Watershed Monitoring for the Lake Decatur Watershed, 1998 - 1999

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Prepared for:

City of Decatur
Keith Alexander, Project Manager

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Abstract

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 with an original water 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). 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. 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 high concentrations of total dissolved solids and nitrates, and nitrate concentrations have been exceeding drinking water standards 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 IEPA 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 an initial two-year monitoring study of the Lake Decatur watershed to better understand nitrate yields in the watershed. In 1993, the Illinois State Water Survey received a grant from the City of Decatur, conducted a two-year monitoring study, and developed land use management strategies that could assist the city comply with the IEPA drinking water standards (Demissie et al., 1996). This technical report presents the annual data for all six years of monitoring (May 1993-April 1999) and monthly data for the sixth year of monitoring (May 1998-April 1999).

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Watershed Monitoring for the Lake Decatur Watershed

by
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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 high concentrations of total dissolved solids and nitrates, and nitrate concentrations have been exceeding drinking water standards 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. These exceedances generally occur on a seasonal basis (spring through mid-summer and late-winter)

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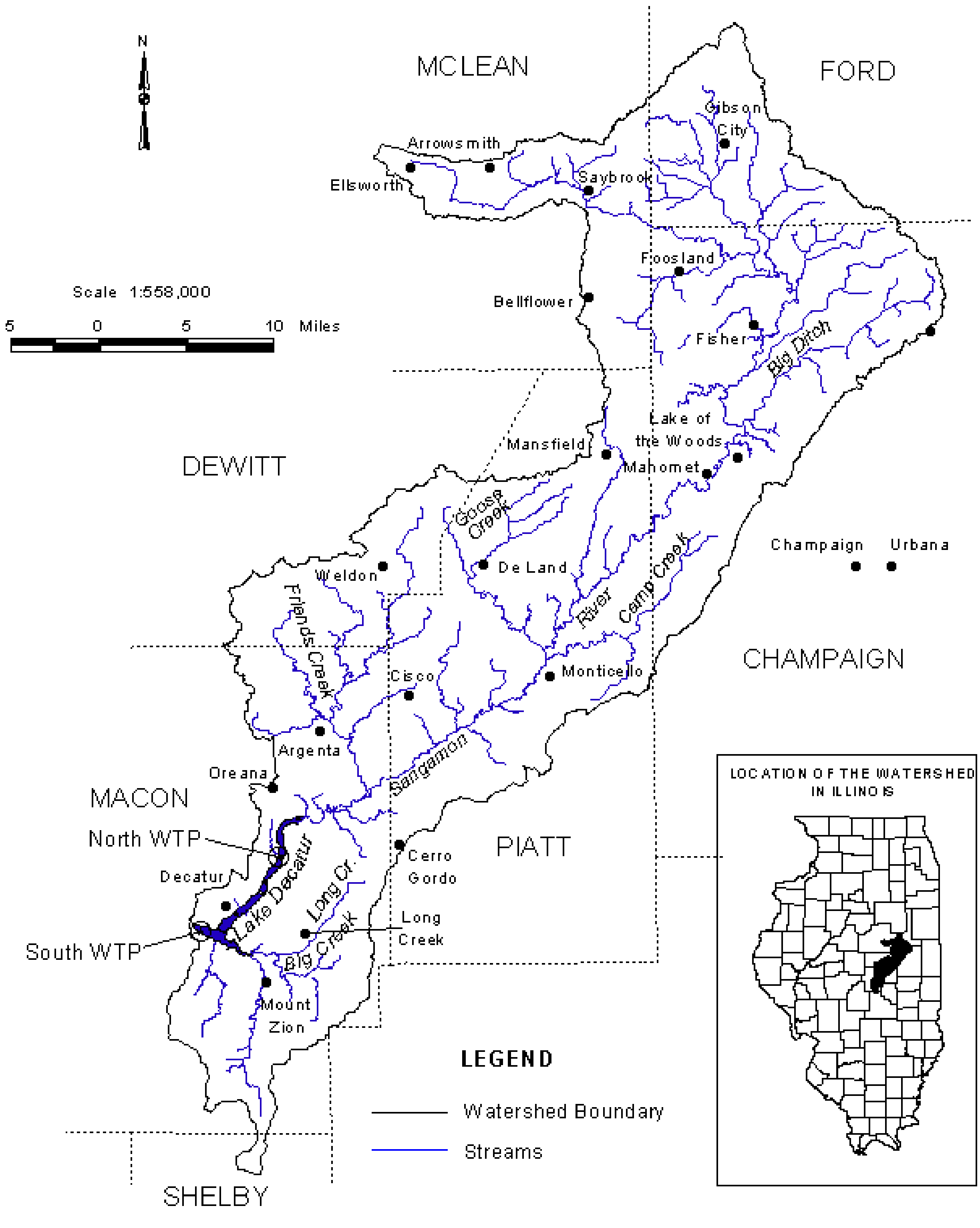

Figure 1. The Lake Decatur watershed

Decatur, conducted this initial two-year monitoring study, and developed land use management strategies that could assist the city comply with the IEPA drinking water standards. Demissie et al. (1996) present the results of that two-year study. The monitoring study has continued past the initial two years of data collection through the support of the City of Decatur. Keefer et al. (1997) present the results of the third and fourth years of monitoring, and Keefer and Demissie (1999) present the results of the fifth year of monitoring in context of longer-term records.

This technical report presents the annual data for all six years of monitoring (May 1993-April 1999) and monthly data for the sixth year of monitoring (May 1998-April 1999). The report is organized into three sections: Introduction, Background, and Hydrologic and Nitrate Monitoring. The first two 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 six 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 processing and presenting data used in this report. Amy Russell assisted in the data analysis.

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 Amy Russell, Erin Hessler, and William Bogner of the Watershed Science Section. 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 for almost 20 years. Past studies by the U.S. Environmental Protection Agency (USEPA) and the Illinois 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 suspended solids and nitrates. Currently, the most pressing water quality problem in Lake Decatur is a high concentration of nitrates.

The nitrate loads that eventually reach Lake Decatur originate in the watershed of the Upper Sangamon River that feeds into Lake Decatur (figure 1). 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 city 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 a 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 periodically measuring water discharge. Water samples were collected and analyzed for nitrate-nitrogen (referred to as nitrate-N or nitrate for the remainder of this report) on a weekly basis. The network has been collecting data for six years (May 1993-April 1999). The annual data collection period starts in May and concludes in April of the following year. For example, the "Year 1" study period began in May 1993 and ended in April 1994. This report presents the monthly data collected during "Year 6" (May 1998-April 1999) and annual data for all six years of data collection.

Hydrologic Monitoring

Continuous hydrologic monitoring (water levels) at each station facilitates the calculation of continuous streamflow (discharge). This is essential for establishing the nitrate contribution to Lake Decatur from the Sangamon River and its tributaries. Table 1 presents the names of the streams, locations of the monitoring stations, and the corresponding drainage areas for the monitoring stations.

Precipitation

Precipitation data for selected locations around the watershed have been retrieved from the Midwestern Regional 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. It should be noted

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

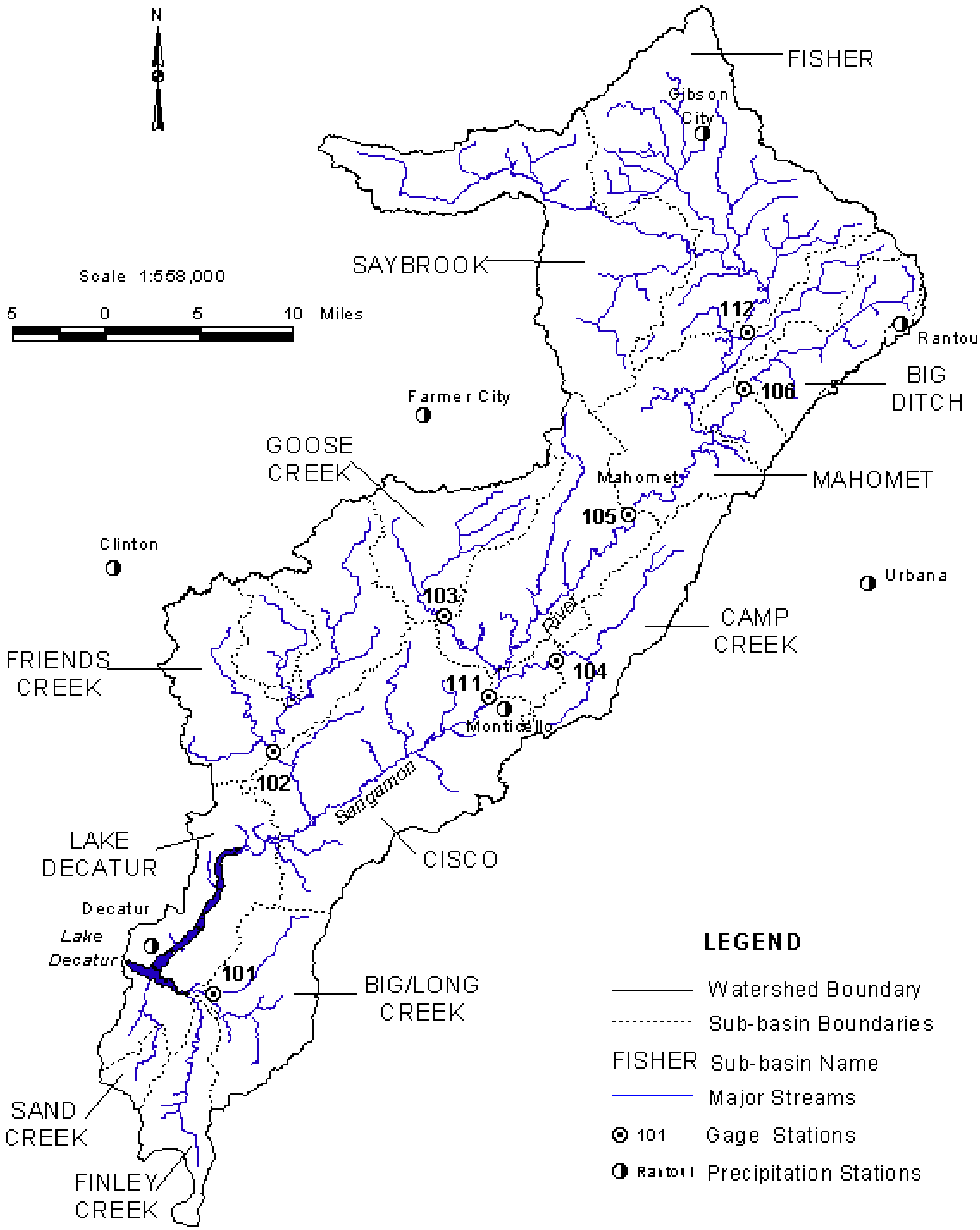

Figure 2. Stream and rain monitoring stations in the Lake Decatur watershed

Table 2. Monthly and Annual 30-Year (1961-1990) Mean Precipitation for Selected Stations, in inches

Month	*Gibson City*	*Rantoul*	*Urbana*	*Clinton*	*Monticello*	*Decatur*
May	3.81	3.91	3.97	4.43	3.94	4.31
June	3.47	3.63	4.07	3.79	3.82	3.87
July	3.89	4.51	4.46	3.87	4.61	4.29
August	3.33	3.82	4.03	3.90	4.09	4.07
September	3.38	3.35	3.36	3.37	3.25	3.40
October	2.54	2.58	2.66	3.04	2.62	2.82
November	2.69	2.94	3.10	2.96	3.10	3.05
December	2.76	2.86	3.02	3.06	3.03	3.16
January	1.64	1.60	1.83	1.63	1.83	1.97
February	1.47	1.63	1.97	1.81	1.82	1.98
March	3.09	3.09	3.30	3.53	3.31	3.44
April	3.60	3.76	3.94	4.10	4.10	3.80
Annual	35.67	37.68	39.71	39.49	39.52	40.16

that these stations are listed in the order in which they are encountered in the watershed proceeding from headwaters to Lake Decatur. The Gibson City station is closest to the headwaters of the watershed and Decatur is the station that is nearest Lake Decatur. Table 2 presents the monthly and annual 30-year precipitation means for these stations.

