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ATMOSPHERIC SCIENCES DIVISION

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INSTALLATION AND OPERATION OF A DENSE RAINGAGE NETWORK TO IMPROVE PRECIPITATION MEASUREMENTS FOR LAKE MICHIGAN DIVERSION ACCOUNTING: WATER YEAR 1990

By
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Prepared for the
U.S. Army Corps of Engineers, Chicago District

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U.S. Army Corps of Engineers, Chicago District

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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 into 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 the 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 as a means of cross-checking 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, 1991). 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 that the accounting procedure used (Figure 1). Inspection of these sites (Vogel, 1988), which are irregularly distributed over the region, revealed that the low totals

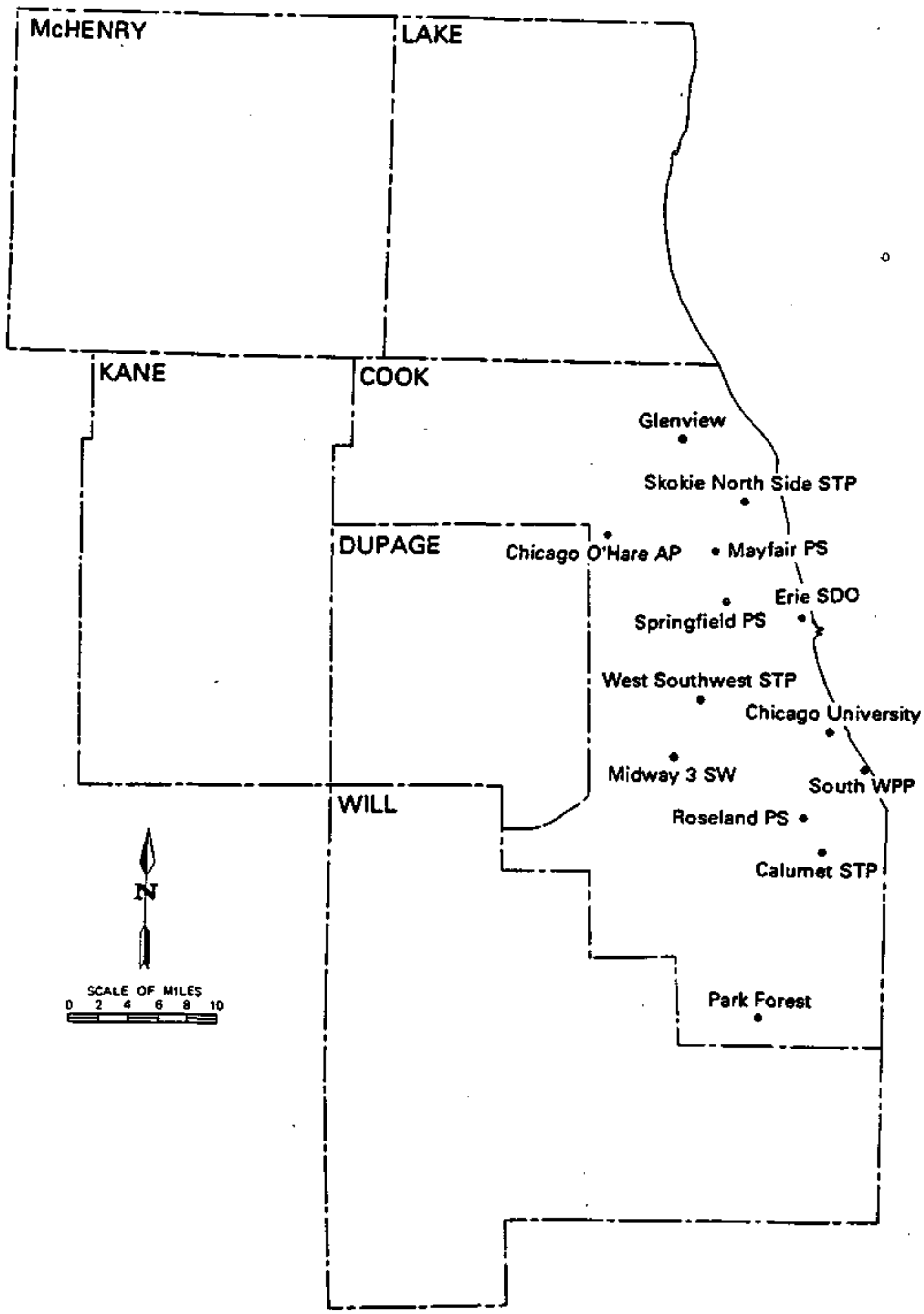

Figure 1. For Lake Michigan diversion accounting purposes, 13 raingage sites were used prior to Water Year 1990. Chicago O'Hare AP, Midway 3 SW, Chicago University, and Park Forest are National Weather Service sites; Mayfair PS, Springfield PS, South WPP, and Roseland PS are City of Chicago sites; Glenview, 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 Corps of Engineers jointly decided in late 1988 to devise, install, and operate a new raingage network, funded by the Corps of Engineers, 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 design, installation, maintenance, and operation of the network, along with the data reduction and analysis techniques employed, and presents the data and analyses for Water Year 1990, to evaluate the network's effectiveness at collecting precipitation.

2. NETWORK DESIGN AND INSTALLATION

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 constructed using a 6-mile grid spacing between gages (Figure 2). 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. Also, to have a consistent set of gages operated by one group (the Water Survey), an initial plan to incorporate the three NWS recording gages at Chicago O'Hare AP, Midway 3 SW, and Chicago University into the network was scuttled.

Using the idealized grid, 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.

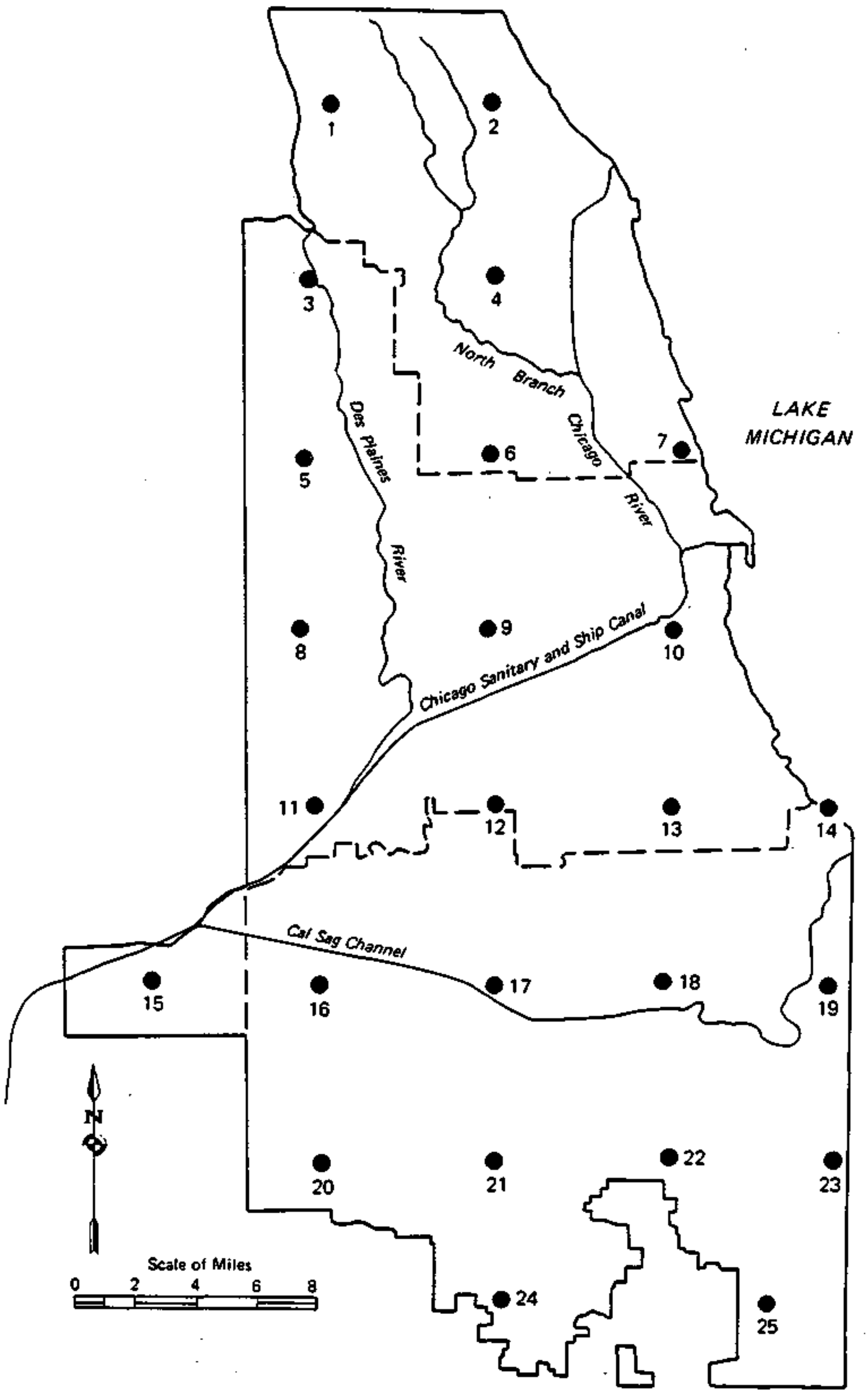

Figure 2. Original 25-site grid of the proposed raingage network.

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 the summer of 1989 seeking permission to use the locations as raingage sites. This was sometimes a frustrating venture due to the urbanization of the region, making the identification of good catchment areas free of barriers for ground-level placement difficult. When selecting sites, highest priority was given to those at ground level in relatively open areas that were secure, 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 due to an impending move, and a third was due to the closing of a Chicago Park District facility.

In late September and early October 1989, the entire 25-gage network was installed. The Belfort weighing-bucket raingage was used throughout the network, and each fitted each with a battery-powered electric chart drive for more consistent and reliable operation. The Water Survey donated all raingages needed from its inventory. Figure 3 shows the current configuration of the network (as of July 1991), while Table 1 gives further information for

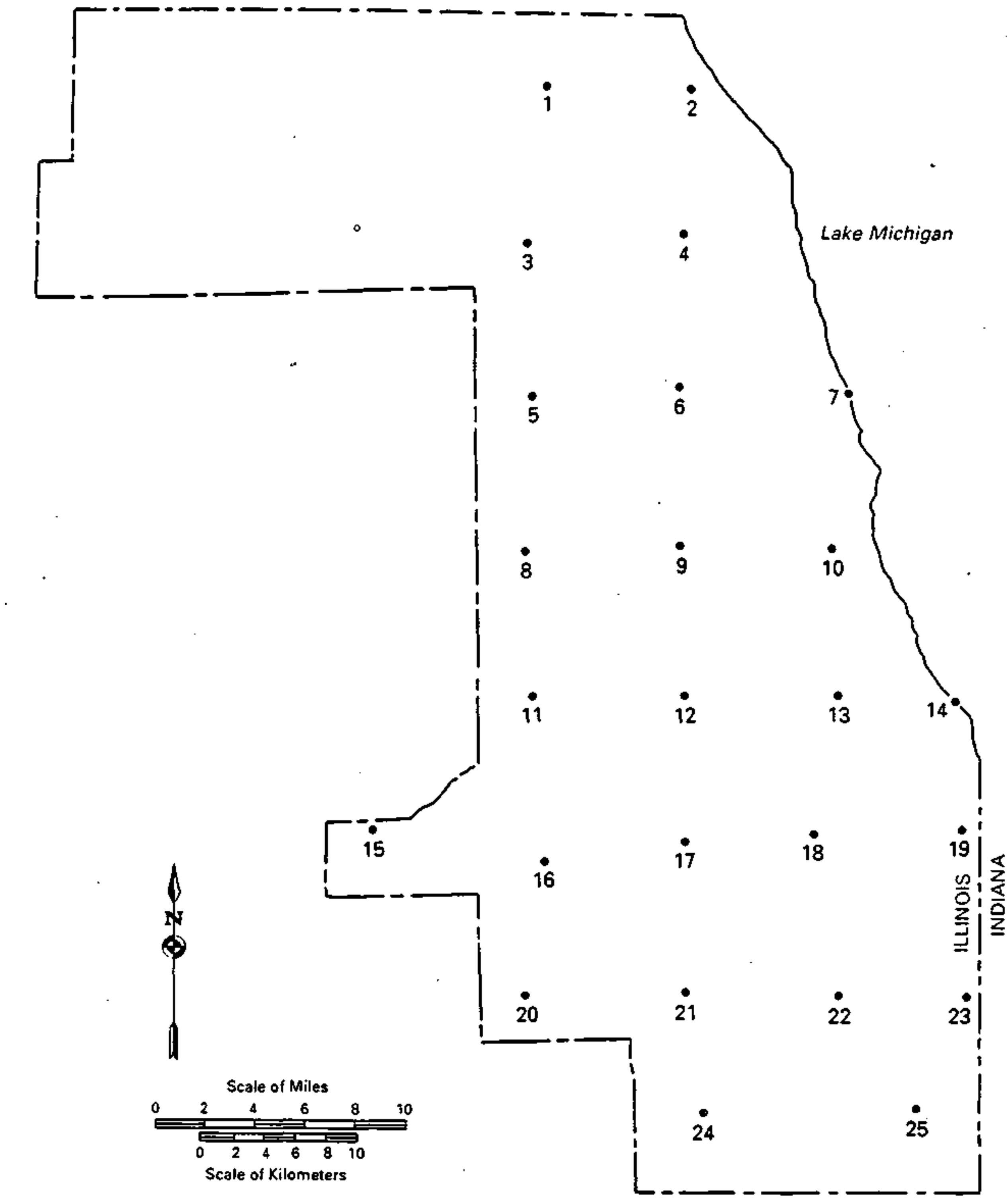

Figure 3. Current configuration of the 25-site raingage network.

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	Chicago Park District	425 McFetridge Dr. Chicago, IL 60605
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 Eggleston St. Chicago, IL 60621
14	City of Chicago South Filtration Plant	3300 E. Chiltenham Place Chicago, IL 60649
15	Metropolitan Water Reclamation District	13 Stephen Street Lemont, IL 60439

Table 1. Concluded.

Site Number	Name	Address
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, IL 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

each site. Appendix I contains complete site descriptions as of July 1991 for each network location.

Weighing-bucket raingages were used. These recording gages 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 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 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. Service 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 allow the weighing mechanism to give a proper reading. Refer to Appendix II for a complete listing of service 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 June 1991 (i.e.,includes first nine months of Water Year 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 matched 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 "l", 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 the 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, which is discussed further. 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, 1991) to define storms for Water Years 1984-1989. For each storm, values are summed and plotted on maps using all available data and stations, and isohyetal patterns are drawn.

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 missing, 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 is being sought and will allow much quicker data reduction in general, perhaps within a week after all the information has been collected for a calendar month.

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

Using the final, corrected, filled-in data array, several analyses were performed on the 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 4-10), (2) monthly and water year totals at all sites (Table 3), (3) spatial correlation pattern analyses of the region (Figures 11-14), (4) statistical techniques assessing the validity of the correlation patterns (Figures 15-16), and (5) comparisons to data collected by NWS and CC raingages during this water year and past ones (Figures 17-19). The correlation patterns examine the degree of interrelation between the respective sites, which may be useful for identifying regions of preferred storm movement and categorizing the sites as well as for identifying and eliminating redundant sites. These analyses are done on a water year basis only.

Figure 4 contains the Water Year 1990 analysis. Isopleths are drawn to every inch. The figure reveals precipitation highs in the north central, east central, and extreme southwestern portions of Cook County encompassed by the network, centered on Sites #6, #13, and #24, respectively. Areas of lower precipitation were located in the extreme northern, northeastern, west central, southwestern, and southeastern portions of the region, centered on Sites #4, #7, #11, #17, and #25, respectively. The maximum at Site #6 seems to coincide 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 (e.g., Peppier, 1991). The minima in the extreme north and northeast may be associated with the stabilizing effect exerted by Lake Michigan on convective rainfall, as noted in data by Huff and Vogel (1976).

