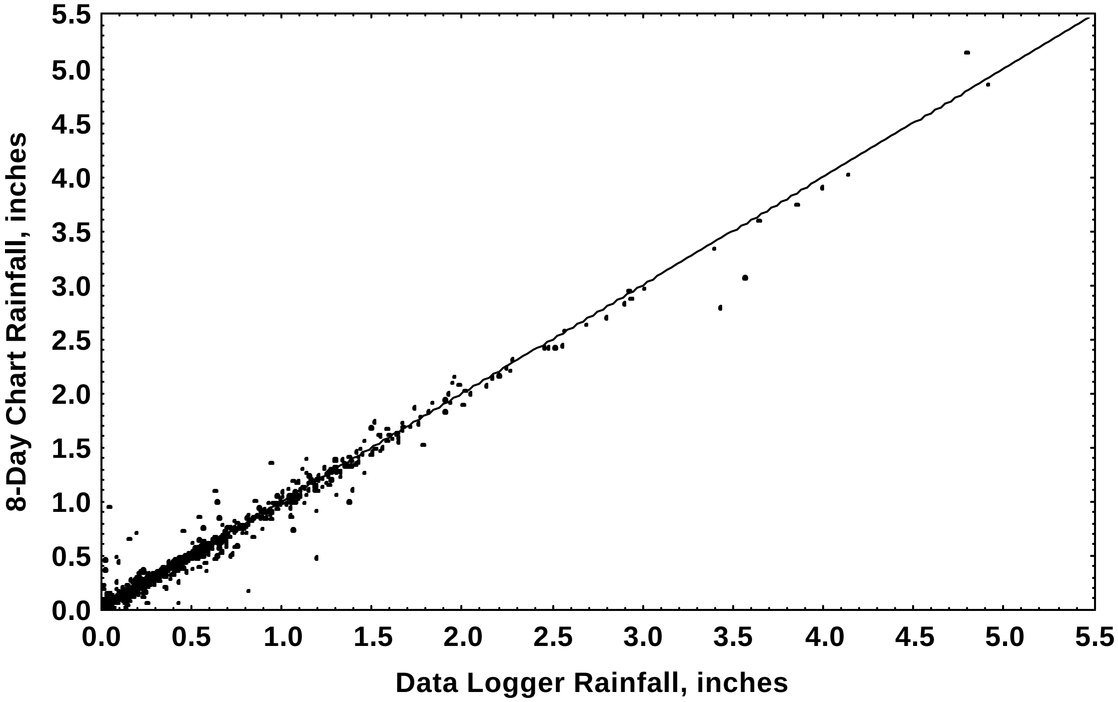


Figure 4. Storm total precipitation at individual gages for the data loggers and the 8-day (N35) chart data, February 1 – September 30, 2001.

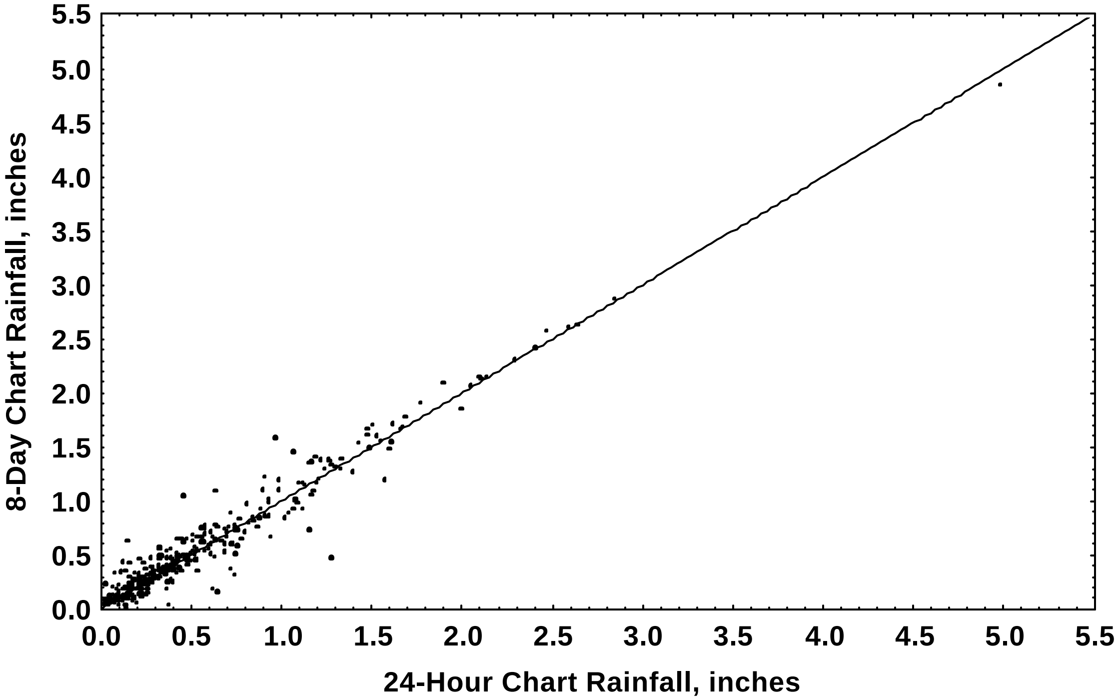


Figure 5. Storm total precipitation at individual gages for the 24-hour and the 8-day chart data, February 1 – September 30, 2001.

The percent frequency of gage storm total precipitation pairs with differences of ≤ 10, 20, and 30 percent is shown in Table 1. Only values where both the data logger and the raingage reported some precipitation are included. The percent differences were computed as ((Logger – Chart) / Logger) *100.0 and ((N34 – N35) / N34) * 100.0. When the data logger storm total value was at least 0.25 inches, only 8 of 636 8-day chart values differed by as much as 50 to 90 percent from the data logger, and 12 of 256 24-hour chart values differed by greater than 50 percent from the data logger, with one 24-hour chart value greater than 100 percent. The large differences are mainly due to the performance of the chart drive or pen mechanism.

For precipitation amounts greater than 0.25 inches, the data logger and gages performed extremely well. At smaller precipitation amounts there is more uncertainty in both the data loggers and the 8-day charts. Electronic noise resulting from wind or other vibrations is common for data logger measurements, and sometimes poor connections also can result in noise. While much of the electronic noise is eliminated by computer software and manual checks, not all can be eliminated with assurance. Noise will have the greatest impact upon the smaller precipitation values. Small amounts of a few hundredths of an inch are difficult to read on the 8-day charts. However, the 8-day charts will continue to be digitized both for backup purposes and to evaluate the performance of the potentiometer, data logger, and the pen mechanism.

Table 1. Percent Frequency of Rainfall Values Falling within the ± 10, 20, and 30 Percent Difference Range for All Rainfall Pairs and for Values above the 0.25-, 0.5-, 0.75-, 1.0- and 1.5-inch Thresholds.

| *Frequency* | *All* | *³ 0.25* | *³ 0.50* | *³ 0.75* | *³ 1.00* | *³ 1.50* |
|---|---|---|---|---|---|---|
| DL vs. N35 | *N = 1004* | *N = 639* | *N = 404* | *N = 250* | *N = 177* | *N = 68* |
| ± 10 | 66 | 82 | 84 | 88 | 89 | 93 |
| ± 20 | 73 | 93 | 93 | 96 | 97 | 100 |
| ± 30 | 96 | 97 | 97 | 98 | 99 | 100 |
| DL vs. N34 | *N = 361* | *N = 256* | *N = 149* | *N = 84* | *N = 60* | *N = 25* |
| ± 10 | 39 | 46 | 52 | 64 | 73 | 96 |
| ± 20 | 59 | 67 | 72 | 83 | 88 | 96 |
| ± 30 | 75 | 85 | 88 | 96 | 95 | 96 |
| N34 vs. N35 | *N = 349* | *N = 245* | *N = 140* | *N = 84* | *N = 58* | *N = 24* |
| ± 10 | 43 | 52 | 56 | 65 | 71 | 92 |
| ± 20 | 63 | 73 | 77 | 87 | 93 | 96 |
| ± 30 | 72 | 83 | 89 | 93 | 95 | 100 |

**Note:** Rainfall in each pair of gages exceeded zero inches. *N* indicates the number of rainfall pairs. DL indicates data loggers.

## 6. DATA ANALYSIS

The Water Year 2001 data set was used to produce various analyses, including: 1) monthly and Water Year 2001 amounts at all sites, 2) water year amounts and comparisons to patterns from network Water Years 1990-2000, 3) monthly amounts as documentation of the data collected, and 4) an analysis of the 12-year network precipitation average for Water Years 1990-2001).

