Contract Report 520

Continued Operation of a Raingage Network for Collection, Reduction, and Analysis of Precipitation Data for Lake Michigan Diversion Accounting: Water Year 1991

by Randy A. Peppier
Office of Special Programs

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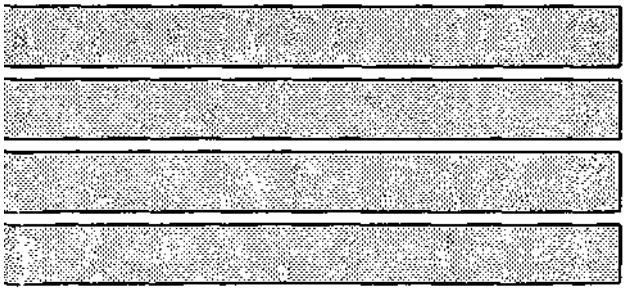

Illinois State Water Survey
Administration Division
Champaign, Illinois

A Division of the Illinois Department of Energy and Natural Resources

Department of Energy & Natural Resources
325 West Adams
Springfield, Illinois 62704-1892

CONTINUED OPERATION OF A RAINGAGE NETWORK FOR COLLECTION, REDUCTION, AND ANALYSIS OF PRECIPITATION DATA FOR LAKE MICHIGAN DIVERSION ACCOUNTING: WATER YEAR 1991

By

Randy A. Peppier

FINAL REPORT

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U.S. Army Corps of Engineers, Chicago District

on Contract

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F. A. Huff, D. M. A. Jones, and R. A. Peppier
Principal Investigators

Office of Special Programs
Office of Applied Climatology
Office of Cloud and Precipitation Research
Illinois State Water Survey
2204 Griffith Drive
Champaign, Illinois 61820-7495

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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 the U.S. Supreme Court Order of 1967, 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. It has been affected over the years 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 this century that attempted to ensure 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 the Cook County, Illinois region.

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 sewer systems and watercourses. The combined sewers mix sanitary systems with the runoff, and this water then goes to the treatment plants or, during major flood events, becomes surcharge into the watercourses. 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 one of three facilities located along the shoreline: Chicago River Controlling Works, O'Brien Lock and Dam, and Wilmette Controlling Works.

There are two methods by which diversion is computed. The first 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, groundwater supply whose effluent is discharged into the canal, and Indiana water supply that is discharged to the canal via the Calumet River system and the Calumet Sag Channel.

The second method estimates diversion 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 computation is performed to cross-check the first method.

In both of these procedures, it is necessary to estimate runoff from the Des Plaines River and the Lake Michigan watersheds. Since a significant portion of this area is not gaged with respect to water flows, runoff is estimated through hydrologic simulation. 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 be a substantial portion of the diversion. For example, in Water Year 1984 (a water year extends from 1 October through 30 September of the following calendar year), runoff from the Des Plaines River watershed constituted a 196.5 cfs (5 percent) deduction from the Romeoville measurement record in the diversion computations. In the verification computations, the Lake Michigan watershed runoff constituted an 829.0 cfs (27 percent) deduction from the total diversion.

However, the precipitation data available for use in the accounting procedure in recent water years (1984-1989) have displayed patterns inconsistent with known, long-term Chicago-area patterns (e.g., Changnon, 1961,1968; Huff and Changnon, 1973; Vogel, 1988, 1989, 1991; Peppier, 1990, 1991a, 1991b). These patterns also diverge from the known urban effects found within the isohyetal patterns for the Cook County region for heavier rainfall distributions from 1949-1974 (Huff and Vogel, 1976), particularly towards the south, and within patterns observed during the operation of a dense raingage network and a radar system in the Chicago area during the late 1970s (Changnon, 1980, 1984). The recent unusual patterns have been 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 totals

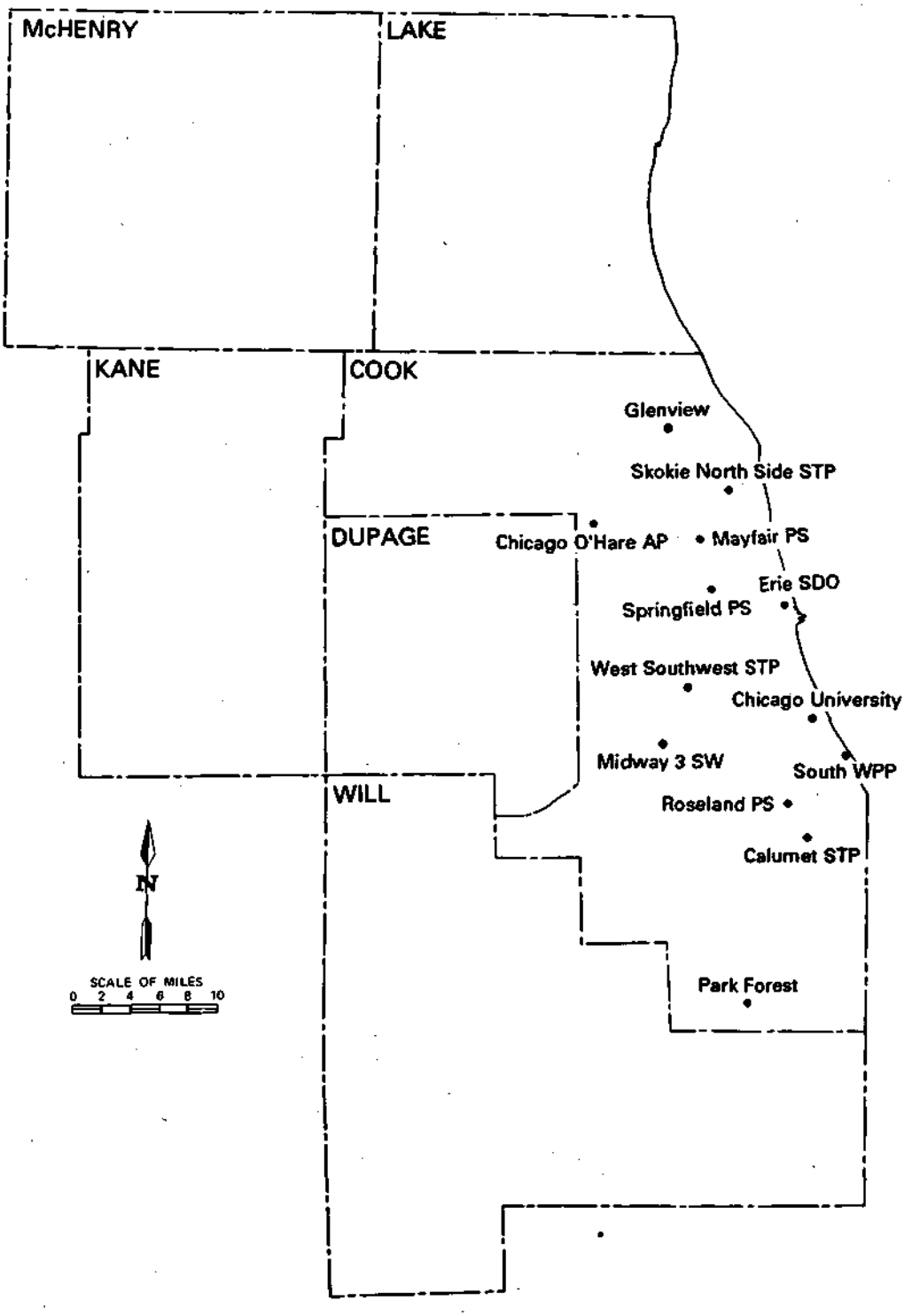

Figure 1. For Lake Michigan diversion accounting purposes, 13 raingage sites were used prior to Water Year 1990. Chicago O'Hare AP, Midway 3 SW, Chicago University, and Park Forest are National Weather Service sites; Mayfair PS, Springfield PS, South WPP, and Roseland PS are City of Chicago sites; Glenview, Skokie North Side STP, Erie SDO, West Southwest STP, and Calumet STP are Metropolitan Water Reclamation District of Greater Chicago sites. Abbreviations are as follows: AP = Airport; SDO = Sanitary District Office; SW = Southwest; WPP = Water Purification Plant; PS = Pumping Station; and STP = Sewage Treatment Plant.

were caused by 1) inadequate raingage exposure (e.g., gages situated on rooftops or too near natural or man-made, flow-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 an improvement on the original values. This procedure also illuminated difficulties experienced when trying to merge data observations from several different observing platforms 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 exposure 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."

Thus, using this recommendation as a model, the Water Survey and the COE jointly decided in late 1988 to devise, install, and operate a new raingage network, funded by the COE, that would produce consistent, accurate data for the diversion accounting, free of the need for adjustment. The 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 1991, the second year of the network's operation.

2. NETWORK DESIGN

The Water Survey has operated dense raingage networks in the past (e.g., Huff, 1970,1979), which tested gridded raingage spacings of 6 feet to 6 miles. Adequate sampling of convective-type precipitation (spring and summer) required 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 encompassed by the Lake Michigan and Des Plaines River watersheds within the MWRDGC North, Central, South, and Lemont basins. However, due to cost considerations, some catchment ability was sacrificed, especially in the warmer seasons, and a 25-site grid was devised using a 6-mile grid spacing between gages. Also due to cost considerations, a further step of placing raingages outside the watershed boundaries to better define isohyetal patterns at those boundaries was not pursued. Twenty-five raingages, more than Vogel had originally envisioned (10-15), are necessary to provide adequate coverage for precipitation catchment. This number, though, is consistent with the "best current engineering practice" as specified in the Supreme Court decree.

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 field trips were made and letters were written in summer 1989 seeking permission to use the locations as raingage sites. Due to the urbanization of the region, this was sometimes a frustrating venture, making it difficult 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 Water Survey practice, each raingage was placed with its base approximately 8 inches above ground level on stakes and the top of its orifice at about 4 feet. When asked for permission to site on their property, most individuals, businesses, and municipalities were extremely receptive. In fact, only three of the sites have been relocated since the network began operation in October 1989: one landowner no longer wanted a raingage on site, another was moved due to an impending move, and a third has been shifted several times due to problems siting a gage on Chicago Park District property.

In late September and early October 1989, the entire 25-gage network was installed (Figure 2). Each Belfort weighing-bucket raingage used throughout the network was fitted with a battery-powered electric chart drive for more consistent and reliable operation. The Water Survey donated all raingages needed from its inventory. Table 1 gives further information for each site. Appendix I contains complete site descriptions as of October 4, 1991 for each network location.

The weighing-bucket recording raingages used are as reliable as any others available. 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 global catch." Undercatch is generally much less

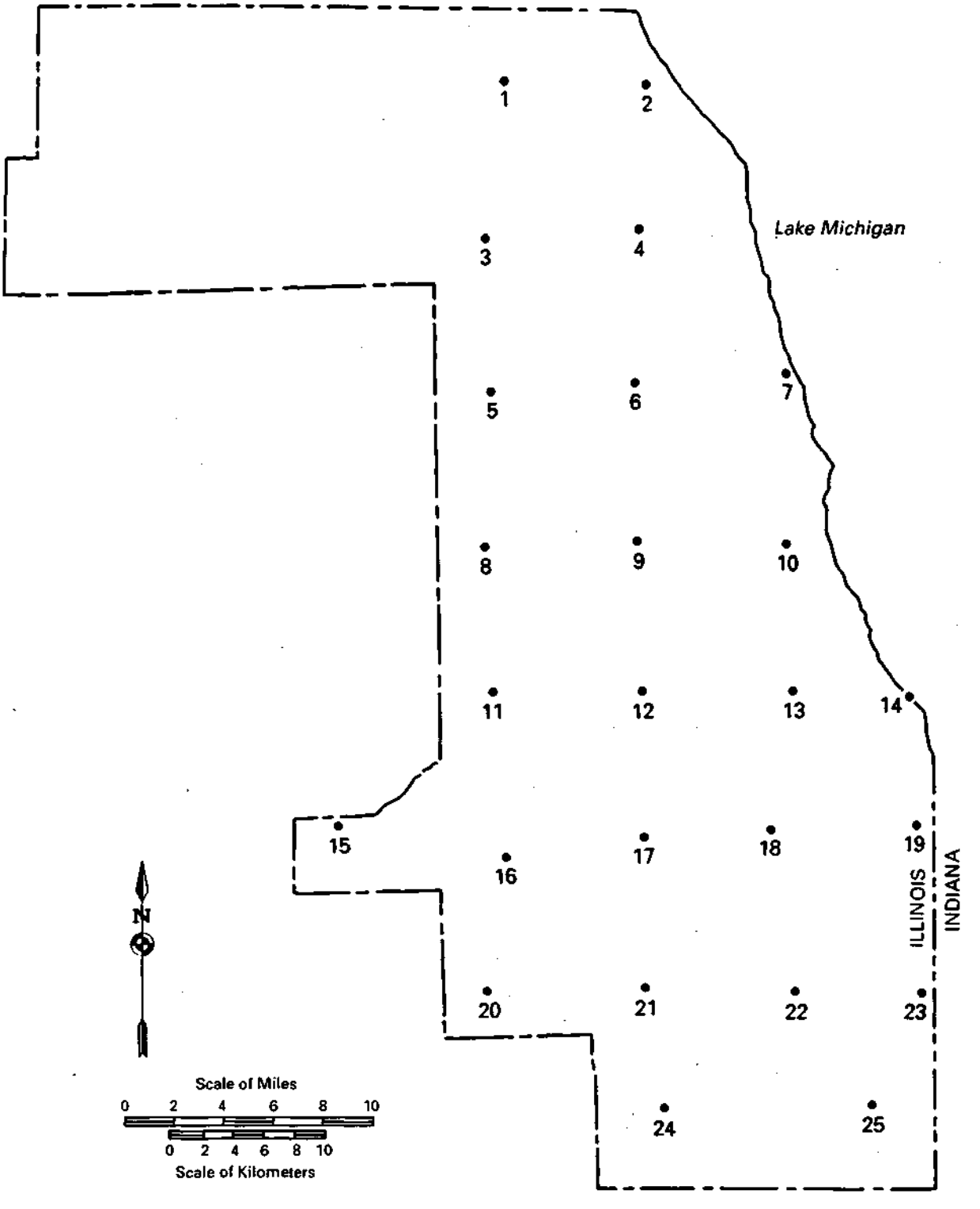

Figure 2. Current configuration of the 25-site raingage network.