Water Year 1990

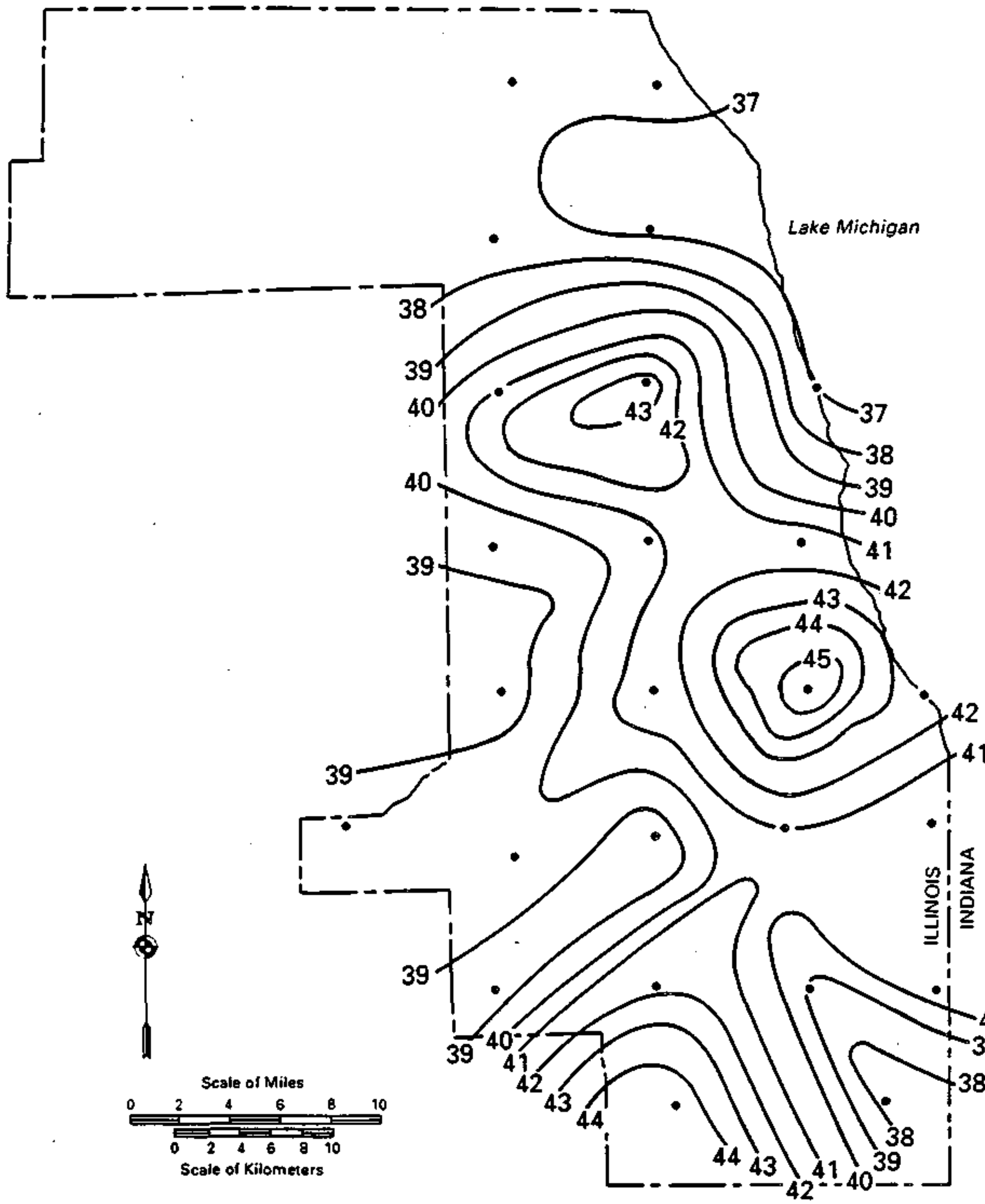

Figure 4. Precipitation pattern (inches) for Water Year 1990. Dots indicate network sites.

Table 3. Monthly and Water Year 1990 Precipitation Totals for All Sites in the New Raingage Network.

Month	G 1	G 2	G 3	G 4	G 5	G 6	G 7	G 8	G 9	G 10	G 11	G 12	G 13	G 14	G 15	G 16	G 17	G 18	G 19	G 20	G 21	G 22	G 23	G 24	G 25
Oct 1989	1.69	1.70	1.51	1.67	1.74	1.80	1.87	1.89	1.75	1.89	1.52	1.66	1.97	1.50	1.44	1.61	1.72	1.91	2.08	1.63	1.94	1.92	1.76	2.15	1.82
Nov 1989	1.96	2.48	2.11	2.05	2.15	2.42	2.99	2.25	2.48	3.17	2.41	2.88	2.44	2.55	2.11	2.61	2.76	2.74	2.91	2.57	2.45	2.12	2.94	3.15	2.83
Dec 1989	0.48	0.57	0.62	0.40	0.49	0.43	0.72	0.51	0.68	0.64	0.59	0.44	0.73	0.43	0.54	0.56	0.33	0.52	0.63	0.48	0.73	0.54	0.49	0.44	0.56
Jan 1990	2.09	2.06	2.35	2.21	2.41	2.48	1.82	2.14	2.59	2.57	2.48	2.43	2.55	2.28	2.60	2.66	2.41	2.34	2.03	2.53	2.67	2.37	2.07	2.59	2.41
Feb 1990	2.57	3.29	2.42	2.62	3.57	4.11	2.92	3.55	4.14	3.93	2.97	2.74	3.61	2.84	2.79	2.99	2.45	3.00	3.66	2.91	3.57	3.30	3.57	3.60	2.77
Mar 1990	2.78	2.97	2.86	2.62	3.25	3.33	2.97	3.28	3.43	3.53	3.32	3.29	3.66	3.54	3.45	3.62	3.71	3.46	3.65	4.03	3.70	3.84	3.57	4.37	3.04
Apr 1990	1.57	1.79	1.69	1.54	1.55	1.69	1.59	1.72	1.75	1.80	1.71	2.05	2.54	2.86	2.23	2.17	2.18	2.22	2.14	2.12	2.31	1.79	1.97	2.95	2.04
May 1990	6.16	6.51	7.11	7.21	7.94	7.96	7.03	8.22	7.92	7.18	7.56	6.66	7.51	6.68	7.19	6.78	6.68	6.85	6.91	6.54	7.55	6.88	6.45	9.32	6.18
Jun 1990	4.78	5.32	4.88	4.30	4.58	3.97	4.19	5.33	4.83	4.59	5.68	5.06	5.08	5.02	6.50	5.22	4.42	5.30	4.15	4.32	4.49	3.97	4.02	4.91	3.78
Jul 1990	4.66	2.91	2.57	2.43	2.84	3.48	3.23	3.45	3.59	4.01	5.15	7.25	6.45	7.84	5.38	7.00	6.66	5.85	6.57	5.11	4.81	4.52	6.01	4.08	3.76
Aug 1990	7.12	6.60	8.27	7.82	8.07	9.35	5.74	4.90	5.81	5.27	3.59	4.99	7.85	5.57	3.61	3.23	4.06	5.78	4.87	5.17	5.24	5.77	6.09	4.82	6.81
Sep 1990	1.25	1.31	1.09	1.37	2.52	2.24	1.46	1.96	2.02	2.57	1.58	1.70	1.50	1.78	1.60	1.52	0.96	1.02	0.66	1.51	2.18	2.07	1.44	1.96	1.49
W-Y 1990	37.11	37.51	37.48	36.24	41.11	43.26	36.53	39.20	40.99	41.15	38.56	41.15	45.89	42.89	39.44	39.97	38.34	40.99	40.26	38.92	41.64	39.09	40.38	44.34	37.49

The minimum in the west central region appears similar to adjusted ones found in Water Years 1988 and 1989 (Peppier, 1991), while the maximum in the east central region extending toward the Indiana border also resembles those 1988 and 1989 patterns (Peppier, 1991). Thus, the Water Year 1990 pattern, as collected by the raingages in the new network, displays characteristics found in previous established data. It generally disagrees with the unusual anomalies associated with the collection of raingages from the NWS, MWRDGC, and CC used to generate precipitation information in Water Years 1984-1989. Therefore, the new network can be considered to have improved collection properties.

Figures 5-10 contain monthly analyses for the water year period. Generally, light precipitation occurred in October, December, which had the lightest precipitation of the water year, April, and September (Figures 5, 6, 8, and 10, respectively). Heavier amounts occurred in May and over parts of the region in July and August (Figures 8-10, respectively). Looking at some of the more interesting cases, December's monthly amounts (Figure 6) ranged from just 0.33 inches at Site #17 to 0.73 inches at both Sites #7 and #21. February particularly showed the increased precipitation region in the north central portion of the area (Figure 7), as did August (Figure 10). Site #6 in August had the highest monthly total recorded during the water year at any site, 9.35 inches. May had high values throughout the entire network (Figure 8), with a maximum of 9.32 inches at Site #24 in the extreme southwestern portion of the grid. Both July and August had the greatest ranges of amounts over the network (Figures 9-10, respectively). In July, monthly totals ranged from only 2.43 inches at Site #4 in the north to 7.84 inches in the southeast at Site #14. A band in the 7-inch range spread from Site #16 in the southwest to Site #14, while values were below 3 inches north of Site #5. In August (Figure 10), values ranged from 3.23 inches at Site #16

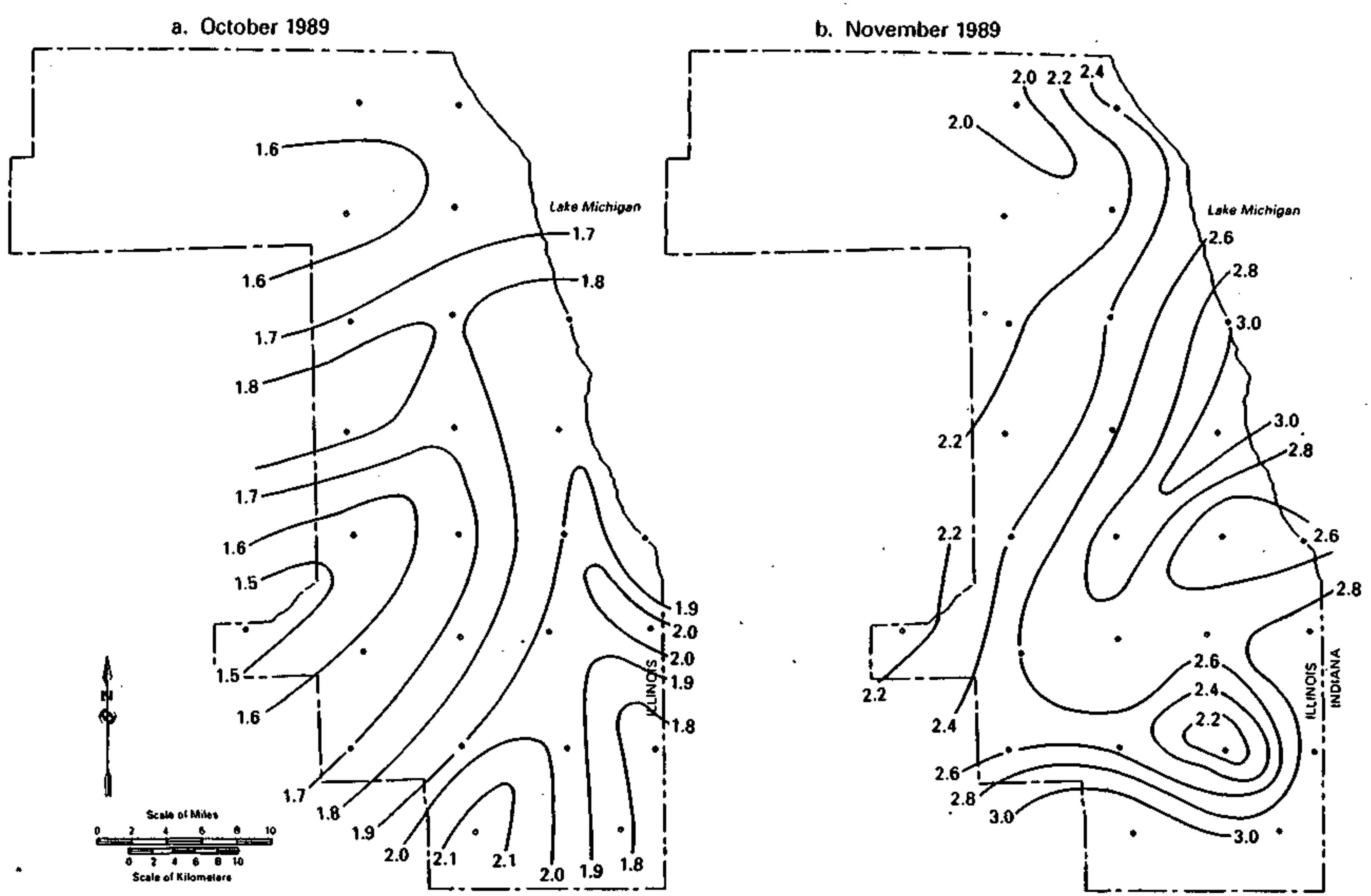

Figure 5. Precipitation patterns (inches) for October 1989 (Panel a) and November 1989 (Panel b). Dots indicate network sites.

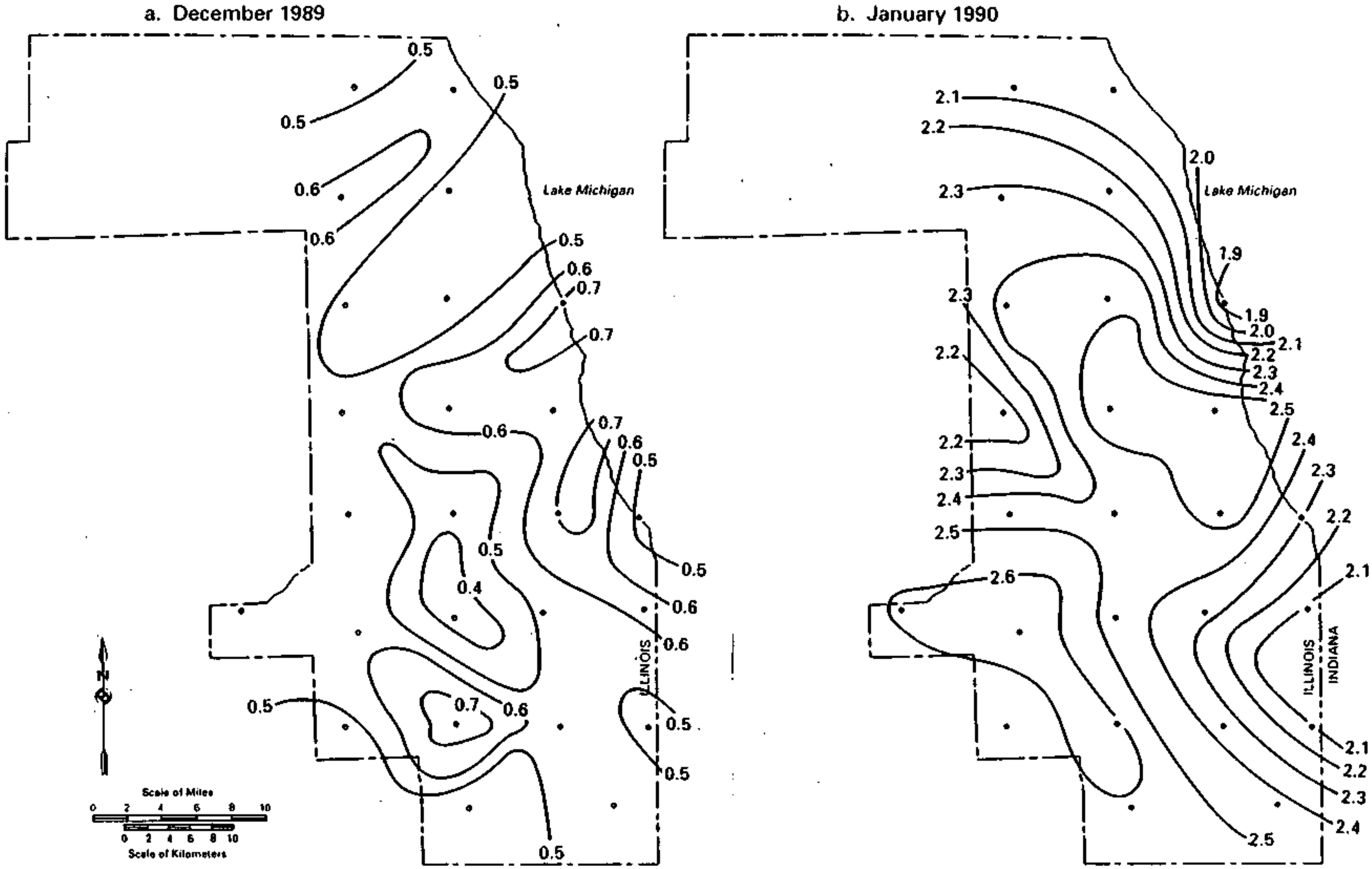

Figure 6. Precipitation patterns (inches) for December 1989 (Panel a) and January 1990 (Panel b). Dots indicate network sites.