Figure 3 presents the monthly precipitation in inches at all six stations for May 1998-April 1999. The highest monthly precipitation occurred at the Gibson City station in June 1998 (9.6 inches). The lowest monthly rainfall was at the Monticello station in September 1998 (0.6 inches). Precipitation during five months was above to much above their monthly 30-year means (May and June 1998; and January, February, and April 1999), while precipitation during four months was below to much below the monthly 30-year means (September, November, and December 1998; and March 1999). Except for a few stations, precipitation during July and August 1998 was also much below the monthly means. October 1998 precipitation was near normal at all stations.

Figure 4 presents the annual precipitation for the 6-year study period and the 30-year (1961-1990) long-term means at the six stations. As can be seen, precipitation during the first year (1993-1994) was much above the long-term mean. All stations, except Decatur, received precipitation 12-17 inches above the annual means during 1993. The second to the sixth years varied between slightly below to near normal rainfall as compared to the 30-year long-term means. Rainfall data for the sixth year at Rantoul, Urbana, and Monticello stations were slightly above normal but near normal at the Gibson City, Clinton, and Decatur stations. The highest annual rainfall, 45.2 inches, occurred at the Urbana station.

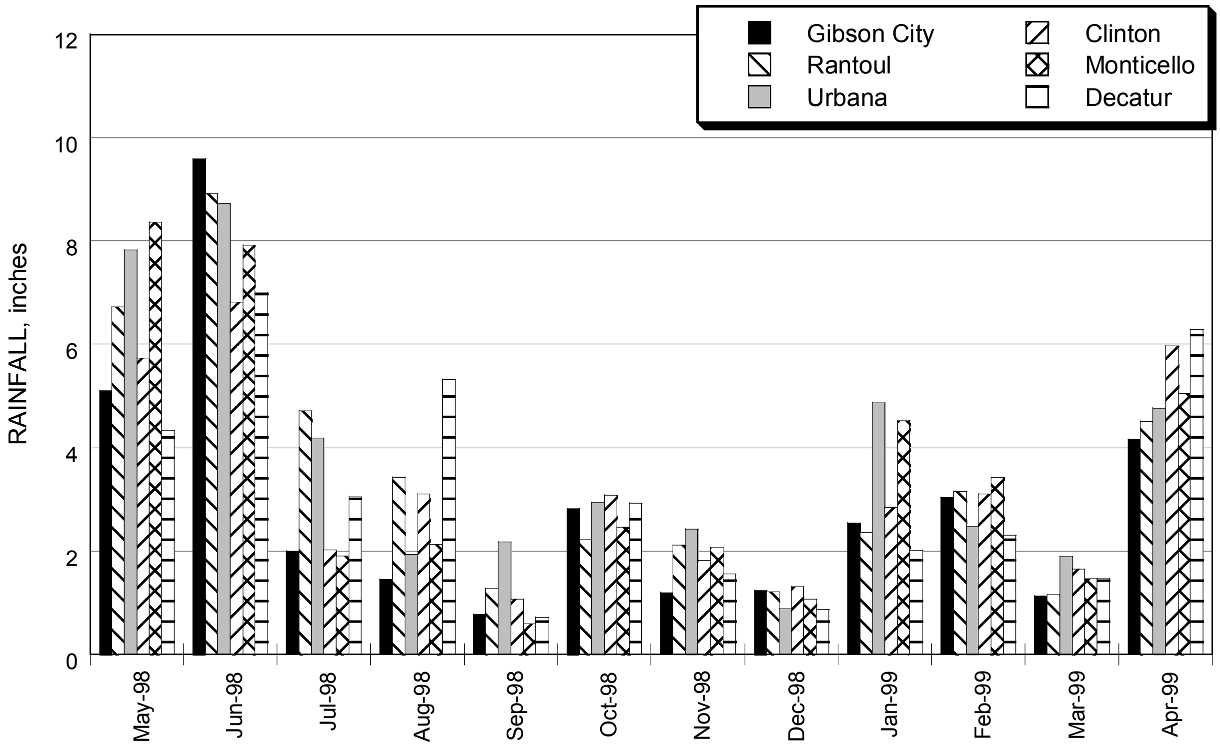

Figure 3. Monthly precipitation, May 1998 - April 1999

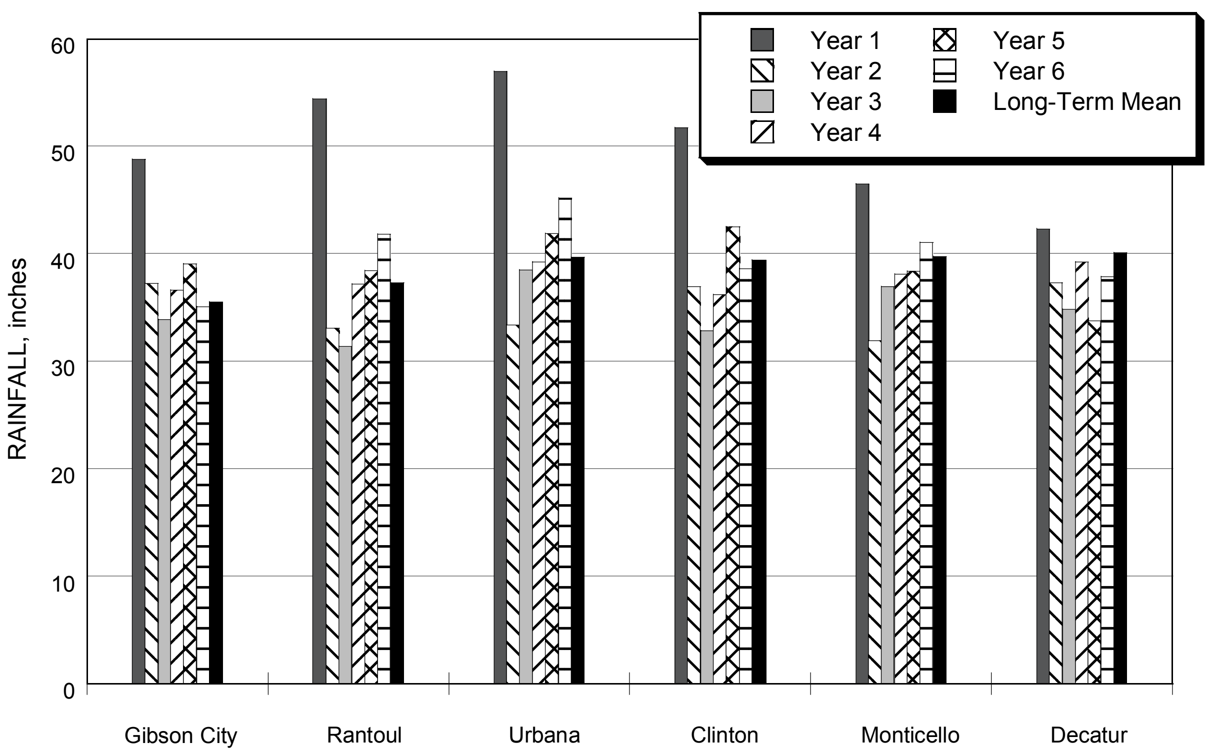

Figure 4. Annual precipitation during six-year study period, May 1993 - April 1999

Streamflow

Streamflow data are derived from the stream stage record for each of the monitoring stations. Stage data are converted to mean daily streamflow data by applying a stage-to-discharge rating curve. After 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 updated as more discharge field measurements are taken. Discharge data from the U.S. Geological Survey (USGS) already exists for the continuous streamgaging stations on the Sangamon River at Route 136 (station 112) and at Monticello (station 111). May 1998-April 1999 data were retrieved for this report. The USGS has officially published the discharge data for May 1998-September 1998. However, October 1998-April 1999 discharge data for these two stations have not been officially published by the USGS and are considered "provisional" data.

Streamflow Data. Monthly streamflow data presented in this report are for the period May 1998-April 1999, and annual streamflow data are presented for the six-year monitoring period.

Figures 5 and 6 show the monthly discharge data results for the sixth monitoring year. Figure 5 shows the monthly discharge for the stations located on tributaries of the Sangamon 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 were below 5,000 cubic feet per second (cfs) for most of the year except during May and June 1998, and April 1999. Friends Creek had the three highest discharges of 10,800, 9,900, and 7,100 cfs in May and June 1998, and April 1999, respectively. Discharges were 6,800 cfs at Camp Creek (May 1998) and 6,000 cfs at Long Creek (June 1998). All stations had low flows below 1,000 cfs from August to December 1998, except Long Creek for which the duration was shorter (October-December 1998).

Figure 6 shows the main Sangamon River stations with the same trends as the tributary stations for the sixth year of monitoring. Discharges were highest in May and June 1998, and April 1999. Monticello, which has the largest drainage area of the three river stations, had the highest flows for the year, 55,000 and 57,000 cfs, during May and June 1998. All three stations had their highest monthly discharge during the sixth year in June 1998. The lowest discharges at all river stations ranged from near zero to less than 2,500 cfs (August-December 1998). The USGS streamgaging station at Fisher experienced problems due to ice during parts of December 1998 and January 1999. Therefore, total discharge data during those months was estimated based on information provided by the USGS.