Table 1. Raingage Network Site Information

Site Number	Name	Address
1	Mission Brook Sanitary District	**P.O.** Box 2362 Northbrook, IL 60065
2	Winnetka Park District	510 Green Bay Rd. Winnetka, IL 60093
3	Private Residence	1885 Riverview Dr. Des Plaines, IL 60018
4	Village of Skokie	5127 Oakton St. Skokie, IL 60077
5	Private Residence	2925 N. Sarah Dr. Franklin Park, IL 60131
6	Private Residence	5340 W. Fletcher St. Chicago, IL 60641
7	Broadway United Methodist Church	3344 N. Broadway Chicago, IL 60657
8	Cook County Forest Preserve District	10400 Windsor Dr. Westchester, IL 60154
9	Mary Queen of Heaven Parish	5314 W. 24th Place Cicero, IL 60650
10	Rental Residence	527 W. 26th Street Chicago, IL 60616
11	Private Residence	10180 5th Ave. Cutoff LaGrange, IL 60525
12	Boyle Midway	5151 W. 73rd St. Bedford Park, IL 60638
13	Private Residence	7409 S. Eggleston St. Chicago, IL 60621
14	City of Chicago South Water Purification Plant	3300 E. Chiltenham Place Chicago, IL 60649

Table 1 (Concluded)

Site Number	Name	Address
15	Metropolitan Water Reclamation District	13 Stephen Street Lemont, IL 60439
16	Private Residence	240 Timber Edge Lane Palos Park, IL 60464
17	Sardee Industries	11900 S. Laramie St. Alsip, IL 60658
18	Ingersoll Products Company	1000 W. 120th St. Chicago, IL 60643
19	Graycor Industries	12233 Avenue O Chicago, IL 60603
20	Private Residence	10595 W. 167th St. Orland Park, IL 60462
21	Private Residence	16710 Lockwood Rd. Tinley Park, IL 60477
22	U. S. Army Reserve Center	400 E. 167th Street Harvey, IL 60426
23	City of Lansing Public Works	3300 E. 171st St. Lansing, EL 60438
24	Village of Matteson	3625 W. 215th St. Matteson, IL 60443
25	Big John's Farm Stand	1754 E. Joe Orr Rd. Chicago Heights, IL 60411

in tropical areas than near the poles. To prevent loss due to blowing snow during winter, the Nipher shield and the shield used by Lindroth (1991) are helpful, but were not considered for the new network. Most likely they would also have been subject to vandalism.

Jones (1969) compared the effectiveness of several types of raingages in a controlled setting. A weighing-bucket raingage fitted with a standard 8-inch diameter orifice with sloping shoulders caught 2.5 to 6.0 percent less precipitation than a standard 8-inch nonrecording device, and 2.5 percent less than a weighing-bucket raingage fitted with a 12-inch diameter orifice (a right-cylinder). However, the maximum amount of precipitation that the latter gage can record, compared to one with the standard orifice, is reduced from 12.0 to 4.8 inches. Thus, the 8-inch diameter orifice was chosen for the new network since occasionally more than 4.8 inches of precipitation will fall into a gage between the weekly visits by the observer.

3. NETWORK OPERATION AND MAINTENANCE

Each raingage in the network was fitted with 24-hour chart drive and chart cylinder gears that rotate the chart cylinder once every 24 hours. The 24-hour chart allows adequate resolution down to 15-minute periods. Because a chart can measure up to 12 inches of precipitation, each gage is fitted with a galvanized bucket capable of holding that amount. 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, 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 single team of observers, living in Cook County, services each gage every 6-8 days, which means that 6-8 traces are drawn on each chart. Servicing includes removing and replacing the current chart, re-inking the pen, 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 portion of the year, evaporation shields are fitted into the collection orifice just above the galvanized bucket to mitigate evaporation. During the cool portion of the year (November-March), these shields are removed and a 1-quart charge of antifreeze is added to each bucket. This allows snow and sleet to melt in the bucket as they are caught and allows the weighing mechanism to give a proper reading. Refer to Appendix II for a complete listing of servicing instructions used by the raingage observers.

A complete set of 25 charts collected by the observers is mailed to the Water Survey,

along with notations about problems. The next section on data reduction explains what happens to the data collected as ink traces on the charts.

Approximately once a month, the project leader at the Water Survey visits the network to perform maintenance and repairs for which the observers do not have adequate expertise. This includes a site assessment of a previously noted problem and the determination of a solution. Because most problems pertain to the chart drives, the solution is often to replace the drive. The old drive is cleaned and readied for re-use at the Water Survey. Two spare chart drives allow for this. The other frequent problems (mentioned above) can be solved on these trips as well. A complete maintenance history, including site relocations, is given for each of the 25 raingages in Appendix HI, which more fully describes the kinds of repairs made. The information is current through October 4, 1991.

4. DATA REDUCTION

When a set of charts arrives at the Water Survey, it is edited to identify the various traces on the charts and to number sequentially by date those with precipitation. This is perhaps the most important step in the reduction procedure. A running inventory of "on" and "off chart times is maintained to ensure that the on-times on the newly received chart set match the off-times on the most recent chart set previously analyzed. Occasionally, the observers will make inadvertent errors in the on-/off-time designations, particularly when Illinois time zones change in October and March (charts are always on Central Standard Time). The on- and off-times are marked on the charts: the first revolution is designated

"1", and the last designated as appropriate. Then, the various rain periods (storms) are identified and numbered based on their sequence in relation to the first and last revolutions. This is sometimes difficult, but with 25 charts to study, often with different starting days, all rain traces can be identified. This editing procedure also acts as a good "trouble-shooting" exercise to identify most chart-drive problems (running too slow, too fast, or stopped altogether). Raingage instability problems can also be identified by a shaky trace. Skipping or unusually heavy traces point to 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 logged in with respect to on- and off-times, and all rain traces and missing periods have been identified, the charts are ready to be digitized.

A Summagraphics Microgrid II digitizer is used to digitize the charts. All values are fed into a Zenith Z-386 personal computer. Each chart is handled and logged into the computer separately. The four corners of a chart are digitized to set the grid, then the on- and off-times are entered, and their locations are digitized. The number of revolutions on the chart is noted. Each trace with precipitation is digitized by "clicking-in" each breakpoint along the respective trace. Once a chart is digitized, computer output gives details on the precipitation that was measured on the chart, in storm format, with appropriate beginning and ending times. Also included is an analysis of whether the chart drive is running slow or fast by comparing the on- and off-times with the chart's beginning and end points. This helps assess whether a chart drive needs to be replaced. Errors made during the editing stage can also be caught during digitization. If a chart drive stopped during a collection period, the beginning and ending points of the missing information are digitized and

appropriately stored in the computer.

Once a calendar month of data is logged into the computer, a C-language program, written at the Water Survey, 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 various traces. The newly 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 stations across the top as columns and data down the array as rows in chronological, hourly order. Monthly totals appear at the bottom. Missing values are denoted as dashes.

This data array is then used to check for time and space consistency, to divide the data into storm periods, and to fill in missing values 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 was 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, 1991), and Peppier (1990, 1991a, 1991b) to define storms for Water Years 1984-1990. For each storm, values are summed and plotted on maps using all available data and stations, and isohyetal patterns are drawn. During Water Year 1991, 101 such storms were defined.

After a generalized precipitation pattern is obtained for each storm, interpolated storm totals are estimated from the pattern for each site having missing information during that storm. Wind information, if available (usually the resultant direction and speed at Chicago O'Hare Airport), and known urban effects in the Chicago area (Huff and Vogel, 1976; Changnon, 1980,1984) are taken into account when drawing isolines and interpolating

values. The newly found storm values are then redistributed into hourly values using the existing hourly percentage breakdown at "neighboring" nonmissing sites and the weighting factors are assigned to them. For each site in the network, neighbors identified for this purpose are weighted according to both distance and direction from the gage. See Table 2 for the designated neighbors and alternates (in case a neighbor is also unavailable) for each site and their associated weights. The weight given an alternate may vary from what is listed in Table 2, depending upon who is unavailable. For example, for Site #1, if neighbor #1 (Site #2) is unavailable, then Neighbor #2 (Site #3) is weighted 0.667 instead of 0.333, and the alternate (Site *#4)* is used and weighted 0.333.

Filling in missing values is the most labor-intensive data-reduction step. Once the missing hourlies are computed, they must be hand-entered into the computer. An automated process for this data-reduction step has been identified that will allow much quicker data reduction in general. It involves the use of an International Mathematical and Statistical Library (IMSL) routine designed to interpolate data from an irregular array to a grid. It can also be used to create values at points that have missing information using all available information. This technique will be used to fill in missing values during Water Year 1992, and will be more fully described in the final report for that water year.

Table 2. Neighboring Sites Used for Missing Value Fill-in Procedure (Weighting Factors in Parentheses)

Site Number	Neighbor #1	Neighbor #2	Neighbor #3	Alternate
1	2 (0.667)	3 (0.333)		4 (0.333)
2	1 (0.667)	4 (0.333)		3 (0.333)
3	4 (0.500)	1 (0.250)	5 (0.250)	2 (0.250)
4	3 (0.500)	2 (0.250)	6 (0.250)	5 (0.250)
5	6 (0.500)	4 (0.250)	9 (0.250)	8 (0.250)
6	5 (0.500)	7 (0.500)		4 (0.500)
7	6(0.500)	4 (0.250)	9 (0.250)	10 (0.250)
8	9 (0.500)	6 (0.250)	12 (0.250)	11 (0.250)
9	8 (0.500)	10 (0.500)		7 (0.333)
10	9 (0.500)	6 (0.250)	12 (0.250)	7 (0.250)
11	12 (0.667)	8 (0.333)		9 (0.333)
12	11 (0.500)	13 (0.500)		10 (0.333)
13	12 (0.500)	14 (0.500)		10 (0.500)
14	13 (0.500)	10 (0.250)	18 (0.250)	19 (0.250)
15	16 (0.500)	11 (0.250)	20 (0.250)	12 (0.250)
16	15 (0.500)	17 (0.500)		12 (0.333)
17	16 (0.500)	18 (0.500)		13 (0.333)
18	17 (0.500)	19 (0.500)		14 (0.333)
19	18 (0.500)	14 (0.250)	23 (0.250)	22 (0.250)
20	21 (0.500)	16 (0.250)	24 (0.250)	17 (0.250)
21	20 (0.500)	22 (0.500)		18 (0.333)
22	21 (0.500)	23 (0.500)		24 (0.500)
23	22 (0.500)	25 (0.500)		19 (0.500)
24	21 (0.500)	22 (0.500)		25 (0.333)
25	22 (0.500)	24 (0.500)		23 (0.500)

5. DATA ANALYSIS AND METHODOLOGIES

Using the final, corrected, filled-in array of data, several analyses have been and will be performed on the Water Year 1991 data using methods employed on Water Year 1990 data. These include: (1) a water year total plot and monthly plots for the entire region as documentation of the data collected from the network (Figures 3-9), (2) monthly and water year totals at all sites (Table 3), (3) spatial correlation pattern analyses of the region, (4) statistical assessments of the validity of the correlation patterns, and (5) comparisons with data collected by NWS and CC raingages during this and past water years. **Only** analyses (1) and (2) will be shown in this report, as (3)-(5) will be sent soon to a refereed journal, along with analyses from Water Year 1990. The correlation patterns will examine the degree of interrelation between the respective sites, which will be useful for identifying regions of preferred storm movement and categorizing the sites into coherent precipitation regime regions.

Figure 3 contains the Water Year 1991 analysis (see also Table 3). Isopleths are drawn in inches. During the water year, precipitation highs occurred in the extreme northeastern, west central, southeastern, and extreme southwestern portions of Cook County covered by the raingage network, centered on Sites #2, #8, #19, and #24, respectively. Precipitation lows were located in the northwestern, east-northeastern, west-southwestern, and extreme southeastern portions of the region, centered on Sites #1, #7, #15, and #25, respectively. The general north-to-south increase in precipitation noted during this water year agrees with patterns from other water years and known long-term patterns (e.g., Peppier 1991b).