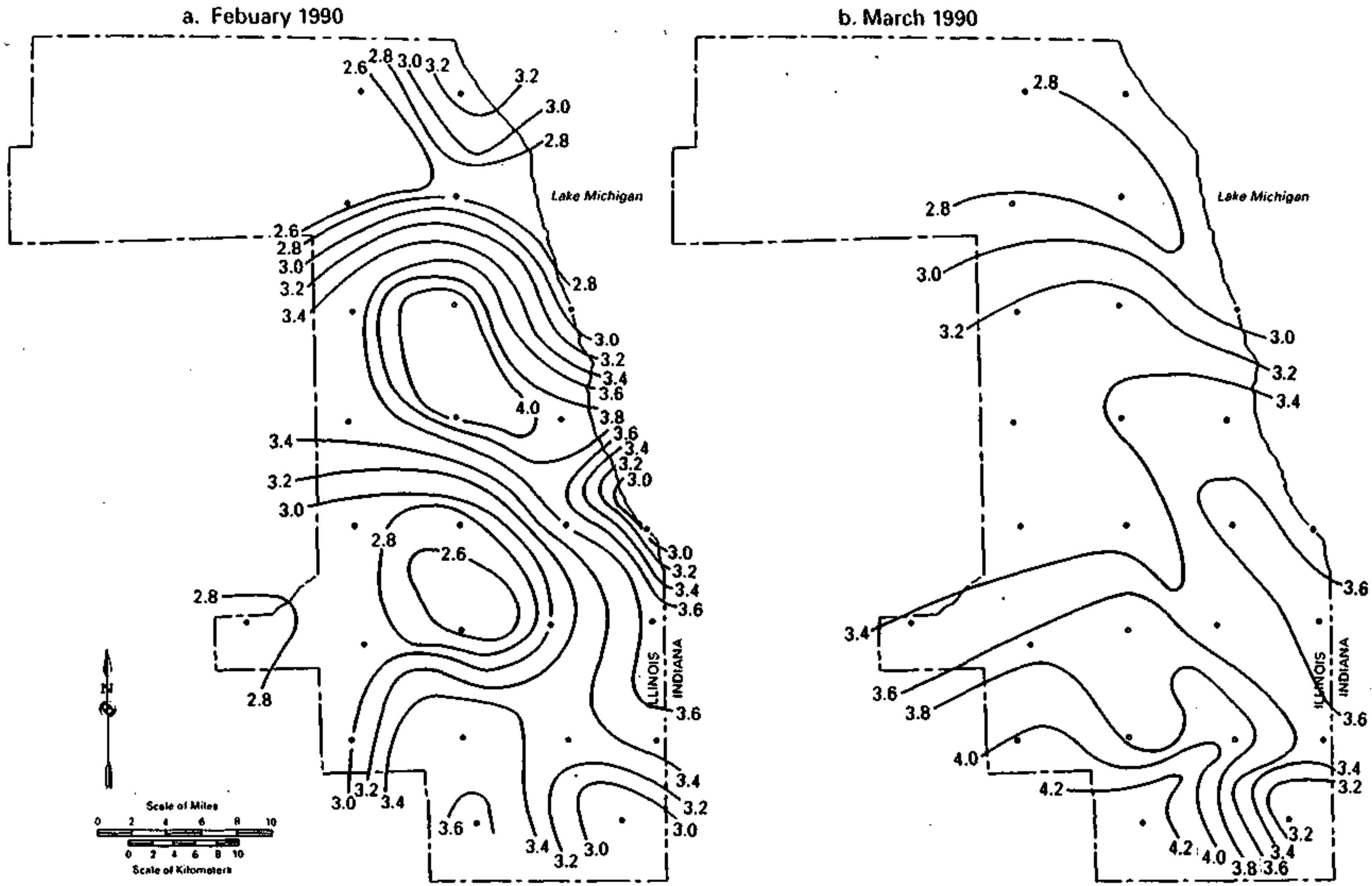

Figure 7. Precipitation patterns (inches) for February 1990 (Panel a) and March 1990 (Panel b). Dots indicate network sites.

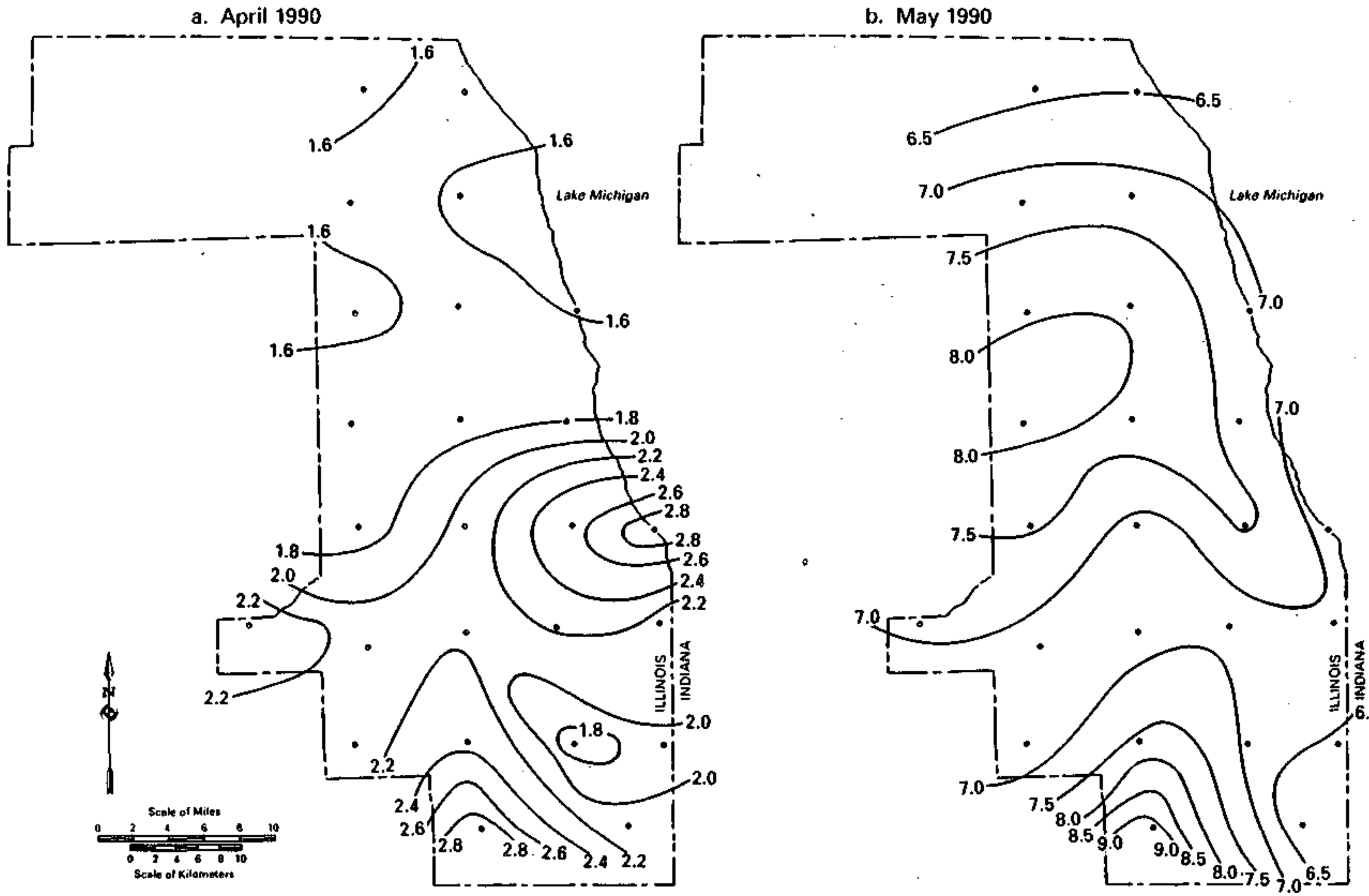

Figure 8. Precipitation patterns (inches) for April 1990 (Panel a) and May 1990 (Panel b). Dots indicate network sites.

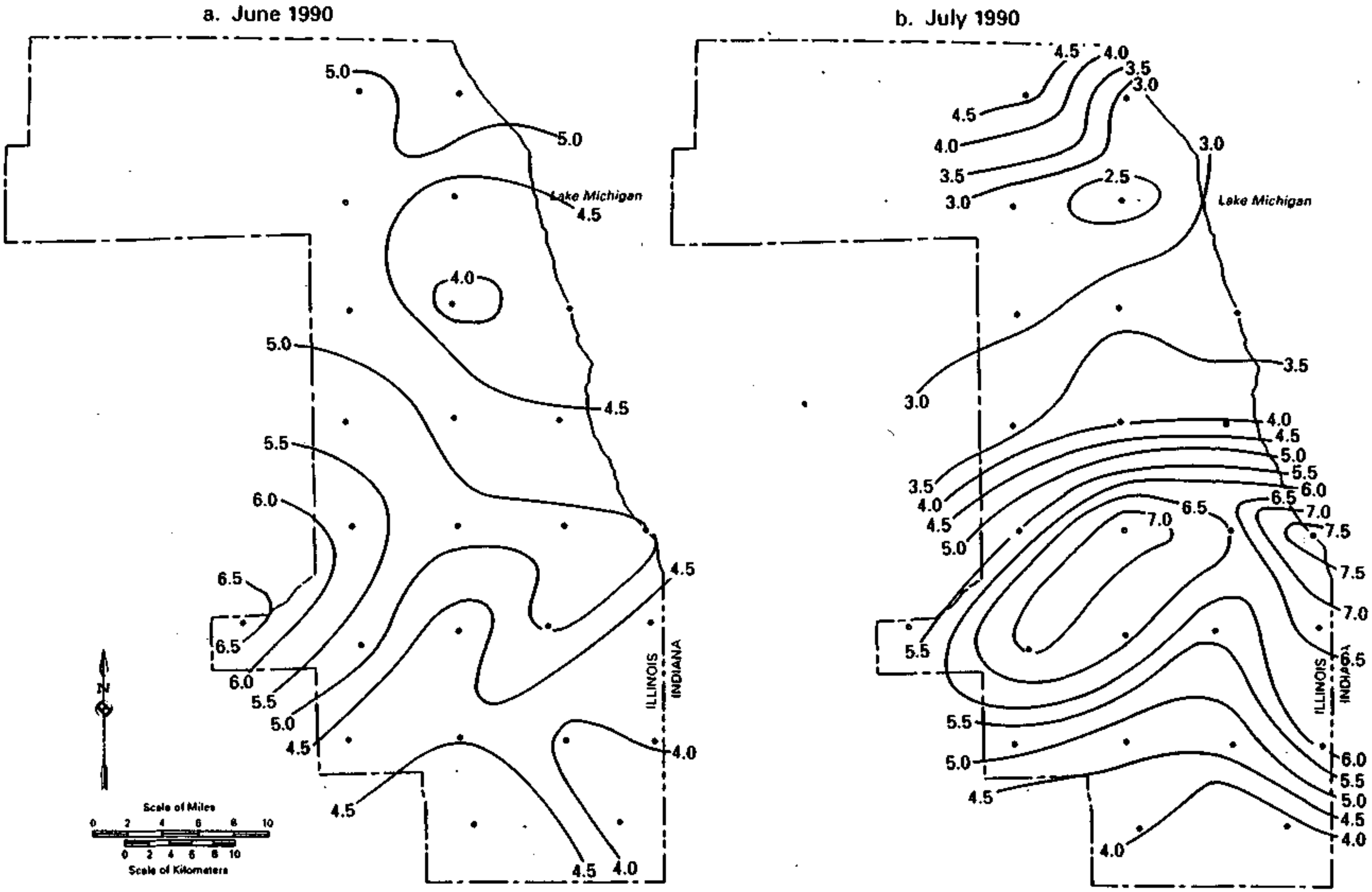

Figure 9. Precipitation patterns (inches) for June 1990 (Panel a) and July 1990 (Panel b). Dots indicate network sites.

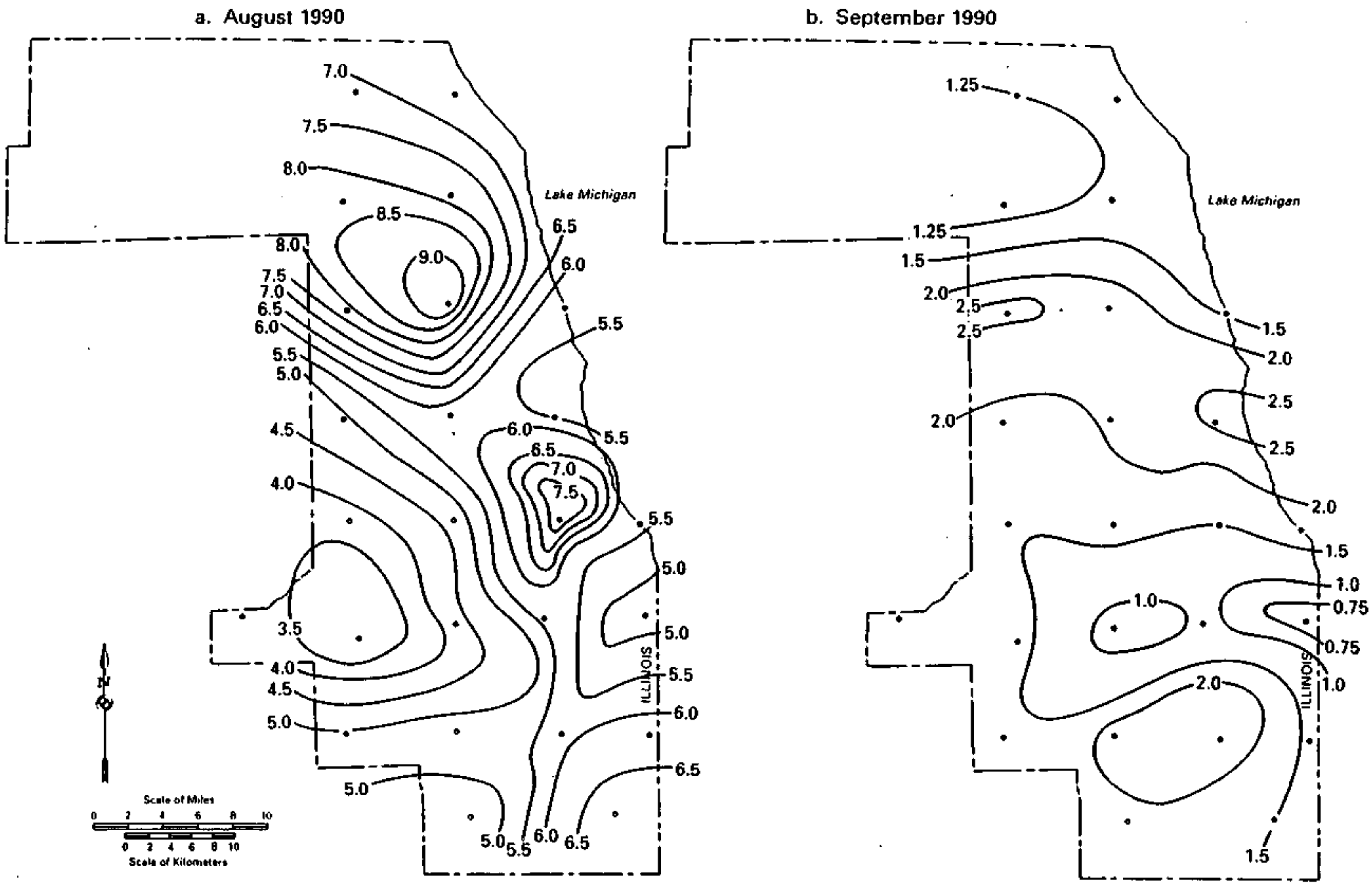

Figure 10. Precipitation patterns (inches) for August 1990 (Panel a) and September 1990 (Panel b). Dots indicate network sites.

to the previously mentioned water year high of 9.35 inches at Site #6 to the north. This month displayed a very cellular pattern of precipitation. In both July and August, most of the rainfall occurred in a few well-defined storm systems: Storm 84 in July and Storms 89, 90, 91, 92, and 94 in August. Some produced serious localized flooding. Storm 84 on July 19-20 was particularly prominent; over 4 inches fell on Sites #12-14, #17, and #19 in the south central and southeast portions of the region. The storm high for the water year, 5.72 inches, occurred at Site #14. Finally, September (Figure 10) included two sites (#17 and #19) that had monthly amounts of less than one inch (0.96 and 0.66 inches, respectively). Appendix IV gives storm totals for all events greater than an annual event (one-year recurrence interval), considering storm periods of one hour to ten days.