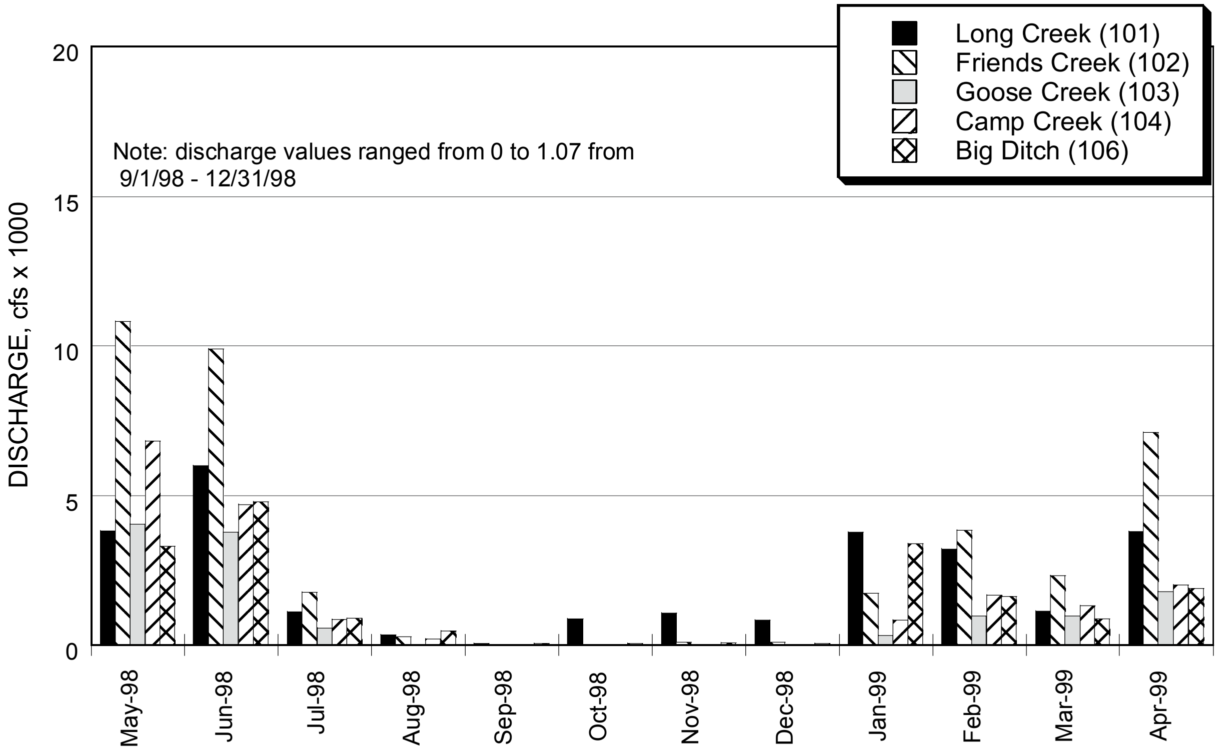

Figure 5. Monthly discharge for tributary stations, May 1998 - April 1999

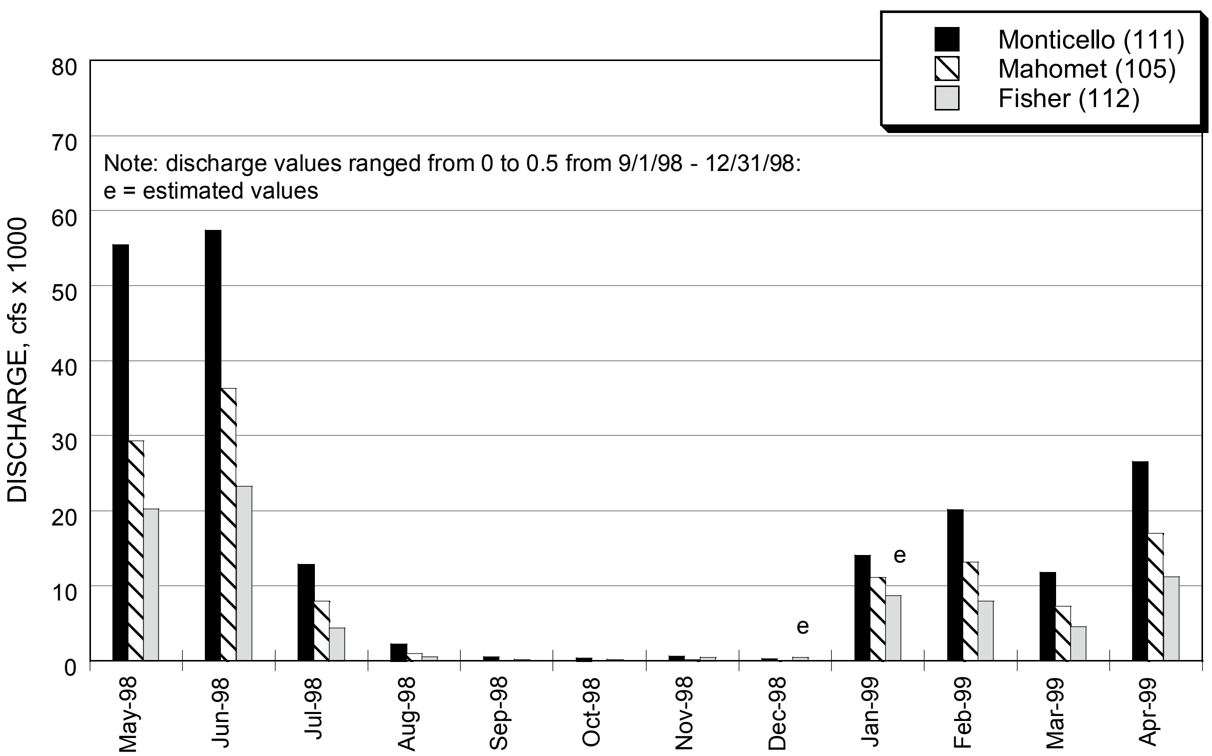

Figure 6. Monthly discharge for Sangamon River stations, May 1998 - April 1999

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 sixth-year monthly runoff in inches for the tributary and Sangamon River stations, respectively. The variation of runoff between stations is due to the spatial variability of rainfall events throughout the entire watershed.

Figure 7 shows that the highest monthly tributary runoff during the sixth year was from Camp Creek (5.4 inches) in May 1998. The next highest runoffs for the entire year occurred in June 1998 at Long Creek (4.9 inches) and Big Ditch (4.7 inches). All tributary stations had greater than 3 inches of runoff during May and June 1998. The lowest runoff during the year (near zero runoff) occurred at all stations (September-December 1998) except Long Creek. Runoff at all tributary stations was at or less than 1 inch during seven months (July-December 1998 and March 1999). Runoff at any one station exceeded 3 inches during four months (May and June 1998, and January and April 1999).

Figure 8 shows the monthly runoff for the three main Sangamon River stations. All three stations had runoffs greater than 3 inches during March and April 1998, ranging from approximately 3 to 4 inches. Five months of the year (May and June 1998; and January, February and April 1999) had runoffs greater than 1 inch. Runoff was nearly zero during September and December 1998 and below 1 inch July-December 1998 and March 1999.

Figure 9 presents annual runoff during all six monitoring years at the tributary and Sangamon River stations. The long-term average annual runoff (1908-1998) over the Lake Decatur watershed, as measured at the Monticello station, is 10.4 inches (LaTour et al., 1998). Figure 9a shows annual runoff at the tributary stations. All five tributary station annual runoff values were averaged together for each monitoring year (1 through 6) and are as follows: 20.3, 6.0, 7.5, 10.4, 10.4, and 15.1 inches, respectively. Runoffs during the first monitoring year were extremely high, while they were quite low the second year. Runoffs have been increasing since the second year. However, the figure shows some variability in runoffs between tributary stations, as well as between monitoring years. Five of the six tributary stations had their highest runoffs in the first year, and the second highest runoffs occurred during the sixth year. Long Creek is the only station where the highest annual runoff for the study period occurred during the sixth year. The second highest runoff occurred in the first year at Long Creek.

The sixth-year runoffs from river stations at Monticello, Mahomet, and Fisher were 13.9, 12.6, and 12.5 inches, respectively (figure 9b). It should be noted that the annual runoff for Fisher and Monticello during the fifth year of monitoring (see figure 9b) is slightly different in this report than in Keefer and Demissie (1999). The USGS 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.