Table 2 and Figure 6 show Water Year 2001 precipitation amounts. Isopleths in Figure 6 (and remaining Figures) are labeled in inches, while values in Table 2 are given to the nearest hundredth of an inch. Considering the total annual network precipitation amount and the total number of precipitation events, Water Year 2001 was an average year. The Water Year 2001 network average of 36.39 inches was about 102 percent of the 1961-1990 Chicago O'Hare Airport annual precipitation normal of 35.82 inches. Network average precipitation for Water Years 1990-2000 was 40.00, 39.19, 36.56, 51.78, 29.23, 34.68, 36.88, 34.09, 36.12, 36.33 and 33.33 inches, respectively. The 11-year (1990-2000) network average precipitation was 37.11 inches. The Water Year 2001 network average of 36.39 inches was about 98 percent of the 11-year network average. There were 137 precipitation events in Water Year 2001. Eight of the 137 precipitation events included at least one site at which the storm total exceeded the one-year recurrence interval (Appendix IV). On average, seven such heavy rainstorms occurred in Water Years 1990-2000.

The largest precipitation amounts during Water Year 2001 occurred in the north-central portion of the network (sites #4, #5, #6, and #10), (see Figure 2 and Appendix I for site information). The lightest amounts occurred in the far southern portion of the network (sites #23, #24, and #25) and central sites #12 and #16. The heaviest precipitation in the network during Water Year 2001 (40.8 inches) fell at site #4, while the lightest fell at site #23 (32.0 inches).

Figure 7 provides maps of precipitation amounts for network Water Years 1990-2001). The general pattern for Water Year 2001 is similar to that of 1997 and 1999 with the largest precipitation in the north-central portion of the network extending southward along the coast of Lake Michigan. The "urban high" of the near lake, central Chicago area noted in other network water years and in other Chicago-area research (e.g., Huff and Vogel, 1976) was noted in the 2001 rainfall pattern.

As in the case of the other network water year patterns, the spatial pattern for Water Year 2001 does not contain the wildly varying anomalies found in an analysis using sites operated by the MWRDGC, the NWS, and the Cook County raingages for Water Years 1984-1989. Precipitation data from those sites were the input for diversion accounting before construction of the present network (see Peppler, 1993b for those patterns). While there is a 5.5-inch gradient in the annual amount between sites #12 and #13, these values are supported by surrounding sites. Additionally, gradients of 15 to 20 inches were common in the 1984-1989 analysis.

Table 2. Monthly and Water Year Precipitation Amounts for Water Year 2001 (inches)

| | *Oct* | *Nov* | *Dec* | *Jan* | *Feb* | *Mar* | *Apr* | *May* | *Jun* | *Jul* | *Aug* | *Sep* | *Total* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.42 | 2.82 | 2.44 | 0.79 | 2.11 | 1.98 | 2.38 | 3.79 | 3.35 | 2.84 | 6.84 | 6.37 | 37.13 |
| 2 | 1.63 | 2.86 | 2.86 | 0.72 | 2.09 | 1.67 | 2.47 | 4.56 | 2.85 | 2.75 | 7.30 | 4.28 | 36.04 |
| 3 | 1.74 | 2.94 | 2.24 | 1.17 | 2.25 | 1.39 | 2.52 | 3.35 | 2.85 | 2.72 | 9.15 | 5.51 | 37.83 |
| 4 | 1.62 | 2.65 | 2.57 | 0.84 | 2.52 | 1.71 | 2.64 | 4.29 | 2.97 | 4.37 | 9.78 | 4.87 | 40.83 |
| 5 | 1.88 | 2.97 | 2.46 | 0.92 | 2.23 | 1.40 | 3.41 | 3.25 | 2.91 | 4.38 | 9.75 | 4.80 | 40.36 |
| 6 | 1.98 | 2.87 | 2.94 | 1.00 | 2.87 | 1.45 | 3.73 | 4.21 | 2.70 | 2.71 | 9.12 | 4.80 | 40.38 |
| 7 | 1.98 | 2.17 | 3.60 | 0.89 | 2.56 | 1.38 | 3.00 | 4.30 | 2.25 | 2.69 | 10.26 | 4.28 | 39.36 |
| 8 | 1.73 | 2.98 | 2.15 | 1.20 | 2.69 | 1.44 | 3.51 | 4.40 | 1.82 | 2.98 | 6.50 | 4.67 | 36.07 |
| 9 | 1.84 | 2.37 | 2.47 | 0.85 | 2.76 | 1.70 | 3.98 | 5.06 | 2.04 | 4.09 | 7.23 | 4.37 | 38.76 |
| 10 | 2.50 | 2.51 | 3.13 | 0.96 | 2.90 | 1.28 | 3.44 | 4.73 | 2.52 | 3.13 | 9.15 | 4.46 | 40.71 |
| 11 | 1.59 | 2.71 | 2.10 | 0.95 | 3.02 | 1.55 | 3.09 | 4.19 | 1.56 | 3.58 | 6.32 | 3.88 | 34.54 |
| 12 | 1.68 | 2.01 | 1.88 | 0.96 | 2.74 | 1.40 | 2.88 | 4.25 | 2.13 | 3.09 | 6.96 | 3.66 | 33.64 |
| 13 | 2.56 | 2.57 | 2.51 | 1.16 | 2.95 | 1.44 | 3.18 | 5.40 | 2.24 | 2.93 | 8.74 | 3.46 | 39.14 |
| 14 | 2.74 | 2.41 | 1.94 | 0.80 | 2.68 | 1.36 | 3.06 | 4.36 | 2.24 | 3.10 | 7.66 | 3.97 | 36.32 |
| 15 | 1.36 | 3.17 | 1.74 | 1.62 | 2.86 | 1.26 | 2.77 | 4.10 | 1.53 | 6.01 | 6.10 | 3.08 | 35.60 |
| 16 | 2.01 | 2.51 | 2.43 | 1.17 | 2.81 | 1.39 | 2.81 | 3.90 | 2.17 | 3.95 | 5.29 | 3.52 | 33.96 |
| 17 | 2.42 | 2.42 | 2.36 | 1.08 | 2.76 | 1.11 | 2.90 | 4.53 | 2.21 | 4.21 | 6.05 | 2.82 | 34.87 |
| 18 | 2.26 | 2.47 | 1.78 | 1.03 | 2.93 | 1.01 | 3.35 | 3.69 | 2.24 | 4.94 | 8.08 | 2.80 | 36.58 |
| 19 | 2.74 | 2.51 | 2.24 | 1.07 | 2.89 | 1.41 | 3.05 | 4.08 | 2.21 | 4.79 | 5.00 | 3.18 | 35.17 |
| 20 | 2.24 | 2.74 | 2.13 | 1.32 | 2.36 | 1.01 | 2.57 | 4.10 | 2.15 | 6.56 | 4.52 | 2.96 | 34.66 |
| 21 | 2.31 | 2.69 | 2.32 | 1.22 | 3.28 | 1.17 | 2.75 | 3.55 | 2.86 | 3.76 | 7.36 | 2.47 | 35.74 |
| 22 | 2.28 | 2.78 | 2.12 | 1.21 | 2.86 | 0.97 | 3.16 | 3.73 | 2.99 | 4.08 | 5.29 | 2.81 | 34.28 |
| 23 | 2.71 | 2.75 | 2.07 | 1.10 | 2.89 | 1.01 | 2.69 | 3.03 | 3.10 | 3.87 | 3.51 | 3.29 | 32.02 |
| 24 | 2.29 | 2.77 | 1.51 | 1.34 | 2.63 | 0.92 | 2.56 | 2.97 | 2.33 | 4.84 | 5.49 | 2.55 | 32.20 |
| 25 | 2.09 | 2.41 | 1.11 | 0.92 | 2.71 | 0.93 | 2.51 | 3.38 | 2.76 | 7.16 | 3.92 | 3.73 | 33.63 |
| *Avg* | 2.06 | 2.64 | 2.28 | 1.05 | 2.69 | 1.33 | 2.98 | 4.05 | 2.44 | 3.98 | 7.01 | 3.86 | 36.39 |