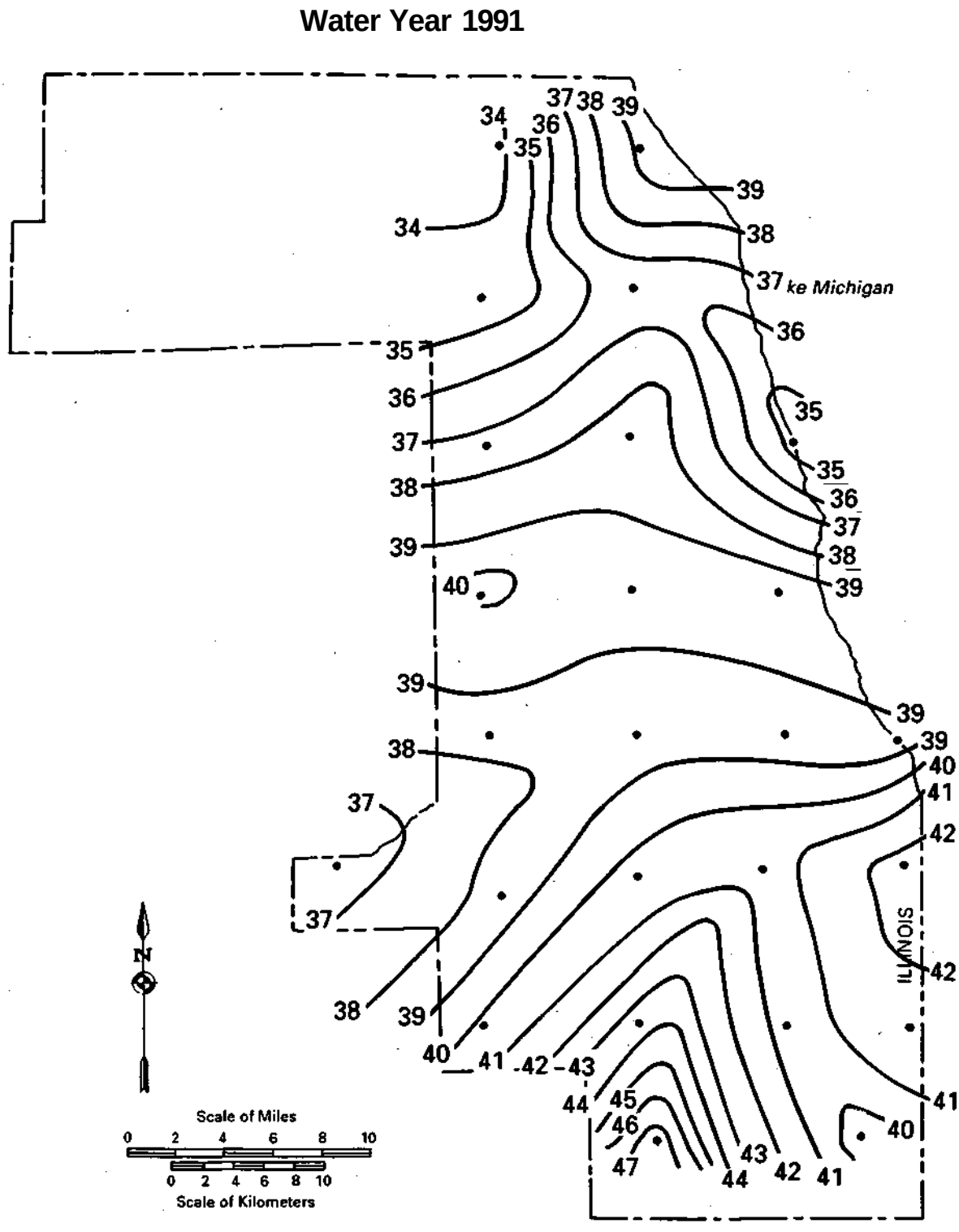

Figure 3. Precipitation pattern (inches) for Water Year 1991. Dots indicate network sites.

Table 3. Monthly and Water Year 1991 Precipitation Totals for All Sites in the Raingage Network

	Gage																								
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Oct 1990	4.48	4.67	4.31	4.39	4.38	4.84	4.60	4.80	5.26	5.13	4.58	4.71	4.43	4.56	4.02	4.65	4.52	4.36	4.52	4.48	4.61	4.71	4.65	6.03	4.55
Nov 1990	5.61	6.39	5.46	5.50	6.13	6.38	4.71	6.32	6.08	6.38	6.23	6.18	7.04	7.04	6.35	6.40	6.41	6.93	8.12	6.67	6.94	6.88	6.70	9.31	7.50
Dec 1990	2.27	2.55	1.98	2.14	2.40	2.71	1.91	2.60	2.61	2.46	2.44	2.31	2.45	2.13	2.44	2.29	2.20	2.28	2.25	2.63	2.54	2.66	2.77	2.81	3.09
Jan 1991	1.56	1.84	1.52	1.68	1.73	1.85	1.35	1.69	1.72	1.89	1.59	1.34	1.78	1.16	1.40	1.51	1.49	1.66	1.52	1.36	1.62	1.47	1.61	1.32	1.14
Feb 1991	0.59	0.59	0.48	0.53	0.53	0.56	0.33	0.47	0.55	0.51	0.56	0.60	0.58	0.66	0.53	0.61	0.71	0.75	0.70	0.57	0.75	0.54	0.77	0.71	0.96
Mar 1991	3.21	4.02	3.13	3.50	4.23	4.25	3.37	4.74	4.63	3.84	4.00	4.33	4.26	3.91	4.57	4.74	4.41	4.22	4.40	4.46	5.01	4.62	5.37	5.41	4.57
Apr 1991	4.07	5.43	3.75	4.94	4.88	5.32	5.13	5.62	6.02	6.96	6.52	6.22	5.05	5.12	5.99	5.49	5.39	5.34	4.89	4.94	5.05	4.29	4.80	4.12	3.71
May 1991	3.51	5.84	5.23	5.14	4.86	5.28	4.08	5.60	4.84	4.27	4.78	5.34	4.61	5.73	4.94	5.34	6.99	5.91	6.37	8.37	9.55	6.51	6.49	7.77	5.77
Jun 1991	1.15	0.34	0.64	0.61	1.30	0.96	1.08	0.82	1.17	1.56	1.01	1.08	2.02	1.18	0.84	1.08	1.39	1.31	2.21	1.32	1.14	0.87	0.58	1.20	0.47
Jul 1991	1.37	1.14	1.93	1.26	1.27	0.78	1.96	1.21	0.96	1.22	0.83	1.23	0.62	0.85	0.22	0.30	1.42	1.32	1.73	0.00	0.51	0.70	0.70	0.59	0.55
Aug 1991	2.53	3.21	2.96	3.76	2.50	2.81	2.62	3.10	2.70	2.81	2.39	2.71	2.29	2.90	2.71	3.39	3.24	4.08	3.30	3.02	3.25	4.61	4.23	4.81	4.69
Sep 1991	3.44	3.22	2.96	2.67	3.08	2.79	3.37	3.03	2.69	2.55	3.40	2.69	3.58	3.60	2.75	2.76	2.13	2.74	2.58	2.18	2.65	2.87	2.88	3.46	2.99
WY 1991	33.79	39.24	34.35	36.12	37.29	38.53	34.51	40.00	39.23	39.58	38.33	38.74	38.71	38.84	36.76	38.56	40.30	40.90	42.59	40.00	43.62	40.73	41.55	47.54	39.99

Several areas within the network deserve special mention. An area of slightly higher precipitation near Site #6 coincides with an urban high noted by Huff and Vogel (1976) from data for 1949-1974 ("north central high") and from data for other water years in the 1980s and in 1990 (e.g., Peppier, 1991a, 1991b), but it is less pronounced during Water Year 1991. The minima near Site #7 may be associated with the stabilizing effect exerted by Lake Michigan on convective rainfall, as also noted by Huff and Vogel (1976). The minimum in the west-south western region appears similar to adjusted ones found in Water Years 1988 and 1989 (Peppier, 1991a), while the maximum in the east central region, which extends toward Indiana, resembles the 1988-1990 patterns (Peppier, 1991a, 1991b). The relative maximum/minimum flip-flop between Sites #24 and #25 very much resembles what occurred during Water Year 1990. The main differences between the two water year patterns collected by the current network are that the 1990 high near Sites #5 and #6 is much less pronounced in 1991, and the east central high in 1990 is shifted southeastward in 1991. In general, the 1991 pattern is smoother across the central portion of the network, but the networkwide range of values is greater. In Water Year 1990, totals ranged from 36.24 inches at Site #4 to 45.89inches at Site #13, while during 1991 the totals ranged from 33.79 inches at Site #1 to 47.54 inches at Site #24. Like the 1990 pattern, the pattern for Water Year 1991 is in great contrast to the unusual anomalies associated with the collection of raingages from the NWS, MWRDGC, and CC used to generate precipitation patterns for Water Years 1984-1989.

Figures 4-9 contain monthly analyses during Water Year 1991 (see also Table 3). Generally, the lightest precipitation occurred in December, January, February, June, and July, with February being the driest month during the water year (Figures 5-8, respectively).

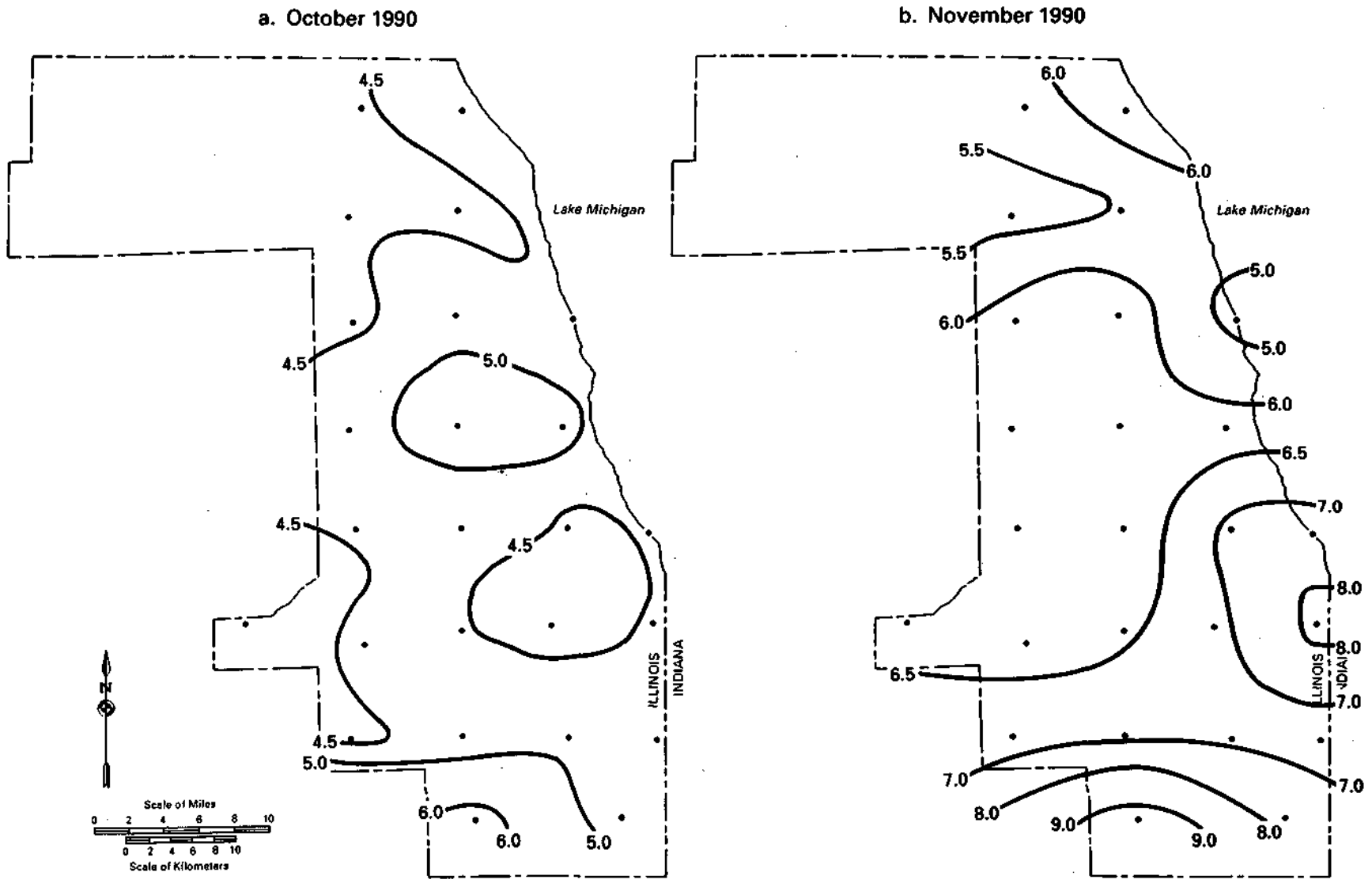

Figure 4. Precipitation patterns (inches) for October 1990 (Panel a) and November 1990 (Panel b). Dots indicate network sites.