The results of the spatial correlation analysis for the Water Year 1990 period are shown in Figures 12-14. Table 4 gives the magnitudes of the entire matrix of correlations. Figure 11 gives the alignment of the network for the maps produced by this analysis. Linear correlation coefficients range in value from -1.00 to +1.00 and assess the degree of linear relationship between the hourly precipitation values at one site with those of each of the other 24 sites. In general, the maps indicate that each site has a high degree of correlation with one to four of its surrounding neighbors, with correlations dropping rather rapidly with distance away from a site. The two sites most alike in this sense were Sites #16 and #17, with a linear correlation of 0.8766 (Figures 13 and 14), while the site least related to any others in the network was Site #1, which had only a correlation of 0.5418 with Site #2 (Figure 12). As can be seen from the figures, most of the patterns are oval-shaped around the site in question, with a west-east rather than a north-south orientation. It is hypothesized that these orientations will vary by season (e.g., southwest-northeast during

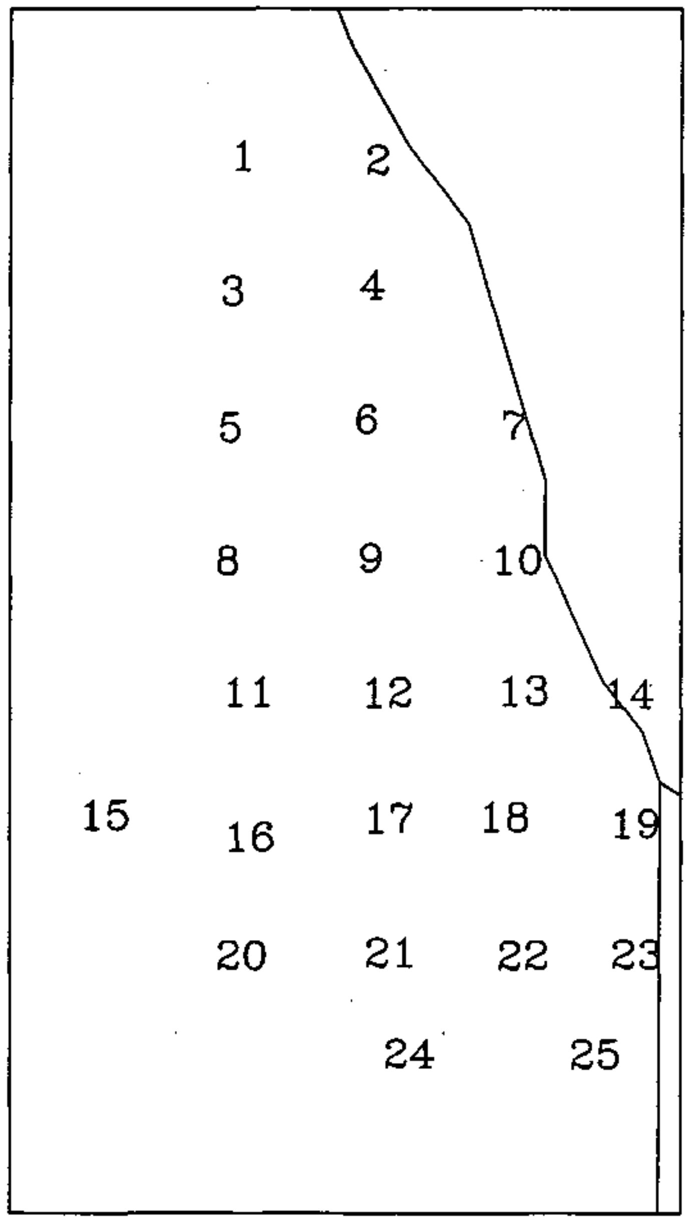

Figure 11. Computer-drawn configuration of current network layout, compatible with Figures 12-14 and Figure 16.

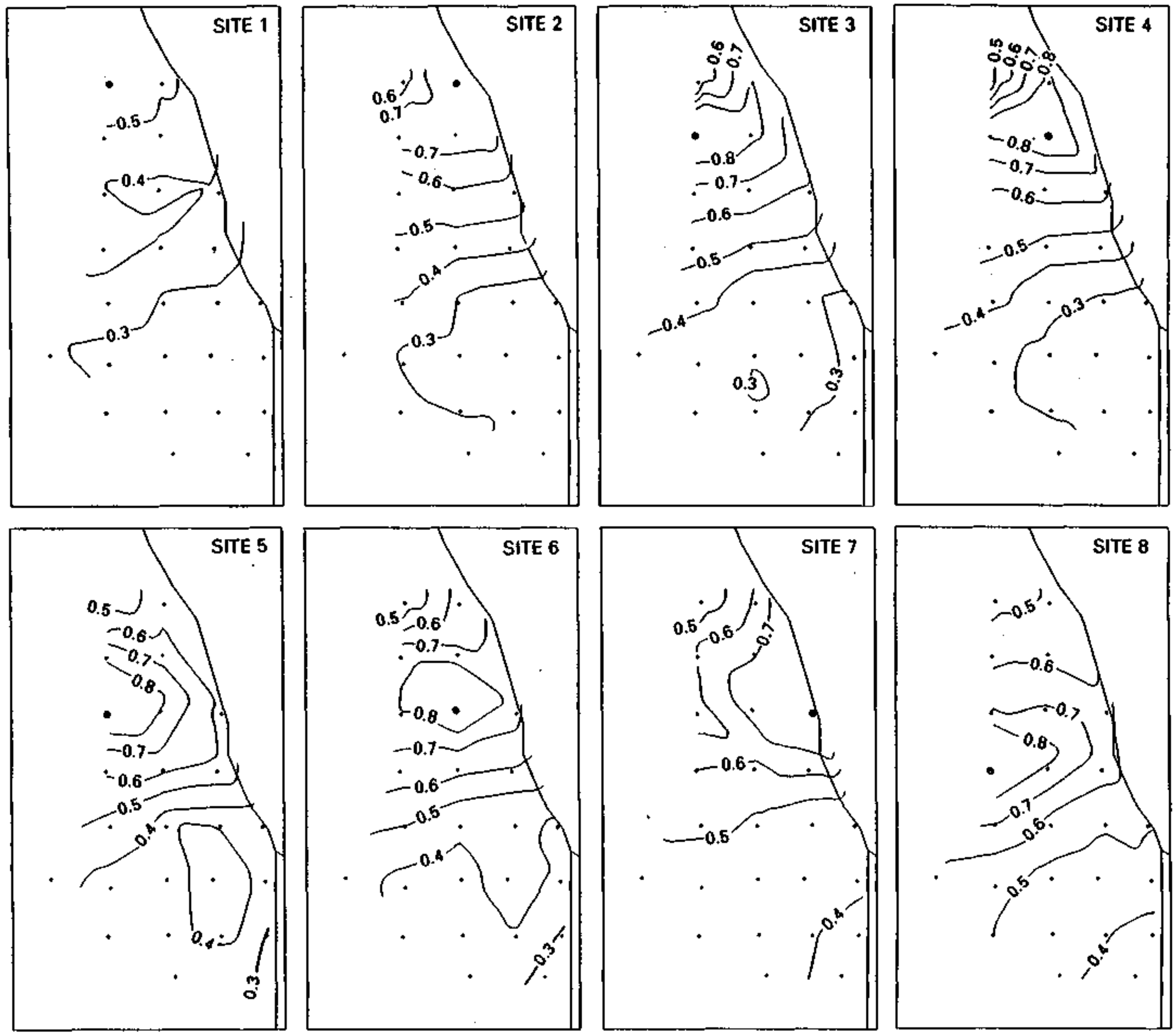

Figure 12. Correlation coefficient patterns for Sites #l-#8. Isopleths (no units) represent linear correlation magnitudes with the labeled site, which is indicated on the map by a large dot. Smaller dots indicate the other sites.

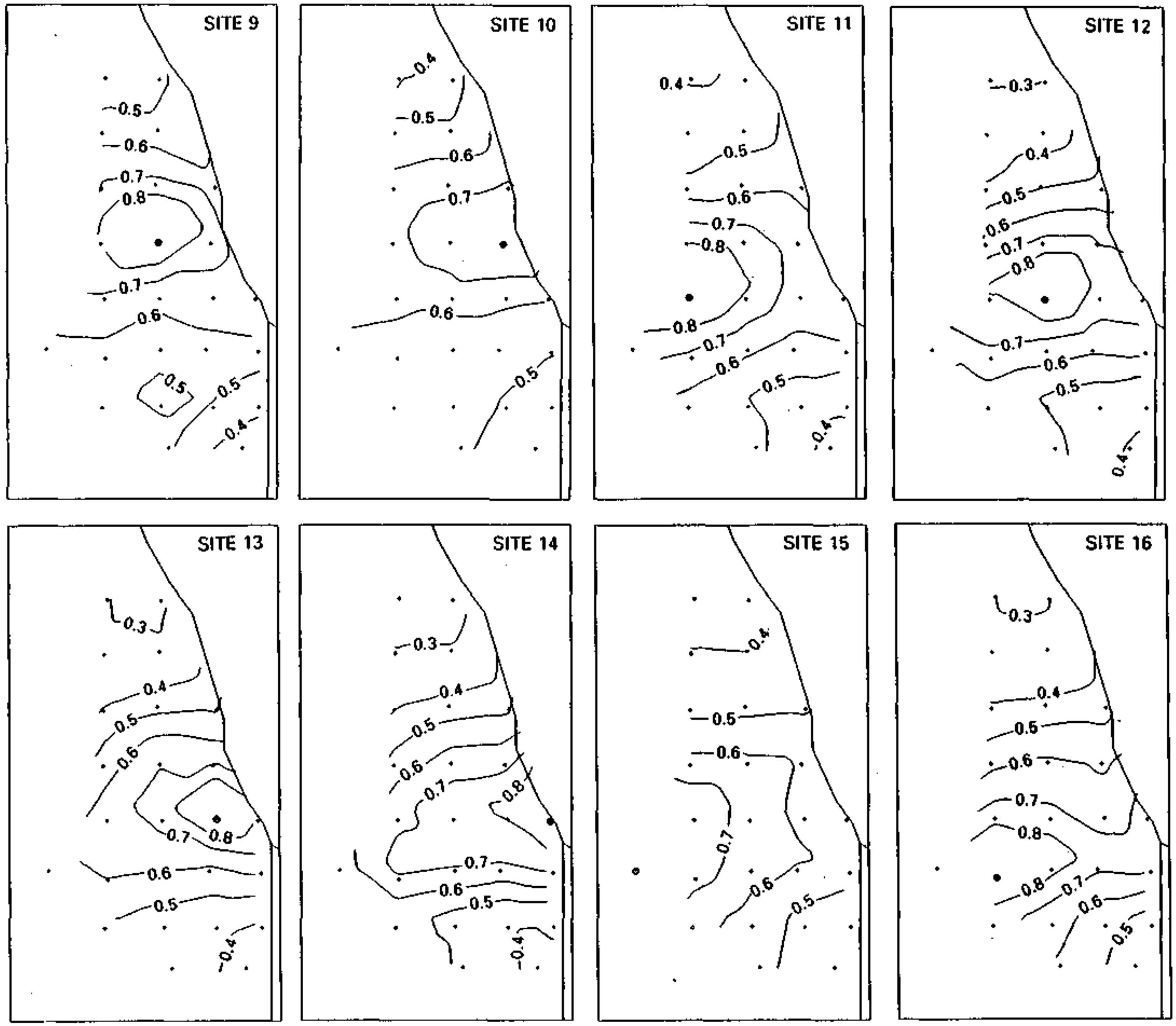

Figure 13. Correlation coefficient patterns for Sites #9-#16. Isopleths (no units) represent linear correlation magnitudes with the labeled site, which is indicated on the map by a large dot. Smaller dots indicate the other sites.

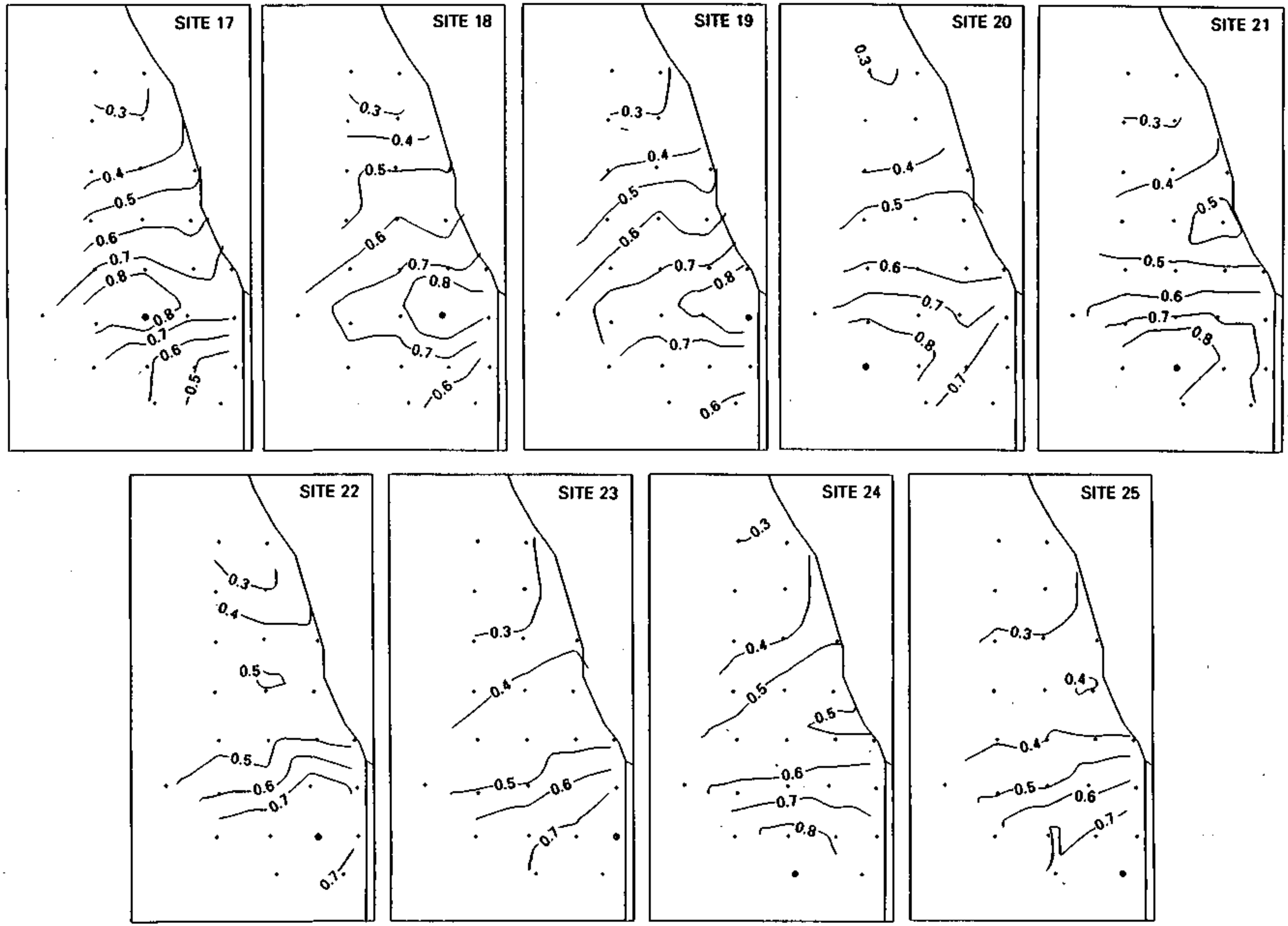

Figure 14. Correlation coefficient patterns for Sites #17-#25. Isopleths (no units) represent linear correlation magnitudes with the labeled site, which is indicated on the map by a large dot. Smaller dots indicate the other sites.