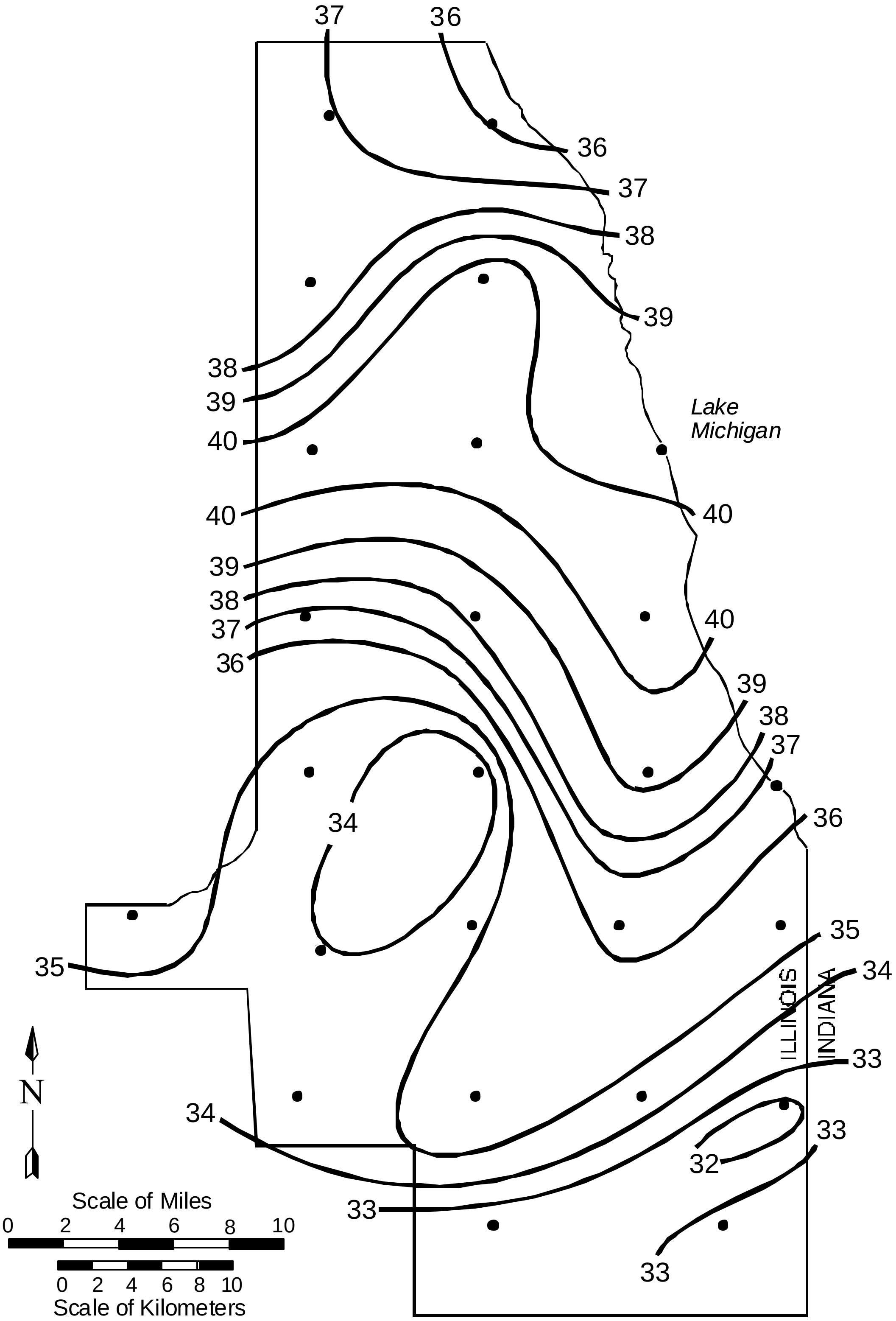


Figure 6. Precipitation pattern (inches) for Water Year 2001.

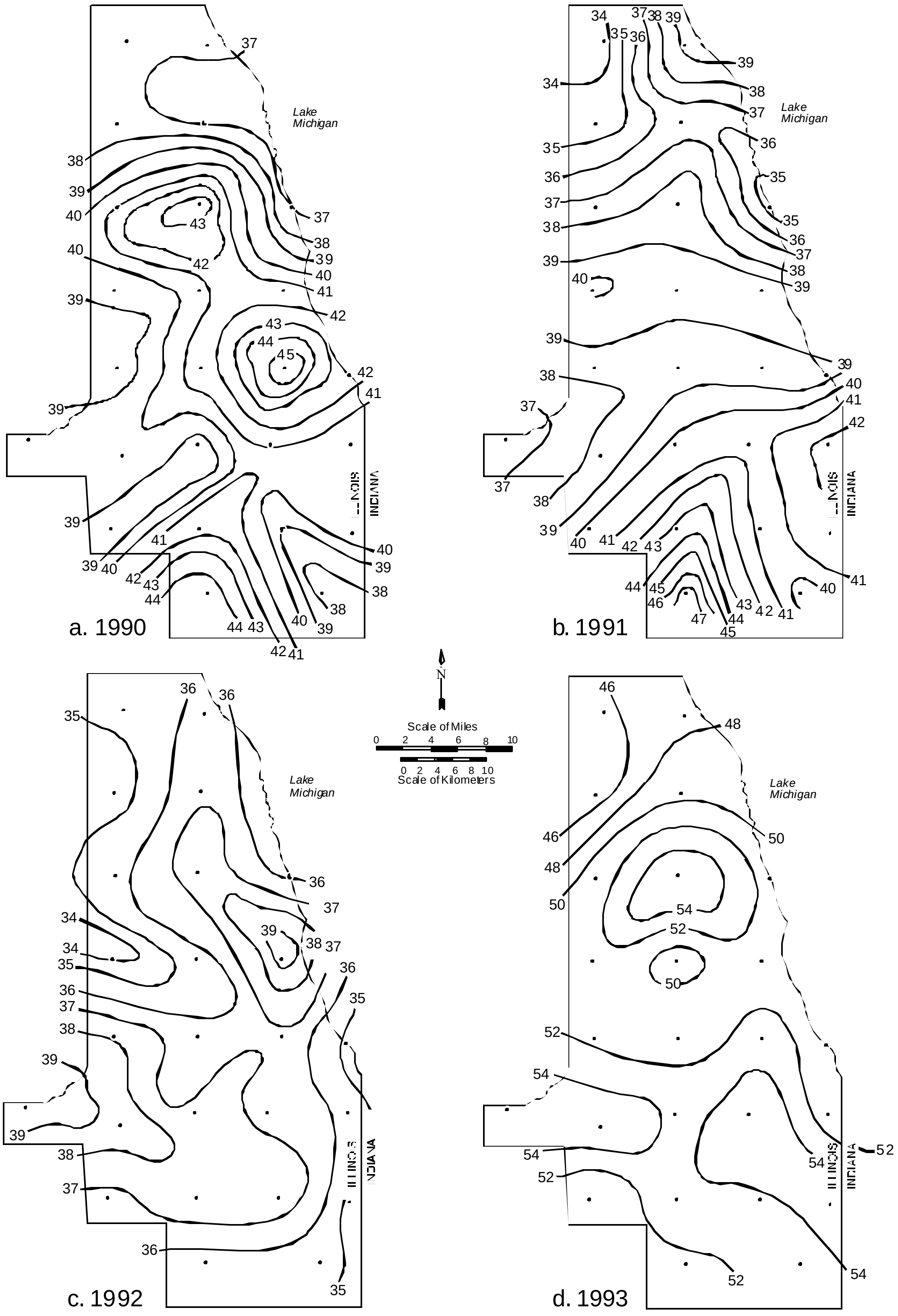
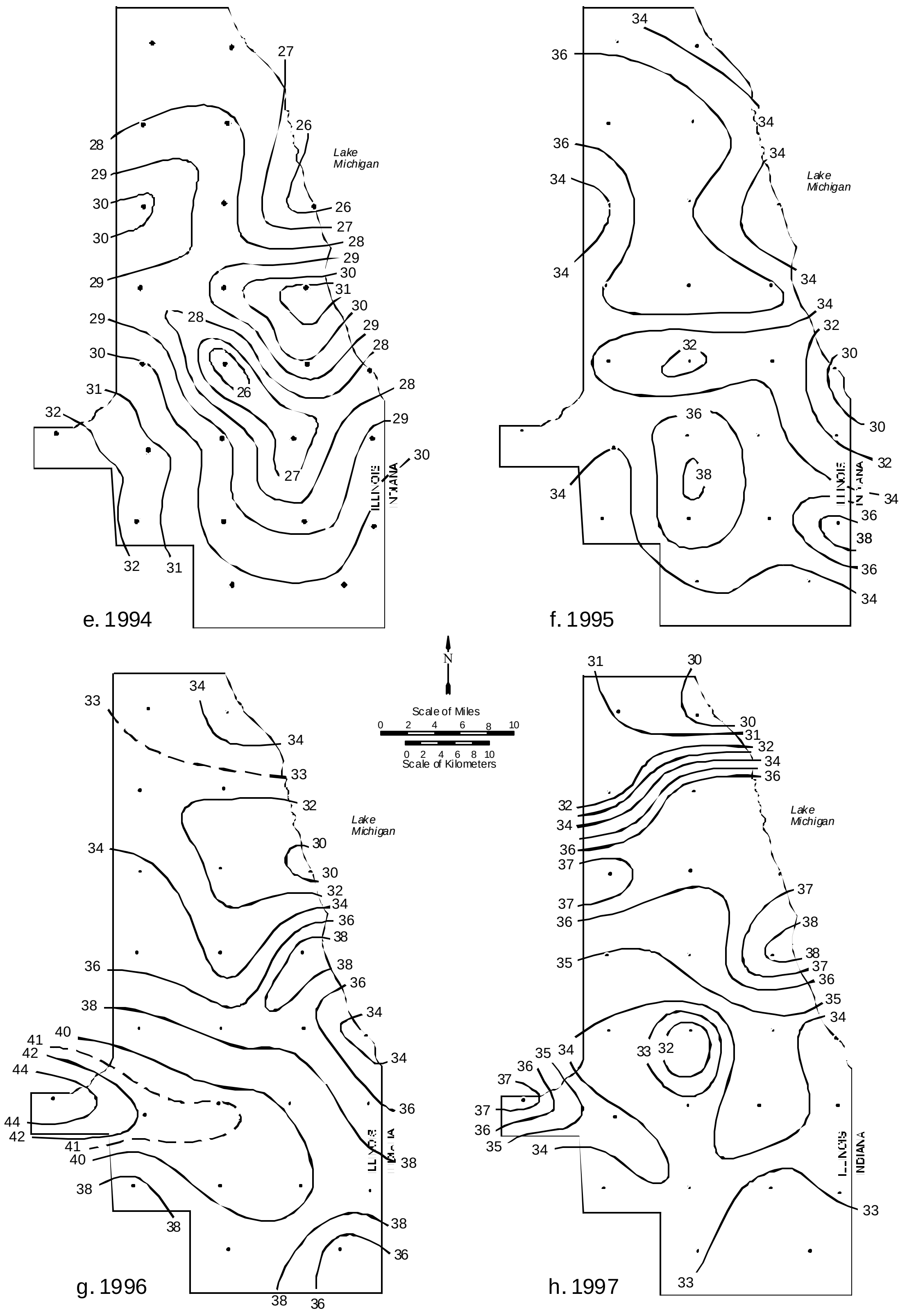


