Contract Report 637

Watershed Monitoring for the Lake Decatur Watershed 1997 - 1998

by
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Prepared for the
City of Decatur

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Illinois State Water Survey
Watershed Science Section
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

Watershed Monitoring for the Lake Decatur Watershed, 1997-1998

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Introduction

Lake Decatur is the water supply reservoir for the City of Decatur. The reservoir was created in 1922 by constructing a dam to impound the flow of the Sangamon River. The original dam had a crest elevation of 28 feet above the river bottom and a length of one-third of a mile. The dam created a lake with a volume of 20,000 acre-feet and an area of 4.4 square miles. The dam was later modified in 1956 to increase the maximum capacity of the lake to 28,000 acre-feet. Water withdrawal from the lake has been averaging 37 million gallons per day (mgd). It is projected that demand will increase in the near future.

The drainage area of the Sangamon River upstream of Decatur is 925 square miles. The watershed includes portions of seven counties in east-central Illinois as shown in figure 1. The predominant land use in the watershed is row crop agriculture comprising nearly 90 percent of the land area. The major urban areas within the watershed are Decatur, Monticello, and Gibson City.

Lake Decatur has been experiencing water quality problems for some time. The lake has high concentrations of total dissolved solids and nitrates, and nitrate concentrations have been relatively high in recent years. This has created a serious situation for the drinking water supply of the City of Decatur. Nitrate-N concentrations in Lake Decatur have exceeded the Illinois Environmental Protection Agency (IEPA) drinking water standard of 10 milligrams per liter (mg/l) for the period between 1979 and 1998, except from 1993 to 1995.

On June 10, 1992, a Letter of Commitment (LOC) was signed between the EPA and the City of Decatur. The LOC requires the city to take several steps to reduce nitrate levels in Lake Decatur to acceptable concentrations within nine years of signing the LOC. Nitrate-N cannot be removed from finished drinking water through regular water purification processes. One of the steps required the city to conduct a two-year monitoring study of the Lake Decatur watershed to better understand nitrate yields in the watershed. The Illinois State Water Survey (ISWS) received a grant from the City of

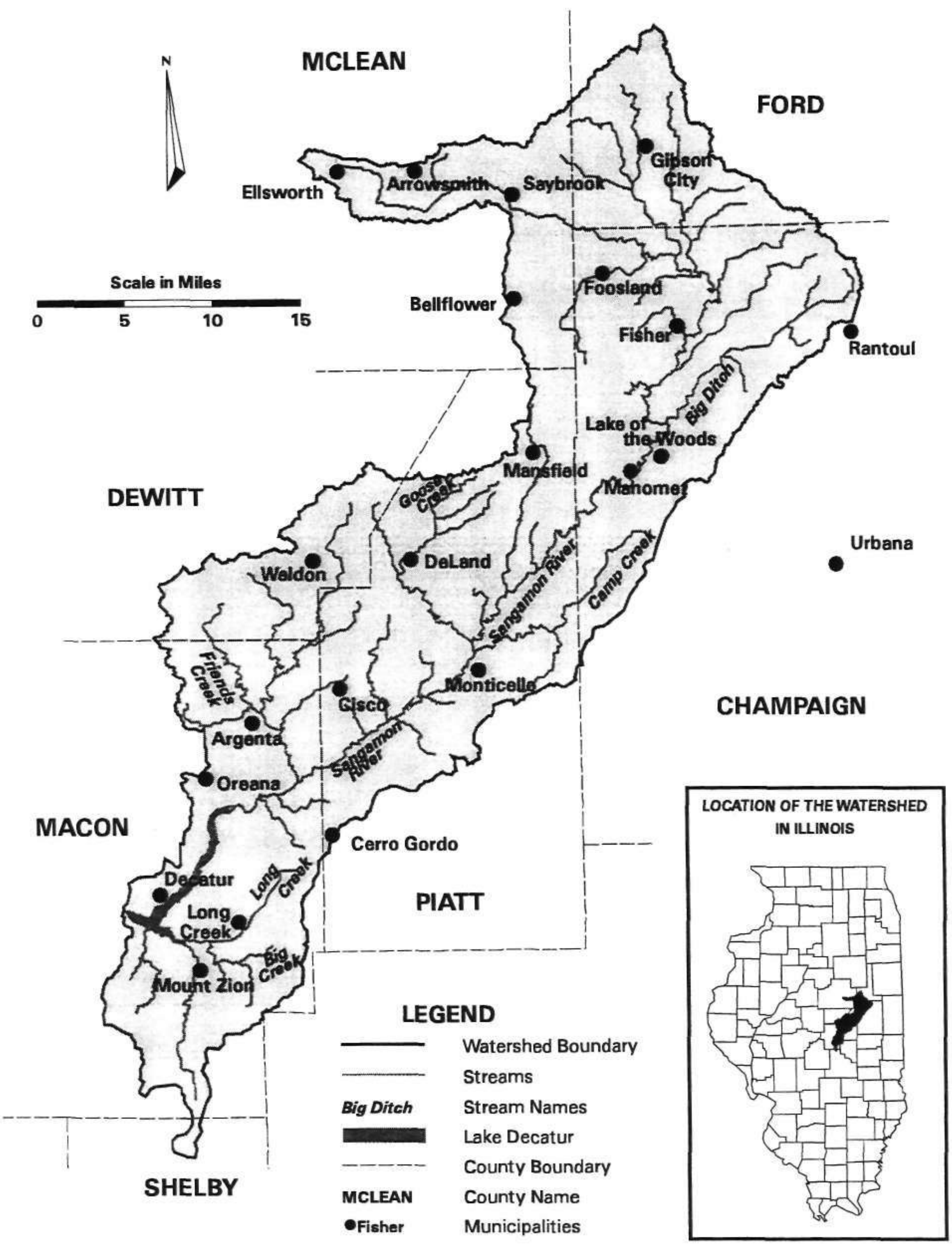

Figure 1. The Lake Decatur watershed

Decatur, conducted the two-year monitoring study, and developed land use management strategies that could eventually help the city comply with the IEPA drinking water standards. Demissie et al. (1996) present the results of that two-year study. Keefer et al. (1997) present the results of the third and fourth years of monitoring.

This technical report presents the annual data for all five years of monitoring (May 1993-April 1998) and monthly data for the fifth year of monitoring (May 1997-April 1998). The report is organized into three sections: Introduction, Background, and Hydrologic and Nitrate Monitoring. The introduction and background sections are condensed versions of the corresponding sections in Demissie et al. (1996). The section on hydrologic and water quality monitoring discusses the monitoring results of the five years of data collection.

Acknowledgments

This work was supported by the City of Decatur. Keith Alexander, Lake Manager, served as project manager, and his cooperation and assistance are greatly appreciated. Several other city officials and staff have also been very cooperative and supportive: Terry M. Howley, Mayor; James Williams, Jr., City Manager; Bruce A. McNabb, Public Works Director; and John Smith, Water Production Manager. The views expressed in this report are those of the authors and do not necessarily reflect the views of the sponsor or the Illinois State Water Survey.

The authors wish to acknowledge the significant contributions performed by the following project staff toward the completion of this report. Susan Shaw has been the field technician since the beginning of the project in 1993 and was responsible for the field data collection. Sandy Jones and Susan Shaw were responsible for the processing and presentation of the data used in this report.

We gratefully acknowledge the nitrate analyses performed by the following chemists at the Illinois State Water Survey in Champaign: Loretta M. Skowron, Lauren F. Sievers, and Daniel L. Webb. Assistance in fieldwork, data entry, and/or analysis were provided by Ben Bromiel, engineering undergraduate student at the University of Illinois at Champaign-Urbana, and Robert Gardner, undergraduate student at Parkland College. Becky Howard prepared the camera-ready version of the report, which was edited by Eva Kingston. Linda Hascall provided expert advice on illustration layout.

Background

Water Quality Problems in Lake Decatur

Lake Decatur has experienced water quality problems over the years. Past studies by the U.S. Environmental Protection Agency (USEPA) and the Dlinois Environmental Protection Agency (IEPA) have documented water quality problems in the lake (USEPA, 1975; IEPA, 1978). Most of the problems are associated with nonpoint source pollution generated in the watershed of the Upper Sangamon River. The lake generally has high levels of total dissolved solids and nitrates. Currently, the most pressing water quality problem in Lake Decatur is a high concentration of nitrates.

The nitrate yields that eventually reach Lake Decatur are found in the watershed of the Upper Sangamon River that feeds into Lake Decatur. To characterize and quantify the spatial and temporal distribution of nitrate yield in the Upper Sangamon, the City of Decatur has continued to support further watershed monitoring through a grant to the Illinois State Water Survey (ISWS). The purpose of the monitoring is to collect reliable hydrologic and water quality data throughout the watershed for use by planners and resource managers to develop watershed management alternatives based on scientific data.

Physical Characteristics of the Lake Decatur Watershed

The Lake Decatur watershed lies in a climate region classified as humid continental, which is typical for central Illinois and is located in the Till Plains section of the Central Lowland physiographic province. The Till Plains section is generally characterized by broad till plains, which are mostly in a youthful erosion stage. The Upper Sangamon watershed is located on the Bloomington Ridged Plain, a subdivision of the Till Plains section, and is characterized by low broad morainic ridges with intervening wide stretches of relatively flat or gently undulating ground moraine. Demissie et al. (1996) provide more detailed presentation of the watershed physical characteristics.

Hydrologic and Water Quality Monitoring

A watershed monitoring network was established to provide streamflow and water quality data for the Sangamon River and its tributaries upstream of Lake Decatur for the purpose of monitoring nitrate yields throughout the watershed. The network is comprised of eight stations (see figure 2) at which water stage is continuously recorded. These stages are then converted to water discharges using rating curves developed by measuring discharge periodically. Water samples are collected and analyzed for nitrate-nitrogen (referred to as nitrate-N or nitrate for the remainder of this report) on a weekly basis. Table 1 presents the names of the streams, locations of the monitoring stations, and drainage areas.

Hydrologic Monitoring

Continuous hydrologic monitoring at each station facilitates the calculation of continuous streamflow for the entire study period. This is essential for establishing the nitrate contribution to Lake Decatur from the Sangamon River and its tributaries.

Precipitation

Precipitation data for selected locations around the watershed have been retrieved from the Midwestern Climate Center database, which is operated by the ISWS. Figure 2 shows the locations of the six stations selected from within and around the Lake Decatur watershed: Gibson City, Rantoul, Urbana, Clinton, Monticello, and Decatur. Figure 3 presents the monthly precipitation in inches at all six stations for May 1997-April 1998. Figure 4 presents the annual precipitation for the 5-year study period and the 30-year long-term means. It should be noted that the stations appear on the figure as they are located in the watershed from north to south (Gibson City is the station closest to the north end of the watershed, and Decatur is the farthest south).