Table 4. Matrix of Correlation Coefficients for the Entire 25-site Network from Actual Data.

	Gaga 1	Gage 2	Gage 3	Gage 4	Gage 5	Gage 6	Gage 7	Gage S	Gage 9	Gage 10	Gage 11	Gage 12	Gage 13	Gage 14	Gage 15
Gage 1	1.0000	0.5418	0.4951	0.4559	0.3931	0.3960	0.4005	0.4563	0.4034	0.3685	0.3712	0.2990	0.2941	0.2370	0.3109
Gage 2	0.5418	1.0000	0.7985	0.7941	0.5623	0.6316	0.5948	0.5001	0.4805	0.4568	0.4171	0.3001	0.2787	0.2515	0.3643
Gage 3	0.4951	0.7985	1.0000	0.8586	0.7120	0.7104	0.6080	0.5569	0.5326	0.5067	0.4507	0.3317	0.3041	0.2908	0.3947
Gage 4	0.4559	0.7941	0.8586	1.0000	0.6151	0.6786	0.6634	0.5462	0.5079	0.4923	0.4461	0.3199	0.3020	0.2872	0.3888
Gage 5	0.3931	0.5623	0.7120	0.6151	1.0000	0.8260	0.5827	0.6489	0.6806	0.6133	0.4981	0.3840	0.3730	0.3652	0.4360
Gage 6	0.3960	0.6316	0.7104	0.6786	0.8260	1.0000	0.7722	0.6794	0.6752	0.6374	0.5295	0.4461	0.4133	0.3970	0.4348
Gage 7	0.4005	0.5948	0.6080	0.6634	0.5827	0.7722	1.0000	0.6123	0.6070	0.6676	0.5548	0.4972	0.4488	0.4375	0.4581
Gage 8	0.4563	0.5001	0.5569	0.5462	0.6489	0.6794	0.6123	1.0000	0.8356	0.6756	0.7402	0.5984	0.5260	0.5056	0.5953
Gage 9	0.4034	0.4805	0.5326	0.5079	0.6806	0.6752	0.6070	0.8356	1.0000	0.7785	0.7183	0.6700	0.6711	0.6122	0.5960
Gage 10	0.3685	0.4568	0.5067	0.4923	0.6133	0.6374	0.6676	0.6756	0.7785	1.0000	0.6448	0.6758	0.6406	0.6288	0.5928
Gage 11	0.3712	0.4171	0.4507	0.4461	0.4981	0.5295	0.5548	0.7402	0.7183	0.6448	1.0000	0.8162	0.6466	0.6730	0.7772
Gage 12	0.2990	0.3001	0.3317	0.3199	0.3840	0.4461	0.4972	0.5984	0.6700	0.6758	0.8162	1.0000	0.7668	0.7760	0.6601
Gage 13	0.2941	0.2787	0.3041	0.3020	0.3730	0.4133	0.4488	0.5260	0.6711	0.6406	0.6466	0.7668	1.0000	0.8260	0.5647
Gage 14	0.2370	0.2515	0.2908	0.2872	0.3652	0.3970	0.4375	0.5056	0.6122	0.6288	0.6730	0.7760	0.8260	1.0000	0.5889
Gage 15	0.3109	0.3643	0.3947	0.3888	0.4360	0.4348	0.4581	0.5953	0.5960	0.5928	0.7772	0.6601	0.5647	0.5889	1.0000
Gage 16	0.2778	0.2893	0.3244	0.3130	0.3792	0.3835	0.4237	0.5339	0.5836	0.5651	0.7172	0.7042	0.6305	0.7377	0.7600
Gage 17	0.2649	0.2821	0.3027	0.2888	0.3289	0.3581	0.4349	0.4877	0.5369	0.5439	0.6529	0.7004	0.6349	0.7385	0.6416
Gage 18	0.2648	0.2712	0.3133	0.2732	0.4768	0.4648	0.4779	0.4588	0.5878	0.5526	0.5925	0.6600	0.6260	0.7199	0.6136
Gage 19	0.2681	0.2716	0.2928	0.2849	0.3619	0.3851	0.4231	0.4871	0.5967	0.5250	0.6042	0.6700	0.6603	0.7733	0.5834
Gage 20	0.2797	0.3132	0.3421	0.3156	0.3605	0.3725	0.4415	0.5032	0.5249	0.5310	0.5837	0.5571	0.5068	0.5318	0.6403
Gage 21	0.2617	0.2753	0.2950	0.2781	0.3301	0.3352	0.4257	0.4356	0.4758	0.5319	0.4976	0.4890	0.4690	0.4781	0.5714
Gage 22	0.2757	0.2787	0.3146	0.2679	0.4926	0.4111	0.4155	0.4208	0.5108	0.4971	0.4552	0.4498	0.4284	0.4155	0.4697
Gage 23	0.2751	0.2858	0.2894	0.2617	0.2898	0.2897	0.3792	0.3765	0.4085	0.4296	0.4161	0.4094	0.4074	0.4174	0.4185
Gage 24	0.2911	0.3308	0.3398	0.3206	0.3269	0.3582	0.4883	0.4557	0.5160	0.5326	0.5151	0.5095	0.4813	0.4815	0.5384
Gage 25	0.2290	0.2354	0.2467	0.2301	0.3009	0.2826	0.3434	0.3322	0.3843	0.4057	0.3810	0.3923	0.3662	0.3678	0.4026

	Gage 16	Gage 17	Gage 18	Gage 19	Gage 20	Gage 21	Gage 22	Gage 23	Gage 24	Cage 25
Gage 1	0.2778	0.2649	0.2648	0.2681	0.2797	0.2617	0.2757	0.2751	0.2911	0.2290
Gage 2	0.2893	0.2821	0.2712	0.2716	0.3132	0.2753	0.2787	0.2858	0.3308	0.2354
Gage 3	0.3244	0.3027	0.3133	0.2928	0.3421	0.2950	0.3146	0.2894	0.3398	0.2467
Gage 4	0.3130	0.2888	0.2732	0.2849	0.3156	0.2781	0.2679	0.2617	0.3206	0.2301
Gage 5	0.3792	0.3289	0.4768	0.3619	0.3605	0.3301	0.4926	0.2898	0.3269	0.3009
Gage 6	0.3835	0.3581	0.4648	0.3851	0.3725	0.3352	0.4111	0.2897	0.3582	0.2826
Gage 7	0.4237	0.4349	0.4779	0.4231	0.4415	0.4257	0.4155	0.3792	0.4883	0.3434
Gage 8	0.5339	0.4877	0.4588	0.4871	0.5032	0.4356	0.4208	0.3765	0.4557	0.3322
Gage 9	0.5836	0.5369	0.5878	0.5967	0.5249	0.4758	0.5108	0.4085	0.5160	0.3843
Gage 10	0.5651	0.5439	0.5526	0.5250	0.5310	0.5319	0.4971	0.4296	0.5326	0.4057
Gage 11	0.7172	0.6529	0.5925	0.6042	0.5837	0.4976	0.4552	0.4161	0.5151	0.3810
Gage 12	0.7042	0.7004	0.6600	0.6700	0.5571	0.4890	0.4498	0.4094	0.5095	0.3923
Gage 13	0.6305	0.6349	0.6260	0.6603	0.5068	0.4690	0.4284	0.4074	0.4813	0.3662
Gage 14	0.7377	0.7385	0.7199	0.7733	0.5318	0.4781	0.4155	0.4174	0.4815	0.3678
Gage 15	0.7600	0.6416	0.6136	0.5834	0.6403	0.5714	0.4697	0.4185	0.5384	0.4026
Gage 16	1.0000	0.8766	0.7554	0.7629	0.7582	0.6528	0.5485	0.4718	0.5981	0.4471
Gage 17	0.8766	1.0000	0.7852	0.7719	0.7256	0.6171	0.5102	0.4586	0.5897	0.4221
Gage 18	0.7554	0.7852	1.0000	0.8513	0.6728	0.6518	0.7079	0.5768	0.6201	0.5372
Gage 19	0.7629	0.7719	0.8513	1.0000	0.7087	0.6613	0.6302	0.6285	0.6401	0.5937
Gage 20	0.7582	0.7256	0.6728	0.7087	1.0000	0.8457	0.7247	0.6213	0.7545	0.6022
Gage 21	0.6528	0.6171	0.6518	0.6613	0.8457	1.0000	0.7864	0.6844	0.8003	0.7046
Gage 22	0.5485	0.5102	0.7079	0.6302	0.7247	0.7864	1.0000	0.7069	0.7423	0.6832
Gage 23	0.4718	0.4586	0.5768	0.6285	0.6213	0.6844	0.7069	1.0000	0.7089	0.7775
Gage 24	0.5981	0.5897	0.6201	0.6401	0.7545	0.8003	0.7423	0.7089	1.0000	0.7025
Gage 25	0.4471	0.4221	0.5372	0.5937	0.6022	0.7046	0.6832	0.7775	0.7025	1.0000

spring and summer), reflecting the seasonal differences in the region's preferred storm tracks. A study of this phenomenon is needed. The west-east orientations for the water year shown here likely represent a combination of patterns. There is a general low relationship (correlations less than 0.40 or even 0.30) between far northern Sites #l-#7 and far southern Sites #15-#25 (see Figures 12-14 and Table 4). This demonstrates the great precipitation variability that can occur over relatively small areas given the physics controlling the scale of precipitation. Though water year amounts can be similar, the timing of the precipitation events (storms) affecting the far northern and southern regions was likely quite different. If seasonal patterns were constructed, time-lag relationships may be revealed that could give further insight into the region's precipitation variability.

Several questions arise.

- Is the 6-mile spacing used between raingages satisfactory, more than adequate, or inadequate?
- Is there a sufficient degree of autocorrelation in the individual sites' precipitation time-series to inflate the significance of the correlation values?
- Would these patterns be replicated by other water years or by "reshuffling" the current water year's data, or are they simply some random statistical artifact?

Each question will be addressed in turn and in context to results from two papers (Huff and Shipp, 1969; Huff, 1979) where spatial correlations were computed on raingage networks similar to the present one.

Concerning the adequacy of grid spacing of the network, it is suggested that if neighboring stations were very highly interrelated, the correlations between them would have been much closer to 1.0 (e.g., at least 0.95 or higher). However, no inter-site correlation exceeded 0.8766, corresponding to a shared variance of 76.84 percent (Sites #16 and #17). Only 9 of 300 possible site pairings produced correlation values at or above 0.80 corresponding to a shared variance of 64 percent (refer to Table 4 for all correlation values). Site #1, in the northwest corner of the domain, had as its highest inter-site correlation just 0.5418 with Site #2 (shared variance of only 29.35 percent), as previously mentioned. All other sites had at least one inter-site correlation of 0.70 or higher (approximately 50 percent of the shared variance). These numbers are not overwhelmingly high for a rather fine time resolution (hourly). All of this suggests that when considering an entire water year, the 6-mile grid spacing is probably inadequate or just barely adequate to properly capture the nature of the area's precipitation, and that it is inadequate in some of the network's fringe regions. If computed for a seasonal data breakdown, the correlations would most likely be lower during the summer months when convective-type precipitation systems, which are more highly variable in space and time, dominate, and higher during winter when larger-scale systems provide most of the area's precipitation, which tends to be more widespread and continuous. It is presumed that a tighter grid spacing, advocated by Huff (1970, 1979) for convective-type precipitation, would produce higher inter-site correlations, thereby allowing a more detailed examination of the precipitation that falls on Cook County.

Indeed, Huff and Shipp (1969) and Huff (1979) examined the spatial and temporal correlation patterns of precipitation over all of Illinois and for some specific raingage networks deployed. Correlations of annual precipitation between Chicago and 35 sites across Illinois for 1906-1955 displayed a southwest-northeast orientation, reflecting prevailing storm movement, with correlation maxima above 0.80 in the northeastern Illinois region.

Correlations were also computed between 49 raingages in the East Central Illinois Network (ECIN) operating from 1955-1967, which encompassed an area of 400 square miles. Raingages were spaced approximately 3 miles apart. Data were subdivided into the warm season (May-September) and the cool season (October-April), and precipitation events were further subdivided into basic synoptic weather categories such as low-center passages, frontal storms, and air-mass storms. For the center gage in this network, correlations between it and all other stations were well over 0.90 for low centers, with a large area of 0.98 and higher in the center of the domain. For frontal storms, a large area of 0.95 and greater correlations was observed, but values dropped to 0.75 at the boundaries of the network. For convective air-mass storms, a small area of 0.95 and higher correlations existed near the center raingage, but the correlations dropped to less than 0.60 in some parts of the network near its boundaries. When precipitation was subdivided into thunderstorms/rainshowers and steady rain, the patterns looked very much like those for fronts and low centers, respectively. Correlations were also generally less for decreasing storm duration (below 12 hours) and increasing storm duration (above 12 hours). Thus, the correlations from the ECIN, which had a tighter grid spacing than the Cook County network uses, are larger than those for the new network. It is suggested that by using a tighter spacing in the new network, correlations could also be expected to be higher, explaining more of the precipitation variance. Huff (1979) and Huff and Shipp (1969) also found that correlations were lower for convective precipitation than for more continuous and widespread types, and thus were lower during the warm season. This characteristic would also be expected for data from the new network if stratified like this.

Huff and Shipp (1969) and Huff (1979) were further able to determine raingage sampling requirements for a desired level of explained precipitation variance. It was found that warm-season precipitation requires a substantially greater density than cool-season precipitation. For all storms, 90 percent of the precipitation variance (correlation of 0.95) can be explained by a gage spacing of 2 miles during the warm season and only 6 miles during the cool season. Thus, in the new raingage network, some information is being lost during the warm season by using the 6-mile spacing, which theoretically explains about 78 percent of the precipitation variance (correlation of 0.88). But during the cool season this spacing is adequate to explain 90 percent of the variance (correlation of 0.95). The largest correlations found in the new network for the entire water year were nearer the warm-season level. For particular precipitation types, the recommended grid spacings vary. Air-mass storms require a one-mile grid spacing during both seasons to adequately capture this convective event; frontal storms require grid spacings of 2 and 4 miles during the warm and cool seasons, respectively; and low centers only require spacings of 10 and 8 miles, respectively. Therefore, it appears that it would also be highly instructive to subdivide the current data not only by season but also by storm type to more accurately determine how effective the new network is at capturing the Chicago region's precipitation.

Concerning the second question, autocorrelation within a time-series can artificially inflate the significance of correlation coefficients computed between time-series. By falsely assuming that the individual observations in the time-series are independent, a large correlation may have much less significance than was computed initially. In fact, the "effective" sample size (size of the sample's independent information) of the time-series may be much smaller than the actual number of data observations due to autocorrelation, rendering the result of a significance calculation much less impressive. This study uses 8,760 hourly data values for each of the 25 sites. Using this value in a one-sided t-test produced significance levels of less than 0.000001 for every unique pairing of sites (300 total). In other words, each correlation is at least 99.99999 percent significant. Because significance typically is compared to the 0.05 or 0.01 levels (95 or 99 percent significant), all of the correlations computed here on the actual data are extremely significant. The amount of autocorrelation in each time-series can be assessed and an effective sample size computed by comparing the autocorrelation functions computed from each of the 25 precipitation time-series to those functions computed from a series of pseudorandom standard normal variates. These autocorrelation functions were plotted (the only example shown is Site #4 in Figure 15). The degree of autocorrelation for each time-series was found by first noting the largest deviation on the standard normal autocorrelation function plot, from the level of "white-noise" or randomness associated with a sample size of 8,760 observations (one divided by the square root of 8,760, or 0.0107). This deviation was 0.0360. Each of the 25 autocorrelation function plots was then analyzed to find the first occurrence of the difference of the autocorrelation function with the white-noise level dropping below 0.0360. The lag there, minus one, denotes the length of the autocorrelation in the series, in hours. Lags of up to 48 hours were computed. Other subsequent large differences were also noted and will be discussed below.