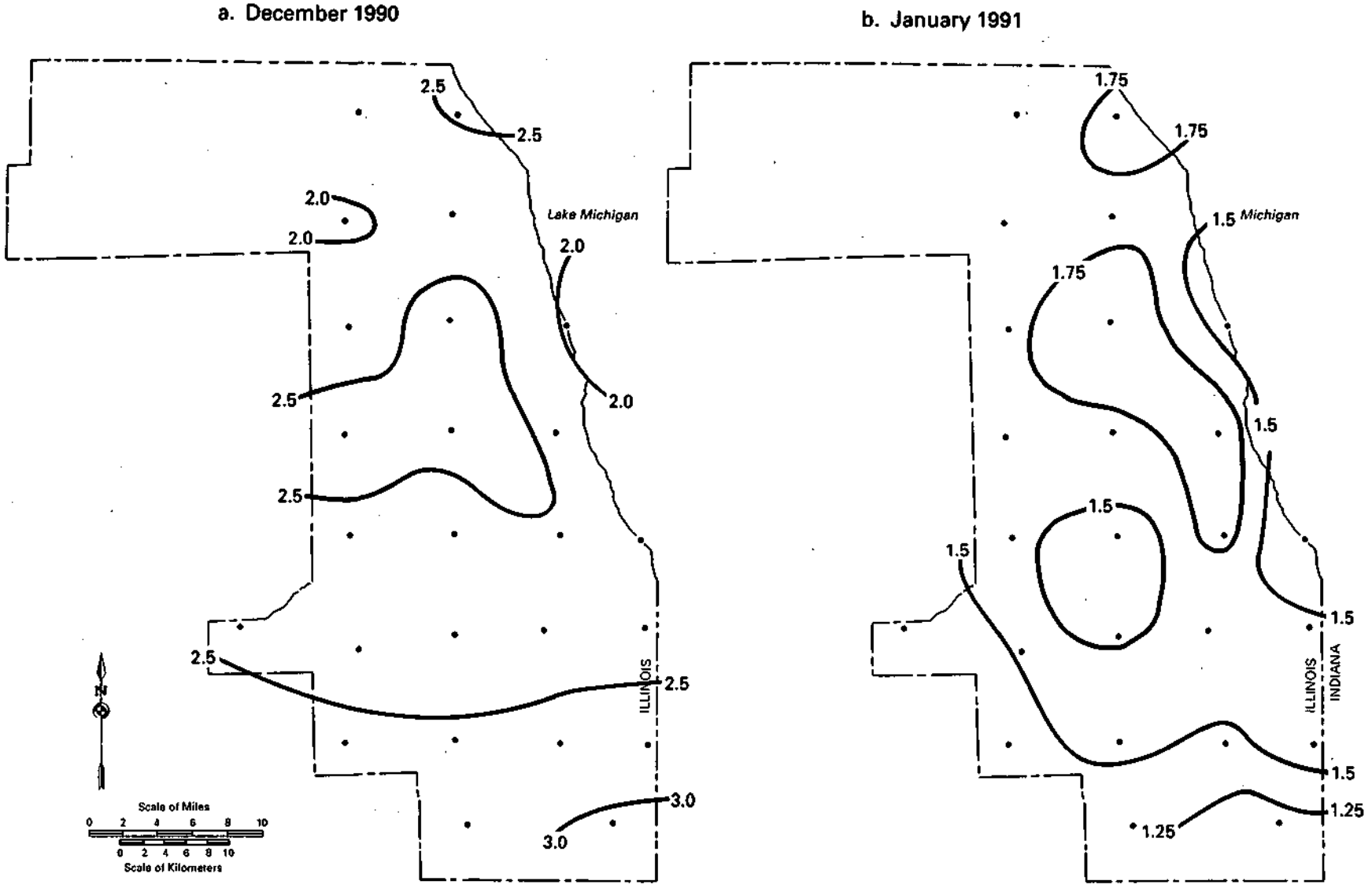

Figure 5. Precipitation patterns (inches) for December 1990 (Panel a) and January 1991 (Panel b). Dots indicate network sites.

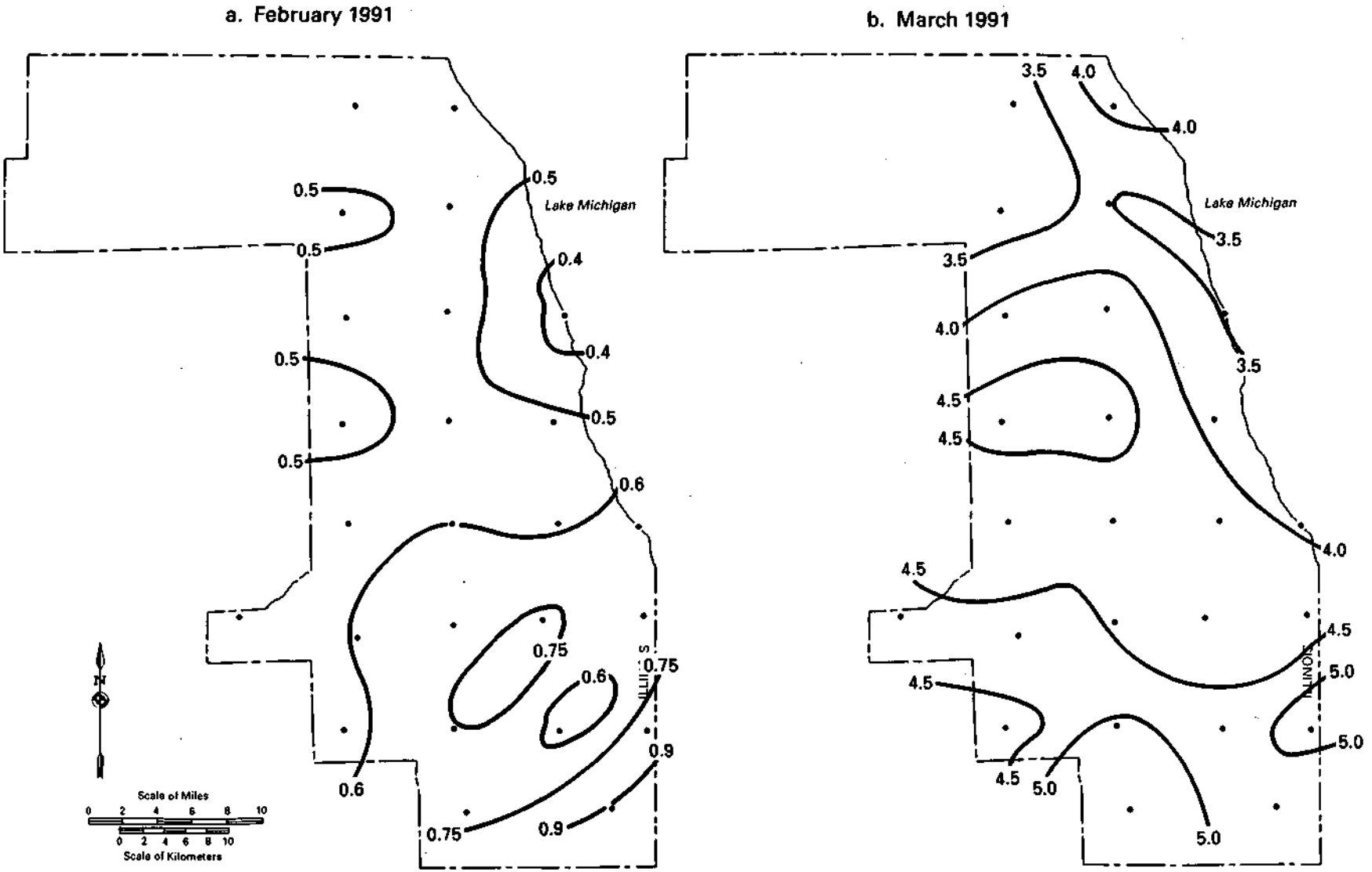

Figure 6. Precipitation patterns (inches) for February 1991 (Panel a) and March 1991 (Panel b). Dots indicate network sites.

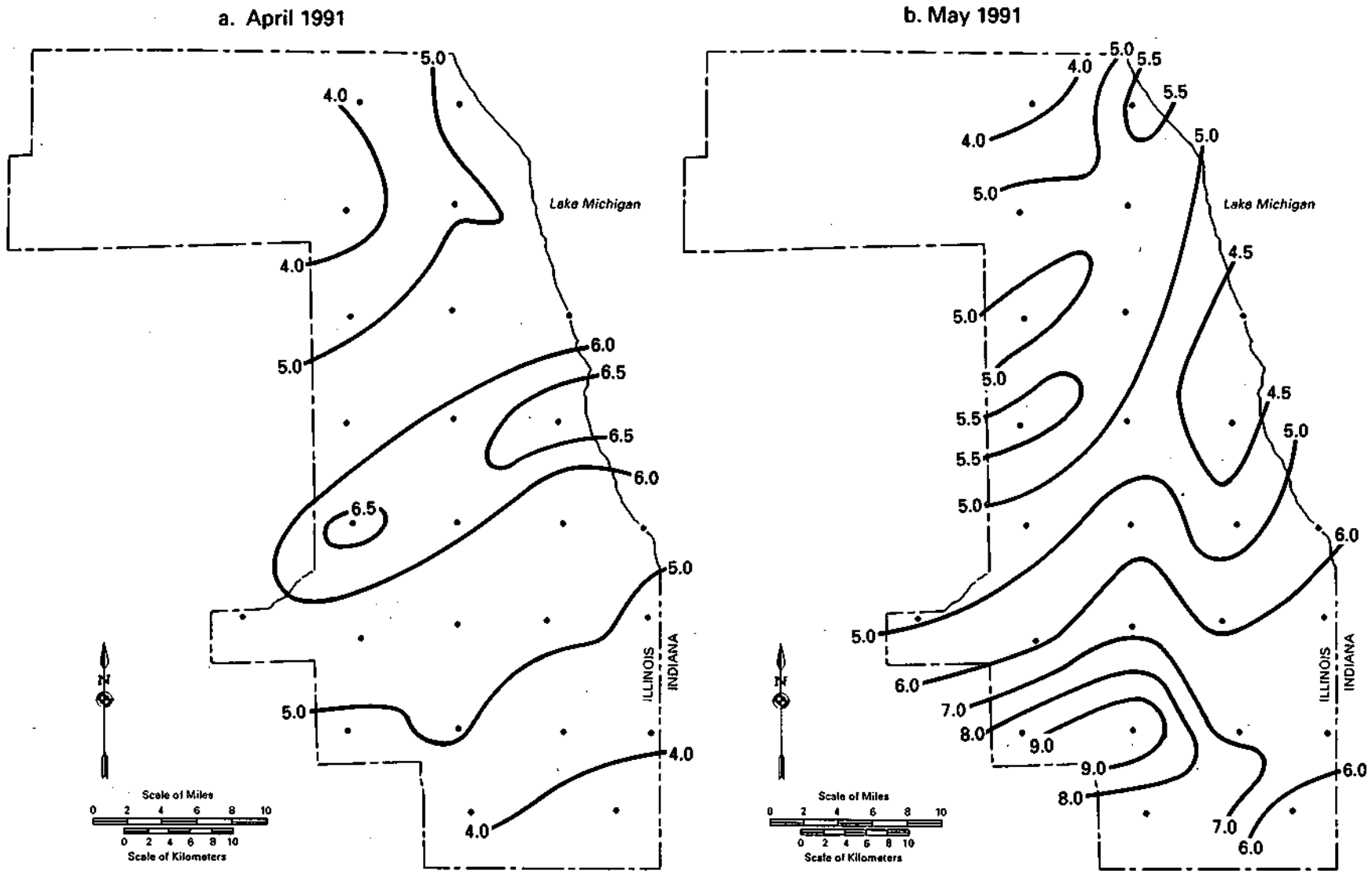

Figure 7. Precipitation patterns (inches) for April 1991 (Panel a) and May 1991 (Panel b). Dots indicate network sites.

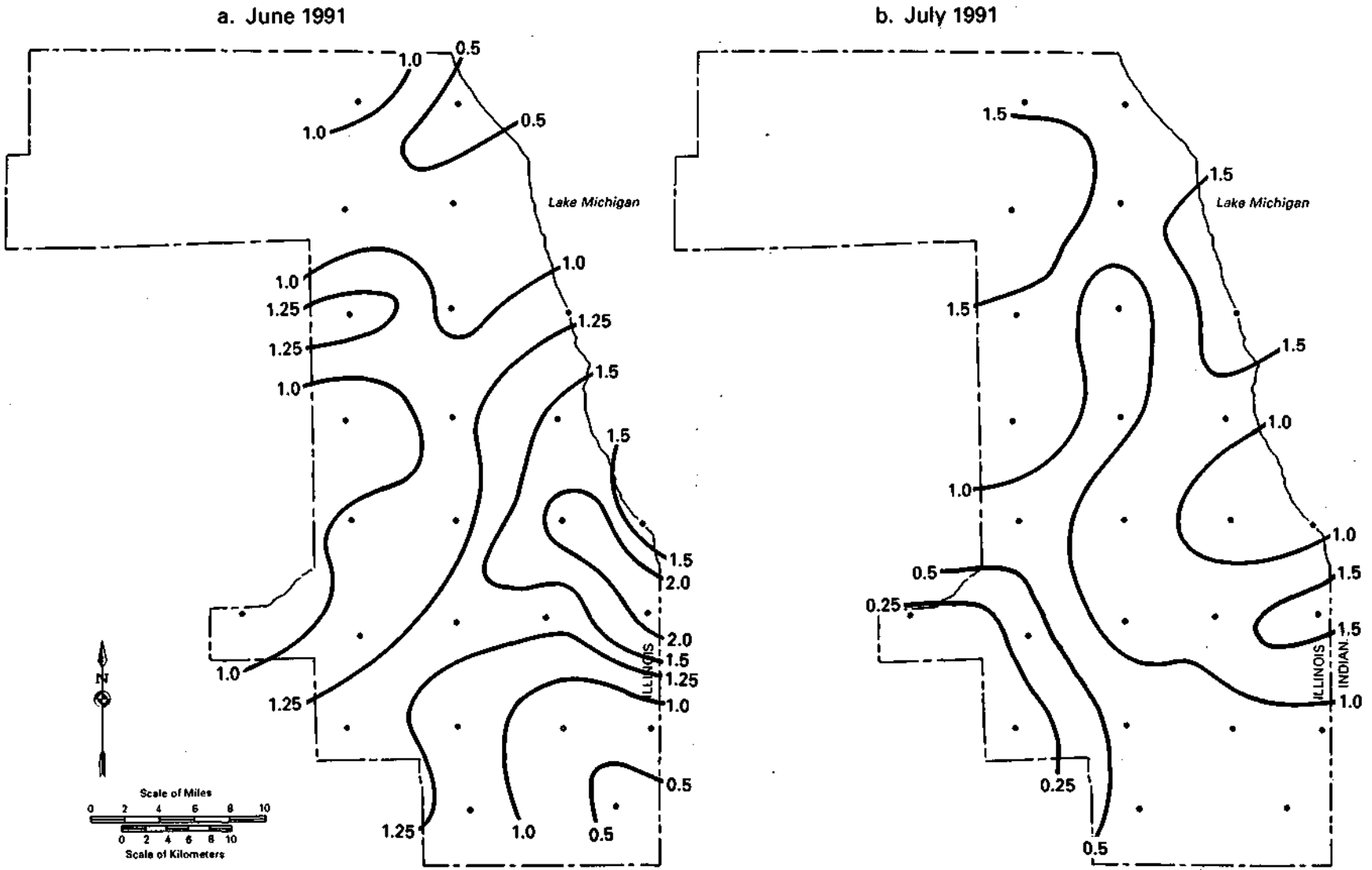

Figure 8. Precipitation patterns (inches) for June 1991 (Panel a) and July 1991 (Panel b). Dots indicate network sites.