Figure 7. Precipitation pattern (inches) for Water Years 1990 - 2000.



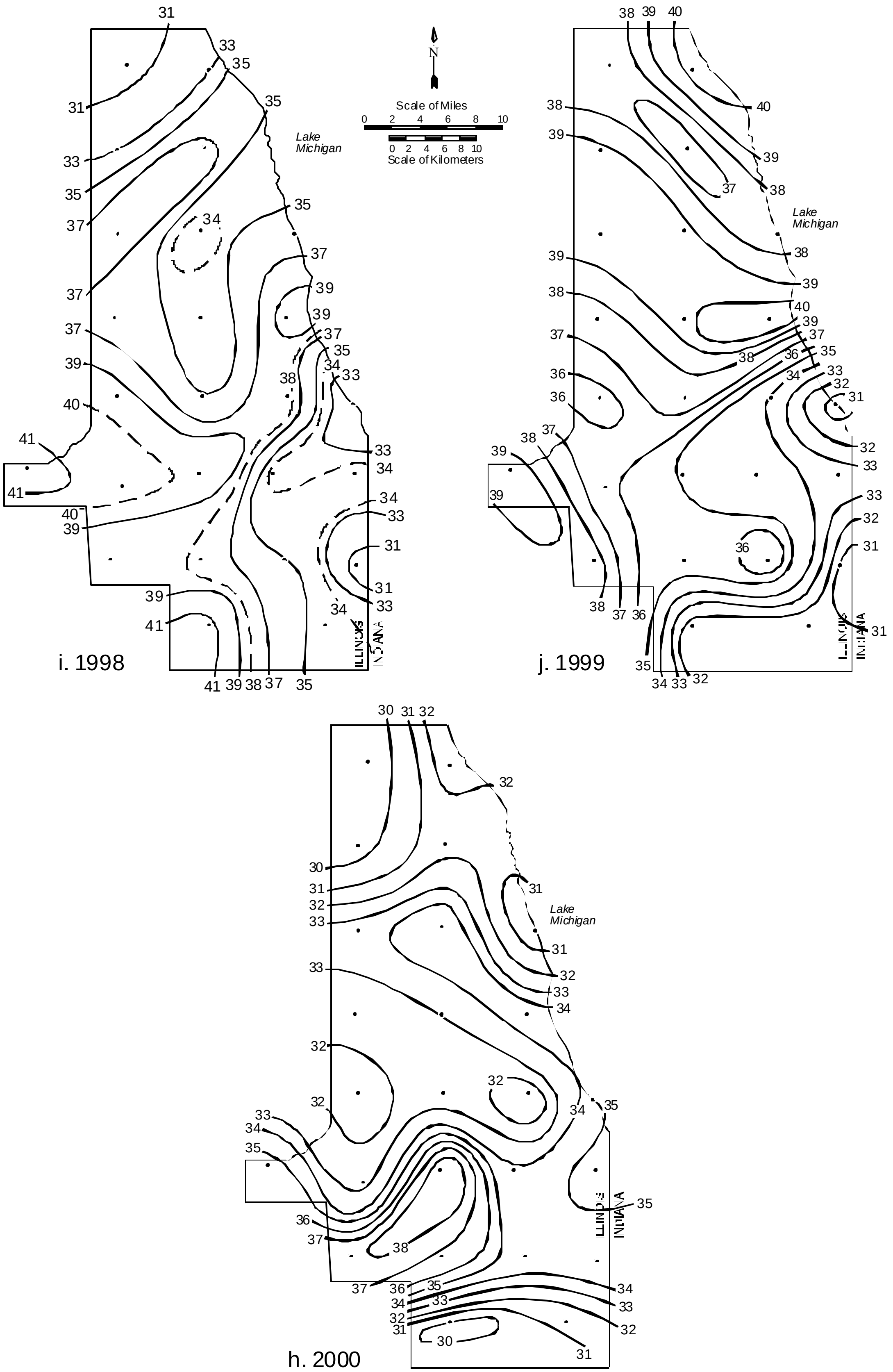
e. 1994

f. 1995

g. 1996

h. 1997

Figure 7. Continued.



i. 1998

j. 1999

h. 2000

Figure 7. Concluded.

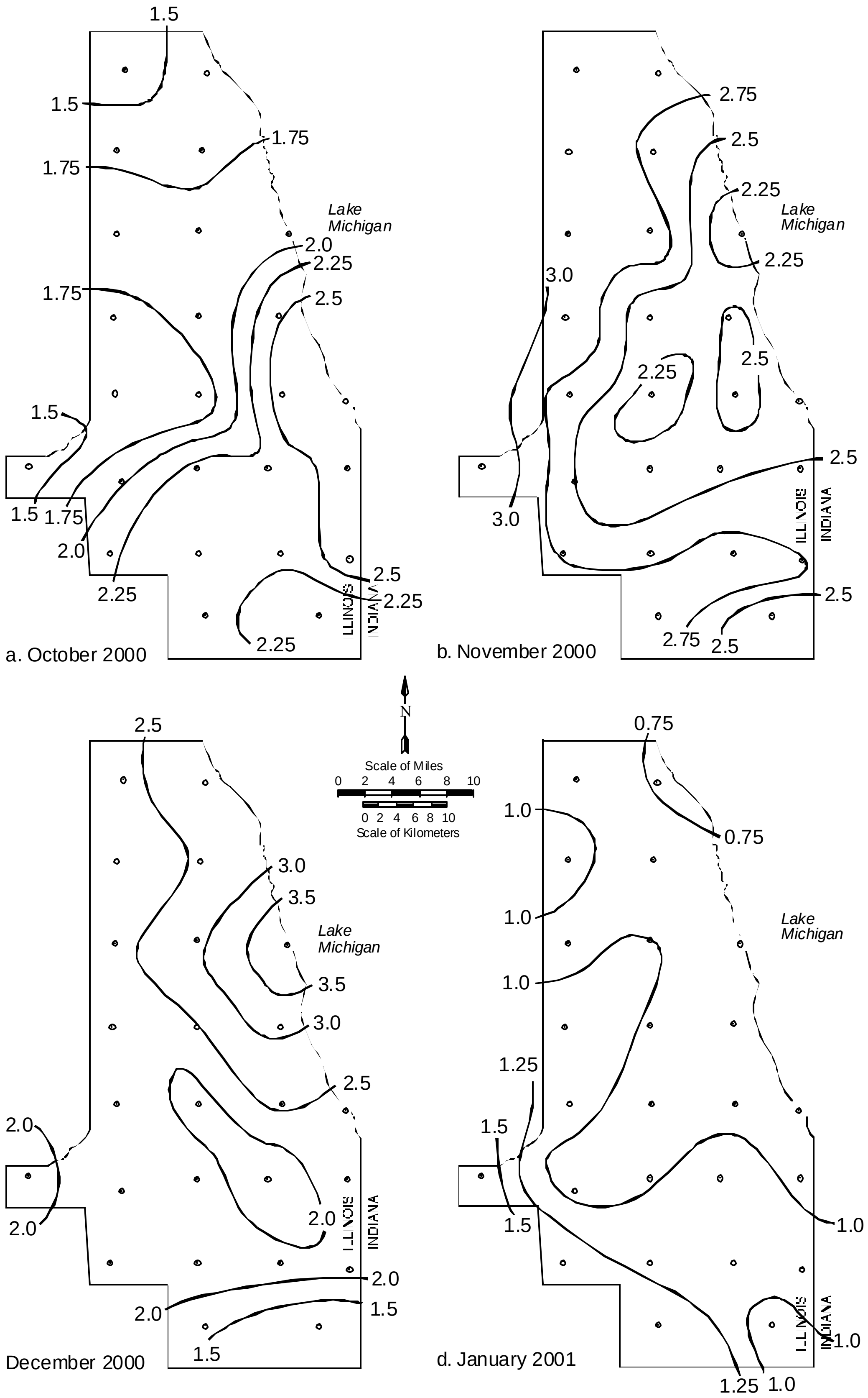
Monthly analyses for Water Year 2001 are shown in Figure 8a-l (see also Table 2). The rainiest month of the water year was August when the network average precipitation exceeded 7.0 inches, about 174 percent of the 11-year August network average of 4.03 inches. Other months when network precipitation equaled or exceeded 3.75 inches include May, July, and September. Heavy precipitation amounts were generally found in the central portion of the network during May and August, in the south and southwest in July, and in the northwest in September. The August total spatial rainfall pattern (Figure 8k) greatly influenced the Water Year 2001 annual rainfall pattern (Figure 6).