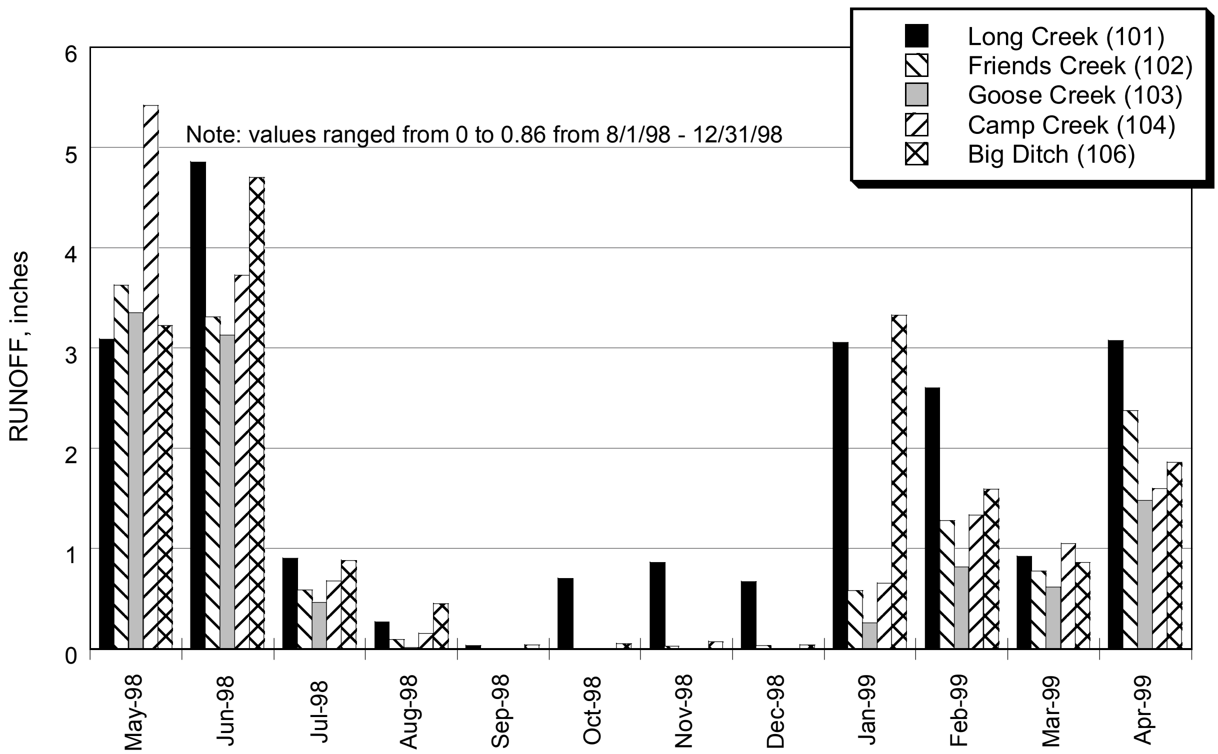

Figure 7. Monthly runoff for tributary stations, May 1998 - May 1999

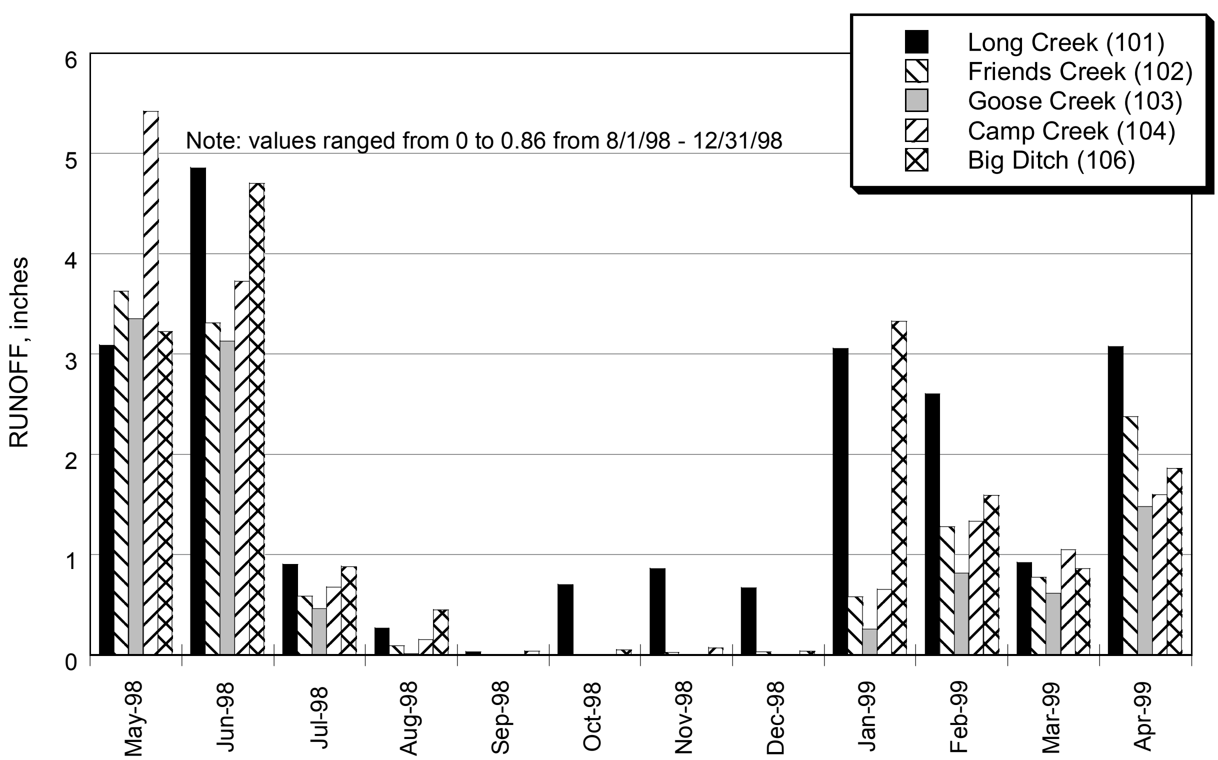

Figure 8. Monthly runoff for Sangamon River stations, May 1998 - April 1999

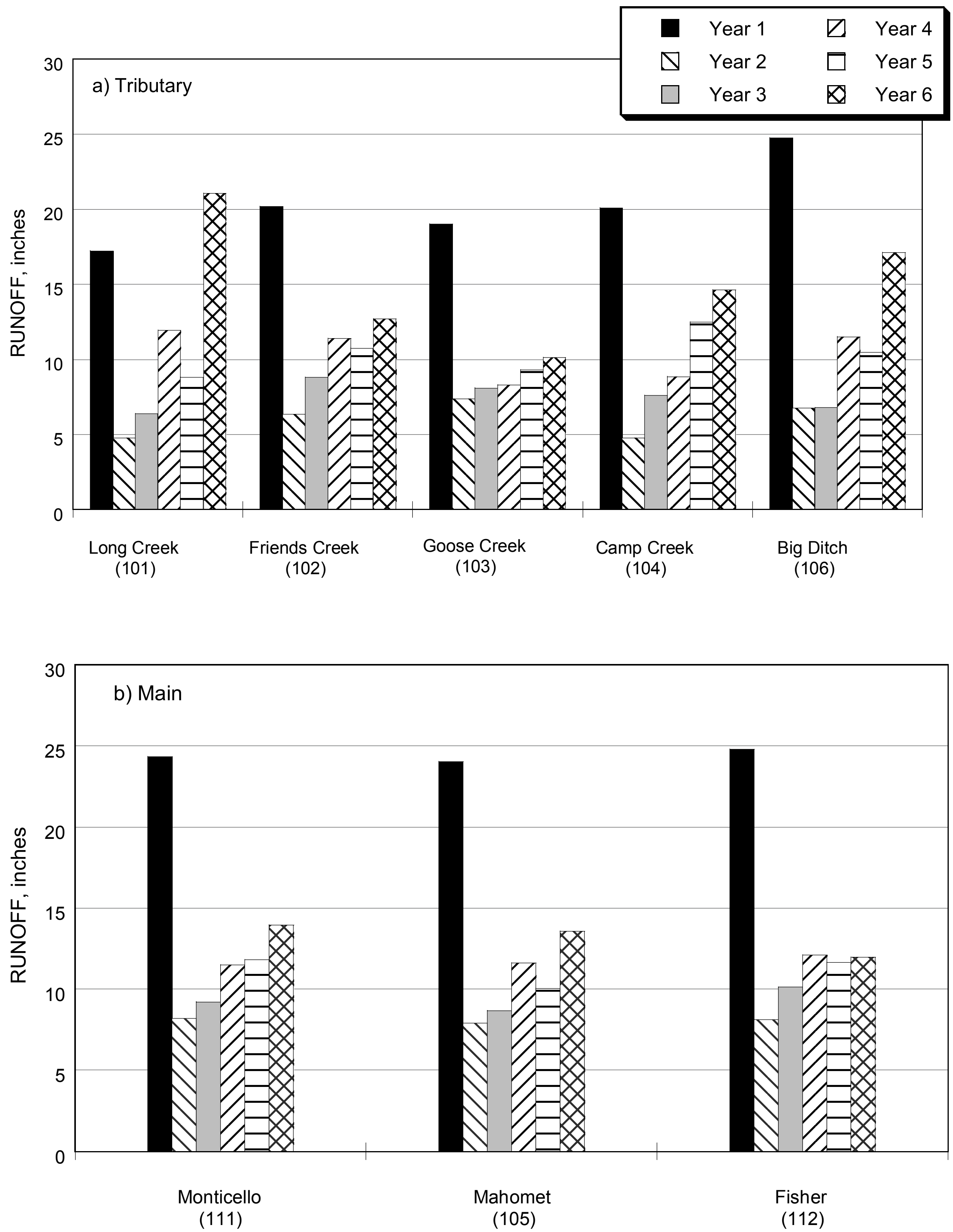

Figure 9. Annual runoff for tributary and Sangamon River stations during six-year study period

Nitrate Monitoring

Nitrate was sampled at each of the eight monitoring stations for all six years. During the first two years (May 1993-April 1995), two additional nitrogen parameters were collected: 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 sixth-year monthly nitrate-N concentration data at the eight tributary streams and Sangamon River monitoring stations. Keefer and Demissie (1999) present annual nitrate-N concentration data for the first five 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; Keefer and Demissie, 1999). Concentrations in May and June 1998 predominantly ranged from 10 to 15 mg/l. Nitrate-N concentrations for all tributary stations decreased through the months of July and August 1998, to approximately below 2 mg/l. Concentrations remained below 1.5 mg/l through October 1998. Some stations had periodic spikes due to locally concentrated fall rains between November and December 1998. Very few samples were obtained during January 1999 due to thick ice cover on the streams. Nitrate-N concentrations increased dramatically to levels between 11 and 14 mg/l through mid-April 1999. Concentrations during the latter half of April 1999 ranged from approximately 12 to below 17 mg/l. The highest nitrate-N concentration, 16.96 mg/l, occurred at the Camp Creek station in April 1999. The next highest concentrations were at Goose Creek, 16.14 mg/l, and Camp Creek, 16.04 mg/l also in April 1999. The lowest concentration was 0.9 mg/l at all stations in October 1998.

Figure 11 shows the nitrate-N concentration data for the three stations on the Sangamon River during the sixth monitoring year. The seasonal variation in concentration throughout the year also follows the pattern seen in past data and also similar to the pattern for tributary stations discussed above. Nitrate-N concentrations ranged from approximately 10 to 14 mg/l during May 1998 and decreased to less than 1 mg/l by late August 1998. Concentrations remained low (1 mg/l or less) through December 1998. Due to very thick ice cover on the Sangamon River, no samples were collected from late December 1998 through mid-January 1999. Concentrations rebounded from mid-January through mid-March 1999, ranging from approximately 9 to 13 mg/l. Concentrations decreased to below 10 mg/l in late March and early April 1999 and then increased to more than 14 mg/l, with some stations peaking over 16 mg/l. All three stations had their highest concentrations of the year in April 1999. Fisher had the highest nitrate-N concentration of 16.32 mg/l; Mahomet and Monticello had 15.59 mg/l and 14.54 mg/l, respectively. Overall, nitrate-N concentrations were 1-2 mg/l less than concentrations reported for the tributary stations, as shown in figure 10.

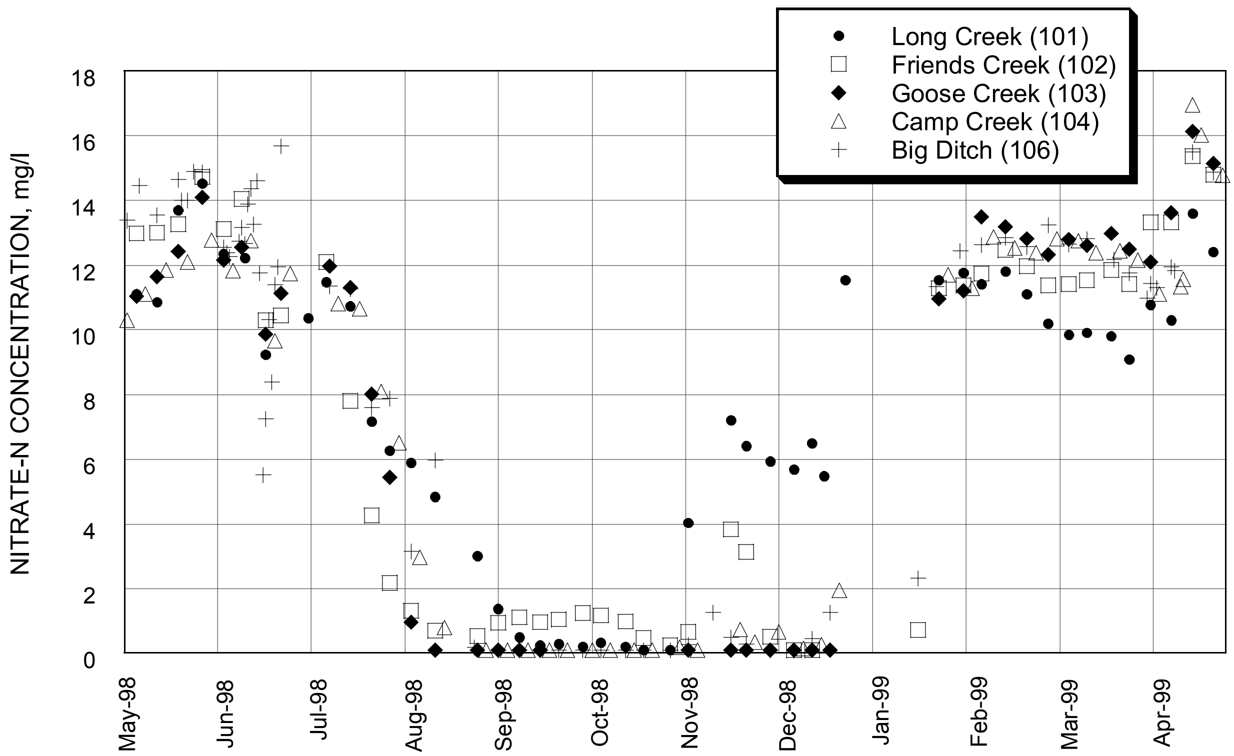

Figure 10. Nitrate-N concentrations for tributary stations, May 1998 - April 1999