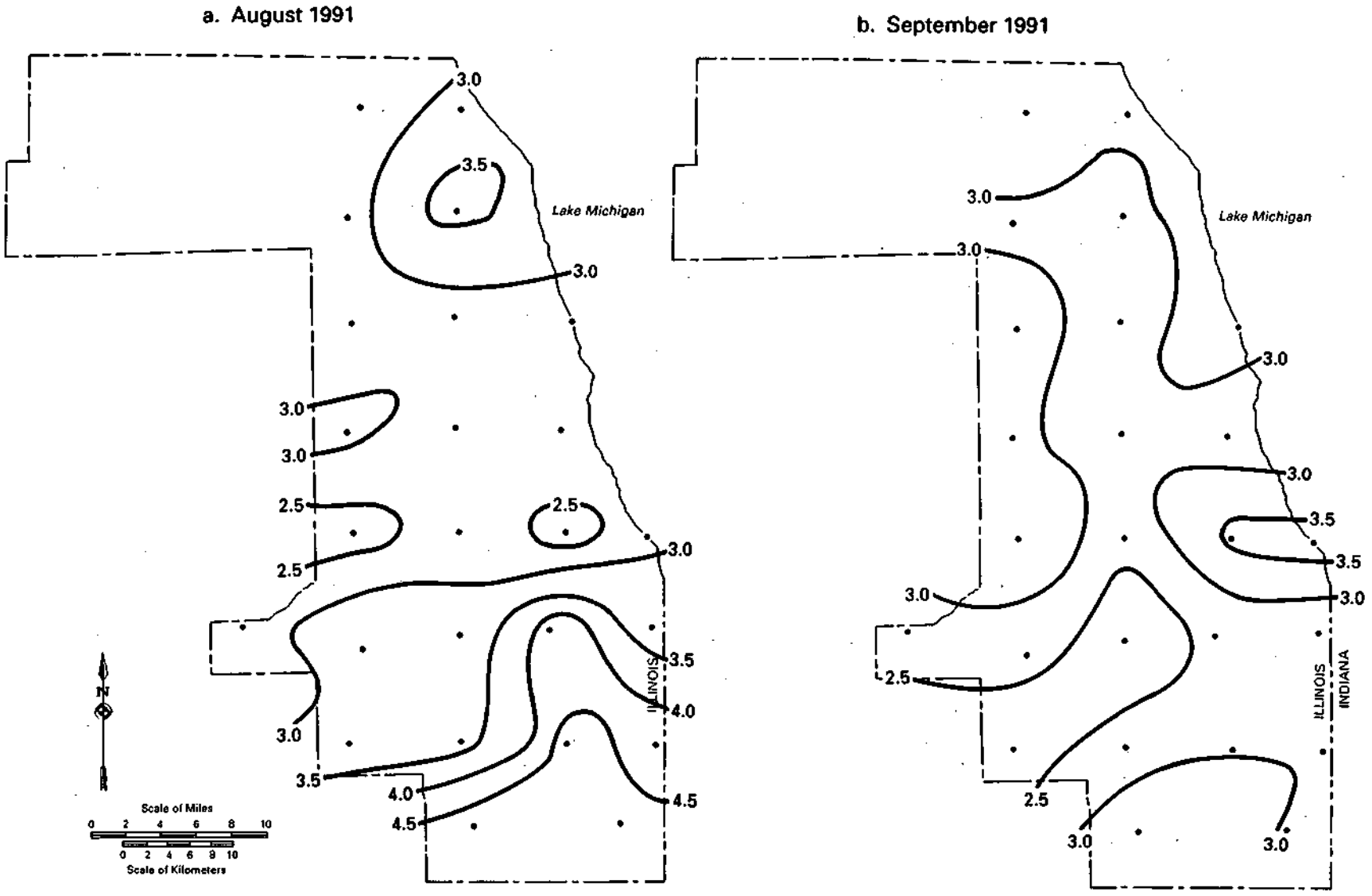

Figure 9. Precipitation patterns (inches) for August 1991 (Panel a) and September 1991 (Panel b). Dots indicate network sites.

Heaviest amounts occurred during November, April, and May, with November being the wettest month overall during the water year (Figures 4 and 7, respectively). Also, August and September (Figure 9) had relatively light precipitation, while October (Figure 4) and March (Figure 6) had relatively heavy amounts. Looking at some of the more interesting light precipitation cases, February's monthly amounts (Figure 6) ranged from just 0.33 inches at Site #7 to 0.96 inches at Site #25. Very light rainfall during the summer drought that occurred in June and July (Figure 8) were also reflected in the network's readings, with June values ranging from 0.34 inches at Site #2 to 2.21 inches at Site #19, and July values ranging from no precipitation at Site #20, the water year low, to 1.96 inches at Site #7. Only 0.22 inches of precipitation occurred at Site #15 as well in July. December and January precipitation (Figure 5), though light, was relatively uniform across the network. Looking at heavier precipitation, November (Figure 4) was quite wet, with values ranging from 4.71 inches at Site #7 to 9.31 inches at Site #24. Site #19 had 8.12 inches of precipitation during this month as well. May (Figure 7) saw the greatest range of precipitation values over the network, from a low of 3.51 inches at Site #1 to a high of 9.55 inches at Site #21, the water year high. At Site #20, 8.37 inches were recorded in May. In April (Figure 7), another heavier month, values ranged from 3.71 inches at Site #25 to 6.96 inches at Site #10.

Out of the 101 storms during Water Year 1991, several well-defined ones produced amounts that surpassed an annual event (one-year recurrence interval, considering storm periods of one hour to ten days in northeastern Illinois - Huff and Angel, 1989). These include Storm 4 in October, Storms 10 and 15 in November, Storm 48 in April, and Storm 67 in May. Storm 15, during a 23-33-hour period on November 26-27, was the heaviest over

the entire network, with over 2.5 inches falling on all sites, over 4 inches falling on Sites #19, #22, #23, and #25 (4.66,4.03,4.50, and 4.78 inches, respectively), and a water year storm-high of 5.06 inches falling on Site #24 in the extreme southwestern portion of the network. Other storm totals exceeding 4 inches during the water year included 4.70 inches at Site #21 during Storm 67, a 21-hour period during May 24-25. Appendix IV lists all storm totals for all events greater than an annual event, considering storm periods of one hour to ten days in northeastern Illinois, with special notation given for storms exceeding events of 2, 5, 10, 25, 50, and 100 years, respectively.

A comparison is also made between the unadjusted data from Water Years 1984, 1985,1987,1988, and 1989 (Figure 10) and network totals from Water Years 1990 and 1991 (Figure 11). Excluding the low values at West Southwest Sewage Treatment Plant (an MWRDGC site in the center of the region - see Figure 1), which had many missing observations during Water Years 1987-1989, network patterns from 1990 and 1991 do **not** show the unusual, highly cellular patterns found in the water year patterns defined by the NWS, CC, and MWRDGC gages that required adjusting. Thus, the current raingage network is continuing to sample the precipitation that falls over the Cook County region **much** more consistently than the previously used gages did during the 1980s.

Finally, a composite 1990/1991 two-year network plot (Figure 12) was drawn. It clearly shows the general north-to-south increase in precipitation across the network, the lows along the northern lakeshore and in the west-central and extreme southeastern portions of the grid, the "urban" high peaking northward towards Site #6, and the high values in the southwestern part of the network.

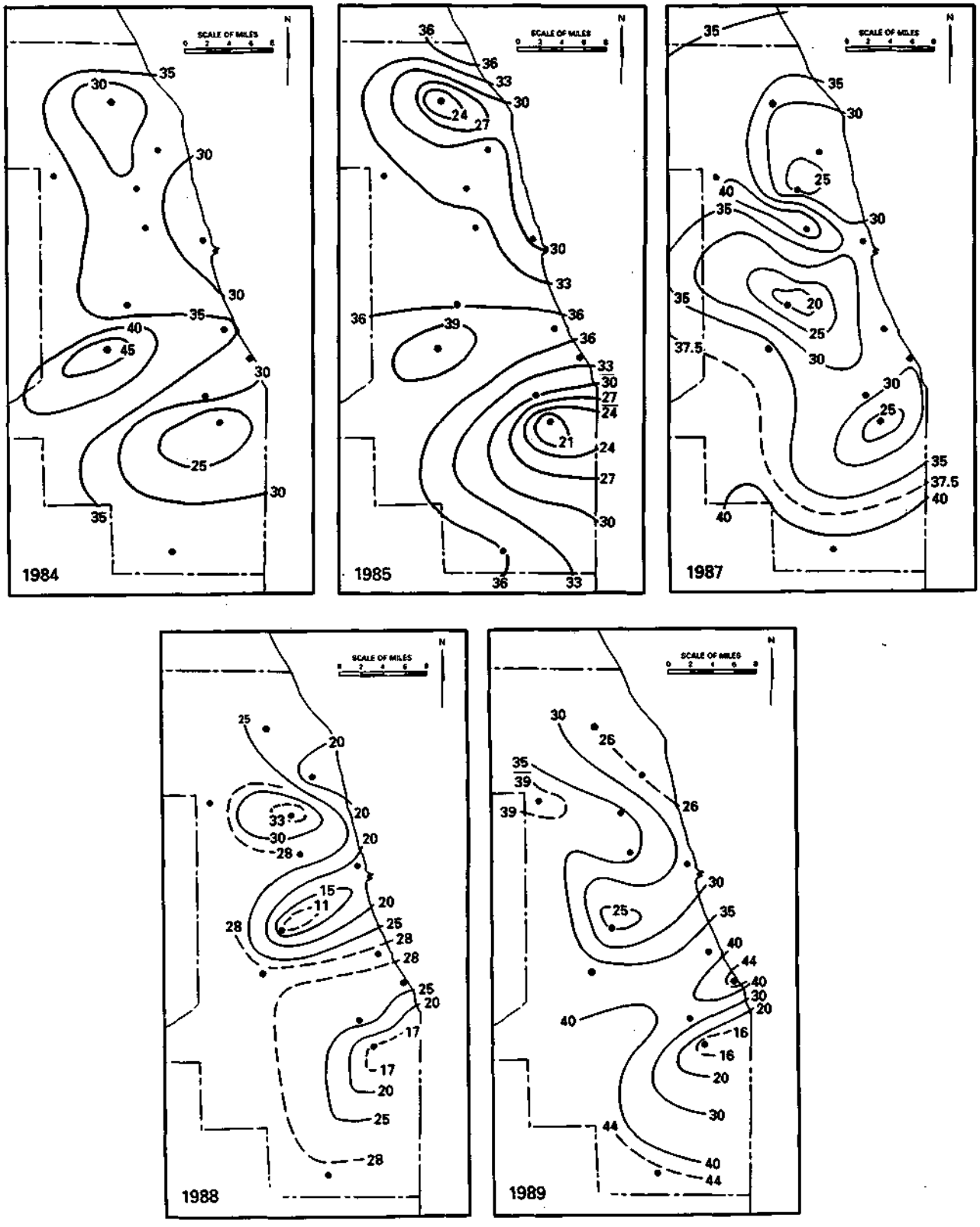

Figure 10. Raw precipitation patterns (inches) for Water Years 1984-1989 from NWS, CC, and MWRDGC raingages.