All stations had autocorrelations within their hourly precipitation data ranging from 6 to 12 hours (Table 5). Thus, the effective sample size is about an order of magnitude less than the sample size of 8,760 (8,760 divided by the lag). In other words, the amount of independent information contained in each time-series is much less than the total number of observations would indicate. Within this range of autocorrelation, succeeding values are

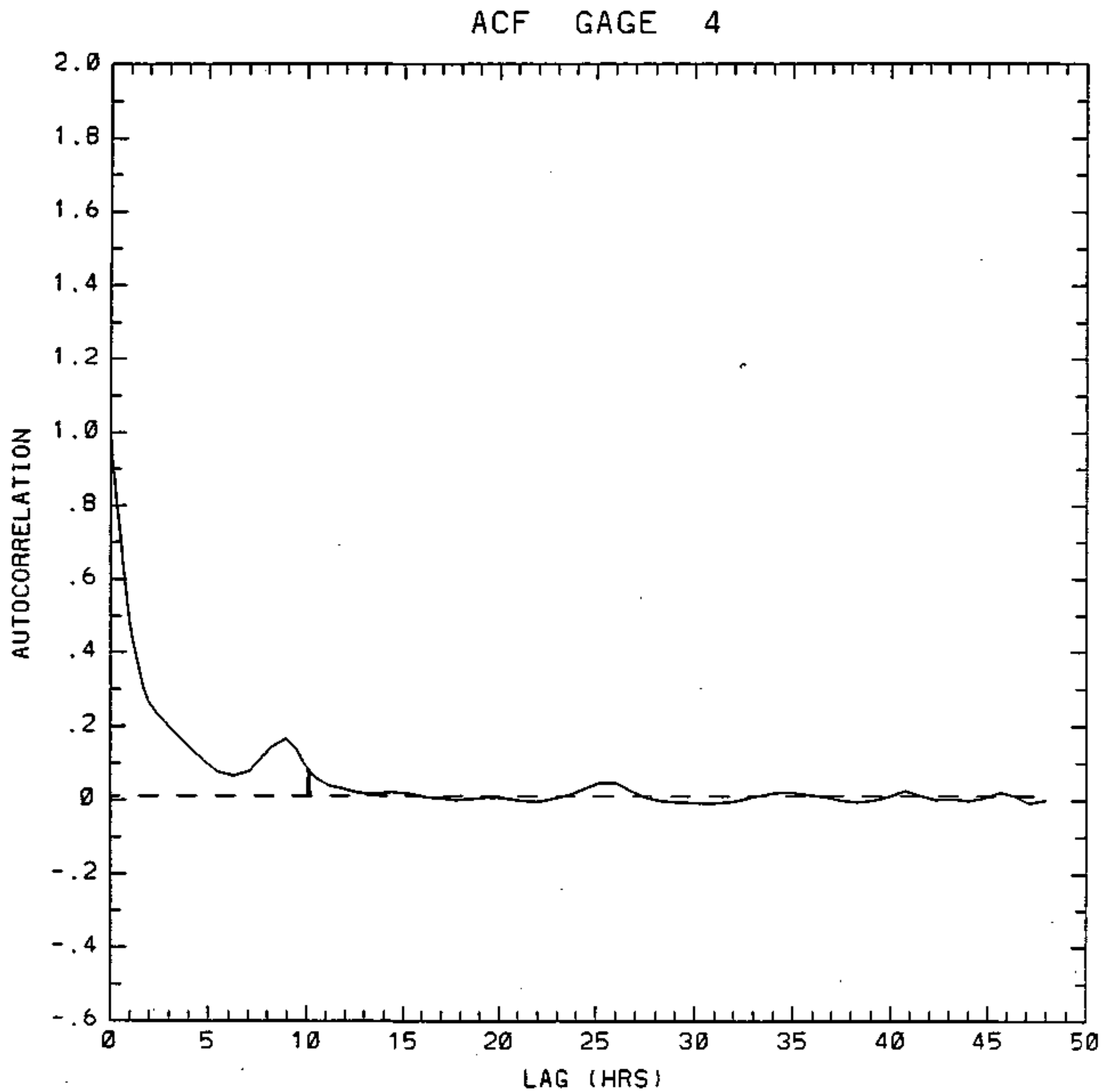

Figure 15. Autocorrelation function for Site #4 (solid curve). Dashed line represents the level of white noise associated with a sample size of 8,760 hourly data values. Vertical line between the autocorrelation function and white-noise line at lag 10 represents the last lag (hour) of autocorrelation greater than the maximum found from a similar function for pseudorandom standard normal variates.

Table 5. Autocorrelations Found within the Hourly Precipitation Time-series, in Hours.

Site Number	Autocorrelation Lag	Other Lags of Note
1	7	21-24/37-38
2	10	8/18/23-26
3	11	9/26/40
4	10	9/25
5	8	25/43
6	9	40
7	12	9
8	10	7-8
9	9	7/12
10	11	6
11	9	5
12	9	6-7
13	8	6-7
14	8	6-7
15	8	6/31
16	9	7/12/32
17	8	7/15
18	8	6-7
19	9	6-7
20	7	—
21	7	—
22	6	15/41
23	8	—
24	9	14
25	8	—

dependent on previous ones, which is meteorologically represented by the passing of a storm through the area. Significance values computed for the site-to-site correlations are thus inflated: the correlations themselves are likely less significant statistically than the traditional t-tests would indicate and may not be terribly physically significant. Paragraphs at the end of this section will discuss a bootstrapping method for determining the robustness of the correlation patterns shown in Figures 12-14, a technique that will attempt to replicate the patterns given by the actual data while trying to minimize the autocorrelation within the data.

The autocorrelations within the precipitation data tended to be longer (9-12 hours) in the northern half of the study region, roughly defined as Sites #11 and #12 northward. Sites to the south had autocorrelations generally in the range of 6 to 9 hours. A possible explanation is that storms passing through the northern half of the region either had longer durations or were slower moving than those traversing the southern part of the network, which may be the result of a lake effect.

Additional interesting features were indicated in many of the autocorrelation plots (Table 5). At nearly all of the sites north of those bounded by Sites #20-#25, a relatively high autocorrelation "peak" occurred within the autocorrelation lag period, usually centered on hours 5 to 9. These peaks seemed to be more pronounced at sites closer to Lake Michigan, Sites #2, #4 (see Figure 15), #7, #13, #14, and #19, and could be indicative of some type of interaction between passing storms and the lake, perhaps the collision of storm flows with lake flows that were present. It should be noted that water year totals at some of the sites nearer the lake were lower than those at more inland locations (Figure 4), particularly in the northern part of the network. The early-peak phenomenon also occurred to some extent at Sites #9, #12, #16, #17, and #18 in the south central part of the network. Less pronounced peaks in autocorrelation magnitude also occurred around hours 12-15 at a few scattered sites (Table 5), and also at hours 21-26, 31-32, and 37-43. The peaks during hours 21-26, which generally occurred at the northernmost sites (#l-#5), are likely indicative of some diurnal cycle, while those occurring at the other lags require further investigation to determine their causes (e.g., analysis of weather maps for the period).

To answer the final question, a technique called "bootstrapping" (e.g.,Wu, 1986) was used to determine the robustness of the inter-site correlation patterns if the data covering the 8,760 hours of the water year were statistically reshuffled. As mentioned before, this technique should help mitigate the presence of autocorrelation in the data while maintaining the integrity of the data observations over the network at any particular hour. If the same general patterns reappear after each reshuffling of the data, then the original pattern can be said to be fairly reliable, or robust.

Using a uniform random number generator over the range of integer values (1 to 8,760) a number was drawn from within that range 8,760 times, placing the drawn number back for consideration each time ("sampling with replacement"), creating a time-series of integer numbers. Using this series of integers, a reshuffling of the precipitation data over the water year could be determined. For example, if the integer 567 was drawn as the first uniform random number, all 25 precipitation values for hour 567 of the original data series were assigned to hour 1. If integer 2,306 was drawn second, the precipitation values for hour 2,306 in the original data series were assigned to hour 2, and so on, thus creating a new time-series of precipitation data over the network, with autocorrelation theoretically randomized. This process was carried out 10 times to produce 10 reordered data samples on which correlation coefficients were computed to see if the correlation patterns and magnitudes produced by the actual precipitation data set held up, or if they were simply some statistical artifact. If they did hold, this would provide evidence for the robustness of the patterns produced by the actual data, in spite of autocorrelation in the data. This analysis was performed for the entire water year but should also be performed for seasonal periods within the water year.

Ten sets of 25 correlation patterns each, similar to the set shown in Figures 12-14, were computed and drawn from the bootstrapped data samples. General results will be discussed, but only those patterns for Site #17 are shown as examples (Figure 16). Overall, the patterns held up very well for most of the sites, the exceptions being in the extreme northern portion of the network (Sites #l-#3), at two of the Lake Michigan proximity locations (Sites #7 and #10), and some sites in the extreme southern part of the network (Sites #20 and #22). In a correlation magnitude sense, the highest inter-site correlations for each site in the bootstrapped samples fell within some range around the highest values found from the actual data, with more values slightly below the actual ones, indicative of a slight inflating effect in the actual data by autocorrelation. Thus, the effect of the bootstrapping, which attempted to randomize the autocorrelation • of the time-series, was to not significantly dilute the correlations in the actual data, so it appears that most of the correlation patterns and magnitudes in the actual data are "real". The sites that had the most resilient correlation structures are generally in the central part of the network, including Site #17 (Figure 16). Site #1 seems to have had the poorest correlation structure of any raingage location. The correlation patterns within close proximity of a site were generally elongated from west-to-east, rather than north-to-south, as in the actual data.

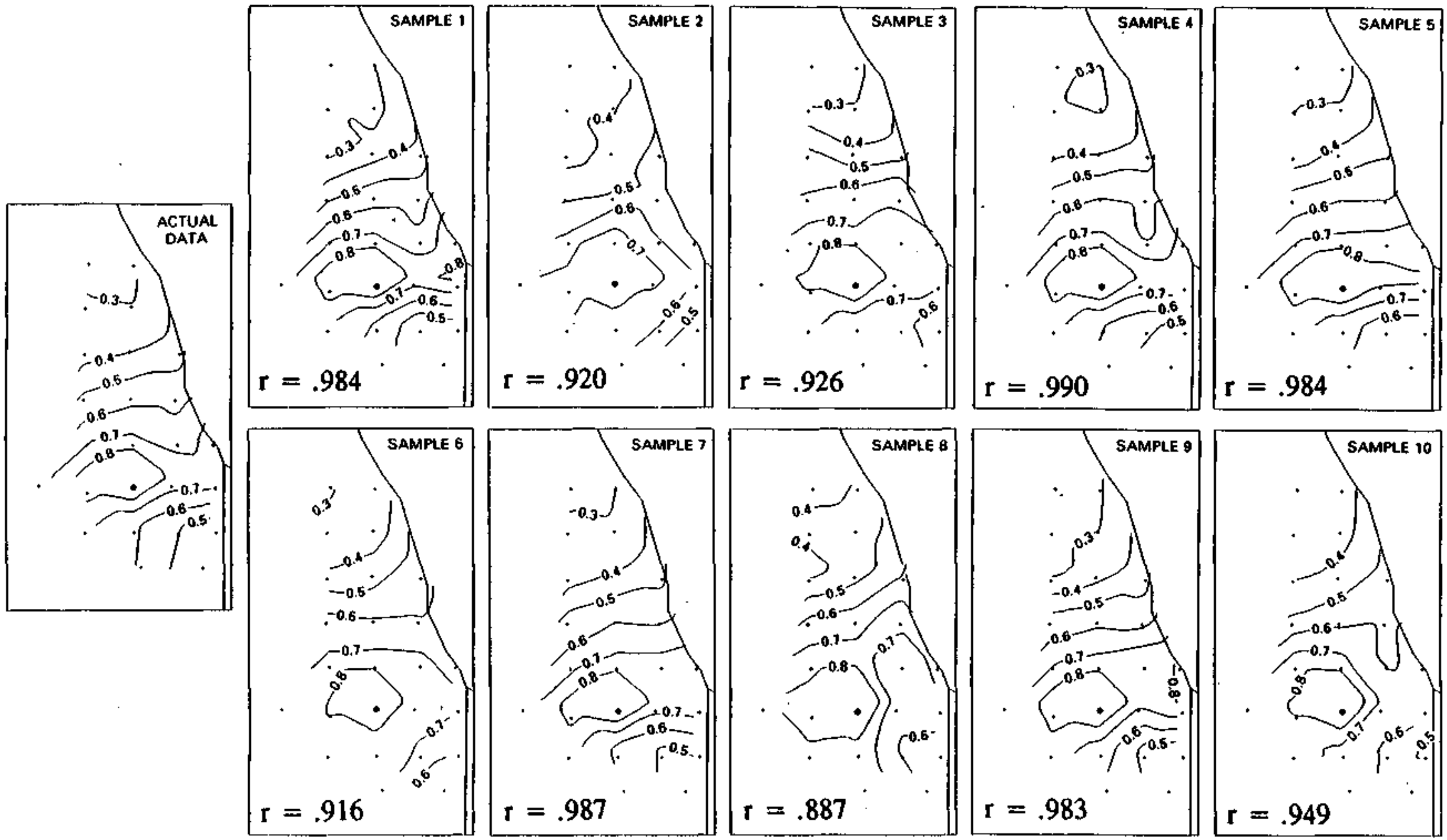

Figure 16. Correlation coefficient patterns for Site #17 from the original data (left panel) and from ten replication samples extracted from the original data. Isopleths (no units) represent linear correlation magnitudes with the labeled site, which is indicated on the map by a large dot. Smaller dots indicate the other sites. Numbers in lower left corners of the sample panels indicate the correlation of that pattern and the actual data.

Again, it would be highly instructive to repeat this exercise on a seasonal basis.

Looking specifically at Site #17 (Figure 16), which had the highest inter-site correlation with a neighboring raingage in the network (Site #16), the pattern given by the actual data is quite well duplicated by most of the ten bootstrapped data sets, particularly by samples 1, 4, 5, 7, and 9. The values given in the lower left corner of each of the ten replication map panels are the correlations of the respective sample map with the map from the actual data. As can be seen, samples 1, 4, 5, 7, and 9 all replicated the actual pattern with correlations of 0.983 or higher. Sample 8 gave the least duplication, with a correlation of "only" 0.887. The duplication in the patterns decreased slightly with distance away from Site #17, as was expected, since most of the correlations dropped fairly rapidly with distance away from a site throughout this network. Samples 4 and 7 gave remarkably good pattern duplication (correlations of 0.990 and 0.987, respectively).

Thus, the results of the statistical analyses performed revealed that the correlation patterns and magnitudes found were fairly robust despite the presence of autocorrelation in the data. The 6-mile grid spacing between raingages is probably the largest one able to resolve the detail in the precipitation of the region. The correlation patterns produced give some sense, on a water-year basis, of how storm patterns are aligned over the network, so that a finer time resolution analysis, for seasons or even months, would likely yield further important information about the precipitation affecting the Cook County region.

6. EVALUATION OF THE NETWQRK TO DATE

Some individual station comparisons were made between values at network sites and available totals from nearby NWS and CC raingages to evaluate the effectiveness of the network's purported better catchment ability. Unfortunately, most of the improvement shown by the network would have been revealed in comparisons with data from MWRDGC sites, which were not available. The NWS and CC sites analyzed include Midway 3 SW, Chicago O'Hare Airport, Chicago Botanical Gardens, Chicago University, Park Forest (NWS), Mayfair Pumping Station, Springfield Pumping Station, Jardine Water Purification Plant, South Water Purification Plant, and Roseland Pumping Station (CC). See Figure 1 for the locations of all of these sites except for Chicago Botanical Gardens in extreme northeastern Cook County and Jardine Water Purification Plant, which is very near the Erie Sanitary District Office (SDO). Plots of monthly precipitation totals were compared at each of these raingages and the nearest corresponding network site(s) for the water year for the NWS gages (Figure 17), and for the period October 1989 - April 1990 for the CC gages (Figure 18).