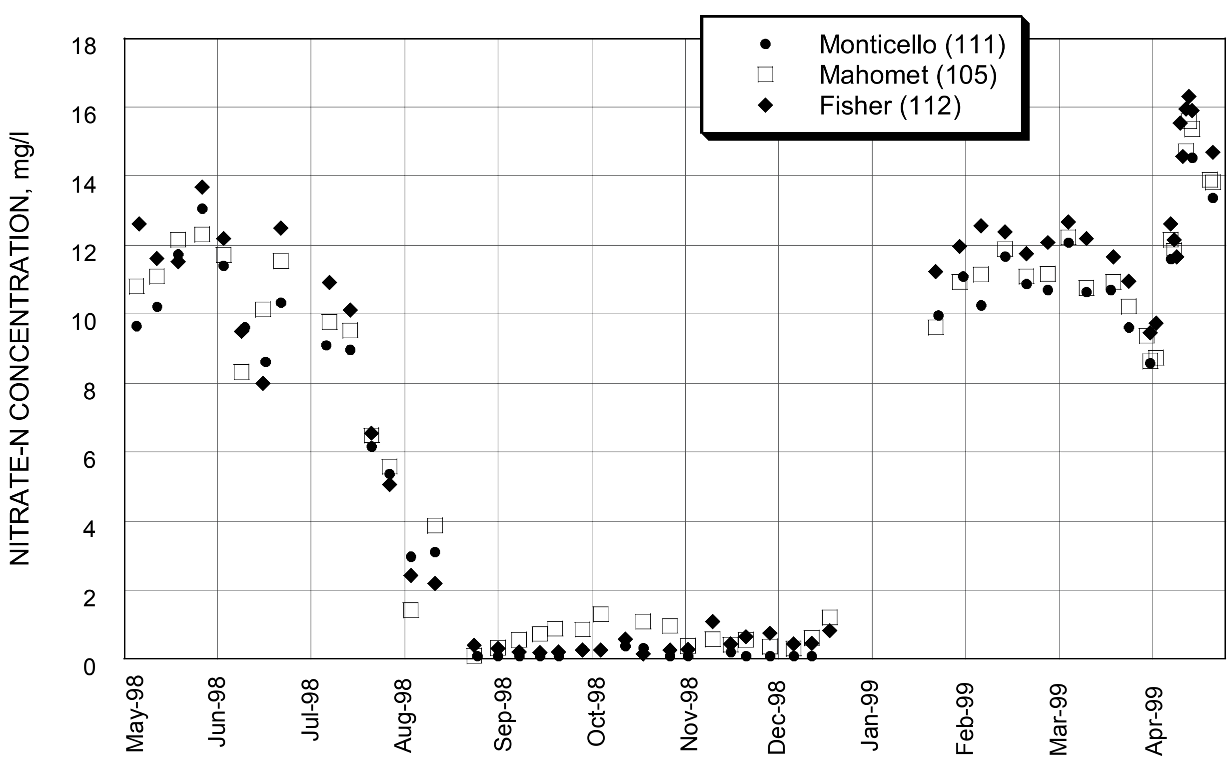

Figure 11. Nitrate-N concentrations for Sangamon River stations, May 1998 – April 1999

Figure 12 shows nitrate-N concentration data for Lake Decatur, provided by the City of Decatur for use in this study. Figure 12a shows the nitrate-N concentrations for the north and south water treatment plant (WTP) intakes in Lake Decatur during the sixth 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 at the river stations, just as concentrations at the river stations are lower than those at the tributary stations. Nitrate-N concentrations range from 6 to 10 mg/l during May and June 1998. Concentrations generally range from 6 to 8 mg/l through most of July 1998 and then decrease through September 1998 to below 1.5 mg/l. Concentrations from October 1998 through late January 1999 ranged from 0.5 to slightly greater than 2 mg/l. Nitrate-N concentrations increased steeply from late January levels that ranged from approximately 7 to 10 mg/l through mid-April 1999. The highest concentrations, 12.7 and 11.2 mg/l, occurred in April 1999 at the south WTP and north WTP, respectively. The lowest concentration for both treatment plants occurred during October 1998.

Figure 12b shows some variability of nitrate-N concentrations in Lake Decatur. Data were retrieved from the City of Decatur at the South Water Treatment Plant (SWTP) from 1967-1999. The data show that the annual maximum nitrate-N concentrations ranged from 7.6 to 16 mg/l, with the 16 mg/l readings occurring in 1981 and 1989. The next highest concentrations, 12.7 and 12.0 mg/l, occurred in 1999 and 1967, respectively. The average of the annual maximum nitrate-N concentration was 10.7 mg/l. The annual mean nitrate-N concentrations ranged from 2.2 to 8.8 mg/l in 1994 and 1981, respectively. The average of the annual mean concentrations from was 5.2 mg/l. The annual minimum nitrate-N concentrations ranged from 0.1 to 2.4 mg/l. The 2.4 mg/l reading occurred in 1993, and the 0.1 reading occurred many times throughout this period, with the average of the annual minimum concentration being 0.5 mg/l.

Figures 13-15 show the maximum, mean, and minimum concentrations of nitrate sampled at the a) five tributary and b) three river stations in the watershed and the north and south water treatment plants during the six-year study period. As seen in figure 13a, Camp Creek had the highest nitrate-N reading (16.96 mg/l) during the sixth monitoring year, with the next highest reading at Big Ditch (16.5 mg/l) during the fourth monitoring year. The lowest maximum concentration was in the second monitoring year at Goose Creek (10.97 mg/l). Figure 13b shows that Fisher had the highest maximum nitrate-N concentration (16.32 mg/l), during the sixth monitoring year and Monticello had the lowest maximum concentration (10 mg/l) during the second monitoring year. It should be noted that during the sixth monitoring year all stations, except Big Ditch, established new record high nitrate-N concentrations for the entire study period. The Big Ditch record maximum concentration was recorded during the fourth monitoring year. A comparison of Figures 12b and 13b shows that for the south water treatment plant, the maximum nitrate-N values in the 1980s were much higher than in the sixth year of monitoring.

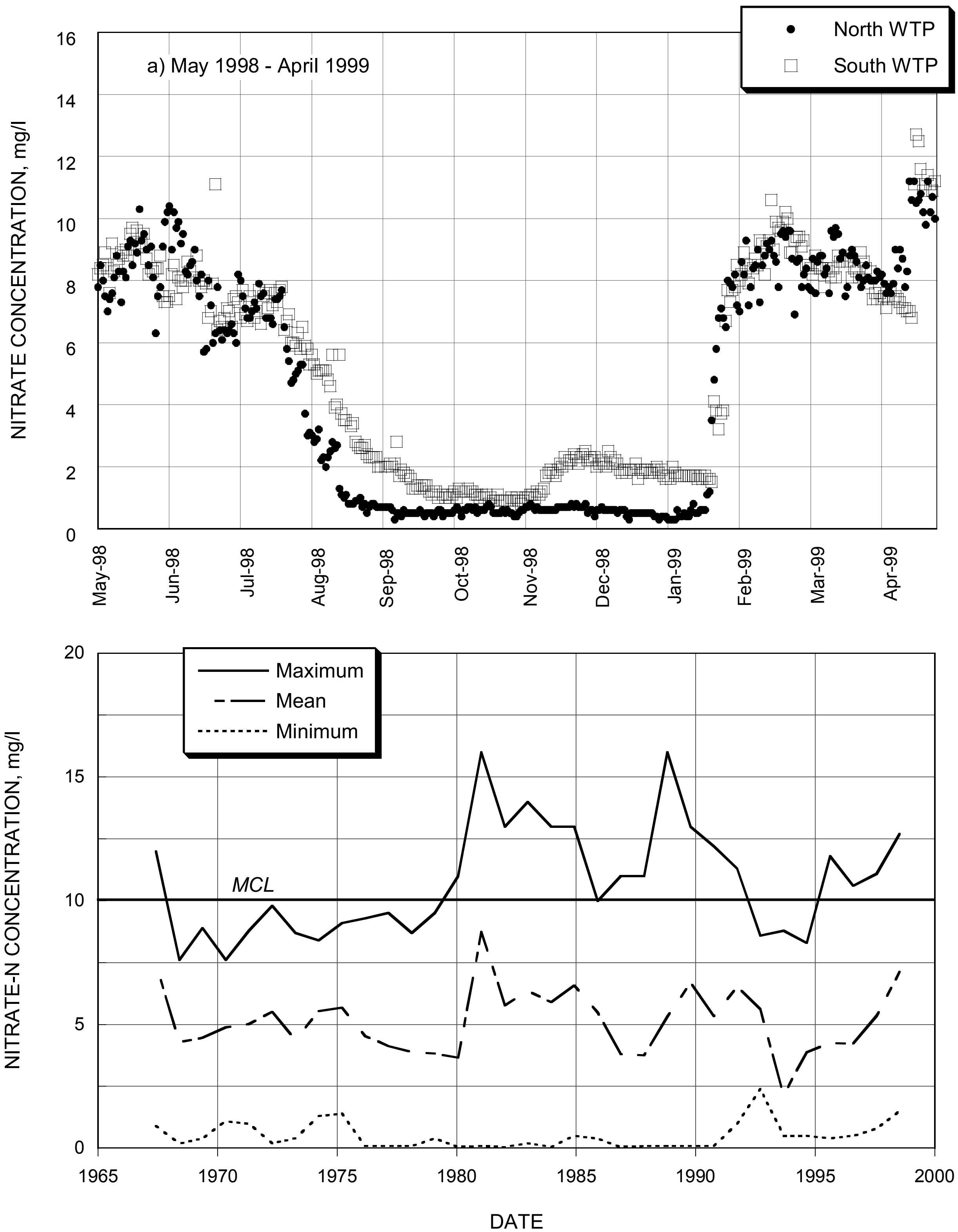

Figure 12. Nitrate-N concentrations for Lake Decatur: a) daily values from May 1998 to April 1999 for the north and south water treatment plants, and b) annual maximum, mean, and minimum concentrations from 1967-1999 for the south water treatment plant