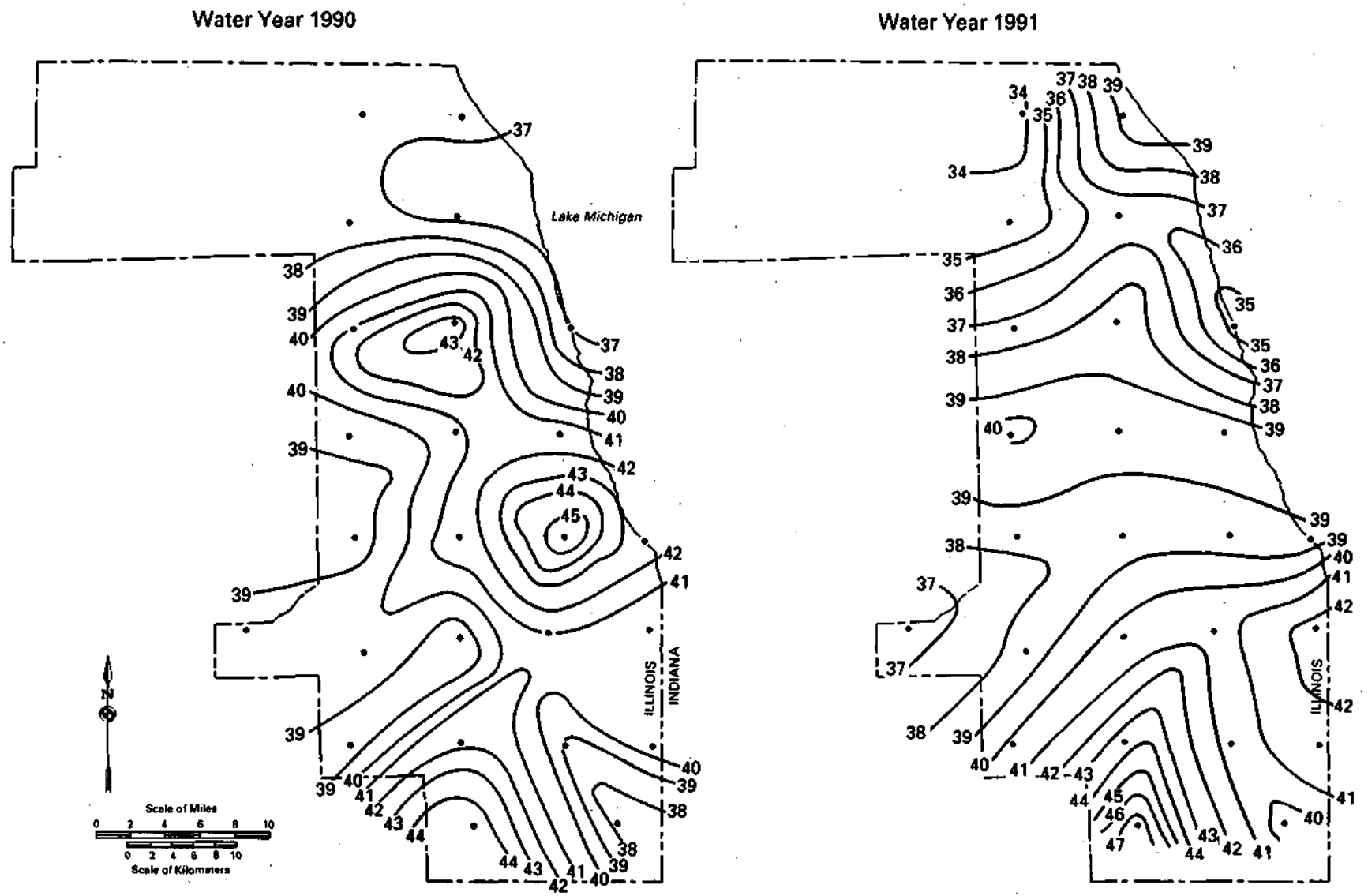

Figure 11. Precipitation patterns (inches) for Water Years 1990 and 1991 from the current network.

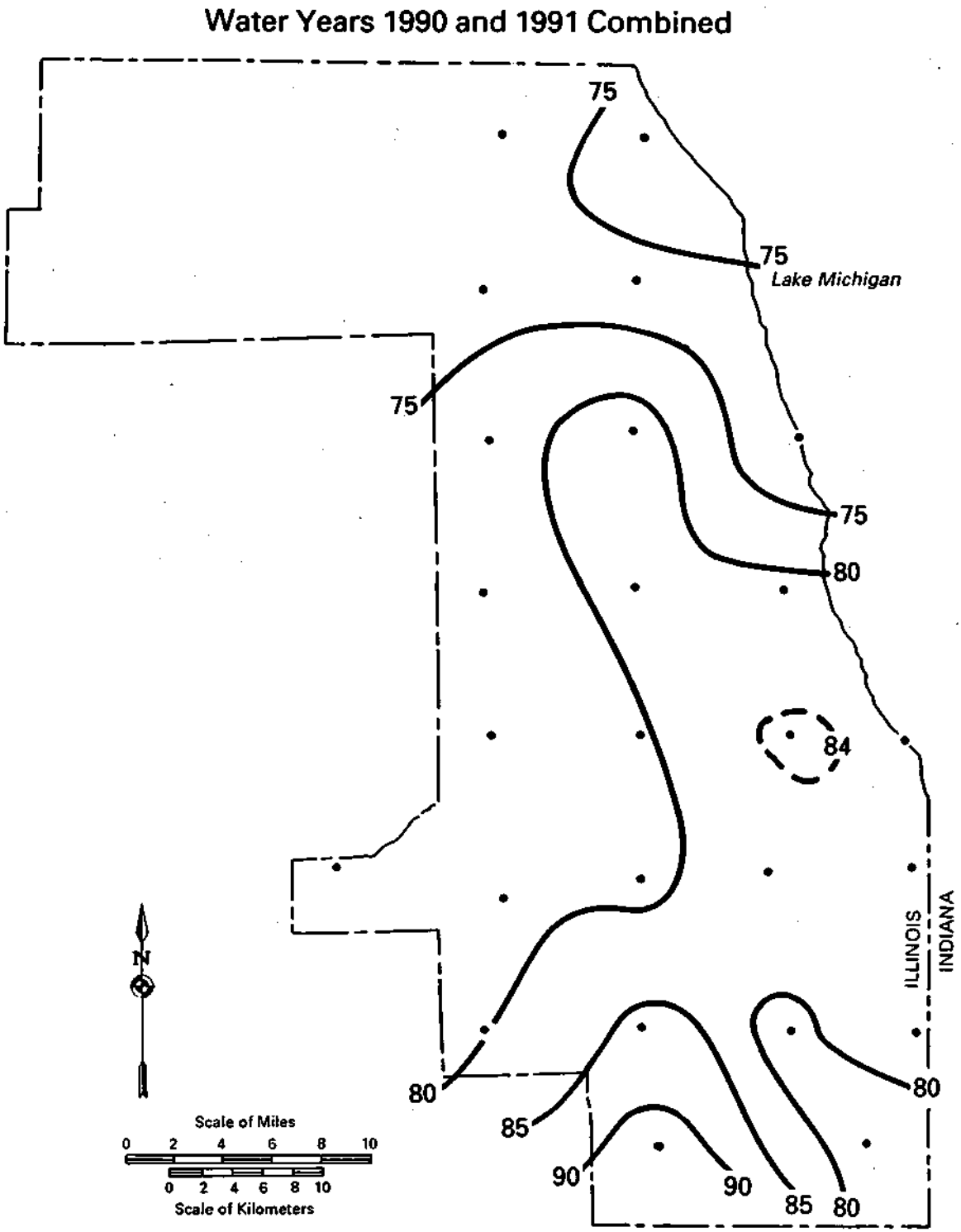

Figure 12. Combined precipitation pattern (inches) for Water Years 1990 and 1991.

6. SUMMARY

With collection, reduction, and analysis of precipitation data now complete for Water Years 1990 and 1991, the Cook County raingage network appears to be accurately capturing the precipitation that falls on the region. Its exposure and areal coverage continue to be superior to the previously used combination of NWS, CC,and MWRDGC raingages. These data are greatly enhancing the ability of the U.S. Army Corps of Engineers, Chicago District, to properly assess the storm runoff portion of the diversion of waters from Lake Michigan. Also, because of the relatively dense spacing of the raingages, the continued operation of the network provides great potential for high-quality research on precipitation in the Cook County region. Network operation has become quite routine, as final hourly precipitation data are now available within a few weeks of the end of a calendar month.

7. ACKNOWLEDGMENTS

This work was contracted by the U.S. Army Corps of Engineers, Chicago District, under Grant DACW 23-89-C-0005. Diane Peppier computed and plotted storm totals, disaggregated storm values interpolated at missing sites into hourly ones, and performed data entry and correction. Doug Ward established the digitizing system, including software, and made the digitization of charts an extremely simple task; his various computer assistance and advice are greatly appreciated. Linda Hascall skillfully drafted all figures, and Eva Kingston carefully edited the report. Statistical advice from Mike Richman was of great help in the analysis of results. Tim Lormand, U.S. Army Corps of Engineers, provided the support for this project and helpful suggestions, as well as editing the draft version of this report. Floyd Huff and Doug Jones were mainly responsible for bringing this project to fruition, and their continuing advice and editing of this report are greatly appreciated.

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APPENDIX I: RAINGAGE SITE DESCRIPTIONS

Contained below are descriptions of the 25 raingage network sites. All represent the current siting as of publication. Sites that have been relocated since the beginning of network operation in October 1989 are noted in the "Placement" section of the descriptions.

SITE DESCRIPTION		
Site Number: 1		
County: Cook	Township: 42N	Range: 12E
Section: 20	Lat/Long: 42° 06'38"/ 87° 52'05"	Ouadrangle: Park Ridge
Property Owner: Mission Brook Sanitary District, Attn: John Tomaras		
Address: P.O. Box 2362, Northbrook, Illinois 60065		
Telephone: 708/272-2956		
Permission Date: September 14. 1989		
Installation Date: September 27. 1989		
Gage Mfrs. No.: 7378	Gage ID No.: 6561	Clock Mfrs. No.: E 7292
Placement: Placed in southeast corner of pump station lawn at southwest corner of intersection of Post and Cornflower Streets. Tri-State Tollway fence is just to the west. Enter area from west at Landwehr Road (north of Willow Road) at Sunset Ridge.		

SITE DESCRIPTION		
Site Number: 2		
County: Cook	Township: 42N	Range: 13E
Section: 19	Lat/Long: 42°06'28"/ 87° 45'05"	Ouadrangle: Park Ridge
Property Owner: Winnetka Park District, Attn: Richard Blust		
Address: 510 Green Bay Road, Winnetka, Illinois 60093		
Telephone: 708/446-2397		
Permission Date: September 14. 1989		
Installation Date: October 3. 1989		
Gage Mfrs. No.: 1703	Gage ID No.: 6560	Clock Mfrs. No.: 10383
Placement: Located between maintenance building and parking lot in grassv area. The facility closes at 1600 local time on workdays. Enter facility west off of Hibbard Street, north of Willow Road.		

SITE DESCRIPTION		
Site Number: 3		
County: Cook	Township: 4IN	Range: 12E
Section: 28	Lat/Long: 42° 01'20"/ 87° 52'38"	Ouadrangle: Arlington Heights
Property Owner: Private Residence		
Address: 1885 Riverview Avenue. Des Plaines. Illinois 60018		
Telephone: 708/824-1093		
Permission Date: September 14. 1989		
Installation Date: September 28. 1989		
Gape Mfrs. No.: 4730	Gape ID No.: 5062	Clock Mfrs. No.: E 7373
Placement: Placed in northwest corner of the yard by the fence. Enter Riverview Avenue west off of Des Plaines River Road.		

SITE DESCRIPTION		
Site Number: 4		
County: Cook	Township: 4IN	Ranee: 13 E
Section: 21	Lat/Long: 42° 01'35"/ 87° 45'22"	Ouadrangle: Park Ridge
Property Owner: Village of Skokie, Attn: Eddy Nakai		
Address: 5127 Oakton Street, Skokie, Illinois 60077		
Telephone: 708/673-0500		
Permission Date: September 18, 1989		
Installation Date: September 27, 1989		
Gage Mfrs. No.: 4656	Gage ID No.: 5040	Clock Mfrs. No.: E 7630
Placement: Located in grassy strip between municipal parking lot and Floral Street just north of Oakton Street (across from Village Hall). En ter from Oakton Street.		

SITE DESCRIPTION		
Site Number: 5		
County: Cook	Township: 40N	Range: 12E
Section: 28	Lat/Long: 41° 55'57"/ 87° 52'42"	Ouadrangle: Elmhurst
Property Owner: Private Residence		
Address: 2925 North Sarah Drive, Franklin Park, Illinois 60131		
Telephone: 708/455-1226		
Permission Date: September 13.1989		
Installation Date: September 28.1989		
Gape Mfrs. No.: 4717	Gage ID No.: 5105	Clock Mfrs. No.: E 7413
Placement: Placed in northeast corner of backyard near a fence and a hedge. Enter Schiller Avenue east off of Mannheim Road, then south on Sarah Drive (one-way).		

SITE DESCRIPTION		
Site Number: 6		
County: Cook	Township: 40N	Range: 13E
Section: 28	Lat/Long: 41° 56'17/ 87° 45'38"	Ouadrangle: River Forest
Property Owner: Private Residence		
Address: 5340 West Fletcher Street, Chicago. Illinois 60641		
Telephone: 312/736-0106		
Permission Date: September 28. 1989		
Installation Date: September 28,1989		
Gage Mfrs. No.: 5300	Gage ID No.: 5304	Clock Mfrs. No.: E 7625
Placement: Placed in middle of backyard along walkway halfway between house and garage. Was closer to alley before garage was built (9-28-89 through 9-19-90). Enter alley east off of Long Street, which is south off of Belmont Avenue.		

SITE DESCRIPTION		
Site Number: 7		
Countv: Cook	Township: 40N	Range: 14E
Section: 21	Lat/Long: 41° 57'07"/ 87° 38'24"	Ouadrangle: Chicago Loop
Property Owner: Broadway United Methodist Church. Attn: Pastor Fred Morris		
Address: 3344 North Broadway. Chicago. Illinois 60657		
Telephone: 312/348-2679		
Permission Date: October 4.1991		
Installation Date: October 4. 1991		
Gaee Mfrs. No.: ——	Gage ID No.: 5303	Clock Mfrs. No.: E 7293
Placement: Just northeast of parking lot in grass strip between lot and black wrought iron fence. Enter parking lot from Buckingham Place (one-way westbound from Broadway). Was located at Belmont Harbor boat landing (10-1-89 through 12-27-89), on the Lincoln Park Gun Club roof (12-27-89 through 6-28-91), and just north of Diversey Harbor in a playground (6-28-91 through 10-4-91).		

SITE DESCRIPTION		
Site Number: 8		
Countv: Cook	Township: 39N	Range: 12E
Section: 29	Lat/Long: 41° 50'41"/ 87° 52'51"	Ouadrangle: Hinsdale
ProDertv Owner: Cook County Forest Preserve District. Attn: Frank Grippo		
Address: 10400 Windsor Drive. Westchester. Illinois 60154		
Telephone: 312/562-7628		
Permission Date: September 21. 1989		
Installation Date: September 27. 1989		
Gage Mfrs. No.: 4669	Gage ID No.: 5070	Clock Mfrs. No.: E 7292
Placement: Located in southeast corner of backyard between pool and grape hedge. Enter Windsor Drive east from Belleview Drive, south from Cermak Road and into Forest Preserve residence facility. Just west of Salt Creek and parallel bike trail.		