Table 1. Streamflow and Stage Monitoring Stations in the Lake Decatur Watershed

Station number	*Location*	*Drainage area (sq mi)*
101	Long/Big Creek at Twin Bridge Road	46.2
102	Friends Creek at Rte. 48 near Argenta	111.9
103	Goose Creek near DeLand	45.1
104	Camp Creek near White Heath	47.2
105	Sangamon River at Shively Bridge near Mahomet	368.2
106	Big Ditch near Fisher	38.2
111	Sangamon River at Monticello	543.4
112	Sangamon River at Fisher	245.6

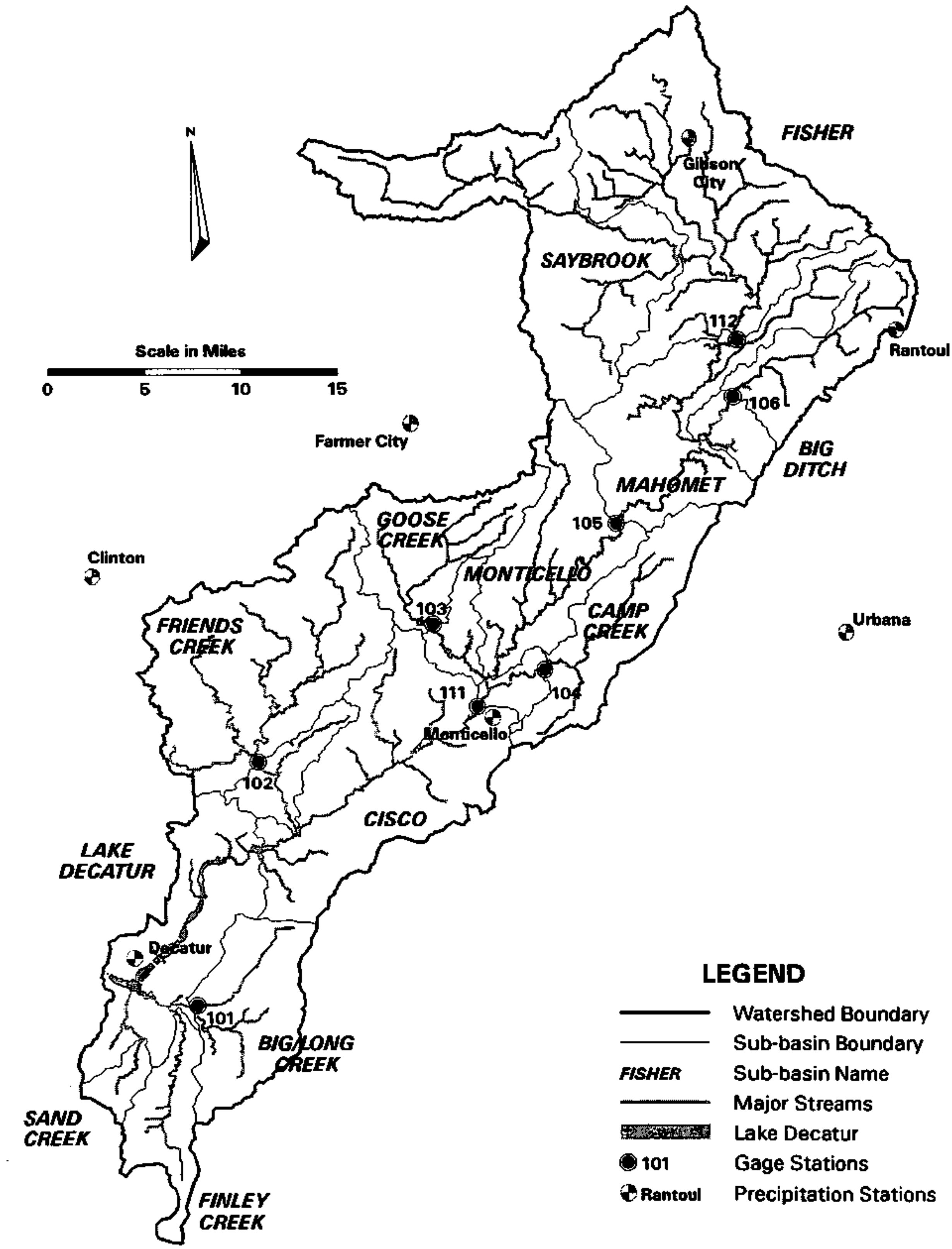

Figure 2. Stream and rain monitoring stations in the Lake Decatur watershed

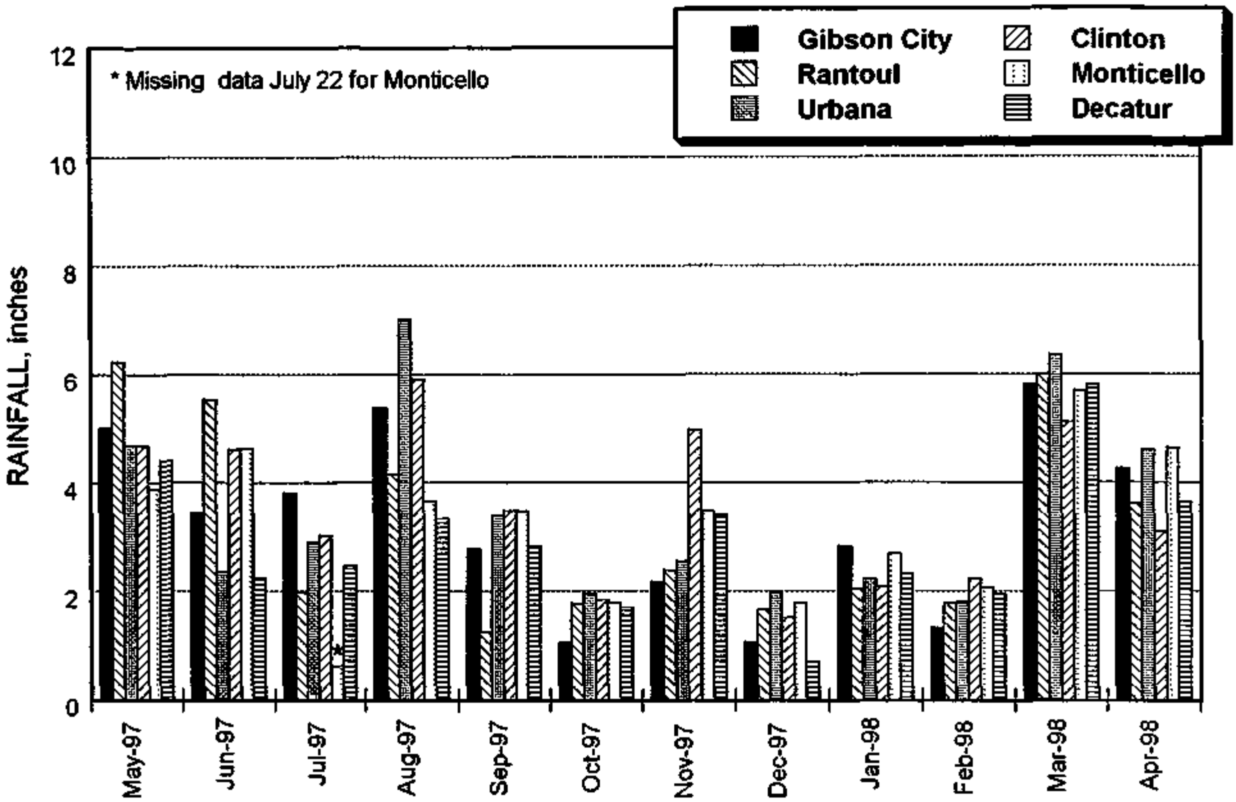

Figure 3. Monthly precipitation, May 1997 - April 1998

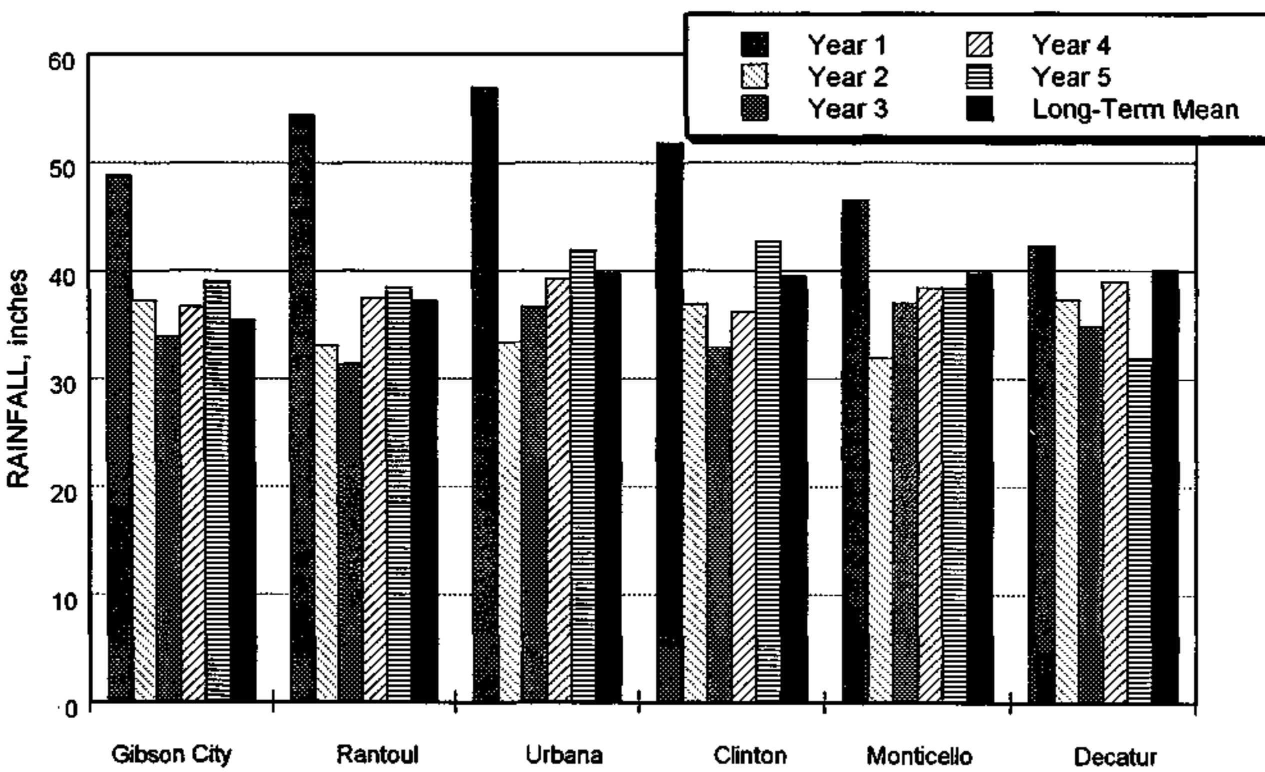

Figure 4. Annual precipitation during five-year study period

Figure 3 shows the variation in monthly precipitation during the fifth monitoring year. The two highest monthly precipitation amounts occurred at the Urbana station in August 1997 (7.0 inches) and March 1998 (6.35 inches). The lowest monthly rainfall was at the Decatur station in December 1997 (0.7 inches). Precipitation during five months was above to much above their monthly 30-year means (May, June, and August 1997; and January and March 1998), while precipitation during three months was below the monthly 30-year means (July, October, and December 1997). The remaining months were near the 30-year monthly means. Data for the Monticello station, which experienced a data loss in July 1997, may be slightly underreported (figure 3).