With the exception of a few noticeable differences, trends and amounts of NWS and network raingages agreed closely (Figure 17). Discrepancies of note occurred in February 1990 between Chicago O'Hare AP and Sites #3 and #5, in July-September 1990 between Midway 3 SW and Site #12, and during much of the period March-September 1990 between Chicago University and Sites #13 and #14 when Chicago O'Hare AP, Midway 3 SW, and Chicago University, respectively, had less precipitation. Other discrepancies occurred in February 1990 between Chicago Botanical Gardens and Site #2, and in May-

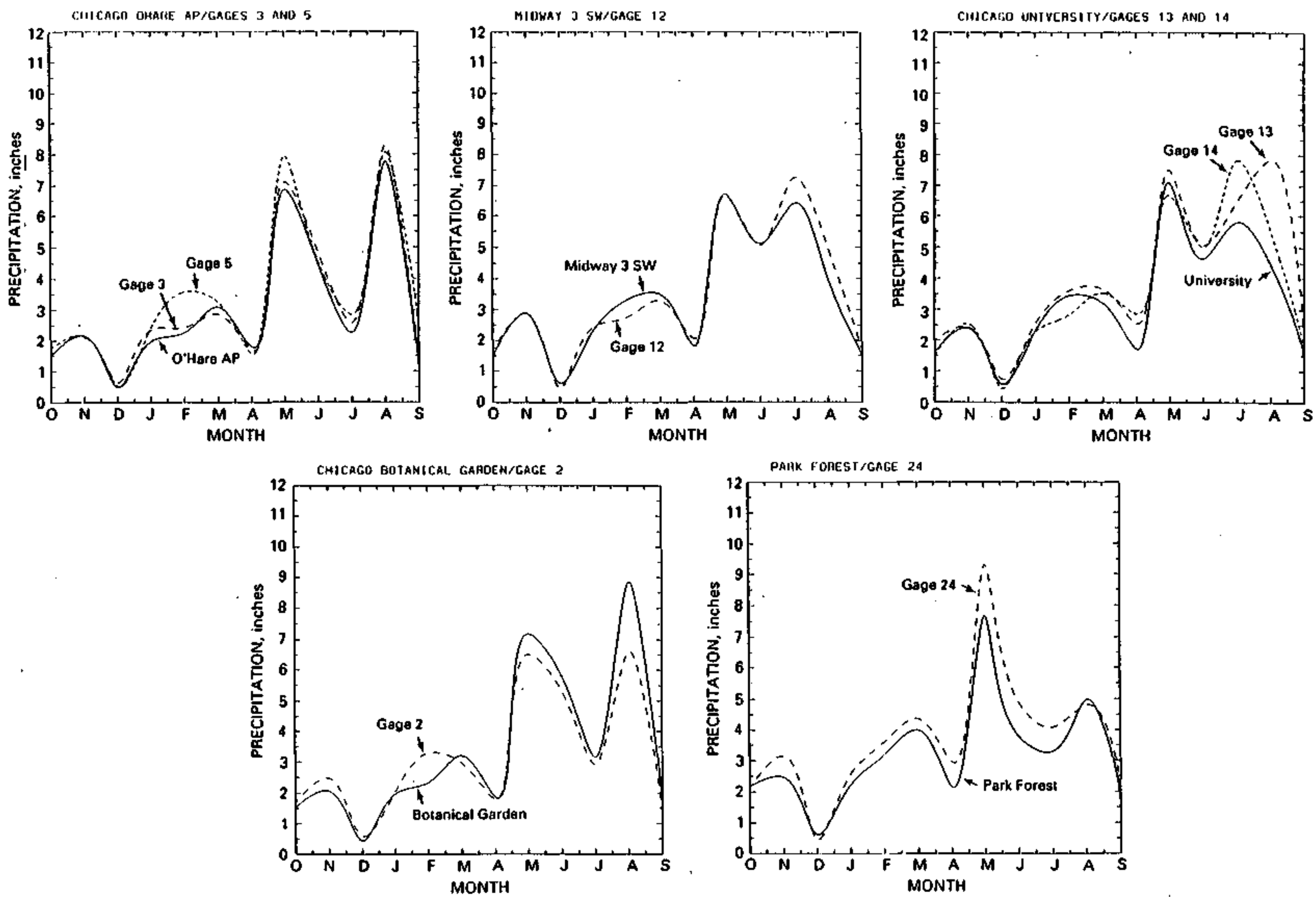

Figure 17. Comparisons of monthly precipitation amounts (inches) between network raingages and nearby NWS raingages, spanning the entire Water Year 1990 period.

September 1990 when the Botanical Gardens had less and more precipitation, respectively. Finally, the Park Forest NWS site consistently underestimated precipitation throughout the water year in comparison to Site #24. Overall, these comparisons reveal that differences were usually within the natural spatial variability associated with precipitation. In all cases, except for the Chicago Botanical Gardens (39.95 inches), the NWS sites captured less precipitation than did their nearby network counterparts over the water year (Table 3): Chicago O'Hare AP (35.59 inches); Midway 3 SW (39.60 inches); Chicago University (38.73 inches); and Park Forest (approximately 38.50 inches [March 1990 is missing]).

Comparisons between network raingages and their CC counterparts (Figure 18) for October 1989-April 1990 were much more variable, as expected. Although trends were generally similar between sites, amounts varied much more than they did for the NWS comparisons. Mayfair PS overestimated precipitation in comparison to network Sites #4 and #6 during October 1989-January 1990; Jardine WPP generally underestimated precipitation in comparison to Sites #7 and #10 throughout the entire October-April period; and Roseland PS greatly underestimated precipitation in comparison to Site #18 over the period. Amounts at Springfield PS tended to vary between amounts at Sites #6 and #7, while Site #14 and South WPP, which are located near each other, showed very good agreement. It had been noted in the adjustment work for other water years (e.g., Peppier, 1991) that some CC sites (and several MWRDGC ones) had consistently underestimated precipitation, due to both poor raingage exposure and to the use of tipping-bucket raingages, which inherently tend to underestimate precipitation. These months indicate that Roseland PS and Jardine WPP particularly underestimated precipitation.

Data records for the entire water year from the CC and previously unavailable

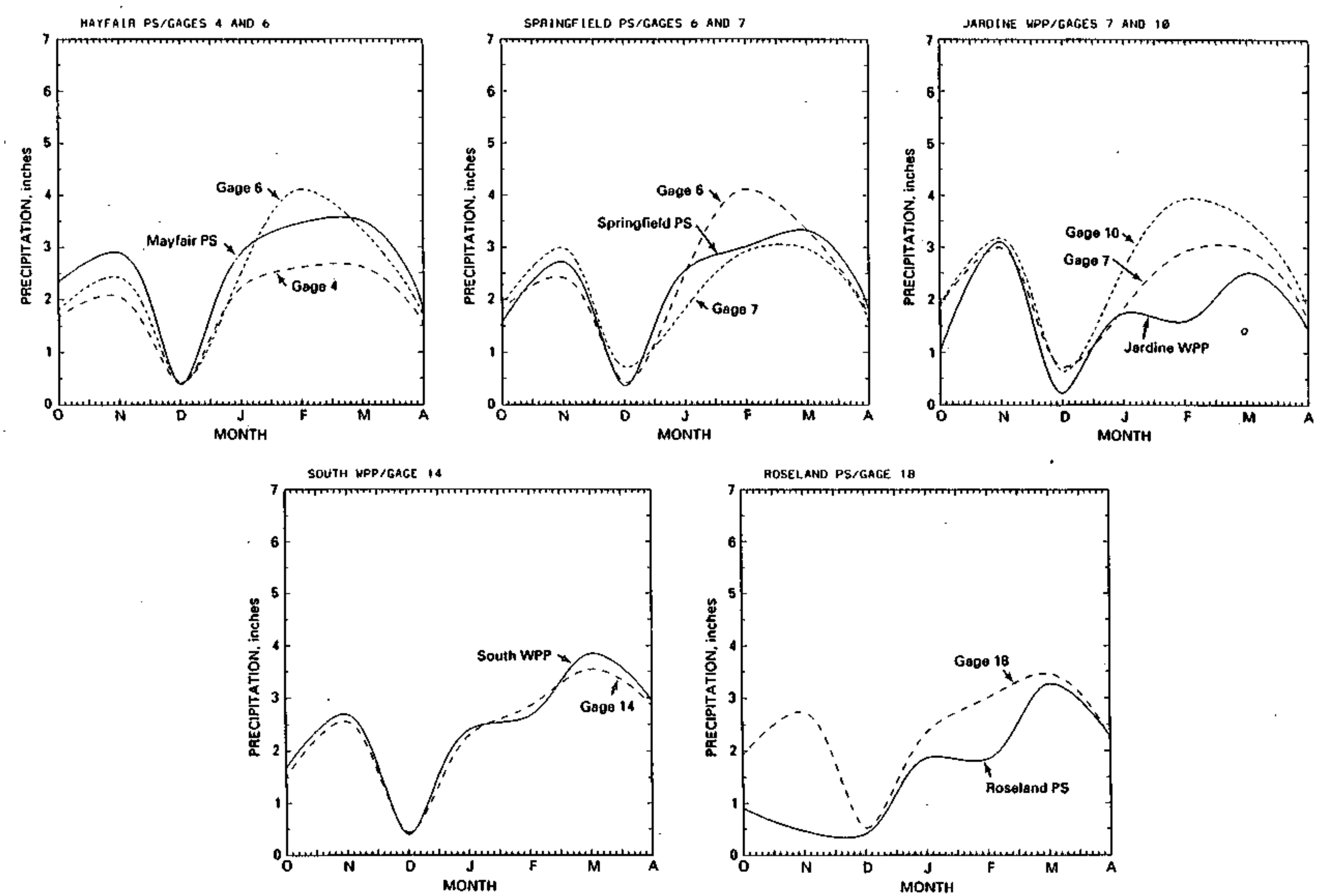

Figure 18. Comparisons of monthly precipitation amounts (inches) between network raingages and nearby CC raingages for the period October 1989-April 1990. Jardine WPP is located just east of Erie SDO (see Figure 1).

MWRDGC sites need to be compared to their network counterparts. When complete data sets are available, more quantitative comparisons should be made to further validate the network sites. This could also be carried out for more than one water year as more network data is collected.

One final comparison is made here between the unadjusted data from Water Years 1984, 1985, 1987, 1988, and 1989 (Figure 19) and network totals from Water Year 1990 (Figure 4). Excluding the low values at West Southwest Sewage Treatment Plant (a MWRDGC site in the center of the region - Figure 1) which had many missing observations during Water Years 1987-1989, the network pattern for 1990 does not show the unusual patterns found in the other water years from the NWS, CC, and MWRDGC gages that necessitated the adjustment of those data. In this sense alone, the new network is sampling the precipitation of the Cook County region much more consistently than the previously used gages did in the 1980s, and the data it provides are a great improvement over data collected prior to October 1989.

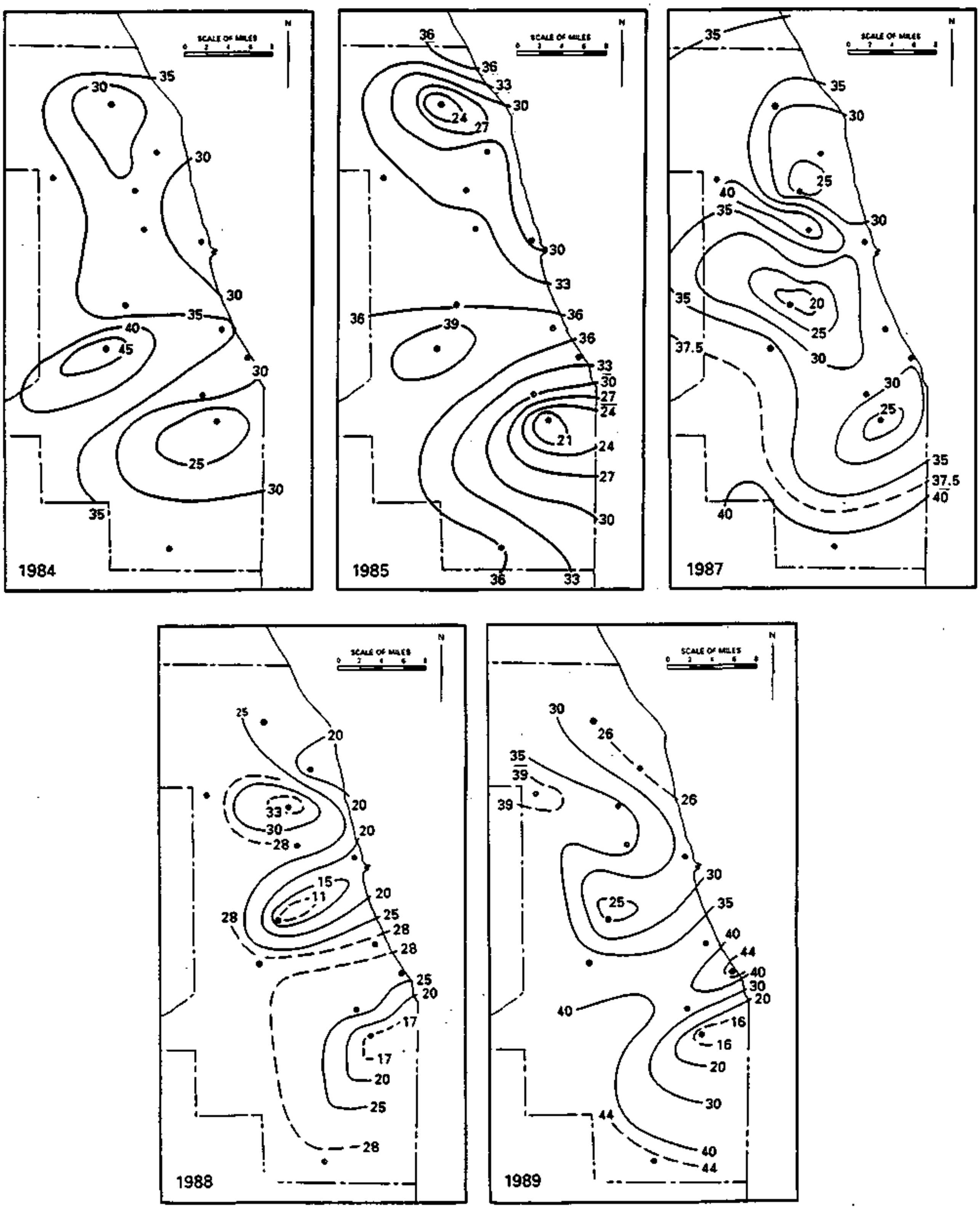

Figure 19. Raw precipitation patterns (inches) for Water Years 1984-1989 from NWS, CC, and MWRDGC raingages. Compare to Figure 4 for patterns from Water Year 1990 network raingages.

7. SUMMARY

After collecting, reducing, performing quality-control, and analyzing data collected from Water Year 1990, the new Cook County raingage network's first year of operation, the network appears to accurately capture the precipitation that falls on the region. Its exposure and areal coverage are superior to the previously used combination of NWS, CC, and MWRDGC raingages. This will greatly improve 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. It is strongly recommended that this network continue operation indefinitely to provide the best quality precipitation available for diversion accounting. And, as has been shown in Section 5, because of the relatively dense spacing of the raingages, the new network provides great potential for future research on precipitation in the Cook County region. The operation of the network itself has stabilized since October 1989; final hourly precipitation data are now available within a week or two after the end of a calendar month. The analysis of data from Water Year 1991, the second year of data collection, should provide more interesting comparisons and contrasts with data collected from Water Year 1990.

8. ACKNOWLEDGEMENTS

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 finally 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

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 description. Descriptions are current as of July 1991.

<table>
<tr><th colspan="3">SITE DESCRIPTION</th></tr>
<tr><td colspan="3">Site Number: 1</td></tr>
<tr><td>County: Cook</td><td>Township: 42N</td><td>Range: 12E</td></tr>
<tr><td>Section: 20</td><td>Lat/Long: 42°06'38"/
87°52'05"</td><td>Quadrangle: Park Ridge</td></tr>
<tr><td colspan="3">Property Owner: Mission Brook Sanitary District. Attn: John Tomaras</td></tr>
<tr><td colspan="3">Address: P.O. Box 2362. Northbrook. Illinois 60665</td></tr>
<tr><td colspan="3">Telephone: 708/272-2956</td></tr>
<tr><td colspan="3">Permission Date: September 14, 1989</td></tr>
<tr><td colspan="3">Installation Date: September 27, 1989</td></tr>
<tr><td>Gage Mfrs. No.: 7378</td><td>Gage ID No.: 6561</td><td>Clock Mfrs. No.: E 7345</td></tr>
<tr><td colspan="3">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.</td></tr>
</table>

<table>
<tr><th colspan="3">SITE DESCRIPTION</th></tr>
<tr><td colspan="3">Site Number: 2</td></tr>
<tr><td>County: Cook</td><td>Township: 42N</td><td>Range: 13E</td></tr>
<tr><td>Section: 19</td><td>Lat/Long: 42°06'28"/
87°45'05"</td><td>Quadrangle: Park Ridge</td></tr>
<tr><td colspan="3">Property Owner: Winnetka Park District, Attn: Richard Blust</td></tr>
<tr><td colspan="3">Address: 510 Green Bay Road. Winnetka, Illinois 60093</td></tr>
<tr><td colspan="3">Telephone: 708/446-2397</td></tr>
<tr><td colspan="3">Permission Date: September 14, 1989</td></tr>
<tr><td colspan="3">Installation Date: October 3, 1989</td></tr>
<tr><td>Gage Mfrs. No.: 7379</td><td>Gage ID No.: 6560</td><td>Clock Mfrs. No.: E 7420</td></tr>
<tr><td colspan="3">Placement: Anchored on concrete pavement of the maintenance storage vard. The yard closes at 1600 local time on workdays. Enter facility west off of Hibbard Street, north of Willow Road.</td></tr>
</table>

SITE DESCRIPTION		
Site Number: 3		
County: Cook	Township: 41N	Range: 12E
Section: 28	Lat/Long: 42°01'20"/ 87°52'38"	Quadrangle: Arlington Heights
Prooertv 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		
Gage Mfrs. No.: 4730	Gage ID No.: 5062	Clock Mfrs. No.: E 7419
Placement: Placed in northwest corner of the vard bv the fence. Enter Riverview west off of Des Plaines River Road.		