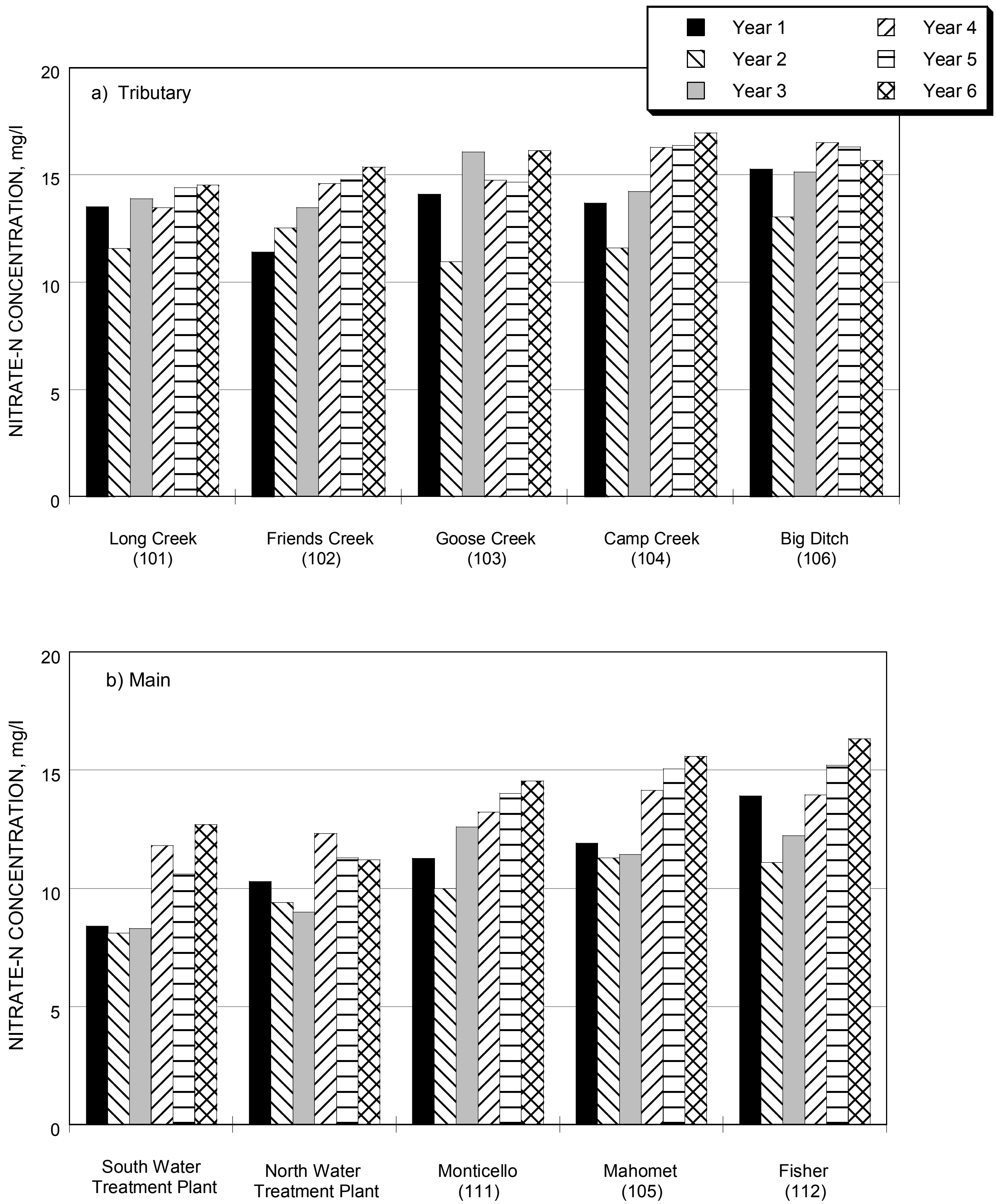

Figure 13. Maximum nitrate-N concentrations during six-year study period

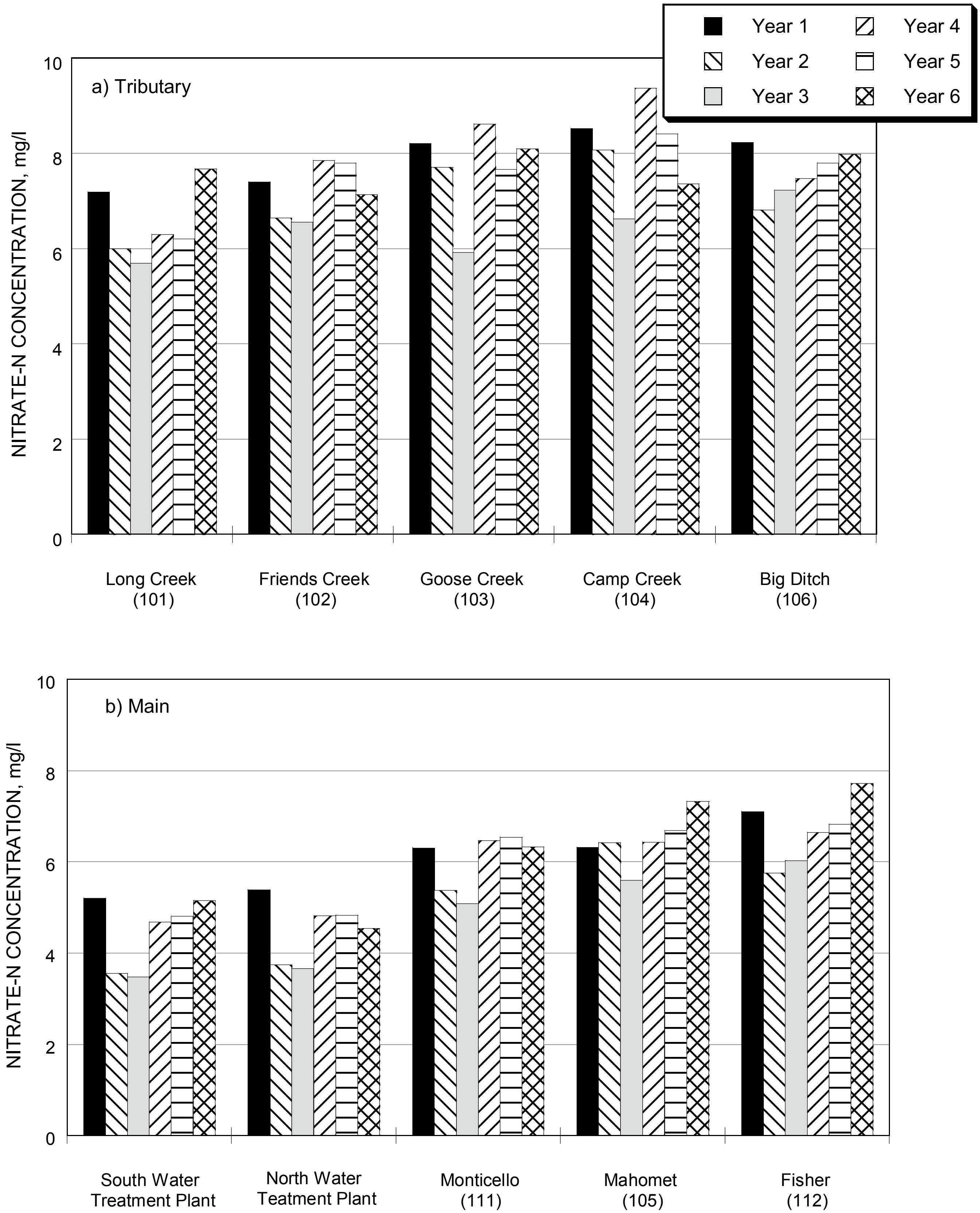

Figure 14. Mean nitrate-N concentrations during six-year study period

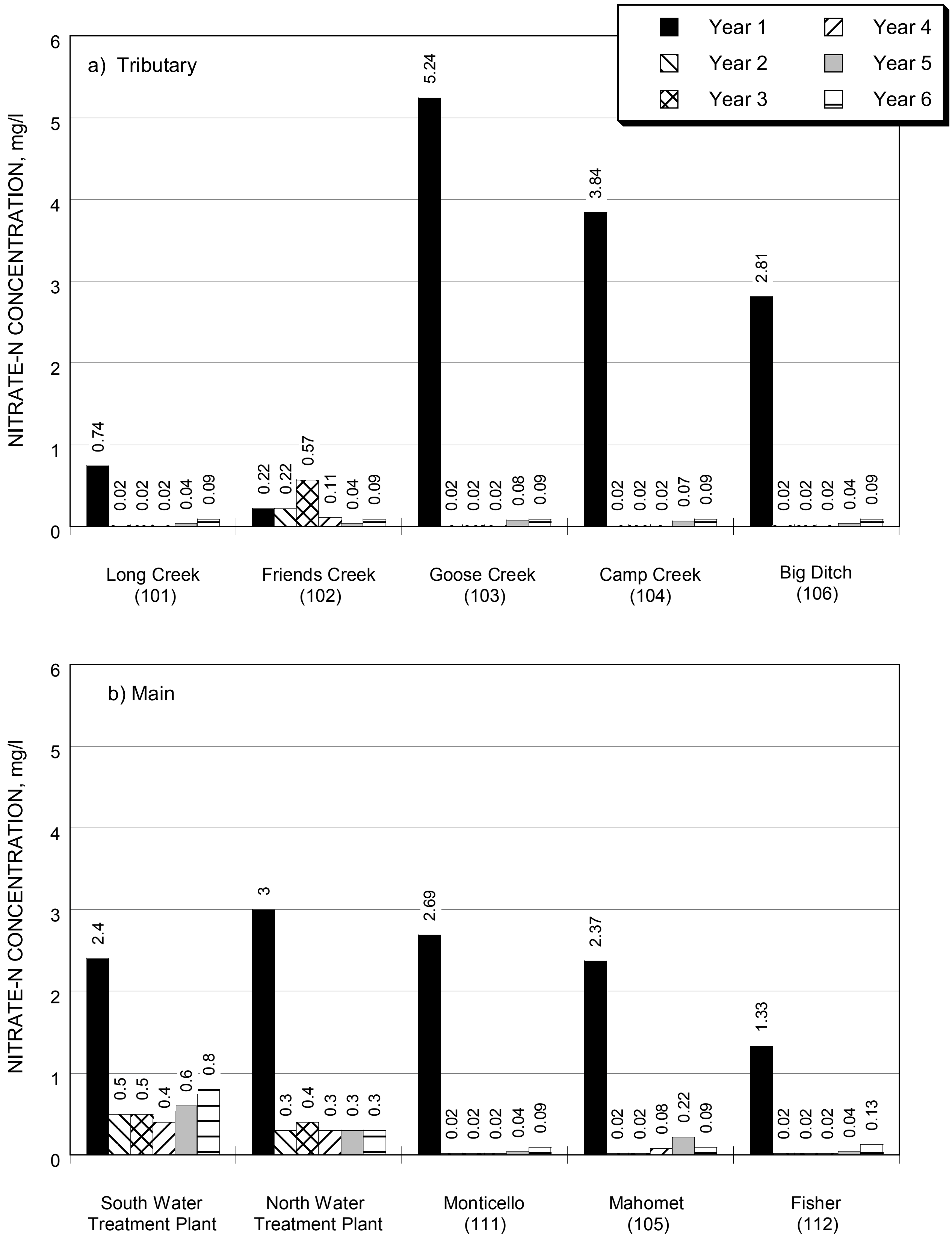

Figure 15. Minimum nitrate-N concentrations during study period

Figure 14 shows the mean nitrate-N concentrations during the six years of monitoring. The average annual nitrate concentrations for all tributary stations during each of the six monitoring years are 7.9, 7.0, 6.5, 7.9, 7.6, and 7.8 mg/l, respectively. The average annual concentrations for all the river stations are 6.6, 5.8, 5.5, 6.5, 6.7, and 7.1 mg/l, respectively. The average annual nitrate concentrations from the north and south water treatment plants in Lake Decatur during the six monitoring years are 5.3, 3.5, 3.4, 4.8, 4.8, and 4.8, respectively. Thus the average nitrate concentrations decrease as water proceeds from the tributaries to the Sangamon River and finally to Lake Decatur. Figure 15 shows the minimum nitrate concentrations measured. During the sixth year of monitoring no station exceeded 0.15 mg/l of nitrate-N concentration. Otherwise, the highest minimum concentrations occurred during the first year of monitoring (May 1993-April 1994) for all stations except Friends Creek.

Nitrate Loads

Even though the main water quality concern at Lake Decatur is nitrate concentration, the critical issue for watershed management is nitrate load. 