Figure 4 shows the annual precipitation at the six monitoring stations during the five monitoring years. As can be seen, precipitation during the first year was much above the long-term mean. All stations, except Decatur, received precipitation 12-17 inches above the mean. The second-fifth years oscillated between slightly below to near normal rainfall as compared to the 30-year long-term means. Rainfall data for the fifth year at Gibson City, Rantoul, Urbana, and Clinton stations were slightly above normal but near normal at the Monticello and Decatur stations. The highest annual rainfall, 42.6 inches, occurred at the Clinton station.

Streamflow

Streamflow data are generated from the stream stage record for each of the monitoring stations. Stage data are converted to streamflow data by applying a stage-to-discharge rating curve. The stage-to-discharge rating curve is developed by taking several detailed field measurements of the stream discharge at known stages throughout the monitoring period. The discharges are plotted with corresponding stages, and a stage-to-discharge rating curve is developed for each station. Rating curves were developed for Long Creek at Twin Bridge Road (station 101), Friends Creek at Route 48 near Argenta (station 102), Goose Creek near DeLand (station 103), Camp Creek near White Heath (station 104), the Sangamon River at Shively Bridge near Mahomet (station 105), and Big Ditch near Fisher (station 106). The calibration is continuously updated as more discharge field measurements are taken. Discharge data from the U.S. Geological Survey (USGS) continuous streamgaging stations already exist for the Sangamon River at Route 136 (station 112) and at Monticello (station 111). Consequently, provisional discharge data for these two stations (October 1997 to April 1998) were retrieved from the USGS before being officially published. The USGS has officially published discharge data (May 1997-September 1997) since Keefer et al. (1997).

Streamflow Data. Monthly streamflow data presented in this report are for the period May 1997-April 1998, and annual streamflow data are presented for the five-year monitoring period.

Figures 5 and 6 show the monthly discharge data results for the fifth monitoring year. Figure 5 shows the monthly discharge for the stations located on tributaries of the Sangamon

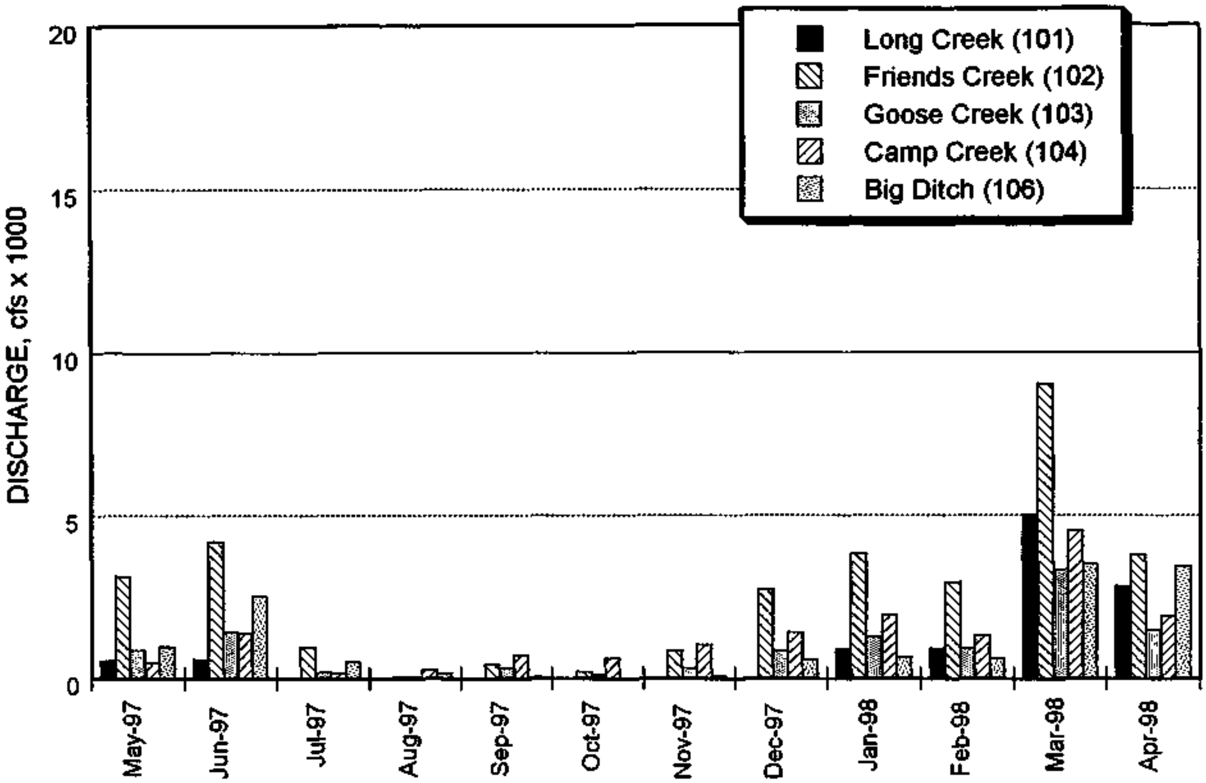

Figure 5. Monthly discharge for tributary stations, May 1997 - April 1998

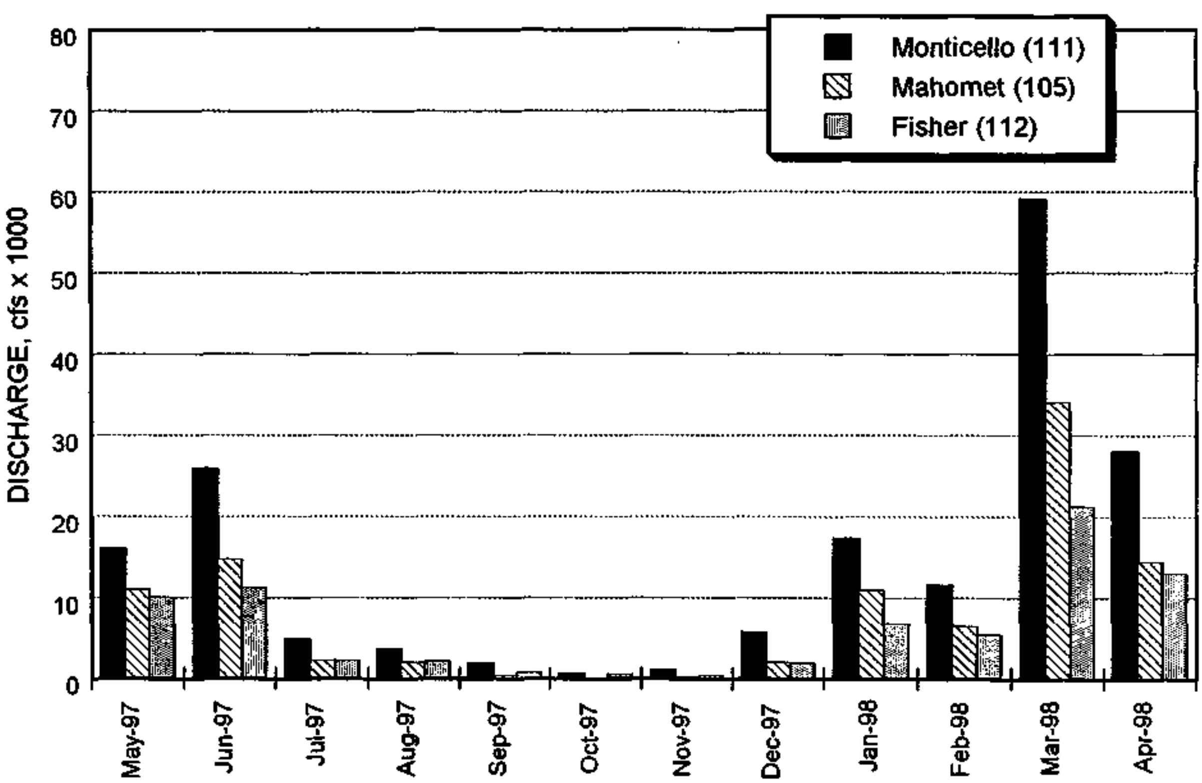

Figure 6. Monthly discharge for Sangamon River stations, May 1997 - April 1998

River (stations 101, 102, 103, 104, and 106), and figure 6 shows the stations located on the Sangamon River (stations 111, 105, and 112). Discharges for the tributary streams stayed below 5000 cubic feet per second (cfs) for most of the year except during March 1998, when the Long Creek and Friends Creek values were 5,000 and 9,000 cfs, respectively. The highest flows during the year occurred during March 1998, followed by April 1998 when Friends Creek and Big Ditch recorded more than 3,500 cfs. All stations had low flows below 1,000 cfs from July to November 1997.

Figure 6 shows the main river stations with the same trends as the tributary stations for the fifth year of monitoring. The highest discharge months were June 1997, March 1998, and April 1998. Monticello, which has the largest drainage area of the three river stations, had the highest flow for the year, 59,000 cfs, during March 1998. The discharges ranged from near zero to less than 5,000 cfs during the lowest streamflow months (July-November 1998).

Discharge is converted to inches over the contributing watershed for the purposes of comparing streamflow to rainfall and comparing streamflow between basins. The monthly discharge is divided by the drainage area upstream of the streamgaging station to determine the streamflow in inches, which is termed "runoff volume. Figures 7 and 8 show the fifth-year monthly runoff in inches for the tributary and Sangamon River stations, respectively. Runoff varies between stations due to the spatial variability of rainfall events throughout the watershed.