SITE DESCRIPTION		
Site Number: 4		
County: Cook	Township: 41N	Range: 13 E
Section: 21	Lat/Long: 42°01'35"/ 87°45'22"	Quadrangle: Park Ridge
Prooertv Owner: Village of Skokie, Attn: Eddy Nakai		
Address: 5127 Oakton Street. Skokie. Illinois 60077		
Telephone: 708/673-0500		
Permissipn Date: September 18, 1989		
Installation Date: September 27. 1989		
Gage Mfrs. No.: 4656	Gage ID No.: 5040	Clock Mfrs. No.: E 7392
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"	Quadrangle: 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		
Gage 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"	Quadrangle: River Forest
Prooerty 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 halfwav 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		
County: Cook	Township: 40N	Range: 14E
Section: 28	Lat/Long: 41°56'03"/ 87°38'02"	Quadrangle: Chicago Loop
Property Owner: Chicago Park District. Attn: Tom Creech		
Address: 425 McFetridge Drive. Chicago, Illinois 60605		
Telephone: 312-294-2282		
Permission Date: June 28. 1991		
Installation Date: June 28. 1991		
Gaee Mfrs. No.:	Gage ID No.: 148832	Clock Mfrs. No.: E 7375
Placement: Placed in secluded plavground adjacent to Diversev Driving Range, just north of Diversey Harbor. Park in lot between harbor and driving range, walk up service drive (north) to fenced-in playground (no gate). Gage in north comer of playground near driving range fence. Was located at Chicago Park District site at Belmont Inner Harbor (10-3-98 through 12-27-89) and then at the Lincoln Park Gun Club (12-27-89 through 6-28-91).		

SITE DESCRIPTION		
Site Number: 8		
County: Cook	Township: 39N	Range: 12E
Section: 29	Lat/Long: 41°50'41"/ 87°52'51"	Quadrangle: Hinsdale
Property Owner: Cook Countv Forest Preserve District. Attn: Frank Grippo		
Address: 10400 Windsor. 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 backvard between pool and grape hedge. Enter Windsor east from Belleview Drive, south from Cermak Road and into Forest Preserve residence facility. Just west of Salt Creek and paLrallel 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 Queen 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 7370
Placement: Located in southwest comer of school yard 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		
County: Cook	Township: 39N	Range: 14E
Section: 28	Lat/Long: 41°50'42"/ 87°38'27"	Quadrangle: 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 has key). In Chinatown area, block betveen 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
Property Owner: Boyle Midway		
Address: 5151 West 73rd Street. Bedford Park. Illinois 60638		
Telephone: 312/594-1100		
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 platf orm 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	Range: 14E
Section: 28	Lat/Long: 41°45'34"/ 87°38'07"	Quadrangle: Englewood
Property Owner: Private Residence		
Address: 7409 South Eggleston, 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 Eggleston south from 74th Street.		

SITE DESCRIPTION		
Site Number: 14		
County: Cook	Township: 38N	Range: 15E
Section: 29	Lat/Long: 41°45'27"/ 87°32'40"	Quadrangle: 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-covered roof) over sand filtration beds. Two distant buildings are east and west of the site. Enter facility east off of 79th Street from South Shore Drive.		

SITE DESCRIPTION		
Site Number: 15		
County: Cook	Township: 37N	Range: 11E
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"/ 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 ll, 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 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: Ingersbll 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	Gage 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"	Quadrangle: Lake Calumet
Property Owner: Graycor Industries		
Address: 12233 Avenue O, Chicago. Illinois 60603		
Telephone: 312/221-8400		
Permission Date: September 11, 1989		
Installation Date: September 26, 1989		
Gage Mfrs. No.: 5298	Gage ID No.: 5291	Clock Mfrs. No.: E 7274
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"	Quadrangle: Mokena
Property Owner: Private Residence		
Address: 10595 West 167th Street, Orland Park, Illinois 60462		
Telephone: 708/349-9388		
Permission Date: March 16. 1990		
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 rural property. Shop is east building of home/shop complex. Three dachshunds outside. 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: Harvev
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		
Gage 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 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: Harvev
Property 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"	Quadrangle: Calumet City
Property 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	Gaee 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	Range: 13E
Section: 16	Lat/Long: 41°31'16"/ 87°43'59"	Quadrangle: 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"	Quadrangle: 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 gear and the chart drive gear mesh.

4) Quickly, remove the collector from the top of the gage by rotating it clockwise to disengage the tongue-and-grove 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 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

This appendix gives complete documentation of all maintenance work carried out at each of the sites in the raingage network since the inception of the network in October 1989, including visits when no action was taken. Organized chronologically by site number, this documentation is current through June 1991.

SITE #1: MISSION BROOK SANITARY DISTRICT

10-89: Straightened dented raingage case near sliding door. Cause of dent unknown.

7-23-90: Taped collector joint. Sprayed ants residing in gage with ant killer. Reset upper limit stop, since the downward traverse was too short.

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

SITE #2: WINNETKA PARK DISTRICT

10-89: Original siting destroyed by a truck backing over the gage. Replaced entire instrument except for chart drive. Bolted case bottom into concrete.

5-18-90: Readjusted the pen for zero.

6-13-90: Corrected binding in the meshing of the chart drive and drum gears to prevent chart-drive stoppages.

7-23-90: Rezeroed pen, and adjusted level of reversal.

9-19-90: Outer case found damaged upon arrival, as 3 of 5 case screw holes were stripped. Retightened everything for time being.

11-2-90: Replaced outer case.

5-29-91: Chart drive fine.

SITE #3: DES PLAINES

4-6-90: Turned pen arm toward drum slightly to remedy skipping problem.

5-18-90: Replaced chart drive and rezeroed pen.

7-3-90: Replaced pen arm and point. Raised clock to match time line and reversal. Releveled gage and tightened outer case screws. Shortened clip to prevent interference during drum rotation.

7-23-90: Releveled gage. Calibration fine.

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

SITE #4: VILLAGE OF SKOKIE

7-23-90: Reset upper and lower limit stops. Releveled gage.

8-23-90: Gage operating properly.

11-2-90: Releveled gage.

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

SITE #5: FRANKLIN PARK

7-3-90: Releveled gage and cleaned pen point.

7-23-90: Calibration fine.

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

SITE #6: WEST FLETCHER STREET

7-3-90: Reset chart drive height. Removed locking screw to prevent interference with lower limit stop. Releveled gage.

7-23-90: Exchanged drum to lower the chart level in relation to the pen traverse.

8-17-90: Pen tip had been getting caught under drum lip. Found to be fine.

9-19-90: Repositioned gage on walkway between house and new garage. Had been moved (unauthorized) by garage builder. New drum installed, pen arm adjusted, and pen rezeroed.

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

3-27-91: Releveled gage.

SITE #7: CHICAGO PARK DISTRICT

10-89: Straightened bent case (boat had rammed it) - Belmont Harbor site.

11-89: Water had entered dashpot during October 1989 accident, causing weighing mechanism to lock up when freezing occurred. Replaced dashpot - Belmont Harbor site.

12-27-89: Removed destroyed instrument from Belmont Harbor site, and relocated a new instrument at the Lincoln Park Gun Club. Gage needs underpinning timbers to provide stability.

1-11-90: Attached "t-base" of 2x4 lumber sections to base of gage. Stability greatly increased.

3-16-90: Evidence of water on chart drive. Replaced chart drive, dried interior of gage.

5-18-90: Adjusted and lubricated pen arm.

5-24-90: Checked site, but gained access by ladder since Gun Club door lock was broken.

7-24-90: Lubricated drum shaft. Relieved locking screw and locking nut.

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

SITE #8: COOK COUNTY FOREST PRESERVE DISTRICT - WESTCHESTER

5-18-90: Replaced chart drive and rezeroed pen.

7-3-90: Replaced chart drive upon finding the old one dead. Chart drive height fine. Releveled gage after bending collector tab.

7-23-90: Releveled gage. Calibration fine.

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

5-29-91: Replaced chart drive.

SITE #9: MARY QUEEN OF HEAVEN PARISH - CICERO

12-27-89: De-iced and dried dashpot. Replaced it and filled pot with Mobil 90 oil - 24th Street site. The bucket had disappeared and then reappeared, causing rain to reach the gage workings during its absence.

1-31-90: Replaced fine adjustment thumb screw - 24th Street site.

5-18-90: Replaced chart drive. Gage moved to facilitate landscaping, to spot between garages with bucket over collector (out-of-service) - 24th Street site.

5-24-90: Moved site to Mary Queen of Heaven Parish schoolyard, about 2 blocks northeast of previous site.

7-23-90: Calibration fine.

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

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

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

SITE #10: WEST 26th STREET

7-24-90: Calibration fine. Releveled gage.

SITE #11: LAGRANGE

7-24-90: Calibration fine. Releveled gage.

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

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

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

SITE #12: BOYLE MIDWAY - BEDFORD PARK

7-24-90: Releveled gage. Trace about 0.10" short on reversal, but not changed.

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

SITE #13: SOUTH EGGLESTON AVENUE

7-3-90: Corrected chart drive height and rezeroed gage.

8-23-90: Moved gage at request of owner to new spot in backyard, approximately 7 feet northwest of old location. Reset pen arm up a little. Gage operation explained to landowner.

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

SITE #14: SOUTH WATER PURIFICATION PLANT

7-24-90: Pen point off slightly with respect to following time line on chart. Efforts to correct failed. Releveled gage.

11-2-90: Stakes refortified to prevent a 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.

SITE #15: MWRDGC - LEMONT

11-89: Straightened vandalized sliding door on outer case.

12-27-89: Replaced outer case with one having a better sliding door.

3-16-90: Replaced outer case again for same reason. Could be some tampering. Rerouted chart drive battery wires to prevent drum clip from getting caught on them. Instructed Jim Ivers in reading of device.

4-6-90: Replaced drum to prevent dragging of clip.

5-3-90: Replaced chart drive. Installed evaporation shield for observer.

7-23-90: Reversal about 0.10" high. Left as is. Time trace fine.

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

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

SITE #16: PALOS PARK

10-89: Spilled oil indicated a dashpot leak. Dashpot replaced and refilled with oil. Shorted out chart drive when reinstalling, so replaced it and batteries.

4-6-90: Replaced bucket and rezeroed. Old bucket was rubbing against case and causing pen vibrations.

7-24-90: Calibration fine. Releveled gage.

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 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.

SITE #17: SARDEE INDUSTRIES - ALSIP

5-24-90: Rezeroed pen.

6-13-90: Cleaned pen nibs to prevent skipping and rezeroed pen.

7-24-90: Reversal and both stops a little high, but not changed. Releveled gage.

3-27-91: Changed batteries.

SITE #18: INGERSOLL PRODUCTS - WEST 120th STREET

4-6-90: Rezeroed pen with pseudo-bucket weight since bucket filled with antifreeze.

7-24-90: Releveled gage with sledgehammer. Reversal and upper limit stop a bit high, but not changed.

8-17-90: Raingage stolen sometime on August 11 or 12 during factory break-in. New gage installed at previous site. Original stakes and nuts and bolts were left on site by thieves. The stolen chart drive was the main casualty. This location has an 8-foot high chain link and barbed wire fence around perimeter, along with a guarded security gate.

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

1-15-91: Replaced chart drive.

SITE #19: GRAYCOR INDUSTRIES - AVENUE O

4-6-90: Rezeroed pen with pseudo-bucket weight since bucket filled with antifreeze.

7-24-90: Calibration fine.

8-17-90: Skipping problem previously, but fine at this visit.

9-19-90: Tightened pen arm, tilted in towards drum, and cleaned pen tip nibs.

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

6-28-91: Straightened, drum clip.

SITE #20: ORLAND PARK

1-31-90: Replaced batteries and antifreeze - S. 104th Avenue site.

3-16-90: Moved gage from S. 104th Avenue site to present location on 167th Street in Orland Park, roughly 0.25 miles northwest.

7-24-90: Calibration fine. Releveled gage.

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.

SITE #21: TINLEY PARK

4-6-90: Cleaned pen point and well.

7-24-90: Lowered drum a bit. Upper limit stop a little high, but left as is. Releveled gage.

1-15-91: Replaced chart drive.

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

7-24-90: Calibration fine. Releveled gage.

9-19-90: Found drum not rotating, but chart drive operating. Observer had not correctly meshed the chart drive and drum gears. Business development going up next door, very near gage. Cleaned pen point.

11-2-90: Unauthorized move of gage made by building contractor in late October, and destroyed outer case while doing so. Moved gage about 100 feet southeast between the parking lot and the Reserve building. Replaced the 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.

SITE #23: CITY OF LANSING PUBLIC WORKS

4-6-90: Cleaned pen point.

5-3-90: Straightened pen arm and recleaned pen point. Installed evaporation shield for observer.

5-18-90: Changed pen point. Inking difficult.

7-24-90: Calibration fine. Releveled gage.

9-19-90: Replaced pen point (had been skipping). Rezeroed pen.

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

SITE #24: VILLAGE OF MATTESON

1-31-90: Replaced chart drive. Later found batteries to be reversed by observer in dead drive.

4-6-90: Straightened pen point and cleaned nibs.

5-18-90: Rezeroed pen.

7-24-90: Calibration fine. Releveled gage. Sprayed ants with killer.

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

6-28-91: Changed chart drive.

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

6-13-90: Releveled gage, and rezeroed pen with a dry bucket. Cleaned pen nibs.

7-24-90: Calibration fine. Releveled.

9-19-90: Checked out fine (chart drive had been intermittent).

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.

APPENDIX IV

Included here are storm totals for all events greater than an annual event (one-year recurrence interval) during Water Year 1990. Storm durations of one hour to ten days were considered. The rainfall amounts for a one-year recurrence interval and these 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 table below exceed the numbers above for the given storm duration. An "E" indicates a partial or full estimate for that particular site and storm. The last column indicates whether a particular storm total 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
8	24	11-14/15-89	38	2.67	
55	1	5-9/10-90	21	2.58	
	2		21	3.10 E	2-year
	3		22	3.30 E	2-year
	4		22	3.56	2-year
	5		21	3.66	5-year
	6		22	3.96	5-year
	7		20	2.94	2-year
	8		22	3.88	5-year
	9		22	3.45 E	2-year
	10		21	2.95	2-year
	11		22	3.27	2-year
	12		21	2.46	
	13		19	3.05	2-year
	14		21	2.45	
	15		21	3.08	2-year
	17		20	2.40 E	
	18		19	2.76	
	21		19	2.77	
	22		19	2.34	
	24		20	3.35	2-year
84	11	7-19/20-90	18	3.26	2-year
	12		19	4.44	10-year
	13		17	4.41	10-year
	14		21	5.72	25-year
	15		23	2.81	
	16		29	3.85	2-year
	17		28	4.13	5-year
	18		18	3.58	5-year
	19		24	4.06	5-year
90	5	8-10-90	4	2.05	
	6		3	1.80 E	
	13		5	2.77	2-year
	18		2	1.89 E	2-year
	22		1	1.25	

Storm Totals (Concluded)

Storm #	Site #	Date	Duration (hours)	Amount (inches)	Other Events Exceeded
92	1	8-17/18-90	24	3.41	2-year
	2		23	3.21	2-year
	3		22	2.79	
	4		16	3.50	5-year
	6		24	2.83	
	25		23	2.84	
94	6	8-19/21-90	44	2.79	