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 is necessary to determine the contribution of different areas over time 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 over time. Using discharge and concentration data collected from each station, nitrate loads are calculated as the product of nitrate concentration and discharge, converted to the desired units (pounds or tons) by using the appropriate conversion factors, over a certain period of time. The total loads are then normalized per unit area for determining the relative contribution of different areas in the Lake Decatur watershed. For example, a tributary may have some of the highest nitrate concentrations, but if it is one of the smallest sub-watersheds, its total contribution of nitrates could be small as compared to other larger sub-watersheds. Figures 16 and 17 present monthly nitrate loads (lb/acre/month) during the sixth 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 sixth monitoring year, in which the average monthly load at all stations is 3.2 lb/acre. Monthly nitrate-N loads were highest at Camp Creek in May 1998 (14.2 lb/acre) and at Big Ditch in June 1998 (12.6 lb/acre). All tributary stations had nearly zero nitrate-N loads in September and October 1998. Nitrate-N loads were highest in May and June 1998 for all the tributary stations.

Figure 17 presents the monthly nitrate loads for the three Sangamon River stations, which had an average monthly load of 2.6 lb/acre for the sixth year. The highest monthly load occurred at the Monticello station in May 1998 (9.6 lb/acre). Nitrate loads were near zero at all river stations (August-December 1998).

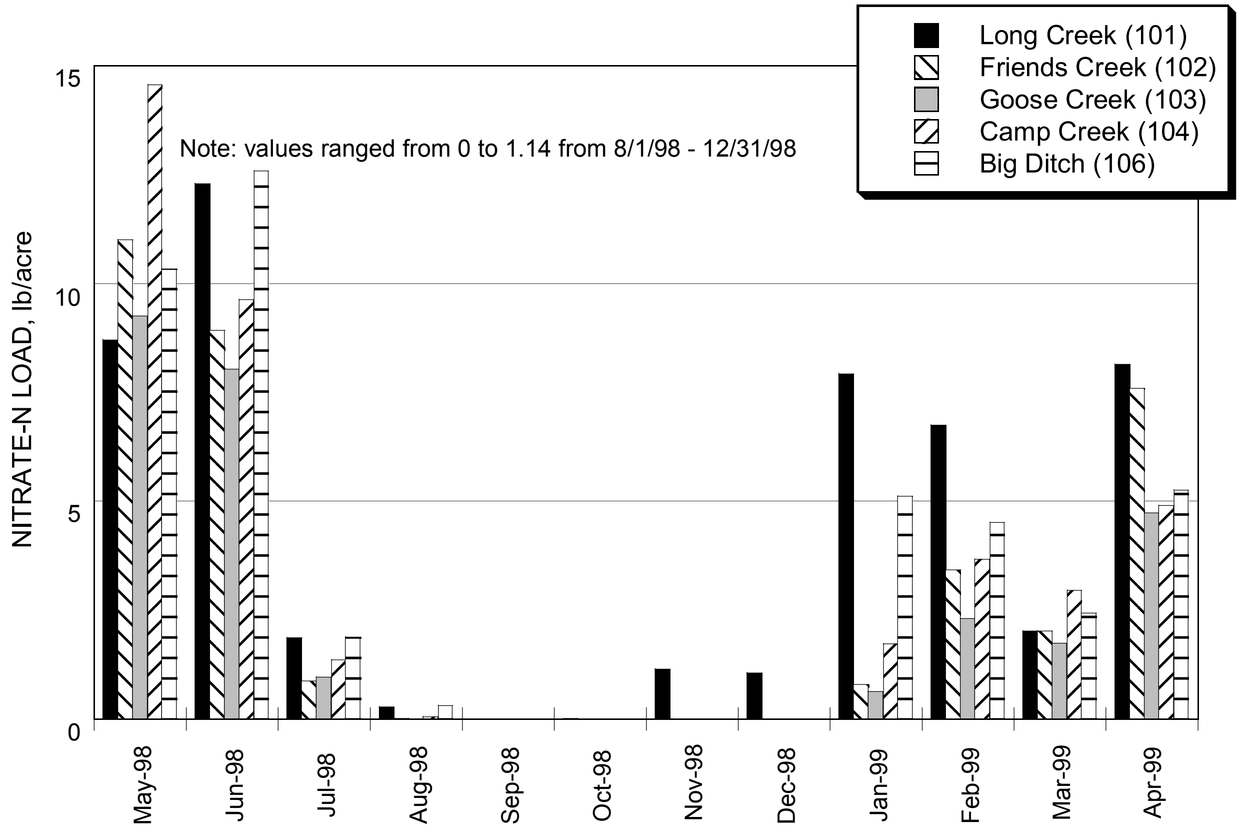

Figure 16. Monthly nitrate-N load for tributary stations, May 1998 – April 1999

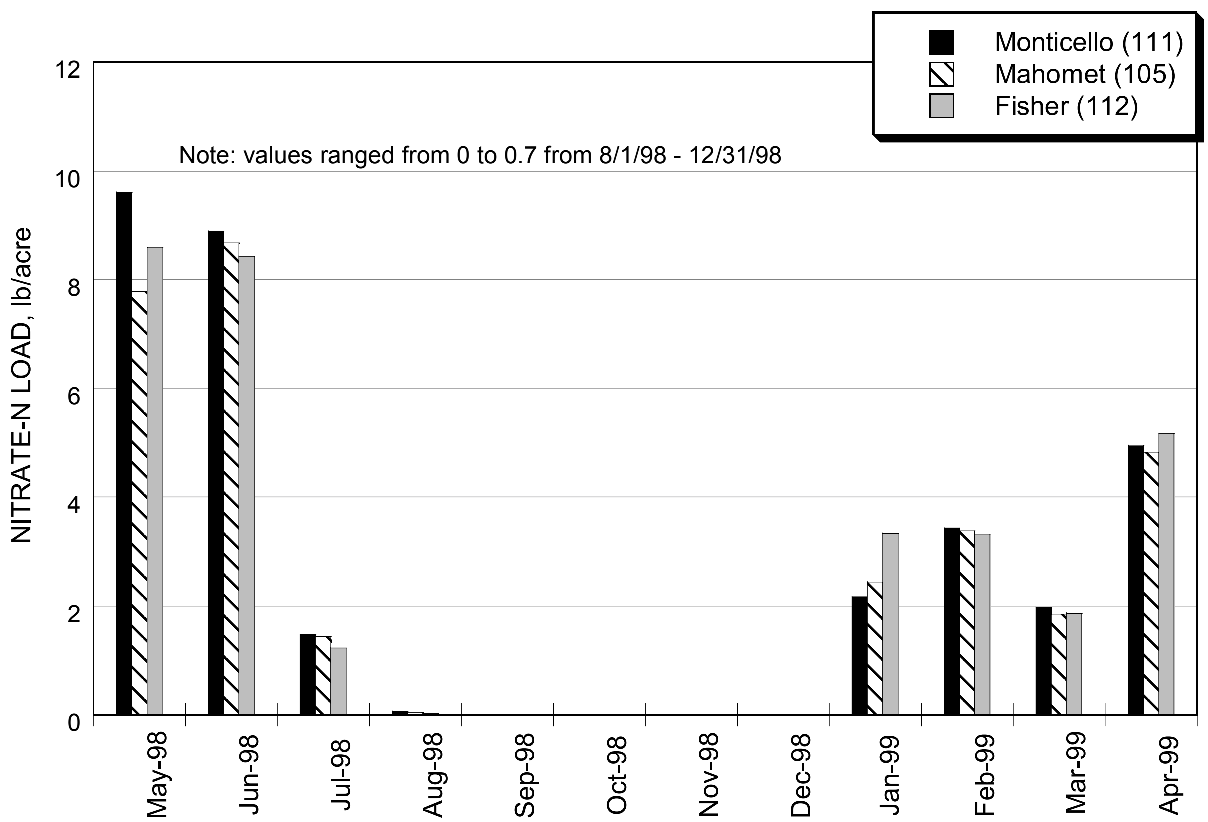

Figure 17. Monthly nitrate-N load for Sangamon River stations, May 1998 – April 1999