Figure 7 shows that the highest monthly tributary runoff the fifth year was from Long Creek in March 1998. March 1998 was when the highest runoff occurred at all the tributary stations during the monitoring year. Runoff at all stations ranged from 2.77 to 4.06 inches during that month. The lowest runoff during the year (zero runoff) occurred at Long Creek (August-October 1997). Runoff at all tributary stations was less than 1 inch during five months (July-November 1997). Runoff exceeded 1 inch for seven months of the year (May, June, December 1997; and January-April 1998). Runoff at any one station exceeded 2 inches during only three of the seven months (June 1997, March 1998, and April 1998).

Figure 8 shows the monthly runoff for the three Sangamon River stations, and all three stations had runoff greater than 3 inches during March 1998, ranging from 3.24 to 4.08 inches. Four months of the year (May and June 1997; and January and April 1998) had runoff greater than 1 inch, including the highest (nearly 2 inches) in April 1998. Runoff was nearly zero (October and November 1997) and below 1 inch (July-December 1997 and February 1998).

Figure 9 presents annual runoff during all five monitoring years for the tributary and Sangamon River stations. The long-term average annual runoff over the Lake Decatur watershed is 10.2 inches (Demissie et al., 1996). Annual runoff during the first year (24.3 inches) was more than double the long-term annual average. The second year runoff was much lower (8.2 inches), but annual runoff has steadily increased since then to 9.2, 11.5, and 12.2 inches. The fifth monitoring year was similar to the second-fourth years, which showed no spatial tendencies in runoff. As shown in figure 9a, the tributary stations had an average runoff of 10.9 inches that ranged from 8.8 (Long Creek) to 12.8 (Big Ditch) inches. Runoff from river stations at

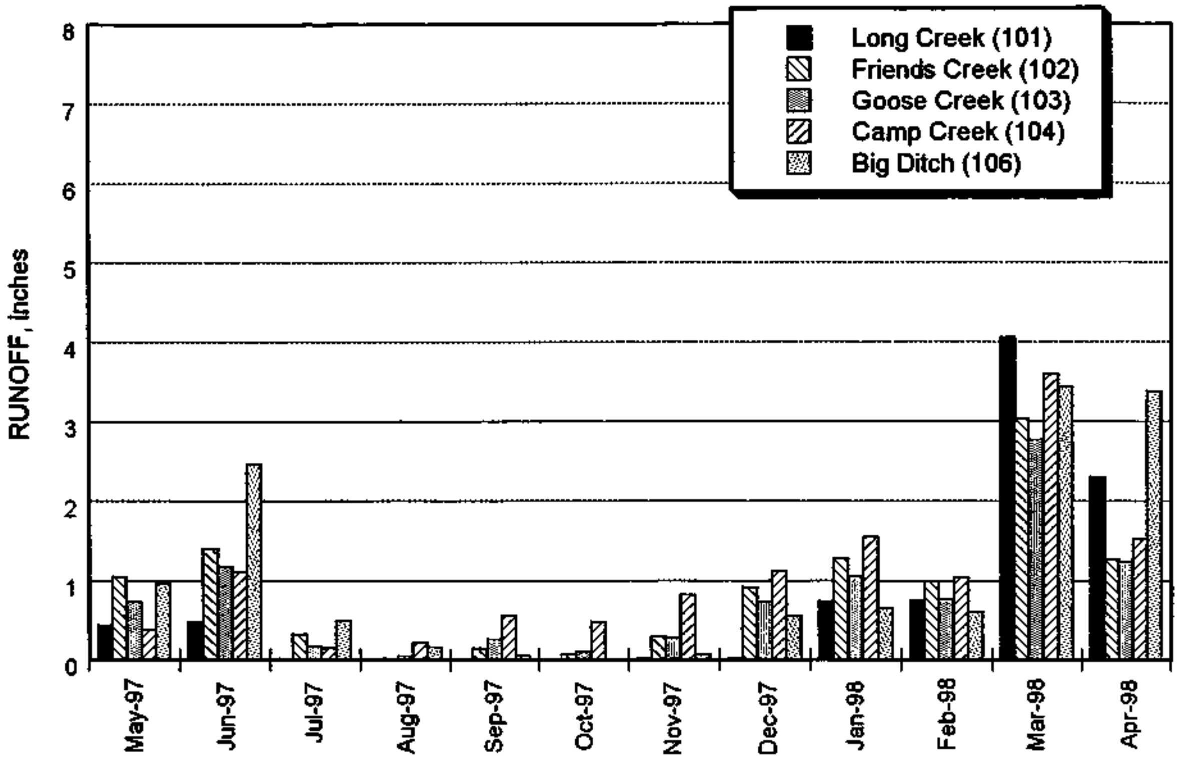

Figure 7. Monthly runoff for tributary stations, May 1997 - April 1998

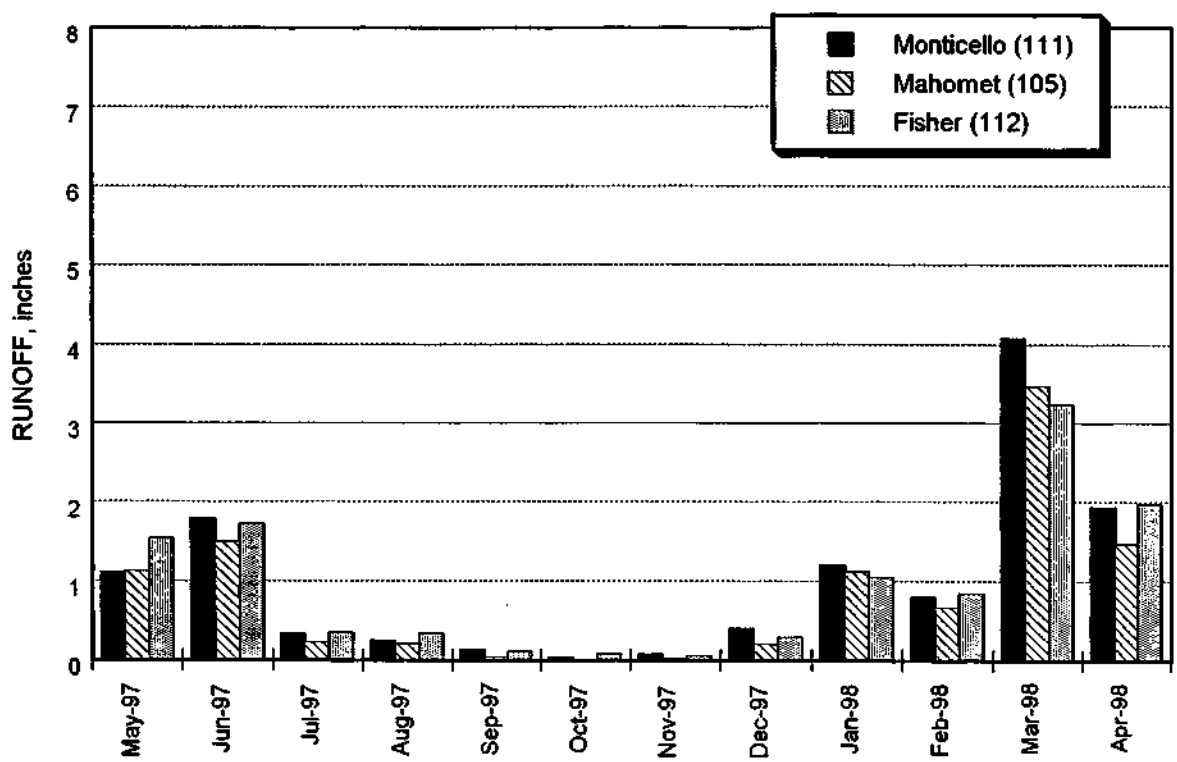

Figure 8. Monthly runoff for Sangamon River stations, May 1997 - April 1998

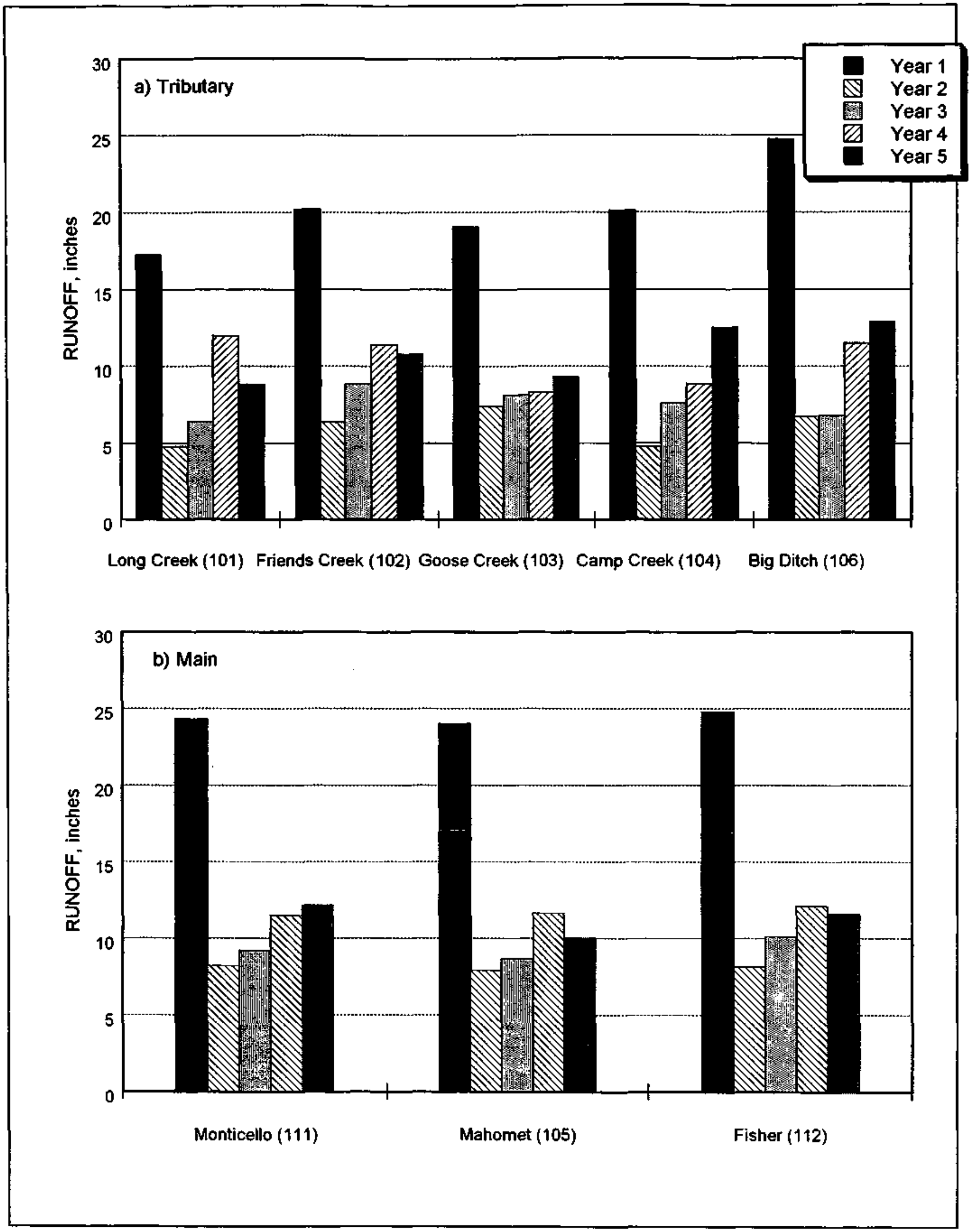

Figure 9. Annual runoff for tributary and Sangamon River stations during study period

Monticello, Mahomet, and Fisher was 12.2, 10.0 and 11.6 inches, respectively (figure 9b). The annual runoff for Fisher and Monticello during the fourth year of monitoring is slightly different in this report than in Keefer et al. (1997). The U.S. Geological Survey operates these stations and the data retrieved for the earlier publication were available only on a provisional basis. However, those data have been finalized by the USGS and adjusted accordingly in this report.