Twenty-one precipitation events occurred in May, and 15 events in April and July. Eleven events from Water Year 2001 resulted in a network average of greater than one inch. These events occurred three times in August, two times in February, and once in October, November, March, May, July, and September. In August, the average network rainfall exceeded 2.0 inches for one of the three storm events and 1.5 inches for another of the events.

Precipitation amounts smaller than 65 percent of the 11-year average occurred during October, January, March, and June in Water Year 2001, and 63, 45, 56, and 56 percent of the 11-year (1990-2000) network monthly average precipitation, respectively, was observed. Less than 2 inches of precipitation fell during the cold season months of January and March. During October, January, and March, fewer than nine precipitation events occurred. Precipitation amounts and the spatial gradient in precipitation amount generally were small in magnitude during these later three months (Figure 8).

The 12-year (1990-2001) average precipitation pattern (Figure 9) reveals an area of higher values across southwestern Chicago (sites #15, #16, #17, and #21), reaching northward to site #10. Lower values occurred at northern sites #1, #2, #7, at the lake site #14, and in the southeastern corner of the network at site #25. The 12-year network-wide average is 36.88 inches.

For high precipitation events, storm durations of one hour to three days were considered, and recurrence intervals were determined according to the standards set for northeastern Illinois (Huff and Angel, 1989). Of the 137 precipitation events identified during Water Year 2001, eight had at least one gage for which the amount surpassed the one-year recurrence interval for the given storm duration. Within these eight storms, 11 gages were in the one-year recurrence interval category, 13 gages in the two-year recurrence interval category, eight gages in the five-year category, seven gages in the ten-year category, three gages in the 25-year category, one gage in the 50-year category, and one gage exceeded the 100-year recurrence interval.



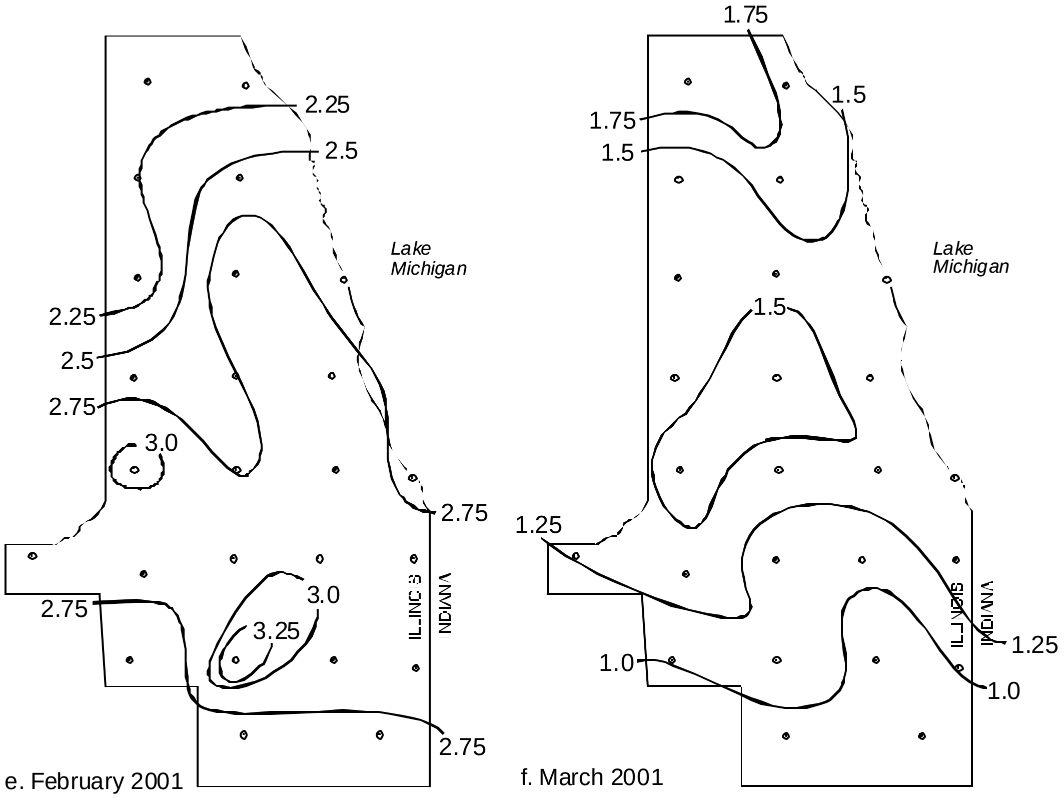
a. October 2000

b. November 2000

c. December 2000

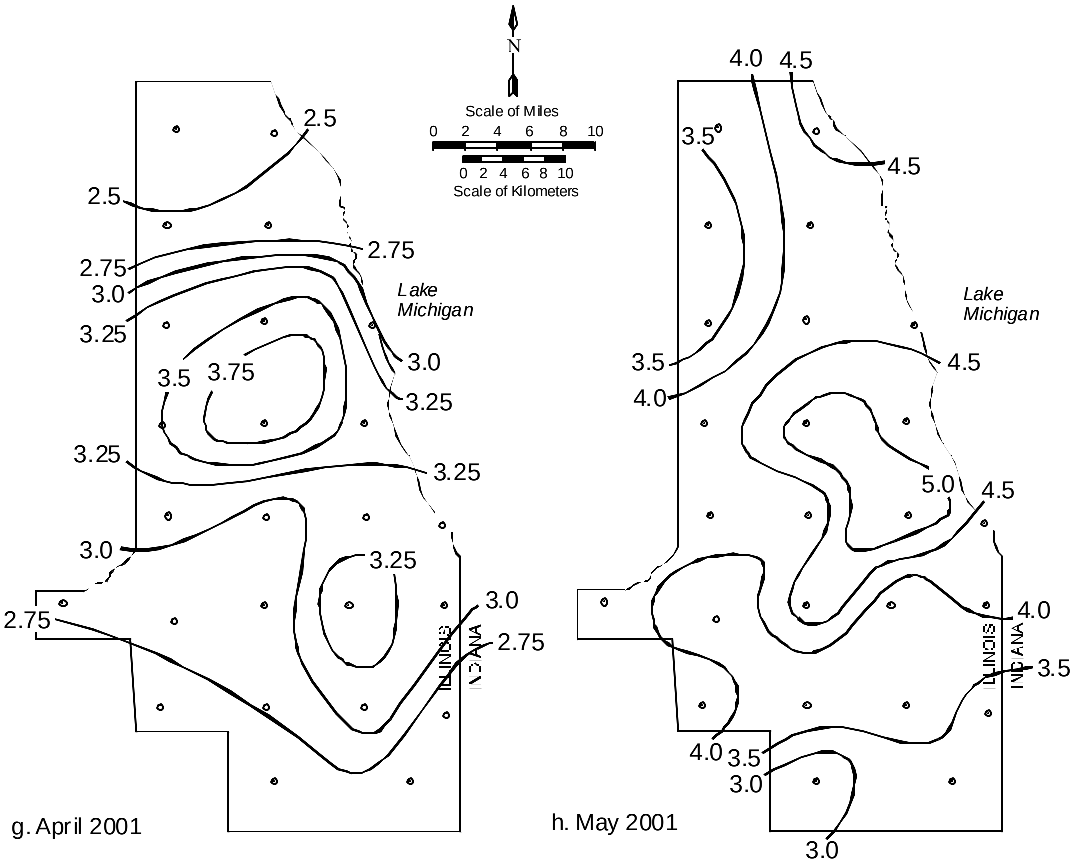
d. January 2001

Figure 8. Precipitation pattern (inches) for October 2000 to September 2001.