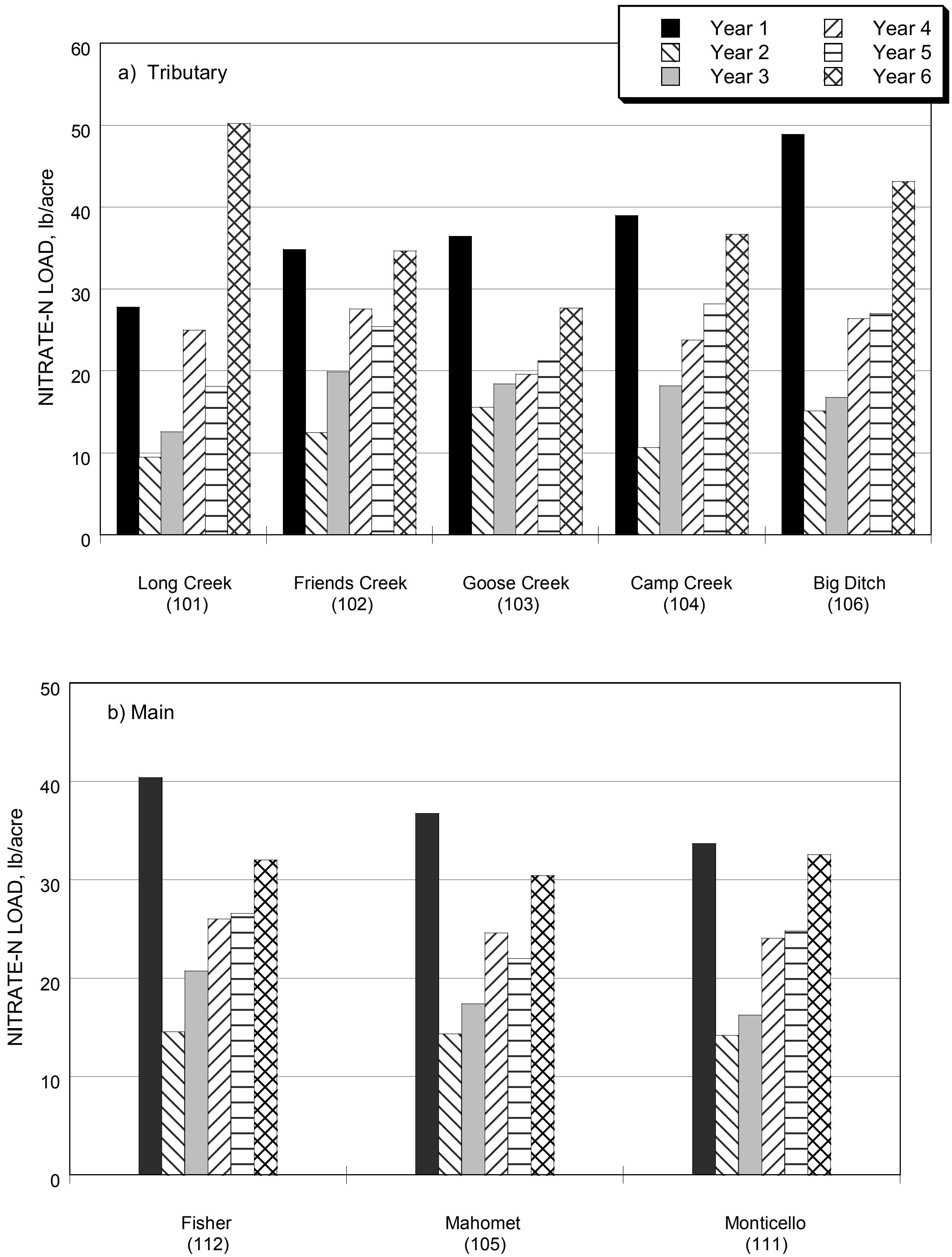

Figure 18. Annual nitrat-N load for tributary and Sangamon River stations during six-year study period

Table 3. Annual Nitrate-N Loads in the Sangamon River Basin

Station	*Drainage area (acres)*	*Annual nitrate-N load (lb/acre/yr)*						*Average*
		Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*	
Tributary stations								
Long Creek (101)	29,539	28	9	13	25	18	50	24
Friends Creek (102)	71,647	35	12	20	28	25	35	26
Goose Creek (103)	28,892	36	16	18	20	21	28	23
Camp Creek (104)	30,242	39	11	18	24	28	37	26
Big Ditch (106)	24,421	49	15	17	26	27	43	30
Sangamon River stations								
Fisher (112)	157,177	40	15	21	26	27	32	27
Mahomet (105)	235,653	37	14	17	25	22	31	24
Monticello (111)	347,747	34	14	16	24	25	33	24
Annual yield into Lake Decatur*	586,868	32	12	16	25	23	38	24

*Area-weighted using Long Creek, Friends Creek, and Monticello.

Annual Nitrate Loads. Table 3 summarizes the annual nitrate-N loads during the six-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.

For the tributary stations, the annual nitrate load for the sixth year (Figure 18a) ranges from a low of 28 lb/acre for Goose Creek to a high of 50 lb/acre for Long Creek. The other tributary stations (Friends Creek, Camp Creek, and Big Ditch) generated loads ranging from 35 to 43 lb/acre/yr during the sixth year. The six-year average annual load for all the tributary stations was 26 lb/acre. It was observed that on the average over the entire six-year study period Big Creek had slightly higher nitrate load per unit area and Goose Creek had slightly lower nitrate load per unit area. Figure 18b presents the annual nitrate loads for the three Sangamon River stations. During the sixth monitoring year, the average annual load for the main river stations was 32 lb/acre, and annual loads ranged from a low of 31 lb/acre at the Mahomet station to a high of 33 lb/acre at the Monticello station.

Table 3 presents the nitrate loads from the entire watershed into Lake Decatur during the six-year study period. The six-year average annual nitrate-N loads from the tributary and river stations are 26 and 25 lb/acre, respectively. The sixth monitoring year had the highest load (38 lb/acre) and the second monitoring year had the lowest load (12 lb/acre). The total nitrate delivered into Lake Decatur was determined by using the Long Creek, Friends Creek, and Monticello station data to calculate area-weighted average annual yields. The stations of Goose Creek, Camp Creek, Big Ditch, Fisher, and Mahomet are not considered in the calculation because they are all upstream of Monticello. Based on this, the average annual nitrate delivered to Lake Decatur for the six-year study period is 24 lb/acre, which is equal to approximately 7,336 tons per year.

Based on the data, it can be concluded that the unit nitrate loads are relatively uniform over the entire watershed but tend to be slightly higher at the tributary streams in the upper Sangamon River watershed than at the main stem stations closer to the lake. On the Sangamon River, the nitrate load is generally highest at Fisher and lowest at Monticello. Based on the load data calculated for the last six years, it can be concluded that the nitrate loads vary from monitoring station to station and can change significantly from year to year.

Summary and Discussion

The data collection over the six-year monitoring period (May 1993-April 1999) provides a breadth of data which allows for some important observations.

- Streamflow and nitrate-N concentrations decreased significantly from the first (May 1993-April 1994) to the second monitoring year (May 1994-April 1995) and have been rebounding for most stations since the second monitoring year. Year 2, which followed the wettest monitoring year (May 1993-April 1994), had the lowest flow and concentrations during the entire study period.

  Table 4 presents the average rainfall, average annual streamflow, flow-weighted nitrate-N concentrations, and annual nitrate-N loads for the Sangamon River at Monticello (543.4-square-mile drainage area, representing approximately 60 percent of the Lake Decatur watershed) during the monitoring period. The flow-weighted nitrate-N concentration was determined by summing the product of the monthly average nitrate concentrations and the monthly total streamflow then dividing that summation by the total annual streamflow.

  Average annual rainfall for stations above Monticello shows that rainfall during the first year was extremely high then decreases significantly in the second year with the subsequent years rising gradually to nearly 5 inches above the second year (34.5 inches).

  As can be seen from table 4 and figure 19 for the Monticello station, the first monitoring year was an extremely wet hydrologic period with the highest streamflow. The 961 cfs streamflow rate was surpassed only twice in the nearly 90-year record period for this station (Demissie et al., 1996). The second monitoring year was significantly drier than the first. During the next four monitoring years the streamflow has been gradually increasing from 323 cfs, well below the long-term mean of 424 cfs, to 556 cfs, well above the long-term mean. Figure 11 shows the monthly nitrate-N concentrations at the Monticello station for the six monitoring years. Data for the entire monitoring period are summarized by the flow-weighted annual concentrations in table 4 and figure 19 and show an increase in flow-weighted nitrate-N concentrations during the study period at the Monticello station from 6.17 to 10.39 mg/l.
- As a result of streamflow and nitrate-N concentrations, nitrate loads significantly dropped from the first to the second year and have been increasing since the second monitoring year (as seen in table 3 and figure 18).
- The highest nitrate concentrations during the six-year monitoring period were observed in the sixth year at all the main stem stations and at four of the five tributary stations.

Table 4. Summary of Rainfall, Flow, Flow-Weighted Nitrate-N Concentration and Load for the Sangamon River at Monticello for the Duration of the Monitoring Period

Monitoring year	*Average Rainfall (inches)*	*Average streamflow (cfs)*	*Flow-weighted Nitrate-N concentration (mg/l)*	*Nitrate-N load (lb/acre/yr)*
1	51.7	961	6.17	34
2	34.5	323	7.72	14
3	34.3	362	7.88	16
4	37.4	460	9.29	24
5	40.0	469	9.32	25
6	40.3	556	10.39	33
Long-term mean		424	-	-

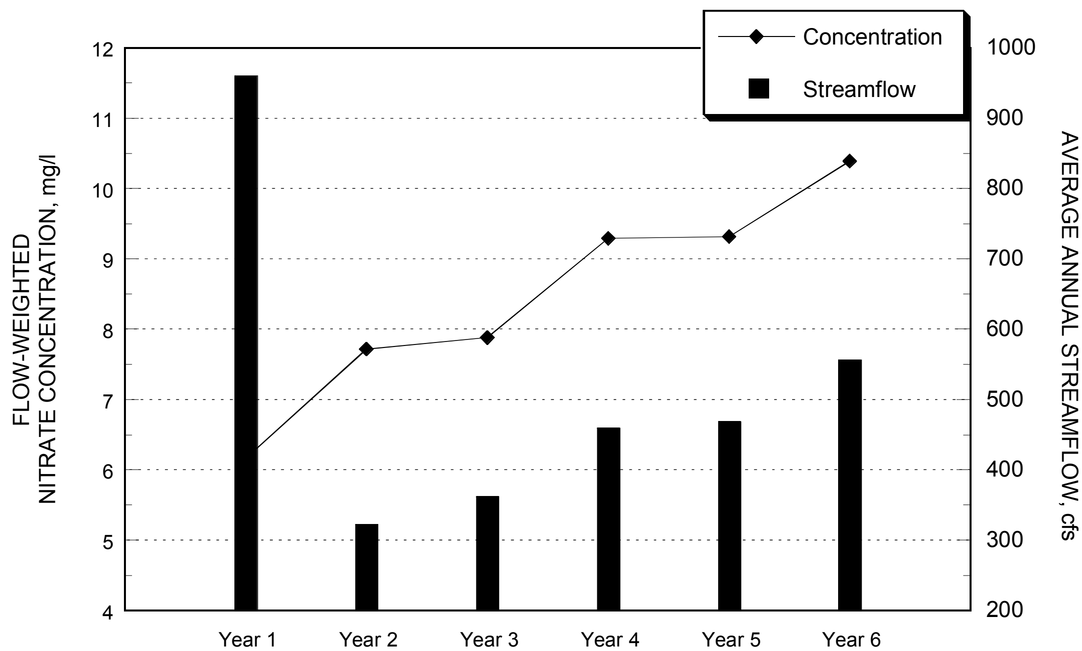

Figure 19. Average annual streamflow and flow-weighted mean nitrate-N concentrations on the Sangamon River at Monticello during study period

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