Nitrate Monitoring

Nitrate was monitored at each of the eight monitoring stations for all five monitoring years. During the first two years (May 1993-April 1995), two additional nitrogen parameters were analyzed: ammonium-nitrogen (ammonium-N) and total Kjeldahl nitrogen (TKN). Demissie et al. (1996) report ammonium-N and TKN concentrations for the eight monitoring stations.

Nitrate Concentrations

Figures 10-11 present the fifth-year monthly nitrate-N concentration data at the eight tributary stream and Sangamon River monitoring stations. Keefer et al. (1997) present nitrate-N concentration data for the first four years of the monitoring study.

Figure 10 shows the seasonal variation of nitrate-N concentrations that has been demonstrated in the previous years (Demissie et al., 1996; Keefer et al., 1997). The highest concentrations occur in the late spring to early summer months of May and June. The highest nitrate-N concentration of 16.36 mg/l occurred at the Camp Creek station in May 1997. Concentrations at Big Ditch were 16.21 and 16.31 in May and June 1997, respectively. The highest nitrate-N concentrations for each tributary station occurred in June 1997. July 1997 concentrations steadily dropped throughout the month from the highest values near 13 mg/l at the beginning of the month to the lowest values below 0.5 mg/1 near the end of the month. The average nitrate-N concentration for all tributary stations in July 1997 was 6.2 mg/1. The seasonal pattern shows that the lowest concentrations (nearly 0 mg/1) usually occur in the late summer to early fall months of (August-October). However, during the fifth year of monitoring, unlike the second-fourth years (Keefer et al., 1997), Long Creek was the only tributary station that had nitrate-N concentrations decrease to nearly 0 mg/1. Inspection of daily precipitation records showed that two severe rainfall events occurred during mid-August and early September in most of the upper watershed area. The fifth-year monitoring data show nitrate concentrations steadily increasing (November-April). December 1997 nitrate-N concentrations had a wide range of readings from approximately 2 to 10 mg/1. Nitrate-N concentrations ranged from 8 to 12 mg/1 (January-March 1998) and from 9 to 13 mg/1 (April 1998).

Figure 11 shows the nitrate-N concentration data for the three stations on the Sangamon River during the fifth monitoring year. The seasonal variation in concentration throughout the year follows the pattern seen in past data, similar to the tributary stations discussed above. Fisher had the highest nitrate-N concentration (15.2 mg/1) and Mahomet had the next highest (14.9

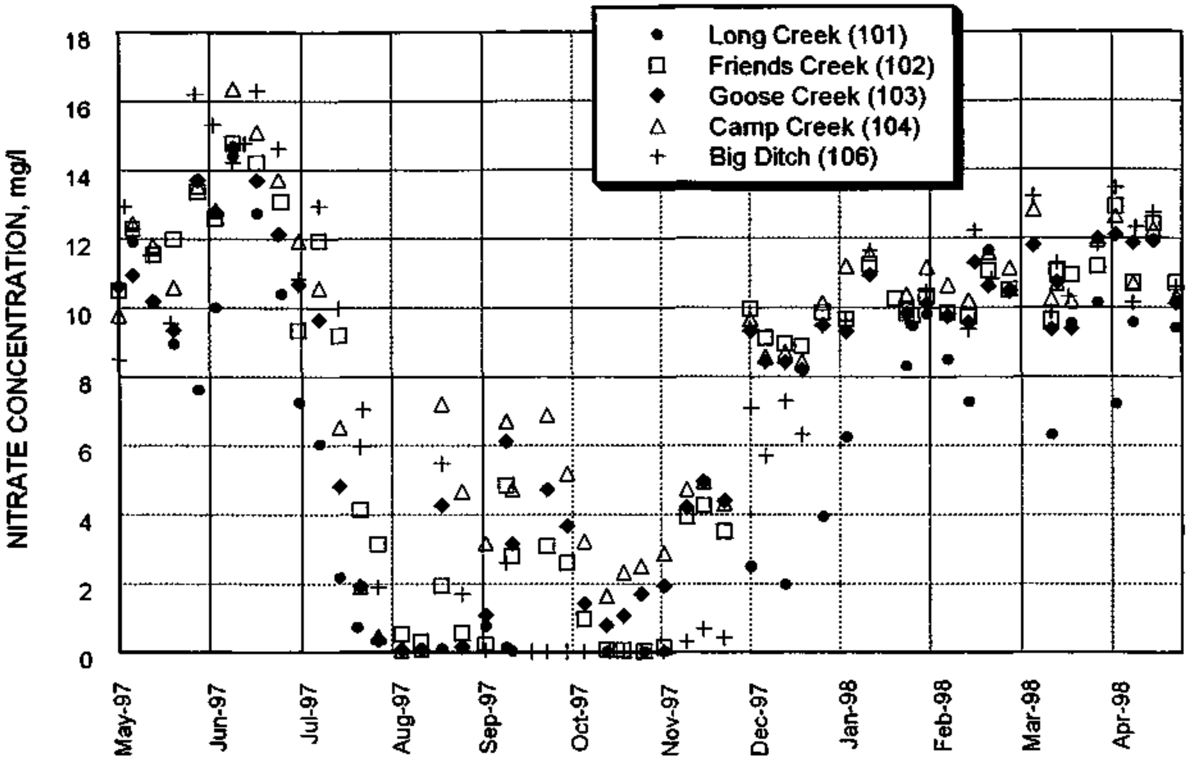

Figure 10. Nitrate-N concentration for tributary stations, May 1997 - April 1998

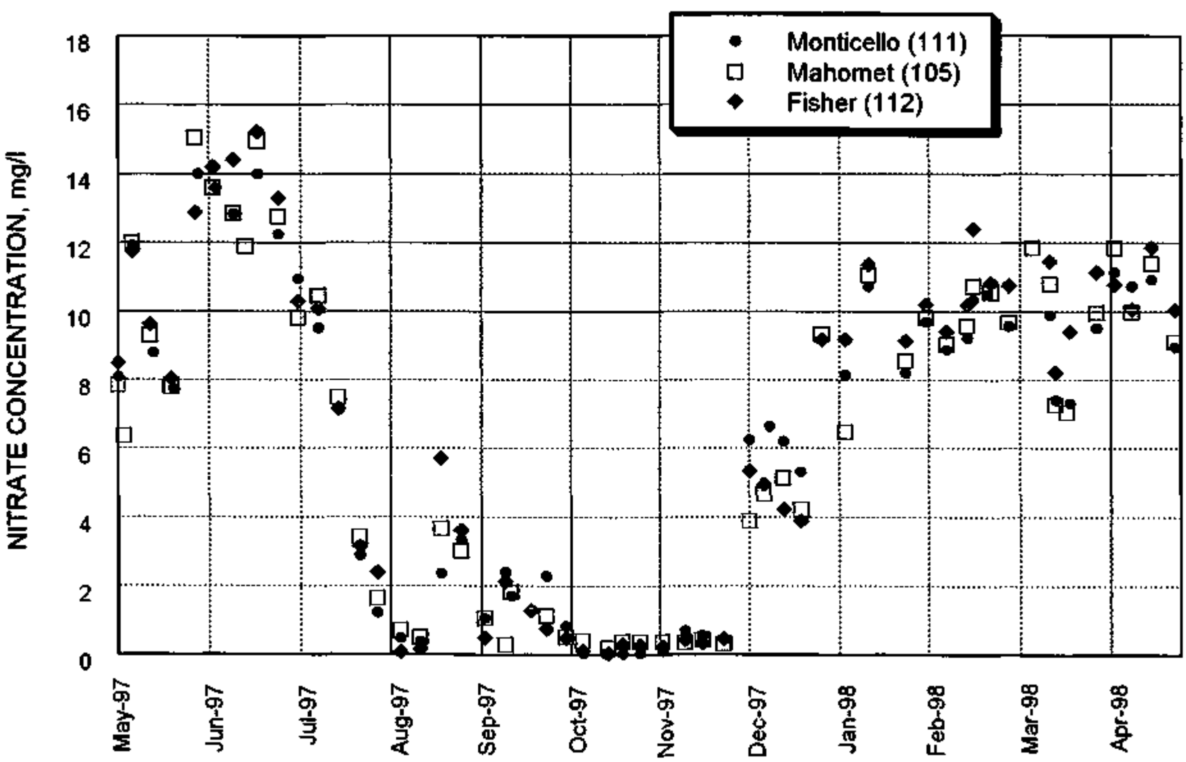

Figure 11. Nitrate-N concentrations for Sangamon River stations, May 1997 - April 1998

mg/l) in June 1997. Monticello peaked at 14.0 mg/l in May 1997. All stations dropped to below 1 mg/l near the beginning of August but rebounded during a severe storm in mid-August (as mentioned above). Nitrate-N concentrations responded slightly (averaging 2 mg/1) to the storm in early September. October and November 1997 saw the expected early fall lows in concentrations to mostly below 0.5 mg/1. Concentrations rose sharply in early December, responding to a large rainfall event in late November. Nitrate-N continued to rise and vary until April 1998. Concentrations ranged from 7 to 12 mg/l (January-April 1998). Overall, nitrate-N concentrations were 1-2 mg/1 less than concentrations reported for the tributary stations, as shown in figure 10.