e. February 2001

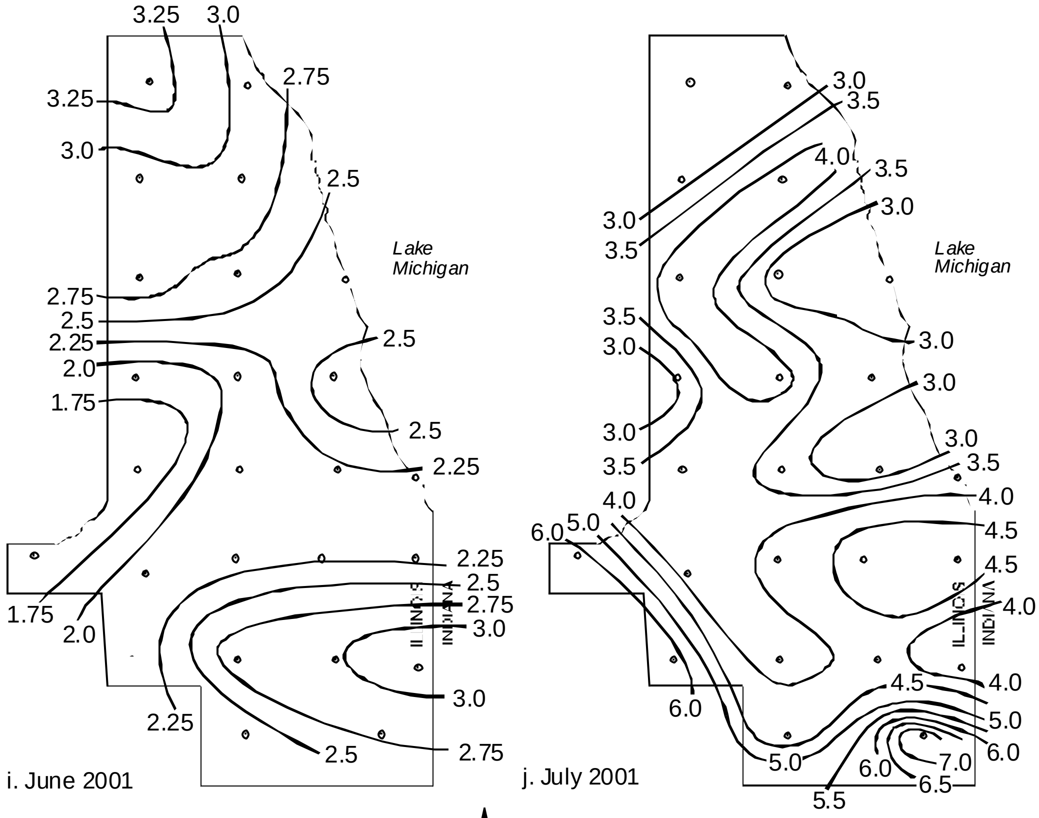
f. March 2001



g. April 2001

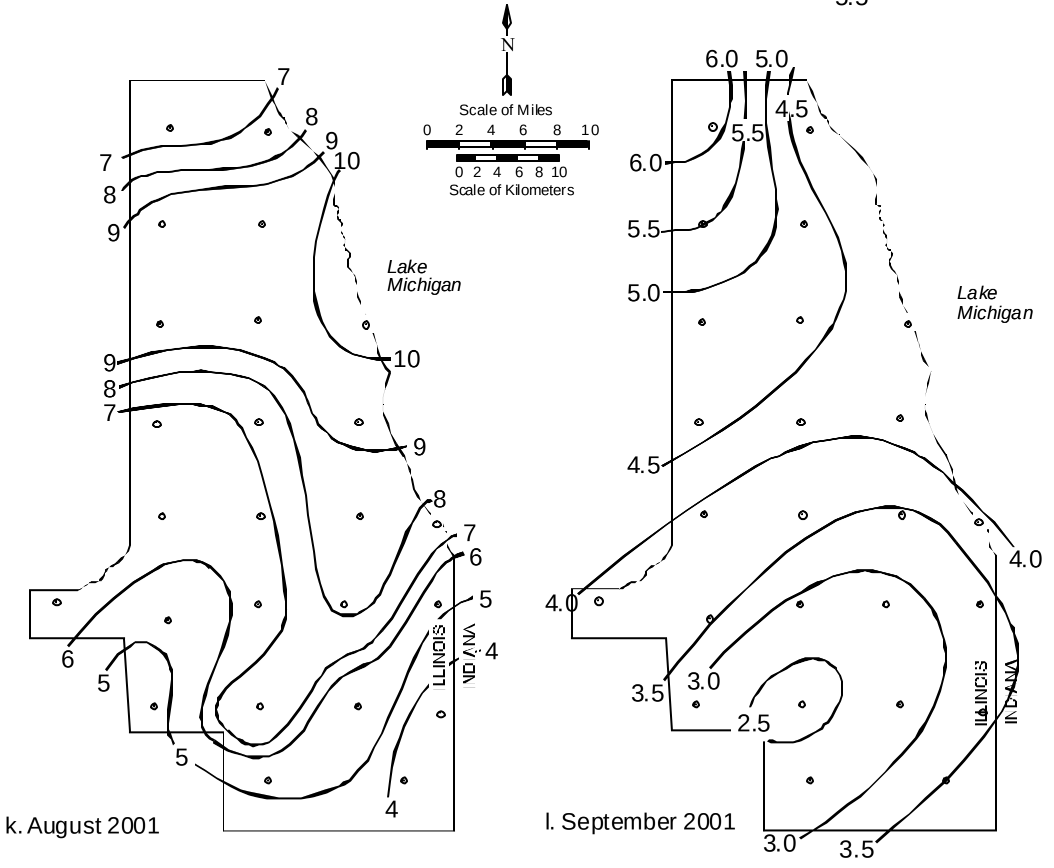
h. May 2001

Figure 8. Continued.



i. June 2001

j. July 2001



k. August 2001

l. September 2001

Figure 8. Concluded.

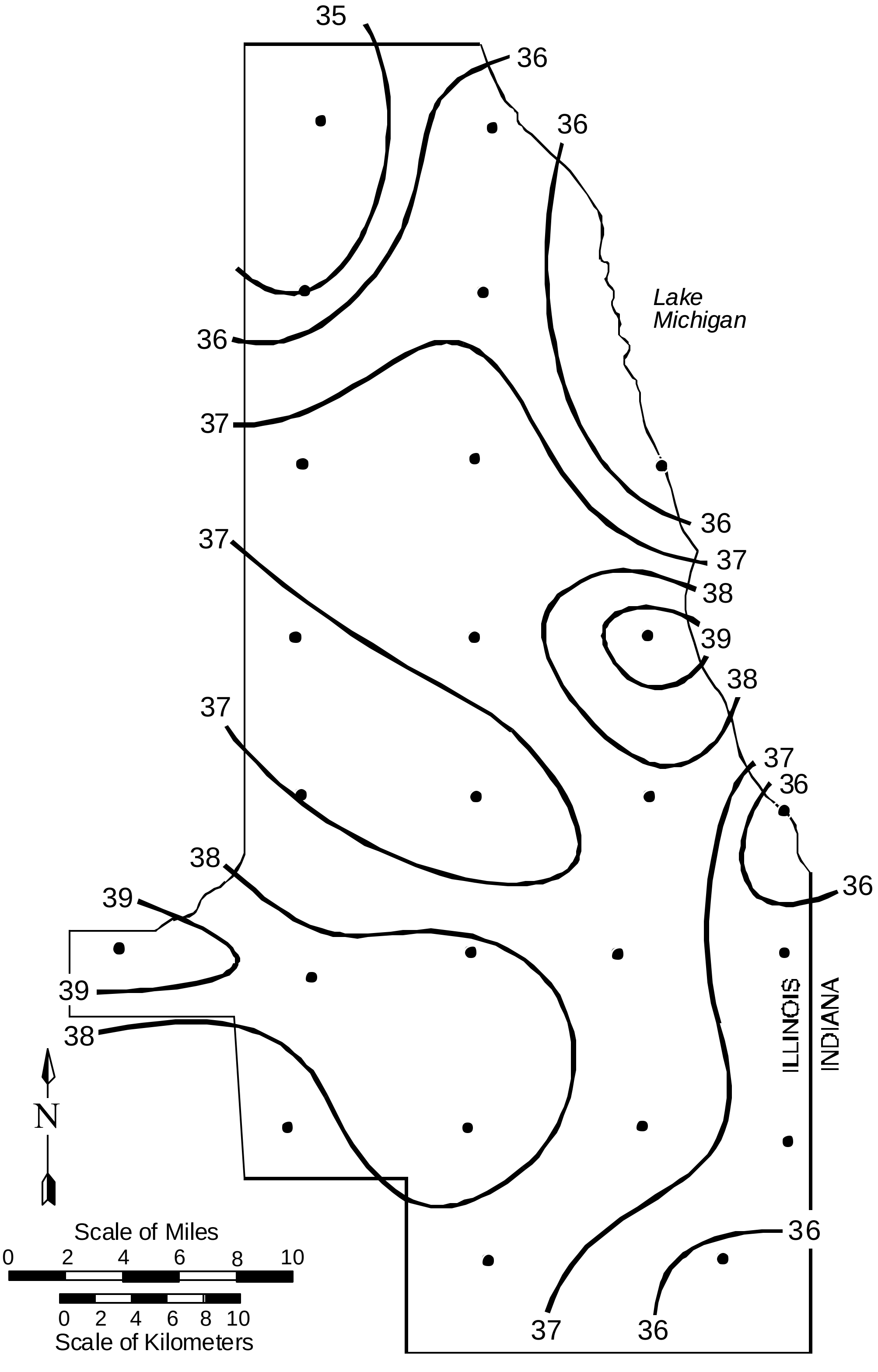


Figure 9. Twelve-year average precipitation pattern (inches), Water Years 1990-2001.