SITE DESCRIPTION		
Site Number: 9		
County: Cook	Township: 39E	Range: 13E
Section: 28	Lat/Long: 41° 50'48"/ 87° 45'26"	Quadrangle: Berwyn
Property Owner: Mary Oueen of Heaven Parish, c/o Father John Price		
Address: 5314 West 24th Place, Cicero. Illinois 60650		
Telephone: 708/863-6608		
Permission Date: May 24. 1990		
Installation Date: May 24. 1990		
Gage Mfrs. No.: 7376	Gage ID No.: 6559	Clock Mfrs. No.: E 7627
Placement: Located in southwest corner of schoolyard about 12 feet from south fence line and along a west fence, west of the nunnery. Was located at 5530 West 24th Street (9-28-89 through 5-24-89). Enter 24th Place (one-way east) from Central Avenue, south from Cermak Road.		

SITE DESCRIPTION		
Site Number: 10		
Countv: Cook	Township: 39N	Range: 14E
Section: 28	Lat/Long: 41° 50'42"/ 87° 38'27"	Ouadrangle: Englewood
Property Owner: Rental Residence		
Address: 527 West 26th Street. Chicago. Illinois 60616		
Telephone: 312/225-8066		
Permission Date: September 13. 1989		
Installation Date: September 28. 1989		
Gage Mfrs. No.: 4720	Gage ID No.: 5113	Clock Mfrs. No.: E 7416
Placement: Placed in backyard near edge of walk north of a garage and east of a spruce tree. Enter off of alley south of 26th Street, where locked gate is to be entered (observer keeps key). In Chinatown area, block between Wallace and Normal.		

SITE DESCRIPTION		
Site Number: 11		
County: Cook	Township: 38N	Range: 12E
Section: 28	Lat/Long: 41° 45'30"/ 87° 52'18"	Quadrangle: Berwyn
Property Owner: Private Residence		
Address: 10180 5th Avenue Cutoff. LaGrange. Illinois 60525		
Telephone: 708/354-3161		
Permission Date: September 13. 1989		
Installation Date: September 29. 1989		
Gage Mfrs. No.: 3348	Gage ID No.: 4452	Clock Mfrs. No.: E 7297
Placement: Placed 6 feet east of clothesline pole in center of backyard near edge of a large garden. Access from Willow Springs Road, south of Joliet Road (parcel of land is between Interstate-55 and Tri-State Tollway).		

SITE DESCRIPTION		
Site Number: 12		
County: Cook	Township: 38N	Range: 13E
Section: 28	Lat/Long: 41° 45'29"/ 87° 45'08"	Quadrangle: Berwyn
ProDertv Owner: Boyle Midway. Attn: Jerry Kemper		
Address: 5151 West 73rd Street. Bedford Park. Illinois 60638		
Telephone: 708/594-1100		
Permission Date: September 13. 1989		
Installation Date: September 28. 1989		
Gage Mfrs. No.: 4661	Gage ID No.: 5111	Clock Mfrs. No.: E 7369
Placement: Located 50 feet southwest of truck scale platform in the third fenced-in area. Facility is locked on the weekend. Access from gate on 73rd Street (few blocks west of Cicero Avenue).		

SITE DESCRIPTION		
Site Number: 13		
County: Cook	Township: 38N	Ranee: 14E
Section: 28	Lat/Long: 41° 45'34"/ 87° 38'07"	Quadrangle: Englewood
Property Owner: Private Residence		
Address: 7409 South Eggleston Street, Chicago, Illinois 60621		
Telephone: 312/224-3807		
Permission Date: September 13, 1989		
Installation Date: September 29. 1989		
Gape Mfrs. No.: 4687	Gage ID No.: 5058	Clock Mfrs. No.: E 7353
Placement: Located just north of barbecue pit. 3 feet from 8-foot high chain-link fence. About the only secure location in the vicinity. Entry is through a locked garage gate (observer has key). Otherwise, ring upper bell at front door. Was placed east of barbecue pit, 4 feet from fence (9-29-89 through 8-23-90) and 7 feet southeast of present location. Enter South Eggleston Street from 74th Street.		

SITE DESCRIPTION		
Site Number: 14		
County: Cook	Township: 38N	Range: 15E
Section: 29	Lat/Long: 41° 45'27"/ 87° 32'40"	Ouadrangle: Jackson Park
Property Owner: City of Chicago - South Water Purification Plant, Attn: Robert Sambol		
Address: 3300 East Chiltenham Place, Chicago, Illinois 60649		
Telephone: 312/933-7107		
Permission Date: September 12. 1989		
Installation Date: September 28. 1989		
Gage Mfrs. No.: 3370	Gage ID No.: 4453	Clock Mfrs. No.: E 7624
Placement: Located in center of large grassy area (turf-ccvered roof) over sand filtration beds. Two distant buildings are east and west oi" the site. Enter facility east off of 79th Street from South Shore Drive.		

SITE DESCRIPTION		
Site Number: 15		
County: Cook	Township: 37N	Range: HE
Section: 20	Lat/Long: 41° 40'38"/ 87° 59'52"	Quadrangle: Sag Bridge
Property Owner: Metropolitan Water Reclamation District of Greater Chicago. Attn: Jim Ivers		
Address: 13 Stephen Street. Lemont. Illinois 60439		
Telephone: 708/257-7371		
Permission Date: September 11. 1989		
Installation Date: September 27. 1989		
Gape Mfrs. No.: 3373	Gage ID No.: 4421	Clock Mfrs. No.: E 7323
Placement: Placed about 100 feet east of entrance road, and several hundred feet south of MWRDGC building. Just north of Illinois and Michigan Canal. Access from Stephen Street in downtown Lemont. Exit Interstate-55 south on Lemont Road and then downtown, or enter from east on McCarthy Road. Hours are 0700-1530 local time.		

SITE DESCRIPTION		
Site Number: 16		
County: Cook	Township: 37N	Range: 12E
Section: 28	Lat/Long: 41° 39'47"/ 87° 52'14"	Quadrangle: Palos Park
Property Owner: Private Residence		
Address: 240 Timber Edge Lane. Palos Park. Illinois 60464		
Telephone: 708/361-0853		
Permission Date: September 11. 1989		
Installation Date: September 27, 1989		
Gage Mfrs. No.: 4733	Gage ID No.: 5022	Clock Mfrs. No.: E 7423
Placement: Placed along west edge of lawn in backyard, about 20 feet south of property line and utility. Was moved about 2 feet on 4-26-91 to facilitate landscaping. Enter subdivision from 125th Street (off of Route 45), just south of McCarthy Road. West-southwest of Papoose Lake.		

SITE DESCRIPTION		
Site Number: 17		
County: Cook	Township: 37N	Range: 13E
Section: 28	Lat/Long: 41° 40'33'7 87° 45'03"	Quadrangle: Palos Park
Property Owner: Sardee Industries. Attn: Andy Chakonas		
Address: 11900 South Laramie Street. Alsip. Illinois 60658		
Telephone: 708/597-7330		
Permission Date: September 11. 1989		
Installation Date: September 27. 1989		
Gage Mfrs. No.: 4719	Gage ID No.: 5415	Clock Mfrs. No.: E 7300
Placement: Placed about 50 feet west of last loading dock in grassy field northwest of factory. Enter Laramie Street from 122nd Street, west of Cicero Avenue. Northeast of Tri-State Tollway, just south of Restvale Cemetery.		

SITE DESCRIPTION		
Site Number: 18		
County: Cook	Township: 37N	Range: 14E
Section: 29	Lat/Long: 41° 40'35'/ 87° 39'06"	Quadrangle: Blue Island
Property Owner: Ingersoll Products Company. Attn: Don Recupido		
Address: 1000 West 120th Street, Chicago, Illinois 60643		
Telephone: 312/264-7800		
Permission Date: September 12. 1989		
Installation Date: September 27. 1989		
Gage Mfrs. No.: 7130	Gase ID No.: None	Clock Mfrs. No.: E 7410
Placement: Located at southwest end of property just southwest of a truck scale and east of property fence. Must enter at guarded gate on 119th Street.		

SITE DESCRIPTION		
Site Number: 19		
County: Cook	Township: 37N	Range: 15E
Section: 20	Lat/Long: 41° 40'20"/ 87° 32'21"	Ouadrangle: Lake Calumet
Property Owner: Graycor Industries		
Address: 12233 Avenue 0, Chicago, Illinois 60603		
Telephone: 312/221-8400		
Permission Date: September 11_T1989		
Installation Date: September 26.1989		
Gage Mfrs. No.: 5298	Gage ID No.: 5291	Clock Mfrs. No.: E 7294
Placement: Placed in grassy area just south of entrance drive and just west of the main parking lot. Office building and shops to north, and shops to southwest.		

SITE DESCRIPTION		
Site Number: 20		
County: Cook	Township: 36N	Range: 12E
Section: 29	Lat/Long: 41° 35'08"/ 87° 52'37"	Ouadrangle: Mokena
Property Owner: Private Residence		
Address: 10595 West 167th Street, Orland $Park_T$ Illinois 60462		
Telephone: 708/349-9388		
Permission Date: March 16_T1990		
Installation Date: March 16. 1990		
Gage Mfrs. No.: 4667	Gage ID No.: 5061	Clock Mfrs. No.: E 7293
Placement: Sited about 30 feet east of welding shop on ru ral property. Shop is east building of home/shop complex. Three dachshunds outsic e. Was located about 0.25 mile southeast on South 104th Avenue (9-26-89 through 3-16-90).		

SITE DESCRIPTION		
Site Number: 21		
County: Cook	Township: 36N	Range: 13E
Section: 28	Lat/Long: 41° 35'14"/ 87° 44'56"	Quadrangle: Harvey
Prooerty Owner: Private Residence		
Address: 16710 Lockwood Road. Tinley Park, Illinois 60477		
Telephone: 708/560-0213		
Permission Date: September 16. 1989		
Installation Date: September 28, 1989		
Gape Mfrs. No.: 4686	Gage ID No.: 5037	Clock Mfrs. No.: E 7374
Placement: Placed in north end of backyard west of (behind") garage. Enter Lockwood Road south off of 167th Street.		

SITE DESCRIPTION		
Site Number: 22		
County: Cook	Township: 36N	Range: 14E
Section: 21	Lat/Long: 41° 35'08"/ 87° 38'08"	Quadrangle: Harvey
ProDertv Owner: U.S. Army Reserve Center. Attn: Commander Al Dixon		
Address: 400 East 167th Street, Harvey, Illinois 60426		
Telephone: 708/339-0001		
Permission Date: September 12. 1989		
Installation Date: September 26. 1989		
Gage Mfrs. No.: 4676	Gage ID No.: 5035	Clock Mfrs. No.: E 7334
Placement: Located between parking lot and reserve building, just north of fenced-in reserve storage lot, about 150 feet south of 167th Street. Was located about 100 feet northwest on Army property, just west of parking lot before a building was constructed on property just to the west (9-26-89 through 11-2-90). Enter 167th Street east off of Halsted Avenue.		

SITE DESCRIPTION		
Site Number: 23		
County: Cook	Township: 36N	Range: 15E
Section: 29	Lat/Long: 41° 35'10"/ 87° 32'16"	Ouadrangle: Calumet City
Prooertv Owner: City of Lansing Public Works. Attn: Al Poortenga		
Address: 3300 East 171st Street, Lansing, Illinois 60438		
Telephone: 708/895-7190		
Permission Date: September 12, 1989		
Installation Date: September 26, 1989		
Gage Mfrs. No.: 4660	Gage ID No.: 5043	Clock Mfrs. No.: E 7344
Placement: Placed 6 feet from east fence in northeast corner of storage yard of Public Works complex. Northeast of office and maintenance building. Enter north gate east off of 170th Street. Closes at 1530 local time.		

SITE DESCRIPTION		
Site Number: 24		
County: Cook	Township: 35N	Ranee: 13E
Section: 16	Lat/Long: 41° 31'16"/ 87° 43'59"	Ouadrangle: Harvey
Property Owner: Village of Matteson. Attn: Frank W. Denman		
Address: 3625 West 215th Street, Matteson, Illinois 60443		
Telephone: 708/748-1411		
Permission Date: September 12,1989		
Installation Date: September 26,1989		
Gage Mfrs. No.: 7573	Gage ID No.: WMU81122	Clock Mfrs. No.: E 7573
Placement: Located at Police Station on Cicero Avenue. about 0.5 mile north of U.S. 30. Placed 5 feet west of telephone terminal box on grass north of parking lot and northeast of police station.		

SITE DESCRIPTION		
Site Number: 25		
County: Cook	Township: 35N	Range: 14E
Section: 13	Lat/Long: 41° 31'14"/ 87° 34'26"	Ouadrangle: Calumet City
Property Owner: Big John's Farm Stand, Attn: John DeBoer		
Address: 1754 East Joe Orr Road. Chicago Heights, Illinois 60411		
Telephone: 708/758-2711		
Permission Date: September 12, 1989		
Installation Date: September 26, 1989		
Gage Mfrs. No.: 7467	Gage ID No.: WMU80955	Clock Mfrs. No.: E 7628
Placement: Placed just northeast of farm stand parking lot. northwest of house and northeast of farm stand. Small ditch between parking lot and gage, and large trees near house. Just east of Interstate-394 and Stony Island Avenue, and west of Torrence Avenue.		