Figure 12 shows the nitrate-N concentrations provided by the City of Decatur for the north and south water treatment plant (WTP) intakes in Lake Decatur during the fifth year of watershed monitoring. The lake water shows the same patterns in nitrate concentrations exhibited in the tributary and river stations. Concentrations in the lake are lower than those in the river stations, just as concentrations at the river stations are lower than those at the tributary stations. The highest concentrations, 11.3 and 10.6 mg/l, occur in June 1997 for the north WTP and south WTP, respectively. The nitrate-N drops to an average of 1 mg/1 (September-November 1997). Values rise through December 1997 and then remain steady with some oscillation through April 1998. Concentrations during this period range from 5 to 10 mg/1. The north WTP seems to react to the mid-August and early December rainfall events. Another observation is that, for the most part, the south WTP nitrate-N concentrations lag but follow the north WTP concentration patterns. However, the south WTP overtakes the north WTP values during the winter and spring months. This was also observed in the third (May 1995-April 1996) and fourth (May 1996-April 1997) monitoring years (Keefer et al., 1997).

Figures 13-15 show the maximum, average, and minimum concentrations of nitrate sampled at the eight main stations in the watershed during the five-year study period. As seen in figure 13, out of all the tributary stations, Camp Creek and Big Ditch had the highest nitrate-N readings at 16.3 mg/1 each, while Long Creek had the lowest maximum concentration, 14.4 mg/1. Fisher had the highest maximum river station nitrate-N concentration, 15.2 mg/1, and Monticello had the lowest maximum, 14.0 mg/1. It should be noted that highest maximum concentrations occurred at six of the eight stations in the fifth year of the study period. Maximums occurred at Goose Creek and Big Ditch in the third and fourth year, respectively. Figure 14 shows the average nitrate concentrations for the fifth year of monitoring. The tributary station average annual nitrate concentrations for the five monitoring years are 7.9, 7.0, 6.5, 7.9, and 7.5 mg/l, respectively. The river station average annual concentrations are 6.6, 5.8, 5.5, 6.5, and 6.7 mg/1, respectively. Figure 15 shows the minimum nitrate concentrations measured. During the fifth year of monitoring all stations never exceeded 0.25 mg/1 of nitrate-N. Otherwise, the highest minimum concentrations occurred during the first year of monitoring (May 1993-April 1994) for all the stations except Friends Creek.

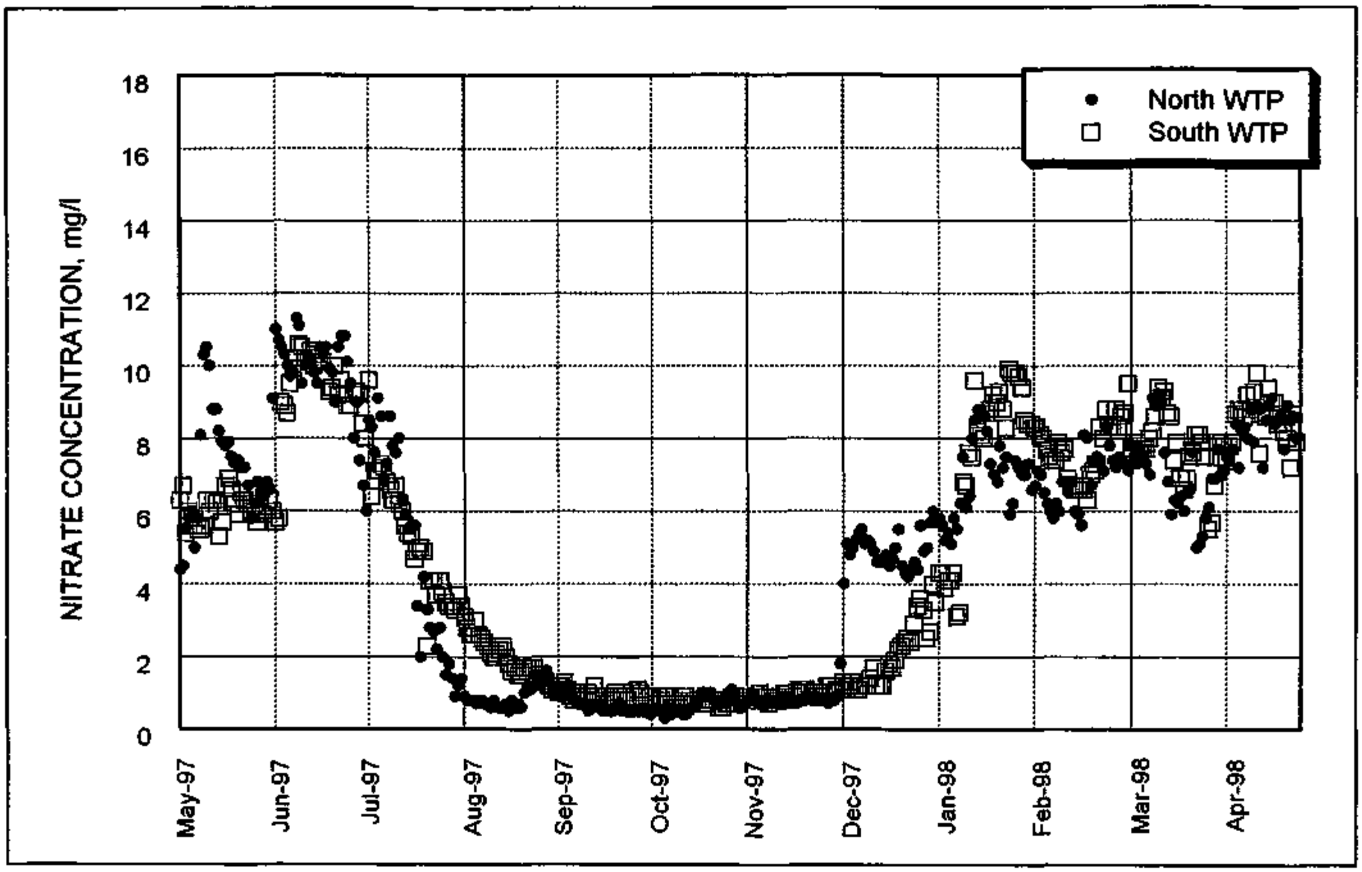

Figure 12. Nitrate-N concentrations for north and south water treatment plants, May 1997 - April 1998