Of the eight Water Year 2001 heavy precipitation events, all events occurred during the summer months and included one or more gages exceeding at least the two-year recurrence interval. Five events included gages that exceeded at least the five-year recurrence interval, and three events included gages that exceeded the ten-year interval. One-event included three gages that exceeded the 50-year interval (2 August 2001), and one event had one gage that exceeded the 100-year interval (21 July 2001).

The 2001 summer had more storms in each recurrence interval category than in any of the preceding 11 years. The storms were of short duration, with the two most intense storms (July 21 and August 2) only lasting 2 and 3 hour, respectively. The heavy rainstorms in 2001 were generally small in areal coverage, with seven or fewer gages exceeding the one-year recurrence interval during seven of the eight storms. Only the August 2, 2001 storm had a large areal extent with 19 gages exceeding the one-year recurrence interval. This storm also resulted in widespread flooding (Changnon and Westcott, 2002). Appendix IV contains specific information concerning the eight Water Year 2001 precipitation events with gages that exceeded the one-year recurrence interval.

## 7. SUMMARY

The Cook County raingage network has now collected precipitation data during 12 water years, 1990-2001. Siting of the raingages, areal coverage of the network, installation of potentiometers and data loggers, and careful quality control of the data allow the U.S. Army Corps of Engineers, Chicago District, to more accurately estimate the storm runoff portion of the diversion of water from Lake Michigan into Illinois. Because of the relatively dense spacing of the raingages, the network also provides high-quality data for research on the precipitation variability of the Cook County region.

## 8. ACKNOWLEDGMENTS

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## 9. REFERENCES

Changnon, S.A., 1961: Precipitation contrasts between the Chicago urban area and an offshore station in southern Lake Michigan. *Bulletin of the American Meteorological Society*, **42**, 1-10.

Changnon, S.A., 1968: *Precipitation Climatology of Lake Michigan Basin*. Illinois State Water Survey Bulletin 52, 46p.

Changnon, S.A., 1980: Evidence of urban and lake influences on precipitation in the Chicago area. *Journal of Applied Meteorology*, **19**, 1137-1159.

Changnon, S.A., 1984: Urban and lake effects on summer rainfall in the Chicago area. *Physical Geography*, **4**, 1-23.

Changnon, S.A., and N.E. Westcott, 2002: A record number of heavy rainstorms in Chicago in 2001. *Transactions Illinois Academy of Sci*ence, accepted.

Huff, F.A., 1967: Time distribution of rainfall in heavy storms. *Water Resources Research*, **3**, 1007-1019.

Huff, F.A., 1970: Sampling errors in measurement of mean precipitation. *Journal of Applied Meteorology*, **9**, 35-44.

Huff, F.A., 1979: *Spatial and Temporal Correlation of Precipitation in Illinois*. Illinois State Water Survey Circular 141, 14p.

Huff, F.A., and J.R. Angel, 1989: *Frequency Distributions and Hydroclimatic Characteristics of Heavy Rainstorms in Illinois*. Illinois State Water Survey Bulletin 70, 177p.

Huff, F.A., and S.A. Changnon, 1973: Precipitation modification by major urban areas. *Bulletin of the American Meteorological Society*, **54**, 1220-1232.

Huff, F.A., and J.L. Vogel, 1976*: Hydrometeorology of Heavy Rainstorms in Chicago and Northeastern Illinois*. Illinois State Water Survey Report of Investigation 82, 63p.

Jones, D.M.A., 1969: Effect of housing shape on the catch of recording gages. *Monthly Weather Review*, **97**, 604-606.

Koschmieder, H., 1934: Methods and results of definite rain measurements. *Monthly Weather Review*, **62**, 5.

Legates, D.R., and C.J. Willmott, 1990: Mean seasonal and spatial variability in gauge-corrected, global precipitation. *International Journal of Climatology*, **10**, 111-127.

Lindroth, A., 1991: Reduced loss in precipitation measurements using a new wind shield for raingages. *Journal of Atmospheric and Oceanic Technology*, **8**, 444-451.

Peppler, R.A., 1990: *Reduction of 1987 Water Year Precipitation Data for Lake Michigan Diversion Accounting*. Illinois State Water Survey Contract Report 498, 16p.

Peppler, R.A., 1991a: *Reduction and Adjustment of Water Year 1988 and Water Year 1989 Precipitation Data for Lake Michigan Diversion Accounting*. Illinois State Water Survey Contract Report 510, 24p.

Peppler, R.A., 1991b: *Installation and Operation of a Dense Raingage Network to Improve Precipitation Measurements for Lake Michigan Diversion Accounting: Water Year 1990*. Illinois State Water Survey Contract Report 517, 87p.

Peppler, R.A., 1991c: *Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1991*. Illinois State Water Survey Contract Report 520, 65p.

Peppler, R.A., 1993a: *Reduction and Adjustment of 1986 Water Year Precipitation Data for Lake Michigan Diversion Accounting*. Illinois State Water Survey Contract Report 550, 13p.

Peppler, R.A., 1993b: *Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1992*. Illinois State Water Survey Contract Report 551, 59p.

Peppler, R.A., 1994: *Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1993*. Illinois State Water Survey Contract Report 573, 60p.

Peppler, R.A., 1995: Continued *Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1994*. Illinois State Water Survey Contract Report 585, 60p.

Vogel, J.L., 1986: *Significant Storm Distribution in Chicago, 1949-1979*. Illinois State Water Survey Contract Report 388, 30p.

Vogel, J.L., 1988: *An Examination of Chicago Precipitation Patterns for Water Year 1984*. Illinois State Water Survey Contract Report 449, 44p.

Vogel, J.L., 1989: *Reduction of 1985 Water Year Precipitation Data for Chicago*. Illinois State Water Survey Contract Report 459, 15p.

Westcott, N.E., 1996: *Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1995*. Illinois State Water Survey Contract Report 601, 48p.

Westcott, N.E., 1997: *Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1996*. Illinois State Water Survey Contract Report 618, 50p.

Westcott, N.E., 1998: *Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1997*. Illinois State Water Survey Contract Report 628, 51p.

Westcott, N.E., 1999: *Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1998*. Illinois State Water Survey Contract Report 647, 52p.

Westcott, N.E., 2000: *Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1999*. Illinois State Water Survey Contract Report 2000-7, 52p.

Westcott, N.E., 2001: *Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 2000*. Illinois State Water Survey Contract Report 2001-02, 52p.

## APPENDIX II: INSTRUCTIONS FOR RAINGAGE TECHNICIANS

1. Supplies required for proper servicing of the instruments in the Cook County raingage network:

   a. A supply of 8-day rotation raingage charts (Belfort number 5-4047-B)
   b. A supply of spare felt-tipped pen points
   c. A roll of paper towels or similar absorbent material
   d. A ball-point pen or pencil
   e. Grass clippers and/or sickle
   f. A clipboard
   g. A spare 12-quart bucket
   h. Batteries for the 25 data loggers
   i. A spare data logger
   j. A set of weights for calibration
   k. A laptop computer and an a/c adapter

2. Make sure you have the correct time in the Central Standard Time zone:

   Please coordinate your watch with the broadcast tone from radio station WGN, on the hour, before starting a day's servicing schedule, and recheck if possible when out in the field. Try to be within 15 seconds of the correct time.

3. Order of servicing upon arrival at a site:

   1) Cut the grass around the raingage if necessary or applicable. Do this to the specifications of the landowner or below the level of the raingage door, whichever is shorter.

   2) Open the sliding door on the side of the instrument case by pushing out on the hinge lock and pulling up on the door handle; depress the bucket platform upright casting to ink the OFF time on the chart (a vertical line). Note the time on your watch, and move the pen point and arm away from the chart by pulling out on the pen bracket. Lift up on the drum cylinder to disengage it from the electric chart drive, and remove it from the instrument case. Write the OFF date and time on the chart. Carefully remove the chart from the drum to avoid smearing the fresh ink at the end of the trace.

   3) Write this OFF time as the ON time on a new chart, and apply the chart to the drum cylinder, making sure the horizontal lines are properly aligned, the crease at the right end of the chart is sharp, and the chart is tight on the cylinder. This helps prevent skipping when the pen point travels over the drum clip, as well as preventing false indications of a precipitation event. Make a small mark with your pen or pencil on the chart at the half-inch line to indicate the ON time. Reinstall the chart cylinder

onto the electric chart drive, making sure the chart cylinder and drive gears mesh. Set the pen point at the ON time.