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 24-hour rotation raingage charts (Belfort number 5-4047-B)
b. A bottle of raingage ink (Belfort #10 Purple)
c. A roll of paper towels or similar absorbent material for ink spills
d. A ball-point pen or pencil
e. Grass clippers and/or sickle
f. A clipboard
g. A 12-quart bucket

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

Please coordinate your watch with the broadcast tone from WMAQ or WGN, etc., 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 (try to complete within 5-10 minutes of arrival):

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 pushing out on the pen bracket. Lift up on the drum cylinder to disengage it from the electric chart drive, and remove it out the door. 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 it to the drum cylinder, making sure 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 spurious indications of a rain event. Make a small mark with your pen or pencil on the chart near the zero-inch line to indicate the ON time. Try to match the chart reading with the ON time as closely as possible. Reinstall the chart cylinder onto the electric chart drive, making sure the chart cylinder and drive gears mesh.

4) Quickly, remove the collector from the top of the gage by rotating it 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) and dump the water on the ground. Reposition the bucket on the platform and reinstall the collector by setting it on top of the raingage case and turning counterclockwise until the tongue-and-groove assembly meshes. During wintertime operation when a charge of antifreeze is in the bucket, leave the antifreeze in until the chart reading passes the 6-inch mark. At that point, dump the bucket contents into a large plastic bucket and dispose of properly. DO NOT POUR SOLUTION ONTO THE GROUND! If wintertime conditions prevail, recharge the empty bucket with a quart of antifreeze. At any time of the year, once the collector is repositioned, check the gage to make sure the collector orifice top edge is level. With a level positioned on the collector orifice, depress the stakes on the side(s) reading high with your shoe or boot, lightly or firmly depending on how much out of level the gage is and how soft the ground is.

5) Re-ink the pen with a drop or two of ink. If the pen point appeared dirty or the previous chart's trace was rough, pull a small sheet of lint-free paper through the pen nibs to clean them. 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 again to see why the ink is not drawing. It helps if the word "ON" is written on the chart near the ON line for later chart editing purposes. Remember not to overfill the pen reservoir: extra ink will only spill and create a blotch on the new chart. Rezero the pen point if necessary by turning the fine adjustment screw. It isn't a bad idea to "zero" the pen near the 0.25-inch mark instead to prevent evaporation from taking the pen point below the zero line.

6) Wipe up any excess ink from the 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 of the chart. As you are doing this, keep an eye on 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. Disposition of recorded raingage charts:

When a complete set of 25 charts has been collected for a week, place them in numerical order, put them in one of the postage-paid envelopes provided, and mail them to the State Water Survey, noting the name of the project director on the envelope. If any serious problems were encountered during servicing, please call the project director "collect" to relay the information to him. Situations worthy of immediate attention include chart-drive stoppages, unauthorized movement of the raingage, vandalism, and theft. Repairs will then be scheduled as soon as possible. Go ahead and make minor repairs (e.g.,pen point stuck under drum cylinder, debris in the collection bucket, etc.). Major repairs will require the attention of the State Water Survey.

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, please alert the State Water Survey immediately so that the project director can contact 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. Any questions from them concerning the project and your job that you are unable to answer should be referred to the project director.

APPENDIX III: DOCUMENTATION OF RAINGAGE MAINTENANCE

This appendix gives complete documentation of all maintenance work carried out at each of the sites in the raingage network during Water Year 1991, including visits when no action was taken. Organized chronologically by site number, this documentation is current through October 4, 1991.

SITE #1: MISSION BROOK SANITARY DISTRICT

11-2-90: Replaced the vandalized outer case.

8-22-91: Checked calibration and cleaned/relubricated gage.

10-4-91: Replaced collector, outer case, chart drive, and pen point. Releveled gage.

SITE #2: WINNETKA PARK DISTRICT

11-2-90: Replaced outer case.

5-29-91: Chart drive fine.

7-31-91: Site relocated to a grassy area near a Park District office building. Move was necessitated because previous site 15 feet southeast was destroyed a week earlier when a truck ran over it. A new gage was placed at the relocated site.

SITE #3: DES PLAINES

4-26-91: Replaced chart drive and rezeroed pen. Releveled gage.

8-22-91: Checked calibration and cleaned/relubricated gage.

10-4-91: Replaced outer case and added ink to pen point.

SITE #4: VILLAGE OF SKOKIE

11-2-90: Releveled gage.

6-28-91: Releveled gage, checked chart-drive operation.

7-31-91: Replaced chart drive.

8-22-91: Checked calibration and cleaned/relubricated gage.

10-4-91: Replaced chart-drive batteries.

SITE #5: FRANKLIN PARK

5-29-91: Chart drive fine. Releveled gage.

8-22-91: Checked calibration and cleaned/relubricated gage.

SITE #6: WEST FLETCHER STREET

2-5-91: Replaced chart drive. Releveled gage.

3-27-91: Releveled gage.

8-22-91: Checked calibration and cleaned/relubricated gage.

SITE #7: BROADWAY UNITED METHODIST CHURCH

11-2-90: Replaced chart drive.

1-15-91: Gage operating correctly.

2-5-91: Replaced chart drive again. Gage checked out otherwise.

3-27-91: Once again, replaced chart drive.

6-28-91: Moved gage from Lincoln Park Gun Club site to an area in Lincoln Park north of Diversey Harbor, just west of old site. Replaced chart drive. Site now located at ground level.

7-31-91: Attached two locks to gage, replaced outer case and chart drive due to vandalism.

8-23-91: Checked calibration and cleaned/relubricated gage. Evidence of continued vandalism.

10-4-91: Installed new gage at Broadway United Methodist Church, about 0.5 mile northeast of previous location. Vandalized gage on Chicago Park District property was removed. New location is in a secure, secluded grassy area.

SITE #8: COOK COUNTY FOREST PRESERVE **DISTRICT - WESTCHESTER**

4-26-91: Replaced chart drive. Releveled gage.

5-29-91: Replaced chart drive.

7-31-91: Replaced chart-drive batteries.

8-22-91: Checked calibration and cleaned/relubricated gage. Replaced chart drive.

SITE #9: MARY QUEEN OF HEAVEN **PARISH - CICERO**

11-2-90: Loosened collector fit onto outer case at request of observer.

3-27-91: Replaced chart-drive batteries. Releveled gage.

6-28-91: Checked chart drive. Reinked pen.

8-23-91: Checked calibration and cleaned/relubricated gage.

10-4-91: Replaced chart drive and shortened chart clip. Reinked pen and releveled gage.

SITE #10: WEST 26th STREET

8-23-91: Checked calibration and cleaned/relubricated gage.

SITE #11: LAGRANGE

12-17-90: Site visited, but everything fine.

2-5-91: Replaced chart drive. Releveled gage.

4-26-91: Straightened drum clip to prevent further skipping on the trace.

8-22-91: Checked calibration and cleaned/relubricated gage. Replaced chart drive.

10-4-91: Replaced chart drive and shortened chart clip. Reinked pen.

SITE #12: BOYLE MIDWAY - BEDFORD PARK

5-29-91: Replaced chart drive. Releveled gage. Large dirt mounds observed near gage.

8-23-91: Checked calibration and cleaned/relubricated gage.

SITE #13: SOUTH EGGLESTON AVENUE

4-26-91: Bent pen arm down a bit to prevent shakiness in trace. Releveled gage.

8-23-91: Checked calibration and cleaned/relubricated gage.

SITE #14: **SOUTH** WATER PURIFICATION **PLANT**

11-2-90: Stakes refortified to prevent shaky trace. Releveled gage.

12-17-90: Replaced chart drive. Fortified stakes again and releveled gage.

2-5-91: Pushed stakes down, and releveled gage.

3-27-91: Releveled gage, pushed stakes down a bit. Loose soil at this site, above the filtration bed.

8-23-91: Checked calibration and cleaned/relubricated gage.

SITE #15: MWRDGC - LEMONT

12-17-90: Replaced chart drive. Releveled gage.

2-5-91: Replaced chart drive again, and drum cylinder.

8-22-91: Checked calibration and cleaned/relubricated gage.

SITE #16: PALOS PARK

3-27-91: Replaced chart drive. Releveled gage. New home going up next door.

4-26-91: Unauthorized move of gage made by contractor to facilitate landscaping. Gage relocated very near original site during this visit. Raised drum for better time line trace. Relubricated moving parts of gage.

5-29-91: Replaced chart drive again. Clip fine. Releveled gage. Tilted pen down a bit and cleaned it.

8-22-91: Checked calibration and cleaned/relubricated gage.

SITE #17: SARDEE INDUSTRIES - ALSIP

3-27-91: Changed batteries.

8-23-91: Checked calibration and cleaned/relubricated gage. Replaced chart drive batteries.

SITE #18: INGERSOLL PRODUCTS - WEST **120th STREET**

12-17-90: Site visited, but gage fine.

1-15-91: Replaced chart drive.

8-23-91: Checked calibration and cleaned/relubricated gage.

SITE #19: GRAYCOR INDUSTRIES - AVENUE O

3-27-91: Pen arm loose (looked like tampering), so tilted it in a bit towards drum. Releveled gage.

6-28-91: Straightened drum clip.

8-23-91: Checked calibration and cleaned/relubricated gage.

SITE #20: ORLAND PARK

1-15-91: Replaced chart drive. Changed pen point. Gage was badly out of level.

3-27-91: Releveled gage again, tilted pen arm in a bit towards drum.

4-26-91: Releveled gage again and cleaned pen nibs.

8-22-91: Checked calibration and cleaned/relubricated gage. Replaced chart drive.

SITE #21: TINLEY PARK

1-15-91: Replaced chart drive.

8-22-91: Checked calibration and cleaned/relubricated gage.

SITE #22: U.S. ARMY RESERVE CENTER - HARVEY

11-2-90: Outer case destroyed during unauthorized move of gage by a building contractor in late October. Thus, gage was resited about 100 feet southeast to new location between the parking lot and Reserve Building. Replaced outer case and applied a new drum gear (other one stolen).

12-17-90: A bent lower traverse rod was causing the reversal to occur at 2.35 inches instead of at 6 inches. Straightened the traverse and recalibrated the gage.

8-23-91: Checked calibration and cleaned/relubricated gage.

SITE #23: CITY OF LANSING PUBLIC **WORKS**

11-23-90: Pen wouldn't zero. Removed case and recalibrated.

8-23-91: Checked calibration and cleaned/relubricated gage. Replaced chart drive.

SITE #24: VILLAGE OF MATTESON

3-27-91: Releveled gage. Pen point fine (had been caught under drum lip).

6-28-91: Changed chart drive.

7-31-91: Replaced chart-drive batteries and releveled gage.

8-22-91: Checked calibration and cleaned/relubricated gage. Replaced chart drive.

10-4-91: Replaced collector, releveled gage, and reinked pen.

SITE #25: BIG JOHN'S FARM STAND - CHICAGO HEIGHTS

11-2-90: Readjusted fine adjustment screw, repositioned battery pack lines under pen arm.

11-23-90: Rezeroed pen.

12-17-90: Replaced chart drive.

8-23-91: Checked calibration and cleaned/relubricated gage.

APPENDIX IV: DOCUMENTATION OF HIGH STORM TOTALS

This appendix documents all storm totals that exceeded an annual event (one-year recurrence interval) during Water Year 1991. Storm durations of one hour to ten days were considered. The rainfall amounts for a one-year recurrence interval and the aforementioned storm durations in northeastern Illinois are given below (Huff and Angel, 1989).

Storm Duration	Rainfall Amounts (inches)
1 hour	1.18
2 hours	1.48
3 hours	1.60
6 hours	1.88
12 hours	2.18
18 hours	2.30
24 hours	2.51
48 hours	2.70
72 hours	2.93
5 days	3.25
10 days	4.12

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. The last column indicates whether a particular storm during the water year exceeded other events greater than an annual event (2-year to 100-year recurrence intervals considered).

Storm Totals

Storm #	Site #	Date	Duration (hours)	Amount (inches)	Other Events Exceeded
4	2	10/8-10/90	53	3.01	
	6		51	3.01	
	7		48	3.00 E	
	8		60	2.86	
	9		58	3.14	
	10		55	3.25	
	11		52	2.78	
	12		54	2.78	
	14		48	2.79	
	16		54	2.89	
	19		50	2.80	
	21		57	2.86	
	22		57	3.05 E	
	23		53	2.99	
	24		55	3.82	2-year
10	2	11/3-5/90	45	2.88	
	3		43	2.81	
	5		43	2.81	
	7		44	2.98	
	18		43	2.69	
	19		43	2.86	
	24		43	3.45	2-year
15	1	11/26-27/90	25	2.68	
	2		23	3.11	2-year
	3		24	2.86	
	4		25	2.96	
	5		27	3.09	2-year
	6		27	3.15	2-year
	7		26	2.55	
	8		25	3.04	
	9		25	2.98	
	10		27	3.08	2-year
	11		26	3.06	
	12		26	3.24	2-year
	13		28	3.67	2-year
	14		27	3.69	2-year
	15		28	3.46	2-year

Storm Totals (Concluded)

Storm #	Site #	Date	Duration (hours)	Amount (inches)	Other Events Exceeded
15	16	11/26-27/90	29	3.28	2-year
	17		28	3.23	2-year
	18		26	3.63	2-year
	19		28	4.66	10-year
	20		33	3.80	2-year
	21		31	3.96	5-year
	22		25	4.03	5-year
	23		26	4.50 E	5-year
	24		33	5.06	10-year
	25		27	4.78	10-year
48	10	4/7-10/91	55	3.41	
67	12	5/24-25/91	22	2.76	
	17		23	2.93	
	19		23	2.95	
	20		24	3.69	2-year
	21		21	4.70	10-year
	22		23	2.89	
	23		22	2.70	
	24		6	3.49	10-year