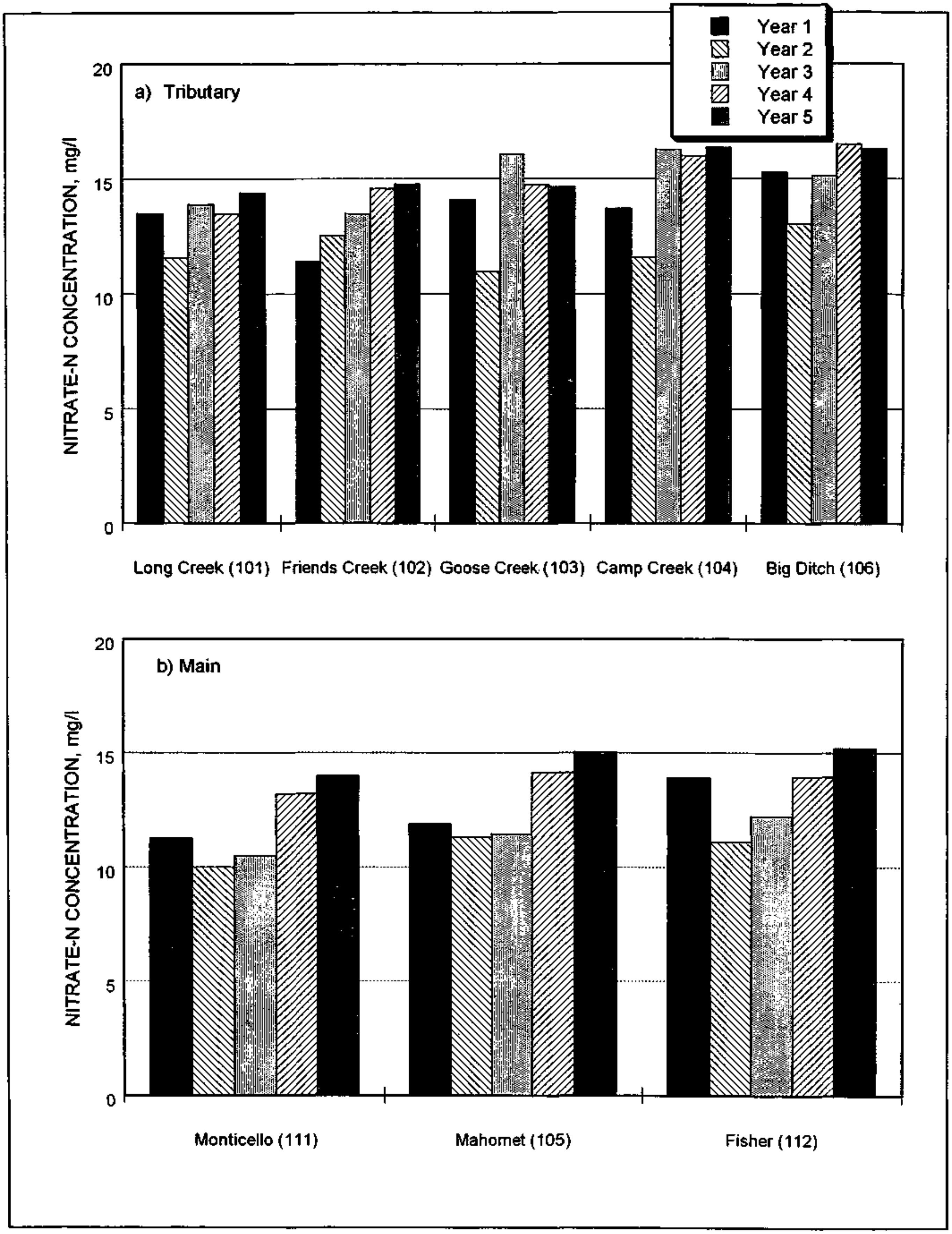

Figure 13. Maximum nitrate-N concentrations during study period

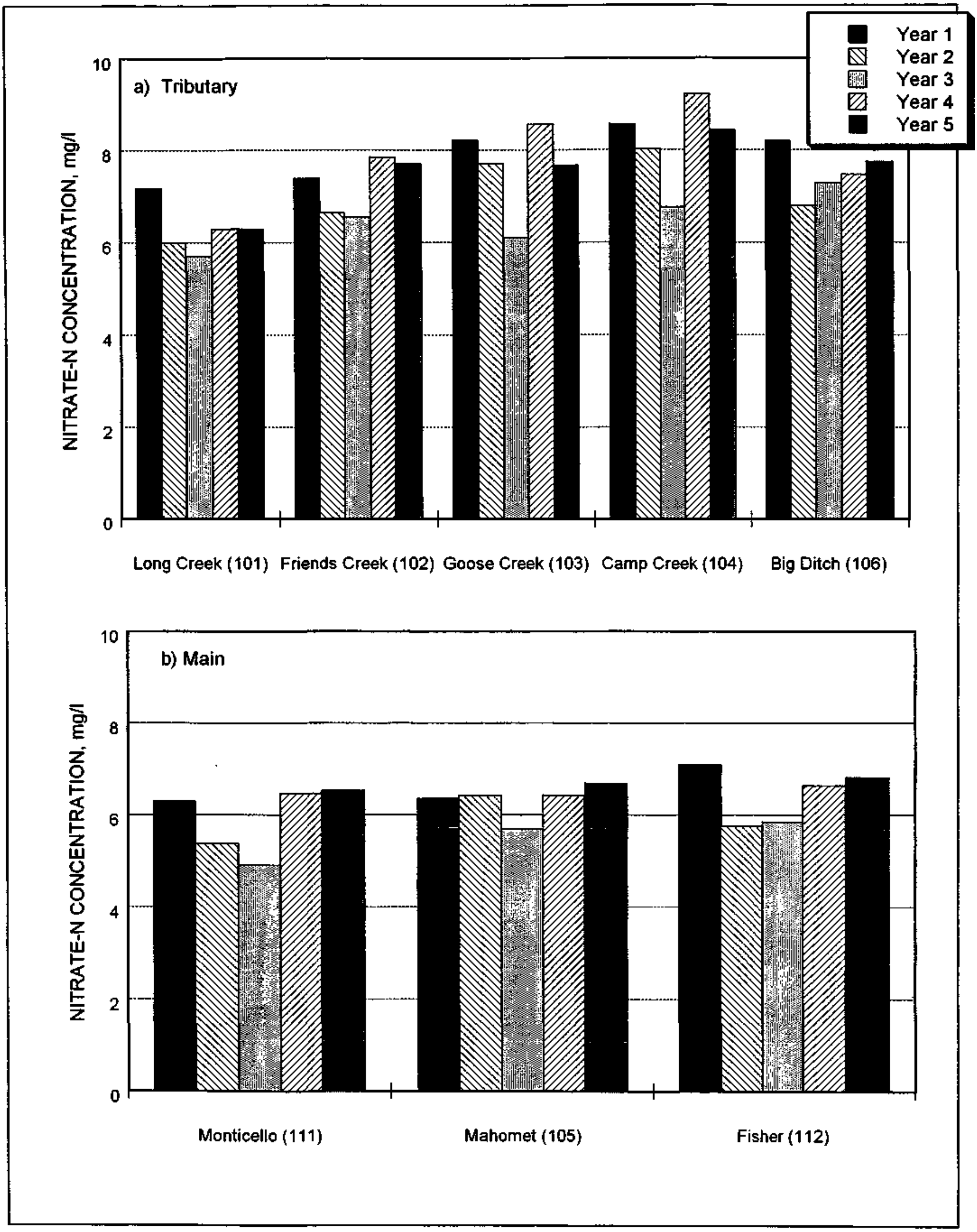

Figure 14. Average nitrate-N concentrations during study period

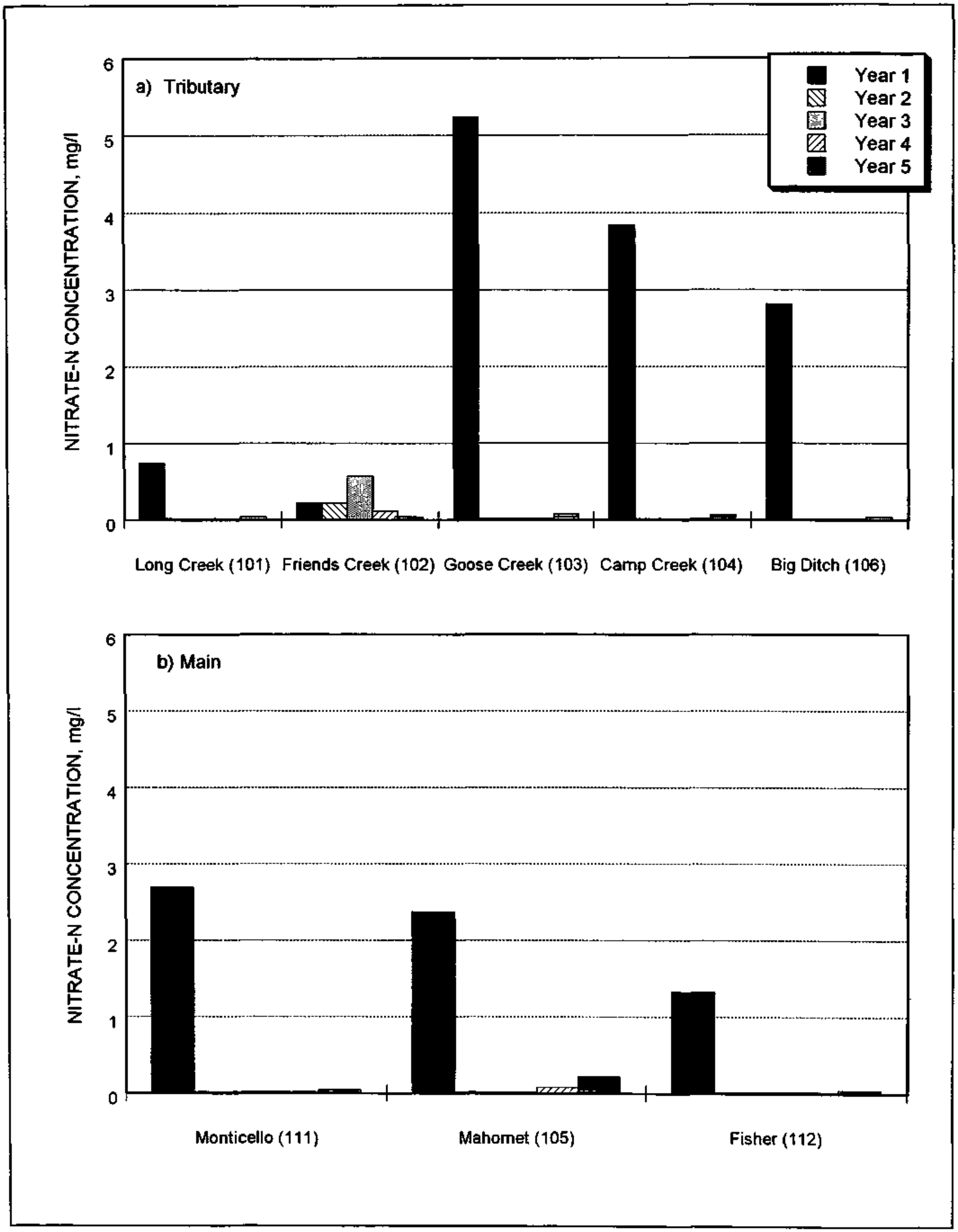

Figure 15. Minimum nitrate-N concentrations during study period

Nitrate Loads

Even though the main water quality concern at Lake Decatur is nitrate concentrations, the critical issue for watershed management is nitrate loads. It is impossible to reduce the nitrate concentration without reducing the nitrate load into the lake. Management alternatives are more easily understood in terms of load reduction than reduction in concentration.

The calculation of nitrate loads, or yields, is necessary to determine the contribution of different areas to the total nitrate input into the lake. Nitrate concentrations are used for regulatory purposes but are not sufficient to determine the relative contribution of nitrates from different areas. The nitrate load combines the effects of concentration and discharge and thus provides a more accurate picture of the relative contribution of different areas. For example, a tributary may have some of the highest nitrate concentrations, but if it is also one of the smallest sub-watersheds, its total delivery of nitrates could be quite small as compared to other sub-watersheds and thus not a significant contributor. Figures 16 and 17 present monthly nitrate loads during the fifth monitoring year for all eight stations.

Figure 16 shows the monthly nitrate-N loads in pounds per acre (lb/acre) for the tributary stations during the fifth monitoring year, which averaged 2.1 lb/acre. Monthly nitrate-N loads were highest at Big Ditch in April 1998 (9.0 lb/acre) and at Camp Creek in March 1998 (8.90 lb/acre). Long/Big Creek had zero nitrate-N loads from July through November 1997. Nitrate-N loads were highest in March 1998 for all the tributary stations, except Big Creek.

Figure 17 presents the monthly nitrate loads for the three Sangamon River stations, which averaged 2.0 lb/acre for the fifth year. The highest monthly loads at all stations occurred in March 1998, including the highest monthly load at Monticello (7.8 lb/acre). Nearly zero nitrate loads occurred August-November 1997.

Annual Nitrate Loads. Table 2 summarizes the annual nitrate-N loads during the five-year study period at all stations monitored, and these are presented in figure 18. The tributary and main river results are presented separately for comparison purposes.

Figure 18a shows the annual nitrate loads for the study period. For the tributary streams, the annual nitrate load for the fifth year ranges from a low of 18 lb/acre for Long Creek to a high of 33 lb/acre for Big Ditch. The other tributaries (Friends Creek, Goose Creek, and Camp Creek) generated loads ranging from 21 to 28 lb/acre. The average annual load for all the tributaries was 25 lb/acre. It is observed that on the average over the five-year study period Big Creek delivers the highest nitrate load per unit area and Long Creek delivers the lowest nitrate load per unit area.