4) Quickly remove the collector assembly (top cap) from the top of the gage by rotating the collector assembly clockwise to disengage the tongue-and-groove assembly, set it down, and then carefully lift the bucket off of the weighing platform (if there is water in it). During the warm season, pour the water into the 2-inch measuring tube and record the amount of precipitation collected for use in checking the calibration. During wintertime operations when a charge of antifreeze is in the bucket, leave the antifreeze until the chart reading passes the 6-inch mark. At that point, pour the bucket contents into a sealed container and dispose of properly. DO NOT POUR SOLUTION ONTO THE GROUND! If wintertime conditions prevail, recharge the empty bucket with one liter of antifreeze. Reposition the dry bucket on the platform and reinstall the collector assembly by setting it on top of the raingage case and turning counterclockwise until the tongue-and-groove assembly meshes. At any time of the year, once the collector is repositioned, check the gage to make sure the collector orifice top edge is level.

5) Move the pen arm and point over near the chart cylinder and rotate the cylinder counterclockwise until the pen point coincides with the pencil mark on the chart denoting the ON time. Let the pen point rest on the chart there, and depress the platform casting again to make a vertical pen line at the ON time. This also assures that the pen point is writing correctly. If not, check the tip of the pen point to see why it is not drawing. Replace if necessary. It helps if the word "ON" is written on the chart near the ON line for later chart editing purposes. Re-zero the pen point if necessary by turning the fine adjustment screw. It is a good idea to "zero" the pen near the 0.25-inch mark to prevent evaporation from taking the pen point below the zero line.

6) Unplug the data logger from the connection to the potentiometer. Plug the data logger into the laptop computer and download data. Save data to a file on the laptop and to a file on a three-inch diskette. Check the battery voltage. Change the batteries in the data logger if necessary. After changing the batteries, check the battery voltage again, reload the program, plug the data logger into the connection with the potentiometer, and complete a five-point calibration of the gage.

7) To make a five-point calibration of the gage, set three weights at a time into the center of the bucket. As each set of weights is added, enter that point as instructed by the data logger software, and note the position of the pen on the chart. After the calibration is complete, be sure that the pen on the chart agrees with the data point indicated as each set of weights is removed from the bucket.

8) Wipe the inside base of the gage to keep it relatively clean. Check the just-removed chart for any irregularities and note them on the upper right corner. Observe the new chart to make sure the drum is rotating and the pen is writing.

When you are sure everything is operating correctly, carefully close the gage door and push the hinge lock in to secure it. Make sure you have removed all supplies and tools from the site before moving on to the next one.

4. Completed raingage charts and site repairs:

   When a complete set of 25 charts has been collected for a month, place them in numerical order. Note any serious problems encountered during servicing. Situations worthy of immediate attention include chart-drive stoppages, unauthorized movement of the raingage, vandalism, and theft. Make minor repairs (e.g., pen point stuck under drum cylinder, debris in the collection bucket, etc.). Major repairs will be scheduled as soon as possible.

5. Change in site status:

   If you become aware that there has been or will be a change of status of one of the sites in the network, or one of the landowners requests movement of the raingage, alert the project director so that contact can be made with the landowner to work out a new arrangement. It is important to try to keep the sites as permanent as possible during the course of this project.

6. Public relations:

   As a representative of the State of Illinois, it is imperative that you make your contacts with the landowners and others as cordial as possible and respect their property. They are providing an important service by agreeing to have the instrumentation on their property, so please keep their good will. Refer any questions they have concerning the project and your job that you are unable to answer to the Project Principal Investigator. Remind them of the toll-free number, (866) 292-7305.

## APPENDIX IV: DOCUMENTATION OF HIGH STORM TOTALS

This appendix documents individual station storm totals (within the 137 storms) that exceeded an annual event (one-year recurrence interval) during Water Year 2001. Within the storm period, if several precipitation periods were present at an individual gage and were separated by six hours or more, only the heaviest precipitation period was considered. Leading and trailing precipitation amounts of 0.03 inches or less were ignored. Storm durations of one hour to three days were evaluated. The precipitation amounts for one-year to 100-year recurrence intervals, and the aforementioned storm durations for northeastern Illinois, are given below (Huff and Angel, 1989).

| *Storm Duration* | *Precipitation Amounts (inches)* | | | | | | |
|---|---|---|---|---|---|---|---|
| | *1-yr* | *2-yr* | *5-yr* | *10-yr* | *25-yr* | *50-yr* | *100-yr* |
| 1 hour | 1.18 | 1.43 | 1.79 | 2.10 | 2.59 | 3.04 | 3.56 |
| 2 hours | 1.48 | 1.79 | 2.24 | 2.64 | 3.25 | 3.82 | 4.47 |
| 3 hours | 1.60 | 1.94 | 2.43 | 2.86 | 3.53 | 4.14 | 4.85 |
| 6 hours | 1.88 | 2.28 | 2.85 | 3.35 | 4.13 | 4.85 | 5.68 |
| 12 hours | 2.18 | 2.64 | 3.31 | 3.89 | 4.79 | 5.62 | 6.59 |
| 18 hours | 2.30 | 2.79 | 3.50 | 4.11 | 5.06 | 5.95 | 6.97 |
| 24 hours | 2.51 | 3.04 | 3.80 | 4.47 | 5.51 | 6.46 | 7.58 |
| 48 hours | 2.70 | 3.30 | 4.09 | 4.81 | 5.88 | 6.84 | 8.16 |
| 72 hours | 2.93 | 3.55 | 4.44 | 5.18 | 6.32 | 7.41 | 8.78 |

The values listed in the following table exceed the numbers above for the given storm duration. An "e" indicates a partial or full estimate for a particular site and storm, based on a spatial interpolation of the hourly precipitation values of neighboring gages. The last column indicates whether a particular gage within the given storm exceeded a precipitation value greater than an annual event (2-year to 100-year recurrence intervals considered).

## STORM TOTALS

| *Storm #* | *Date* | *Site #* | *Duration (hour)* | *Amount (inch)* | *Storm Recurrence Frequency* |
|---|---|---|---|---|---|
| 109 | 7 / 21 / 01 | 15 | 1 | 2.53 | 10-year |
| | | 20 | 2 | 4.91 | >100-year |
| | | 21 | 2 | 1.82 | 2-year |
| | | 22 | 1 | 1.77 | |
| | | 23 | 2 | 1.54 | |
| | | 24 | 2 | 2.60 | 5-year |
| | | 25 | 2 | 2.91 | 10-year |
| 110 | 7 / 22/ 01 | 5 | 2 | 1.90 | 2-year |
| 112 | 7 / 23 / 01 | 22 | 1 | 1.76 | 2-year |
| | | 25 | 1 | 1.94 | 5-year |
| 114 | 7 / 24-25 / 01 | 9 | 9 | 2.19 | |
| | | 15 | 9 | 2.50 | 2-year |
| | | 19 | 4 | 2.13 | 2-year |
| 116 | 8 / 2 / 01 | 2 | 3 | 2.63 | 5-year |
| | | 4 | 4 | 2.90 | 5-year |
| | | 6 | 3 | 2.75 | 5-year |
| | | 7 | 3 | 3.95 | 25-year |
| | | 8 | 2 | 1.90 | 2-year |
| | | 9 | 4 | 2.44 | 2-year |
| | | 10 | 4 | 4.80 | 50-year |
| | | 11 | 2 | 2.92 | 10-year |
| | | 12 | 3 | 3.80 | 25-year |
| | | 13 | 4 | 4.07 | 25-year |
| | | 14 | 3 | 2.66 | 5-year |
| | | 15 | 3 | 1.76 | |
| | | 16 | 3 | 2.29 | 2-year |
| | | 17 | 4 | 1.86 | |
| | | 18 | 3 | 2.25 | 2-year |
| | | 20 | 3 | 1.93 | 2-year |
| | | 21 | 3 | 2.87 | 10-year |
| | | 22 | 2 | 1.72 | |
| | | 24 | 2 | 2.14 | 10-year |

| *Storm #* | *Date* | *Site #* | *Duration (hour)* | *Amount (inch)* | *Storm Recurrence Frequency* |
|---|---|---|---|---|---|
| 125 | 8 / 24-25 / 01 | 7 | 9 | 2.30 | |
| | | 8 | 10 | 2.11 | |
| | | 14 | 9 | 2.09 | |
| | | 17 | 4 | 2.14 | 2-year |
| | | 18 | 14 | 3.39 | 5-year |
| | | 21 | 14 | 3.01 | 2-year |
| 128 | 8 / 30-31 / 01 | 3 | 3 | 3.36 | 10-year |
| | | 4 | 4 | 3.51 | 10-year |
| | | 5 | 3 | 2.33 | 2-year |
| | | 7 | 4 | 1.75 | |
| 134 | 9 / 18-19 / 01 | 1 | 9 | 3.61 | 5-year |
| | | 3 | 10 | 2.17 | |

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