Figure 18b presents the annual nitrate loads for the three Sangamon River stations. The fifth-year loads for tributaries in the upper portion of the watershed (Goose Creek, Camp Creek, and Big Ditch) were the second highest observed during the study period. The highest loads occurred in the first year of monitoring. The average annual load for the main river stations for

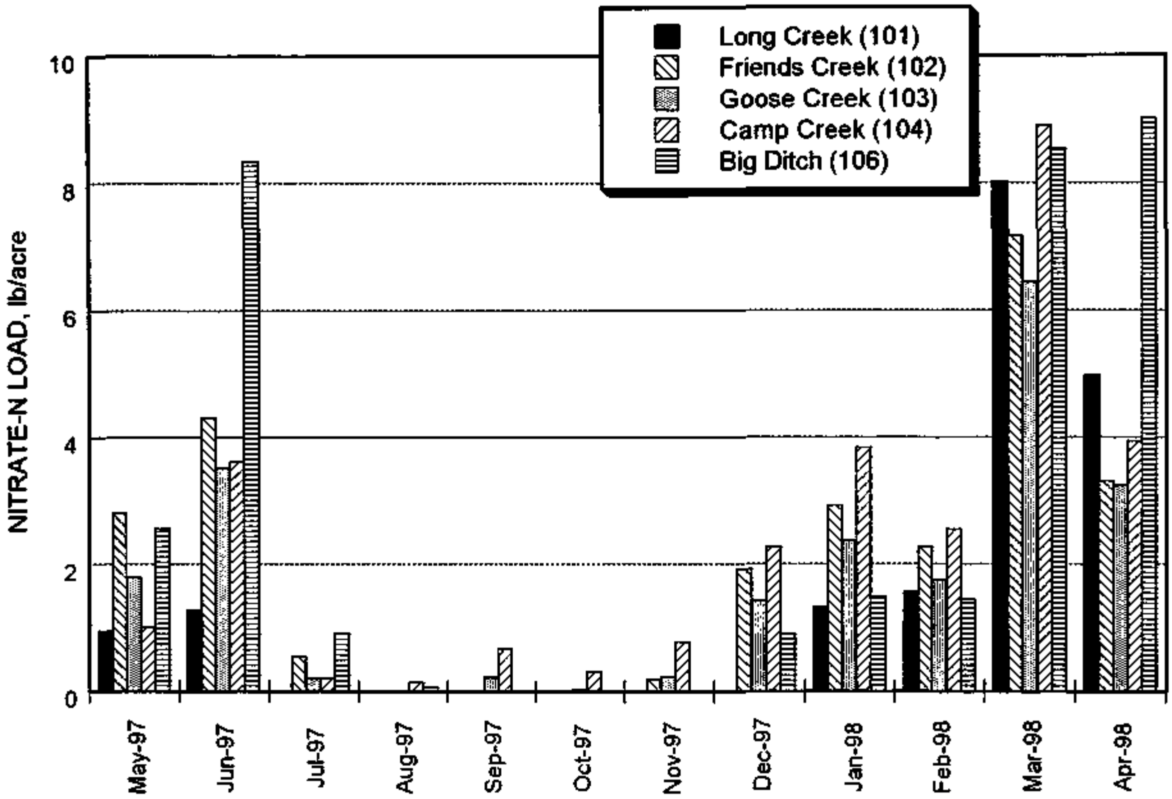

Figure 16. Monthly nitrate-N load for tributary stations, May 1997 - April 1998

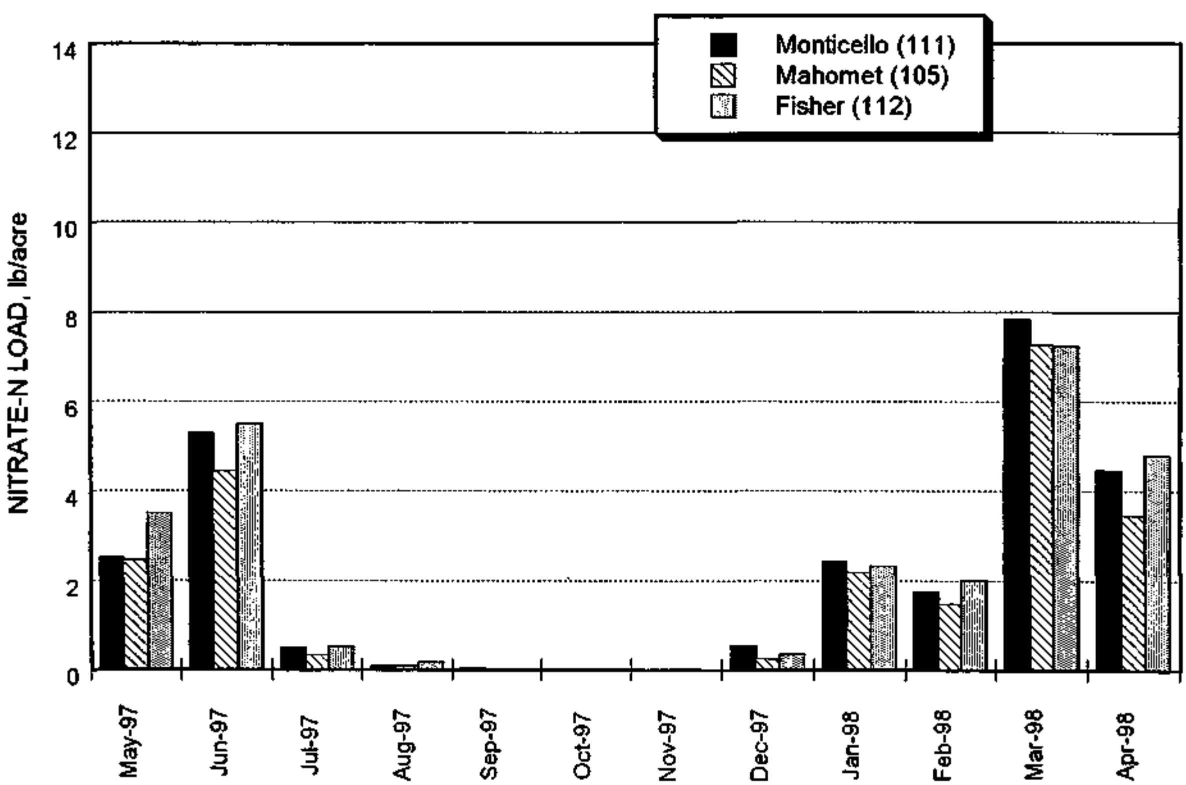

Figure 17. Monthly nitrate-N load for Sangamon River stations, May 1997 - April 1998

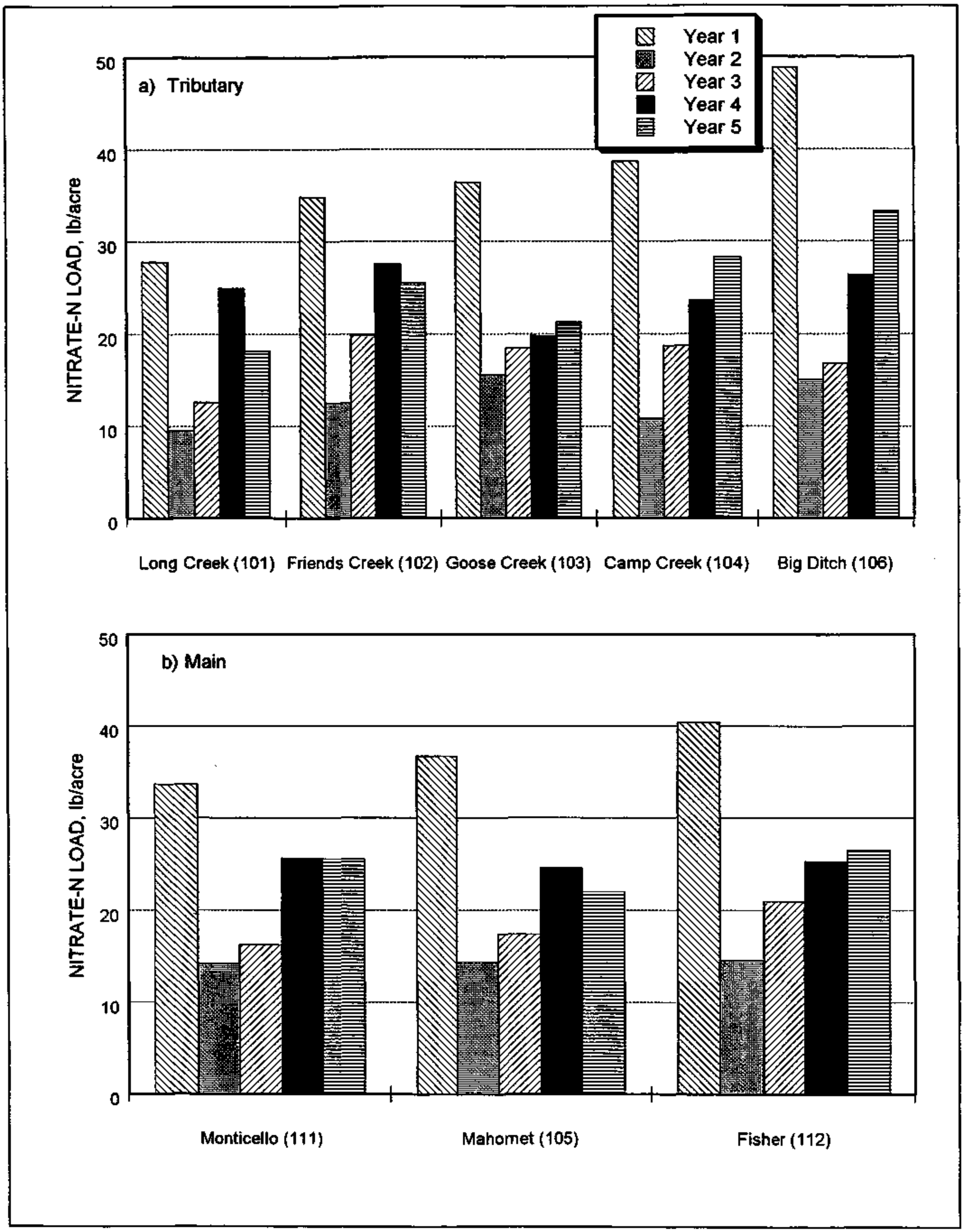

Figure 18. Annual nitrate-N load for tributary and Sangamon River stations during study period

Table 2. Annual Nitrate-N Loads in the Sangamon River Basin

Station	*Drainage area (acres)*	*Annual nitrate-N yield (lb/acre)*					
		Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Average*
Tributary stations:							
Long Creek (101)	29,539	28	9	13	25	18	19
Friends Creek (102)	71,647	35	12	19	28	25	24
Goose Creek (103)	28,892	36	16	18	20	21	22
Camp Creek (104)	30,242	39	11	19	24	28	24
Big Ditch (106)	24,421	49	15	17	26	33	28
Main river stations:							
Sangamon River at Fisher	157,177	40	14	21	25	26	26
Sangamon River at Mahomet	235,653	37	14	17	25	22	23
Sangamon River at Monticello	347,747	34	14	16	26	26	23
Total inflow into Lake Decatur	586,868	32	12	16	26	23	22

the fifth year was 25 lb/acre, and loads ranged from a low of 22 lb/acre at the Mahomet station to a high of 26 lb/acre at the Monticello and Fisher stations.

Table 2 also presents the total nitrate load into Lake Decatur for the study period. The first monitoring year had the highest load (32 lb/acre) and the second monitoring year had the lowest load (12 lb/acre). The average nitrate load to Lake Decatur during the fifth year is 23 lb/acre. The average annual nitrate load to Lake Decatur for the five-year study period is 22 lb/acre.

Based on the data, it can be concluded that the unit nitrate yields are higher at the tributary streams in the upper Sangamon River than at the main stem stations closer to the lake. On the main stem Sangamon River, the nitrate load is either the highest at Fisher and the lowest at Monticello or relatively the same for some years. Based on the load data calculated for the last five years, it can be concluded that the nitrate yields vary from tributary to tributary and change significantly from year to year.

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